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ACTIVE ANTENNA FOR THE VLF TO HF OBSERVER

This report is a prepublication manuscript submitted to one of the contemporary electronics magazines as part of a series on VLF-LF signal reception problems. The report presents a simple and low-cost method of fabricating an active antenna preamplifier system covering the range of 10 KHz to 10 MHz, for use with tunable communications receivers. The same type of preamplifier system can be used with airborne VLF navigation receivers.

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I. INTRODUCTION

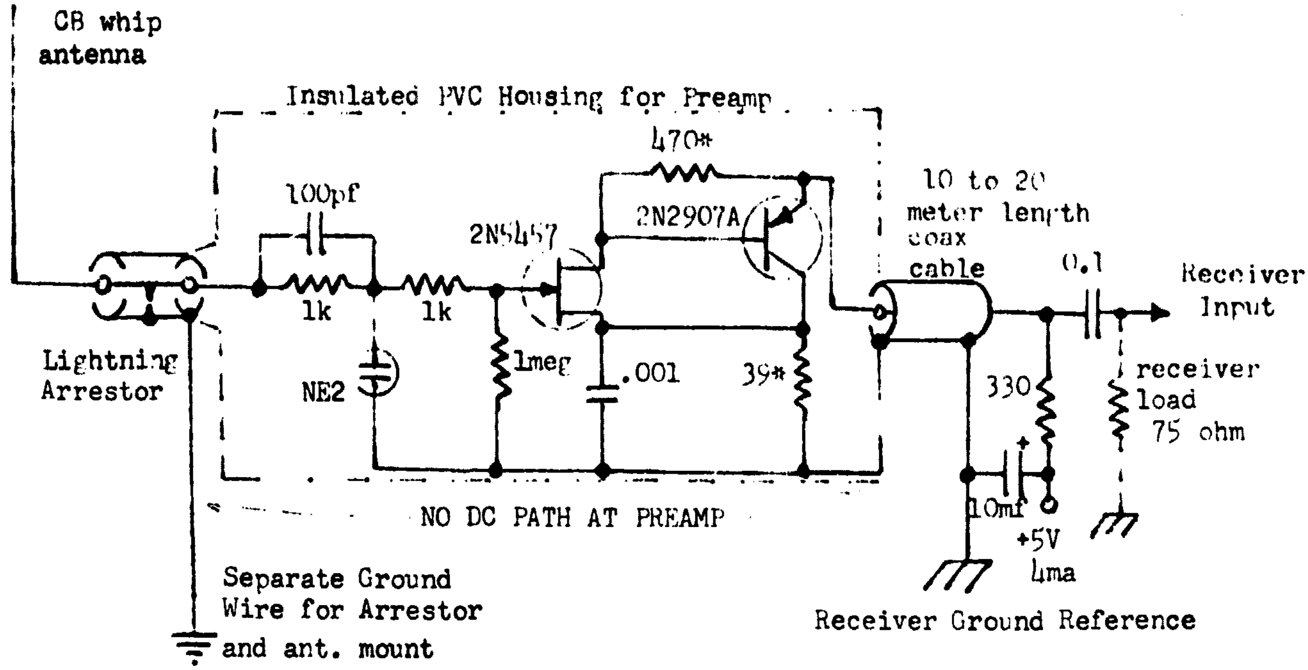
Many recent communications receivers are capable of tuning down to 10 KHz to cover the very low frequency (VLF) as well as the medium and long-wave ranges below 1 MHz. If you try to connect up a random wire to the receiver antenna input terminal to check reception in these ranges, severe local 60 Hz, harmonic noise is often all that is heard. In order to obtain satisfactory reception from a wire antenna below 500 KHz, it is very desirable to place the antenna as high as possible and to minimize the capacitance to ground at the antenna. A long wire antenna parallel to the ground usually picks up much more variable ground current noise than signal. One way of solving the problem is to fabricate a high-impedance preamplifier and operate it as a wide-band device directly at the base of a short vertical antenna. In this way, we can drive the signal back to the receiver on a length of coaxial cable and place the antenna up high, well away from local ground current noise sources. Some commercial active antenna systems operate this way, but they are quite expensive at the present time. The antenna can be as short as 1 meter and still give excellent results when the capacity to ground at the antenna is low.

We have experimented with dozens of active antenna systems in an attempt to come up with a really low-cost solution to the problem. There is no foolproof method of receiving low-frequency signals in a very noisy urban environment, but if you happen to be located such that you do not have too much power line and ground current 60 Hz noise, then an active antenna system can provide good results.

II. PREAMPLIFIER CIRCUIT

A circuit diagram and frequency response plot of one method of providing an active antenna system is illustrated in Figure 1. This circuit covers the range of 10 KHz to 10 MHz or so. A low I_{DSS} spec JFET is chosen as the input active impedance converter driving an emitter follower with power for the preamp coming up the same coax cable that provides signal back to the receiver. It is very important to isolate ground loops from this circuit by insuring that the coax cable provides the only ground return for the DC power to the preamp. Parallel ground currents such as flowing from an antenna mast can create severe intermodulation distortion due to poor system joints and leakage effects.

A PC board layout for the preamp is illustrated in Figure 2. Here a narrow board is designed to be inserted in a short length of 1/2 inch PVC water pipe which provides both weather protection and insulation of the preamp from the whip mount and lightning arrestor. The preamp has additional protection in the form of a neon bulb which will fire at about 70V peak. This is sufficient to keep the JFET from burning out in most cases. Thin-wall brass tubing of the type available at model airplane and model railroad hobby shops is used as short male connectors in the 5/32" diameter size to just fit UHF type coax fittings. At the cable end the large ground pads are soldered to the shell of a PL258 double female connector and the 5/32" tubing soldered to the center of the board by cutting 1/8" deep slots with a jewelers or fret saw in the board as indicated. The antenna end is similarly provided with a brass tube center fitting but is not grounded to anything. The PVC tubing is hand turned onto the PL258 cable end and held in place with silicone



GENERAL CHARACTERISTICS OF ACTIVE ANTENNA SYSTEM

Effective antenna height	30 to 50 cm
Bandwidth with CB whip	10kHz to 7 MHz
Voltage Gain	0 to +3db
Dynamic range	0.2 to 100,000 µv rms
Input Z	300kohms//70pf(lightning arrestor in place)
Internal overload protection	70V peak pulse

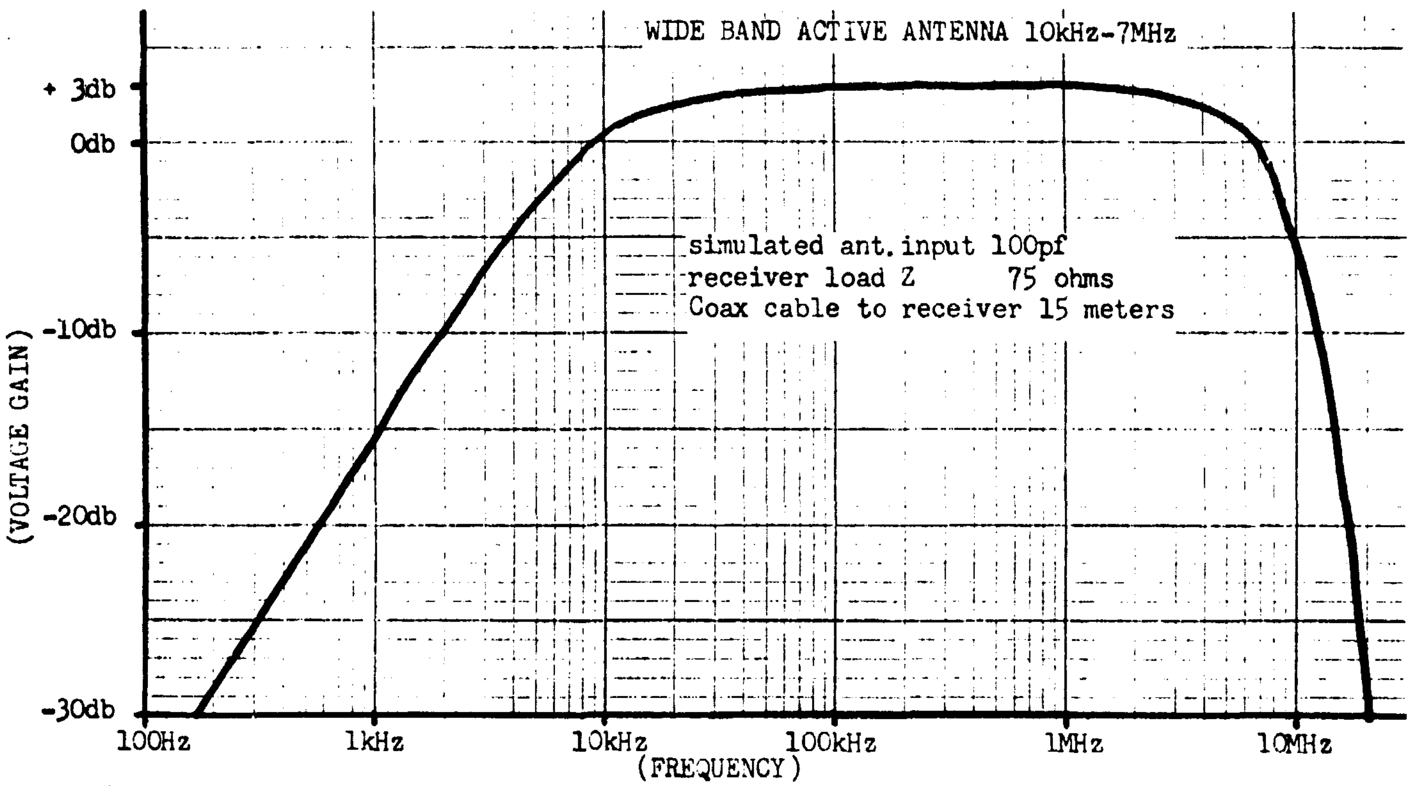
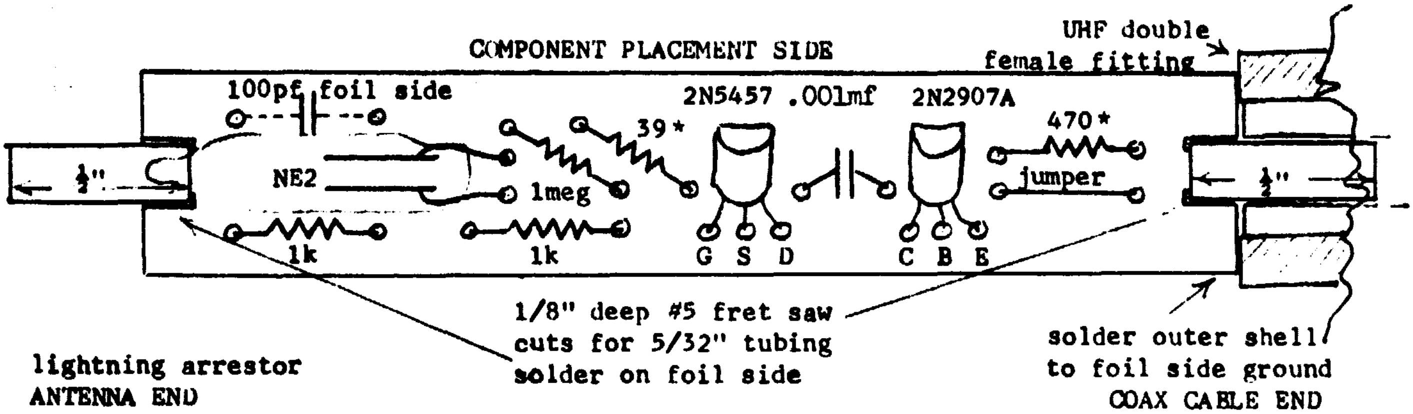


Figure 1. General Characteristics of Active Antenna System.



Finished preamp mounted inside 3 3/4" length of ½" PVC pipe housing with silicone cement sealer at ends.

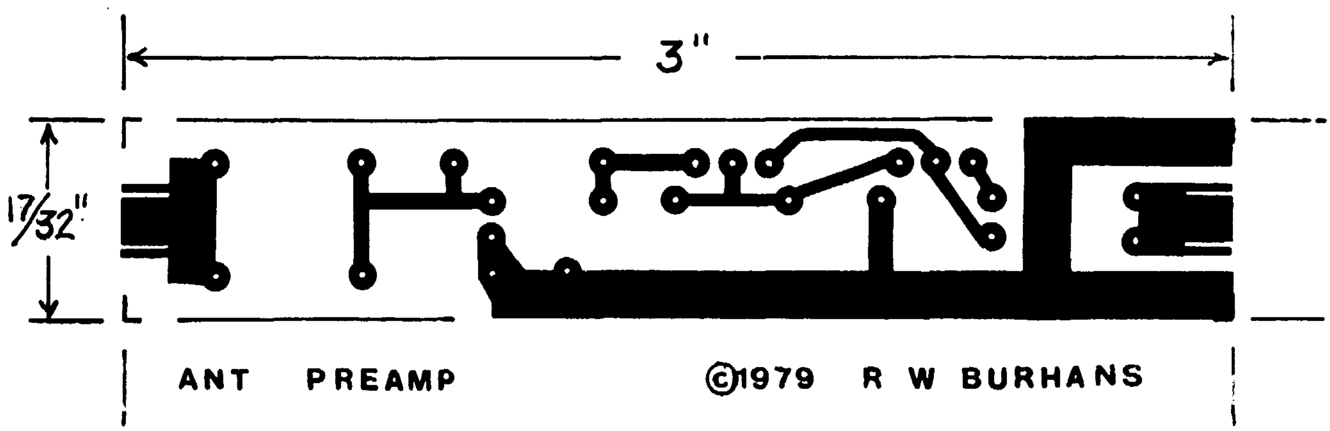


Figure 2. A PC Board Layout for the Preamp.

sealer compound placed on the threads. The final assembly is provided with a lightning arrestor of the inline coaxial type which is screwed into the opposite end with similar sealing of the threads using silicone sealer compound. This makes a very compact assembly for connection to a UHF fitting at the base of the whip antenna. The antenna must, of course, be of the ungrounded type. If you have trouble finding a suitable mount, a mobile mount can be modified with a very short (2-4") length of cable to the protective lightning arrestor. Try to keep the capacitance of the whip antenna to the mount at a minimum. The capacitance of the lightning arrestor to the outer shell is about 15pf or so, which starts to degrade the performance of the preamplifier at frequencies above 10 MHz. The total capacitance at the input with the lightning arrestor in place connected to a CB whip will typically be 70pf or more. This limits the frequency response as well as the choice of transistors used.

III. SUGGESTIONS

The JFET was chosen for low cost and ready availability as well as a low current spec. In initial testing of the preamp, it is wise to tack temporarily the (*) marked resistors with long leads to the circuit board and test the amplifier. With a fixed 33 ohm or 39 ohm resistor at the 2N2907 collector lead to ground, change the other 470 ohm resistor marked (*) over the range of 470, 560, 680, and 820 ohms until the amplifier exhibits unity gain or higher at a test frequency of 100 KHz or so, coupled to the preamp input through a temporary 100pf capacitor from your signal generator. A 100 mv signal from the generator should give 100 mv at the receiver 75 ohm load with a scope display, and power applied as in the circuit of Figure 1. If a particular 2N5457 JFET cannot be adjusted for at least unity gain at the receiver load, then reduce the value of the 39* resistor to something like 27 ohms. The amplifier operates best with a power supply of +5V from a regulator which might be easily obtained directly from the receiver through a dropping resistor and low current 5V regulator chip such as the 78L series. Some sort of minibox housing for the receiver input circuitry and power decoupling resistor-capacitor with a coax connector for the antenna cable should be fabricated, or the whole power input assembly might be built into your receiver rear antenna terminal with a suitable changeover switch arrangement.

IV. PERFORMANCE

The preamplifier has been evaluated on a number of VLF to HF receivers over the range from the 10.2 KHz Omega navigation band up to 10 MHz WWV. It is difficult to prevent overload or cutoff of the amplifier from nearby strong transmitter sources which generate many volts of RF at the antenna terminal. However, the preamp will not burn out except possibly in the most severe "act of God" case of a direct lightning hit on the antenna. This active antenna system can provide many hours of listening pleasure in the low and medium frequency ranges including overseas DX. We regularly receive Hawaii, Japan, Germany, Great Britian, and sometimes the USSR in the VLF range between 10 KHz and 100 KHz.[1] There are thousands of signals in the beacon range between 150 KHz and 500 KHz worldwide. It really does not take much in the way of an antenna to receive this <u>if</u> the antenna is located in a relatively noise-free place, and mounted up as high as possible to minimize capacitance to ground. A vertical whip is far superior to a horizontal wire when used with this active preamplifier. The whip inherently has more effective capacitance to the free space electric field of the signal and less capacity to noisy harmonics radiating from the ground. Figure 3 is an example of VLF reception.

The circuit board of Figure 2 may be used for other types of transistors and can even be operated substituting an NPN type for the 2N2907 (by reversing the E-C leads). In this case, the (*) marked resistors are juggled around to provide a feedback voltage amplifier instead of an emitter follower, which will also drive a length of cable back to the receiver. In general, we feel that the circuit shown is better because it is less prone to intermodulation distortion caused by strong nearby transmitters.

If the receiver does not have a low impedance (50 to 75 ohm) antenna terminal, it may be wise to place an additional 100 ohm or so resistor across the receiver antenna terminal to help stabilize the amplifier. 50 or 75 ohm cable may be used.

V. PARTS LIST FOR PREAMPLIFIER

Quantity	Item
2	1k ohm ¼w carbon resistors
1	1 megohm ¼w carbon resistor
1	39* ohm ¼w carbon resistor (selected from 27 to 47 ohm)
1	100pf 500V ceramic disk
1	.001mf 50V ceramic disk
1	470* ohm ¼w carbon resistor (selected from 470 to 820 ohm)
1	2N5457 N-type JFET transistor (* resistors selected for I_{DSS})
1	2N2907A PNP general purpose transistor
2	1/2" long, 5/32" OD, 1/8" ID thin brass tubing for male connections to UHF-type fittings
1	PC board
1	NE2 neon bulb for gross overload protection

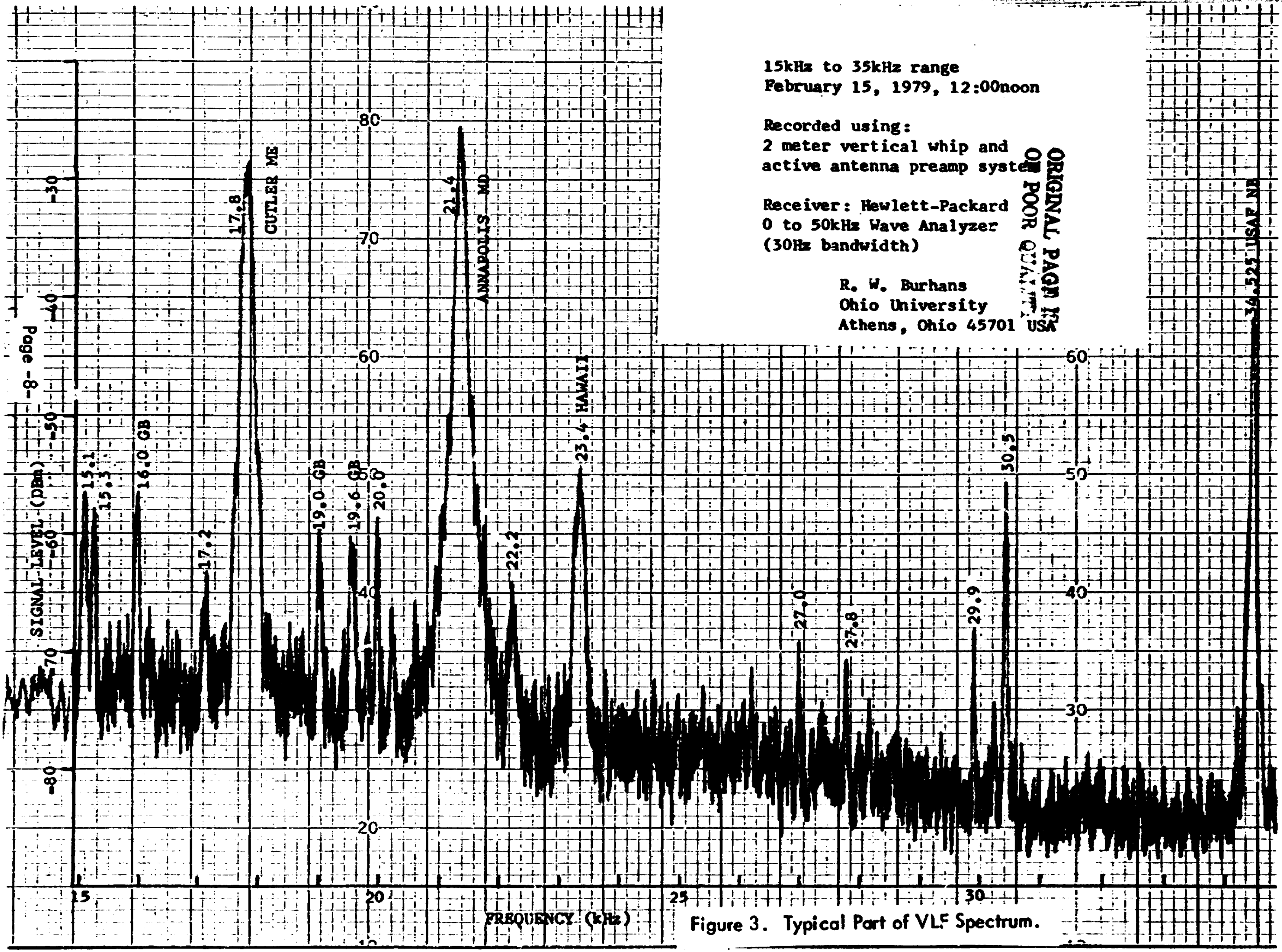


Figure 3. Typical Part of VLF Spectrum.

VI. ADDITIONAL PARTS REQUIRED TO ASSEMBLE ACTIVE ANTENNA

1	Insulated mount for standard CB-type whip such as RS - 21-950 for 3/8"-24 thread whip to 3/8" hole
1	Standard CB 102" whip with 3/8"-24 thread such as RS - 21-905
1	Coaxial lightning arrestor similar to RS - 21-1049
1	3-3/4" length of 1/2" PVC black water pipe (housing for preamp)
1	Double female UHF fitting like PL-258 or RS - 278-1369
and:	Length of coax cable with UHF cable fittings to receiver input.
	Ground wire and rod for lightning arrestor ground - separate from coax cable shield return at the receiver.
	Suitable vertical mast hardware to mount antenna whip with U-bolt brackets, etc.
	5V regulated source with isolating resistor-capacitor at receiver and coax fittings at receiver end of circuit.
	Silicone sealer for preamp housing assembly, solder and misc. wire.

VII. ACKNOWLEDGEMENT

The material presented here is an additional application of methods developed for low-cost VLF navigation receivers for the general aviation community, supported by NASA Langley Research Center, Grant NGR 36-009-017.

VIII. REFERENCE

[1] Longwave radio listeners may obtain information on frequencies and activity in the bands by subscribing to:

The Lowdown (Newsletter of the Longwave Club of America)
Box 33188
Granada Hills, California 91344 USA

subscription rate: 12 issues $6/year USA, $12/year overseas airmail.