North Alabama Repeater Association

Learning about Repeaters

Rev 3.0

W4XE 12/28/04

Preface

What we are going to cover:

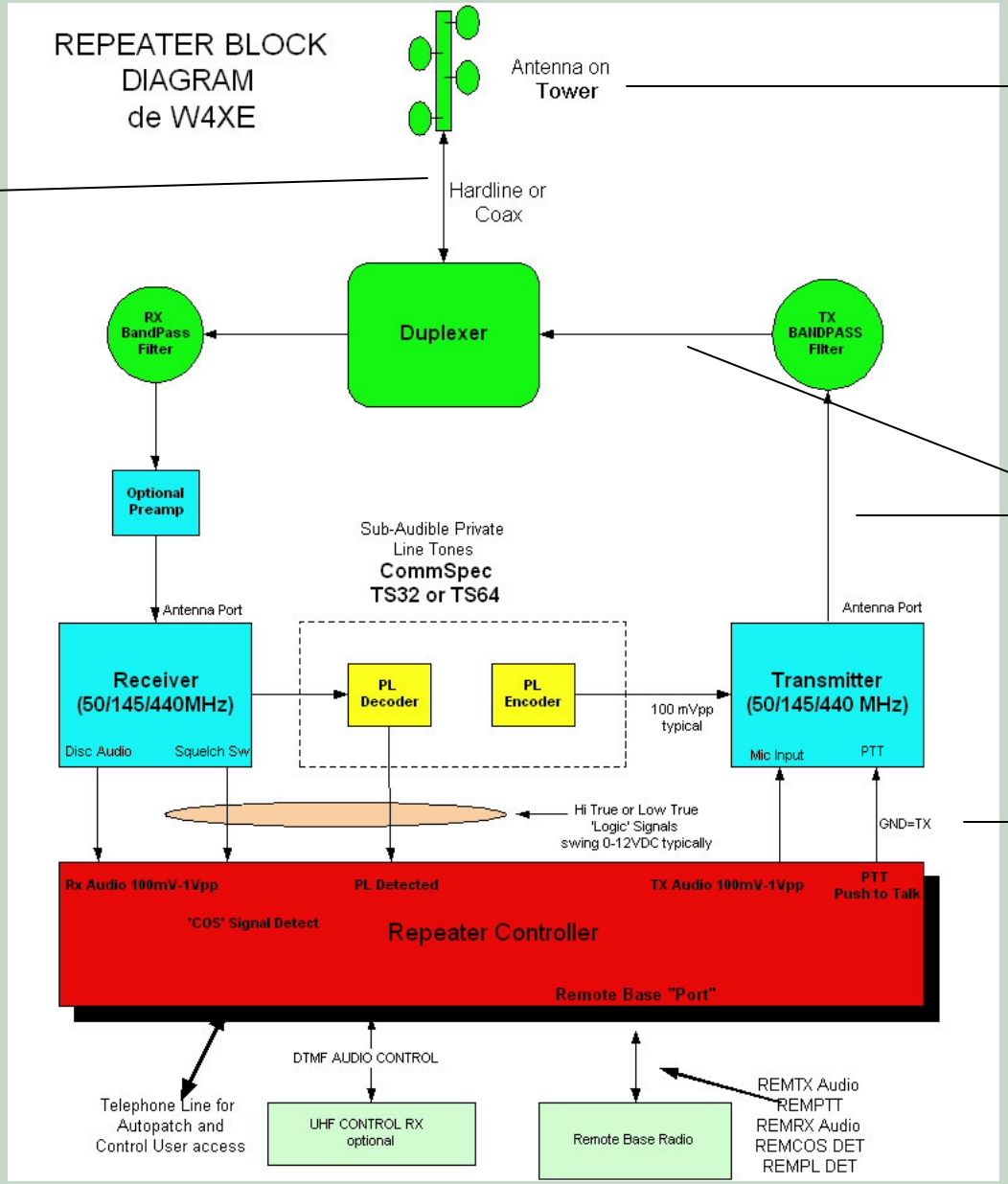
- Repeater Basics
- Terminology
- What does a ‘controller’ do?
- Components of a repeater system
- What is COS and PL?
- Typical PL encoders and decoders in use
- Nara specific repeater site information
- Conversion of GE Master 2 mobiles to backup/link usage
- A note on Remote base radios
- Other GE radios related to GE Master II

Repeater Basics

Basic components of a repeater system:

- Receiver & Transmitter (including PA)
- Controller: Microprocessor controls all repeater operation
- Duplexer: Allows RX & TX to use one antenna without interfering with each other.
- Power Supply: 12 VDC @ 30-50 Amps
- Audio, Control and RF cabling for interconnections
- PL Encoders and Decoders
- Antenna & feed-line

Andrews ½" Hardline



Commercial Quality Ant

All interconnect Coax must be Double-shielded!

Shielded Audio cables

GE MASTER II Repeater Front View

We are moving toward 100% of our repeaters using GE Master II's

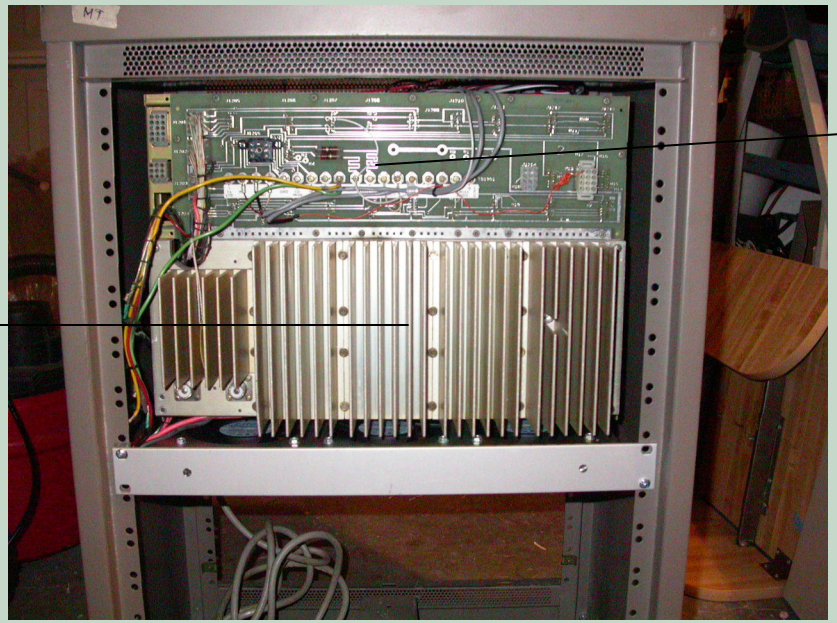
Fold Down RF drawer

12 VDC 30 Amp Power Supply

Card Rack

PA

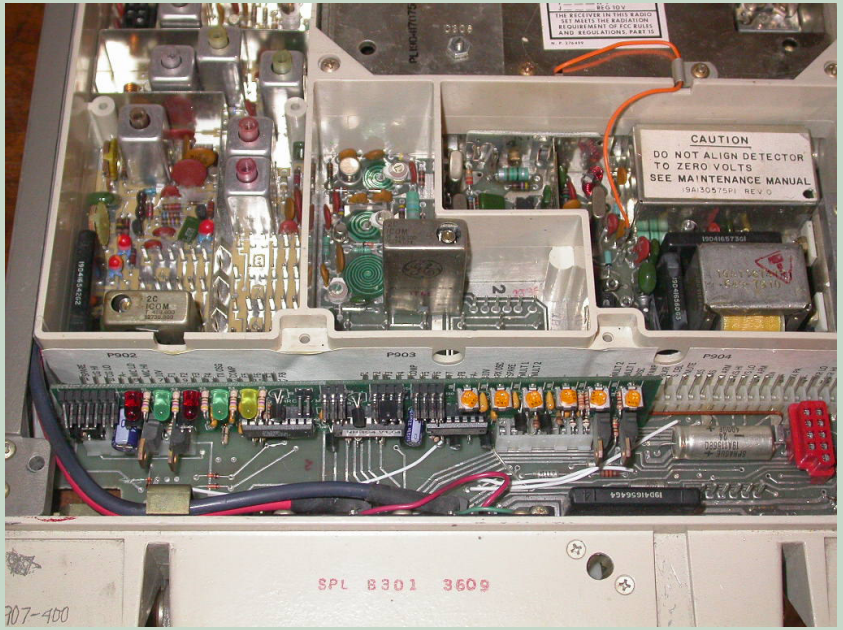
GE Master II rear view



Rear of Card Rack.
Ham controller
Access points

110W PA

NHRC-4 installed in GE Master 2 UHF mobile radio



Compact drop-in controller for remote voter site or backup repeater. Mobile is modified for full duplex operation.

Terminology

- **COS**: Carrier Operated Squelch. This is a signal derived from the receiver squelch circuit. It denotes the receiver is actively picking up a user's signal.

  We use a stock GE SOR card: Squelch Operated Relay card to generate this signal for the controller.
- **TOT**: Time out Timer. This is a programmable limit on how long the transmitter is continuously keyed by a user's signal. Sometimes called a 'windbag' timer for excessive rag chewers. This prevents an open squelch receiver from keying the transmitter perpetually, thus melting down the transmitter/PA. When the courtesy beep is heard, this typically denotes the timer has reset.
- **Courtesy Beep**: This is a tone that is generated right after a user lets off of his PTT. Other users should wait until after the beep to allow others to enter a QSO. Also signals the TOT has reset.
- **TAIL**: A programmable delay to keep the transmitter up after a user stops transmitting. This is a to prevent excessive up/down keying of the repeater hardware. During the tail, the receiver audio is squelched.
- **PL**: Sub-audible access tone. A 60-250 Hz continuous tone on a users audio signal. Not used for preventing access (i.e.. a closed system). It's purpose is to exclude extraneous noise sources from bringing a repeater up. A PL decoder card is used to detect the proper tone (i.e. 100 Hz) and generate a detect signal.
- **Audio Delay**: An analog delay line is used to remove long squelch burst from being transmitted.
- **Discriminator Audio:** Audio usually taken off the high side of the volume pot. It is not squelched (muted) and not de-emphasized. Use of this audio requires later de-emphasis (with R/C combination) and muting.

Terminology

- **12 dB SINAD FM receiver sensitivity**:

  Sinad is an acronym for "Signal Noise And Distortion". The lower the number, the more sensitive your FM receiver is. It's defined as: SINAD = 20 * LOG((RMS Value of Signal, Noise and Distortion)/(RMS Value of Noise & Distortion)). It takes a special piece of test equipment called a 'Sinadder' to measure this. You inject a 1 KHz tone (with 3 KHz deviation) into the FM RF signal generator feeding the test subject RX and the 'Sinadder' produces a reading off of the receivers speaker output. For a properly tuned receiver this should be between 0.3 uV and 0.5 uV.

- **20 dB quieting sensitivity:**

  This is another unit of measure for a receiver's sensitivity. You only need an AC voltmeter and FM signal generator with adjustable output to take this reading. To measure 20 dB quieting, connect the AC voltmeter across the speaker leads. Open the squelch, with no signal applied. Adjust the volume control to get a 1 VAC reading. Now inject a no-audio carrier signal using an FM signal generator. Adjust the signal generators RF output for a reading on the voltmeter that is 0.1 VAC. 20 dB is a ration of 10:1. Read the uV setting of the signal generators output dial. This is the 20 dB quieting level.

Terminology

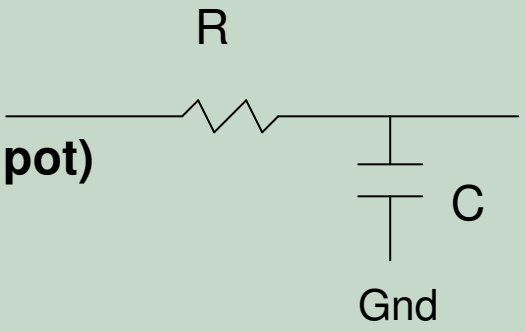
Emphasis: Most FM equipment uses a 6 db per octave pre-emphasis in the transmitter audio. The opposite happens at the receiver called de-emphasis. Emphasis in originating audio and de-emphasis in destination audio is similar to "Dolby" used in audio tape systems, which increases the highs during recording and decreases the highs during play back.The reason this is done is that the FM demodulator (discriminator, quadrature detector or whatever) has a response which rises at a 6 dB per octave slope. This is the mathematics of the design. Emphasis is used to counter this effect.

Flat Audio:

"Flat Audio" refers to a spectrally flat input to output, neither accentuating the highs or the lows. In other words, what comes in goes out. **The NARA systems uses de-emphasis of discriminator audio and the built-in pre-emphasis in our repeater transmitters audio path.** Some repeater groups use FLAT Audio along the repeater and link audio path. They never de-emphasis the audio and bypass pre-emphasis in the transmitter. This is a desirable approach, but opens up a can of worms. Circuits like the touchtone decoder and the auto-patch need to have de-emphasis components added. The transmit audio sources like auto-patch, dvr, cwid and speech synthesizer need to be pre-emphasized. Finally the transmitter has to be directly FM'd instead of using its audio circuit. When this is done, a peak deviation limiter (clipper) will also be required. Whew, a lot of hacking for flat audio….

De-emphasis Circuit

RX Discriminator
Audio (top of volume pot)



Receiver
Audio Input
Of Controller

Typical Values of R & C:

R=10 K, C=0.1 uF Fc=160 Hz
R=6.8K, C=0.068 uF, Fc=344 Hz
R=75K, C=0.01 uF, Fc= 212 Hz
R=4.7K, C=0.1 uF, Fc= 338 Hz
R=15K, C=0.22 uF, Fc= 48 Hz !!

Fcorner=1 / (2piRC)

Should keep Fc < 300 Hz

Other values:
100 ohms .75 Mf
220 ohms .34 Mf
470 ohms .16 Mf
1,000 ohms .075 Mf
2,200 ohms .034 Mf
4,700 ohms .016 Mf
10,000 ohms 7500 Pf
22,000 ohms 3400 Pf
47,000 ohms 1600 Pf
100,000 ohms 750 Pf
220,000 ohms 340 Pf
470,000 ohms 160 Pf

Some repeater controllers already have de-emphasis built-in. We use the GE M2 audio board which provides this function. However, remote base radio audio will usually need to be de-emphasized.

Notes on COS and PL

- Typically a commercial or ham radio unit does not conveniently generate these signals for a ham controller. A commercial radio will either generate COS only or PL only but not both. In a ham repeater we typically want to detect both conditions. This allows us to remotely command the repeater to PL only access or open it up to carrier access (no PL). GE calls the squelch signal CAS and the PL signal RAS.
- The signals we pick off of the receiver for COS and PL typically need to be buffered, else we'll load down the RX circuits excessively. Also, sometimes we need to invert these signals to satisfy the controller input requirements. They will demand either active HI or active LOW. For COS active high, with no signal, the COS is 0 VDC and with a signal the COS is typically 5-12 VDC. For COS active low, with no signal, the COS is 5-12 VDC and with a signal the COS is close to 0 VDC. To invert the detection signals (COS & PL), we use a simple NPN 2N3904 inverter circuit. To just buffer it a PNP 2N3906 buffer circuit is used.

What is a controller?

Basic Functions:

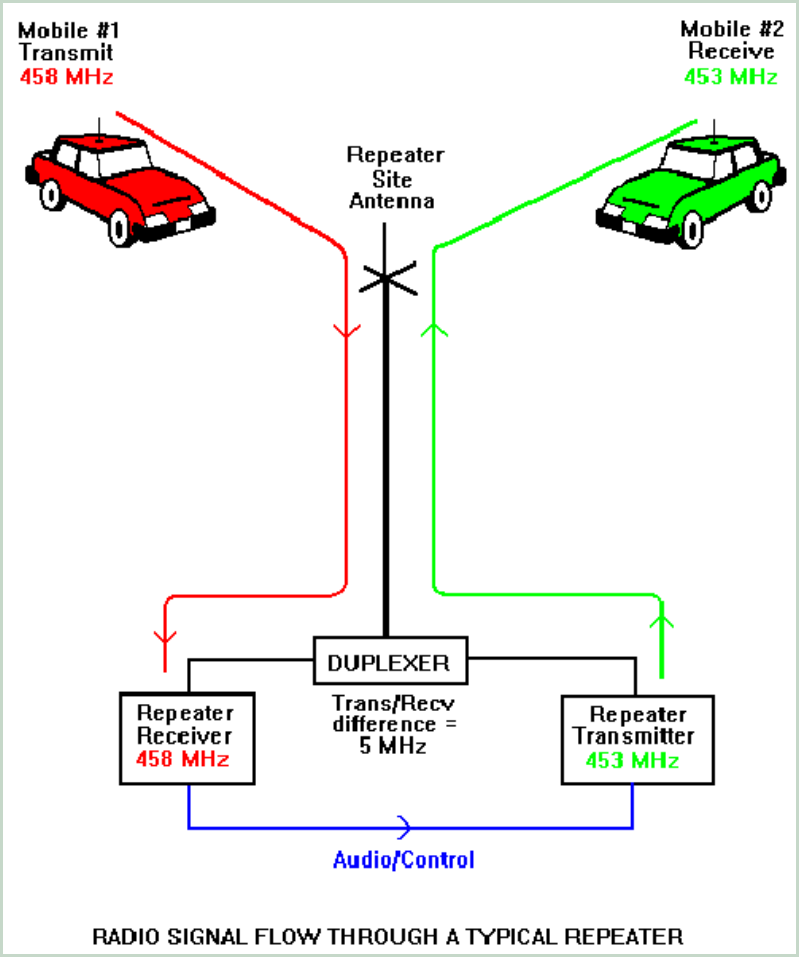
- Monitor receiver and when active retransmit audio to the transmitter.
- Provide a TOT Time out Timer function
- Provide a TAIL timer: The short time the repeater is up after a signal goes away.
- Provide CW or Voice ID of the system (every 10 minutes)

Auxiliary Functions:

- Provide ‘Auto patch’. Access to telephone lines.
- Provide interface to remote base or link radio's)
- Provide Voice (DVR) recordings for club announcements
- If required, monitor for a PL sub audible access tone
- Provide for DTMF remote control of the system functions
- Shape the receiver audio signal:
  - De-emphasis
  - Mute audio during silent periods of no signal
  - Remove user’s PL tone

Note: Currently NARA uses several types of controllers in our system. Each is tailored to system requirements.

Duplexers



RADIO SIGNAL FLOW THROUGH A TYPICAL REPEATER

A duplexer allows us to simultaneously receive and transmit off of one antenna without the transmitter interfering with the receiver signal.

Graphic by
The Jack Daniel Company
TX RX Systems Representative
California, Arizona, Nevada

Duplexer Connections

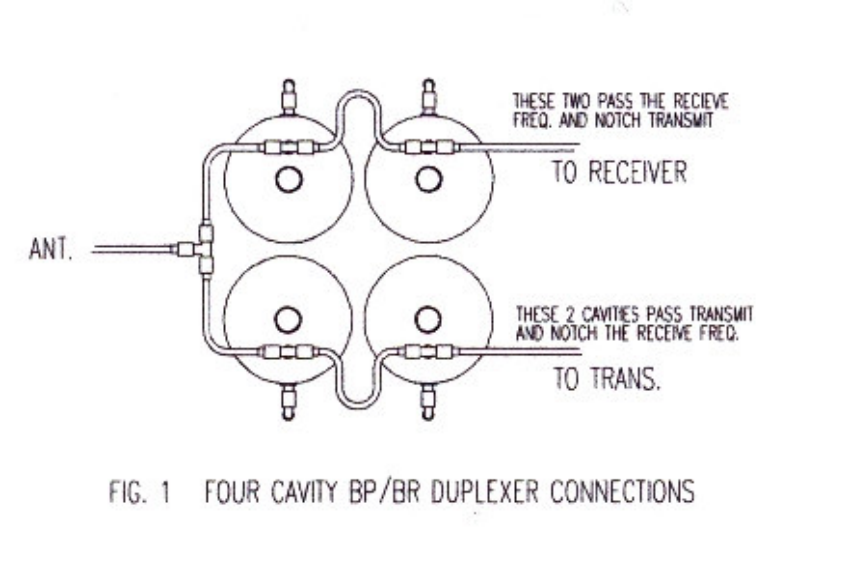


FIG. 1 FOUR CAVITY BP/BR DUPLEXER CONNECTIONS

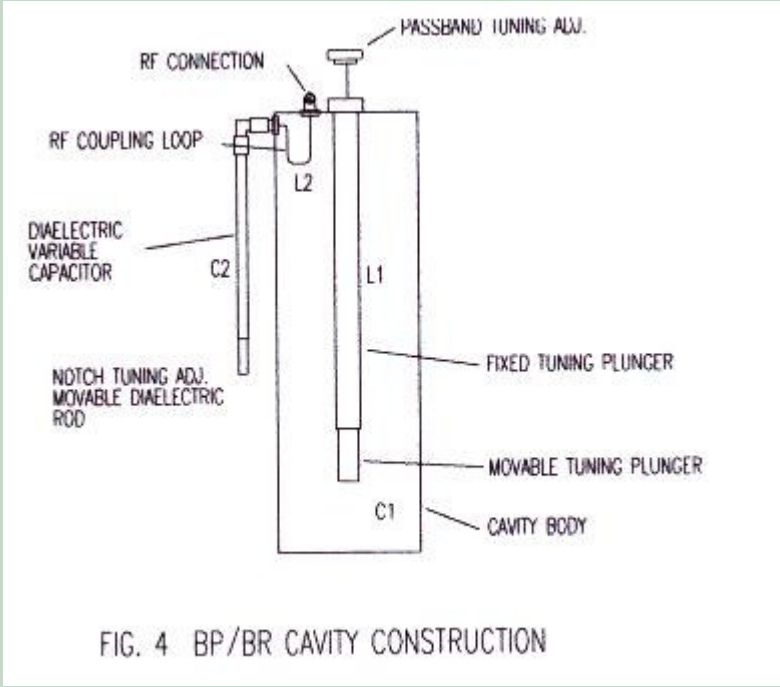


FIG. 4 BP/BR CAVITY CONSTRUCTION

Graphics by
SEITS: Southeast Iowa Technical Society

Duplexers are precision machined mechanical assemblies. Quality units are necessary for high performance repeaters.

Band pass, Notch and BPBR

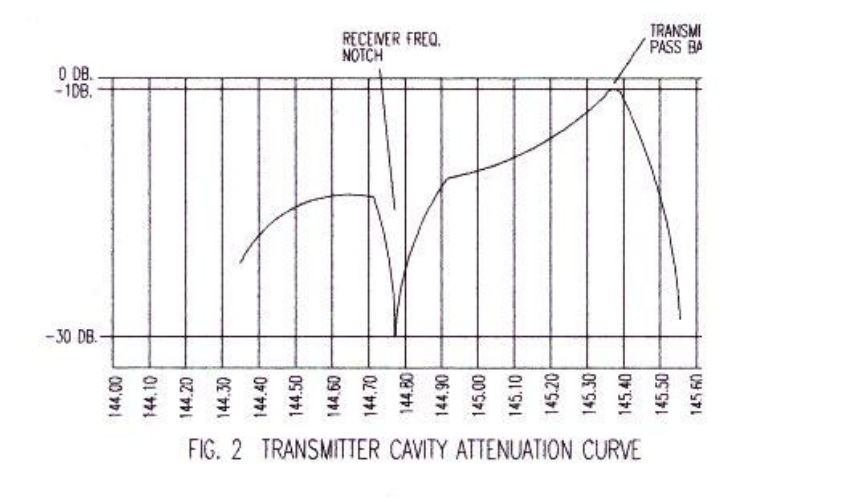
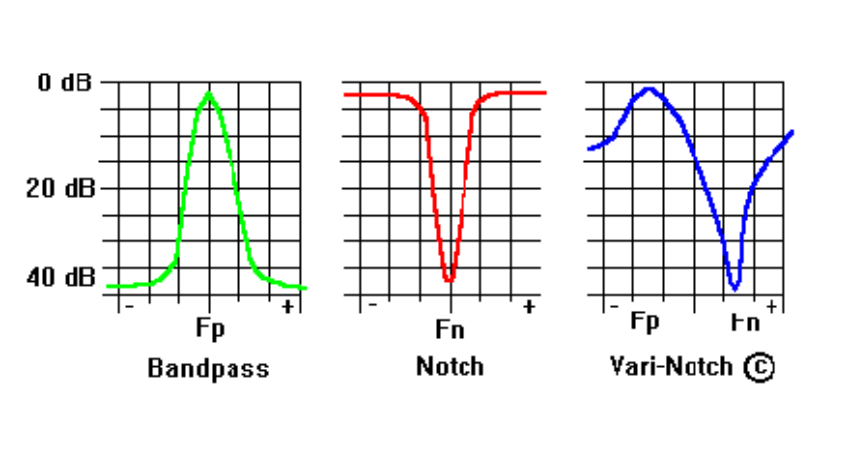


FIG. 2 TRANSMITTER CAVITY ATTENUATION CURVE

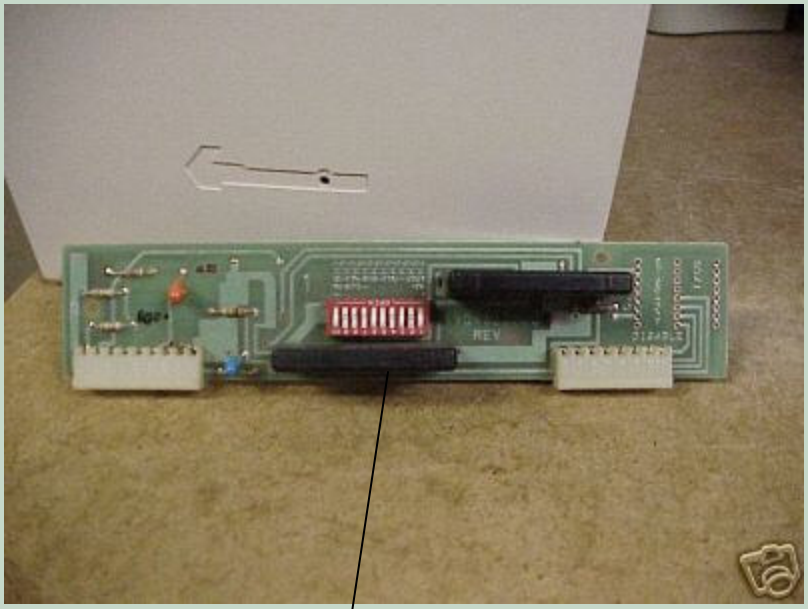


BPBR: Band-Pass Band-Reject or 'Vari-Notch'
This is the most desirable duplexer for repeaters

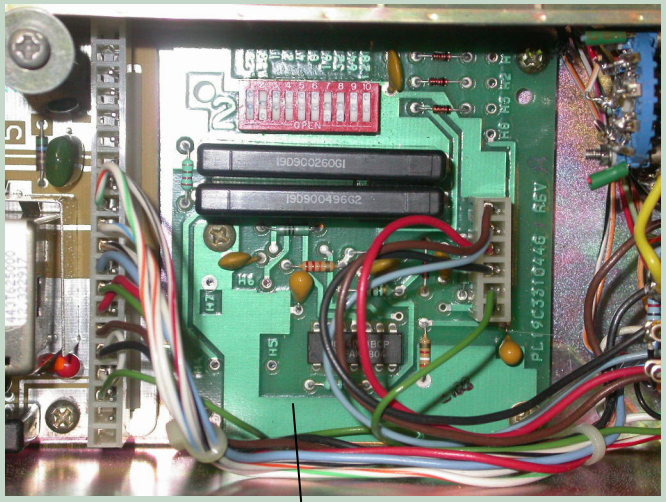
Graphics by
SEITS: Southeast Iowa Technical Society
and
The Jack Daniel Company
TX RX Systems Representative
California, Arizona, Nevada

The tuning of a duplexer can be roughly accomplished with two handhelds. However, it is best done with the proper test equipment: a tracking signal generator and Spectrum analyzer combination.

Private Line Encoders/Decoders



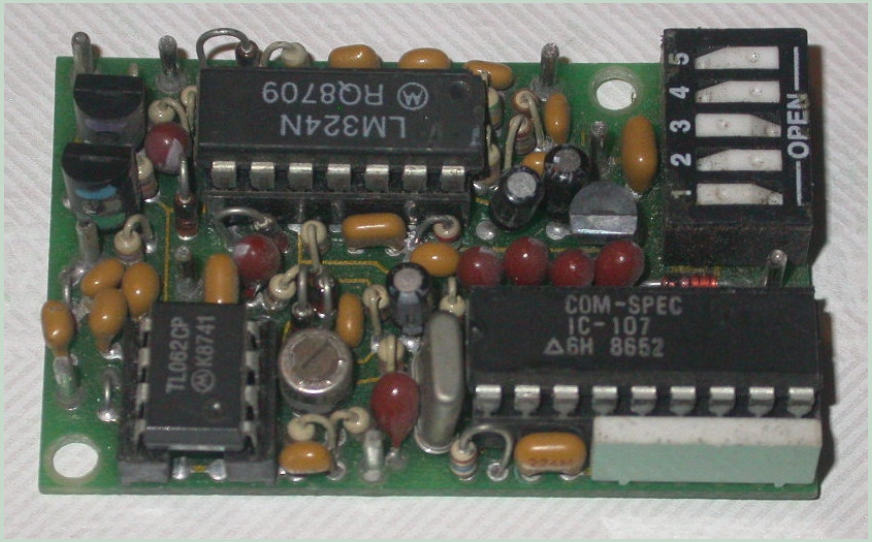
GE stock digital PL card.
Simplex encode or Simplex decode.
Will not do full duplex (encode and
Decode simultaneously).



GE stock PL encode only
Deck. Used in base/repeaters.

GE and aftermarket PL encoder/decoder decks are used to provide PL Capability to our NARA repeaters.

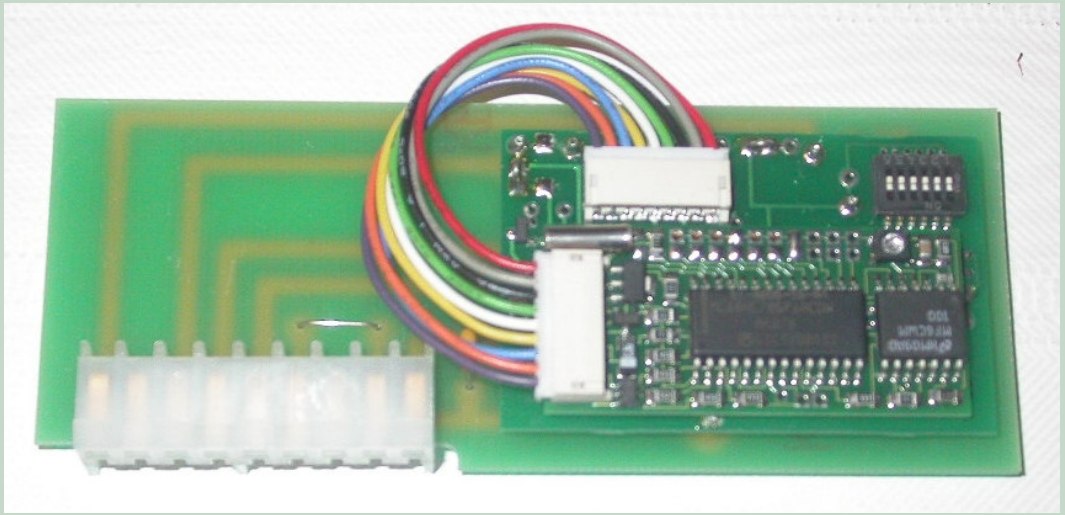
Communications specialist TS-32



Full duplex PL Encode (dip sw sets pl tone) and PL decode
Audio High pass filter (used to remove pl from Users signal)
The TS-32 was discontinued but is still very popular.

Communications specialist TS-64

We use a special version that plugs directly into the GE: TS-64MSTII



New Surface Mount packaging
PL Encode (dip sw sets pl tone) & PL decode (same tone as encode)
PL High pass filter (use to remove pl from Users signal)

New feature is it is capable of ‘Reverse Burst’. Reverse Burst is usually not seen on ham radio models. It provides removal of the long Squelch burst after a user signal goes away. Hams use audio delay in the controller to provide this feature.

Repeater System Interconnection

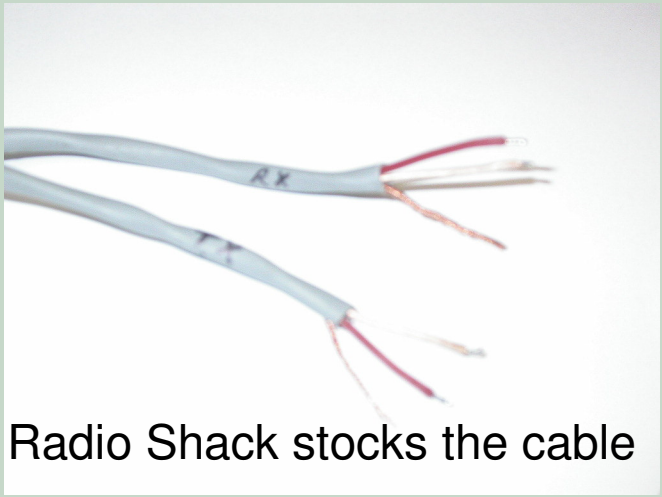
It is important to connect the various sub-systems correctly for proper operation. The audio lines should use shielded wires. The RF connections should use double shielded coax (RG-142). NARA uses a standard for audio lines.
We use 3 conductor audio cables (Radio shack Catalog #: 278-513).
The outer shield is ground. The two internal wires carry audio and control. The RED (or Blue) wire is always the control line. The Clear (or White) carries audio.

Audio Cable RX (The gray cable is labeled 'RX' on both ends)
Shield: Ground
Clear or White: Receiver Audio
Red or Blue: COS detect

Audio Cable TX (The gray cable is labeled 'TX' on both ends)
Shield: Ground
Clear or White: Transmitter Audio
Red or Blue: Push to Talk PTT

This leaves just a single extra wire needed for carrying PL detect from the repeater to the Controller.

Standard Nara Controller Cables



Radio Shack stocks the cable

DB-9
Female on
Controller Side

DB-9
Male on Radio
Side

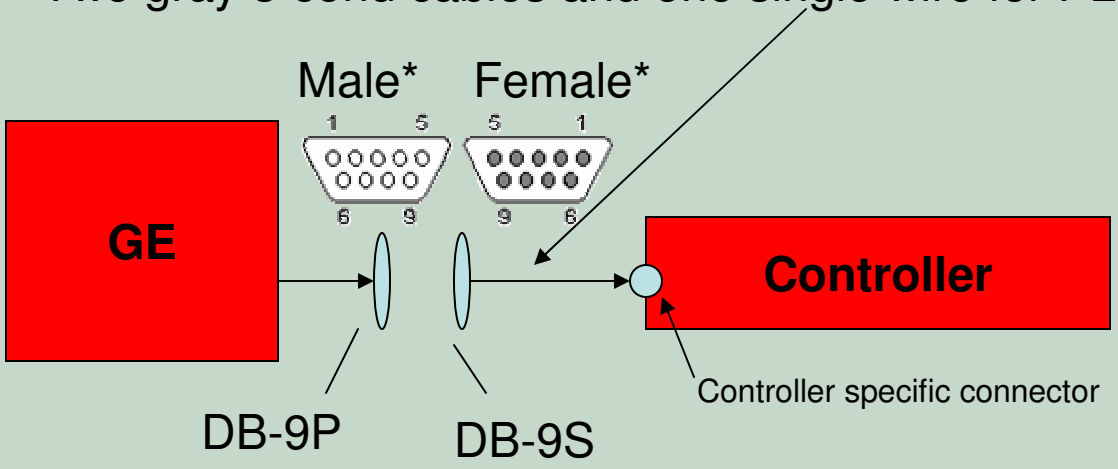
A receiver and transmitter cable pair ready for wiring to a connector. We usually identify both ends of a cable with permanent marker as RX or TX. Thus anyone can walk up, look at a cable and determine immediately what the signals are on that cable. Strip only enough Insulation away as required by the connector. Leave no excess bare wires hanging off a connector. It is also highly recommended to use heat shrink tubing on all individual wires that are soldered to a connector. If you don't, the wires could short circuit, making for an unreliable repeater.

NARA standard connector

We use a standard for connecting the repeater to a controller. The NHRC-2 DB-9 wiring pin out is used. A cable is made to connect the GE to a DB-9 male. Another cable is made to connect a DB-9 female to the particular controller port requirements.

This allows easy connection of a backup controller (like NHRC-2). Note: We usually use the power pins (Pin 2) to provide Controller power (+12 VDC) from the GE.

Two gray 3 cond cables and one single wire for PL.



DB9P (Male) GE MII Connector

1. GND
2. +13.6 VDC
3. PTT
4. TX AUDIO
5. RX AUDIO
6. PL Active HIGH
7. COS* Active LO
8. GND
9. GND

* Follows DB9 pin out of NHRC-2 controller

*-viewed from pin side (not solder side)

Controller connectors

RC85

J1 Power

1	**Digital GND**
2	**+12.6**
3	Battery Input
4	Analog GND

Logic J3

1	**RX COS input**
2	Link RX COS input (hi true)
3	**Cntl RX COS input**
4	**PL Logic Input (high true)**
5	Courtesy Tone Select Input
6	Ext Device Busy (DVR) input
7	Alarm Input
8	Phone line Busy input
9	Control Output 2 (CX2)
10	**Rpt TX PTT output**
11	Control Output 3 (CX3) (link PTT)
12	Control Output 1 (CX1)
13	Reset (ext switched to gnd)
14	Digital GND

Audio J4

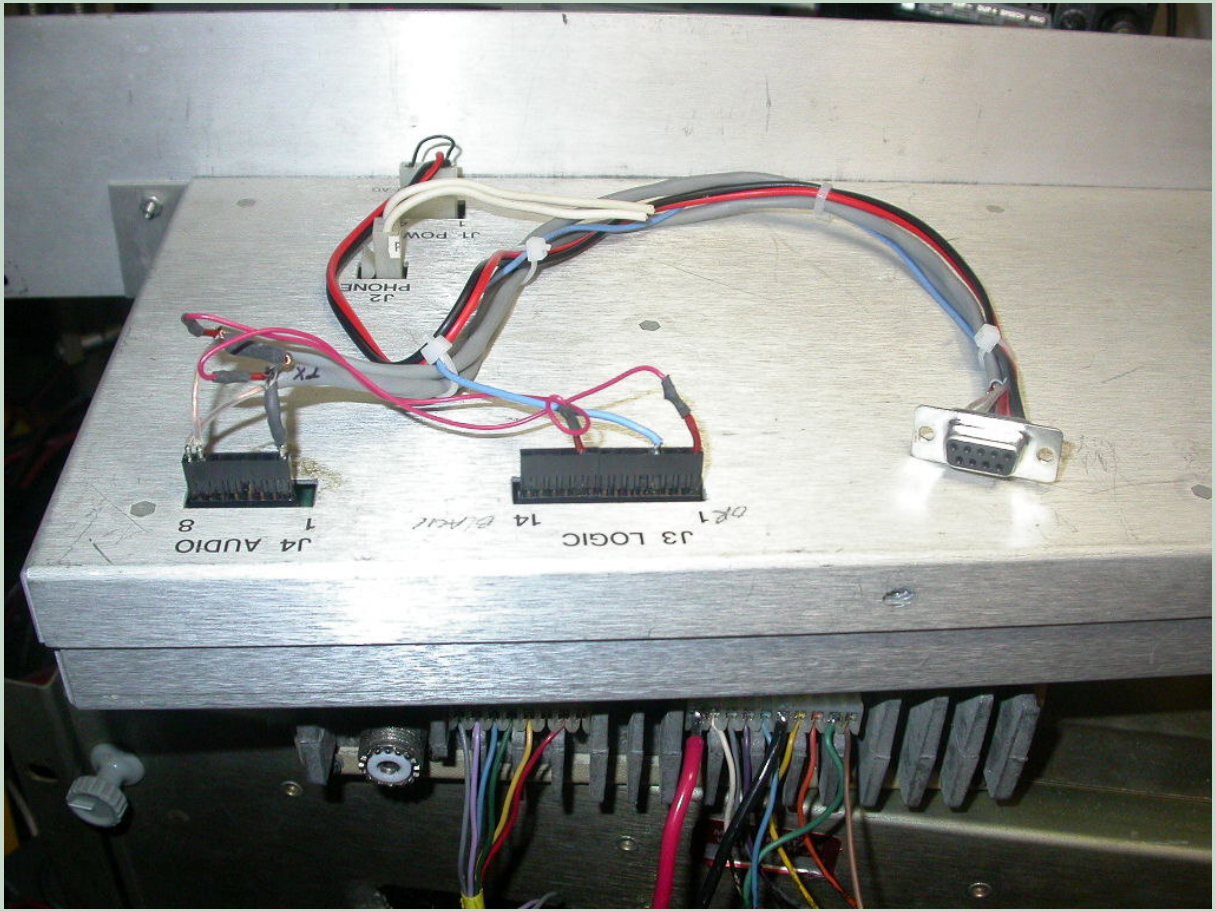
1	Analog GND
2	Direct TX Mixer Audio Input
3	Direct Phone Mixer Audio Input
4	S Meter Analog In
5	Control RX audio in
6	Link/spare Audio in
7	**Rptr RX audio input**
8	**Rptr TX audio output**

CAT-1000

J4 (DB25-F)	J1 (DB25-M)
1. BUSY #2 (DVR)	1. INPUT #1
2. BUSY #1 (TELEPHONE)	2. TTL OUTPUT
3. CTCSS #2	3. TTL INPUT
4. CTCSS #1	4. RS-232 INPUT
5. COR #2	5. OUTPUT #1
6. COR #1	6. OUTPUT #2
7. SERIAL DATA	7. OUTPUT #3
8. SERIAL CLOCK	8. OUTPUT #4
9. PTT #2	9. OUTPUT #5
10. PTT #1	10. INPUT #2
11. TX AUDIO #1	11. INPUT #3
12. RX AUDIO #2	12. INPUT #4
13. RX AUDIO #1	13. INPUT #5
14. SERIAL STROBE #1	14. GROUND
15. SERIAL STROBE #2	15. GROUND
16. +12VDC	16. TTL OUTPUT
17. GROUND	17. RS-232 OUTPUT
18. GROUND	18. OUTPUT #6
19. GROUND	19. OUTPUT #7
20. GROUND	20. OUTPUT #8
21. AUX AUDIO INPUT	21. GROUND
22. AUX AUDIO OUTPUT	22. GROUND
23. TX AUDIO #2	23. INPUT #6
24. GROUND	24. INPUT #7
25. GROUND	25. INPUT #8

Make interface cable from DB9F to Molex connectors for RC85 or DB-25 connectors for CAT-1000

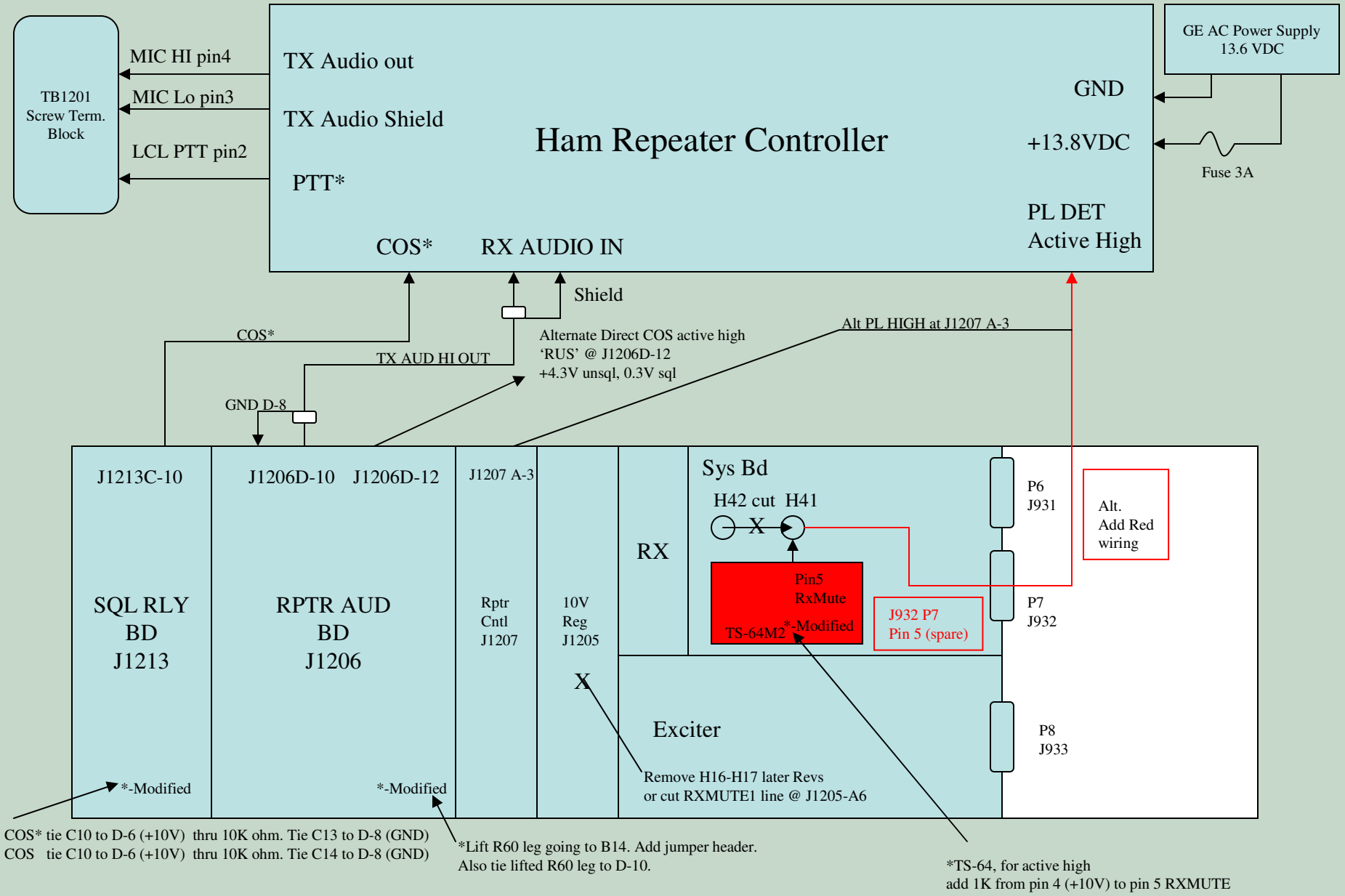
RC-85 wiring ready for repeater use



Basic Complement of Rack Cards

GE MASTER 2 BASE/REPEATER CONNECTIONS

GE M2
Repeater/Controller
W4XE 3/8/03 Rev 1



NARA Repeater Systems

1. 146.940 Monte-Sano Mountain
2. 147.180 Brindlee Mountain
3. 145.330 Monte-Sano Mountain
4. 443.500 Monte-Sano Mountain
5. 223.940 Monte-Sano Mountain
6. 443.800 South Huntsville
7. 53.210 Monte-Sano Mountain

As of 11/28/04

146.940

- Hardware: GE Master 2 Base
- Controller: CAT-1000
- Remote Base: Icom mobile
- Duplexer: Wacom WP-641
- Coax: 1/2” Hard-line
- Antenna: Phelps Dodge Super Station Master
- Auto patch
- PL: Communication Specialist TS-64MSTII
- MISC: No SOR relay card, CAS drives controller directly
- GE Power Supply 12V @ 30 Amps

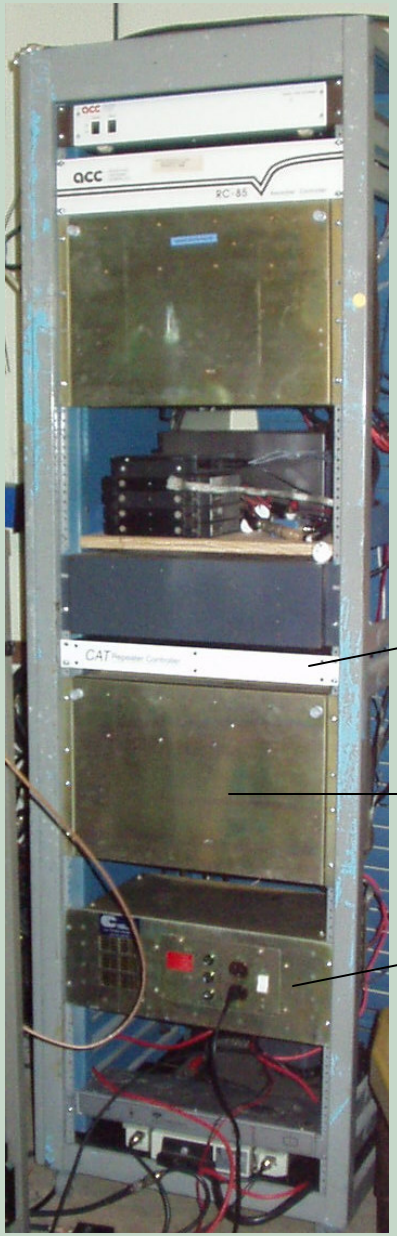
Our Main Flagship repeater

This is the 146.94 system as it existed at Chn 31 site.

Radio equip on top of rack is the old UHF patch link to 147.18.

The old non-GE PA and Astron PS has been replaced by stock GE.

Temporary Home of 146.940.

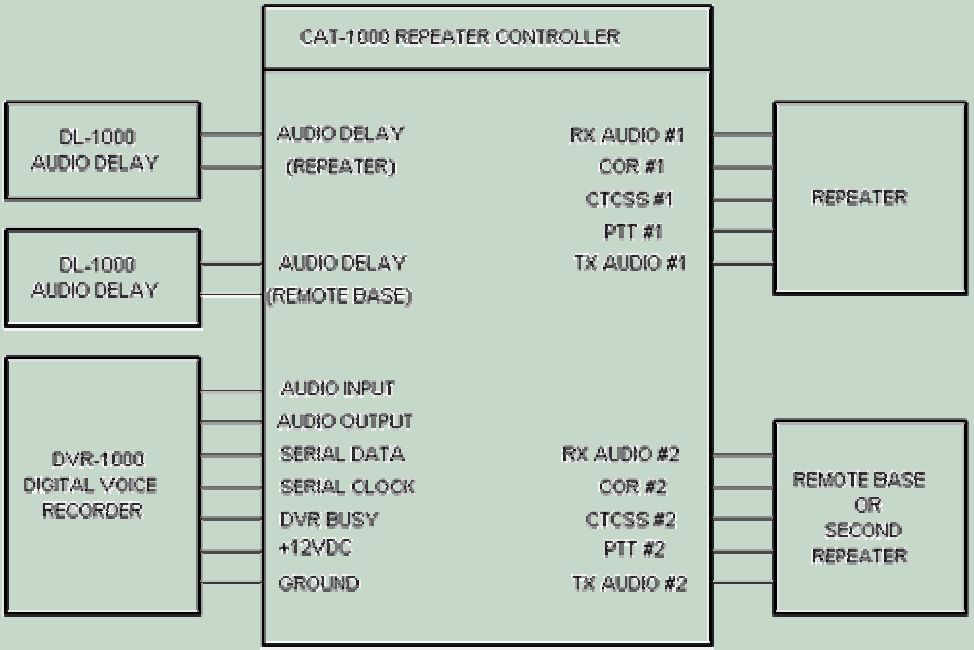


CAT-1000 Controller

146.94 GE Master 2

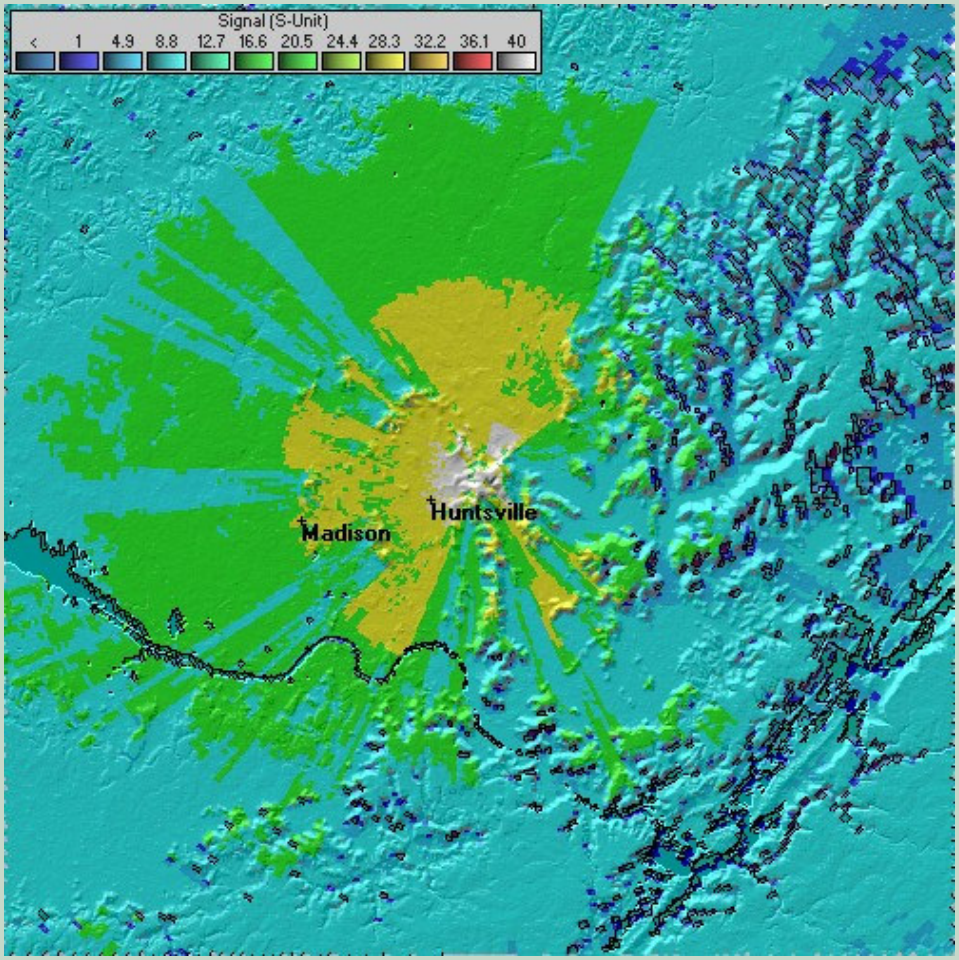
GE 12V Power supply

CAT-1000 Controller



The Channel 31 TV station site for 146.94

Coverage Plot



147.180

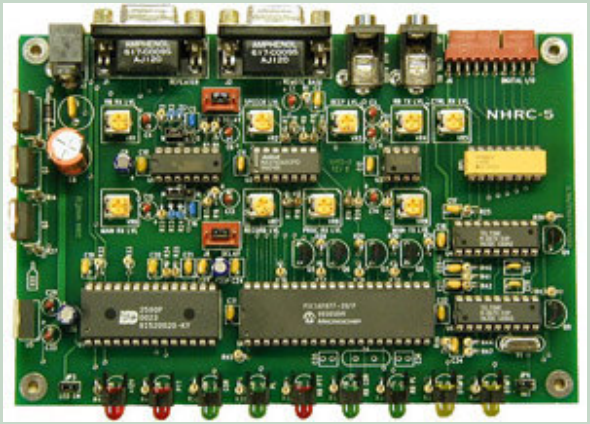
- Hardware: GE Master 2 Base
- Controller: NHRC-5
- Remote Base: Icom mobile
- Duplexer: Wacom WP-641
- Coax: 1/2” Hard-line
- Antenna: Phelps Dodge Super Station Master
- IRLP through UHF link
- PL: Communication Specialist TS-64MSTII
- MISC: SOR relay card for CAS Buffer
- GE Master 2 power supply

Our secondary VHF repeater system

Front View of repeater

Rear view of 147.18 repeater

NHRC-5 Controller

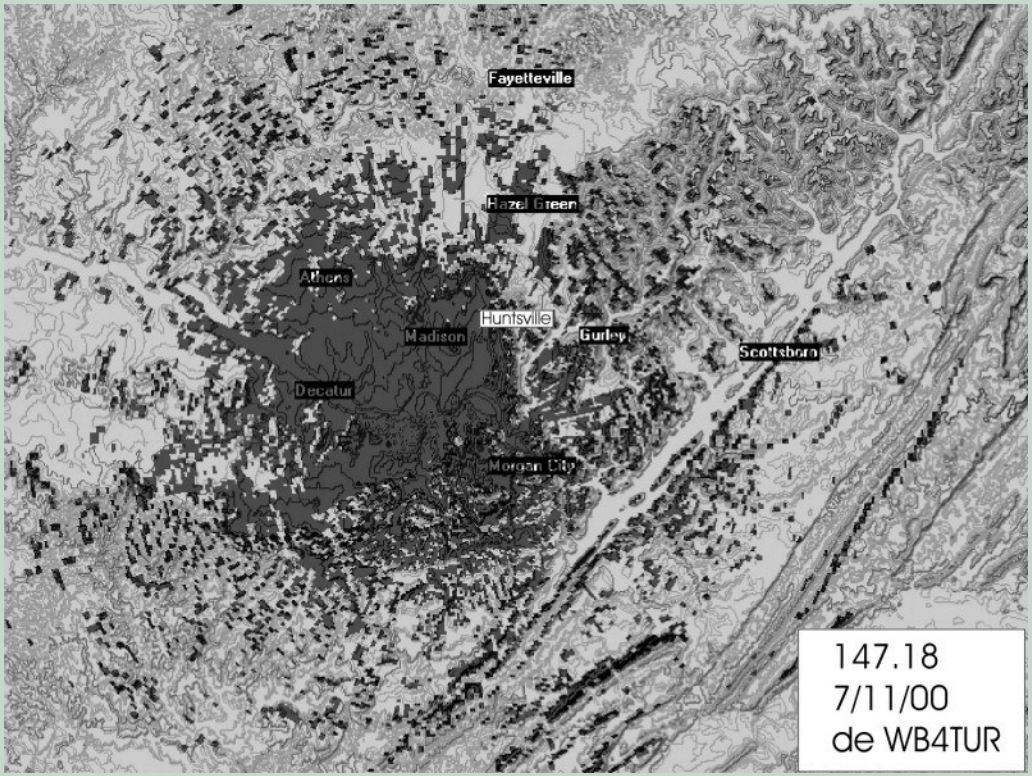


Features:

•Secondary port for remote base, link radio or slaved duplex repeater.
•Control Receiver Input.
•Two Separate DTMF Receivers. Primary Receiver. Control Receiver
•User Audio Test Mode allows Repeater User to hear their own audio.
•CAS, CAS and CTCSS, CAS or CTCSS and DTMF Access Modes
•Auxiliary Audio Input for weather receiver, site audio, etc..
•Two saved setups.
•Seven Stored Voice Messages:
•Distinctive Courtesy Tones
•Four Digital Inputs Four Digital Outputs.
•Dedicated Fan Control Output/Digital Output.
•Touch-Tone remote control and programming.
•Individual audio gating on each port
•Jumper-selectable receiver de-emphasis.
•LED CAS, CTCSS, PTT, and DTMF indicators for each port.
•Connectors for each port to attach optional NHRC-DAD Digital Audio Delays

147.18 Repeater Tower

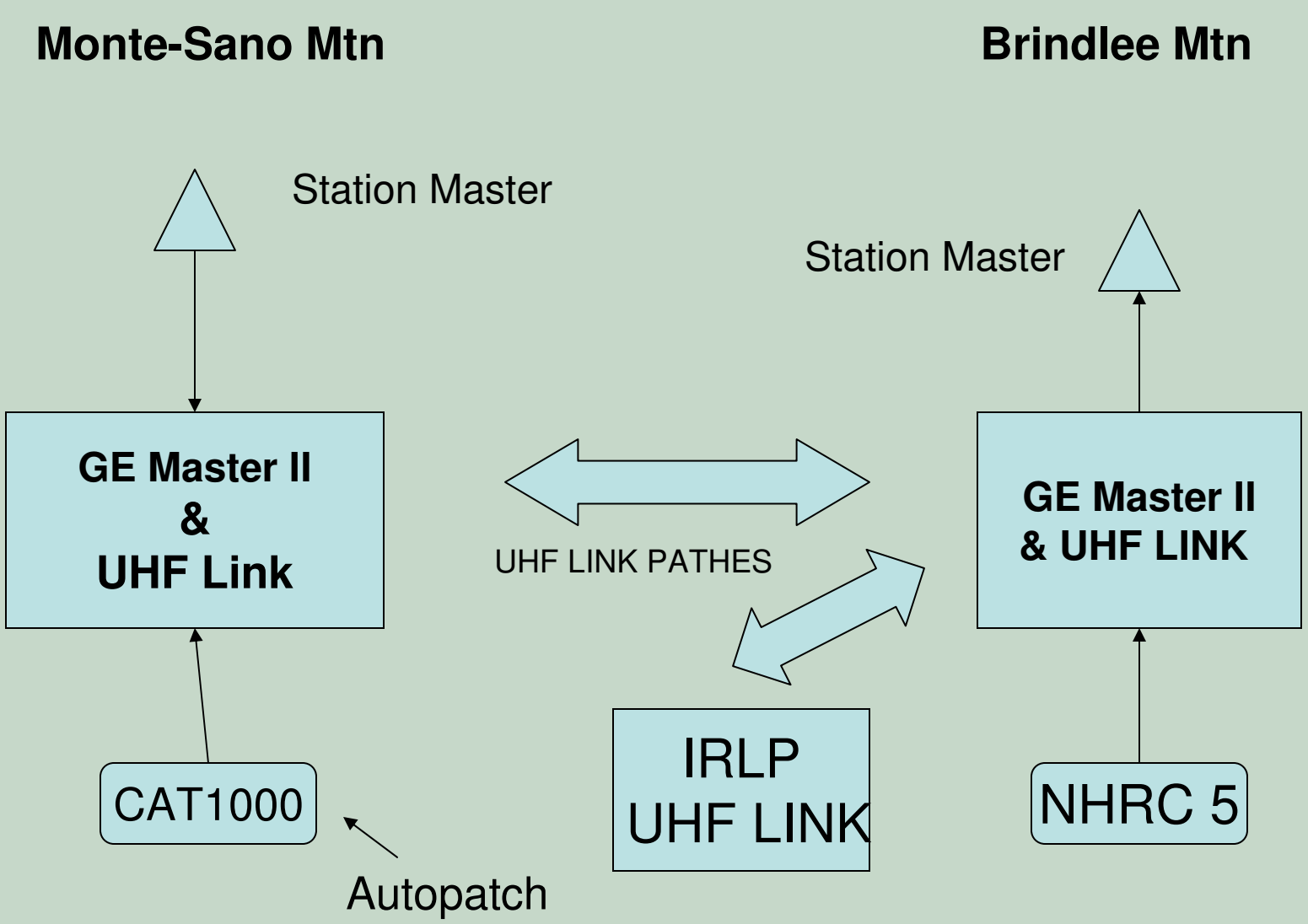
Coverage Map



(Radio Mobile prediction)

Nara LINKED VHF REPEATERS

Combined coverage for special events



443.500

- Hardware: GE Master 2 Base
- Controller: ACC RC-85
- Remote Base: Icom IC-900 10 mtr, 2, 220, 440, 1.2 GHz
- Duplexer: DB products
- Coax: 1/2” Hard-line
- Antenna: Cushcraft ARX-270 (dual bander)
- Auto patch
- PL: Communication Specialist TS-64MSTII
- MISC: SOR relay card buffers CAS
- Astron 50A power supply

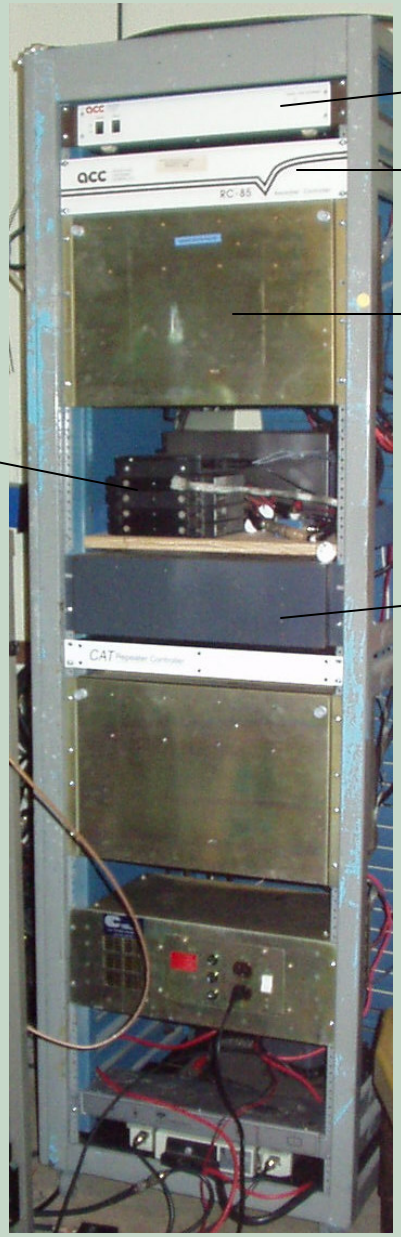
Our full feature UHF repeater with remote base.

Digital Voice Recorder

ACC RC-85 ham controller

GE Master II 443.500

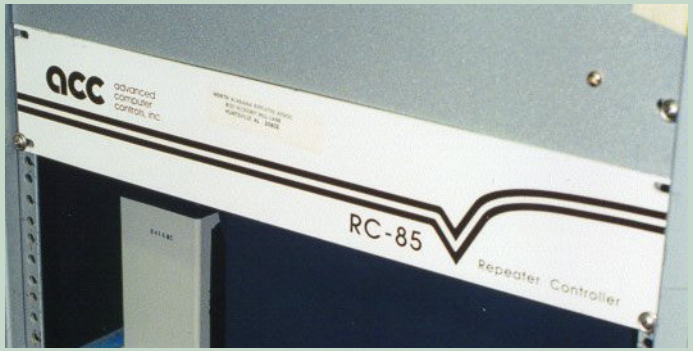
Icom 900 remote base
Stack: 2/440/220/1.2 GHZ
(Astron :PS in rear)



440 Duplexers

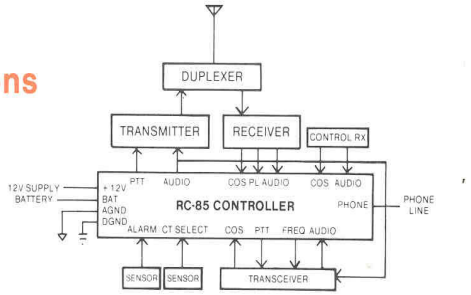
New rack at Ernie's QTH.

ACC RC-85 Controller

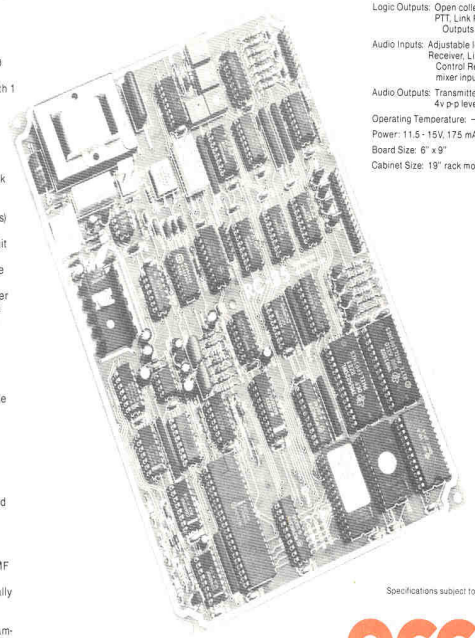


Features & Specifications

REPEATER BLOCK DIAGRAM



- Complete standalone repeater controller
- Remotely programmable with Touch-Tone commands:
  - Messages—over 25 (ID's, tails, Bulletin Board, etc.) May be Morse code, synthesized speech, or Digital Voice Recorder tracks (w/DVR)
  - Morse code parameters Speed—12-30 WPM Pitch—dc-3000 Hz
  - Control Op and user command codes (12 prefix groups, up to 7 characters each)
  - Courtesy tone selection (from 10 predefined sets)
  - Timers—10 sets, 0-30 minute with 1 second resolution
  - Autodial numbers (200)
  - Non-volatile E²PROM storage
- Autopatch / Autodial
  - Built-in telephone interface
  - Store/forward, DTMF or rotary
  - Optional phone number readback
  - User Loadable Autodial (190 numbers)
  - Emergency Autodial (10 numbers) with message readback
  - Toll restrict—leading 1/0 and digit count Activity timer with warning warble
- Reverse patch
- Natural sounding speech synthesizer for effective user/repeater interface with custom ham/repeater oriented vocabulary
- Analog measurement for Talking S-Meter
- Paging—two-tone sequential plus group call (over 3000 pager codes)
- Remote base control—commandable frequency and mode (BCD type transceiver)
- PL access and control modes
- Touch-Tone access mode with programmable timeout
- Remote control logic outputs—3 expandable to 8
- Low distortion computer synthesized tone generation
- Noise and kerchunker filtering
- Control receiver provisions
- Alarm input
- Fully integrated CMOS 16 digit DTMF decoder
- Intelligent ID algorithm—automatically selects from up to 7 programmable ID's
- Tail messages—3 selectable, programmable repetition rate
- Command acknowledgement with unique messages
- Low power, single supply operation with built-in battery backup circuitry
- Attractive 19" rack mount enclosure option



Microprocessor: 8085 AH

Memory: Total 36K byte
EPROM - 16K
E²PROM - 2K
RAM - 2K
Speech ROM - 16K

Logic Inputs: Low <.8 volts
High >2.4 volts
COS, Link COS, Control Receiver COS, PL, Courtesy Tone select, Alarm, spares

Logic Outputs: Open collector, 60V, 100 mA
PTT, Link PTT, Control Outputs (3, expandable to 8)

Audio Inputs: Adjustable levels
Receiver, Link Receiver, Control Receiver, spare mixer inputs

Audio Outputs: Transmitter Audio
4v p-p level

Operating Temperature: −15 to +55 degrees C.

Power: 11.5 - 15V, 175 mA

Board Size: 6" x 9"

Cabinet Size: 19" rack mount, 3.5" high

Specifications subject to change without notice.

acc advanced computer controls, inc.
10816 Northridge Square
Cupertino, CA 95014
(408) 749-8330

145.330

- Hardware: Current: Mixture of equipment
  Goal: GE Master 2 Mobile (already converted & tuned)
- Controller: TBD
- Duplexer: Wacom
- Coax: 1/2” Hard-line
- Antenna: Phelps Dodge Super Station Master
- PL: TBD: Communication Specialist TS-64MSTII

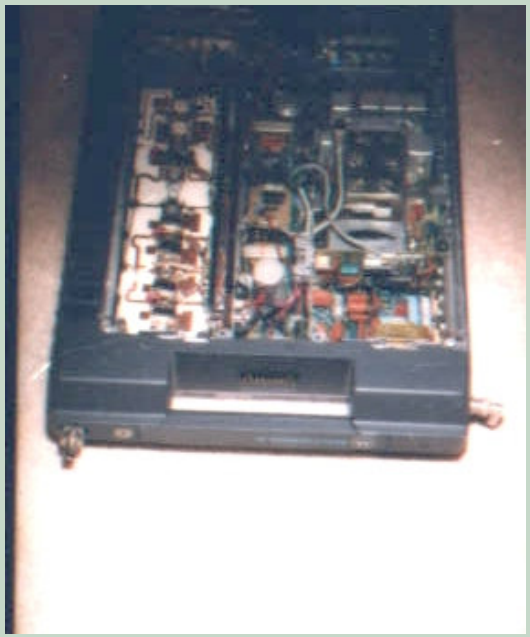
A repeater that supports ATV activity and Fall back for 146.94

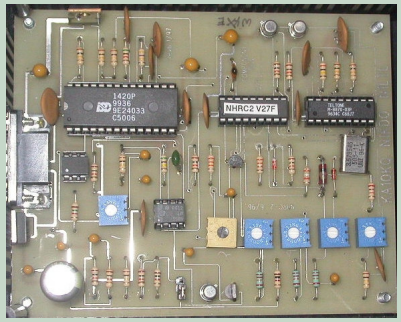
443.800

- Hardware: Motorola Micor converted mobile
- Controller: NHRC-2
- Duplexer: Mobile Duplexer

A repeater that covers the south Huntsville RF black hole. We may redefine what the role of this repeater is.

Hardware: Motorola Micor and NHRC-2 controller.





223.940

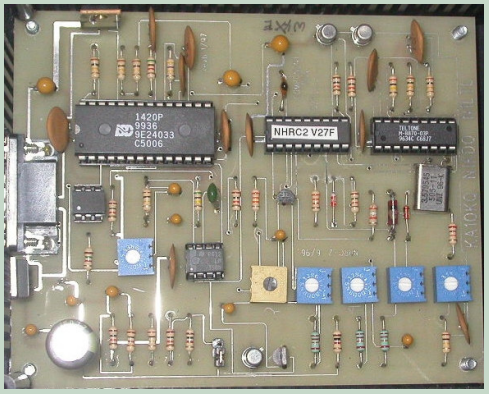
- Hardware: Hamtronics Repeater. Synthesized TX replaced xtal TX.

  GE Master2 VHF conversion pending
- Controller: NHRC-2 (W4XE loaner). Pending: RC-1000
- Duplexer: Wacom
- Coax: 1/2” Hard-line
- Auto patch: Pending new controller
- PL: Hamtronics

Nara’s support for the 220 MHz band.

Hamtronics 220 MHz Rptr

Not an exact photo, but close enough



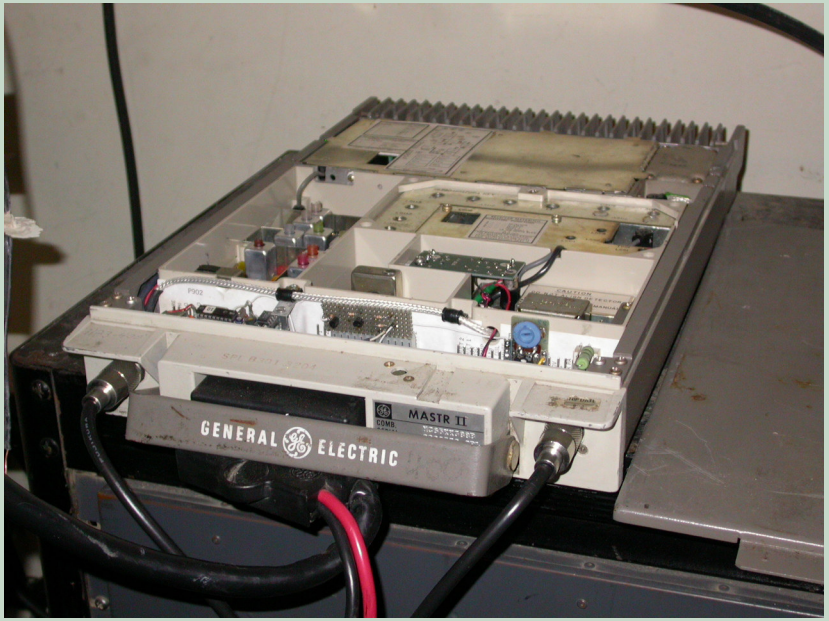
Currently
NHRC-2
controller

52.210

- Hardware: GE Master 2 (split site)
- Controllers: NHRC-4 & NHRC-2
- Duplexer: Coaxial Stub
- Coax: 1/2” Hard-line
- Antenna: Comet tribander (2,6,440)
- PL: Communication Specialist TS-64MSTII
- Master II power supply
- MISC: Currently this is a split site. We are converting to single site with new coaxial duplexers.

Co-project with NARA & W4XE.

6 meter split site repeater



Monte-Sano RX Site

Current Green Mtn TX site

A note on remote base radios

Typically a simplex radio is installed to provide access to another frequency band or for linking purposes. Since we use ACC controllers, we use ICOM IC-900 band stackable Radios (from 10 meters to 1.2 GHz). The controller allows us to remotely set frequency (both tx/rx) and PL tone. Any radio may be used as long as it can provide a COS and/or PL detect signal. For remote programmability, the controller and radio must have a compatible programming interface.

Remote Base Radios

Icom IC-900 stack of 2, 220 and 440 modules shown with FC-900 acc interface

TEST SET

GE Master Pro (single black plug)
GE Master 2/Exec2/MVP (Y cable black/red plugs)

While the receiver and transmitter can be tuned up with a Volt meter, these test sets allow easy selection of the tuning Points. A microphone and PTT button are provided. Also, access to speaker audio is provided.

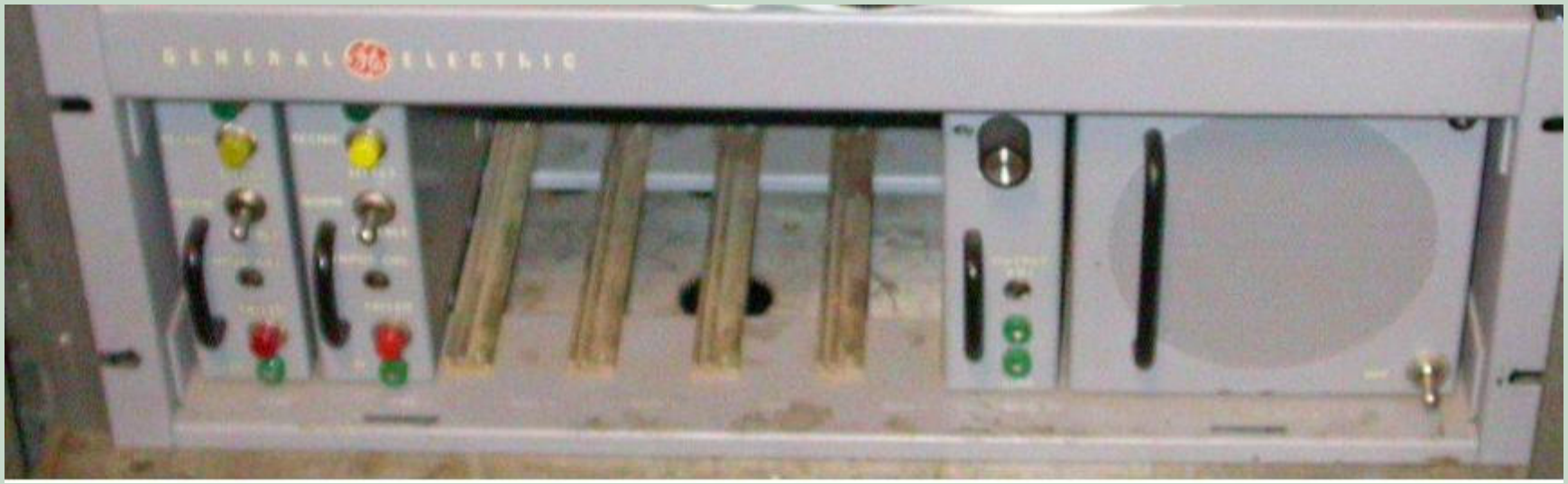
Standard GE Master II hand mike.
Can be plugged into GE repeater for
Local communication at site.

Remote voter site equipment

- GE M2 UHF full duplex converted mobile.
- Remove UHF RX and install VHF RX
- NHRC3 Master 2 drop in controller
- Comspec TS-32 or TS-64 PL encoder/decoder
- Power supply +12 VDC @ 10-15 amps
- Feedline (1/2” hardline preferred or short run of coax.)
- Antenna system:
  - VHF omni Rx antenna, UHF 3 element beam
  - Alternative: Diplexer and dual band vertical

- Note- the club has several GE M2 uhf mobiles and vhf mobiles for this purpose. One has been completed for use above.

GE Voter chassis

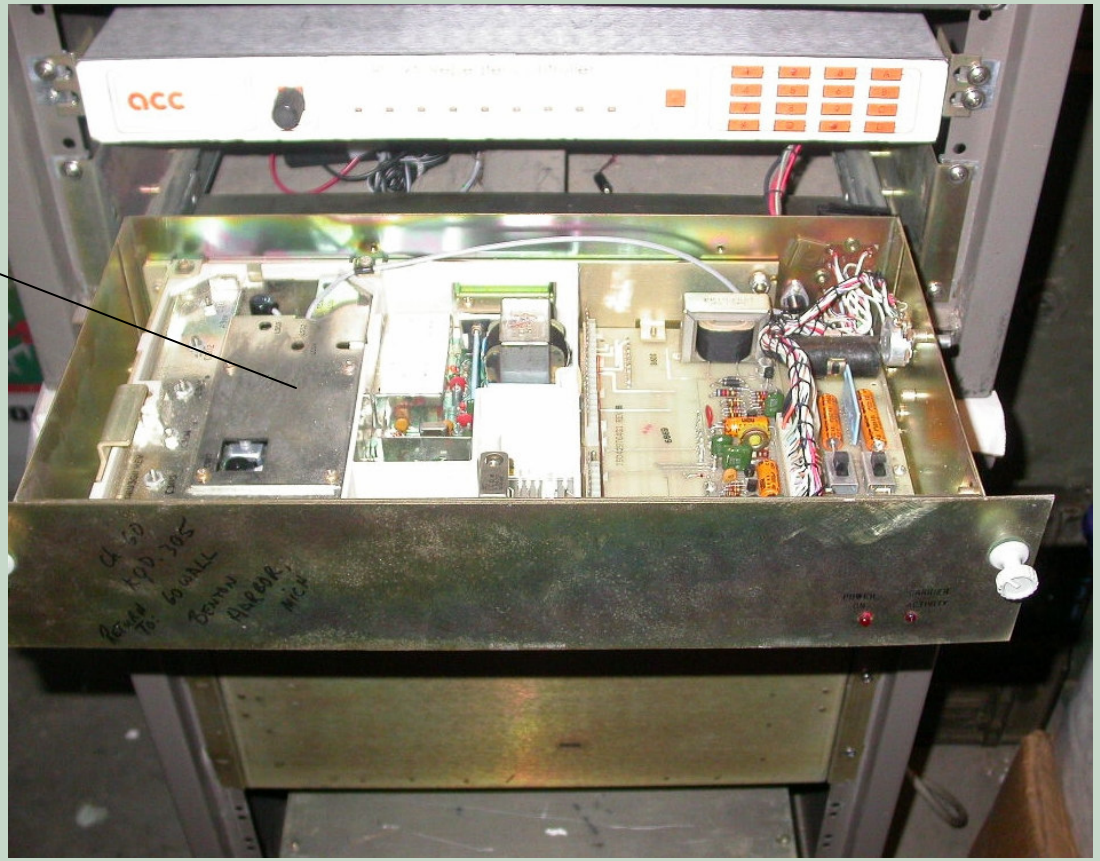


Up to six plug in cards support remote voter sites. Each remote site requires an associated repeater site local receiver. Each RX must be on a unique UHF frequency. The voter chassis picks the best signal from the 5 remote sites or main site RX for the repeater to rebroadcast on a continuous basis.

GE Master 2 Remote voter Rx

You need one each of these for every remote site you have.

Same RF Modules As Mobile And repeater



Linking is typically done on UHF.

GE related radios

- The following are mobile radios that are nearly identical to the GE Master 2 series and are popular for ham repeater use.
- These can be deployed as backup repeaters or link radios.

GE EXEC II

(A very close relative of GE Master 2)

40W Desktop base w/internal AC PS.
Both make great repeaters!

Trunk mount version up to 110W.

GE Custom MVP

A lower power (40W max) under-dash version of EXEC II

There is a drop in NHRC controller for making this into a very compact repeater.

GE Phoenix SX

The S or SX model is synthesized. The non-S is xtal. There are 2 chn to 16 chn versions. You can NOT full Duplex this radio for repeaters. It takes 2 radios, one for rx and one for tx. However, they are good radios and also make Great ½ duplex link radios. 2/6/440 and up to 40 watts. Programming tools are in-house.

Conclusion

We've learned:

- The basic components of a repeater system
- The terminology of a repeater
- The interconnects of the various parts of the system
- The NARA repeaters and site specific hardware