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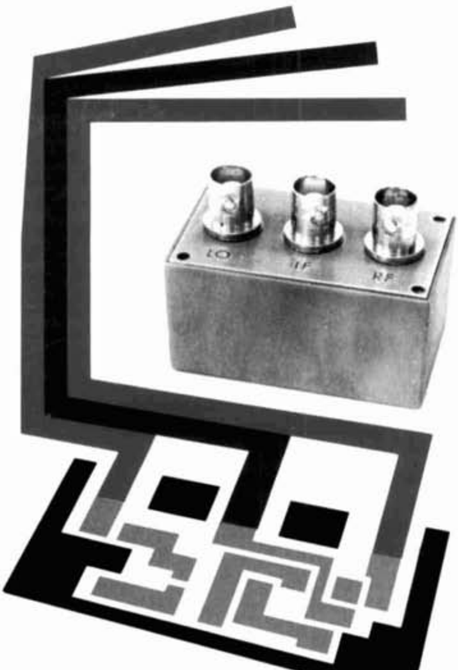
ham radio

magazine

MARCH 1970



BROADBAND DOUBLE-BALANCED MODULATOR

this month

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So let's look at the NCX-1000, starting with the double-conversion, solid state receiver. After the received signal is processed by a double-tuned preselector, a stage of RF amplification, and another preselector, it is applied to the first mixer for conversion to the first IF frequency. The first IF contains passband filters and a stage of amplification. A second mixer then converts the signal to the second IF frequency for additional processing by a 6-pole crystal-lattice filter and four IF stages. Finally, the signal is detected and amplified by four audio stages. The unparalleled high dynamic range lets you tune in weak stations surrounded by strong interfering signals. The result? High performance for SSB, AM, CW, and FSK. Sensitivity of 0.5 EMF microvolt (for a 10 db S+N/N ratio).

In the transmitter you'll find three stages of speech amplification followed by a balanced modulator, a crystal-lattice filter, a filter amplifier, and an IF speech processor (clipper). A mixer converts the signal to a first IF frequency for processing by two crystal passband filters, and two IF amplifiers. A second mixer converts the signal to the transmitting frequency where it is amplified in five RF stages before it gets to the grid of the 6BM6 driver. Final power amplification takes place in a forced-air-cooled 8122 ceramic tetrode which feeds the antenna through a pi network. Other features? You bet! Grid block keying for CW. Complete metering. Amplified automatic level control (AALC).

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ham radio *magazine*

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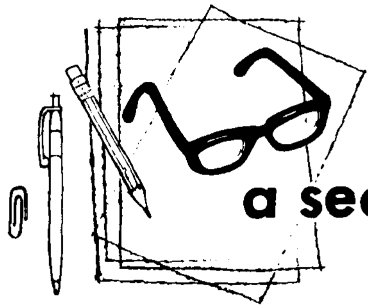


a second look

by jim fisk

If your main interest in ham radio is experimenting, you've probably tried all the published solid-state circuits plus some ideas of your own. Here are some suggestions for the experimenter who's run out of new fields to conquer in semiconductor applications.

Of the many devices on the market, few offer more interesting possibilities than the photodetectors. These emit a current in response to photon impingement, and have a spectral response determined by the energy band gap in their semiconductor material. Photodetectors with response in the infrared are especially interesting. In addition to their use as detectors in pulsed light-beam communications, they can be used in optical-electronic instruments for astronomy experiments.

Astronomers throughout the world are interested in obtaining data from amateurs as well as professional observers. Here's an opportunity to contribute to science and broaden your technical background as well.

Data is needed on the behavior of certain stars known to emit infrared radiation. Some of these stars are surrounded by gas and dust clouds. Much of their energy is absorbed by the dust and reradiated at longer wavelengths. Measurements at these wavelengths help clarify how the dust is distributed around the stars, thus providing clues as to their evolution.

A typical photometric system uses two in-line arrays of germanium bolometers with interference filters. To reduce noise equivalent power, detectors and filters are cryogenically cooled. Each detector looks at an optical telescope through a small-diameter focal-plane diaphragm. The filter for the first detector has a typical passband of 10-20 microns; that for the second detector has a passband of 25-50 microns. A dual-beam chopper, also cryogenically cooled, shifts the field of view of each detector through an arc equal to its angular diameter. A tracking system and finder telescope complete the assembly.

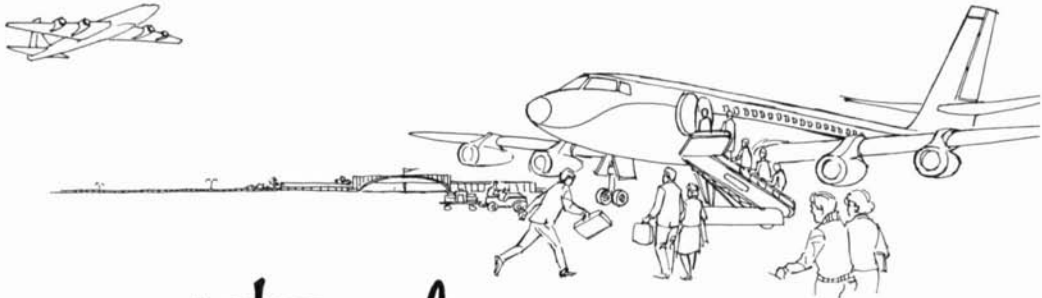
The system is aimed at an appropriate section of sky and locked onto a bright guide star offset from the infrared source, which may be invisible. Statistical fluctuations of the infrared source are measured, and the data is recorded on magnetic tape for later playback through a printer.

An elaborate setup such as this is beyond the means of most amateurs, but some interesting applications of semiconductors are implied. Some examples:

A photodetector array or photomultiplier could be placed at the focus of a telescope of moderate aperture, and detector output could be stored in a digital register driven by an a/d convertor. The output could be stored on tape or drive a counter directly. You could also probably improve on the clock drive used in most amateur telescopes with a system using IC op amps.

The rig would have to be used at the top of the highest mountain you could find because of atmospheric opacity at lower levels. Your first attempts might not yield much useful data, but don't be discouraged. Projects like this require much patience and equipment debugging. In any event, it's a pleasant way to spend a summer evening, especially if your best girl is along to help record data and maintain the log.

Jim Fisk, W1DTY
editor



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a word from the publisher

I am sure that by now you have noticed that *ham radio* has a new look this month. Like many other publications both large and small we have gone to what is known as "cold composition". By doing this we are able to take advantage of many new innovations in the graphics arts field.

As is usually the case with major changes, there are both advantages and shortcomings. One reader is sure to prefer our old type style, while another will think that our new one is an improvement. We will have more freedom to try new ideas, but last minute changes are now more difficult.

Of course, as this is written, I have not seen the very issue that you are now looking at. There may be parts which we will not like at first. You can be sure that we will be going over the results carefully to insure that we reach a new high in easy-reading and attractive appearance.

This issue also marks the first issue from our new printer: Wellesley Press. They have been chosen as experts in the periodical field. We felt they could add much to *ham radio* because of their great experience in the production of monthly magazines. Among the benefits should be more uniform quality and a great desire to give you, our readers, the magazine you want.

You will see a slight change in size. This has been done to permit us to take maximum advantage of the best high-speed printing equipment in use today. Our previous size was chosen because it was the same as *QST*. It turned out that there was a tremendous penalty involved and many excellent printers were virtually uninterested in working with it. This new size is a modern industry standard and gives us a marked advantage in holding down costs both to you and our advertisers.

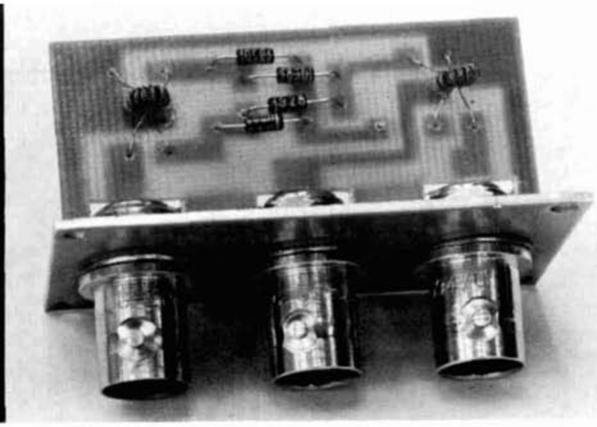
Ham radio is continuing to write one of the best success stories in the history of amateur radio publishing. 1969 saw our subscription list well more than double in size. This trend is continuing in 1970. We are still quite a way from being the biggest, but *ham radio* is a lot closer in size to some of its competitors than they would care to admit. Considering that we are now only two years old it certainly would seem that the ideas on which we based have been well proven.

another topic

Our mailbox produced an interesting letter the other day which I thought a number of readers might like to share with us. It was from Mr. J. Cooper, G3DPS, General Secretary of the Royal Signals Amateur Radio Society in England.

This organization is now opening its membership to past and present members of the U.S. Army Signal Corps who have been attached to or worked in close liaison with Royal Signals. Many U.S. hams were sent to Britain during World War II and served in such a capacity. If you are eligible, this might well be an interesting chance to renew old friendships in other parts of the world. You can write to Mr. Cooper at the Royal Signals Amateur Radio Society, 15 Valley Road, Blandford Camp, Blanford Forum, Dorset, England.

Skip Tenney, W1NLB
publisher



broadband double-balanced modulator

Practical construction details of a hot-carrier-diode double-balanced mixer that covers the range from 200 kHz to 250 MHz

William Ress, WA6NCT, Eimac Division of Varian, 301 Industrial Way, San Carlos, California 94070

Double-balanced ring modulators have been used since 1915, when they were developed by Bell Laboratories for carrier telephone systems. The earliest models were capable of good carrier suppression, but they suffered from high conversion losses because they used copper-oxide rectifiers. This, as well as excessive diode noise, limited their use to audio and low-frequency rf applications. With the improved semiconductor diodes that are available today, the double-balanced mixer circuit can be used in many communications applications that were formerly impossible; the home-built version presented here provides outstanding performance from 200 kHz to over 250 MHz.

Although double-balanced ring modulators require relatively high local-oscillator injection power, have some conversion loss, and must be followed by a low-noise amplifier, they have a number of operational advantages:

1. High port-to-port isolation (same as carrier suppression)

2. Wide dynamic range (large signal-handling capability)

3. Low intermodulation and cross modulation

4. Good noise figure

5. Reduction of spurious mixing products

It is also simple to build, easy to reproduce, fairly inexpensive and has a wide variety of applications in the radio communications field.

diode mixers

The most simple diode mixer, of course, is the single diode type shown in **fig. 1.** This circuit is widely used in electronic equipment operating from audio through microwave — it's a good bet that you'll find at least one circuit like this in the amateur radio gear in your shack. However, this simple circuit has

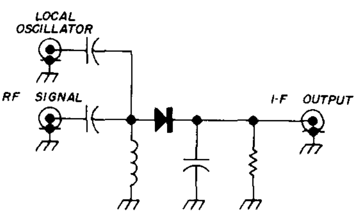


fig. 1. Simple single-diode mixer lacks isolation between ports.

one very serious disadvantage: poor port-to-port isolation.

The circuit of **fig. 2** was developed to improve isolation. Since transformer T1 is electrically balanced (center tapped), the local oscillator signal is split into two equal, but out-of-phase signals in the secondary, and cannot be induced into the primary. In the circuit of **fig. 3** the rf and local oscillator signals are isolated from the i-f output by virtue of the balanced secondary of transformer T2.

Further performance improvements can be obtained by going to the circuit of **fig. 4.** This four-diode double-balanced ring mixer allows energy to be exchanged on a full-wave cycle rather than half cycles as in the previous circuits and offers higher efficiency and lower conversion loss.

theory of operation

Consider the circuit of **fig. 4** with the rf input disconnected; with only local oscillator injection, there is no i-f output. When point A is negative, current flows through T1, diodes D2 and D3, and transformer T2, as shown by the arrows. Since the currents on each side of the center tap are 180°out of phase, they cancel,and there is no output. When point A is positive, current flows through T1, diodes D1 and D4, and transformer T2, again with no output.

If an rf signal is applied to T2, an output voltage appears across the i-f output terminals; the local-oscillator signal essentially switches the rf input voltage on and off. With high-conductance hot-carrier diodes, switching is nearly instantaneous and rectangular pulses controlled by rf signal amplitude appear across the i-f output port.

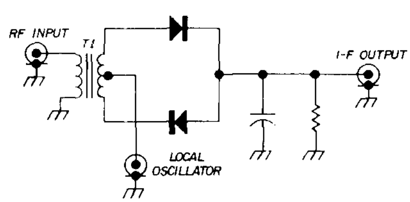


fig. 2. The balanced transformer in this single-balanced mixer effectively isolates the rf port from the rest of the circuit.

With a properly designed and constructed double-balanced mixer, carrier suppression on the order of 40 dB is not

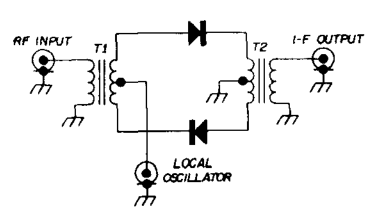


fig. 3. Basic double-balanced mixer circuit.

*Available from any Hewlett-Packard sales office; consult the Yellow Pages or write to Hewlett-Packard, 620 Page Mill Road, Palo Alto, California 94304. The matched quad, HPA 5082-2805 is $4.40. HPA 5082-2800 ($0.99 each) may be used but the matched quad provides better port-to-port isolation. These diodes are also available from HAL Devices, Box 365, Urbana, Illinois 61801.

difficult to obtain. With this type of mixer, third-order distortion products are typically suppressed by 50 dB. Since the even harmonics are inherently suppressed by the double-balanced circuit, the only spurious signals that may give trouble are those created by odd-numbered harmonics.

mixer components

The modern broadband balanced mixer is possible through the use of ferrite transformers and semiconductor diodes — diodes that exhibit high front-to-back ratios and ultra-fast switching times. Great strides in ferrite device technology has provided materials that operate efficiently from dc to microwave. With the proper ferrite and suitable windings, transformers can be made that will act as nearly purely resistive transformers over a wide range of frequencies.[1, 2, 3, 4]

Although nearly any high-conductance diode will give adequate performance in a

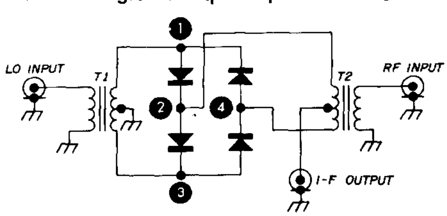


fig. 4. Double-balanced ring mixer circuit improves performance. Transformer construction is shown in fig. 6. Diodes are Hewlett-Packard 2800 series.

diode ring, many characteristics of the hot-carrier diode make it the ideal choice. To achieve electrical balance in the mixer for example, the diodes in the ring should have closely matched transfer characteristics — *this is inherent in the fabrication* of hot-carrier diodes.

For lowest mixer conversion loss, the ring diodes should have no forward resistance when conducting, and infinite resistance when turned off. The front-to-back ratios of several different diodes are listed in **table 1**. For efficient operation on the very-high and microwave frequencies, the mixer diodes should feature extremely fast switching speeds and contribute very little noise to the circuit. These requirements are best met by hot-carrier diodes.

The hot-carrier diodes currently on the market consist of a rectifying metal-to-semiconductor junction; n-type silicon in conjunction with evaporated gold, platinum, palladium or silver. In the hot-carrier diode, current conduction is based on majority carriers, and in normal operation the diode exhibits virtually no stored charge carriers. In practical terms

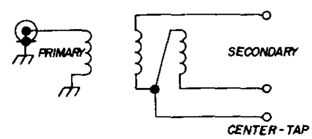


fig. 5. Schematic showing the connections of the trifilar windings.

this means that the reverse recovery time is very short: typically 100 picoseconds, more than four times faster than the fastest silicon junction diode. This results in more efficient signal rectification at vhf.

The construction of the hot-carrier diode results in uniform contact potential and uniform current distribution throughout the junction. In terms of operation, this means lower series resistance, lower contributed noise, higher power capability and greater resistance to transient pulse burnout.

transformer construction

The transformers used in the practical double-balanced mixer shown in the photographs are wound on Indiana General Cf102-Q1 ferrite cores. These cores are available from Newark Electronics*. Each transformer consists of 12 trifilar turns of number 32 enameled wire; number 30 or 34 is also satisfactory. I experimented with a number of different cores and winding techniques to find a wideband design that could be

*Newark Electronics Corporation, 500 N. Pulaski Road, Chicago, Illinois 60624. Order catalogue number 59F1509, $1.20 each plus shipping. ($2.50 minimum mail order).

easily reproduced; the design described here performed the best.

To obtain the desired wideband performance, the coupling between windings must be as tight as possible. To obtain this, the three wires in each winding are twisted together: chuck two 2-foot lengths of number 32 wire into a hand drill (electrical drill if you're extremely careful); crank the drill until the wires have a reasonably tight twist. Then take this twisted pair and re-chuck it with the

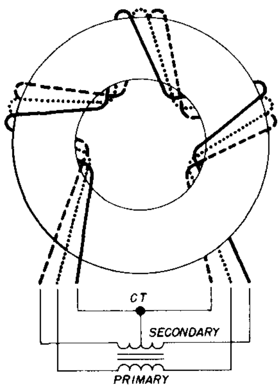


fig. 6. Toroid winding; wires are shown untwisted for clarity.

third wire and repeat the twisting process until you have a tight trifilar length of wire.

Each transformer consists of 12 turns of this trifilar wire on a CF102-Q1 ferrite core. A schematic of the complete transformer is shown in **fig. 5**; the pictorial diagram in **fig. 6** should explain the windings more fully. The windings must be connected properly, or the finished double-balanced mixer will not work. This can be simplified if you use different colored wire for each winding. I've been able to find the wire in two colors and even this is a big help.

Pick one set of wires for the primary. Wrap these two wires with a piece of tape to identify them and keep them out of your way. You should have four wires (two sets) left. Separate the two sets by checking for continuity with an ohmmeter. Take one wire from one set and twist it together with one wire from the remaining set; this is the secondary center tap. The two remaining wires will be the two outer ends of the secondary.

Now all the wire in the secondary will show continuity, and the two wires in the primary will be isolated from the secondary. The choice of wires for the primary and secondary is completely arbitrary – the only important thing to observe is the connection sequence.

To obtain the same wideband performance that I have achieved, the transformers must be duplicated. If you want to experiment, you might try some of the small cores from Indiana General in Q1, Q2 or Q3 material. Q3 material, for example, will improve the high-frequency performance at the expense of operation on the low-frequency end. Powdered-iron toroids should not be used because they will not operate over a very broadband frequency range.

construction details

After the transformer windings have been selected you are all set to assemble the other parts of the ciruci t. Here again I recommend following the layout I have developed; if at all possible, use the printed-circuit layout shown in **fig. 7.** If you use a different layout you won't duplicate my results. However, don't be afraid to try your own design – you may end up with better balance than I did. Just remember to use good vhf construction techniques: short leads and short ground returns.

The printed circuit is one area where

table 1. Front-to-back ratio of various diodes.

diode type	forward resistance (ohms)	reverse resistance (ohms)	ratio
Copper oxide	400	350k	875
Small-junction germanium (1N270)	5	500k	100k
Point-contact germanium (1N98)	200	1M	5k
Low-conductance silicon (1N457)	50	2400M	48M
High-conductance silicon (1N645)	2.5	1200M	480M
Hot-carrier (HPA 2800)	1.5	3000M	2000M

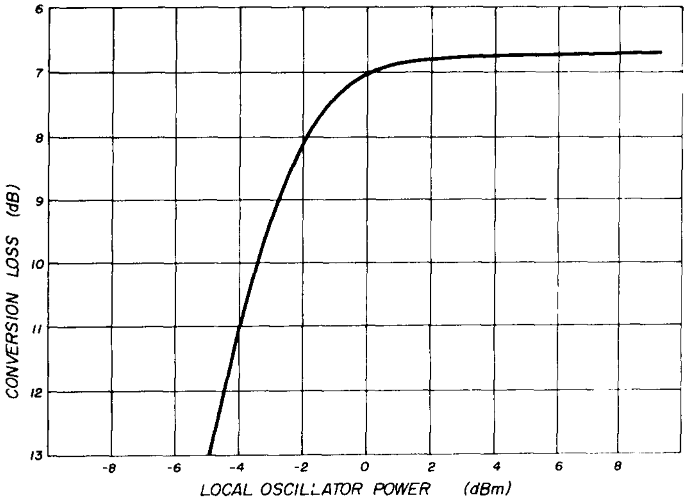


Fig. 8. Conversion loss vs local oscillator power for this double-balanced mixer circuit.

commercial manufacturers of these mixers use a touch of magic to obtain optimum balance. By using the stray capacitances associated with the circuit board and the components, it is possible to obtain nearly perfect electrical symmetry.

For proper operation, the completed mixer unit must be enclosed in a box that provides good rf shielding. In the unit shown in the photographs, I used a small cast-aluminum chassis manufactured by Pomona (model 2428). This enclosure sells for $1.50 at major electronics suppliers.

applications

Probably the most important application of the double-balanced mixer in amateur equipment is as a frequency mixer. To obtain optimum performance as a mixer, three factors must be considered: local-oscillator power, conversion loss and the need for low-noise amplification of the i-f output.

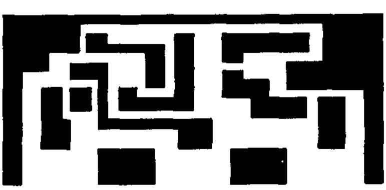


Fig. 7. Printed-circuit board for the double-balanced mixer.

The graph of **fig. 8** shows conversion loss versus local oscillator power for this double-balanced mixer. This curve is typical of all passive mixers and shows that conversion loss decreases with increasing local-oscillator power up to approximately zero dBm (1 milliwatt or 0.22 volts across 50 ohms). Beyond zero dBm more local-oscillator power does little for conversion loss, but note how fast conversion loss rises as local-oscillator power drops below zero dBm.

Many active mixers work properly with as little as 0.1 mW (−10 dBm) of local oscillator injection, and are usually much more tolerant of variations in injection level. The relatively high local-oscillator power requirement of the double-balanced mixer is a disadvantage, particularly at uhf and microwave where it is harder to generate.

Conversion loss can be analyzed by putting an attenuator in front of the stage that follows the i-f output port. As an example, consider that you're using this mixer as a 144-MHz down-converter to 28 MHz, and you run the mixer's i-f output directly into the station receiver. Assume that the noise figure of the receiver is 10 dB at 28 MHz. Also assume that the mixer has a conversion loss of 7 dB.

The converter's noise figure is the

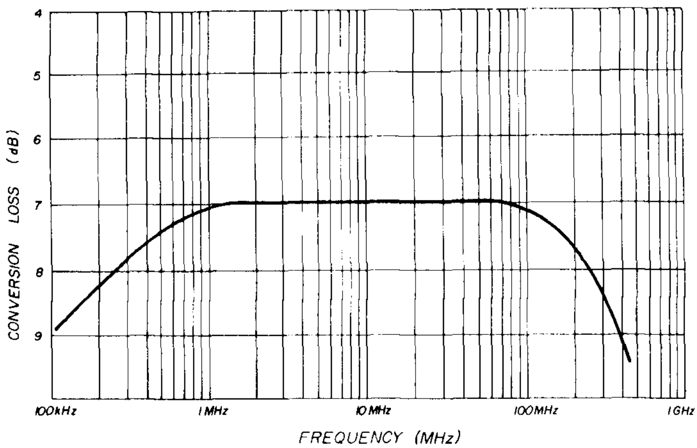


fig. 9. Typical conversion loss for this double-balanced mixer over the range from 100 kHz to 400 MHz (local oscillator power +7 dBm, rf input - 5 dBm).

receiver's noise figure *plus* the conversion loss, or 17 dB. This represents the noise contribution from both the mixer and receiver and assumes that the mixer is tuned to reject the image frequency. If the rf port is not tuned to reject the image the noise power in the image can add an additional 3 dB of noise; the converter would end up with an effective noise figure of 20 dB. This borders on the ridiculous for vhf converter applications but if we analyze the problem further we can find solutions that will change the mixer into a very useful vhf device.

To eliminate the images a filter is needed in the rf input. This can be a simple tuned circuit with a 50-ohm tap. The filter will eliminate noise contribution from the image but adds insertion loss. This must be added to the mixer's conversion loss. It's obvious that the filtering must have the lowest possible insertion loss. This can be accomplished with a wide bandwidth filter (same as low loaded Q). A good rule of thumb is to choose a filter with a bandwidth one-third the i-f output frequency.

We must also reduce the noise figure of the i-f. This is most easily done by adding low-noise amplification ahead of the receiver. A properly designed amplifier using transistors or fet's can yield noise figures as low as 1 dB at frequencies up to 60 MHz.

Let's take a look at an application using an rf input filter which has an

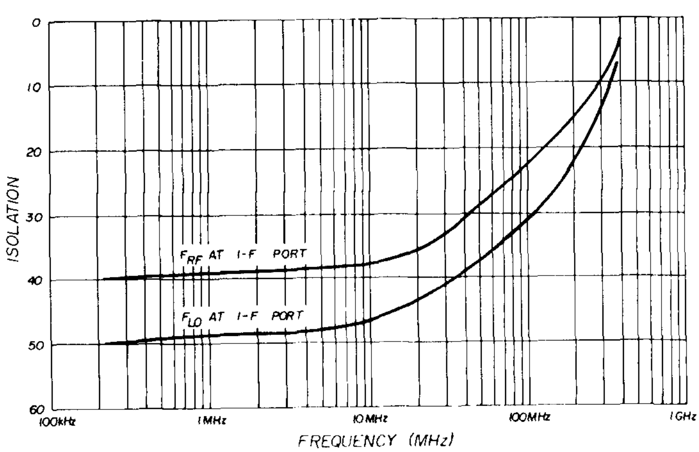


fig. 10. Mixer balance in terms of isolation from i-f port (rf frequency at 0 dBm, local oscillator at +5 dBm).

insertion loss of 0.2 dB and a low-noise amplifier ahead of the receiver which has a 2 dB noise figure. The mixer still has 7 dB conversion loss. We must add this to the insertion loss of the filter for a total of 7.2 dB; this 7.2 dB is added to the 2 dB noise figure of the i-f amplifier so the converter has an effective noise figure of 9.2 dB.

A front end with a 9.2 dB noise figure is useful for local ragchewing, fm repeater work and mobiling. For serious DX a low-noise preamplifier is required, but a 9.2 dB NF mixer can handle 1 milliwatt of signal before gain compression, cross modulation or intermodulation becomes a problem; only exotic active mixing schemes can accomplish this.

When you use a preamplifier ahead of the double-balanced mixer to reduce noise figure remember that the amplifier must have sufficient gain to overcome the mixer noise figure before you can realize the lower noise figure of the preamplifier. It's a good rule of thumb to design the preamplifier with at least 10 dB more gain than the noise figure of the following stage. In our example this would require

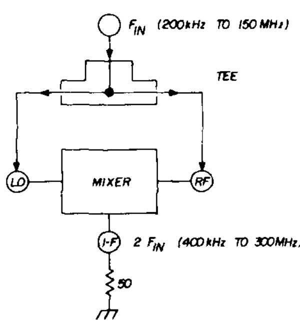


fig. 11. The double-balanced mixer as a frequency doubler.

19.2 dB preamplifier gain. Then the converter's noise figure would be set by the noise figure of the preamplifier.

I'd like to point out that the performance graphs for this mixer (**fig. 8, 9,** and **10**) compare closely with commercially available designs, although some mixers in the $100 class have improved port-to-port isolation and conversion losses as low as 6 dB.

I have discussed conversion loss of the double-balanced mixer, but have neglected noise figure. This is because the hot-carrier diodes contribute so little noise that it can't accurately be measured. Above about 1 GHz (1000 MHz) diode noise begins to become noticeable, and in the microwave region more exotic hot-carrier diodes are available that per-

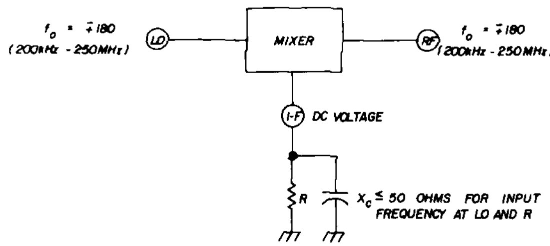


fig. 12. Using the double-balanced mixer for a phase detector.

form better than their more common silicon counterparts.

If you are using a diode mixer on 1296 MHz a properly selected hot-carrier device will offer a slight improvement in noise figure as compared to the old standby 1N21 series. Improved performance is even more noticeable on 2300 MHz and up, since the noise figure of hot-carrier diodes does not rise as fast with frequency as does the noise contribution of conventional point-contact and p-n junction devices.

In addition to its use as a simple frequency converter, the double balanced mixer is also useful for frequency doubling, phase detection, current-controlled attenuation, amplitude modulation, product detection and balanced modulation as shown in **figs. 11** through **17.**

frequency doubler

The double-balanced ring modulator can be used as a broadband frequency doubler by simply applying the rf signal to both the local-oscillator and rf ports as shown in **fig. 11.** Since the sum and difference frequencies will appear across the i-f port, the i-f output will be twice the rf input (since the difference frequency is zero).

phase detector

When using the double-balanced modulator as a phase detector as shown in **fig. 12** one rf signal is applied to the local-oscillator terminals while the other rf signal is connected to the rf port. The dc signal available across the i-f port is zero when the two input signals are 90° out of phase; the dc voltage at the i-f port is maximum when the phase difference between the two signals is either zero or 180°.

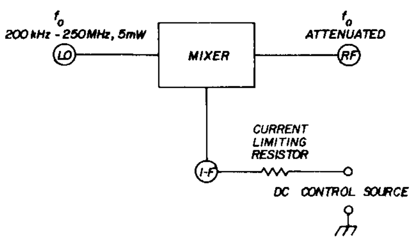


fig. 13. Current-controlled attenuator; performance is plotted in fig. 14.

current-controlled attenuator

If you want to use the double-balanced mixer as a current-controlled attenuator, the rf input signal is connected to the local-oscillator port as shown in **fig. 13.** With no current input at the i-f port, the signal at the local oscillator port will appear greatly attenuated at the rf port. A curve of attenuation versus control current is shown in **fig. 14.** When using the mixer as a current-controlled attenuator, a current-limiting resistor should be connected in series with the i-f port to limit diode current to 40 mA. Appropriate values of resistance versus applied voltage are shown in **table 2.**

table 2. Current-limiting resistance versus control voltage.

voltage	minimum resistance (ohms)
1	27
5	150
10	270
50	1500
100	2700
500	15k

If you refer to **fig. 4** you can see that a dc control voltage across the i-f terminals will cause two of the diodes in the ring to conduct. When sufficient dc current flows through the diodes they appear as very small resistors connecting the secondaries of T1 and T2 together, and any signal at the local-oscillator port will appear at the rf port with little attenuation. Varying the control current changes the resistance of the diodes, and hence, the magnitude of the output voltage.

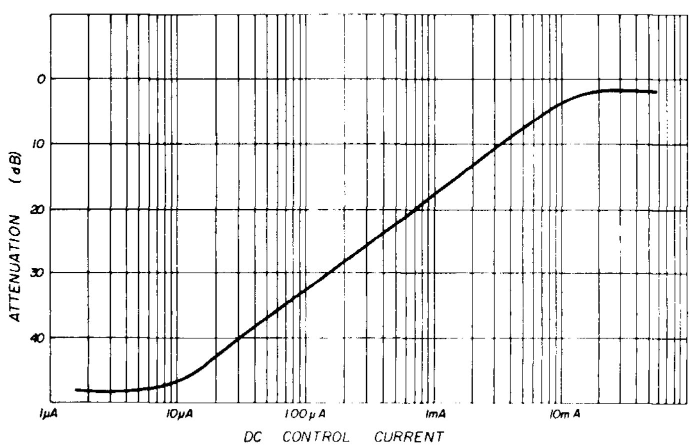


fig. 14. Attenuation vs dc control current.

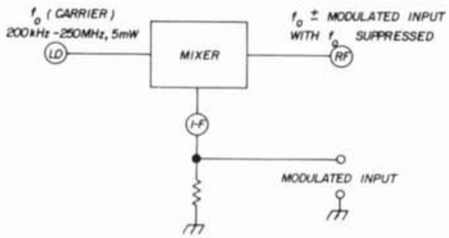


fig. 15. Balanced modulator.

balanced modulator

To use this device as a balanced modulator, it is connected into the circuit as shown in **fig. 15** with the rf signal (carrier) at the local-oscillator port, the modulating signal at the i-f port and the output signal across the rf port. The signal across the rf port consists of the local oscillator plus and minus the modulating signal with the local-oscillator (carrier) greatly attenuated.

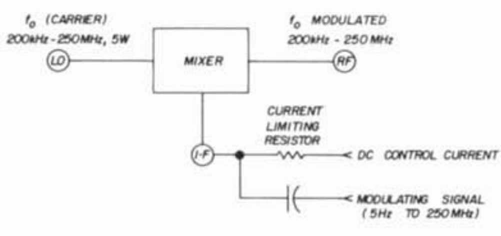


fig. 16. Amplitude modulator.

amplitude modulator

To obtain amplitude modulation from the double-balanced mixer, the operations as a balanced modulator and current-controlled attenuator are combined as shown in **fig. 16.** A modulating signal containing both ac and dc components is applied to the i-f port. The ac components will produce sidebands and the dc component will vary the amplitude of the carrier appearing at the rf port. For 100 percent modulation the modulating signal should be about 200 mV rms and the dc control current should be approximately 4 mA.

product detector

This is simply a mixer that has its i-f output in the audio range. A suitable circuit is shown in **fig. 17.** The double-balanced ring mixer is particularly useful in this application because of its very low intermodulation performance and large dynamic range.

two-meter converter

The two-meter converter shown in **fig. 18** is based on the hot-carrier-diode double – balanced mixer shown earlier. This converter has all the design features that should be considered when using an hcd mixer in the converter, including an input filter, low-noise i-f amplifier and a spectrally clean local oscillator.

The two-meter converter shown in the photo has a noise figure of 9 dB; and gain can be adjusted from zero to 20 dB. Main image rejection (84 to 88 MHz in this case) is 30 dB; all other images are down at least 60 dB. Local oscillator leakage at the input and output ports is 500 microvolts. The gain compression

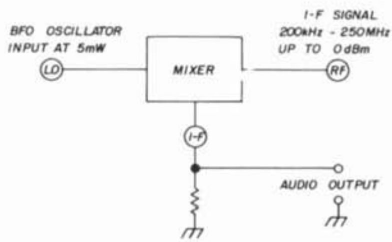
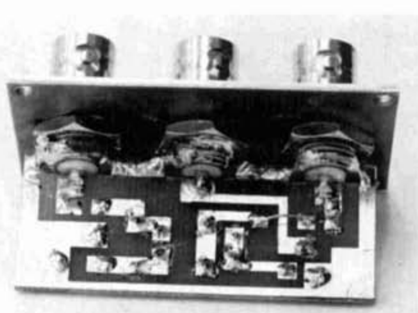
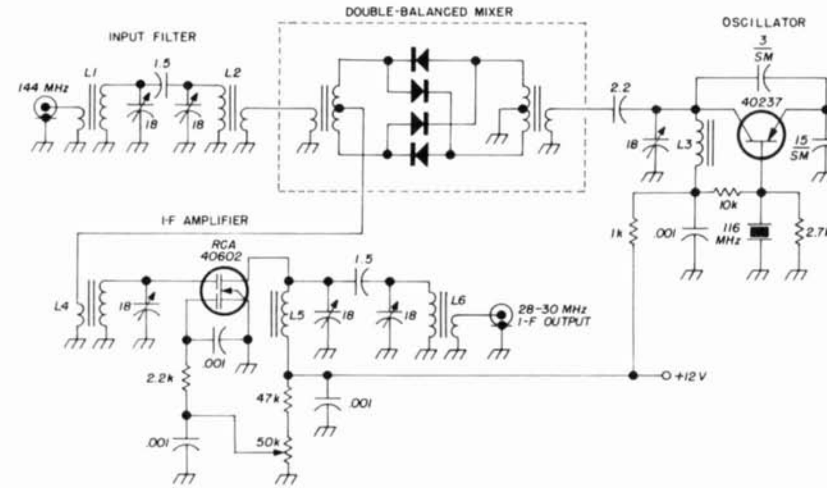


fig. 17. Using the double-balanced mixer as a product detector.

Construction of the hot-carrier-diode double-balanced mixer showing the circuit side of the printed-circuit board.





L1, L2 Primary is 10 turns no. 24 on Micrometals* T30-10 toroidal core; secondary is 4 turns no. 24 on cold end of primary

L3 7 turns no. 26 on Micrometals T30-22 core
L4 24 turns no. 28 on Micrometals T30-6 core
L5, L6 24 turns no. 28 on Micrometals T30-6 core Secondary of L6 consists of 3 turns no. 28

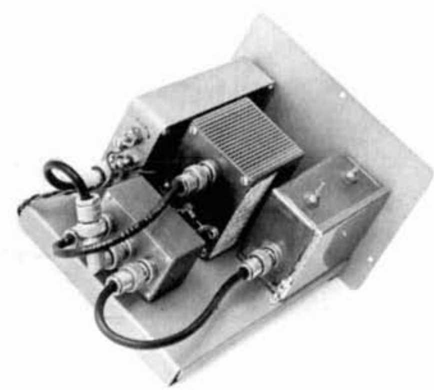
fig. 18. High-performance two-meter converter is based on the double-balanced mixer package.

point the point where the output departs from linear change relative to the input change is 1 volt rms.

In the converter shown in the photo, each of the main components was built into a separate chassis. This improves shielding between stages and facilitates experimentation with different converter configurations.

The hot-carrier-diode double-balanced mixer used in this converter has dramatically demonstrated to me the ability of a passive mixer to offer high dynamic range and resistance to overload, desensitization, cross modulation and intermodulation, while providing a respectable and useable noise figure.

Two-meter converter using the double-balanced mixer. The mixer is on the rear of the chassis; in front of it, from left to right, are the low-noise 30-MHz i-f amplifier, 116-MHz local oscillator and 144-MHz input filter.



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* Micrometal toroidal cores are available from Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607. Package of six cores for the two-meter converter is $2.75 postpaid.

ham radio

compact dual-band antennas

Simple but effective antenna systems for city-lot dimensions or portable use

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It's hard to "be loud" when your antenna is on a city lot. Power lines and apartment buildings make it almost impossible to put up a full-sized antenna. It is possible, however, to reduce the length of a dipole by one-half using the folding technique. A shorter dipole combined with a folded dipole is an efficient two-band antenna system that can be erected in a restricted space. Such an arrangement is also useful for portable or Field Day work. Versions of this system are discussed in this article.

basic concepts

Two dipoles may be connected in parallel at a current loop as shown in **fig. 1**, provided an even-harmonic relationship exists between them. End separation of both antennas need be only a few inches. Although a small amount of detuning will exist, the usual formulas for dipole length apply.

Various combinations are practical for two-band systems: 160/80, 80/40, 40/20, 20/10, and so on. The 40/20-meter combination will work on 15 meters if the 40-meter antenna is operated on its third harmonic. An 80/20 or 80/10-meter system can be built (using the even-harmonic rule) with a reasonably low standing wave ratio on the transmission line. As with any system using an unbalanced transmission line feeding a balanced antenna, a balun should be used to preserve antenna pattern and to avoid feed problems.[1]

folded half-wave radiator

The length of this simple dual-band system can be reduced by folding the lower-frequency antenna back on itself. A three-wire antenna is shown in **fig. 2.** The feed point is connected to one of the outside pairs of wires and also to the inner pair. The two outside wires are jumpered at their far ends; they are the elements of the low-frequency dipole.

Folding the antenna has a minimum effect on its resonant frequency. If you'd like to refine the resonant frequency adjustment, compensation may be made in the manner shown in **fig. 3.** The low-frequency dipole should be trimmed for the low-frequency end of the band. The resonant frequency can then be raised by moving an adjustable jumper across the wires at the end. If the jumpers are adjusted in unison, resonant frequency may be varied over several-hundred kHz.

The higher-frequency dipole (center wire) will be unaffected by this adjustment. It may be adjusted by changing its length until resonance is achieved.

system bandwidth

The bandwidth of any antenna may be defined in terms of the allowable standing wave ratio on its transmission line. Beam antennas with close-spaced parasitic elements have very low radiation resistance and limited bandwidth. If they are operated at an swr much higher than 2:1, forward field and front-to-back ratio will deteriorate rapidly at frequencies only a few percent from resonance. Simple dipoles, on the other hand, can operate over a much wider frequency range. This is because there's no problem involving phase and reactance relationships between elements as with parasitic beams.

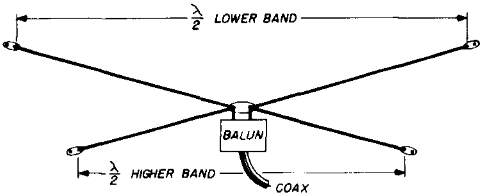

fig. 1. Basic dual-band antenna. Dipoles are parallel-connected; an even-harmonic relationship must exist between them.

Equipment limitation is probably the most important factor that affects allowable transmission-line swr. Many commercial amateur transmitters and transceivers have limitations of 2:1 for standing wave ratio to avoid ruining output-circuit components (usually a pi network). It is therefore prudent to operate such equipment into antenna transmission lines with an swr of 2:1 or less. Let's see how the dual-band radiator measures up to this criterion.

height above ground

Taking an swr of 2:1 as par, the plot of **fig. 4** shows the swr of the dual-band dipole when operated at optimum height above ground. The data for these curves was taken at the end of a 100-foot length of 50-ohm coaxial cable.

The 40-meter dipole has greater bandwidth: more than 400 kHz, with an swr of 2:1 or less. The 80-meter folded dipole's bandwidth is about 75 kHz over the same swr range. This indicates that the 80-meter antenna height is more important, in terms of swr, than that of the 40-meter antenna. I raised and

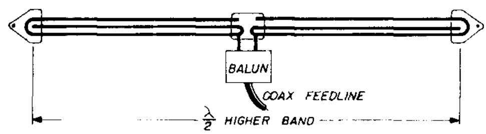

fig. 2. Dual-band system using the folding technique. Center wire is the higher-frequency dipole; the two outer wires comprise the lower-frequency dipole. Interaction is negligible.

lowered my 40-meter antenna and observed its swr across the band. It performed satisfactorily at heights above 20 feet or so, with a rather small change in swr. The swr reached a broad optimum at a height of 30 feet and again at 60 feet. Highest swr was at about 45 feet.

The 80-meter antenna is a different breed of cat. Because of folding, the 80-meter dipole's radiation resistance is lower. It's about 60 percent of the usual measured value at all heights above ground. The 80-meter antenna plot of **fig. 4** occurred at about 50 feet and remained reasonably constant down to 40 feet. Below this height, minimum swr increased rapidly, tending to decrease the over-all bandwidth.

Accepting these facts of life, I finally mounted the antenna so that the flat top was about 45 feet high. The 40-meter-band swr wasn't as good as shown in **fig. 4**; however, it remained below 2:1 from

7.1 to 7.3 MHz It was still acceptable at 7.0 MHz, as no equipment-loading problems were encountered at this frequency. The 80-meter swr values were as shown in **fig. 4.**

feed system

The transmission line must be decoupled from the antenna to obtain lowest swr. Decoupling will keep the line from radiating. A sure way to create transmission-line problems is to attach an unbalanced coaxial line to a balanced antenna. The reason is that current flows down the outside of the line instead of being confined to the inner conductor. A balun placed at the dipole feed point will decouple the line's outer shield from antenna currents. The balun is shown in **fig. 5.** It's mounted directly at the center antenna insulator.

balun construction

The balun consists of three trifilar windings of no. 14 enamelled copper

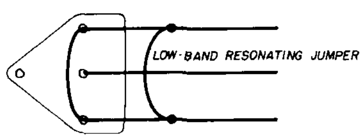

fig. 3. End insulator and resonating jumper. Each side of the assembly should be of equal length; jumpers should be moved in unison.

wire. Each winding consists of 8 turns. The coils are wound over a length of high-Q ferrite rod, ½-inch in diameter.* Nick the rod with a file around its circumference at the desired length, then break it with a sharp blow. Connect the ends of the windings as shown in **fig. 5.**

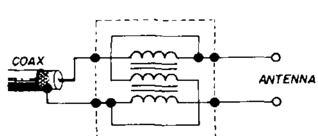

fig. 5. Balun for optimum performance. Inductances are wound over ferrite cores; see text.

Note that the coax shield is connected to the outer winding and also to the opposite end of the center balanced winding.

transmitter loading

The RG-8/U feed line (or RG-58/U if power is below 250 watts PEP) should drop vertically as far as possible. The line then may be run horizontally when near ground level. Since a relatively high swr exists, it may be necessary to vary line

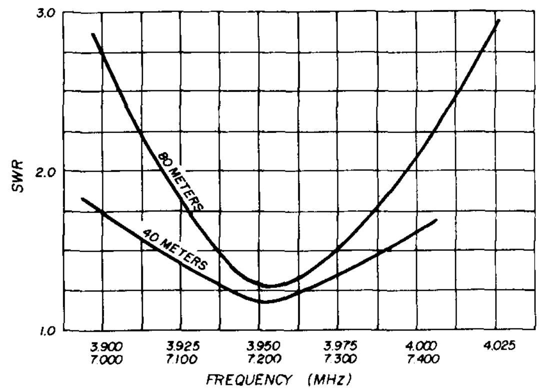

fig. 4. Standing wave ratio versus frequency for the compact dual-band dipole. Curves were optimized for antenna height.

length to obtain optimum transmitter loading. This doesn't change the swr; it merely provides conditions for a better impedance match at the transmitter end of the line. Make a couple of ten-foot lengths of line with appropriate connectors. Try inserting one or both sections into the main transmission line until the transmitter loads properly. If loading difficulty still persists, a longer line section may be necessary to obtain proper loading on both bands. Line length isn't nearly as critical as it may seem — I mention it only because loading difficulties might develop.

dual-dipole construction

Construction is simple. The end and

*Indiana General CF-503 rod, available from Newark Electronics. Catalog part no. 59F-1521.

center insulators may be made of 3/8-inch plywood squares about six inches long. For outdoor use the insulators should be treated with spar varnish to make them waterproof.* Holes for the antenna wires should be about two inches apart. String the wires, then stretch the system between two supports about waist high. You'll notice that separators will be needed between the wires, spaced at about 5-foot intervals. You can make these from short pieces of plastic rod.

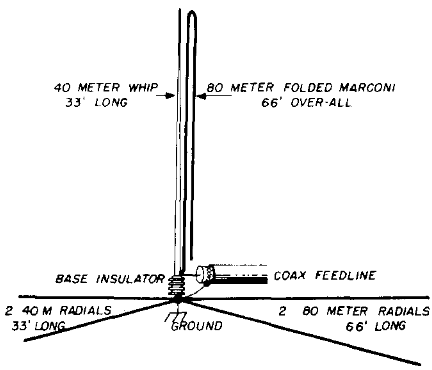

fig. 6. Compact dual-band Marconi antenna. Ground system is important; a ground rod was used in addition to the radials, which can be oriented at random.

Drill the separators to accept the wire, then thread the separators onto the wires. Secure the separators with small-diameter wire ties.

The first antenna of this type that I built had untreated insulators and separators. They lasted about a year, then succumbed to a combination of weather and birds. This construction isn't recommended except for temporary installations.

Commercial versions of this compact antenna system are available. When used with a balun, performance will be as described here. Again, I'd like to emphasize that this antenna, when operated without a balun, will lead to unusual or puzzling operating conditions. Play it safe and do the job right.

Typical antenna dimensions are given in **table 1**.

dual-bank Marconi antenna

The parallel-feed system may be adapted to Marconi antennas as well as to dipoles. With a Marconi, a ground system is required for proper operation **(fig. 6)**. The random "water-pipe" ground is not recommended. Two or three radials should be used at the ground connection in a Marconi antenna installation. Two ¼-wavelength radials for each band will be adequate. The radials may be of insulated wire; they don't necessarily have to form the spokes of a wheel from the ground connection. They can be fastened to fences or any handy anchoring device.

The Marconi is usually in the form of a base-supported whip. The easiest way to erect a Marconi antenna for two-band operation is to use a ¼-wave whip made of tubular material for the higher-frequency band, which acts as a support for a folded-wire section cut for the lower-frequency band. Insulators such as those used for tv lead-in may be installed on the whip to support the folded-wire antenna The folded-wire antenna will require insulated spreaders, as discussed previously.

Radiation resistance of the whip antenna is lower than that of the dipole system. However, height above ground has less effect on the whip's bandwidth. A typical 80/40-meter Marconi, for example, has an swr of 2:1 or less across the 40-meter band. An 80-meter system has a bandwidth of about 80kHz.

An added benefit of the vertical Marconi is a low radiation angle, which is good for DX work. Best results will be obtained only if a good radial system is used.

*Another time-honored method of waterproofing wooden insulators is to boil them in paraffin. A one-pound block of paraffin is less expensive than a quarter-pint of spar varnish. *Editor.*

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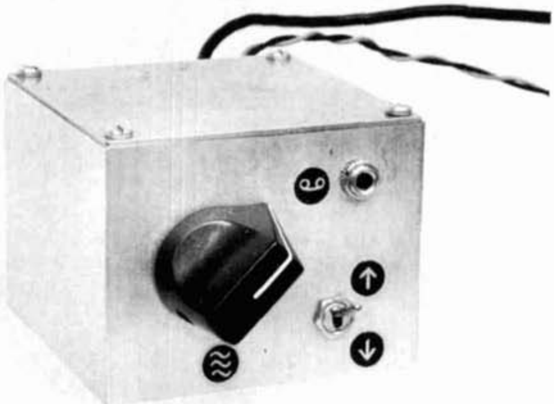

tunable peak-notch audio filter

Solid-state circuits featuring the twin-T network - useful in test equipment or for improving receiver selectivity

John H. Schultz, 40 Rossie Street, Mystic, Connecticut

Numerous filters have been described that provide selectivity at audio frequencies. The usefulness of many such filters is somewhat limited for several reasons. Some provide only one function: either peaking or notching. Others, such as the Selectoject[1], provide both functions over a tunable audio-frequency range. However, these haven't been adapted to solid-state circuits, nor have their RC networks been optimized for frequency selective peaking or notching. Still other designs have appeared from time-to-time, but are rather complex and expensive because of the several cascaded tuned circuits required to obtain good selectivity characteristics.[2,3,4]

A tunable audio frequency peaking and notching (rejection) filter is one of the most useful accessories you can have. Besides providing effective audio selectivity for ssb or cw reception, the audio filter is a useful adjunct in conducting *harmonic-* and *intermodulation*-distortion measurements and in measuring frequency in the af range.[5]

The audio-frequency-selective network described in this article is not new, although it has been overlooked in recent years. What is new, however, is the manner in which the network is employed to provide a selectable frequency-peaking or frequency-notching function, tunable over a wide portion of the audio-frequency spectrum, using only resistors and capacitors. The basic network is discussed as well as some practical circuits in which it can be used. Many other applications for the network will probably suggest themselves.

basic network

The basic frequency-selective network is shown in **fig. 1A.** Called a twin-T network, its theory is discussed in electronic texts, so I won't repeat it here. The network is equivalent to the Wien bridge. It passes all frequencies except one, where the relationship

$$\text{rejection frequency} \simeq \frac{1}{2RC}$$

is met. If the capacitor values are fixed and the resistors are variable, a tunable notch, or rejection, circuit results. By rearranging the network, a single-frequency peaking circuit results **(fig. 1B).** Thus, with appropriate switching, a selectable notching or peaking filter can be designed.

As mentioned before, the basic network has been around for some time and has been used by amateurs with different degrees of success. Its unsuccessful use can be traced to several factors. First, the network can't be loaded on either its input or output; it must be used in high-impedance circuits. Secondly, the components (mainly the capacitors) must have low internal impedance and be closely matched. The usual assortment of capacitors in the junkbox simply will not work. Finally, to be truly tunable, all three resistor legs must be variable, not just two.

circuit applications

Fig. 2 shows the basic network, switchable for either peaking or notching, in a low-level transistor amplifier circuit. The amplifier can be used between the stages of another amplifier where audio selectivity is desired, or it can be used to drive a pair of high-impedance headphones directly from a receiver or test instrument.

Network component values were chosen on the basis of being readily available in the correct ratios and providing a reasonably wide tuning range. Coverage is from about 300 to 10,000

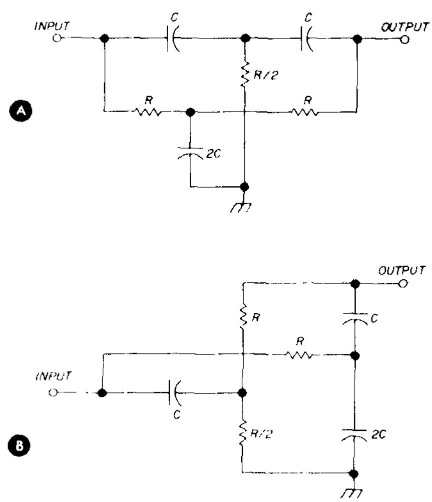

fig. 1. Basic twin-T notch circuit, A. An alternate arrangement for peaking is shown in B.

Hz, which should satisfy most requirements. The frequency can be made lower by increasing both resistor and capacitor values.

The impedance across the input transistor base-emitter junction isolates the network from loading effects. A feedback path is provided from the output stages to one leg of the filter. This raises the terminating resistance presented to the filter, which improves selectivity characteristics.

The selective network in a complete, self-contained audio unit using an IC is shown in **fig. 3.** It can be plugged into the headphone jack on a piece of equipment. The input transformer's secondary-winding impedance prevents network

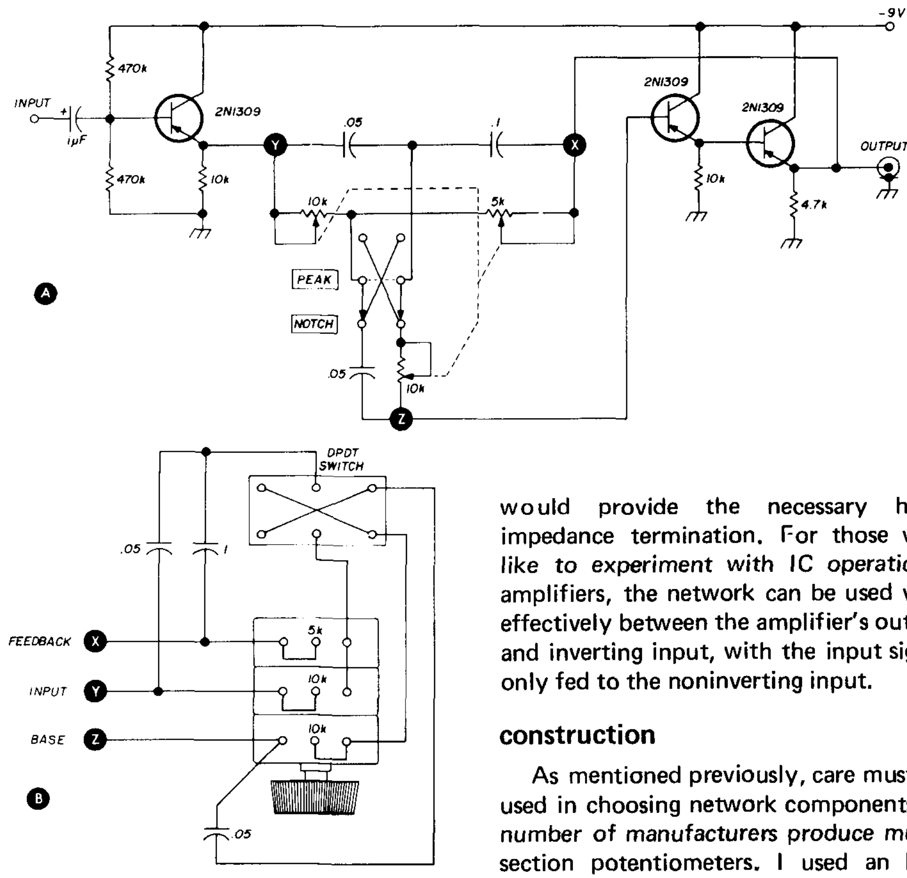

fig. 2. Variable-frequency peak-notch filter with feedback, A, that can drive high-impedance headphones or an audio amplifier. B shows potentiometer and switch wiring.

loading. Transformers with much low impedances should **not** be used. The audio amplifier was designed originally for use with a crystal phone pickup; thus it provides a high terminating impedance for the network. A 9-volt transistor battery can be used for power; however, if the unit is used at its maximum ½-watt power output for an extended period, a heavier-duty power supply would be required.

The basic network can be used in other circuits as well. For example, in circuits employing fet's, these devices would provide the necessary high-impedance termination. For those who like to experiment with IC operational amplifiers, the network can be used very effectively between the amplifier's output and inverting input, with the input signal only fed to the noninverting input.

construction

As mentioned previously, care must be used in choosing network components. A number of manufacturers produce multi-section potentiometers. I used an IRC three-section pot with linear tapers. Capacitors were Sprague 10-percent tolerance tantalum.* Similar low-loss components may be used, of course.

The photo shows how the circuit of **fig. 2** is assembled in a small 2-inch-cube Sta-loc enclosure. This enclosure allows all six sides to be separated and is convenient for compact construction. A small minibox can also be used. The transistor circuit is assembled on the

*Potentiometer is Allied stock no. 46F1892C. Specify 45D103, Md103, Md50218 for each section. Capacitors are Allied stock no. 43F4923 (0.47 μF) and 43F4926 (0.1 μF). Allied Radio, 100 N. Western Avenue, Chicago, Illinois 60680.

vector board mounted next to the potentiometer.

Power was taken from the unit with which the filter was used, but a slightly larger enclosure would accommodate a 9-volt transistor battery.

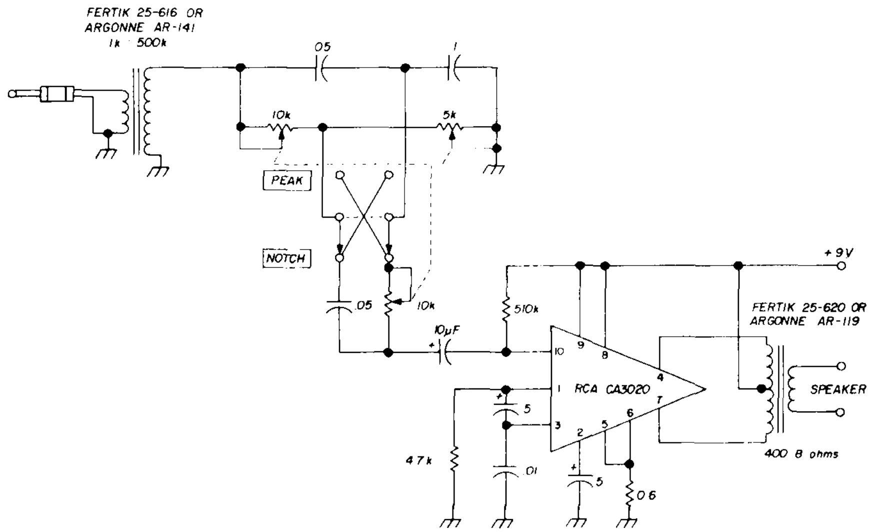

fig. 3. Twin-T filter combined with an IC. Unit provides about ½ W output and can be plugged into the headphone jack on your receiver.

summary

This simple network can provide a remarkable degree of selectivity in circuits where a gradual frequency rolloff is acceptable. It doesn't require complex arrangements using toroids, multiple tuned circuits, etc. Peaking and notching response of the circuit of **fig. 2** is depicted in **fig. 4.** Filter response is narrower as frequency setting increases.

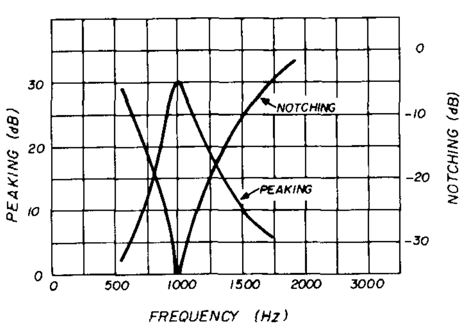

fig. 4. Typical response of the circuit in fig. 2. Response broadens somewhat at lower frequencies and is narrower at higher-frequency settings.

Despite the comments made earlier about not loading the network, you might want to try the basic network in a headphone circuit. I couldn't resist trying it with 400-ohm phones. Results were moderately successful but hardly equal to those using the transistor circuit. Although using the network alone can't really be recommended, it does work to some degree and provides some selectivity as a passive circuit.

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3. Donald J. Sommer, WA7FBO, "Selectable Bandwidth Filter", *QST*, August, 1968, p. 47.
4. Harry J. Gensler, Jr., K8OCO, "The OCO Audio Filter", *QST*, January, 1962, p. 16.
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ham radio

further automation for typewriter-type electronic keys

Robert L. Kurtz, W6PRO, Micro-Z Company, Box 2426, Rolling Hills, California 90274

Some time ago I developed an automatic typewriter-type keyer that features self-completing characters, automatic character spacing, wide speed range and includes special characters used by hams.* In response to several queries the possibility of adding another bank of memory storage within the same keyer case was investigated; this would permit the operator to type ahead of the actual transmission—or to slow down momentarily while hunting for a key—and still produce faultless Morse code.

With an added "buffer storage module" you type at the same average speed as the keyer (as normal), but if you hit two keys close together and a third much later, the keyer sends perfect code. The buffer storage results in several subtle changes. In the basic keyer, for example, a key is held down to repeat a character. With the buffer storage, you tap the key twice just as when using a typewriter to repeat a character. If you press a key before the logic circuits are ready for it, with or without the storage module, you cannot affect the stored characters; simply hold the key down, and when the memory circuit is clear, the new character is stored automatically, and the key can be released.

With the added buffer storage, two keys can be tapped rapidly and a third key held down until the first character is complete, a fourth key held down until the second character is complete, etc. Your average typing speed is not increased, but you have a backlog of two characters that gives you a much wider operational flexibility.

basic keyer

The basic keyer consists of two circuit boards (matrix and logic board) and a keyboard. The matrix board contains the information on each character and mounts on the keyboard. The logic board stores the information on the selected character, scans this storage at the selected speed, provides the proper spacing between characters and contains the output relay and side-tone circuitry. A simplified block diagram of the basic keyer is shown in **fig. 1.**

Thirteen wires carry the information from the matrix board to the logic board - one trigger wire to signal the logic board that a key has been pressed and six pairs of dot/dash wires that carry character information. This permits the formation of

*This keyer is marketed as the Pro-Key Kit and is available from Micro-Z Company, Box 2426 Rolling Hills, California 90274 for $149.50 postpaid. The buffer storage unit described in the article is available as a kit for $34.50 additional.

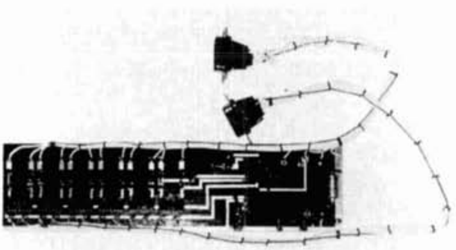
characters with up to six dot/dash combinations such as SK, period and question mark. If the "A" button is pressed, a positive voltage appears on the "dot" line of the first pair of wires, on the "dash" line of the second pair of wires, and on the "trigger" wire.

The trigger signal starts the keyer clock and opens the insert gates momentarily to store the selected character in the main storage elements on the logic board. After the gates close, the stored character cannot be disturbed. The logic circuits then scan the main storage to create the Morse character. If a new key is held down, the new character is automatically inserted only after the first character is complete and the proper spacing time has elapsed.

buffer storage module

The additional storage module is inserted between the keyboard and the main logic board **(fig. 2)**. When a key is pressed, the trigger signal is differentiated, stored in the module, and is used to open the module signal input gates so the selected character can enter the buffer memory.

As soon as the selected character has been entered into secondary storage, the trigger memory is erased, and the input gates close. The presence of a stored character in the module generates a trigger signal which is sent to the basic keyer. This starts the clock and inserts the character in the main storage, just as if the signals were coming directly from the keyboard. The pulse that opens and closes the main insert gates on the basic keyer is used to clear the secondary storage in the storage module (after a slight delay). The total process takes only a few microseconds, and the storage module is ready to accept another character from the keyboard. Meanwhile, the logic in the basic keyer is leisurely scanning the main storage to create the first character at the selected sending speed.



Buffer storage module

Another key can be tapped immediately and the buffer storage process is repeated. However, since the first character is still being transmitted, the second character remains in storage until the main storage in the basic keyer is ready to accept it. The presence of a stored signal in buffer storage "locks out" – or inhibits – the storage module input gates so the second character cannot be disturbed until it moves into main storage and the buffer storage is cleared.

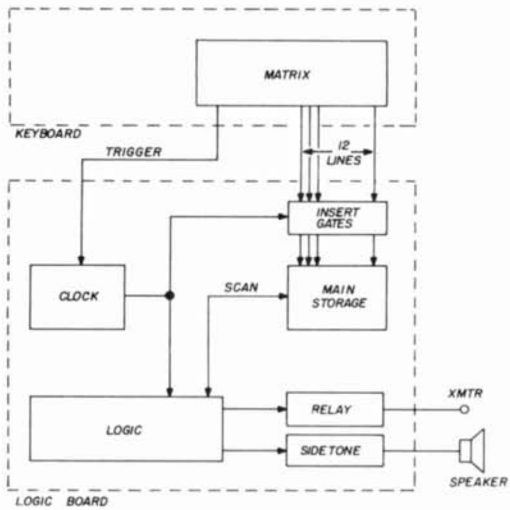


fig. 1. Block diagram of the basic pro-key typewriter-type electronic keyer.

A third key can be pressed immediately after the second. When the keyer has completed the first character, the character in buffer storage automatically moves into main storage, and the buffer is cleared. The buffer storage will then accept the third character, the third key can be released, and the operator can move on to the fourth character while the second is being transmitted.

An entire CQ or DE is stored by simply tapping two keys, just as you would on a typewriter, and the Morse characters are des are raised above ground. This is accomplished by a positive trigger signal from the keyboard operating through the trigger storage flip-flop and inhibit

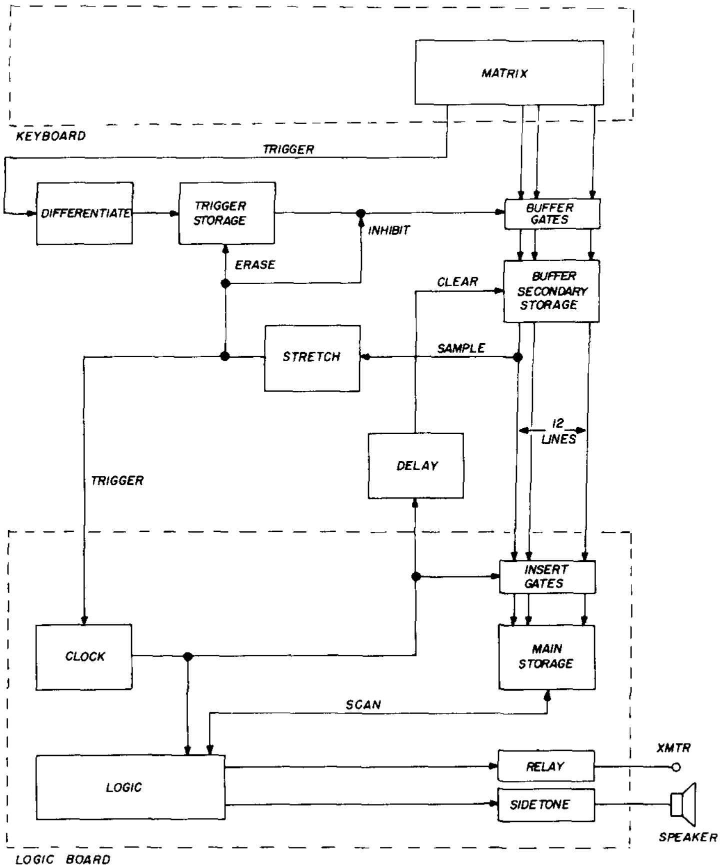


fig. 2. Block diagram of the keyer with the added buffer storage module.

transmitted at the speed set by the operator. The operator can speed up or slow down his typing but the keyer transmits smooth, even code. This is particularly useful for hunt-and-peck typists who use a typewriter-type keyer at 20 to 25 wpm.

circuit

In the logic diagram of the buffer shown in **fig. 3**, only three of the twelve storage RS flip-flops are shown for simplicity. Keyboard signals set the proper storage flip-flops to provide a positive output only if the cathode ends of the gate diodes are raised above ground. gate to apply a positive signal to all gate diode cathodes. The first two storage flip-flops are sampled by a two-input NOR gate which resets the trigger flip-flop and closes, or grounds, the input gate diodes through the inhibit gate when either of the two storage flip-flops have been set. The output of this NOR gate is stretched by the series 5k resistor and .01 μF capacitor to give all of the appropriate storage flip-flops a chance to set before closing the input gates.

If another key is pressed while the buffer storage is full, the trigger flip-flop is again "set" and tries to open the input gates, but the inhibit gate prevents this until the storage flip-flops are cleared by the main logic board. The NOR gate that fer. This provides the delay necessary to assure sufficient time to insert the stored signal in the keyer prior to clearing the buffer.

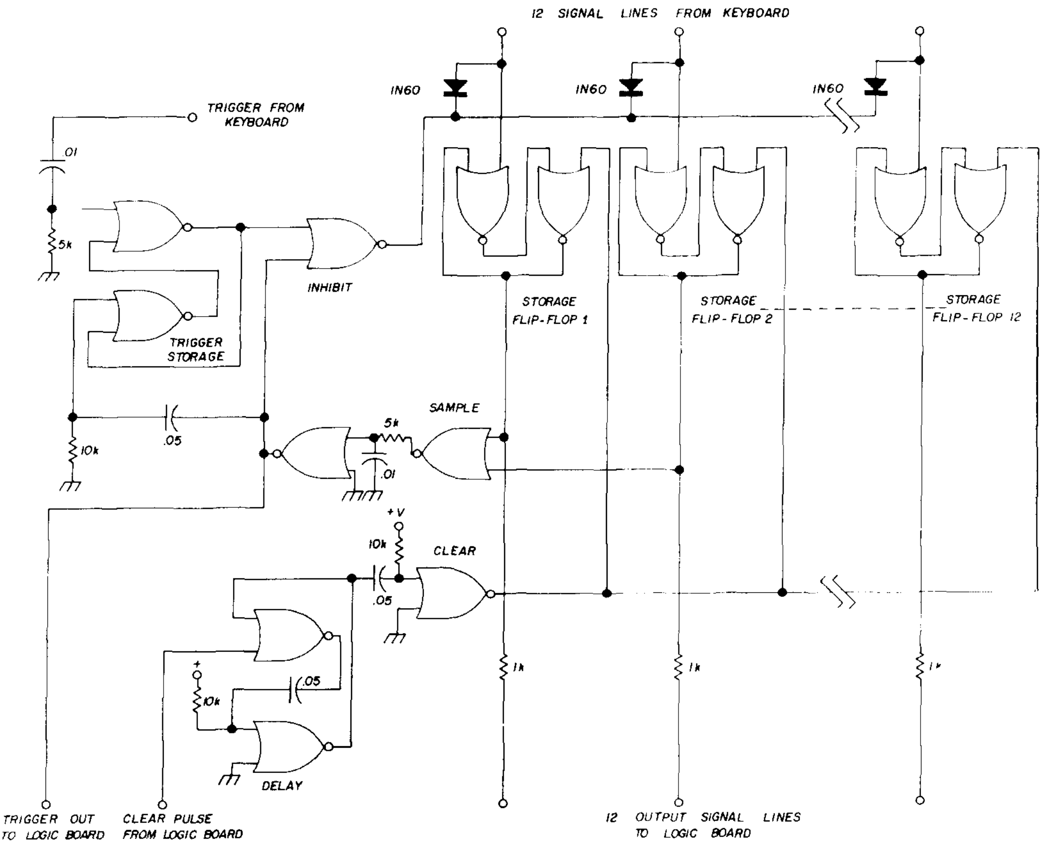


fig. 3. Logic diagram of the buffer storage unit. The author used eight Motorola MC724P quad two-input gates in his model.

detects the presence of a stored signal and inhibits the opening of the input gates also supplies a positive trigger to the basic keyer, just as if the signals in buffer storage were coming directly from the keyboard. With this logic, if a key is pressed while the storage is empty, the character will be inserted only once, and the key must be pressed again for a repeat.

When the main insert gates are opened, a positive pulse triggers a one-shot circuit. The negative-going trailing edge of the output pulse of this stage is inverted and used to reset all flip-flops in the buffer. This provides the delay necessary to assure sufficient time to insert the stored signal in the keyer prior to clearing the buffer.

adding more storage

Since the output of the buffer storage appears as a virtual keyboard, and is compatible to input and output signal logic polarity, buffer modules can be stacked to provide banks of four, five, six or more character storage. I have connected four of these together to store any five-letter word (such as my call) but the utility is questionable since the first character is generally complete by the time you are typing the third or fourth character, except at very low code speeds.

ham radio

photographs by Ted Stites

homebrew five-band linear amplifier

A conservatively designed circuit using time-proven 811-A's

Harry R. Hyder, W7IV

It is customary to preface a construction article with a few remarks about why the author decided to build rather than buy the equipment described. In my case, there's only one reason why I build radio equipment: I enjoy it.

I don't enjoy hole drilling or coil winding any more than an artist enjoys mixing paint or cleaning brushes. My satisfaction comes from creating something unique from my own mind and hands.

I read the construction articles in **ham radio** and other magazines every month, but I've never built equipment that exactly duplicates a published description. What I look for is not something to copy, but rather the construction hints and ideas that I can adapt to my own requirements.

This article is presented in that spirit. You may not wish to copy this linear amplifier, but you could do worse. Perhaps you'll find something you can use in your next construction project.

circuit description

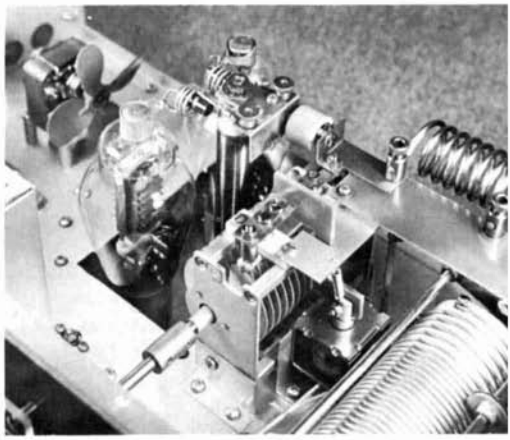
Parallel 811-A's are used in a grounded-grid circuit **(fig. 1)**. In terms of watts-per-dollar of tube cost, the 811-A must head the list. Some hams complain of a short life for these tubes when operated at ICAS ratings as these are; however, I find it's easier to buy a couple of inexpensive tubes frequently rather than a single expensive tube occasionally.

The cathode circuit has a matching network to transform the 50-ohm input to approximately 150 ohms required by the tubes. A cathode matching network is often dispensed with, but it has its virtues. A 3:1 mismatch is frequently beyond the capability of some exciters. If the exciter doesn't have some power to spare, it may not be possible to drive the amplifier to full output without the network. With the matching network, the transmission line is "cold" and may be of any reasonable length. Some writers have reported that the matching network also improves amplifier linearity. Therefore, since it's simple and requires no tuning, it's cheap insurance.

The network is an L configuration on 80, 40 and 20 meters, changing to a pi network on 10 and 15 meters. The high effective cathode-to-ground capacitance, consisting of tube and wiring capacitance plus the distributed capacitance of the filament choke, precludes the use of an L network on the two higher frequency bands. The tapped 20-, 40- and 80-meter cathode inductance is in the circuit at all times. On 10 and 15, small self-supporting airwound coils are connected in parallel with it. This is merely a switching convenience.

The plate tank coil is a roller-type inductor for the low-frequency bands, with a series-connected small coil for 10 meters. The variable inductor permits adjustment for optimum Q on all frequencies.

Detail of the amplifier tank circuit. The small coil in the binding posts is the 10-meter inductor.



Circuit details and component layout of input section. Attention to detail results in a professional appearance.

The plate tank capacitor is from a BC-375 tuning unit. Its original capacitance range was 23 to 140 pF. I wanted to reduce minimum tank capacitance on the high-frequency bands to lower the loaded Q and increase efficiency. I carefully split the stator with a fine saw. Only one of the sections is used on the high-frequency bands, reducing the minimum tank capacitance by about 12 pF. This decreases the loaded Q on 10 meters from 26 to 20, and on 15 meters from 19 to 15. The photos show the switching arrangements to cut in the second section. The contacts are from an old relay, and the solenoid is a 115 Vac unit I happened to have in my junk box. The solenoid is controlled by a front-panel switch.

The loading capacitor is a five-gang 420-pF-per-section unit that came from an MN-26 radio compass. Two sections in parallel are used on the higher frequencies; the remaining three are cut in by a relay controlled by the tank capacitor switch. The capacitor is available from Barry Electronics.

At 1500 volts, 811-A's require about 4.5 volts bias, which is supplied by a 4.7-volt zener in the filament return. This is less expensive and more reliable than a bias supply, and has a very low impedance. A 100-volt zener is also in the filament return, with a small amount of dc current bled through it. This provides full cutoff bias. It can be cut out by a front panel switch, or by external relay contacts.

The plate-current meter is also in the filament return, but reads plate current only; not total cathode current. The grid-current meter is in the dc grid return.

The high-voltage bleeder consists of four 150-k ohm 2-watt resistors in series, since it is not good practice to put more than about 500 volts across a single 2-watt resistor. I like redundant bleeders; should the one in the power supply open, the one in the amplifier will discharge the filter capacitors in a few seconds. A neon lamp indicates high voltage on the amplifier.

construction

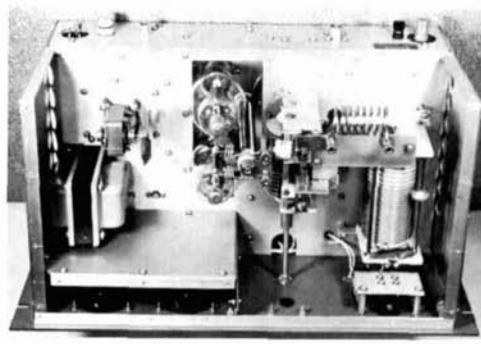
The chassis is aluminum, 10 x 17 x 3 inches. The 811-A's are mounted on a 4 x 6 x 1½-inch aluminum chassis upside down. I made these chassis sides and the meter shields from pieces bought in a scrap-metal yard.

The cover shield is cane-pattern sheet aluminum from a "do-it-yourself" department of a hardware store. This material is rather flimsy, so I stiffened it and improved the rf shielding with ½ x 1/16-inch aluminum strips on the outside. The ½ x ½ x 1/16-inch aluminum angle stock that holds the shield assembly was also obtained in the scrap-metal yard, but the same material is sold as trim in most hardware stores.

wiring

All power and control wiring should be installed first. Plan the wiring so that when the individual wires are joined into cables, the cables will run parallel to the main chassis dimensions. Strip each wire and tin it at both ends before placing it into the chassis. Leave a generous "service loop" when determining length; this makes parts replacement easy.

Lacing the cables adds a lot to appearance. Flat nylon ties are good. Start at the cable center and work toward the ends, bringing out individual wires as required.

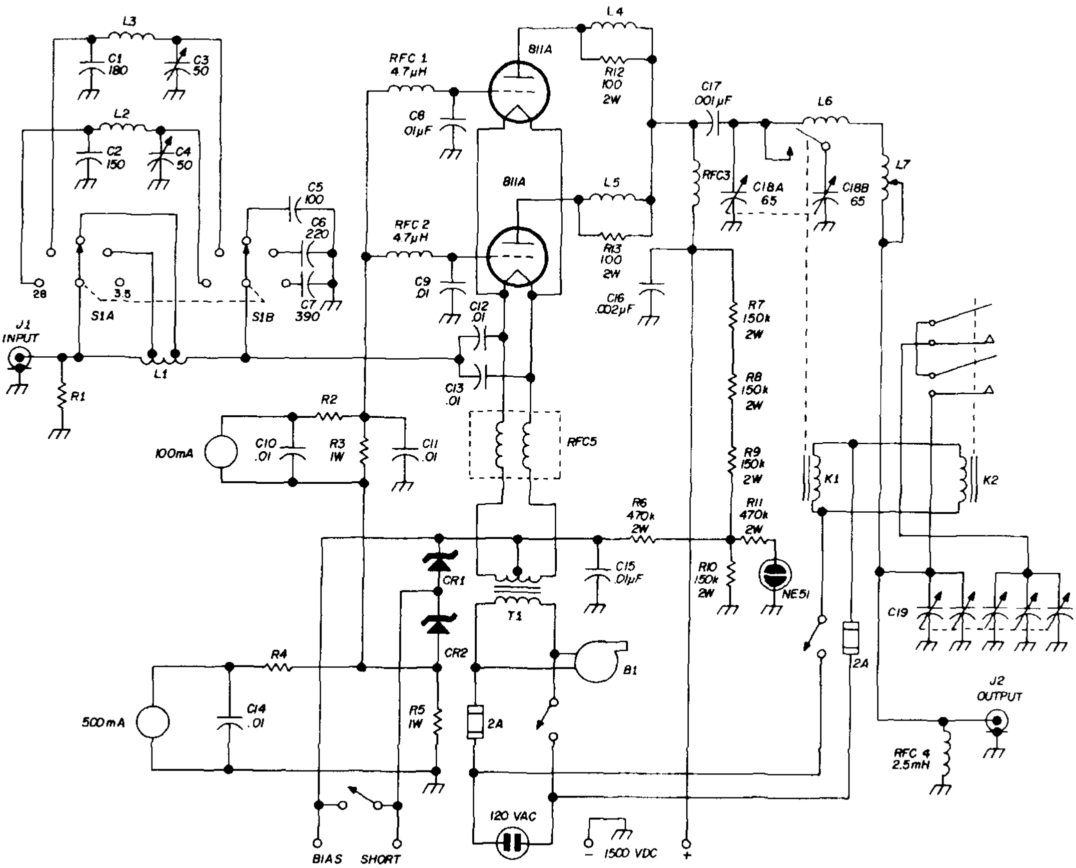


Conductors in low-level rf circuits consist of bare tinned bus bar. Output circuits are brass or copper strip about 0.02-inch thick. These strips should be secured with screws and nuts rather than solder. For appearance, sand the strips and spray them with clear lacquer.

the panel

I prefer gray wrinkle to all other finishes. I purchase a blank panel with a black-wrinkle finish, complete all drilling, then spray it with "machine gray" lacquer. Several light coats are better than one heavy coat; the lacquer adheres better, and there's less tendency for the lacquer to fill in the original black finish. This makes for color standardization, because no two gray-wrinkle panels are of the same hue, even from the same manufacturer's lot.

Another finish, used on my amplifier,



B1	Cooling fan (Japanese import; see photo)
C18A,B	Variable, 2 section, 65 pF per section, 0.07 = inch spacing
C19	5 section, 420 pF per section
K1	See text
K2	Relay, dpst, 10 A contacts, 117 Vac coil
L1	7 = ½ turns 1 = ½ inch diameter, 2 inches long, tapped 3rd and 5th turns. Approximately 4.5 uH total inductance, tapped at 2.4 uH and 1.2 uH
L2	9 turns number 14, 5/8 inch ID, approximately 0.8 uH
L3	12 turns number 14, 5/8 inch ID, approximately 1.0 uH
L4,L5	3 turns number 14, 5/8 inch ID, wound around R12 and R13 (see photo)
L6	8 turns 1/8 inch copper tubing, 3/4 inch ID, 2 inches long
L7	Inductor, variable, 18 uH maximum (E.F. Johnson 229-202)
R2,R4	Adjust for correct reading of M1 and M2
RFC1,RFC2	4.7 uH pigtail
RFC3	90 uH, 500 mA (B & W
RFC4	2.5 mH, pie wound
RFC5	Filament choke (B & W FC-15)
SW1	2-gang rotary, 2 poles, 5 position
SW2,SW4	Spst toggle switch
T1	Filament transformer, 117 V pri., 6.3 V 10 A sec., CT (Triad F-21A)

fig. 1. Schematic of the 811-A grounded-grid linear amplifier. Matching section in cathode circuit provides a 3:1 transformation ratio, assuring adequate drive from most exciters.

requires nothing but a wire brush. Clamp the piece to a flat surface and make straight, even strokes with the brush. It produces a beautiful grained finish.

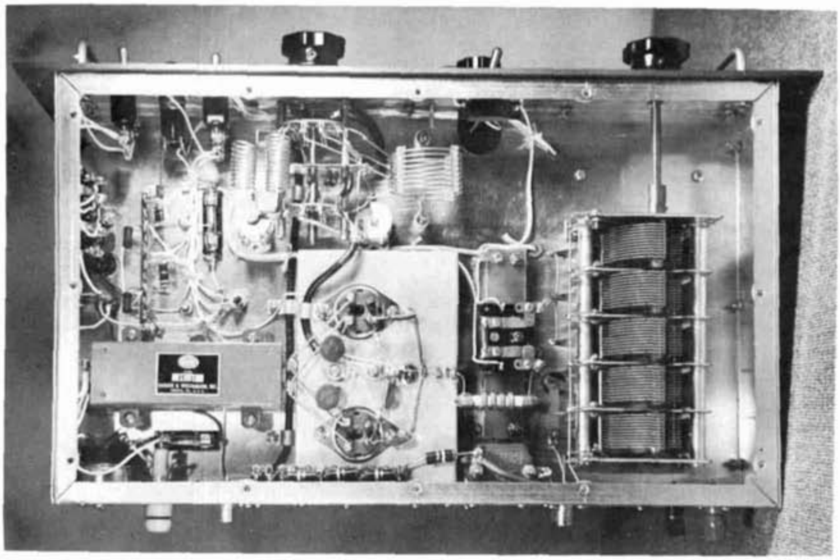
Whatever finish you use, handle the pieces with cloth gloves — fingerprints really stand out. Dust off the pieces and give them a couple of light coats of clear lacquer. Surfaces to be joined should be masked to obtain good electrical contact.

accessories

The fluted knobs and nickel-silver dial may look old fashioned, but I like them. They're still available commercially. The dial pointer was lost years ago, so I made

decals

You'll want to label your controls and other accessories. I prefer the water-type decals to the dry-transfer labels because mistakes are easier to correct. With the latter, you're committed to a position on the panel, and it's difficult to remove dry-transfers without ruining the finish. After you've positioned the decals, spray them with clear lacquer.



Bottom view of the linear amplifier. Note lead dress and method of securing cables.

one from a scrap of plastic. The pinch drive provides just enough drag to keep the [illegible] capacitor from getting out of adjustment.

The meters are su[illegible]ms. Their sensitivity wasn't what I wanted, [illegible] this was corrected using standard techniques.[1]

The roller-coil dial is homemade. I bought a 3-digit counter from a surplus dealer for a dollar. The miter gears were obtained from a standard right-angle drive. I cut the escutcheon from 1.8-inch-thick sheet aluminum. It's finished in black-wrinkle lacquer. A possible source of wrinkle finishes in spray cans is your neighborhood Speed Shop; the hot-rod set seems to favor these finishes nowadays.

a final word

If this is one of your first major construction projects, and you've made a few mistakes in mechanical work, all is not lost. Most goofs can be remedied. Extra holes can be occupied with screws and solder lugs, as if this is what you intended all along. Or you can strip the finish and fill the hole with auto-body solder, then refinish the panel. This takes a few hours of extra work, but it reflects your pride in a job well done.

references

1. "The Radio Amateur's Handbook," 46th edition, 1969, American Radio Relay League, p. 528.

ham radio

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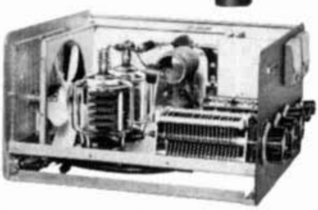

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a new approach to equipment rack construction

Here's a low-cost rack that can be easily built to accept any panel width

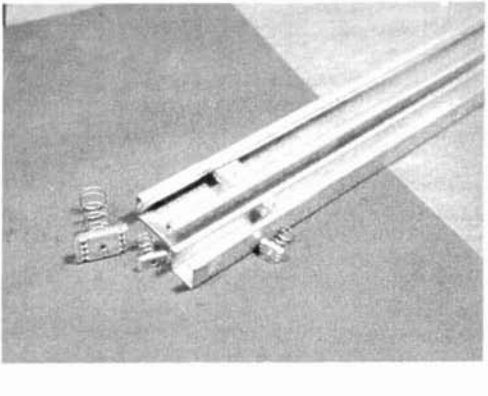
George R. Allen, K1EUJ, Route 2 Robin Circle, Tolland, Connecticut 02891

Equipment racks are a useful asset to almost any amateur station. Known also as "relay racks," they are available commercially only in sizes for standard 19-inch panels. This article describes a simple, inexpensive approach to rack construction whereby racks can be built to accept panels of any size. Material costs range from $4 to $8 per rack.

design

Commercially available racks consist of a metal frame with the front portion drilled and tapped to accept 10/32 screws

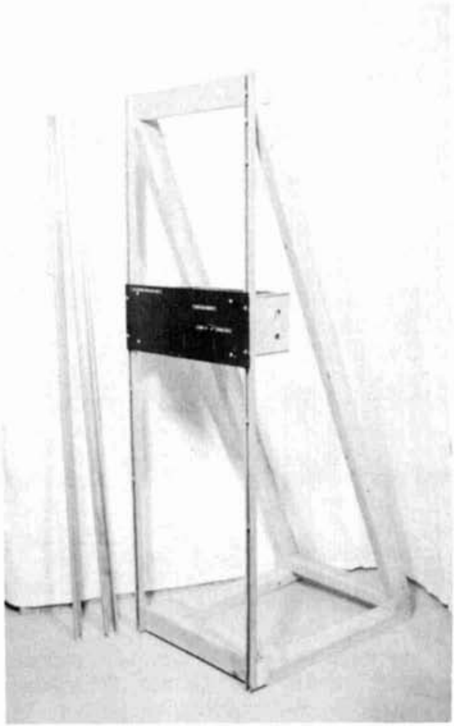
Two sizes of steel channel with spring-loaded nuts for mounting panels.



for panel mounting. The racks I've built consist of a wooden frame with two pieces of channel steel attached to the front for panel mounting. The channel steel, called *WHIZ STRUT,* comes complete with spring-loaded nuts that may be inserted into the channel at any location where a panel is to be attached to the frame. The spring, attached to the nut, forces the nut against a flange on the channel, causing the nut to stay in place. The photo shows large and small sizes of strut with associated spring-loaded nuts. These nuts are for 10/32 screws; however, other sizes are available.

a simple homemade rack

A sketch with dimensions for constructing the rack shown in the photo is given in fig. 1. This rack is 58 inches high and accepts 19-inch panels. However, there's no reason why the width can't be changed to accept panels longer or shorter than this. The cost of the rack in the illustrations was $5 for the struts and spring-loaded nuts, and about $2 for the lumber.



Homemade equipment rack with 19-inch panel spacing. Panels of any size can be accommodated by varying width of channel supports.

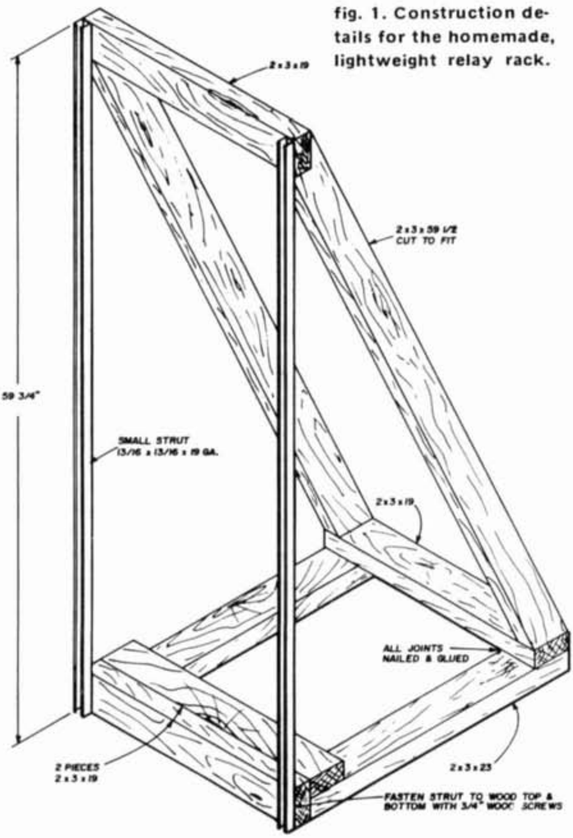


fig. 1. Construction details for the homemade, lightweight relay rack.

Heavy equipment can be mounted easily in this rack by one person. The equipment is loosely fastened to the nuts while the equipment rests on the bottom of the rack. The equipment is then slid up the rack until it's in the proper position, where it will stay with little effort. Once in position, the equipment may be securely fastened.

Struts and hardware may be obtained from the distributor, who will send you a price list upon request.*

*Donald S. Tunnel, Box 331, Fort Washington, Pennsylvania 19034. Ask for amateur price sheet "A".

ham radio

solid-state radio direction finder

Sam Kelly, W6JTT, 12811 Owen Street, Garden Grove, California 92641

Radio direction finding has come a long way since F. Braun did his "Research on a Method of Directive Wireless" early in 1903. One of several early experimenters, Braun conducted his DF work with the German army balloon department.

Much early DF work was confined to observing weather phenomena and experimenting with antenna directivity. The Russian scientist Popov, for example, was primarily interested in tracking thunderstorms. By 1911, Italians Bellini and Tosi were experimenting with DF on shipboard. Military requirements spurred DF development during World War I.

From 1918 until the late 1940's, radio direction finding advanced with improvements in receivers, antennas, and servo systems. Today, commercial DF is giving way to more advanced navigational aids such as satellite repeaters, Loran-C, Omega, Decca and inertial systems. Radio direction finding, however, is still important for navigation in small vessels and as a backup where long-range navigation systems don't provide coverage.

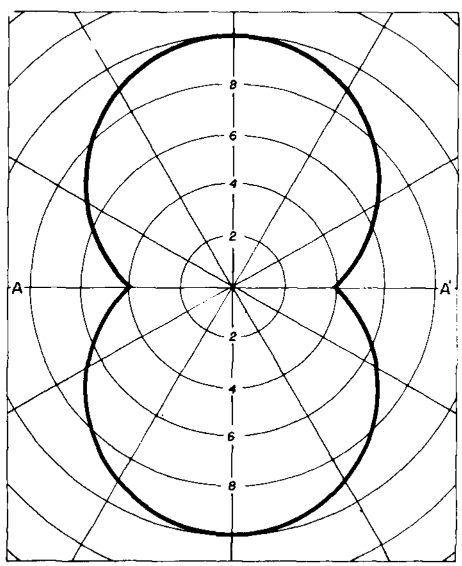
This article describes a small DF adapter for communication receivers, using a simple diode detector and transistor audio amplifier. It's useful for locating radio interference sources, hidden transmitters in radio club contests, or as an addition to your boat's communication equipment.

df principles

Radio direction finding is based on the directional characteristics of antennas. The idealized pattern of a loop antenna is shown in **fig. 1.** Under ideal conditions, this pattern can be plotted by measuring the voltage at the antenna's terminals as it is rotated 360 degrees in the horizontal plane. A maximum voltage is obtained at the antenna terminals when the transmitter is in line with the loop.

The minimum voltage, or null, is obtained when the loop is broadside to the transmitter. The nulls are of great importance, as they provide the most sensi-

fig. 1. Idealized pattern of loop antenna. Line A - A' is in direction of transmitting station.

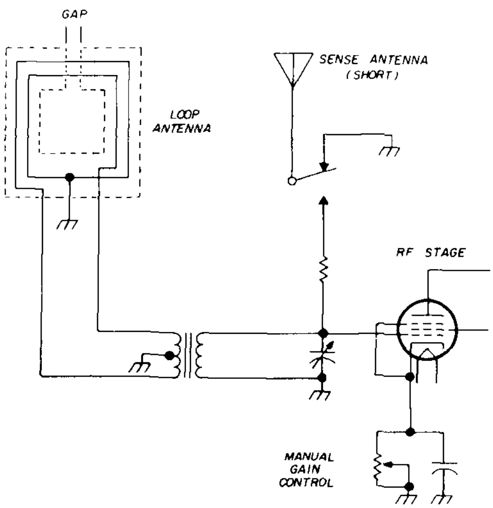


tive means of determining the signal path.

You can see from **fig. 1** that a peak or null can be obtained with a transmitter in either of two directions with respect to the loop. This is called the "180-degree ambiguity."

In the early days of radio direction finding, the 180-degree ambiguity caused many accidents. A conventional DF antenna is shown in **fig. 2.** A separate vertical or "sense" antenna is used with the loop to resolve the 180-degree ambiguity of the transmitter location. In practice, the operator adjusts the loop for minimum signal with the sense antenna disconnected. He then finds the sense, or general direction, of the transmitted signal by rotating the loop 90 degrees with the vertical antenna connected. If the addition of the vertical increases the signal in one direction, then minimum signal indicates that the transmitter is in the opposite direction. Adding the vertical antenna changes the pattern of the basic loop to a cardioid(**fig. 3**).

fig. 2. Input circuit of direction finder. Sense antenna modifies loop pattern to that shown in fig. 3.



The cardioid pattern is much too broad *to give an accurate bearing.* It is used only to sense the general direction of the transmitter.

the goniometer

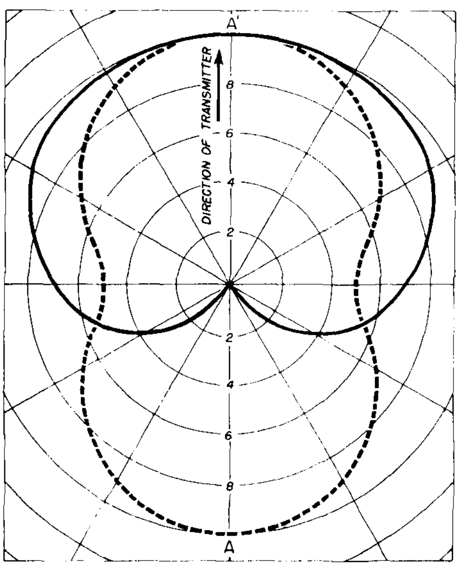
An interesting variation of the DF loop is the Bellini-Tosi antenna shown in **fig. 4.** This consists of two fixed loops at right angles to each other. Loop outputs are coupled to two identical rf coils accurately mounted at right angles to each other. A secondary coil is free to rotate around the fixed coils, making a rotary transformer to couple the output to the receiver. The shaft of the secondary is attached to a calibrated dial.[1]

The Bellini-Tosi system has several advantages such as convenient shipboard mounting (all rotating components can be below deck), and the ability to match a long transmission line. It can also be used at fixed locations, since the torque required to turn the shaft of the rotary transformer is within the capability of typical synchros.

df adapter

The ferrite loops used in transistor radios can be readily modified for DF work. A small DF adapter for use with a

fig. 3. Cardioid pattern of loop caused by addition of vertical sense antenna. Loop is rotated 90 degrees to determine "sense", or general location, of transmitted signal.



communications receiver is shown in the photo. Its schematic is shown in **fig. 5.** The crystal detector and transistor audio amplifier allow the adapter to be used without a receiver. It can be used to locate sources of interference or hidden transmitters in club activities. The signal must be either broadband noise or an a-m transmitter, since there's no provision for product detection.

using a signal generator. The sense antenna is a small transistor-radio whip. The loading coil was salvaged from a DAV antenna. The loading coil is peaked on the frequency to be tracked by tuning in the signal, depressing the sense button, and adjusting the tuning slug for maximum signal.

Inexpensive British surplus headphones were used. These have a very low

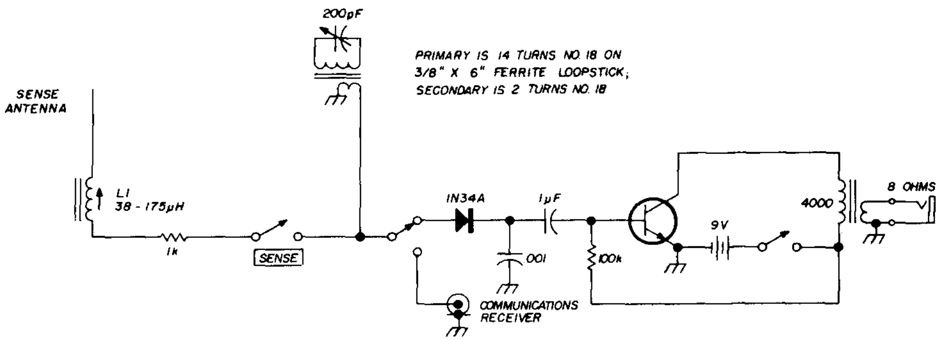


fig. 5. Direction finding adapter schematic. Sense antenna is a piece of vertical wire or small tubing 3 - 4 feet long; loop is made from transistor radio ferrite loopstick.

construction

The adapter was built in a small aluminum box. Care was taken to shield the sense lead and the lead from the switch to the coaxial connector for the external receiver. The dial was calibrated

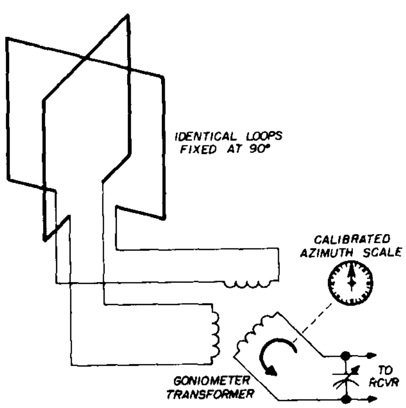


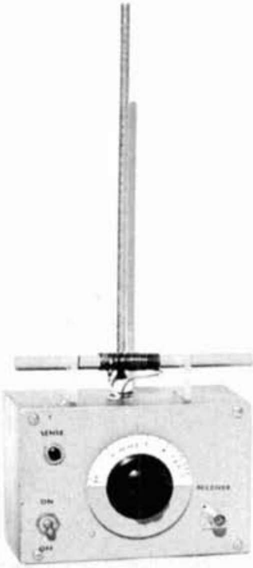
fig. 4. System using the Bellini-Tosi goniometer principle. Loops are fixed; goniometer transformer is rotated to obtain bearing.

impedance so the transformer is required. If you are using 2000- to 4000-ohm magnetic headphones, the transformer can be omitted.

operation

As you gain experience, you'll quickly learn the limitations of direction finders. There are two major problem areas: location problems and multipath signals due to propagation phenomena. Take bearings from high points in flat, unobstructed areas. Remember that bearings taken in or near buildings having a lot of metal will be inaccurate. Operation in dense foliage or rough terrain will also cause errors. The easiest way to determine if the bearing is wrong is to take bearings at frequent intervals. Then any odd bearing will be obvious.

Night effect is quite pronounced in the 2- to 8-MHz region. This is a propagation phenomena resulting in changes in the polarization of the sky wave signal. The symptoms can range from complete



DF adapter for use with communications receiver or as a "walk-around" sensor.

absence of a null to pronounced nulls as much as 90 degrees from the correct bearing. This effect is most pronounced at sunrise and sunset – periods that correspond to the most rapid changes in the height of the ionosphere. Fortunately, the effects of the polarization changes are reduced the closer you are to the transmitter. In most transmitter hunts these aren't evident. If you have plenty of space, you can reduce the night effect by using a vertical antenna system such as the Adcock.

Like most crafts, the best way to become proficient in direction finding is to practice. How long has it been since your club had a hidden-transmitter hunt or tracked an irritating source of radio frequency interference?

reference

1. F. E. Terman, "Radio Engineers' Handbook," McGraw-Hill, New York.

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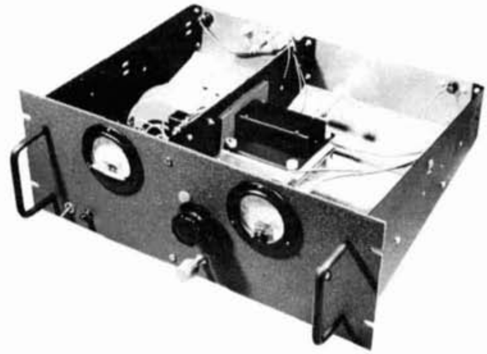


a power amplifier for 1296 MHz

Dual planar triodes in a half-wave resonant cavity provide 100watts output with 10 dB power gain

R. E. Fisher, W2CQH, C. W. Schaible, W2CCY, G. W. Schober, W2OJ, R. H. Turrin, W2IMU

One reason for the limited amount of activity on the uhf bands is lack of commercially available equipment or proven designs for homebuilt projects. This article presents a grounded-grid power amplifier for 1296 MHz using two 3CX100 A5/7289 planar triodes. Easy-to-work materials are featured, and very little soldering is required. Although material substitutions and modifications to the construction methods are feasible, we recommend that the amplifier be built according to the directions given. This will ensure correct performance and a minimum amount of debugging.

The amplifier will deliver a minimum of 100 watts into a 50-ohm load, at 50 percent efficiency, with a power gain of 10 dB. The circuit is similar to one described in reference 1. The difference is mainly in the placement of tubes in the cavity and in the cavity tuning circuit. The initial design, developed by W2CCY, was water cooled and very rugged. A later version, built by W2CQH, featured air cooling and simplified construction. Tests have shown that air cooling is adequate, but quieter operation is obtained with water cooling.

circuit description

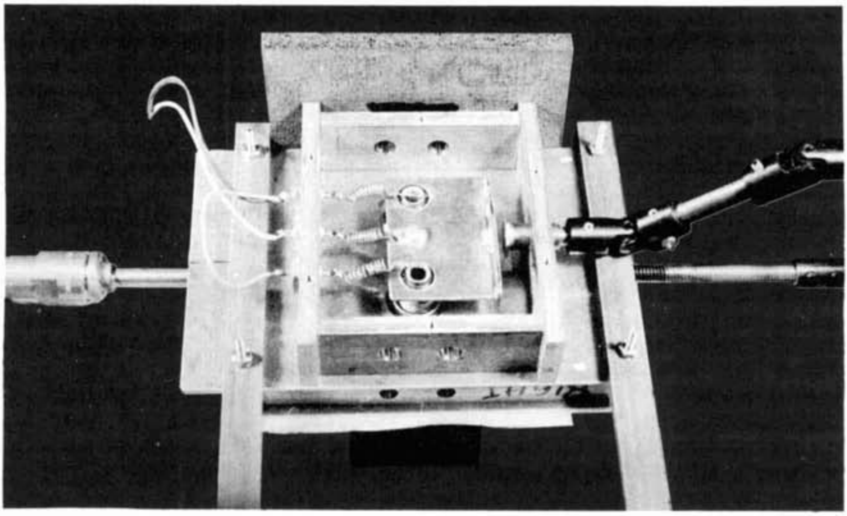
A conventional grounded-grid circuit is used, with bias provided by a zener diode in the cathode **(fig. 1)**. A 27-volt, 10-watt zener is satisfactory for class-C amplifier operation. However, partial or full resistor bias, which has the advantage of being fully adjustable could be used. The resistance must be bypassed with a large capacitor for a-m operation. This arrangement isn't recommended, because each time the amplifier is turned on it receives no bias initially. Thus, it will draw heavy anode current until the capacitor charges.

The zener, on the other hand, provides **immediate** bias and also presents a low impedance at audio frequencies. Since grid current flows through the cathode-bias circuit, a zener minimizes drive power loss that would occur across a cathode resistor. Several zeners may be connected in series if a single unit isn't available.

anode cavity

The anode cavity is a loaded half-wave resonant circuit, which extends along the centerline through the tubes. Immovable brass bars, which form the sides of the cavity, determine the approximate resonant frequency. A sliding plunger allows vernier tuning near 1296 MHz.

A magnetically coupled link provides a wide range of output loading. The input circuit uses a low-inductance strap that ties the cathodes in parallel and extends as a short stripline, which resonates as a half-wave tank. Approximately one-quarter wavelength of this tank is the internal cathode structure of the tubes. Capacitive tuning is provided at the other end of the tank. Input coupling is by means of a capacitive probe. Since the external connections to cathodes and heaters are in a low-rf field, simple wirewound rf chokes can be used in the bias and heater lines.



Inside view of cathode cavity showing the panel-bushing tuning capacitor. Sponge rubber plenum is visible at the top.

Metering is included in both anode and cathode leads to maintain the grid at earth potential. Both meters are necessary to determine grid current. Grid current is simply the difference between cathode and anode current. Grid current is a sensitive indicator of correct operation when adjusting tuning, loading, and drive for optimum efficiency.

construction

Both anode and cathode resonant circuits are constructed of brass sheet and rod, which are available at most metal supply houses and some hobby stores. The brass rod used for cavity walls has uniform dimensions and a smooth finish, therefore no soldering is required at the joints. Instead, 4-40 or 6-32 machine screws on 3/4-inch centers provide sufficient contact.

Both the plate cavity top cover and bypass capacitor, **fig. 3**, are made of 1/16-inch thick brass sheet. Finger stock, which contacts the tube plate rings, is soldered to the edges of the 1.18-inch-diameter holes in the top bypass capacitor plate. To facilitate alignment, the tube may be inserted into the structure during the soldering operation if a large soldering iron is used. Care must be taken to prevent solder from reaching the tube plate ring. The bypass capacitor plate is secured to the top cover with 8-32 Nylon screws. Teflon, 0.010 to 0.020 inch thick is used as the capacitor dielectric; although polyethylene, Mylar or mica will probably work as well.

Fig. 2 shows the plate cavity interior and grid contacts, which are soldered in finger stock similar to the plate contact arrangement. The sidewalls of this cavity are constructed of 1/4-inch thick brass rods, which are 5/8-inch high. The tuning plunger is made of 1/4 x 1/2-inch brass rod, with finger stock soldered to the top and bottom edges. The plunger assembly is moved by a 1/4-inch-diameter threaded lead screw, which is turned by a knob on the front panel.

The output coupling link is attached to a piece of homemade rigid coax (**fig. 2**), which comes through the center of the rear-cavity wall. The coax is retained by a shaft lock once the position for best loading is located. The rear wall should be temporarily clamped in place until cavity resonance is assured, then it may be permanently fastened to the top and bottom cavity plates with several small machine screws. Note that the ends of the tuning plunger and the rear wall *do not* contact the side walls at the corners of the cavity. Electrical contact is not nec-

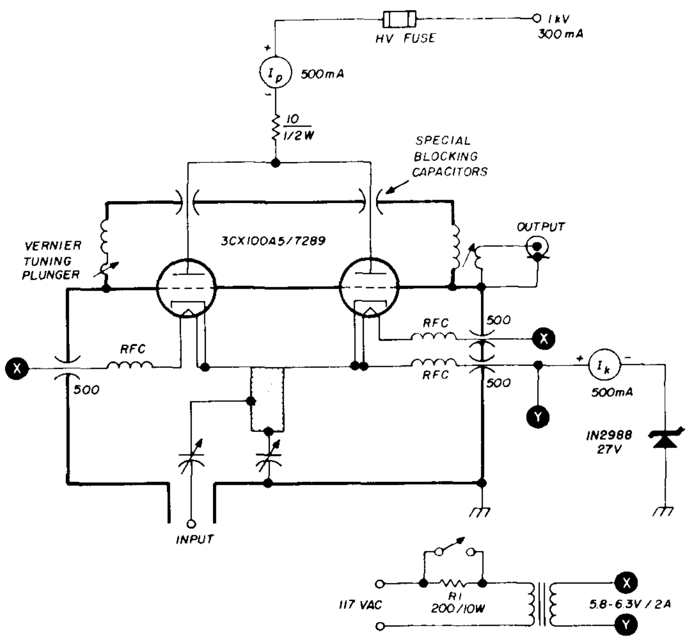


fig. 1. Schematic of the dual 3CX100A5/7289 grounded-grid amplifier for 1296 MHz. Each RFC is 10 turns no. 22 solid copper wire on a 1/8-inch diameter form.

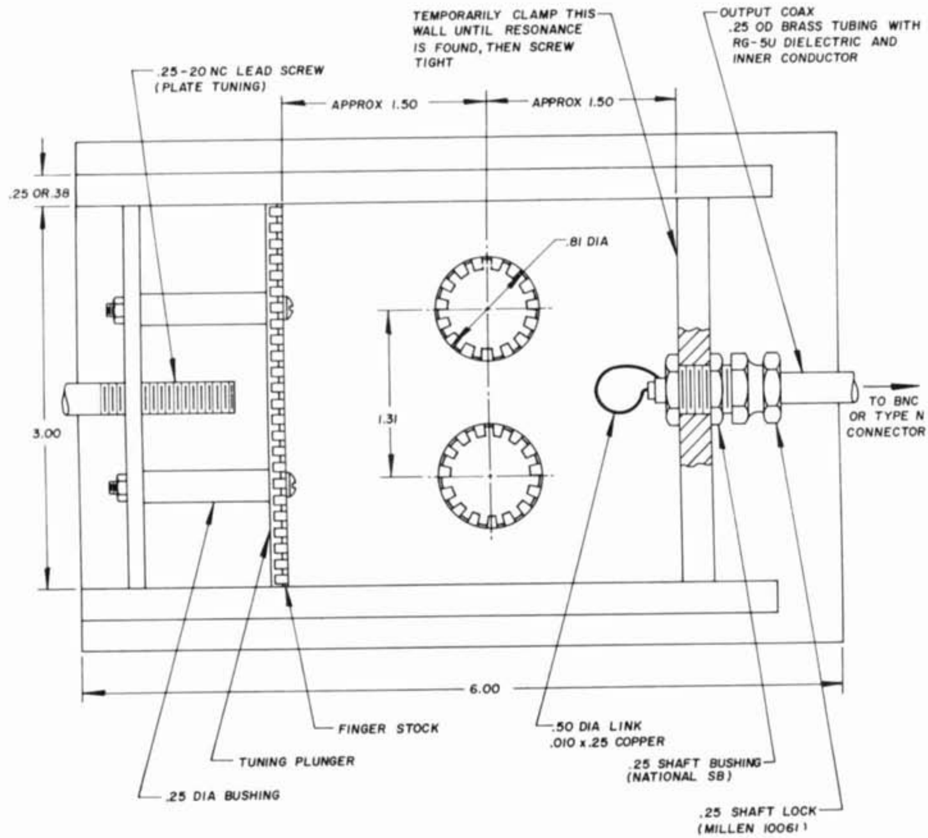
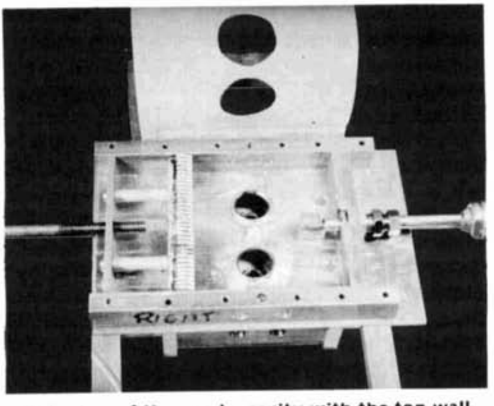


fig. 2. Construction of the plate cavity.

essary since essentially zero current is present in these regions.

Fig. 4 shows the cathode enclosure, which has walls constructed of ¼ x 1-inch brass rod stock. The stripline center conductor, which contacts both cathodes, is made from 1/16-inch copper and is supported by a single ½-inch-long ceramic standoff located midway between the two tubes. A 1/16 x ¼-inch strip soldered to the strip line forms one end of the tuning capacitor. The adjustable plate of the cathode tuning capacitor is the end of a threaded 3/8-inch panel bushing soldered to a ¼-inch-diameter brass rod, which is in turn coupled to a front-panel tuning knob via two universal joints. The small rf heater chokes are connected to the tube heater contact by small clips made of thin brass strip or pieces of finger stock material. The small spring strip is bent into a U shape and pressed into the heater contact.

Fig. 5 shows a cross section of both cavities. Input coupling to the cathode



This view of the anode cavity with the top wall removed shows the output link and finger-stock pluger.

cavity is provided by a probe that consists of a 5/16-inch-diameter brass disc soldered to the end of a threaded BNC connector. Not shown are several ¼-inch-diameter holes in the side walls of both cavities to facilitate air cooling of grid and cathode seals. A bakelite air duct covers both tube anodes. The blower air plenum should be arranged so that air will pass through the duct and also through the holes in the cavities. Note particularly the bushing at the tube anodes, which limits the insertion of the tube into the cavities. The tube should seat as shown by **fig. 5** to preserve cavity resonance.

tune-up accessories

Before applying power to the amplifier, you'll need a few simple accessories.

Substitute an adjustable resistor of about 200 ohms for the zener. This will be used to adjust cathode bias during tune up. You'll also need a 50-ohm dummy load and some kind of relative power indicator. If you don't have a 50-ohm load for 1296 MHz, a very good substitute can be made from sections of coaxial cable. Fifty feet of RG-8/U followed by 100 feet of RG-58/U will provide about 27 dB attenuation. This assembly will simulate a matched 50-ohm load at 1296 MHz.

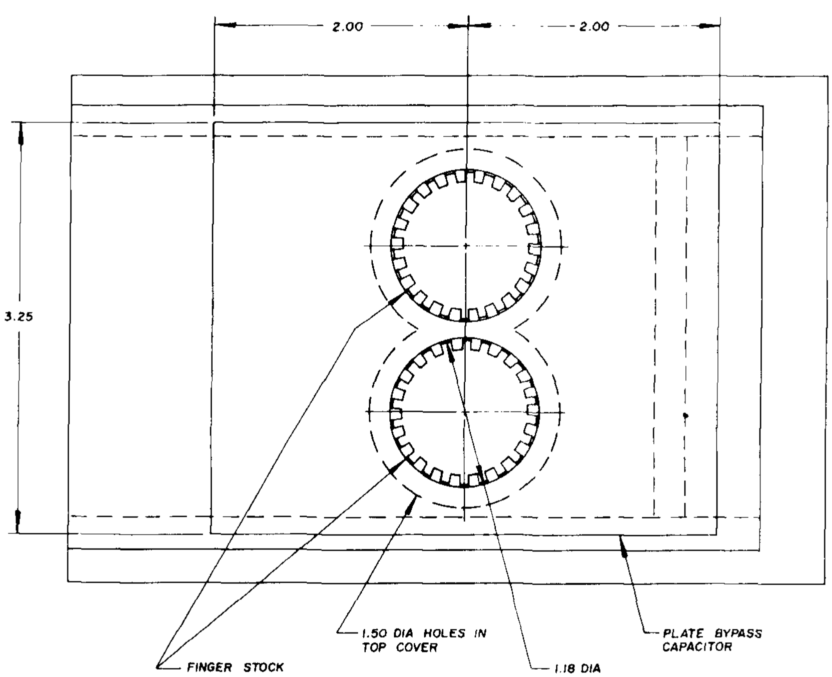
A diode detector and voltmeter circuit, such as that shown in reference 2, can be used as a power output indicator. The indicator circuit should be loosely coupled to the end of the dummy load. It's not necessary to calibrate the rf voltmeter since an indication of relative power is sufficient for initial adjustment of the amplifier. The coax sections may be coiled and taped.

Use only BNC and type N connectors. Don't use uhf connectors, as they will introduce a mismatch into the load.

tuning up

With the blower running, dummy load and indicator connected, and no rf drive, apply about 500 Vdc to the amplifier anodes. Adjust the resistor for about 50 mA of anode current. Next, apply about 5 watts of drive power. Adjust cathode

fig. 3. Layout of the plate cavity top cover and bypass capacitor.



tuning for maximum anode current. Input and output coupling may now be adjusted for maximum output consistent with minimum dc input power. Bear in mind that coupling adjustments will alter the resonance of the tuned circuits. Therefore, both input and output circuits should be retuned only with optimum coupling.

Under these conditions, output power will be about 100 watts minimum.

preventing self-oscillation

Unless a 50-ohm load remains on the output, the circuit may self-oscillate due to the high unloaded Q of the anode circuit. If an antenna switching device is to be used in which amplifier output is not

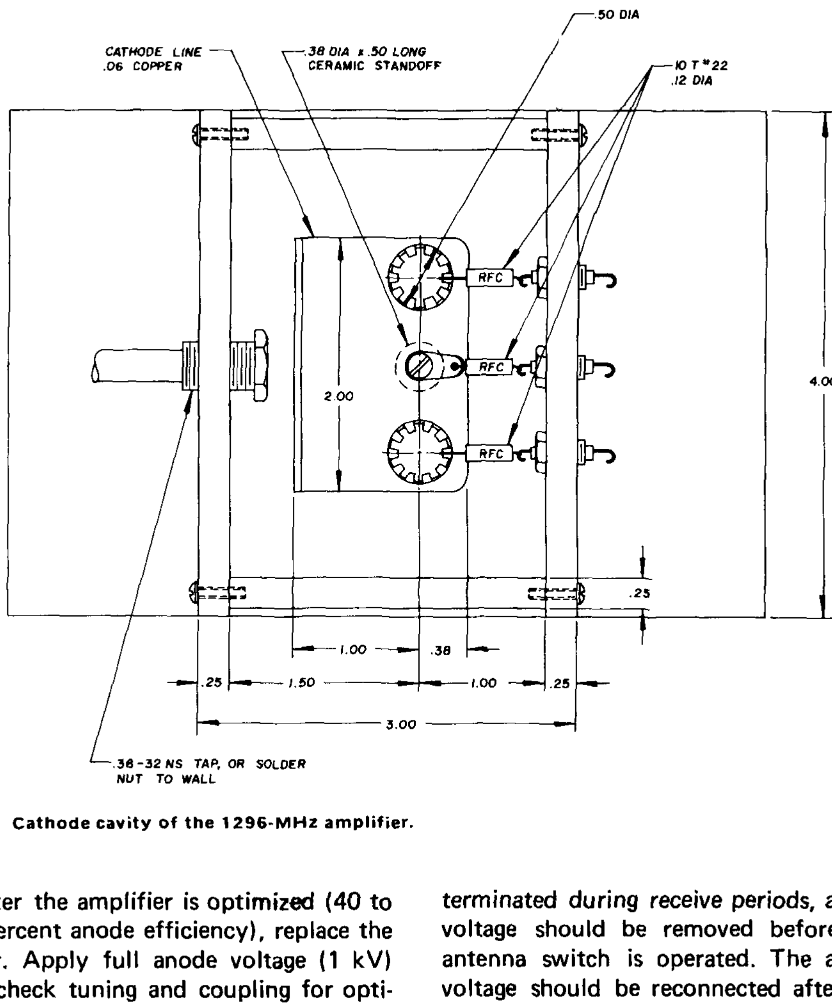


fig. 4. Cathode cavity of the 1296-MHz amplifier.

After the amplifier is optimized (40 to 50 percent anode efficiency), replace the zener. Apply full anode voltage (1 kV) and check tuning and coupling for optimum with about 10 watts of drive power. Grid current should be 50 mA if sufficient drive is available and all circuits are optimized. The tubes should not draw anode current when rf drive is removed.

With 1 kV on the anodes, the amplifier should load to 200 mA (anode) and 250 mA (cathode) with 10 watts of drive.

terminated during receive periods, anode voltage should be removed before the antenna switch is operated. The anode voltage should be reconnected after the antenna has been switched to the amplifier in a sequential manner.

tube dissipation

A quick check of the tube specifications indicates that a single 3CX100A5 is capable of 100 watts of anode dissipation, but our operating conditions call for only half of this. We are being conservative for several reasons. The primary reason is to obtain reliable, long-term life in view of the highcost of the tubes (approximately $20 each). Amplifiers of this design have been operated with anode voltages up to 1.2 kV and output power up to 175 watts for short periods. Although rated anode dissipation is still not exceeded, grid and cathode heating can become severe should the amplifier be mistuned, lightly loaded, or over-driven.

We also found that, at the higher-power operating conditions, heater power could be removed entirely as long as the amplifier was operated continuously. These results point out an interesting property of most uhf planar triodes; maximum output is not usually limited by anode dissipation but more often by grid dissipation, since it is more difficult to extract heat from the relatively frail grid structure. A close-fitting grid ring connection with as much thermal conductivity as possible should be used. In addition, as we have done with this amplifier, vent holes should be provided next to the grid ground plane. This allows forced air to be applied directly to the grid and cathode seals, which is highly desirable.

heater power

During operation we found that at 100 watts output, full heater power could be maintained with no serious consequences. However, it's recommended that heaters be operated at 5.8 instead of 6.3 volts. This will maintain adequate cathode temperature while minimizing back heating of the cathode during long standby periods. A more sophisticated method might be to include a relay that switches heater voltage under control of cathode current. Thus, when no drive is present, and cathode current is zero, the full heater voltage could be applied.

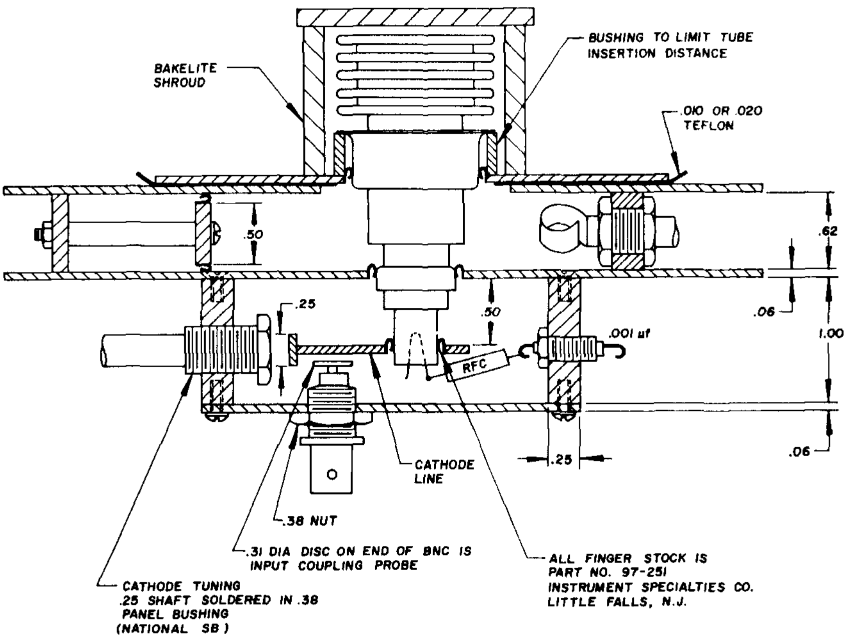


fig. 5. Cross section of the amplifier, showing the plate cavity, cathode cavity, plate bypass capacitor and 3CX100A5 tube.

the dc blocking capacitor

The plate dc blocking capacitor deserves special mention, since its design is *not* based on capacitance alone. This capacitor is considered as a flat parallel-plate transmission line. Its dimension in a radial direction from where dc blocking is desired is adjusted for a quarter wavelength or less. Thus, the physical length of the capacitor is reduced by the inverse square root of the capacitor's dielectric constant.

For example, Teflon has a dielectric constant, ϵ , of about 2.1. The radial length, L, of a dc blocking capacitor is then

$$L = \frac{\lambda}{4\sqrt{\epsilon}} = 9.14/4\ (2.1)$$

= 1.6 inches or less for 1296 MHz

Additionally, the parallel-plate transmission line's characteristic impedance should be as low as possible. This is why a dielectric is used to load the line and to provide uniform close spacing. The reasoning is that, if the blocking capacitor looks like a quarter-wave section of transmission line, the end outside the rf cavity will be open. It will then reflect a very low impedance back into the cavity where blocking is desired.

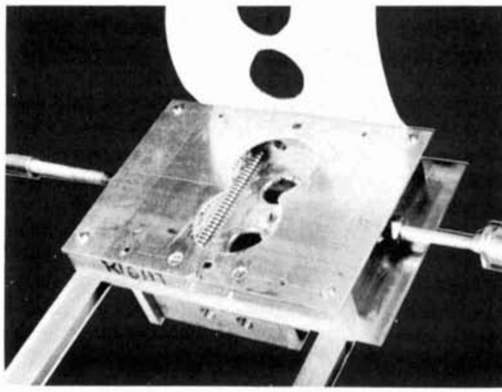
You might ask the question as to how much rf voltage appears at the "hot" end of the quarter-wave section outside the cavity. This is simply the product of the rf current entering the line and the line's characteristic impedance, Z_o.

Typically, Z_o for a close-spaced parallel plate line with dielectric loading will be a few ohms. The current into the line is determined by where the line ends in the cavity. It is most desirable to place the dc blocking capacitor at a high field point where rf current is minimum. In most cases, this is impractical, and the block is placed where some current flows. However, even if the current is of the order of several amperes, the product of current and Z_o would still be about 10 volts, a not too objectionable level. This approach to dc blocking in uhf amplifiers is very practical for most applications.

concluding remarks

Note that very little soldering is required in assembling the cavity and enclosures, except for securing finger stock. Tight joints where necessary and mechanical stability are provided by the large area overlaps of the bar and sheet stock. This method of construction is less tedious but more costly.

The glass-sealed 2C39 tube, which is more commonly available, has been tried in this circuit with inferior results. Gain, efficiency, and output power suffer by at least 3 dB, and no attempt should be made to obtain more than 50 watts output with these tubes. A number of tubes failed because of punctures and cracks in the glass seal between grid and anode due to rf heating losses in the glass.



Anode cavity top wall with the anode plate removed. The teflon dielectric for the blocking capacitor is at the top.

For those who need a high-power tripler to operate from an existing 432-MHz transmitter, it is suggested that the same amplifier be modified in the cathode circuit to resonate at 432 MHz. This can be done in several ways. Perhaps the most simple way is to increase the stripline inductance until resonance at 432 MHz is achieved. Output power of about 40 watts should be readily obtained at reduced efficiency.

1. P. Laakmann, WB6IOM, "Cavity Amplifier for 1296 MHz," QST, January, 1968, p. 17.
2. The Radio Amateur's Handbook, ARRL Staff, 1969 edition, p. 547.

ham radio

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The will to improvise, plus salvaged tv parts, resulted in this little bomb

W. G. Eslick, KØVQY, 2607 East 13th Street, Wichita, Kansas 67214

I wanted a portable 2-meter transmitter, so I built one described in another magazine. I wasn't satisfied with its output nor with the critical tuning to obtain upward modulation, so I decided to "roll my own." The rig shown here is the result.

It produces 250 mW output measured on a Bird wattmeter. Unfortunately, I wasn't able to use inexpensive transistors in all stages. After trying several types in the final amplifier, the only device that provided upward modulation was the 2N3866.

construction

The schematic is shown in **fig. 1.** I'd suggest staying away from PC boards on this band. I built several 2-meter units on PC boards, even on ground lines. A metal chassis is recommended for this rig.

I made the coils from old i-f transformers salvaged from a tv' set. The transformer is the type whose slug has a hex slot (for a tuning tool) instead of a threaded brass screw. Most of the resistors and capacitors can be scrounged from tv sets as well.

The slug for the doubler coil was

sawed in half to obtain sharper tuning. If the unit won't load into your antenna, add a 10- to 20-pF capacitor across C10.

cooling

Heat sinks are available most anywhere. Mine were scrounged from old IBM circuit boards. Wakefield fin types are fine. Mine is the slip-on type, which is held to the transistor with three set screws. I once blew the modulator transistors by using them without heat sinks. I replaced these with 2N1374's from some surplus boards from Radio Shack, and they work fine.

grid dip oscillator. The output from the 72-MHz stage and that from the doubler (145 MHz) was sufficient to peg the meter on my Millen gdo when in the diode position.

A trick described in reference 1 is interesting. A resistor connected between B+ and Q3's base will change Q3's operating angle. For example, a 10K-ohm resistor will make Q3 operate at something less than class C, or close to class AB. I didn't find this necessary for proper operation of the transmitter, however, I mention it for those who might wish to experiment.

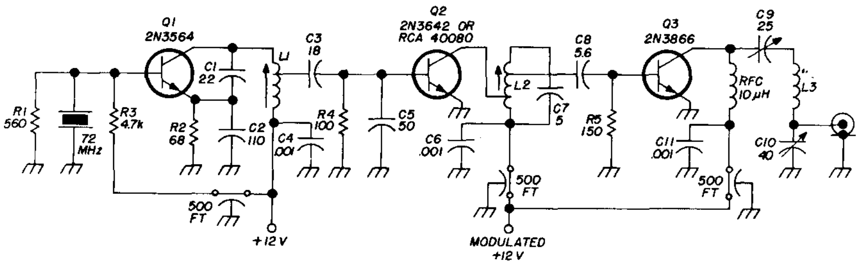

fig. 1. Schematic of the two-meter transmitter. A metal chassis is recommended, rather than a printed-circuit board, to avoid rf feedback problems. L1 and L2 are modified tv i-f transformer coils. A a-m modulator should provide at least 125 mW of power to adequately modulate this little rig.

L1 4 turns no. 20 bare tinned, spaced 1 wire diameter, tapped 3/4 turn from hot end

L2 4 turns no. 20 bare tinned, spaced twice wire diameter. Collector tap 1½ turns from cold end; C8 tap 3/4 turn from top end

L3 5 turns no. 18 bare tinned, ½-inch ID x 9/16-inch long

the modulator

A suitable modulator for this transmitter is the Birnback modulator available from Round Hill Associates*. Other modulators that provide at least 125 mW of audio power can also be used. On a 6-meter transmitter, I had a hard time keeping rf out of the modulator. A clue to this was a low audio howl from the modulator output transformer, and the transistors ran very hot. Shielding, rf chokes, and bypass capacitors were required to tame the six-meter rig.

adjustment

Each stage should be checked with a

performance

With the transmitter in the basement, and a type 49 lamp as a dummy load, I worked as far as two miles fairly well. A whip antenna increased reports. Audio reports were crisp and clear.

One thing that might have caused the modulation problems with different final-amplifier transistors is that the modulator's 500-ohm output impedance is too high. But in homebrewing, you try to use what's available in your junk box.

With the transistors shown in the schematic, all worked well. One thing that should be remembered: connect the power backwards, and goodbye transistors.

*Round Hill Associates, 434 Avenue of the Americas, New York, New York 10011.

ham radio

economical beam for ten meters

Improving the "Wonderbar" antenna for effective DX work

R. A. Clymer, W1FPF, Pine Island Road, Mattapoisett, Massachusetts 07239

You've heard this old saw many times, but it bears repeating: without a beam antenna, it's futile to compete seriously for S/X. I was listening to everybody working all the goodies on ten meters recently and recalled the antenna I used in the mid-fifties during the last sunspot cycle peak. It was a simple piece of plumbing that allowed you to get on ten meters in a hurry. In its basic form, it's called a Wonderbar, or bow-tie antenna. Why not try it again, only this time crank some gain into it?

For those who may have forgotten, or who have recently joined the ham fraternity, I'll describe the procedure I used to adapt the original design[1] into an inexpensive beam for ten meters.

construction

The main source of material was an old biconical tv antenna. My beam was modeled after the original Wonderbar design using these materials and some hardware from my junkbox. The basic Wonderbar antenna that resulted in shown in **fig. 1**.

I dismantled the tv antenna completely. I cut two 30-inch crossbars from the old elements. Each end of the crossbar was flattened and drilled to accept 3/16-inch machine screws (I used a 13/64-inch drill). Next, the crossbars were attached to the open ends of each of the two elements. This forms a couple of isosceles triangles, or wing-shaped elements.

I used a handy piece of 3/4-inch pine board, 13-inches long by 10-inches wide, for the base. Any material can be used that's sufficiently rigid to hold the assembly. Standoff insulators, female coax connectors, and a length of 5/8-inch OD heavy-wall plastic tubing (for spacers) were produced from my junkbox.

assembly

Place the wing-shaped elements on the floor over the base. Space them about three inches apart. Drill six 13/64-inch holes (**fig. 1**) through the elements and completely through the base. (This will ensure alignment during final assembly.) Mount the female coax receptacle as shown near the top of the base. Place the standoff insulators and spacers as shown, and assemble them loosely with 3/16-inch machine screws. Don't tighten the screws on the standoff insulator where the coil will be attached.

the loading coil

If you don't have a B&W 3013 miniductor handy, it's easy to wind your own 1-3/4-inch form for the primary. This coil was removed from the form and slipped over the loading coil.

Attach the loading coil to the elements by securing each lead to the screws at the apex of the V formed by each element. Place a solder lug between the head of the screw and the element. Now solder the primary coil leads to the coax connector. Tighten all machine screws.

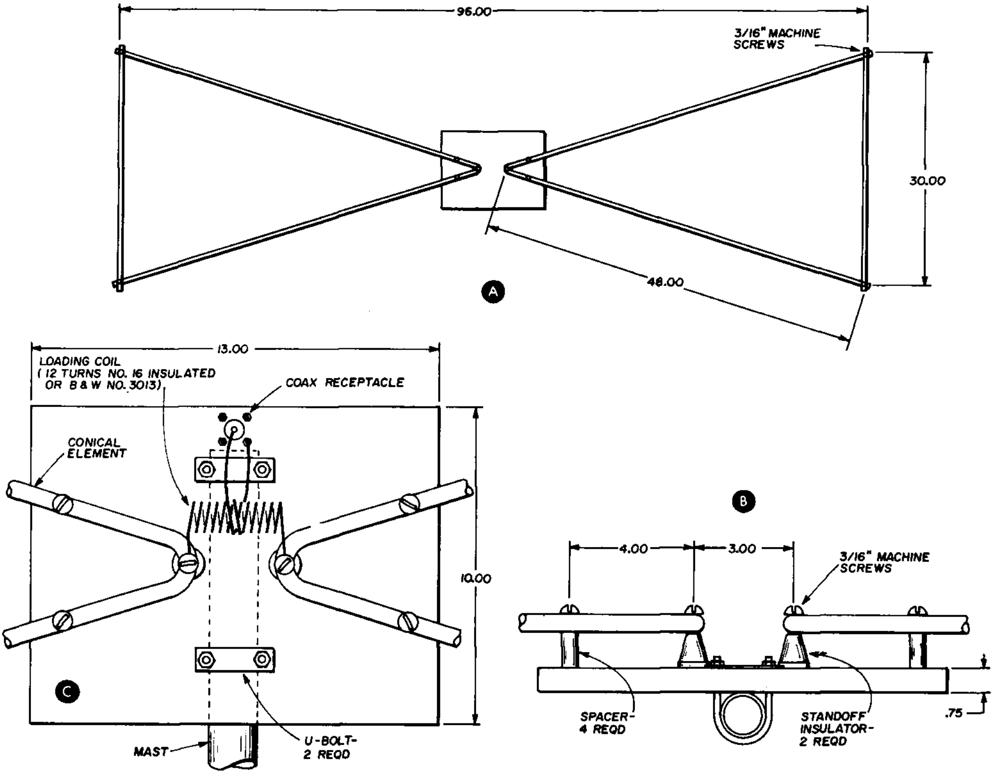

fig. 1. Dimensions, A, and mounting details, B, of the Wonderbar beam driven element. Mounting base is a simple pine board.

coil. I used what was available: number 16 insulated solid copper wire. Considerable latitude can be used here. Just make sure the coil is sufficiently rigid to be self supporting. I wound my loading coil around a 1-inch dowel, using 12 turns, close spaced. Then I removed the dowel and stretched the coil until it was about 3 inches long. Next I wound 2 turns of number 12 solid copper wire around a

mast mount

Four holes are drilled to accept U bolts, which will secure the antenna to the mast. I used 5/16-inch holes, positioned over the centerline of the base. The first two were immediately below the coax connector, and the second two were about one-half inch from the bottom of the base. Use your own ideas here to fit your available hardware.

preliminary tests

I attached a ten-foot piece of 1-1/4-inch conduit to my antenna for initial tune-up. I raised this assembly, with a piece of RG-8/U coax attached, in a vertical position and firmly lashed it to a picnic table. I found the best loading by tapping down on the loading coil; 10-1/2 turns seemed to be optimum. I made a permanent connection at this point by soldering. The lowest standing wave ratio (about 1.4:1) occurred at about 28.95 MHz.

With 65 watts input, I made contacts with two WØ stations, and got 5-9 plus reports. The next day, I worked a KV4 and a couple of G's. This simple antenna did indeed put out a good signal. But I wanted it to put out a better signal, so I added a reflector.

the wonderbar beam

At this point you can enjoy this inexpensive antenna without further embellishments. It will provide a good signal on ten meters, it doesn't cost much, and you'll work some DX. However, if you like to experiment a little, as I do, you'll want to improve its performance. A simple reflector placed behind the Wonderbar antenna will produce from 3 to 5 dB gain over a reference dipole. This will effectively double your radiated power over the Wonderbar alone.

"I'll go over in a couple of days and see how the beam held up..."

Handbook data showed that the shortest spacing for a reflector to improve performance was 0.15 wavelength (a little more than 4 feet on ten meters). This meant I could use the boom from the old tv antenna by merely adding a short extension. I decided to depart a bit from convention, for ease of assembly, and attached the boom and reflector immediately below the point where the Wonderbar was attached.

I made the boom extension about 5 inches longer than required. Then I put a bend of approximately 110 degrees radius in the extension about 4 inches from the end. I drilled two holes through the shorter leg of the boom extension and through the mast. This made an easy means of attachment. You could use the more conventional method of attaching the driven element and reflector at opposite ends of a one-piece boom. It would look prettier, perhaps, but wouldn't work any better. I wanted to use the materials on hand, so I used a short extension on the old tv boom.

the reflector

This element is simplicity itself. I cut my reflector from the remaining pieces of the old tv antenna tubing. It is 98 inches long **(fig. 2)**. I used a pair of sheet metal cross braces I'd stripped previously from the tv antenna boom to attach the reflector.

how far, wonderbar?

That's it. A simple, low-cost beam antenna made from materials on hand. The whole thing cost less than ten dollars. Results; I've worked fifteen different countries, many of them several times, including a ZS6. All this was done with a 60-watt a-m transmitter and my Wonderbar beam only twenty feet above ground.

references

1. E.T. Bishop, K6OFM, "The Wonderbar Antenna," QST, November, 1956.

ham radio

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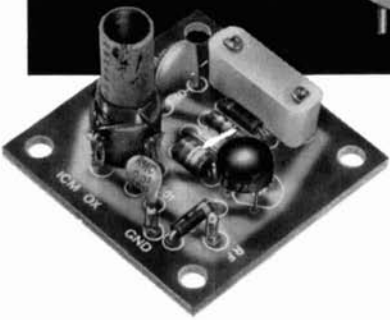

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a stable small-signal source for 144 and 432 MHz

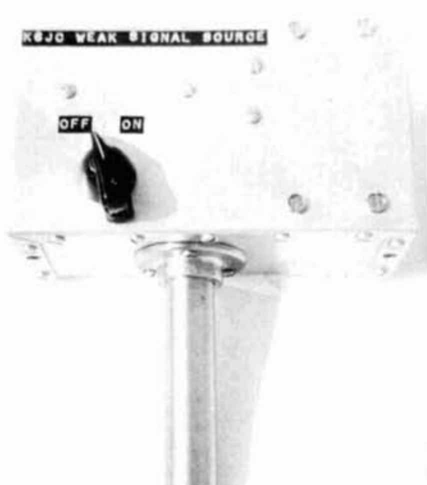
This simple circuit features variable frequency and amplitude control of a reference signal for vhf converter adjustments

James W. Brannin, K6JC, 424 Anson Avenue, Rohnert Park, California 94928

Have you ever made changes to your 144 or 432-MHz converter and tried to determine if the changes actually resulted in improved operation? Adjustments to converters on these bands can be disconcerting (and at times deceiving) without a stable signal source. The variable-output, crystal-controlled weak-signal generator described in this article allows immediate evaluation of converter adjustments as the work progresses. The signal is variable in amplitude on both hands, from several microvolts to below noise level. Frequency can be varied over a range of about 6 kHz on the 432-MHz band. The signal source can be calibrated against a commercial signal generator if one is available, although this isn't absolutely necessary.

circuit description

The schematic is shown in **fig. 1.** A crystal oscillator, operating at 48 MHz in the emitter-base circuit of transistor Q1, triples to 144 MHz in the collector



Stable, small-signal source for receiver front-end adjustment. Close-spaced screws are necessary to avoid signal leakage.

circuit. A second stage, transistor Q2, triples to 432 MHz. The crystal holder should be grounded to obtain maximum tuning range of the crystal. The 52-ohm resistor in the attenuator should be non-inductive.

construction

An LMB JB-880 or Bud CU-3006A Minibox may be used for a housing. These boxes have overlapping flanges that permit self-tapping screws to be placed about an inch apart. This seals the unit so no leakage exists.

The small subchassis is made from a 3½- x 2½-inch piece of aluminum with one edge bent for mounting to the top of the box with two 4-40 screws. The battery is held in place with a ½-inch aluminum strap fastened to the top of the box.

the attenuator

The attenuator **(fig. 2)** is made from two pieces of brass tubing. The BNC connector may be sweated or screwed into the end of the smaller section. The cost to have the attenuator made by a machinist shouldn't be excessive.

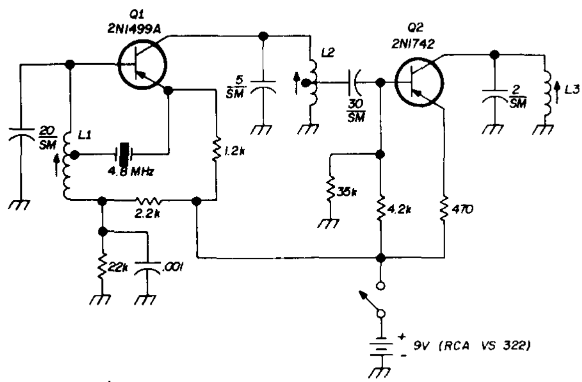


fig. 1. Schematic of the 144/432-MHz signal source. Frequency is adjustable over about 6 kHz on 432 MHz by slug in L1. Attenuator pickup look is spaced equal distances between L2 and L3. SM indicates silver-mica capacitor.

L1 11 turns no. 26 9/16" long, spacewound on 3/16" slug-tuned coil form, tapped 2 turns from bottom.

L2 7 turns no. 26 3/8" long, spacewound on 3/16" slug-tuned coil form, tapped 3 turns from bottom.

L3 2½ turns no. 26 5/16" long, spacewound on 3/16" slug-tuned coil form.

Mount the attenuator on the side of the box so that the pickup loop is about the same distance from the 144- and 432-MHz tuned circuits. Output will be the same when using the signal source on either frequency.

tuneup and adjustment

A vtvm with an rf probe should be used to peak the three tuned circuits. However, a grid-dip oscillator could be used. After the circuits are peaked, the frequency can be changed about 6 kHz on 432 MHz by adjusting the slug in L1. A receiver S-meter can also be used to peak the tuned circuits if the signal source is placed close enough to the converter or receiver front end.

After alignment is complete and the unit is carefully sealed with the self-tapping screws, practically no drift will be noted.

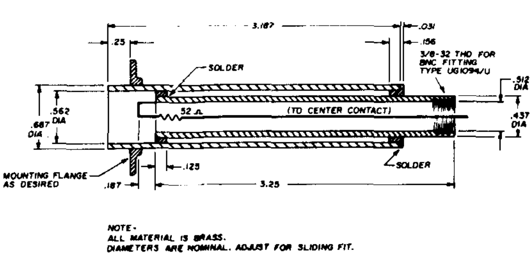


fig. 2. Construction details for the attenuator. Soft brass is used throughout.

My thanks to W6PBC for the circuit design and to W6SPB for building the attenuator.

ham radio

regenerative detectors
and a
wideband amplifier
for experimenters

Easy projects to acquaint you with transistor circuits, with hints on determining component values and some good advice on power-supply design

Bill Wildenhein, W8YFB, RD 2, Blanche Avenue, Elyria, Ohio 44038

When testing converters, i-f strips, and similar equipment, it's desirable to have a simple "tail end" that covers a fairly wide frequency range, includes a means for receiving ssb and cw signals, and has good sensitivity. Another handy piece of equipment to have around your station is a general-purpose wideband amplifier. Presented here are some circuits I've found to be useful for experimental and general shop work. They're solid-state adaptations of proven, reliable circuits that have been around a long time. If you've never experimented with transistors, these projects will provide a good starting point to get acquainted with the fascinating world of solid-state devices. The circuits are simple, easy to build, and parts are quite inexpensive.

regenerative detectors

For occasional bench work, I had been using a little regenerative receiver that dates back to the days of the big Kurz-Kasch dials. With only two tubes, it was completely adequate for the job. But one day I became annoyed at having to hook up both a vacuum-tube power supply and a solid-state supply. An era of profanity prevailed as I tried to get common transistors to perform as well as the old type 75 tube. Finally, the circuit of **fig. 1** was devised. Greatest gain occurs with fairly heavy drain current on Q1 (R3 almost zero). The source tap should be adjusted for the point nearest the ground end of the coil that will sustain oscillation.

The circuit of **fig. 1** worked quite well. The original haywire breadboard setup picked up shortwave broadcast stations from all over the world on 32 meters.

Next, I tried a version using the Colpitts feedback principle, **fig. 2.** I found that the antenna could be connected to the source instead of the gate. This resulted in lighter coupling to the antenna with fewer dead spots as compared to the Hartley circuit. I used a short length of RG-174 coax to feed the signal to the source. The coax capacity is in parallel with C8, which makes a convenient means of isolation. An advantage of this circuit is that feedback can be adjusted by C7 to obtain optimum performance.

crystal-controlled detector

Going one step further, a crystal was substituted for L1, and now we have a crystal-controlled detector (**fig. 3**). In this circuit, R10 provides a dc return for the gate. Don't try to use an rf choke here, because the detector will take off simultaneously at the crystal frequency and that formed by the rf choke in parallel with the capacitances in the gate circuit. I found that C8 will vary considerably due to circuit layout and gain of the fet. The best way to proceed is to set the feedback capacitor (C7) to its midpoint, then connect various values of mica capacitors at C8 to find one that just barely produces oscillation. C7 can then be adjusted to compensate for variations in antenna loading and supply voltage.

Old timers familiar with the "blooper" regenerative detector will wonder where the grid leak and its capacitor went. They aren't necessary; the circuits will oscillate vigorously without them. In fact, if one of the circuits is to be used as a "tail end", it should be packaged in a small minibox to minimize stray radiation.

Somewhat more gain can be obtained from the circuit of **fig. 4.** The source bias circuit (C3, R1) should be retained. This contributes to smooth regeneration control. As with the old bloopers, the gate leak (R11) should have a high value for maximum sensitivity — 3 to 8 megohms. However, this may be at the expense of increased crankiness. In general, all three detectors seem to perform best with minimum capacity at C2. The antenna may also be fed at the tap on L1 in the circuit of **fig. 4.**

oscillators

The detector circuit may also be used as a general purpose oscillator. If you wish to use it as a crystal oscillator as in **fig. 3,** C8's value will largely determine frequency range. Appropriate values for C8 in this case are:

0.1 – 0.4 MHz, C8 = 0.005 μF
0.4 – 4.0 MHz, C8 = 0.001 μF
4.0 – 10 MHz, C8 = 100 pF

Oscillation occured at all three ranges with a 7-100 pF compression trimmer for C7. I found, however, that C7's value had to be increased to about 500 pF to obtain zero beat with WWV using certain 100-kHz crystals. The waveform was not sinusoidal and had high harmonic content; output was 6 volts peak.

variable-frequency oscillator

The circuits of **fig. 1** or **fig. 2** may be used as a general-purpose vfo. However, I'd recommend using a Vackar in preference to these circuits. While acceptably stable, neither circuit will compare to a Vackar oscillator. I've used a vfo version

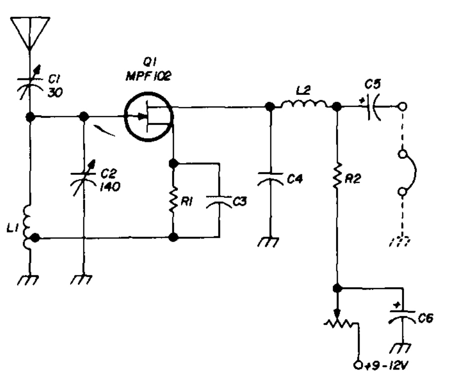


fig. 1. Original Hartley circuit used to replace a two-tube "blooper" for bench work. With a Motorola MPF 102 jfet, the set received shortwave broadcast stations from all over the world on 31 meters.

of the detector circuit in an experimental receiver. While it was stable as a detector in a 1700 kHz i-f amplifier, its amplitude stability over a wide frequency range was far inferior to the Vackar. Both this circuit and the Vackar have the same general ratio of maximum-to-minimum frequency range, but I can't recommend this oscillator as being competitive with the Vackar.

audio amplifier

Detectors such as those shown can be improved with the addition of a high-gain audio amplifier. The amplifier shown in **fig. 5** is very useful around this station. It has quite good frequency response. **Fig. 6** shows what can be obtained with inexpensive epoxy-encapsulated silicon transistors. The amplifier will deliver a clean sine wave of 8 V p-p at frequencies from less than 10 Hz to at least 8 MHz.

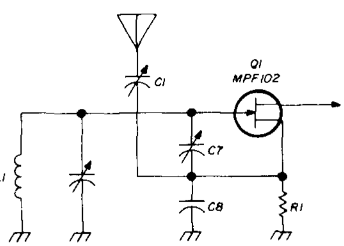


fig. 2. Regenerative detector using the Colpitts circuit. Antenna can be connected to transistor's source, which results in fewer dead spots across the tuning range.

This should be sufficient warning that decoupling the supply voltage may, in some cases, be necessary to prevent "motorboating" or other evidence of undesirable feedback. If you use a stiff, well-regulated power supply, or batteries, this shouldn't be much of a problem. However, if the power-supply impedance is too high, you will have problems (more of this later).

amplifier applications

I've built several of these amplifiers and have found many uses for them. For example, many excellent solid-state vfo's are limited to less than a volt output. This amplifier will boost the vfo output to several volts without additional tuned circuits. It will also make a good i-f amplifier.

If you experiment with filters, your vtvm possibly won't have a range low enough to allow measurements below about 40 dB. One of these amplifiers, well shielded and battery operated, can extend the average vtvm's range to about 1 mV full-scale. However, it's well to calibrate the amplifier to be certain of its gain linearity. The response isn't flat, but this won't matter if measurements cover a limited frequency range, such as that of an ssb filter, for example.

Still another factor to consider is the amplifier's impedance. It won't compare to that of the usual vtvm. With a high beta transistor at Q2 in the amplifier, you can expect an input impedance of about 10 kilohms. Therefore, any high-impedance circuit (1 megohm or more) will be loaded by this amplifier. However, it's adequate for most solid–state measurements.

If the amplifier is overdriven, it will clip, producing a pretty good square wave. If it's used as a vtvm amplifier, it should be checked on an oscilloscope. This will indicate the maximum voltage available to your vtvm before the amplifier's waveform becomes degraded. Stay well within the maximum voltage range. Amplifiers I've built show that this voltage remains pretty constant throughout the amplifier's range. If you have an inexpensive oscilloscope, you can find

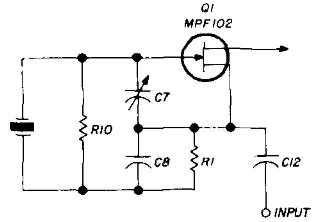


fig. 3. The Colpitts circuit with a crystal substituted for L1. Capacitor C8's value will vary, depending on circuit layout and transistor gain; use a value that just produces oscillation.

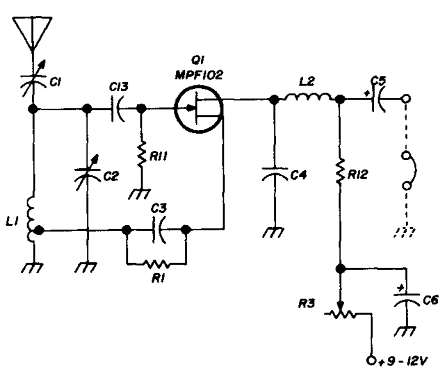
table 1. Parts list for the detectors and wideband amplifier.

C1	3-30 pF trimmer
C2	140 pF variable
C3	0.005-0.02 µF disc ceramic or mica
C4	0.001-0.005 µF disc ceramic or mica
C5, C6	1-4 µF 25 V electrolytic
C7	3-30 pF compression trimmer or APC variable
C8	200-1500 pF mica (depends on fet, and degree of coupling)
C9*	33 µF tantalum
C10*	47 µF tantalum
C11	0.005-0.05 µF disc ceramic or paper tubular (see text)
C12	50-200 pF mica
C13	50 pF mica
R1	270-470 ohms ½ W
R2	1-1.5 kilohm ½ W
R3	2.5 kilohm
R4*	10 kilohm ½ W
R5*	1 kilohm ½ W
R6*	100 ohms ½ W
R7*	100 kilohm ½ W
R8*	350 ohm ½ W
R9	10-25 kilohms
R10	47 kilohms-1 megohm ½ W
R11	2.2-6.8 megohms ½ W
R12	1-4.7 kilohms ½ W
L1	5/8 inch diameter, 32 pitch Miniductor 7/8 inch long, tapped 3 turns from ground end for 5-12 MHz range. (A 45 µH slug-tuned coil worked well in a 1700 kHz i-f strip.)
L2	2.5 mH rf choke
Q1	MPF102 jfet
Q2, Q3	100 MHz plastic encapsulated silicon transistors. Dc betas: Q2, 200; Q3, 100.

this point at, say, 60 Hz; then if you don't go above 50 percent of the point where distortion occurs, you can pretty well depend on the amplifier's response over its range.

amplifier construction

Let's set up this little amplifier using



parts from your junk box. A complete list of parts for all the circuits described here is given in **table 1**. Because the amplifier is somewhat more critical as to transistor characteristics and resistor and capacitor values, I've included a discussion on how to grade your surplus devices and how to select resistors and capacitors to obtain optimum performance. The values in **table 1** marked with an asterisk were those I used in the amplifier whose response is depicted in **fig. 6**.

grading transistors

Select only silicon transistors. With

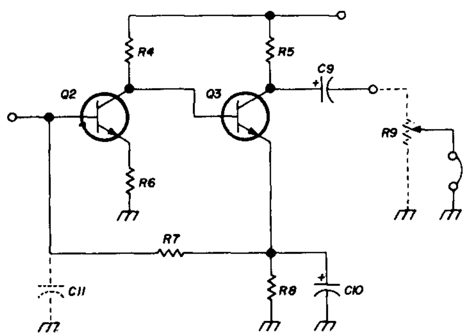


fig. 5. The detector circuits can be improved with with this wideband audio amplifier. Several applications of this basic circuit are discussed in the text.

high-gain, high-frequency types available on the surplus market at prices around four for a dollar, it's pointless to use less expensive germanium units with their higher leakage. As a rule of thumb, select transistors with a gain-bandwidth product, f_T at least ten times as high as the expected pass frequency.

Illustrated in **fig. 7** is a circuit for using your vtvm to measure transistor current gain. Although this reveals little of a transistor's high-frequency gain, it will give a good relative indication of which surplus device is hottest. A simple method of grading your surplus transistors is as follows.

*Components used in an amplifier whose response is shown in fig. 6. See text for determination of values.

1. Set the 1-megohm pot to maximum resistance.
2. Set the switch to Ic.
3. Close the battery switch.
4. Set the 1-megohm pot to give a reading of 5 V dc on the vtvm.
5. Set the switch to Ib.
6. Note the reading in dc volts. (Assume it is 0.5V.)

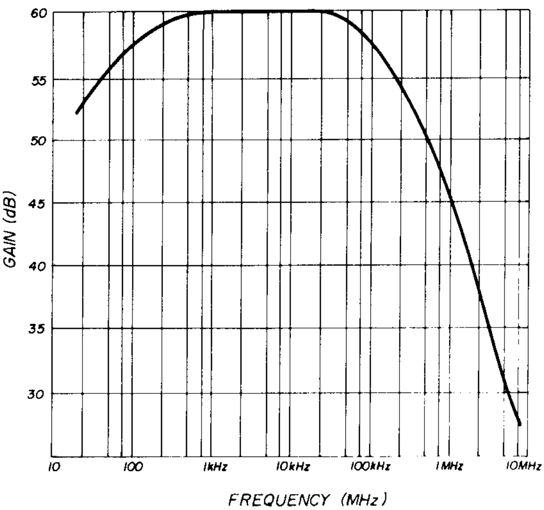


fig. 6. Voltage gain as a function of frequency for the wideband amplifier. A pure sine wave of 8V p-p is produced over the entire range using inexpensive silicon transistors.

7. Calculate the cd current gain:

$$I_c = \frac{E}{R} = \frac{5.0}{1000} = 0.005 \text{ A}$$

$$I_b = \frac{E}{R} = \frac{0.5}{10{,}000} = 0.00005 \text{ A}$$

$$G = \frac{I_c}{I_b} = 100$$

Using this method, you can grade transistors with dc betas between 5-500 with ease, which will give you a good idea of which transistor to use for Q2 in the amplifier. It reveals little about the transistor's ac characteristics, but it's a good starting point. Now select another transistor, which can have a lower beta, for Q3. We'll now "ballpark" the other component values.

resistor and capacitor values

R5 is chosen to drop the collector voltage to about 50 percent with a chosen safe collector current. If the collector current is too low, gain will decrease. If it's too high, collector dissipation will be exceeded. A safe value for most surplus transistors is 5 mA. Using a 12-V power supply, we wish to drop about 6 V across R5:

$$R = \frac{E}{I} = \frac{6.0}{0.005} = 1200 \text{ ohms}$$

Next, R8 is chosen to drop about 10 percent of the power-supply voltage:

$$R = \frac{E}{I} = \frac{1.2}{0.005} = 250 \text{ ohms}$$

(270 ohms is adequate.)

Now the base voltage of Q3 is determined. Since Q3 is a silicon npn transistor, its base voltage will be about 0.5 to 0.7 V more positive than its emitter. From the above, we see that Q3's emitter is biased by R8 to about 1.2 V positive. Add the base-emitter voltage of Q3, and we find that Q3's base should be about +1.8 V.

Transistor Q2 can operate at a lower current to save total power. Let's say we'll operate it at 1 mA. The lower end of R4 is connected to Q3's base. We know that Q3's base will be 1.8 V. The total voltage drop across R4 is then 12 V minus 1.8 V. Current is 1 mA plus Q3's small base current, which can be neglected. R4's value then becomes

$$R = \frac{E}{I} = \frac{10.2 \text{ V}}{0.001 \text{ A}} = 10.2 \text{ kilohm}$$

A 10 kilohm resistor will be fine.

R6 provides a small amount of degenerative feedback. As its value is increased, the amplifier's input impedance increases and frequency response improves, but at a sacrifice in gain. Values between 100 and 330 ohms will be adequate for general use.

C10 can have a capacitive reactance of about one-tenth the value of R8 at the lowest frequency of interest. R8 was determined to be 270 ohms. If response to 100 Hz is desired, a reactance chart (see the ARRL handbook) will give a value that represents about 27 ohms at 100 Hz; this will be about 60 μF. A 500 μF capacitor would be required to extend coverage to 10 Hz.

Large values of electrolytics cease to be bypass capacitors at these frequencies, so to obtain good high-frequency response it's advisable to parallel them with mica or disc ceramic capacitors. C9's reactance can be ten times as high as that of C10 in this circuit, so values of 5 μF or higher will be adequate.

selection by substitution

R7 is best determined by experiment. After the entire circuit is wired except for R7, connect a 1 megohm potentiometer in place of R7. Connect your vtvm from Q3's collector to ground. Turn on the power, and adjust the pot so the voltage from Q3's collector to ground is about 6 V. Turn off the power, and measure the pot resistance. Choose a resistor that measures the same, and substitute it for the pot. The resistor value doesn't have to be precisely correct. If this fixed resistor produces a collector voltage of 5 – 7 V, the amplifier will operate all right, but permissible signal-voltage swing before clipping will be reduced somewhat.

When the amplifier is used following a regenerative detector, a volume control is desirable. A pot of 10 – 25 kilohms connected as shown (R9 in **fig. 5**) will be adequate.

the importance of C11

C11 is added to the amplifier to limit frequency response. When used with a regenerative detector, high-frequency hiss is annoying. A capacitor of 0.05 – 0.1 μF at C11 will do much to make listening more enjoyable. It will also make the amplifier more stable in this instance. Even though the regenerative detector uses an rf choke and capacitor to filter rf components, rf can still sneak through to cause overloading in the amplifier. C11 will eliminate this.

Still another benefit of C11 is this: without C11, the turn-on surge of voltage from the detector drain is sufficient to cause momentary pumping in the audio amplifier. Voltages soar up and down drastically. In one such amplifier, high voltage was severe enough to zap Q2. With C11 in the circuit, these wild excursions are minimized.

as a speech amplifier

This little amplifier will also make an excellent speech amplifier for a high-impedance microphone. Connect the hot lead from the microphone to Q2's base

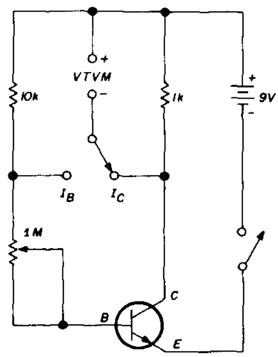


fig. 7. Circuit for using your vtvm to grade surplus transistors. It will give a good idea of which transistor is hottest.

through a resistor of about 27 – 47 kilohms. C11 is proportioned to serve as an rf filter; use about 0.01 – 0.005 μF.

i-f amplifier application

In i-f amplifier use, R5 can be replaced with a tuned circuit. If so, it would be well to decouple Q2. Add a 270 ohm resistor from the top of R5 to the top of R4. Connect an 0.01 uF capacitor from the junction of the 270 ohm resistor and R4 to ground. C9 and C10 can be much smaller than when used in an audio amplifier. At 455 kHz, C10 can be 0.01 μF, and C9 can be 0.001 μF. These values will allow operation well into the megahertz region.

power-supply impedance

This piece is written to encourage the vacuum-tube gang to experiment with solid-state circuits. An item I mentioned previously – power-supply impedance — is worth some discussion.

With tube circuits, you may have seen many examples of what happens with poorly regulated power supplies. When you were servicing an ac-dc set, for instance, perhaps it broke into oscillation. Merely replacing the electrolytic in the power supply possibly solved the problem.

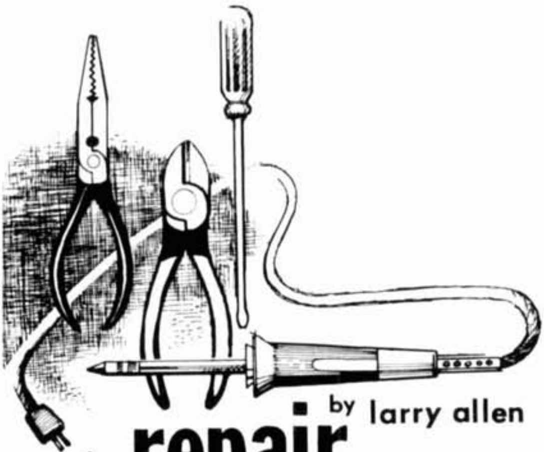
As another example, you may have had a modulator with push-pull 807's. If this modulator were fed from a "limp" power supply that allowed screen voltage to drop as you hit the mike harder, you may have found that by regulating modulator screen voltage you apparently picked up a lot of modulator power. Many high-gain circuits have been cussed endlessly, when in reality the poorly regulated power supply was the real culprit.

Poor regulation is even more critical in solid-state work. One simple solution is to use batteries. Fresh batteries do a very good job. Even better is a 12 V car battery. But the best solution is to build a properly regulated power supply for transistor work.

Many people ask "What do you mean — power supply impedance?" Suppose you have a power supply that's supposed to deliver 100 V at 200 mA. Maybe it delivers 100 V with no load, but at 0.2 A load, it skids to 75 V output. This means you've lost 25 V at 0.2 A. It's the same as saying the power supply looks like a good 100-V job with a 125-ohm resistor in series with the supply lead. What you want is, ideally, a power supply that will deliver the same voltage regardless of load — a "zero-ohm" power supply. You won't achieve this, but a properly built supply's impedance will be way down in the milliohm region.

I can't stress too highly that if you're just starting out in solid-state work, a well-built, regulated power supply will be one of your best investments. With it you can build high-gain circuits with far less bugs than would be possible with the limp and soggy supplies being used by many amateurs.

ham radio



the repair bench

by larry allen

From what I hear, many amateurs consider an oscillator the hardest kind of stage to repair. That's too bad, because ham rigs are full of them. Maybe oscillators seem tough because of their bootstrap nature–making a signal out of what seems like nothing.

"If an oscillator quits," ask a good many hams, "just where do you begin looking for the fault?"

Instead of giving a quick, simple answer, I'll first explain what an oscillator really is. That'll prepare you for the easy testing methods I use. The truth is, an oscillator shouldn't be hard to fix.

the four needs

Every oscillator has four requirements. Take away any one of them, and it just won't work. They're the key to an oscillator's operation–and also to its quitting.

1. An oscillator needs **amplification.** That's why the stage has a tube, bipolar transistor or field-effect transistor. The reason for this need becomes clear as you understand the second requirement.

2. An oscillator needs **feedback.** A small amount of signal from the output of the amplifier is fed back to the input. There, the tube or transistor amplifies it again. Then a sample of that output is again fed back. It's a sort of round-robin. Without this positive or regenerative feedback, the stage is only an amplifier.

3. An oscillator needs **dc power.** The tube or transistor needs dc voltages. Further, no amplifier is 100 percent efficient, and some power is wasted keeping the signal going round-and-round. The plate or screen-supply line in tube oscillators, or the collector or drain supply in transistor oscillators, makes up for this wasted power.

4. An oscillator needs **frequency** control. An oscillator is a signal-generating device. By its very nature, a signal has some frequency. Inductor-capacitor circuits or crystals set frequency in rf oscillators, and RC time-constant circuits do it for audio oscillators.

So there you have the four needs of any oscillator, no matter what its purpose. It is the method of developing these four requirements that distinguishes the various kinds of oscillators. Be assured, every oscillator has all four.

some oscillators

Just so you know what I'm talking about, here are a few oscillator stages. The four requirements are met in each one.

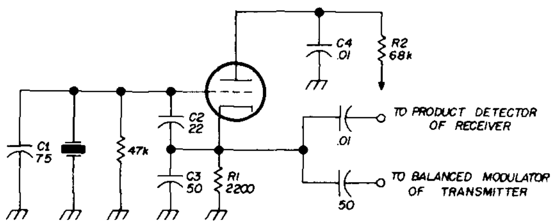
The first is in **fig. 1.** One of the most simple and popular oscillators in ham gear is this crystal-controlled Colpitts.

Amplification is by triode tube. It receives dc power through a resistor in the plate circuit. The cathode has a resistor that develops bias for the tube.

Feedback is by a capacitive divider connected between grid and ground. Notice that the plate is grounded for rf through C4. R1 is the load for the tube. Signal developed across R1 is divided up. Part goes to ground through C3, and a small amount goes to the grid through C2. The signal fed to the grid is amplified by the tube and developed across the cathode load, and the process starts over. This regenerative feedback produces oscillation in the stage.

Frequency of the generated signal is controlled by the crystal from grid to ground. A crystal is common in communications rf oscillators, because of its extreme accuracy. The stage in **fig. 1** is called untuned because there is no LC circuit, but in reality it is tuned by the

fig. 1. Colpitts oscillator is used often in amateur radio equipment; it is distinguished by capacitive-divider feedback.



crystal. Without the crystal, there would be a coil in its place, resonated by C1 and the series combination of C2-C3. C1 or the coil would probably be made variable for tuning.

The Colpitts configuration could be used just as easily with a transistor. In that case, the collector would probably be the element receiving dc power; the

would take the place of the plate, its gate the place of the grid, and its source the place of the cathode. A Colpitts stage using a fet can be exceptionally stable.

One of the most popular crystal oscillators is the Pierce, and versions of it. Two of them are shown in **fig. 2.** The identifying characteristic of the Pierce is the plate-to-grid connection of the crystal. In that position, it supplies *two* of the oscillator's needs: feedback and tuning.

Dc power for the tube amplifier in **fig. 2A** comes through the plate load resistor. The variable capacitor lets you warp the crystal slightly, to pinpoint its frequency precisely. The capacitive divider in the output cuts down the amount of signal injected into the next stage; the vacuum-tube Pierce is a strong oscillator.

The version in **fig. 2B** is an electron-coupled Pierce. The screen grid (grid 2) of the tube is considered the oscillator plate. The crystal is thus connected from plate to grid in regular Pierce style. However, the generated signal is injected into the electron stream that goes to the plate, from which output is taken. The output load thus has little effect on oscillator frequency.

From what's already been said, you can imagine a transistor Pierce circuit. With a fet, it would look like **fig. 3A.** The resemblance between it, the bipolar transistor version in **fig. 3B,** and the triode in

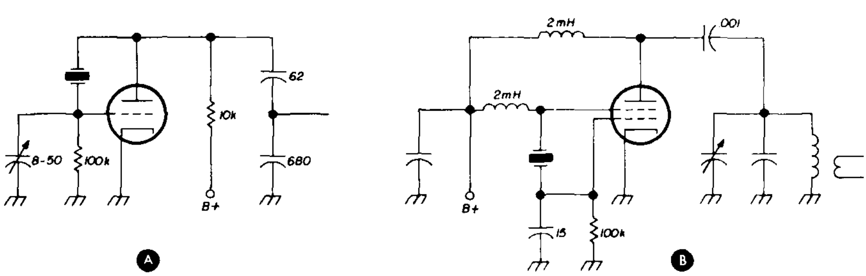


fig. 2. Pierce oscillators are characterized by a crystal between the plate and grid.

base would be connected where the grid is; and the emitter would replace the cathode.

A fet could be used, too. Its drain

fig. 2A makes it look as if you could just plug in a transistor in place of the tube. With a fet, you can; just reduce the plate voltage to a drain voltage that is safe. For a bipolar, you must change resistor values, devise a base-bias system, as well as lower the supply voltage.

Keep in mind that all the oscillators I've shown you have those four requisites; amplification, dc power, feedback, and frequency control.

the dead oscillator

What would lead you to suspect an oscillator of being dead in the first place? In a straight cw or a-m transmitter, that's pretty elementary. There just isn't any carrier when the oscillator quits. In an ssb transmitter, or in a receiver, the symptom might not be that simple. It all depends on which oscillator quits.

In one ssb transmitter, there are four different oscillators. One is the carrier generator. Without it, no sidebands can be produced, so the transmitter has no output. Unfortunately, other problems can cause the same symptom, so lack of output in a sideband transmitter doesn't prove the carrier oscillator is dead.

The other three transmitter oscillators are for heterodyning the sideband up to the transmitting frequency. Any one of them can block the sideband before it reaches the transmitter output stage. Usually, the tuned circuits that follow the frequency converter or mixer stage eliminate any sidebands but those of the desired frequency. Without correct oscillator injection, the mixer output can be nothing more than the sideband input from the preceding stages. Output is thus blocked.

A receiver using triple conversion can have as many as five oscillators. The unit diagramed in **fig. 4** is an example. The calibration oscillator and the second version oscillator (feeding what's labeled the "first converter," but really is the second) are both crystal controlled. The third conversion oscillator is fixed in frequency; a stable Hartley stage is used.

The receiver is tuned to the incoming signal by the first conversion oscillator (feeding the "mixer"). It's a high-frequency variable oscillator that beats against the desired incoming sideband signal to form a sideband i-f at 3.035 MHz.

And, finally, there's the bfo. It's usually frequency-fixed in an ssb receiver. In a set that receives icw code transmissions, the bfo is generally variable over a small range so you can select the pitch of code signals you hear.

If any of the three conversion oscillators goes dead, you simply can't get a signal through the receiver. If the calibration oscillator stops, the only sign of it is a lack of birdies when you're checking calibration.

The bfo is what furnishes the injection carrier that lets the product detector recover the voice signals from the sideband. If it quits, you're likely to get a very weak and distorted sound from the phones or speaker.

which one's dead?

The nature of an oscillator makes it easy to test, if you have the right equipment. I have a fet voltmeter, and I've

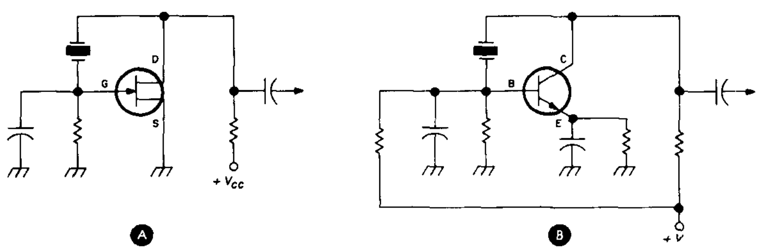


fig. 3. Solid-state Pierce oscillators using a field-effect transistor, A, and npn bipolar, B.

built a little probe that lets me measure rf. With it, I can find out if an oscillator is working just by touching the probe to its output.

Usually, the oscillator side of the injection capacitor is the best place to start. If there's a healthy signal there, indicated by a dc reading on the voltmeter, move the probe to the other side of the capacitor; it could be open you know.

Back when tube-type oscillators were more common, one way of telling if an oscillator was running was with a plain dc voltmeter touched to the grid. A dead oscillator develops no grid current, so there's no dc bias voltage on the grid. If the dc voltage is present, it's a sign the oscillator is running.

This isn't much help with transistors. Oscillator stages may run with forward bias, reverse bias, or zero bias between base and emitter. It all depends on the particular circuit and the transistor type. Bias doesn't tell you whether the oscillator is running or not.

So it's better that you get accustomed to checking for the presence of rf output from the oscillator. You'll not waste time trying to fix an oscillator stage that's working after all.

For your particular vtvm or fet vm (a vom loads down oscillators too much), buy or build a simple diode probe that rectifies rf and converts it to pure dc. Be sure it has a blocking capacitor at the input; a 470-μF 2500-volt type is good, if you build your own probe. Actually, the rf probe for almost any vtvm will do if it can be connected to your instrument. Don't try to use a scope rf probe; it's only a demodulator, and won't work.

Then go through all your own transmitter and receiver equipment. On the block diagram or schematic in the manual for each set, write down the rf voltage measured on your meter at the output of each oscillator. The dc reading you get is relative; that is, it doesn't mean there's really that many volts of rf. So you need to know what's a normal reading so you can later evaluate whether an oscillator is weak or stopped.

Be sure you're measuring the right point in the stage. The output is connected by a capacitor or a transformer to the stage that follows—a buffer amp, mixer, converter or frequency multiplier.

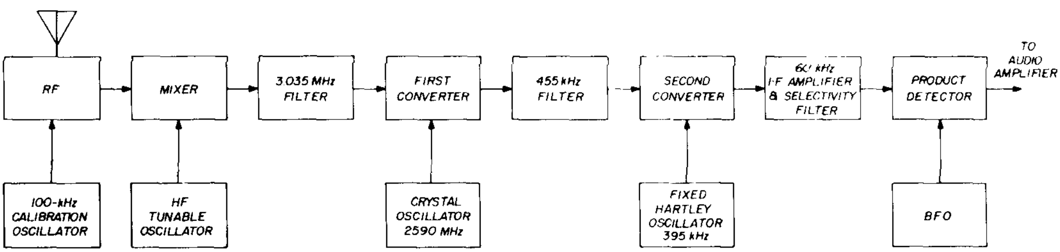


fig. 4. Typical triple-conversation superhet uses five separate oscillators.

inside the stage

Once you've identified which oscillator is dead, your next job is to find what killed it. Here is a procedure that works well for me.

Take the transistor oscillator in **fig. 5** as an example. It's an "inverted" version of a Hartley oscillator. Feedback to the base develops in the portion of the tapped coil between collector and B-plus. With the base grounded and the emitter not, conditions are right for regenerative feedback. The coil and capacitors in the collector resonate; the coil is variable, because this is a tuning oscillator.

Suppose you've checked at the emitter and found no rf. Start troubleshooting the stage by using your plain dc voltmeter. Measure the regulated B-plus source. Then check dc at the collector and at the base.

At the base, the measured value is important, so check it against what the schematic or the voltage chart in the manual says is right for the set. At the collector, the value depends on too many things, particularly if there's a collector resistor. So just check to make sure the collector is getting voltage.

If the transistor is wired so the emitter gets the supply voltage, the collector should have a dc ground connection—perhaps through a transformer winding. Check that. Then make sure the emitter is getting the dc supply voltage it should.

After you're sure dc power is reaching the stage, check the action of the amplifier. One way to do this is to disable the feedback path and feed in a signal near the normal frequency of the oscillator.

In the oscillator of **fig. 5**, for example, you could move the connection of C3 to the tap on the coil. Or, easier yet, just clip another .01-μF capacitor from the tap to ground. That destroys the feedback and leaves the stage operating as just an amplifier. Open C1 and you can apply an rf signal to the base. Then, with your vtvm and probe, check for rf output across R3. It should be only a little less than the signal you feed in. It also should be tunable. That is, you should get a slight change in reading as you change the frequency of the signal generator or tune the coil in the collector circuit.

In a stage like the one in **fig. 1**, you just disconnect the tap between capacitors C2 and C3. Then a signal at about the frequency of the crystal, fed to the grid, should develop a signal in the cathode circuit. In the stages of **fig. 2**, the crystal is the feedback device, so you just unplug (or disconnect) it. Then check amplifier operation of the tube. You can do this with virtually any oscillator stage.

Next thing to check is the feedback system itself. One way is to keep feeding the test signal in and probe for feedback energy with your rf voltmeter.

In **fig. 1**, with the tap disconnected, check for a small amount of signal energy at the junction of C2-C3.

In **fig. 2**, leave only the plate end of the crystal connected. Probe at the other end of the crystal for signal energy. If you vary the generator frequency dial up and down, there should be a sharp resonant point at the crystal's frequency, revealed by a sudden sharp increase in the voltmeter reading at resonance.

In **fig. 5**, disconnect the supply end of the coil, and probe for signal energy.

Finally, you should check the oscillator for frequency. Even if it's running, an

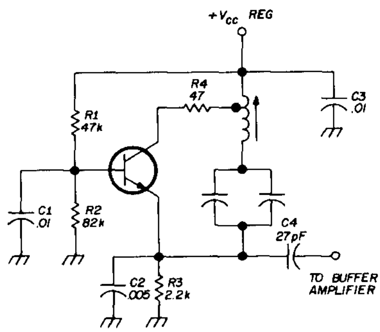


fig. 5. Unusual version of the Hartley oscillator is inverted from the normal hookup.

oscillator that's off frequency can't do what it's supposed to. If it's the carrier oscillator in an ssb unit, the generated sidebands that come out of the balanced modulator won't match the sideband filter. Or, an off-frequency bfo can't demodulate sidebands in the product detector.

A bad crystal is usually the cause of an off-frequency oscillator. If you know the oscillator works, yet the receiver or transmitter acts as though it doesn't, try a new crystal. If the stage is controlled by tuned circuits or a resistor-capacitor combination, check them.

You can check frequency of an oscillator with a frequency meter or with an accurate all-wave receiver set for cw reception. In the latter case, a whistle or birdie shows up at the dial setting that indicates the oscillator frequency. The only trouble is, sometimes even slight crystal drift can stop operation of a set, and an all-wave receiver may not be accurate enough to spot the drift.

That sums up the way to check an oscillator. Actually, most troubles boil down to dc power or feedback. That's because you probably check the tube or transistor right off the bat. Anyway, if you check those four things in an oscillator, you'll always find the trouble without replacing whole strings of parts.

next month

Some time ago, I promised to show you how to use a sweep generator on your repair bench. In the meantime, I've found out that some hams don't even know what a sweep generator is.

So. . .the time has come to learn. The instrument is versatile, and has many uses. I'll show you some of them.

One last thing: if there's some odd circuit or set you'd like explained, drop me a line and I'll see if we can't work it in some month. After all, the purpose of this department is to help you keep your equipment working in top order. Tell us what help you need most.

ham radio

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new products

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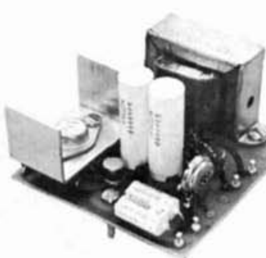
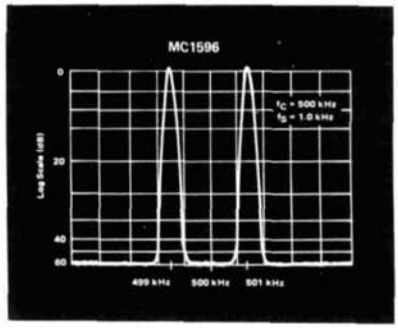


Viking Electronics has just introduced a full-range low-voltage regulated power supply for instrumentation and test applications, as well as original equipment manufacturers. The model PZ-10-A provides outputs from zero to 25 volts at currents up to 100 mA; load regulation is less than 50 mV, line regulation is ±10 mV and ripple is less than one millivolt at full rated load. The PZ-10-A has built-in provisions for remote control of current limiting and voltage output. The output terminals are floating. Also available is the model PZ-10-B which provides zero to 6 volts at 500 mA; and the model PZ-10-C which provides zero to 15 volts at 200 mA. Price of the PZ-10-A is $27.00. For more information, write to Viking Electronics of Wisconsin, 721 St. Croix Street, Hudson, Wisconsin 54016.

balanced-modulator ic



Motorola's new MC1596 balanced modulator/demodulator for communications work features typical carrier suppression of 65 dB as well as adjustable voltage gain and signal handling, balanced inputs and outputs, typical carrier feedthrough of 90 microvolts at 500 kHz and high common-mode signal rejection ratio of 85 dB typical.

The MC1596 is designed for uses where the output voltage is the product of an input voltage (modulating signal) and a switching function (carrier), such as in ssb and a-m transmission, ssb product detector, synchronous a-m detection, fm and phase detection, frequency doubling and frequency mixing. The device can be used up to 100 MHz in modulator/demodulator applications and up to 400 MHz in other circuits.

The circuit of the MC1596 integrated circuit consists essentially of an input differential amplifier driving a pair of closely matched current-mode transistor gates. These closely matched transistors are responsible for the excellent input balance that cannot be equaled by a discrete circuit of comparable cost. For more information on the versatile new MC1596, write to Technical Information Center, Motorola Semiconductor Products, Inc., Box 20924, Phoenix, Arizona 85036.

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The Hustler model BBL-144 is a co-linear power gain antenna that mounts in a 3/4" hole on any flat surface; it's supplied with 17 feet of RG-58/U, a PL-259 connector and optional stainless-steel spring and 180° swivel ball. The Hustler model BBLT-144 is the same as the BBL-144 but with a Hustler trunk-lip mount for no-holes-to-drill installations. For complete specifications, write to the Sales Department, New-Tronics Corporation, 15800 Commerce Park Drive, Brookpark, Ohio 44142.

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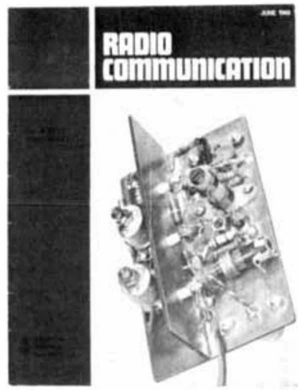

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HALLICRAFTERS SX-110, excellent condition. Best offer. Raymond Martin, Greenville, N. H. 03048. Phone 603-878-2758.

WINTER BLUES? Cheer up! You have the ARRL Hudson Division Convention to look forward to! Exhibits, Lectures, Contests, Gabfests, New York City Sightseeing, Fun. October 17-18, Hilton Motor Inn, Tarrytown, N. Y. Hudson Amateur Radio Council, Box 58, Central Islip, N. Y. 11722 has the happy news.

WANT TO QUIT SMOKING? — also all Ham singers, and musicians — a copy of CIGARETTES, the anti-smoking song by WA8FLE is yours for a self addressed stamped envelope. Write Floyd Fellows, WA8FLE, 1673 Cedar Ave., Cincinnati, Ohio 45224.

TOROIDS. 88 or 44 mhy., center tapped, not potted, 5/$2.00 POSTPAID. NOTE!! 40/$10.00 POSTPAID. Model 32KSR page printer on pedestal, complete 60 or 100 speed printer, little used . . . $200. FRXD10 typing reperferator with TD on same base $25. Model 19 set $95. Model 14TD sync motor $18. MXD three head TD $35. Tape winder $6. Oiled reperferator tape $3/box/10 or $10/case /40 rolls. FACSIMILE paper (12″ x 19″) 250 sheet package $4. Double squirrel cage blower (110VAC 60 cycle) silent type $5. RCA CV57/URR terminal unit $85. New Clegg 66er transceiver $150. WANTED: Ham M rotor. Stamp for list. Van, W2DLT, 302H Passaic Avenue, Stirling, N. J. 07980.

WANTED INFORMATION on Westex receiver model Navfax 6010 manuals, schematics. V. T. Kalup, 4213 Bent Lane, Chester, Penna. 19014.

HALLICRAFTERS SR400 transceiver, HA20 DX adapter (outboard vfo with swr meter), P500 ac power supply, 1½ years old, mint condition, $800. Used as second station, never mobile, must sell. Box C, Ham Radio, Greenville, N. H. 03048, or call (617) 762-5863.

CHICAGO Suburban Radio Association annual Hamboree on March 22nd at East Avenue and 55th Street, Countryside, (La Grange), Illinois. Flea Market and prizes. For further information contact Wilson Thomas, W9KWA, 4017 Vernon Ave., Brookfield, Ill. 60513. Phone: (312) HU 5-0451.

FOR SALE FM GEAR operating and ready to use. 5 channel progress line with transistor supply, $225.00. Single channel Motorola T33, draws 500 ma on rec. with 34-.94 xtals., $75.00. Progress line on 52.525 mc 30 wts. with ACC, clean $150.00. Link freq. and deviation meter on 146.94, $75.00. W1KGZ, 540 Clay Street, Manchester, N. H. 603-623-5602.

WORLD QSL BUREAU — see ad page 92.

HAVE TWO COMMERCIAL RF sections suitable conversion 432 SSB transverter. January Ham Radio. 6939-6939 and 6252 PA stage w/tubes $30 ppd. W4API, Box 4095, Arlington, Va. 22204.

POLICE — FIRE — AIRCRAFT — MARINE Calls on your broadcast radio with TUNAVERTER S! Tunable — Crystal! Brochure. Salch Company, Woodsboro HMC, Texas 78393.

HELP. I need a good used Collins 310B Exciter, National FB7 or FB7-X and a National SW-3. All letters answered via air mail. Jock White, ZL2GX, 152 Lytton Road, Gisborne, New Zealand.

ORIGINAL EZ-IN DOUBLE HOLDERS display 20 cards in plastic, 3 for $1.00, 10 for $3.00 prepaid. Guaranteed. Patented. Free sample to dealers. Tepabco, John K4NMT, Box 198R, Gallatin, Tennessee 37066.

SELL: Viking 6n2 transmitter, 6n2 VFO, Eico Modulator, as package $85. SASE for further info and photos of above. Jim Hagedon, K8YQH, 1335 Brainard Woods Drive, Dayton, Ohio 45459.

FOR SALE: HENRY 3-K (the latest!), $745. SR-400, P-500-AC, P-500-DC, HA-20, $800. 32S3, 516F2, $615. 75S3, $395. KWM2, PM2, $725 . 312B5, $275. 30L-1, $375. Collins R-390-A, cabinet, $875. Eldico SSB-100F, $250. 1000-F, spare 4CX-300's, $250. R4A, factory updated, in sealed carton, $315. Galaxy 300, PSA-300, $225. P & H "Spitfire" linear, DCPS, $125. Camera, Nikon "Photomic-F", F 1.4 500MM lens, 18 mos. old, $275 with carrying case. Camera, movie, 16 MM, Bell & Howell model 200-EE, carrying case, six (6) cartridges kodachrome film, $150. NOTE: will trade cameras for Drake or Collins late production. WANTED: Henry 2K-D (serial over 400). James W. Craig, W1FBG, 29 Sherburne Avenue, Portsmouth, N. H. 03801. (603) 436-9062.

HAMMARLUND SUPER-PRO BC-779-B in working order. *Rack mounting model less cabinet.* Includes power supply. Covers 200-400 kc, 2.5 to 20 mc. Only $75. Hallicrafters S-40B & S-20R receivers both in good condition. S-40B $40; S-20R $25. All prices fob my shack. W1DHZ, Box 185, Amherst, N. H. 03031. Phone 603-673-4885.

'ROTARY' QSL FILE: Pockets for 160 cards included (File maximum: 500) $8.00 postpaid; M-B Sales, 1917 N. Lowell, Chicago, Illinois 60639.

DAYTON HAMVENTION April 25, 1970: Sponsored by Dayton Amateur Radio Association for the 19th year. Technical sessions, exhibits and hidden transmitter hunt. An interesting ladies program for XYL. For information watch ads or write Dayton Hamvention, Dept. H, Box 44, Dayton, Ohio 45401.

HAM RADIO MAGAZINE March 1968 thru March 1969 *all in good condition. What am I offered?* Donald Guptill, 17 Park St. Ct., Medford, MA 02155.

TOROIDS 44 and 88 mhy. Unpotted, 5 for $1.50 ppd. W. Weinschenker, Box 353, Irwin, Pa. 15642.

RAGS HAMFEST, Syracuse, New York, April 11, 1970 at Song Mountain. Box 88. Liverpool, New York 13088.

QSLS. SECOND TO NONE. Same day service. Samples airmailed 25¢. Ray, K7HLR, Box 331, Clearfield, Utah 84015.

MOTOROLA FM EQUIPMENT. See our full page ad on page 81 *in the February issue of Ham Radio.* Newsome Electronics, 1967 Allen Road, Trenton, Michigan 48188.

GREENE DIPOLE CENTER INSULATOR . . . see ad page 96, September 1969 Ham Radio.

THE STICK THAT DOES THE TRICK — Be TVI free with Joystick VFA — World Record Antenna — 160 thru 10 — 7'6" long — details: Partridge Electronics, Broadstairs, Kent, England.

THE EAST COAST VHF Societies annual Dinner will be held Saturday, March 21, 1970, at the Neptune Inn, Route 4, Paramus, N. J., at 7:00 p.m. W4FJ, Ted Mathewson will talk on "VHF - Past, Present, and Future". Awards will be given by W1HDQ, Ed Tilton, including awards for highest single and multi-operator station in the September VHF contest. Menu will be Prime Ribs of Beef and tickets are $7.50. Group reservations available in blocks of 5 to 10. Ticket deadline is Wednesday, March 11th. Write the East Coast VHF Society (WA2WEB), P. O. Box 1263, Paterson, N. J. 07509.

1916 QST'S wanted. Especially May and June. Any unreasonable price paid! Ted Dames, W2KUW, 308 Hickory Street, Arlington, N. J. 07032.

NORTHERN CALIFORNIA Hams: Best deals — new and reconditioned equipment. Write or stop for free estimate. The Wireless Shop, 1305 Tennessee, Vallejo, California 94590.

AUCTION — March 22, 1970, at Lamb's Auction House, 1600 N. Oak, Champaign, Illinois. Sponsored by the Twin City Amateur Radio Club. Details, contact K9QZI, Milt Forsberg, 807 W. Charles St., Champaign, Illinois 61820.

QSL'S — BROWNIE W3CJI — 3111-B Lehigh, Allentown, Pa. 18103. Samples 10¢. Cut catalogue 25¢.

FOR SALE: Bramco 4 tone reed relays for tone squelch, $2.95 each. Utica high band 30W 12VDC front or rear mount transceiver, used $34.95, with *schematics, limited quantity.* E. S. P., P. O. Box 328, Brookfield, Illinois 60513.

NEW JERSEY'S largest Ham auction Friday, April 3, 1970, sponsored by the Key Klickers of Stirling. Watch for further details.

TUBES — Lowest World price. Foreign-American. Obsolete, current. Receiving, Special Purpose, Transmitting tubes. Send for tube and parts catalog. United Radio Company, 56-HR Ferry Street, Newark, New Jersey 07105.

SAVE. On all makes of new and used equipment. Write or call Bob Grimes, 89 Aspen Road, Swampscott, Massachusetts, 617-598-2530 for the gear u want at the prices u want to pay.

THE 3rd ANNUAL BLOSSOMLAND Amateur Radio Auction will be held Sunday, March 15, 1970 at the Youth Memorial Building, Berrien County Fairgrounds, one mile northwest of beautiful downtown Berrien Springs, Michigan. Free parking, hot food, prizes, swap tables.

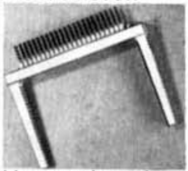
ANNUAL ST. PATRICK'S DAY SWAPFEST. Midland Amateur Radio Club, March 14th and 15th. Write MARC, Box 967, Midland, Texas 79701 for details.

ROCHESTER, N. Y. is again Hamfest, VHF meet and flea market headquarters for largest event in northeast, May 16, 1970. Write WNY Hamfest, P. O. Box 1388, Rochester, N. Y. 14603.

NEMS-CLARKE, CEI, DEI and other special purpose receivers wanted. Send accurate description of what you have to Tucker Electronics, P. O. Box 1050, Garland, Texas 75040.

YOUR AD belongs here too. Commercial ads 25¢ per word. Non-commercial ads 10¢ per word. Commercial advertisers write for special discounts for standing ads not changed each month.

PRINTED CIRCUIT EDGE CONNECTOR



We have been lucky enough to obtain a large quantity of these connectors which take a 4"x5½"x1/16" thick printed circuit board (or two 4"x2 1/2" boards side by side using a 1/2" center partition). The connector has 48 gold plated contacts, spaced on 0.200 inch centers, suitable for solder or wire w/cap connections. Manufactures O.E.M. Price for this connector is $7.60 each. We have suitable unetched copper clad board approximately 4"x5 1/2" available to fit this connector as well as pretched Universal Logic cards described elsewhere in this ad. Take advantage of this special while they last. From what we have heard the gold alone is worth over 50 cents.
PCEC $1.50 each, 10 for $12.00, 100 for $100.00
PCEC-BOARD Matching, approx. 1/16"x4"x5½" Double clad board unetched 25 cents each, any quantity but only available with purchase of connectors.

SYLVANIA TYPE 5ES INDICATOR LAMPS

These hard to get lamps are made to operate directly from the output of DTL or TTL Integrated Circuits. Draws only 40 milliamps at 5 volts. Eliminate the complexity of using driver transistors and separate supplies and conserve power. Solder directly to P.C. Board. Brand new, factory fresh, packaged with full 7/8" leads. ...**S5ESIL 10 for $4.00 pp**

COMPUTER GRADE GIANT CAPACITORS

These brand new capacitors are in great demand as filter capacitors for I.C. Logic Circuits, Power Supplies, etc. These will take the noise out of the most stubborn circuits, where all else fails.

Net Price is from $4.00 to $18.00 each.

WT.	SIZE	PRICE EA.	12 FOR
2#	110,000Mf 15V	$2.00	$20.00
2#	25,000Mf 25V	1.50	15.00
1#	9,300Mf 15V	1.00	10.00
2#	6,000Mf 75V	1.50	15.00
1#	4,000Mf 50V	1.00	10.00

TACHOMETER KITS

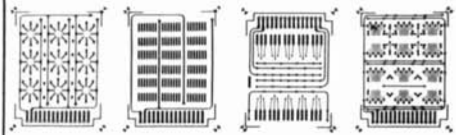
We bought a large quantity of Tachometer meter movements and dials as shown, and while we were wondering how to sell them, one of our customers showed us some ingenious Tachometers he developed, using this meter movement. We bought the designs and are offering them to you as kits of electrical parts only, which we are selling at far below the price of the meter alone.

KIT 1 — Tachometer and dwell meter, operates from distributor of 4, 6 and 8 cylinder engines. Transistorized .... **TK1 $5.00 ppd.**

KIT 2 — Outboard motor, engine tachometer. Simply hold wire lead near spark plug wire and pulses are picked up and registered. Works on 2 or 4 cycle 1, 2, 4, 6 or 8 cylinder engines. Transistorized .... **TK2 $12.50 ppd.**

KIT 3 — Photo electric tachometer. This is very ingenious. Point the pickup head at propeller of model airplane, or other rotating parts and meter registers RPM by measuring frequency of interrupted light. **TK3 $12.50 ppd.**

UNIVERSAL LOGIC CIRCUIT CARDS
Instant Logic!



— LOGIC CIRCUIT BOARDS AVAILABLE—

CB 8 TO5 — for 9 — 8 pin TO5 can I.C.
CB DIP — for 9 — Dual-in-line I.C.
CB FP — for 9 — Flat Pack I.C.
CB FDC — for transistors & components.
CB 10 TO5 — for 9 — 10 pin TO5 can I.C.

NEW LARGER BOARDS

Our previous Universal Logic Cards are still available as advertised, but for those of you who like to put more circuitry on a single board new varieties are available.

These boards are the most useful items we have ever offered, and one of the best sellers. We offer them at 1/5 the price of others. How? By using surplus connectors and copper clad board, and etching them in huge quantities. We have sold 10,000 of these boards in the past few months, and orders keep climbing as customers find out how useful they are. The use of the boards is simple. The board has a pattern etched on it for mounting integrated circuits. You drill out the desired hole pattern. The power leads are already routed around the boards. Discrete components and transistors can be mounted in the locations between the I.C.'s. Then you route the wires between the I.C.'s and to the connector, and you are ready to count compute or whatever.

Here are the cards available: ILCC — original — pads for 14 pin dual-in-line on one side, 10 pin to 5 on the other, transistor pads on both sides as previously advertised, complete with a surplus PC card with edge connector, and mating connector. You take the connector off the surplus card, and throw it away (or salvage lots of useful components from it). Will mount four integrated circuits, and two transistors. Size 2 1/2"x2 1/". See previous ad for illustrations.

2 Cards & mating connectors 2ILCC $ 2.50 pp
10 Cards & mating connectors 10ILCC $10.00 pp
100 Cards & mating connectors 100ILCC $88.00 pp

LILCC-New larger size cards 3"x4" mounts 9 integrated circuits in pattern as illustrated above. Specify which type pattern you want. Pattern on one side only. Same connections and salvage board as ILCC provided.

2 Cards & mating connectors 2LILCC $3.50 pp
10 Cards & mating connectors 10LILCC $15.00 pp

SPECIFY PATTERN DESIRED

ULILCC-Still larger 4"x5 1/2" size, mounts 16 integrated circuits into edge connector PCEC shown on left of page

2 Cards & mating connectors 2ULILCC $ 5.00 pp
10 Cards & mating connectors 10ULILCC $22.00 pp

SPECIFY PATTERN DESIRED

Send 25¢ for catalog 703. Jam packed with surplus bargains . . . Best yet . . . Just fantastic . . . Free with an order.

BF Enterprises

P. O. BOX 44, HATHORNE, MASS. 01937
1-617-532-2323

TRANSISTOR AUTO RADIOS

Brand new factory packed automobile radios, vintage around 1962. 12 volt neg. ground. No choice of models. The exceptional sensitivity of an auto radio makes it superior for use in car-boat-truck-camper, etc., where you are quite a distance from xmtr location. This is also the best kind of radio to use with short wave converters. Each with large original equipment hi-fi speaker. Some with noise suppressor kit. High quality, most made to sell in the $100 range. A real "find". **$15.00**

FT-243 CRYSTALS $1.00

Gov't surplus, each guaranteed. Range of 5675 thru 8650 kc in 25kc steps. Such as 5675-5700-5725, etc. Take your pick at **$1.00 each.**

HAMMARLUND APC CAPS

Midget style, brand new, 4.5-100 mmfd. .... **3/$1.00 12/$3.00**

APC GRAB BAG

Unused assortment of various sizes and styles. Thousands on hand & bargain priced.

5/$1.00 30/$5.00

RF FERRITE CORE CHOKE

Hi-permeability, ultra midget style, coated for moisture resistance, color coded. Used in xmtrs, receivers, converters, TV-peaking. Brand new, worth 40¢ each. Assortment of 1.8, 27.0, 330 uh. Pack of 30, $12.00 value.

#A-71 30/$1.00 180/$5.00

TRANSISTOR MOUNTING PADS

Round fibre glass insulating pads, used under 3 legged TO-5, TO-18, etc. Raises and insulates transistors from PC board. Permits longer leads to be used with less danger of heat destruction. Adds professional touch to finished circuits. Bag of 50 pre-drilled pads.

#A-3 50/$1.00 300/$5.00

SILVER MICAS

Misc. assortment of CM type small silver micas. Supply varies & will give a mix of available on-hand stock. Unused, long leads, standard codes stamped on each.

#A-4 30/$1.00 180/$5.00

2 METER ARC-3

Just uncovered a batch of the famous ARC-3 rcvrs & xmtrs with all tubes. Range 100-156 mc, 8 xtl channels. Cheap way to get on 2 meters, CD nets, MARS nets, etc. With conversion details. Rcvr $15, Xmtr $15;

both units $25.00

PHOTOFLASH TRIGGER XMFR

Thordarson #22R44 brand new, produces 15KV pulse. With spec. sheets.

#22R44 $1.75 each 10/$15.00

FIBRE OPTICS KITS WITH IMAGE TRANSMITTER

An experimenters delight, fantastic display of the unique properties of clad-fibre-optics to pipe light as well as images. Kit #1 includes PVC sheathed bundle of glass fibres with polished ends (light pipe), bundle of plastic fibre optics, bundle of glass fibres, coherent light pipe (transmits images), instructions & experiments.

BLISS-FULL PAK #1 $5.00

Kit # 2 includes all of the above but more fibres, longer lengths, fatter bundles and also includes light source, heat shrink tubing, a 5 ft. light pipe, a longer coherent bundle (image transmitter) & more experiments.

BLISS-FULL PAK #2 $10.00

FLEXIBLE FIBER-OPTICS LIGHT GUIDES

FIBRE OPTIC LIGHT PIPE

1 ft length jacketed glass fibres (200 fibres) each end sealed and optically polished for maximum light conduction. Pipe light around corners, into difficult locations, etc.

#LP-1 $1.00

BULK LIGHT PIPE

3 feet of fibre glass (200 fibres) with jacketing. Make your own light pipes, Christmas tree displays, psychedelic lighting, etc. Any length you wish at 3 feet for $1.00.

FIBRE OPTIC OPTICAL SCANNER $5.00

Photo optics scanner, as used in IBM punch card scanner system. We offer the 12 position optical scanner consisting of 2 ft. assembly light pipe fanning out into a 12 channel scanner. All terminations optically polished. Make your own card scanner, light chopper, etc. A value for the 22 inch light pipe alone. With 4 page evaluation & application data. ....**#LP-3 $5.00**

Above equipment on hand, ready to ship. Terms net cash, f.o.b. Lynn, Mass. Many other unusual pieces of military surplus electronic equipment are described in our catalog.

Send 25¢ for catalog #70

JOHN MESHNA JR.

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P. O. BOX 62, E. LYNN, MASS. 01904

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NCX-500 ONLY $249.95*

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Frequency range: 80, 40, 20, 15 and 10 meter bands (full coverage of 10 meters with optional crystals). 500-watt PEP input on SSB, grid-block keying on CW and compatible AM operation. Receive vernier ±3 KHz. Sidetone monitor, plus built-in code practice oscillator. Rugged heavy-duty 6LQ6's.

PRICE SCHEDULE

NCX-500 w/AC500	$299.95
NCX-500 w/NCXB (spkr & cab inc.)	319.95
NCX-500 w/Linear Systems 400-12	359.95
NCX-500 without supply	249.95
XC-28 plug-in solid state crystal calibrator	19.95

SPECIAL!

CLEGG 66'er

SPECIFICATIONS

Receiver: dual conversion; sensitivity better than $.35\mu$ V for 10 db $\frac{S+N}{N}$; frequency coverage 49.9 to 52.1 MHz; switchable ANL; speaker built-in.

Transmitter: 22 watts input, output, 52 ohm; ptt operation; operates with 8.3, 12.5, or 25 MHz crystals or external VFO; spotting switch for transmitter frequency checks; built-in solid state power supply for both 115 volt AC and 12 volt DC operation.

Only $175.00

VARITRONICS FDFM-2S

2 METER FM — $310.00

SPECIFICATIONS

6 cnannels; 10 watts input, complete squelch, .5 microvolt sensitivity for 20 db signal to noise.

ACCESSORIES

Microphone, speaker, mounting bracket, power cables, plugs, 3 crystals are included (crystals provide the following frequencies: channel 1 receives 146.94, transmits 146.34; channel 2 simplex 146.94).

DIMENSIONS

6½" W x 3" H x 7½" D; 4 lb., 4 oz.

* ALL PRICES FOB HARVARD, MASS.

USED EQUIPMENT

RECONDITIONED, WITH FULL SIX MONTHS WARRANTY — NO TRADES AT THESE PRICES

Hammarlund HX500	$259.95
Johnson Viking II	79.95
Hallicrafters S85	75.00
Hallicrafters S108	85.00
Hallicrafters SX100	145.00
Knight TR108	110.00
Johnson Invader 200	225.00
SBE SB33 w/SB1-LA	350.00
Drake 2B	195.00

BARGAIN SPECIALS

PTT mobile mikes/standard plug	$10.00
Coax 5-6 ft. lengths RG8/u w/PL259's each end	1.00
National 1¼ meter converters 453-1929 (new)	15.00
For the DX'er-DX QSO recorder *(displays no. of countries contacted* and/or confirmed-reg. $2.50)	1.00
American Beauty 100W soldering iron	4.95

HERBERT W. GORDON CO., WOODCHUCK HILL RD., HARVARD, MASS. 01451 (617) 456-3548

NOW—DIRECT TO THE AMATEUR SPECTRONICS OFFERS THE HIGHEST QUALITY PRE-WIRED EQUIPMENT BELOW KIT PRICES.

[A] FTdx560 TRANSCEIVER

Successor to the widely acclaimed FTdx400 Transceiver, the new FTdx560 features maximum input power of 560 watts PEP in SSB mode and still maintains $\frac{1}{2}$uv receiver sensitivity. Utilizes double conversion tunable I.F. system resulting in drift free operation and maximum image rejection. Velvet smooth planetary dial gearing provides accurate frequency readings to less than 500 Hz. Twenty tubes and forty-two silicon semiconductors make up the complement of devices used in the FTdx560 Transceiver.

SPECIFICATIONS:

Maximum input: 560 W PEP SSB, 500 W CW, Sensitivity: 0.5 uv, S/N 20 db. Selectivity: 2.3 KHz (6db down), 3.7 KHz (60 db down). Carrier suppression: More than 40 db down. Sideband Suppression: More than 50 db down at 1 KHz. Frequency range: 3.5 to 4, 7 to 7.5, 14 to 14.5, 21 to 21.5, 28 to 30 (megahertz). Frequency stability: Less than 100 Hz drift in any 30 minute period after warm-up. Weight 45 pounds.

Only $449.95

[B] SP-560 SPEAKER

Companion speaker for the FTdx560, specially designed for superb voice quality, finished in matching blue-gray color.

Only $19.95

NOT SHOWN:
FV-400S External VFO — $99.95
FLdx2000 Linear Amplifier — $229.95

COST COMPARISON CHART

FTdx560	**$449.95**
Built-in AC Power Supply	No charge
Built-in WWV 10 MHz Band	No charge
25 and 100 KHz Calibrators	No charge
VOX	No charge
Clarifier	No charge
Break-in CW with Sidetone	No charge
1 KHz Readout	No charge
Selectable SSB	No charge
One Year Warranty	No charge
YOUR COST	**$449.95**

Order direct from your nearest Spectronics Sales and Service Center

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New from YAESU the FTdx560.

B

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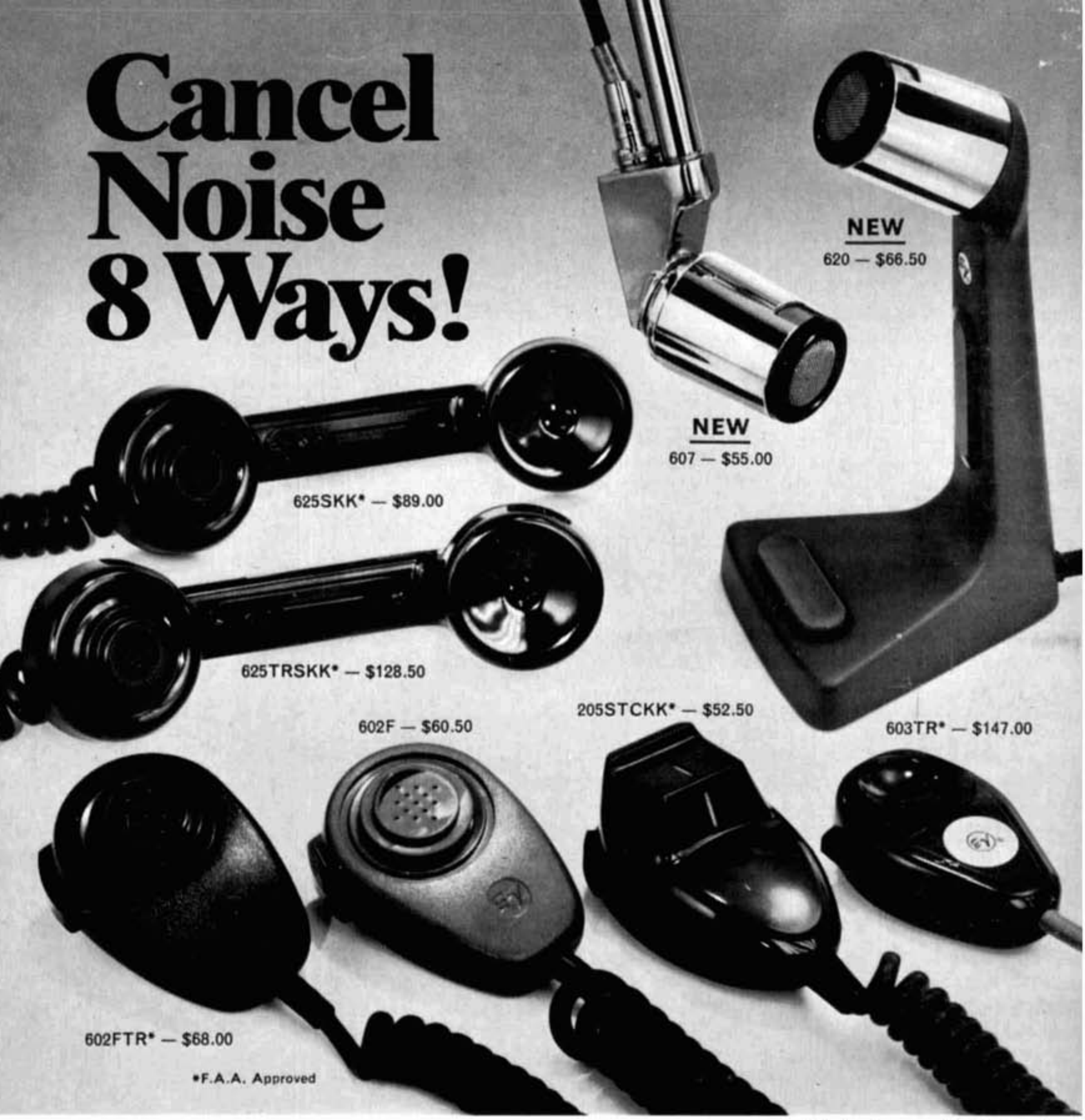

List prices less normal trade discounts.

Intelligibility. It's the essential ingredient in voice communications. As field tests prove (and lab tests confirm) the Electro-Voice noise cancelling microphones perform best when the going gets toughest. E-V offers better cancellation over a wider range of frequencies, with a special advantage over common (and troublesome) low frequency noise.

But improved signal/noise ratio is just part of E-V superiority. E-V dynamics offer as much as 50% less total harmonic and IM distortion when compared to reluctance types, a clear advantage in critical voice communications.

And E-V hand-held models have improved RF shielding, a new positive-detent switch (you *know* when you're on the air), high impact Cycolac® cases, and a host of other features. Indeed, the Model 602FTR is one of the few civilian products of any type to earn a military designation (M-109) with no more significant change than a new nameplate.

Your choice of dynamic, transistorized, or carbon models in hand-held or handset form. Plus the handsome new Model 607 stud-mounted, or Model 620 with unitized dispatcher stand. It's the widest array of noise-cancelling microphones offered today. All from your local E-V microphone specialist. Write today for free catalog. It's the first step (and the last word) in improved communications.

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high fidelity systems • tuners, amplifiers, receivers • public address loudspeakers
microphones • phono needles and cartridges • aerospace and defense electronics

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