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## Active Antennas for the Frequency Range from 10 kHz to 50 MHz

Active receive antennas permit broadband reception from long waves to the 6 metre band and are widely used in the commercial field (e.g. aboard ships). In amateur circles, however, they have acquired a reputation as "intermod generators" and their advantages are not recognised.

The aim of this article is to spread knowledge of some basics on the theme "active antennas" and stimulate people to conduct their own experiments, while keeping circuitry within limits.

For a long time the author has been investigating broadband receiving antennas for the long to short wave bands and first considered a damped vertical antenna of the type made commercially by Telefunken and described in (1).

Stimulated by an exercise in CQ-DL (2), some trials were made of active antennas, the results of which are described now.

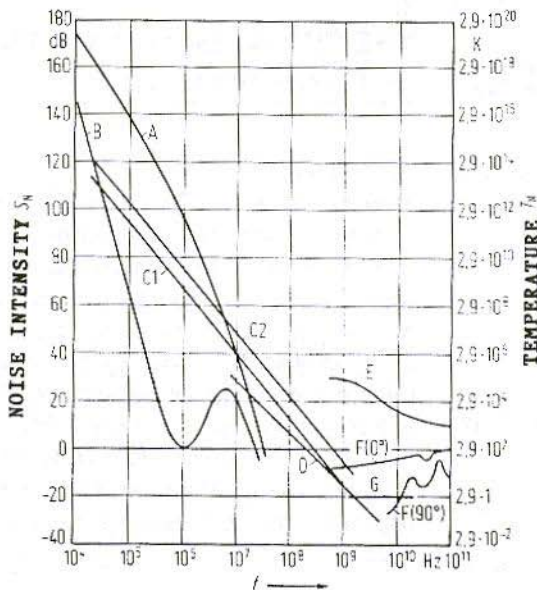
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### 1. RADIO PROPAGATION AND INTERFERENCE LEVELS IN THE REGION BELOW 30 MHz

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In amateur radio practice it is customary to use the same antenna for transmitting and receiving, since we have all learned that "a good antenna is the best RF amplifier"! In the case of transmitting this is unreservedly correct; field strength at the receiving location increases by orders of magnitude with a correctly set up antenna with a corresponding directional diagram. On the receiving side matters look different and need to be considered from another perspective.

In the frequency range above, say, 100 MHz the quality of reception (i.e. signal-to-noise separation) is determined chiefly by internal disturbances (noise figure of the first RF stage) and antenna downlead



**Diagram 1:**  
Average values of the various Noise Intensities and Temperature compared with Frequency

- A = Atmospheric Noise (maximum value)
- B = Atmospheric Noise (minimum value)
- C1 = Industrial Noise (rural receive site)
- C2 = Industrial Noise (urban location)
- D = Galactic Noise
- E = Quiet Sun
- F = Noise from Hydrogen and Oxygen
- G = Cosmic background Noise at 2.7K

attenuation. Under these circumstances a good antenna, which couples plenty of energy from the wave field, does make a real improvement in sensitivity. In addition, individual sources of interference can be nulled out with a directional antenna.

At frequencies below 100 MHz there is a steep rise in the interference level with falling frequency, as shown in diagram 1 from (3). In this the interfering components atmospheric noise, man-made noise and galactic noise (from outer space) are compared with frequency. As can be seen, the noise figure from external factors lies well above the internal noise of a receiver.

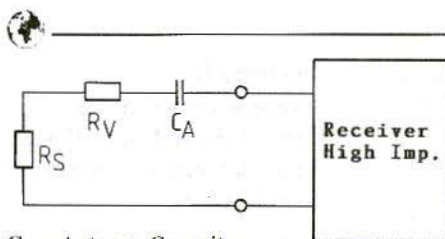
Since these sources of interference come in from no single preferred direction, they cannot be nulled out with directional antennas. With good antennas it is often the case that the combined level of wanted and interfering signals is too high for the receiver and the user must insert an attenuator ahead of the receiver input.

## 2.

### THE OPTIMAL RECEIVE ANTENNA

At frequencies below 100 MHz the task of a receiving antenna is thus not the production of a large signal but of a signal with the greatest possible separation from interference.

A transmitting antenna that is fixed on the roof of a house in a good spot for radiating almost always pulls in interference from the electricity mains. This leads to specific results in reception. If we recognise the fact that the interference field strength in the near field of a source of interference falls off with the square of the distance, then a remote receive antenna in the garden will certainly produce a lower level of signal but better separation from interference. With common shortwave receivers having a noise figure of 10dB, a whip



$C_A$  = Antenna Capacity  
 $R_V$  = Loss resistance of the Antenna  
 $R_s$  = Radiating Resistance; this can be approximated for an Antenna of Length  $l$  to:

$$\text{with } Z_0 = 377\Omega$$

**Fig.1: Equivalent Circuit of a Short Antenna**

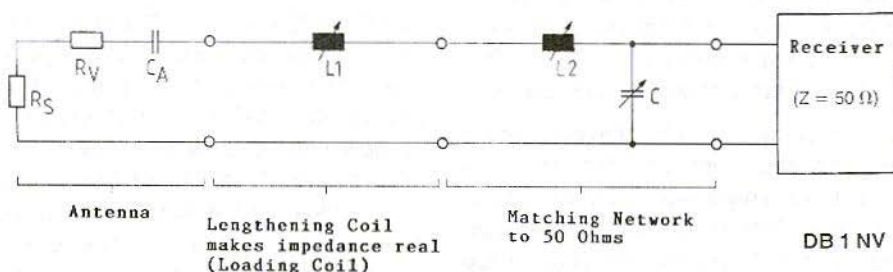
aerial about one metre long has so much receive efficiency that it will overcome the external interference level. A whip of this kind is easy and inconspicuous to erect.

Against far-field interference from terrestrial or atmospheric sources that kind of antenna is certainly no better than other designs, but a significant proportion of atmospheric disturbance arises from discharges from the air onto exposed antenna parts. In this respect a small antenna mounted low down is advantageous.

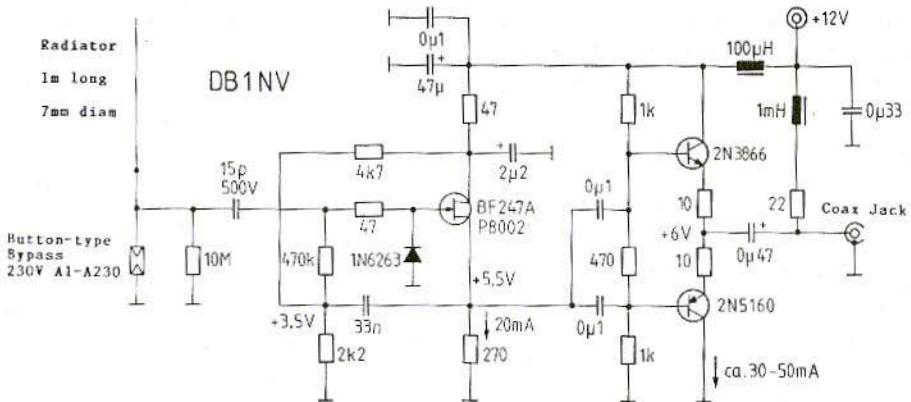
### 3. THE CONSTRUCTION OF AN ACTIVE ANTENNA

An antenna element that is short in comparison to the wavelength has an input impedance which can be described as a capacity (in the order of magnitude 10pF) with a radiating resistance of some milliohms to ohms, as shown in the equivalent circuit (Fig.1). For matching this to the cable and receiver input impedance of 50 $\Omega$  a matching network is necessary. Following the rules of conventional RF technology, one would first make the antenna impedance real and then transform it to 50 $\Omega$ .

As Fig.2 shows, the antenna capacity is first tuned with a loading coil to series resonance and the resulting real resistance transformed to 50 $\Omega$  with the help of a transformation element (low-pass half-element). In practice the two inductances in series are included in the same coil. It is clear that this network operates only in a narrow band around the resonant frequency and must be changed each time the frequency is altered. The matching network is also suitable for transmitting use.



**Fig.2: Matching a Short Antenna**



**Fig.3: Circuit of an Active Antenna for VLF to VHF**  
 (\* only required for remote voltage feed via coaxial cable)

The alternative is to take the no-load voltage of the whip antenna in a high impedance, low capacity fashion with an impedance changer and undertake the impedance transformation in a broadband manner using active components. The advantage is that one can make a receive antenna in this way that works broadbandly from the longest waves to the lower end of the VHF region without tuning elements.

Since the impedance changer is working with signals across the whole frequency spectrum, it must operate extremely linearly to avoid producing intermodulation within the antenna. This is also no justification for the poor reputation that active antennas have in amateur circles. Most of the active antennas forced on amateurs have too small a dynamic range and include a preamplifier with 10 to 20dB gain following the impedance changer, which has to operate with the full signal spectrum and further decreases the dynamic range. In this there are close parallels with preamplifiers in the VHF/

UHF region, where their effectiveness is judged by how far they bring up the S-meter and not how much they improve the signal-to-noise ratio.

#### 4. A SIMPLE ACTIVE ANTENNA

In order to gain an impression of the power capabilities of active antennas, the author developed some simple antenna electronics that consisted of just a barrier-layer FET and a push-pull emitter follower as cable driver. The circuit is shown in Fig.3. The antenna element used is a piece of 1/4" diameter brass pipe about a metre long, but these dimensions are not critical. A 10 megohm resistor conducts away weak static build-ups. With heavy overload, for instance with a thunderstorm close by, a gas discharge lightning arrester, wired in shunt, will strike: this is a so-called button spark-gap which conducts at 230 volts. Gas discharge arresters are

significantly lower in capacity than equivalent transient protection diodes and therefore load the antenna to a lesser degree. The arrestor type used on the prototype (A1-A230 by Siemens) is normally used in telephone systems as an over-voltage protection device and should therefore be simple to find. [Translator's note: a similar component is used inside telephone master sockets in Britain for high-voltage surge protection; Astralux of Horsham is a supplier.] As regards the effectiveness and necessity of this protection measure the author has not yet reached any conclusions.

The RF passes via a 15pF coupling capacitor to the gate of a barrier layer FET BF247A or P8002 wired as a source follower. By varying the coupling capacitor it is possible to influence the signal level within some limits. This coupling capacitor must be able to withstand at least 500 volts so that during voltage surges the arrestor can strike before the capacitor breaks down. The operating point of the source follower is tightly determined by DC feedback to around 20mA drain current; a bootstrap circuit achieves a high input resistance without the use of high-value resistors.

A protection diode guards against negative surges on the input that would drive the Gate to Source path into breakdown; with positive surges the Gate to Source path conducts and self-limits the over-voltage. This circuitry is copied from oscilloscope preamplifiers, where it is commonly used.

In this connection it's worth recalling that a MOSFET offers no advantages in this situation since MOSFETs are significantly "noisier" in the audio and low HF regions than barrier layer FETs.

The source follower supplies a push-pull emitter follower made up of complementary transistors 2N3866 and 2N5160. The quiescent current of the emitter follower lies in the region of 30 to 50mA, so common or garden small signal transistors would be overtaxed here. A 50Ω source impedance was dispensed with, since the input of the receiver connected afterwards would normally provide this. Completing the circuitry are a remote power feed splitter and some components for smoothing the power supply to the two stages.

In view of the low component count, construction of the active antenna can be made on a scrap of experimenter's printed circuit board having a continuous ground plane. The only thing to watch is a low-capacity path for the Gate of the BF247A, since any capacity at this point creates a voltage divider between the capacitance of the antenna and the input capacitance of the source follower, reducing the voltage available. The author enclosed his prototype in a round plastic container 40mm in diameter and 50mm long, that happened to be available; a fixing for the aerial whip and the coax socket was also provided. To make the whole arrangement waterproof, the complete assembly was placed inside a length of 50mm diameter cold water piping.

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## 5. TEST RESULTS AND PRACTICAL EXPERIENCE

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Since testing antennas in true far-field conditions exceeds amateur test capabilities, the following substitute measurements were undertaken.



- The frequency range of the active section was determined by connecting a test generator directly to its 50Ω input; this showed a lower frequency limit of 7 kHz at -3dB and an upper frequency limit of 40 MHz at -3dB.
- Signal limiting set in at an output voltage of 5 volts peak-to-peak, corresponding to an output power of around 60mW.
- Output power for harmonic suppression of 60dB was determined at 10 MHz as 10mW.
- The output power for 60dB intermodulation suppression at test frequencies of 10 MHz and 12 MHz was determined as +5dBm.

The two last measurements should be treated with caution since these tests were probably more of the harmonic and/or intermodulation suppression of the two test generators.

After connecting the antenna to the author's Kenwood R2000, the following tests were made to check the correct dimensioning of the antenna.

The whip was removed and with the receiver switched on, power was fed to the active antenna. This should give rise to a slight rise in noise level. This is a sign of correct functioning of the preamplifier and adequate sensitivity of the receiver. With older, less sensitive receivers a (selective) preamplifier can be called in to lift the antenna signal above that of the internal noise of the receiver.

The second stage was to re-connect the whip and here too, a slight increase of noise should be audible on a clear frequency. This indicates, as described above, that external interference is

stronger than internal noise. If this doesn't occur, check all the voltages against those shown on the circuit diagram.

Since the antenna is designed for remote powering via the feeder co-ax, it is possible that undesirable interference from the power supply feeding the co-ax could be coupled into the antenna input; this would be detected by noticing a high noise threshold when the PSU is on but the active antenna is disconnected. In most cases (the R2000 included), an internal power source of 10 to 15V within the receiver can be used for this purpose, being led via a 1mH choke to the antenna connector. You should, however, check first whether there is DC on the antenna cable and if so, fit a blocking capacitor in the RF path.

For commissioning, the antenna was placed on the roof peak of the garage, about 10 metres from the nearest house. In practical tests on the HF amateur bands this antenna gave results practically identical to normal passive antennas, even if pure S-meter readings were more decisive.

This antenna is also suitable for long wave to short wave broadcast reception, which was noticeably less subject to interference than a long wire strung up in the vicinity of the house.

Even reception of various time signal and navigation beacons in the long wave region (such as DCF, LORAN-C and DECCA) come in at signal levels of some millivolts. A DCF or LORAN-C standard frequency device could be driven by one of these antennas.

The author hopes this article will stimulate readers to experiment for themselves and would be pleased to hear of their results.