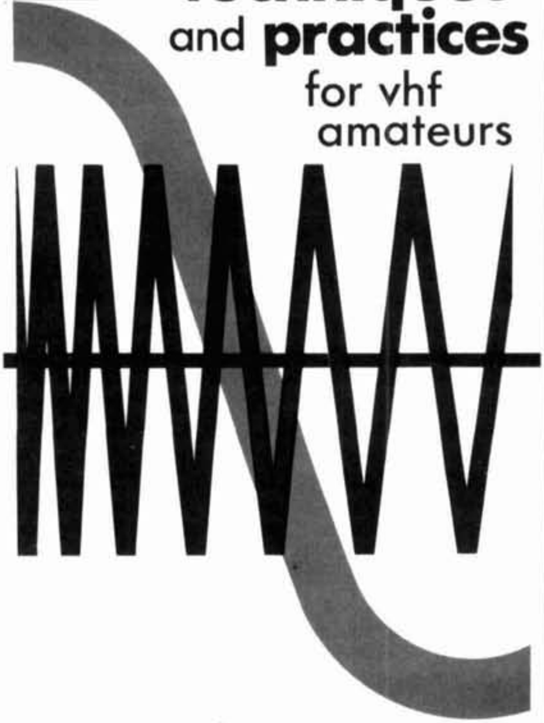
75 cents

focus
on
communications
technology . . .

# ham radio

magazine

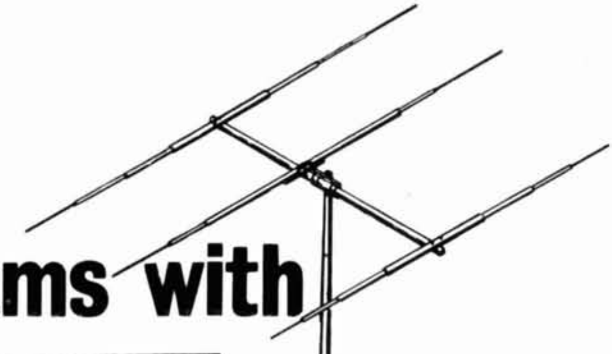
## fm techniques and practices for vhf amateurs

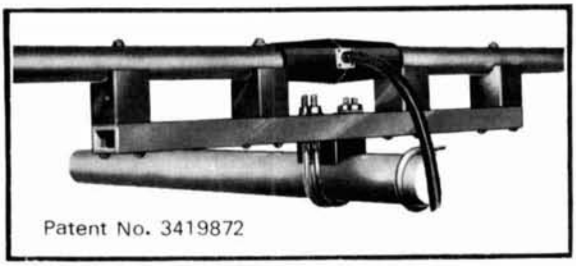


this month

# NEW! FROM MOSLEY

## Two Single-Band Beams with





Patent No. 3419872

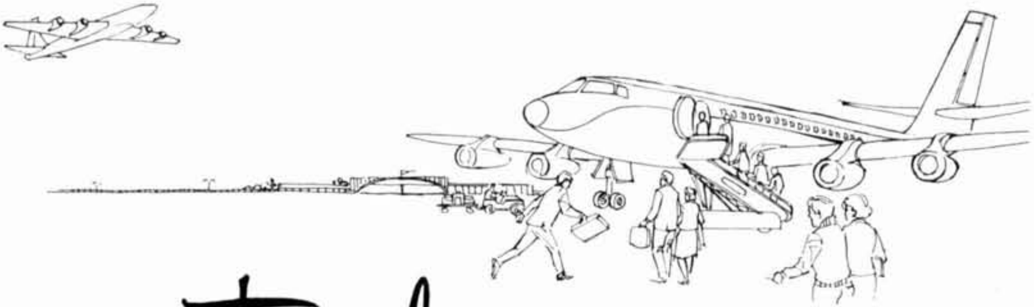
## The Classic FEED

According to forecast, 1969 should be another great year for h. f. propagation conditions. Make the most of the DX openings on 10 and 15 meters with new Mosley single-band beams, the Classic 10 (Model CL-10) and the Classic 15 (Model CL-15). These beams offer the optimum spacing possible only on single-band arrays. But even more advantageous is their famous Classic Feed System (pat. no. 3419872) This "Balanced Capacitive Matching" provides maximum gain, increased bandwidth and more afficient performance because of its better electrical balance and weather proof design.

See these DX champions at your nearest Mosley dealer. For complete specifications and performance data, write factory direct for free brochure, Dept. 189.

**Mosley Electronics Inc**

4610 N. LINDBERGH BLVD., BRIDGETON MO. 63042



ham
radio
magazine

september 1969

volume 2, number 9

**offices**

Greenville, New Hampshire
03048
Telephone: 603-878-1441

**ham radio** magazine is published monthly by Communications Technology, Inc., Greenville, New Hampshire 03048. Subscription rates, world wide: one year, $6.00, three years, $12.00. Second class postage paid at Greenville, N.H. 03048 and at additional mailing offices.

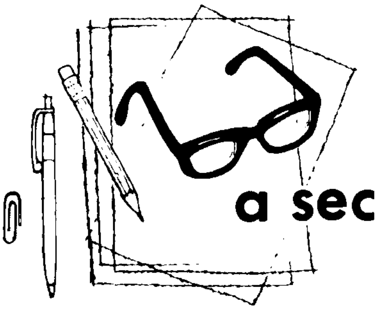
Printed by Capital City Press, Inc. in Montpelier, Vermont 05602, U.S.A.

Microfilm copies of current and back issues are available from University Microfilms, 313 N. First Street, Ann Arbor, Michigan 48103.

Postmaster: Please send form 3579 to **ham radio** magazine, Greenville, New Hampshire 03048.

# contents

## departments



# a second look

by jim fisk

**One of the things that makes** amateur radio stand out among other recreational pursuits is the diversification it offers. Many hams like to relax after a hard day's work and talk to friends, handle traffic, or chase DX. To others, amateur radio is a means for intellectual development and personal achievement. Some fellows have a drive that makes them explore beyond the canned circuit and ready-made construction project. They like to improve, modify, innovate. These are the experimenters, and their greatest satisfaction comes from finding new ways to do things. They must know what makes things tick and why. The experimenters are truly responsible for the perpetuation of our hobby. Without them, it's doubtful if amateur radio would have existed as we know it today.

If you're a serious experimenter, ham radio can be a means of enhancing your advancement in electronics. An example is the ham who is also an engineer. When solving a design problem at work, he may remember something he's read that somehow correlates with his immediate task. He may even work on the idea at home. Often these experimenters make significant contributions to the advancement of electronics—you see their results published in the literature.

One of the many areas open to experimenters is medical electronics. Doctors working on research projects in the medical disciplines can use the help of electronic engineers and technicians. For example, a physician working in radio isotope research needed an interface between his computer and a photoelectric sensor. This would be a fairly simple task for one familiar with digital circuits. The doctor needed a buffer memory and an analog-digital converter. He couldn't find anyone to help him, so he boned up on theory and actually built the thing himself—it worked!

Remember the tunnel diode? Engineers in the Device Research Branch of NASA's Electronic Research Center found that pressure applied to a tunnel diode made of gallium antimonide caused the diode's band gap to vary. Apparently, pressure differential in this region changes the inflection point on the diode's characteristic current-voltage curve. The resulting change in negative resistance (and hence maximum gain) makes the device useful as a transducer.

The NASA research people built a tunnel diode transducer using these principles. The transducer was about 0.05 mm thick—small enough to pass through the eye of a needle. Power requirements were 50 $\mu$W with 50 mV input. When inserted into the cardiovascular system, the diode reproduces minute changes in blood pressure. To the physician, these variations reveal essential data on heart activity and the circulatory system. The transducer's extremely small size allows doctors to monitor blood-pressure parameters heretofore undetectable with conventional sensors.

These are but a few things open to electronic experimentation. You probably won't come up with anything as exotic as a cardiovascular transducer, of course, but surely you must have some ideas that are worth developing in your home workshop. For example, how many different applications can you think of for the IC operational amplifier? Think about it, work up a design, then heat up your soldering iron.

**Jim Fisk, W1DTY**
**editor**

TOP OF THE YAESU F LINE

# THE FT DX 400 TRANSCEIVER

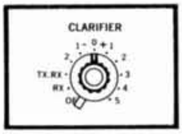
Conservatively rated at 500 watts PEP on all bands 80 through 10 the FT dx 400 combines high power with the hottest receiving section of any transceiver available today. In a few short months the Yaesu FT dx 400 has become the pace setter in the amateur field.

FEATURES: Built-in power supply • Built-in VOX • Built-in dual calibrators (25 and 100 KHz) • Built-in Clarifier (off-set tuning) • All crystals furnished 80 through the complete 10 meter band • Provision for 4 crystal-controlled channels within the amateur bands • Provision for 3 additional receive bands • Break-in CW with sidetone • Automatic dual acting noise limiter • and a sharp 2.3 KHz Crystal lattice filter with an optimum SSB shape factor of 1.66 to 1.

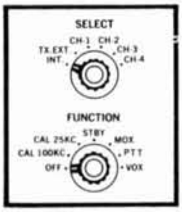
Design features include double conversion system for both transmit and receive functions resulting in, drift free operation, high sensitivity and image rejection • Switch selected metering • The FT dx 400 utilizes 18 tubes and 42 silicon semi-conductors in hybrid circuits designed to optimize the natural advantages of both tubes and transistors • Planetary gear tuning dial cover 500 KHz in 1 KHz increments • Glass-epoxy circuit boards • Final amplifier uses the popular 6KD6 tubes.

This imported desk top transceiver is beautifully styled with non-specular chrome front panel, back lighted dials, and heavy steel cabinet finished in functional blue-gray. The low cost, matching SP-400 Speaker is all that is needed to complete that professional station look.

SPECIFICATIONS: **Maximum input:** 500 W PEP SSB, 440 W CW, 125 W AM. **Sensitivity:** 0.5 uv, S/N 20 db. **Selectivity:** 2.3 KHz (6 db down), 3.7 KHz (55 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.

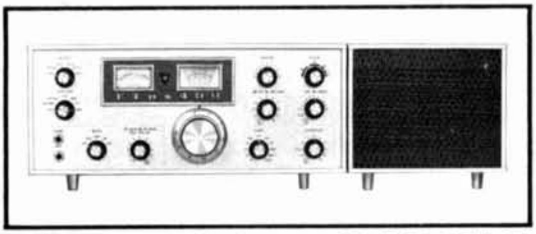


**CLARIFIER CONTROL** — Does the work of an external VFO — allows operator to vary receive frequency 10KHZ from transmit frequency, or may be used as an extra VFO combining transmit and receive functions.



**SELECT CONTROL** — Offers option of internal or outboard VFO and crystal positions for convenient preset channel operation.

**FUNCTION CONTROL**—Selects crystal calibration marker frequency and desired transmit mode of operation.

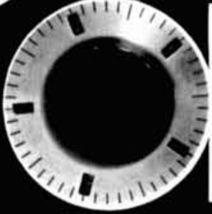


**FT DX 400 $599.95 — SP-400 $14.95**

**SPECTRONICS** BOX 356, LOS ALAMITOS, CALIFORNIA 90720

— PROFESSIONAL EQUIPMENT FOR THE AMATEUR —

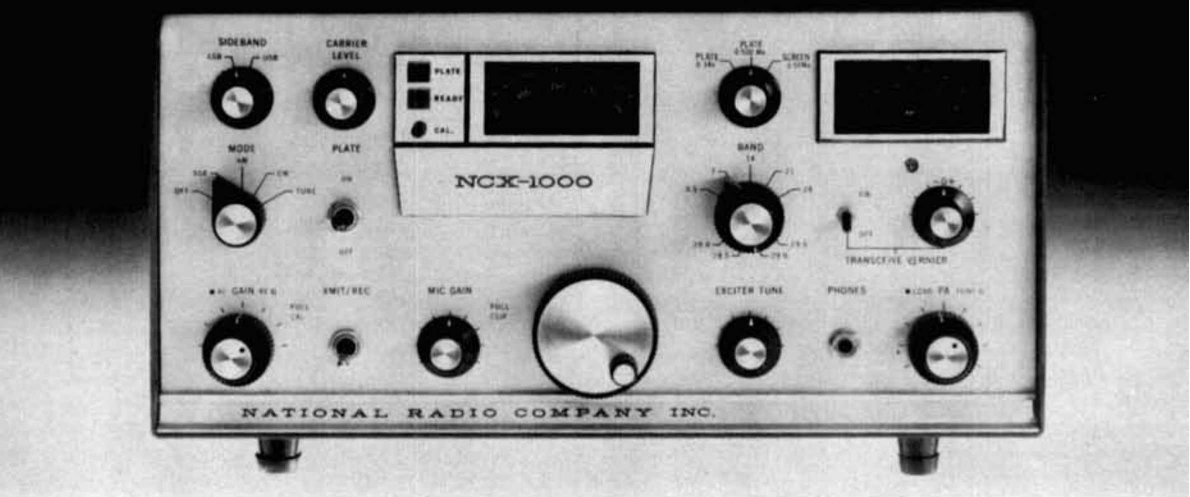
# the Great One



from NRCI

# MEET THE NCX-1000 TRANSCEIVER...

## THE NEW DESKTOP POWER PACKAGE FROM NRCI



NRCI's compact new happening puts you on the air with *complete* SSB, CW, and AM coverage of the 80 through 10 meter bands. There's a lot in it for you, including built-in AC power supply and monitor speaker. Check these features, and you'll see this is the rig to stay with!

- 1000 Watts PEP on SSB, 1000 Watts CW, 500 Watts FSK, 500 Watts AM.
- All-solid-state except for driver and PA.
- Built-in RF speech clipper.
- Wide-range fast attack/slow decay AGC.
- Receive Vernier with separate on/off control.
- Suggested amateur net price, $995.

For complete (and impressive) specifications and details, write:

**NATIONAL RADIO COMPANY, INC.**
**NRCI** 37 Washington St., Melrose, Mass. 02176

International Marketing through:
Ad Auriema, Inc., 85 Broad St., New York, N.Y. 10004

# fm techniques and practices for vhf amateurs

William I. Orr, W6SAI, Eimac Division of Varian, San Carlos, California 94070

**In 1937 the residents along** the New York and New Jersey sides of the Hudson River were awed and mystified by the appearance of a gigantic spidery structure that arose near Alpine, New Jersey. It was whispered by the local wags that this tower transmitted "secret waves," and rumors flew that the tower was used to contact inhabitants of Mars, that it was used for death-ray experiments, and that it was used for secret communications with the hereafter.

None of these wild stories, of course, were true. The appearance of the tower was the first public knowledge of a new mode of radio communication, based upon experiments of Major Edwin H. Armstrong of Columbia University, an early wireless pioneer and inventor of the regenerative receiving circuit.

## static-free radio

Major Armstrong had long realized that amplitude-modulated broadcasting suffered badly from static interference generated by electrical machinery and from crashes and noises created by natural electrical discharges in the atmosphere. It was Armstrong's belief, supported by the 1922 mathematical studies of John Carson,[1] that the way to avoid static was to artificially produce a radio signal differing as radically as possible from the static signals that wreaked havoc with a-m broadcast transmissions. If this could be done, a receiver could be built which would be insensitive to static interference.

Armstrong reasoned that random noise and static were amplitude variations that had no orderly variations in frequency. He proposed that a receiver be built that would be sensitive to frequency shifts but insensitive to amplitude variations. He started to work on such a receiver, plus a companion transmitter to generate a **frequency modulated** (fm) signal. During the course of his experiments in the Alpine, New Jersey laboratory, a 400-foot tower was erected. This impressive structure, with three large crossarms, was visible for miles along the banks of the Hudson River.

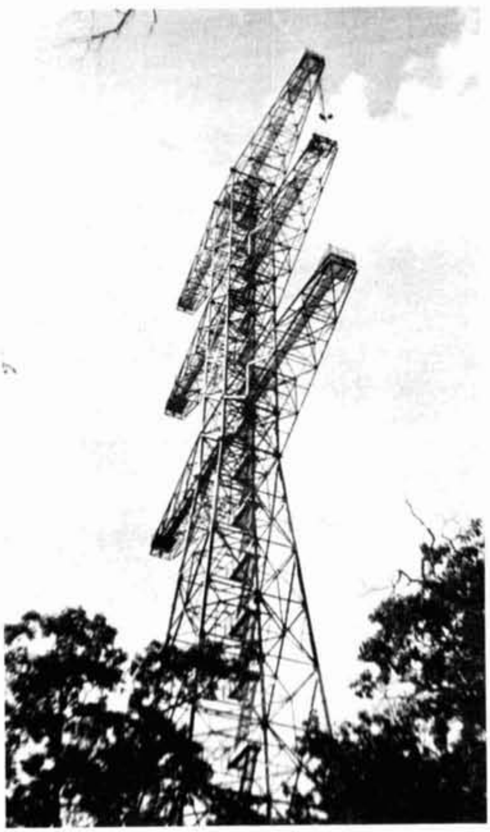
In 1934, before the tower was built, Armstrong conducted preliminary experimental frequency-modulated tests with a 50 watt fm transmitter atop the Empire State Building. These tests were run in conjunction with W2AG, Yonkers, New York, who operated a 50-watt fm transmitter at 120 MHz in the old 2½-meter amateur band. Voice, music, facsimile and multiplex telegraphy were transmitted by fm to W2AG.

In 1935, encouraged by the results of the tests, Armstrong applied to the FCC for an experimental fm license and was granted the call W2XMN for use in the experimental frequency region around 40 MHz. Armstrong's fm tests were soon followed by others, particularly by Connecticut State College, operating stations W1XCS and W1XPW near 43 MHz. Finally the FCC set aside four channels—200 kHz bandwidth each—for exclusive fm broadcasting in the 40-MHz band. Commercial fm broadcasting was finally launched, although it was nearly eclipsed by World War II and the advent of commercial television.

Radio amateur interest in fm techniques was aroused by the W2AG tests, and during the period from 1935 to 1940 a series of classic articles in *QST, Radio* and *Electronics*[3-8] provided practical circuitry for the transmission and reception of fm signals in the amateur 5-meter band. Amateur experiments before the war showed that fm promised excellent prospects for static-free, reliable mobile communication on the "ultra high" frequencies of $2^1/_2$ and $1^1/_4$ meters.

## post war fm

Frequency modulation proved its worth during World War II when it was extensively used for vhf vehicular communication and over-the-horizon military relay circuits. Unfortunately, the times were against amateur fm usage in the late 1940's. Aside from sporadic use on the higher frequencies, fm languished in the amateur bands. In the vhf bands where it would have been effective, fm was obliterated by the flood of surplus a-m gear that invaded the market.



**The tower at Alpine, New Jersey as it appeared in 1940. The man working on the 42.8-MHz turnstile antenna is supposedly Armstrong in his bucket sling.**

The SCR-522 a-m transmitter-receiver was king as far as the new 2-meter band was concerned. Aside from a few eccentrics, vhf operators restricted themselves to a-m, with a sprinkling of cw for DX work. Some narrow-band fm experiments took place on the hf amateur bands, but nbfm never proved popular except as a means for escaping broadcast interference. By 1950 or so, amateur fm was largely forgotten.

While amateurs limited their efforts to a-m in the world above 50 MHz, the mobile radio service, quick to see the advantages of fm, made a complete conversion to that mode, using 50-kHz channels and crystal-controlled transmitters and receivers. Eventually, the scarcity of channels in the mobile radio service spectrum became so acute that channel spacing was halved to 25 kHz. This released a flood of obsolete mobile fm gear to the amateur surplus market.

Amateurs soon realized the inherent advantages of this "new" form of vhf communication, and today the use of fm is increasingly popular on the higher frequency bands. Indeed, I predict that fm will eventually supplant a-m and ssb on the 144-, 220- and 432-MHz amateur bands in the metropolitan areas of the United States and Canada. The application of fm techniques in combination with stationary, remote repeater systems will bring about a revolution in the operating habits of vhf oriented amateurs during the coming decade.

This article covers frequency modulation fundamentals and techniques and discusses the use of fm equipment and repeaters. It is hoped that it will serve as an introduction and stimulant to amateurs who have not yet experienced the thrill of using vhf fm communication as a means of reliable short range communication.

## fm: what is it?

Intelligence may be superimposed upon a steady radio signal (carrier wave) by altering the structure of the wave in some way. The amplitude of the wave may be changed as is done in amplitude modulation or ssb. Or, the frequency, or phase, of the wave may be varied. In either case, the process of altering the radio wave in accord with the transmitted intelligence is called **modulation.** Modulation imparts a distinguishing characteristic to the radio wave which enables a properly designed receiver to convert it back into a replica of the original intelligence.

**Fig. 1A** shows an rf carrier that is amplitude modulated by a sinusoidal audio signal. The modulated rf wave varies about the zero axis at a constant rate, and the strength of the individual cycles of the wave is proportional to the amplitude of the modulating signal. The carrier is modulated 100 percent when the peak-to-peak amplitude of the modulating signal is equal to the peak-to-peak amplitude of the unmodulated carrier.

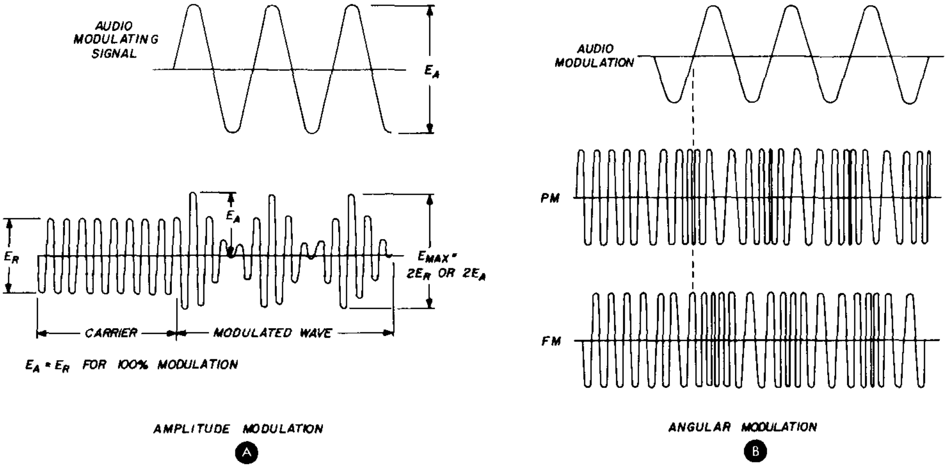


**fig. 1. Amplitude modulation (A) and angular modulation (B) of an rf carrier by the same audio signal.**

In **fig. 1B** the rf carrier is *frequency* and *phase* modulated by the same audio signal. It can be seen that modulation voltage of one polarity causes the carrier frequency to decrease, as shown by the fact that the individual rf cycles are spaced farther apart. A modulating voltage of the opposite polarity causes the frequency to increase; this is shown by the fact that more rf cycles are completed in a given time interval. If the phase-modulated (pm) wave is shifted 90°, the two waves in **fig. 1B** look alike. No amplitude variation takes place in either wave.

When an rf carrier is amplitude modulated, additional side frequencies are generated. These frequencies (sidebands) are located on each side of the carrier, spaced from the carrier by an interval equal to the *modulation frequency.* The strength of the carrier does not vary during modulation, but the strength of the sidebands depends upon the percentage of modulation. When the carrier is modulated 100 percent, the power in the sidebands is equal to one-half that of the carrier.

When an rf carrier is frequency modulated, many more than two additional side frequencies are generated. The first two are spaced from the carrier by the modulation frequency; additional side frequencies are located on each side of the carrier, spaced from each other by an amount equal to the modulating frequency. Theoretically, there are an *infinite* number of side frequencies; but, practically, the strength of those beyond the frequency swing of the modulated carrier is relatively low.

Unlike amplitude modulation, the strength of the carrier component of an fm wave varies widely; under certain conditions it may even disappear entirely. This variation in the strength of the carrier component is useful in measuring the modulation index, as will be discussed later.

## fm terms

There are several terms which convey considerable information about the character of a frequency-modulated signal: deviation, swing, modulation index and deviation ratio.

**Deviation** specifies the amount of frequency shift to each side of the unmodulated carrier when the transmitter is modulated. Deviation is directly proportional to the amplitude of the modulating signal and is usually measured in kilohertz. The limits of frequency shift on either side of the carrier are known as the frequency deviation limits.

**Swing** is the total frequency range covered by an fm transmitter when modulated with a symmetrical signal (equal deviation to each side of the carrier frequency). If, for example, a transmitter operating on 50,000 kHz has its frequency shifted to 50,010 kHz, back to 50,000 kHz, then to 49,990 kHz, and back again to 50,000 kHz during one cycle of the modulating wave, the deviation is 10 kHz and the swing is 20 kHz.

**Modulation index** of an fm signal is the ratio of the maximum frequency deviation to the audio modulating frequency, when both are expressed in the same units. Thus, in the previous example, if the signal is varied from 50,000 kHz to 50,010 kHz to 49,990 kHz and back to 50,000 kHz at a rate (frequency) of 2000 times per second (modulation frequency = 2 kHz), the modulation index would be 5, since the deviation (10 kHz) is 5 times the modulating frequency (2 kHz). Expressed as a formula, the modulation index is:

$$\text{Modulation Index} = \frac{\text{Maximum Frequency Deviation}}{\text{Maximum Frequency of modulating signal}}$$

**Deviation ratio** is similar to the modulation index in that it involves the ratio between the modulating frequency and deviation. In this case, however, the deviation in question is the peak frequency shift obtained under full modulation, and the audio frequency considered is the highest one transmitted by the system. For example, if the maximum audio frequency to be transmitted is 3000 Hz, a deviation ratio of 3 would call for a peak deviation of 3 x 3000, or 9 kHz at full modulation.

The noise suppression capabilities of fm are directly related to the deviation ratio. When the deviation ratio is increased, noise suppression is better when the signal is stronger than the noise. When the noise approaches the signal in strength, however, lower deviation ratios allow communications to be maintained in many cases where high-deviation-ratio fm is incapable of giving service. This assumes that a narrow-band fm receiver is used.

For each value of received signal-to-noise ratio there is a maximum deviation ratio. Beyond this maximum deviation ratio the output audio signal-to-noise ratio decreases. Up to this critical deviation ratio, noise suppression becomes progressively better as the deviation ratio is increased.

For high-fidelity fm broadcasting, a deviation ratio of 5 is ordinarily used. The maximum audio frequency is 15 kHz and the peak deviation at full modulation is 75 kHz. For tv sound, the deviation ratio is 1.67, the maximum audio frequency is 15 kHz, and the peak deviation is 25 kHz.

Narrow-band fm has been standardized by the public services and business radio service. A maximum deviation of 5 kHz is used by these services in the vhf region with 25 kHz channel separation. In the uhf region a deviation of 15 kHz is used along with 50 kHz channel separation.

In the amateur service, the bandwidth of an fm signal on frequencies below 29 MHz and between 50.1 and 52.5 MHz cannot exceed that of an a-m signal having the same audio characteristics [Section 97.65(c)]. Thus, wideband fm can be used above 29 MHz on 10 meters, above 52.5 MHz on the 6-meter band and in all the amateur vhf and uhf bands. Most fm stations in the vhf amateur bands use deviations between 5 and 25 kHz, with a trend toward the lower values.

## fm sidebands

I mentioned earlier that additional side frequencies over and above those generated by a-m are created by frequency modulation. For distortionless transmission and bandwidth conversion a study of the spectrum of a frequency-modulated wave is useful. Mathematical studies and observation of the fm sidebands with a wave analyzer can provide information that will allow efficient modulation under conditions of maximum deviation and *minimum* bandwidth.

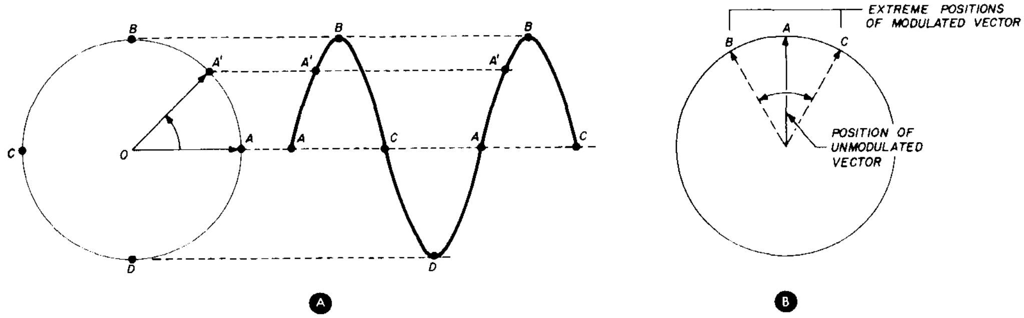


**fig. 2. A rotating vector may be used to represent a sinusoidal wave (A). An fm signal may be regarded as a constant-length vector rotating with slowly varying speed; *the angular displacement in advance or retard of* normal is caused by angular modulation (B).**

The mathematical expressions for an fm or pm signal may be written as an infinite series having coefficients known as Bessel functions, named after a German mathematician who first studied variations of this kind. A physical representation of an fm or pm signal may be achieved by the use of a vector. The vector may be drawn as an arrow, with its length denoting the magnitude of the voltage and the arrow indicating direction. The position of the vector with respect to various reference axes can be used to indicate angular displacement as is commonly done in vector representations of electric and magnetic fields. The frequency of an alternating voltage represented by a vector, for example, is proportional to the speed of rotation of the vector with respect to time.

The frequency-modulated carrier shown in **fig. 1B** may also be represented by visualizing the carrier as a vector rotating counterclockwise with time (**fig. 2A**). For each cycle of the sinusoidal carrier, the vector rotates one complete circle or 360°. This is the period of the wave; the vector rotates at a frequency equal to the wave it represents.

For the case of amplitude modulation, the vector rotates at the carrier frequency but alternately changes amplitude (at the modulation frequency) about its unmodulated value. Since the carrier frequency is much higher than the modulation frequency, the vector undergoes many rotations during each modulation cycle. As a result, the tip of the vector moves alternately inwards and outwards over a close multiturn spiral path.

Since the angular position of the vector is unaffected by amplitude modulation, the observer may ignore its rotation by considering it from the point of view of an observer who is rotating with it, and restrict his attention to its changing length. For a-m then, the representation can be reduced to a line which expands and contracts at the modulation frequency and reverses its direction each time the modulation goes through zero.

When the amplitude of the carrier vector is held constant, modulation may only be accomplished by changing the otherwise uniform rate of rotation of the vector. A constant amplitude, variable frequency signal can be represented by a vector of constant length, rotating with slowly varying speed. When the angular velocity of a vector is varied higher or lower about its mean value, its angular position is advanced or retarded from the angular position the unmodulated vector would have occupied (**fig. 2B**). Therefore, variations in angular velocity produce an alternate advance and retardation in the phase of the carrier.

Conversely, if it were desired to advance the angular position of the rotating vector by a certain amount it could only be done by temporarily increasing its angular velocity (frequency). Likewise, a backward shift of the rotating vector could only be produced by reducing the frequency from the normal value. To preserve any lead or lag that was introduced, the frequency would be restored to its normal value.

Modulation based upon the advancement or retardation of the angular position of a rotating vector representing the carrier wave is called **angular modulation.** Two practical forms of angular modulation are **frequency modulation** and **phase modulation.**

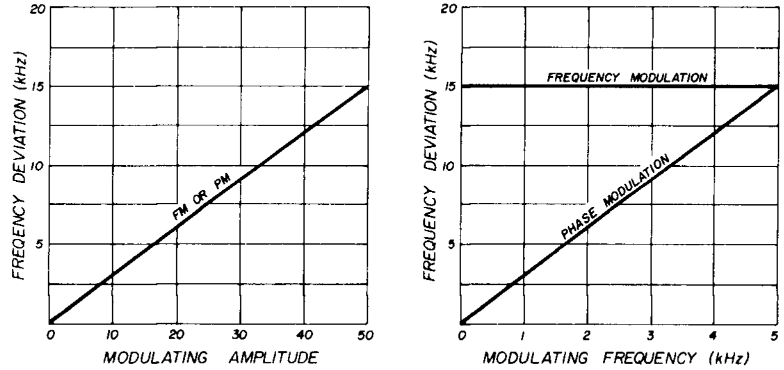


**fig. 3. Relationships between fm and pm. The only difference between pure fm and pm is the fact that the deviation is a function of the amplitude only of the modulating signal for fm while the frequency of the modulating signal also determines the deviation for pm.**

## frequency and phase modulation

When frequency modulation is used, the phase of the carrier wave is indirectly affected. Similarly, when phase modulation is used, the carrier frequency is affected. You cannot vary frequency without changing phase and vice-versa. In view of the interrelationship between frequency and phase, with the two quantities changing together under angular modulation, the distinction between frequency and phase modulation is only a nominal one.

The only difference between pure frequency modulation and phase modulation is the fact that deviation is a function of **amplitude only** of the modulating signal for pure frequency modulation, while the **frequency** of the modulating signal **also** determines the deviation for phase modulation. A comparison of the two signal characteristics is shown in **fig. 3.**

Most modern fm transmitters use phase modulation, because frequency modulation can only be applied to an oscillator stage, while phase modulation may be readily applied to any amplifier stage. Therefore, phase modulation is easily applied to crystal-controlled transmitters. With phase modulation, if an audio signal of 1000 Hz causes a deviation of 0.5 kHz, for example, a 2000 Hz modulating signal of the same amplitude will produce a deviation of 1 kHz, and so on. To produce an fm signal with this technique, it is only necessary to make the deviation independent of the frequency of modulation, and proportional only to the amplitude of the modulating signal. This is accomplished by including a frequency correcting network in the transmitter.

The only disadvantage of pm, as compared to direct fm, is the fact that very little frequency deviation is produced directly by the phase modulator.* The degree of deviation is dependent only upon the phase deviation produced on the modulation frequency:

$$F_d = M_p$$

---

*This is the only obvious practical disadvantage. In reality, phase modulation suffers one other serious disadvantage. In pure fm, the spectrum width can be made nearly independent of the modulating frequency; this is not true with pure pm. The undesirable variation of bandwidth with modulating frequency in phase modulation can be corrected with a tailored audio clipper. The clipper is both pre-and post-equalized: audio with a 6-dB-per-octave rising characteristic is fed to the clipper; clipper output is then passed through a network with a 6-dB-per-octave falling characteristic. The processed audio going to the phase modulator has a flat response, but with tailored clipping which results in constant peak deviation after modulation.

where $F_d$ is the frequency deviation one way from the mean value of the carrier, and $M_p$ is the phase deviation accompanying modulation (expressed in radians per second). Note that the deviation is completely independent of the carrier frequency. The amount of phase shift that can be obtained with good linearity is such that the maximum practical modulation index is about 0.5.

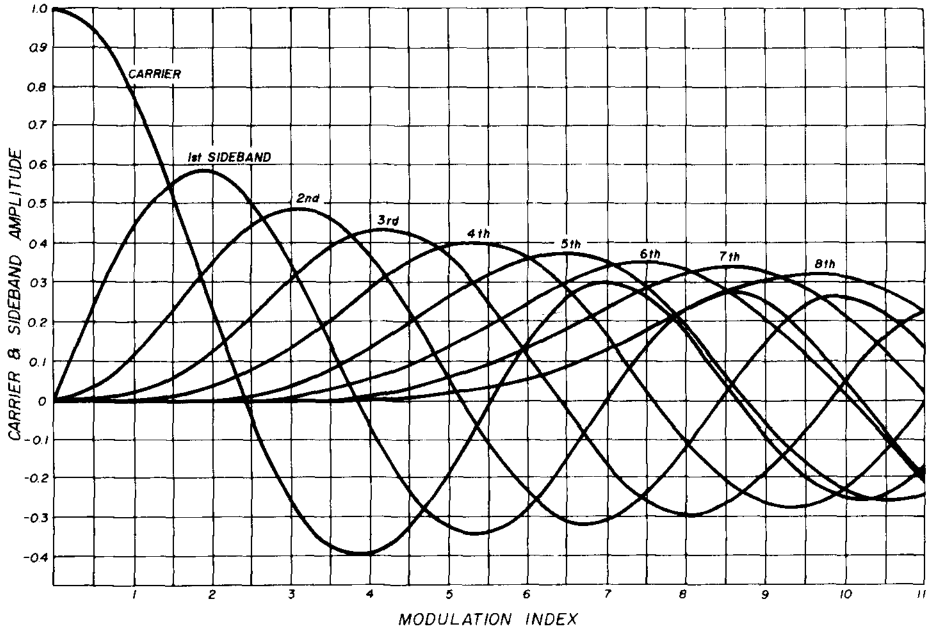


**fig. 4. Bessel curves show variation in carrier and sideband amplitude with modulation index.**

The degree of frequency deviation achieved by phase modulation can be increased by multiplying the signal frequency **after** modulation. Since there are no amplitude variations in any form of angular modulation, the signal may be amplified by a nonlinear stage such as a frequency multiplier or a class-C amplifier. Modulation can take place at a low level and at a low frequency, and then be amplified by frequency multipliers or straight amplifiers. The modulation index of the signal is multiplied by the same factor by which the carrier frequency is multiplied.

Many vhf fm transmitters are crystal controlled by a crystal that is 1/24 or 1/32 of the carrier frequency. A deviation of 15 kHz at 144 MHz, for example, is equivalent to a deviation of 625 Hz at a crystal frequency of 6 MHz: this is well within the linear capability of a phase modulator. Some high-frequency fm gear designed for operation from 30 to 50 MHz uses crystals in the 200- to 500-kHz region to allow for sufficient frequency multiplication for satisfactory wideband phase modulation at the carrier frequency.

| Zero Carrier Point | Modulaton Index (m) | To Obtain Bandwidth Multiply Modulating Frequency By |
|---|---|---|
| 1 | 2.40 | 6 |
| 2 | 5.52 | 8 |
| 3 | 8.65 | 12 |
| 4 | 11.79 | 14 |
| 5 | 14.93 | 16 |
| 6 | 18.07 | 18 |
| 7 | 21.21 | 20 |
| 8 | 24.35 | 22 |
| 9 | 27.49 | 26 |
| 10 | 30.64 | 28 |

Odd-harmonic distortion is produced when fm is obtained by the phase modulation technique, and the amount of distortion that can be tolerated determines the amount of phase modulation that may be used. Since the audio-frequency correction network causes the lowest modulating frequency to have the greatest amplitude, maximum phase modulation takes place at the lowest modulating frequency, and the amount of distortion that can be tolerated at this frequency determines the maximum deviation that can be obtained by the phase-modulation technique. Normally, for vhf fm, the deviation ranges from 5 kHz to 25 kHz. With a maximum audio frequency of 3000 Hz for voice operation, this represents a maximum deviation of about 8. Therefore, low-frequency crystals followed by multiplier stages are mandatory for this type of service.

## fm sidebands

Until mathematical analysis proved otherwise, some people believed that varying the carrier frequency by an amount less than the actual audio frequency (for example, causing a 10-kHz modulating signal to vary the carrier frequency by plus or minus 1 kHz) would allow transmission over a frequency band smaller than that required by amplitude modulation. However, no matter how small the frequency swing in fm may be, the upper and lower sideband frequencies that are produced in a-m are also present in fm.

Moreover, not only are these two side frequencies present, but also present are an infinite number of pairs of such frequencies mathematically related to the frequency of modulation. Fortunately, only a limited number of these pairs (those nearest to the carrier frequency) are of significant amplitude for concern. However, when Armstrong first conducted his experiments with wideband fm, he used a frequency spectrum of about 250 kHz for high-fidelity transmission of music. For this reason modern fm broadcasting must be carried out in the vhf region, since it is only here that sufficiently wide channels are available.

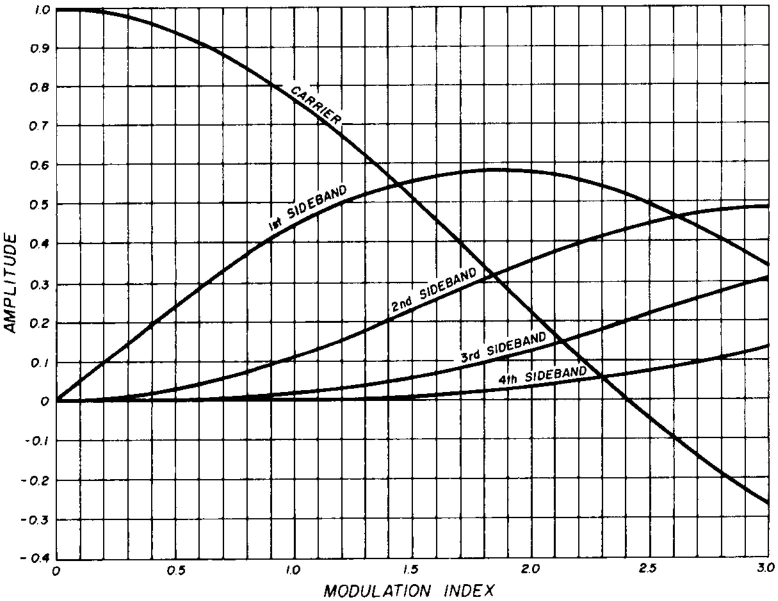


**fig. 5. An expansion of the Bessel curves of fig. 4 for modulation indexes up to three.**

The sidebands generated in fm differ from those resulting from a-m in that they occur at integral multiples of the modulating frequency; in a-m a single set of sidebands is generated for each modulating frequency. A simple method of determining the amplitude of the various f-m sidebands is the family of Bessel curves shown in **fig. 4.** There is one curve for the carrier and one for each pair of sideband frequencies.

The Bessel curves show how the carrier and sideband frequency pairs rise and fall with increasing modulation index, and illustrate the particular values at which they disappear as they pass through zero. Since the

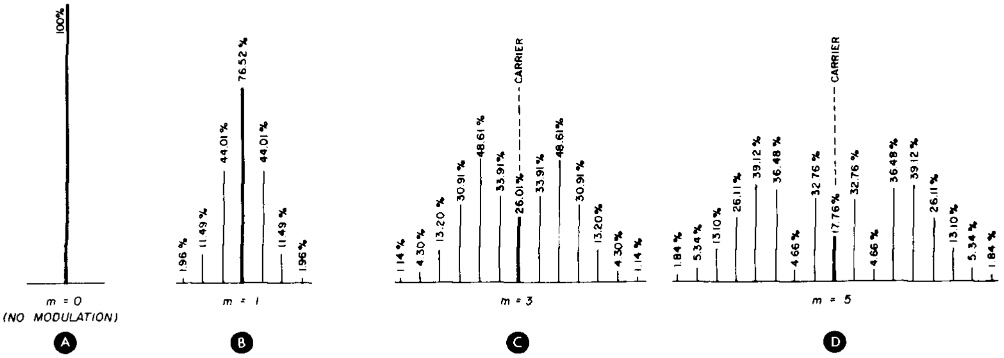


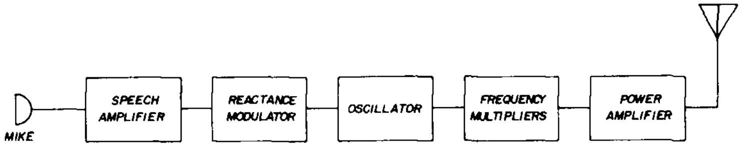
**fig. 6. Effect of modulation index showing sideband frequency amplitude and distribution for modulation indexes 1, 3 and 5.**

carrier drops to zero at particular values of modulation index (2.4, 5.5, 8.7, 11.8, etc.), the modulation index can be measured by noting the disappearance of the carrier. An expanded set of Bessel curves for modulation indexes up to 3 is plotted in **fig. 5.**

The relative amplitudes of carrier and sideband frequencies for any modulation index can be determined by finding the y-axis intercept for the particular function. Representative spectrum plots for three different values of modulation index are shown in **fig. 6.** The negative amplitude in the Bessel curves indicates that the phase of the particular function is reversed as compared to the phase without modulation. In fm, the energy that goes into the sideband frequencies is taken from the carrier; the total power in the over-all composite signal remains the same regardless of the modulation index.

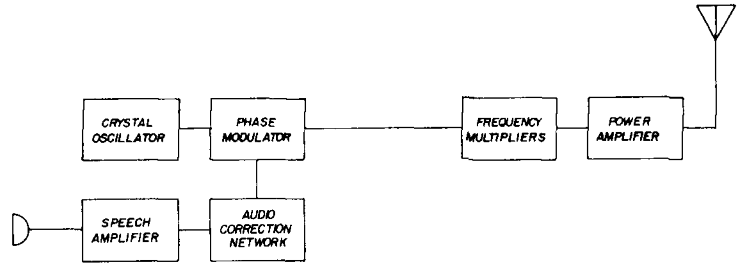
It should be noted that the frequency spectrum for fm is relatively constant for a given modulation depth regardless of the modulation frequency. On the other hand, the bandwidth of a pure pm signal increases with both modulation amplitude and frequency.

This situation does not occur in amplitude modulation. You might think that the large number of sideband frequencies would make the frequency spectrum produced by an fm transmitter prohibitively



FREQUENCY - MODULATED TRANSMITTER

A



PHASE - MODULATED TRANSMITTER

B

**fig. 7. Block diagrams of fm and pm transmitters.**

wide. However, the additional side frequencies are of small amplitude, and instead of increasing the bandwidth, modulation by a complex wave actually reduces the effective bandwidth of the fm spectrum. This is especially true when speech modulation is used, since most of the power in voice sounds is concentrated in the lower audio frequencies.

## generation of fm signals

Frequency modulation can be obtained directly by changing the frequency of an oscillator with the modulating signal, or indirectly with a phase modulator. Phase modulation circuits will be discussed later.

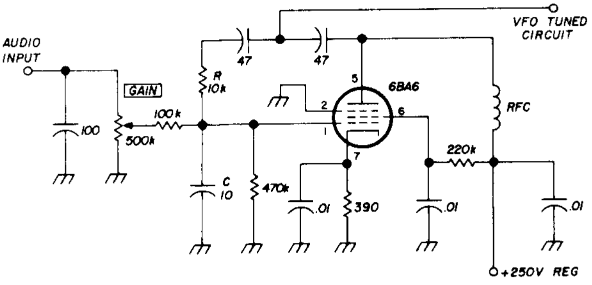


fig. 8. Simple reactance-tube modulator.

Simple frequency modulation of an oscillator avoids the need for phase- to frequency-modulation conversion. In addition, it produces a large proportional frequency change, so less frequency multiplication is needed.

A block diagram of an fm transmitter is shown in **fig. 7A**. In the fm transmitter, the output of the speech amplifier is usually connected directly to a modulator stage, which produces an equivalent reactance that varies with the modulating signal. This causes the frequency of the oscillator to vary in the same way. The frequency-modulated signal of the oscillator is then multiplied to the desired output frequency by the multipliers; a power amplifier boosts the signal to the desired output level.

## the reactance modulator

The reactance modulator is a device that is connected across the oscillator tuned circuit to vary its resonant frequency in accord with applied modulation. A vacuum tube or transistor can be made to appear as a capacitive or inductive reactance by exciting the modulator with a voltage which either leads or lags the oscillator tank voltage. This leading or lagging input voltage causes a corresponding leading or lagging current, and the output circuit appears as a capacitive or inductive reactance across the oscillator tank circuit.

The transconductance of a vacuum-tube reactance modulator has an inverse effect on the impedance across the oscillator tank circuit. Since transconductance changes with grid voltage, the magnitude of the reactance across the tank circuit is varied with the grid signal of the reactance tube. If the impedance is complex (composed of reactance and resistance)

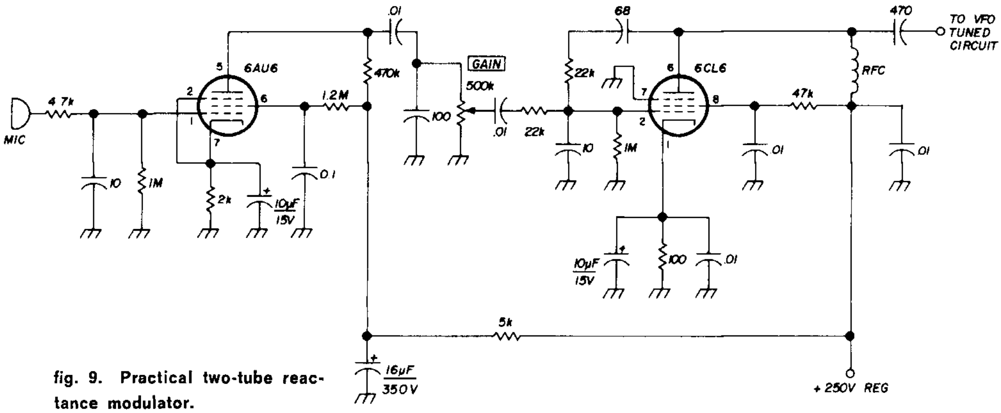


fig. 9. Practical two-tube reactance modulator.

the composite reactance will be varied about its zero-signal value when an audio signal is applied to the modulator. When properly designed and operated, the reactance modulator provides linear frequency modulation and is capable of providing large frequency deviations.

## practical reactance modulator circuits

There are many possible configurations for reactance modulator circuits. The principal difference between various arrangements is the type of phase-shifting circuit that is used to produce a grid voltage which is in phase quadrature* with the rf voltage of the modulator plate.

A practical reactance-tube modulator is shown in **fig. 8**. The modulator tube is a high-gain pentode, such as the 6BA6. The plate is coupled through a blocking capacitor to the oscillator circuit; a second capacitor couples the phase-shift network to the modulator grid circuit. If resistor R is made large in comparison to reactance C at the oscillator frequency, the current through R-C will be nearly in phase with the voltage across the tank circuit, and the voltage across C will lag the oscillator tank voltage by almost 90 degrees. The result of the 90 degree lagging voltage on the modulator grid is that its plate current lags the oscillator voltage by 90 degrees, and the reactance tube appears as an inductance in shunt with the oscillator inductance, thus raising the oscillator frequency. Capacitance C in **fig. 8** is often the grid-cathode capacitance of the reactance tube.

Two tubes are used in the practical reactance modulator circuit shown in **fig. 9**. A 6AU6 serves as a high-gain speech amplifier followed by a 6CL6 reactance modulator. The 6CL6's high transconductance permits a large value of lagging current to be drawn during the modulation swing.

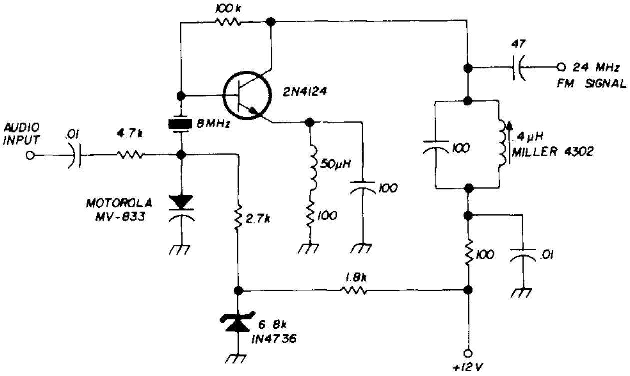


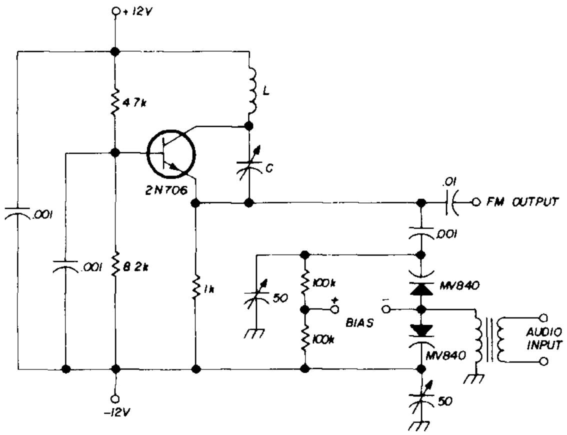
**fig. 10. Frequency-modulated crystal oscillator uses a variable-capacitance diode across the crystal.**

A frequency-modulated crystal-controlled oscillator is shown in **fig. 10**. In this circuit a voltage-variable capacitor (**varactor**) is used to alter the resonant frequency of the crystal by varying the shunt capacitance to ground. One or two volts of audio are sufficient to provide suitable deviation for transmitter operation at 50 MHz when 8.33-MHz crystals are used. Oscillator output is at 25 MHz.

In the circuit of **fig. 10** the audio voltage driving the varactor appears in the oscillator circuit and produces a small amount of a-m. This is eliminated by the use of two varactors in the back-to-back circuit shown in **fig. 11**. The audio signal is coupled by a high impedance transformer to the diodes through capacitors that are small in comparison with diode capacitance.

The bridge diode circuit presents only a capacitance change, and no component

**fig. 11. Back-to-back varactors produce fm without amplitude variations. Modulation transformer should present a high impedance to the diodes.**



---

*When two voltages are in quadrature, they are displaced 90° in phase.

of bias or drive voltage is presented to the oscillator. Oscillator frequency is determined by L and C, plus the effect of the modulator. Bias voltage is used to adjust the center frequency of the oscillator, providing reverse bias for the diodes to place them in the linear portion of their operating curve. For best results the bias resistors and coupling capacitors should be matched.

## determining linearity

It is often desirable to run a static test on a reactance modulator to determine its linearity. A frequency-vs-control voltage curve is plotted on graph paper, and linearity is checked by comparing equal increments in control voltage—both positive and negative—against resulting changes in frequency. A circuit that provides a calibrated negative and positive control voltage is shown in **fig. 12**. The calibrated control voltage may be checked against the frequency deviation produced by the modulator stage and an appropriate graph plotted.

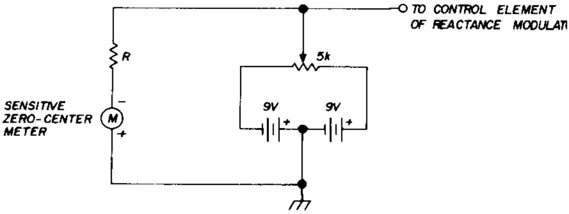
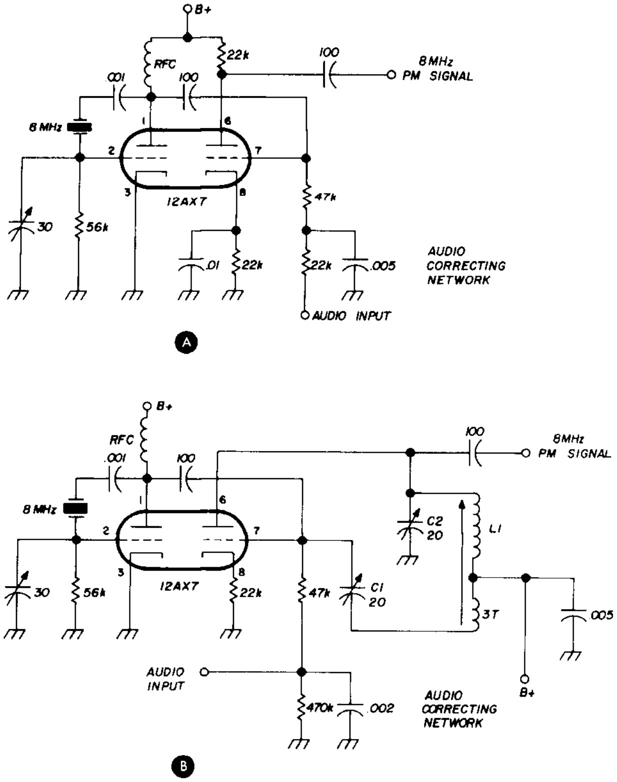


**fig. 12. Linearity checking circuit provides calibrated control voltage to the reactance modulator. Resistor R is chosen for full-scale meter deflection when 5k pot is at one end of its range.**

**fig. 13. Vacuum-tube phase modulators. The circuit in B provides approximately 6 times more deviation than circuit A. Inductor L1 should be approximately 27 $\mu$H for resonance at 8 MHz.**



## generation of pm signals

To generate a phase-modulated signal, the carrier is generated in a constant frequency oscillator, and then passed through a device which introduces phase variations in time with the modulation signal.

A change in the phase of a signal can be produced by passing the signal through a network containing both a resistance and a reactance. If the series combination is considered to be the input, and the output voltage is taken across the resistor, a definite amount of phase shift is introduced, the amount depending upon the frequency of the signal and the ratio of the resistance to the reactance. If the resistance can be varied with an applied audio signal, the phase angle of the output signal changes in direct proportion to the audio signal amplitude and a phase-modulated signal is produced.

Two practical phase modulators are shown in **fig. 13**. Circuit A is an R-C phase-shift network with the phase resistance replaced by the variable plate resistance of a vacuum tube. Since the plate resistance of the triode changes with the applied audio, the phase between the input and the output changes in accord with the audio signal.

In **fig. 13B** phase modulation is adjusted by capacitor C1. Capacitor C2 acts as both a phase angle and magnitude control. Both capacitors are adjusted for maximum modulation. Resonance is established by inductance L1. This circuit provides about six times the deviation of the circuit in **fig. 13A.**

Audio and carrier signals are applied to the control grid. The rf signal reaches the plate circuit by two paths; one through the grid-plate capacitance and the other by the normal amplification action of the tube. When a large, unbypassed cathode resistor is used, tube amplification is greatly reduced, and the two signal voltages across the plate circuit are approximately equal.

The instantaneous plate voltage of the triode is 180° out of phase with the grid voltage, but the feedthrough voltage via the grid-plate capacitance is in phase with the grid voltage. Therefore, the feedthrough is out of phase with the amplified voltage. When a modulating audio voltage is applied to the grid of the modulator, amplification is varied at an audio rate, and the amplified component across the plate circuit likewise varies in amplitude. However, the feedthrough voltage does not change in either amplitude or phase. The **resultant** plate voltage changes in amplitude and phase in accordance with the modulating signal. The small degree of amplitude modulation introduced by this simple modulator can be eliminated in the following stages.

## the balanced modulator

Armstrong's original method of generating pm is still widely used, and a variation of the basic circuit is shown in **fig. 14**. Ssb fans will recognize this as a form of balanced modulator which produces a double-sideband, suppressed-carrier signal. The grids of the modulator tubes are fed through an R-C network in the output circuit of the oscillator. Out-of-phase voltages are coupled through small capacitors to a phase-shift network (R1-C3) in the grid circuit of the modulator. This network introduces a 45° phase shift between the grids of the modulator with respect to the reference phase of the oscillator, and 90° with respect to each other.

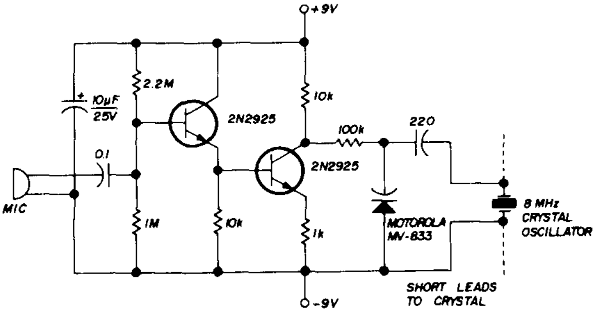


**fig. 15. Compact-varactor modulator for low-frequency crystal oscillator.**

The suppressor grids are fed by a push-pull audio signal, thus one tube conducts at a time. The combination of balanced modulator action with an rf carrier that

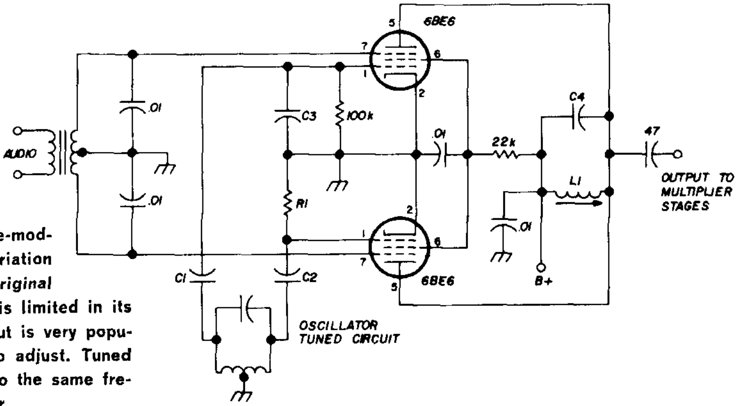


**fig. 14. Balanced phase-modulator circuit is a variation of Major Armstrong's *original* modulator. This circuit is limited in its modulation capability but is very popular because it's easy to adjust. Tuned circuit L1-C4 is tuned to the same frequency as the oscillator.**

is shifted in phase by 90° creates a phase-modulated output signal. Thus, amplitude modulation may be converted to phase modulation by removing the carrier, shifting the double sideband 90° and reinserting the carrier.

When the phase-shifted modulation is combined with the carrier, the resultant signal varies in amplitude as well as in frequency. This defect is small when the modulation amplitude is kept small in comparison with the carrier. As a result, this circuit is somewhat limited in modulation capability. It is, nevertheless, used in many types of commercial fm transmitters because of its ease of adjustment.

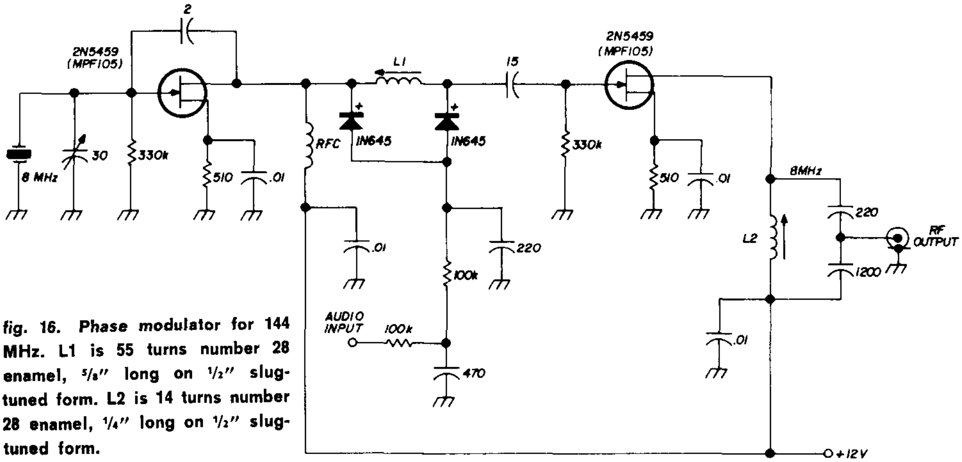


**fig. 16. Phase modulator for 144 MHz. L1 is 55 turns number 28 enamel, 5/8" long on 1/2" slug-tuned form. L2 is 14 turns number 28 enamel, 1/4" long on 1/2" slug-tuned form.**

## solid-state modulators

A solid-state phase modulator that may be used with a crystal oscillator is shown in **fig. 15**. In this circuit a two-stage amplifier places the modulating audio voltage across a varactor which is applied as a shunt capacitance across the crystal. The degree of phase modulation is limited with this approach, and the lowest possible crystal frequency should be used so high deviation ratios can be obtained through frequency multiplication.

A phase modulator designed especially for vhf crystal-controlled fm transmitters is shown in **fig. 16**. The inexpensive field-effect transistor is used in a crystal oscillator operating in the 4- to 8-MHz range. A second fet is used as a phase modulator, with the modulating network in the gate circuit. Two silicon diodes used as varactors across a phasing coil are driven by the modulating voltage. There is a small amount of amplitude modulation with this circuit, but it is "washed out" by the succeeding stages of the fm exciter. The audio system is designed for a high-gain carbon microphone for mobile service. Under these conditions, the rf output of the fet amplifier is about 30 milliwatts.

Bias for the diode modulator is adjusted for maximum deviation with a given amount of audio as monitored in a nearby fm receiver. Channel adjustment is accomplished by the trimmer across the crystal.

## conversion of phase modulation to frequency modulation

Phase modulation may be received on an fm receiver with no difficulty, but the modulation will sound harsh and the human voice will sound peaked and tinny. To solve this problem in early designs, the phase modulation was changed so the modulation index decreased in inverse proportion to the modulating frequency. This is accomplished by shaping the response of the transmitter speech amplifier with an audio correction network (**fig. 17**) so that the output voltage is inversely proportional to the modulating frequency. In current commercial practice, flat-response audio with tailored clipping is fed to the phase modulator in the transmitter (see footnote, page 13); this results in constant peak deviation after modulation, and requires the use of post-equalization at the receiver discriminator.

## the fm transmitter

The various direct and indirect methods for producing frequency modulation involve changing either the frequency or the phase of an rf carrier in accordance with the modulating signal. The fm signal is then raised to the operating frequency by passing it through a series of frequency multipliers. When the frequency is multiplied, the frequency deviation is multiplied by a like amount.

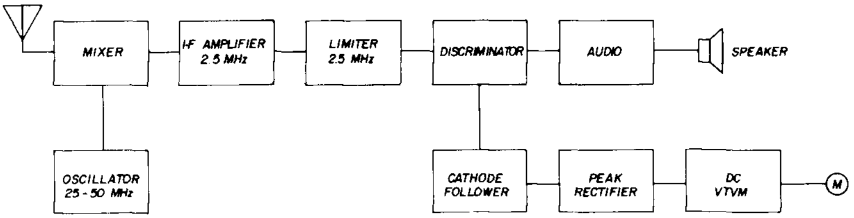


**fig. 18. Fm modulation meter depends upon an increase in discriminator output with frequency deviation.**

Inexpensive, highly stable quartz crystals are available in the 3- to 10-MHz range, and many popular vhf fm transmitters use these crystals, multiplying the crystal frequency by a factor of twelve, eighteen or twenty-four. Some of the earlier military fm gear which used wideband fm in the 20- to 30-MHz region used special low-frequency crystals (type FT-241) that operated in the 250- to 500-kHz region. These crystals allowed sufficient frequency multiplication to obtain the desired degree of deviation at the output frequency.

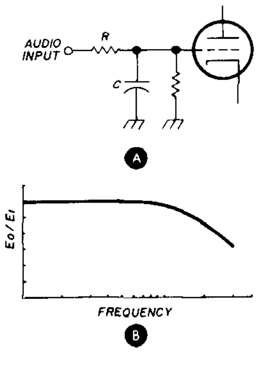


**fig. 17. Audio correction network and its effect on frequency response.**

Generally speaking, the circuitry used in conventional transmitters may be used for fm. In fact, aside from the modulator stage, the circuitry should be familiar to any amateur who has worked with a-m, cw or ssb.

Because the amplitude of an fm signal is constant, the signal may be amplified by nonlinear stages such as doublers and class-C amplifiers without introducing signal distortion. Actually, it is advantageous to pass an fm signal through nonlinear stages, since any vestige of amplitude modulation generated in the reactance modulator may be smoothed out by the inherent limiting action of a class-C amplifier.

## deviation measurement

Deviation of an fm transmitter must be limited to that bandwidth authorized for the service. When a single signal is used to modulate an fm transmitter, the relative amplitudes of the various sideband frequencies vary widely as the deviation is changed as shown in **fig. 4**. Since we know the relationship between the amplitude of the sideband frequencies and carrier to the modulating frequency, a simple method of measuring deviation is possible. This measurement is expressed as the modulation index (m).

The Bessel function plot of an fm signal shows that at certain values of the modulation index, carrier amplitude falls to zero and all the power is contained in the sidebands. By applying a sinusoidal audio signal of known frequency to the transmitter, and increasing the modulation until the amplitude of the fm carrier reaches zero, deviation can be determined. The modulation index at this point may be found from a table, such as accompanies **fig. 4**.

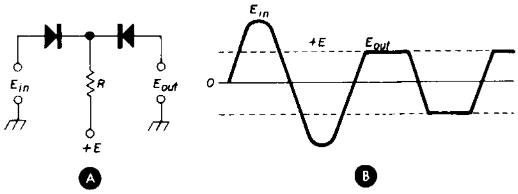


**fig. 19. Simple audio clipper and its output waveform. Clipping level is determined by bias voltage E.**

The first point of zero carrier is reached when the modulation index is 2.405 (when the deviation is 2.405 times the modulation frequency). For example, if the transmitter is modulated by a 1000-Hz tone and the modulation level increased until the first carrier null is obtained, the deviation will be 2.405 kHz. If the modulation frequency is 2000 Hz, the deviation at the first carrier null is 4.810 kHz. Other carrier nulls occur when the modulation index is 5.52, 8.65, 11.79, etc.

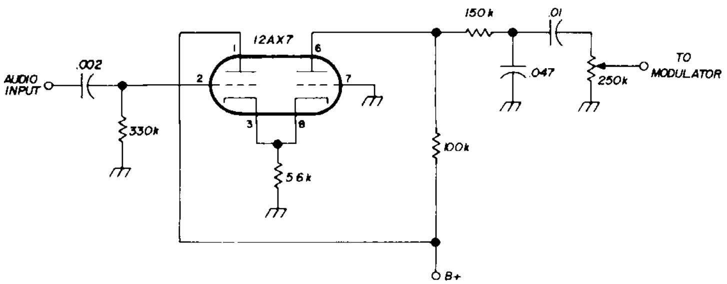
Carrier nulls may be accurately noted with a communication receiver that has a selective i-f system incorporating a crystal or mechanical filter. The output of the fm transmitter is loosely coupled to the front end of the receiver, and the unmodulated carrier is monitored with the bfo turned on and adjusted to a pleasant note, such as 800 Hz. The modulating signal is turned on, and the frequency deviation is varied by increasing the amplitude of the modulating signal until the 800-Hz tone first disappears.

If an fm transmitter has a maximum frequency deviation of 15 kHz, the modulating frequency that will produce carrier disappearance at an index of 2.405 is 6237 Hz (f = 15,000/2.405 = 6237). An audio signal of this frequency, when applied to the fm modulator and gradually increased in amplitude, will extinguish the carrier. In the measurements setup this adjustment produces a steady lessening of the beat note until it becomes inaudible.

Since 6237 Hz is above the audio range of most communications systems, it may be desirable to use the third carrier null at 8.65. For a maximum deviation of 15 kHz, the test modulating signal would be 1734 Hz (15,000/8.65 = 1734). This test frequency is better for amateur systems since it falls within the desired speech range. For this test, the amplitude of the 1734 Hz tone is increased until the beat note disappears for the third time.

A second method of monitoring deviation is the fm modulation meter. This device consists of a simple fm receiver equipped with a vtvm calibrated in kilohertz of deviation (**fig. 18**). The instrument depends upon an increase in discriminator output as frequency deviation increases. Commercial versions of this instrument will measure modulation of an fm transmitter operating in the range from 25 to 500 MHz. Harmonics of the local oscillator are used at the higher frequencies.

**fig. 20. Cathode-coupled twin-triode speech clipper.**



## modulation limiting

Frequency deviation in an fm transmitter can be controlled with a circuit that keeps the audio signal level within prescribed limits. Simple audio clipping circuits may be used, as well as more complex deviation control circuits that are designed for fm transmission. The audio clipping circuit shown in **fig. 19** uses two back-to-back diodes which clip each half of the audio cycle at a preset level. The clipping level is determined by the bias *voltage E. Normally the clipper is* followed by a low-pass filter which removes the higher harmonics created by clipping action, thus greatly attenuating sidebands which could cause adjacent channel interference.

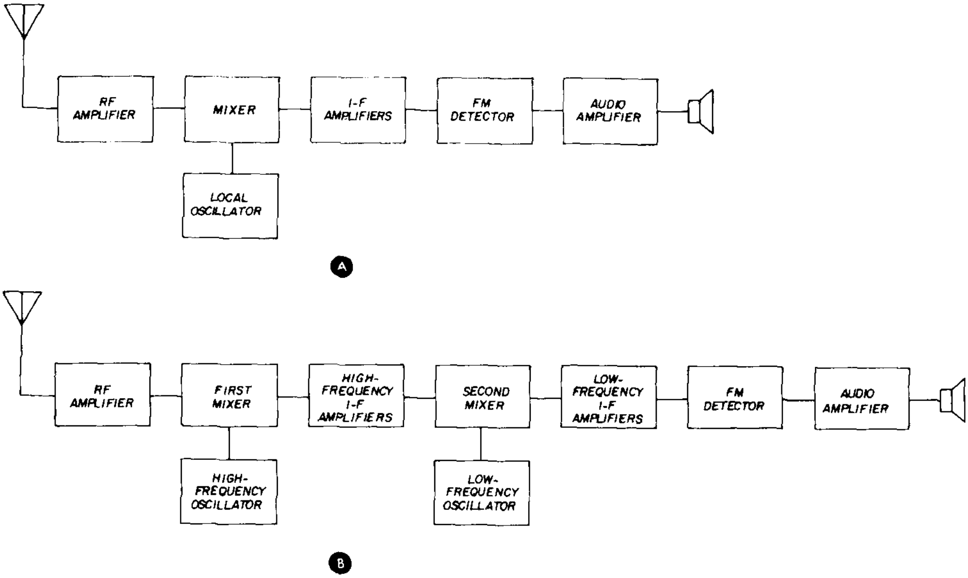


**fig. 21. Single- and -double-conversion fm receivers.**

A twin-triode cathode-coupled clipping circuit (**fig. 20**) is used in some commercial fm transmitters. When the grid signal at the first triode swings too far positive, the common cathode bias resistor cuts off the second triode; on an excessively large negative driving signal, the first triode section is cut off because of the combined effect of the signal and *cathode bias. Therefore, both positive and* negative signal peaks are evenly clipped.

## fm reception

The fm receiver used by Major Armstrong consisted of several heavy cabinets of equipment that stretched the full length of his laboratory. In 30 years this formidable pile of gear has shrunk to the battery operated, transistorized fm import selling for under ten dollars at the corner drug store.

An effective fm receiver should be insensitive to changes in signal amplitude and sensitive only to frequency changes in the received signal. By using slope detection, a conventional a-m receiver may be used to receive fm[10] although *performance will be much poorer than with a receiver designed for this service.*

## receiver requirements

There are three main requirements for a practical fm receiver:

**1**. Bandwidth sufficient to pass the desired fm signal while rejecting adjacent interfering signals.

2. Detector for converting frequency into audible amplitude changes.

3. *Limiting systems to eliminate signal* amplitude variations before the detector.

A block diagram of a typical fm receiver is shown in **fig. 21A.**

Most vhf fm receivers are double conversion receivers such as **fig. 21B**. When good selectivity is necessary, a low intermediate frequency is desirable; this, however, degrades image signal rejection. Similarly, if good image rejection is required, a high i-f should be used, but this is not compatible with good adjacent channel rejection. These difficulties may be overcome by combining the advantages of low and high i-f amplification in the double-conversion arrangement. First the received signal is mixed with a local oscillator signal to produce a high intermediate frequency; a second local oscillator signal is then mixed with the high i-f signal to produce a low frequency i-f signal.

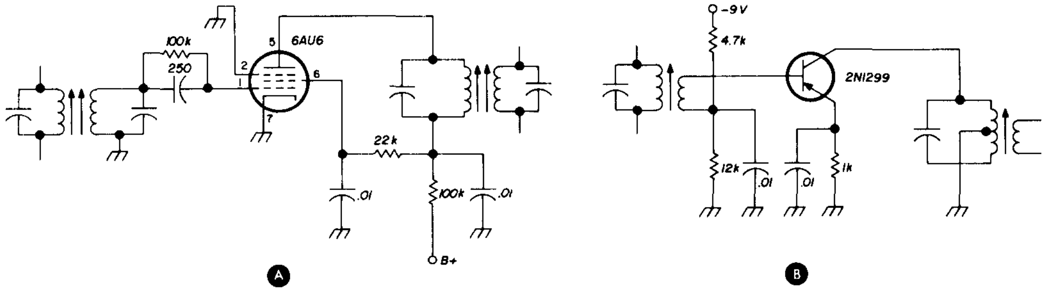


**fig. 22. Typical i-f limiter circuits.**

Low noise rf amplifiers and mixers in fm receivers are the same as their counterparts in a-m receivers. Since most vhf fm receivers work on crystal-controlled channels, the local oscillators may also be crystal controlled. Channel switching is accomplished with either mechanical or electrical switching systems.

The f-m detector requires signals on the order of several volts for proper operation. Since the front end works in the microvolt region, the i-f amplifier must perform most of the voltage amplification. The i-f system must provide sufficient selectivity to discriminate against stations operating on adjacent channels, and still have sufficiently broad response that the outer sidebands of the desired fm signal are not distorted.

To obtain the required selectivity consistent with the proper passband, special bandpass i-f filters are used, such as mechanical or crystal filters, or even L-C filters (Motorola Permakay filter). If the transmitter deviation is changed, the filter may be replaced with one having a passband that matches that of the transmitter.

## i-f limiting

Most fm detectors are sensitive to changes in the amplitude of the received signal so they must be preceded by a limiter that removes all amplitude fluctuations from the signal. The limiting circuit may be an i-f amplifier stage having very low plate voltage and grid-resistor bias so that it overloads easily. Thus, when a certain signal level is reached, further increases in input signal produce no change in the output. If sufficient gain exists ahead of such a stage, variations in amplitude of the received signal are removed. Although a limiter may provide some amplification before the saturation point is reached, its main purpose is to limit the amplitude variations caused by fading and noise.

The limiter circuits shown in **fig. 22** are similar to conventional i-f amplifiers except for the bias system. The R-C network produces a bias voltage that is equal to the peak rectified voltage between grid and cathode or between emitter and base. Short amplitude disturbances such as noise are longer than the time constant of the R-C circuit and are clipped off. Longer signal variations such as fading appear in the output. To take care of the slower fading, it is common practice to follow the first short-time-constant limiter with another limiter with a longer time constant.

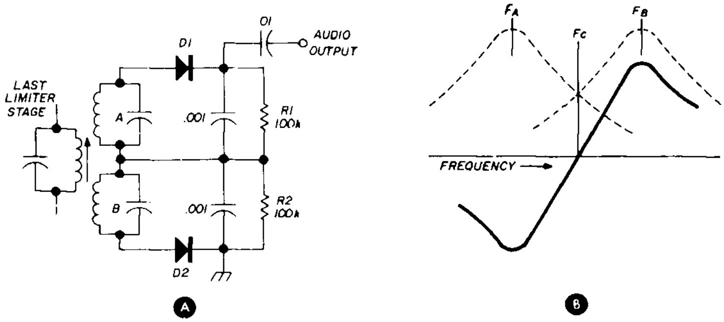
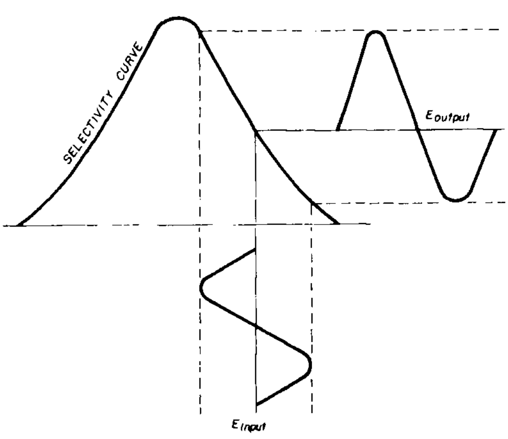


**fig. 24. Double-tuned discriminator and its a-m output craracteristic. Curves shown by dotted lines are undesirable responses of this circuit.**

## fm detectors

A device that converts frequency-modulated signals into audio signals is called a discriminator. The simplest form of discriminator is an ordinary tuned circuit that is tuned to a frequency that differs somewhat from the average frequency of the fm carrier as shown in **fig. 23**. As the carrier frequency fluctuates, the current in the detuned circuit varies, increasing as the impressed frequency approaches the resonant frequency of the circuit, and decreasing as the impressed frequency departs from the resonant frequency. The output is an a-m wave that may be demodulated by an ordinary diode detector. Since the side of the resonance curve is not linear, only a small portion of the resonance curve is useful for linear conversion of frequency variations to amplitude variations.[10] Also, a receiver used in this manner is vulnerable to noise as well as interference from a-m signals appearing at the peak of the resonance curve and fm signals on the opposite slope.

**fig. 23. Slope detection using the response curve of an ordinary tuned circuit.**



## double-tuned discriminators

The linearity can be greatly improved by using two stagger-tuned circuits instead of one and choosing the difference between the two outputs.[11] A double-tuned discriminator circuit is shown in **fig. 24A.** In this circuit the input tuned circuit is resonated to the resting fm carrier frequency, and the resonant frequencies of tuned circuits A and B are spaced slightly more than maximum transmitter deviation. The audio output from this circuit is practically free of distortion because of the linear operating characteristic about the resting carrier frequency.

However, the response curve in **fig. 24B** shows that reception is possible at three points, corresponding to each outer portion of the resonant curves plus the desired linear operating region in the center.

The output from each tuned circuit is applied to a diode detector. When the fm signal is at its resting frequency, the voltages across load resistors R1 and R2 are equal and of opposite phase, and the output voltage is zero. When the fm carrier goes higher than the center frequency, more voltage is developed across one tuned circuit than the other; when the frequency swings lower than the center frequency, the voltage developed across the other tuned circuit is greater. By careful adjustment of the circuit constants the rectified audio voltage is a linear function of the impressed frequency.

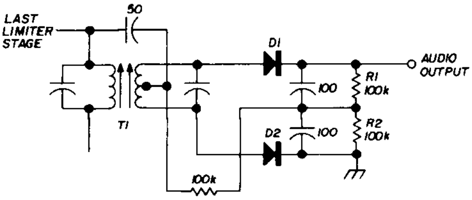


**fig. 25. Foster-Seeley discriminator; output voltage vs frequency is the same as fig. 24.**

Another discriminator circuit is shown in **fig. 25**. It can be shown that this circuit is essentially a double-tuned pair[12] and that the output vs frequency curve of **fig. 24B** also applies to this circuit.

Circuit operation is based on the phase relationships in a transformer with a tuned secondary. At the resonant frequency of the secondary the rf voltage across each half of the winding is 90° out of phase with the primary; the voltages are 180° out of phase with each other since the winding is center tapped. When the received signal is at resonance, equal rf voltages are applied to each diode; the rectified voltages across the diode load resistors are equal but of opposite polarity so the net voltage output is zero.

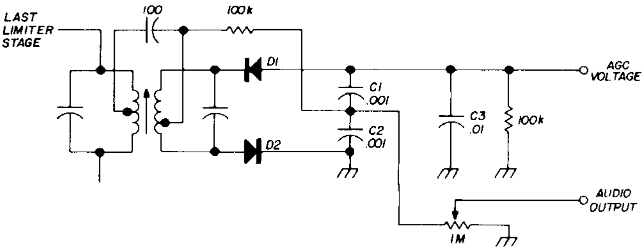
When the fm carrier shifts frequency, one diode conducts more than the other because of disturbed circuit balance. If, for example, D1 conducts more than D2, the voltage drop across R1 would be greater than the drop across R2 and the output terminal would be positive. If the carrier shifts in the other direction, D2 conducts more than D1, the voltage drop across R2 increases, that across R1 decreases, and the output terminal is negative. Thus, when the carrier deviates above and below its resting frequency, an audio voltage is developed at the output terminal—the same frequency as the original modulation and proportional to deviation.

## ratio detector

A disadvantage of the discriminator circuit of **fig. 25** is that its output is affected by amplitude variations at the input as well as frequency variations. The ratio detector in **fig. 26** was developed as an fm detector that responds only to input frequency variations because the output depends upon the ratio of the currents through the diodes rather than the voltage difference between them. Since the ratio detector is insensitive to a-m, it is not necessary to use a limiter ahead of it.

In the ratio detector in **fig. 26**, the large

**fig. 26. Ratio detector is relatively insensitive to amplitude modulation.**



value of C3 tends to maintain the voltage across C1 and C2 at a constant level. As with the two discriminator circuits discussed earlier, the relative average currents through the diodes vary with input frequency. The voltages across C1 and C2 vary correspondingly, one increasing as the other decreases, while their sum remains constant. If the two diode circuits are carefully balanced, the output voltage is practically independent of any amplitude variations on the incoming signal.

At the carrier resting frequency, C1 and C2 are charged to a constant value. When the frequency decreases, C2 acquires a greater charge than C1; when the frequency increases, C2 is charged less than C1, although the sum of the charges remains the same. The audio output at the junction of C1 and C2 follows the frequency deviation.

## cycle-counting detector

An fm detector that uses no tuned circuits is shown in **fig. 27.** This cycle-counting detector operates with a resistance-coupled i-f amplifier and responds directly to the number of cycles impressed upon it. The square waves from the limiting amplifier are rectified by the diodes to negative pulses which charge the output capacitor C. As the frequency increases, the average rate of charge increases; when the frequency decreases, so does the voltage across the capacitor. The charge on the capacitor depends upon the deviation of the signal from the resting frequency. The shunt resistor lowers the time constant of the circuit so the stored charge can change fast enough to reproduce an audio signal.

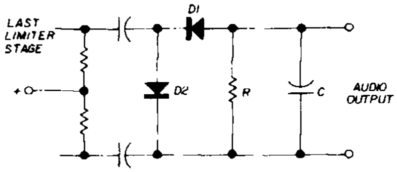
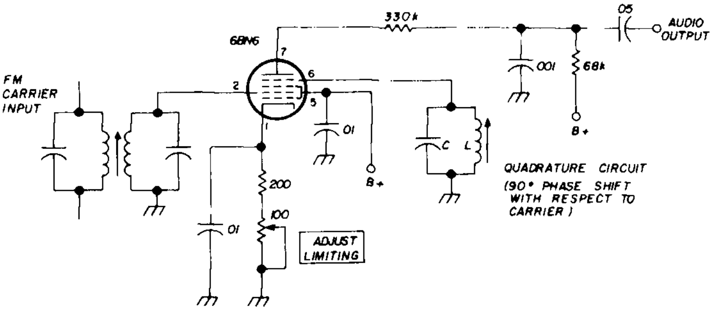


**fig. 27. Cycle-counting detector charges capacitor C at rate proportional to modulation frequency.**

**fig. 28. Gated-beam discriminator uses specially designed vacuum tube. Quadrature circuit is tuned to the same frequency as the fm carrier.**



Finally, mention should be made of the 6BN6 gated-beam detector shown in **fig. 28**. This fm demodulator is a special single-tube circuit that features excellent sensitivity and high output. With one or two volts on the input, incoming signals need little amplitude to cut the tube off for negative peaks; similarly, for positive peaks of the incoming signal, saturation is reached. Limiting action may be adjusted by a variable bias resistor in the cathode circuit.

Discriminator action in the gated-beam tube takes place as a result of signal phase shift between two control grids which are 90° out of phase with each other by virtue of a quadrature circuit connected between them. When the quadrature circuit is properly tuned, the electron beam is modulated in proportion to the modulation on the incoming signal.

## squelch circuits

Squelch circuits are used to mute the audio when no signals are present. In a high-gain receiver, speaker noise can be very annoying to operators who must monitor a channel for long periods. When the receiver is squelched, no background noise is heard; when an rf signal comes on, squelch is turned off and the audio system becomes operative.

A simple squelch circuit is shown in **fig. 29**. The squelch voltage is derived from the discriminator circuit. The center of the discriminator load resistors develops a negative voltage when a signal is applied. This voltage is passed through an R-C network and is sufficient to bias the squelch tube to cutoff and permit a signal to pass through the audio amplifier.

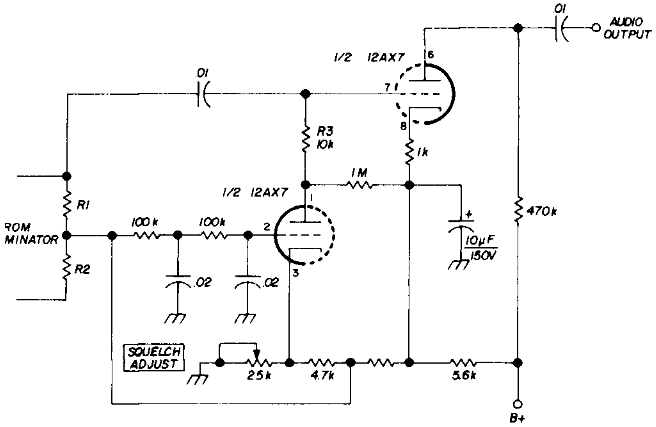


**fig. 29. Discriminator derived squelch circuit.**

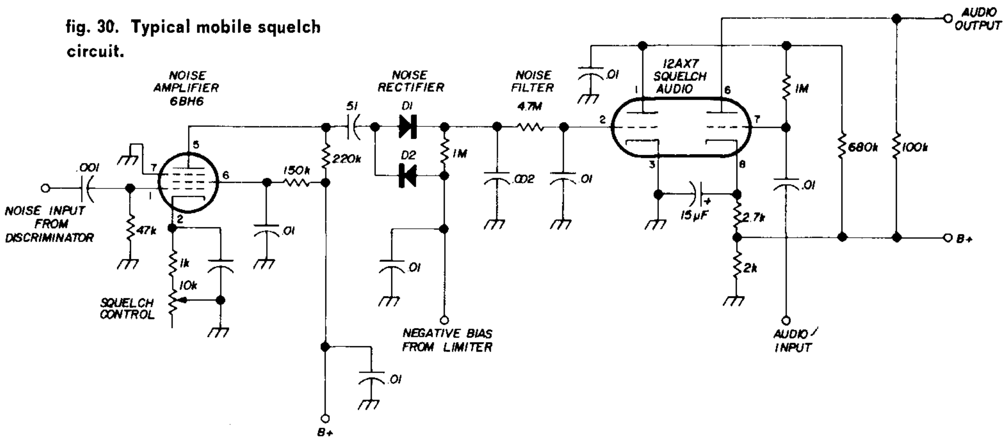
Without an input signal, a positive bias (applied to the junction of R1 and R2) is greater than the bias applied to the cathode of the squelch tube; this causes the tube to conduct, dropping the plate voltage and cutting off the audio tube through resistor R3.

A more complex squelch circuit is shown in **fig. 30.** This circuit consists of three stages; a noise amplifier, a noise rectifier and a squelch control tube. In the absence of signal, the limiter stages of the fm receiver pass a continuous and constant level of noise voltage to the discriminator. Noise higher than the voice frequencies is amplified and passed to the noise rectifier developing positive voltage across the load resistor.

A negative bias voltage from the grid circuit of the second limiter is applied to the anode end of the load resistor. The sum of the negative limiter voltage and the positive rectified noise voltage appears across the load resistor. When a signal is received, the signal voltage overrides the noise voltage, reducing the positive noise voltage at the noise rectifier.

The dc amplifier is biased near cutoff, the audio stage is biased to normal operating conditions, and squelch is removed. The variable squelch level control is set to limit the gain of the noise amplifier tube, thus limiting the noise voltage to a value that will just bias the audio stage to cutoff. Hence, when even a weak carrier signal is received which quiets the noise, the squelch is opened.

**fig. 30. Typical mobile squelch circuit.**



## transistorized squelch

The transistorized squelch circuit shown in **fig. 31** consists of a noise amplifier Q1, noise detector D1, and a squelch gate (switching circuit) Q2. In the absence of an rf carrier, noise output from the discriminator is amplified by Q1. The ac output of Q1 is rectified and applied as bias to the base of Q2. With no noise signal applied, Q2 is cut off and Q3 is conducting; thus, the desired audio signals are amplified by Q3 and applied to the audio driver stage Q4.

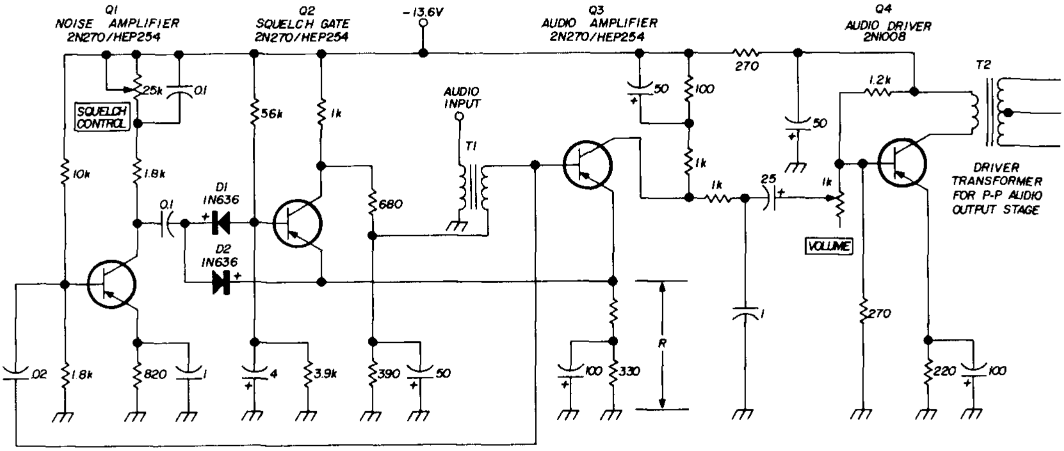


fig. 31. Transistorized squelch circuit.

In the absence of carrier, noise at frequencies at 4000 Hz or higher is applied to noise amplifier Q1, rectified and applied to the base of squelch-gate transistor Q2. When this voltage reaches a predetermined level (**threshold**) *determined by the squelch control*, the squelch-gate transistor conducts. Since the squelch-gate and preamplifier emitters are returned to ground through a common emitter resistance (R), conduction of the squelch gate results in a more negative voltage at the emitter of the audio amplifier, Q3. This increased negative voltage cuts off the audio stage and no signal reaches the audio driver.

Most of the objectionable noise is in the frequency range above 4000 Hz, but the desired audio is in the 300- to 3000-Hz range. The squelch circuit is designed so that signals above 4000 Hz open the squelch gate and signals below 4000 Hz do not. This is accomplished in the input circuit to the noise amplifier. The time constant is such that signals below 4000 Hz are greatly attenuated and do not provide sufficient rectified voltage to overcome the squelch threshold voltage at the base of the squelch-gate transistor.

Some squelch circuits substitute a relay in place of the blocking tube or transistor, with the relay contacts breaking the speaker circuit or activating auxiliary control circuits when the fm carrier appears.

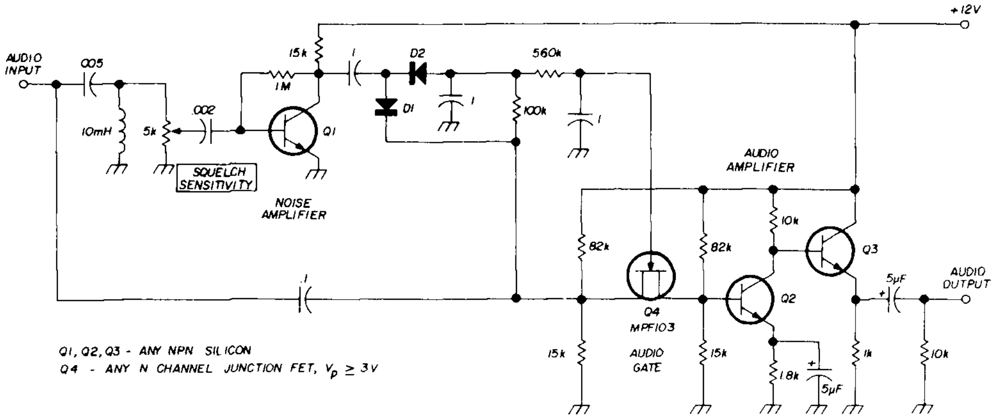
## automatic frequency control

Some fm receivers are equipped with an automatic-frequency-control (afc) circuit which adjusts the frequency of the mixer oscillator *to compensate for variations in the* received signal frequency or frequency drift in the oscillator.

In an afc system, a discriminator is used to provide a dc voltage which is proportional to the frequency of the received signal. The potential at the output of the discriminator is used to control a reactance modulator shunted across the oscillator tuning circuit. Circuit constants are chosen so the tuned circuit varies the oscillator frequency to cancel out drift. The response of the system must be sufficiently slow so that variations in carrier frequency caused by modulation have no effect on the afc; only slow variations in the average frequency are able to operate the reactance tube (**fig. 32**).

## fm repeaters

Vhf radio transmission is essentially short range, limited to line of sight unless sophisticated equipment is available to take advantage of unusual modes of propagation. A two-way radio relay station or repeater may be used to extend the communication range between two or more fm stations. Various types of repeaters are in use in the United States and Canada, their operation and mode depending upon the requirements of the circuit they cover.



**Solid-state squelch circuit suggested by K6HWJ uses an n-channel fet as a series audio gate.**

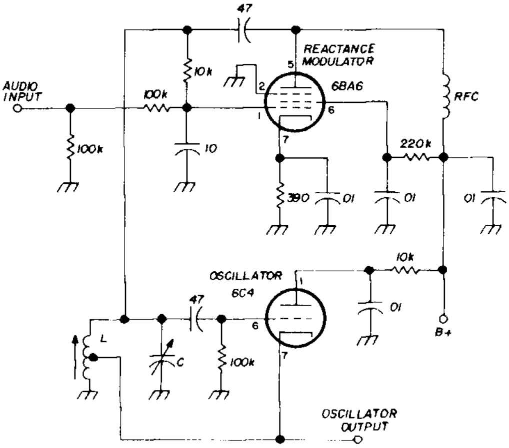
A repeater receives on one frequency and transmits on another. It may use separate antennas or a single antenna and diplexer so both reception and transmission can occur simultaneously. The user's transmitter is on the input frequency of the repeater, while his receiver is tuned to the output. The remote base (**fig. 34**) is a form of repeater whose location has a height or tactical advantage.

An unattended repeater may be operated by remote control under the provisions of Section 97.43 of the FCC Rules; control may be by wire, or by radio on an amateur frequency above 220 MHz. In some instances, remote repeaters serve on common frequencies so that individual groups operating their own installations may cross-communicate.

The repeater receiver is normally in a standby condition, as is the transmitter section. Upon remote command a carrier-operated relay is allowed to place the repeater on the air, with receiver audio fed through a coupler to the transmitter modulator. After transmissions are complete the relay opens and the repeater is removed from the air.

**Simplex** operation refers to communication between individual units operating on a common transmit and receive frequency, which may, in turn, be interfaced with repeater operation, using either a local or re-

**fig. 32. Automatic-frequency-control circuit.**



mote base. While most repeaters are limited to a single communication channel, multiplex operation, or simultaneous transmission of two or more signals on a common carrier, is sometimes employed by means of narrow band filter techniques. For example, simultaneous voice and RTTY transmissions may occur on a single fm channel. It is also possible to insert traffic at a repeater for transmission in either or both directions. **Duplex** (simultaneous two-way) transmissions through the repeater may be achieved in many cases.

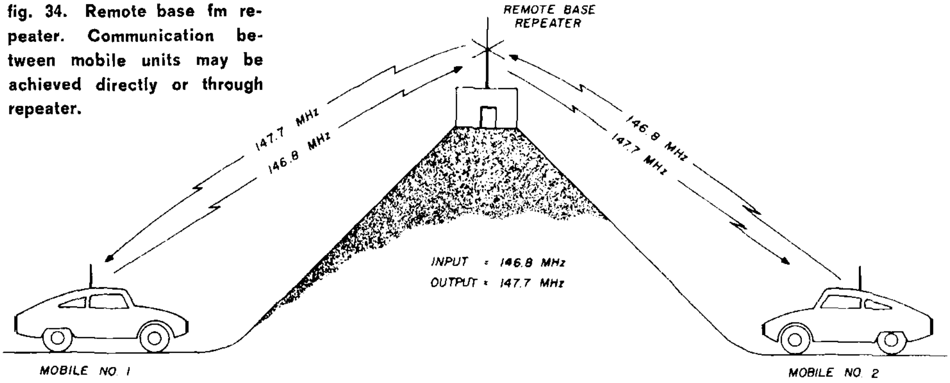
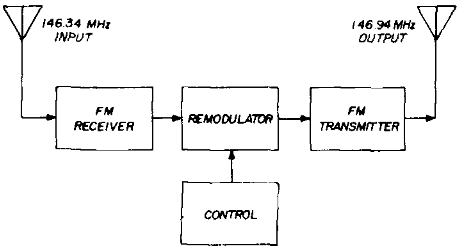


**fig. 34. Remote base fm repeater. Communication between mobile units may be achieved directly or through repeater.**

## vhf amateur fm operating standards

Generally speaking, vhf amateur fm techniques are based upon the channel concept. Transmitters and receivers are mainly crystal controlled on a given channel and random tuning techniques common to the lower frequency amateur bands are absent. Channel spacing on the 6-meter band is usually 40 kHz, beginning with 52.56 MHz, in addition to the national calling channel at 52.525 MHz. Some narrow-deviation fm is used on the West Coast on 51.0, 51.1, 51.2 and 51.3 MHz, with additional channels near these frequencies for limited-access repeaters. Fm channels on the 2-meter band are usually 60 kHz apart, starting at 146.040 MHz, including the national calling frequency at 146.94 MHz. A spot frequency of 29.6 MHz is often used for fm operation on 10 meters, with channel spacing of 40 kHz starting at 29.040 MHz. On the 420-MHz band, channel spacing is 50 kHz. Standard deviation for all bands is 15 kHz, with some trend towards narrower deviation of 5 kHz. Antenna polarization is vertical. In some areas where both wide- and narrow-band equipment is in use, a compromise deviation of 7.5 kHz peak is used.

**fig. 33. Block diagram of a typical vhf fm repeater.**



## getting started

Vhf fm is an increasingly popular facet of amateur radio. The contrast in operating techniques from the QRM-filled lower frequency bands appeals to many operators. A big advantage of fm is the "quiet intercom" style of operation. Crystal-controlled transmitters and receivers eliminate tuning and missed call letters, fading is conspicuously absent, and interference is minimum.

Radio clubs and technical groups find fm perfect for club communication, and semi-private fm nets are springing up in the larger cities, as are "open" nets. Several nationwide channels have been established so that fm'ers from one area can quickly establish communication in another area when mobiling across the country.

Second-hand fm equipment is available from many sources at prices ranging from ten dollars for "junkers" up to $100 or so. A good mobile two-way fm installation should probably be available for under $70, depending upon power, model and condition of the gear. Motorola, General Electric and RCA are some of the more popular makes of equipment, as circuit diagrams and replacement parts are readily available.

Some imported equipment for 2- and 6-meter fm is starting to show up on the American market; and other U.S. brands such as Link, DuMont, Kaar, Aerotron and Bendix are common also. Conversion of commercial gear for amateur use entails the purchase of new crystals and retuning of various stages to the amateur bands. Some vhf commercial gear (for the 148- to 170-MHz range) requires padding capacitors in the rf stages.

A gold mine of information on the latest in amateur fm techniques and equipment may be found in the monthly magazine *FM*[13] For additional background on fm techniques, the reader is referred to references 14 to 22.

**This battery-operated fm handie-talkie provides one watt output on two meters and is typical of surplus gear used on the amateur bands.**

## references

1. J. R. Carson, "Notes on the Theory of Modulation", *Proceedings I.R.E.*, February, 1922, p. 57.
2. E. H. Armstrong, "A Method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation", *Proceedings I.R.E.*, May, 1936, p. 689.
3. D. E. Noble, W1CAS, "Frequency Modulation Fundamentals", *QST*, August, 1939, p. 11.
4. G. Grammer, W1DF, G. Goodman, W1DX, "Wideband Frequency Modulation in Amateur Communication", *QST*, January, 1940, p. 11.
5. R. S. Kruse, W1FG, "The Armstrong System of Modulation", *Radio*, January, 1936, p. 62 (reprinted in *Radio*, April, 1940, p. 42).
6. P. Ferrell, Jr., "Weak Signal FM Reception", *Radio*, December, 1940, p. 11.
7. D. G. Fink, "Phase-Frequency Modulation", *Electronics*, November, 1935, p. 17.
8. J. R. Day, "A Receiver for Frequency Modulation", *Electronics*, June, 1939, p. 32.
9. J. F. Rider, "Frequency Modulation", John F. Rider Publisher, Inc., New York, 1940.
10. C. C. Drumeller, W5JJ, "Distortion in FM Systems", *ham radio*, August, 1969, p. 26.
11. C. Travis, "Automatic Frequency Control", *Proceedings I.R.E.*, October, 1935, p. 1125.
12. L. B. Arguimbau, "Vacuum Tube Circuits", John Wiley & Sons, Inc., New York, 1948, pp. 486-494.
13. *FM*, VDB Publishing Co., 2005 Hollywood Street, Grosse Pointe, Michigan 48236.
14. S. H. Wolf, editor, "FM Schematic Digest", Two-Way Radio Engineers, Inc., Dept. H., 1100 Tremont Street, Boston, Massachusetts 02120.
15. J. Helmi, "Two-Way Radio Handbook", Howard W. Sams, Indianapolis, 1964.
16. "FM Transmitters and Receivers", Technical Manual TM-11-668, $1.50, U. S. Government Printing Office, Washington, D. C. 20402.
17. J. Connors, W6AYZ, "Amateur VHF FM Operation", *ham radio*, June, 1968, p. 36.
18. A. Hund, "Frequency Modulation", McGraw-Hill Book Co., Inc., New York, 1942.
19. C. E. Tibbs, "Frequency Modulation Engineering", Chapman and Hall, Ltd., London, 1947.
20. N. Marchand, "Frequency Modulation", Murray Hill Books, Inc., New York, 1948.
21. M. S. Kiver, "F-M Simplified", D. Van Nostrand Company, Inc., New York, 1947.
22. A. B. Cook, A. A. Liff, "Frequency Modulation Receivers", Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1968.
23. "Communications Equipment Schematic Manual", Howard W. Sams Photofact, Indianapolis, Indiana.

**ham radio**

*New Readers*

# WE'VE BEEN LOOKING FOR **YOU!**

*we hope you've been looking for*

**ham radio**

Here is an exciting new amateur magazine devoted to the very best in home construction and technical articles. This is the magazine which has amateurs from coast to coast talking.

Look it over carefully. Read the finest authors in our field. See the clean crisp new layout. Can you afford to be without the **best magazine** in amateur radio today?

---

**ham radio** *magazine, greenville, new hampshire 03048*

Please enter my subscription to **Ham Radio** as checked below. My check or money order is enclosed.

☐ One Year $6.00

☐ I'd like **one year free.**
Here is $12.00 for 3 years.

**Name**........................................ **Call**..........

**Address**........................................

**City**........................................ **Zip**..........

# using integrated circuits with single-polarity power supplies

This clears up the question of power-supply connections to linear IC's and presents some hints on lead dress and bypassing

John J. Schultz, W2EEY, 40 Rossie Street, Mystic, Connecticut 06355

**Although an IC may specify a** dual-polarity power supply, a single-polarity supply can usually be used. This applies to almost all IC's but should be of particular interest to those who read my article in the May 1968 issue of **ham radio**.[1]

The article showed the uses for an IC operational amplifier in amateur radio circuit applications. Apparently, however, some readers have been confused as to how the power-supply connections to the IC should be handled. Since similar confusion can develop when using an IC—not just the one shown in the article—I thought it would be worthwhile to explain in some detail how proper power supply connections to an IC can be made.

## basic mistake

Perhaps the simplest mistake was to misunderstand the power-supply voltage requirements. For instance, in **fig. 1**, which is a simple wideband rf amplifier, some builders connected a 6-volt battery between terminals 4 and 6, and others connected a 12-volt battery between the same terminals. Both connections are wrong. The IC won't function and will probably be ruined by the 12-volt battery. Note there are three reference points for the power supply connections: terminals 1 and 3, 4 and 6. Terminal 4 must be 6 volts negative with respect to terminals 1 and 3. Thus, two 6-volt batteries are required, or a power supply that will deliver a plus and minus 6-volt output. This basic dual-voltage requirement is common to most operational amplifier IC's.

## a dual-polarity supply

There should be no problem in obtaining the dual-polarity voltages. The simple circuit of **fig. 2** can be used for light loads. An additional rectifier/filter can also be included in an existing power supply to obtain the voltage (of either polarity). However, situations exist where you might want to use only a single-voltage supply, either because only one battery source is available (such as in an automobile), or it's too complicated to modify an existing supply that has an exceptionally well-filtered output of given polarity. Therefore, it's worthwhile to see how IC's can be modified to operate from a single-voltage power supply.

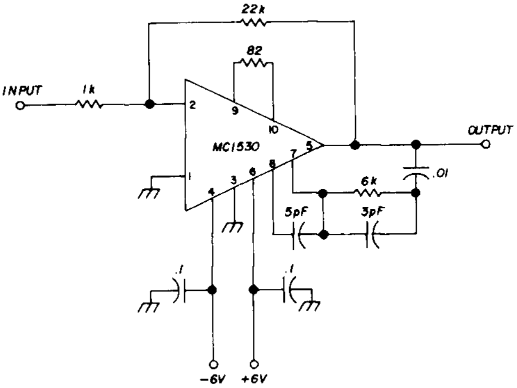


**fig. 1. Wideband IC amplifier is normally wired for use with a dual-polarity power supply.**

## operation from single-voltage power supply

As mentioned for the IC shown in **fig. 1**, three reference points exist for supplying power: −6, 0, and +6 volts (or simply −V, 0, and +V on other IC's). Whatever power supply is used, these reference levels must be maintained. One possibility for using a single-voltage supply is to make the reference levels 0, +V, and ++V. Thus a 12-volt supply with a 6-volt tap could be used to power the IC shown in **fig. 1**.

The most important point to remember, however, is that the former zero reference (terminals 1 and 3 in **fig. 1**) now requires a +V level. You cannot simply connect terminal 4 in **fig. 1** to ground, place a 12-volt source on terminal 6, and leave all other connections alone. Terminal 1 of the input differential amplifier in the IC is normally at ground potential when using dual-supply voltages and must be biased to one-half the total single-supply voltage.

## ic's with external and internal grounds

Some IC's have an external ground terminal, as shown in **fig. 3A**, while others have only an internal ground reference point, as shown in the equivalent circuit of **fig. 4A**. This doesn't change the basic condition for properly biasing the input terminal when an IC designed for a dual-voltage-polarity power supply is used with a single-polarity supply. An example of how each IC can be biased is shown in **figs. 3B** and **4B**. The circuit in **fig. 3B** shows only the dc power connections to the IC and is quite straightforward.

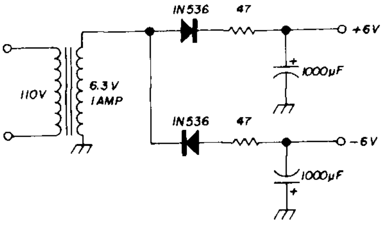


**fig. 2. Simple power supply that delivers dual-polarity output. With some audio circuits it may be necessary to add another 47-ohm resistor/1000 µF capacitor in each output lead to reduce hum to a very low level.**

Some IC's of the type shown in **fig. 4** have a terminal marked "offset adjustment" which, for most amplifier uses, is connected to the +V terminal of the IC. Isolating resistors R1 and R2 in **figs. 3B** and **4B** ensure that the IC input impedance is not degraded by the power supply connection. Resistor R1 can usually be from 50k to 1000k ohms. R2 may or may not be required, depending on what use was made of this differential input terminal in the original circuit. If the terminal in the original was grounded, R2 will probably not be needed, and terminal 1 in

**figs. 3B** and **4B** can be connected directly to +V.

If the original circuit had terminal 1 connected in some sort of feedback or dual-input function, then R2 must be used. Its value can be best determined by experimentation, so that the original circuit function isn't disturbed. A practical rule, however, is to make R2's value equal to about the parallel combination of R1 and the feedback resistor used in a specific circuit (the 22k-ohm resistor between terminals 5 and 2 in **fig. 1**).

## some samples

Probably the best way to clarify the principles just mentioned is to illustrate their application to a specific circuit. Suppose you want to operate the wideband amplifier shown in **fig. 1** from a single-polarity power supply. **Fig. 5** shows two ways of accomplishing this.

In **fig. 5A** a zener voltage divider is used to obtain 6 and 12 volts from the power supply. Terminal 6 of the IC goes to the 12-volt point. The terminal 4 dc-reference shown in **fig. 1** is now connected directly to ground. The 100k-ohm resistor between terminals 1 and 2 performs the isolating function of R1 as described for **fig. 3B.**

**Fig. 5B** shows almost exactly the same connections, except that a simple resistive voltage divider, instead of a zener-diode divider, is used to obtain the 6-volt level.

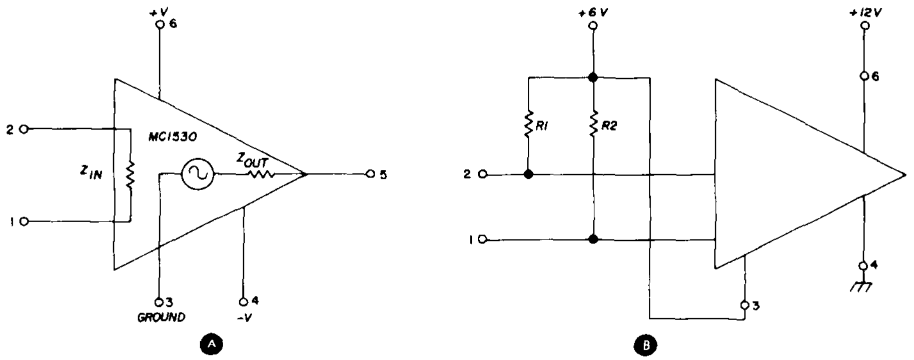


**fig. 3. Equivalent circuit and signal-polarity supply connection for an IC having an external ground terminal. Signal connections are not shown.**

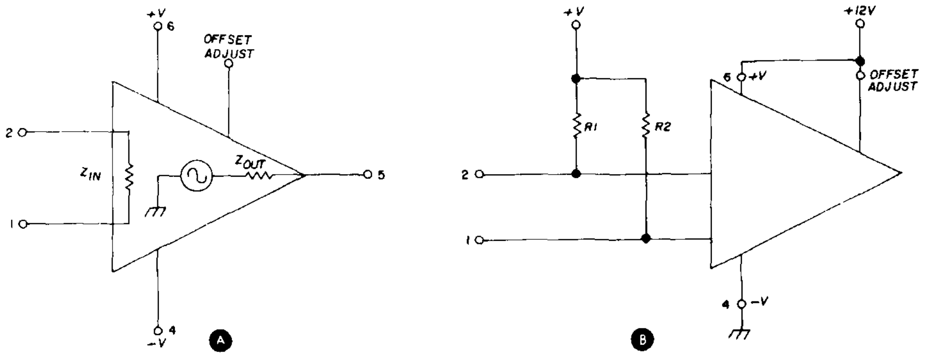


**fig. 4. Equivalent circuit and single-polarity supply connection for an IC with an internal ground terminal. Terminal marked "offset adjustment" may not be present on all operation-amplifier ICs.**

Either circuit can be used, depending on the components available and the regulation of the basic power supply.

Note that either circuit places a dc-bias voltage on the input and output terminals of the IC, which was not present before. Therefore, if the original circuit used direct coupling to the input and output stages, a dc-blocking capacitor will be required in the input and output leads. Normally, this won't alter circuit performance. The only exception would be if the IC were used as a dc amplifier. In this case, additional circuitry may be necessary, or it may not be feasible to operate the IC from a single-polarity power supply.

## an exception

Almost all IC's require the techniques described. However, if a unit designed for a dual-polarity power supply is to be used properly with a single-polarity supply, you'll find that manufacturers are designing their IC's to be used with different power supplies. The IC internal circuits are arranged to avoid the necessity for biasing the IC input terminals for different power supplies.

**Fig. 6** illustrates such an IC: the Motorola

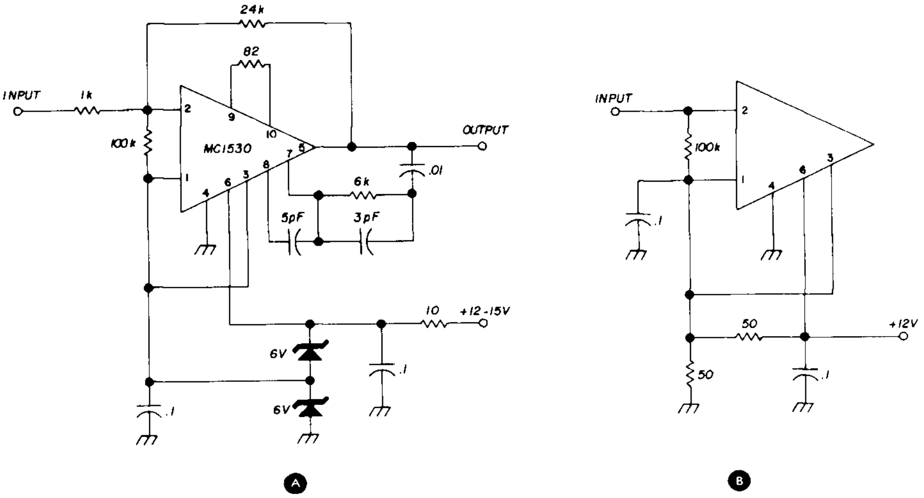


**fig. 5. Two methods of providing a voltage divider. Complete circuit is shown in A; only dc-power connections are shown in B.**

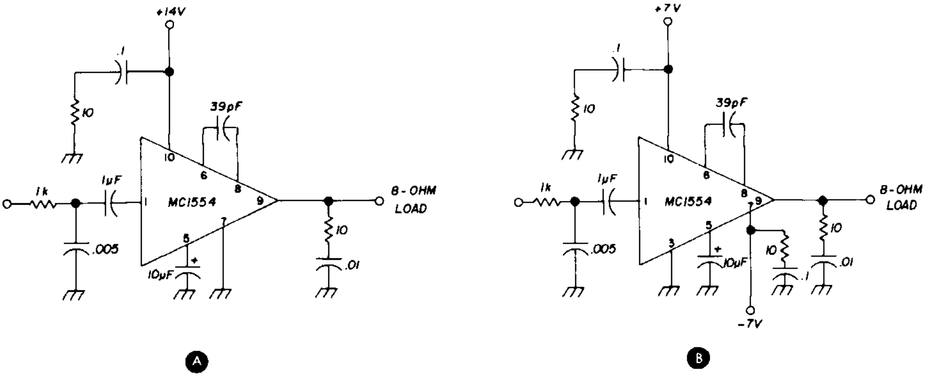


**fig. 6. The Motorola MC1554 (HEP 593) audio power amplifier IC is especially designed to simplify operation from either a single- or dual-polarity supply (A and B respectively).**

MC1554, which is a complete 1-watt audio power amplifier. **Fig. 6A** shows IC connections using a single-polarity power supply, and **fig. 6A** those using a dual-polarity supply. The connections are similar and involve no modification to the input circuit. Terminal 10 (V+) is connected to the positive power-supply terminal in both cases. Terminal 7 (V−) is connected either to ground or to the negative power-supply terminal. Terminal 3, called the bias-reference terminal to avoid confusion with the V-terminal (which may also be connected to ground), is either unused or grounded as shown.

## decoupling and suppression

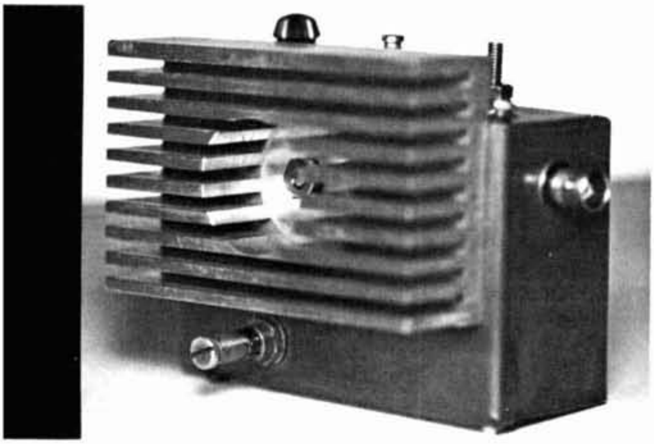
Care must be taken in any amplifier to prevent oscillation and instability due to signal coupling via power supply or other leads. The requirements are even more stringent for IC's because (1) the IC is a concentrated package of high gain capability, and (2) it has an extremely wide frequency response. An audio-amplifier IC, for instance, may have a response up to several hundred kHz. Therefore, feedback capacitances or coupling circuits small enough not to affect a tube or transistor audio amplifer may well cause an IC amplifier to oscillate. These oscillations may not be heard because of their high frequency, but nonetheless can cause the IC to heat up and possibly be destroyed.

The 10-ohm resistor and the 0.1-$\mu$F capacitors shown in **fig. 5A,** the 0.1-$\mu$F capacitors shown in **fig. 5B,** and the series 10-ohm and 0.1- or 0.01-$\mu$F networks shown in **fig. 6** are examples of decoupling or bypassing components. They should never be eliminated to simplify construction. These components are shown at various places in the schematics, but in practice they should be mounted as close as possible to the IC terminal with which they are associated. All lead lengths should be kept as short as possible to avoid the buildup of lead inductance, which can cause instability.

### reference

1. John J. Schultz, W2EEY, "Amateur Uses of the MC1530 IC," *ham radio,* May 1968, p. 42.

**ham radio**



# a frequency tripler for 1296 MHz

Introducing the varactor as an efficient microwave harmonic generator for transmitting use

Joseph J. Moraski, K4SUM, Charles E. Spitz, W4API,
1420 S. Randolph Street, Arlington, Virginia 22204

**Of the many pursuits** available to experimenters in amateur radio, perhaps none offers more challenge and personal satisfaction than working in the frequency region above one gigahertz. It's challenging because tubes and components obey physical laws in a different manner than at the lower frequencies. Personal satisfaction occurs when you've mastered the techniques and special discipline required to make microwave circuits perform properly (or at all).

The objectives of this article are to encourage more amateur activity in our microwave bands and to show how we resolved one of the many problems one encounters at the "last frontier"—obtaining useful drive power in a frequency tripler at 1296 MHz through the use of a simple homemade cavity.

## some background information

An excellent discussion of the behavior of grid-controlled power tubes at the higher frequencies is contained in reference 1. One of the things the article points out is that, as frequency increases, the internal structure of the tube becomes an appreciable part of the resonant circuit. Driving voltage decreases because of the reactance presented by tube lead inductance. Because of this and other peculiarities, tubes operating at uhf and beyond are inefficient as frequency multipliers, at least in amateur work.

## the varactor

Solid-state technology has developed a device that seems, presently, to be the only answer for obtaining usable amounts of power with reasonable efficiency in multiplier circuits at the higher frequencies. The device is known as a varactor, or voltage-variable capacitance diode.

By definition a diode is a two-terminal p-n junction. Normally it operates as a rectifier (forward conduction), or as a voltage regulator (zener) conducting in the reverse direction. True, the varactor **is** a two-terminal p-n junction, but it's not correct to call it a *diode* per se. As with all p-n junctions, the varactor has a junction capacitance. This is what makes the varactor work as a frequency multiplier. The junction capacitance varies with applied voltage, which *results in harmonic production.*

A very readable treatment of varactor principles is contained in reference 2. Equations are derived showing the relationship of junction capacitance and applied voltage. The end result is a voltage across the varactor containing two dc components and a second component rich in harmonic content.

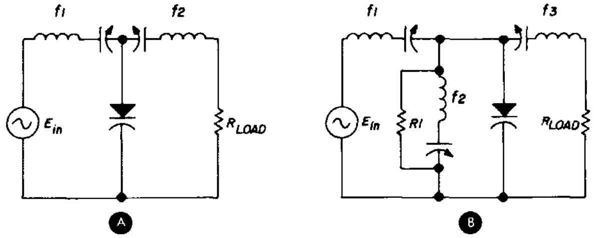
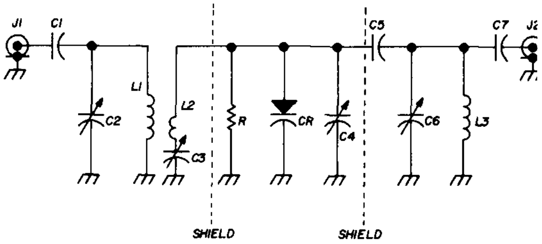


**fig. 1. The varactor as a frequency multiplier. In A f1 is tuned to the fundamental and f2 to its second harmonic. Part B shows a tripler circuit with f2 tuned to the second harmonic (the so-called idler). Series circuit f3 is tuned to the third harmonic of f1. Bias voltage is developed across R1 when the varactor is driven into conduction on peaks of the input voltage.**

## higher-order harmonic generation

In varactor application if frequencies higher than the second harmonic are desired, idler circuits are used. These are tuned circuits that pass or attenuate harmonic currents to obtain the desired output frequency. **Fig. 1** shows the development of a frequency multiplier varactor for generating third-order harmonics. The tuned circuits are affected by the varactor capacitance, which in turn varies as a function of the applied voltage. In a harmonic generator this voltage varies sinusoidally, so the **average** varactor capacitance is used in the design. The capacitance varies with signal power, and some circuit detuning occurs if there is a substantial change in input power. The effect is undesirable, especially in a-m ap-



| | |
|---|---|
| **C1, C5, C7** | **Brass or copper disc, 0.4 inch diameter** |
| **C2, C6** | **Brass or copper rod, 10/32 thread** |
| **C3** | **0.6 — 30 pF piston (Johanson JMC 1901*)** |
| **C4** | **0.6 — 5 pF piston (Johanson JMC-1375)** |
| **L1** | **Brass or copper tubing, 5/16 inch diameter, 2.55 inches long** |
| **L2** | **No. 14 copper wire, 3½ inches long** |
| **L3** | **Brass or copper tubing, 5/16 inch diameter, 1.1 inch long** |
| **J1, J2** | **Single-hole-mount female BNC connectors** |
| **R1** | **100k to 1 megohm, ¼ W (see text)** |

**fig. 2. Schematic of the 1296-MHz tripler. The varactor can be a Motorola 1N5149, Amperex H4A (1N4885), or Microwave Associates MA-4060—all were successfully tried in this circuit.**

---

* Surplus units available from Fertik's Electronics, 5249 "D" Street, Philadelphia, Pennsylvania, 19120. The small ones are 3 for $1.00; larger ones are $.65 each.

plications, but is practically eliminated in step-recovery junction varactors, as discussed below.

## junction characteristics

Varactors are of two types, step junction and step recovery junction. In the former, the impurity level is constant in the p-n layers, while in the latter the impurity level is concentrated at the lead contacts and decreases toward the junction. This makes for high resistivity near the junction and low resistivity at the lead contacts.

An important parameter of varactors is the equivalent series resistance, composed of the bulk and contact resistance of the semiconductor material. This resistance is directly related to varactor efficiency, and therefore kept as low as possible. By employing a constantly decreasing impurity profile from lead contact to junction, the average series resistance remains at a desirable low value when a reverse voltage is applied. This is because the depletion layer dissipates the high resistivity region. The average series resistance is therefore kept low.

Why use step recovery junction varactors for harmonic generators? Because they provide higher power and a more linear relationship of power output to power input. What this means in terms of efficiency (power out/power in x 100) is demonstrated in **table 1,** which shows the power linearity characteristic of a typical step-recovery varactor used as a frequency doubler.

The average efficiency of this particular varactor is about 66 percent, which is typical when operating a frequency doubler. However, we were able to obtain yields of 50-percent plus, using similar varactors as **frequency triplers** with output at **1296 MHz.**

Essential to the performance of any rf generator are the tuned circuits. This is especially true at microwave frequencies for the reasons pointed out earlier. The easiest way to solve this problem is to use resonant cavities. If the procedures used in commercial practice are followed, cavities are difficult for the average amateur to build. However cavities need not be round, as in most commercial applications. Frequencies in the 1-GHz region are high enough to permit a small rectangular chassis to be used, with divider strips acting as cavity partitions. Commercial test jigs have been made in a similar manner, but with facilities and materials beyond usual amateur resources.

If you're reasonably adept with hand tools and like to work with soft metal, you should be able to duplicate the tripler described here. With an input of 20 to 25 watts on 432 MHz, we built three units that put out a respectable 10 to 15 watts on 1296 MHz. All have been operating for almost a year. The schematic is shown in **fig.** 2. Capacitors $C_1$, $C_5$, and $C_7$ are single discs; the other capacitor plate is formed by the tubing ($L_1$ and $L_3$).

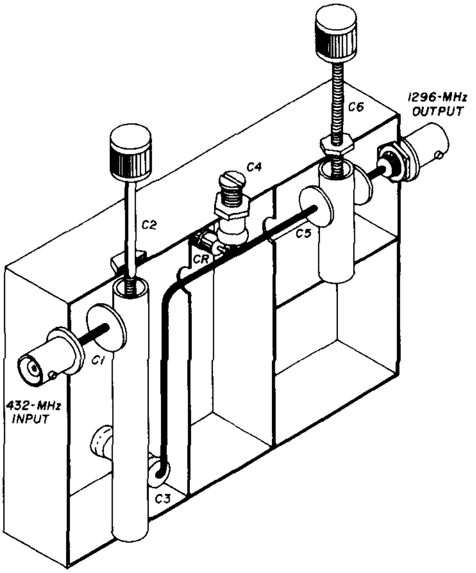


**fig. 3. Assembled 1296-MHz tripler.**

The chassis and cavity partitions were made from 0.032-inch sheet brass. It might be possible to use a commercially available chassis of nearly the same dimensions, such as the Bud CU-341 Convertabox. The partitions could be made and added as shown. However, we haven't tried this, and for best results we recommend using the materials and dimensions shown. The tripler we built is shown in the photo and in **fig. 3**. **Fig. 4** shows component layout.

In **fig. 3** the varactor stud protrudes through the rear wall where a heat sink was placed over the stud. A solder lug was placed at the varactor base for grounding the bias resistor. The resistor is shunted directly across the varactor.

The brass sheet is cut to the shape of **fig. 5.*** Drill holes to sizes indicated. When the ends are bent, a chassis will be formed 4 inches wide x 2-3/4 inches deep x ½ inch high. Solder corners using a heavy iron or torch. Next, cut out the partitions and cover following the scale-size template. Insert partitions C, D and E making sure the holes D and F are drilled before soldering the partitions into place.

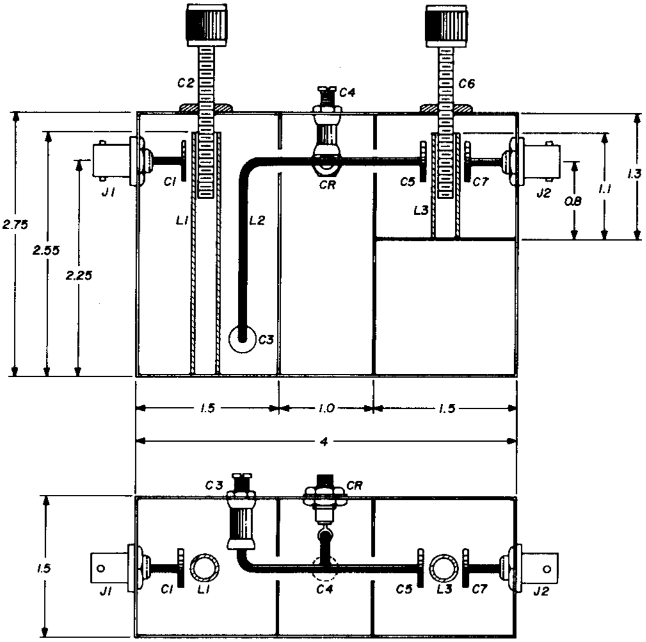


**fig. 4. Plan and side views of the 1296-MHz varacter tripler.**

The cover is also shown in **fig. 5**. Bend the corners as indicated, solder smoothly, file, and buff. The idea is to get a good fit without warping the chassis.

The 432-MHz and 1296-MHz cavities are capacitively tuned by turning their 10-32 threaded rods ($C_2$ and $C_6$) into tubing inductances $L_1$ and $L_3$. It is important to maintain constant metal-to-metal contact between the tuning screws and the chassis. A 10-32 brass nut is soldered over holes A. It may be necessary to use a locking nut and spring between the knob and soldered nut if the threads don't mate well enough for continuous contact.

Solder the bases of the brass tubing flush with holes D. Try to make this a tight and straight fit before soldering. Screw the threaded rods through the tubing to ensure centering and alignment, then solder the base. This is where a torch works best. A teflon washer may be forced on the bottom of each threaded rod to prevent shorting or teflon spaghetti may be used.

The next step is to install BNC fittings $J_1$ and $J_2$ with their discs, $C_1$ and $C_7$. Spacing between the discs and the brass tubing is approximately 1/32 inch. On one model we made, the BNC nuts were soldered to the outside of the chassis so these spacings could be made variable. A short wire lead will be necessary between the disc and BNC inner conductor. This dimension is not given, as the length of the center conductor may vary between different BNC chassis fittings. The critical factor is the spacing of the disc.

Install plunger tuning capacitors $C_3$ and $C_4$ with serrated washers under the nuts. Install $L_2$ in one piece, soldering one end to $C_3$ and the other to the $C_5$ disc. Approximate spacing of $C_5$ from $L_3$ is about 1/16 inch. Be very careful to apply **minimum heat** or use heat sinks when soldering to the plunger capacitors. Too much heat can crack the glass or warp the glass-to-metal seals so the plungers won't enter the stator cups. Many plunger capacitors are ruined this way. Solder only to lugs or pins provided.

Place a solder lug on the varactor stud, then place the stud through hole I. Fasten with serrated washer and nut. If a heat sink is used, make it secure but not overly

---

* Full-scale templates available from **ham radio** magazine for $.25.

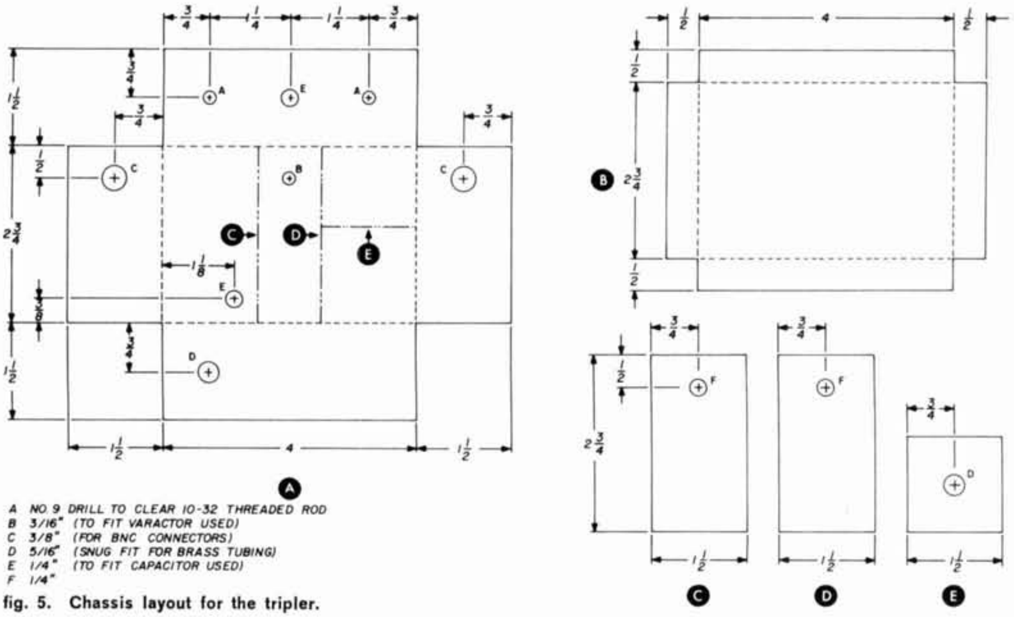


**fig. 5. Chassis layout for the tripler.**

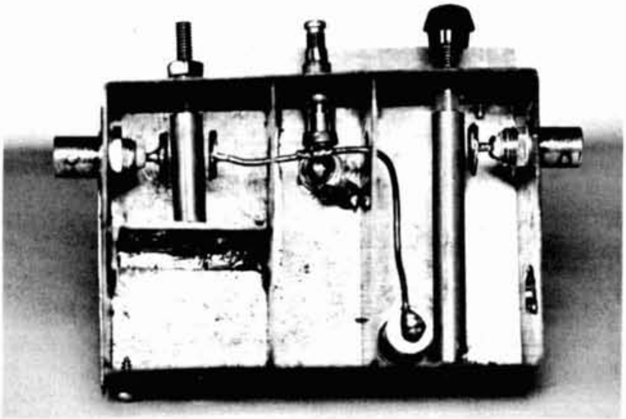
tight until soldering is done, when the nut can be loosened for final placement of the heat sink. Solder the resistor to the lug as reasonably short and straight as possible so it's parallel with the varactor. Join varactor, resistor, and $C_4$ idler capacitor at a common point on $L_2$, then solder. Maximum output will be obtained with a 1-megohm resistor; however if the driver is modulated greater linearity will result if 100k is used.

The teflon tubing may be kept from falling out by using Scotch X-1181 copper foil tape with conducting pressure-sensitive adhesive. The tape can also be used instead of finger stock to seal the compartments. "Sticky Fingers," a pressure-sensitive-backed finger stock made by Instrument Specialties Company, of Little Falls, New Jersey was also considered, but the size of the available stock was too large for use with the small cavity.

## cool it

Overheating the varactor at this power level can and does occur. The DO-5 case mounting stud, which protrudes through the chassis may be felt for heat. Another sign of overheating is a gradual decrease in output power with no change in the input. The best preventive measure is to use a heat sink and preferably air from a fan. We used some finned aluminum heat sink stock 4 inches long x 2½ inches wide x 1 inch deep. It was a piece of surplus used for power transistors and had one flat side. The varactor stud goes through a hole in the heat sink, then is fastened with its nut and washer to clamp the

**Underchassis view of the 1296-MHz tripler. Note lead dress, especially of capacity C5. Some bending might be necessary to optimize output.**



varactor, heat sink and chassis together. A Whisper fan furnished more than enough air to keep the varactor cool at extended periods with maximum power.

## operation and tuning

The input and output levels were measured and monitored using a Bird Model 43 coaxial line section, panel meter, and 400-1000-MHz element. With this element readings are about 1 dB low on 1296, but the cost was about one-third of an element with greater accuracy. Frequency readings were taken with a surplus F-26/UPR wave trap, which is calibrated from 1.25 to 6.0 GHz. Although the idler frequency is off scale at 864 MHz, it can be read. Since varactors will readily double with high efficiency, care must be taken to minimize idler output while maximizing 1296-MHz output during tuneup. The surplus TS-186 frequency meter, which has a range of 100 MHz through 10,000 MHz, with visual as well as audible output, may also be useful. While all this test gear is not absolutely necessary, it does speed things up for the initial alignment.

If the output is less than at least 7 watts with 20 watts input, and all tuning controls have been optimized, a greater yield may be possible by repositioning the disc capacitors, either in spacing or by a slight upward or downward deflection. However, each change must be accompanied by completely retuning all variable elements for maximum output at the desired frequency. A great deal of time can be saved if you can monitor the input power, output power, and output frequency during tuneup. If you do get 50 percent efficiency, leave it alone!

An input filter at 432 MHz is necessary if you use a stripline varactor tripler, a tube tripler, or grounded-grid stage as a driver, because all these circuits contain harmonic and mixing frequencies that would be seen and used by the 1296-MHz varactor tripler. On the other hand, the tripler output cavity should have about 30 dB rejection of unwanted frequencies when properly adjusted. If the output is fed directly to an antenna, a filter may be called for. If it's used to drive an amplifier with tuned input and output circuits at 1296, one may not be necessary.

**table 1. Power conversion in watts of the IN5150 without retuning.**

| Output | Input |
|---|---|
| 4 | 4 |
| 6 | 9 |
| 8 | 12 |
| 10 | 16 |
| 12 | 18 |
| 14 | 20 |

$f_{in} = 0.5$ GHz, $f_{out} = 1$ GHz

The cover should be used at all times. This reduces radiation loss, prevents having to retune when the cover is placed on the chassis, isolates the compartments in the chassis, and avoids a real hazard of biological injury from radiation at these power levels. If screws are used to fasten the cover, sheet-metal screws as small as possible should be used, with two at the top and bottom of the varactor compartment, one at the center of the 432-MHz cavity, and one just below the bottom of the 1296-MHz cavity.

Fairly acceptable modulated signals for local use have been produced where the basic modulated transmitter was on 144 MHz and passed through two triplers. With the varactor input reduced so that a cool ICAS output of 7.5 watts was maintained on 1296 MHz, a pair of 7289's (improved 2C39A, 3CX100A5) as an amplifier produced 40 watts output with a plate voltage of 800 and plate current of 200 mA. There was no sign of creeping or overheating.

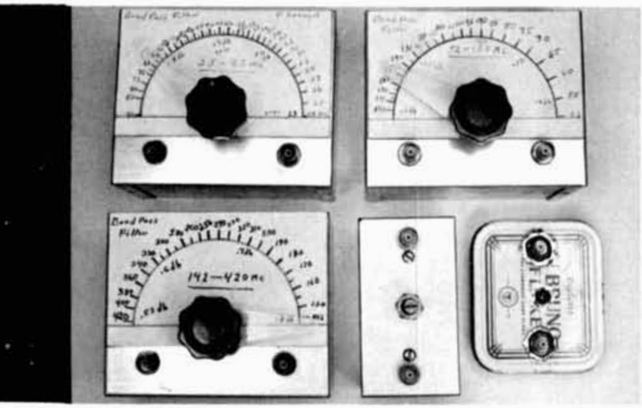
Construction and operation of the unit is simpler than it might appear from the description given, but we felt these details would be helpful since most amateur data on the subject seemed meager.

### references

1. R. I. Sutherland, W6UOV, "Vhf/uhf Effects in Gridded Tubes," *ham radio,* January, 1969, p. 8.

2. "The Semiconductor Data Book," Motorola, Inc., Semiconductor Products Division, 2nd Edition, p. 16-89.

**ham radio**



# tunable bandpass filters for 25 to 2500 mhz

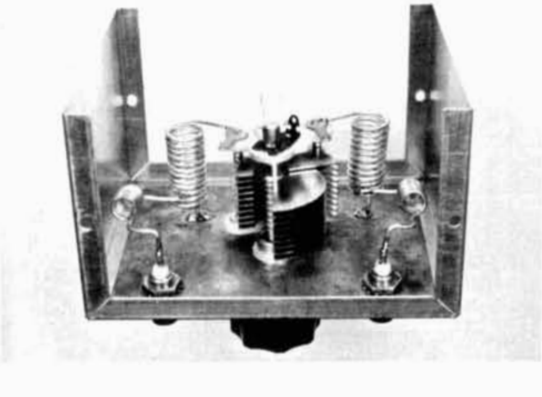
Here are some useful additions to your vhf and uhf test equipment

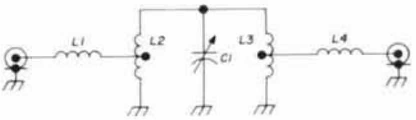
Del Crowell, K6RIL, 1674 Morgan Street, Mountain View, California 94040

**For all their advantages,** solid-state devices are not without their problems, especially when used in amplifier and multiplier circuits in the vhf and uhf regions. If you have used these devices in such applications, you've probably run into the same problems I have—is the output at the desired frequency?

The bandpass filters and accessories described here are great additions to your test equipment. They will allow you to build and adjust many circuits that would otherwise be

**Construction of a bandpass filter that covers from 25 to 85 MHz.**





| Filter | Frequency Range (MHz) | L1, L4 | L2, L3 | C1 |
|---|---|---|---|---|
| A | 25 to 35 | 6 turns no. 14 ¼" diameter, ⅝" long | 12 turns no. 14, ½" diameter, 1½" long; tapped 1½ turns from ground | 9—140 pF (Hammarlund MC140M) |
| B | 52 to 190 | 4 turns no. 16 ¼" diameter, ½" long | 4 turns no. 16, ½" diameter, ⅝" long; tapped 1½ turns from ground | 7.7—100 pF (Hammarlund MC100M) |
| C | 142 to 420 | 2 turns no. 16 3/16" diameter ¼" long | 3½ turns no. 14, 3/16" diameter, ⅜" long; tapped 2 turns from ground | 6.3—50 pF (Hammarlund MC50M) |
| D | 230 to 1350 | see fig. 3 | see fig. 3 | 0.7—30 pF piston |
| E | 2000 to 2500 | see fig. 5 | see fig. 5 | see fig. 5 |

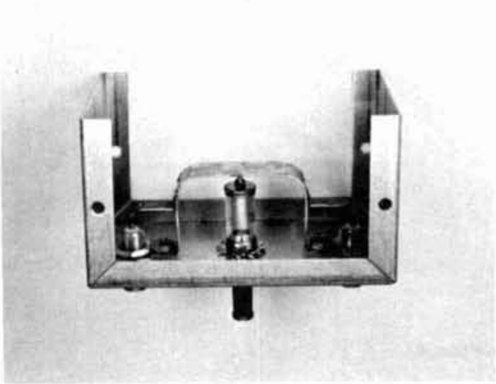
fig. 1. Bandpass filters cover the frequency range from 25 to 1350 MHz and 2.0 to 2.5 GHz.

almost impossible. An accurately calibrated, general coverage receiver with a panadaptor will give good results when making circuit adjustments using these filters.

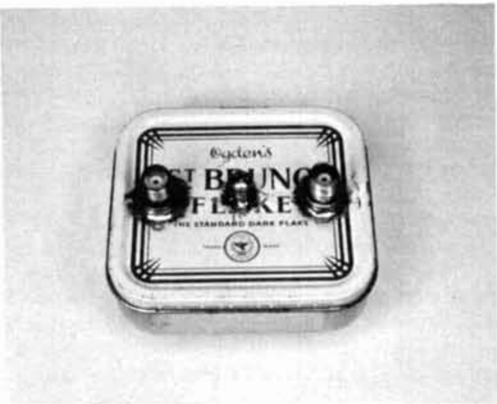
## description

Filters A through D in **fig. 1** use a half-wave resonant circuit with series matching coils. This helps maintain a constant impedance and provides a balanced circuit with good operating Q. The circuit diagram and coil table show the L-C relationships. Bandwidth is primarily governed by the amount of loading, which is determined by the tap point on L2 and L3. L1 and L2 are used to maintain a more constant loading with frequency; the tap points given in the table are optimum for general-purpose use. Filters with a tuning range of three to four octaves can be constructed using this principle.

Bandpass filter for 230 to 1350 MHz uses a brass-strap inductor.



The 2.4 GHz bandpass filter is built around an old tobacco tin.



## construction

Bandpass filters covering 25 to 420 MHz are basically the same, with only L and C changes required to cover the desired ranges. The filters can be duplicated by referring to **fig. 1** and the photos. Filters A, B and C are constructed using a brass plate

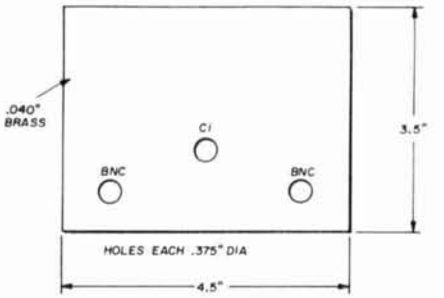


**fig. 2. Brass mounting plate for filters A, B and C.**

(see **fig. 2**) to mount the components. Coils are soldered directly to this plate. The assembly is then mounted inside an LMB779 5x4x3-inch chassis box.

The filters can be calibrated with a grid-dip oscillator; however, a good signal generator would be more accurate, of course. Referring to the circuit in **fig. 1**, the 3-dB bandwidth and total insertion loss can be varied by changing the points on L2 and L3. Tapping down on the coils gives greater selectivity but more insertion loss.

Filter D uses the same principle as A, B and C, except a strap inductor is used in place of coils L2 and L3 (see **fig. 3**). An expensive capacitor was used in the model shown in the photo, but the simple screw-and-disc capacitor shown in **fig. 4** will do the job nicely. A low minimum capacity must be used to reach above 1296 MHz.

Filter E is mounted in a discarded pipe tobacco can. I drilled holes in the ends for the input-output connectors and soldered a coupling wire from the connector to the

**table 1. Bandpass filter data.**

| Filter | Frequency Range (MHz) | Frequency (MHz) | 3 dB Bandwidth (MHz) | Loss |
|---|---|---|---|---|
| A | 25 to 85 | 25 | 0.8 | 1.3 |
| | | 32 | 0.9 | 1.1 |
| | | 40 | 1.2 | 0.93 |
| | | 60 | 2.0 | 0.80 |
| B | 52 to 190 | 55 | 6 | 0.40 |
| | | 80 | 8 | 0.32 |
| | | 110 | 10 | 0.30 |
| | | 180 | 12 | 0.32 |
| C | 142 to 420 | 160 | 14 | 0.78 |
| | | 210 | 20 | 0.70 |
| | | 300 | 24 | 0.65 |
| | | 380 | 30 | 0.56 |
| D | 230 to 1350 | 230 | — | 3.0 |
| | | 250 | — | 2.5 |
| | | 400 | — | 1.7 |
| | | 432 | 45* | 1.5 |
| | | 480 | — | 1.4 |
| | | 950 | — | 0.6 |
| | | 1296 | 585* | 0.35 |
| | | 1350 | — | 0.35 |
| E | 200 to 2500 | 2300 | 400 | 1.0 |

* 20 dB bandwidth

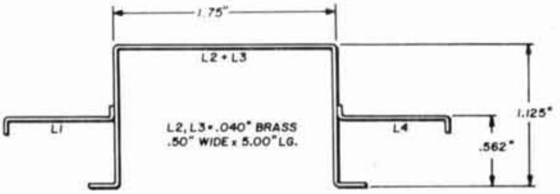
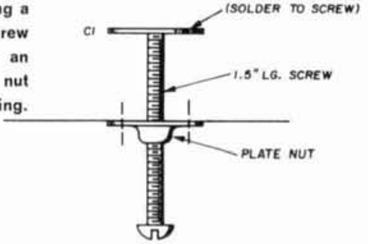
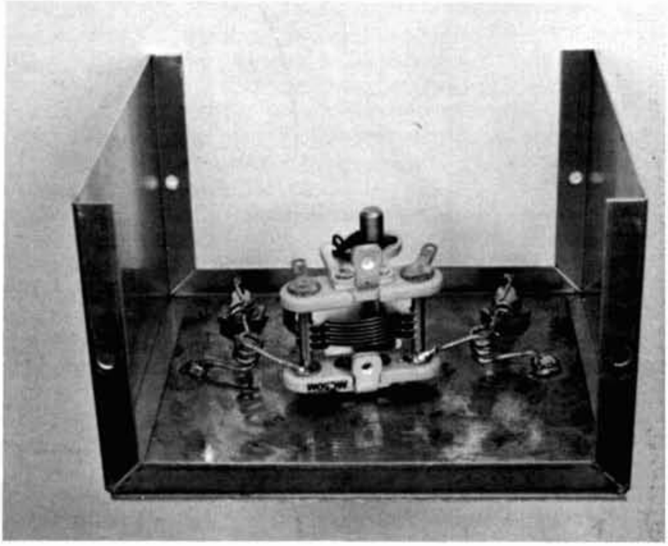


**fig. 3. Inductor detail for filter D.**

**fig. 4. C1 for filter D is made by soldering a disc to a brass screw about 1½" long; an aircraft-type plate nut is used as a bearing.**



**Filter B tunes from 52 to 190 MHz.**



bottom of the can (see **fig. 5**). Tuning is done with a threaded shaft and nut soldered in the center of the box; a friction lock nut is recommended. The last two filters don't have a calibrated dial, but once set they need be changed only slightly. A turns-counting dial with calibration chart could be used if desired.

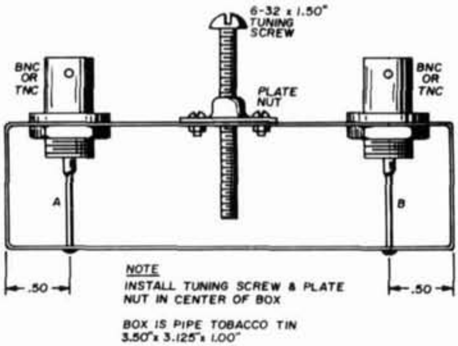
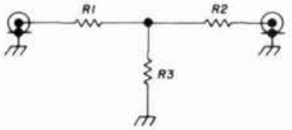


**fig. 5. Bandpass filter that will tune from 2.0 to 2.5 GHz; filter will tune to 1296 MHz if a disc is attached to the end of the tuning screw. The position of the coupling probes A and B determines bandwidth and insertion loss. Space the probe 1/4" from end of tobacco tin for less bandwidth; however, insertion loss will be slightly increased.**



| Attenuation | R1, R2 (Ohms) | R3 (Ohms) |
|---|---|---|
| 1 | 2.7 | 430 |
| 2 | 5.6 | 210 |
| 3 | 8.2 | 130 |
| 6 | 18 | 68 |
| 10 | 27 | 36 |
| 20 | 39 | 9.1 |
| 30 | 47 | 3.3 |

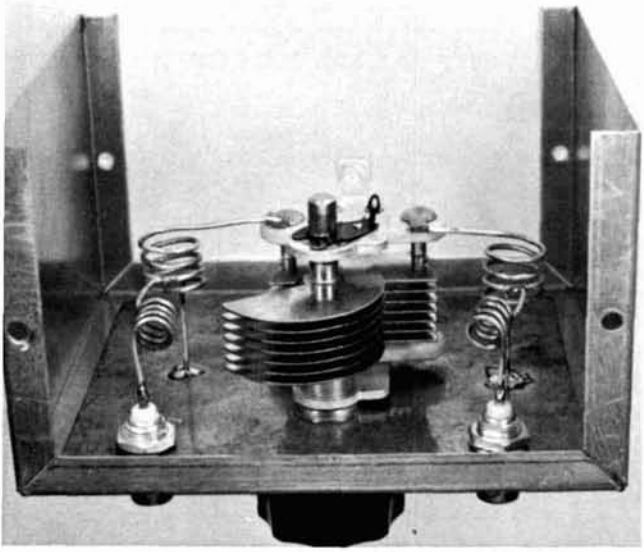
**fig. 8. Attenuator circuit using standard 5% carbon resistors is not exact, but very close. Put all three half-watt resistors in a brass tube 2" long and solder BNC connectors to the ends.**

## application

Using a filter at the output of a circuit will help you determine what signals are being generated. The filter will pass only the desired signal. Output level will then be the one desired; also by tuning the filter through the harmonic ranges, you can see what harmonic power is being contributed.

**fig. 6. Typical test setup using the bandpass filters.**

**Filter C tunes from 142 to 420 MHz.**



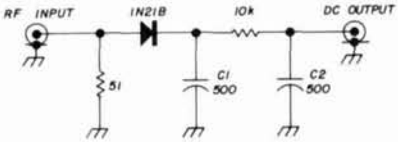


**fig. 7. Sensitive rf detector probe. Capacitors C1 and C2 should be good quality ceramics.**

The output power of low-level amplifiers or multipliers is sometimes only a few milliwatts, and of course most power-measuring devices won't indicate in this range. The only alternative is to use an expensive milliwatt meter or a home-made detector with a 50-ohm load. One is shown in **fig. 7.** I also recommend that an attenuator be used between the test circuit and the filter input as in **fig. 6** because the filter inductance can upset circuit tuning.

**ham radio**

**Now SEE the**

**HQ-215 Mk-II**

**New Radio — New Price**

**At your distributor now**

# The Hammarlund HQ-215

## The solid state receiver for those who want to be [illegible]

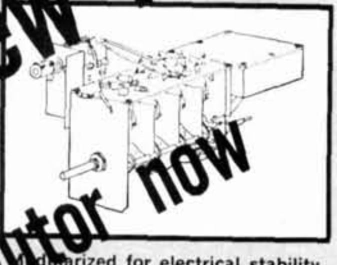
The Hammarlund HQ-215 brings to amateur radio a fully transistorized receiver offering a new high in sensitivity, selectivity and drift-free operation. Revolutionary unitized I-beam construction coupled with modularized design provides an unusually high degree of electrical and mechanical stability. A unique carousel dial with 22" of frequency calibrations means easy reading and resetability to within 20 cycles. And the [illegible] operation gives you [illegible] peak operating [illegible]. Here are the facts:

FREQUENCY COVERAGE: Complete ham band coverage, 80-15 meters; 28.5 — 28.7 mcs on 10 meters. Provision for 13 optional crystals providing 200 kc segments from 3.4 — 30.2 mcs built in.

FREQUENCY READOUT: Visual dial accuracy is ±200 cycles on all bands.

FREQUENCY STABILITY: Less than 500 cycles per hour.

**I-beam construction for strength**



**Modularized for electrical stability**

TRANSISTORS: 26 transistors, 13 diodes and [illegible] Zener regulator diodes.

SELECTABLE FILTERS: 2.1 kc mechanical filter supplied. Plug-in space for two optional filters. Any filter may be switch-selected from front panel.

MODE: Selectable USB, LSB, CW, OR AM.

SERVICE: SSB, CW, AM, and RTTY.

SENSITIVITY: Better than 0.5 microvolt for 10db signal-to-noise ratio.

SELECTIVITY: SSB-2.1 kc mechanical filter, 2:1 shape factor.

DIMENSIONS: Size: 6.8" H x 15.8" W x 14" D.

WEIGHT: 21 lbs.

**$399.99**

S215 Matching Speaker

$24.95

**Suggested User Net**

*Established 1910*

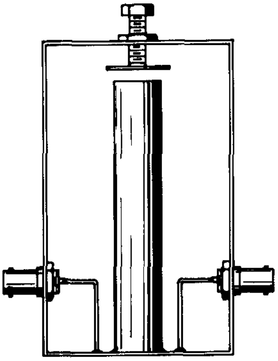
The **HAMMARLUND**
Manufacturing Company Incorporated
*A subsidiary of Electronic Assistance Corporation*
73-88 Hammarlund Drive, Mars Hill, North Carolina 28754

# single-pole bandpass filters

Fred Brown, W6HPH, Pine Cove, Idyllwild, California 92349

**Probably the most common** type of bandpass filter for amateur uhf work is the coaxial-cavity arrangement of **fig. 1.** This filter can be made to have very low insertion loss. However, the close proximity of the coupling loops results in some inductive coupling between input and output at all frequencies. The stop-band attenuation is consequently not as high as a single-pole filter can be.

**fig. 1. The coaxial cavity filter commonly used at uhf.**

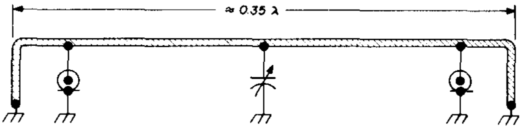


The arrangement of **fig. 2** places the input and output at opposite ends of the filter and results in better isolation. It also lends itself admirably to strip-line or trough-line construction. I built this filter to reject the usually strong, unwanted harmonics from a 432-MHz varactor tripler. Performance of the filter turned out to be quite remarkable, considering it was thrown together in twenty minutes total construction time with no attempt to optimize anything. Attenuation vs frequency between 200 and 1000 MHz is plotted in **fig. 3.**

## construction

Construction details for the 432-MHz trough-line filter are shown in **fig. 4.** The trough is a 12-inch section of aluminum extrusion of the type used for sliding glass doors. The tuning capacitor is a miniature piston type with a range of 1.2 to 10 pF. It's a Triko 108-02M imported from West Germany. I was concerned that some of the 432-MHz insertion loss might be due to capacitor losses. To check this out I tried the filter in the output of the "big rig."

**fig. 2. This trough-line filter is not only easier to construct than the cavity type of fig. 1 but also gives superior performance.**



## performance

At high-power level the lossy components in a filter will become hot. It wasn't possible to run more than 30 watts through the filter without the tuning capacitor arcing over, but at this power level there was very little capacitor heating. It did become just perceptibly warm to the touch, but so did the number 12

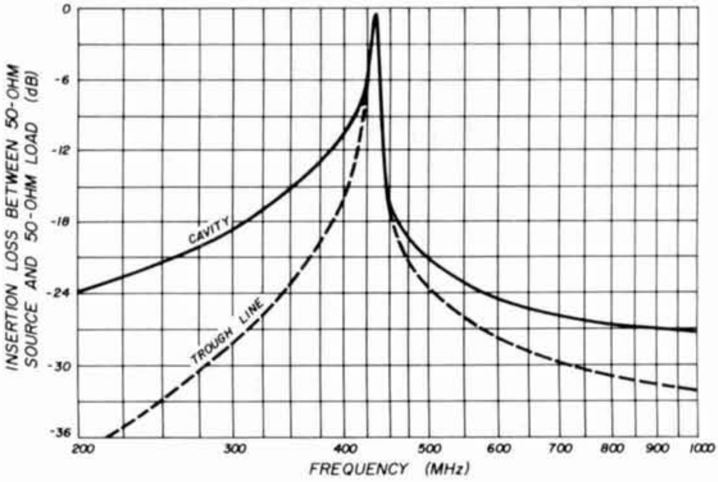


**fig. 3. Comparison curves of the coaxial-cavity and trough-line 432-MHz filters. Note the superior stop-band rejection characteristics of the trough line.**

copper wire center conductor. Probably the most important single factor for reducing insertion loss would be the use of a larger center conductor.

Also shown in **fig. 3** is the performance of a conventional cavity filter. It, too, was designed to reject unwanted harmonics from a varactor tripler. The filter was made by K6JYO from a surplus TS1/ARR-1 gold-plated cavity.

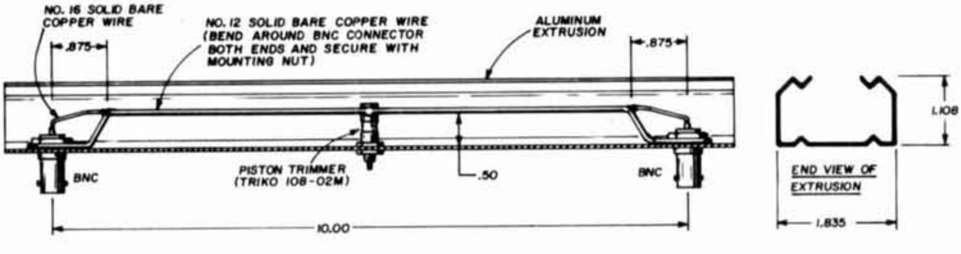
Note that the stop-band attenuation of the trough-line filter is better throughout the entire measurement range of 200 to 1000 MHz. The cavity filter did have slightly lower insertion loss: 0.4 dB as compared to 0.8 dB for the trough line. This is to be expected because of the higher-Q construction of the cavity. Loaded Q's of both filters were comparable, as indicated by the 3-dB bandwidth of 9 MHz for the trough line and 7 MHz for the cavity.

## low-frequency version

The success of this uhf filter inspired construction of a low-frequency version using

**The aluminum trough-line filter outperforms conventional coaxial cavity below.**

**fig. 4. Construction details of the 432-MHz trough-line filter.**



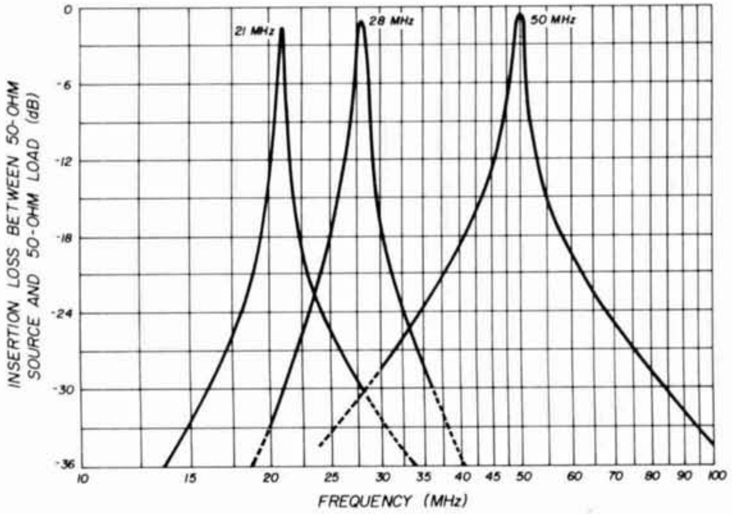
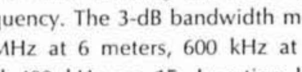


**fig. 6. Performance curves of the low-frequency, lumped-constant version of the trough-line filter. Attenuation characteristics were measured with the filter tuned to three different frequencies: 21, 28 and 50 MHz.**

lumped constants. It is built on a 2 x 4 x 8-inch chassis and consists merely of two coils, two BNC fittings, and one tuning capacitor. The schematic is shown in **fig. 5.** The LC combination gave a tuning range that covered the 15, 10 and 6 meter bands, so the filter response was measured at 21, 28 and 50 MHz.

**fig. 5. Low-frequency version of the trough-line filter. L1 and L2 are 13 turns of number 16 bare copper wire, 5/8-inch diameter, 1-3/8-inch long, air wound, and tapped 1¼ turns from ground. The coils should be oriented to minimize inductive coupling.**



## performance

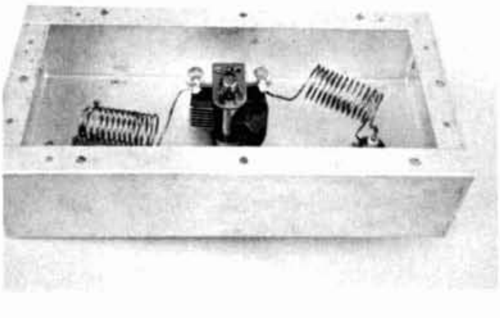
As can be seen from the curves of **fig. 6,** this gadget should make an excellent tvi filter if you don't mind retuning whenever you change frequency. The 3-dB bandwidth measured 2.2 MHz at 6 meters, 600 kHz at 10 meters, and 400 kHz on 15. Insertion loss was 0.7 dB at 50 MHz, 0.8 dB at 29 MHz, and 1.2 dB at 21 MHz.

The insertion loss could have been reduced by using higher-Q coils (number 14 wire instead of number 16, for instance); or by tapping the input and output higher up on the coils, say two turns from ground. This would also increase the 3-dB bandwidth.

Power-handling capability will be determined by the voltage breakdown point of the tuning capacitor. I've run 40 watts into this filter at 29 MHz, resulting in 35 watts delivered to the load. At this power level there is no tendency for the small variable capacitor to break down, but the coils become warm to the touch, indicating this is where the other 5 watts are being lost.

**ham radio**

**Low-frequency lumped-constant version of the trough-line filter. This filter can be tuned to 6, 10 or 15 meters.**



# standards for amateur microwave communications

This standard microwave system offers a practical means for amateur work above 1 GHz

Richard B. Kolbly, K6HIJ, 26334 Community Boulevard, Barstow, California 92311

**In 1956, the San Bernardino** Microwave Society was incorporated to further the art of amateur communications above 1000 MHz. A prime objective of this organization has been to develop equipment and techniques for amateur operation that can be duplicated by the average amateur experimenter at moderate cost. It soon became apparent to the members that it would be necessary to develop a set of standards for amateur microwave work if the art was to be developed in other than a haphazard manner.

This article, which I hope will be first of many in amateur microwave techniques, explains the working standards that the SBMS members have evolved for their own use. These have been used by the members for a number of years and have proved to be very practical in field operation. The standards pertain to operating frequencies, polarization, modulation, power supplies and component interconnections. The standard SBMS system is full duplex, allowing simultaneous transmitting and receiving, with the transmitter frequency removed 30 MHz from the receiver frequency.

The microwave amateur bands are very large compared with the lower bands. In order to communicate effectively over long distances, it is necessary to have certain standard frequencies and operating techniques that are understood and used by the station on the other end. For example, the 3300-MHz band (high S-Band) is two-hundred megahertz wide—far too wide to search for a weak signal with a 1-kHz bandwidth receiver!

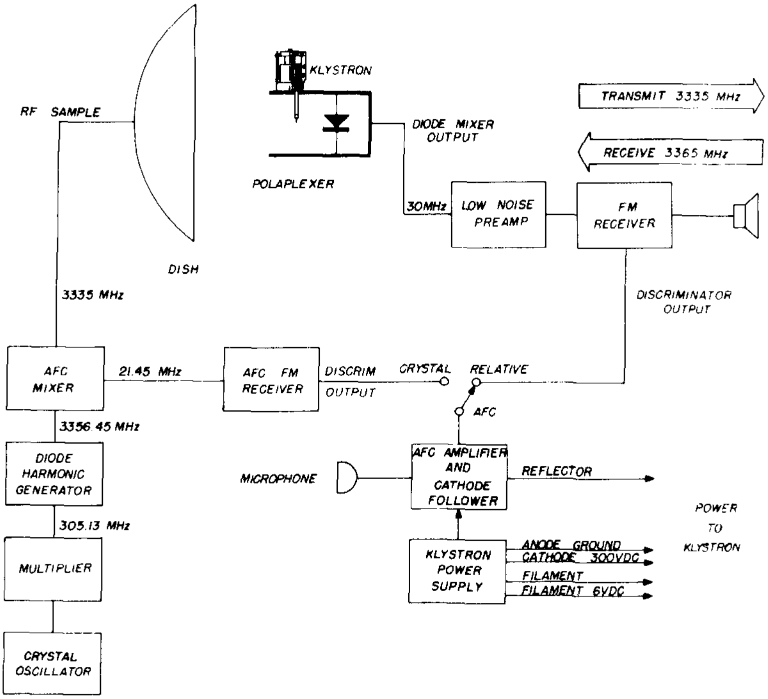


**fig. 1 A 3300-MHz ROCLOC station as used by members of the San Bernadino Microwave Society, Inc. (from W6OYJ).**

A large amount of surplus microwave equipment is available on the market, which is suitable for amateur work, with a wide range of possible interconnections. The members of the SBMS felt it was necessary to standardize interconnections to allow rapid replacement of system components.

## a typical station

The SBMS members operate a full-duplex system, with the transmitter also acting as the receiver local oscillator. The transmitter is frequency-locked to a crystal-controlled reference oscillator for stability. **Fig. 1** is a block diagram of a typical SMBS microwave station. The antenna feed also acts as a receiver mixer. This system is designated ROCLOC, meaning **Relative Or Crystal Local Oscillator Control.** It was developed primarily by Don Thompson, W6IFE, and George Tillitson, K6MBL. This ROCLOC system has proved to be an effective and versatile ham microwave setup. Interconnections are more or less standardized to allow equipment to be easily interchanged and tested.

## frequencies

Standard operating frequencies are a necessity, as most members operate with narrowband receivers that have a limited tuning range. The selection of standard frequencies for microwave hamming was based on readily available klystrons and a safe separation from the band edges.

The selection of the frequencies listed in **table 1** was based on a 5-MHz safety factor to prevent out-of-band operation of a station accidentally tuned to the other side of an incoming signal. For example, W6IFE transmits to K6HIJ on 3335 MHz. K6HIJ is supposed to have his transmitter on 3365 MHz, 30 MHz away, but since his receiver has no *image rejection*, he accidentally tunes his transmitter to 30 MHz **below** W6IFE. He is on 3305 MHz, still 5 MHz inside the amateur band. All SBMS work is based on an i-f of 30 MHz.

Since the transmitter polarization is at right angles to the receiver polarization, (standard polaplexer), all SBMS members polarize transmitted and received signals 45 degrees from vertical, with the transmitted signal polarized 45° to the right of vertical in the direction of propagation.

## klystron voltages

A large number of klystrons available on the surplus market will operate satisfactorily with 300 volts of beam voltage, so the SBMS has standardized on this beam voltage, with the positive terminal (klystron body) at ground potential. Also, direct-current heater operation has been found necessary. Therefore a low-ripple, dc filament supply (5.8-6.3 V; 1.5 A), isolated from ground is required. The klystron reflector voltage (referred to the klystron cathode) will operate from −100 to −300 volts at very low current drain. Ripple, hash and noise on all power supplies should be less than ten millivolts (0.01 volt). The reflector supply is most critical in this respect.

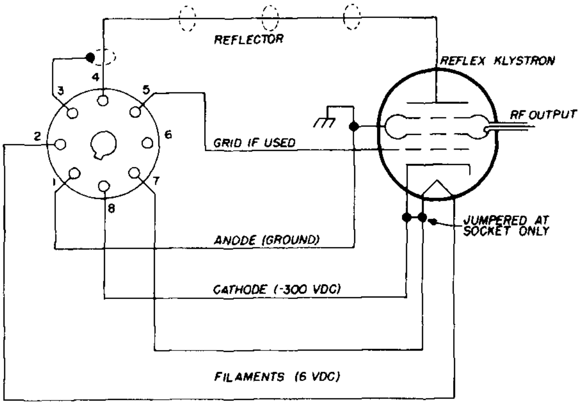


**fig. 2. Typical klystron power connections.**

For power connections to the klystron, standard octal plugs and sockets are used. The pin connections are shown in **fig. 2**. The supply side of the connection should be the female connector. By using these socket connections, it's possible to interchange klystrons with a minimum danger of damage to the klystron or power supply or of improper klystron operation.

## modulation modes

Amplitude moduation of a reflex klystron is difficult, so frequency modulation is used by the SBMS. For wideband operation, deviation is set to be compatible with the receiver, usually ±50 kHz, as most of the members use BC-683 fm tank receivers as 30-MHz i-f strips. For weak signal work, it's necessary to go to narrow bandwidths and smaller deviation.

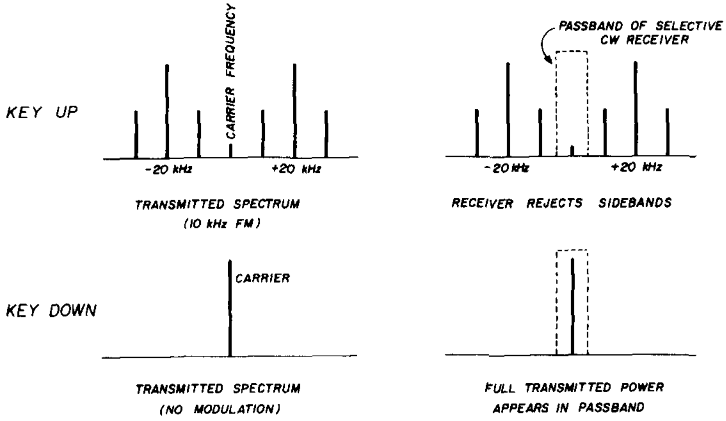


**fig. 3. Principle of pseudo-cw modulation.**

**table 1. Standard amateur preferred microwave frequencies.**

| band | band limits (MHz) | preferred frequencies (MHz) |
|---|---|---|
| low S | 2300-2450 | 2385 & 2415 |
| high S | 3300-3500 | 3335 & 3365 |
| C | 5650-5925 | 5860 & 5890 |
| X | 10,000-10,500 | 10,035 & 10,065 |
| K | 21,000-22,000 | 21,035 & 21,065 |
| | | 21,935 & 21,965 |

Usually the receiver has a bandwidth of 1 to 2 kHz, and deviation is set accordingly.

For very long-haul, weak-signal work, cw offers the best performance. To accomplish this form of modulation, the SBMS has developed "**pseudo-cw**" modulation. **Fig. 3** illustrates the principles involved. The transmitter is frequency modulated at a high audio rate (10 kHz or so), and the deviation is adjusted to the first carrier null, with all the transmitter power in the sidebands. A narrowband receiver tuned to the carrier frequency will not receive a signal, as the sidebands are outside the receiver passband.

This modulation corresponds to a "key up" condition. Depressing the key ("key down") removes the modulation from the signal, and all transmitter power appears on the carrier frequency. This "**pseudo-cw**" signal is received exactly as a standard cw signal, with the receiver bfo on.

This technique has been as effective as standard "on-off" cw modulation for long distance work yet allows the klystron to be frequency stabilized at all times.

## conclusion

I have attempted to outline the standards for amateur microwave work used by the members of the San Bernardino Microwave Society. Using these techniques, communications have been accomplished over long, indirect paths over mountainous terrain. We've observed that a frequency change of one megahertz will result in a 20-dB change in signal strength over an indirect path. The **ROCLOC** system allows rapid changes in transmitter frequency with stable operation. (Any amateur system should have the capability of making frequency changes.)

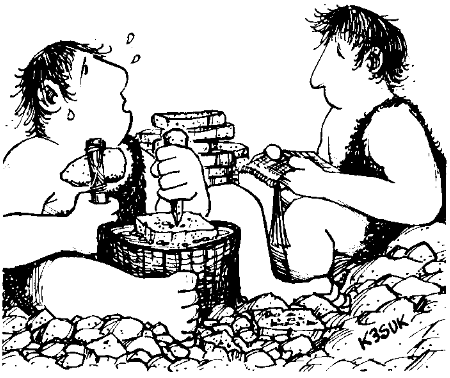
In review, the standards used by the SBMS are:

| | |
|---|---|
| operating frequencies | refer to table 1 |
| intermediate frequency | 30.0 MHz |
| polarization | linear, 45 degrees, transmit and receive |
| beam voltage | 300 volts, ±1%, less than 10 mV ripple |
| fm, wide | ±50 kHz |
| fm, narrow | ±1 kHz |
| morse code | "pseudo cw" (**fig. 3**) |
| rf-tuning range | greater than ±1 MHz |

If you are planning to move up to the microwave bands, I'm sure you will find these operating standards practical.

**ham radio**

### a look at those days before spark...



**"I love to operate . . .
but these QSL's are pure drudgery."**

# solid-state modification of a mobile converter

## An easy way to modernize a Gonset tube-type converter for mobile use

John R. Schuler, P. O. Box 37, Hanover, Maryland 21076

**I was thinking of installing** an old Gonset converter in my car, but the car's 12-volt system presented some problems. The converter tubes had 6-volt filaments, which would require a dropping resistor or heavy-duty zener. Also a power supply of +180 volts or more would have been necessary. Both these items would have represented considerable wasted power, more expense, installation problems, much more work, noise pickup problems, hash filtering, etc. Besides, I had a new all solid-state bc radio.

I felt that fet's and/or transistors would eliminate all these problems, and the small amount of filtered dc power required could be readily supplied by the bc set after it had been adequately filtered to eliminate input noise. Additional benefits would be instant warmup, no oscillator drift, no tube-pin noise from road shocks, and no worry over failure of tube filaments, element shorts, etc.

If mechanical redesign could be eliminated and electrical redesign limited to changing a few resistors and capacitors, the overall expense and effort would be drastically reduced even further. With this in mind, a most satisfactory modernization was achieved with equal or better performance than when the converter left the factory.

## construction

A most troublesome problem after removal of the tubes was finding a place to mount the transistors, since clearance was negligible between the tube socket connection ears and the bottom of the enclosing chassis. I finally decided to "spread-eagle" the short wires of the solid-state devices, use ¼-inch pieces of spaghetti, then solder the wires directly to the socket ears where old and new components would also be convenient for connection. An all-fet converter was originally planned. However, the great improvement in conversion gain afforded by an npn transistor justified its use as the mixer.

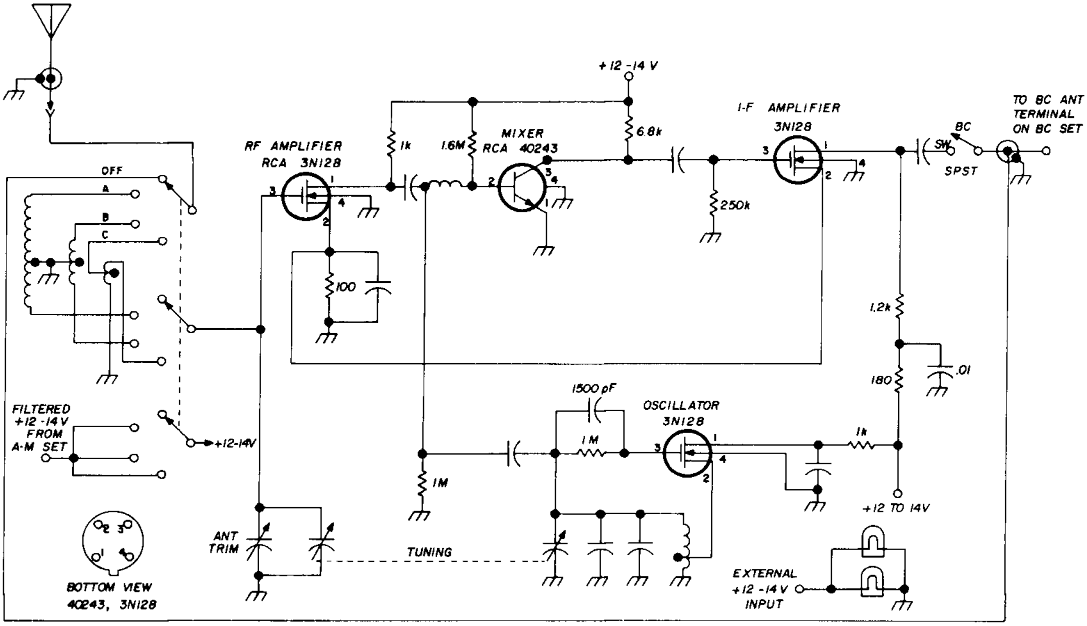


**fig. 1. The solid-state Gonset converter. Mosfet's and an npn transistor eliminate tube problems of noise, drift and high power drain. Components without values are unchanged from the original converter.**

The modifications are shown in **fig. 1.** I found it necessary to put in a slide switch to disconnect the antenna circuit from the output fet (during bc reception only), otherwise the loading effect was sufficient to ruin the Q and gain of the bc set. But this was the only mechanical change. There was plenty of room on the back apron of the converter to install this switch.

Where values of components are not given on the schematic, the value is the same as originally furnished by Gonset. Of course, the filament wiring, screen-grid wiring, screen-grid bypass capacitors anl dropping resistors may be cut out of the chassis; and good riddance. Note that the pilot lights were changed from 6-volt 47's to 12-volt types and disconnected from the line feeding the collector and drains. They may be separately fed from a battery clip and wire attached to the instrument panel light to lessen the IR drop from the bc set hash filter. In this way, when the bc set is turned off, the converter is "fail-safe" turned off too, irrespective of converter switch position. Wire from the on-off switch on the bc set should be shielded and fed to the shielded B+ line of the converter via phono pin and jack, or similar means, so each may be separated at will.

**ham radio**

# affect of mismatched transmitter loads

Does the character of the load affect power amplifier efficiency?

Carl Drumeller, W5JJ, 5824 N.W. 58th Street, Warr Acres, Oklahoma 73122

**Assume, if you will,** that a radio transmitter feeds a "lossless" transmission line terminated in a non-reactive load equal to the characteristic impedance of the line; the vswr will be unity, of course. Further assume that the transmitter runs 1000 watts input power and operates with an efficiency of 60%. A through-line wattmeter in the transmission line would then indicate 600 watts power output. For a final assumption, let's say that the plate of the vacuum tube in the final rf amplifier stage shows a faint trace of "color" under these operating conditions.

Now remove the non-reactive load and replace it with a complex load—partially-resistive and partially-reactive. Also, its total impedance is not equal to the characteristic impedance of the transmission line. This, of course, upsets the tuning of the transmitter; so quickly retune it to resonance and reload the final to draw 1000 watts dc input power.

## the question

Now the question: will the power amplifier plate show less, the same or more "color?"

This question will educe a lot of discussion among technical people—even a bit of argumentation. Opinion, even among well-qualified engineers, will be sharply divided. Most agree that a final solution can be reached only by setting up an experimental circuit and observing the results under carefully controlled conditions.

## the conditions

Pending such an empirical solution, however, there are several thought-provoking aspects that should be considered. First, let's tie down some conditions. Assume that the unloaded Q of the plate tank circuit is very high; that the tank circuit normally has a loaded Q of 12; that the inductor of the tank has low resistive losses; that a moderate change in the inductance of the tank inductor will produce no change in its total resistance; that the transmitter is operating on a relatively low frequency in the high-frequency range so that tank losses are mostly concentrated in the inductive leg of the tank; that the variable tuning element in the tank circuit is a variable inductor of the variometer type. Having assumed all this, we're ready to look at the schematic diagram in **fig. 1**.

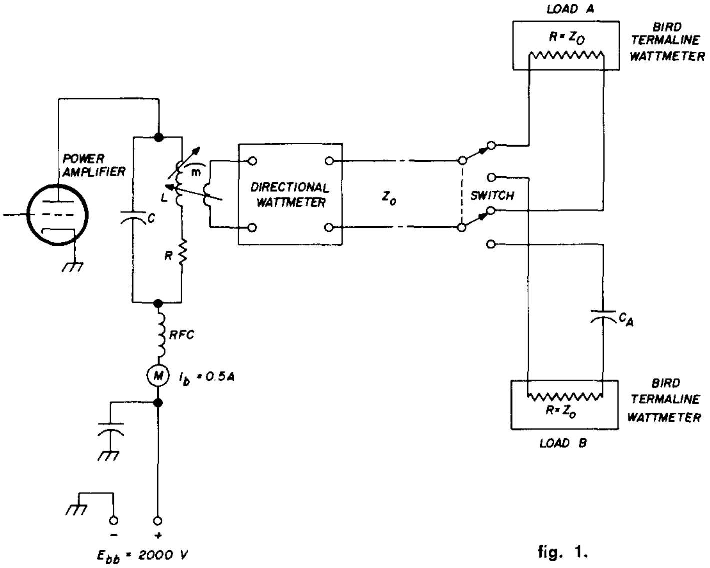


**fig. 1.**

You will recall that the question stipulated an over-all efficiency of 60% with a purely resistive load. The important factors determining the degree of operating efficiency are grid bias, rf excitation and the plate load. We shall assume that grid bias and rf excitation have been adjusted to optimum and will remain unchanged throughout the test. The third factor, plate load, is a variable depending upon the loaded Q of the plate tank circuit. Assuming the capacitor has negligible contributory loss, we can say that tank Q is equal to the inductor's reactance divided by its resistance ($Q = X/R$). This Q, in turn, determines the impedance into which the tube works. When the tank circuit is tuned to resonance it may be stated that

$$Z = \frac{X^2}{R} = XQ$$

Keep in mind that the capacitance of the tank circuit is fixed. Therefore, for a state of resonance ($X_L = X_C$) at a given frequency, the effective value of inductance must be constant. This is important, for we shall be tuning the variometer to maintain a status of resonance. Now slip back a notch and consider the matter of impedance. Look at the *formula* $Z = X^2/R$*—if* $X_C$ *is fixed and* $X_L$ must always equal $X_C$, it's evident that resistance is the only variable that can be manipulated to attain a desired value of impedance. We shall assume we have reached that desired value when the dc plate current has a value of 0.5 ampere with the tank circuit in resonance.

Since we stipulated that the unloaded Q of the tank circuit is high (same as saying that the inductor's resistance is low), the effective resistance of the tank must actually be predominantly made up of resistance reflected from the load through the mutual coupling, m, that links the tank inductor to the transmission line pick-up coil.

## the experiment

Connect load A to the transmission line, fire up the transmitter, and adjust the plate variometer and the mutual coupling, m, so that when in resonance the dc plate current is 0.5 ampere. The directional wattmeter indicates 600 watts incident power and zero reflected; the meter on the Termaline® wattmeter used for load A also indicates 600 watts. The extent of the glow on the plate of the final amplifier tube is carefully observed and recorded. This concludes the first step.

For the second step, the transmission line is shifted from load A to load B. Load B consists of a Termaline® wattmeter in series with a capacitor. The total impedance of this load is expressed by:

$$Z = \sqrt{X_C^2 + R^2}.$$

It is evident that the new load is not matched to the transmission line so there will be standing waves present on the line. To simplify matters, let's assume that the transmission line is a half-wave long (at the operating frequency). Then the capacitive reactance ($X_C$) of the load will be present at the sending end of the line. It will be reflected into the inductive leg of the plate tank circuit as a value of $X_L$, causing the total $X_L$ to be too great to maintain an equality with the fixed value of $X_C$. Therefore, the plate tank will not be in resonance. You quickly restore it to resonance by adjusting the variometer. Now total tank-circuit $X_L$ is back to its original value.

Although the value of resistance in the load has not been changed, it is probable that m will have to be altered to maintain the tank R at a value that will permit a dc plate current of 0.5 ampere at resonance; make the necessary adjustment.

## the results

The tube now has a dc input power of 1000 watts. The directional wattmeter in the transmission line will now indicate something other than 600 watts incident power; also, it will show some reflected power. The question, though, is what has happened to plate dissipation? The answer is short and sweet: nothing!

This is because the power generator, the tube, sees exactly the same load it saw when the transmission line was terminated with a resistive load equal to the characteristic impedance of the transmission line. This condition was established when the plate-tank variable inductor was returned to resonance and the coupling adjusted for the same dc plate current.

The plate tank circuit is the key to the situation. It performs three functions: it provides an optimum value of non-reactive load for the generator to work into, it provides frequency selection by offering this load only at the selected frequency, and it serves as a transforming device, transliterating random loads into the load that is optimum for the power generator. It is the third function that seems to be least understood.

Although a rather unusual type of tank circuit has been used in this illustration, other tank configurations work equally well and perform precisely the same service. The sending-end impedance can be (and usually is) almost anything but the 52 ohms resistive that the transmitter is designed to work into. The impedance may vary over the range from 15 to several hundred ohms—and it may be purely resistive, resistive plus inductive or resistive minus capacitive! This is what the tank circuit must cope with to perform its vital third function.

Fortunately, almost any properly designed tank circuit is capable of making this transformation. The limitations are mostly those that are built in by the designer's choice of *components. There are two factors* that have a lot to do with this choice: cost and ease of tuneup. The first is a matter of keeping the selling price low to compete in a highly competitive market. The other is to keep tuning procedures simple so the equipment won't be damaged during tuneup. If the tubes go out in a blinding flash or the tank circuit melts down into a sodden mess, either the designer cut too many corners or the operator lacked the skill to make the necessary corrective adjustments. Consider that before you cuss the designer!

**ham radio**

# For The Experimenter!

## International EX Crystal & EX Kits

OSCILLATOR / RF MIXER / RF AMPLIFIER / POWER AMPLIFIER

## Type EX Crystal

Available from 3,000 KHz to 60,000 KHz. Supplied only in HC 6/U holder. Calibration is ±.02% when operated in International OX circuit or its equivalent. (Specify frequency)

**$3.95**

### OX OSCILLATOR

Crystal controlled transistor type.
Lo Kit 3,000 to 19,999 KHz
Hi Kit 20,000 to 60,000 KHz
(Specify when ordering)

**$2.95**

**MXX-1 Transistor RF Mixer** **$3.50**
A single tuned circuit intended for signal conversion in the 3 to 170 MHz range. Harmonics of the OX oscillator are used for injection in the 60 to 170 MHz range.
Lo Kit 3 to 20 MHz
Hi Kit 20 to 170 MHz
(Specify when ordering)

**MXX-1**

**SAX-1**

**PAX-1**

**BAX-1**

**SAX-1 Transistor RF Amplifier** **$3.50**
A small signal amplifier to drive MXX-1 mixer. Single tuned input and link output.
Lo Kit 3 to 20 MHz
Hi Kit 20 to 170 MHz
(Specify when ordering)

**PAX-1 Transistor RF Power Amplifier** **$3.75**
A single tuned output amplifier designed to follow the OX oscillator. Outputs up to 200 mw can be obtained depending on the frequency and voltage. Amplifier can be amplitude modulated for low power communication. Frequency range 3,000 to 30,000 KHz.

**BAX-1 Broadband Amplifier** **$3.75**
General purpose unit which may be used as a tuned or untuned amplifier in RF and audio applications 20 Hz to 150 MHz. Provides 6 to 30 db gain. Ideal for SWL, Experimenter or Amateur.

*Write for complete catalog.*

**INTERNATIONAL**

**CRYSTAL MFG. CO., INC.**
10 NO. LEE • OKLA. CITY, OKLA. 73102

by larry allen

# the repair bench

## putting a scope to work in ham gear

Here I am to continue with scopes. I told you last month how to fire up the scope and get displays locked into position on the screen. This month I'll give you some specific uses for it on the ham repair bench.

A scope, remember, lets you **see** the exact shape of an ac waveform. You can identify sine waves, square waves, tv sync pulses or any unusual waveshape. More than that, and often more important, you can measure peak-to-peak values of waveform voltages, whether they're nice round sine waves or crazy, misshapen oddballs.

### measurement methods vary

Probably the chief difference in various brands of service-type scopes lies in how you measure voltages with them. Yet, they're all fairly easy. There are three main ways. Each uses the scope's variable **vertical input** control, but in different ways. The **vertical input** switch is always a decade-type multiplier. And the marked graticule on the face of the scope is important to voltage measuring.

In one method, you first feed in a signal of known value and adjust the **vertical input** control to make the trace coincide with that voltage marking on the scope graticule. That calibrates the input amplifier. You can thereafter read the voltage value more or less directly on the scope graticule.

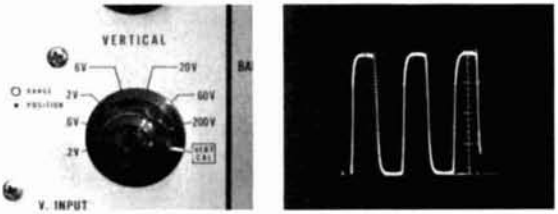
The second way of measuring peak-to-peak voltage is almost identical, except that the calibrating voltage is inside the scope. You just turn a switch to **calibrate,** and adjust the **vertical input** knob till the waveform display fits between two "calibrate" lines on the graticule. Then, you can read any signal-voltage value from where it fits on the graticule. The switch and the waveform are shown in **fig. 1.**

You've probably figured out that you can't mess with the **vertical input** knob once it's set. If the display is too small, you turn the input multiplier switch to a more sensitive position. If the display is too large (off-screen), switch to a less sensitive multiplier.

The third common method of measurement lets you read the voltage value directly from the **vertical input** knobs. **Fig. 2** illustrates the controls. You adjust the **vertical input** controls to make the waveform display exactly 2 inches high on the graticule (which is marked in inches). Then, you read the number pointed to by the variable knob and multiply it by the multiplier setting. That tells you the peak-to-peak voltage of the input waveform, no matter what its shape.

The waveforms that follow are photographed from a B&K model 1450 servicing scope. Its lighted graticule, shown in **fig. 3,** has two numbered scales: 0-2 and 0-6. The multiplier switch determines which scale

**fig. 1. Before measurements, the vertical input amplifier must be calibrated to a standard voltage. Switching to vertical applies internal signal to deflection amplifier in this scope. Display is adjusted to fit the full-scale graticule mark.**



lights up. The correct full-scale voltage is listed on each waveform photo so you can read peak-to-peak amplitude accurately. As you go along, reading voltages on a scope like this becomes second nature.

## tracing input power

A simple use for the scope, and a good one to practice with, is checking input ac voltage to a receiver or transmitter. It's the same thing you'd ordinarily do with your ac voltmeter.

The diagram in **fig. 4** shows the test points in a popular ssb transmitter. The photo below the input wiring shows the waveshape. Ac line voltage is a sine wave.

The 120 volts your voltmeter reads is a root-mean-square (rms) value, and the scope shows peak-to-peak (p-p) values. Line voltage is 335 volts peak-to-peak. The highest full-scale voltage reading on this scope is 200 volts, but its probe has a 10X switch on it. That attenuates any signal voltage by a factor of 10.

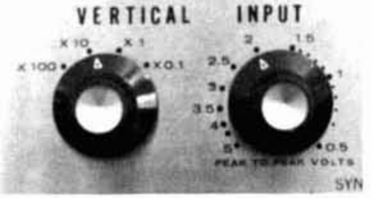
The multiplier switch for the photo in **fig. 4** is set at 60. A voltage of 600 will therefore reach all the way to the top of the 6 scale. The waveform you see goes about a subdivision and a half above the 3 mark.

The **sync** is set for **−int,** but it could just as easily be set for **line;** either would lock the line-voltage waveform in tightly.

The **sweep** control must be set for 10–50 Hz, and the **fine frequency** adjustment is turned so four cycles appear on the display. Adjust positioning controls so the bottom of the waveform is on the base line of the graticule.

Use an isolation transformer between the plug of any chassis you're testing and the power line. Otherwise, you can blow fuses with a direct short between the scope ground lead and one side of the power line. (Not to mention the big chance of a nasty—even deadly—shock.)

**fig. 2. Waveform peak-to-peak amplitudes can be read directly from the knobs of this scope. The display is made exactly two inches high on the graticule by turning the knobs; then voltage is read.**



Clip the ground lead of the scope to the ground side of the power cord. Then, move the test probe from point 1 to point 3 as shown. You should get the same waveform at every point. If you get a waveform when you probe the grounded end of the transformer primary, however, it's a sign the ground is open. You can test the primary winding, too, by opening its ground connection and probing at the ground end; if you get a waveform, the primary is okay (**fig. 4** shows this test).

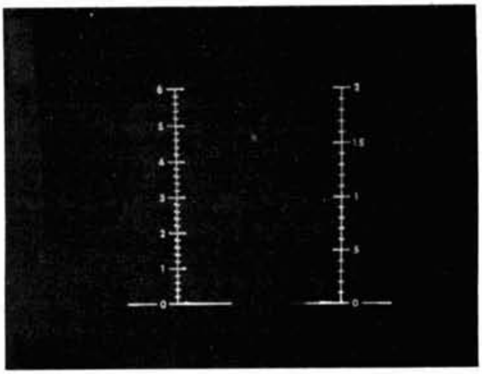


**fig. 3. You read p-p voltages on scales with this scope, much like you do with a voltmeter. Either scale is used with decimal multiples chosen by the vertical input switch. Scales light one at a time.**

You can test the secondaries, too. Just probe points 4, 7, 9, 12, and 13. Remember that the **Vac** readings listed on a schematic are rms values. To know what p-p reading you should expect, multiply rms voltage by 2.8. Probing at point 10 also tests the doubler filter that couples ac voltage to the first rectifier.

## power-supply filter capacitors

A scope is a fine tool for testing power-supply filters. It lets you actually see how much ripple is left in the dc output of the supply.

Here's a good rule-of-thumb: Ripple should not exceed 1% of the dc voltage across the filter, **with the equipment drawing full load.** Thus, in a 500-volt dc supply, output ripple under load should be no more than 5 volts. If it is, the filter capacitors aren't doing their job.

For a regulated supply, the ripple percentage should be even lower. The regulator circuit or its capacitors are faulty if the ripple at the output exceeds 0.1% of the dc value. Ripple voltages are always measured peak-to-peak.

The waveform photo in **fig. 5** is taken across the filter of a 400-volt dc power supply. The full scale is 20 volts, so the ripple waveform is 4 volts p-p. The scope **sweep** is set for 10–50, and **fine frequency** is set to display four cycles. **Sync** is **–int.**

## sine waves in amplifiers

Here is where a scope begins to shine. It can show up distortion at the same time it's measuring gain in an amplifier. Suppose you suspect trouble in the speech amplifier section of a transmitter.

You feed about 50 mV of audio signal into the microphone input jack **(fig. 6).** Any frequency around 1000 Hz works fine. Then you move the scope probe from stage to stage, at inputs and outputs, all the way to the modulator. Each amplifier stage should multiply the signal voltage by at least 10 or 20.

A clipper, on the other hand, is supposed to prevent overmodulation. It limits how much audio signal reaches the modulator. You can check the clipper with a scope.

Connect the probe at the modulator grid or at the output of the clipper stage itself. Turn up the audio generator output, watching the scope as you do. When the audio signal gets strong enough to cause 100% modulation, the clipper starts acting. The sine wave begins flattening out as the second photo of **fig. 6** shows. From that point on, you should be able to turn the generator wide open without getting a higher waveform on the scope. The shape only gets flatter.

You can trace rf amplifiers with the scope, too. Just feed in a modulated rf signal, and use a demodulator probe with your scope. With amplitude-modulated signals, any circuit fault that cuts down the rf signal also cuts down the audio modulated on it.

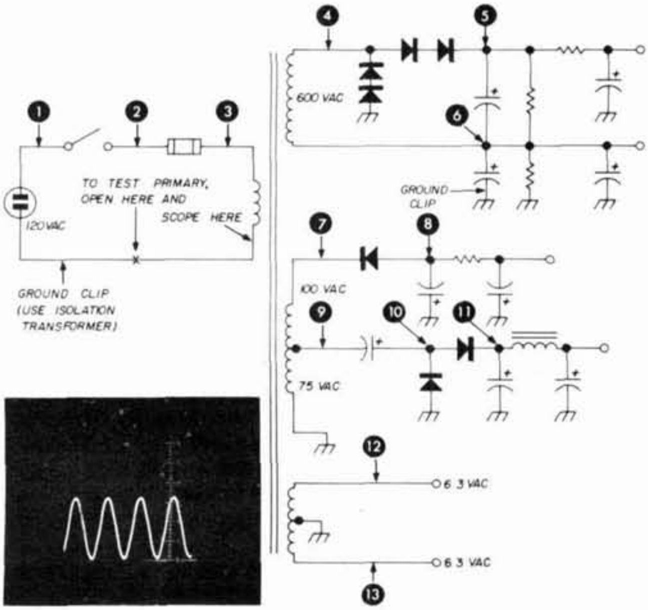
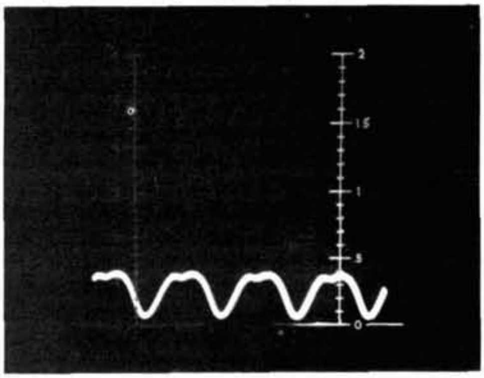


**fig. 4.** Power-supply test points. Waveform of input voltage. Full scale in this photo is 600 volts; peak-to-peak voltage therefore appears to be about 335 volts.

You can even peak up receiver alignment with a scope fed by a demodulator probe. Just use the amplitude of the waveform on the scope as an indicator of peaking as you turn the adjustments. You can move the

**fig. 5.** Ripple voltage found in one fullwave power supply. Taken across input filter. Full scale of graticule is 20 volts; 4-volt p-p reading indicates filter capacitor is doing its job fairly well.



probe from stage to stage as you progress with tuning adjustments, or you can connect it following the last rf or i-f stage. If you go beyond an a-m detector, you don't need the demodulator probe. However, you can align the i-f and rf stages in an fm or ssb receiver using an a-m signal and the demodulator probe with a scope.

## ham television

In recent years, hams have found it logical to stick with the commercial tv standards. Thus, they can use standard receivers with modified tuners. Also, surplus and used transmitting equipment is more available.

For examining and measuring signal voltages in television stages, a scope is indispensable. The photos in **fig.** 7 are the most common waveforms.

**Figs.** 7**A** and 7**B** are photos of the signal voltage that contains both the video that makes the picture and the sync pulses that keep it steady. The scope probe is connected to the output of the tv set's video detector. Full scale of the graticule when these photos were taken was 6 volts p-p; the waveform is just under 5 volts p-p.

In **7A,** the scope sweep is set for about 5 kHz; that shows three cycles of the signal at the 15,750-Hz line rate. **Fig. 7B** is the same signal, but with the scope sweep set for about 20 Hz. That displays three cycles at the 60-Hz frame rate. Peak-to-peak voltage is the same, no matter what display rate is used.

From the vertical sweep section of the tv set, the signal voltage in **fig. 7C** is taken. It is a trapezoid, displayed on the 600-volt scale. Its amplitude is 220 volts p-p. The scope sweep is set for 20 Hz.

**Fig. 7D** is also a trapezoid, this time taken in the horizontal sweep section of a television receiver. The scope is set to sweep at about 5 kHz, to display three cycles. The full-scale voltage range on the graticule is 200; the waveform is 120 volts p-p.

You'll discover that waveforms in any television receiver are viewed at either of just two scope-sweep rates. The 5-kHz sweep rate is for all waveforms that bear any relation to the horizontal line rate of the tv receiver. The 20-Hz sweep rate is for waveforms that relate to the vertical frame rate.

**Fig. 7E** is a special waveform found in the automatic frequency control circuit of the tv-set horizontal oscillator. The scope sweeps at the line rate. The graticule is at 200 volts full scale; the waveform is therefore 100 volts p-p in amplitude.

Another special circuit in TV receivers is the automatic gain control. In most modern sets, it is a keyed type. That is, a pulse is applied to it from the horizontal sweep transformer (called the flyback). The photo in **fig. 7F** is a sample of the keying signal voltage. The scope is set to display horizontal-rate signals. Peak-to-peak amplitude of the keying signal is 175 volts.

## next month

These last two installments have given you a sample of how you can use a scope on the ham repair bench. A little practice makes

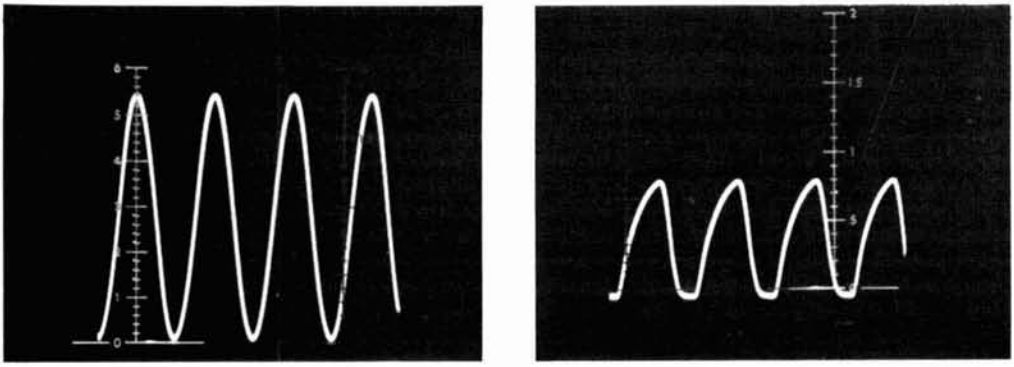
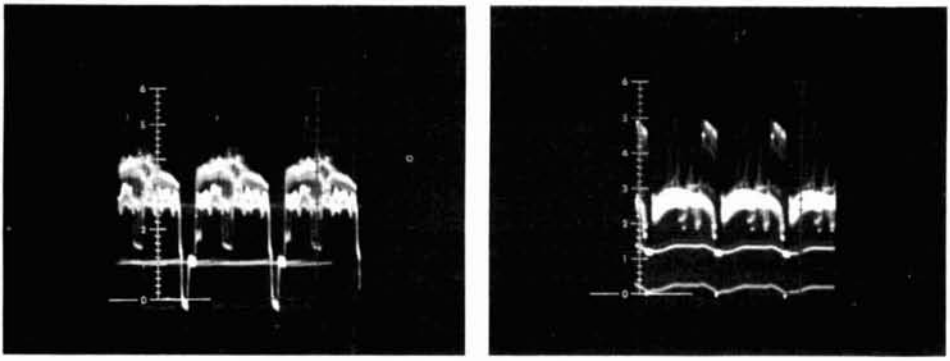
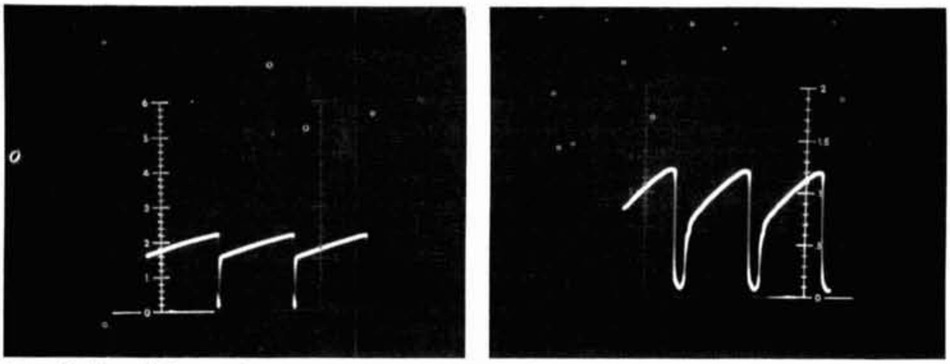


**fig. 6. Sine-wave audio signal gets flattened in clipper when too much signal is fed in. That's normal, because clipper should keep signal at modulator from exceeding voltage for 100 percent modulation.**



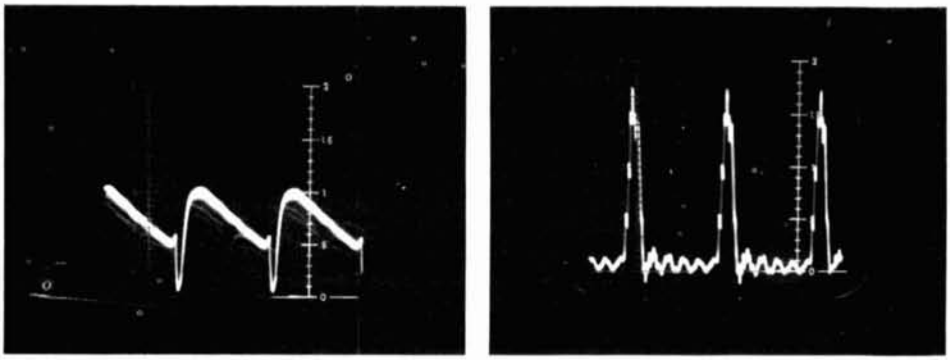
**A. video waveform at line rate**

**B. video waveform at frame rate**



**C. vertical oscillator waveform**

**D. horizontal drive signal**



**E. afc comparison signals**

**F. agc keying pulse**

**fig. 7. Typical waveforms from television receiver that can be used for amateur tv reception. Video waveform, displayed at line rate (A), video waveform, displayed at frame rate (B), vertical oscillator waveform, at frame rate (C), drive signal to horizontal output tube, displayed at line rate (D), waveform of comparison signals in afc stage, shown at line rate (E) and keying pulse for agc stage, at horizontal rate (F).**

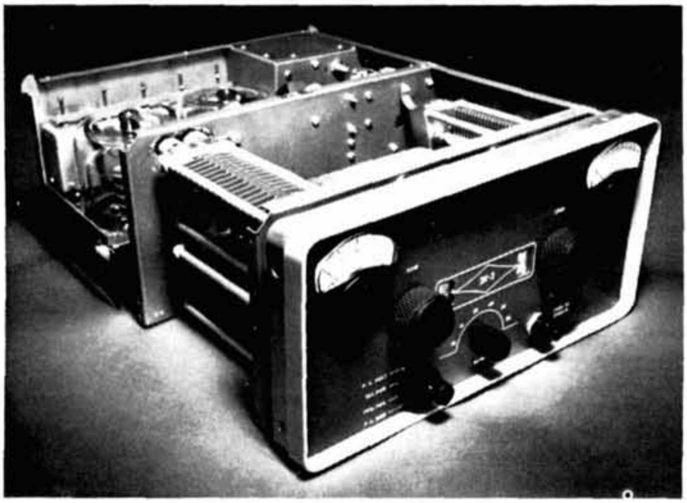
you as familiar with your scope as you are with your voltmeter. And you'll find the scope is far more versatile.

Next issue, I shift to a new topic: single-sideband. Tuning up an ssb transmitter has some things in common with any other ham transmitter. But, there are important differences. Those are the subject of **repair bench** next month.

**ham radio**

## *The Henry 2K-3 Linear Amplifier*

# LISTEN TO IT SPEAK



Five years ago the first 2K started speaking for itself. The entire amateur world has gotten the message. The BIG, SHARP, CLEAN 2K signals have been passing the message of quality since that day. This is the way an SSB signal should sound. Now after two model changes and as we approach the three thousand mark in the 2K series, the message is even louder and clearer. Let us help you produce that same strong, clean signal that you hear coming in from 2K owners the world over. Come in, call, or write for literature describing the superb 2K-3 in detail. And then let us work out terms that will fit your budget.
The 2K-3 (console or desk model) $745.00

**Henry Radio now has representatives in different areas of the United States to simplify ordering for those living near one. Or you can order direct and we will ship . . . across the street or around the world. Call or write for detailed specifications and terms.**

| New York area: | Cleveland area: | Chicago area: |
|---|---|---|
| **John Richardt, W2WIY** | **Al Gross, W8PAL** | **Bill Reynolds, K9ZXD** |

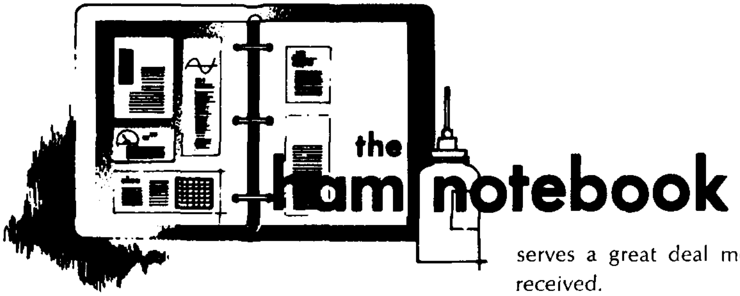
EASY FINANCING • 10% DOWN OR TRADE-IN DOWN • NO FINANCE CHARGE IF PAID IN 90 DAYS • GOOD RECONDITIONED APPARATUS • Nearly all makes & models. Our reconditioned equipment carries a 15 day trial, 90 day warranty and may be traded back within 90 days for full credit toward the purchase of NEW equipment. Write for bulletin.

CALL DIRECT . . . USE AREA CODE

**Henry Radio Stores**

| | |
|---|---|
| 11240 W. Olympic, Los Angeles, Calif., 90064 | 213 477-6701 |
| 931 N. Euclid, Anaheim, Calif., 92801 | 714 772-9200 |
| Butler, Missouri, 64730 | 816 679-3127 |

*"World's Largest Distributor of Amateur Radio Equipment"*



# the ham notebook

## mono-loop antenna

Nothing new or startling is claimed for this antenna. However, like the open-wire-line fed flat top, the one-wavelength loop deserves a great deal more attention than it's received.

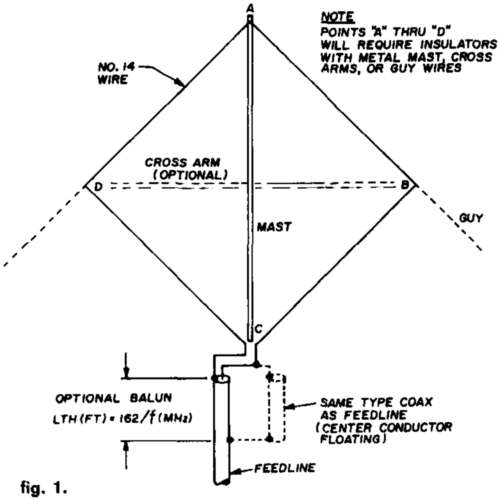


fig. 1.

| f (MHz) | total length | length per side |
|---|---|---|
| 14.0 | 71′ 10″ | 17′ 11½″ |
| 14.1 | 71′ 4″ | 17′ 10″ |
| 14.2 | 70′ 9″ | 17′ 8¼″ |
| 14.3 | 70′ 3″ | 17′ 6¾″ |
| 21.0 | 47′ 10″ | 11′ 11½″ |
| 21.1 | 47′ 8″ | 11′ 11″ |
| 21.2 | 47′ 5″ | 11′ 10¼″ |
| 21.3 | 47′ 2″ | 11′ 9½″ |
| 28.0 | 35′ 10″ | 8′ 11½″ |
| 28.5 | 35′ 3″ | 8′ 9¾″ |
| 29.0 | 34′ 8″ | 8′ 8″ |
| 29.5 | 34′ 1″ | 8′ 6½″ |

Almost everyone using a quad parasitic array is pleased with the results. The quad has a good capture area, and for modest height above ground, a favorable low angle of radiation. A quad mono-loop has these same advantages, but with the disadvantage of being bidirectional.

My new location precluded a tower and rotary beam. As an alternative I erected thirty feet of tv mast on the chimney of the house; and from the top, some forty feet above ground, suspended a 20-meter quad loop (**fig. 1**)*. Because of limitations in guying the sides at the proper height, the antenna looks like an ARRL diamond, but it works like a gem (pun intended)!

Reports broadside to the antenna are generally 6 to 12 dB higher than those received from a three-half-wave doublet (100 feet long, center fed; 40 feet high) favoring the same directions. In fact, except that the antenna is fixed, it performs just about as well as a two-element quad in a former location.

For a 20-meter loop, I suggest starting with sides 17 feet 10 inches long and trimming to optimize the swr. In my case, the regular formula length $250/f_{MHz}$ = side in feet resulted in a resonant frequency higher than desired; probably because the sides are elongated into a diamond shape.

Hams having towers high enough to accommodate a 40-meter loop might find it would outperform a conventional inverted-V doublet, even though the bottom current loop is close to the ground.

**James A. Gundry, W8BW**

---

* **Editor's note:** Suggestions for crossarm braces and a balun are included. The balun is recommended for optimum efficiency.

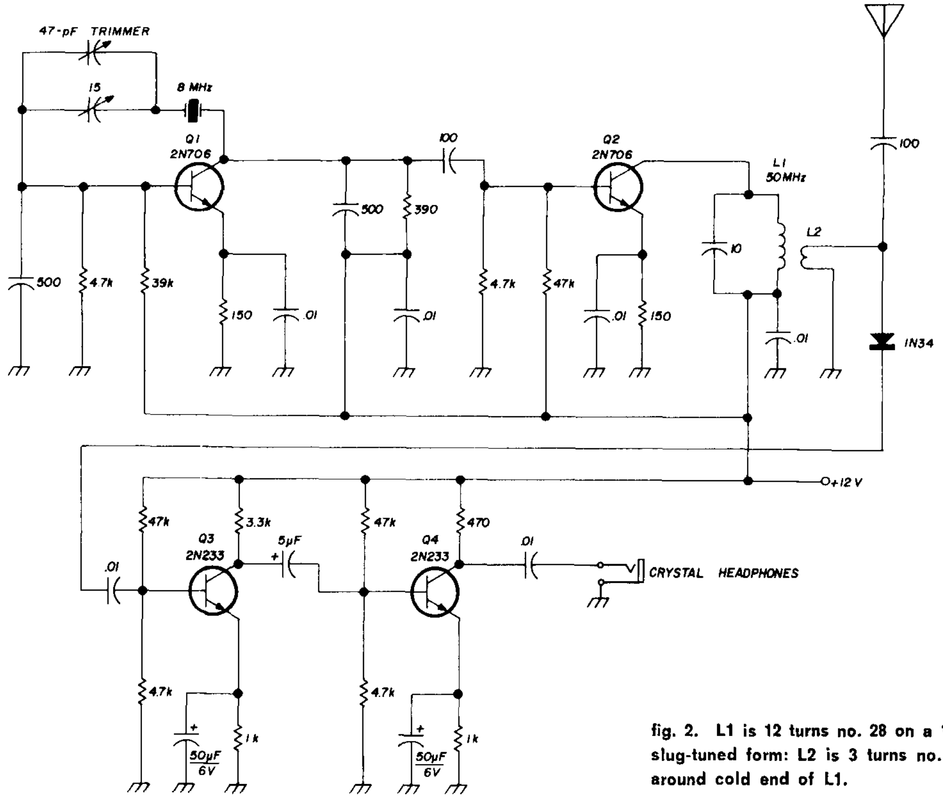


fig. 2. L1 is 12 turns no. 28 on a ¼" slug-tuned form: L2 is 3 turns no. 28 around cold end of L1.

# crystal-controlled frequency meter

For the past couple of years amateur radio magazines have been running articles about sophisticated frequency measuring devices, mostly using integrated circuits and other solid-state components. The crystal-controlled frequency meter shown here is as simple as can be constructed and is based on the old method of zero beating one frequency against another.

The oscillator in **fig. 2** is an untuned crystal-controlled oscillator. The crystal frequency can be "pulled" from 2 to 4 kHz, depending on the crystal. I use an 8 MHz crystal and multiply it to 50 MHz; the 50 MHz signal is rectified and fed to an audio amplifier. With this carrier turned on, every time another carrier of the same frequency is fed to the amplifier a zero beat is heard. It even radiates enough to check receiver frequency.

The stability of the oscillator was checked with a digital frequency counter and only ±10 Hz drift was observed at 8 MHz during a two-hour period. The frequency meter uses a 12 volt battery supply; current drain is 8 mA—due chiefly to the low-level of amplifier used in the circuit.

Construction is not critical. It can be hand wired or everything can be put on printed circuit boards; I prefer printed circuit boards because it is quicker as well as compact and neat. Transistors are the four-for-$1 type and crystals were 50¢ each. The transistors in the amplifier should be npn germanium with a beta of at least 90; the 2N233 or 2N170 will do the job fine.

Crystals from 5 to 13 MHz will work in the oscillator. Adjust the 47-pF trimmer to zero a certain frequency with the proper crystal; make sure the 15-pF capacitor is half open. You should be able to deviate the crystal frequency ±1.5 kHz. To set a transmitter vfo, set the 15-pF capacitor to the desired frequency, plug in a crystal headphone, load the transmitter into a dummy load and vary transmitter vfo to zero beat.

**John J. Sury, W5JSN**

# simple microphone stand

A microphone is usually easy and inexpensive to obtain, but getting a microphone stand is something else again. The few commercially available stands are rather expensive, often costing as much or more than the mike they support. So after looking for an easy method of building a stand, I got the idea of using a common, stamped steel bookend turned on its side.

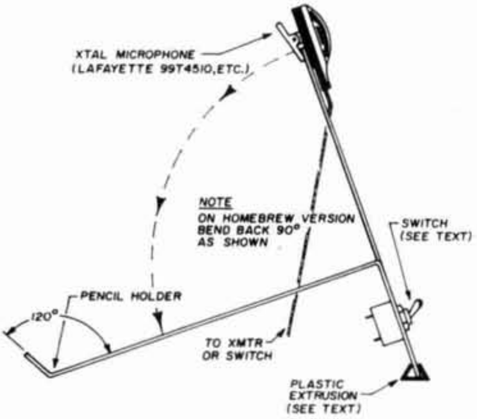


fig. 3. Simple microphone stand.

The microphone is attached to the flap of the bookend. The inexpensive, Japanese crystal mikes can be clipped directly to the flap, as they are sold with a built-in clip. Other microphones will require other means of mounting. Epoxy glue should be used if a permanent microphone and stand combination is desired.

A switch may also be installed on the stand at any convenient location. Details will depend on the type of switching desired (i.e., push-to-talk, etc.).

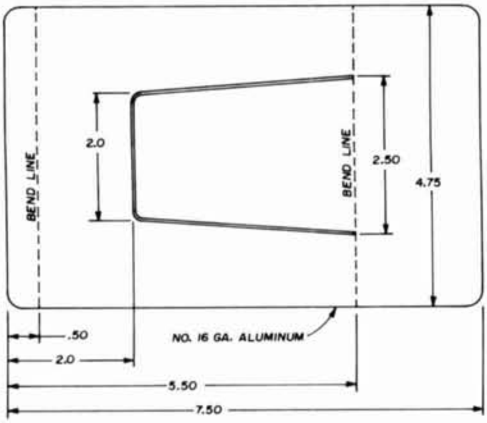
To prevent marring the surface of your operating desk, attach a rubber or plastic moulding to the bottom of the stand. A good item for this is a piece of the triangular, extruded plastic strips sold for pennies at a stationery store. This material is used for binding loose pages into a report or cata-

---

* My bookend was purchased in a book store and is made by the W. T. Rogers Company in Madison, Wisconsin.

logue. You may even want to attach a small calendar to the extrusion.

The rear end of the stand can be grooved by bending the steel as shown. This provides a handy place for pen or pencil and prevents scratches as well.



Though a bookend of the type shown* can be bought completely finished and painted for about fifty cents, for those who prefer to make one out of aluminum or steel sheet, a suggested layout is given in **fig. 3**.

**D. E. Hausman, VE3BUE**

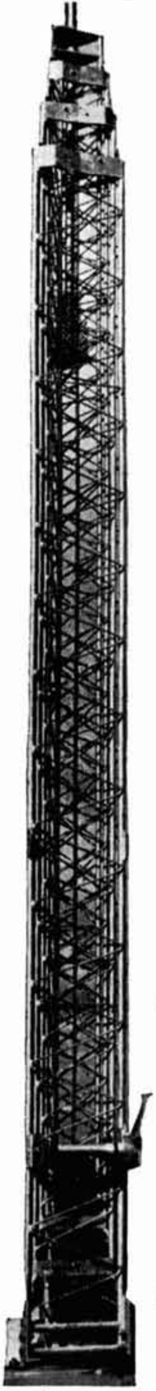
## uhf tuner tester for tv sets

Most amateurs have tv sets, so I thought this idea would appeal to **ham radio** readers. It's an adaptation of a miniature solid-state GE tuner for use as a piece of test equipment. With this tester, you can check the uhf front end of your tv set without a signal generator.

A number of surplus-type uhf tuners are available that will work nicely as signal generators. I purchased mine for $5.20 postpaid from Arcturus Electronics.*

---

* GE transistorized tuner, catalogue number GE 85 Arcturus Electronics, 502 22nd Street, Dept. HR, Union City, New Jersey 07087.



Remove the tuner from its cover by unhinging the securing wire. Note the junction of two resistors feeding the stator of the oscillator section of the tuning capacitor. Attach a one-half-inch piece of insulated wire to this junction. Drill a hole in the cover to accommodate the wire when the cover is replaced. Leave about one-eighth inch of bare wire at the other end. Replace the cover.

Connect a half-watt, 330-ohm resistor to the insulated stud. (This is the spot where the tuner instructions say to install the 15 kilohm resistor furnished.) Attach a few inches of wire to the other end of the resistor. Tape wire and resistor to the tuner case. Install the mounting bracket and nut according to tuner instructions, as well as the fine and coarse tuning knobs. Connect a 6-volt battery charger (must be unfiltered), with negative lead to the case and positive lead to the wire connected to the 330-ohm resistor.

Tune the tv set to a known uhf channel. Adjust the tuner slightly so the picture just disappears. Run a jumper from the wire emerging from the oscillator section of the tester to the uhf antenna terminals of the tv set. Apply power to the tuner, and tune until two black and two white bars appear on the tv screen. (This assumes a full wave charger or rectifier circuit.) Set the tester dial to read the same as the uhf dial on the tv set minus the offset to make the picture disappear.

This completes the tune-up and tester calibration. Other modulated 6-12 volt sources may be used, providing the transistor in the tester isn't overdriven.

**John R. Schuler**

## transistors for vhf transmitters

Amplitude modulation, although popular with hams on the vhf bands, is not popular with transistors. If you really want to know how to get high quality a-m, get copies of the RCA 40290/40292 transistor data sheets. If a particular rf power transistor is not rated for a-m use, then, "10 watts out," means 2 or 3 watts of carrier power and 10 watts on a-m peaks. For a-m operation with a 12-volt power

supply use a 28-volt transistor and modulate the last two or three stages.

For single sideband, a 10-watt rf power transistor runs 10 watts PEP—not very attractive. Since transistors heat up in thousandths of a second, they don't "average" very well. Also, there's no such thing as ICAS ratings for rf power transistors.

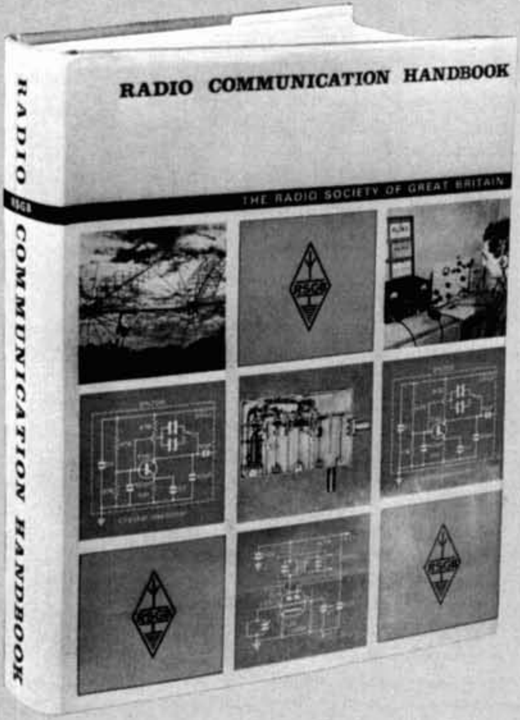
| Type | Power Output (Watts) 6M | 2M | 220 | 432 | Comment | Price |
|---|---|---|---|---|---|---|
| 40405 | 0.5 | 0.4 | 0.4 | | 12-V doubler or amplifier | $ 1.65 |
| 2N3866 | 1.6 | 1.5 | 1.3 | 1.0 | 28-V driver but good with 12-V supplies | 2.97 |
| 2N4073 | 1.0 | 0.6 | 0.3 | | 12-V driver | 2.70 |
| 40290 | 2.0* | 2.0* | | | rated for 12-V a-m | 2.48 |
| 40292 | 6.0* | 6.0* | 4.0 | | insulated collector; rated for 12-V a-m | 10.45 |
| 2N2631 | 7.5 | | | | up to 40-V, poor with 12-V supplies | 3.47 |
| 2N3553 | 8 | 5 | 3 | | TO-39 case | 4.37 |
| 2N3375 | 10 | 8 | 6 | 2.0 | insulated collector | 10.80 |
| 2N2632 | 15 | 13 | 10 | | insulated collector | 12.75 |
| 2N3733 | 20 | 20 | 15 | 8 | insulated collector | 15.80 |
| 2N5016 | | | 25 | 20 | | 43.50 |

* amplitude modulated

For fm or CW exciters, rf power transistors perform well. However, if the last stage is driven hard, it will require some sort of protection from mismatched loads—either a directional-coupler scheme or an isolator. High power rf amplifiers that are used to drive varactor frequency multipliers are especially likely to have mismatch problems.

The power gains of the transistors listed in **table 1** are comparable to commonly used vacuum tubes; net efficiencies, including circuit losses, are often greater than 70%. Those listed are ones I consider best buys in terms of results.

**Hank Cross, W1OOP**


RADIO COMMUNICATION HANDBOOK
THE RADIO SOCIETY OF GREAT BRITAIN
RADIO
RSGB
COMMUNICATION HANDBOOK

# COMDEL
# CSP-II

**$120.00**
Postpaid
U. S. & Canada

The only practical device some people* can buy that will provide an advantageous improvement to their SSB performance.

*Assuming you have the best antenna installation, maximum legal power input and the savvy to operate your rig properly. Write for literature today, or better yet send for the Comdel — Full guarantee of course.

HERBERT W. GORDON COMPANY
**Harvard, Massachusetts 01451 • Telephone 617 — 456 — 3548**
*"Helping Hams to Help Themselves"*

# flea market

■ **RATES** Commercial Ads 25¢ per word; non-commercial ads 10¢ per word payable in advance. No cash discounts or agency commissions allowed.

■ **COPY** No special layout or arrangements available. Material should be typewritten or clearly printed and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** can not check out each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue. Deadline is 15th of second preceeding month.

■ **SEND MATERIAL TO:** Flea Market, Ham Radio, Greenville, N. H. 03048.

**SALE:** Collins 30L1 $345. Motorola Hi Band Transmitter Strip. Matching 115 V supply, P. S. needs work, cases rough, inside good $10. each. Link Model 2975 hi band base floor model. Xtals for 146.94 all tubes, as is $60. LM. 10 AC Supply, book $35. Motorola 80D on 146.94 2 Freq. Xtal for .34 included. All accessories $85. Gonset recvr power supply for G77, new $10. I-199C Polar test set $16. Motorola VRC-6 Xmttr, all tubes and manual $10. K. B. Crowell, 710 Powder Mill La., Philadelphia, Pa. 19151.

**TOURS, CRUISES, AIR AND STEAMSHIP TICKETS, DX-PEDITIONS, CONVENTIONS,** everything arranged by the ham's travel agent: Barber Travel Service, 711 Cottage Grove Road, Bloomfield, Connecticut 06002. Members A.S.T.A. Ruth K1IIF, Jack W1PRT. (203)242-2279

**OCTOBER** 12th is the date of the year's big event. The Miami County ARC Hamboree Fleamarket at Fairgrounds in Troy, Ohio. Open sales from 10:00 a.m. till ? ?. Auction from 3:00 till 5:00 p.m. Table space $1.00. HW-100, TA-33JR, Drake W-4. Plus many other prizes. Donation $1.00. Held indoors rain or shine. For more info write W8FW, Box 214, Troy, Ohio 45373.

**HIGH-AMPERAGE** Low voltage 750VA Transformer 24/12 Volts 30/60 Amps from 115/230 $10.00, Nicklecad Batteries 4AH — $1.95, 8 AH $2.50. Free Catalog With Order. Arrow Sales, 2534 S. Michigan, Chicago, Illinois 60616.

**TOROIDS. 88 & 44 mhy.,** Center-tapped, not potted, 5/$2.00 POSTPAID. Model 32KSR latest page printer, excellent little used condition $200. FRXD 14 typing reperferator-TD combination $25. Deskfax #6500 facsimile transceiver $20. Brand new Clegg 66'er, original box $160. National NCX5 and NCXA like new $400. Drake 2B&2BQ $175. 11/16" reperferator tape $3/box/10. B&W 51SB sideband adapter $50. WANTED: Ham-M. Stamp for list. Van W2DLT, 302H Passaic Avenue, Stirling, N. J. 07980.

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

**THE ANNUAL HAMFEST FOR THE WASHINGTON, D.C.,** metropolitan area, sponsored by the Foundation For Amateur Radio, will be held at the Gaithersburg Fairgrounds in nearby Gaithersburg, Maryland, on Sunday the 21st of September from 1000 until 1700 hours.

**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.

**TAMPA HAMFEST** — Hillsborough Amateur Radio Society, Inc., announces its Annual Tampa Hamfest to be held October 12, 1969, at Lowry Park, Sligh Ave. & North Blvd., in Tampa, Fla. Plenty of free parking — lots of prizes.

**FOR SALE: KWM-2 #12566** (latest series), 516F-2, $850. 75A-4 (0.5 & 3.1 kcs, Noise Blanker), KWS-1 #1451, spkr, $1000. 312B-4 (latest), $140. 75S3-B #15066 (0.5, 2.1 kcs), $525. 399C-1 (VFO/spkr for KWM-2), $165. Henry 2K-2, spare 3-400-Z, $575. HT-31-A, $275. R4-A, T4X, AC-4, MS-4, $625. Swan 350, 117-XC, 14-117 DC, $400. HW-32-A, $85. HP-13, $50. Tektronix 514-D, $175. 136B-2 Noise Blanker, $70. Heath HD-15 "patch", $16. Condel CSP-11 (new), $95. Drake TV-1000-LP, $10. Collins 70E-24 VFO (75A-4), $20. Advance CB1C2C (115AC), $15; CB1C2C (115DC), $15. Powerstat, 115V/12 amp (new), $19. Power supply: 115input/1800/300 reg/105 reg, excellent, $30. Capacitors: 50 mf/3KV, $20; 15 mf/1.5KV (new), $3; 10 ea. 500 mf/310 VDC for $19. WANTED: 30S-1, 30L-1, 312B-5. James W. Craig, W1FBG, 29 Sherburne Avenue, Portsmouth, N. H. 03801. Area Code 603 436-9062.

**COMMERCIAL LICENSE EXAMS:** Second $17.50; First $25.00; Sample Questions; Price List $1.00 refundable; (C) Enterprises, 605 Imperial, Reno, Nevada 89503.

**WRL'S USED GEAR** has trial-terms-guarantee! KWM1 — $249.95; HW-32 — $89.95; Swan — $249.95; TR-3 — $369.95; NCX3 — $169.95; SB34 — $299.95; Galaxy V — $229.95; Galaxy Vmk2 — $279.95; Ranger — $99.95; HT32A — $259.95; 100V — $259.95; Galaxy 2000 linear — $329.95. Many more. Free "blue-book" list. WRL, Box 919, Council Bluffs, Iowa 51501.

**WANTED — QST'S** Last four issues needed to complete 1916. Feb., May, June, July. Any reasonable price paid. K2EEK, 75 - 15 177th St., Flushing, N. Y.

**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.

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

**DEALERS.** Do you carry R.S.G.B. publications? They are real best sellers. Interesting and well priced. For complete information write Comtec, Box 592, Amherst, N. H. 03031.

**WANTED:** Schematic diagram for Morrow "Falcon" receiver manufactured back in the a-m days. G.V.O. Johnstone, ZL1TU, 16 Main Road, RNZAF Hobsonville, Auckland, 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.

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

**SELLING OUT** — Stamp for list. W3CNS, 21 Terrace Lane, Elizabethtown, Pa. 17022.

**S-40 RECEIVER** Recently realigned, very clean, $40. W1DHZ, Box 185, Amherst, N. H. 03031. 603-673-4885.

**I NEED** the April 1968 Ham Radio magazine. Ron Clabo, WA0DWM, 6411 Knox Avenue So., Minneapolis MN 55423.

**MANUALS** — TS-323/UR, TS-173/UR, LM-18, BC-638A, SSB-100, $5.00 each. Many others. SASE brings reply. S. Consalvo, W3IHD, 4905 Roanne Drive, Washington, D. C. 20021.

**DECADE COUNTER KITS** — $13.95. Professional quality readout. Free information. Display Electronics, Dept. HR, Box 1044, Littleton, Colorado 80120.

**JOB WANTED:** Have second telegraph, Merchant Mariner's Document extra amateur. Will consider employment in or out of U. S. Roger Allen, 271 Petersham Road, Athol, Mass. 01331.

**THE ELECTRONIC MAIL ADVERTISER** published by WO Bargains Galore, is the fastest, most readable listing of electronic bargains. Twice a month, 6¢ a word when you subscribe. For a free sample send your QTH to Electronic Mail Advertiser, 1949 Van Reek Lane, St. Louis, Missouri 63131.

**RARE COUNTY ACTIVITY.** The NJDXA will operate from the "very rare" Warren County in New Jersey. Call sign: W2JT/2. Continuous operation from 1600 GMT on October 18th to 2000 GMT on October 19th. Frequencies: CW 3555, 7055, 14055, 21055, & 28055 KC. SSB 3855, 7255, 14255, 21355, & 28555 KC. QSL information: SASE to W2JT or to the "W2" QSL Bureau.

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

**THE WORLD DX ROUND TABLE** operating on 14270 KHz Wednesday and Saturday from 0500-0800 GMT.

**73 MAGAZINE — COMPLETE COLLECTION.** 1st year bound volume, rest single issues. No splitting. Complete set only. K1PSR, Box 132, Amherst, NH 03031.

**QSL'S,** 15¢, Nicholas Print, P. O. Box 11184, Phoenix, Arizona 85017.

**RTTY — TERMINAL UNIT —** Epoxy PC board page 38 June HR $10 postpaid. Cashion Electronics, Box 7307, Phoenix, Arizona 85011.

**NEW AND USED HAM GEAR** — Also surplus equip. Ham gear taken on consignment. Satellite Amateur Radio, 292 Boston Post Road, Waterford, Conn. 203-443-8841.

**QST'S WANTED:** December 1915, January to December 1916. Any unreasonable price paid! Ted Dames, 308 Hickory St., Arlington, N. J. 07032.

**SEPTEMBER 14th** Third Annual Jester Park Ham Fest. For information contact Des Moines Radio Amateur Assn., Box 88, Des Moines, Iowa 50301.

**SELL OR SWAP,** make offer. S-76, LM-10, Zenith "Transoceanic", Simpson 262, Eico 460. T. Gosman, 143 Roxton, Plainview, N. Y. 11803.

**MAGAZINES.** QST since March 1944. CQ since 1947. Sold as individual copies. What issues do you need? Write K1PSR, Box 132, Amherst, NH 03031.

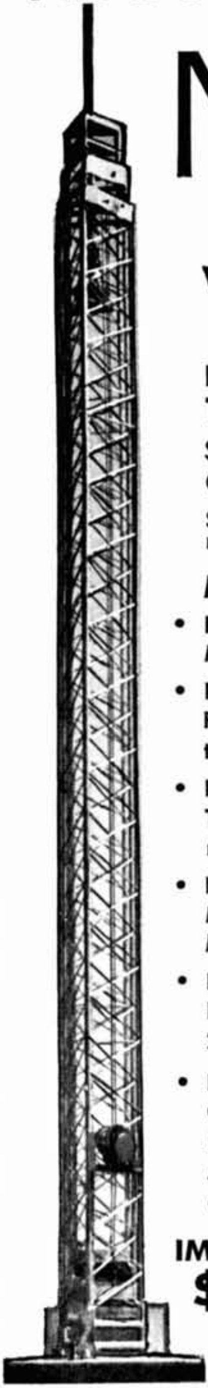
**NORTHERN CALIFORNIA** Hams: Best deals — new and reconditioned equipment. Write or stop for free estimate. The Wireless Shop, 1305 Tennessee, Vallejo, California 94590.

**NEEDED — DEC. 1945 CQ.** W1DHZ, Box 185, Amherst, NH 03031. 603-673-4885.

**DALLAS AREA HAM-SWAP FEST** — Texas Instruments Activity Center — Sunday September 14, 1969 — 9 to 5 — Prizes: Swan 350C, TH-6, plus many more — Pre-registration prize — Register now — $2/person — John Zagrodnick, 3823 Antigua Drive, Dallas, Texas, 75234.

**QSLS, QUALITY SAMPLES** 25¢ (refundable). LJ Publications, Box 982, Lynwood, CA 90262.

**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.



ABSOLUTELY NEW

**TRI-EX**

**W-51**

**FREE STANDING TOWER.**

SUPPORTS 9 SQ. FT. OF ANTENNA.

Shown with internal Ham M rotator and 2" mast.

***INCLUDES***

- **FREE: RIGID BASE MOUNT**
- **PRE-DRILLED TOP PLATE — For TB-2 thrust bearing.**
- **HIGH STRENGTH STEEL TUBING LEGS. Solid rod, "W" bracing.**
- **EASY MAINTENANCE — *No guys or house brackets needed.***
- **RISES TO 51 FT. — Nests down to 21 ft.**
- **HOT DIPPED GALVANIZED AFTER FABRICATION! All welding by certified welders.**

**IMMEDIATE DELIVERY**

**$393⁴⁰**

FREIGHT PREPAID INSIDE
CONTINENTAL U.S.A.

**Tri-Ex TOWER CORPORATION**

**7182 Rasmussen Ave., Visalia, Calif. 93277**

signal/one

HEAR IT NOW!

HARRISON RADIO CORP.
●8 Barclay St., N.Y., N.Y. 10007
●Rt. 110 at Smith St., Farmingdale,
L.I., N.Y. 11735
●139-20 Hillside Ave., Jamaica,
L.I., N.Y. 11418

NOVICE CRYSTALS

Fundamental frequencies in FT-243 holders. Pin size .093 in., spacing .486 in. Tolerance .03% measured in oscillator with 32 mmfd. capacity.

| | | |
|---|---|---|
| **80 meters** | **3705-3745 kc.** | **$1.75 ea.** |
| **40 meters** | **7155-7195 kc.** | **1.25 ea.** |
| **15 meters** | **7034-7082 kc.** | **1.25 ea.** |

Add for postage and handling per crystal: 8¢ first class; 12¢ airmail. Specify frequency desired and nearest available will be sent. Other frequencies in stock. Send for free list. Satisfaction guaranteed.

**NAT STINNETTE,** P. O. Drawer Q-1, Umatilla, Fla. 32784

**NOW, FOR THAT "*Extra Class*",**

**2 POWERFUL LINEARS**

**Built to Operate Dependably With Plenty of Reserve**

**Listen for the hundreds of LK-2000 linears now on the air and judge for yourself. Write for free illustrated brochure or send $1.00 for technical and instruction manual.**

- **Dependable Operation**
- **Rugged Eimac 3-1000Z**
- **Instant Transmit • ALC**
- **Fast Band Switching**
- **Easy Load and Tune**
- **Real Signal Impact**

**BTI LK-2000 . . . For maximum legal amateur input . . . SSB, CW, RTTY. Price . . . . $795⁰⁰**

**BTI LK-2000HD . . . For heavy duty applications such as MARS, high power RTTY and SSB. Price . . . . $895⁰⁰**

**BTI AMATEUR DIVISION**

**Hafstrom Technical Products**

**4616 Santa Fe, San Diego, Ca. 92109**

signal/one

## HEAR IT NOW!

HENRY RADIO STORES
- 11240 W. Olympic, L.A., Calif. 90064
- 931 N. Euclid, Anaheim, Calif. 92801
- Butler, Mo. 64730

## CQ de W2KUW

### BEST OFFER!!

**Paid ............. for any piece of aircraft or ground radio units, also test equipment. All types of tubes. Particularly looking for 4-250 • 4-400 • 833A • 304TL • 4CX1000A • 4CX5000A et al. 17L • 51X • 390A • ARM • GRM • GRC • UPM • URM • USM units.**

**TED DAMES CO., 308 Hickory St., Arlington, N.J. 07032**

## Radio Amateurs Reference Library of Maps and Atlas

**WORLD PREFIX MAP** — Full color, 40" x 28", shows prefixes on each country . . . DX zones, time zones, cities, cross referenced tables ........ postpaid **$1.00**

**RADIO AMATEURS GREAT CIRCLE CHART OF THE WORLD** — from the center of the United States! Full color, 30" x 25", listing Great Circle bearings in degrees for six major U.S. cities; Boston, Washington, D.C., Miami, Seattle, San Francisco & Los Angeles. .................. postpaid **$1.00**

**RADIO AMATEURS MAP OF NORTH AMERICA!** Full color, 30" x 25" — includes Central America and the Caribbean to the equator, showing call areas, zone boundaries, prefixes and time zones, FCC frequency chart, plus informative information on each of the 50 United States and other Countries .... postpaid **$1.00**

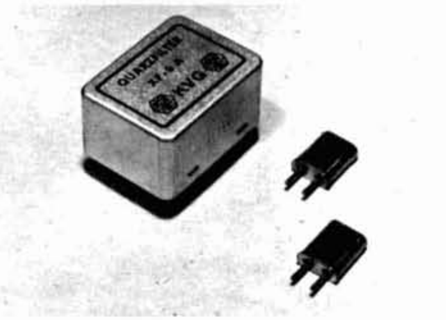
**WORLD ATLAS** — Only atlas compiled for radio amateurs. Packed with world-wide information — includes 11 maps, in 4 colors with zone boundaries and country prefixes on each map. Also includes a polar projection map of the world plus a map of the Antarctica — a complete set of maps of the world. 20 pages, size 8¾" x 12" ..................... postpaid **$2.00**

**Complete reference library of maps — set of 4 as listed above** ............................... postpaid **$3.00**

**See your favorite dealer or order direct.**

***WRITE FOR FREE BROCHURE!***

RADIO AMATEUR **callbook** INC
Dept. E. 925 Sherwood Drive
Lake Bluff, Ill. 60044



# 9MHz Crystal Filters

## by KVG of W. Germany

KVG miniaturized high performance crystal filters with symmetrical attenuation characteristics for use in AM, CW and SSB transmitters and receivers. Circuit matching is simplified by the use of input and output transformers, which are an integral part of the filters.

| Filter Type | | XF-9A | XF-9B | XF-9C | XF-9D | XF-9M |
|---|---|---|---|---|---|---|
| Application | | SSB Transm | SSB | AM | AM | CW |
| Number of Filter Crystals | | 5 | 8 | 8 | 8 | 4 |
| Bandwidth (6 db down) | | 2.5 kHz | 2.4 kHz | 3.75 kHz | 5.0 kHz | 0.5 kHz |
| Passband Ripple | | 1 db | 2 db | 2 db | 2 db | 1 db |
| Insertion Loss | | 3 db | 3.5 db | 3.5 db | 3.5 db | 5 db |
| Input Output Termination | R | 500 ohms | 500 ohms | 500 ohms | 500 ohms | 500 ohms |
| | C | 30 pF | 30 pF | 30 pF | 30 pF | 30 pF |
| Shape Factor | | (6:50 db) 1.7 | (6:60 db) 1.8 | (6:60 db) 1.8 | (6:60 db) 1.8 | (6:40 db) 2.5 |
| | | | (6:80 db) 2.2 | (6:80 db) 2.2 | (6:80 db) 2.2 | (6:60 db) 4.4 |
| Stop Band Attenuation | | 45 db | 100 db | 100 db | 100 db | 90 db |
| Price | | $19.95 | $27.50 | $29.50 | $29.50 | $20.95 |

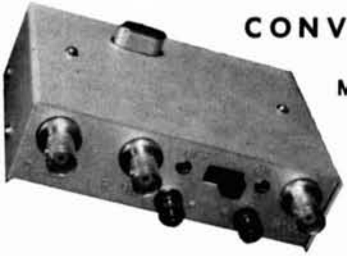
Matching HC 25/U crystals 8998.5 (USB), 8999.0 (BFO), 9000.0 (carrier), 9001.5 (LSB)
**$2.50 each**

**si**

**SPECTRUM INTERNATIONAL**
**BOX 87 TOPSFIELD**
**MASSACHUSETTS 01983**

. . . THE BEST

## 2 METER CONVERTER



**Model 407**

**$34.95**

**ppd.**

**144-146 MHz in. 28-30 MHz out or 146-148 MHz with a second crystal available for $3.95 extra**

A full description of this fantastic converter would fill this page, but you can take our word for it (or those of hundreds of satisfied users) that it's the best. The reason is simple – we use three RCA dual gate MOSFETs, one bipolar, and 3 diodes in the best circuit ever. Still not convinced? Then send for our free catalog and get the full description, plus photos and even the schematic.

Can't wait? Then send us a postal money order for $34.95 and we'll rush the 407 out to you. NOTE: The Model 407 is also available in any frequency combination up to 450 MHz (some at higher prices) as listed in our catalog. New York City and State residents add local sales tax.

## VANGUARD LABS

**Dept. R, 196-23 Jamaica Ave., Hollis, N.Y. 11423**

---

signal/one

## HEAR IT NOW!

**PIONEER-STANDARD ELECTRONICS, INC.**
**SREPCO ELECTRONICS DIVISION**
● 314 Leo St.
Dayton, Ohio 45404

**PIONEER DIVISION**
● 5403 Prospect Ave.
Cleveland, Ohio 44103

---

**Have you seen**

## THE RADIO DATA REFERENCE BOOK?

**See page 80**

---

## ANNOUNCING a PHASED VERTICAL

ANTENNA SYSTEM:

the PHASAR-40tm

BY

Worthinghamtm

**BIG GAME HUNTERS:** Don't lose your quarry in the QRM — on 40 or 15 meters the Worthingham Phasar-40 is **your** big gun!

Imagine two 34′ self-supporting aluminum radiators standing sentinel in your back yard — ready to reach out and snare that rare one. On versatile 40 meters the Phasar's high-gain bi-directional beam can be electronically rotated 90° to cover all compass points, or to null interfering foreign broadcast stations. On 15 meters, its low angle of radiation combined with narrow beam width provides superb performance on DX hunts. A remote phasing control allows instantaneous pattern selection with the turn of a switch.

The Phasar covers the entire 15 or 40 meter band with less than 2:1 SWR and negligible pattern distortion. The physical separation of the radiators (34 or 68 feet) results in diversity reception, lessening QSB.

Regardless of your game — ground wave contacts or long-haul DX — the Worthingham Phasar-40 is leading the way to new adventure in amateur radio.

**SPECIAL INTRODUCTORY PRICE: $74.95**
FOB Factory — Expires August 30
Shipping Weight: 25 pounds

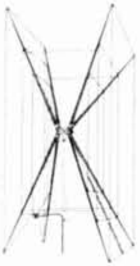
**WORTHINGHAM ELECTRONICS CO.**
**P. O. BOX 507**
**WARREN, MICHIGAN 48090**

**Dealer inquiries invited**


IC KEYER
SPEED
VOLUME
HOLD
OFF
PALOMAR ENGINEERS

GEM-QUAD FIBRE — GLASS

ANTENNA FOR 10, 15, and 20 METERS.



Two Elements $77.73
Extra Elements $45.00 ea.
Shipped Freight Collect
INCLUDES U.S. Customs Duty

**KIT COMPLETE WITH**
- **SPIDER**
- **ARMS**
- **WIRE**
- **BALUN KIT**
- **BOOM WHERE NEEDED**

*SEE OUR FULL PAGE IN JUNE ISSUE*

*Buy two elements now — a third and fourth may be added later with little effort.*

*Enjoy optimum forward gain on DX, with a maximum back to front ratio and excellent side discrimination.*

*Get a maximum structural strength with low weight, using our "Tridetic" arms.*

*MANITOBA DESIGN INSTITUTE*
*AWARD WINNER*

S/G
Structural Glass
LIMITED
20 Burnett Avenue, Winnepeg 16, Manitoba, Canada

signal/one

HEAR IT NOW!

**STELLAR INDUSTRIES**
10 Graham Road West
Ithaca, N.Y. 14850

*LIBERTY PAYS MORE!!*

WILL BUY FOR CASH — ALL TYPES
Electron Tubes · Semiconductors · Test Equipment
· Military Electronic Equipment
Wire, write, phone collect! We pay freight on all purchases!
**LIBERTY ELECTRONICS, INC.**
**548 Broadway, New York, N. Y. 10012**
**Phone: 212/925-6000**

***VHF FM MONITOR RECEIVER***

**Only**
**$69.95**
**Postpaid**
**in the U.S.A.**

NEW

100% MADE
IN U.S.A.

The new **VANGUARD FMR-150** is not just another frequency converter but a complete FM receiver with outstanding performance.

Check the following features and see why it's the best. Collins IF filter for separating those closely spaced stations you hear together on other sets · Double conversion to eliminate interference from image frequencies · Dual Gate MOSFET RF stage for low noise, .2 uv. sensitivity, and minimum cross modulation · Automatic squelch for eliminating noise · Self-contained speaker · Operates on 12 v. D.C. negative ground · Heavy gauge anodized aluminum case 6″ x 7″ x 1 3/8″ · Provision for 4 crystal controlled channels at the push of a button · One channel of your choice supplied with receiver. Additional channels available just by plugging in another crystal at $4.95 ea. No need to buy another RF unit as in some other sets · Factory tuned to cover any 6 MHz segment from 135 to 175 MHz.

**HOW TO ORDER:** The **VANGUARD FMR-150** is available only direct from our factory. Include remittance in full plus sales tax if you reside in N. Y. Be sure to state the 6 MHz segment you will want to cover and the exact push button frequencies to be included.

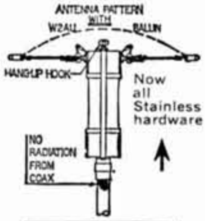
**VANGUARD LABS** **Dept. H, 196-23 Jamaica Ave., Hollis, N. Y. 11423**

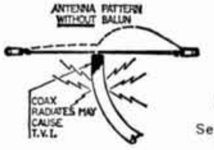
signal/one

HEAR IT NOW!

DOUGLAS ELECTRONICS
1118 South Staples
Corpus Christi, Texas 78404

W2AU BALUN LETS ENTIRE ANTENNA RADIATE!





STOP WASTING YOUR SIGNAL! REMEMBER, YOUR ANTENNA IS THE MOST IMPORTANT PIECE OF GEAR YOU OWN.

- No Radiation from Coax
- No Center Insulator Needed
- Perfect for Inverted Vees (Use Hang-up Hook)
- Built-in Lightning arrester
- Broad Band 3 to 40 mc.
- Takes Legal Power Limit and then some
- Two Models:
  1:1 50 ohm coax to 50 ohm balanced
  4:1 75 ohm coax to 300 ohm balanced
- A must for Inverted Vees, Doublets, Quads, Yagis and Multiple Dipoles.

$12.95 AMATEUR NET

See QST and May 73 for more details

| | |
|---|---|
| W2AU Complete pretuned Fiberglas Quad | $99.95 |
| W2AU Complete pretuned Vinyl Quad | $64.95 |

UNADILLA RADIATION PRODUCTS
Unadilla, N. Y. 13849 607-369-2985

REVIEWED IN MARCH, 1968 HAM RADIO

mark 2 oscillator/monitor

- makes an audible tone to monitor the RF of any CW transmitter from 10Mw to 1 Kw & 100Kc to 1000Mc, using only an 8" pickup antenna.
- can be self-triggered for code practice or the testing of solid state components and circuits.
- aids in tuning up & testing RF oscillator and power circuits.
- 4 transistor, 2 diode circuit, speaker, tone adjust, AA pencell, test leads, 8" ant., & magnetic base.
- cabinet is 16 gauge black & clear anodised aluminum, 3.4 x 2.3 x 1.2" US made & guaranteed for 1 year.

14.95 complete, ppd usa & can.
send a check or m.o.
sold by mail only

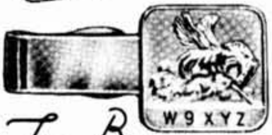
James Research company, dep't: HR-M
11 schermerhorn st., brooklyn n.y. 11201

radio amateur callbook

Radio Amateur Emblems engraved with your call letters.

Charm

☐ Gold
☐ Rhodium
call letters
$5.00 Ea.



Tie Bar

☐ Gold
☐ Rhodium
call letters
$5.00 Ea.

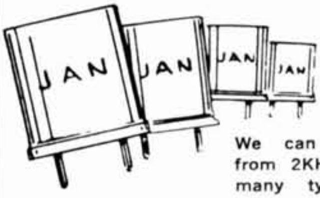
All illustrations are actual size.

Lapel Pin

☐ Gold
☐ Rhodium
call letters
$5.00 Ea.

**Rush Order To: RADIO AMATEUR CALLBOOK, Inc.**
Dept. E. 925 Sherwood Drive, Lake Bluff, Ill. 60044

NEED CRYSTALS?



48 Hr. DELIVERY

We can supply crystals from 2KHz to 80 MHz in many types of holders.

SPECIALS

| | | |
|---|---|---|
| Color TV crystal (3578, 545KHz) wire leads | $1.60 | 4 for $5.00 |
| 100KHz frequency standard crystal (HC13/U) | 4.50 | |
| 1000KHz frequency standard (HC6/U) | 3.50 | |
| Any CB crystal transmit or receive | 2.25 | |
| Any amateur band crystal (except 80 meters) | 1.50 | 4 for $5.00 |
| Any marine frequency (HC6/U) | 2.85 | |
| 80 meter crystals in FT243 holders | 2.50 | |

We have in stock over six million crystals which include types CR1A/AR, FT243, FT241, MC7, FT249, HC6/U, HC13/U, HC25/U, HC18/U, etc. Send 10¢ for our 1970 catalog with oscillator circuits, listing thousands of frequencies in stock for immediate delivery. (Add 10¢ per crystal to above prices for shipment 1st class mail, 15¢ each for air mail).

JAN CRYSTALS

Special Quantity Prices to Jobbers and Dealers.
ORDER DIRECT
with check or money order
to

2400 Crystal Drive
Fort Myers, Florida 33901

NEW!

FMT-1

5 Watt 6 Channel

All Solid State 2 Meter

FM TRANSCEIVER

12-15 Volt Operation
142-149 MHz with 1 MHz maximum spread
Receiver sensitivity .3 microvolt for 20 db quieting
Dual Conversion
Mechanical Filter for sharp 28 KHz bandwith
5 watt RF minimum power output
6 Channels - One set crystals for operation 146.34-146.94 supplied
Adjustable 5 to 15 KHz deviation

**Ready to operate - Just connect to 12 volts and an antenna**

**$289.95** FOB DENVER

— Certified Check or Money Order please —

**Including mobile mount & dynamic microphone**

**Extra transmit or receive crystals $7.00 each**

**order from**

**VHF Associates, Incorporated**
P. O. BOX 22135, DENVER, COLO. 80222

NEW!

FREQUENCY MARKER

- KEEP YOUR RECEIVER CALIBRATED
- LOCATE THOSE SUB BANDS
- READOUTS AT 5, 10, 25, 50, 100 kHz useful to 50 MHz

**SPECIFICATIONS**

**Glass epoxy board**
**Adjustment to zero beat with WWV**
**Uses 100 kHz crystal (not supplied)**
**3 to 4 VDC at approx. 75 ma — 2 "D" Size Batteries**
**Compact — 1.75 x 3.75 inches — Install Anywhere**

Complete easy-to-assemble KIT **$15.00** Wired & Tested **$18.50**

**Prices are postpaid less crystal & batteries**

**LAB 1**
**THE RADIO SHOP**
**48 ELM STREET**
**NEW CANAAN, CONN. 06840**

signal/one

HEAR IT NOW!

AMATEUR ELECTRONIC SUPPLY
4828 West Fond Du Lac Ave.
Milwaukee, Wisc. 53216

**Buy - Sell - Trade**

**MILITARY SURPLUS RECEIVERS**

R-220/URR, R-388/URR, R-390/URR, R-390A/URR, SP-600 JX-17, RBL, URR-27, URR-29.

**Military Surplus Technical Manuals**

**SLEP ELECTRONICS CO.**
2412 NORTH HIGHWAY 301 N. ELLENTON, FLORIDA 33532
PHONE (813) 722-1843

HAVE YOU READ

**The RSGB VHF-UHF Manual?**

SEE PAGE 72

REVIEWED IN DECEMBER, 1968 HAM RADIO

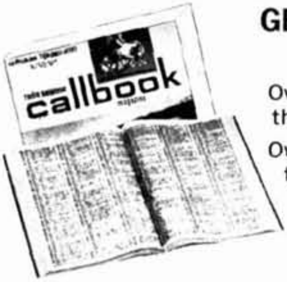
**the permaflex key**

- both a twin lever & straight hand key in a pivotless 2 paddle design.
- gives instant choice of automatic semi-automatic & straight hand keying.
- use directly with any transmitter or through an electronic keyer.
- 8 amp. gold diffused silver contacts adjust from 0-.060" & 5-50 grams.
- distinctive blue paddles are of rugged G-10 fiberglass epoxy.
- cabinet is 16 gauge polished chrome steel: 1.95" sq. x 3.75", paddles extend 1.25", weight app. 1 pound.
- silicone rubber feet for stability.
- 100% US made & guaranteed for 1 yr.

19⁹⁵ complete, ppd usa & can.
send a check or m.o.
sold by mail only

**James Research company, dep't: HR-K**
**11 schermerhorn st., brooklyn n.y. 11201**

radio amateur
**callbook**



**GET YOUR NEW ISSUES NOW!**

Over 290,000 QTHs in the U.S. edition **$6.95**

Over 140,000 QTHs in the DX edition **$4.95**

**NEW EDITION EVERY:**
**MARCH 1 — SEPT. 1**
**JUNE 1 — DEC. 1**

These valuable EXTRA features included in both editions!

- **QSL Managers Around the World!**
- **Census of Radio Amateurs throughout the world!**
- **Radio Amateurs' License Class!**
- **World Prefix Map!**
- **International Radio Amateur Prefixes**
- **Radio Amateurs' Prefixes by Countries!**
- **A.R.R.L. Phonetic Alphabet!**
- **Where To Buy!**
- **Great Circle Bearings!**
- **International Postal Information!**
- **Plus much more!**

See your favorite dealer or order direct (add 25¢ for mailing in U.S., Possessions & Canada. Elsewhere add 50¢).

**WRITE FOR FREE BROCHURE!**

RADIO AMATEUR **callbook** INC.
Dept. E. 925 Sherwood Drive
Lake Bluff, Ill. 60044

*signal/one*

**HEAR IT NOW!**

**DAKOTA SUPPLY COMPANY**
P.O. Box 57
8th and Walnut Sts.
*Yankton, South Dakota 57078*

**ZENERS**

**ALL DEVICES TESTED AND GUARANTEED**

**400 MILLIWATT UNITS**

3 3.3 3.6 3.9 4.3 4.7 5.1 5.6 6.2 6.8 7.5 8.2 9.1 10 11 12 13 15 16 18 20 22 24 27 VOLTS

**1 WATT-UNITS**

20 22 24 27 30 33 36 39 43 47 51 56 62 68 75 82 91 100 110 120 130 150 160 180 200 VOLTS

**PRICE: ALL UNITS 10% 4 for $1.00 ppd.**
**5% 3 for $1.00 ppd.**
**PA. RESIDENTS ADD 6% PA. SALES TAX**

**M. WEINSCHENKER K3DPJ**
**PO Box 353 · Irwin, Pa. 15642**

KEEP UP TO DATE ON YOUR DXING

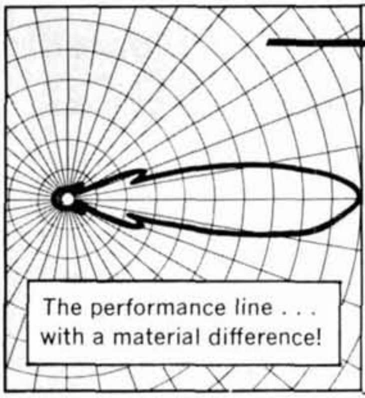
A weekly magazine (16 to 24 pages each week.

Current DX that's on the air, and info about what's planned for the immediate future. What's being heard by the boys. Etc.

FULL DX INFO EVERY WEEK.

Per year—*Surface mail* (they say most 1st class mail actually goes via air) $11.00

**The DXERS Magazine, (W4BPD)**
**Route 1, Box 161-A,**
**Cordova, S.C. 29039**



The performance line . . . with a material difference!

**telrex**

**PREFERRED AND SPECIFIED WORLD-WIDE BY COMMUNICATION ENGINEERS AND ADVANCED AMATEURS**

Don't settle for anything less than the very best! Use Telrex Communication products — for long lasting optimum performance and value!

**FREE** . . . Tech data and pricing catalogs describing off-the-shelf and custom-built antennas, systems, "Inverted-vee kits"®, towers, mono-poles and rotable "Berthas".

For commercial and military applications write for CM69 . . . for amateur applications write for PL69.

COMMUNICATION SYSTEMS SINCE 1921 **telrex** *Communication Engineering Laboratories*

ASBURY PARK,
NEW JERSEY 07712, U.S.A.

signal/one

HEAR IT NOW!

AMRAD SUPPLY, INC.
● 3425 Balboa St.
San Francisco, Calif. 94121
● 1025 Harrison St.
Oakland, Calif. 94607

Have you read
THE WORLD
AT THEIR FINGERTIPS?
See page 80

LET US DO
YOUR QSLing

**We supply the QSLs — make out your QSLs — deliver your QSLs — all for the amazing price of 8¢ each.**

This is how it works: On request we will send you free, a copy of our special log form, in duplicate. When you complete the first page of log you mark stations you wish to QSL to, send us copy of log, two copies of your QSL, and an order, paid in advance, for a minumum of 200 QSLs for $16.00 or the bargain rate of 1000 QSLs for $75.00. We print QSLs similar to yours, one side, two colors, and hold them for you. We transfer data, in your handwriting, from completed pages of your log to your QSLs, and mail to destination (any place in world), and send you additional log sheets.

WORLD QSL BUREAU
5200 Panama Ave.
Richmond, Calif. U.S.A. 94804

**PS: If you insist on the old fashioned way of supplying and filling out your own QSLs we will forward them for you to any place in the world for 4¢ each.**

REGUL. PWR SPLY FOR COMMAND, LM, ETC.:

PP-106/U: Metered. Knob-adjustable 90-270 v up to 80 ma dc; also select an AC of 6.3 v 5A, or 12.6 v 2 1/2 A or 28 v 2 1/2 A. With mating output plug & all tech. data. Shpg wt 50# ...... 19.50

BARGAINS WHICH THE ABOVE WILL POWER:

| | |
|---|---|
| LM-(*) Freq. Meter: .125-20 MHz, .01%, CW or AM, with serial-matched calib. book, tech data, mating plug. Checked & grtd. | 57.50 |
| TS-323 Freq. Meter: Similar to above but 20-480 MHz, .001%. With data | 169.50 |
| TS-175 Freq. Meter: 85-1000 MHz | 75.00 |
| A.R.C. R11A: Modern Q-5'er 190-550 KHz | 12.95 |
| A.R.C. R22: 540-1600 KHz w/tuning graph | 17.95 |
| A.R.C. R13B: 108-132 MHz w/tuning graph | 27.50 |

HI-SENSITIVITY UHF RECEIVER:

375-1000 MHz. Stoddart RFI Meter NM-50A with pwr sply, cords, dipole holder, 3 pair dipoles. Input 50 ohms. IF 60 MHz. Bandwidth 1 MHz at 370 and 1.8 at 1 ghz RF. Image & spurious-response reject. better than 40 db. Sensit. as a 2-terminal tuned voltmeter is 10 uv; will be less with 1-pair dipole, but you can make an array to bring it up. If the voltage-attenuation calib. charts didn't get lost it would be worth $1250 in surplus, $2852 from the factory . . . so we will sell it as a simple receiver in grtd-excel. condition for only ... 275.00

ULTRA-WIDE-BAND RECEIVER:

AN/ALR-5: Late postwar AM/FM Countermeasures rcvr. Has S-Meter; variable IF Atten. & passband (0.2 or 2 MHz from 30 MHz center); AF. Video & Pan. outputs. New, modified for 120 v 60 Hz. Includes new (Method II pack) 4-band plug-in converter .038-1 GHz. 4 Type-N plugs automatically select correct ant. as bands are switched. Sensit. at -6 db setting: 6 1/2 uv thru 132 MHz. 13 thru 780 MHz & 45 1/2 at 1 GHz. BRAND NEW, with book & mating pwr-input plug, only 275.00

Versatile Plate & Filam. Transformer:

Depot Spares for SP-600-JX: Pri. 95/105/117/130/190/210/234/260 v 50/60 Hz. Sec. 1: 305-0-305 v, 150 ma. Sec. 2: 5 v 3A. Sec. 3: 6.3 v 5 A. Sec. 4: 7 1/2 v, 3/4 A. Sec. 5: 7 1/2 v, 1 1/4 A. Legend for pins is plainly marked. Herm. sealed.. 2.95

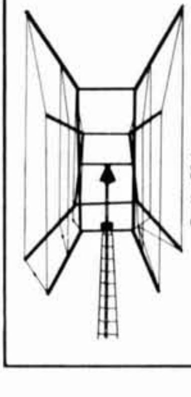
FOUND! A NEAT & COMPACT SCOPE XFRMR!

Freed 12691: DAS Loran Spares, supplied 5" CR, plates & htrs. Pri. 105-130v 50/60Hz. Sec's insul. 5 kv: 1490 & 1100 v, 5 ma; 390-0-390 v 100 ma; electrostatically-shielded 6.3 v, 0.8 A; two 2 1/2 v, 2 A. Sec's insul. 1 1/2 kv: two 6.3 v, 6 A; 5 v, 3 A; 2 1/2 v, 5A. Case 5 1/4 x 5 x 7 1/4. With diagram. Shipped only by collect REA Express. ...... 2.95

FAIRCHILD SOLID-STATE SCOPES all w/dual-trace plug-ins 25 & 50 MHz, w/delayed time-base plug-ins, w/books, overhauled & grtd. As low as 825.00

WE PROBABLY HAVE THE BEST INVENTORY OF GOOD LAB TEST EQUIPMENT IN THE COUNTRY, BUT PLEASE DO NOT ASK FOR CATALOG! ASK FOR SPECIFIC ITEMS OR KINDS OF ITEMS YOU NEED! WE ALSO BUY! WHAT DO YOU HAVE?

R. E. GOODHEART CO. INC.
Box 1220-HR, Beverly Hills, Calif. 90213



2 Element
QUAD
FOR 10 - 15 - 20

The POPULAR 2 element Joga Quad for 10-15-20 now distributed state side for your convenience. Write for further information to:

GUARANTEE RADIO SUPPLY CORPORATION
1314 Iturbide St., Laredo, Texas Phone RA 3-6913
TEXAS TECHNICAL PRODUCTS
Route 2, Box 324-D . San Antonio, Texas 78228
Phone (512) 695-8430

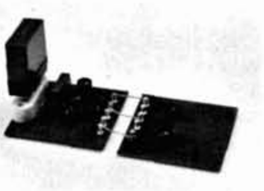
PRODUCTOS JOGA
CALLE 50 X 45 NUM. 431
MERIDA, YUC., MEX.

## CRYSTAL CALIBRATOR
## 100 KC to 25 KC

**K100C-2** 100 KC CRYSTAL CALIBRATOR. First P. C. board kit contains components for 100 KC *output*. The output of this little unit is really very stable, ± .005% or better at 100 KC. Voltage requirement is 4.5V DC (3 — 1½ V flashlight batt.). Complete with crystal, integrated circuits and all components.
ONLY $4.95

**K100C-2A** Contains two P. C. boards with components of Kit No. 1 and has additional components to deliver outputs of 50 KC & 25 KC band edge markers. Complete Kit K100C-2A will deliver stable harmonic-rich outputs of 100 KC, 50 KC, and 25 KC band edge markers. Units deliver a square wave which gives useful harmonics up to 50 MC.
ONLY $7.95

ASSEMBLE IN 5 MINUTES



**UTC-S20 TRANSFORMER** 55 watts Universal *modulation complete with connection chart.* ........ $3.49

12 V 5 A. w/Breaker ........ $3.00

**88 MH TOROIDS** ........ **10 / $3.75**

**1000 PIV 1½ Amp. EPOXY DIODES**
**10 / $3.75**

**BUTTERFLY OSCILLATOR CAPACITOR**
*135 to 485 MC* ........ $4.95 Ea.

**COPPER P.C. BOARDS**

| | | |
|---|---|---|
| R & R DOZEN (13) for PRICE of twelve. | 2″ x 2″ | 15¢ ea. |
| | 3″ x 6″ | 35¢ ea. |
| | 4″ x 6″ | 45¢ ea. |
| | 12″ x 12″ | $2.25 ea. |
| ETCHING SOLUTION | | 99¢ Pt. |
| RESIST PAINT | | 75¢ Bt. |

## INTEGRATED CIRCUITS

New straight from factory Fairchild I.C.'s UL 914 with 30 projects. Diagrams 80¢ ea., 10/$7.50 100/$65.00

UL 923 J.K. flip flop with spec. sheet. *$1.50 ea.* *10/$13.50* 100/$110.00

## STEREO HEADPHONES

High fidelity stereophonic headphone model SH-1 freq. range 25-15,000 C/S 8-16 ohm weight 350 gr. Retail price of these beauties ........ $12.95
R & R price new ........ $6.95

## Two Locations

**R & R ELECTRONICS**
**311 EAST SOUTH ST.**
**INDIANAPOLIS, IND.**
**46225**
**R & R ELECTRONICS**
**1953 S. Yellowsprings**
**SPRINGFIELD, OHIO**
**45506**

Please refer all mail order to Ohio store.

---

*signal/one*

# HEAR IT NOW!

**AMATEUR-WHOLESALE ELECTRONICS**
280 Aragon Ave.
Coral Gables, Fla. 33134

---

ELECTRONIC MAIL ADVERTISER

**published by W ø Bargains Galore, is the fastest, most readable listing of electronic bargains. Twice a month, 7¢ a word, based on 2 insertions. For a free sample send your QTH to ELECTRONIC MAIL ADVERTISER, 1949 Van Reek Lane, St. Louis, Mo. 63131.**

---

*Don't Forget!*

**HAM RADIO BINDERS** **$3.95**

**HAM RADIO BOUND VOLUMES**
**Volume 1, 1968** **$14.95**

**Order from**
**HAM RADIO MAGAZINE**
**GREENVILLE, N. H. 03048**

signal/one

HEAR IT NOW!

ELECTRONIC DISTRIBUTORS, INC.
1960 Peck St.
Muskegon, Mich. 49441

WE PAY **HIGHEST**
PRICES FOR ELECTRON
TUBES AND SEMICONDUCTORS

H & L ASSOCIATES
ELIZABETHPORT INDUSTRIAL PARK
ELIZABETH, NEW JERSEY 07206
(201) 351-4200

ALL BAND TRAP ANTENNA !

**Reduces Interference and Noise on ALL Makes Short Wave Receivers. Makes World-Wide Reception Stronger.** Complete with 96 ft. 72 ohm feedline. Sealed resonant traps. For **novice and class radio amateurs!** Eliminates 5 separate antennas with better performance guaranteed. 80-40-20-10 meter bands. Complete 102 ft. **$19.95.** 40-20-15-10 meter bands. 54 ft. (best for world wide short wave reception) **$18.95. Send only $3.00** (cash, ck., mo) and pay postman balance COD plus postage on arrival or send full price for postpaid delivery. Complete instructions included!

**For ALL Amateur Transmitters. Guaranteed for 1000 Watts Power. Light, Neat, Weatherproof.**

**WESTERN ELECTRONICS . Dept. B . Kearney, Nebr. 68847**

MIDLAND
SWR AND
POWER
METER

Reads output and reflected power simultaneously. May be left in line up to 2000 watts. Low insertion loss. Size 5x2x2. Good to 175 Mhz. **PRICE $15.95, FOB HOUSTON.**

**MADISON ELECTRONICS SUPPLY**
**1508 McKINNEY — HOUSTON, TEXAS 77002**
**(713) 224-2668**

**ARROW** IS ON THE MOVE TO NEW QUARTERS

LISTED ARE SOME OPENING SPECIALS — THIS MONTH ONLY!

| | |
|---|---|
| **R-105/ARR 15** — Collins receiver — with tubes | Exc. $54.50 |
| **R11/ARC 12** — Q-5'er — 190 to 550 kc receiver. Exc. cond. with 6 tubes | $8.75 |
| **ART 13** — Transmitter, less tubes | $24.50 |
| **HI-AMPS — LO-VOLTS.** Transf. 12 and 24 volts @ 60 and 30 amps from 115 or 230 60 cycles | $10.00 |
| or 16 and 32 volts @ 34 and 17 amps from 115 or 230 | $14.95 |
| (either of above weighs 19 lbs.) | |
| **NICKLECAD BATTERIES** | |
| 4 AH — New w/vent cap. | $1.95 |
| 4 AH — Used | $1.59 |
| 8 AH w/ vent cap. | $2.95 |
| **TS 146** — "X" Band Test Set — with tubes | $18.75 |
| **TS 147D** — "X" Band Generator as low as with tubes | $29.95 |
| **CRT 3** — Dual Channel Gibson Girl Transmitter | $20.00 |
| **IP 274/ALA10** Panadapter with tubes | $14.95 |

| | | |
|---|---|---|
| **RTTY** — 255 Polar relay | | $2.95 |
| Socket | | $1.25 |
| **CV 89/URA8** — Converter sub-assembly (discriminator) | | $39.95 |
| **GH-1203-2H (W2EWL)** Lionel Transformer | 98¢ each, 10 for | $7.50 |
| **HS 33** — Headphones, Lo-Imp. | NEW | $5.95 |
| **HS 23** — Headphones, Hi-Imp. | NEW | $5.95 |
| **RS 38A** — Aircraft Mike | NEW | $6.95 |
| **T17D** — Aircraft Mike | NEW | $6.95 |
| **LM** — Navy Freq. Meter | | |
| with book | Exc. | $49.95 |
| less book | Exc. | $24.95 |
| **I-81** — Azimuth Indicator | | $2.95 |
| **Mystery** Test Oscillator complete with — 0-1 MA 2½" Weston meter, 3 crystals, 6 tubes cavity — IN21, switches, etc. etc | | $5.95 |
| **BLOWER** — Squirl-cage low voltage AC or DC | NEW | $2.95 |

**If you don't already have our Catalog #145 we'll send one along with your order for the asking.**

Our New Address

**ARROW SALES — CHICAGO, INC.**

2508 S. MICHIGAN AVENUE · CHICAGO, ILLINOIS 60616

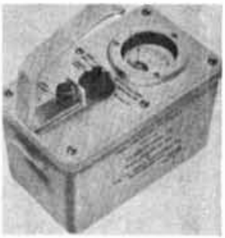
### DUAL TRANSISTOR IGNITION SYSTEM

This system was made by Canadian Tire to sell for $35.00. These are Brand New fully wired surplus, not rejects. The extra high voltage coil provides smoother running at high speeds and longer plug life, and the lower current through the points makes for longer point life and faster winter starts. Special connector allows instant change over to conventional ignition. Fully Guaranteed, with instructions ready to install for 6 or 12 volt negative ground car. CLOSE OUT SPECIAL
**DTI** .......... **$10.00 p.p.**

### POOR MAN'S HI FI HEADPHONES

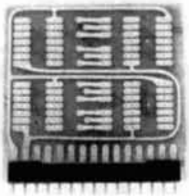
The Canadian Air Force has surplus also and we were fortunate to obtain over 500 headsets from them and are passing the savings on to you. They are unused and in the original cartons. The headphone elements are actually miniature speakers, as pictured, and this is the way Hi-Fi phones are constructed. Will give excellent fidelity with either voice or music. They have rubber pads with chamois-type covering, metal headband, cord and plug. 4 to 16 ohm impedance for use with any radio or TV, etc., by attaching to the speaker leads. May be converted to "stereo" by making connections at each ear phone. This is a real bargain for quality RCAF head sets.
**RCAF HP** .......... **$3.00 p.p.**

### GEIGER COUNTER - GOV'T SURPLUS



"CD" Type Radiation Survey Detectors are in like new condition, with instruction manual, and straps. Picture shows typical unit. Bright yellow plastic case, waterproofed. Meter readings may be made from 0.01r/hr to 50r/hr. Units are clean and are offered untested as is at a low price of $10.00 less batteries, battery price about $1.50. With life of 400 hrs. or intermittent operation.
CD MD. No. 710 GC 710 .......... **$10.00 p.p.**

### UNIVERSAL LOGIC CIRCUIT CARDS



Instant
logic!-!-!
for
10 pin
TO-5
or
14 lead
dual
in-line

INTEGRATED CIRCUITS

These boards are the most useful items we have ever offered for breadboarding with low cost integrated circuits. The cards are made from 1/16" G-10 Glass Epoxy, with pads for 14 lead dual in-line mounting pads on one side and 10 lead TO-5 pads on the other. 8 lead TO-5 cans will mount in the 10 lead TO-5 pads also. Discrete Transistors and components can be mounted in the locations between the I.C.'s, power supply leads are already routed around the board. Our competitors charge $9.50 each for circuit card and mating connector. We give you a surplus, unused p.c. board with components on it (that you can keep for your junk box), a connector and its mate, and our great circuit card. You drill out the desired hole pattern, unsolder the connector from the surplus card and install it on the new card, wire in the I.C.'s and compute. A few minutes of your time, and you save over 80% of the cost of comparable p.c. cards. Get enough for your breadboarding needs now because these are going to go fast.

| | | |
|---|---|---|
| **2 Cards & mating connectors** | **2 ICCC** | **$ 2.50 p.p.** |
| **10 Cards & mating connectors** | **10 ICCC** | **$10.00 p.p.** |
| **100 Cards & mating connectors** | **100 ICCC** | **$88.00 p.p.** |

### MAGNETIC MEMORY DRUM

This Memory drum originally cost the government over $6400.00, and is a truly fantastic piece of equipment. It was made by Hughes Aircraft Co. as part of an aircraft computer. The unit is completely sealed and therefore the drum surface is in excellent condition. It has 146 heads mounted in 11 columns, 12 are phase adjustable timing heads, the drive motor requires 115 VAC 400 cycle(Hz) 150 VA, and has a speed of 800 RPM. Sh. Wt. 50#.
**MMD-59** .......... **$100.00**

**SEND 25¢ FOR OUR LATEST, BEST CATALOG YET, JAM PACKED WITH ELECTRONIC BARGAINS . . . FREE WITH AN ORDER . . .**

**BF Enterprises**

P. O. BOX 44, HATHORNE, MASS. 01937

## LOW PRICE, QUALITY, COAXIAL SWITCHES . . .

Don't pay for the 5th and 6th position. The average HAM rarely uses more than 4!

SPECIFICATIONS: Silvered Contacts. Write-on ERASABLE escutcheon plate. AVAILABLE EITHER 4 PST (COAX-9) OR LINEAR (COAX-LINEAR) IN-OUT VERSION. Handles 1000 W AM or 2000 W SSB. Insertion loss negligible to 160 Mc. VSWR: Less than 1.2 at 160 Mc. Size: 3⅜" dia. x 1⅝" overall. Single hole mount. SPECIFY MODEL. $7.65 ea.

## COAXIAL LIGHTNING ARRESTORS

Zero power loss. No increase in SWR at 150 Mc. Does not alternate signals. Model 210 for 1000 W (AM) or 2000 W (SSB). Model 211 Electronic static arrestor for 50 W (AM) or 100 W (SSB). SO-239 UHF type fittings. Other fittings available. Size approx. 3½" x ¾" dia. #210 $3.15 ea. #211 $4.65 ea. SPECIFY model #.

PRICES above are amateur net. Shipped ppd. in U.S.A. Send Check or M.O. (N.J. ADD 3% Sales Tax)

OTHER PRODUCTS: Feed thru capacitors. Tuned noise filters. Alternator, generator, low-pass and field filters. SEND FOR CATALOG.

**"COMMUNICATION ENGINEERED"**
By "HAMMIE" RICHARDT—W2WIY

**ELECTRONIC APPLICATIONS CO.**
ROUTE 46, Pine Brook, N. J. 07058

---

## "ARCTURUS" SALE

1700 transistor types at 39¢ each.

40 watt germanium power transistor, same as Delco 501, 2N278 (etc), Cat: 349, 59¢ each.

Color TV cartridge focus rectifier *6.5 kv. Used in every color TV. Cat: CFR-20, 79¢ each.

Motorola 2500 ma. at 1000 piv, high voltage/current epoxy silicon rectifier, axial leads. Cat: HEP-170, 49¢ each.

2 Printed circuit I.F. transformers, 4 lug, 455 kc input and output, Cat: 1909P4, 99¢ each.

RCA UHF transistor type TV tuners, KRK-120 (long-shaft) Cat: UHF-20; KRK-120 (short-shaft) Cat: UHF-21, each $4.98.

RCA VHF transistor type TV tuners, KRK-146; Cat: VHF-74, $9.99 each.

Transistorized UHF tuners used in 1965 to 1967 TV sets made by Admiral, RCA, Motorola, etc. Removable gearing may vary from one make to another. Need only 12 volts dc to function. No filament voltage needed. Easy replacement units. Cat: UHF-567, $4.95.

UHF tuner original units as used in TV sets such as RCA, Admiral, etc., covering channels 14 through 82, as part no. 94D173-2. Complete with tube. Drive gearing is removable. Can be used in most sets. Cat: UHF-3, $4.95.

Color yokes. 70° for all around color CRT's. Cat: XRC 70, $12.95. 90° for all rectangular 19 to 25" color CRT's, Cat: XRC-90, $12.95

Kit of 30 tested germanium diodes, Cat: 100, 99¢

Silicon rectifier, octal based replacement for 5AS4-5AW4-5U4-5Y3-5T4-5V4-5Z4. With diagram, Cat: Rect-1, 99¢ each.

7", 90° TV bench test picture tube with adapter. No ion trap needed, Cat: 7BP7, $7.99

Tube cartons 6AU6 etc., size, $2.15 per 100. 6SN7 etc., size $2.55 per 100. 5U4GB size $2.95 per 100. 5U4G size $.04 each.

Send for complete free catalog. Include 4% of dollar value of order for postage. $5 MINIMUM ORDER. Canadian check, 8% dollar differential.

**ARCTURUS ELECTRONICS CORP.**
502-22nd St., Union City, N.J. 07087 Dept. HR
Phone: 201-UN 4-5568

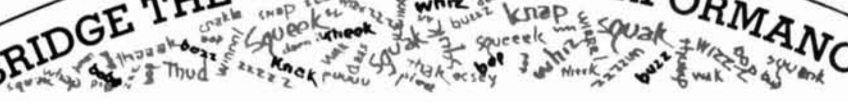
---

**WE PAY CASH FOR TUBES**

**LEWISPAUL ELECTRONICS INC.**
303 W. Crescent Avenue
Allendale, New Jersey 07401

---

## BRIDGE THE GAP TO PEAK PERFORMANCE



. . . . through either of these antenna noise bridge units, which provide accurate and fast testing of antennas and feed lines at a reasonable cost.

**Model TE 7-01**
- Antenna Noise Bridge
- Range — 1 to 100 MHz
- RCA Tip Jacks
- Resistance Testing: 0 — 100 ohms

**$24.95**

**Model TE 7-02**
- Extended Range Antenna Noise Bridge
- Range — 1 to 300 MHz
- BNC Connectors
- Resistance Testing — 0 to infinity, calibrated 25-100 ohms

**$34.95**

**Features Applicable to Both Models:**
- Test antenna for both resonant frequency and impedance.
- Replace VSWR bridges or other antenna test equipment.
- Optimum performance through alignment and test of mobile or fixed station antennas.
- Test beams, whips, dipoles, quads, or complete tuner systems.

*Applications data and operating instructions included. For descriptive literature write:*

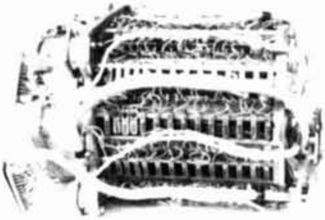
*omega-t systems incorporated*

300 TERRACE VILLAGE · RICHARDSON, TEXAS 75080
(214) 231-5121

## WIRELESS ELECTRONIC TACH $20

Portable transistorized, wireless (no connections required). May be used on 2 or 4 cycle engines, 1-2-4-6 or 8 cylinder, outboards, marine, autos, trucks. 2 scales, 6,000 & 12,000 rpm.

## $6,400.00 MEMORY DRUM



Military surplus made by HUGHES for the AF. Condition appears excellent due to being enclosed in air tight aluminum case with terminations on plug connections. 134 read/write heads, 12 phase adjustable timing heads. Integral drive motor 115 volts 400 cycle AC.

Shipping wgt. 39 lbs. #DRUM **$100.00**

## INTEGRATED CIRCUITS

| | | |
|---|---|---|
| 900 | Buffer | $1.00 |
| 910 | Dual 2-input NOR | 1.00 |
| 2-903 | Dual input gate | 1.00 |
| 914 | Dual 2-input gate | 1.00 |
| 914-925 | Dual 2-input gate dual expander | 1.00 |
| 923 | JK flip flop | 1.00 |
| 925 | Dual 2-input gate exp. | 1.00 |
| 946 | DTL 4 2-input NAND/NOR gate | 2/1.00 |
| DTL | Clocked flip flop | 2/1.00 |
| 1M5 | Dual 4-input logic gate | 2/1.00 |
| 7M6 | 6 NPN transistors in one package, gen. use | 3/1.00 |
| 12M2 | Diff. Amp | 1.00 |
| 711 | Dual Comp Amp | 2.00 |

# JOHN MESHNA JR.

19 ALLERTON ST., LYNN, MASS. 01904
P. O. BOX 62, E. LYNN, MASS. 01904

## COMPUTER GRADE CAPS

| | | | |
|---|---|---|---|
| 15 volt | 110,000 mfd | $2.00 ea. | 12/$20 |
| 18 volt | 6,500 mfd | 1.00 ea. | 12/$10 |
| 50 volt | 4,000 mfd | 1.00 ea. | 12/$10 |
| 450 volt | 600 mfd | 2.00 ea. | 12/$20 |

## VARIABLE DISC TRIMMER

Miniature ceramic variable trimmer capacitor. Piston type tuning, size .375 diam, .275 deep. Printed circuit mount. Amateur net on this is $1.68 each. Our price only 25¢ each or 24 for $5.00. All are brand new. State size, may be assorted if you wish.

#N300 2.5-11 pf
#NPO 5.5-18 pf
#N650 9-35 pf

## 0.5 MFD 7,500 VOLT

Brand new Military surplus oil filled transmitting cap. Ceramic standoffs.

5 lbs. #69-210 **$5.00**

## H. V. CAPACITOR

GE oil filled capacitor. A real brute, rated 1 mfd at 15,000 volts. Terrific savings due to being Govt. surplus.

30 lbs. #69-63 **$10.00**

## "IF" TRANSFORMERS

262.5KHz tube, Miller type 6572
262.5KHz transistor, Miller type 8008
10.7MHz tube, Miller type 1463
10.7MHz transistor, Miller type FM-IF

The above 6/$1.00 36/$5.00

# AdverTiSers iNdeX

# A
# DIFFERENT
# *KIND OF TOWER!*

To one not familiar with the products of the Heights Manufacturing Co. this may sound like little but sales talk. A look at these most interesting towers, however, will quickly dispel any notion that the Heights Tower is like any other and will clearly demonstrate that here is a product which offers some unique and very desirable features.

These towers are constructed of aluminum, thus, offering a lightweight, maintenance free design. Like most of the antennas you might put on these towers they never need painting or any similar type of protection. This means that your investment is far better protected. A Heights Tower will look like new many years after installation.

This lightweight design makes these towers much easier to handle With the Heights fold over design one man can easily raise and lower a complete tower including the antennas by himself. And he can do all of this standing on the ground. There is no need to climb a Heights Tower (or to have to hire someone to do it for you). This makes it much easier for you to adjust or repair existing antennas or to install a new one. In fact, one man can make the complete tower installation by himself.

The Heights Tower has been designed to be used without any wires or other supports. Thus, you can eliminate many of the problems normally encountered in this area and at the same time further speed and simplify your tower installation.

Many sizes of these towers are available for heights up to 120 feet and for wind loadings as great as 26 square feet at 80 M.P.H. Accessories are also available to permit their use in a maximum variety of installations.

We stock several designs of these wonderful towers and are able to provide delivery of other models in a very short time. Write for a complete catalog on these excellent products or better yet let us quote on one of these fine towers for your antenna installation.

**HERBERT W. GORDON COMPANY**
**Harvard, Massachusetts 01451 • Telephone 617 — 456 — 3548**

***"Helping Hams to Help Themselves"***


MODEL PT PREAMPLIFIER
AMECO
POWER
OFF
GAIN
TUNING
OUT
PREAMP
AN AEROTRON PRODUCT


GSB-201