# A Simple Regenerative VLF-LF Receiver

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## Introduction

In an earlier issue of of Amateur Radio, I described a superheterodyne receiver for the VLF-LF bands, This was followed by a series of articles on front end tuning and loop aerials for these bands. Now I will describe a more basic form of VLF-LF receiver.

In earlier days of radio, quite successful reception of low frequency radio waves was achieved with a single valve stage as a regenerative amplifier-detector and a valve audio amplifier. At low frequencies, a modest value of Q factor in a single tuned circuit achieved workable station selectivity which was further improved by regeneration to increase the effective Q and further reduce the circuit bandwidth. Furthermore, by increasing the regeneration to the point of oscillation, a beat frequency was produced to enable reception of CW signals (or radio teletype if used today). As the voltage magnification of a tuned circuit is equal to Q, the regeneration also improved the sensitivity of the receiver well beyond that achievable with its single RF stage as a straight amplifier.

The receiver I will describe is based on the above principles but is designed around more modern solid state amplifier packages. It tunes between 10kHz and 430kHz with quite reasonable selectivity. A selectable audio bandpass filter is included to improve the reception of narrow band signal modes in the VLF region.

## Circuit Description

The regenerative RF section of the receiver is shown in figure 1a.

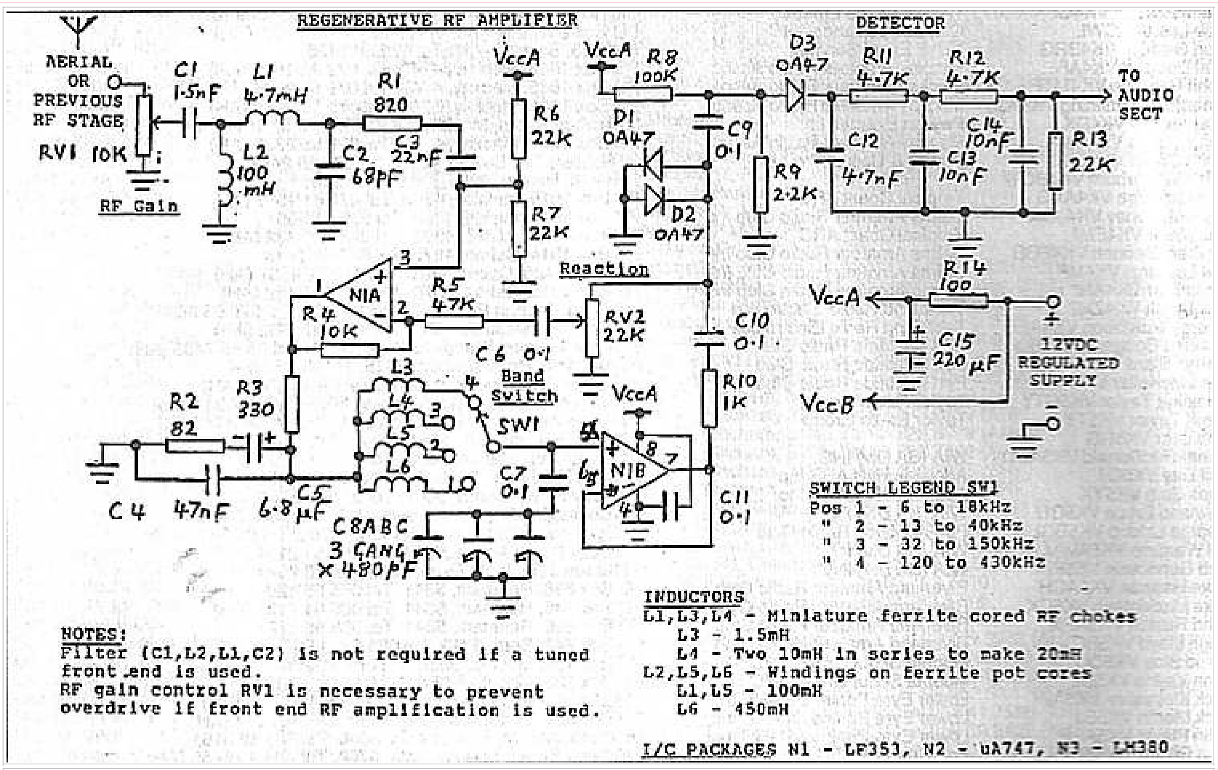


**Figure 1a: VLF-LF Receiver, Regenerative RF Section**

The single tuned circuit is made up of the paralleled sections of 3 gang tuning capacitor C8 and one of the switched inductors L3, L4, L5, or L6. The tuned circuit is connected within the closed loop containing the two amplifiers of an LF353 integrated circuit package. These are JFET amplifiers with a gain-bandwidth product of 4 MHz.

Amplifier N1B is connected as a voltage follower which, with it's high input resistance, prevents loading of the tuned circuit thus allowing its high Q. factor to be realised. Positive feedback, or regeneration,is fed via the inverting input of N1A. The level of feedback is controlled by the setting of the reaction control RV2. The input signal is fed to the non-inverting input of N1A and combined with the regenerated signal within the amplifier. The combined signal is injected into the tuned circuit across C4. The capacitance value of C4 is large by comparison with that of the tuning capacitance and hence the injected signal source resistance has little effect on the circuit Q. The injected signal can be considered to be applied in series with the tuned circuit and whilst its developed voltage across C4 is small, it is multiplied by the circuit Q at the input of N1B.

Additional loop gain is provided by N1A and with phase reversals at N1A and at the point of injection, the circuit can be made to oscillate when the reaction control RV1 is advanced to the critical point. The circuit is different from the accepted method of applying regeneration via the RF transformer in which one winding is used for the tuned circuit, a second winding for the feedback signal and a third for the input signal. One reason for avoiding this method was to make use of single winding inductors which were on hand. The additional windings would have meant making special transformers for the job.

There are also some operational advantages in using the circuit of figure 1A. One problem in coupling an aerial directly into the tuned circuit is that when regeneration is set for oscillation, the whole thing works as a small transmitter, radiating a signal via the aerial and causing interference to others. Another problem is the changed loading on the tuned circuit for different lengths of aerial and the interaction it causes with the setting of the reaction control. By injecting the input signal and the feedback signal via different inputs of N1A, both these effects are avoided.

Some specific components in the circuit require explanation. Diodes Dl and D2 limit the amplitude of oscillation when the circuit is set in the oscillating or beat frequency mode. The curved characteristic of the diodes also give a more gentle slide into oscillatiion when RV2 is advanced.

Initially, when using the input directly connected to a long aerial, I had some problems with local broadcast station pick-up and low frequency power mains generated noise. Components L1 and C2 make up a low pass filter which attenuates signals above 400 kHz and eliminates the broadcast station interference. The mains generated noise was considerably reduced by the addition of R2 across capacitor C4 to limit the impedance of the tuned circuit injection point. Without this addition, the reactance of C4 at very low frequencies became very high, allowing a high level of noise at these frequencies to be injected. High pass filter C1,L2 further attenuates low frequencies below 10kHz. If the regenerative circuit is preceded by a tuned stage, rather than directly connected to an aerial, filter components C1,L2,L1, C2 can be omitted.

RF gain control RV1 is included to reduce the input level on strong signals when the input is driven from a previous RF stage. If the circuit is connected directly to an aerial, the level is lower and RV1 is not necessary.

Diode D3 and low pass filter C12,R11,C3,R12,C14 form the detector circuit, At very low frequencies (near 10kHz) the RF signal frequency approaches the frequency spectrum of the audio amplifier with a consequent tendency for the whole RF-audio link to become unstable, The second section of filtering, R12,C1, was found necessary to control this problem.. There is a small positive bias applied to the detector diode via resistor R8. This shifts the diode operating point further up its characteristic curve to improve the receiver sensitivity on weak signals.

## The Audio Section

The detected output is fed to the input of the audio section of the receiver (figure 1b).

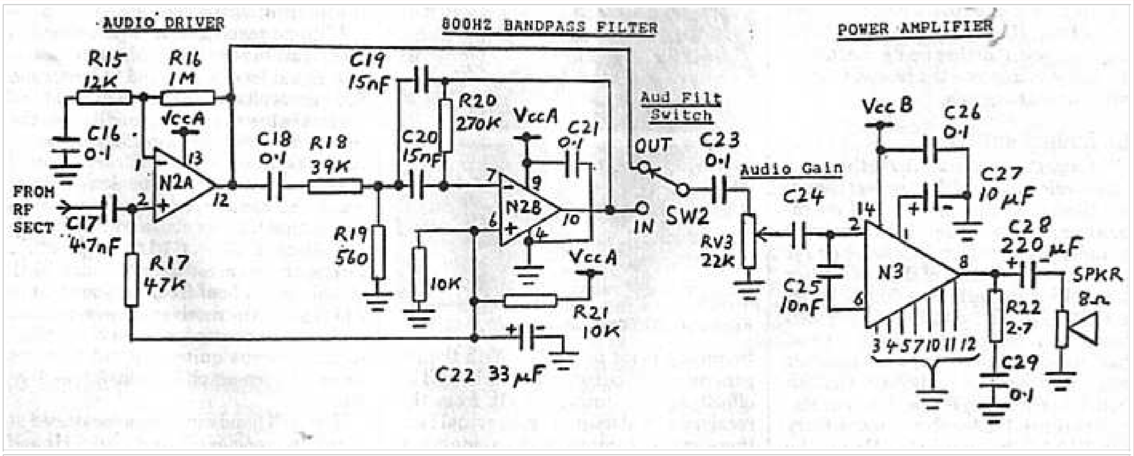

Figure 1b: VLF-LF Receiver - Audio Section

Device N2 is a uA747 dual operational amplifier package. N2A is used as an audio driver which feeds the power amplifier N3. Operation of the audio filter switch SW2 connects in a 800Hz band-pass filter formed by N2B and its associated circuit components. This type of filter, which requires only one amplifier unit, was described by Gilbert Griffith VK3CQ in Pounding Brass, Amateur Radio, February 1989 and credited to Gary Bold ZL1AN in Break In. Using the component values shown in figure 1a, the filter centre frequency is 800Hz with a bandwith of 84Hz (as measured). The centre frequency and bandwidth can be altered,if required, by altering the values of R19, R20, C19 & C20. The design formulae for these are included in Gilbert's article.

With the high noise level at VLF, the audio filter is a desirable addition to restrict the detected noise when receiving morse or radio teletype signals in the VLF band. To use the filter, the beat
frequency is set to 800Hz. With the regenerative RF circuit, this is achieved by off-setting the tuning 800Hz from the received signal frequency. In actual fact, there are two tuning positions, one below the signal frequency and one above the signal frequency. You pick the one which gives the least interference from adjacent signals or noise. This characteristic of the regenerative circuit which gives two

tuning positions is very noticeable at VLF. For a 800Hz beat note, the two tuning positions are 1600Hz apart. At a typical frequency of 16kHz, this represents a tuning shift of 10% of the operating frequency.

The speaker is driven by power amplifier type LM380 (N3). This IC is available in either a 14pin version or the smaller 8 pin version. I used the 14 pin version because I happened to have one already wired up with associated components on a board. (In my superhet receiver, AR Dec 1989, I did in fact use the 8 pin. version).

The DC load current for the LM380 swings between 10mA and 150mA, depending on the audio power level. Hence the DC power supply to the receiver must be well regulated. The remainder of the receiver load is only 5mA and this is decoupled from the supply by R14 and C15. Even with this decoupling, instability can occur between the audio and RF sections if the supply regulation is inadequate. The nominal supply voltage is 12 but any voltage between 10 and 15 can be used.

## Performance

Sensitivity of the receiver referred to its input was measured in terms of minimum discernible signal level using a calibrated signal generator as the source. Below the point of oscillation in the regenerative circuit, the measurements were carried out with the signal generator carrier modulated with tone at 30%. At the point where oscillation just commenced (the most sensitive state), unmodulated carrier was used to beat with the internal oscillation.

With no regeneration, ie the reaction control set to zero, the minimum discernible signal level was found to be around 500 microvolts. With the reaction control set just below the point of oscillation, the figure improved to around 50 microvolts. At the point of oscillation, carrier could be detected at 3 microvolts.

Sensitivity is much the same over the tuning range except that it drops above 300 kHz due to the effect of filter C1-L2. In practical terms, the receiver detects quite weak signals in the beat frequency mode, For AM signals,the receiver is less sensitive. It can receive more localised Non-Directional Beacons quite well but requires some RF pre-amplification for weaker stations.

The 3dB bandwidth was measured at input frequencies of 20kHz, 100kHz and 350kHz. The bandwidth with no regeneration measured 270Hz at 20kHz, 2.6kHz, at 100kHz and 4.9kHz at 350kHz. This implies a circuit factor of 70 at 20kHz, 38 at 100kHz and 70 at 350kHz.

Increasing the regeneration to just below the point of oscillation, the bandwidth improved to 12Hz at a centre frequency of 20kHz, 100Hz at 100kHz and 157Hz at 350kHz. The regeneration thus increased the effective Q to 1700 at 20kHZ, 1000 at 100kHz and 2200 at 350kHz.

Bandwidth measurement at the point of oscillation was not attempted as this appeared to be rather difficult to resolve. In any case, I have already pointed out that, in the beat frequency mode, the tuned circuit is offset from the incoming frequency.

In the beat frequency mode, the receiver strongly receives VLF-LF stations such as Omega around 11 to 13kHz, the North West Cape on 23.3kHz and Belconnen Navy Station on 44kHz. However, there is some limitation on adjacent channel rejection. Firstly there are two signal frequencies which can beat with the internal oscillation, one above and one below the oscillation frequency. If one of these is the desired signal frequency, the other could correspond to an adjacent operational signal frequency. Secondly, although the tuned circuit has high effective Q and narrow 3dB bandwidth, being a single circuit, the slope of the sides of its resonance curve is not as steep as that of a ceramic filter in an IF channel, or even a number of cascaded tuned circuits.

## Components

Apart from some of the inductors, commonly available components are used in the receiver. For the lower values of inductor, miniature ferrite RF chokes up to 10mH are obtained from Dick Smith Electronics stores. The larger inductors can be wound on almost any form of ferrite pot core but one can often find ready wound units which have been discarded from other electronic equipment. There is no need to be too fussy about the precise values of inductance.The frequency band coverage for each band switch position can always be juggled around the inductors and tuning capacitor which are on hand. Old broadcast receiver tuning gangs with sections paralleled are ideal for VLF-LF tuning and these often change hands at amateur radio buy and sell marts. I must say that a lot of my odd components come from just that source.

## Pre-amplification & Tuning

The performance of the regenerative receiver, both in sensitivity and adjacent channel rejection, can be irnproved by the addition of a sharply tuned RF amplifier in front of the receiver. I described such a tuner (figure 2) in Amateur Radio July 1990 and this unit has been used in conjunction with the regenerative receiver to make it, in terminology, a TRF receiver. The front end is tuned to the incoming signal frequency and this provides rejection of an adjacent channel, mentioned as being a possible nuisance when operating in the beat frequency mode. Furthermore, the additional gain in the front end improves the sensitivity and hence the reception of weak signals. With the increased signal level, RF gain control RV1 is necessary to reduce the level of strong signals and prevent overload.

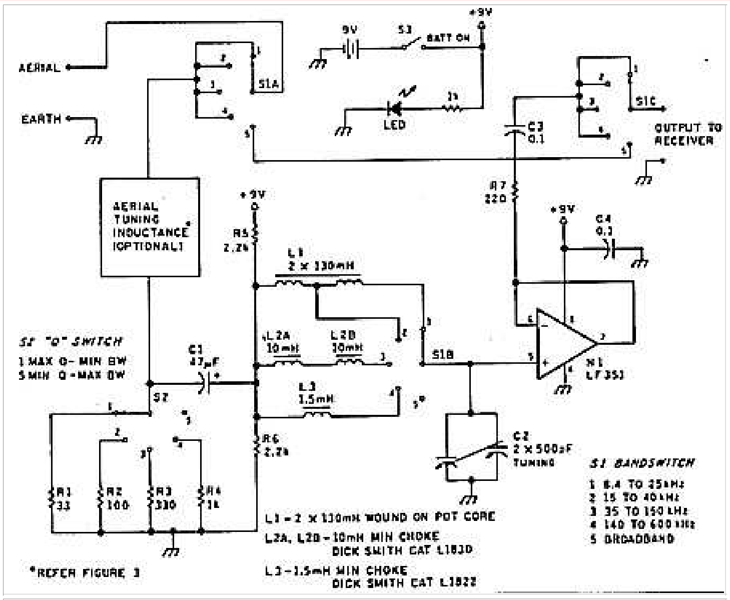


**Figure 2: VLF-LF Front end tuner (AR July 1990)**

With the RF front end in circuit, minimum discernible signal level is around 3 to 5 microvolta for the regeneration set just below the point of oscillation, At the point of oscillation, the figure is less than 1 microvolt.

One difficulty with the separate front end tuner is manually tracking the two tuned circuits when scanning the band. By using identical tuning inductors and variable capacitors in the two tuned circuits, one could mechanically gang the two tuning capacitors (each of which is already several ganged sections paralleled). Of course in the beat frequency mode, the regenerative tuned circuit must be offset in frequency from that of the front end. To adjust for this, a small manually controlled variable capacitor across one of the two tuned circuits might be needed. It would also allow manual correction of any small tracking error.

## Loop Aerial

The receiver works very well connected to a tuned loop aerial via the loop preamplifier (figure 3) which I described in Amateur Radio, August 1990. I recommend a Loop aerial of 20 turns of at least 1mm diameter wire spaced 1cm apart on a 0.8metre square frame (refer figure 4). Used with circuit of figure 3, the loop can be brought to near resonance over the full tuning range of the receiver. The large wire diameter is important. The greater the wire diameter, the higher is the Q to produce higher loop sensitivity.

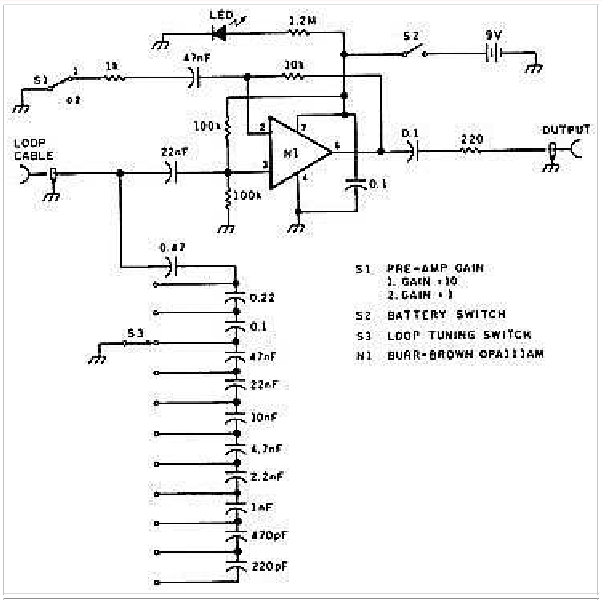


**Figure 3: Loop aerial tuning & pre-amp circuit (From AR Aug 1990)**

**Figure 4: 20 turn Loop Aerial**

I found that, provided the loop aerial was directed towards the source of signal, the signal received was stronger and less noisy using this loop than using my long wire aerial.

## Summary

Whilst the simple single tuned circuit regenerative receiver has been discarded as obsolete for high frequency operation, it can provide quite good signal selectivity at very low frequencies. In beat frequency operation (for CW or teletype) its tuned circuit must be offset in frequency to produce the beat note and the disadvantage of this is discussed in the text.

Accepting that there is some limitation on its ability to receive weak AM signals and on its ability to reject strong adjacent signals, the receiver described works quite well. These limitations can be largely corrected by using a sharply tuned RF pre-amplifier in front of the receiver. Good performance can also be obtained using a high Q tuned loop aerial system such as that described.

This simple receiver is hardly in the category of a high rating unit but if you are interested in learning a little about what signals appear on the VLF-LF bands, it might be adequate to satisfy your curiosity.

## References


1. Lloyd Butler VK5BR - A VLF-LF Receiver 10kHz to 500kHz with Resistance Tuning - Amateur Radio, Dec 1989.

2. Lloyd Butler VK5BR - A Front End Tuner for the VLF-LF Receiver -Amateur Radio, Nov 1990.

3. Lloyd Butler VK5BR - VLF-LF and the Loop aerial -Amateur Radio, Aug 1990.

4. Gilbert Griffith VK3CQ - Audio Filter - Pounding Brass - Amateur Radio, Feb 1989.

Also refer to VK5BR Web Site for reproduction of the above articles (References 1,2,&3) and others on VLF/LF.

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