The New Zealand ***Amateur Radio Study Guide*** **BOOK 2**

All you need to know...to

BECOME a RADIO AMATEUR!

Compiled by MED-Approved Radio Examiner ARX2106*

Version: 2.0 September 2011

The ***Syllabus Cluster Number*** is in the footer of each ***Study Note***

Cluster	**Study Note**
1 to 7	**Regulations** (This is a *REFERENCE document* for general Amateur Radio use.)
8 & 9	**Radio Frequency Bands**
10 & 11	**Electronics Fundamentals**
12	**Measurement Units**
13 to 19	***A:*** **Resistor Colour Code** ***B:*** **Ohm's Law** ***C:*** **Ohm's Law Applied**
20	**Alternating current** and supplement: **What's 230v?**
21 & 22	**Capacitors, Inductors, Resonance**
23	**Safety**
24 & 25	**Semiconductors**
26	**Electronic Devices**
27	**Meters and Measuring**
28	**Decibels**
29	**HF Stations**
30 to 36	**Receivers**
37 to 39	**Transmitters**
40 & 41	**Harmonics and Parasitics**
42 & 43	**Power supplies**
44	**General Operating Procedures**
45 &46	**Practical Operating Knowledge**
47	**Q signals**
48 & 49	**Transmission lines**
50 to 53	**Antennas**
54 to 56	**Propagation**
57 to 59	**Interference & Filtering**
60	**Digital Systems**

Check your study progress!

The 600-question examination ***Question-Bank*** is publicly available in two Books:

Book 3 – all answers have been removed.

Book 5 – is the full Question-Bank, it has the answers to all questions.

You can easily self-test yourself!

Use **Book 3** and attempt (say) **question 5** from all clusters 1 through to 60.

Note your selections on the chart at the last page of this Book, ***Book 2.***

Then check your answers using **Book 5** – mark your own paper.

Check regularly (with other numbered questions) to see your progress.

Forty or more correct answers out of 60 are required for a pass!

Are you ready for the examination? Contact an ARX or your local Amateur Radio Club. A formal test can be arranged for you at a mutually-agreed time and place.

Supplementary papers follow Cluster 60:

Signals, **Mixers and Modulators**, **Amplifiers and Oscillators.**

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*An '***Active ARX***' list is at the MED RSM website: **http://www.rsm.govt.nz/cms**

The SIX books in the *STUDY GUIDE* series:

The six books in the ***New Zealand Amateur Radio Study Guide*** prepare the candidate for the New Zealand Amateur Radio Examination. The books can be bound together *back-to-back* to form ***three volumes***:

VOLUME 1 "*Theory*":

Book 1. "***What YOU do ...to Become a Radio Amateur***" explains the Syllabus and other features of the examination system. (13 pages.)

Book 2. "***All you need to know...to BECOME a RADIO AMATEUR!***" (this book), a theory text-book or, if required, the source of classroom "hand-out" notes. (129 pages.)

VOLUME 2 "*NO answers*":

Book 3. "***The Amateur Radio Question-Bank (WITHOUT Answers)***", all the genuine questions for self-testing! (60 pages.)

Book 4. A ***Sample of a typical examination paper (WITHOUT Answers)***, with a candidate's answer sheet on its last page. (12 pages.)

VOLUME 3 "*WITH Answers*":

Book 5. "***The Amateur Radio Question-Bank***", same as Book 3 but ***with answers***, (60 pages.) **This is the Question-bank MASTER copy for this examination system**.

Book 6. A short "Statement" version of "***The Amateur Radio Question-Bank***", the questions ***with answers*** but without the distractors! (30 pages.)

The books can be freely downloaded from the published website. Each book can be viewed on-screen or printed on paper. If printed, they should be printed double-sided so only half of the number of sheets of paper are used. The books have been laid out with presentation carefully developed for the convenience of students.

Planning a STUDY COURSE with the printed booklets:

Book 2 is a collection of ***free-standing class hand-out notes*** for the study topics. It is also a course "textbook", with explanatory study material for "Clusters" of questions.

The Study Notes are presented so that each "Note" can be separately printed as a distinct separate document if required (by telling the printer which pages to print) to form **class hand-outs**. Or, the complete document can be printed to provide a complete "**textbook**".

The first two pages in BOOK 2 are not numbered. The numbering starts with 1 being the first page of the first Notes, the Notes with the title "*Amateur Radio – The Rules explained*". These Notes can be separately printed (20 pages) as a "Regulatory" reference document, a booklet for general use by radio amateurs. This start-point is deliberate to ensure that the page numbers shown on the CONTENTS table in that internal Regulatory booklet (on page 1) remain correct.

When printing **extracts** from Book 2, the **software** "page numbers" for the required start and finish pages should be used for printing the extracts. That method adjusts for the inclusion of the (two un-numbered) additional pages at the front of the textbook.

The Study Guide BOOK 2 provides:

your *personal textbook*, for your own self-study course, or,

separate *class hand-outs* for Instructors and Students to use in a conventional classroom, or,

a pre-course directed *Reading Reference Resource* for each participating student prior to and during an "Amateur Radio week-end camp".

When binding: Book 1 with Book 2, Book 3 with 4, and Book 5 with 6, can be spiral-bound back-to-back with one book inverted. This gives each volume two transparent "front covers" - the content details are then readily visible! Just flip the volume over to move to the other book!

AMATEUR RADIO – THE RULES explained

Establishing and Operating an Amateur Radio Station in New Zealand

This booklet was first compiled in the 1950s and maintained since by Fred Johnson MNZM ZL2AMJ, (ARX2106).

The *'Regulatory'* topics you need to be familiar with for the New Zealand Amateur Radio Examination are here.

CONTENTS

INTRODUCTION

The Ministry of Economic Development, Radio Spectrum Management, appoints and audits "Approved Radio Examiners" (ARXs) to provide and to administer examinations and callsign procedures in accord with the Ministry's "Public Information Brochures" (PIB46).

Enquiries about training materials, examination arrangements and callsigns should be directed to an ARX listed as currently active at the Ministry's website, and who has Examiner status in the category "amateur". Go to: http://www.rsm.govt.nz/cms. Insert "ARX" or "PIB46" in the Search Box at top right of the screen then click the appropriate links.

For qualification purposes to ensure the integrity of the examination process is maintained, an examination must be conducted within an ARX's approved examination system and procedures.

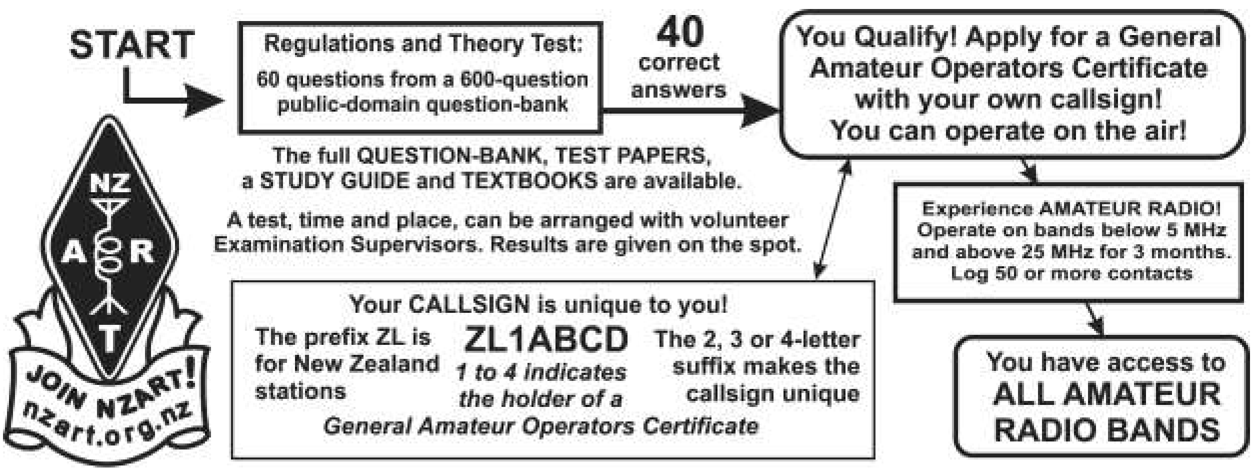
You will need some 'technical books'. Excellent books on the basics of amateur radio and radio theory are available including a downloadable "Study Guide" and the complete Question-bank – ask your ARX.

Overseas books do not cover the ***New Zealand regulatory requirements*** for the examination, that need is filled by this "***Rules Explained***" booklet. Many "Amateur Radio Handbooks" cover the technical topics of the Syllabus. Borrow or buy them.

When you are ready for the examination, make contact with an ARX of your choice who will guide you. An examination can be arranged for you at a mutually-agreed time and place.

Good luck with your studies! We'll "see you on the air"!

WELCOME TO AMATEUR RADIO!



AMATEUR RADIO – The RULES explained

Establishing and Operating an Amateur Radio Station in New Zealand

The New Zealand Radiocommunications Regulations and Amateur Radio

These notes cover the regulatory topics for the Amateur Radio Examination and are for reference use by New Zealand radio amateurs.

The "*regulatory aspects*" of Amateur Radio are very important, so important that these notes cover many topics in *very much greater detail* than is necessary for the examination. As a radio amateur you need to be aware of many regulatory things and to know where to find them in the various documents!

Operating a radio transmitter in the crowded radio frequency spectrum requires a good understanding of what you are ***permitted*** to do, what you are ***required*** to do, and what you ***MUST NOT*** do.

There are many privileges and responsibilities to being a radio amateur:

- Radio amateurs are not constrained to any fixed frequencies but may operate on frequencies of their own choosing within the frequency bands allocated to amateur radio distributed throughout the radio frequency spectrum.
- Radio amateurs may use communication modes of their own choosing.
- The equipment used by radio amateurs need not be 'type-approved' like the equipment used by most other radio services.
- Radio amateurs can construct and operate their own equipment on any of the many amateur radio frequency bands.

There are **TWO** important documents. These are:

1. The "***General User Radio Licence for Amateur Radio Operators***". It can be viewed by anyone at an official government website and downloaded and printed.

(This **G U R L** permits the holder of a "***General Amateur Operators Certificate of Competency***" to operate an amateur radio station in New Zealand. This G U R L lists terms, conditions and restrictions, including a schedule of the amateur radio frequency bands.)

2. The "***General Amateur Operators Certificate of Competency***". Amateur Radio Operators are qualified persons, they have each passed a written examination and each is the holder of an individual ***Certificate of Competency***.

(Each operator's name, address and other information is entered and held in an official on-line database ("SMART"). The Certificate is downloaded and printed from this SMART and is kept in the possession of the individual operator.)

Each **"*Certificate of Competency*"** identifies the operator and lists one or more individual and unique ***callsigns***, unique to that individual operator. The callsign(s) listed on the Certificate are used on-air by the named operator to identify that particular station.

You must know and understand more about these two documents.

The GURL: A copy is attached in *Appendix 3*. Study it carefully. It is available at: **http://www.rsm.govt.nz/licensing/gurls/gurl-amateur.html**

The Certificate of Competency: The Amateur Radio ***database records*** are held by the ***Ministry of Economic Development, Radio Spectrum Management Group's*** **SMART -** "***S****pectrum* ***M****anagement* ***A****nd* ***R****egistration* ***T****echnology*". SMART is accessible on-line by anyone for viewing any certificate-holder's callsign and information: **http://www.rsm.med.govt.nz/pls/web/dbssiten.main**

With the aid of a supplied confidential "*Client Key*" and "*Password*", each amateur operator, i.e. you as a certificate and callsign holder, has access to your personal contact details in the database. You are required to keep your own address and other contact details up-to-date. You can also order a replacement *Certificate of Competency* and it can be emailed to you.

If you don't have the facilities to do this on-line, an **ARX** (Approved Radio Examiner) can do it for you. An ARX is a person authorised to make new entries to the database for candidates who pass the Amateur Radio Examination and, among other things, to arrange callsigns for newly-qualified amateurs.

A list of persons with ARX privileges can be found on the web at: **http://www.rsm.govt.nz/cms/licensing/radio-operator-certificates-and-callsigns/list-of-approved-examiners**

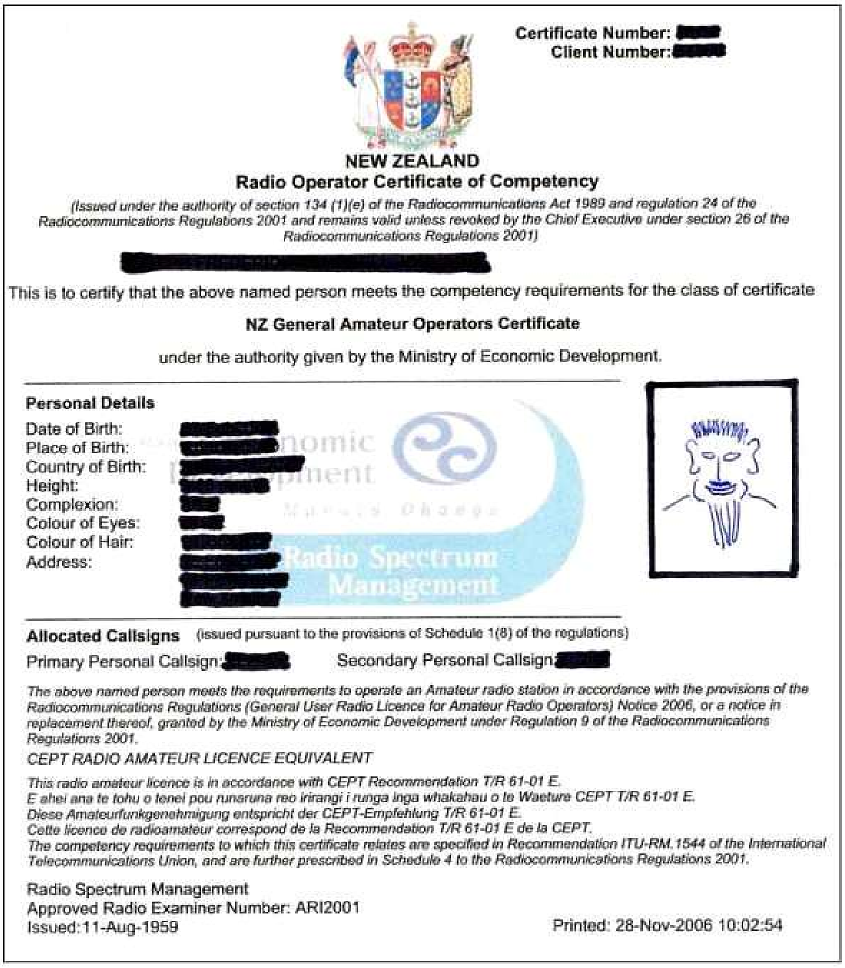
An ARX can attend to these matters for you. There may be a fee charged by some to cover the costs of these administrative services. Exact procedures may vary between ARXs.

The Regulations:

The **Amateur Radio Examination** requires a knowledge of the relevant ***national*** and ***international*** regulations, as covered in this booklet. An understanding of some basic radio theory and some radio operating knowledge is also required.

Please refer to the downloadable **SYLLABUS** and **QUESTION BANK** documents to see the ***coverage*** and the ***standard of knowledge required*** for the examination.

There are two "Radio Regulations" documents - the **International Radio Regulations** and our **New Zealand Radio Regulations**. You are expected to have an understanding of both of them. ***It is not necessary to learn them off in parrot-fashion!*** The important parts are here:



Certificate Number: [redacted]
Client Number: [redacted]

NEW ZEALAND
Radio Operator Certificate of Competency
(Issued under the authority of section 134 (1)(e) of the Radiocommunications Act 1989 and regulation 24 of the Radiocommunications Regulations 2001 and remains valid unless revoked by the Chief Executive under section 26 of the Radiocommunications Regulations 2001)

[redacted]

This is to certify that the above named person meets the competency requirements for the class of certificate

NZ General Amateur Operators Certificate

under the authority given by the Ministry of Economic Development.

Personal Details
Date of Birth: [redacted]
Place of Birth: [redacted]
Country of Birth: [redacted]
Height: [redacted]
Complexion: [redacted]
Colour of Eyes: [redacted]
Colour of Hair: [redacted]
Address: [redacted]

Allocated Callsigns (issued pursuant to the provisions of Schedule 1(8) of the regulations)
Primary Personal Callsign: [redacted] Secondary Personal Callsign: [redacted]

The above named person meets the requirements to operate an Amateur radio station in accordance with the provisions of the Radiocommunications Regulations (General User Radio Licence for Amateur Radio Operators) Notice 2006, or a notice in replacement thereof, granted by the Ministry of Economic Development under Regulation 9 of the Radiocommunications Regulations 2001.

CEPT RADIO AMATEUR LICENCE EQUIVALENT

This radio amateur licence is in accordance with CEPT Recommendation T/R 61-01 E.
E ahei ana te tohu o tenei pou runaruna reo irirangi i runga inga whakahau o te Waeture CEPT T/R 61-01 E.
Diese Amateurfunkgenehmigung entspricht der CEPT-Empfehlung T/R 61-01 E.
Cette licence de radioamateur correspond de la Recommendation T/R 61-01 E de la CEPT.
The competency requirements to which this certificate relates are specified in Recommendation ITU-RM.1544 of the International Telecommunications Union, and are further prescribed in Schedule 4 to the Radiocommunications Regulations 2001.

Radio Spectrum Management
Approved Radio Examiner Number: ARI2001
Issued: 11-Aug-1959 Printed: 28-Nov-2006 10:02:54

Regions:

For regulatory purposes, the International Radio Regulations divide the world into three 'Regions':

Region 1 is Europe, the 'old USSR' areas and Africa.

Region 2 is North and South America.

Region 3 is the rest of the world, including New Zealand.

The radio frequency allocations can differ between the three regions, but at this time this does not concern your studies for the amateur radio examination.

More background:

You should know about these **INTERNATIONAL** and **LOCAL** organisations:

The ITU: The world telecommunications body

The International Telecommunication Union

The International Telecommunication Union, headquartered in Geneva, Switzerland, is an international organisation within which governments and the private sector coordinate global telecom networks and services. It is an agency of the United Nations.

It can be viewed as an assembly of ***representatives from governments***. Further details may be obtained from the ITU web page: http://www.itu.int/

Through its various conferences and activities, the ITU produces the ***International Radio Regulations***. This document is constantly evolving through the work of ITU conferences.

As shown in *Appendix 1*, the Amateur Service is listed in these regulations, with many matters concerning the Amateur Service in Article 25. This sets many aspects of the activities of radio amateurs.

New Zealand is a member of the ITU and the Ministry of Economic Development (MED), Radio Spectrum Management Group (RSM) attends to ITU matters for the New Zealand government.

The New Zealand ***Administration*** is ***the Ministry of Economic Development (MED) Radio Spectrum Management*** *group* ***(RSM).***

The MED web page with spectrum management detail is at: **http://www.med.govt.nz/rsm**

1. Extracts from the *International* Radio Regulations:

The International Radio Regulations of interest to radio amateurs are collected here in *Appendix 1***.** Important regulations are in Article 25.

2. Extracts from the *New Zealand* Radio Regulations:

A copy of **Schedule 1** from the New Zealand Radiocommunications Regulations 2001 is attached here. See *Appendix 2*.

(Note the reference to the ***International Radio Regulations*** *in* ***1*** *and* ***2*** *of* ***Schedule 1 to the NZ Regulations****.)*

(**For reference purposes:** The complete NZ Radiocommunications **Regulations** 2001 and the Radiocommunications **Act** can be found at: **www.legislation.govt.nz**)

Both the International and the New Zealand Radio Regulations give authority for the issuing of radio licences - but we don't need to go looking to find the exact regulations or to study their words.

Two important **Amateur Radio** definitions taken from the ***International Radio Regulations*** are:

1.56 *amateur service:* A *radiocommunication service* for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest.

1.57 *amateur-satellite service:* A *radiocommunication service* using *space stations* on earth *satellites* for the same purposes as those of the *amateur service*.

The IARU: The world amateur radio body

The International Amateur Radio Union

Because it uses an international natural resource, the radio spectrum, Amateur Radio must organise nationally and internationally for better mutual use of the radio spectrum among radio amateurs throughout the world, to develop Amateur Radio worldwide, and to successfully interact with the agencies responsible for regulating and allocating radio frequencies.

At the international level, national societies throughout the world work together for the international good of Amateur Radio under the auspices of the International Amateur Radio Union (IARU). The IARU web page is at: **http://www.iaru.org**

The IARU is an organisation in which its ***Members*** are Amateur Radio ***societies***.

Created in Paris in 1925, the IARU has been the watchdog and spokesman for the world Amateur Radio community.

The IARU Constitution organises the Union into three Regional Organisations that correspond to the three administrative regions of the ITU. (See IARU Region 3 following.)

The IARU is a member of the ITU Radio Sector and the ITU Development Sector. Representatives from IARU may attend ITU meetings and conferences, representing the Amateur Service and the Amateur Satellite Service.

The IARU has its headquarters, the 'International Secretariat', at the headquarters of the USA society, the American Radio Relay League (ARRL), in Newington, Connecticut, USA.

The prime purpose of the IARU is the ***protection of the Amateur Services***. The IARU objectives, as shown in the IARU Constitution, are:

1. The name of this organization is the International Amateur Radio Union (IARU), hereinafter also referred to as the IARU.

2. Its objectives shall be the protection, promotion, and advancement of the Amateur and Amateur-Satellite Services within the framework of regulations established by the International Telecommunication Union, and to provide support to Member-Societies in the pursuit of these objectives at the national level, with special reference to the following:

a) representation of the interests of amateur radio at and between conferences and meetings of international telecommunications organizations;

b) encouragement of agreements between national amateur radio societies on matters of common interest;

c) enhancement of amateur radio as a means of technical self-training for young people;

d) promotion of technical and scientific investigations in the field of radiocommunication;

e) promotion of amateur radio as a means of providing relief in the event of natural disasters;

f) encouragement of international goodwill and friendship;

g) support of Member-Societies in developing amateur radio as a valuable national resource, particularly in developing countries; and

h) development of amateur radio in those countries not represented by Member-Societies.

The IARU Constitution may be viewed at:
http://www.iaru.org/iarucnst.htm

NZART: New Zealand's society for radio amateurs

The New Zealand Association of Radio Transmitters Incorporated

Founded in 1926, the New Zealand Association of Radio Transmitters (NZART), is recognised by the New Zealand Government as the body representing New Zealand's radio amateurs. Further details about NZART can be obtained from its web page: **http://www.nzart.org.nz/**

There are several categories of NZART membership which include 'Transmitting' and 'Non-Transmitting'. Anyone interested in radio can join. YOU SHOULD JOIN TODAY! Enquiries to NZART, P.O. Box 40 525, Upper Hutt or to **nzart@nzart.org.nz**

The Objectives of the NZART are given in the NZART Constitution at:
http://www.nzart.org.nz/nzart/nzart/NZARTConstitution.pdf

NZART has been a member of IARU since 1929.

IARU Region 3: The REGIONAL amateur radio body:

IARU Region 3

IARU has adopted the same three Regions as the ITU and each Region has its own amateur radio organisation. IARU Region 3 was founded in Sydney in 1968 with NZART one of the founding member societies. The Headquarters of IARU Region 3 is in Tokyo, Japan, at the headquarters of the Japan Amateur Radio League (JARL).

The Objects of IARU Region 3 are similar to those of IARU but centred on the Asia-Pacific area. An IARU Region 3 web page is at:

http://www.jarl.or.jp/iaru-r3/

The following extract is from the IARU Region 3 Constitution:

‘The name of the organisation shall be the International Amateur Radio Union Region 3 herein called 'IARU Region 3.

Object and Activities:

The object of IARU Region 3 is to

promote, represent and advance in whatsoever manner IARU Region 3 thinks fit, the interest of Radio Amateurs in all countries of Region 3 of the International Telecommunications Union (and without limiting the generality of the foregoing)

by the furtherance of the objects of the International Amateur Radio Union and

having regard to the special interest of radio amateurs in Asia and Oceania

which interests are to protect and enhance radio amateur privileges in all of the countries in the Region,

to encourage an awareness of the value of radio amateurs by the administrations of all the countries in the Region,

to educate and encourage potential radio amateurs in all of the countries of the Region,

to represent radio amateurs both nationally and internationally, and

to protect and retain amateur radio frequency allocation as frequencies allocated for the sole use of radio amateurs

and provided always shall exercise its powers in support of IARU and not in substitution for the exercise of power by IARU.'

How does all this fit together?

Every two years or so, the **ITU** holds an international **conference**, at which the ***International Radio Regulations*** and other documents are discussed and modified. New Zealand is represented at these conferences by a delegation led by the New Zealand *Ministry of Economic Development* (MED), *Radio Spectrum Management Group* (RSM). An NZART member may sometimes be a part of the New Zealand Delegation to represent the Amateur Service. The MED RSM is **the New Zealand "Administration"**.

Each **IARU Region** holds a **conference** every three years and these are arranged in sequence, so there is a regional amateur radio conference held each year in one of the three regions.

National Radio Regulations:

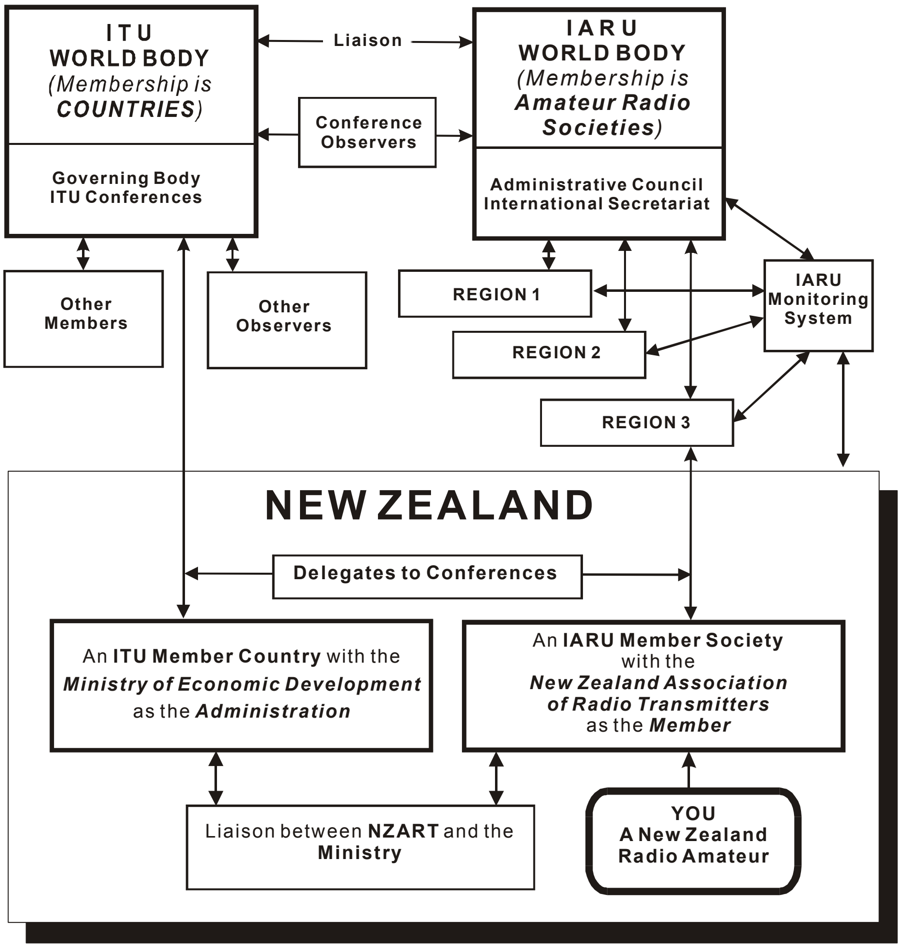
Countries set additional local licensing conditions for their radio amateurs. These differ greatly in detail, but all should conform to the *International Radio Regulations*.

As stated earlier, the current document is the ***New Zealand Radiocommunications Regulations 2001***. Those Regulations set many things a radio amateur must observe. Many of these are considered below.

So, how do I get started?

If you require assistance with your studies, or wish to attend a class, or when you are ready for an examination, you should contact your local Amateur Radio club. Contact details are given on web sites.

You will soon require the services of an "Approved Radio Examiner" (ARX) - approved by the Ministry of Economic Development, Radio Spectrum Management Group. The ARX will be pleased to provide any further information you may require. Contact details are on the MED RSM website.



A "***General Amateur Operators Certificate of Competency***", in your name, with a ***callsign,*** can be granted after passing a written examination.

The diagram shown on the front page of this booklet gives the sequence to follow to obtain the amateur radio qualification.

The Examination Process:

*(In New Zealand there is only **one** amateur radio examination and **one** grade of licence. Some countries have several examinations that must be attempted and passed in sequence - with several grades of licence too.)*

The written examination comprises 60 multiple-choice questions covering **Regulations** and **Theory** in a single two-hour examination. This is conducted by appointment and held at a mutually-agreed place and time by volunteer Examination Supervisors.

The written test uses questions randomly selected from a 600-question public-domain question-bank. The STUDY GUIDE contains ***ALL*** those questions and some sample tests for you to try! A booklet with all the questions in the question-bank can be downloaded from the website.

A **pass** requires **40 or more** correct answers. Your (provisional) result is given to you after the examination, on the spot. A successful "*Radio Examination Result*" (RER) is recognised by the MED RSM for certificate/callsign application purposes. An ARX can enter the results of a successful candidate into SMART and set up the records for a new client radio amateur, including selecting a callsign.

Variations to the established Examining Process:

The Radiocommunications Regulations 2001 Regulation 28 (2) provides, at the MED Chief Executive's discretion, for variation to the manner in which an examination is carried out. If there is need to vary the examination process for a candidate with a particular disability, the local Examination Supervisors should ensure the candidate is fully aware of the established exam procedure and is encouraged to state a preferred variation to the examination procedure as determined by personal circumstances. The Supervisors should approach the MED RSM Head Office with a recommendation for a variation to the examining process and obtain approval for that variation before the examination takes place. The Ministry will deal with each case as it arises and sees referral by a medical expert and use of a neutral reader/writer as its preferred option.

Receiving a Certificate:

A *Radio Examination Result* (RER) is issued on-the-spot after each examination by the examination Supervisors. This is provisional until the results are checked and confirmed by the ARX. A successful RER is recognised for certificate-application purposes. The Certificate of Competency is emailed after the ARX has successfully put the entries into SMART. *(RSM's Spectrum Management and Registration Technology*). You can feel really proud and hang a ***certificate*** on your wall to recognise your achievement. You have a qualification that has international recognition.

Callsigns:

The ARX will set up your callsign at the time when your personal and examination result details are first entered into SMART.

The arrangements and the format for the ARX to follow when generating an amateur radio callsign are given in the Ministry's public information brochure "***Approved Radio Examiners (ARX) Manual – Radio Operator Certificate and Callsign Rules***" document **PIB46**. This Brochure is available from the Ministry of Economic Development, Radio Spectrum Management Group web site.

More can be learned about callsigns by investigating the MED RSM website and by checking existing and yet-to-be-allocated callsigns using the SMART on-line facility.

Find some not-yet-allocated ones! Your callsign selections should fit the regular broad patterns: ZL1, ZL2, ZL3 or ZL4, with a two-or-three-letter suffix.

After a successful examination you will be asked to provide your choice of ***several* callsign selections, *in priority order***, to the ARX with your **RER** and **Radio4A** form, all completed and legible. This is your application to become a radio amateur.

An operator can request the address to be withheld for privacy reasons - but remember that some stations worked prefer to post their QSL cards direct to you (to confirm your contact) and will require your address. Let your address be seen.

Applications for a New Callsign

Candidates wishing to sit the amateur radio examination must present some official document to confirm their identity and must also **present a passport photo ID** complete with a witness' signature confirming the identity of the candidate. For a successful candidate, this will later be placed electronically on the Certificate of Competency.

Application form **Radio 4A** will be provided by the Supervisors and must be completed by the applicant and sent together with the **passport photo ID** and the RER to the ARX for checking and processing.

Please ensure that ALL the information entered on these forms is accurate, clear and READABLE!

Where an e-mail address is provided by the candidate, upon completion by the ARX of processing a new amateur's details on-line in SMART, a copy of the certificate will be sent direct to the candidate by e-mail.

If all the information above is not provided at the processing time, or if the information provided is illegible, the application will be delayed and a callsign cannot be issued.

Existing Callsign Holders

Existing callsign holders have received a special Client ID and password from the RSM Office giving on-line access to their records in the Ministry's new SMART system.

The callsign holder can make change-of-address, amend other contact details and request a replacement certificate on-line. There are no fees to access your own information or to make any amendments yourself. A hard-copy certificate, printed in colour, and framed, can then be arranged by yourself.

NOTE: You are required by the Radio Regulations to make updating changes to your permanent address within 7 days or arrange for an ARX to do it for you.

Should your Client ID and password have been misplaced, reactivate it by contacting the RSM Processing Centre Freephone: 0508 776 463.

Amateur Radio Operating Conditions:

The amateur radio qualification does not permit operation for commercial or business purposes, or for "pecuniary gain" (i.e. for making money). (See the ***definition*** of the **Amateur Service.)**

A General Amateur Operators Certificate of Competency entitles the holder to operate transmitters in the ***bands of frequencies*** designated for amateur radio use in the GURL.

Please note that the GURL and the Certificate do not specify any ***transmission mode*** to be used on any ***amateur band***. That is the licensee's choice. (Note too the details about Band-planning discussed below.)

Note that ***radio amateurs*** are permitted to use the designated industrial, scientific and medical (***ISM***) band at 27.12 MHz ***for telecontrol and telemetry operation only.*** It is ***not an amateur band*** but all amateurs are permitted to use it.

Amateur stations may communicate with other amateur stations ***only***. Amateurs may **not** communicate with commercial or other stations operating legally or illegally either inside or outside the designated amateur bands.

The only exception to this is under ***emergency conditions***. This approval is specified in the *International Radio Regulations* (see **RR 4.9**). If safety of human life is at risk, communication on any frequency by anyone is permitted. Very occasionally a distress call has been received by an amateur operator. If no official station replies, an amateur may make contact and should also immediately alert the NZ Police. If an official station does reply, all other stations are obliged to clear the frequency.

A visiting amateur should use his/her own callsign if in control of a station visited. If the owner is present and in control, it is permitted to use the owner's callsign.

Regulatory information undergoes frequent revision and circumstances change, so you are advised to check the MED RSM web site from time-to-time to check for up-to-date versions of the GURL and other documents. **http://www.med.govt.nz/rsm.**

The MED RSM will give sympathetic consideration to requests for ***reasoned variation*** to individual amateur operating conditions. An example is the temporary use of higher-power for moon-bounce experiments.

Other important points are:

There is no upper or lower age limit.

Your certificate can be inspected by an authorised officer from the MED at any time.

You must be a citizen or a permanent resident of New Zealand, to receive a New Zealand callsign.

If you change your residential address, you must change your contact information on the Ministry's database within 7 days. If you cannot do this yourself, ask an ARX to do it for you.

To replace your lost certificate, you yourself can download one or get a new one downloaded by an ARX from the MED RSM's SMART.

All amateur stations, regardless of the mode of transmission used, must be equipped with a reliable means for determining the operating radio frequency.

You must announce your callsign at least once in 15 minutes when operating.

It is important to note that radio amateurs are not "broadcasters". The transmission of music and entertainment by radio amateurs is ***not permitted***.There is a separate ITU definition for broadcasters: "*Broadcasting Service:* A *radiocommunication service* in which the transmissions are intended for direct reception by the general public ..."etc. You are not permitted to make broadcasts.

When first on the Air:

On receiving your certificate and callsign you are permitted to operate only on the bands below 5 MHz and on the bands above 25 MHz. After experiencing three months of practical operating and with 50 or more contacts in your log book, you are then permitted to operate on all the amateur bands. You must keep the log book and produce it on request. See paragraph 3(3) in the GURL.

Log Books:

You are required to keep a station log book to log at least 50 contacts when you are first qualified. This is the only regulatory requirement for a log book. However, it is recommended that radio amateurs keep a log book for at least two important reasons:

First, it is a record of your operating and may be a useful record and protection for when a neighbour reports interference to broadcast or television reception. Were you actually operating at the time claimed?

Second, it is an important document for amateur radio contests and awards – and for keeping track of each QSO and its QSL card actions, noting the cards sent and the cards received.

A suitable station log book with columns for the appropriate entries can be purchased from amateur radio suppliers.

Third Party Traffic:

Other people ("third parties") may pass "brief personal messages" using an amateur's station ***only if*** the owner/operator is present and in control of the station. They should not manipulate the transmitting controls of the station. Under no circumstances may an unqualified person operate an amateur's station.

New Zealand permits third party traffic with any other country. But **BEWARE**! Other countries **may not be permitted to handle third party traffic with you**. Some countries have country-to-country diplomatic agreements for amateur radio third-party traffic. New Zealand is not a party to any such agreement. This situation can only be changed by the other country, it is not New Zealand's problem. So make sure that the station you work is permitted to handle third-party traffic with you before doing so. Don't put your certificate or the certificate/licence of the distant station at risk.

NZART has developed a document "*Guidelines for THIRD PARTY TRAFFIC*". A copy can be obtained from NZART Headquarters.

The internet is now frequently used for station linking. Be sure that unlicensed persons cannot get access to amateur radio spectrum.

Mobile and portable operating:

A separate licence/qualification and callsign is not necessary when "operating mobile" or when "operating portable". Use your home station callsign and *call*/P or *call*/M when using CW and "*callsign* Mobile", or "*callsign* Portable" when away from home for short periods.

No "secret codes":

Amateur radio communication is **NOT** permitted to use ***"secret codes"*** at any time. Encryption of messages for the purpose of *hiding the contents* from other amateurs or listeners is illegal.

The only exception is for ***licensees*** of repeaters and beacon stations and for satellites to carry out control functions. A different licence is issued for a repeater station and for a beacon station. Establishing a repeater or beacon station is ***not permitted under the amateur operator GURL***.

Some modes (for example packet radio and PSK31) *do* use forms of encryption, but these are legal because the decoding protocols are public knowledge and can in principle be decoded by other amateurs and by monitoring stations. The Q-Code is public knowledge!

Overseas Travellers:

Overseas radio amateurs visiting New Zealand:

The amateur radio GURL provides for overseas radio amateurs who intend to visit and to operate their own station in New Zealand.

In effect, the overseas visitor can walk down the gangplank and commence operating immediately upon arrival in New Zealand! A "*General User Radio Licence*" (GURL) is a licence that provides for a given class of radio transmitter to be used without requiring a licence in the owner's own name.

New Zealand radio amateurs travelling overseas:

New Zealand amateur radio qualifications are widely recognised overseas. Reciprocal licensing agreements of several different kinds exist between New Zealand and many other countries.

New Zealand operators who are contemplating travelling overseas are advised to contact the ***NZART Reciprocal Licensing Bureau***, (an NZART Service), for up-to-date information about using the New Zealand qualification overseas or getting a local licence to operate in other countries. There are different systems in place in different countries. Check the website of the amateur radio society in the country you intend to visit.

If a Morse code test pass is required for a reciprocal licence, a Morse test can be arranged with NZART Morse Testers.

Overseas regulatory arrangements and requirements are always changing so an early enquiry before travel would be wise. The web pages of some overseas administrations may give the information and the procedures required. See also:
www.arrl.org/field/regulations/io/recip-country.html

Harmful Interference:

Harmful interference is defined in the International Radio Regulations (See **RR 1.169**). In short, it is *any radiation or emission which seriously obstructs or repeatedly interrupts other licensed radio services.*

Amateurs are not permitted to block or to interfere with another amateur's transmissions. Such deliberate transmissions would create "malicious" interference.

Television interference (TVI) caused to neighbours is *not necessarily harmful interference* if the amateur is transmitting signals free from spurious radiation within the terms of the GURL.

It is ***correct operating practice*** to check that the frequency you propose to use is free from other users ***BEFORE*** you transmit.

Unwanted Emissions

The GURL in para 5 (9) refers to ***unwanted emissions*** and to the ETSI document: ETS 300 684. (You can find this on-line using Google.) The important points are on page 6 (where it refers to commercial "amateur" equipment only) and on page 23 (where levels of measurement are given).

The GURL makes it clear that these measurements refer to ***all*** unwanted transmissions from amateur gear that fall ***outside amateur bands***. This is encouragement for home-constructors of transmitting equipment. The view taken is that "*what amateurs do within their own bands is their own problem and for them to fix*". Keep your transmissions "clean"!

Transmitter Power Output:

The GURL in para 5 (5) states that the radio frequency power output shall not exceed 500 watt peak envelope power (PEP). Note: It is independent of mode. The definition **1.157** is in the International Radio Regulations.

The technicalities of this matter are considered in the Study Guide.

At *all times* amateurs are required to use *the **minimum** power and **minimum** bandwidth necessary to ensure satisfactory service.*

Frequency Bands:

A knowledge of the frequency bands between 130 kHz and 440 MHz is required for the examination. (See the GURL, *Appendix 3*).

The International Radio Regulations, in Article 2, say that as the unit of frequency is the hertz (Hz), frequencies shall be expressed:

– in kilohertz (kHz), up to and including 3 000 kHz;

– in megahertz (MHz), above 3 MHz, up to and including 3 000 MHz;

– in gigahertz (GHz), above 3 GHz, up to and including 3 000 GHz.

Note: Prefix: k = kilo (10^3), M = mega (10^6), G = giga (10^9).

Symbols	Frequency range (lower limit exclusive, upper limit inclusive)	Corresponding Metric Subdivision
VLF	3 to 30 kHz	Myriametric waves
LF	30 to 300 kHz	Kilometric waves
MF	300 to 3 000 kHz	Hectometric waves
HF	3 to 30 MHz	Decametric waves
VHF	30 to 300 MHz	Metric waves
UHF	300 to 3 000 MHz	Decimetric waves
SHF	3 to 30 GHz	Centimetric waves
EHF	30 to 300 GHz	Millimetric waves
	300 to 3 000 GHz	Decimillimetric waves

Sharing of Bands:

Amateurs share some frequency bands with stations of other services. Full details about "sharing" are provided in the *International Radio Regulations* but only the general principles of sharing and the bands involved are needed for this examination.

Several ***Notes*** to the Amateur Frequency Allocation Chart (in the GURL), explain the use by amateur stations of the "shared bands". See ***"Notes 2 and 3 to the Table".***

Favourable access by radio amateurs to some bands used by other radio services has been given by the regulatory authorities. It is very important that these arrangements be respected so they can continue. The golden rule is: **Don't cause any interference to any other stations.**

As an amateur station licensee, you have "frequency agility", you can change your operating frequency to avoid other stations. Other services may be licensed for one assigned frequency only and cannot shift.

Additional note regarding other bands:

The band 50 to 54 MHz is shown in the *International Radio Regulations* as AMATEUR but in New Zealand, only 51 to 53 MHz is available. Because the band 50 - 51 MHz is used by commercial television in New Zealand, a special permit is required and may be available from MED RSM for amateur stations wishing to operate there. Special conditions apply. (Permits can usually only be considered for amateur stations located outside the coverage areas of 44 to 51 MHz television stations.)

Two spot frequencies near 5 MHz are available for use by the ***Amateur Radio Emergency Communications*** (AREC). Special conditions apply.

AREC is also permitted to use the band-edge 3.9 MHz upper-sideband.

A special band for Amateur Television (ATV) repeater use is under negotiation and will have special conditions which are administered by FMTAG.

Frequency Band	Metre Band
130-190 kHz	1750 metres
505-515 kHz	600 metres
1800-1950 kHz	160 metres
3.50-3.90 MHz	80 metres
7.00-7.30 MHz	40 metres
10.10-10.15 MHz	30 metres
14.00-14.350 MHz	20 metres
18.068-18.168 MHz	17 metres
21.00-21.45 MHz	15 metres
24.89-24.99 MHz	12 metres
27.12 MHz	11 metres
28.00-29.70 MHz	10 metres
50.00-54.00 MHz	6 metres
144.0-148.0 MHz	2 metres
430-440 MHz	70 centimetres

Amateur Radio Bandplanning and Frequency Coordination:

NZART has a group called FMTAG, the ***NZART Frequency Management and Technical Advisory Group***, to coordinate the use of the amateur radio bands in New Zealand. This is a group of volunteers who advise the NZART Council on technical matters, including those relating to the frequencies to be used for VHF/UHF repeaters and beacons.

The ***Amateur Frequency Allocation Chart*** (in the GURL) sets down the bands ***to which a radio amateur has access***. How radio amateurs can best organise themselves for operations ***within those bands*** is notified by the ***Bandplans*** which are published from time-to-time usually in the NZART Annual CallBook and on the website.

A letter from the New Zealand Administration, the NZ Post Office at that time and published in "*Break-In*", July 1983, pages 2, 3 and 4, made radio amateurs ***responsible for their own band-planning***. FMTAG is the NZART response for this national task.

The bandplans are ***to ensure that your operations do not impose problems on other operators and that their operations do not impact on you.*** It is to the mutual advantage of all operators that the published bandplan provisions be respected.

Please note that all radio amateurs have equal "rights" to use amateur radio frequencies. This means that courtesy in operating must prevail.

It is ***correct operating practice*** to check that the frequency you propose to use is free from other users ***BEFORE*** you transmit.

No radio licence confers upon its holder a monopoly on the use of any frequency or frequency band specified on the radio licence. (See the NZ Regulations, *Schedule 1*, 6, in *Appendix 2*.)

Compliance and Enforcement:

The enforcement for non-compliance with, or breaching of, any regulatory condition is a clear ***Ministry function***. There is no question about this – it is a statutory function. **The Ministry has compliance auditing and enforcement arrangements in place, active and being strengthened.**

You have worked hard to obtain your AMATEUR RADIO QUALIFICATION. Value it. Don't put it at risk. Be aware of the conditions and restrictions under which you can operate. By world standards these are very liberal. Respect them at all times.

Possession and Presumptions

The Radiocommunications **ACT** (note: the ***ACT*** not the Regulations – see Reference on page 3) says (in Part 13, Radio Licences):

"114 Presumptions

(1) For the purposes of section 113, any person who erects, constructs, establishes, maintains, or is in possession of any radio transmitter is presumed to have used the radio transmitter unless and until the contrary is proved.

(2) Where a radio transmitter is temporarily inoperative or has been partially dismantled, that radio transmitter is deemed to be, and to remain, capable of transmitting radiocommunications unless the Secretary is satisfied that the transmitter has been rendered inoperative."

Possession of a (temporarily disabled) transmitter by someone who is not holder of a licence of some sort or another can be deemed illegal. This point is also in other legislation in various ways. Responsible common-sense is exercised by the authorities.

Amateur Radio - a Summary:

As already explained above, all radio amateurs must hold a *General Amateur Operators* ***Certificate of Competency*** to operate in the frequency bands and under the terms and conditions given in the ***General User Radio Licence*** *for Amateur Radio Operators* and must observe the requirements of the international and national regulations.

Read, re-read, revise, look at the question lists! ***Keep up-to-date with any changes too!***

Appendix 1
Extracts from the International Radio Regulations

The International Radio Regulations are important to all New Zealand radio licence holders. The local *New Zealand Radiocommunications Regulations* include the words:

> "Any radio transmitter operating under a radio licence must comply with the requirements of the International Radio Regulations (to the extent that they reasonably apply to the category of service specified on the radio licence or exemption)".

A complete copy of the *International Radio Regulations*, published by the International Telecommunication Union, can be obtained from the ITU at Geneva. It fills several volumes and is ***very*** expensive (CHF 252). It is also available on CD-ROM at a similar cost.

The following regulations, extracted from the International Radio Regulations, are those of most importance to radio amateurs.

ARTICLE 1

Terms and Definitions

1.2 *Administration:* Any governmental department or service responsible for discharging the obligations undertaken in the Constitution of the International Telecommunication Union, in the Convention of the International Telecommunication Union and in the Administrative Regulations.

1.56 *Amateur Service:* A *radiocommunication service* for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest.

1.57 *Amateur-Satellite Service:* A *radiocommunication service* using *space stations* on earth *satellites* for the same purposes as those of the *amateur service*.

1.157 *peak envelope power* (of a radio transmitter)*:* The average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle at the crest of the modulation envelope taken under normal operating conditions.

1.166 *Interference:* The effect of unwanted energy due to one or a combination of *emissions*, *radiations*, or inductions upon reception in a *radiocommunication* system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.

1.169 *Harmful Interference: Interference* which endangers the functioning of a *radionavigation service* or of other *safety services* or seriously degrades, obstructs, or repeatedly interrupts a *radiocommunication service* operating in accordance with these Regulations.

ARTICLE 4

Assignment and Use of Frequencies

Section I. General Rules

4.4 Administrations of the Members shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations.

4.9 No provision of these Regulations prevents the use by a station in distress, or by a station providing assistance to it, of any means of radiocommunication at its disposal to attract attention, make known the condition and location of the station in distress, and obtain or provide assistance.

ARTICLE 17

Secrecy

17.1 In the application of the appropriate provisions of the Constitution and the Convention, administrations bind themselves to take the necessary measures to prohibit and prevent:

17.2 *a)* the unauthorized interception of radiocommunications not intended for the general use of the public;

17.3 *b)* the divulgence of the contents, simple disclosure of the existence, publication or any use whatever, without authorization of information of any nature whatever obtained by the interception of the radiocommunications mentioned in No. **17.2**.

ARTICLE 18

Licences

18.1 (1) No transmitting station may be established or operated by a private person or by any enterprise without a licence issued in an appropriate form and in conformity with the provisions of these Regulations by or on behalf of the government of the country to which the station in question is subject (however, see Nos. **18.2**, **18.8** and **18.11**).

ARTICLE 22

Space Services

Section I. Cessation of Emissions

22.1 § 1. Space stations shall be fitted with devices to ensure immediate cessation of their radio emissions by telecommand, whenever such cessation is required under the provisions of these Regulations.

ARTICLE 25

Amateur services

Section I – Amateur service

25.1 § 1 Radiocommunication between amateur stations of different countries shall be permitted unless the administration of one of the countries concerned has notified that it objects to such radiocommunications. (WRC-03)

25.2 § 2 1) Transmissions between amateur stations of different countries shall be limited to communications incidental to the purposes of the amateur service, as defined in **No. 1.56** and to remarks of a personal character. (WRC-03)

25.2A 1A) Transmissions between amateur stations of different countries shall not be encoded for the purpose of obscuring their meaning, except for control signals exchanged between earth command stations and space stations in the amateur-satellite service. (WRC-03)

25.3 2) Amateur stations may be used for transmitting international communications on behalf of third parties only in case of emergencies or disaster relief. An administration may determine the applicability of this provision to amateur stations under its jurisdiction. (WRC-03)

25.4 (SUP - WRC-03)

25.5 **§ 3** 1) Administrations shall determine whether or not a person seeking a licence to operate an amateur station shall demonstrate the ability to send and receive texts in Morse code signals. (WRC-03)

25.6 2) Administrations shall verify the operational and technical qualifications of any person wishing to operate an amateur station. Guidance for standards of competence may be found in the most recent version of Recommendation ITU-R M.1544. (WRC-03)

25.7 § 4 The maximum power of amateur stations shall be fixed by the administrations concerned. (WRC-03)

25.8 § 5 1) All pertinent Articles and provisions of the Constitution, the Convention and of these Regulations shall apply to amateur stations. (WRC-03)

25.9 2) During the course of their transmissions, amateur stations shall transmit their call sign at short intervals.

25.9A § 5A Administrations are encouraged to take the necessary steps to allow amateur stations to prepare for and meet communication needs in support of disaster relief. (WRC-03)

25.9B § 5B An administration may determine whether or not to permit a person who has been granted a licence to operate an amateur station by another administration to operate an amateur station while that person is temporarily in its territory, subject to such conditions or restrictions it may impose. (WRC-03)

Section II – Amateur-satellite service

25.10 § 6 The provisions of Section I of this Article shall apply equally, as appropriate, to the amateur-satellite service.

25.11 § 7 Administrations authorizing space stations in the amateur-satellite service shall ensure that sufficient earth command stations are established before launch to ensure that any harmful interference caused by emissions from a station in the amateur-satellite service can be terminated immediately (see No. **22.1**). (WRC-03)

Appendix 2

*Extract from the **New Zealand**:*

RADIOCOMMUNICATIONS REGULATIONS 2001

SCHEDULE 1

TERMS, CONDITIONS, AND RESTRICTIONS APPLYING TO EVERY RADIO LICENCE AND EXEMPTION FROM RADIO LICENSING

1. Technical compliance—

Any radio transmitter operating under a radio licence or an exemption must comply with the requirements of the International Radio Regulations (to the extent that they reasonably apply to the category of service specified on the radio licence or exemption), and with any technical specifications or standards that are specified on the radio licence or exemption, or that may be notified from time to time by the chief executive by notice in the *Gazette*.

2. Operational compliance—

The operation of any radio transmitter operating under a radio licence or exemption must comply with the requirements of the International Radio Regulations to the extent that they reasonably apply to the category of radiocommunication service specified on the radio licence or exemption.

3. Responsibility for observance of provisions—

Observance of all terms, conditions, and restrictions relating to a radio licence or exemption by any person authorised to operate a radio transmitter under a radio licence or exemption remains the personal responsibility of the holder of the radio licence or exemption, as the case may be.

4. Notification of change of address—

If a radio licence applies specifically to a radio transmitter at a particular address, the licensee must, within 7 days of removing the radio transmitter from the address, notify the chief executive of the removal.

5. Compliance with directions—

The holder of a radio licence or an exemption must comply with any directions given by the chief executive, or by any person authorised by the chief executive to give directions on the chief executive's behalf, for the use of the radio transmitter operating under the radio licence or exemption.

6. No monopoly conferred—

No radio licence or exemption confers upon the holder of the radio licence or exemption a monopoly on the use of any frequency or frequencies or frequency band or frequency bands specified on the radio licence or exemption.

7. Operator of radio transmitter to hold valid operator certificate—

If a radio licence specifies that the operator of any radio transmitter operating under the radio licence must be the holder of a certificate of competency of the class specified on the radio licence, the radio transmitter must not be operated by any person who is not the holder of a certificate of competency of the required class or of a certificate recognised by the chief executive.

8. Callsigns—

(1) If a radio licence requires the use of a callsign, the callsign of the person operating the radio transmitter in accordance with the radio licence must be—

(a) the callsign shown on the radio licence; or
(b) the callsign shown on the certificate of competency of the person who is operating the radio transmitter; or
(c) a temporary callsign that the operator is authorised to use in accordance with subclause (2).

(2) The chief executive may, by notice in the *Gazette*, authorise a person or a class of persons to use a temporary callsign for the period, and in accordance with the terms and conditions, specified in the notice.

9. Documents must be available for inspection—

The holder of a radio licence or exemption must arrange for the radio licence or exemption, as the case may be, to be available at all times for inspection by an authorised officer.

10. Dismantling of radio transmitter when contravention has taken place—

If an authorised officer is of the opinion that a contravention of the Act or these regulations has taken place and requires that a radio transmitter cease operating, the licensee under the relevant radio licence must comply with the requirement.

Appendix 3

Extract from the *New Zealand Gazette*, 15/7/2010, No. 83, p. 2270

[The text is spread out here to make it more "readable"!]

Amateur radio operators

Pursuant to section 111 of the Radiocommunications Act 1989 and Regulation 9 of the Radiocommunications Regulations 2001, and acting under delegated authority from the chief executive, I give the following notice.

Notice

1. Short title and commencement

1. This notice is the Radiocommunications Regulations (General User Radio Licence for Amateur Radio Operators) Notice 2010.
2. This notice comes into force on 12 August 2010.

2. General user radio licence

A general user radio licence is granted for the transmission of radio waves by amateur radio operators in New Zealand, for the purpose of communications in the amateur radio service in accordance with the terms, conditions and restrictions of this notice.

3. Terms, conditions and restrictions applying to New Zealand amateur operators

1. Persons who hold a General Amateur Operator's Certificate of Competency and a callsign issued pursuant to the Regulations may operate an amateur radio station in New Zealand.
2. The callsign prefix of "ZL" may be substituted with the prefix "ZM" by the callsign holder for the period of, and participation in, a recognised contest, or as the control station for special event communications.
3. Operation on amateur bands between 5 MHz and 25 MHz is not permitted unless a person has held a General Amateur Operators Certificate of Competency for three months and logged 50 contacts during this period. The person must keep the logbook record for at least one year and, during this period, produce it at the request of the chief executive.

4. Terms, conditions and restrictions applying to visiting amateur operators

1. Persons visiting New Zealand who hold a current amateur certificate of competency, authorisation or licence issued by another administration, may operate an amateur station in New Zealand for a period not exceeding 90 days, provided the certificate, authorisation or licence meets the requirements of Recommendation ITU-R M.1544 or CEPT T/R 61-01 or CEPT T/R 61-02 and is produced at the request of the chief executive.
2. The visiting overseas operator must use the national callsign allocated by the other administration to the operator, in conjunction with the prefix or suffix "ZL" which is to be separated from the national callsign by the character "/" (telegraphy), or the word "stroke" (telephony).

5. Terms, conditions and restrictions applying to all amateur operators

1. The use of callsigns, including temporary and club callsigns, must be in accordance with publication PIB 46 "Radio Operator Certificate and Callsign Rules" published at www.rsm.govt.nz
2. Callsigns must be transmitted at least once every 15 minutes during communications.
3. National and international communication is permitted only between amateur stations, and is limited to matters of a personal nature, or for the purpose of self-training, intercommunication and radio technology investigation, solely with a personal aim and without pecuniary interest. The passing of brief messages of a personal nature on behalf of other persons is also permitted, provided no fees or other consideration is requested or accepted.
4. Communications must not be encoded for the purpose of obscuring their meaning, except for control signals by the operators of remotely controlled amateur stations.
5. Except as provided to the contrary in this notice, transmitter power output must not exceed 500 watts peak envelope power (pX), as defined in ITU Radio Regulation 1.157.

6. Amateur stations must, as far as is compatible with practical considerations, comply with the latest ITU-R recommendations to the extent applicable to the amateur service.
7. In accordance with Article 25 of the International Radio Regulations, amateur operators are encouraged to prepare for, and meet, communication needs in support of disaster relief.
8. Amateur beacons, repeaters and fixed links may not be established pursuant to this licence.
9. Unwanted emissions outside the frequency bands specified in this schedule must comply with the requirements of technical standard ETSI ETS 300 684 published by the European Telecommunications Standards Institute (ETSI). This general user radio licence applies only to transmissions within the frequency ranges set out in the Schedule to this licence. All such transmissions must be made in accordance with the notes for the frequency range in which that transmission take place and in accordance with the other conditions set out in this licence.

6. Consequential revocation of licences

The Radiocommunication Regulations (General User Radio Licence for Amateur Radio Operators) Notice 2010 dated the 9th day of February 2010 and published in the New Zealand Gazette, 18 February 2010, No. 18, page 430, is revoked.

Schedule

Frequency Range	Notes
130 to 190 kHz	2, 4, 6
505 to 515 kHz	2,4,7,8
1.80 to 1.95 MHz	2
3.50 to 3.90 MHz	2
7.00 to 7.10 MHz	1
7.10 to 7.20 MHz	
7.20 to 7.30 MHz	2
10.10 to 10.15 MHz	2
14.00 to 14.35 MHz	1
18.068 to 18.168 MHz	1
21.00 to 21.45 MHz	1
24.89 to 24.99 MHz	1
26.95 to 27.30 MHz	2, 3, 5, 6
28.00 to 29.70 MHz	1
51.00 to 53.00 MHz	2
144.00 to 146.00 MHz	1
146.00 to 148.00 MHz	2
430.00 to 440.00 MHz	1, 2, 3
921.00 to 928.00 MHz	3, 7
1.24 to 1.30 GHz	1, 2
2.396 to 2.45 GHz	1, 3
3.30 to 3.41 GHz	1, 2
5.65 to 5.85 GHz	1, 3
10.00 to 10.50 GHz	1, 2
24.00 to 24.05 GHz	1, 3
24.05 to 24.25 GHZ	3
47.00 to 47.20 GHz	1
75.50 to 76.00 GHz	1, 2
76.00 to 81.00 GHz	1, 2
122.25 to 123.00 GHz	2, 3
134.00 to 136.00 GHz	1
136.00 to 141.00 GHz	1,2
241.00 to 248.00 GHz	1, 2, 3
248.00 to 250.00 GHz	1
275.00 to 1000 GHz	2, 4

Notes to Schedule

1. The following ranges of frequencies may also be used for amateur satellite communications:

7.00 to 7.10 MHz	3.40 to 3.41 GHz
14.00 to 14.25 MHz	5.65 to 5.67 GHz (a)
18.068 to 18.168 MHz	5.83 to 5.85 GHz (b)
21.00 to 21.45 MHz	10.45 to 10.50 GHz
24.89 to 24.99 MHz	24.00 to 24.05 GHz
28.00 to 29.70 MHz	47.00 to 47.20 GHz
144.00 to 146.00	75.50 to 81.00 GHz

MHz	
435.00 to 438.00 MHz	134.00 to 141.00 GHz
1.26 to 1.27 GHz(a)	241.00 to 250.00 GHz
2.40 to 2.45 GHz	

a. Limited to the earth-to-space direction.

b. Limited to the space-to-earth direction.

2. These frequencies are, or may be, allocated for use by other services. Amateur operators must accept interference from, and must not cause interference to, such other services.
3. The frequencies:

27.12 MHz	(26.957 - 27.283 MHz),
433.92 MHz	(433.05 - 434.79 MHz),
921.5 MHz	(915 - 928 MHz),
2.45 GHz	(2.4 - 2.5 GHz),
5.8 GHz	(5.725 - 5.875 GHz),
24.125 GHz	(24.00 - 24.25 GHz),
122.5 GHz	(122 - 123 GHz), and
245 GHz	(244 - 246 GHz)

4. are designated for industrial, scientific and medical (ISM) purposes. These frequencies may also be allocated to Short Range Device (SRD) services. Amateur operators must accept interference from ISM and SRD services within these frequency ranges.
5. Allocated to the amateur service on a temporary basis until further notice.
6. Telecommand and telemetry operation only.
7. Radiated power must not exceed 5 watts e.i.r.p.
8. Radiated power must not exceed 25 watts e.i.r.p.
9. The bandwidth of emissions must not exceed 200 Hz

Dated at Wellington this 12th day of July2010. SANJAI RAJ, Group Manager, Radio Spectrum Management, Business Services, Ministry of Economic Development.

Explanatory Note

This note is not part of the notice, but is intended to indicate its general effect.

*This notice prescribes that, pursuant to Regulations made under the Radiocommunications Act 1989, a general user radio licence is granted for the transmission of radio waves by amateur radio operators in New Zealand, for the purpose of communications in the amateur radio service, in accordance with the terms, conditions, and restrictions of this notice. This notice comes into force on **12 August 2010.***

This replaces Radiocommunications Regulations (General User Radio Licence for Amateur Radio Operators) Notice 2010. The principal change from that notice is the deletion of the frequency range 928 MHz to 929 kHz from the schedule.

Appendix 4
The Q-code

Newcomers are often puzzled by the codes and abbreviations used by radio amateurs. These codes make international communication possible with operators with little knowledge of English and they save time conveying information.

A full listing of the Q-code can be found in publications of the International Telecommunication Union.

Listed below are some Q-codes used by radio amateurs.

The Q-code is used in two ways - with or without a question mark. Sometimes a figure, a callsign or a frequency, accompanies a Q-code. For example:

QTC? (note the question mark) means "have you any messages for me?".

QTC3 means "I have three messages for you".

QRG	Will you tell me my exact frequency (or that of ...)? Your exact frequency (or that of ...) is ... kHz
QRH	Does my frequency vary? Your frequency varies
QRK	How intelligible are my transmissions? The intelligibility of your signal is … (1, 2, 3, 4, 5)
QRL	Are you busy? I am busy
QRM	Am I being interfered with? You are being interfered with
QRN	Are you troubled by static? I am troubled by static
QRO	Shall I increase power? Increase power
QRP	Shall I decrease power? Decrease power
QRQ	Shall I send faster? Send faster
QRS	Shall I send slower? Send slower
QRT	Shall I stop sending? Stop sending
QRV	I am ready. Are you ready?
QRW	Shall I inform ... that you are calling him on ... kHz? Please inform ... that I am calling on ... kHz
QRX	When will you call me again? I will call you again at ... hours.
QRZ	Who is calling me? You are being called by ...
QSA	What is my signal strength? Your signal strength is ... (1, 2, 3, 4, 5)
QSB	Are my signals fading? Your signals are fading
QSK	Can you hear me between your signals? I can hear you between my signals
QSL	Please acknowledge receipt. I acknowledge receipt
QSO	Can you communicate with ... ? I can communicate with ...
QSP	I will relay to … Will you relay to …?
QSY	Shall I shift frequency? Shift frequency to ...
QTC	Have you any messages? I have ... messages for you
QTH	What is your location? My location is ...

Appendix 5
Callsigns

Identification of Stations

The ***Identification of Stations*** is in **Article 19** of the International Radio Regulations. It includes the ***Formation of callsigns*** for stations and the formats to be followed for the callsigns used in different radio services.

The International Call Sign Series

The "***Table of allocation of international call sign series***" is in **Appendix 42** of the International Radio Regulations. *(Copies of Article 19 and Appendix 42 are available upon enquiry.)*

The information contained in the Appendix is simply a compilation of what has been supplied to the ITU by administrations.

The callsign series **ZKA-ZMZ** is allocated to **New Zealand**.

So, the ZK, ZL and ZM prefixes are allocated to the New Zealand administration. What use is made of these prefixes is an internal matter for the New Zealand administration.

As far as the ITU is concerned, the purpose of a call sign prefix is only to identify the responsible administration, not to identify the geographic location of the station.

Frequencies for Amateur Radio Operating in New Zealand

This section contains extra material for background knowledge and for reference. Browse through it to determine its content before trying to find the answers to the examination questions!

Section 1:

This is an extract from the International Radio Regulations, from Article 2:

As the unit of frequency is the hertz (Hz), frequencies shall be expressed:

– in kilohertz (kHz), up to and including 3 000 kHz;

– in megahertz (MHz), above 3 MHz, up to and including 3 000 MHz;

– in gigahertz (GHz), above 3 GHz, up to and including 3 000 GHz.

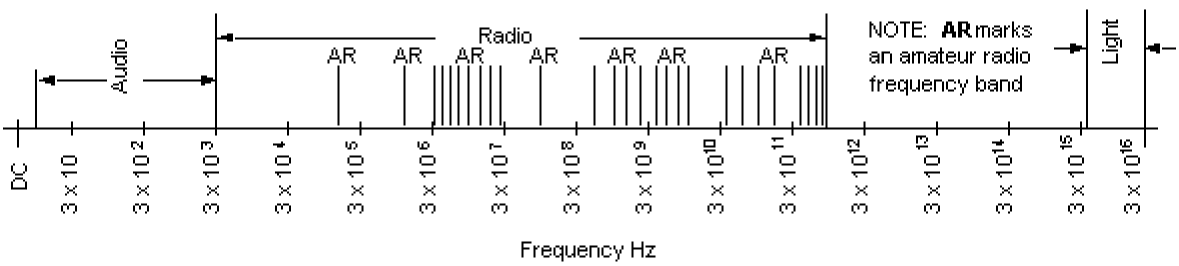
This Table is extracted from the same ITU Article:

Symbols	Frequency range (lower limit exclusive, upper limit inclusive)	CorrespondingMetricSubdivision
VLF	3 to 30 kHz	Myriametric waves
LF	30 to 300 kHz	Kilometric waves
MF	300 to 3 000 kHz	Hectometric waves
HF	3 to 30 MHz	Decametric waves
VHF	30 to 300 MHz	Metric waves
UHF	300 to 3 000 MHz	Decimetric waves
SHF	3 to 30 GHz	Centimetric waves
EHF	30 to 300 GHz	Millimetric waves
	300 to 3 000 GHz	Decimillimetric waves

Note: Prefix: k = kilo (10^3), M = mega (10^6), G = giga (10^9).

The Radio Frequency Spectrum

This diagram shows *Frequency* on the horizontal axis, shown "from DC to Daylight". Note that the horizontal axis is logarithmic (each horizontal interval increases by x10). The range subdivides into "*audio frequencies*", "*radio frequencies*", and "*light*".



Frequency "**bands**" are allocated to the **Amateur Service** at points throughout the spectrum, shown in this diagram as **AR**.

The next Sections following below identify the frequency limits and other licensing details for the bands available to New Zealand's radio amateurs.

Section 2: Table of Frequency Bands and Metres equivalent:

Frequency Band	Metre Band
130-190 kHz	1750 metres
505-515 kHz	600 metres
1800-1950 kHz	160 metres
3.50-3.90 MHz	80 metres
7.00-7.30 MHz	40 metres
10.10-10.15 MHz	30 metres
14.00-14.350 MHz	20 metres
18.068-18.168 MHz	17 metres
21.00-21.45 MHz	15 metres
24.89-24.99 MHz	12 metres
27.12 MHz	11 metres
28.00-29.70 MHz	10 metres
50.00-54.00 MHz	6 metres
144.0-148.0 MHz	2 metres
430-440 MHz	70 centimetres

SECTION 3: Amateur Radio Frequency Allocations

For study and for examination purposes, the bands up to 440 MHz should receive priority consideration.

The current **Amateur Frequency Allocation Chart** with its **Notes** is in the ***General User Radio Licence (GURL)*** for Amateur Radio Operators – on its page 2.
PRINT IT AND STUDY IT! (It is included in the “Regulations” booklet with this Study Guide – see Syllabus 1 to 7.)

This chart undergoes revision as regulatory circumstances change, so please occasionally check the MED RSM web site for any later version: http://www.rsm.govt.nz/cms

The MED will give sympathetic consideration to requests for reasoned variation to individual amateur licence conditions. An example is the temporary use of higher-power for moon-bounce experiments.

Operating conditions and courtesies:

Please note that all radio amateurs have equal "rights" to use amateur radio frequencies. This means that courtesy in operating must prevail. Refer to: GENERAL OPERATING PROCEDURES

SECTION 4: Sharing of bands:

Amateurs share some frequency bands with stations of other services. Full details about "sharing" are provided in the *International Radio Regulations* but only the general principles of sharing and the bands involved are needed for this examination.

Several ***Notes*** to the Amateur Frequency Allocation Chart in the ***General User Radio Licence (GURL)*** for Amateur Radio Operators - on page 2 - explain the use by amateur stations of the "shared bands". See Notes 2 and 3.

Favourable access by radio amateurs to some bands used by other radio services has been given by the regulatory authorities. It is very important that these arrangements be respected so they can continue. The golden rule is: **Don't cause any interference to any other stations**

As an amateur station licensee, you have "frequency agility", you can change your operating frequency to avoid other stations. Other services are usually licensed for one assigned frequency only.

Electronics Fundamentals

Matter

All **matter** is comprised of molecules. A molecule is the smallest part of matter which can exist by itself. It contains one or more atoms, which are comprised of protons, neutrons and electrons.

The light in your room requires energy to glow. The energy must find a path through the light switch and through the copper wire. This movement is called ***electron flow***.

The word **matter** includes copper, wood, water, air....everything. If we take a piece of matter such as a drop of water, divide it into two, and keep dividing it by two, finally when we will find that it can be divided no more and still exist by itself, we have a molecule of water. The molecule contains atoms.

An atom is divisible and can be divided into electrons and nuclei. The component of interest to us is the electron. Electrons are the smallest and lightest parts of the atom and are said to be ***negatively*** charged. Another part, protons, are about 1800 times the mass of electrons and are ***positively*** charged.

Electrons repel electrons and protons repel protons. Electrons and protons attract one another.

Like forces repel, unlike forces attract.

When an electron and a proton are brought to close proximity, the electron moves because the proton is much heavier. The electron is small, its field is strong negative, and is equal to the positive field of the proton.

When electrons move, the result is an electron flow - electricity. To move an electron, a negatively charged field will "push it", a positively charged field will "pull it". Or there can be combined efforts!

Ionisation

When an atom loses an electron, it lacks a negative charge. It is then a called a positive ion. In most metals the atoms are constantly losing and gaining free electrons. In this condition the metal is a good conductor. When gas is ionised under certain conditions, this too becomes a good conductor. Examples are lightning, neon lights and fluorescent lights.

Conductors and insulators

Materials with atoms or molecules with many free electrons will allow an easy interchange of their electrons.

Examples of good conductors are: Silver; Copper; Aluminium; Gold. (*Metals*)

If the free electrons are numerous and loosely held the element is a good conductor.

If there are few free electrons the element is a poor conductor.

If there are virtually no free electrons, the element is a good insulator.

Examples of good insulators are: Glass; Mica; Rubber, Plastics.

Semiconductors

Semiconductors exhibit conductivity somewhere between that of good conductors and good insulators. Examples are silicon and germanium.

Electromotive Force

To produce a drift of electrons or electric current along a wire, there must be a difference in "pressure" or *potential* between the two ends of the wire. This ***potential difference*** can be produced by connecting a source of electrical potential to the ends of the wire.

For example, and simply put, there is an excess of electrons at the negative terminal of a battery and a deficiency of electrons at the positive terminal. This is due to chemical action within the battery.

A potential difference is the result of the difference in the number of electrons between the terminals. The force or pressure due to a potential difference is termed e.m.f. - electromotive force.

An emf also exists between two objects whenever there is a difference in the number of free electrons per unit volume of the object. If the two objects are both negative, and they are connected together, current will flow from the more negatively charged to the less negatively charged . There will also be an electron flow from a less positively charged object to a more positively charged object.

The emf is expressed in a unit called the ***volt***. A volt can be defined as the pressure required to force a ***current*** of one ampere through a ***resistance*** of one ohm.

Consider the following example: Consider the water pressure (volts) required to pass water (current) through a copper pipe of a certain small diameter (resistance).

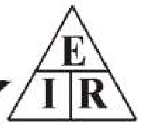
Try to visualise water going through other pipes of varying diameters. The water pressure required will vary and the volume delivered will vary, or both.

(The hydraulic analogue is a clear description of what goes on. That's not coincidence as the science of fluid mechanics was developed about 100 years before electromagnetism and the words and mathematics were carried across by Maxwell and others working on electromagnetism (hence sources, sinks, current, flow, conduction, etc.). It should be noted that friction is the analogue of resistance.)

This is Ohm's law, where E = Volts; I = current in amperes and R = resistance in ohms:

$I = \frac{E}{R}$ $E = I \times R$ $R = \frac{E}{I}$

Remember this triangle:
Cover up the value you require



Remember: Cover up the value you seek - and the formula to get it using the two remaining values is given!

Electromotive force can be generated in many different ways.

Some examples: Chemical (batteries) e.g. dry cell 1.5V, wet cell storage about 2.1V

- o Electromagnetic (generators)
- o Thermal (heating junctions of dis-similar metals)
- o Piezoelectric (mechanical vibration of certain crystals)
- o Photoelectric (light sensitive cells)

Cells - Primary cells (Non-rechargeable)

A common method for producing emf is the chemical action in a cell. Two or more cells form a battery. A flashlight cell is in common use in many small appliances. It is likely to consist of a zinc can (the negative terminal), a carbon centre rod with a copper cap (positive terminal), and a black, damp, paste-like substance called an electrolyte between them.

These materials were selected from substances so that electrons are pulled from the outer orbits of the molecules or atoms of the positive carbon terminal chemically by the electrolyte and deposited on the zinc can. The massing of these electrons on the zinc produces a backward pressure of electrons, or an electric strain, equal to the chemical energy in the cell. The cell remains static at 1.5V until it is connected to some load.

Once connected, the electrons flowing through the circuit start to fill up the deficient outer orbits of molecules of the positive rod in a continuous stream. It is important to understand that this motion produces the same current throughout the circuit at the same time. There must be a complete circuit for a current to flow.

Alkaline cells 1.5V, have more energy capacity. The mercury cell 1.34V is long working. The nickel-cadmium or Nicad 1.25V is rechargeable. Other rechargeable cell types are used in cellphones, digital cameras and the like.

Cells - Secondary cells (Rechargeable)

The nickel-cadmium or Nicad 1.25V is rechargeable. Other rechargeable cell types are used in cellphones, digital cameras and the like.

The lead-acid storage battery is in near universal use as a vehicle battery. The cell delivers about 2.1V and is rechargeable. This particular battery is made of coated lead plates immersed in a solution of sulphuric acid and water. The acid content of the dielectric varies with the state of the charge. This may be determined by measuring the specific gravity of the electrolyte. A reading of about 1.27 indicates a full charge while a reading of 1.15 or below indicates the cell needs recharging.

A 12V battery of these cells may be fast charged **PROVIDED** that care is taken to let escaping gases free themselves and **PROVIDED** the electrolyte temperature is below 50^{o}C or 125^{o}F.

The automotive battery was specifically designed for rapid charge and rapid discharge. For example, starting a car can cause currents well in excess of 500 amperes to flow - this is why jumper leads use thick wires. This battery was not designed for continuous use - such as running a radio or headlights in a stationary position for an extended period of time.

Similar types of cells are 'sealed lead acid' which may be used for emergency stand-by power.

The connection of cells

When two or more cells are connected together in series, they form a battery. The voltages add together. Some flashlights or portable radios comprise four cells to make up 6V (4 x 1.5V). A car battery has 6 cells in series - so we get 6 x 2.1V = 12.6V. In actual practice we can get a higher voltage when a vehicle battery is under charge.

If we put two batteries or cells in parallel, we get the same voltage, but twice the capacity. Twice the energy is available to us.

Measurement Units

The units for voltage, current, resistance and power are covered in other parts of this Study Guide.

You must become familiar with the smaller and larger units often used in radio work. For example, be sure that you know the relationships between and can convert (say) millivolt to volt, volt to kilovolt, microamp to a milliamp, megohms to ohms, kilo-ohms to ohms, watt to milliwatt, etc. The following table will be useful.

Multiples and sub-multiples of electrical units

Symbol	Unit Name	Multiply/Divide by	Scientific Notation
T	tera	x 1 000 000 000 000	10^{12}
G	giga	x 1 000 000 000	10^{9}
M	mega	x 1 000 000	10^{6}
k	kilo	x 1 000	10^{3}
m	milli	÷ 1 000	10^{-3}
µ	micro	÷ 1 000 000	10^{-6}
n	nano	÷ 1 000 000 000	10^{-9}
p	pico	÷ 1 000 000 000 000	10^{-12}
f	femto	÷ 1 000 000 000 000 000	10^{-15}
a	alto	÷ 1 000 000 000 000 000 000	10^{-18}

The ***ohm*** is the unit for resistance. It is also the unit for impedance. What is impedance?

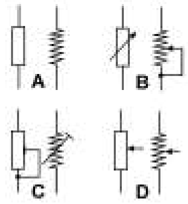
The capacitor and the inductor each exhibit ***reactance***. See: Capacitors and Inductors.

As a first concept, ***reactance*** can be broadly viewed as an AC "resistance equivalent" for capacitors and for inductors. This is only satisfactory as a first approach to the subject.

Impedance is a combination of both **resistance** and **reactance.** The term "impedance" implies that RF circuitry is involved, with either discrete components or with transmission lines.

Resistors and the Colour Code

Resistors



These are components made to provide resistance in circuits. They are made in various resistance values, physical sizes, and can be of fixed or variable value.

The circuit symbols used for different types of resistors are shown in the diagram. The symbols at A are those used for fixed value resistors, at B are those for variable resistors, at C those for preset resistors or trimpots, and at D a variable resistor used as a potentiometer, with provision for tapping off part of the voltage across the resistor, and being able to vary the tap.

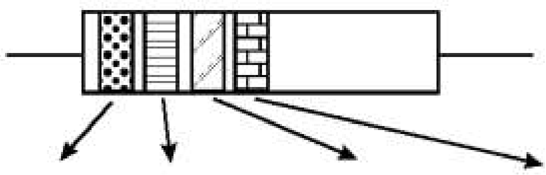
Resistor power ratings:

Fixed resistors are available in a wide range of power ratings. The power rating of a resistor depends on its ability to dissipate heat and to keep its operating temperature below a value at which its resistance value is seriously affected. To do this, it must have a certain surface area. The larger the power rating, the larger the resistor.

Usual ratings are 0.125, 0.25, 0.5, 1, and 2 watt in carbon and the more modern film resistors; above these levels, wire-wound or other types are used.

The “Resistor Colour Code”:

Resistor values are usually marked on the resistor itself by using colour rings or bands. Because the range of resistor values used in electronics goes from fractions of an ohm to tens of megohms, it is impossible to manufacture resistors in every possible value, so resistors are produced in “preferred values”. Resistors are marked with their preferred value, and a tolerance value, which indicates the spread of the resistance value you can expect.



Colour	1st ring = 1st digit of value	2nd ring = 2nd digit of value	3rd ring = multiplier	4th ring = tolerance %
None				±20%
Silver			$10^{-2}\ \Omega = 0.01\ \Omega$	±10%
Gold			$10^{-1}\ \Omega = 0.1\ \Omega$	±5%
Black	*0*	*0*	$10^{0}\ \Omega = 1.0\ \Omega$	
Brown	*1*	*1*	$10^{1}\ \Omega = 10\ \Omega$	±1%
Red	*2*	*2*	$10^{2}\ \Omega = 100\ \Omega$	±2%
Orange	*3*	*3*	$10^{3}\ \Omega = 1\ k\Omega$	
Yellow	*4*	*4*	$10^{4}\ \Omega = 10\ k\Omega$	
Green	*5*	*5*	$10^{5}\ \Omega = 100\ k\Omega$	±0.5%
Blue	*6*	*6*	$10^{6}\ \Omega = 1\ M\Omega$	
Violet	*7*	*7*	$10^{7}\ \Omega = 10\ M\Omega$	
Grey	*8*	*8*	$10^{8}\ \Omega = 100\ M\Omega$	
White	*9*	*9*	$10^{9}\ \Omega = 1000\ M\Omega$	

The Table shows the colour code and the tolerance colours for the four ring colour code

Sometimes the value of a resistor is printed on the component itself. The letters "R", “M” and "k" have a purpose.

Note in this next table how these letters act as the decimal indicator:

Marking	Resistance value
R05	0.05 ohms ohms
1R5	1.5
15R	15 ohms
1k5	1500 ohms or 1.5 kilohms
15k	15 000 ohms or 15 kilohms
1M5	1.5 megohms

Some equipment requires increased precision. To meet this need resistors with a precision of ±0.5% are required. For these types of resistor a five ring or band colour code is used to give a third digit value for more precise resistor values and tolerances.

Remembering the Colour Code:

The colouring starts with **Bl**ack (which is Zero). The sequence is:

0 1 2 3 4 5 6 7 8 9

Black, **B**rown, **R**ed, **O**range, **Y**ellow, **G**reen. **B**lue, **V**iolet, **G**rey, and **W**hite.

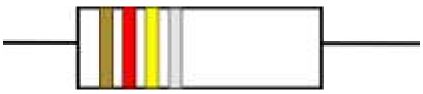
Just remember the ditty:

"**B**etter **B**e **R**ight **O**r **Y**our **G**reat **B**ig **V**enture **G**oes **W**est"

Remember that it starts at ***Zero*** which is **B**lack!

An example:

This figure shows a fixed resistor with its colour rings. To read the colour code, put the tolerance ring to your right and



read off the colours as number values. The first two rings give a number between 10 and 100 and the third ring is the power of 10 or multiplier needed for the final value. The fourth ring indicates the "tolerance".

For example, the resistor coded *brown, red, yellow, silver* is a 12 x 10^{4} or 120 kilohm resistor, and the tolerance of 10% indicates that the value could lie between 108 kilohms and 132 kilohms.

Gold and silver are also used as multipliers. Gold = multiply the value by 10^{-1} (multiply the value by 0.1) and silver = multiply the value by 10^{-2} (multiply the value by 0.01).

Preferred ranges for resistors:

The preferred ranges depend on the tolerance.

For 10% resistors the preferred values are 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82, and multiples of each value. For example, you can have a 10 ohm, a 10 kilohm, and a 10 megohm resistor value.

For 5% resistors the preferred values are 10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91, and multiples of each value.

For 1% resistors the "Preferred values of Resistor" are 100, 102, 105, 107, 110, 113, 115, 118, 121, 124, 127, 130, 133, 137, 140, 143, 147, 150, 154, 158, 162, 165, 169, 174, 178, 182, 187, 191, 196, 200, 205, 210, 215, 221, 226, 232, 237, 243, 249, 255, 261, 267, 274, 280, 287, 294, 301, 309, 316, 324, 332, 340, 348, 357, 365, 374, 383, 392, 402, 412, 422, 432, 442, 453, 464, 475, 487, 499, 511, 523, 536, 549, 562, 576, 590, 604, 619, 634, 649, 665, 681, 698, 715, 732, 750, 768, 787, 806, 825, 845, 866, 887, 909, 931, 953, 976, and multiples of each value. For example, you can have a 16.5 ohm, a 165 kilohm, and a 16.5 megohm resistor value.

Ohm's Law

Ohm's Law states that current flowing in a circuit

is ***directly*** proportional to the electromotive force (voltage) applied and

inversely proportional to the resistance of the circuit.

As a formula it is:

I = E/R amperes

where

I = current flow, (ampere)

E = e.m.f. (volt)

R = resistance (ohm)

The symbol for *volt* can be either *V* or *E*. For consistency we will use ***E*** (remember ***E***lectromotive force). Resistance is abbreviated to ***R*** and ohms are written using the Greek letter **Ω** (omega).

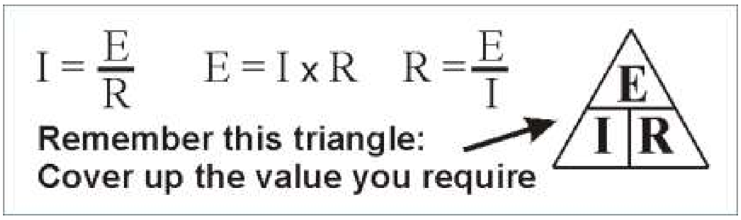
This law is fundamental to all theoretical work in radio and electronics.

The emf is expressed in a unit called the ***volt***. A volt can be defined as the pressure required to force a ***current*** of one ampere through a ***resistance*** of one ohm.

Consider the following example: Consider the water pressure (volts) required to pass water (current) through a copper pipe of a certain small diameter (resistance).

Try to visualise water going through other pipes of varying diameters. The water pressure required will vary and the volume delivered will vary, or both.

This is Ohm's law, where E = Volts; I = current in amperes and R = resistance in ohms. By transposing we get the following:



Remember: Cover up the value you seek - and the formula to get it using the two remaining values is given

Resistors

Many problems are straight substitution of values in one of the above three expressions. If you are given two of the values of E, I or R, find the third! First find the expression that suits your problem from the values you are given.

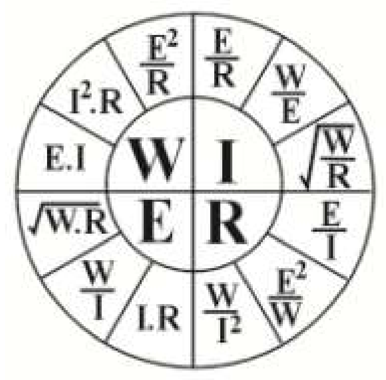
Remember that you must use the units: **Volt, Ohm, and Ampere**. If you are given millivolt, milliamp, or kohm (kilo-ohm), be careful with your arithmetic! Convert to the basic values, **Volt, Amp or Ohm** before you start!

Power

The unit of electrical power is the **watt** (**W**).

Power is the ***rate of doing work***. (Remember: *With higher power you can cook something faster!*)

Power is dissipated in a resistance - the resistor warms up!



We can develop a diagram to include "power calculations" too, see this circular diagram. It looks very complicated but it is just a lot of variations of the same thing! You know many of these already - they appear in our triangle.

There are four sectors, for **W**, **I**, **E** and **R**. Look at the three relationships from the triangle and locate them on this diagram.

The relationship between the watt **W**, volts **E**, and amperes **I**, is:

W = E times **I** or **E . I = W**. Find this on the diagram.

E . I = W is perhaps the most fundamental of all the "power" relationships.

To involve resistance (**R**) in a circuit, we can find a substitute for **E** or for **I**.

For example, **W = E . I**. But perhaps we don't know **E** but we know both **I** and **R**.

So we can substitute **E = I . R**. for **E** in this **W = E . I** .expression.

This now means that **W = I . R . I.**

This can also be written as **W =** I^2**R**. (Say it out loud! **Watt = I "squared" R**)

This diagram looks complicated, but what it really tells us is that there are many ways of saying the same thing! All it shows is that the "basic" Ohm's Law formula (I = E/R) can be used to make substitution in the basic formula W = E x I in many different ways!

Check another case too - for when you don't know **I,** but you know both **E** and **R** and wish to find **W**!

Power is dissipated in a resistor

Remember: When current flows in a resistance, heat is produced.

(This is how a fuse works! Heat resulting from excessive current melts the metal link in the fuse!)

For your reference: A table of multiples and sub-multiples of units

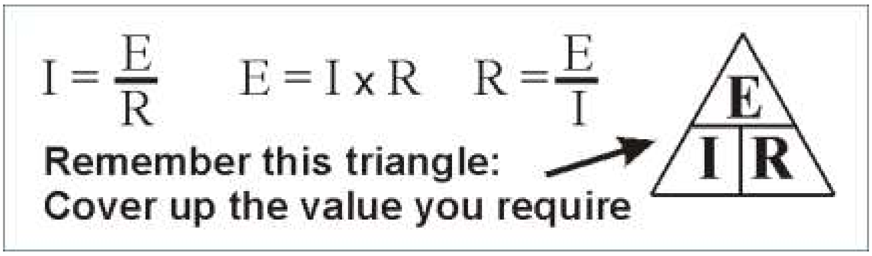
Symbol	Unit Name	Multiply/Divide by	Scientific Notation
T	tera	x 1 000 000 000 000	10^{12}
G	giga	x 1 000 000 000	10^{9}
M	mega	x 1 000 000	10^{6}
k	kilo	x 1 000	10^{3}
m	milli	÷ 1 000	10^{-3}
µ	micro	÷ 1 000 000	10^{-6}
n	nano	÷ 1 000 000 000	10^{-9}
p	pico	÷ 1 000 000 000 000	10^{-12}
f	femto	÷ 1 000 000 000 000 000	10^{-15}
a	alto	÷ 1 000 000 000 000 000 000	10^{-18}

Ohm's Law Applied

This study is about the application of Ohm's Law to examples using more than one resistor.

You will recall Ohm's law:

Where E = Volts; I = current in amperes and R = resistance in ohms. By transposing we get the following:



Remember: Cover up the value you seek and the formula to get it using the two remaining values is given

Resistors in series

This is EASY! To INCREASE resistance - just ADD UP the value of each of the resistors in series.

Example: a 10k, 47k and a 56 k resistor are in series. Total = 113k.

Resistors in SERIES: Remember - you ADD their values up!

Resistors in parallel

This is a little more complicated - but there are shortcuts in practice!

Resistors in parallel must always have a resultant value that is less than the smallest of any of the component resistors. The current divides between the parallel resistors. The SMALLER resistor will carry the LARGER current. The total current will be the sum of the currents in each leg of the network.

Remember: Where the component resistors are different values, the resultant parallel value must be less than the smallest component value alone.

TWO resistors of the same value in parallel will act the same as one resistor of HALF that value. The wattage rating will be TWICE that of one of the component resistors.

For example: Two 10k resistors in parallel = 5 k.

THREE resistors of the same value in parallel will be ONE-THIRD of the value of a single resistor (but three times the wattage rating).

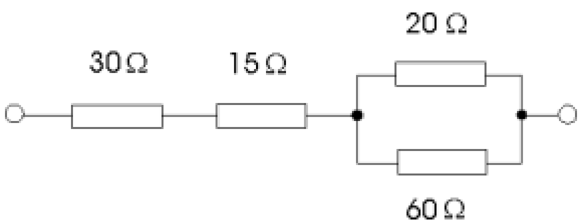
Example: Three 10k resistors in parallel = 3.3k

... and so on!

Networks of resistors

The resulting value of a network of resistors can sometimes be solved without any great skill being required!

Look at this example:



The 30 ohm and the 15 ohm in series, together could be replaced with one (30 + 15) = 45 ohm resistor. Happy so far?

The 20 and 60 ohm resistors in parallel can be solved with a little thinking!

The 20-ohm could be replaced with three 60-ohm resistors in parallel. So a 20-ohm and 60-ohm in parallel could be replaced with FOUR 60-ohm resistors in parallel.

So the resulting resistance of the two parallel resistors is one-quarter of 60, i.e. = 15 ohm.

So the resulting value of this whole network is (45 + 15) = 60 ohm. Easy?

Sketch the circuit!

It is important in all network problems to be able to "visualise" the circuit. Sketch the circuit, ***then*** place the value of each component alongside it. ***Study it carefully***.

Put all the information you are given on to your diagram. Determine what it is that you are expected to find.

Careful consideration of the components in a network will often lead to an easy evaluation.

If you are asked for the voltage across PART of a circuit, remember that two EQUAL resistors in SERIES will have HALF of the applied voltage across each resistor.

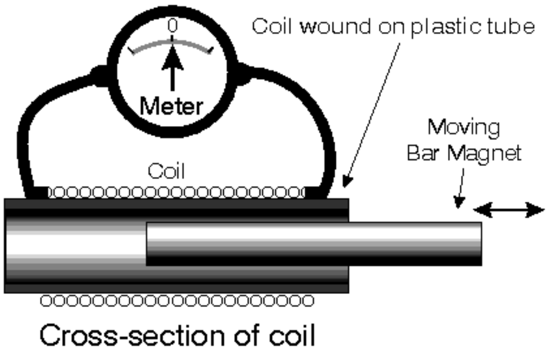
If you are asked about the current in a network containing two resistors of EQUAL value in PARALLEL, remember that the current will DIVIDE EQUALLY through each resistor.

"Internal Resistance"

Batteries, and power-supply substitutes for batteries, exhibit "internal resistance". It is this characteristic that causes the voltage from any source to "droop" or "sag", that is, drop or decrease when a heavy load current is drawn from it.

Alternating Current and the generation of a *sinewave*

Introduction



The household electrical supply and the signal from a radio transmitter are similar. Both are AC (alternating current) signals, but they differ in frequency. We will first consider how a simple generator / dynamo / alternator works to produce electricity and then consider typical radio frequency signals.

Consider a coil of fine insulated wire wound on a plastic or cardboard tube. Connect the ends of the coil to a DC milliammeter or galvanometer (for demonstration purposes!). A sensitive center-zero meter is preferred for this demonstration.

Now take a bar magnet and thrust the magnet into the coil. The meter will deflect.

Now withdraw the magnet. The meter deflects the other way.

As we insert and withdraw the magnet, the meter deflects from one side to the other.

With the magnet stationary, the meter reads zero.

What's happening?

We see that when the magnet is moving, a current is ***induced*** in the coil. The moving magnetic field, from the moving magnet, ***cuts the conductors*** forming the coil.

We can, by this simple experiment, deduce that the amplitude of the current depends on several things:

the strength of the magnet,
the rate of cutting of the conductors (i.e. the speed of movement of the magnet) and
the number of conductors (i.e. the number of turns on the coil).

We are converting **mechanical energy** (the movement of the magnet) into **electrical energy**. We have demonstrated Faraday's law of induction.

Other considerations

This conversion of mechanical energy (the movement of the magnet) into electrical energy, has other important aspects too.

The magnet could be stationary and the coil could move - we will consider this case again below.

This principle is the basis of generators, meters, loudspeakers, relays, and lots of other things too.

Consider the reverse operation too: A current could be fed to the coil. This would force the magnet to do the moving.

The magnet need not be a permanent magnet - it could be another coil, wound over the top. We could feed an AC signal to one coil, the rising and falling magnetic field from it sweeps across the other coil, generating an induced signal in the second coil (the secondary winding). The two coils are insulated from each other, the ***coupling*** is by the sweeping magnetic field. Nothing needs to make any physical movement. So we have a ***transformer.***

Frequency

Placing the magnet into the coil and then removing back to the start point is one cycle. If we could take the magnet in and out of the coil every second, the polarity of the induced voltage would go through one cycle in one second. One cycle per second is one hertz (Hz). So when you see 'hertz' or 'Hz' just think of 'cycles per second'.

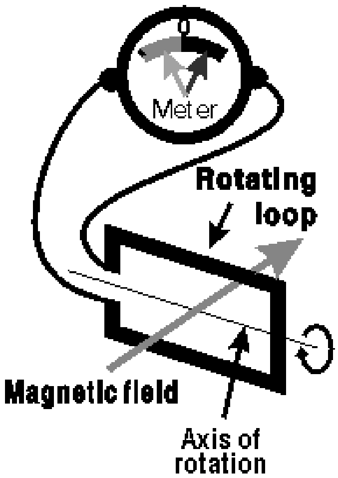
The alternating voltage provided to your house from the power grid repeats polarity 50 times a second and reaches 230 volts rms (the "rms" will be treated later). It is 230v 50 Hz.

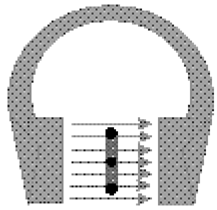
The AC supply causes the electrons in the conductors in your house to first move one way and then the other. They are probably the same electrons that were there when the wiring was first installed. They just seesaw back and forth.

The device which creates your household power is called a generator. It works by creating relative motion between a conductor and a magnetic field.

The Generator

Consider a magnetic field that is constant in its intensity. In this field is a rotating coil. For simplicity, this diagram on the left shows it as a single-turn loop. The ends of the coil are brought out to a meter - the same type of meter as before. In practice, slip-rings would be used to prevent the wires tangling by rotation - but this complication has not been shown here.



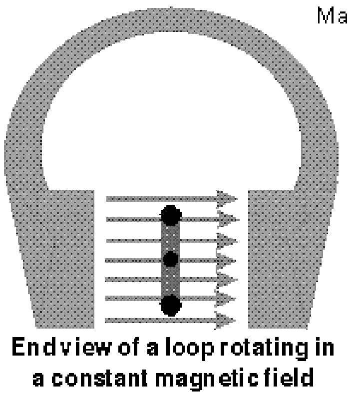


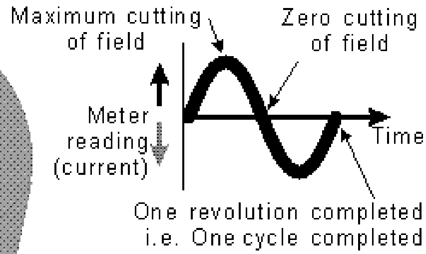
Please note that this meter has red and blue scale sections to show the change in polarity of the current as the coil rotates.

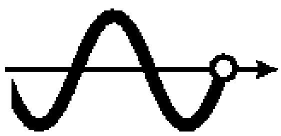
The coil is rotated in the constant magnetic field by mechanical means (in practice by water power or by diesel power etc.). Of course the design of a real generator is quite different - we are looking at the simple principles.

We are considering the current induced in each of the longer elements of the loop only - so please ignore any complications brought on by the end parts of the loop!

When the plane of the loop is vertical between the jaws of this magnet, the loop elements are moving parallel with the direction of the magnetic field. The loop is not cutting any lines of force. So the meter will read zero.







When the plane of the loop is horizontal, the loop elements will be moving vertical in the jaws of this magnet, a maximum cutting of the magnetic field. So the meter will read maximum current.

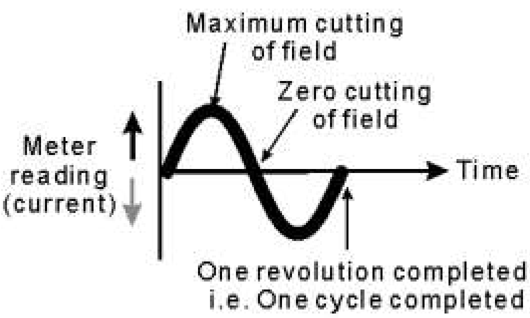
As the loop rotates, the meter will read a current first in one direction, pass through zero, and then show a current in the other direction, then back to zero - one full cycle. It is shown here by the red and blue readings on the meter - a variation of our first example when we used a meter with a bar magnet.

Consider the angle made by the the plane of the loop with any vertical line on the diagram. This angle is significant. When the plane of the loop is vertical in the diagram, the plane of the loop is at zero degrees with a vertical line. When the plane of the loop is horizontal, this angle is 90 degrees.

The output current indicated on the meter follows this angle change - a **sinewave**.

At 30 degrees, the current will be sin30 = 0.5 of the maximum, at 45 degrees, the current will be sin45 = 0.707 of the maximum, at 60 degrees, 0.866, and so on.

The frequency of the wave is related to the revolutions, one revolution produces one cycle. One cycle in one second is a 1 Hz signal.



The 50 Hz mains supply can be produced by mechanical means, and examples are in every powerhouse supplying the national grid. Fifty cycles in one second (50 Hz) is 3000 revolutions in each minute. Multi-polar machines are used in practice with a slower rotation speed.

It is difficult to produce radio frequencies by mechanical means so these are generated by electronic means. For example 7 MHz represents 7 million revolutions in one second.

You can work out how many in one minute!

For your reference: A table of multiples and sub-multiples of units

In practice, the hertz, Hz; the kilohertz, kHz; the megahertz, MHz; and the gigahertz, GHz; are used in radio work. These relationships are shown in this general table:

Symbol	Unit Name	Multiply/Divide by	Scientific Notation
T	tera	x 1 000 000 000 000	10^{12}
G	giga	x 1 000 000 000	10^{9}
M	mega	x 1 000 000	10^{6}
k	kilo	x 1 000	10^{3}
m	milli	÷ 1 000	10^{-3}
µ	micro	÷ 1 000 000	10^{-6}
n	nano	÷ 1 000 000 000	10^{-9}
p	pico	÷ 1 000 000 000 000	10^{-12}
f	femto	÷ 1 000 000 000 000 000	10^{-15}
a	alto	÷ 1 000 000 000 000 000 000	10^{-18}

The time for one period

The time taken for one cycle, or one period, is the reciprocal of the frequency.

For example, a frequency of 50 cycles in one second, (i.e. 50 Hz), means that the time for one period is one-fiftieth of one second.

The time for one period of a 7 MHz signal is one-seven-millionth of one second, or one-seventh of one microsecond.

Harmonics

It is difficult to produce a pure sinewave. Signal impurities known as "harmonics" are exact multiples of the original fundamental signal. The harmonics can be odd-multiples or even-multiples of the fundamental signal, or both.

The presence of harmonics has the effect of altering the resulting wave-shape from being sinusoidal to being some other distorted waveform. The level of harmonic content can be very small and the wave-shape changes are often not detectable without the use of test equipment to determine the relative level of the harmonic frequency components.

Harmonics bring interference problems in radio operating too.

Alternating Voltage and Current measurements

New Zealand has a 230v AC 50 Hz mains supply. The measurement of an alternating voltage or current is not straightforward. Considering voltage, if the "height to the crest of the wave" is measured, this is known as the "**Peak Voltage**". But it is not a measurement that is frequently used.

The "root mean square" (**r m s**) value is more usual – but **what does that mean**?

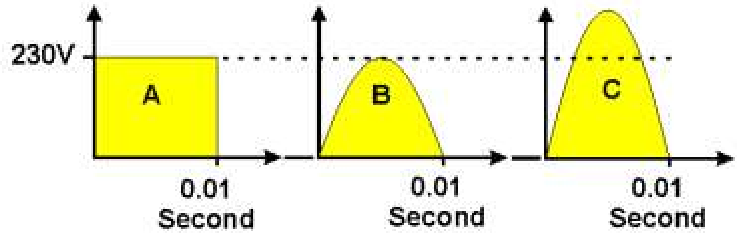


Diagram A shows a **DC** 230V supply. (Note: **DC**). It runs here for one-hundredth of one second.

The rate at which heat is produced by a current is proportional to the square of its value (P = $\mathbf{I^2R}$, "*I-squared R* ").

If it had been feeding a resistance, i.e. an electric heater of (say) resistance R with a current of I Ampere, the heat dissipation would have been $\mathbf{I^2R}$ watts.

Diagram B shows an **AC** 50 Hz sinusoidal supply in which the ***voltage*** peaks to 230V during the period of ***one half-cycle***. The ***current*** will have also been continuously changing, following the sinusoidal waveform.

The AC supply reaches 230V for only an instant. The heat produced is less than the DC case.

In Diagram C, the AC voltage has been deliberately increased so that the heating effect in C from this sinusoidal waveform is ***the same effective heating as in A*** for the same time period.

With ***the same effective heating***, the level in case C is known as the "**r m s**" value and is 230V. This is the "***root-mean-square***" value. It is the level to produce the same "heating effect" from an AC waveform as from a DC supply.

The current is time-varying so the "*I-squared R*" formula must be re-considered to reflect that the current (and thus the instantaneous power) is varying with time. We can calculate that by sampling the power at small intervals:

Take the current (or potential difference) at each interval in turn and square it,

add up the squares,

then divide by the number of samples to find the **average** (i.e. the **mean)** square.

Then take the ***square root*** of that square.

This is the 'root mean square' (**r m s**) value, the ***square root* of the *mean* of the *squares***.

Reinforcement: With the load R being constant, at many short intervals while it follows the waveform as seen in diagram C, we can determine the ***sum*** of the ***squares*** of many instantaneous values of the current. The ***square root*** of this ***sum of the average*** of these ***instantaneous values*** is our ***r m s*** value.

For a ***sinusoidal AC signal***, the values you should know are:

the **peak** value is **1.414 (√2)** times the **r m s** value, and,

the **r m s** value is **0.707 ($\mathbf{^1/_{\sqrt{2}}}$)** times the **peak** value.

These relationships are explained in standard electrical textbooks. Remember, these are for the "equivalent heating effect" for a ***sinusoidal*** waveform. They will be different for other waveforms.

*(It should be noted that the 0.707 r m s value is different to the "mean" or "average" value.
Over one full cycle, the "average voltage" would be zero. But over one half-cycle, the average value for a sinewave is 0.637.
The ratio of r m s to the mean value (0.707 to 0.637) is 1.11 for a sinewave. This is known as the "form factor" and is very dependent on the shape of a waveform.)*

Don't confuse r m s with the mean (average) value.

Alternating currents and voltages are usually measured by their r m s values, but, all insulation must be able to withstand the PEAK voltage.

Question 1: For a 230V 50 Hz mains supply, what is the Peak Voltage?

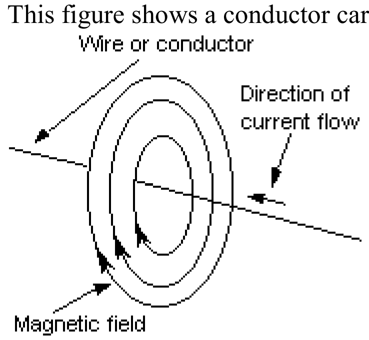
Question 2: How many times in each cycle is the Peak Voltage reached?

Answers: Q1 = 325V Q2 = Twice

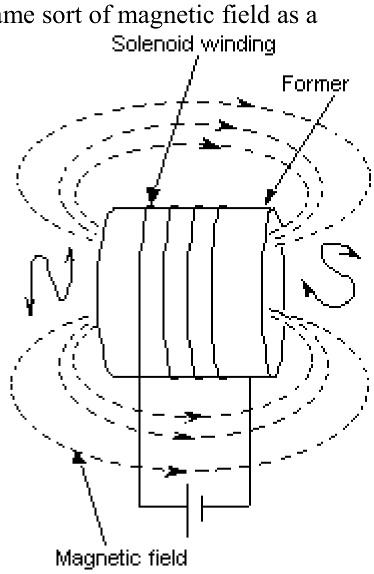
Capacitors, Inductors & Resonance

We'll start with **the inductor**!

This figure shows a conductor carrying a current. A magnetic field is set up around the conductor as concentric circles.



If a coil of wire has a current flowing through it, the magnetic flux due to each turn will link with every other turn and produce the same sort of magnetic field as a permanent magnet. Such a coil is called a solenoid as shown here. It acts as a magnet only when current is flowing through it.



The magnetic polarity of the solenoid can be determined from the direction of current flow as seen looking in the ends, as shown in the diagram. From that the direction in which the magnetic field is acting can also be found.

Solenoids or electro-magnets are widely used in electronic equipment. Loudspeakers, headphones, moving coil microphones, measuring instruments, transformers and such things, depend on electromagnetism for their operation.

An inductor may be air-cored or have a solid core.

Magnetic materials

Magnetic materials in common use for the cores of solenoids are:

Soft iron: easy to magnetise and demagnetise. Used for motor pole-pieces.

Silicon iron: used for transformer laminations and AC motors. Low-loss.

Nickel iron alloy: also known as radio metal and mu-metal, is used for high-class audio transformers and cathode-ray tube screens.

Ferrites: iron oxide based materials used for a wide range of applications in radio and electronics generally. The characteristics depend on the mix of materials in the core and are extremely varied. Also known as ferroxdure and ferroxcube.

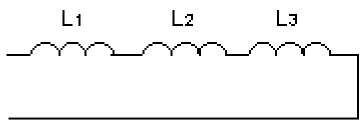
Permanent magnets: tungsten steel, and alloys of iron, nickel, aluminium, cobalt, ceramic, and titanium are used. Iron oxides can also be used.

The magnetic field surrounding a coil does not appear immediately the circuit is connected. It takes time to grow from nothing at the moment of switch-on to its maximum. The time taken for this depends on many factors, including the number of turns in the coil, the current, the core material, and the self-resistance of the coil. Similarly, when the current is switched off the field takes time to decay.

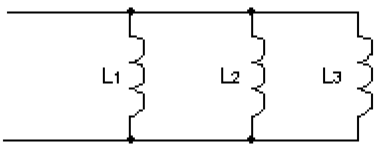
It should be noted that the current in the coil takes time to rise to its maximum. This must be compared to the capacitor where at switch-on, the voltage across the capacitor takes time to rise to its maximum (see below).

Inductors in series and parallel

A coil has ***inductance***, measured in ***henries***. The values of practical inductance used in radio range from several henries (H) to parts of a microhenry (µH). The inductance of a coil depends on the number of turns and the core details.



(a) Series Inductors



(b) Parallel Inductors

When inductors are connected in series, the number of turns is effectively increased. So too is the inductance, and the effective inductance of the circuit is the sum of the individual inductances.

The diagram shows series and parallel inductors. These calculations apply only to inductors which are not coupled magnetically. Where there is coupling between coils, the total inductance is also affected by the amount of coupling.

As with the resistor, for amateur radio examination purposes, you can visualise the resulting value of inductors like this:

Putting two inductors in series in effect increases the number of turns so the inductance value increases.

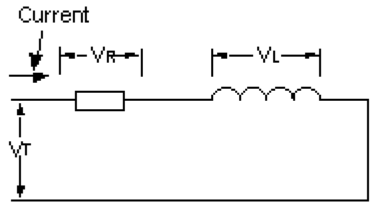
Putting two inductors in parallel, in effect decreases the effective inductance.

Like the resistor, we can use visualised examples to easily work out what happens with two (or more) typical inductors of the same value. Put two in parallel, the value will halve. Put two in series and the effective inductance value will be double.

In a perfect inductor there is no loss of energy. The energy is stored in the magnetic field surrounding the inductor and (in an AC circuit) it changes in magnitude and sign twice in each cycle. The opposition to the flow of current is called the inductive reactance and is denoted by X_L. Reactance is an opposition to current resulting from a storage of energy. The relationship is:

$X_L = 2\pi f L$ where **f** is the frequency in ***hertz***, **L** is the inductance in ***henries***, and $\mathbf{X_L}$ is the ***reactance*** expressed in ***ohms***. For our purposes, 2π can be taken to be the value **6.28**.

Note that as the ***frequency rises***, the ***inductive reactance also rises***.



In practice there is no such thing as a perfect inductor and it is usual to consider the practical component to be a circuit containing both a resistor R (the inductor's resistance) and L the inductor.

Where resistance and inductance (inductive reactance) exist in a circuit together, they are combined into a term, called ***impedance***, representing their combined total opposition to current flow.

Reactances can be added together directly. But resistances and reactances must be added together ***vectorially*** (as vectors), to get impedance. More about this follows below.

Types of inductors

Inductors used in radio can range from a straight wire at UHF to large chokes and transformers used for filtering the ripple from the output of power supplies. Values of inductors range from nano-henries to tens of henries. It is convenient to group them into three categories.

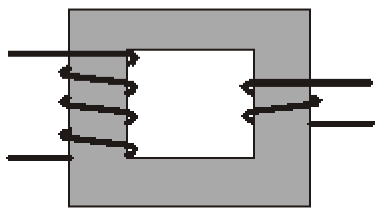
Air core: to keep losses to a minimum it is necessary to keep the self-resistance of coils as low as possible.

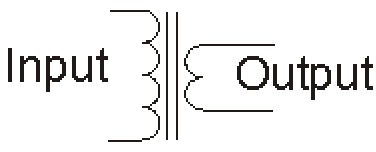
This means using the thickest possible wire within the space available. Another reason for using thick wire or sometimes tubing is to reduce the *skin effect* losses at high frequencies. Direct current is spread uniformly over the cross-section of the conductor, but alternating current moves closer to the surface as the frequency increases. Thus it is necessary to provide a large surface to minimise radio frequency resistance which is known as *skin effect*.

Inductors used can range from a 25 mm diameter tube for an antenna on VHF to 50 turns of 22 swg wire on a 7.5 cm diameter former for the tank circuit of a 1.8 MHz transmitter.

The only adjustment available with air core inductors is by tapping all or part of a turn, or by varying the spacing between turns.

Ferrite or iron dust core: by inserting a ferrite or iron dust core in a coil it is possible to double its inductance. This means that it is also possible to halve the size of a coil for a given inductance. If the core is threaded, its position within the coil can be varied to alter the inductance. Some high-grade communications receivers have a system of cam-operated cores which are used for tuning. The type of material used for the cores or *slugs* is of importance and care must be taken to use the right grade for the right frequency band. This type of coil is used throughout the HF range, and into the VHF, for low-level signal circuits. Losses in the cores make them unsuitable for use in power circuits. Values range from a few microhenries to about a millihenry.





Similar types of coils have been made using brass cores instead of ferrite. The effect of this is to reduce the inductance by about 20%. They also increase the losses.

Iron core: this classification includes chokes and transformers, both of which have laminated iron cores. Transformers are described in the next section. A choke is a ***single*** winding and a transformer has ***two or more*** windings. Typical values of inductance for chokes range from 0.1 of a henry to 50 henries.

The transformer

Any two coils magnetically linked will act as a transformer. Transformers come in as many forms as inductors, air or dust cored as well as the more familiar iron-cored type. The iron-core can take several forms.

The simple transformer comprises two or more inductors (windings) sharing a common core.

An alternating current is fed to one of the windings. The operation can explained by considering the magnetic field of the input winding, the primary, sweeping through the secondary winding to induce an AC current in the secondary.

The "*turns ratio*"

A common task for a transformer is to provide an AC supply at a voltage suitable for rectifying to produce a stated DC output.

The number of turns on each winding determines the output voltage from the transformer. The output voltage from the secondary is proportional to the ***ratio*** of the turns on the windings.

For example, if the secondary has half as many turns as there are on the primary, and 100V AC is applied to the primary, the output from the secondary will be 50V.

Transformers can be step-up or step-down (in voltage). With twice as many turns on the secondary as there are on the primary and 100 V applied, the output would be 200V.

The ***impedance ratio*** is proportional to the square of the turns ratio. We can use transformers to change impedances. This property is one of the most important properties in the use of transformers.

The power output from the secondary winding cannot exceed the power fed into the primary. Ignoring losses, a step-down in voltage means that an increase in current from that lower-voltage winding is possible. Similarly, a step-up in voltage means a decrease in the current output. So the gauge of wire used for the secondary winding may be different to the wire used for the primary. (The term "gauge of wire" relates to its cross-sectional area.)

In effect, a transformer changes "Watts of one form (E_1 x I_1), into the same number of Watts of another form (E_2 x I_2)".

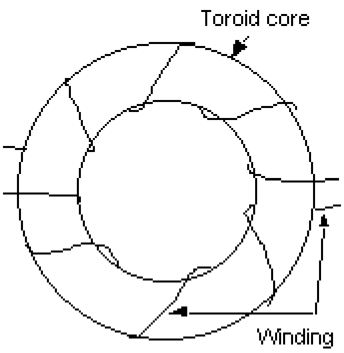
Iron-cored transformers are used for audio frequencies and for power supplies. Audio frequency transformers are designed to give suitable efficiency at frequencies up to 25 kHz.

For speech and domestic quality radio reproduction the core material used is stalloy, while the laminations of high-fidelity transformers are made of mu-metal. The construction is the same as for chokes and the same considerations of size and power rating apply.

Transformer losses

There are two main types of loss in a transformer, the iron loss and the copper loss. Copper loss is due to the resistance of the wire used for the windings. Copper loss can be reduced by using large diameter wire for the windings, but there is a limit to the size and weight and some copper loss is unavoidable.

One of the principal iron losses is caused by "eddy currents" flowing in the core. The magnetic circuit (core) can be considered to be a one-turn coil and heavy currents could flow causing very high losses. To reduce this eddy current loss the core is made up from many thin slices of iron called laminations which are insulated from each another.



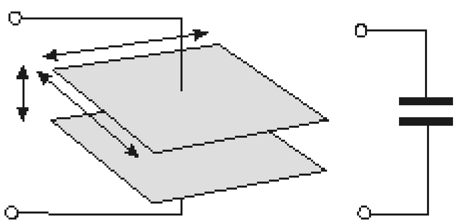
Toroidal core transformers

If the core of a transformer is of specially-selected material and is formed into a complete loop as shown in this diagram, nearly all the flux lies within the core and there is very little leakage, or flux outside the core.

This results in very little unwanted coupling to adjacent magnetic circuits, and is a very desirable feature in some circuits. An application is in the common SWR Bridge.

The Capacitor

The capacitor has a wide range of uses in radio. Its fundamental construction comprises a pair of metal plates. The plates are separated by a dielectric which may be air or some insulating material. The diagram shows a diagrammatic capacitor with its circuit symbol.



A capacitor exhibits capacitance, a value measured in farads (F). In practice, capacitors range from a few picofarads (pF) to many microfarads (µF) in value.

The value of a capacitor is determined by the dimensions of its plates, the distance between the plates, (see the arrows on the above diagram) and the characteristics of the dielectric.

For amateur radio examination purposes, you can visualise the value of a capacitor like this:

The capacity is proportional to the area of the plates. So putting two capacitors in parallel in effect increases the size of the plates so the capacity value increases.

The capacity is inversely proportional to the distance between the plates - increase the spacing (the thickness of the dielectric) and the capacitance will decrease.

Putting two capacitors in series, in effect does the same thing, it increases the effective distance between plates so the value decreases.

Like the resistor, we can use this visualised example to easily work out what happens with two typical capacitors of the same value. Put two in parallel, the value will double. Put two in series and the effective value will be half.

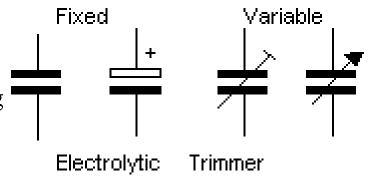
Voltage ratings

The dielectric space between the capacitor plates may be made very small, to achieve a high capacitance in a component of small physical size. A high voltage applied between the plates may cause a break-down in the dielectric causing a short-circuit or other damage. So each capacitor must be given a voltage rating by its manufacturer in addition to its capacitance rating.

In practice, capacitors may sometimes be wired in series to achieve higher effective voltage ratings for special applications. Two capacitors of the same voltage rating wired in series will produce a resulting capacitor of double the effective voltage rating but of half the capacity. (In practice, there are other things that should be taken into consideration too, but these are not of concern for this amateur radio examination.)

Most types of capacitors have low leakage. This means that they can hold high levels of charge for long periods after voltage has been removed, and for this reason should be treated with caution when servicing equipment in which high voltages are used.

Capacitor types and characteristics



Air-spaced: are used mainly as variable capacitors for *tuning*. Air-spaced capacitors consist of a set of fixed plates, with a set of moving plates, mounted on a spindle, that exactly mesh with the fixed plates. The moving plates are controlled by a knob or by a screwdriver adjustment. Values from 5 to 500 pF and voltage rating up to 500 V for receivers, and several thousand volt for transmitters are available. There are special types for some applications.

Electrolytic: in this type of capacitor the dielectric is a very thin layer of aluminium oxide formed on the plates by a conducting chemical compound when a DC potential is applied. The surface of the plates, which are made of aluminium foil, may be etched to increase the surface area and hence the capacitance value. The large surface area and the very thin dielectric means that a very large capacitance value can be obtained. Another similar type uses tantalum oxide as the dielectric. Tantalum range from 0.01 to 3000 µF with voltages up to 100 volts, while aluminium types range from 0.1 µF to nearly 1 F with a voltage range of from 3 to 700 volts. The higher the value of capacitance, the lower is the voltage range. In both types a leakage current is essential to maintain the dielectric, and they are generally used on a DC voltage for smoothing and de-coupling. The polarising voltage must also be high enough to keep the leakage current flowing, otherwise the capacitance value will be reduced.

Capacitive reactance

In a capacitor, energy is not dissipated but is continually being stored and released. Opposition is to current flow, which results from energy storage rather than energy loss and is called ***reactance***. It is dependent on frequency and is denoted by Xc.

$$X_C = \frac{-1}{2\pi f C}$$

The unit for ***capacitive reactance*** is ***ohms.*** The formula, where ***f*** is the frequency in ***hertz***, **C** is the capacity in ***farads***, and **Xc** is the capacitive reactance in ***ohms***, is shown:

Note that ***capacitive*** reactance is expressed in ***ohms***, and for purposes of easier explanation, we here give it a ***negative*** sign. This will be considered again in the explanations following below. This is a convenient way for us to make a distinction between capacitive reactance and inductive reactance.

Note that as the ***frequency rises***, the ***capacitive reactance decreases***. (Compare this with inductive reactance - see above.)

Current, voltage and phase

As mentioned earlier, resistance and reactance must be added vectorially. For a first and elementary understanding for the purposes of this amateur radio examination, a visual approach is possible.

When a capacitor is first connected to a DC supply, a large current flows while the capacitor builds up its charge. The current ***leads*** on the voltage. At full-charge, the voltage across the capacitor will be high but the current will be zero.

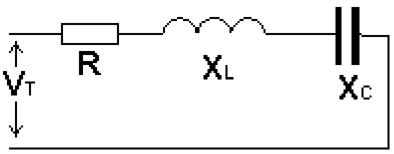
This is in contrast with an inductor. When an inductor is first connected, there is a large voltage drop across it which decreases as the current rises as the magnetic field builds up. The voltage ***leads*** on the current. After a period, the voltage across the inductor will be low but the current through it will be high.

The behaviour of inductors, capacitors, and resistors (L, C, and R), in AC circuits is more complex than it is in DC circuits. Fortunately we can envisage the basic principles.

Resistance is an opposition to current that results in ***power loss***, while ***reactance*** is an ***opposition*** to current resulting from a ***storing of energy***. For our purposes (at the moment), keep resistance and reactance separate.

The resistor-inductor-capacitor (LCR) or *series circuit*

The diagram shows a series circuit of R, L, and C. The total ***reactance*** is the resulting **difference** between X_L and X_C. The voltage across each component adds up to the **total** input voltage, V_T.



Consider a change in the frequency of this input voltage. If we start off with V_T at a low frequency, the voltage across the capacitor is much greater than that across the inductor, and the resultant reactance is capacitive. As the frequency increases, the capacitive reactance decreases and the inductive reactance increases, and at very high frequencies the resultant reactance is inductive.

At some intermediate frequency the two reactances are equal (but of opposite sign). At this frequency, the impedance of the circuit is purely resistive due to R, and there is no resultant reactance. The sum of the two reactances is zero. This is called the ***resonant frequency***.

The resonant frequency ***f*** (in Hz) is given by this formula, in which **L** is in henries and **C** is in farads:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

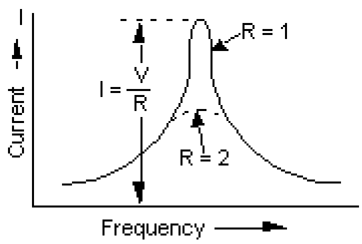
(This formula can be easily derived from the relationship $X_L + X_C = 0$ (*at resonance*) by substituting for X_L and for X_C and then solving for *f*. Do it!)

There is only one frequency at which resonance occurs. The reason for resonance is that L and C have exact opposite numerical values at resonance. In an inductor the voltage leads the current by 90 degrees while in a capacitor the voltage lags the current by 90 degrees. We have observed this earlier by adopting a different sign for capacitive reactance.

It is important to note that ***in a series circuit at resonance*** the reactances (being equal but of different sign), in effect disappear (i.e.= 0), leaving only the ***resistance*** R.

Note the effect of the square root in this reciprocal relationship. If the inductance (or, separately, the capacitance) is quadrupled in value, the frequency is reduced to half.

The Q of a circuit



As the input frequency signal moves away from resonance, the impedance of the circuit rises and the current through it falls. This diagram shows the variation of current with frequency for a series LCR circuit for two different values of R.

Note that the current at high and low frequencies is fixed by inductive and capacitive reactances respectively, while the current at resonance is determined by the resistance. Having a low value of resistance in a tuned circuit is very desirable to be sure of maximum selectivity. The effectiveness of a resonant circuit is stated by its "Q".

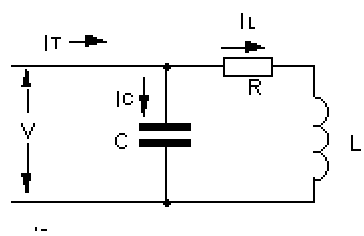
The ratio of the voltage across the inductor to the input voltage V_T is the magnification factor or ***quality*** factor of the circuit. Expressed another way, Q is the reactance divided by the resistance. The ***smaller*** the ***resistance***, the ***higher the Q***.

Q is a ***ratio*** of two numerical values and hence is a figure alone and has no unit.

Note that the term Q can also apply to capacitors as well as inductors, they are both "storers" of energy.

The Q or magnification factor, or quality factor, of the circuit, depends on the coil construction, and can range from 5 to 500 in transmitting tuned circuits, to 150 in transformers and to 3000 or so in helical and VHF cavity resonators.

The Parallel LCR circuit



The other common LCR circuit is that with L and C in parallel. This diagram shows the parallel circuit. In practice there is always some resistance in the inductor, so it is usual to consider a resistor in series with the inductor.

At frequencies below resonance, the reactance of the inductor is much less than that of the capacitor and the circuit is mainly inductive reactive. At frequencies higher than resonance, the capacitor has the lower reactance and the circuit is mainly capacitive reactive. In between the two frequencies, there is a frequency at which the two reactances are equal. Only a very small current flows in the circuit at this frequency.

The parallel resonant circuit obeys the same formula for resonant frequency as the series resonant one, but at resonance the parallel resonant circuit has a ***very high impedance***. The resistance at resonance offered by the parallel resonant circuit is very high if the resistance of the inductance is very small, and is known as the dynamic resistance.

The parallel tuned circuit is used to select one particular signal frequency from among others. It does this by rejecting the resonant frequency because of its high impedance. For this reason, it is sometimes called the *rejector* circuit.

Both series and parallel resonant circuits may be found in radio receivers and transmitters. In oscillators and transmitters they are sometimes known as *tank* circuits. This comes from their ability to store energy in the electrostatic field of a capacitor or in the magnetic field of an inductor.

The selectivity of a tuned circuit is the ability of the tuned circuit to select a signal at the resonant frequency and reject other signals that are close to that frequency. A measure of the selectivity is the Q, or quality factor.

Q can be the quality factor of either the capacitor or the inductor in the circuit, but it is generally taken as the quality factor of the inductor. Inductors have Q at any frequency, not just at resonance. The Q of an inductor falls with frequency. Q is dependent on the resistance of the coil up to about 30 MHz, and above this losses in the capacitor may be significant.

Measuring Q

One way to determine the the Q of a tuned circuit is to measure the bandwidth (BW) between the two points referred to as the ***half-power points***.

In a series-tuned circuit. these are the two frequency points at which the current has fallen to 0.707 of its value at resonance. There are two of these half-power points in a resonant circuit, one above and one below resonance.

If the frequency difference between the half-power points is given as the bandwidth **BW**, (the difference in frequency is a number), and if the resonant frequency is **f**, then:

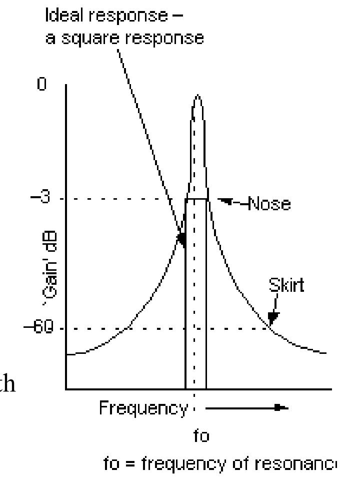
$$Q = \frac{f}{BW}$$

Because Q is a ratio, f and BW can be in the same units, Hz, kHz, or MHz.

Bandwidth

As we have seen, Q is related to the bandwidth of the response curve. Different bandwidths are optimum for different modes. For example:

1. TV signals require 5.5 MHz or more,
2. AM broadcast stations require 9 kHz or more,
3. Single sideband (SSB) signals require 2.4 kHz,
4. Continuous wave (CW) signals require 100 Hz.

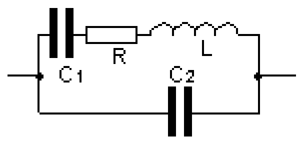


This diagram shows the ideal shape of a response curve, a square response, with the width exactly the bandwidth required.

This ideal shape is difficult and expensive to achieve. The bandwidth is measured at the half-power or - 3 dB points which are where the voltage has fallen to 0.707 of its value at resonance (we'll deal with dB later). This is also called the *nose* of the curve. The *skirt* bandwidth is usually measured at the - 60 dB point and the ratio between the two is a measure of the quality of tuned circuits, particularly filters. The ideal is 1 to 1, but is never achieved.

The quartz crystal

Crystals are thin slices cut from various planes of a quartz crystal. In its simplest construction form, a quartz crystal can be considered as a very thin slice of quartz sandwiched between two metal plates.



This diagram shows the equivalent circuit of a crystal. Quartz crystals are a much-used form of resonant circuit. The piezoelectric properties of quartz are used to produce the equivalent of a highly-stable resonant circuit with a very high Q. Crystals are not high power devices, at low frequencies their power dissipation is limited to about 10 mW and for the higher frequencies it is limited to 2 mW.

C_2 is the capacitance of the crystal holder. The Q of a crystal is of the order of 20 000. The crystal has two resonances, one series and one parallel. C_1 and L resonate as a series circuit. C_2 together with L and C_1 resonate as a parallel circuit.

Safety

Equipment used in an amateur radio station may contain very high voltages. There may be voltages high enough and the current may be enough to kill you. This is serious business. Be very careful.

Until you know what you are doing - **KEEP OUT!**

Keep your fingers and other conducting material away from the insides of power supplies, amplifiers and transceivers.

Electricity can, and does, kill. It takes between 100 and 200 mA to kill you, 10 mA to frighten you, and you can feel 2 mA. An ungrammatical expression sums it up — ***It's the volts what jolts but the mils that kills***. Your skin resistance controls the strength of the current. Head to toe, it can be a dry 500 000 ohm or a wet 1000 ohm. A typical figure for hand to foot, the usual path of the current, is 500 ohms. Between the ears the resistance is about 100 ohm.

Common-sense precautions are very necessary. Work on live gear only when absolutely necessary, and, even then, keep one hand in your pocket. Even after switching off, earth all high voltage points to discharge capacitors, as some of these retain lethal charges. Ensure that equipment is well earthed. Stand on an insulated floor and avoid working in damp conditions.

Display a mouth-to-mouth resuscitation chart on the shack wall. Do not be lulled into a sense of false security about low voltages. Death by electrocution has occurred at 42 volt.

Don't play with *anything* -

unless you *know* what you are doing!

THINK OF YOUR OWN SAFETY! Should you come across someone who has been electrocuted, ensure that ***all live circuits have been turned off*** before attempting a rescue.

An R F Earth

Your station must have an RF earth. All modern equipment has an earthing terminal on the back panel and this should be connected to a good earth. Drive a length of water pipe into the ground - a couple of metres long. A thick copper cable should be connected from the back of the radio to the earth pipe.

Connecting to the mains

Other Regulations that are not a part of the radio world but which affect you are New Zealand's electrical regulations. These apply up to the primary winding of any transformer and cover the AC side of any mains power supply. There are published circuits, particularly from American sources, which do not comply with the New Zealand requirements.

In New Zealand the MEN (Multiple Earthed Neutral) system of mains wiring is used. The neutral wire is normally connected to earth at the transformer or, in a domestic installation, at the switchboard. Thereafter, it should be completely isolated from earth. A separate earth wire is run to all equipment, and used to securely bond any exposed metal to earth at the switchboard. If a live wire now contacts the metal, a short-circuit to earth is caused and the fuse or circuit breaker will operate. If this was not done, the metal could remain live and be a real hazard.

Regulatory requirements that must be observed are:

1. It is illegal to switch the neutral wire only. If this is done, any capacitive or resistive leakage will raise the potential of the chassis to 230 V, the full-phase voltage. While a lethal shock under these conditions is unlikely, a non-lethal shock may be very unpleasant. The danger is when two chassis, livened to different phases or one to phase, one to neutral, should come into contact. Similarly, if a fault should occur on a chassis, then there is no way of finding out until an accident occurs. It is permissible to switch both phase and neutral, and if you are operating your equipment off a long extension cord it would probably be safest to do this.

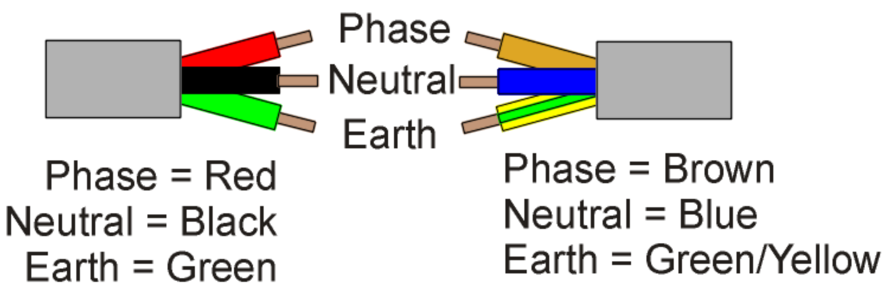
2. It is illegal to insert a fuse in a neutral line, even if the phase is also fused. There is no guarantee that two fuses of nominally the same rating will fail at the same time. If the neutral one goes first, a similar situation as when switching the neutral only could arise.

3. For your own protection you should check that all the equipment you buy or construct complies with New Zealand's electrical regulations.

4. A lot of imported Amateur Radio equipment designed for other wiring systems should be modified to comply with the New Zealand requirements.

Flexible cords

This diagram shows the colour-coding in use with flexible mains cords. The more modern equipment use the colour code: **brown, blue, green / yellow**.



Rescue breathing

While on the subject of safety, it is a good idea for both you and someone in your household to be able to carry out rescue breathing or some other form of resuscitation if required. Classes are usually available in most communities.

If you find someone who has suffered an electric shock, be sure to switch off the supply before attempting to make a rescue. Avoid further tragedy.

Safety devices

The importance of having a good earth lead from an appliance cannot be over-emphasised. Check your appliances and equipment regularly.

If you are going to work on a mains power supply unit which is transformer-less, or which has an unusual transformer arrangement, it is advisable to use an ***isolating transformer*** between that power supply unit and the mains.

An isolating transformer is a double-wound transformer - it has identical primary and secondary windings. The secondary "floats" rather than having one side connected to earth. This is unlike the mains which has the neutral lead connected to earth at the switchboard.

Both wires from the transformer are "hot" with respect to each other but not "hot" with respect to earth. Should a fault develop in an attached appliance such as a leakage to a metal case, that case will not be "hot" (and dangerous) with respect to earth.

An ***earth-leakage circuit breaker*** or ***residual current device*** is another safety device that you may find in some installations. It consists of a relay arranged so that if the mains phase and neutral currents become unequal, as could happen with a fault in an appliance causing a current in the earth wire, the supply is very quickly switched off.

Semiconductors

Devices

The diode is used extensively in radio equipment. It is a two terminal device that passes current in only one direction.

Transistors are three-terminal devices. We look at the junction transistor and then the field effect transistor.

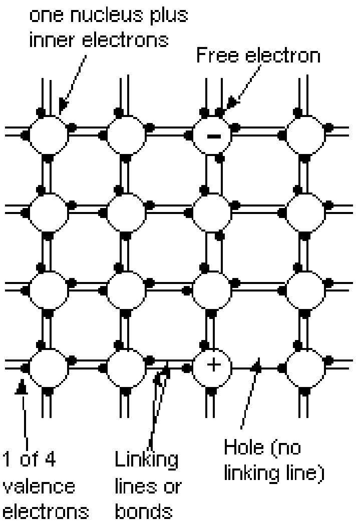
Materials

In ELECTRONIC FUNDAMENTALS we discussed the atomic structure of various materials.

Materials composed of atoms whose outer electrons are loosely bound to the nuclei are classified as conductors because their electrons can be moved about easily by an applied potential, and so produce an electric current. Materials with strong bonds between electrons and nuclei are classified as insulators because their electrons cannot be moved about easily by an applied potential, to produce an electric current. Between these two extremes there is a category of materials which can have their properties controlled to vary between conductors and insulators. This class of material is called semiconductors. In electronics, silicon, germanium, and gallium are the semiconductor materials that are of major interest.

Atomic structure

The peculiar properties of semiconductors are due to their crystal structure. Each atom has four outer electrons, and each of these electrons, called valence electrons, is bonded to one of the neighbouring atoms.



This diagram shows the crystal form and a typical bonding through linking lines.

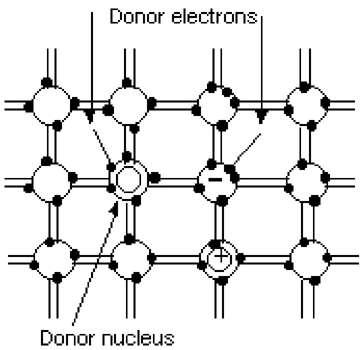
At very low temperatures the crystal structure is complete and the resistivity of the material is very high. As the temperature increases, an increasing number of electrons acquire enough energy to break the bond, and they become free and able to contribute to a current flow. The resistivity decreases as temperature is increased, therefore, the material has a negative temperature coefficient. It is important to remember that this effect can, if left unchecked, result in permanent damage to a semiconductor device.

When an electron breaks away from its parent atom, a hole is left behind. Since this is caused by the loss of a negative charge, the hole can be considered to be a positive charge. The hole will be filled by another electron, and another hole created. As this happens throughout the crystal lattice, there is not only conduction by electrons in one direction, but also an apparent conduction of holes (positive charges) in the opposite direction. This diagram shows a free electron and a hole in a crystal lattice.

Impurity additives

To ensure control of conduction, the materials silicon and germanium are refined to a very high degree of purity. Other materials called impurities are carefully added, in a process called doping, to the silicon or germanium so that they behave as required for use in electronic circuits.

As already noted, both germanium and silicon have four valence electrons. If a material having five valence electrons is added as the impurity, it will *lock in* to the crystal structure, leaving one electron free. There will be a surplus of negative charge carriers, and the germanium or silicon so treated is known as N-type material.



The atoms which produce the additional electrons are called donors. The donors most used are arsenic, antimony, and phosphorus. It is important to remember that, the material as a whole is electrically neutral because the spare electron is balanced by its own atomic nucleus, which carries a positive charge.

If a material having only three valence electrons is added to the germanium or silicon there will be the absence of a bond between two atoms. This creates a hole, which is a positive charge carrier. Such material is known as P-type and conduction is mainly by holes, in contrast to N-type in which conduction is mainly by electrons.

N-Type semiconductor

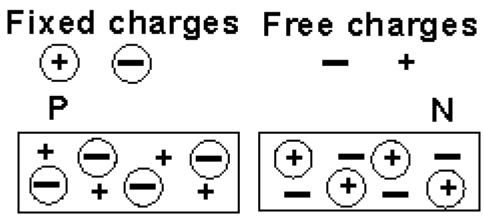
In each type of material there will be some conductors of the opposite type caused by thermal effects. These conductors are known as minority carriers. Atoms which produce P-type material are called acceptors and are aluminium, gallium, and indium.

This diagram shows N-type semiconductor material.

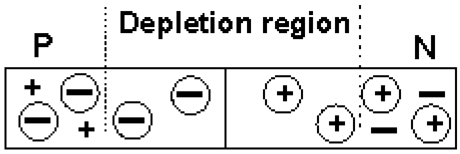
Many semiconducting devices are formed by mixing donor and acceptor atoms in a crystal by themselves. The commonest of these is Gallium Arsenide, used in many transistors, including RF power transistors, UHF RF amplifying transistors, and light emitting diodes.

Diodes

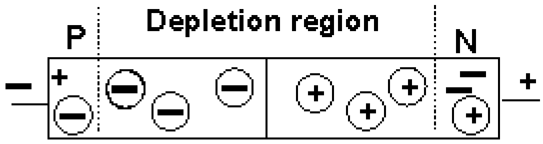
This diagram shows the state of the junction between a piece of P-type and a piece of N-type material for four conditions.



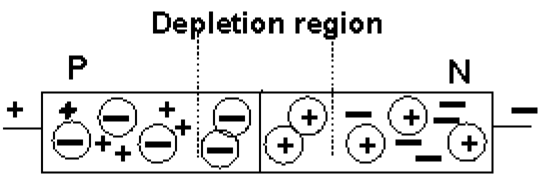
(A) P and N pieces



(B) No external voltage applied



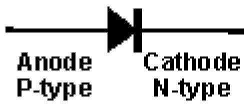
(C) Reversed biased



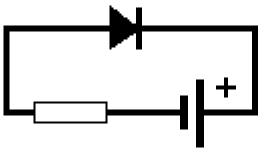
(D) Forward biased

(A) shows the state of the junction when the pieces of semiconductor material are not together.

(B) shows a junction formed by doping the opposite ends of a crystal of semi-conductor material with acceptor atoms and donor atoms. When there is no external voltage applied the free electrons and holes near the junction drift across and combine. The N-type material loses electrons and is positive, while the P-type gains electrons and is negative. This process sets up a field in the region of the junction which prevents any further carriers from crossing the junction. The area immediately on either side of the junction is reduced of carriers by this field, and is known as the depletion region. Some current flows through the junction because temperature effects produce electron-hole pairs in the junction area. This current is called leakage current.

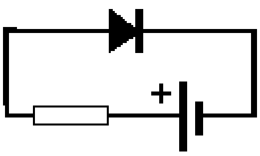


(C) shows the condition when a positive voltage is applied to the N-type material and a negative one to the P-type, the depletion layer is reinforced, and the width of the depletion is increased. Under these conditions, the diode is reverse-biased and very little current can flow.



Reverse-biased

(D) shows the condition when a negative voltage is applied to the N-type material and a positive one to the P-type, the depletion layer is reduced, and the width of the depletion is decreased.



Forward-biased

If the potential is high enough the junction will conduct. This is known as forward bias. The voltage required to forward bias the junction depends on the material, and is about 0.6 volt for silicon and 0.2 or 0.3 volt for germanium.

The ideal diode would be one that appeared to be at zero ohms when forward biased, and infinite ohms when reverse biased. In practice, leakage current always flows and typical values are 1 µA for silicon and 50 µA for germanium.

This diagram shows the symbol used for the diode and the names given to the terminals. Conventional current flows from the anode to the cathode.

The arrowhead on the circuit symbol shows the direction of conventional current flow, so this indicates flow from positive to negative potentials.

Point contact diodes

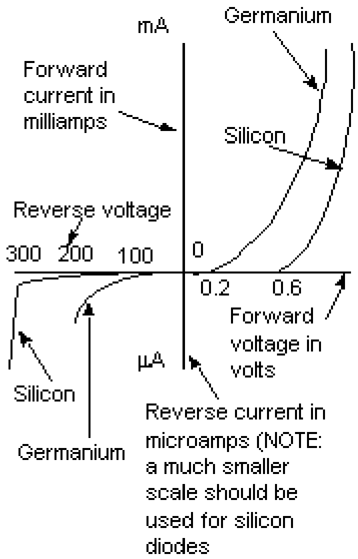
Junction diodes have high internal capacitance and are restricted to relatively low frequency use. The point contact diode has a capacitance of only a few picofarads and can be used at frequencies in the VHF and UHF ranges for such purposes as signal monitoring and for signal detection.

Varicap or Varactor diodes

When a junction diode is reversed biased, the depletion region of a diode is cleared of carriers, and the depletion region acts as an insulator. The reverse-biased diode therefore forms a capacitor, and by varying the width of the depletion layer by varying the reversed biasing voltage, the capacitance of the junction can be made to vary. Varicap or varactor diodes are used as frequency modulators or to vary the tuning of resonant circuits.

Diode characteristics

This diagram shows the characteristics of typical semiconductor diodes.



The curves are for signal diodes. For power diodes the reverse voltage is within the limits of 50 and 1200 volts.

Diodes have three characteristics of importance, which can be obtained from manufacturers' data sheets. They are:

1. ***Peak Inverse (or reverse) voltage (PIV):*** the maximum voltage in the reverse direction that the diode can withstand before breaking down.

2. ***Maximum forward current:*** usually two values are given one for non-repetitive peak current, such as a switch-on surge, and the other for repetitive peaks.

3. ***Average forward current:*** is accepted as the working current with natural cooling.

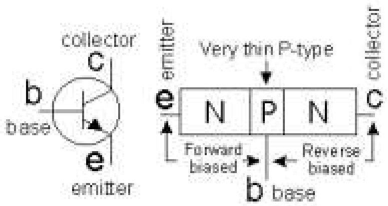
The Zener diode

The zener diode is a diode with special doping to use the reverse voltage characteristics for voltage-regulation applications.

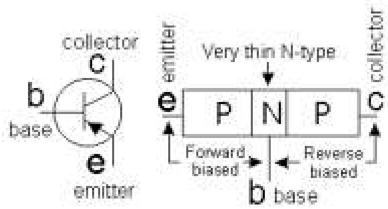
Diode packages

Diodes come in a variety of shapes and sizes, depending on the application. Their physical size is large for power diodes and small for low power applications. The main problem is how to identify the leads.

Usually, the cathode is marked with a ring or band, a dot or a red end. Sometimes, a diode symbol is marked on the diode to indicate the connections. If a diode is unmarked, an ohm-meter can be used to find out which end is which. The diode is reversed biased when the meter shows a high resistance and forward biased when the meter shows a low resistance. Do not forget that most analogue multimeters used for measuring resistance have voltage on the probes of opposite polarity to that marked, for example, a negative voltage on the red probe. If in doubt, check with a known diode.



(A) NPN transistor



(B) PNP transistor

Transistors

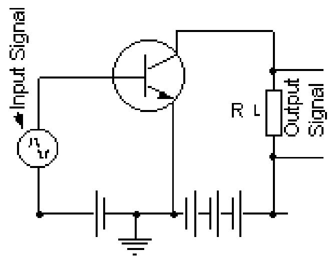
The name *transistor* is derived from the words *transfer* and *resistor*.

The diagram (**A**) shows the transistor symbol and the block representation of an NPN transistor.

The emitter-base junction is forward biased with about 0.6 V (for a silicon device) so that it has a low resistance. The base-collector junction is reverse biased with about 6 V and has a high resistance. The centre connection, the base, is very thin and most of the current entering it goes right through to the collector circuit.

When the base-emitter junction is forward-biased electrons flow from the emitter into the base. Because of the thinness of the base region and the attraction of the higher collector voltage, most of the electrons go right through the base into the field of the reverse-biased collector-base junction. Here, they are swept through the depletion layer and out through the collector terminal.

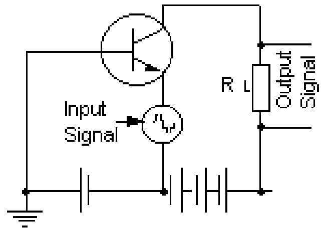
(**B**) shows the symbol and the block representation for a PNP transistor.



(a) Common Emitter

Transistor circuits

There are three methods of connecting transistors into circuits. The diagram shows the three type of circuits as common emitter, common base, and common collector. They are identified by the terminal which is common to both input and output circuits.

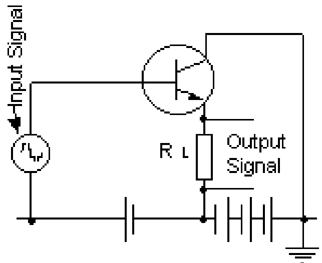


(b) Common Base

Common emitter circuit: is the one that is most used because of its moderate input impedance and high power gain (see (a)).

Common base circuit: is where most of the emitter current flows through to the collector, and the input current is high. Current gain is always less than one. Because of the high current in the input, the input impedance is low. Output impedance is high (see (b)).

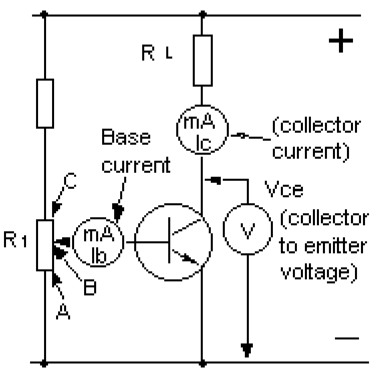
Common collector or emitter follower circuit: has a high input impedance and low output impedance. Because the base to emitter voltage is constant (0.6 V for silicon, 0.2 V for germanium), the emitter voltage closely *follows* any variations in base voltage. Voltage gain is always less than one, but there is a current gain in this circuit (see (c)).



(c) Common Collector

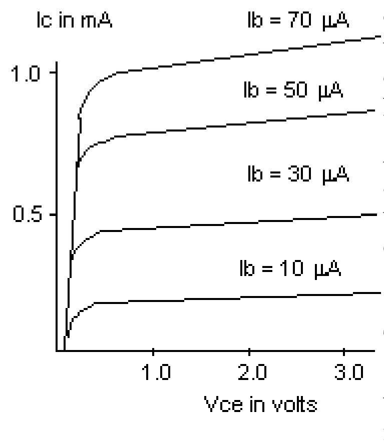
Transistor operation

This diagram shows a transistor in a circuit where the voltage supplying the base can be adjusted. If the base is held at the bottom end of the potentiometer R_1, point A, the base-emitter voltage will be zero and no current will flow from emitter to collector. There will be no voltage across the load resistor R_L, and the collector voltage will equal the supply voltage. The transistor, in this condition, is said to be cutoff.



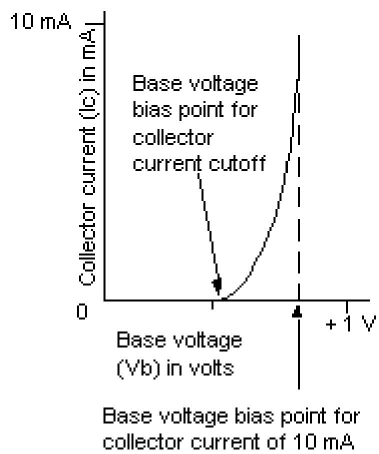
If the base voltage is increased by moving the potentiometer towards point B, base current will start to flow once it exceeds the threshold voltage for the material (approximately 0.2 V for germanium and 0.6 V for silicon). Base current will produce a corresponding collector current, and there will be a drop in collector voltage. As the base voltage is further increased towards point C, the collector voltage will continue to fall until it reaches a voltage just above zero. The transistor is now said to be saturated. Any further increase in base voltage will not increase the collector current.

Transistor manufacturers provide characteristic curves which show information about the transistor. The commonest curve is one relating collector current to collector voltage for different fixed values of base current. Typical curves for the common-emitter collector characteristics for a small-signal silicon NPN transistor are shown in this diagram.



Another important characteristic curve for an <u>active</u> device is the *transfer curve*. The transfer curve relates the input voltage or current to the output voltage or current.

This diagram shows the transfer curve for a small-signal NPN transistor. It shows how the collector current changes with a change in base input voltage.



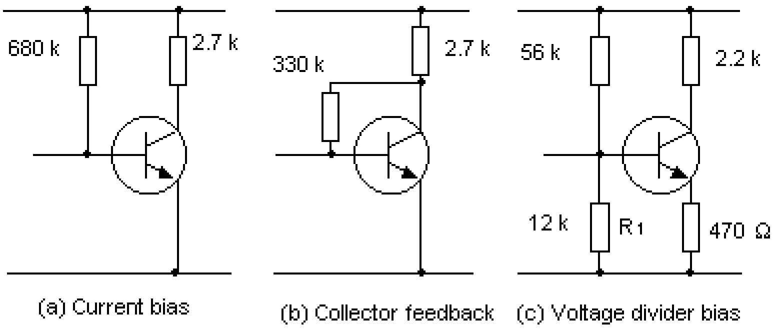
When the base voltage is zero no collector current flows. This is the base voltage bias point for collector current cutoff. If the base voltage is increased, collector current flows. A point is marked on the graph where 10 mA of collector current flows for about 0.7 base voltage.

The base voltage and the corresponding collector current is important in amplifier applications.

Methods of biasing

Biasing of transistors is the process of setting up the DC operating conditions for the application intended.

This diagram shows three common biasing methods. The first point to note is that supply polarity is opposite between PNP and NPN transistors.



The ***PNP*** transistor requires a *positive* ***emitter*** *supply*, (see arrow on symbol) with the base and collector at a more negative potential.

The ***NPN*** transistor requires a *negative* ***emitter*** *supply*, with the base and collector at a more positive potential.

A problem to be considered in biasing some transistors in some circuits is compensation for the change in transistor operating conditions with a change in temperature. This is called the *thermal drift* of a transistor.

At high temperatures, a certain number of electron-hole pairs form in the collector-base junction, and the resulting leakage current in the base circuit is amplified just as a signal current would be. The collector current is then increased and the transistor gets hotter. The process is self-perpetuating and is known as *thermal runaway*. Germanium transistors are more likely to be damaged in this way, but silicon devices are not immune. To avoid these effects, bias circuits have been devised to compensate for the change in transistor operating conditions with a change in temperature.

(**a**) shows the simplest bias circuit using current biasing. A resistor between the supply rail and base is used to set base current to the required value. This circuit has no provision to compensate for the increased collector current that causes thermal runaway.

(**b**) shows the circuit when the base resistor is connected to the collector rather than to the supply. The increase in collector current causes the collector voltage to fall thus reducing the base voltage, and bringing the collector current back to near the original value. This type of circuit is termed a collector ***feedback*** circuit using current biasing. This connection roughly halves the input impedance of the stage compared to that of circuit (a).

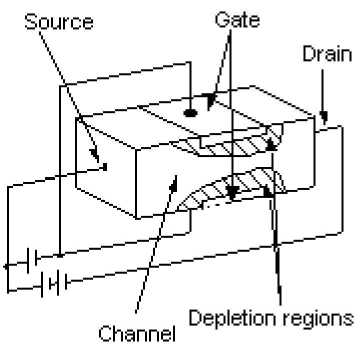
(**c**) shows the circuit that is most frequently used.

The base bias is obtained from a voltage divider arrangement that is arranged to keep the base voltage at a constant value. The small resistor in the emitter lead provides voltage feedback. An increase in collector current increases the emitter voltage and because the base voltage is fixed by the base voltage divider, the base-to-emitter voltage is reduced thus reducing the collector current back towards its original value. This is known as voltage biasing with emitter feedback.

Bipolar junction transistors are called bipolar devices because both majority and minority carriers are involved in their operation. They have two junctions. A diode is a "uni-polar" device.

Field Effect Transistors

Field effect transistors are uni-polar as only one form of carrier is involved, and this carrier is the majority carrier for the material used. These are junction FETs and are known as JFETs. This diagram shows the principle of operation.

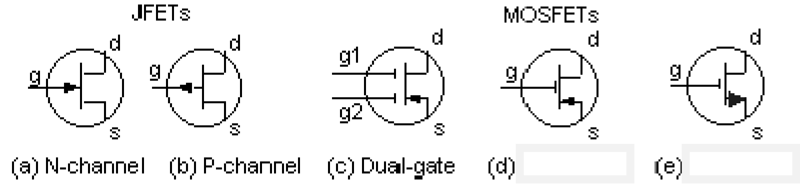


The depletion regions between the gate layers and channel causes a variable width of the channel, depending on the gate-to-source voltage. The channel acts as a voltage-controlled variable resistor with a very-high input resistance. The two ends of the channel are known as the source and the drain. The source corresponds to the emitter of a transistor, and the drain to the collector.

For HF and VHF use, the usual circuit configuration is the common source, and for UHF the common gate circuit. JFETs are available in both P-channel and N-channel types.

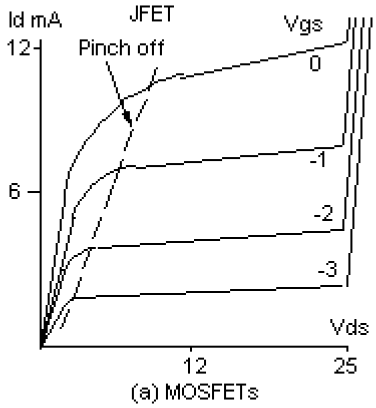
The diagrams (**a**) and (**b**) show the circuit symbols for two types of JFET. Both are depletion types.

The channel conducts when there is no gate potential, and as the gate is reverse-biased, the channel becomes depleted until the device is cutoff. In the N-type, the channel is of N-type material, and the carriers are electrons. In the P-type, the channel is of P-type material, and the carriers are holes.



For the examples shown in (**c**), (**d**), and (**e**), the full name for these are metal oxide semiconductor field effect transistor, ***MOSFET***. Various symbols are used to indicate MOSFETs and are shown in (**c**), (**d**), and (**e**). They are made in both N-channel and P-channel, and also in depletion and enhancement types. The enhancement types pass little or no current if the gate is unbiased, and the gate must be forward biased to increase conduction.

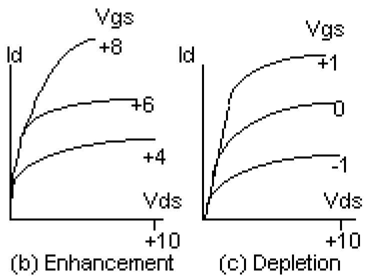
The gate is insulated from the channel, and this gives a very high input resistance. For a JFET the input resistance is up to 1000 megohm for silicon types. For the MOSFET it is 10^9 to 10^{16} ohms. Because of the very high input resistance, static voltages can build up to a very high value in MOSFETs, and can destroy the oxide film between gate layers and channel. Once damaged it can never be repaired. To overcome this problem many types of MOSFETs have built-in gate-protective zener diodes. Without this provision the gate insulation may be perforated easily by small static charges on the user's hands or the application of excessive voltages. The protective diodes are connected between the gate(s) and the source of the MOSFET.



These devices are used at HF, VHF, and UHF as amplifiers, oscillators, product detectors, and mixers. They have excellent temperature characteristics, and have lower internal noise than bipolar devices.

FET biasing

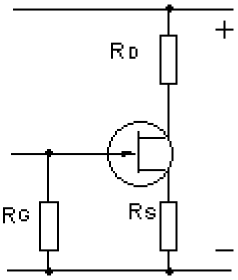
This diagram shows curves for various FETs.



Characteristic curves can be drawn for FETs as for bipolar transistors. The main one is a plot of drain current versus drain voltage for different fixed values of gate voltage.

As the drain voltage is increased, the drain current first rises rapidly, then steadies and remains at an almost constant level. This is due to pinch-off , a point where the full width of the channel is almost totally depleted. The sudden rise in the right-hand side of the curves of (a) is because a breakdown voltage has been reached and the JFET looses its normal operating characteristics. The value of the drain-source voltage at which this occurs is typically 25 to 50 volts.

Bias control in FETs is normally done by using a source resistor. With the depletion mode FET, the gate must have the opposite polarity to the drain. Biasing therefore would appear to require two supplies of opposite polarities for this device. One a positive supply for the drain and a negative supply for the gate.



In practice, this is rarely done except in special cases. For small-signal applications, the source current is used to provide the bias voltage.

By inserting a resistor in series with the source lead as shown in this diagram, the source current generates a voltage which holds the source a few volts positive over the common or negative supply lead.

The gate is maintained at the common potential by the gate resistor R_G and as no current flows in the gate circuit the gate is effectively at a few volts negative relative to the source.

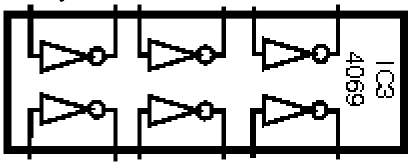
FETs can be connected in three circuit configurations, in much the same way as transistors can. The three are:

1. Common source,
2. Common gate, and
3. Common drain or source follower.

The properties of the three configurations are similar to those of the equivalent transistor connection.

Semiconductors

It would be nice to be able to have standardised connections for the leads of semiconductors. In practice "pin-outs" vary widely and the manufacturer's data must be consulted.



Integrated circuits (IC's) are a network of semiconductors manufactured on the one chip. There are many varieties, both analog and digital. They are as complicated as anyone can make them.

Their drawings vary and many different styles of presentation are possible. A specification sheet may - or may not - give a block diagram of its interior "workings". This diagram here is for illustration only and shows just one very simple component - six inverters in the one package.

Practical considerations

Excessive heat damages semiconductors. The manufacturer's limits of voltage, current, and power dissipation should always be observed to keep the heat of the device to safe limits. When soldering, keep the contact time as short as possible.

Applications for these semiconductor devices

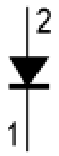
Typical applications are in amplifiers, oscillators, modulators and demodulators, too numerous to mention!

Electronic Devices

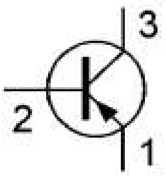
The circuit symbols and the connections to various electronic devices will be explained in sequence. Please refer to your training manuals for pictures or drawings giving examples of the physical construction of these devices.

In all the examples shown below, the electrodes start at the same reference point (usually the source of the electrons) and rotate in a ***clockwise*** direction. This is a standard convention throughout electronics.

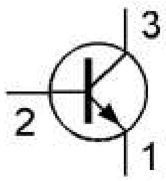
Semiconductors:



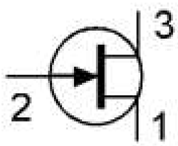
A fundamental device in all electronics is the "**diode**". It has two connections, the ***cathode*** shown here as **1,** and the ***anode***, shown here as *2*. It conducts when the anode is positive when compared or referred to the cathode. In other words, the "arrow" forming the symbol shows the direction of the "conventional" current flow. "Conventional current" means a positive-to-negative flow compared to "electron flow" which is negative to positive.



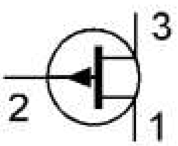
This device is a **transistor -** a fundamental device found in semiconductor amplifiers and similar applications. This is a **bi-polar** transistor - a name used to distinguish it from other types considered below. For our purposes there are two types of bi-polar transistor. This one is a **PNP** transistor. Its operation is explained elsewhere in this GUIDE. The significant indicator is the one with the arrow. There are three electrodes, the ***emitter*** **1**, the ***base*** **2**, and the ***collector*** **3**. Start with the emitter as your reference point and remember **e-b-c**.



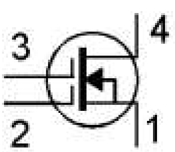
This device is also a bi-polar **transistor.** This one is an **NPN** transistor. Its operation is explained elsewhere in this GUIDE. The significant indicator is again the one with the arrow. Note that it is drawn in the opposite direction to the earlier example. There are again three electrodes, the ***emitter*** **1**, the ***base*** **2**, and the ***collector*** **3**. Again, remember **e-b-c**.



This device is from a different family of transistors. This is a "***field-effect***" transistor or **FET**. Again, to distinguish it from other members of the field-effect family (following below), this is a ***junction field effect transistor*** or **JFET**. To be more distinctive, this is known as an "***n-channel***" **JFET**. Two electrodes are shown as similar, **1** and **3** on this diagram. This is deliberate and is one of the distinguishing features of an FET. The electrode names are ***source*** **1**, ***gate*** **2** and ***drain*** **3**. Remember **s-g-d**.



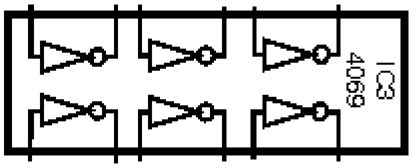
This device is from the same family of transistors, a "***junction field-effect***" transistor or **JFET**. Note the direction of the arrow on the symbol. This change of direction of the arrow also means a change in the polarity of the supply voltages. Again, to distinguish this JFET from the one considered above, this is a "***p-channel***" **JFET**. Once again, two electrodes are shown as similar, **1** and **3** on this diagram. This is deliberate and is one of the distinguishing features of the FET. Again the electrode names are ***source*** **1**, ***gate*** **2** and ***drain*** **3**. Remember **s-g-d**.



Another member from the field-effect group of transistors. This is a **MOSFET -** a ***metal-oxide-semiconductor field-effect transistor***. This device is explained elsewhere in this GUIDE.

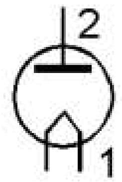
The device shown is an **n-channel** device. As with the JFET, there is a **p-channel** version of the MOSFET too (it has the arrow reversed) - but that is getting beyond the needs for this examination.

There are two "gates", this time 'gate 1' and 'gate 2'. Each is insulated from the "semiconductor slab". The electrodes, in sequence, are: the source **1;** 'gate 1' **2;** 'gate 2' **3;** and drain **4**. It is worth noting that this is a **four-terminal** device, previous transistors are **three-terminal** devices.



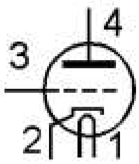
Integrated circuits (IC's) are as complicated as anyone can make them. Their drawings vary and many different styles of presentation are possible. The drawing may - or may not - give a block diagram of its interior "workings". This diagram is for illustration only and shows just one style.

The "odes" of Thermionic valves

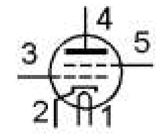


This device is also a ***diode*** - a thermionic diode. It has a hot filament **1** which acts as the source of the electron emission, and a cylindrical ***anode*** **2** surrounding it. This is the basic "valve". These two electrodes are contained in a vacuum-filled (*joke*!) container, usually made of glass.

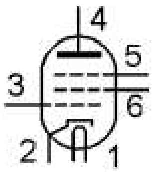
This device is also a ***diode***, this time an "indirectly heated" valve, The filament now becomes a "***heater***" **1** and a very tight sleeve around that, the ***cathode*** **2**, is made hot to the point when electrons boil from its surface.



A wire-mesh "***grid***" **3** is added to the "inter-electrode space" to control the electron flow from cathode to anode. This is a three-electrode valve - cathode **2**, grid **3** and anode **4**. This is a ***triode***.



Add another grid - the "screen grid" **5** - and the valve becomes a "***tetrode***".



Add a further grid **5** - the "suppressor grid" - and the valve is a "***pentode***".

Note that it is placed between the screen grid (shown here as **6**) and the anode. The suppressor grid is usually internally-connected to the cathode inside the glass envelope of the valve and a separate external connection to it is not always possible.

There are other valve types too, called "multi-electrode" valves, used for mixing and for other purposes.

Several valves can be mounted in the one envelope. One example is the 1D8G (or 1D8GT) which is a "diode-triode-pentode", three valves in the one vacuum space. An early "integrated circuit"? This is long obsolete, now just a curiosity!

Meters and Measuring

Test instruments and measurements are the basis to get things working. If your circuit does not work or your receiver stops, the first approach should be to check the supply. You need a meter to measure the supply voltage or current.

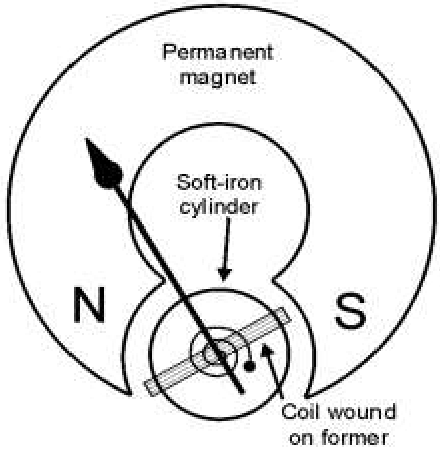
Moving coil meters are in universal use and their measuring range can be extended by adding external resistors. Any meter used for measurements (a multi-meter) is not complete without an ohms range.

Loading of circuits under test is one of the important factors to consider when making measurements.

The success of any electronic or radio project is to make it work. Meters and other test instruments are required for this purpose.

Meter movements

Most common meters use a **moving coil**. This comprises a small, light coil of wire mounted in the field of a permanent magnet which, with a soft-iron core, sets up a radial magnetic field. A DC current through the coil sets up a small magnetic field which causes the coil to rotate in the radial field by the motor principle. This in turn tightens a spring and the coil will only rotate a certain amount, until the force produced by the current equals the force in the spring. A pointer is attached to the moving coil, and moves over a calibrated scale. The coil is wound on a metal former which, by eddy-current action induced by the movement in the field, dampens the needle's movement.



(*This is the reverse operation of a generator. The difference is that a DC input current to the coil produces a mechanical rotation of the coil in the magnetic field.*)

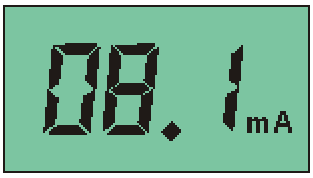
The deflection of the pointer is proportional to the current, or more exactly, to the average value of the current. The moving-coil movement responds only to DC currents. It will only respond to AC if it has been rectified.

Multimeters

The movement found often in meters used by amateurs is the moving coil. This is used in the multimeter for current and for voltage measurement.

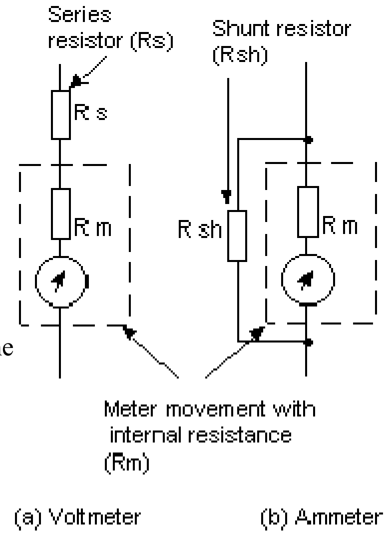
To measure AC with a moving-coil meter requires the addition of a bridge rectifier. Although such a meter reads the average value, the scale is usually calibrated for RMS values of a sine wave. This scale is correct only for sine waves. For any other waveform there will be a different relationship between average and RMS values, and therefore a different indication for the same RMS value.

Some rectifier circuits use capacitors to give a peak reading. This reading is correct for all waveforms and the peak value is quite useful. (See another entry in this Guide for information about RMS and for peak, RMS and average values.)



Multi-meters with digital read-outs use integrated circuits with a liquid crystal display (LCD) consisting of seven segment numbers. The unit of measurement can also appear on the display.

Measurement of voltage and current



The moving-coil movement can be configured to measure both current and voltage. This is the basis of the multimeter, typically using a sensitive movement with a full-scale deflection produced by a current of 1mA or less.

This diagram shows voltmeter and ammeter circuits. Rm represents the "internal resistance" of the moving coil movement,

A voltmeter circuit: To read different voltage values a resistor is put in series with the meter. This is known as a series multiplier resistor and can be calculated using the usual Ohm's Law relationships.

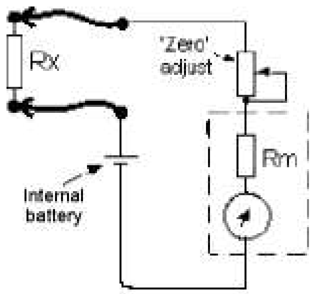
The higher the resistance value of the series resistor, the higher the voltage that can be read by the meter.

When meters are used in high voltage situations care must be taken to avoid accidental shock.

An ammeter circuit: To read different current values a resistor of a low value is put in parallel with the meter, shown in the diagram as Rsh (Shunt resistance). The shunt resistor bypasses the extra current that the meter cannot carry. For example, to measure 500 mA on a 1 mA meter the shunt resistor would have to carry 499 mA leaving 1 mA to produce a **full-scale deflection (fsd)** on the meter. The lower the value of the parallel (or shunt) resistor the higher the current that can be read on the meter.

For example, if a meter of 100 ohms resistance and a full scale deflection of 1 mA is required to measure 500 mA, a shunt must be provided to carry the excess 499 mA current away from the meter. Using Ohm's Law, you can work out the value of the shunt resistor required. Shunt resistors have very low resistance values and usually have to be made for the particular application.

Resistance measurements



Apart from voltage and current the other most useful function for a meter is to measure resistance. This diagram shows the circuit of an ohmmeter.

In its simplest form this is a battery in series with a variable resistance (zero adjust). When the two probes (shown with arrows) are directly shorted together (Rx = 0) the battery current is adjusted until the meter reads full-scale.

So if the circuit under test is a short-circuit (a continuity check) the meter reads full-scale or zero ohms.

If there is some resistance in the circuit (shown in the diagram as Rx) the meter will receive less current and only a partial deflection of the needle will result. The higher the resistance, the less deflection, a *lower* reading. The scale is non-linear with the higher resistances crammed at the lower end of the scale. To minimise this effect, several resistance ranges are built into the meter circuit.

Loading on a circuit

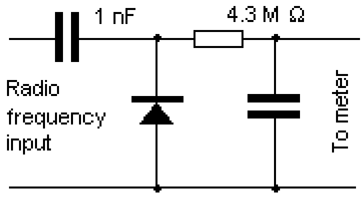
When using a voltmeter one must always keep in mind that the meter will draw some current from the circuit under test. If the meter current is high compared to the currents in the circuit then the meter will load the circuit and consequently the readings will be inaccurate. To reduce loading the circuit, the meter should draw as little current as possible from the circuit.

The loading accuracy of a meter is expressed in *ohms per volt*. In simple terms it means that a 1 mA meter needs 10 000 ohms in series with a 10 V source to produce 1 mA fsd in the meter. The sensitivity is then 1000 ohms per volt.

So a 50 µA meter will require 200 000 ohms in series with 10 V to produce a 50 µA fsd in the meter or 20 000 ohms per volt.

In high-resistance, low-current, circuits, the higher the meter input resistance the more accurate the reading will be. Digital multimeters can put a very small load on the circuit under test.

Some meters are affected if used near an operating transmitter because of the RF energy present in that environment.

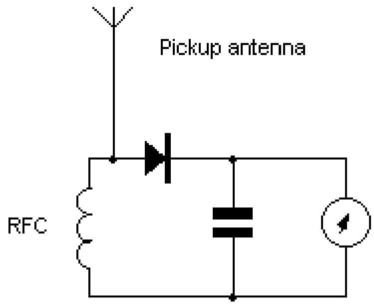


RF voltage probe

This diagram shows a simple circuit that can be used to make RF measurements. This is a rectifier and RF bypass network. Keeping lead lengths short will also help to get useful readings up to about 200 MHz.

Field strength meters

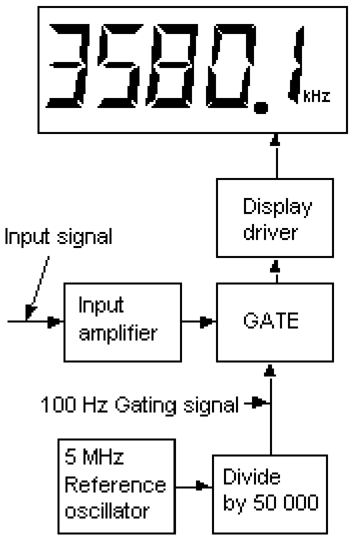
field strength meter is an indicating device. It is used to indicate the relative intensity of a radiated field. It is useful for checking and adjusting directional antennas. This diagram shows the circuit of a field strength meter in its simplest form with a pickup antenna connected to a rectifying diode and a meter indicator.



If the RFC (Radio Frequency Choke) is replaced by a tuned circuit the device can be used as an absorption wavemeter. The frequency measurement accuracy of the device is low, but the device has one useful feature in that it will respond mainly to the frequency to which it is tuned, and not to harmonics.

Frequency counters

Frequency measurement is a frequent requirement by the radio amateur. Many amateur transceivers have digital dials making frequency measurements of RF signals easy and accurate. The frequency of RF signals may also be measured by using a frequency counter. The diagram shows the block diagram of a frequency counter.



The reference oscillator is a stable crystal oscillator with its output signal being divided down in frequency to give the timing required for frequency measurements. An input amplifier, gate, and a display system completes the counter.

An input signal's frequency is measured by opening the gate for an exact time, thus allowing a timed number of cycles through to be displayed. For example, if the gate time is set to 10 milliseconds and the number of cycles passed to the counter was 35 801, then the input frequency displayed would be 3580.1 kHz .

Digital meters

The principle of many digital multimeters is similar to the concept of a frequency counter, but in the digital multimeter the period of measurement is determined by the input voltage or current. An analog-to-digital converter is used to convert the input voltage or current to a timing signal for the counting process. With the exception of the range switching, the circuitry of a digital multimeter is usually contained in a large scale integrated circuit.

RF power measurements

An RF power meter is an RF voltmeter calibrated to measure the voltage across a fixed (normally 50 ohm), resistor load. The resistor load is designed to dissipate the maximum power reading of the power meter, which for amateur use would be 120 watts or so. The resistor is large and carefully constructed to ensure that any stray capacitances and inductances are kept to a minimum so that a wide frequency range can be covered with accurate power measurements.

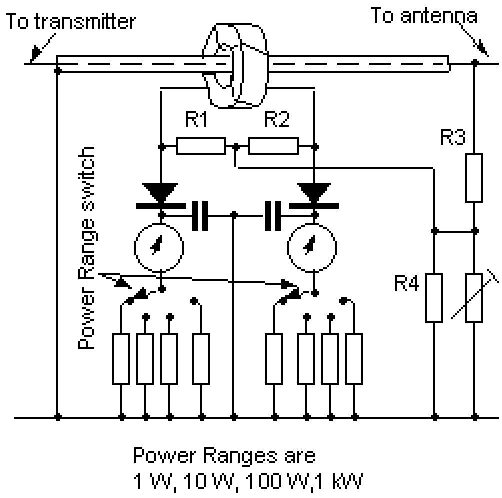
RF current measurement

The **hot wire meter** can measure AC at radio frequencies directly by using the heating effect of a current to lengthen a wire, the lengthening being used to move a pointer. The hot wire meter can be used at RF, but has many disadvantages. It is generally replaced by **thermocouple meters** that use a thermocouple and a moving-coil movement.

Voltage Standing Wave Ratio (VSWR) measurement

The forward and reverse power sent to an antenna are an essential measurement of the effectiveness of the antenna system. If no reverse energy shows on the meter it means that all the power sent to the antenna is radiated. Two common types are available. Sampling is achieved by using a current transformer.

The device is frequency independent so may be calibrated to measure power over a wide frequency range. This diagram shows a circuit of a frequency-independent directional wattmeter.



The short piece of co-axial transmission line passes through the centre of a toroidal transformer. The shield of the co-axial cable is earthed at one end only. That cable forms the primary of a current transformer with the toroidal winding as the secondary.

The output from the toroidal transformer secondary winding is split into two equal parts by resistors R_1 and R_2. This output is then compared to a voltage sample obtained by direct connection to the centre conductor of the co-axial transmission line by the resistors R_3 and R_4. The connection between the two sampling resistor circuits results in the sum and difference voltage being available at the ends of the toroidal transformer secondary winding.

The sum (forward power), and the difference (reflected power), can be indicated on the two meters. Note the range switching for different power levels.

Sometimes an *SWR Bridge*, an *Antenna Tuner*, and a *Dummy Load*, are combined into the one box. Sometimes the two SWR meters are built into one instrument - with *cross-needles*.

The cross-over point of the two needles can be read directly as the SWR value off a separate scale on the face of the meter. Each separate needle indicates the forward and reflected power on its own arc-scale. It must be remembered that all these scales are non-linear.

The knobs on the Antenna Tuner are carefully adjusted using a steady carrier as the transmitted signal until the SWR reading is 1. These adjustments ("tuning up") should be made quickly and with care to avoid interfering with other stations.

An example of a cross-needle meter is seen in the photograph. The transmitter output power is adjusted for 100 watt in the forward direction for each part of the display. Observe the change of position of the needle cross-over points. In practice, the "Antenna Tuner" controls are adjusted for minimum reflected power shown on the meter.

Other test methods

Do not overlook your computer as a test instrument, and a very flexible one too. There are many programs written to run in Windows, with a sound-card, and which provide useful test facilities. Many programs are available by free download from the internet. Spectrum analysers, audio signal generators, and many more, are available and suitable for amateur radio purposes.

Decibels

One cannot go very far in radio communications without encountering the term ***decibel***.

It is used to indicate the difference
between two power levels, or
between two signal levels.

It can be used to indicate two things:

amplification (gain) or,
loss (attenuation).

It should be understood that this is a ratio based on the logarithmic scale.
We are more used to thinking in linear units such as volts, ohms, amps, metres, litres.
So, let's have a look at things logarithmic!

Logarithmic changes

One of the fundamental laws of hearing and sight, and many other forms of physiological stimulus, is that the effect produced by an increase in the stimulus does not follow a simple arithmetic or linear scale. We have to keep doubling the stimulus to get an increase in unit steps. For example, if you stick two pins in your arm, you will find that it hurts twice as much as one pin. But it takes four pins to hurt three times as much and eight pins to hurt four times as much. (Don't bother to try this experiment!)

A system which measures unit steps in this way is the logarithmic scale.

The Bel

We don't need to know much about logarithms but we need to be familiar with the following table:

Unit	Logarithm
1	0
2	0.3010
4	0.6021
8	0.9031

We don't even need to work to four decimal places! We can simplify the table to:

Unit	Logarithm
1	0
2	0.3
4	0.6
8	0.9

Note that the first column doubles while the second column adds by + 0.3 each time!

We also need to know the following:

Unit	Logarithm
1	0
10	1
100	2
1000	3

Observe the pattern shown by this table!
Note the number of zeros in the left-hand column and compare with the numbers in the right-hand column.

The ***bel*** was chosen to represent a power ratio of one logarithmic unit.
So a change of power level of 1 bel represents a power ratio of 10 times. (See the second line of the last table.)
Note too that a power gain of 100 times is 2 bel.

For many applications a bel is too large a unit and the decibel (dB) is used instead. So our two tables can be redrawn:

Power ratio	dB	Power ratio	dB
1	0	1	0
2	3	10	10
4	6	100	20
8	9	1000	30

A **decibel** (dB) is one-tenth of a **bel**.

Power ratios

So, if we double the power, we can use the fact that the log of 2 is 0.3, and this would be a gain of 0.3 bel or 3 dB.
Remember: Doubling the power is a 3 dB increase.

Similarly, if we halve the power, this would be 3 dB attenuation, which we can think of as -3 dB gain. A minus sign is used to indicate a decrease or "negative gain".

Some examples

Using the characteristics of logarithms, you will recognise that you can now multiply your gains by adding the logarithmic units. This is very convenient when you consider (say) a three-stage amplifier with 6 dB power gain in each stage.

The total power amplification will be (6 + 6 + 6) = 18 dB or 64 times.
(6 dB is a 4-times power increase - see tables above - and (4 x 4 x 4) is 64).

Another example: A power ratio of 20 times (i.e. 2 x 10) is the same as (3 dB + 10 dB) or 13 dB.

Voltage ratios

In practice we often like to think in terms of voltage ratios rather than power ratios. We must remember that if we are measuring a signal voltage across an impedance, that if we double the voltage, the current also doubles, so the power has increased by FOUR times. We must remember too that the impedance where we are measuring must remain constant.

Reference levels

Sometimes the dBW is used for the measurement and indication of power level. This means the measurement is compared to a reference level of 1 watt. The same rules apply:

1 watt represents 0 dBW
2 watt represents 3 dBW
4 watt represents 6 dBW
8 watt represents 9 dBW
16 watt represents 12 dBW

... and of course 10 watt represents 10 dBW.

Summary

We can summarise with the following table:

Power ratio	Voltage ratio	dB
10,000:1	100:1	+ 40
100:1	10:1	+ 20
4:1	2:1	+ 6
1:100	1:10	- 20

Note in the third line that doubling the voltage is equivalent to four times the power, this is a + 6 dB change.

Suggestions

Learn the summary table given above and how it is derived.

Remember that RATIOS are involved - so look for the figures given in a question which have the same units (millivolts, watts, etc) from which you can work out a RATIO.

Be careful to use the correct column in the table for power and voltage ratios!

References

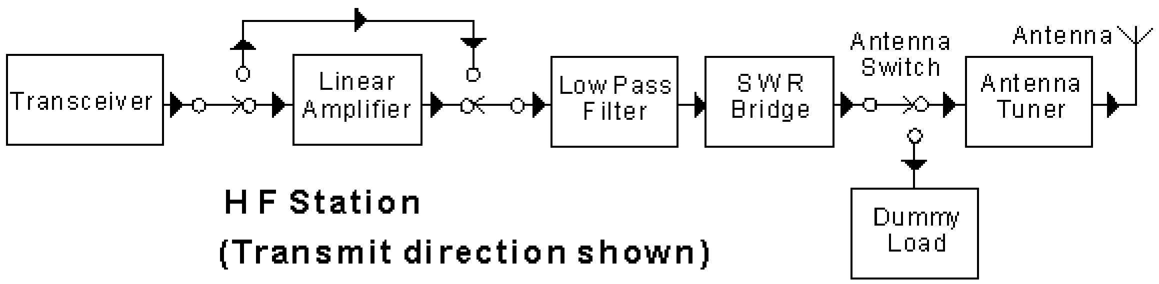
Please refer to standard textbooks and to the internet for good reference documents to learn more about decibels.

Syllabus: 28, Decibels, compiled and maintained by ARX2106

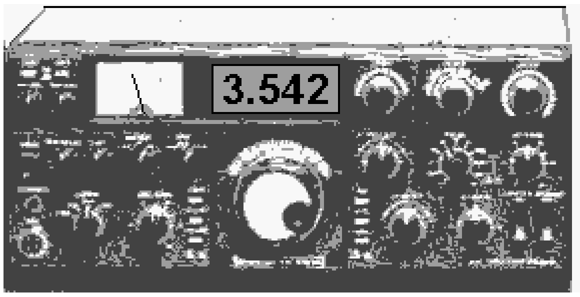
HF Station Arrangements

Station Components

Amateur radio stations range from the very simple to the very elaborate and complex. Some of the common elements are considered here. This block diagram is typical of the High Frequency equipment used in an amateur station. You should know the sequence and purpose of each unit that your signal passes through!



The Transceiver



This is the centre-piece of the station and where most things happen! It contains both transmitter and receiver. These two functions are treated elsewhere in this Study Guide.

The Linear Amplifier

This is switched in to provide a stronger transmitted signal at times of difficult conditions. Not an essential item and not all radio amateurs use them or find them to be necessary. It provides an amplified version of the signal fed into its input. The term "linear" means that the output signal is a replica of the waveform of the signal fed into its input - except that the amplitude of it is greater.

The Low Pass Filter

This device is considered elsewhere in the Study Notes. It is designed to prevent the passing of frequencies above 30 MHz (the limit of HF and where VHF begins) from the transmitter to the antenna. It is good practice to have this item in use but it may not always be required. Many modern transceivers are already fitted with such a filter.

S W R Bridge

This little box (**S**tanding **W**ave **R**atio bridge - or meter) does two things. It gives a measure of the transmitter output power level. It also gives an indication of how well the antenna is working. If the feeder to the antenna is damaged or the antenna itself is faulty, a glance at this meter will indicate a problem. This device is explained elsewhere in this Guide.

The Antenna Switch

Only two positions are shown in this diagram. The switch changes between the external antenna and the "dummy load" or "dummy aerial" (used for testing). In practice, the Antenna Switch may have many positions and be used for selecting between various antennas as well as the dummy load. It is general practice to use a multi-element beam antenna for operating at 14 MHz and above, and to use a "wire antenna" on frequencies below 14 MHz, but there are no hard and fast rules!

The Antenna Tuner

This name is not strictly correct. This device takes the impedance "seen looking down the antenna feedline" and converts it to a correct "match" for the output impedance of the transmitter. This device is treated elsewhere in this Study Guide.

The Dummy Antenna (Dummy Load)

The purpose of this device is to allow you to carry out adjustments to your transmitter without actually transmitting a signal on the air. It is usually a collection of carbon resistors in a can - for shielding. The can may be filled with transformer oil to assist cooling.

It is important to know the power rating for your dummy load. The time that you can use it with a high-power signal may be very short before overheating causes it to be severely damaged. Know your ratings and observe them!

The Dummy Antenna should be connected to your antenna switch as one of your antennas. The device simulates an antenna in all respects except that it does not radiate. It usually has a 50 ohm impedance with a low SWR of 1 to 1.

A practical unit

Sometimes an SWR Bridge, an Antenna Tuner, Antenna Switch and a Dummy Load, are all combined into the one box.

Sometimes the two SWR meters are built into one instrument - with cross-needles. The crossing point of the two needles can be read directly as the SWR value off a separate scale on the face of the meter, while each separate needle indicates the forward and reflected power on its own arc-scale. An example is in the photograph.

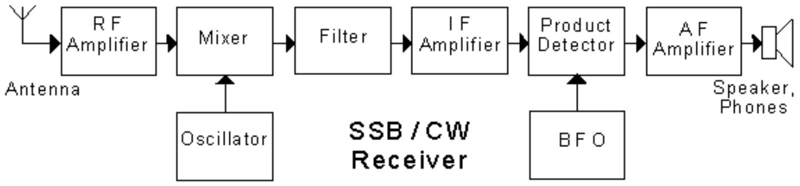
Transmitter off

The operation of the SWR device is explained elsewhere in this Guide.

Receivers

How to draw block diagrams

This is is a "block diagram" of a "superheterodyne" receiver. Before the actual stages are discussed, consider the diagram itself. It is drawn to show the "signal flow" entirely from ***left to right,*** shown by the arrows.



It starts with the antenna (aerial) on the left. The signal flows through many stages, shown by arrows from *left to right.* It ends with the speaker (or phones) on the right.

The "superhet" receiver

The diagram shows a "super-sonic heterodyne" - or "superhet" - receiver, the standard pattern for receivers in general use today. The first thing to note is that ***three*** amplifiers are shown, the RF amplifier, the IF amplifier, and the AF amplifier. Let's look at each in turn.

The Radio Frequency amplifier

This provides amplification for the signal as soon as it arrives from the antenna. The amplified signal is then passed to the "mixer/oscillator". The purpose of the mixer/oscillator is to act as a frequency-changer, to translate the frequency of the incoming signal to the "intermediate frequency", i.e. to the "IF amplifier".

The mixer stage is usually acknowledged as being the noisiest stage in the receiver so an RF amplifier is positioned ahead of it to mask that noise with a higher signal level.

The RF amplifier stage should use a low-noise amplifying device - such as a low-noise transistor - to keep the internally-generated noise of the receiver to as low a value as possible. All the following amplifying stages will amplify this RF stage noise as well as the signal, so a low-noise device at the start of the receiving process is very important.

The Intermediate Frequency amplifier

It is in the IF amplifier ***where most of the amplification in a receiver takes place***. Sometimes there may be two or more stages of IF amplification each with their own pre-tuned transformers. The "IF frequency" is carefully selected, but more about that below. The filter block prior to the amplifier shapes the "pass-band" of the receiver.

The filter pass-band should be tailored to fit the signal being received - in the interests of keeping out unwanted noise and unwanted signals. A 500 Hz pass-band for CW reception, a 3 kHz pass-band for SSB, and 6 kHz for AM, would be typical.

From the IF stages, the signal passes to a detector. Here demodulation of the radio-frequency signal takes place to produce an audio signal.

The diagram shows a "product detector" with a Beat Frequency Oscillator - or Carrier Insertion Oscillator (CIO) - for SSB and CW reception.

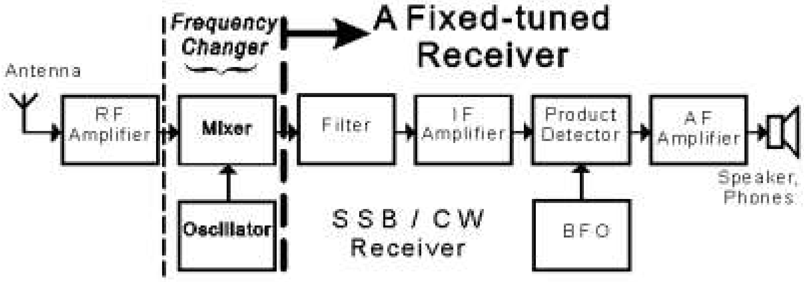
The Audio Frequency amplifier

Finally the audio signal is amplified in the audio amplifier and passed on to a speaker or phones for the listener to enjoy.

Receiving a signal

The superhet receiver is really in two parts:

1. From IF amplifier onwards, it is a "***fixed frequency receiver***", a receiver pre-tuned and optimised for the reception of a signal on the IF frequency.



2. The RF amplifier and mixer/oscillator receive signals from the antenna and then convert them to the frequency of this optimum receiver - to the IF frequency. It is in the RF amplifier and mixer/oscillator sections of the receiver where the actual operator adjustment and tuning for the selection or "***choice of received signal***" takes place.

Tuning a Superhet Receiver

To change the frequency of the incoming signal to the IF frequency, the tuned circuits in the RF amplifier, the mixer input, and the local oscillator, must be adjustable from the front panel. A look inside a typical conventional superhet receiver cabinet may disclose a "three-gang" tuning capacitor. Each "section" of this component tunes part of the first stages of the receiver.

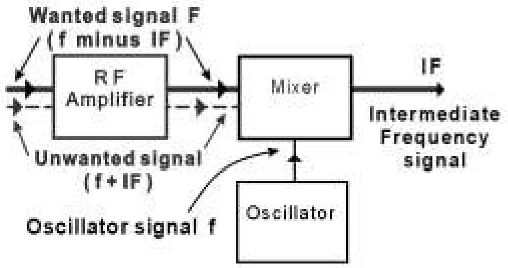
Note that it is the INPUT to the mixer which is tuned by a variable capacitor - the output is fixed-tuned at the IF frequency.

The choice of Intermediate Frequency

There are two conflicts with the choice of the IF Frequency:

A ***low intermediate frequency*** brings the advantage of higher stage gain and higher selectivity using high-Q tuned circuits. Sharp pass-bands are possible for narrow-band working for CW and SSB reception.

A ***high intermediate frequency*** brings the advantage of a lower ***image*** response.



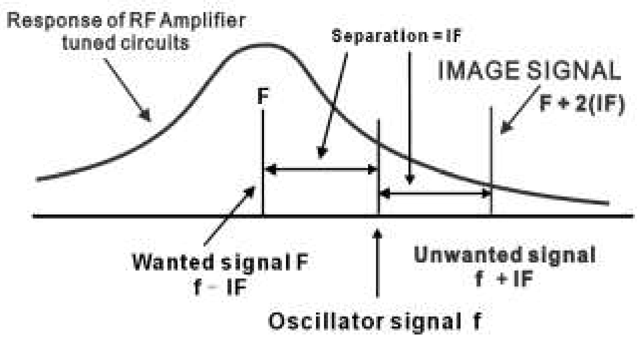
The "image frequency" problem can be seen in this example:

Consider a receiver for 10 MHz using an IF frequency of 100 kHz. The local oscillator will be on either 10.1 MHz - i.e. 100 kHz higher than the required input signal - or on 9.9 MHz. We will consider the 10.1 MHz case - but the principles are the same for the case where the oscillator is LOWER in frequency than the wanted signal frequency.

Because of the way that mixers work, a signal at 10.2 MHz will also be received. The oscillator, being at 10.1 MHz, is 100 kHz on the LOW side of 10.2 MHz. This is known as the IMAGE frequency.

The image rejection of a superhet receiver can be improved by having more tuned circuits set to the required input frequency, such as more tuned circuits in the RF amplifier ahead of the mixer. This brings practical construction difficulties.

Another solution is to choose a high IF frequency so that the required received frequency and the image frequency are well separated. Choosing an IF of 2 MHz for the 10 MHz receiver would put the local oscillator at 12 MHz, the image frequency then being at 14 MHz.



When receiving a signal at 10 MHz, it is easier to reject a signal at 14 MHz (the image in the 2 MHz IF case) than at 10.2 MHz (the image in the 100 kHz IF case).

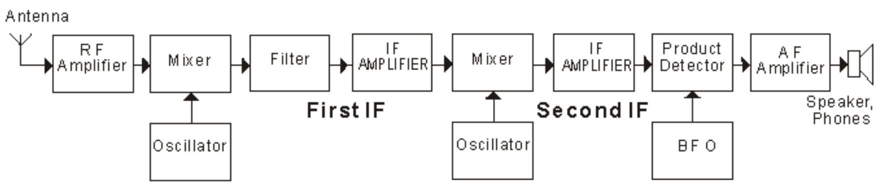
Note that the Image Frequency is ***TWICE*** the IF Frequency removed from the ***WANTED*** signal frequency - on the same side of the wanted frequency as the oscillator.

The "Double Conversion" receiver

The "double-conversion" superhet receiver brings the good points from both IF choices. A high frequency IF is first chosen to bring a satisfactory image response, followed by a low-frequency IF to bring high selectivity and gain.

Typical examples would be a 5 MHz first IF and a 100 kHz second IF - but many designs are possible. There may be front-panel-selectable quartz or mechanical filters used at either or both IF's to give added selectivity.

The only two disadvantages of the double-conversion receiver are the added complexity and the additional oscillators required. These oscillators, unless carefully shielded, can mix with each other and produce unwanted signals at spots throughout the spectrum.



Double Conversion Receiver

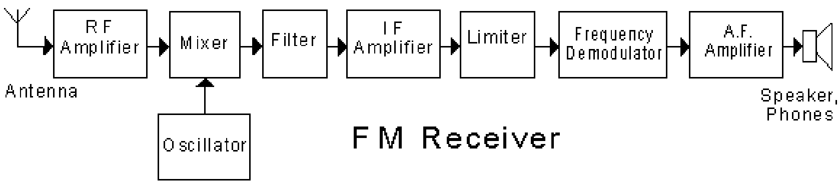
Count up the number of oscillators involved - including the BFO / CIO.

The F M Receiver

A receiver for FM signals follows the same general principles as a receiver for CW and SSB reception.

The frequency coverage for an FM receiver is different to that of a SSB / CW receiver. FM is a distinct VHF-and-higher mode. So FM receivers are for VHF and higher reception. In hand-held transceivers, the receiver will be "channelised" for switch-channel reception.

The IF amplifier is much wider in bandwidth than that of a CW/SSB receiver. So the IF amplifier will be higher in frequency – a very common value being 10.7 MHz.



The demodulator will usually be a "discriminator" and may even be of a "phase-lock-loop" variety. There will be a "limiter" before the discriminator to remove noise peaks and amplitude-changes before detection of the FM signal.

A simple receiver

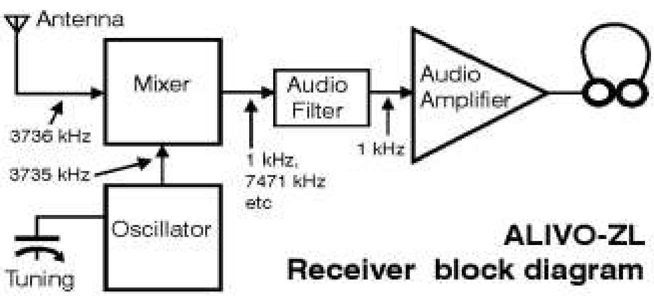
A simple receiver for the reception of amateur radio SSB and CW signals can be constructed by you at home. Yes! You could build it yourself!. It uses the "***direct conversion***" principle.

The details of a simple direct-conversion receiver can be seen at the following web site. The full construction details are given too! http://www.nzart.org.nz/alivo/secret-listening-alivo.pdf

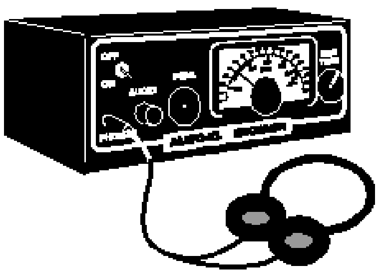
This receiver consists of a mixer stage and an audio amplifier.

The mixer converts the incoming signal frequency down to a lower frequency - this time right down to audio frequencies. It can be considered to be a superhet receiver with a 0 kHz (zero) intermediate frequency. The derived audio is passed through a simple audio filter to an audio amplifier to drive headphones or speaker.

This block diagram of the simple receiver shows the down-conversion process with a numerical example:



Frequency stability



The ability of a receiver to stay tuned to an incoming signal for a long period is related to the frequency stability of its local oscillator. This same requirement applies to transmitters.

Metal shielding is used around oscillator coils and the components used may be specially selected for high frequency stability. Temperature stability is also important.

Sensitivity

The sensitivity of a receiver is its ability to receive weak signals. Selectivity is more important than sensitivity.

Noise

The first stage in the receiving block-diagram chain, the RF amplifier, sets the noise characteristics for a receiver. The RF amplifier should use a low-noise device and it should generate very little internal noise. Measurement of sensitivity requires test equipment, equipment able to measure the "signal plus noise" audio output from the receiver and the "noise alone" with no signal being received.

The ratio: (S+N)/N (i.e. signal plus noise to noise) is often used with this test for comparing receivers.

There is far more to measuring the sensitivity and other characteristics of a receiver than is often realised! Please refer to standard textbooks on the subject.

Selectivity

The ability to separate two closely spaced signals is a receiver's "selectivity". The characteristics of the filter in the IF amplifier determine the frequency response of the IF stages and the "selectivity".

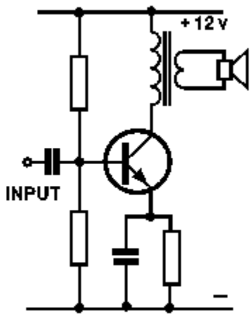
The narrower the filter pass-band, the "better the selectivity".

The receiver pass-band should be tailored to the characteristics of the incoming signal. Too wide a pass-band and unwanted noise and possibly part of unwanted adjacent signals, is received which detracts from the reception of the wanted signal.

We use ***bandwidth*** to measure selectivity. This is how wide a range of frequencies you hear with the receiver tuned to a set frequency. Filters can often be selected by a front-panel switch to provide different receiver bandwidth characteristics.

The audio stage

The audio stage of a receiver amplifies the signal from the detector and raises it to a level suitable for driving headphones or a speaker.



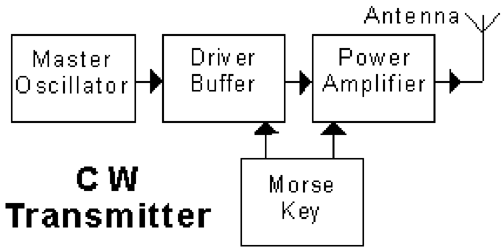
A typical speaker is a load impedance of about 8 ohm. A transformer is generally used to match this low-impedance load to the impedance level required for the best performance of the amplifier.

There are many types of audio amplifier. The circuit shown here is to show the principles. It is typical of that in a very simple radio - with a very small speaker and low audio output.

Transmitter Block Diagrams

How to draw block diagrams

This is a "block diagram" of a simple transmitter. Before the actual stages are discussed, consider the diagram itself. It is drawn to show the "signal flow" entirely from ***left to right,*** shown by the arrows.



The CW Transmitter

The simplest of all transmitters is one for sending Morse code - a CW (Continuous Wave) transmitter as shown in this diagram.

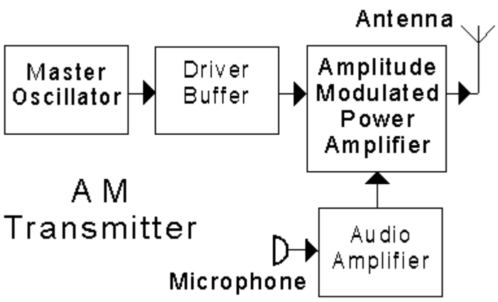
An oscillator generates the signal and it is then amplified to raise the power output to the desired level. A Morse key is used to chop the transmission up into the "dots" and "dashes" of Morse code.

The oscillator runs continuously. The Driver / Buffer are isolation stages, to isolate the oscillator from the sudden load changes due to the keying of the amplifier. This minimises frequency "chirp" on the transmitted signal.

The oscillator is usually supplied with DC from a well-regulated voltage-regulated source to minimise chirp (slight changes in the output frequency) due to variations in the supply voltage.

Several driver and buffer stages may be used. The keying may be in the final amplifier alone - usually in the cathode or emitter lead - or may also be applied to the driver stage too.

A "keying relay" may be used to isolate the Morse key from the transmitter circuits, to keep high voltages away from the operator's Morse key. In the interests of operator safety, the moving bar of the Morse key is **ALWAYS** kept at earth potential.



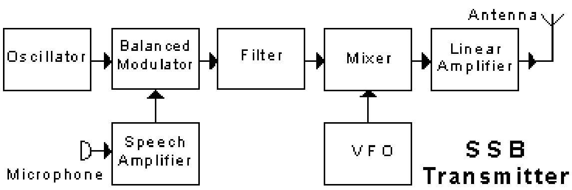
The A M Transmitter

This is a diagram of a typical Amplitude-Modulated transmitter. The principles of each block and the principles of Amplitude Modulation are treated elsewhere in this Guide (Supplementary paper: “Signals”).

The block diagram is derived from the CW transmitter.

The modulated stage is usually the final amplifier in the transmitter. This is known as "high-level" modulation. If a following amplifier is used to raise the output power level, it must be a ***linear*** amplifier.

The SSB Transmitter

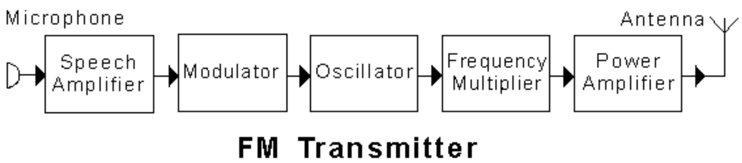


The generation of a SSB signal is treated in another part of this Guide (Supplementary paper: “Signals”). A transmitter takes the generated signal and first translates it with a mixer/VFO combination to the required output frequency then amplifies it to the required power output level using a ***linear*** amplifier. A linear amplifier is needed to preserve the signal waveform in all ways except to increase the output amplitude.

The F M transmitter

Again, the principles of each block have been treated elsewhere in this Guide.

The modulator can be one of several types. The simplest to understand is probably to consider the voltage-controlled oscillator.



Applying an audio signal to the varicap diodes in the circuit example given in the Oscillator paper in this Guide will change the frequency of the oscillator in accord with the modulation. This increases the frequency swing with increased audio loudness, and the rate of swing with increasing audio frequency - hence providing Frequency Modulation.

In VHF hand-held transceivers, the oscillator will be generated by a phase-locked-loop (PLL) to provide "channel switching" facilities. The frequency modulation may then be generated by applying the audio signal to the PLL.

Frequency Multiplier stages comprise an RF amplifier with a tuned output - the output tuned to a harmonic of the input signal.

The Power rating of a SSB linear amplifier

A power amplifier for SSB operation is required to be linear. This means that the waveform of the output signal must be a replica of the input waveform in all ways except amplitude - the output must be an amplified version of the input! The maximum power output before severe distortion takes place is the limit of successful linear amplifier operation.

The power output at the maximum level is the usual rating given for a linear amplifier. This is known as the "Peak Envelope Power", PEP.

The PEP is, by definition, the average power output during one RF cycle at the crest of the modulating envelope.

The PEP rating and measurement are also sometimes used for amplifiers for other modes.

The RF output power from an amplifier is less than the total DC input power and signal input power to the amplifier. The difference is energy loss and appears as heat. Cooling facilities - fans etc. - are sometimes found on solid-state power amplifiers for protection from over-heating.

Harmonics and Parasitics

Harmonics

Harmonics are multiples of a transmitted frequency and are the result of a non-linear action. They are present in any signal which has a distorted sinewave. Harmonics are the even or odd multiples of the fundamental transmitted frequency. For example, a transmitter at 3.5 MHz would have harmonics at 7, 10.5, 14, etc. MHz.

Harmonics are typically produced by an over-driven stage somewhere in the system. An example is over-modulation of a transmitter ("flat-topping"). Reducing the microphone gain in this case will significantly reduce the harmonic output.

Harmonic interference occurs at distinct frequencies.

Harmonics should be suspected if a transmitter on a lower frequency causes interference to a frequency which is a multiple of it. For example, a transmitter on the 10m band, at say 28 MHz, could cause interference to a television receiver tuned to TV Channel 2, which is 54 to 61 MHz. The probable cause is the second harmonic at 2 x 28 = 56 MHz.

For TV and other frequency use, refer to charts and tables in the annual NZART CallBook for the ***New Zealand Radio Spectrum Usage***. This information is also available from the Ministry of Commerce web page.

Harmonics can be produced within transmitters and receivers or outside of both.

Harmonics generated within a transmitter must be filtered out. A filter in the output lead is usually installed by manufacturers. External filters are also used.

Harmonics generated within a receiver generally cause cross- modulation or intermodulation.

Harmonics can also be generated by external causes - for example a bad connection between two metal surfaces, e.g. gutters, metal roofing, and antennas. The joint can oxidise and form a poor quality diode which when excited by an RF field produces harmonics.

Harmonics which are not exactly on the frequency being received can sometimes be removed with a selective filter - band reject, high pass or low pass.

Generally, harmonics should be suppressed at their source.

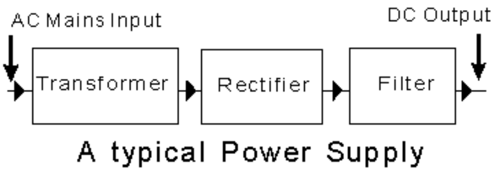
Parasitic oscillations

With parasitic signals there is no simple mathematical relationship between the operating frequency and the interfering frequency. The effects may be the same as with harmonics - a VHF receiver being interfered with by a HF transmission. The cause is an additional and undesired oscillation from an oscillator or amplifier for which it was not designed. The circuit functions normally but the parasitic oscillation occurs simultaneously.

Parasitics are suppressed by adding additional components to the circuit to suppress the undesired oscillation without affecting the primary function of the circuit. A typical solution is to add a VHF choke (an inductor) or a small-value resistor (a "stopper") somewhere close to the active component in the offending circuit.

Power Supplies

The purpose of a power supply is to take electrical energy in one form and convert it into another. The usual example is to take supply from the 230V AC mains and convert it into smooth DC.



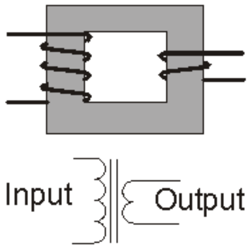
This DC may be at 200 volt to provide (say) 200 mA as the high tension source for valve operation, or 5 volt at (say) 1 Amp to feed transistors and other solid-state devices.

This diagram shows the separate stages in this conversion. Each will be considered in turn.

Protection

There should always be a fuse in the phase or active AC mains lead for protection if a fault develops in the equipment. The fuse should be of the correct rating for the task. Keep some spare fuses handy!

The transformer



When two inductors (or more) are mounted together so their electromagnetic fields interact, we have a transformer. A power supply almost invariably, contains a transformer.

A transformer generally comprises two (or more) sets of coils (or windings) on a single core, designed so that maximum interaction and magnetic coupling takes place. The windings are insulated from each other and insulated from the core. The windings may be wound on top of each other.

At low frequencies the core may be made up from thin laminated soft-iron plates forming closed loops and designed to reduce ***eddy current losses***. At higher frequencies the core may be dust-iron, ceramic ferrite, or air-cored (as for RF coils).

The winding used to generate the magnetic flux is called the ***primary*** (connected to the AC supply). The winding in which current is induced is the ***secondary*** (or secondaries).

The input supply must be an alternating current. The input current sets up a changing magnetic field around the input or primary winding. That field sweeps the secondary and ***induces*** a current in that secondary winding.

The "*turns ratio*"

The number of turns on each winding determines the output voltage from the transformer. The output voltage from the secondary is proportional to the ***ratio*** of the turns on the windings.

For example, if the secondary has half as many turns as there are on the primary, and 100V AC is applied to the primary, the output will be 50V.

Transformers can be step-up or step-down (in voltage). With twice as many turns on the secondary as there are on the primary and 100 V applied, the output would be 200V. With half as many turns on the secondary as there are on the primary and 100 V applied, the output would be 50V.

A function of the transformer is to provide an AC supply at a voltage suitable for rectifying to produce a stated DC output.

The total power output from the secondary cannot exceed the power fed into the primary. Ignoring losses, a step-down in voltage means that an increase in current from that lower-voltage winding is possible. Similarly, a step-up in voltage means a decrease in the current output. So the gauge of wire used for the secondary winding may be different to the wire used for the primary. (The term "gauge of wire" refers to its cross-sectional area.)

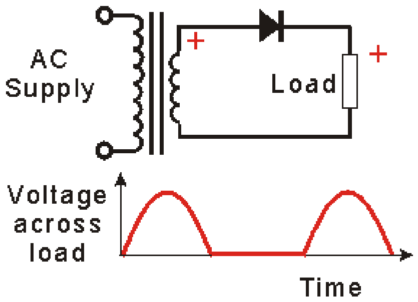
There will be some energy losses in a transformer, usually appearing as heat.

Rectifiers

There are three basic rectifier configurations in general use, half-wave, full-wave and bridge. We will look at each in turn. We will use only semiconductor rectifiers.

The half-wave rectifier

Here is a very basic power supply, a transformer feeding a resistor as its load with a rectifier inserted in the circuit.



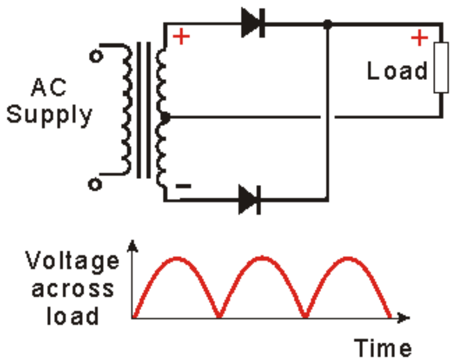
Without the rectifier, the load would have the full secondary alternating voltage appearing across it.

The rectifier will conduct each time its anode is positive with respect to its cathode.

So when the end of the secondary winding shown + is positive, the diode conducts and the + appears across the load. Current flows around the secondary circuit for the time that the diode is conducting. The voltage drop across the diode can be regarded as negligible - about 0.6 volt for a silicon device.

The waveform appearing across the load is shown diagram. One-half cycle of the AC from the transformer is conducted by the rectifier, one half cycle is stopped. This is pulsating DC - half-wave rectified AC. Later we will put this through a filter to "smooth" it.

The full-wave rectifier



This is two half-wave rectifiers combined - it uses a centre-tapped secondary winding and one additional diode.

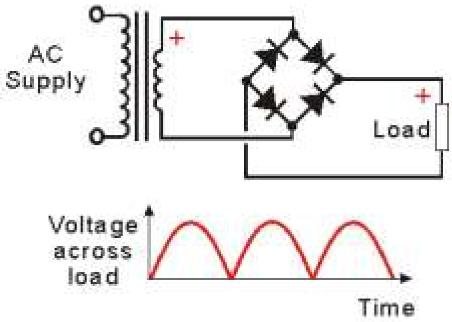
Each side of the centre-tap has the same number of turns as our previous example - and each "works" for half the cycle as our half-wave rectifier did.

The "top half" of the secondary works with one diode like the half-wave circuit we have just considered.

When the polarity of the secondary changes, the upper diode shuts off and the lower diode conducts.

The result is that the lower diode "fills in" another half-cycle in the waveform when the upper diode is not conducting.

The bridge rectifier



This uses one single winding as the secondary and four diodes - two are conducting at any one time.

Note the configuration of the diodes:

Diodes on parallel sides "point" in the same directions.

The AC signal is fed to the points where a cathode and anode join.

The positive output is taken from the junction of two cathodes.

The other end of the load goes to the junction of two anodes.

The operation is simple: Parallel-side diodes conduct at the same time. Note that the two + points are connected by a diode - same as in the two previous cases. The other end of the load returns to the transformer via the other parallel diode. When the polarity changes, the other two diodes conduct.

The output waveform is the same as the full-wave rectifier example shown before.

The main advantage? A simpler transformer - no centre-tap and no extra winding. Diodes can be small and cheap. A bridge rectifier can be purchased as a "block" with four wire connections.

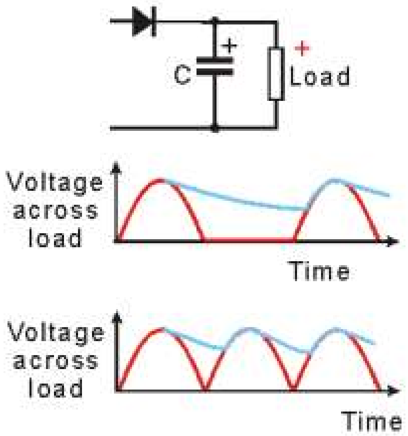
Smoothing the output - the Filter

Each of the three circuits studied above produces an output that is DC, but it is DC with a waveform showing a large "ripple". The ripple is the waveform shown in red in the three examples. DC from a power supply should be smooth and not varying in amplitude.

The half-wave circuit produced a ripple of the same frequency as the input signal, 50 Hz for input from a mains supply.

The other two examples produced a ripple that is twice the frequency of the mains supply - i.e. 100 Hz.

How can we remove the ripple? By using a filter circuit comprising filter capacitors and often a choke.



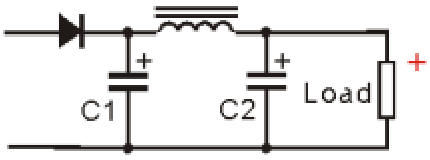
A capacitor wired across the load will charge up when the diode conducts and will discharge after the diode has stopped conducting. This reduces the size of the ripple as is seen in the diagram.

The choice of capacitor is important. Electrolytic capacitors are generally used because a very large value capacity can be obtained in a small and cheap package.

The capacitor value chosen depends on the purpose for the supply. Capacities of the order of thousands of microfarads are common for low-voltage supplies. For supplies of 100V and upwards, the capacity is more likely to be 50 microfarad or so. It depends on other factors too. The voltage rating of the capacitor and its wiring polarity must be observed (electrolytic capacitors have + and - connections).

When a diode conducts, it must supply current to the load as well as charge up the capacitor. So the peak current passing through the diode can be very high. The diode only conducts when its anode is more positive than its cathode. You can see from the diagram how the addition of the capacitor has shortened this time.

The switch-on current through a power supply diode must also be considered. Charging a large capacitor from complete discharge will mean a high initial current.



A choke and an additional capacitor are often used to filter the output from a rectifier, as shown in this diagram.

The choke is an iron-cored inductor made for the purpose and it must be able to carry a rated DC current without its core saturating.

Internal resistance

All power supplies exhibit "internal resistance". A torch light will dim as its battery ages. The internal resistance of its battery increases with age. On open circuit, without the bulb connected, i.e. with no load current being drawn, the battery may show its normal voltage reading. When the load is applied and current flows, the internal resistance becomes apparent and the output voltage "droops" or "sags".

The effects of internal resistance can be reduced substantially by using a "regulator". This added electronic circuitry "winds up the voltage" as the output load current increases to keep the output voltage constant. It keeps the voltage constant as the load current widely varies.

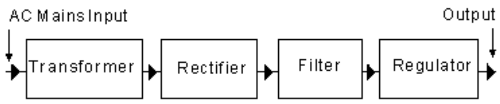
Choice of supply

A power supply (also a battery) must have sufficient reserve energy capacity to provide adequate energy to the device it is working with. For example, pen-light dry cells are not a substitute for a vehicle battery!

Similarly, a power supply for an amateur radio transceiver, (to substitute for a vehicle battery), must be chosen with care to ensure that the maximum load current can be supplied at the correct voltage rating without the voltage "sagging" when the load is applied.

The need for voltage regulation

A voltage regulator is added to a power supply to minimise the "voltage droop" or "sag" when the load is applied and when the current load varies widely..



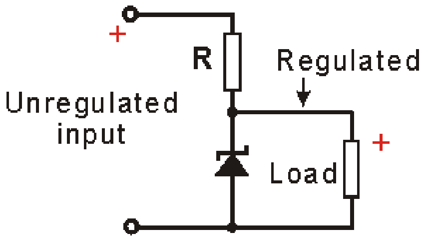
Regulated Power Supply

Some loads, for example a SSB transceiver, present a wide-changing current requirement. The power supply current for a SSB transceiver, supplied from a car battery, can fluctuate while the operator is speaking from a few amps to 50 amp or more, depending upon its transmitter power rating. The battery voltage must remain at a constant level throughout.

Similarly, a mains-powered power supply must be able to keep a constant voltage throughout a wide current range.

A regulated power supply has another stage added to follow the filter as shown here.

A simple regulator

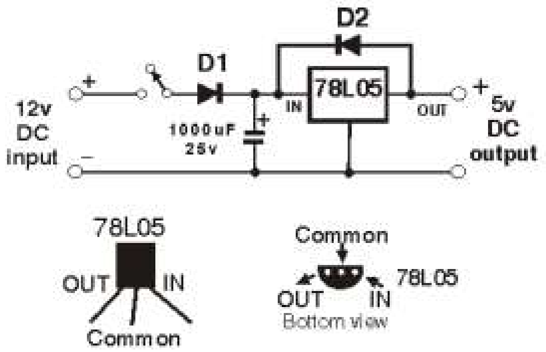


A zener diode is a silicon diode with a special level of doping to set its reverse break-down voltage level. It forms a simple regulator for low-voltage and small-current loads. The zener diode is reverse-biased and the reverse current is determined by the break-down voltage which depends on the doping level of the silicon. The breakdown voltage is repetitive provided the maximum power dissipation is not exceeded. There is a catalogue choice of zener diode across a wide range of voltages. The zener effect occurs below 5 volt, above 5 volt the avalanche effect is used.

The resistor R is to limit the current through the diode and the load.

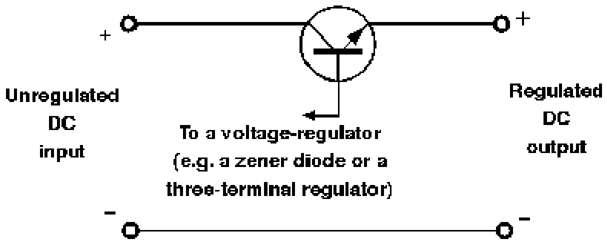
The Three-Terminal Regulator

This diagram is an example of a regulator package, a 78LO5. It looks like a standard transistor but it is a complete regulator for supplying a 5 volt output from (say) a 12 volt DC input. There are many other similar devices available for similar purposes. The pin-connection details are given. ("Three-legged regulators".)



The diode D1 is a hold-off diode, for protection against the possibility of the input connections being inadvertently reversed. The diode will not conduct with reverse input potential so the regulator is protected. Diode D2 is further protection for the regulator device itself.

The Series Pass Regulator



A power transistor can be used to control the output voltage from a supply.

A power transistor (or several in parallel) is in series with the output. The base is fed from a separately-regulated supply such as a three-terminal regulator or a zener diode. The transistor is in an emitter-follower configuration. Its emitter contains the load and the emitter follows the voltage at the base.

Protective measures

All the regulator circuits considered above require the input voltage to be considerably higher than the output. If the regulator fails, there is the distinct possibility that excessive voltage will be applied to the load. Over-voltage could damage the load and be very expensive to repair if the load was a transceiver!

An electronic device known as a "***crowbar***" is usually installed to protect the load as a "last ditch" measure in the case of a regulator failure. The crowbar senses an over-voltage condition on the supply's output and acts instantly, firing a shorting device (usually a silicon-controlled-rectifier) across the supply output. This causes high currents in the supply which blows the mains fuse and effectively turns the supply off.

Current-limiting is another protective measure usually incorporated in a regulated supply. This is to reduce the current through the regulator to a low value under excessive load or short-circuit conditions to protect the series pass transistor from excessive power dissipation and possible destruction.

General Operating Procedures

Note: This section includes: ***Signal Reporting, QSL cards,* the *Phonetic Alphabet,* and *Morse code abbreviations.***

You have passed the examination, been issued with a *Certificate* and you have a *callsign*. You have acquired a transmitter and a receiver. You are now set to begin operating.

The Golden Rules of Operating

LISTEN: This is the ***first*** rule. The strongest reason for listening before transmitting is to ensure that you won't interfere with anyone already using the frequency. The ***second*** reason for listening is that it may tell you a great deal about the condition of the bands. Although a band may be *dead* by popular consent at a particular time, frequent openings occur which you can take advantage of if you are listening at the right time. The ***third*** reason for listening is that if you can't hear 'em you are not likely to work 'em. Several short calls with plenty of listening spells will net you more contacts than a single long call. If you are running low power you may find it more fruitful to reply to someone else's CQ rather than call CQ yourself.

KEEP IT SHORT: If we all listened and never called, the bands would be very quiet indeed. So, if after listening, you have not made a contact, call CQ. The rules for calling CQ are:

1. Use ***your*** callsign frequently. Whoever you are calling knows their own callsign. They are interested in finding out yours.

2. Keep it short. Either they have heard you or they haven't. Either way, it is a waste of time giving a long call. If they are having difficulty in hearing you, use phonetics, but keep the 'overs' as short as possible.

3. Examples**:**

When using CW send a *3 by 3 CQ*. This means the letters *CQ* sent three times, followed by your callsign sent three times, and then the same group sent again, for example:

CQ CQ CQ de ZL1XYZ ZL1XYZ ZL1XYZ

sent twice and finally end with the letter *K* (for over) after the second group.

It is a nice and polite touch to add the end-piece "pse" (please):

"*CQ CQ CQ de ZL1XYZ ZL1XYZ ZL1XYZ PSE K*".

For voice operation you should repeat your call phonetically, for example:

CQ CQ CQ from ZL1XYZ ZL1XYZ ZL1XYZ

ZULU LIMA ONE X-RAY YANKEE ZULU

maybe three times and finish with:

calling CQ and listening.

4. Don't attempt to engage in DX "pileups" (many stations calling a rare callsign station) until you understand the accepted conventions for calling and replying.

A very bad practice may be observed in this activity. A station calling may carry out what amounts to an endurance exercise on the basis that the station who calls the longest gets the contact, purely because it is the only one that the DX station can hear clearly. This is unacceptable behaviour and should be avoided.

5. When you have made contact with that rare DX station make sure that they have your call and town correctly, give her/him your honest report, log your contact details, and then let the next station have its turn. Rare DX stations are not usually interested in the state of the weather in Eketahuna.

DO UNTO OTHERS: This rule if faithfully applied, would make the crowded HF bands far more tolerable.

1. Don't interfere with another station for any reason (except in extreme emergency).

2. Don't use full power to tune your antenna to resonance or when making matching adjustments with your antenna tuner. Always use a dummy load, or a noise bridge which enables you to tune your antenna accurately before transmitting.

3. Keep your power down to the minimum required for good communication.

4. Don't use excess audio drive or compression. This causes splatter and interference to other stations.

If there are other amateur operators in the area, it is courteous to make yourself known to them when you first begin transmitting. Check for things like cross-modulation problems. If you are causing another amateur interference which is unrelated to equipment faults, you will have to come to a mutual arrangement about transmitting hours. The above suggestions apply to all modes of operation. Some modes have their own particular rules, and these will be discussed in detail separately.

Repeater Operation

Repeaters were set up to provide a wider coverage on VHF and UHF as well as to provide facilities for emergency communication. So there are special rules governing repeater operation.

1. ***Keep contacts short***. Three minutes is the generally accepted maximum length for an over using a repeater.

2. ***Leave a pause between overs***. This is to enable weak stations with emergency traffic to make contact or other people to join the conversation. *Three seconds* is the accepted break.

4. ***Don't tune up on a repeater's input frequency***.

These are the main rules for using repeaters.

Other points to note when using repeaters or working simplex channels are:

1. Long CQs are not necessary or desirable on VHF or UHF channels. Just report that you are monitoring the channel. If anyone is listening and wants to contact you they will respond to your brief call.

2. When you want to contact someone through a repeater, it is not necessary to give a series of long calls. Either they are listening or they are not. A short call followed by: *are you are about Bill and Ben?* will usually bring forth a response. Some people respond to their name rather than to their callsign.

Do not keep triggering the repeater to make sure that it is there. This annoys the other people who monitor the repeater and it is not a good operating practice. A better way to announce your presence is to call and request a signal report from someone who may be monitoring the repeater. This may also result in an interesting and unexpected contact.

CW - or Morse Code - operating

Although CW operating appears to be slow compared with the use of voice, widespread use of abbreviations enables a CW contact to be conducted quite quickly. The first point to master in CW operation is the meaning of the various abbreviations for words and phrases in common use. A list is given below.

Other expressions are also used. An expression such as "up 2" means that the operator will be listening 2 kHz higher up the band at the end of his call.

The international Q-code is also used for common instructions and consists of three-letter groups, each of which has a well defined meaning. The Q code is used to ask a question when followed by a question mark, and also used to provide a reply. For instance, if you are asked QRS? it means that the operator you are contacting is asking, *should I send more slowly*. The reply could be *QRS 12* or whatever speed is suitable to the receiving operator.

When used on voice transmissions, many of the Q code signals take on a slightly different meaning, for instance the letters QRP indicate, *low power,* and QRX means, *standby*.

Operating CW is slightly different from voice transmission in that it is essential for the beginner to write everything down. As you become more proficient you will be able to copy in your head, but this comes only with practice.

Have a good supply of writing material handy. It adds to your difficulties if, when having to copy an incoming signal, pencils are lost, or blunt, or the supply of paper has run out. In your early days of CW sending, it helps to have a sheet of card on which is printed the name of your town, your own name, and a few details of the weather and so on. It is amazing how easy it is to forget even the spelling of your own name in Morse code when in the middle of a contact. Operating convenience is fairly easy to arrange and gives a conversational style to CW transmissions. It also enables you to hear any interference on the frequency, and you can then stop to find out if you are still being heard. When calling CQ pause frequently.

Voice operation

Much of your operation on the bands will be by voice, whether in the SSB or FM modes. Here are a few do's and don'ts.

1. ***Speak clearly into the microphone***. It is a good idea to contact a local operator and ask for a critical report. Adjust your speaking distance from the microphone and audio gain control to obtain the best results. If you change your microphone or transceiver, repeat the process with the new equipment. It is often better to talk *across* the microphone instead of into it.

2. ***If conditions are difficult, use phonetics***. A copy of the standard phonetic alphabet is below. This list is used and understood by all operators and will get through far better than any other phonetics you may invent.

3. During overseas contacts ***the use of local slang and abbreviations should be avoided*** as the person you are contacting may have only sufficient English to provide the essential QSL information.

4. The voice equivalent of break-in keying is VOX (voice-operated transmissions). This enables the transmitter to be automatically turned on with the first syllable of speech. Adjustments are provided on transceivers fitted with VOX which enable the audio gain, delay, and anti-vox, to be adjusted. These controls should be carefully set so that the transmitter is turned on as soon as speech commences, and that the delay is just sufficient to hold the transmitter on during the space between words, but released during a reasonable pause in the conversation. This will enable your contact to reply quickly to a comment, and permits an easy conversational flow.

Signal reporting

The RST system of signal reporting is based on a scale of 1 to 5 for ***readability***, and 1 to 9 for signal ***strength***. A ***tone*** figure of 1 to 9 is also given in the case of CW reports - for the purity of tone.

The RST System:

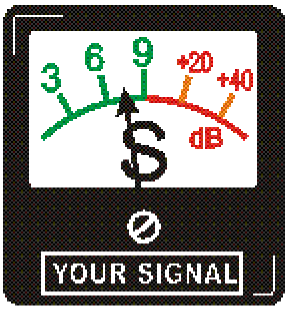
READABILITY
1 - Unreadable
2 - Barely readable, occasional words distinguishable
3 - Readable with considerable difficulty
4 - Readable with practically no difficulty
5 - Perfectly readable

SIGNAL STRENGTH
1 - Faint signals, barely perceptible
2 - Very weak signals
3 - Weak Signals
4 - Fair signals
5 - Fairly good signals
6 - Good signals
7 - Moderately strong signals
8 - Strong signals
9 - Extremely strong signals

TONE
1 - AC hum, very rough and broad
2 - Very rough ac, very harsh and broad
3 - Rough ac tone, rectified but not filtered
4 - Rough note, some trace of filtering
5 - Filtered rectified ac but strong ripple modulated
6 - Filtered tone, definite trace of ripple modulation
7 - Near pure tone, trace of ripple modulation
8 - near perfect tone, slight trace of modulation
9 - Perfect tone, no trace of ripple or modulation of any kind

The **R** readability part of the report is usually easy to resolve with a fair degree of honesty, although you will sometimes hear a report of readability 5, and "could you please repeat your name and location"!

The biggest problem in reporting seems to be the accuracy of the **S** signal strength reports. Some receivers are fitted with an "S" meter. The indication is usually related to the receiver's AGC level (automatic gain control). The meter may be a moving-coil or an LED bar-graph. The usual scale is for an increase of +6 dB in the receiver input signal for each "S" point up to S9, with a +20 dB indication then up to +60 dB. In practice, on the HF bands, an S meter needle makes wide changes and at best is just a simple indicator of variations in the propagation path. Its best use may be for comparing two incoming signals, such as when your contact station changes antennas.



Variations in equipment, propagation, the type of antenna and power of the equipment used by the operator at the other end, can all influence a signal strength report. With these variables the best you can do is to be consistent in the signal strength reports you give and hope that your contact does the same. This applies particularly to DX contacts. However, if your local contacts begin to give you reports that are at variance with what you normally receive, it's time to have a good look at your antenna and equipment, as something may have become disconnected or out of adjustment.

The **T** part of the RST reporting system refers to the tone of the received signal and is used in CW reporting. On a scale of 1 to 9, a 1 would indicate a heavy AC hum. A 9, indicates a clean tone, as from a sine wave audio oscillator. It is unusual to hear a signal that is not T9 these days. The numbers in-between give variations of the above conditions. Again, honesty of reporting, if a signal is not up to standard tell the operator. He will appreciate it. If your signal is not up to scratch, fix it. You owe this to other users of the bands.

When using FM these signal reports become meaningless. The audio level of an FM signal will not change with an increase in signal strength — the background noise will drop as the signal strength increases. This is called "quieting". A typical report could be "strength 5, very little noise". Signal reports from a repeater are generally meaningless, but a report to a user that he is fully limiting the repeater, or that his signal is breaking badly will sometimes help someone who may be checking a new site, or trying to access a repeater that has not been able to be worked into before.

Other modes

The original digital means of communication was the Morse code and this is still in use as a method of transferring information by means other than voice. Today however, Morse has been joined by a number of other methods each with its own advantages and disadvantages. RTTY, AMTOR, Packet Radio and PSK31, have all been given a great boost with the arrival of the computer and the advent of satellites with store and forward facilities. It is now possible to pass information to many parts of the world with a hand held transceiver, modem, and computer. Each of these means of communication has its own particular operating protocol and a study of it is well worthwhile before you venture into digital communications.

Confirming the contact - QSL cards

Most amateurs follow up a contact with an exchange of QSL cards to confirm the contact. When you design one for yourself, remember that these cards are sometimes used to obtain awards and certificates and if used for this purpose must contain the following information:

1. Your callsign, the callsign of the station worked, and your address. This should appear on the same side as other QSL information.

2. The date and time of the contact. The date should have the name of the month written. For example, 5 March 2008. In the United States 5/3/08 means May 3rd 2008. Times should be expressed in Universal Time (UTC). If local time is used this should be stated. Remember that when using Universal Time, the date changes at midday in New Zealand. (1 p.m. during daylight saving time.)

3 Signal Report.

4. Frequency of operation.

5. Mode of operation. Some awards require the mode used by both stations to be stated. For example, 2-way SSB.

6. If the card is to be sent through the NZART QSL Bureau, the call of the station to whom the card is to be sent should be printed on the back of the card. If a QSL manager is used by the recipient, that is the call that should be used.

7. Other information which may be included is a description of equipment, NZART Branch number, County, and Maidenhead Locator.

The New Zealand Association of Radio Transmitters, NZART, operates a QSL bureau. Cards may be forwarded through this if you are a member. Details of the bureau are in the Annual NZART *CallBook.* If you send a card direct, it is a courtesy to send a self-addressed envelope and international reply coupons to cover the cost of return postage.

The Phonetic Alphabet:

This Phonetic Alphabet is extracted from the ***International Radio Regulations:***

APPENDIX 14

Phonetic alphabet

When it is necessary to spell out call signs, service abbreviations and words, the following letter spelling table shall be used:

Letter	*Code word to be used*	*Spoken as*
A	Alfa	AL FAH
B	Bravo	BRAH VOH
C	Charlie	CHAR LEE or SHAR LEE
D	Delta	DELL TAH
E	Echo	ECK OH
F	Foxtrot	FOKS TROT
G	Golf	GOLF
H	Hotel	HOH TELL
I	India	IN DEE AH
J	Juliett	JEW LEE ETT
K	Kilo	KEY LOH
L	Lima	LEE MAH
M	Mike	MIKE
N	November	NO VEM BER
O	Oscar	OSS CAH
P	Papa	PAH PAH
Q	Quebec	KEH BECK
R	Romeo	ROW ME OH
S	Sierra	SEE AIR RAH
T	Tango	TANG GO
U	Uniform	YOU NEE FORM or OO NEE FORM
V	Victor	VIK TAH
W	Whiskey	WISS KEY
X	X-ray	ECKS RAY
Y	Yankee	YANG KEY
Z	Zulu	ZOO LOO

The following are general phonetics used by radio amateurs:

Figure to be transmitted	*Code word to be used*	*Spoken as*
0	Zero	ZAY-ROH
1	One	WUN
2	Two	TOO
3	Three	TREE
4	Four	FOWER
5	Five	FIVE
6	Six	SIX
7	Seven	SEVEN
8	Eight	AIT
9	Nine	NINER
Decimal Point	Decimal	DAY-SEE-MAL
Full Stop	Stop	STOP

Frequency Bands and Metres

Amateur Radio frequency bands are often referred to in terms of wavelength. This Table relates the frequency bands to the wavelength equivalent:

Frequency Band	Metre Band
165-190 kHz	1750 metres
1800-1950 kHz	160 metres
3.50-3.90 MHz	80 metres
7.00-7.30 MHz	40 metres
10.10-10.15 MHz	30 metres
14.00-14.350 MHz	20 metres
18.068-18.168 MHz	17 metres
21.00-21.45MHz	15 metres
24.89-24.99 MHz	12 metres
27.12 MHz	11 metres
28.00-29.70 MHz	10 metres
50.00-54.00 MHz	6 metres
144.0-148.0 MHz	2 metres
430-440 MHz	70 centimetres

Morse Code Abbreviations:

AA	all after
AB	all before
ABT	about
AGN	again
ANT	antenna
BCI	broadcast interference
BCNU	be seeing you
CK	check
CL	closing down
CPI	copy
CQ	calling all stations
CUD	could
CUL	see you later
DE	this is; from
DX	distant foreign countries
ES	and
FB	fine; excellent
GB	goodbye
GE	good evening
GM	good morning
GN	good night
GUD	good
HI	high
HI HI	the CW laugh
HR	here
HW	how is
NR	near; number
NW	now
OC	old chap
OM	old man
OP	operator
OT	old timer
PSE	please
PWR	power
RX	receiver
RFI	radio frequency interference
RIG	equipment
RPT	repeat
SRI	sorry
TNX	thanks
TKS	thanks
TVI	television interference
UR	your
VY	very
WKD	worked
TX	transmitter
XTAL	crystal
XYL	wife
YL	young lady
73	best regards
88	love and kisses

Practical Operating Knowledge

Receiver facilities

RF and IF gain controls - Simple receivers for the broadcast band have one "gain control" only, this sets the level of audio gain. Communications receivers have other gain controls which work on stages in advance of the detector.

An RF gain control sets the gain ahead of the receiver mixer. Adjustment to the gain of the first stage in the receiver can assist reception in cases where front-end-overload may be bothersome. This occurs when trying to receive a weak signal adjacent in frequency to a very strong local signal.

An IF gain control gives an independent control over the amplification prior to the detector stage. Most of the amplification in a receiver takes place in the IF stages. There may be many IF stages and operator-gain-control can effect improved performance.

AGC - "Automatic Gain Control". Tuning a receiver from a weak signal to a very strong signal (and back again) calls for frequent adjustment to the receiver's gain control(s). This becomes tiresome and is a nuisance with a communications receiver when tuning across a band of frequencies.

HF signals fade and the received audio can change from loud to faint and back again, sometimes at very fast intervals. This need to frequently adjust a gain control is also a nuisance and burdensome.

By sampling the strength of the signal being received (by rectifying it to produce a voltage) and by applying it to some of the amplifier stages, it is possible to automatically adjust the overall gain of a receiver. Tuning from a strong signal to a weak one, and the fading of a distant signal, will now have minimal effect on the level of audio heard from the speaker.

The signal-level sample for AGC applications may be taken from the detector or alternatively may be a rectified sample of the received audio. The AGC voltage is usually a DC voltage fed back to the IF amplifier stages where it controls the bias of the amplifiers,

"S" meter - This is usually a meter front-panel-mounted on a receiver and calibrated in signal strength units and dB. It varies as the signal fades. It is usually an electronic voltmeter measuring the AGC voltage. With a strong signal, the AGC level will be high. With a weak signal, there may be no AGC voltage at all.

As an absolute level measurement, an S-meter is generally unsatisfactory. It is useful for making relative measurements between different received signals. Read it with caution!

Noise blanker - Noise at HF is often of the "impulse variety", short sharp spikes of noise that blank out reception. A noise blanker uses such spikes to form a gating signal in the path of the signal through the receiver. A noise spike then automatically mutes the receiver for the period of the noise spike. This makes reception more comfortable on the ears of the operator. The effectiveness of a noise blanker varies and depends on the type of noise and the signal levels being received.

Station switching

PTT - "Push-To-Talk". The simple way to control the send/receive function on a transceiver is to use a "pressel" switch on the microphone. Pushing the switch is a simple and intuitive action when sending a voice transmission. Release the switch and the transceiver reverts to receiving incoming signals. The switch usually operates a relay inside the transceiver. The relay does all the switching changes needed to change from receive to send and back again.

VOX - "Voice-Operated-Relay" or "Voice-Operated-Transmit" This technique can be used to simulate duplex operation (i.e. telephone-type conversations) when operating phone on the HF bands. It is an extension of PTT operating. Just speak! A sample of the speech audio from the microphone is amplified and rectified to provide a DC control signal. That DC signal operates the relay which does the station send/receive switching.

A VOX system must have a "fast attack, slow release" characteristic to be sure that the first syllable of a spoken statement is not severely clipped, and to ensure that the relay does not clatter excessively in and out between the spoken words.

Break-in keying - This system uses the Morse key as the send/receive switch too. When using the key, on first key-down, the station changes to transmit. Stop using the key - and the station receives. The "channel" in use can be monitored during key-up periods when sending. Conversational-type contacts are possible.

Operating techniques

RIT - "Receiver Incremental Tuning". A transceiver is usually a receiver and transmitter combination sharing many common circuits - such as the various oscillators that determine its operating frequency. RIT provides a tuning facility so the receiver can be separately tuned for a few kHz each side of the transmit frequency, hence giving independent control over the receive frequency.

Split Frequency Operating - A transceiver is usually a receiver and transmitter combination which shares many common circuits - such as the various oscillators that determine its operating frequency. There are occasions when separation of the send and receive frequencies is desirable - to receive on one frequency but to transmit on another.

Pileup - Loose colloquial jargon used by radio amateurs to indicate the congestion that can occur when many stations suddenly call and try to work the same station, usually a station in some "rare DX" location. Discipline is needed to minimise this problem.

Station optimising

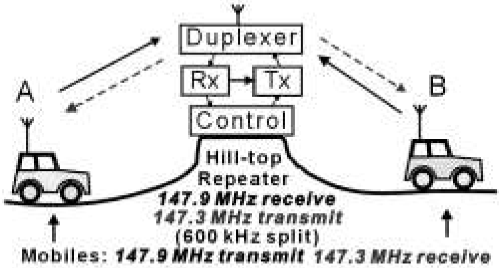
ALC - "Automatic Level Control". Just as we had AGC in a receiver, this is a similar thing for transmitters, usually for the linear amplifiers used in SSB transmitters. Its purpose is to prevent over-driving the linear amplifier stages especially the final amplifier.

It may also permit the peaks of an SSB signal to be limited in amplitude to enable an increase in the mean output power of the transmitter to improve the relative signal level at a distant receiver. This function can also involve processing the audio in the transmitter, known as "***compression***".

SWR bridge - This device has been discussed elsewhere in this Guide. Operating adjustments should be made to the Antenna Tuner for minimum reflected power indication on the SWR bridge. Appropriate antenna and transmission line adjustments should be made during installation for the same purpose.

VHF repeater working

A VHF (or UHF) repeater is a receiver and a transmitter connected together and sited on a hill-top or other high point - to give extended coverage.



In this diagram, the repeater receiver (Rx) audio output is passed to the transmitter (Tx).

The Rx and Tx can share a common antenna. The receive and transmit signals are directed to the appropriate places by the "duplexer". This is a collection of high-Q tuned circuits, a passive device acting as filters for the repeater input and output signals.

The "control" detects a received carrier and switches the transmitter on - until the received carrier disappears when it then switches the transmitter off. So the push-to-talk switch in the mobile station also turns the repeater transmitter on and off for "talk-through" operating. The repeater receiver "squelch" is used to provide the transmitter send/receive control function.

The frequency difference in this example is 600 kHz between the repeater receive and transmit frequencies. This is the standard "split" for repeaters operating in the 146 to 148 MHz band: i.e. it is ***plus*** 600 kHz ***above*** 147 MHz, and ***minus*** 600 kHz ***on or below*** 147 MHz. (The NZART CallBook gives details of the bandplans adopted in New Zealand and lists the frequencies and geographic locations of amateur radio repeaters.) UHF repeaters operating in the 430 to 440 MHz band use a 5 MHz "split".

The carrier-operated switch at the repeater receiver may fail to operate when an input signal gets weak. When mobile stations are operating through the repeater, if a mobile moves into an area with weak and little-or-no signal, the repeater may "drop out", there being insufficient signal to hold the repeater receiver open.

The carrier-operated switch at the repeater receiver is similar to the "***squelch***" operation in an FM receiver. FM receivers are very noisy in the absence of an input signal. To make life comfortable for operators monitoring FM communications channels, a "squelch" mutes the receiver loudspeaker in the absence of an incoming signal. The squelch "opens" when a signal is received and the signal's audio is then heard from the speaker.

Repeater networks New Zealand radio amateurs have built and installed 2-metre band (144 - 148 MHz) repeaters to provide most of the country with local area coverage. The "***National System***" on the 70 cm band (430 to 440 MHz) is a chain of ***linked repeaters.*** These provide communication along the length of the country. Refer to the NZART CallBook for maps and other details about the operation of the National System.

The Q-Code

Newcomers are often puzzled by the codes and abbreviations used by radio amateurs. These codes make international communication possible with operators who have little knowledge of English and they save time conveying information.

A full listing of the Q-Code can be found in publications of the International Telecommunication Union. Listed below are some Q-codes used by radio amateurs.

The Q-Code is used in two ways - with or without a question mark. Sometimes a figure, a callsign or a frequency, accompanies a Q-code. For example:

QTC? (note the question mark) means "have you any messages for me?".
QTC3 means "I have three messages for you".

QRG	Will you tell me my exact frequency (or that of ...)? Your exact frequency (or that of ...) is ... kHz
QRH	Does my frequency vary? Your frequency varies
QRK	How intelligible are my transmissions? The intelligibility of your signal is ... (1, 2, 3, 4, 5)
QRL	Are you busy? I am busy
QRM	Am I being interfered with? You are being interfered with
QRN	Are you troubled by static? I am troubled by static
QRO	Shall I increase power? Increase power
QRP	Shall I decrease power? Decrease power
QRQ	Shall I send faster? Send faster
QRS	Shall I send slower? Send slower
QRT	Shall I stop sending? Stop sending
QRW	Shall I inform ... that you are calling him on ... kHz? Please inform ... that I am calling on ... kHz
QRX	When will you call me again? I will call you again at ... hours.
QRZ	Who is calling me? You are being called by ...
QSA	What is my signal strength? Your signal strength is ... (1, 2, 3, 4, 5)
QSB	Are my signals fading? Your signals are fading
QSK	Can you hear me between your signals? I can hear you between my signals
QSL	Please acknowledge receipt. I acknowledge receipt
QSO	Can you communicate with ... ? I can communicate with ...
QSY	Shall I shift frequency? Shift frequency to ...
QTC	Have you any messages? I have ... messages for you
QTH	What is your location? My location is ...

Transmission Lines

Carrying the Signal

Transmission lines are the link between your station equipment, transmitter, receiver, transceiver, and the antenna. There are many different varieties but two major types of line predominate for frequencies in general use by radio amateurs.

Parallel-conductor line, also known as twin-line, or open-wire line, consists of two parallel conductors held apart at a constant fixed distance by insulators or by insulation. This type of transmission line is "balanced". This means that each wire is "hot" with respect to earth.

Coaxial cable (coax) is the other major type and consists of two concentric conductors. It is a single wire surrounded by insulation and enclosed in an outer conductor, usually a braid. This is an "unbalanced" line, the outer sheath can be at earth potential, only the inner wire is "hot".

The transmitter power radiating from the antenna is less than that generated at the transmitter due to losses in the transmission line. These losses increase with higher SWR values, with higher frequencies and with increasing the length of the line. Most line loss occurs in the supporting insulation so open-wire lines have lower losses than heavily insulated line.

Parallel lines

These come in various types. The flat TV "300-ohm ribbon" is an example. "Ladder-line", in which two parallel conductors are spaced by insulation "spreaders" at intervals is another. These lines are relatively cheap. Open-wire lines can be home-constructed using improvised "spreaders". These lines have low losses at HF frequencies.

These lines do have the disadvantage that they must be kept away from other conductors and earthed objects. They cannot be buried or strapped directly to a tower.

As the frequency increases, the open-wire line spacing becomes a significant fraction of the wavelength and the line will radiate some energy.

Because it is a balanced line, it can feed a dipole directly without the use of a "balun" at the antenna. (Baluns are discussed below.) Most transceivers have an unbalanced 50-ohm output impedance and a balun transformer will be required to feed a balanced line.

Parallel lines vary in impedance depending on the diameter and the spacing of the conductors. TV twin lead has an impedance of 300-ohm and ladder-line is usually 450 or 600-ohm.

Coaxial cable

Coaxial cable consists of two concentric conductors with dielectric insulation in the space between the conductors. The inner conductor carries the signal (i.e. it is "hot"). The outer conductor is usually at earth potential and acts as a shield. This cable can be buried and run close to metal objects with no harmful effects.

Coax comes in various sizes from very small to large diameters. The small sizes are for low powers and short distances. The larger sizes have higher power-handling capabilities and usually lower losses. Most amateurs use 50-ohm cable while TV antenna coax is usually 75-ohm.

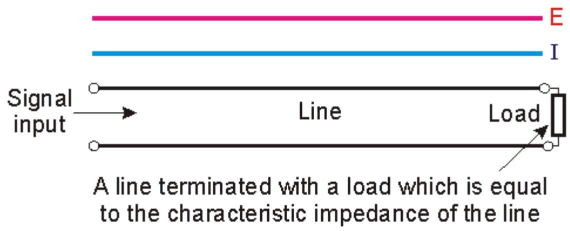
The dielectric insulator is generally the main cause of energy loss. Most coax uses solid polyethylene and some types use a foam version. The foam version is lower loss but the solid version is more rugged. For very low loss purposes, a solid outer is used ("hardline"), and the inner conductor is supported by a spiral insulator or by beads. This type of coax is hard to work, cannot be bent very sharply and is generally expensive.

Characteristic Impedance

An important characteristic of a transmission line is its "characteristic impedance". This can range from about 30 ohm for high-power coax to 600 to 1000 ohm for open-wire wide-spaced line. The unit of measurement is the ohm, but you cannot simply attach an ohm-meter to coax cable to measure its characteristic impedance.

The characteristic impedance of a line is not dependent on its length but on the physical arrangement of the size and spacing of the conductors. (Remember that when simply put, ***impedance is the ratio of the voltage to the current***. A high voltage and low current means a high impedance. A low voltage and high current means low impedance).

Loads attached to the distant end of a line have an effect on the impedance "seen" at the input to the line.



When a line is terminated at the distant end with a termination impedance that is the same as the characteristic impedance of the line, the input to the line will be "seen" to be the characteristic impedance of that line. In other words, looking into the input of this line, you "see" an infinitely-long line. This is ideal for the optimum transfer of power from the transmitter down the line to the antenna.

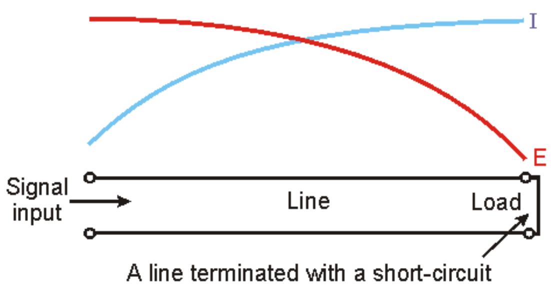
In this diagram, the termination is the same value as the characteristic impedance of the line. The voltage across the line is shown as E for the various points along the line and the current in the line at those same points is shown as I.

Note that the line is "flat" - there is no variation in the ratio of voltage to current (i.e. no variation in impedance) at any point along the line.

If there were such a thing as an infinitely long line, cutting a short length off it and terminating that short piece with a load equal to its characteristic impedance, would still make it indistinguishable at its input from an infinitely long line - as shown in this diagram.

Line terminations

There are several classic cases of line termination which must be known and each will be described in turn.



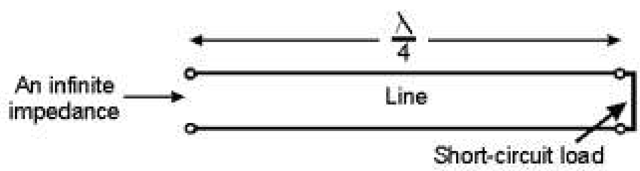
For a line with a ***short-circuit termination***, consider this approach:

A signal starts off and travels down the line. It reaches the distant end and finds the line to be short-circuited! What can it do? It turns around and travels back to the source. So there are now TWO waves travelling on the line but in different directions - the ***forward wave*** being still sent down the line, and the ***reflected wave*** on its way back.

At any point on the line, the voltage across the line will be the **sum** of these two component waves, measured using an appropriate voltmeter.

But the voltage across the line at a short-circuit must be zero. So the reflected wave must be phased in such a way that the resultant voltage at the short-circuit is zero. See the E curve above. Coming back down the line the voltage will increase as shown in the diagram above.

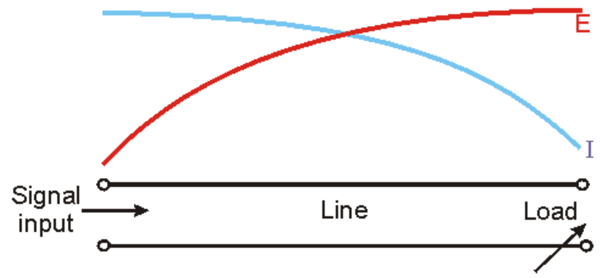
Likewise, at a short-circuit the current will be high. So the current in the line must be high at the termination and will decrease as you measure it back down the line. The current will follow the I curve shown above.



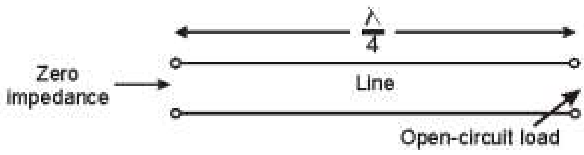
Impedance is the ratio of voltage to current. So at the load (a short-circuit) the impedance will be zero. As you travel back down the line, both E and I vary so the ratio between them is varying. When the line is ***one-quarter wavelength*** long, the impedance will be very high - approaching infinity.

A similar thing happens when the line is ***open-circuited***:

In this case, there will be a high voltage at the end of the line - the open-circuit. The current in the line must be zero there. So the impedance will be very high. Travelling back down the line, the impedance (the ratio of voltage to current) will decrease until at a quarter-wavelength point, the impedance will be seen to be zero.

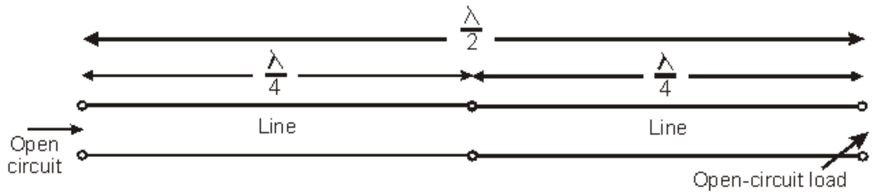


A line terminated with an open-circuit



The quarter-wave length of line in effect ***inverts*** the impedance at its termination. Quarter-wave lengths of line are very useful for many applications especially at VHF and UHF.

The half-wave length of line can be considered as two quarter-wavelengths in cascade and its performance can be deduced from that approach.

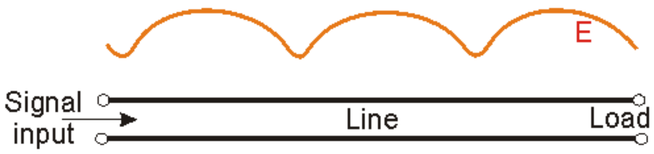


Thus the input impedance of a ***half-wave length*** of line is a repeat of the termination at the distant end.

The Voltage Standing Wave Ratio (VSWR)

We have considered the line with a matched load, with a short-circuit termination and with an open-circuit termination. The practical values of load fall somewhere between these limits.

The VSWR (usually shortened to SWR) can be visualised by considering the forward and reflected waves in a line. If the antenna (the termination at the load end of the line) does not exactly match the line (i.e. is not exactly equal to the characteristic impedance of the line), then some energy will be reflected back down the line. So we have a forward wave (high energy) and a reflected wave (smaller than the forward wave) on the line. A pattern of peaks and troughs in the voltage measured between the line conductors will be found as you measure the voltage at points back down the line.



The SWR can be measured with a device known variously as a "reflectometer" or SWR bridge, or plain SWR meter. The SWR is constant at all points along the line (assuming a lossless line) in contrast to the impedance seen looking into the line, which is a function of the line length.

The SWR meter is usually placed near to the transmitter. It distinguishes between the forward and reflected waves in the line. It gives an indication of whether the antenna is matched to the line by allowing the standing-wave-ratio to be measured. When inserted in the line between the transmitter and the antenna tuning unit, it also permits the antenna tuning unit to be adjusted.

Any variations from a "correct match" at the antenna (or load) end of the line can have a significant effect on the power radiated by the system:

1. The transmitter requires a "correct match" (usually 50-ohm resistive) to the line for the best transfer of energy from the transmitter to the line.
2. The line requires a minimum SWR for least losses, and
3. the match from the line to the antenna should be correct to minimise the SWR on the line.

Variations from a "correct match" can also have undesirable effects on a transmitter to the point of causing overheating in the final stage and arcing in tuned circuits.

The "Antenna Tuner"

The antenna tuner is usually inserted in the transmission line adjacent to the transmitter with the antenna connected at the distant end of the line.

The antenna tuner does not really tune the antenna at all. It does not adjust the length of the antenna elements, alter the height above ground, and so on. What it does do is to transform the impedance at the feedline input to a value that the transmitter can handle - usually 50 ohm. Think of the antenna tuner as an adjustable impedance transformer and you will understand its function.

If the antenna is cut to resonance and is designed to match the impedance of the transmitter and feedline, an antenna tuner is not required. The transmitter is presented with a 50-ohm load (or something close to it) and into which it can deliver its full output power.

The "SWR bandwidth" is important. The SWR bandwidth of many antenna designs is usually limited to only some 200 or 300 kHz. If a dipole is cut to resonate with a 1:1 SWR at 7 MHz, you may find that the SWR is above 2.5:1 at 7200 kHz. Most modern transceivers will begin to reduce output or may automatically completely shut down at SWR's above 2:1.

With an antenna tuner in the same line, you can transform the impedance seen by the transmitter to 50-ohm, and reduce the SWR in the short piece of line between the transmitter and the antenna tuner to 1:1 again. The transceiver then delivers its full output again. The radiated power will be slightly reduced because of the higher losses on the line between the tuner and the antenna, attenuation due to the higher line currents associated with the higher SWR on that stretch of line.

This attenuation is caused by the fact that the matching function of the tuner has not changed the conditions on the line between the tuner and the antenna.

Velocity factor

A radio wave in free space travels at the speed of light. When a wave travels on a transmission line, it travels slower, since it is travelling through a dielectric/insulation. The speed at which it travels on a line compared to the free-space velocity is known as the "velocity factor".

Typical figures are:

Twin line 0.82, Coaxial cable 0.66, (free space 1.0).

So a wave in a coaxial cable travels at about 66% of the speed of light (as an example).

In practice this means that if you have to cut a length of coaxial transmission line to be a half-wavelength long (for, say, some antenna application), the length of line you cut off will have to be 0.66 of the free-space length that you calculated.

Baluns

A balun is a device to convert a **bal**anced line to an **un**balanced line - and vice-versa. It comes in a variety of types.

The "transformer" type is probably the easiest version to understand. Consider a transformer with two windings, a primary and a secondary. The primary can be fed by a coaxial cable - the UNbalanced input. The secondary could be a centre-tapped winding with the tap connected to the outer of the coaxial input cable. The two ends of the secondary are then the BALanced connections. Impedance transformation can also be made by adjusting the number of turns on the primary and secondary windings.

When a balanced antenna, such as a dipole, is directly fed with coax (and unbalanced line), the antenna currents (which are inherently balanced) will run on the outside of the coax to balance the coaxial cable currents which are inherently unbalanced. This feedline current leads to radiation from the feedline itself as well as by the antenna and can distort the antenna radiation pattern. The RF can travel back down the outside of the coax to the station and cause metal surfaces at the station to become live to RF voltages. RF shocks are unpleasant and burn the flesh. They should be avoided. To correct this, a balun should be used when connecting a balanced line to an unbalanced line and vice-versa.

Baluns are used for connecting TV receivers (75-ohm unbalanced) to 300-ohm ribbon (balanced).

Using a single antenna for transmit and receive

A lot of trouble and expense goes into erecting a good feeder and antenna system for transmitting. It should also be used for receiving. This is usually the case with a transceiver.

With a station comprising a separate transmitter and receiver, a change-over relay can be fitted to switch the antenna feeder between the two items. It is usual - and desirable - for the unit not being used to be disabled. Extra poles on this same relay can be used to disable the device not being used.

Antennas

Wavelength and frequency

A useful and fundamental measurement in radio antenna work is the "half wavelength". We must know how to calculate it. It leads to the desired physical length of an antenna for any operating frequency.

Wavelength, frequency, and the speed of light, are related. The length of a radio wave for a given frequency when multiplied by that operating frequency, gives the speed of light.

The relationship is:

Speed of light = f times λ, i.e. $c = f \times \lambda$, (λ = lambda), where f is the frequency and λ is the wavelength.

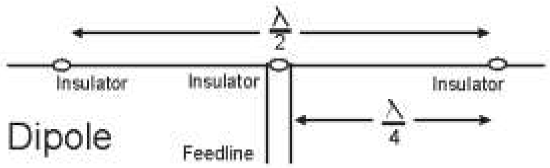
Knowing that the speed of light is $c = 3 \times 10^8$ metres per second, and knowing our operating frequency, we can derive the wavelength of a radio wave by transposition as follows:

Wavelength (***in metres***) = 300 ***divided by*** the frequency ***in MHz***. .

A simple way to remember this is to remember 10 metres and 30 MHz, (to get the value of the constant, 300 !).

That gives a ***wavelength***! The half-wavelength of a wave is ***half*** of the wavelength figure you obtain!

So a half-wavelength at 10 metres (30 MHz) will be 5 metres. The amateur 10 metre band is 28 to 29.7 MHz so a half-wavelength for that band will be a little longer than 5 metres. Pick a frequency and calculate it!



Dipoles

The fundamental antenna is the **dipole**. It is an antenna in two parts or poles.

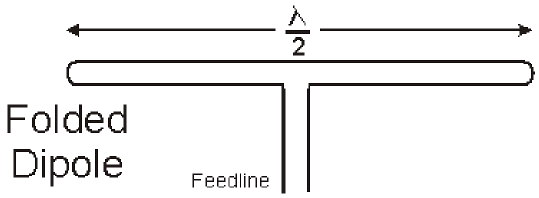
It is usually a one-half wavelength in overall length and is fed at the middle with a balanced feedline. One side of the antenna is connected to one side of the line and the other to the remaining side either directly or through some sort of phasing line.

When making a half-wave dipole for HF frequencies, one usually has to reduce the length by about 2 percent to account for capacitive effects at the ends. This is best done after installation because various factors such as the height above ground and other nearby conducting surfaces can affect it.

The feedpoint impedance of a half-wave dipole, installed about one wavelength or higher above ground (i.e. in "free space"), is 72 ohm. When the ends are lowered (i.e. into an "inverted V"), the impedance drops to around 50 ohms.

The ends of the antenna should be insulated as they are high-voltage low-current points. The connections of the feedline to the antenna should be soldered because the centre of the dipole is a high-current low-voltage point.

The radiation pattern of a dipole in free space has a minimum of radiation in the direction off the ends of the dipole and a maximum in directions perpendicular to it. This pattern degrades considerably when the dipole is brought closer to the ground.

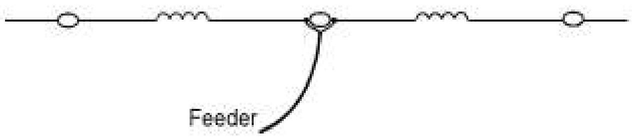


A modified version of the simple dipole is the **folded dipole**. It has two half-wave conductors joined at the ends and one conductor is split at the half-way point where the feeder is attached.

If the conductor diameters are the same, the feedpoint impedance of the folded dipole will be four times that of a standard dipole, i.e. 300 ohm.

The height above the ground

The height of an antenna above the ground, and the nature of the ground itself, has a considerable effect on the performance of an antenna and its angle of radiation.



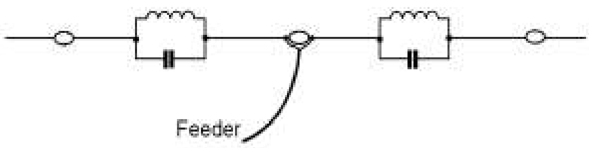
The physical size of a dipole

A wire dipole antenna for the lower amateur bands is sometimes too long to fit into a smaller property. The antenna can be physically shortened and it can still act as an electrical half-wave antenna by putting loading coils in each leg as shown in this diagram. With careful design, performance in still acceptable.

Installing such "loading coils" lowers the resonant frequency of an antenna.

Multi-band dipoles

A simple half-wave dipole cut to length for operation on the 40m band (7 MHz) will also operate on the 15m band without any changes being necessary. This is because the physical length of the antenna appears to be one-and-one-half wavelengths long at 15 metres (21 MHz), i.e. three half-wavelengths long.

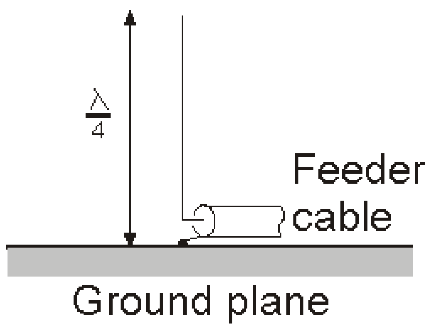


A dipole antenna can be arranged to operate on several bands using other methods. One way is to install "traps" in each leg.

These are parallel-tuned circuits as shown in this diagram (enlarged to show the circuitry). The traps are seen as "high impedances" by the highest band in use and the distance between the traps is a half-wavelength for that band. At the frequencies of lower bands, the traps are seen as inductive and the antenna appears as a dipole with loading coils in each leg. With clever and careful design, operation becomes possible on a range of amateur bands.

Baluns

Dipoles should be fed with a "balanced line". "Baluns' are discussed elsewhere in this Study Guide.



Vertical antennas

The simplest vertical is the Marconi which is a quarter-wave radiator above a ground-plane. It has a feedpoint impedance over a perfect ground of 36 ohm. Above real ground it is usually between 50 and 75 ohm. This makes a good match for 50 ohm cable with the shield going to ground. For a given wavelength it is the smallest antenna with reasonable efficiency and so is a popular choice for mobile communication. It can be thought of as half of a dipole with the other half appearing as a virtual image in the ground.

A longer antenna can produce even lower radiation angles although these antennas become a bit large to easily construct. A length often used for VHF mobile operation is the 5/8th wavelength. This length has a higher feed impedance and requires a matching network to match most feeder cables.

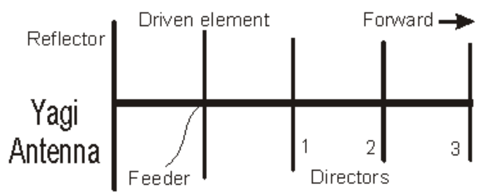
Vertical antennas require a good highly conductive ground. If the natural ground conductivity is poor, quarter-wave copper wire radials can be laid out from the base of the vertical to form a virtual ground.

Vertical antennas provide an omni-directional pattern in the horizontal plane so they receive and transmit equally well in all directions. This also makes them susceptible to noise and unwanted signals from all directions.

Vertical antennas are often used by DX operators because they produce low angle radiation that is best for long distances.

Beams

To improve signal transmission or reception in specific directions, basic elements, either vertical or horizontal, can be combined to form arrays. The most common form is the Yagi-Uda parasitic array commonly referred to as a Yagi array or beam.



It consists of a driven element which is either a simple or folded dipole and a series of parasitic elements arranged in a plane. The elements are called parasitic because they are not directly driven by the transmitter but rather absorb energy from the radiated element and re-radiate it.

Usually a Yagi will have one element behind the driven element (called the reflector), and one or more elements in front (called the directors). The reflector will be slightly longer than the driven element and the directors will be slightly shorter. The energy is then concentrated in a forward direction.

To rotate the beam, the elements are attached to a boom and in turn to a mast through some sort of rotator system.

Other antenna types can be constructed to give directivity. The size and weight, with wind resistance, are important. The ***cubical quad*** is a light-weight antenna for home-construction and it can provide good performance. It consists of two or more "square" wire cage-like elements.

Antenna measurements

Most antenna performance measurements are given in decibels. Important figures for a beam antenna are the forward gain, front-to-side ratio, and front-to-back ratio.

Forward gain is often given related to a simple dipole. For example, if the forward gain is said to be 10 dB over a dipole, then the radiated energy would be 10 times stronger in its maximum direction than a simple dipole.

Another comparison standard is the isotropic radiator or antenna. Consider it to be a theoretical point-source of radio energy. This is a hypothetical antenna that will radiate equally well in all directions in all planes - unlike a real vertical antenna which radiates equally well only in the horizontal plane. A dipole has a 2.3 dB gain over the isotropic radiator.

A front-to-back ratio of 20 dB means that the energy off the back of the beam is one-hundredth that of the front. Similar figures apply to the front-to-side ratio.

Another antenna measurement is the bandwidth or range of frequencies over which the antenna will satisfactorily operate. High gain antennas usually have a narrower bandwidth than low gain antennas. Some antennas may only cover a narrow part of a band they are used in while others can operate on several bands. Other antennas may be able to operate on several bands but not on frequencies in-between those bands.

Dummy loads

A dummy load, or dummy antenna, is not really an antenna but is closely related to one. It is a pure resistance which is put in place of an antenna to use when testing a transmitter without radiating a signal.

Commonly referred to as a termination, if correctly matched to the impedance of the line, when placed at the end of a transmission line it will make the transmission line look like an infinite line.

Most transmitters are 50 ohm output impedance so a dummy load is simply a 50 ohm non-inductive resistor load. The resistor can be enclosed in oil to improve its power-handling capacity. The rating for full-power operation may be for only a short time so be aware of the time and power ratings of your dummy load before testing for long periods at full power. The things can get very hot!

Propagation

The Spectrum

Amateur Radio is all about the transmission of radio waves from place-to-place without wires. Signals travel from the transmitting antenna to the receiving antenna in different ways depending on the frequency used. Some frequencies use the ionosphere to bounce signals around the world while other frequencies can only be used for line-of-sight operations.

Radio waves are part of the spectrum of electromagnetic radiation, with infrared, light, ultraviolet, x-rays and cosmic rays at the extreme upper frequencies. Radio waves further subdivide into different frequency ranges.

All electromagnetic radiation travels at the same speed, commonly referred to as the speed of light, $c = 3 \times 10^8$ metres per second or 300 000 km per second.

Electromagnetic radiation consists of two waves travelling together, the magnetic and the electric, with the planes of the two waves perpendicular to each other.

The polarisation of a radio wave is determined by the direction of the electric field. Most antennas radiate waves that are polarised in the direction of the length of the metal radiating element. For example, the metal whips as used on cars are vertically polarised while TV antennas may be positioned for either vertical or horizontal polarisation. Polarisation is important on VHF and higher but is not very important for HF communications because the many reflections that a skywave undergoes makes its polarisation quite random.

The path

The simplest path to understand is the direct path in a straight line between transmitter and receiver. These are most important for communication on frequencies above 50 MHz. The signal might be reflected off buildings and mountains to fill in some shadows, but usually communication is just line-of-sight.

On lower frequencies the ionosphere is able to reflect the radio waves. The actual direction-change in the ionosphere is closer to **refraction** but ***reflection is easier to envisage***.

For simplicity, we will use the reflection word here, but remember that the mechanism is more truly refractive. Similarly, again for simplicity, we will consider the regions where the change-of-direction takes place to be "layers" although they are more strictly "regions".

The signal reflected off the ionosphere is referred to as the skywave or ionospheric wave. The groundwave is the signal that travels on the surface of the earth and depends upon the surface conductivity.

Groundwaves are the main mode of transmission on the MF bands (e.g. AM broadcast band), but they are not very important for amateur use - except perhaps on the only amateur MF band, 160 metres, 1.8 MHz. The groundwave is usually attenuated within 100 km.

On VHF and higher frequencies, variations in the atmospheric density can bend the radio waves back down to the earth. This is referred to as the tropospheric wave.

The skywave

The skywave is the primary mode of long distance communication by radio amateurs and is usually of the most interest. A skywave will go farther if it can take longer "hops". For this reason, a low angle ($< 30°$) of radiation is best for DX (long distance) communication as it will travel farther before reflecting back to earth. Antennas that produce low angle radiation include verticals or dipoles mounted high (at least half a wavelength) above the ground.

The sun and the ionosphere

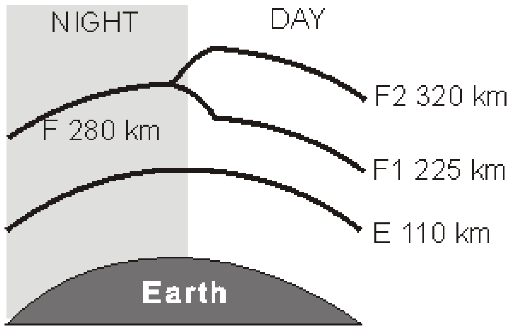
The ionosphere refers to the upper region of the atmosphere where charged gas molecules have been produced by the energy of the sun. The degree of ionisation varies with the intensity of the solar radiation. Various cycles affect the amount of solar radiation with the obvious ones being the daily and yearly cycles. This means that ionisation will be greatest around noon in the summer and at minimum just before dawn in the winter.

The output from the sun varies over a longer period of approximately 11 years. During the maximum of the solar sunspot cycle, there is greater solar activity and hence greater ionisation of the ionosphere.

Greater solar activity generally results in better conditions for radio propagation by increasing ionisation. However, very intense activity in the form of geomagnetic storms triggered by a solar flare can completely disrupt the layer of the ionosphere and block communications. This can happen in minutes and communications can take hours to recover.

Ionospheric layers

The ionosphere is not a homogenous region but consists of rather distinct layers or regions which have their own individual effects on radio propagation. The layers of distinct interest to radio amateurs are the E and F layers.



The E layer at about 110 km is the lower of the two. It is in the denser region of the atmosphere where the ions formed by solar energy recombine quickly. This means the layer is densest at noon and dissipates quickly when the sun goes down.

The F layer is higher and during the day separates into two layers, F1 and F2 at about 225 and 320 km. It merges at night to form a single F layer at about 280 km.

The different layers of the ionosphere can reflect radio waves back down to earth which in turn can reflect the signal back up again. A signal can "hop" around the world in this way. The higher the layer, the longer the hop. The longer the hop the better since some of the signal's energy is lost at each hop.

Lower angle radiation will go farther before it reflects off the ionosphere. So to achieve greatest DX, one tries to choose a frequency that will reflect off the highest layer possible and use the lowest angle of radiation. The distance covered in one hop is the skip distance. For destinations beyond the maximum skip distance the signal must make multiple hops.

The virtual height of any ionospheric layer at any time can be determined using an ionospheric sounder or ionosonde, in effect a vertical radar. This sends pulses that sweep over a wide frequency range straight up into the ionosphere. The echoes returned are timed (for distance) and recorded. A plot of frequency against height can be produced. The highest frequency that returns echoes at vertical incidence is known as the ***critical frequency***.

Absorption

The ionosphere can also absorb radio waves as well as reflect them. The absorption is greater at lower frequencies and with denser ionisation. There is another layer of ionisation below the E layer, called the D layer, which only exists during the day. It will absorb almost all signals below 4 MHz - i.e. the 80 and 160 metre bands. Short-range communication is still possible using higher angle radiation which is less affected. It travels a shorter distance through the atmosphere. The signal can then reflect off the E layer to the receiver. The D and E layers are responsible for you hearing only local AM broadcast stations during the day and more distant ones at night.

Attenuation

The attenuation of a signal by the ionosphere is higher at lower frequencies. So for greater distance communication one should use higher frequencies. But if the frequency used is too high, the signal will pass into space and not reflect back to earth. This may be good for satellite operation but is not useful for HF DX working.

For DX working on HF, one should try to use the highest frequency that will still reflect off the ionosphere. This varies with solar activity and time of day. It can be calculated with various formulas given the current solar indices. This frequency is referred to as the Maximum Usable Frequency (MUF). In the peak of the solar cycle it can often be over 30 MHz and on rare occasions up to 50 MHz. At other times, during the night, it can drop below 10 MHz.

At the low end of the spectrum, daytime absorption by the D layer limits the possible range. In addition, atmospheric noise is greater and limits the Lowest Usable Frequency (LUF). This noise and absorption decreases at night lowering the LUF at the same time as the MUF is lowered by the decrease in solar excitation of the ionosphere. This usually means that by picking the right frequency, long range communication is possible at any time.

Fading

Radio waves can travel over different paths from transmitter to receiver. If a path length varies by a multiple of half the wavelength of the signal, the signals arriving by two or more paths may completely cancel each other. This multi-path action causes fading of the signal. Other phenomena can cause this. Aircraft, mountains and ionospheric layers can reflect part of a signal while another part takes a more direct path.

Sometimes fading may be so frequency-dependent that one sideband of a double-sideband (AM) signal may be completely unreadable while the other is "good copy". This is known as "selective fading". It will often be observed just as a band is on the verge of closing, when reflections from two layers are received simultaneously.

Fading can also occur when a signal passes through the polar regions, referred to as polar flutter, caused by different phenomena. The ionosphere is much more disorganised in the polar regions because of the interaction of solar energy with the geomagnetic field. The same phenomena that cause aurora can cause the wavering of signals on polar paths.

Other atmospheric effects

Other atmospheric effects can affect radio propagation and may often extend the transmission of VHF/UHF and higher SHF band signals beyond the line-of-sight. The lowest region in the atmosphere, the troposphere, can scatter these signals more than 600 km as an expected near limit - tropospheric scatter.

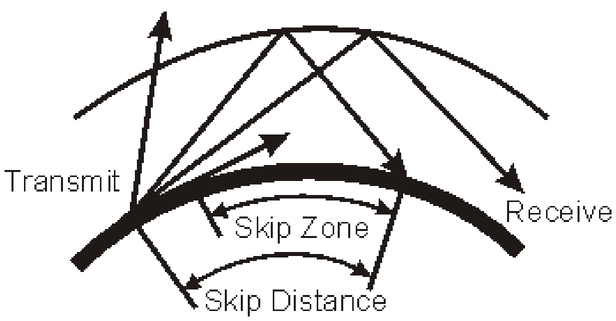
Ducting is a phenomenon where radio waves get trapped by a variation in the atmospheric associated with temperature inversions. The waves can then travel along the curvature of the earth by refraction. Ducting usually occurs over water or other homogenous surfaces. Ducting is more common at higher VHF frequencies and has permitted VHF/UHF/SHF communication over distances greater than 3500 km. This is known as - tropospheric ducting.

Another phenomenon, sporadic E skip, is a seasonal occurrence, usually during the summer. A small region of the E layer becomes more highly charged than usual, permitting the reflection of signals as high in frequency as 300 MHz. These highly-charged regions are sheets of ionisation in the E layer that are formed, and move and are unpredicted. Sporadic E propagation can occur for only a few minutes to a few hours. Hence the name - Sporadic E.

Communication can be achieved by reflection off the ionised trails of meteors. Meteor scatter communication may only last a few seconds so it is feasible with large numbers of meteors, and other trails of debris from comets that enter the atmosphere, particularly more so during times of meteor showers.

Skip zone

Amateurs are usually concerned about working to the maximum possible distances but there are times when one can talk to people thousands of kilometres away but cannot talk to someone only 500 km away. A skip zone can be created by the ionosphere reflecting signals from a shallow angle. Waves at a higher angle pass directly through and are lost into space. The critical angle varies with the degree of ionisation and generally results in larger skip zones at night. The area between the limit of maximum range by direct wave or ground wave, and the maximum skip distance by skywave is known as the skip zone.

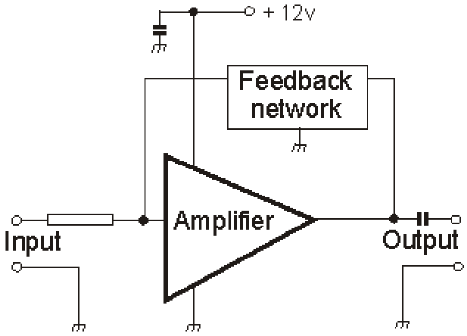


Interference and Filtering

Filters

Filters can be active or passive. Passive filters, comprised of inductors and capacitors, are used for the suppression of unwanted signals and interference. These are treated below.

Active filters use amplifying devices such as transistors or integrated circuits with feedback applied to achieve the required filter characteristics.

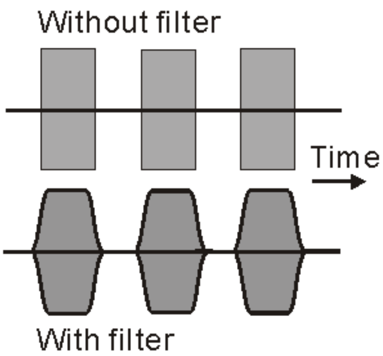


The "operational amplifier" is one such active device with features making it particularly suitable for filter applications up to a few megahertz. This diagram shows a typical example.

These can have a very high gain but with negative feedback applied, are usually operated to produce a circuit with unity gain. The input impedance to such a circuit can be very high. These circuits are compact, and able to have variable Q, centre, and cut-off frequencies. The circuit gain and performance can be adjusted by changes to the feedback network.

Key Clicks

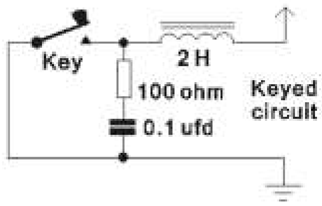
In a CW transmission, the envelope of the keyed RF output waveform may be as shown in this upper diagram - a square-wave. When analysed this will be found to be composed of a large number of sinewaves.



These sidebands may extend over an wide part of the adjacent band and be annoying to listeners - a form of click or thud heard each time your key is operated.

To prevent this happening, the high-frequency components of the keying waveform must be attenuated. In practice this means preventing any sudden changes in the amplitude of the RF signal. With suitable shaping, it is possible to produce an envelope waveform as shown in the lower diagram.

One means for doing this is a key-click filter as shown in this diagram. When the key contacts close, the inductance of the iron-cored choke prevents the key current from rising too suddenly. When the contacts are broken, the capacitor keeps the keyed current going for a short period. The resistor prevents the discharge current from being excessive.



Note that the body of the key is at earth potential at all times - for safety reasons.

Radio transmissions can cause interference to other Radio Services and to nearby electronic equipment. Some Radio Frequency Interference (RFI) can render some equipment completely useless.

The term "Electromagnetic Compatibility" (EMC), is the preferred title and reflects the need for all devices to co-exist together in the same electromagnetic environment.

The responsibility for both the avoidance and the suppression of interference to other Radio Services, is a Radio Regulatory matter and is considered in the section on Regulations.

This *Interference and Filtering* section will consider the causes of and solutions to common RFI problems - problems that arise when your transmitted signal "gets into" your own and other television receivers and other appliances.

It is important, for domestic and for neighbourhood harmony, to be able to correct manufacturing deficiencies in consumer electronics.

Filter passbands

Filters form the basis of many RFI circuits. A filter is a frequency-selective circuit which passes signals of certain frequencies while attenuating others. Filters are able to select desired frequencies from undesired frequencies so they are fundamental to suppressing interference.

Typical measures of a filter are its cut-off frequency and its Q.

The cut-off frequency is defined as the frequency at which the signal will be reduced to half the power of the maximum signal passed. The Q (or quality) of a filter is a measure of how "sharp" the filter is. High-Q filters are those with a relatively narrow bandwidth, while low-Q filters have a relatively wide bandwidth. A filter's bandwidth is the frequency separation between cut-off frequencies.

This diagram shows the four common filter types. They are easy to recognise.

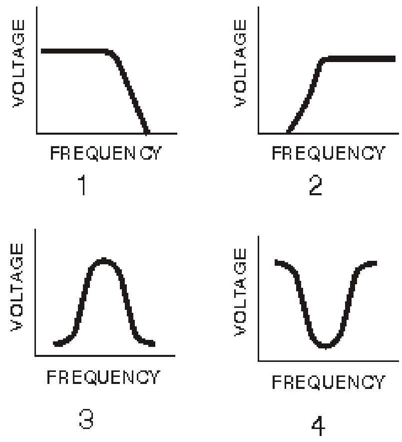
Low Pass filters exhibit the typical characteristic shown in **1**.

High Pass is shown in **2**.

Band Pass is shown in **3**.

Band Stop in **4**.

These diagrams are for demonstration only. Practical filters exhibit considerable differences and have more pronounced characteristics.



Broadcast and Television Interference

TV interference is of two types. The first concerns TV receivers which radiate spurious emissions and cause interference to the signals ***you*** are trying to receive on the amateur bands. The second is interference which ***your*** transmissions cause to TV reception on near-by television receivers.

It is the second variety that is the more important and the more difficult.

The text following is based on the NZART document: "***A Code of Practice for Radio and Television Interference Cases***" dated 1981, published in "Break-In" October 1981.

A copy of the original document can be obtained from NZART Headquarters, P.O. Box 40-525, Upper Hutt or at nzart@nzart.org.nz . Please give this reference to the month and year of this "Break-In" issue and your postal address.

A Code of Practice for Radio and Television Interference Cases

1. Introduction

This is a guide for radio amateurs whose operations come to the attention of neighbours through disturbance to reception of sound broadcast and television transmissions (BCI and TVI). This disturbance is a continuing risk in amateur radio, and all radio amateurs can expect to cause or to be accused of causing BCI or TVI at some time. The interference is not damaging and the accusation does not bring any disgrace.

Interference between one radio service and another is inevitable from time to time, because all services share the one radio frequency spectrum.

You must face the problem only when it arises, and you should not worry about it beforehand. You should not fear a TVI or BCI report in any way or restrict your activities or hours of operation because a report may arise.

The best advice is this: ensure that the apparatus in your own home is free from interference caused by your amateur radio activities--and be active on the air. In all cases of interference, a cure is possible. Problems can be cured only as they arise. In reading this guide, which treats TVI in greater detail, bear in mind that in BCI cases you must take a similar approach.

The exact procedure to follow in interference cases cannot be laid down. Each case differs. Neighbours have been known to complain of interference after a radio amateur has erected a new aerial but before it has been used for transmitting. In other cases, neighbours have tolerated overhearing transmissions because they like to feel informed. Few hard-and-fast rules can be offered.

2. BCI

Interference to broadcast-band receivers is often reported. The broadcast receiver cannot be considered to be of adequate design unless it has a radio-frequency amplifier stage and is connected to an outside aerial. An internal aerial or an aerial in the same room as the receiver is not to be accepted as satisfactory.

The amateur's transmissions may be able to be received at various points on the tuning dial, but the generally accepted rule is that the case is one of interference only when reception of the local broadcast stations is disturbed.

3. Interference to audio devices

By some reports, an amateur's transmissions are heard from record players, stereo grams, and similar audio devices that are not designed for the reception of radio transmissions.

On receiving a report of interference to such an audio device, courteously discuss the matter with the owner, and advise him to contact the supplier or his supplier's agent to arrange for it to receive attention and to have the deficiency cured. These devices are not designed to be radio receivers.

4. TVI

The important point to remember about TVI is that it can be cured. Bear this point in mind at all times. TVI must be challenged head-on and a cure found for each separate case. Unfortunately, there may be no easy way or shortcut.

5 Preliminaries

When you start transmitting from a new neighbourhood or with a new rig, first ensure that your own television set is absolutely free from TVI. Then operate without any self-imposed restrictions of any sort. That is, operate when you want to, for as long as you wish, on any authorised band, with any power up to your legal limit, and with no disturbance to your own television receiver.

A radio amateur's first operating concern should be to ensure that the television receiver in his own home is disturbance-free. It should not display any interference when operation is taking place on the frequented amateur bands.

Your television receiver is very close to the transmitter and its aerial. Having your TV receiver "clean" is important for several reasons, the first being that it promotes domestic or family harmony! Your receiver will be the subject of the first tests the MED RSM Official may want to make--and revealing a clean display on your own television set will incline him in your favour. Revealing a clean set can also help you to deal with neighbours who do not believe that the fault lies in their own installation. If your own TV set is not TVI free, therefore you should make it so!

6. The wait

Do not ask the neighbours for TVI reports. Let the neighbours first report the matter either to yourself or to the MED RSM. Wait for the TVI reports (if any) to come to you - they may never come.

7 . Reports

TVI reports can come from several directions and in several ways.

The neighbour may contact you or a member of your family. An MED RSM Official may contact you. The report may be very complete, may be garbled or incomplete, may be casual, or may be second or third hand. Be sure you recognise a TVI report as such, and note it well.

8. Action upon receiving a report

a. Do not delay. Attend to the matter promptly.

b. Check what you learn against your own operating activities and against your log. Have you changed bands, changed aerials, or built a new amplifier? Does the report coincide with changes to your installation or operating habits?

c. Check that any interference is in fact due to you. Be sure that it is not from a neighbour's new electric drill, arc welder, or other appliance, or from some other source.

d. Check with family members who view your own television set. Was any interference observed at the time claimed?

e. Show concern, but do not admit any responsibility for the interference at this stage. Wait until tests have been conducted.

f. Determine whether the MED RSM staff have or have not been notified.

g. Get full details of the interference, the time, the channel, and the nature of the interference on picture and on the sound. Has it just started, or is the problem of long standing?

h. Details of the model or type of television receiver, feeder, and aerial are also useful.

i. Start a notebook with date, time, and details of the report. Because even cases with big problems have small beginnings, start an accurate record early. You cannot be sure of the final outcome.

j. Above all don't worry.

9. When should you contact the MED RSM?

This depends on the nature of the TVI report reaching you, the degree of co-operation shown by the neighbours, and how well you know them. If the neighbour directs threats or abuse at you, or is not known to you, or claims that the fault is wholly yours, do not hesitate to notify the MED RSM by telephone.

You would be wise to be prepared to give a short history of any previous TVI problems you have experienced in this same location. Have you cured similar problems? This is where the notebook becomes useful.

If you do not show any TVI on your own set, continue to operate until the matter can be investigated.

If your neighbour is co-operative and is prepared to let you or a friend examine the set; then offer to do some tests to try to reproduce the conditions that gave rise to the interference. You may be able to cure the problem without involving the MED RSM staff at all.

Please be aware that the MED RSM may charge someone for their services. Make enquiries first to determine any costs involved and where their account is likely to be directed. This may depend on where the source of the interference is finally found.

10. The cause

The technical mechanism or whatever generates the interference or disturbance must be established early to determine:

a. The cure necessary, and,

b. Who is responsible for affecting a cure, and,

c. Who is to pay any expenses involved.

Because tests must be carried out to determine this mechanism, the following are necessary:

a. Access to the television set for tests,

b. Operation of the transmitting equipment, and,

c. Someone with TVI tracing experience to decide which tests should be done, to carry out the tests, and to interpret the results.

This means that the radio amateur and the neighbour must be present for the period of the tests. That is, co-operation is necessary.

The tests may or may not be conducted by the MED RSM. They could be conducted by some other competent person provided the co-operation of the neighbour is assured.

Note that one or more mechanisms may be creating the interference, and so more than one cure may be necessary at any television installation. At any one transmitter site, the disturbance in adjacent television receivers may be generated by quite different mechanisms.

11. The problems

The two problems that arise with TVI are:

a. Technical, and,

b. Social.

Few people will comment on which is the more difficult! The technical cause may be:

a. At the transmitter installation, or,

b. At the receiver installation, or,

c. Somewhere else, or,

d. Combinations of these.

12. The tests

The first tests should be elementary:

a. Check the TV installation. Is the aerial in good order? Is it installed in accordance with accepted practice? Is the ribbon / coax in good order? Is a balun fitted? Is the aerial adequate for the TV field strength at the site? Is the aerial suitable for the TV channels received at the site? Check the suitability of the aerial mount. Check the joints between feeder and aerial elements. Do not assume that because a television aerial has been commercially installed that it will have been correctly installed. The requirements of a TV aerial to reject interference are more stringent than those for satisfactory reception when interference is absent. An aerial which gives satisfactory reception when installed may prove inadequate later when a source of interference comes into being.

b. Have another operator work the transmitter on the frequency from which interference is suspected. Note any disturbance to picture, colour, or sound. Make adjustments to accessible controls - fine tuning, contrast, and colour. Check all television channels. A VHF link to the transmitter operator is useful for co-ordination

c. Substitute another television receiver (perhaps a different model) and repeat the tests. Use a television set known to be TVI-free in a similar location.

d. Do not remove the back from the television set. Confine tests to operational tests, intended only to identify the nature of the disturbance, but try a high-pass filter (if available) in the television aerial lead if a quick diagnosis decides that this might help, if the neighbour agrees.

e. Obtain details of the set's make and model. Is it under guarantee? How old is it? Who supplied it? Is it under a service contract? Who maintains it? Is it a rental set?

f. Has an official from the MED RSM viewed the set? Does the MED RSM know of the problem ?

g. Keep the test short, make no promises, and do not give an opinion at the site. Withdraw, consult textbooks and other persons for advice, and then decide on a course of action.

13. The rusty-bolt effect

High-pass filters (at the television receiver aerial terminals) and low-pass filters (at the transmitter) do not always cure TVI problems. Substitution of other TV sets can generally show if the cause is a faulty transmitter or faulty television receiver, but if substitution shows the interference effect to continue, then the cause becomes more difficult to establish. The "rusty-bolt" effect is one of the hardest of all these TVI causes to locate.

If a known clean transmitter is causing interference to a known good television receiver, then an external cause can be suspected. Perhaps the transmitter signal is being picked up by a local conductor such as a clothes-line or fence-wire. A rusty or corroded joint in this conductor may be acting as a diode. Harmonics of the transmitter signal could be produced by this spurious diode detector and re-radiated. These harmonics can be received by the television receiver and cause interference to the picture or sound.

Such interference may vary with the weather. It may be intermittent and be affected by wind as well as rain.

Typical offenders are metal-tile roofs, metal gutters and down pipes. A heavy blow with a hammer may sometimes correct an offending joint. Applying water from a hose can sometimes change or remove the interfering source and help to identify the culprit.

Either bonding or insulating the offending joint may solve the problem. More than one joint may be causing trouble. Bonding is generally impossible with metal tiles. Shifting the television aerial away from the offending harmonic source or sources is a more practical cure. A bonded wire mesh over the offending joint may be considered. It is unlikely that a complete metal roof will have to be bonded to effect a cure.

Bonding suspect joints can sometimes produce problems. With bonded conductors, a better signal pick-up may result, larger radio frequency currents may flow, and the problem may shift to another joint that was hitherto not suspect. Insulating the suspect joints may sometimes be more effective. A change to nylon guy-wires may sometimes eliminate problem joints.

The accepted rule is that if the offending joints are on the amateur's property, the problem is his. If the offending joints are on the property of the television set's owner the problem is his, Unfortunately, few set-owners understand this problem and so the radio amateur should offer technical assistance and advice. Re-siting the television set aerial or the transmitting aerial is often the only practicable cure.

14. Guarantees and service contracts

If the television set has been shown to be faulty and is under a guarantee or a service contract, then give the firm concerned early advice of the problem. This is best done after the MED RSM has been advised and the problem discussed. Advise the firm concerned that the MED RSM is aware of the problem. These actions are really the concern of the television set's owner, but the radio amateur may offer to assist.

15. Rental sets

Rental sets should be treated in the same way as a set with a service contract. A rental set has the advantage that a change to another model may be possible, which could cure an otherwise difficult problem.

16. Getting involved with other people's gear

As a radio amateur, you should be aware of the undesirability of agreeing to fix a neighbour's equipment. The equipment may be under guarantee, may be covered by a service contract, or may be rented. It may not belong to the person who is using it, who may not always be honest and forthright about ownership. Where to draw the line depends very much on how well you know the neighbour, and other factors, such as the age of the set, and the nature of the problem itself.

Your "unauthorised tampering" may invalidate guarantees and service contracts. Future problems with the equipment - in no way related to the interference problem - will without doubt be blamed on the radio amateur. No radio amateur wants to be concerned with the maintenance of his neighbour's equipment for evermore. The possibility of double-blame must be avoided (first the interference, and then of damaging the set).

Safety and Regulations are good reasons for keeping out of a neighbour's set. Many modern television receivers may operate with the chassis alive - at about half mains voltage. This also means that short lengths of coaxial cable inside the set (to the aerial isolation unit) could appear to have the outer at earth potential, but in fact this outer could be at a hazardous potential. Under the various Electrical Acts and Electrical Regulations, a radio amateur is not qualified to service mains-operated television receivers.

17. What level of interference is tolerable?

Slight disturbances on a television test pattern which are barely noticed by a trained eye will not be seen on a television picture.

Disturbances of the same level as the noise on the picture, and less than interference from motor vehicle ignition, electrical appliance noise or aircraft flutter, are acceptable.

Tearing of the picture, herringbones, or switching between colour and black and white are unacceptable.

The last trace of TVI may be slight changes at the areas of intense red in a picture. This is acceptable for unless attention is drawn to it, it will be unnoticed.

Noises from an adjacent transmitter should not be heard during pauses in the television sound.

It is wise not to draw the attention of the owner to minor disturbances. Instead, check if he is satisfied with the quality of reception. The neighbour should be unable to tell when you are transmitting.

18. Contact with the equipment manufacturer

Where substitution of another set or other tests have shown that the fault is within a particular television receiver or other piece of commercial equipment, consider approaching the manufacturer of the equipment. When or how this should be done depends on the attitude of the local agent for the equipment, and the status of the guarantee or service contract. Ideally, the local supplier of the equipment should handle communications with the manufacturer in cases where a manufacturer's modification or the expense of a local modification arises. Again the radio amateur may offer to assist the owner.

If you approach a manufacturer, be certain to include details of model type and serial numbers, age of set, installation arrangements, tests conducted and their results, and any other details that will help in an analysis of the problem, diagnosis of its cause, and the development of a cure.

19. The radio amateur's responsibility for the cure

The radio amateur should not accept responsibility for being the cause of TVI unless carefully conducted tests have established:

a. That his transmitting installation is faulty, or,

b. That, in the substitution of another transmitter of comparable characteristics, the problem disappears, or,

c. That, in more than one adjacent television set, previously TVI-free, the same interference symptoms suddenly appear at the same time, and coincide with transmissions from the amateur's transmitter, or,

d. That a parasitic rectifying joint on the radio amateur's own premises is generating interfering signal components.

20. The television set owner's responsibility for the cure.

The owner or user of the television set must accept responsibility for curing the interference if carefully conducted tests show:

a. That no interference is exhibited on the radio amateur's own television receiver on the radio amateur's own premises, or,

b. That a high-pass filter or other trap device on the television aerial eliminates the interference, or,

c. That any parasitic rectifying junction is shown to be located on the property of the television set's owner or user, or,

d. That another television receiver substituted at the television installation fails to display the same interference, or,

e. That other attention at the television installation will cure the interference; for example, repairs to the aerial or feeder, or a shift of the television aerial to another position.

22. The viewers' choice

If a television viewer chooses to view television programmes on a defective set, or a set with a defective installation, he should not expect a radio amateur to cease transmissions to remove the disturbances to his viewing.

25. Terminology

Be careful with the use of words. An amateur transmitter does not "interfere with" or "cause interference" to television reception until properly conducted tests have clearly established that the fault is in the transmitting equipment or the transmitting installation.

A properly adjusted transmitter, radiating a "clean" signal, does not "radiate interference" or "cause interference". Disturbances to television reception should not be described as "interference" if the television set has deficiencies in its design or installation that cause it to respond to signals from a "clean" transmitter.

A faulty television receiver or installation that responds to the amateur transmitter's "clean" signal does not exhibit "interference" - although this is the term often given to it (TVI). "Reception is being disturbed" is a better description.

If the transmitter is faulty and radiates energy that enters the television set at the television channel frequencies, then this is clearly a case of "interference". The amateur transmitter is then "radiating an interfering signal".

If the fault is at the television receiver, and the transmitter is blameless, then the transmitter cannot be said to be "causing interference".

26. The approach

Be tactful when explaining to a neighbour that his television receiver or installation is faulty. An explanation such as follows is satisfactory and typical:

"You have a very good set. It displays each channel very well, with good crisp pictures and pleasant sound. Unfortunately, it also responds to signals not meant for it, and this means it is defective. Other sets in the area are known to be unaffected in this way ... By means of some tests, we can determine if the fault is inside the set, or if it can be cured by changes to your aerial, or if your installation needs a filter or trap added to the aerial lead. The punch line “it also responds to signals not meant for it, and this means it is defective” should be carefully explained.

Contact with the neighbours may be by a visit, telephone, or a formal letter. The procedure to adopt depends how approachable they are, how well you know them, and where the TVI report came from, and how it was conveyed to you. There is a need to explain to the layman what Radio Frequency Interference (RFI) is, and what radio amateurs do.

27. No guarantees possible for TVI cures

The possibility of a TVI report is ever present. Once a cure has been effected to a TVI case, there is no known way of ensuring that the same set will not again become subject to TVI at some later time, perhaps by other cause. Damage and corrosion takes its toll of aerials and earthing systems.

Sets age and become faulty. The radio frequency spectrum is a shared resource, and until we have new knowledge or techniques, all radio amateurs must learn to live with the possibility of a TVI case arising at any time and be trained in how to handle it when it does arise.

A radio amateur should not, and cannot, give a neighbour a guarantee that a TVI cure just made will remain effective for any period.

28. Fitting devices to a neighbour's set

It may be found that a high-pass filter, traps, stubs or other device fitted at the aerial terminals of a neighbour's TV set will cure disturbances to his viewing. It is important to leave a label or tag securely attached to the set, which gives reason for the installation of the device - otherwise the device may be removed by someone in the absence of an interfering signal "because it has no effect"!

29. Extra assistance

Every NZART Branch should designate a member of its Committee as Interference Officer, his duties being to receive requests for assistance on BCI / TVI matters from members. He should have power to enlist other technically qualified members of the Branch into a team to help any member who needs tests, diagnosis, negotiations, advice, and other support until the case is closed. Amateurs should be seen to be united - this is important.

An independent expert third party may be acceptable to a neighbour in difficult cases.

Branches should be aware that the NZART Council is in a position to help with problem BCI / TVI cases, particularly where added technical assistance is required, or where an amateur is under pressure from a local dignitary or influential person. NZART Council has the route through the NZART Administration Liaison Officer available for official negotiations on behalf of a member if the Council deems them necessary.

Difficult technical or social TVI/BCI interference problems should be notified to NZART promptly.

30. Conclusion

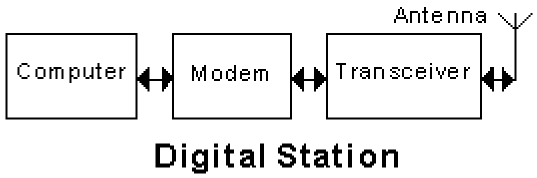
Remember that all BCI and TVI cases are capable of being technically cured. All you need is patience to test, diagnose the problem, and work out a cure. Many good textbook and magazine articles have been published and are available. The problem is not yours alone. Other radio amateurs are available to help you, many having experience with the problem. The MED RSM are there to help. TVI and BCI are accepted as a part of radio life and technical progress.

The neighbour also has a part to play. Cooperation and patience are necessary. Don't allow yourself to worry, and don't allow your neighbour to think that you should stop your operations.

Digital Communications

The original digital means of electrical communication was the Morse code. It is still in use today as a very successful method for transferring information by means other than voice. Today Morse has been joined by some other methods each with its own advantages and disadvantages.

RTTY, AMTOR, PACTOR, PSK31, Packet Radio and other modes have all been given a great boost with the arrival of the computer as a generally available appliance. In fact some of the new modes would be impossible without the computer and the PC sound card. The advent of satellites with store and forward facilities has also enhanced digital operations.



It is now possible to pass information to many parts of the world with a hand-held transceiver, modem, and computer, and also to have real-time conversations around the world using an HF radio and a computer. Each of these means of digital communication has its own protocol.

How Digital Modes are Generated

Two common digital coding schemes are used; the ITU-R ITA2 alphabet, (often misnamed the "Baudot code"), and the ITU-R ITA5 alphabet (or ASCII - American Standard Code for Information Interchange). ITA2 codes each character as a number between 0 and 31 to represent the various letters, digits and punctuation marks. To fit more than 32 different characters into the code, most numbers are used twice, and a special character (a "shift" character) is used to switch between the two meanings. The number can be represented by a 5-digit binary number (e.g. 14 = 01110 in binary). RTTY is one of the few systems that use the ITA2 alphabet today.

The ITA5 alphabet has 128 combinations, so a comprehensive alphabet, including lower and upper case letters, can be represented in seven binary bits. ITA-5 is used by PACTOR, packet radio and many other modes. Some digital modes (such as Morse!) use a scheme called a ***Varicode*** where the different characters are represented as numbers of different lengths. If the more frequently used characters are shorter, the transmission of plain text is therefore more efficient.

The numbers to be transmitted must then be modulated onto a radio signal in some way. There are three main properties of a radio signal; frequency, phase and strength (amplitude), so there are three common modulation methods, and some modes use a combination of two or more of these. Many modes are transmitted using Frequency Shift Keying (**FSK**). This in principle consists of switching between two adjacent frequencies which are used to designate the "0" or "1" data bits. The two tones must maintain a fixed frequency separation or shift and of course the radio frequencies must also be stable. The most common shifts used by amateurs on HF for FSK are 170 Hz and 200 Hz. Wider shifts are used on VHF where data rates and signal bandwidths can be higher. Other modes use more tones (Multiple Frequency Shift Keying, MFSK), or one of the other techniques, such as Phase Shift Keying (**PSK**), where the phase of the tone or carrier is varied, or Amplitude Shift Keying (**ASK**), where the signal strength is varied or even keyed on and off.

To send a character over the radio, one bit (binary digit), 0 or 1, is assigned to one of two states, or if there are more than two possible states (say if there are four tones or four PSK phases), then two or more bits at a time may define the state to transmit. The data changes the properties of the signal to be transmitted (i.e. modulates the signal), as each state is fed successively to the transmitter modulator, to define and transmit each symbol.

For the receiving end to be able to accurately decode the characters sent, the bits must be sent at a constant speed. The signalling speed of serial data transmissions on wires is measured in bits per second (bps), since the bits are always sent one at a time. However, the signalling speed on a radio link is not measured in bits, but in symbols per second (the unit of symbols/sec is the ***baud***). The ***symbol*** is the basic modulated signalling entity on a radio link, and represents the state of each signalling interval. Each symbol may carry one or more (or even less) data bits, depending on the modulation technique. For RTTY, each symbol (a short duration of one tone or another) carries one data bit, so the speed in bps is the same as the baud rate.

The device that produces a modulated tone symbol for each data state, or creates a data state for each received tone symbol, is called a **modem** (a modulator /demodulator). The modem may be a special separate unit rather like a telephone modem, or sometimes the modulation is performed directly on a transmitter oscillator or a modulator, and a separate modem device may not be necessary except perhaps for receiving. Equally, the function of a modem now often takes place in a computer sound card, with the signals fed from it and to it by an SSB transceiver.

RTTY (Radio TeleTYpe) is one of the oldest of the machine-generated digital modes. It does not necessarily require a computer, as it is simple enough to be handled by a mechanical device similar to a typewriter - a teleprinter. RTTY, like most other digital modes, works by encoding characters into a digital alphabet.

Common speeds used by amateurs for RTTY are: 45.5, 50 and 75 baud, equivalent to 60 wpm, 66 wpm, and 100 wpm. (There are five letters and a space in the average "word").

AMTOR is a form of RTTY, now little used, that uses error checking to ensure that the data sent is received correctly. The message being sent is broken up into groups of three characters each. A special alphabet is used which has seven bits per character; every valid character always has a 4:3 ratio of 0s and 1s. This small packet is then transmitted through the modem to the radio. AMTOR always operates at 100 baud and uses 170 Hz shift FSK.

The system can operate in two modes, mode A and mode B. Mode A uses Automatic Repeat Request (**ARQ**) to ask the sending station to resend any packets that are not received properly (correct 4:3 ratio) once contact is established. Mode B sends the data twice, and checks the data, but it will not ask for a repeat. It is used for establishing contact (i.e. calling CQ) and for net and bulletin transmissions.

Packet Radio is an ARQ system like AMTOR, but with more powerful error checking and message handling abilities. Larger packets are used, and encoded in each packet are the sender and destination addresses, and a very efficient error detection scheme called a Cyclic Redundancy Check (CRC).

The Packet protocol allows a limited number of stations to carry on independent conversations on the same frequency without interference. The effective communication rate will be reduced if many stations are using the same frequency and excessive packet collisions occur.

Packets are assembled and prepared for transmission by a Terminal Node Controller (**TNC**), which manages the packet radio protocol and also contains a modem. The individual characters are usually in the ASCII alphabet, and a packet protocol called AX25 is usually used. The assembled packet is then passed to the modem and a radio in the same way as AMTOR or PACTOR.

Packet radio allows automated message forwarding throughout the world. Most activity is on VHF and higher bands where more stable propagation prevails and FM transmitters and receivers are used.

Large cities are centres of activity and cities are connected to each other by a series of relay stations. For longer distances the cities are connected by HF links (using PACTOR) or via internet or satellite gateways. Store-and-forward relaying is used. Most cities have a Bulletin Board System (**BBS**) for packet radio users. These can be used for the circulation of amateur radio information. They can be accessed by stations comprising a home computer, a simple modem and a VHF FM transceiver.

Another popular application of Packet Radio and AX25 is a telemetry technique called the Automatic Position Reporting System (APRS), although it is used for much more than reporting position. Stations with information to pass on send regular standard format messages in the manner of a beacon, which can be retransmitted by other stations. Applications of this type do not use bi-directional error correction, but do use automatic forwarding much the same as conventional packet systems.

PACTOR is derived from AMTOR. Like AMTOR it is a two-way error correcting system, but PACTOR dynamically adapts to conditions, switching from 100 baud to 200 baud. PACTOR can accept a series of imperfect data packets and reassemble them into the correct text. A recent version of PACTOR, called PACTOR II, uses the same protocol, but uses PSK modulation for even higher performance.

PSK31 is the most popular of the new digital modes. It is used like RTTY, for live keyboard-to-keyboard contacts. It uses differential binary PSK modulation at 31.25 baud. It is easy to tune in and to operate. The signal is very narrow (only 50Hz) and the performance very good, due to the high sensitivity and noise rejection of the PSK technique. PSK31 uses advanced digital signal processing (DSP), and can be run on many computer platforms, including Windows with a SoundBlaster type soundcard. The software is available free.

All you need to get going is a stable HF SSB Transceiver of conventional design, and a computer with a soundcard. You run two shielded audio cables between the rig and the sound card. The computer with its soundcard does the job of the modem. You can download FREE software from a web page. When all is set up, you have a live-keyboard system for chatting with other HF stations around the world. This is a really exciting mode. You can get further details about PSK31 from a search on the internet.

Other modes: There are numerous other digital modes in use, and more being introduced all the time. Many of these are designed for specific applications. For example, **MFSK16** was designed for very long distance low power real-time conversations, and also is most effective on lower bands with strong multi-path reception and burst noise. **CLOVER** is an ARQ mode designed for reliable long distance file transfer under poor conditions, while **MT63** was designed for net operation under severe interference. Some of these modes use interesting modulation methods such as single or multi-carrier Binary Phase Shift Keying **BPSK**, Quadrature Phase Shift

Keying **QPSK**, or Orthogonal Frequency Division Multiplex **OFDM**. There are even special modes for moon-bounce, auroral signals, very weak LF comunications and satellite operation. Many of these new modes also use a simple sound card modem and free software.

Don't overlook ***Hellschreiber***. This is a mode with an interesting history. Hellschreiber is a method for sending text by radio or telephone line that involves dividing each text character into little pieces and sending them as dots. Hellschreiber was invented by the German inventor, Rudolf Hell who patented Hellschreiber in 1929.

The same SSB transceiver and computer set-up used for PSK31 can be used for Hellschreiber. Most Hellschreiber operation uses ASK modulation at 122.5 baud. You can check out the world of Hell on the web site at: http://www.qsl.net/zl1bpu and download the latest Hell software from there.

Hellschreiber is becoming popular with HF digital operators, as it provides very good performance with simple equipment and is easy to use. Its application is as a point-to-point mode for live contacts in a similar way to RTTY and PSK31. Modern variations such as **PSK-Hell** and **FM-Hell** provide even better performance with features to overcome specific ionospheric limitations of other digital modes.

Digital Modes and Propagation

While sensitivity and therefore rejection of **Broadband Noise** is an important property of digital modes, there are other specific ionospheric problems that affect digital modes more than is apparent on either Morse or voice modes. **Burst Noise** (electrical machinery, lightning) causes errors, interferes with synchronisation of data modes and impedes error correction systems, while **Carrier Interference**, (TV and mains harmonics, other radio transmissions) will obviously impair reception of most modes.

There are two other effects which are not so obvious. **Multi-path Reception**, where the signal arrives from different paths through the ionosphere with different time delays, can have a devastating effect on digital modes such as RTTY, that no increase in transmitter power will correct. The best solution to this problem is to use a mode with a very low baud rate, such as MFSK16 or MT63, to limit the timing errors. **Doppler Modulation**, caused mostly by fast moving air streams in the ionosphere or the movement of the apparent reflective height through changes in ion density, also has a serious effect, changing especially the phase and even the frequency of signals. This is best countered by using higher baud rates, or avoiding PSK modes. Doppler can be a big problem with long distance PSK31 operation.

Because the requirements for best performance conflict to some extent, and there is no one mode which will defeat all the problems, in all cases the use of an effective error correction system (designed for the conditions) will provide significant improvements. The best solution is to choose an appropriate mode for the conditions prevailing at the time.

(The assistance of Murray ZL1BPU with the preparation of this Study Note is gratefully acknowledged.)

Signals

Notes about the various ***Signal Modes*** used by radio amateurs

Summary

The principles of signal generation and amplitude modulation are covered in another paper: “*Mixers and Modulators*”. Those fundamentals are used here to form signals for transmission.

Speech

For radio communication purposes we can consider the range of audio frequencies in human speech to extend from 300 Hz to 3000 Hz - a band of 2.7 kHz. This audio spectrum for speech can be drawn as shown in Fig. 1. Here the low end of the wedge represents 300 Hz and the high end of the wedge represents 3000 Hz. This diagram is for ***purposes of explanation only*** and should not be taken to represent the voice energy distribution of speech in actual practice. It is usually the other way around - the *low notes contain most of the voice energy,* whilst *the high pitch notes are weak but are very necessary for speech recognition purposes*. The band of audio frequencies 300 to 3000 Hz, this "audio band", when illustrated as a wedge with each end identifiable, is useful for explanation purposes.

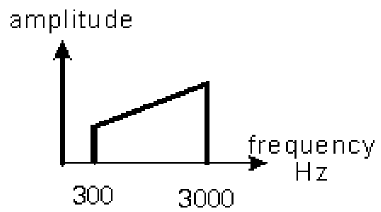


Fig. 1

An “unmodulated carrier”

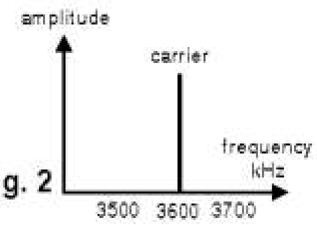
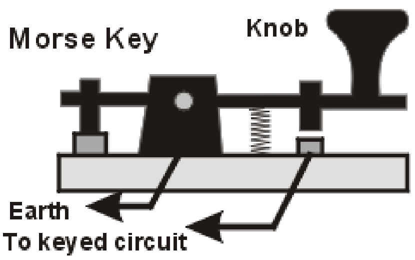


Fig. 2

The signal from a typical simple transmitter is a single-frequency signal, constant in amplitude. Such a signal carries no information. The only information is the deduction that, by its presence at a receiver, it is known that the transmitter is transmitting. Refer to Fig. 2 which represents an unmodulated carrier signal at 3.6 MHz. For our purposes at the moment, such a signal has no "bandwidth" - this matter will be covered elsewhere in these study notes.

CW signals (“continuous wave”)

A fundamental and time-honoured way to transmit information is to turn the transmitter on and off. This can be done by a Morse key (a switch). With the "*key down*", the transmitter is on, with the "*key up*" the transmitter is off. The *dits* and *dahs* (the dots and dashes) of the Morse code can be sent by careful manipulation of the key.



The term "CW" comes from the constant-amplitude signal transmitted with the key down, compared to "damped waves" - waves which changed in amplitude - as generated by spark-transmitters in the early days of radio communication and now totally obselete. The term "CW" can be considered as synonymous with Morse code transmission.

Modulation

The technique to impress information (voice, music, picture, or data) on a radio-frequency carrier wave by varying one or more characteristics of the wave in accordance with the intelligence signal is called ***modulation***. There are various forms of modulation, each designed to alter a particular characteristic of the carrier wave. For our study purposes, the most commonly altered characteristics are ***amplitude*** and ***frequency***.

Amplitude modulation

In amplitude modulation (AM), auditory or visual information is impressed on a carrier wave by varying the amplitude of the carrier to match the fluctuations in the audio or video signal being transmitted. AM is the oldest method of broadcasting radio programs. Commercial AM stations operate at frequencies between 535 and 1,605 kHz and in shortwave radio broadcasts. There is little use of conventional AM systems by radio amateurs today, the SSB and FM modes predominate.

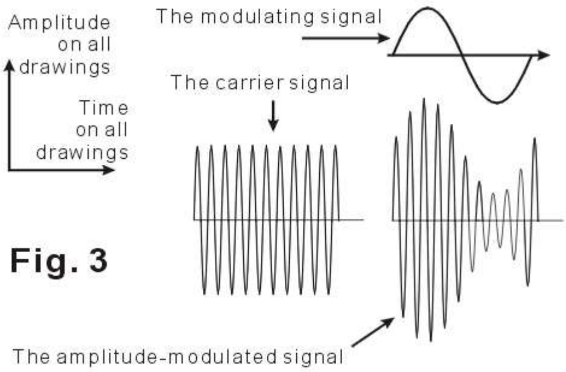


Fig. 3

When a carrier is "amplitude-modulated" by an audio signal, the audio signal will increase the amplitude of the transmitted signal during part of the audio cycle, and at other times in the audio cycle the amplitude of the transmitted signal will decrease. See Fig 3.

Amplitude modulating a carrier signal with a constant amplitude sinusoidal audio frequency tone results in a complex signal. It comprises three separate component parts: the *carrier* (in which most of the signal energy is contained) and ***two side frequencies***. See Fig. 4. (Refer to "*Mixers and Modulators*" where this is explained).

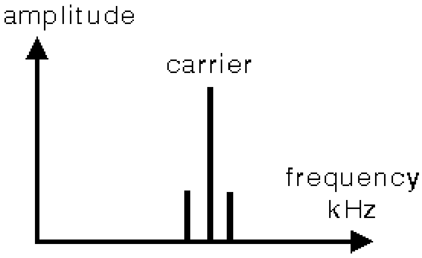


Fig. 4

So an ***amplitude-modulated signal***, with a single modulating tone, can be viewed in two different ways:

The first plot is Fig. 3. Here the plot is ***signal amplitude*** on the vertical axis and with ***time*** on the horizontal axis - an oscilloscope diagram. This is sometimes referred to as the "time domain".

The second plot is Fig. 4. The plot is still ***signal amplitude*** on the vertical axis but with ***frequency*** on horizontal axis - a Spectrum Diagram. This is sometimes referred to as the "frequency domain".

Remember that with NO audio input signal, there is then no modulating signal, so the "modulated output" reverts to being an un-modulated carrier only.

A speech-input "amplitude modulated" (AM) transmission can be shown as Fig. 5 using the diagrammatic "wedge" symbol. Speech is made up of many different audio frequencies - a band of audio frequencies. Here is a radio frequency carrier signal with two adjacent "sidebands" - the wedges shown above and below the carrier frequency - each indicated here as USB (upper sideband) and LSB (lower sideband). The energy of the AM signal is contained in these three components - the lower sideband, the carrier, and the upper sideband.

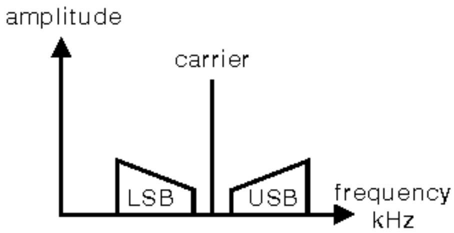


Fig. 5

It can now be seen that with no input speech to the amplitude-modulated transmitter, there are no output sidebands - but the carrier continues on unchanged.

The "bandwidth" of an AM signal can be seen to be: ***Twice** the highest modulating frequency*. So for our 300 to 3000 Hz audio modulating signal, the bandwidth will be 6 kHz.

Distortion considerations

There is a limit placed on the level of audio signal that an AM system can accept. Referring to Fig. 3 above, if the amplitude of the modulating audio signal is further increased, a point is reached at which the level of modulated signal output can no longer be a replica of the input signal. The audio-shaped "envelope" of the modulated wave exhibits peak flattening - introducing distortion. The maximum amplitude audio signal is the point at which the "envelope" shapes meet at the zero-output axis. This level is given the expression "100% modulation".

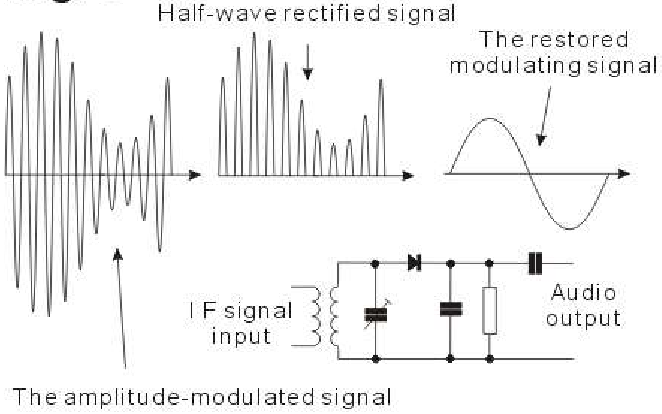
Power considerations

It is important to note the energy distribution in the carrier and the two side frequencies of the resulting AM signal. At the 100% modulation level, the amplitude of the two side frequencies can add together to equal the carrier in amplitude and either add to or subtract from the carrier signal. If the carrier is transmitting 100 watt, and if the amplitude of each single side-frequency is half that of the carrier (full modulation), then the power in the upper side-frequency and the power in the lower side-frequency will each be one-quarter of the carrier power.

The power distribution at full modulation then becomes 100 watt in the carrier, 25 watt in the upper side-frequency and 25 watt in the lower side-frequency. The total radiated power is 150 watt, of which only 50 watt - or 33% - is from the modulating "intelligence". With no modulation, the output power is the unmodulated carrier alone - 100 watt. Modulation changes the output between 100 and 150 watt, from no modulation to full modulation.

So, depending on the modulation level, more than two-thirds of the radiated energy from an amplitude-modulated transmitter is carrier power - which does not contribute to the intelligence of this system.

Fig. 6



AM reception

An AM signal can be successfully demodulated at the receiver in several ways but the easiest is to use a simple diode rectifier followed by a filter smoothing circuit. Refer to Fig. 6.

Single-Sideband (SSB)

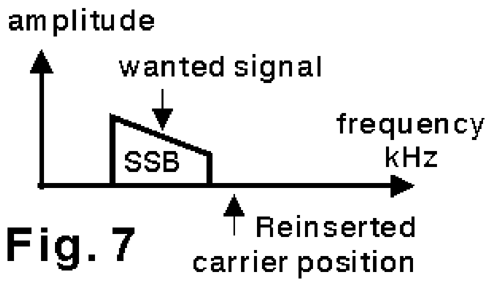


Fig. 7

In a SSB transmission, only one sideband is radiated - both the carrier and the other sideband (of AM) are suppressed. So, with SSB, with no input speech, no signal at all is transmitted! With no carrier signal at all being transmitted, all the radiated energy is related to the input modulating signal. The total transmitter output is useful!

You will now recognise that SSB transmissions are a particular category or variant of "amplitude-modulated" transmissions!

The convention generally followed by radio amateurs is that on amateur bands above 10 MHz the Upper Sideband will be used and on bands below 10 MHz the lower sideband will be used.

So on the 80m band, it is customary for amateur stations to use the lower sideband for a SSB transmission. Amateurs use the (suppressed) carrier frequency when referring to the frequency of a SSB signal. So the Fig. 7 applies. The position for the "re-inserted carrier" (your receiver does this), needed as the reference to restore the signal during demodulation in your receiver, is shown in Fig. 7.

Note that the LSB signal appears "inverted". The 300 Hz component of the speech is now the higher frequency component in the transmitted signal. The 3000 Hz component is the lower frequency component.

The "bandwidth" of a SSB signal is the same as that of the modulating signal. For our speech band 300 to 3000 kHz, the bandwidth is 2.7 kHz. Compare that with the equivalent for the AM signal to see the spectrum-conserving value of SSB - just one of its advantages. Remember too that all the radiated energy from a SSB transmitter is useful energy (there is no power-consuming carrier).

Reception of SSB signals

A local carrier is re-inserted at the receiver and is used as the reference for the demodulation process. You can resolve an SSB signal by carefully adjusting your SSB receiver. This inserted carrier can be the receiver's beat frequency oscillator (BFO). In effect, the BFO "beats" with the incoming side-frequencies to produce the restored audio frequencies. You can hear the full 300 to 3000 Hz range of the transmitted audio in the speaker.

A receiver without a BFO cannot resolve SSB signals. So a receiver fitted with a BFO for reception of CW signals can receive both CW and SSB signals. AM signals can also be received on this receiver when the BFO is switched off - the BFO then being unnecessary.

Sometimes a receiver is fitted with a mixer to demodulate SSB signals. See another paper "*Mixers and Modulators*" for the ***product detector***.

The oscillator in the receiver which provides the re-inserted carrier for SSB reception is sometimes called the "***carrier insertion oscillator***" (CIO). This is especially so if a product detector is used and the receiver is specifically designed for SSB reception. For most amateur radio purposes, receivers are designed for CW and for SSB reception and the terms BFO and CIO are interchangeable.

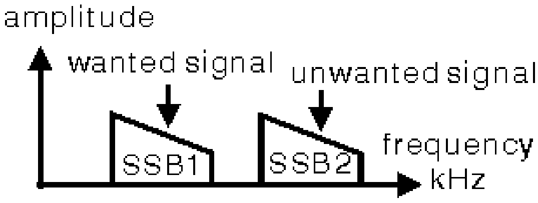


Fig. 8

Depending on the characteristics of the filter in the receiver, at times you may also hear an interfering signal. If there are two quite separate but adjacent SSB signals - shown as SSB1 and SSB2 in Fig. 8, and you are listening to the lower frequency one (SSB1), you may hear the higher frequency one as 'inverted speech'. The 3000 Hz component of that higher-frequency SSB signal will be heard by you as a low-pitch audio signal and its 300 Hz component as a high pitch! Fortunately this interference is almost indecipherable by the human ear. Your ear will tend to discard it as noise and will receive and listen to the 'natural-sounding' wanted signal. Of course this ear-discrimination characteristic also depends upon the relative levels of the two signals.

Frequency modulation

In ***frequency modulation*** (FM), unlike AM, the amplitude of the carrier is kept constant, but its frequency is altered in accordance with variations in the audio signal being sent. See Fig. 9. Note how "compression" and "stretching" of the modulated signal is shown in the diagram of the modulated signal - indicating increase and decrease of the carrier signal frequency.

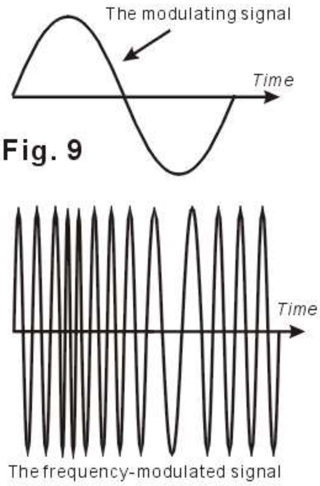


Fig. 9

The frequency of the frequency-modulated signal ***deviates*** up and down in frequency. The extent of the frequency sweep is called the ***deviation*** and it depends upon the ***loudness*** (i.e. *amplitude*) of the modulating signal. The **rate** at which deviations are made depends on the ***frequency*** *of the modulating signal*.

The deviation is usually given the symbol δf ("delta f").

FM is less susceptible than AM to certain kinds of interference, such as random electrical noise from machinery and other related sources. These noise-producing signals affect the amplitude of a radio wave but not its frequency, so an FM signal remains virtually unchanged.

A frequency-modulated signal is passed through a "***limiter***" stage prior to demodulation. The limiter clips off the tops of the FM signal, removing any amplitude changes, restoring the signal to a constant-amplitude signal. In this way, noise-spikes are clipped off, unwanted interfering noise - principally appearing as amplitude changes - is reduced.

Commercial FM broadcasting stations are assigned higher frequencies than AM stations. The assigned frequencies range from 88 to 108 MHz. Amateurs use FM principally on VHF and higher bands for speech communication.

It appears from these diagrams that the amplitude of the frequency-modulated carrier signal remains unchanged. This is not so. Energy from the carrier signal is distributed across a range of frequencies adjacent to the carrier frequency in a complex system of sidebands. So the carrier itself reduces in amplitude as its energy is distributed to the adjacent side-frequencies. The spectrum diagram of a frequency-modulated signal is complex and is beyond the requirements for the amateur radio examination.

The "bandwidth" of a frequency-modulated signal is approximately = $2(\delta f + fa)$. This is an empirical formula. So the bandwidth is approximately ***twice*** *the sum of the deviation* ***plus*** *the audio modulating frequency*. You can now see why FM is generally constrained to the VHF and higher bands.

The typical deviation for an amateur hand-held FM transceiver is about 5 kHz - a transmitted signal bandwidth of about 12 kHz. This depends on how loud you talk into the microphone. Shout, and "over-deviation" can take place, with the received signal being distorted because the receiver bandwidth has been exceeded.

Reception of frequency modulated signals

A circuit known as a "***discriminator***" is used to demodulate frequency-modulated signals. It can take many forms but the general type involves a tuned circuit with a pair of diodes. As the frequency of the input signal moves up and down across the resonant frequency of the tuned circuit, a rectified output voltage varies positive and negative to provide the output audio signal. The exact details are not required for the amateur radio examination but it is recommended that you look up a typical discriminator circuit in a radio textbook.

A phase-locked loop (PLL) can be used as a demodulator for frequency-modulated signals. See another paper: "*Amplifiers and Oscillators*".

Phase modulation

The ***phase*** of a carrier wave can be varied in response to the vibrations of the sound source in phase modulation (PM). This form of modulation is a variation of FM. The two processes are closely related because phase cannot be changed without also varying frequency, and vice versa. Also, the rate at which the phase of a carrier changes is directly proportional to the frequency of the audio signal. For the purposes of the amateur radio examination, PM can be ignored!

Mixers and Modulators

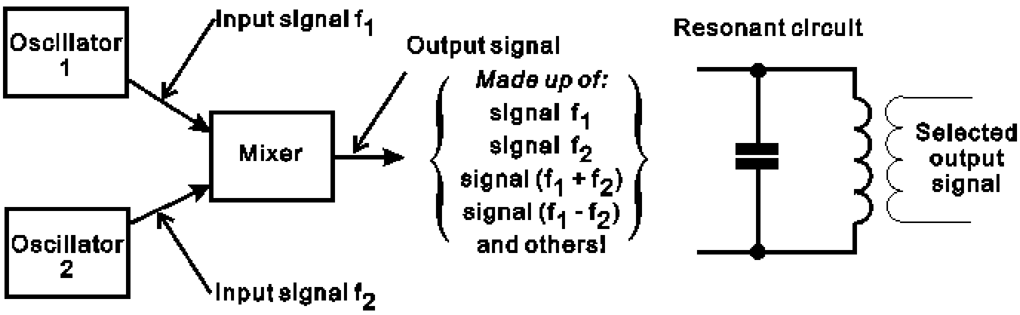
Summary

Mixers (sometimes known as frequency converters), modulators, balanced modulators and other circuit blocks are considered below. Each works on the same basic principles.

How a Mixer works

A mixer circuit normally has two inputs - from two separate signal sources. In the diagram below, the sources are two oscillators. Each oscillator is a generator producing a sinewave output, one at frequency f_1 and the other at frequency f_2. We will use numerical examples later.

The mixer multiplies the signals together. You don't need to know the details! Just remember that the output comprises a complex mixture of separate sinewaves at many different frequencies! The major output frequencies are shown on the diagram.



The main point to note is that the output comprises the two separate input frequencies f_1 and f_2 ***and*** their sum ($f_1 + f_2$), ***and*** their difference, ($f_1 - f_2$). In practice, there are other component signals too - but we can ignore those.

A filter - which can be any one of various sorts - selects the required output from the mixer. In this diagram, a simple parallel tuned circuit is shown. The output will normally be tuned to the **SUM**, ($f_1 + f_2$), or tuned to the **DIFFERENCE**, ($f_1 - f_2$), signal as required.

[For the mathematicians among us, refreshment of school trigonometry can *illustrate* what happens. Note this multiplication:

$$2 \sin A \cos B = \sin (A + B) + \sin (A - B)$$ **]**

Substituting numerical values and using typical examples for the two input frequencies in the diagram can illustrate the effect:

Consider Oscillator 1 to generate a 9 MHz signal and Oscillator 2 to generate a 5 MHz signal. The output from a mixer will contain these two signals, plus their sum, 14 MHz, and the difference, 4 MHz. The mixer output tuned circuit could be tuned to 14 MHz if that output was required, or tuned to 4 MHz, should that output be required.

The output from a mixer contains many more combinations of frequencies - generated from the harmonics of the input signals mixing with the component signals. For purposes of this amateur radio examination these can be ignored.

An alternative name for a mixer is "frequency converter".

What makes a mixer?

Almost any electronic device, diode, transistor, valve, can be used as a mixer. A "square-law" characteristic device is preferred - to minimise unwanted outputs. Refer to a radio text-book for circuits using a single diode, several diodes, transistors - of all kinds - and valves. You need to know the ***principles***, not the details!

The principle is: In a mixer stage, the output contains the SUM and the DIFFERENCE of the input signal frequencies.

Modulators

A modulator ***to produce an amplitude modulated signal*** is generally nothing more than a mixer. In the following example, the radio frequency "carrier signal" (shown as f_c) forms one input, and a "band" of audio frequencies (the incoming speech - shown as f_a), is the other input. (See another paper: *"Signals".*) The audio signal f_a does not appear in the output because of the filter action of the modulator output circuits.

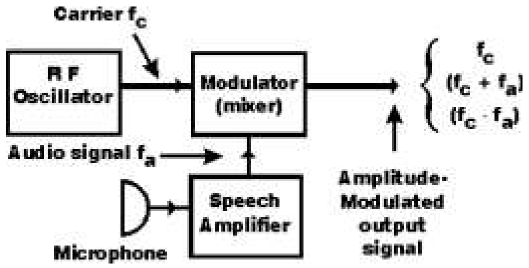
So the output from an amplitude modulator is a band of frequencies above and below the carrier frequency plus the carrier frequency itself.

The signal f_c is known as the "carrier" frequency.

The signal at $(f_c + f_a)$ is the "upper side frequency".

The signal at $(f_c - f_a)$ is the "lower side frequency". (See another paper: *"Signals".*)

To get the feel of the modulation principle, try this numerical example:

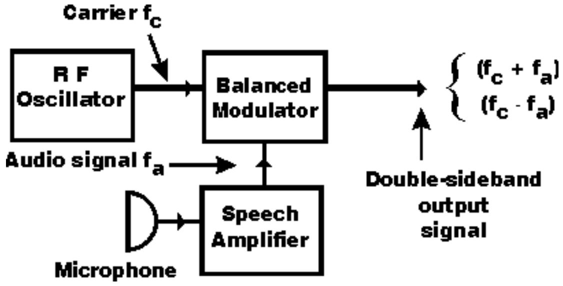


A signal at 3.60 MHz is amplitude-modulated with a 1 kHz tone. What are the output frequencies from this modulator? (Answers at the bottom of the next page!).

The "*Balanced Modulator*"

Using clever circuitry, it is possible to arrange a modulator in which one of the input signals does not appear in the output. Sometimes both of the input signals may be "balanced out" ("suppressed"), so that only the products of the modulation process will appear in the output.

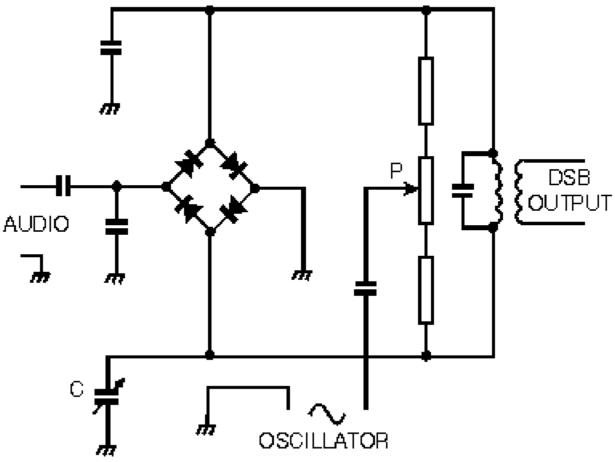
For example, in the modulator example given above, we saw that the output comprised the carrier frequency f_c, the sum, $(f_c + f_a)$, and the difference, $(f_c - f_a)$.



With a ***balanced modulator***, only the sum $(f_c + f_a)$, and the difference $(f_c - f_a)$, components appear at the output. The carrier signal f_c has been cleverly cancelled and does not appear at the output.

So the output from a balanced modulator comprises two side frequencies only - at $(f_c + f_a)$ and at $(f_c - f_a)$. The "carrier" at f_c has been removed. (See another paper: *"Signals".*)

Please refer to a radio textbook to see examples of the symmetrical circuitry of balanced modulators. This diagram is just one example:



This modulator use a ring of diodes (a "ring modulator").

Note the symmetrical form of the circuit. The oscillator is fed to a centre-tap point across a tuned circuit.

The pre-set controls C (a trimmer capacitor), and P (a potentiometer), are used to "balance out" the carrier (the oscillator signal) appearing at the output.

The output signal is a double-sideband signal - i.e. upper sideband and lower sideband with no carrier. The carrier (oscillator signal) has been "suppressed".

The "Product Detector"

This device is just another mixer - used for demodulating a signal in a receiver. The term "product" refers to the multiplication of the two input signals - with sum and difference outputs.

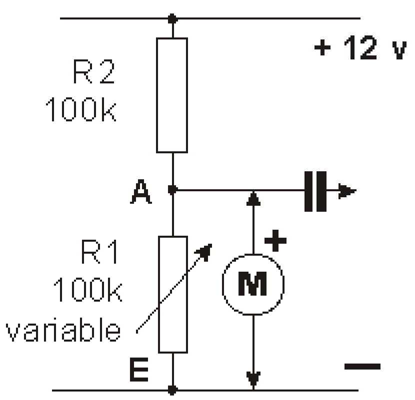
[*Answer to the numerical question posed above (Amplitude Modulation):*

The carrier is at 3600.0 kHz, the Upper Side-frequency at 3601.0 kHz, and the Lower Side-frequency at 3599.0 kHz. **]**

Amplification, Oscillators, Feedback

How does an amplifier work?

Consider this diagram. 12v dc is applied across two resistors R1 and R2 in series.



Point A will therefore be at +6v with respect to the negative rail.

The meter will read + 6v.

The lower resistor R1 is variable.

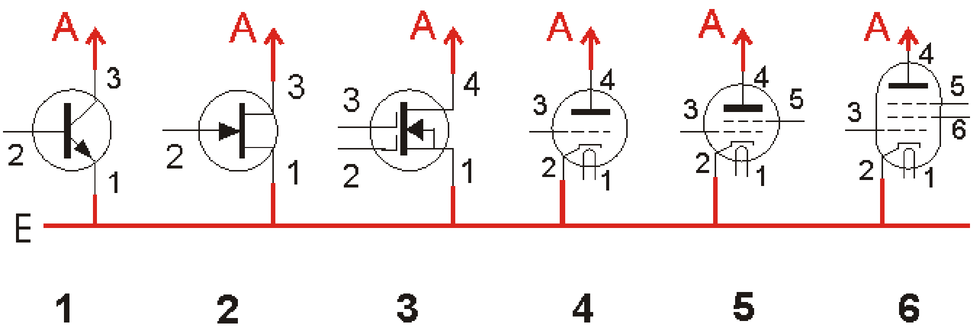
If we increase the value of R1 to 120k, we can calculate the voltage at point A.

If the value of R1 is reduced to 80k, we can also calculate the voltage at point A.

So if the value of R1 is varied, the reading on the meter will decrease or will increase.

Those variations, (in effect an alternating signal), will be passed via the coupling capacitor to the next stage - shown by the arrow to the right.

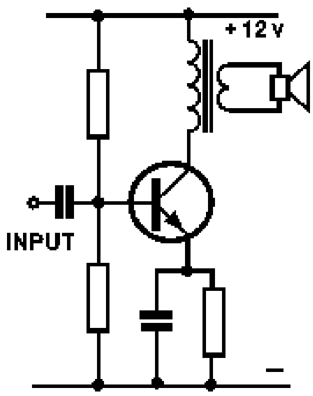
We can replace one variable resistor with another. Consider R1 to now be replaced with any one of the devices shown in this following diagram. Each can act as a variable resistor:



The connections to these devices to replace R1 are shown. (The thermionic devices will require more than a +12v supply - but the principles still apply.)

Other connections must be made to the other electrodes of each device to "bias" it for correct operation so that:

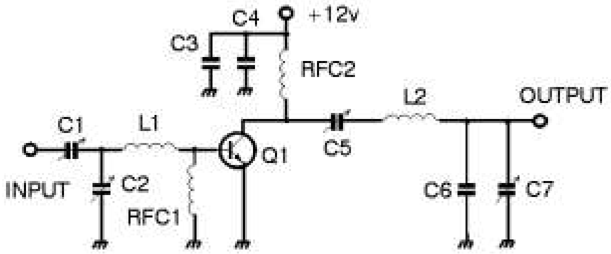
- the input signal can vary the bias which alters the internal resistance of the device, which: in turn
- varies the voltage at point A,
- which is passed on through the coupling capacitor to the next stage for further processing.



The "upper" resistor in the above diagram, R2, is known as the "load". This can take other forms as this diagram (right) shows.
Here the "load" is an audio transformer with a loudspeaker connected to its secondary.

The two resistors connected to the base of this transistor with the resistor in the emitter, form the biasing arrangements. These components set the level of the current flowing through the primary of the transformer - the "collector current".
An input audio signal is fed via a coupling capacitor to the base of the transistor. This varies the "base current" which in turn varies the effective "resistance" of the transistor and hence the collector current.

Only small changes in the base current are needed to make much larger changes in the collector current - amplification!



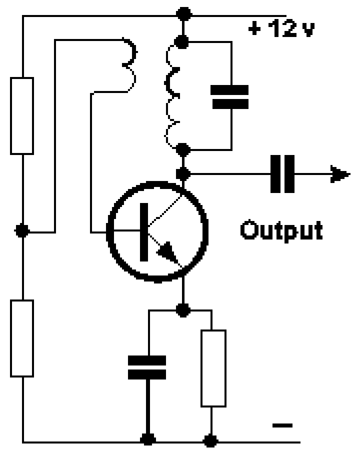
This circuit (left) is a typical transmitter radio frequency amplifier. Here the "load" comprises all the components connected to the collector of the transistor Q1 - C5, L2, etc. and the antenna or whatever is connected to the output. The RF choke RFC2 feeds 12v DC to the device and prevents the RF from getting into the power supply leads. The input signal provides self-bias to the transistor.

Positive Feedback - and Oscillators

If you take part of the output from an amplifier and feed it back to the input, provided some special conditions are met, the device will "oscillate". This means that it generates a signal. The frequency of the signal depends on the circuit component values and the feedback arrangements.

The conditions for oscillation are that the level of signal fed back is at an adequate level, and that the signal is in the correct phase to sustain oscillation. This is ***positive feedback***.

This means that the signal fed back ***adds*** to the signal at the input to the amplifier.

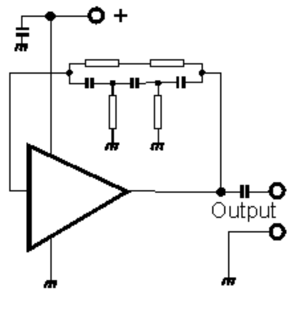


This next diagram shows a simple radio-frequency oscillator. A tuned circuit in the collector circuit sets the frequency of oscillation.

The feedback is taken by a secondary coil and inserts a signal in the base lead, changing the base-current. Provided the secondary coil is correctly polarised, the circuit will oscillate.

This next diagram shows an audio amplifier (the triangle - with "gain" in the direction of the "arrow") and a feedback network - the collection of resistors and capacitors - a bridged-tee network - connected between the output and the input.

This again is a diagrammatic illustration of an audio oscillator. There are many different feedback networks used and they can comprise a wide range of components of all types.

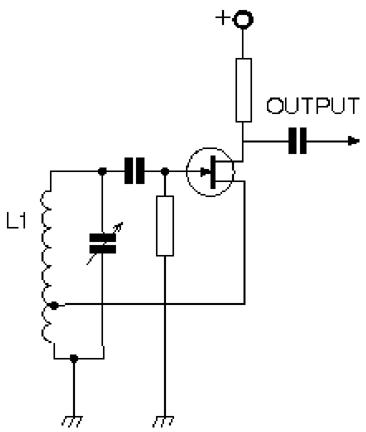


There are many different oscillator circuit types, as reference to a textbook will show!

How does it start?

In practice, when first switching on, an oscillator will usually self-start because a burst of noise or a similar transient at the input to the amplifying device is enough for it to commence oscillation.

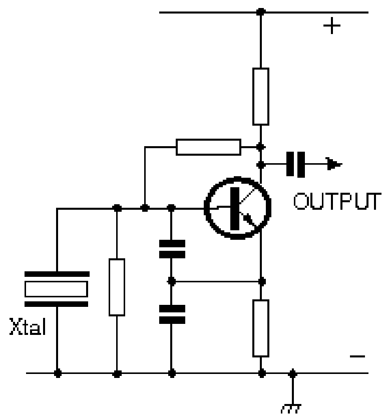
Oscillators can usually be identified because they have an output with no input shown - other than the DC supply.



This diagram (left) is also an oscillator. The bottom end of the coil L1 is common to the source and drain current path and transformer action will cause changes in the base current. This device is self-biasing.

This circuit (right) is a crystal oscillator. A quartz crystal can be regarded as a high-Q tuned circuit.

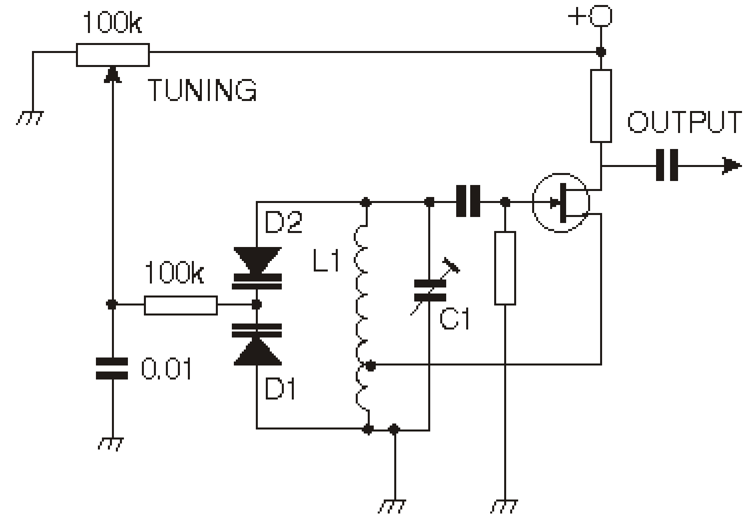
The quartz crystal is shown with two capacitors across it to provide the feedback for oscillation.



A resistor from the collector to the base and from base to earth, together with the emitter resistor, provides some DC bias (base current) for correct operation.

Compare these two diagrams!

The Voltage-Controlled Oscillator (VCO)



This circuit is the same as one shown before with some components added.

A voltage-controlled oscillator is one in which the frequency of oscillation can be varied by changing a voltage applied to it.

Diodes D1 and D2 are varicap or varactor diodes connected across the tuned circuit L1 and C1.

When these diodes are reverse-biased, the depletion region between anode and cathode becomes a dielectric whose width is dependent on the applied voltage. A change of applied voltage changes the width of the dielectric thereby changing the capacitance between anode and cathode.

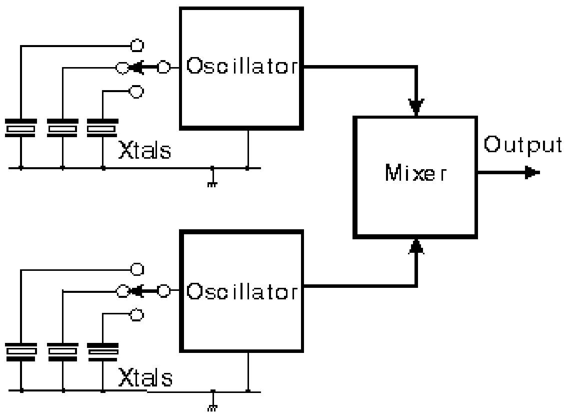
Connected as shown, changing the voltage at the wiper (moving arm) of the ***manual TUNING*** potentiometer shown will change the frequency of the oscillator. The 100k resistor at the junction of the two diodes is to prevent any RF from entering the DC line.

The Frequency Synthesiser

A saving in the number of crystals needed for switched-channel equipment can be made by using a synthesiser.

This diagram shows two oscillators each with a selection of crystals.

A mixer combines these outputs to provide other frequencies by using the sum (or difference) outputs from the mixer. (See another paper: "*Mixers and Modulators*".) A wide selection of "channels' can be provided for a transceiver by this method.



The Phase-Locked Loop

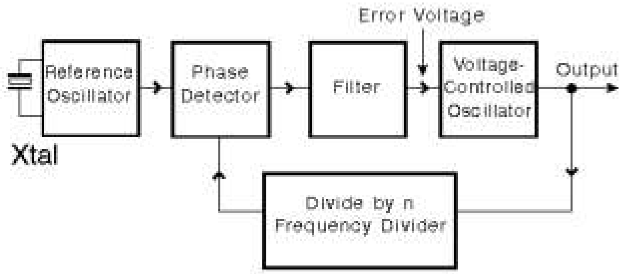
This diagram shows the principle of the phase-locked loop (PLL). It consists of a voltage-controlled oscillator which provides the output frequency. That frequency is compared to a reference oscillator using a phase detector or comparator.

A sample of output from the VCO is passed through a frequency-divider stage to the phase detector.

The phase detector supplies an error voltage to the voltage-controlled oscillator to keep it accurately on frequency.

If we want the output frequency to be the same as the reference oscillator we pass the output frequency through a divide-by-one stage to the phase detector. If the frequencies are not the same, an error voltage proportional to the difference in frequency is produced. This voltage is filtered and applied to the VCO to bring it back on frequency.

If we want a frequency 10 times the reference frequency, we tune the VCO to this frequency. The output is then passed through a divide-by-10 stage to the phase detector which operates as in the previous case.

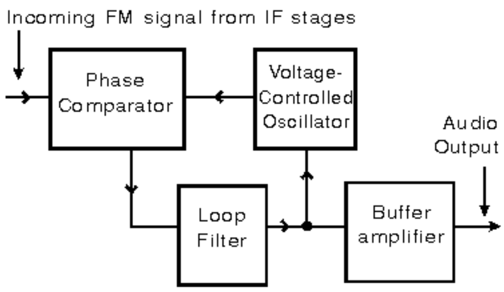


When we want a frequency 20 times the reference frequency, we divide the output by 20 and apply it to the phase detector.

Modern transceivers and other equipment use the phase-lock loop principles and can tune in 1 kHz and often smaller, steps.

The PLL as a demodulator for FM signals

PLL principles can also be used as a demodulator in an FM receiver.



The loop locks on to the input signal and the VCO will follow the instantaneous frequency of the input signal.

Variations in the input frequency are converted into variations in the loop control voltage.

The control voltage must change and it is this voltage that corresponds to the demodulated signal, the audio output. A buffer is used to isolate the output circuitry from the control loop.

Negative feedback

Negative feedback is a signal fed back to the input of an amplifier so that it opposes the input signal - the opposite of positive feedback. It does have great advantages in some applications, in particular in hi-fi audio amplifiers. For amateur radio purposes, there is one useful application - the emitter-follower circuit (or the cathode-follower circuit).

SELF-TEST record sheet: (*Use* BOOK 3)

Name: ___________________________________

Date:										
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TOTAL correct										
Pass?										

Procedure:

Enter today's date in one of the top boxes.

Use BOOK 3 and answer (say) Question 5 in all clusters, enter your choice (a, b, c, or d) in each cluster row.

Use BOOK 5 for the answers and mark your own test.

Total your 'correct' score.

40 correct answers from 60 questions are a PASS!

Repeat again later – with a different Question number.

Remember: **Read more - and try again!**

[You can print additional copies of this page – use the computer file.]