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TECHNICAL MEMORANDUM (NASA) 53

CIRCUIT METHODS FOR VLF ANTENNA COUPLERS

A summary of E-field antenna preamplifiers developed during the course of the NASA Tri-University Program studies on VLF methods for general aviation is presented. The circuit techniques provide useful alternative methods for Loran-Omega receiver system designers.

(NASA-CR-155036) CIRCUIT METHODS FOR VLF
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by

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I. INTRODUCTION

A variety of circuit techniques have been used as antenna couplers or preamplifiers for Loran-Omega receivers with E-field antennas. No one method is best for all-purpose use. The limitations of different circuits are briefly presented to aid system designers in future development of antenna systems for time-frequency monitoring or navigation receivers. All of the circuits have been evaluated on actual Loran or Omega signals. Electric field whip or wire antennas are the simplest types which can be used for reception of VLF signals in the 10 to 100 KHz range. JFET or MOSFET transistors provide impedance transformation and some voltage gain in relatively simple circuits where the power for operating the preamplifier uses the same coaxial cable that feeds the signal back to the receiver.

II. GAIN-BANDWIDTH CONSIDERATIONS

Most all preamplifiers provide power gain in that they convert a signal appearing on an antenna at a high impedance point to a lower impedance for driving a cable connected to the main receiver system. They may also provide some voltage gain and restricted bandwidth. Some designers like to use a very wideband system so that a single whip or blade antenna can be used to drive a variety of different receivers from the same source with suitable isolation. However, this can create problems in cross-modulation and interference depending on the details of the receiver input circuit such as for narrow-band Omega VLF reception. On the other hand, Loran-C receivers usually require a wide-band performance since the time interval measurement precision depends on the RF bandwidth for pulse signals. The RF voltage gain available is usually greater than 0 dB, but is not necessarily high because the atmospheric noise is limiting and not the receiver input circuit noise in determining the ultimate sensitivity of a particular system.

III. CIRCUITS

Figure 1 illustrates a low-noise MOSFET transistor which can provide very high input impedance. One problem with MOSFET's is that they are more susceptible to static discharge problems which cause burn-out due to high voltages induced on the antenna from nearby lightning discharges. A lightning arrester and series current limiting resistor are often used directly at the antenna input terminal.

Figure 2 is probably the simplest type that will work with low gain for most any JFET used. A capacitor across the source resistor inside the preamplifier box can be used to increase the gain and alter the frequency response. There will be an output phase shift due to the cable capacitance in parallel with the drain load resistor in the main receiver, but this is of little consequence in single channel VLF monitoring applications. A lower value of resistor connected at the antenna (100 K) directly to ground provides some measure of protection and a rapid discharge path for precipitation static problems.

Figure 3 is still another variation where some special high frequency zener diodes are used as a protective device. This version also provides an auxiliary output to drive a second LF or BC band receiver from the same antenna preamplifier. A difficulty here is

the additional phase shift caused by the input series limiting resistor from the antenna in the 200 KHz band and above.

Figure 4 is an improved version of the preamplifier originally used with the Mini-O system as described in BYTE magazine, March 1977. This design by Hank Olson of SRI, uses a special wound tunable pot core transformer which can be adjusted to tune the 10 KHz to 20 KHz VLF band. A bypassed emitter resistor improves the performance by adjusting the operating point of the output transistor in the linear region. This is superior to the original Mini-O preamplifier which depended on the audio transformer DC resistance and load resistor in the receiver for current limiting.

Figure 5 also provides two output signals, one for the VLF band, and another for the LF 100 to 400 KHz band. Here a very low value of current limiting resistor at the antenna input is required if the goal is to provide a low phase shift at the 400 KHz region as in ADF sense antenna applications. Where low phase shift at 400 KHz is not a problem, a higher value of input resistor such as 1K to 2 K would be recommended for additional protection. The output coupling transformer used is a low-cost audio type available from Mouser Electronics, 11511 Woodside Ave., Lakeside, CA 92040. UTC subminiature DIT or DOT types can also be used. The 100 ohm emitter resistor (or larger values) is used to adjust the gain of the circuit and a 10 mh inductor provides some bandpass peaking for the VLF output port. If the 10 mh coil is eliminated, the bandwidth of the circuit at the VLF port can be increased up to 100 KHz or so, or limited by the particular audio transformer used.

The typical response of the circuit in Figure 5 is illustrated in Figure 6. When measuring the performance of any of these circuits, the signal generator should be coupled to the input antenna terminal through a small series capacitor to simulate the use of a whip or wire antenna which will have a capacitance of 30 to 100 pf.

Figure 7 is a ground isolating system for driving an antenna preamplifier from a power supply which is independent of the DC ground used in the VLF receiver. This circuit reduces ground loop problems that often obscure VLF signals in urban monitor situations where 60 Hz AC line harmonics are very strong. Some commercial VLF receivers use a balanced coaxial (twin-ax) line and balanced output transformers to help eliminate common mode AC ground loop signal pickup problems. The circuit of Figure 7 may be used single-ended by placing a resistor load (600 ohms) across the unused output terminal and still provide some degree of isolation.

A wideband preamplifier of the circuit in Figure 8 is useful for many Omega and Loran-C receivers. The circuit should be adjusted for the particular JFET used (such as the 2N3819 or MPF 102 types) since they will have a considerable spread. Particularly, the values of the source and drain resistors (330 ohm and 680 ohm as shown in Figure 8) should be adjusted for the best linear operating point. This can be determined by coupling a signal source to the input terminal through a small coupling capacitor and observe the output signal on an oscilloscope. With a fixed 470 ohm to 680 ohm drain load resistor, increase the value of the source resistor for the widest dynamic peak-to-peak amplitude of signal with minimum distortion. The gain and low end frequency response may be adjusted

with the source bypass capacitor. The upper cutoff frequency is determined by the series input resistor from the antenna and the cable capacitance (reactance) in parallel with the output drain load resistance.

IV. RECOMMENDED PREAMPLIFIER FOR MOST VLF SYSTEMS

A JFET preamplifier provides impedance transformation from an E-field whip or wire antenna to a 600 ohm line level sufficient to drive a short length of coaxial cable to the receiver. A circuit is shown in Figure 9. There is a slight phase shift due to the cable, but this can be ignored in most cases since it is a constant. Power for the preamp comes up the same coax cable. In some installations, cable ground loops and common mode 60 Hz noise may be a problem. A modification of the preamp output to drive a balanced, shielded transmission line is shown in Figure 10. This requires an additional transformer at the receiver end to extract the signal. The output transformer tap may be grounded and used to drive two separate receivers such as a Loran-C and a VLF receiver as shown in Figure 10.

The use of a 600 ohm line audio transformer as an output coupling device provides a low pass filter for Loran-C and VLF signals. This is an advantage since it tends to reduce cross-modulation and noise effects in the main receiver caused by broadcast band, LF beacons, or shortwave transmitters. The particular transformer used will pass frequencies to about 300 KHz but the upper cutoff may be changed by the capacitor (Figure 9) as illustrated to restrict the range for different Loran-C or Omega VLF uses. The 1K series input resistor and shunt diodes at the JFET gate terminal provide a measure of static discharge protection during local thundershowers and also help prevent JFET burnout due to nearby high-power transmitter sources on other frequencies.

V. ANTENNAS

Antennas can be anything from a 1 meter vertical whip to a wire of 10 meters or more with best performance obtained when the antenna is mounted in the clear. A vertical antenna is best but quite satisfactory performance is obtained from one run slant-wise such as from an insulated pole on a roof-top down to a window feed-thru insulator at the preamp. Precipitation static is a problem in aircraft installations. Semiconducting coatings on the wire help reduce this and often a coated blade type of capacitive antenna is used mounted on the bottom of the aircraft near the tail. Dry blowing snow and some rainstorms also produce precip static in ground installations which can be recognized with an audio monitor as a slow build-up of a buzzing sound with sharp crackle noises sweeping through the audio spectrum at different repetition rates.

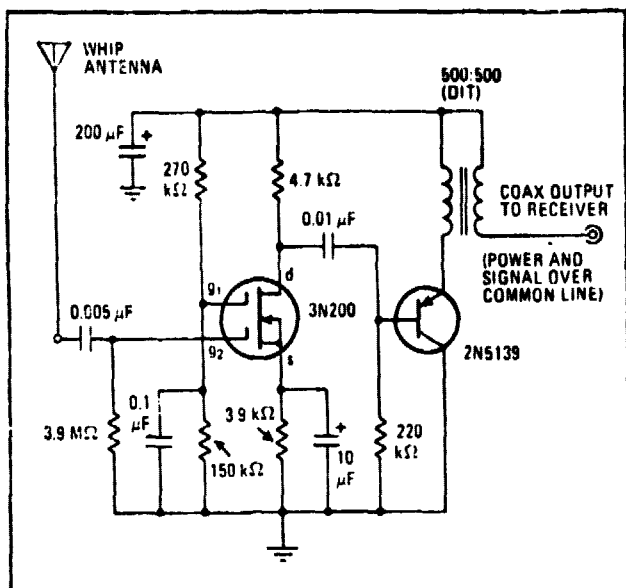
VI. CIRCUIT BOARDS

Printed circuit board layouts have been prepared for the designs of Figures 8 and 9. Both of these systems can be placed on a small board (1" x 2") which is easily mounted in a weatherproof housing with feedthru insulator for the antenna and a coaxial cable

receptacle for connection back to the main receiver system. The boards are available separately to interested experimenters. Inquire to: R.W. Burhans, 161 Grosvenor Street, Athens, Ohio 45701.

VII. ACKNOWLEDGMENTS

These circuit techniques have been developed under the NASA Tri-University Program in air transportation for the general aviation community which has emphasized low-cost VLF methods. The program has been sponsored by NASA Langley Research Center, Grant NGR 36-009-017.



10. Front end. A low-cost front end for a simple Omega receiver uses a dual-gate MOSFET preamplifier located at a whip antenna as here. The preamplifier receives its power through the coaxial cable up to several hundred feet long, connecting the preamp to the rest of the receiver. Two stages of ceramic filters turned to the Omega center frequency set up the signal for an integrated-circuit limiter-detector, which squares off the signal and also provides a measure of signal amplitude for subsequent use in gating circuits. Finally, a comparator circuit senses the zero crossings and provides pulses to be decoded in the phase-measurement circuits.

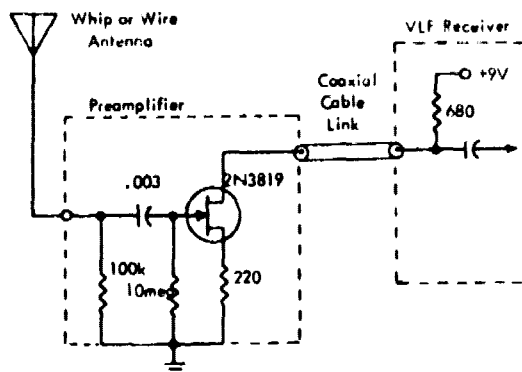


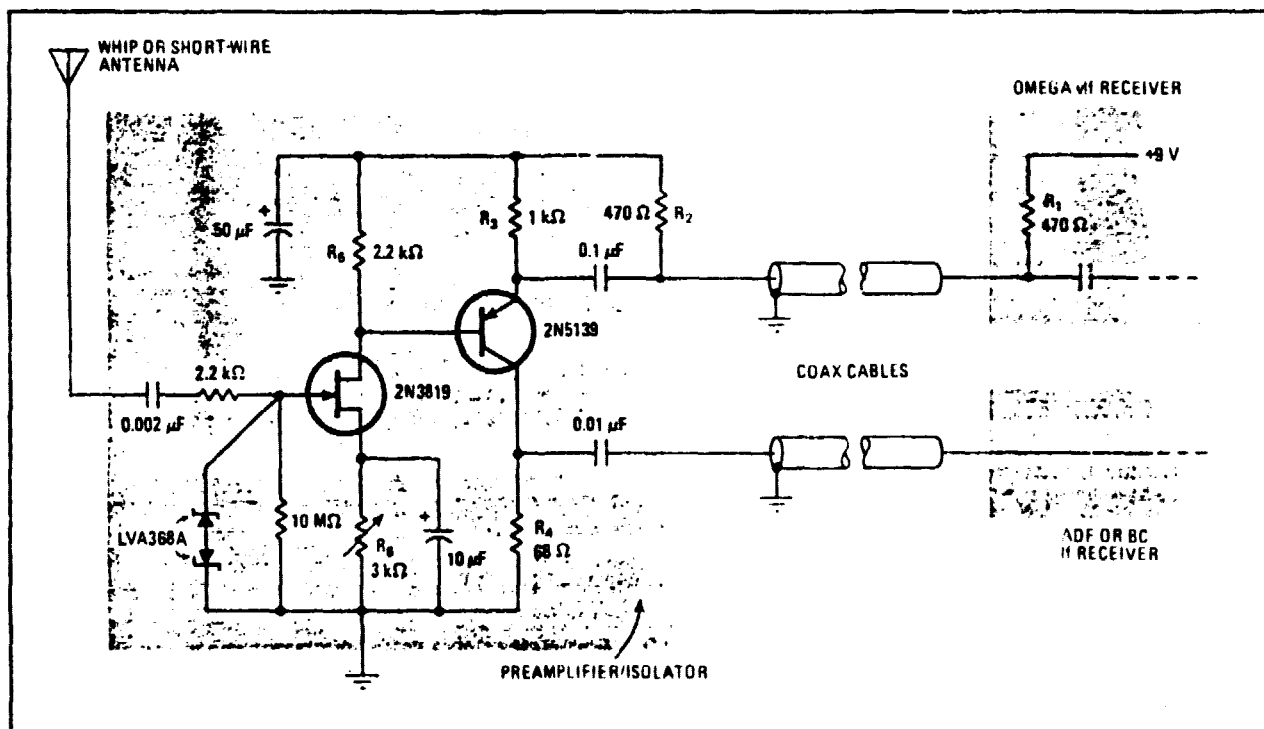
Fig. 2. Simplest VLF preamplifier.

R. Burhans IEEE Trans. IM-26
p 71, March 1977

Figure 2

R.W. Burhans, ELECTRONICS
page 104, Sept. 5, 1974.

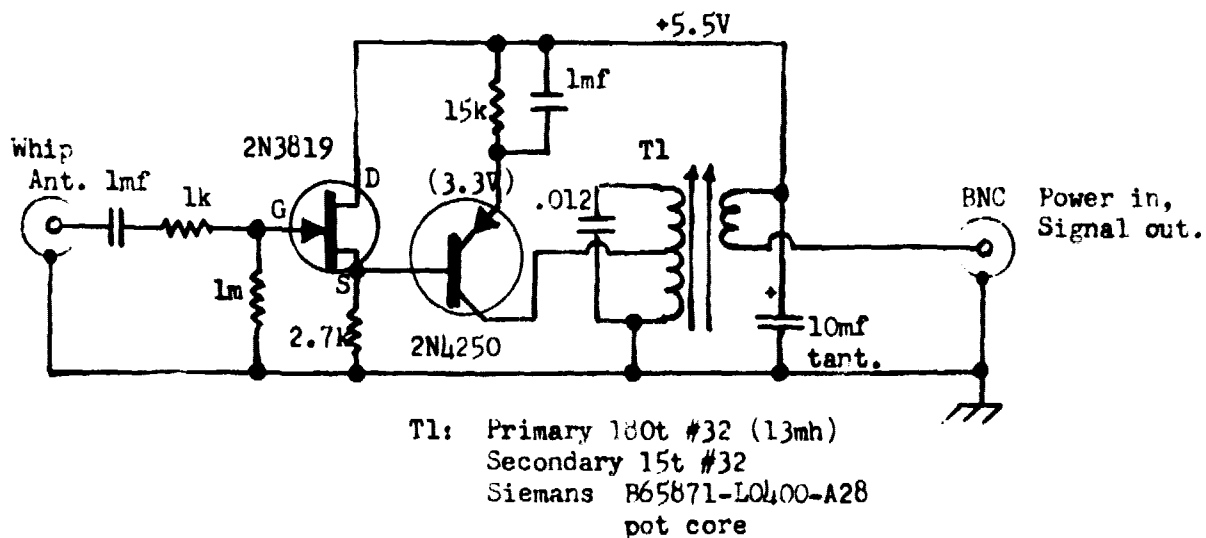
Figure 1



Dual-purpose front end. Preamplifier/isolator circuit, fed by a single antenna, drives a vlf navigation receiver and an if broadcast-band or automatic-direction-finder receiver. The two receivers are connected to the preamp by separate coaxial cables that can be as long as 100 feet. Circuit is designed for small general-aviation aircraft, so size, weight, and cost are minimized and ruggedness is emphasized.

R. W. Burhans, ELECTRONICS page 107, Sept. 4, 1975.

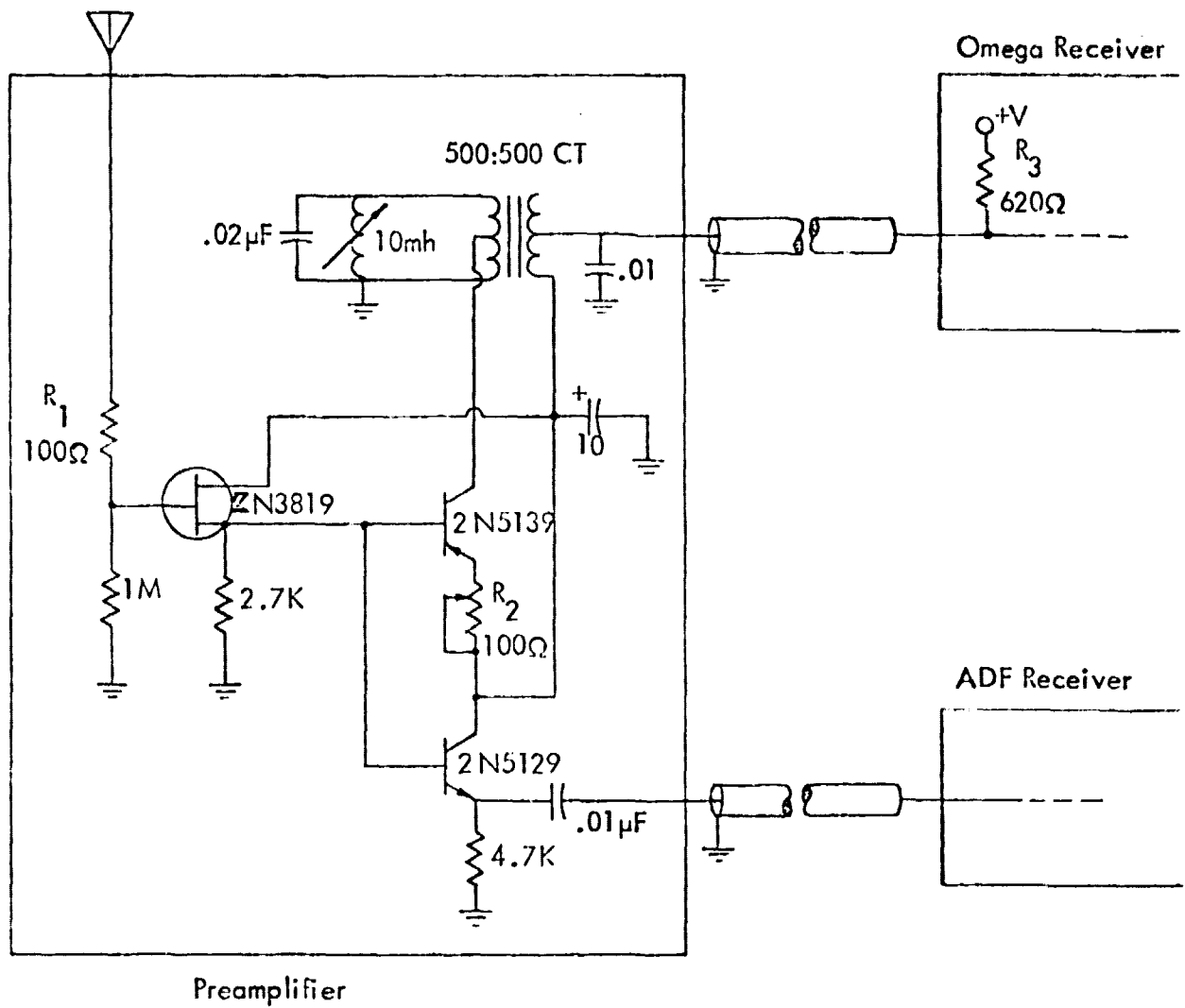
Figure 3



OMEGA REMOTE PREAMPLIFIER

design by: Hank Olson (W6GXN)
 Senior Research Engineer
 Radio Physics Laboratory
 Stanford Research Inst.
 Menlo, Park, CA 94025

Figure 4



Dual Purpose Preamplifier with Tunable Filter

Figure 5

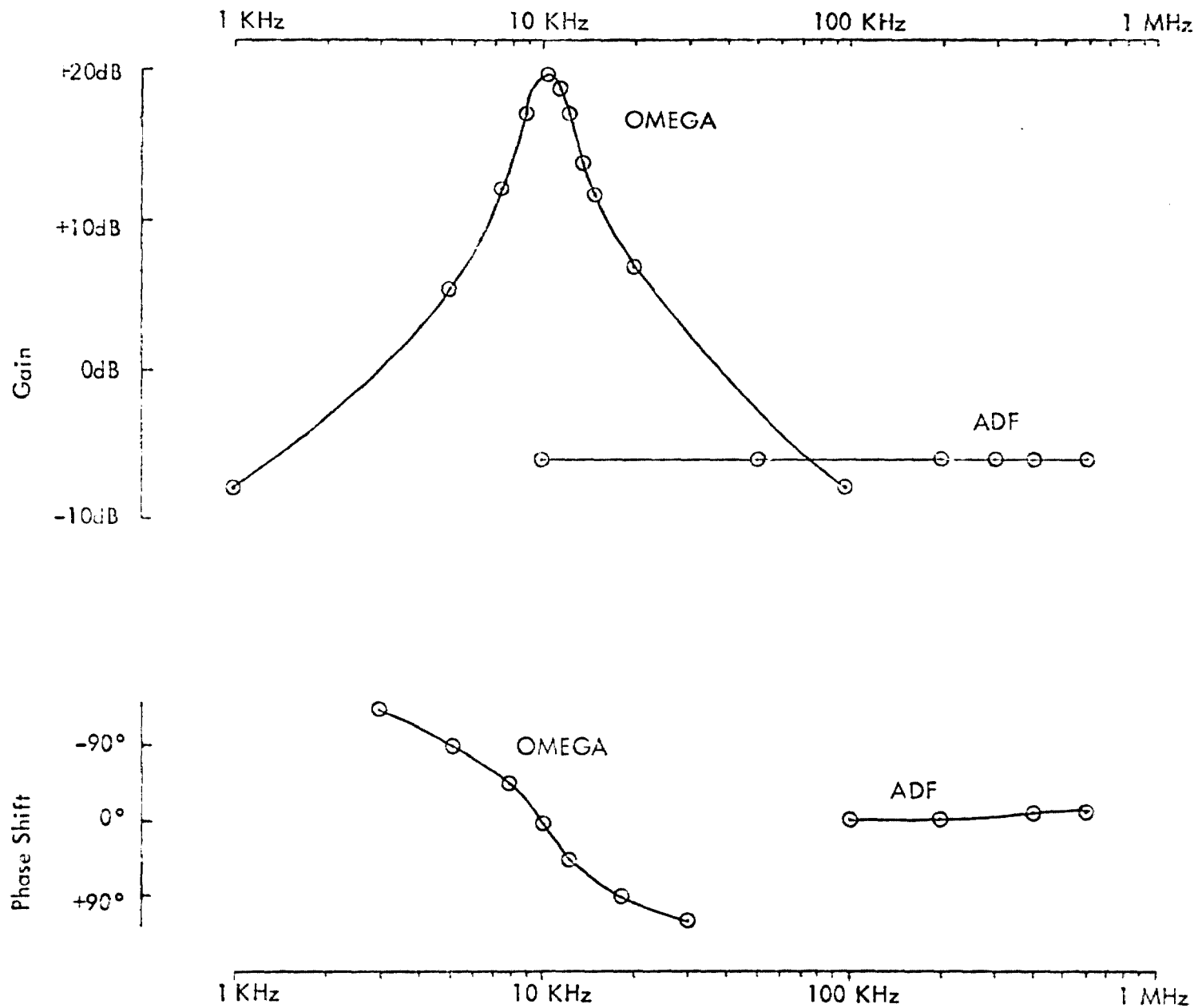
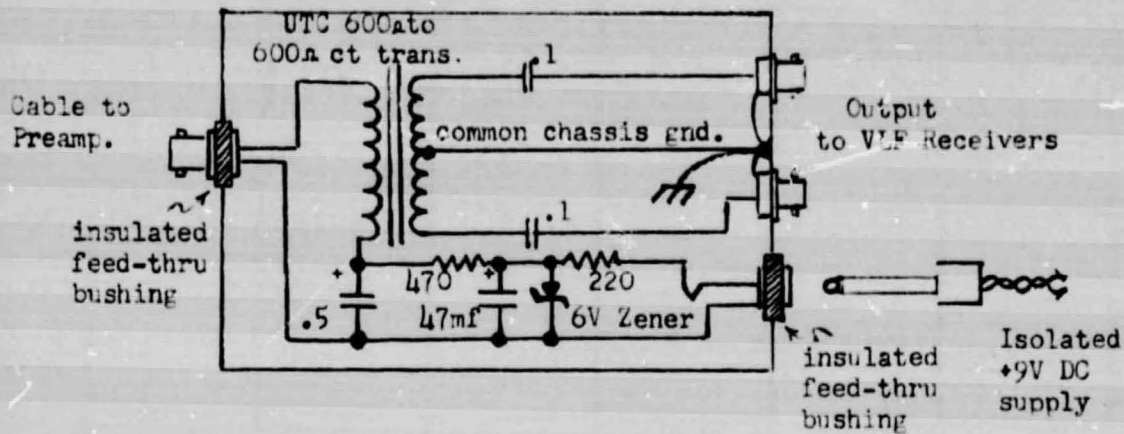


Figure 6. Preamp Characteristics.



ANTENNA CABLE GROUND ISOLATOR

Circuit to reduce 60Hz line interference and stray ground loops for single-ended coaxial cable from preamplifier. Provides independent isolated (ungrounded) power to preamplifier and normal house ground at receiver.

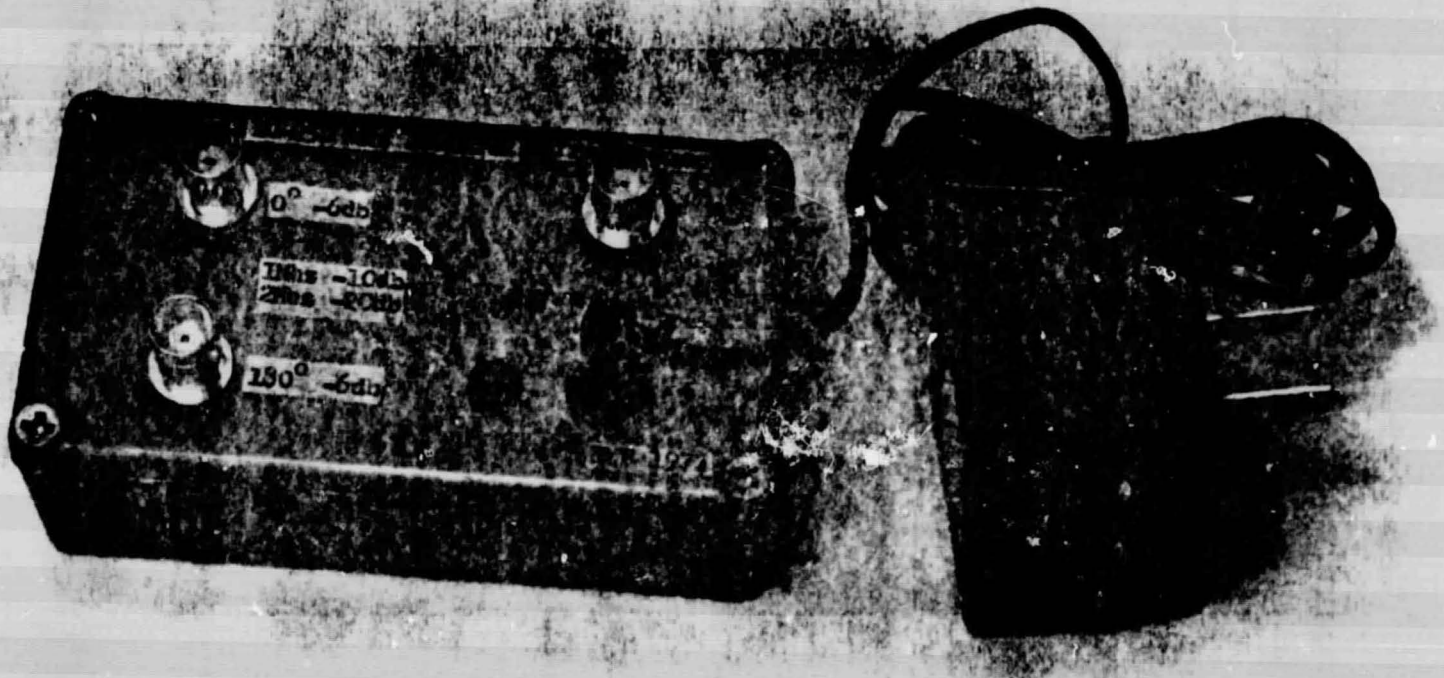
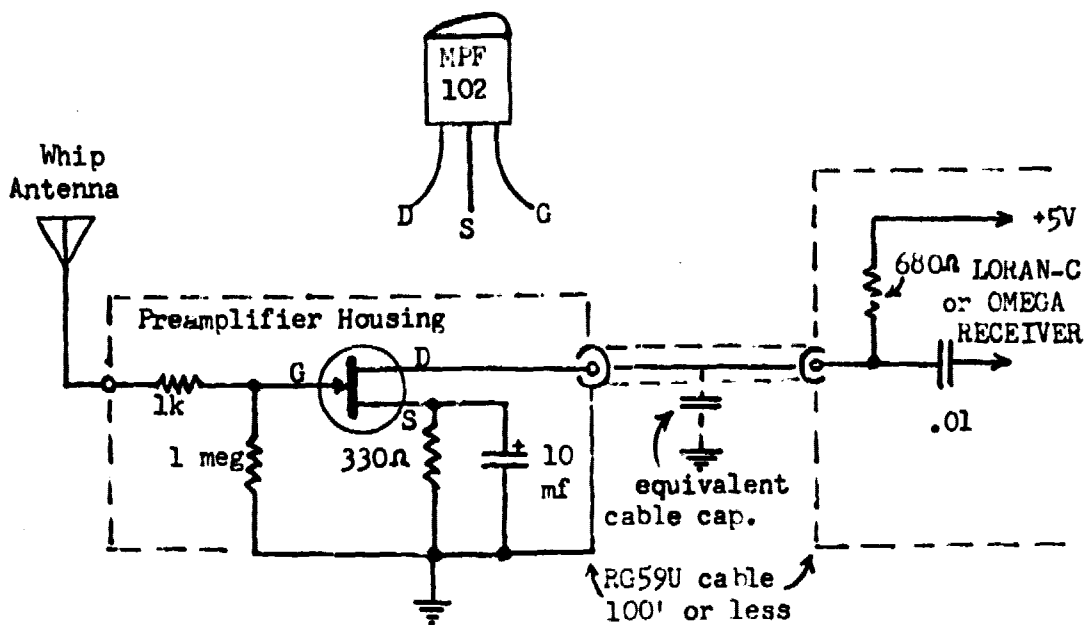
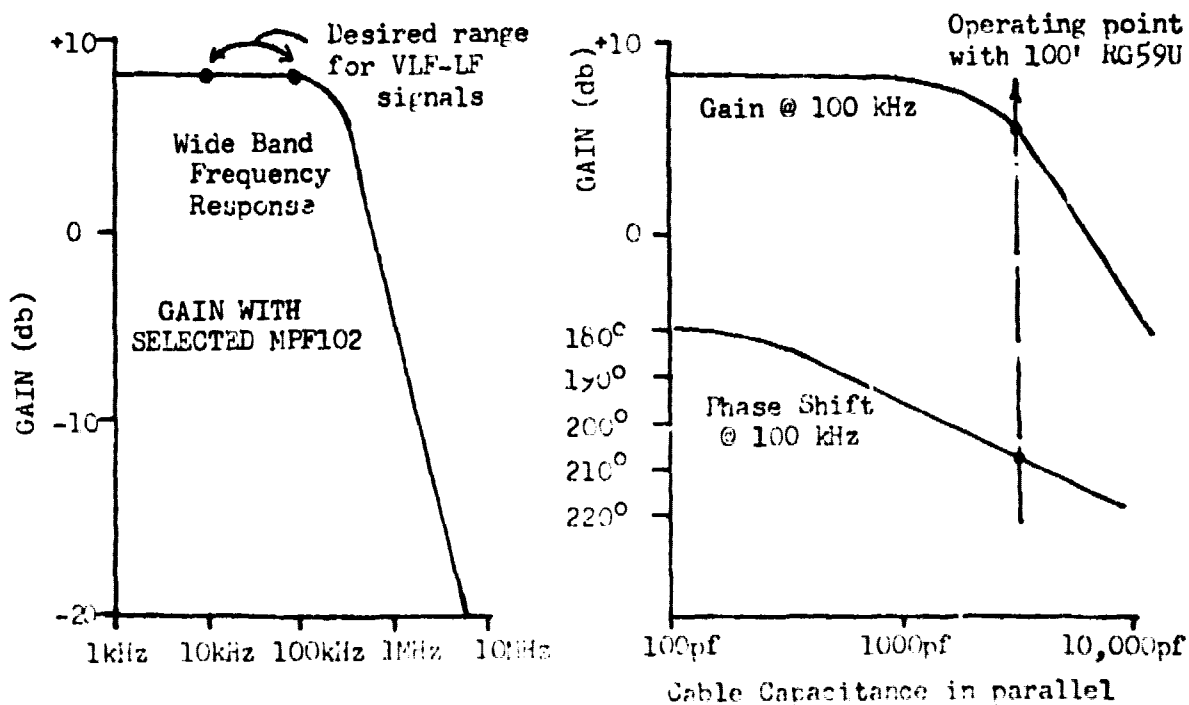


Figure 7



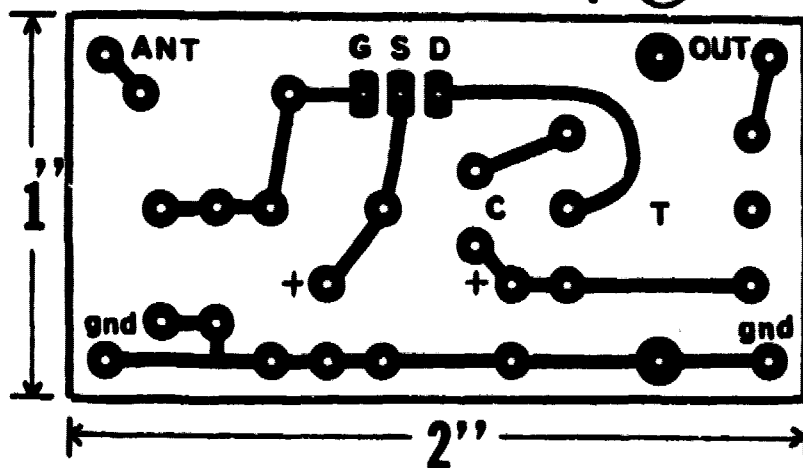
PREAMPLIFIER CIRCUIT



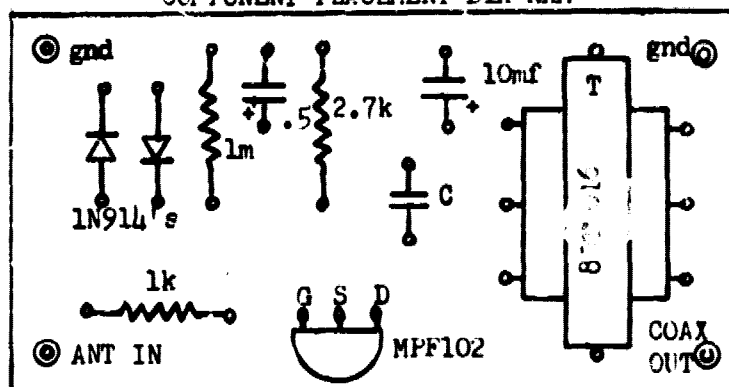
PREAMPLIFIER RESPONSE

Figure 8

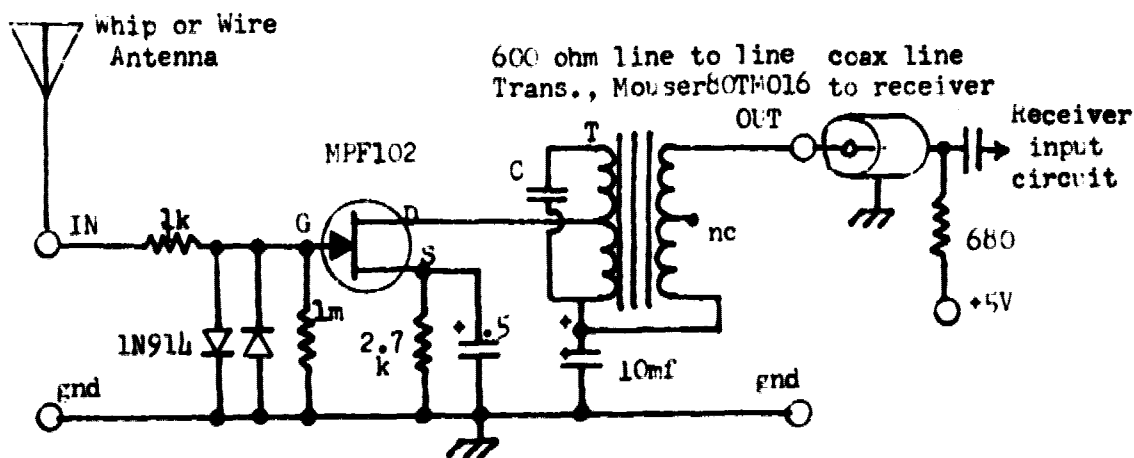
Mini-O, Mini-L Preamp ©1977



COMPONENT PLACEMENT DIA RAM

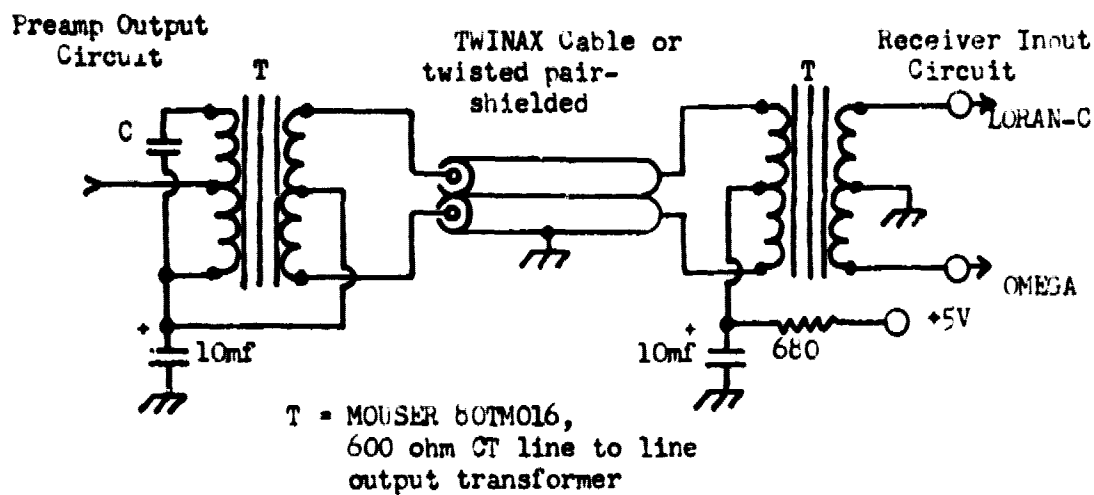


Input impedance 1 megohm
 Output impedance 600 ohms
 gain +1 to +3 db
 Bandwidth 3 to 300 kHz , no C
 3 to 130 kHz , C = 500pf
 3 to 30 kHz , C = 5000pf



VLF PREAMPLIFIER CIRCUIT

Figure 9



COMMON MODE GROUND LOOP NOISE REDUCTION METHOD

Figure 10