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JUNE 1970

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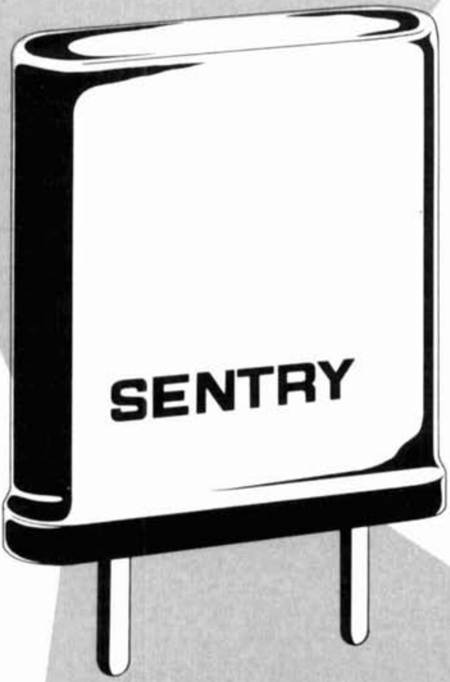
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june 1970
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ham radio magazine is
published monthly by
Communications Technology Inc.
Greenville, New Hampshire 03048

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

Foreign subscription agents:
United Kingdom:
Radio Society of Great Britain,
35 Doughty Street, London WC1, England.

All European countries:
Eskil Persson, SM5CJP, Frotunagrand 1,
19400 Upplands Vasby, Sweden.

Printed by Wellesley Press, Inc.
Wellesley, Massachusetts 02181, U.S.A.

ham radio is available to the blind
and physically handicapped on magnetic tape
from Science for the Blind,
221 Rock Hill Road, Bala Cynwyd,
Pennsylvania 19440.
Microfilm copies of current
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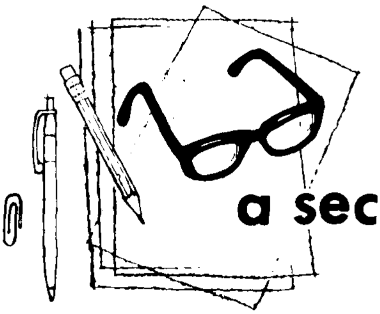

a second look

by jim fisk

Perhaps you've noticed the articles in the national news media aimed at educating the lay public about the electronic computer and its impact on modern society. Some of these news items are well done and reflect the responsibility of the reporter. Others, while leaving something to be desired in authenticity, nevertheless provide some amusing reading. An example of the former is the extensive coverage given to the Apollo 12 lunar landing module navigational computer and its vital role in the success of the mission. These reports did a pretty good job of informing the public about a complex subject in a nontechnical manner. On the other hand, articles in the same publication described the computer as some kind of electronic monster bent on invading personal privacy and generally disrupting the status quo of the credit consumer and taxpayer (i.e., you and me).

Regardless of what the public is led to believe in the national news media, the fact remains that the computer and the vast industry behind it are a solid part of the American scene and will be around for awhile.

A casual glance at the electronic industry trade journals will give an idea of how rapidly computer technology is changing. The intense competition for new markets has resulted in innovations, new devices, higher speeds, and more efficient circuits.

An area of computer innovation not generally known to the public is interactive computer graphics. Simply stated, the technique consists of using hardware designed to enable the engineer to communicate directly with the computer. In a typical application, the engineer watches the problem on a crt screen as the solution is being developed. He can communicate directly with the computer through a light pen and a typewriter. The typewriter allows him to carry on a conversation directly with the computer; he uses it to respond to cues displayed on the crt screen. The light pen, which is a pencil-shaped bundle of fiber optics coupled to the crt, allows the engineer to precisely place lines or circles of desired dimensions on the crt screen, create new shapes, or change the display to the desired scale—all in real time.

The beauty of interactive computer graphics lies in the phrase, "in real time." Using former techniques, the engineer was required to design a program, run it, study the printout, then iterate changes through the system until an acceptable solution was obtained. At upwards of $600 an hour for computer time, it's easy to understand why this new innovation of computer technology has been received with such enthusiasm.

Jim Fisk, W1DTY
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gallium arsenide LED experiments

Theory and application of light-emitting diodes and photodetectors in communications circuits

Ralph W. Campbell, W4KAE, 316 Mariemont Drive, Lexington, Kentucky 40505

One of the most interesting fields of electronics that has been neglected by amateurs is communications by lasers and their relatives, the light-emitting diodes. Experimental data is meager in the amateur literature. Ready-made equipment, of course, doesn't exist.

I became interested in building a diode laser communications link between my home and a local broadcast station, both for the novelty of the idea and to communicate with colleagues. The experiments reported in this article are a first iteration toward achieving the laser link.

The professional literature describes bulky, expensive optical devices as modulators placed in front of equally expensive ruby rods or gas lasers. The light-emitting diode (LED) and diode injection

Broad-area quadrature detector for broadcast-band response. A 1-MHz pilot carrier, injected through the lens shade, produced sidebands above and below 1 MHz in a Hallicrafters SX-122.

laser are well within amateur means, so I investigated those.

My early experiments were made with equipment designed from scratch and with a minimum of help from reference material, because I wanted to learn by doing. After much trial and error, I was able to achieve what I believe is an amateur world record for one-way ranging with LED's: a distance of 250 feet. This was done with the equipment described in the following paragraphs. I used a GE SSL-4 LED transmitter and a broad-area detector comprised of seven GE L14A502 phototransistors in a honeycomb matrix.* The 250-foot range is five times as far as that obtained with commercially designed equipment using a white (incandescent) noncoherent light source and the same type detector.

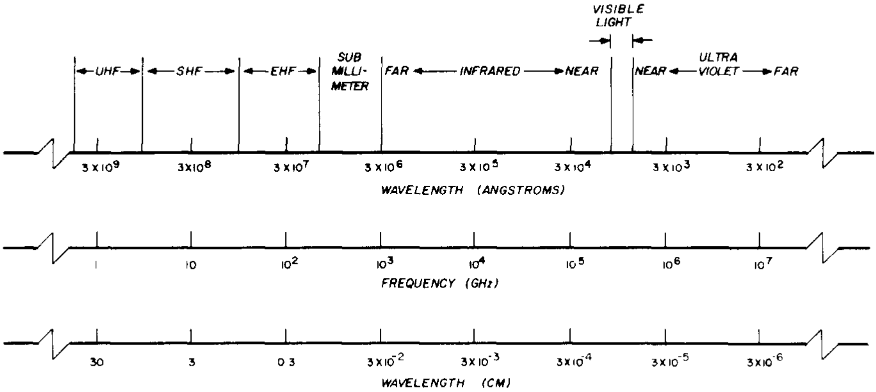


fig. 1. Approximate spectral regions. "Near" IR and UV spectra are referenced to visible light.

a word of caution

Unless you've had experience with laser diodes, I'd recommend starting first with LED's. An early attempt with injection lasers ended in disaster. These devices must be operated with a power supply duty cycle of 0.1 percent—preferably less. The average power of a diode laser must be kept low to avoid overheating, so a pulsed power supply is used. If its duty cycle is much above, say, 0.05 percent the injection laser will go up in smoke no matter how good its heat sink. Cryogenic cooling allows higher duty-cycle pulsing, but this is beyond the means of most hams.

operating frequency

The equipment used in these experiments operated in the infrared region (**fig. 1**). Because of the nearness of infrared to the visible light portion of the spectrum, optical equipment can be used to enhance operation. The optics I used were a surplus NC-3 gunsight, an f/1.9 two-inch-diameter achromatic lens, and a surplus British type CV-148 sniperscope image tube.† The gunsight was used to collimate light rays from the LED; the achromat was used to focus light input and output.

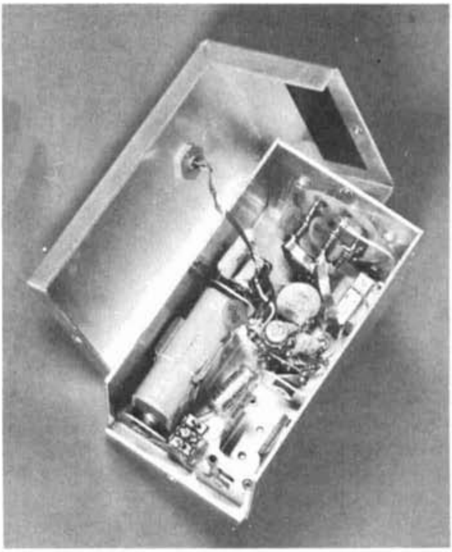
*The SSL-4 is available from G. E. for about $7.50. Write Miniature Lamp Dept., General Electric Company, Nela Park, Cleveland, Ohio 44112. The L14A502's were obtained from G. E. as a sample

†The gunsight ($10.00) and achromat (about $3.50) are available from Edmund Scientific Company, 101 E. Gloucester Pike, Barrington, New Jersey 08007. The CV-148 ($5.00) can be obtained from John Meshna, Jr., Box 62, E. Lynn, Massachusetts 01904.

The image tube was used as an infrared detector in some experiments. Its sensitivity is low for LED work, but it's a good detector for laser use.

how LED's work

When driven by an external power source, certain semiconductor materials produce light. The light can be in the visible or invisible part of the spectrum, depending on certain laws of quantum mechanics. If an LED's p-n junction is forward biased, electrons from the n region (valence band) will flow across the energy-band gap into the p region (conduction band). Here the electrons recombine with electron holes, then fall to a lower energy level where they emit a photon, which is a quantum of light.



Improved Broad-area detector using seven GE L14A502 photo transistors connected as diodes. A maximum range of 250 feet was obtained at twilight with this unit. A surplus NC-3 gunsight was used as a collimator.

The wavelength of the emitted photon depends on the energy-band gap between the n and p regions. LED's constructed of gallium arsenide (GaAs), as used in my tests, have a band gap that permits radiation in the near infrared region (referenced to visible light; **fig.1**). Visible light may be emitted from LED's with a wider band gap. For example, LED's made of gallium phosphide emit green light.

LED output is determined by the geometry of the host material pellet and the device's packaging. Some GaAs LED's are packaged with a parabolic reflector as part of their structure. An epoxy lens collimates the light output to a very narrow region of the device's optical axis.

LED light output is noncoherent, whereas that from a laser is coherent. The significance of these terms will become apparent when we consider the laser, discussed next.

lasers

The first operating laser was demonstrated by T.H. Maiman in 1960. Its principles have been covered extensively in the literature. The following brief description, although considerably simplified, is given to show the comparisons

glossary

responsivity	output signal per unit input signal of photodectector.
sensivity	change in output per unit input change of a photodetector.
spatial coherence	phase relationship between two wave trains in space (determines output directivity of a laser).
spectral coherence	a measure of the restriction of a photodetector's light output to a single wavelength or band of wavelengths (i.e., color response).
lasing	phenomena exhibited by certain materials when the threshold condition has been achieved for self-sustaining photon emission.
monochromaticity	degree of response to one color in the electromagnetic spectrum.

between LED's and lasers.

Laser is an acronym for "light amplification by stimulated emission of radiation." In its most prevalent form, the laser is used as an oscillator. It can be used as an oscillator. It can be used as an amplifier, but its spontaneous (noncoherent) emission is so great that it doesn't perform well as an amplifier at low input levels.*

An LED, as explained above, emits light due to the transition of electrons between energy levels. However, the light output is noncoherent, which means its phase and amplitude are not correlated (recall that if two wavetrains of the same frequency are in phase, their amplitudes are maximum).

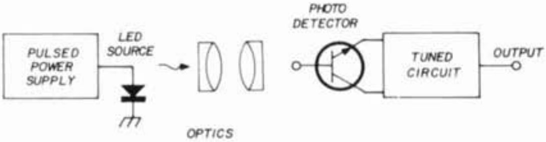


fig. 2. Basic arrangement for a simple pulsed light system. Achromat lenses increase performance, but are difficult to align if separation between source and detector is great.

In a laser, radiation from an external source, called a pump, raises the electrons of the active material from a lower to a higher energy level. Some of the electrons are absorbed, but some will be driven downward to an intermediate level, from which they will return to their original low-energy state and emit photons. This process, called stimulated emission, continues in a chain reaction similar to a nuclear explosion. If the laser output is coupled to a resonant circuit of high Q, and if certain optical arrangements are used, an extremely powerful and coherent light source is produced.

The difference between laser and LED operation is that LED's do not exhibit stimulated emission, and their light output is spatially noncoherent.

coherence

Two types of coherence are involved: spectral and spatial. The former determines how closely light output is restricted to a single wavelength or band of wavelengths, while the latter pertains to waves in space. Spectral coherence is a measure of monochromaticity. Most LED's and all lasers produce monochromatic (single-color) light. Since spatial coherence depends of the frequency of pumping radiation, which does not occur in LED operation, LED's exhibit little spatial coherence.

If the input wave to a laser (supplied by the pump) has plane wave fronts, the laser's output will also contain plane waves. The degree of phase correlation (or regularity) between these plane wave fronts is a measure of spatial coherence, which determines directivity. The laser beam will have almost constant width for a distance, S, according to the following relationship

$$S = \frac{D^2}{4}$$

where D is the diameter of the laser output source, and λ is the wavelength of radiation. Beyond this distance, S, the

The SSL-4 LED mounted in an Amphenol MX-1025/U cable termination, encapsulated with epoxy (right). The surplus CV-148 image tube is shown at left; the battery supplies 510 volts for its photocathode.

---

*Thus the term "loser" is sometimes used; i. e., "light oscillation by stimulated emission."

wave begins to assume a conical shape with wave fronts assuming a sphere, as in radiation at radio frequencies.

pulsed light systems

A simple pulsed light system using LED's is shown in **fig. 2**. This basic system can be modified to include a speech modulator and various postdetection amplifiers, as well as the optics shown focus divergent light to allow wider spatial separation between LED and detector. The theoretical separation is of the order of several miles. In practice, this is limited to several yards because of the difficulty in aligning the optics and LED response to stray fields.

detectors

The limiting element in an LED communications system is the detector. The best detectors for light transmission have high responsivity and sensitivity. Minority carrier lifetime determines responsivity, whether we're discussing photodiodes, photo transistors, or image tubes. A detector with high responsivity will deliver an output signal within picoseconds after an input signal is applied. Sensitivity is a measure of the change in a detector's output per unit input signal change. Some authorities use the word "responsitivity" to describe detector performance—a coined word combining both terms.

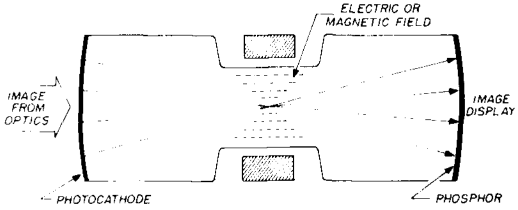


fig. 3. A typical electron image converter tube. These respond well to pulsed light sources but sensitivity is low for LED work.

broad-area response

Another important consideration for light detectors is broad-area response. A simple analogy using the human eye will explain this. If you've ever been on a hilltop at dusk you may have noticed how bright an incandescent lightsource appears on the skyline. Here we have many point sources of light that are partially collimated into parallel rays. With sufficient sensitivity, there's almost no limit to the amount of incident light falling on the broad-area retina of the eye. A photo detector should have an array of at least ten input sources to receive noncoherent radiation from an LED.

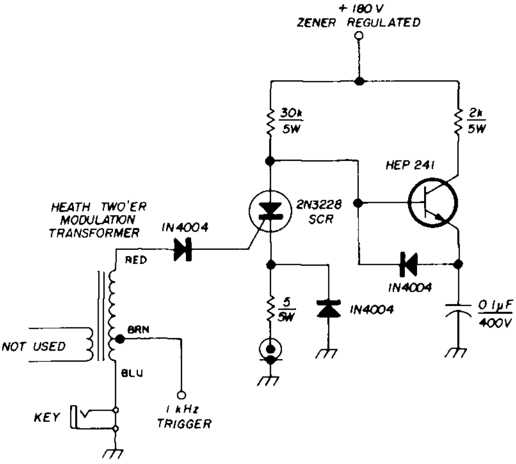


fig. 4. A pulsed power supply for LED's that develops about 900 mW. It's not suitable for an injection laser, however.

I made my broad-area detector array by arranging several GE type L14A502 photo transistors in a honeycomb matrix. These were connected as photodiodes in a lens-in-can arrangement to provide optical gain.

detector response

Photo transistors (or more correctly, photo duo-diodes) are of the npn type. When operated in the reverse-bias mode, I consider them to be p-n diodes. They respond to rms output only. Peak power, as from a pulsed system, can't be sensed by these devices, even with a 6 percent duty cycle. The only diodes that respond to peak input are the p-i-n types such as the

Schottky barrier diodes. However, these are rather expensive.*

The cadmium selenide (CdSe) photo cell has relatively high sensivity, but suffers from the same disadvantage as the common npn photo duo-diodes: linear response. An envelope detector must be used with these for best results. Cadmium selenide cells exhibit a spectral shift further into the visible light region. You must, therefore, make a tradeoff between higher sensitivity and spectral response when considering the CdSe cells.

the image converter tube

The S1 image tube is a good candidate for an infrared detector. A simplified sketch is shown in **fig. 3**. These tubes respond to pulsed light because the phosphor screen (made of Willemite P1 phosphor) has a storage effect on the recombined secondary carriers received from the photocathode. The storage phonomenon results from a sort of mathematical integration of impinging elec-

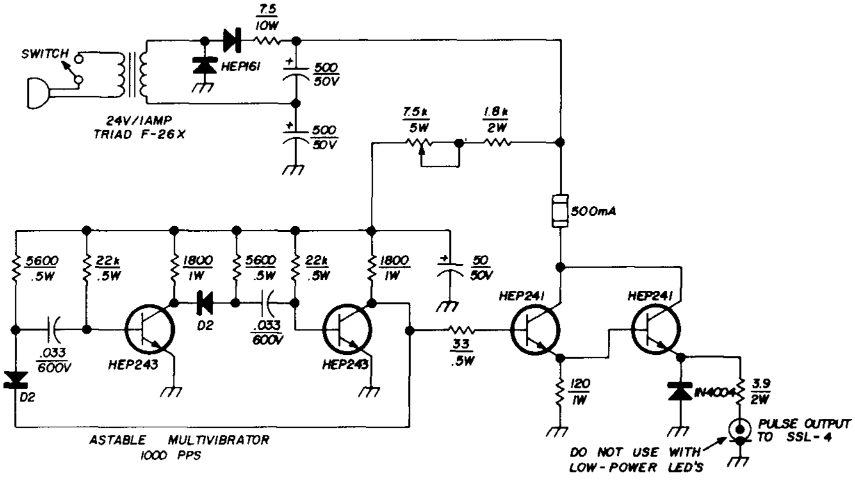
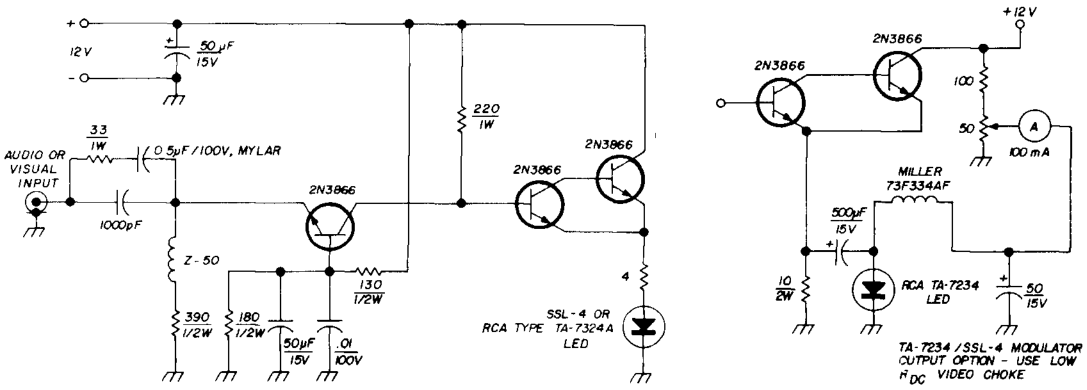


fig. 5. A power supply good for 1.25 watts. Duty cycle is 50 percent. Speed-up diodes D1 and D2 shape the output pulse trailing edges.

fig. 6. An LED modulator. Circuit on right can be used for improved voice modulation (per JA3HA).



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*The type PIN-5 ($24.00 post-paid from United Detector Technology) seems to have greatest responsivity for pulsed light.

trons. Image tubes that respond to repetition rates of the order of 100 pps are made of P20 phosphor. Nonimaging photodiodes, properly biased, operate similarly on pulsed light: the Schottky barrier is an equivalent mechanism to the image tube phosphor in its storage effect.

power supplies

A pulsed power supply that will deliver 900 mW is shown in **fig. 4**. Its duty cycle is about 1 percent. When the capacitor is fully charged the HEP-241 bipolar switches the pulses through the scr, which acts as a gate. The result is a current pulse whose amplitude is determined by dynamic response of the thyristor. Pulse width is determined by the supply's dynamic resistance and the 2k resistor. This circuit is very good for 70-ampere-peak, high-threshold emitting devices but is unsuitable for injection lasers.

A 50 percent duty-cycle pulsed supply is shown in **fig. 5**. The heart of the circuit is an astable multivibrator. The supply puts out square pulses with a rise time of less than 200 nsec. Diodes D1 and D2 shape the trailing edges of the pulses.

The series resistor in the output should be 4, 6 or 10 ohms when the supply is used with LED's such as the ME-2, SSL-4 or TA-7324A respectively. I'd recommend using a no. 248 miniature lamp to replace the LED when testing a new light-source design. It's a lot better to blow up a lamp than an ME-2 at $30.00 each.

modulators

The modulator shown in **fig. 6** is patterned after a circuit in G.E. Solid-State Lamp Manual No. 8270. I made changes to allow use of npn overlay transistors in place of the original pnp's. This circuit will work between audio and video frequencies. Shielding may be a problem when using the modulator with LED's.

The modification shown on the right of **fig. 6** is based on experiments by JA3HA for voice modulation. The LED on the right is forward biased to half maximum cw current value, with no modulat-

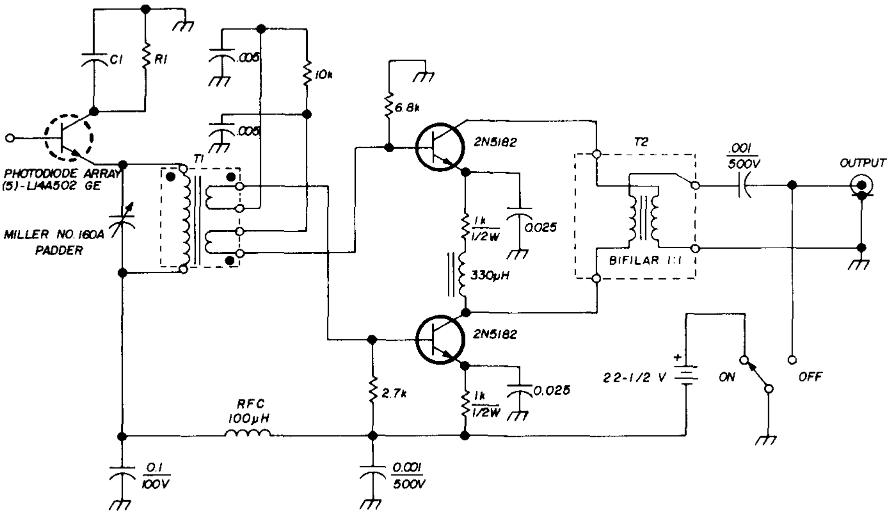


fig. 7. Quadrature detector used for receiving LED output translated to the broadcast band. C1 is five .005 capacitors in parallel; R1 is five 560 ohm resistors in parallel. T1 is a tuned quadrature coil wound on 57-1736 carbonyl sf toroid; primary is no. 32 wire wound to fill 7/8 of the core; secondaries are 1/8 of the core's circumference. T2 is a 1:1 quadrature coil and consists of no. 32 wire wound to fill a 57-1736 toroid.

ing signal present. A 500-Hz tone is then applied, and average forward current is increased to 2 amps. (The LED *must* be in a heat sink.) The 500-Hz source is then replaced with a speech amplifier. Voice peaks will not cause lasing in the LED.

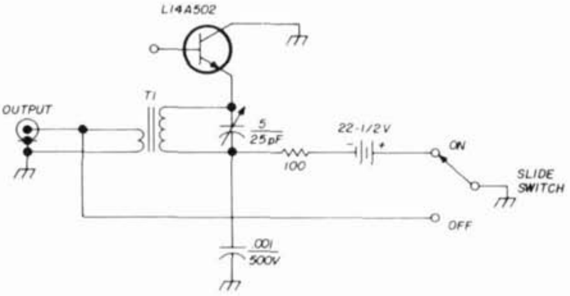


fig. 8. Simple photodetector for 50-MHz response. One or more photo transistors can be used, depending on the tuning method. The primary of T1 is 2 turns, secondary is 7 turns on a Permacor 57-6075 toroid.

quadrature detector

A successful detector for output in the broadcast band is shown if **fig. 7**. The circuit is similar to a 1:1 balun, except that output is obtained at two ports from a single-port input. All three ports, if used, have a common ground. Ninety-degree phasing exists between the two output ports, netting 180° as in a conventional balun. Advantages are reasonably high gain, no neutralization, and limited bandwidth at the lower resonant frequencies. It also has low noise response.

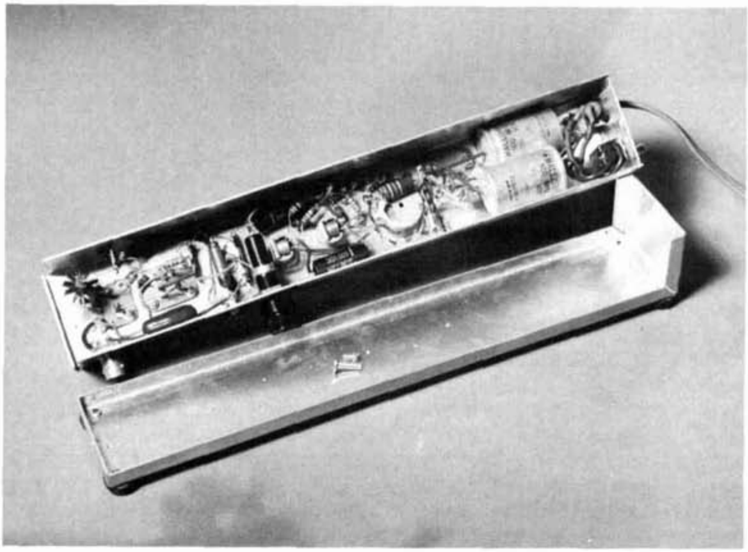
The optical input to this detector consisted of five G.E. L14A502's operating nonlinearily (rms response), connected in a matrix.

detector for 50 MHz

A simple circuit for one or two photodiodes is shown in **fig. 8**. Parallel instead of series tuning is suitable for one photodiode. With a junction capacitance of 2 pF, it should be possible to tune as many as five photodiodes in parallel. In a series-tuned arrangement, 10 pF should allow response to perhaps 400 MHz.

broad-area detector

My most successful broad-area detector used seven GE L14A502 photo transistors connected as photodiodes **(fig. 9)**. Component values were chosen to bring the response of the IC into the audio region. The surplus tape head shown in



The 1.25-watt LED power supply. This supply runs quite hot, and should have a 2.5-ampere transformer and 2.5-ampere epoxy rectifiers. Wakefield 254SI heat sinks are used for the astable multivibrator transistors.

the schematic couples output into high-impedance headphones.

conclusions

It is difficult to pulse modulate LED light beams. Audio and video modulation is practical at 1000 feet or less; however, the limiting parameter is stray fields. Another factor is the requirement of expensive, high-voltage photomultiplier detectors for ranges of the order of a mile.

LED's used with optics allow narrow-beam transmission, but optics alignment is very difficult.

Finally, common light sources have much greater spatial beam spread than LED's. However, ordinary 50,000-hour lamps can be replaced by LED's for perhaps 25 years before the LED output decreases to half power.

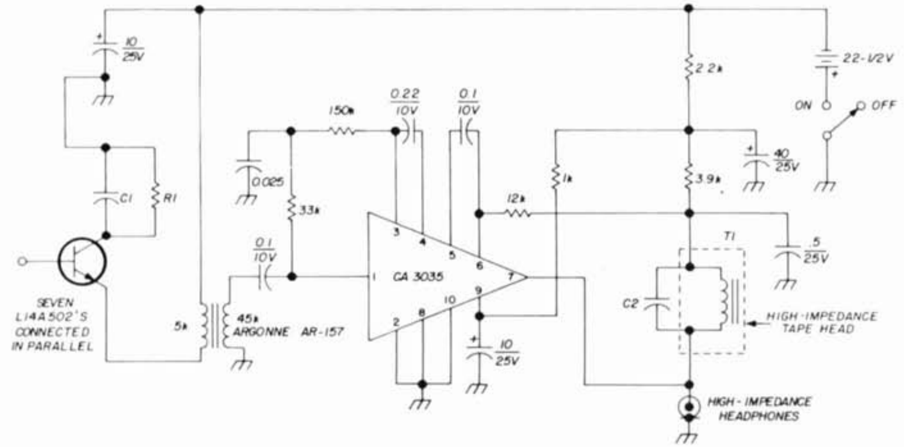
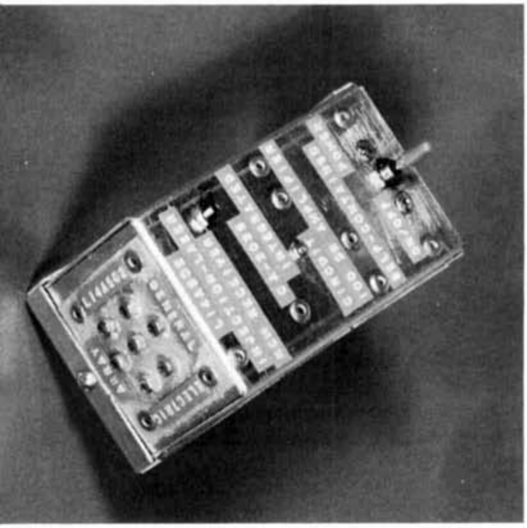


fig. 9. Improved broad-area detector using L14A502 photo transistors and an RCA CA3035 IC audio amplifier. With this unit and an SSL-4 light source, I achieved a range of 250 feet. C1 is seven .01 capacitors in parallel; R1 is seven 680-ohm resistors in parallel. T1 is a surplus magnetic tape head. Capacitor C2 is from .01 to .033, depending upon desired audio response.

Another view of the broad-area detector.



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of fm systems

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It is not widely realized that there are certain variables in frequency modulation or fm that must be defined and standardized before full compatibility is obtained between transmitting and receiving equipment. In this article I will attempt to identify these variables, point out current standard practice and discuss how these standards affect transmitter and receiver circuitry.

modulation level

In amplitude modulation systems the modulation limit is related to carrier level. This limit is called 100 percent modulation. There is no such inherent limitation for fm systems. Any modulation level, or deviation, may be transmitted as long as the receiver bandwidth will accept it.

Two standard receiver bandwidths are currently found in amateur practice. These bandwidths, as well as most of the other standards which we will discuss, stem from commercial practice—and the large amount of commercial fm equipment used by amateurs. The most common bandwidth permits a deviation of ±15 kHz; this referred to as wideband. Newer commercial equipment permits a deviation of only ±5 kHz; this referred to as narrowband. (Narrowband should not be confused with the nbfm permitted on the amateur bands below 30 MHz; nbfm is limited by regulation to ±3 kHz.)

Narrowband may be copied on a wideband receiver with only a slight loss of audio, but wideband is not copyable on a narrowband receiver because of modulation excursions out of the receiver passband. When both types of equipment are in use, modulation levels are set for the narrower receivers.

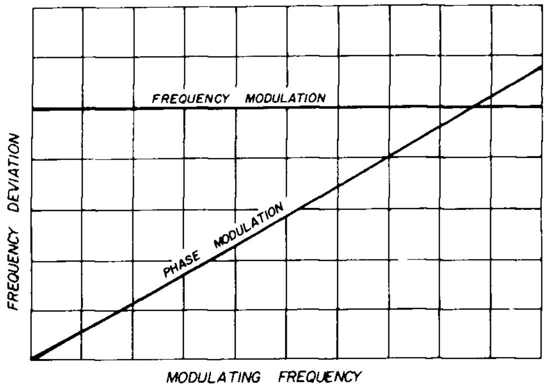

fig. 1. Modulating frequency dependence of fm and pm with constant audio input level.

audio response characteristics

Through use, "frequency modulation" has come to refer to any angular modulation system, either true fm or pm (phase modulation). Although the difference between an fm and a pm modulator is known, it is not widely realized that the two systems result in an inherent difference in audio-response characteristics.

A constant audio level applied to a frequency modulator will result in a certain frequency deviation which does not change with the modulating frequency. However, a constant audio level applied to a phase modulator will only result in a constant peak phase shift. The frequency deviation depends on how rapidly the phase shifts. Since the phase shift becomes more rapid as the modulating frequency is increased, the frequency deviation of a phase-modulated transmitter is directly proportional to the modulating frequency as shown in **fig. 1**.

The result is that a pm signal detected in an fm discriminator will have a 6 dB per octave rising audio characteristic. This can be overcome in one of two ways. If an RC network that will cause a 6-dB-per-octave *rolloff* across the entire audio range is placed in the transmitter audio (before the phase modulator) the transmitted signal will be identical to a true fm signal **(fig. 2B)**. The alternative is to place the same RC circuit after the fm discriminator in the receiver **(fig. 3A)**. In this case

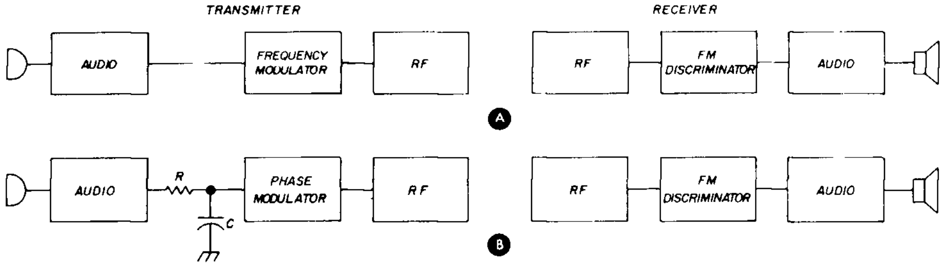

fig. 2. Frequency modulation and fm-equivalent systems.

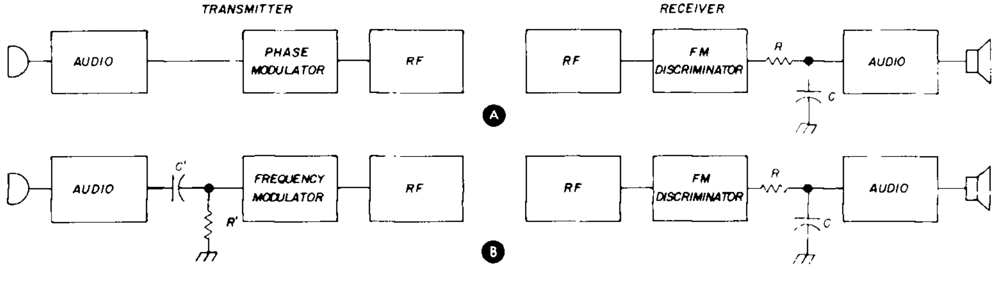

fig. 3. Phase modulation and pm-equivalent system.

the system audio will still have a net flat response but the transmitted signal will be pm.

It is pm which is standard for commercial[1,2] and amateur use. For this reason, when a frequency modulator is used an RC network with a 6-dB-per-octave *rising* characteristic is placed in the transmit audio circuit prior to the modulator **(fig. 3B)**. If steps are not taken to assure standardized audio response different equipment combinations can result in either high- or low-pitched received audio with accompanying loss in intelligibility.

The RC rolloff network used in the above examples should have a time constant of RC=530 microseconds for a low-frequency limit of 300 Hz. The rising response RC network for use with a frequency modulator should have a time constant of R'C'=53 microseconds for a high-frequency limit of 3 kHz (R in ohms, C in farads). The closest standard component values may be used.

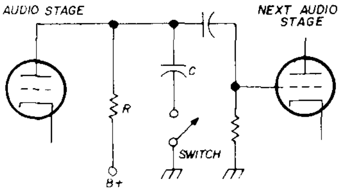

fig. 4. Modifying an a-m receiver to slope detect pm. Capacitor C and switch are added. Shunt circuit impedances are assumed to be high relative to R and are ignored in computing RC.

An improvement in reception may be gained when slope detecting pm on an a-m receiver if audio rolloff is added as with the fm discriminator. Not only will the unnatural high pitched quality be eliminated, some noise reduction will result. A shunt capacitor may be selected for the proper time constant (530 microseconds may be used) in conjunction with an existing plate load resistor (see **fig. 4**).

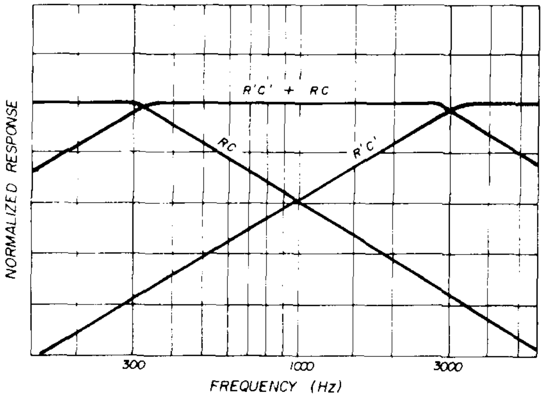

fig. 6. Normalized response of the circuit of fig. 5.

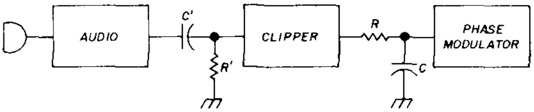

fig. 5. Speech clipping for constant maximum frequency deviation with phase modulation. R'C' = 53 microseconds and RC = 530 microseconds for 3-dB points at 300 and 3000 Hz.

Provision should be made to switch the capacitor out for a-m reception. This arrangement is recommended for monitoring purposes only because of the inferior reception provided by slope detection. Also, tunable receivers are discouraged for fm communications because they encourage poor operating practices.

speech clipping

Speech clipping is a useful method of maintaining high average deviation levels without going beyond the receiver bandpass. It has previously been established that the system in use is phase modulation; since pm exhibits a different deviation level for each modulating frequency it's obvious that fixed amplitude clipping by itself will not work unless it is made frequency dependent. This is normally done as shown in **fig. 5** by preceding the clipper with a network with a 6-dB-per-octave *rising* characteristic. This enables the clipper to take a bigger bite of the higher frequencies. The clipper is followed by a 6-db-per-octave *rolloff* network that restores the unclipped audio to a flat response as shown in **fig. 6**. The net result is a pm signal clipped to a constant maximum frequency deviation.

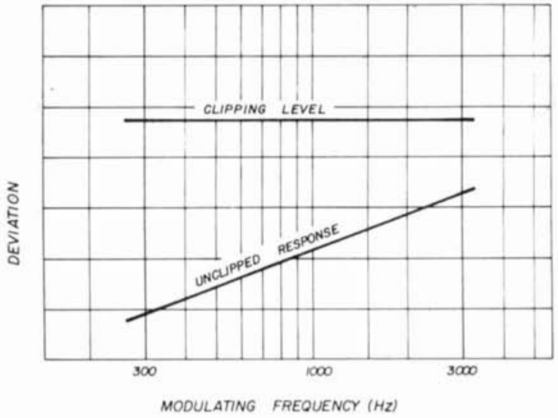

fig. 7. Deviation characteristics of the circuit of fig. 5.

When the audio clipper is used with a frequency modulator rather than a phase modulator, network RC is left out but R'C' is left in. The resulting signal is the same as pm limited to a constant maximum frequency deviation.

It should be noted that excessive clipping with this method will cause a noticeable loss of high audio frequencies. However, at normal clipping levels the spectral distribution of speech is such that little high-frequency clipping takes place, and the highs appear normal. This loss effect has been noted on many improperly adjusted repeaters around the country where the receiver is overdriving the clipper. Not only is excessive distortion created by too much clipping, but further degradation of intelligibility is caused by the muffled highs.

summary

Despite the fact that fm is the general term applied to angular-modulated vhf and uhf work, the truth is that pm is the system in use from the point of view of system audio response. Audio compensation must be used with fm modulators and detectors to maintain correct audio recovery for maximum intelligibility.

Modulation levels are restricted only by receiver bandwidths (except on those lower frequencies where the FCC specifies maximum bandwidths). Speech clipping is almost universally used but special audio frequency processing is necessary in the transmitter to limit a pm signal to a constant maximum frequency deviation. Standard modulation levels are wideband (15-kHz deviation) and narrowband (5-kHz deviation).

reference

1. EIA Standard RS-152A, "Minimum Standard for Land-Mobile Communications FM or PM Transmitters 25-470 Mc.," Electronic Industries Association, 1959, Section 6.
2. EIA Standard RS-204, "Minimum Standards for Land-Mobile Communications FM or PM Receivers," Electronic Industries Association, 1958, Section 11.

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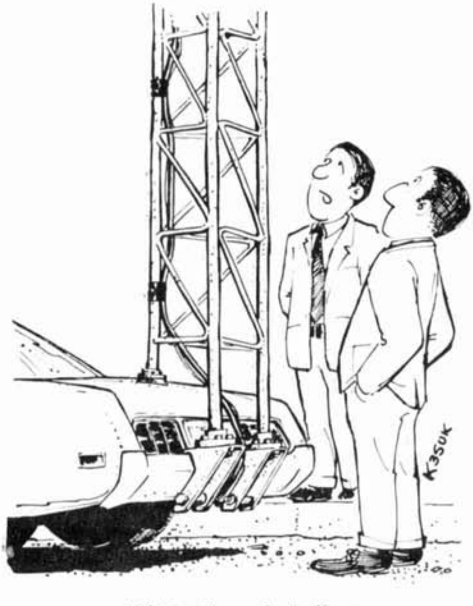

"I'll betcha a steak dinner that he's not married."

solid-state conversion of the gdo

Circuits for modernizing your grid-dip oscillator to obtain greater flexibility and sensitivity

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The grid-dip oscillator is one of the most useful items of test equipment to have around the ham station. The main shortcoming of most tube-type gdo's is their requirement for ac power. This is no problem at the workbench, but it's a definite limitation for portable or mobile work. Anyone who has used a gdo to tune an antenna knows what a chore it can be to run an ac power extension line up a tower– not to mention the safety hazard.

Today's catalogues offer a selection of solid-state "dippers" in an attractive price range. They have the advantage of being usable anywhere. If you already have an older gdo, you may have considered trading it in for one of the comtemporary models, or maybe even building a solid-state unit from scratch.

A simpler and much cheaper solution is to convert your tube gdo to a solid-state circuit. If you're reluctant about tearing into a commercially built unit or kit– don't be. The conversion task is simple, painless, and can be done in an evening. The result will give you the performance and flexibility of the latest models at a fraction of the cost.

the tuned circuit

Before you reach for the soldering iron, inspect your tube-type gdo's schematic. The tuned circuit will influence your decision on the solid-state circuit to use. You'll want to keep the tuned circuit intact as well as the dial calibration. Thus, you won't have to change your plug-in coils.

The gdo is nothing more than a simple oscillator. In tube types, the rectified grid current is measured on a meter to indicate a "dip" when power is absorbed from a nearby resonant circuit. Solid-state devices don't have grids, or course, so *an indication on a solid-state gdo's* meter is obtained from the oscillator's rectified output. The basic operating principle is the same in both circuits.

Common tuned tank circuits used in commercially built gdo's are shown in **fig. 1**. Your schematic will show if your unit has a split-capacitor, parallel-grounded, or *parallel-ungrounded tank. This will* determine the type of solid-state circuit you can use.

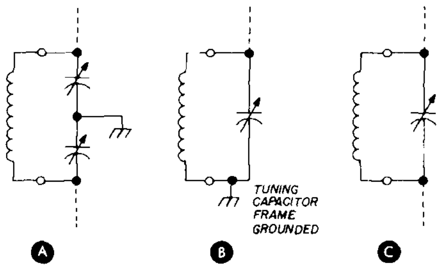

fig. 1. Typical tuned circuits used in gdo's. Split-capacitor tank is shown in A; parallel grounded and parallel ungrounded versions in B and C.

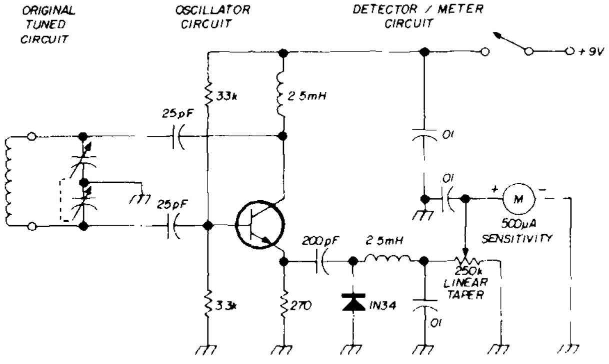

fig. 2. Solid-state gdo with split-stator tank. A pnp transistor could also be used by reversing battery polarity.

For the solid-state device, you have a choice of a bipolar transistor, fet, unijunction transistor, or tunnel diode. All give good performance with minor variations. *For simplicity, only the first two* are considered. However, if you have a favorite unijunction-diode circuit you might try it. Your final decision will probably be based on what's on hand.

npn or pnp circuit

An npn transistor circuit I used in converting a Heath model GD-1B, which has *a split-stator tank, is shown in* **fig. 2.** This circuit worked well with many transistors, including the 2N2926 and 2N706, up to 200 MHz.

A pnp transistor may be used in the same circuit if you reverse the battery polarity. In both cases oscillator output was more stable than in the original tube *circuit. Less frequent adjustment* of the sensitivity control was required during measurements.

common-base circuit

If your tube gdo has an ungrounded parallel tank, the common-base circuit shown on page 442 of the *RCA Transistor Manual,* Series SC-12 (reproduced in **fig. 3**), is suitable.

fet oscillator

The circuit I finally used to convert my Heath GD 1B is shown in **fig. 4**. Advantages over the circuit in **fig. 2** are fewer components and greater sensitivity in obtaining a dip. This circuit requires a higher voltage supply, however. I used two 9-volt transistor batteries in series to obtain full-scale meter deflection over the instrument's range.

Since it is impractical to illustrate all the applicable circuits for gdo conversion, I've included a list of articles in the references that should contain circuits you can use.

construction

After you've selected a suitable circuit, you're ready to start construction. Remove all the original oscillator and power-supply components (if any) and their wiring. Don't remove the tuning *capacitor, coil socket, meter, or sensitivity control.* Take care not to disturb the wiring between the tuning capacitor and coil socket.

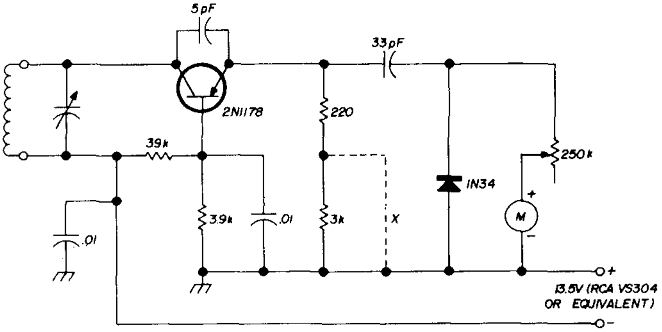

fig. 3. Common-base gdo circuit reproduced from the RCA Transistor Manual.

NOTE: X = JUMPER USED FOR FREQUENCIES OVER 45 MHz

The logical spot for the transistor is that vacated by the tube. You can mount a transistor socket on an adapter plate placed over the tube-socket hole. If you don't like transistor sockets, cut and drill a small piece of perforated board and mount it over the tube-socket hole. Flea clips inserted in the board will allow permanent soldering of the transistor—but don't do this until all other components are mounted.

After assembling and wiring the components, temporarily attach the transistor leads to the flea clips without soldering. This allows preliminary checkout.

The photograph shows how the transistor was mounted in the Heathkit GD-1B. The socket mounting tabs were soldered directly to the copper-plated bracket that originally held the tube. Component leads must be kept short, particularly thoses connected directly to the transistor and the tuned circuit.

Small-value capacitors should be high-grade silver mica. Bypass capacitors should be ceramic, *not* paper, to avoid stray resonances in the oscillator. All resistors are composition type, ¼ or ½ watt.

The battery may be mounted in the space previously occupied by the power supply, using an appropriate bracket for the type of battery suited to your voltage and space requirements. Be sure to wire

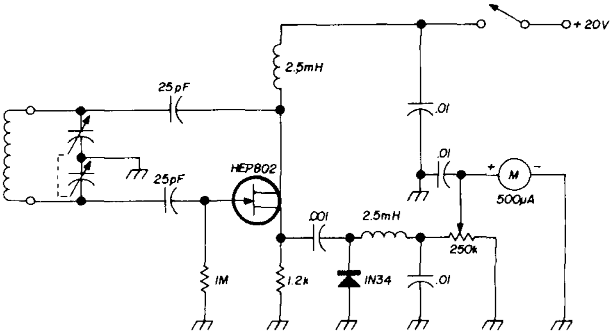

fig. 4. Grid-dip oscillator using an fet. This circuit provides greater sensitivity with less coupling because of fet's high input impedance.

the battery connector with the *correct* polarity for npn or pnp transistors.

In the circuits shown in **fig. 2** and **4** the sensitivity control is a 250k, linear-taper potentiometer. If your gdo uses a lower value, I suggest replacing it with a 250k potentiometer and an spst switch to control battery power.

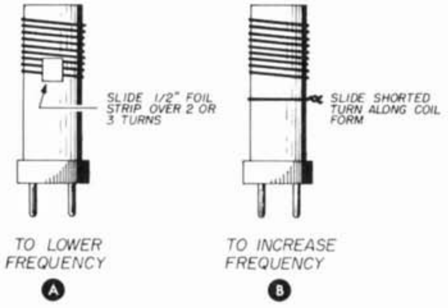

fig. 5. Methods for adjusting gdo coils for calibration correction.

checkout

After wiring and carefully checking the circuit, install the battery and transistor. Plug in a coil, apply power, and turn up the sensitivity control. If you don't get a meter reading, the circuit isn't oscillating or you forgot to use a heat sink when soldering the diode rectifier.

Assuming you obtain a reading, increase the control for full-scale meter indication and tune the capacitor from minimum to maximum to check for full-scale readings over the entire range. Repeat this for each coil. If any false dips are noted without the coil coupled to another circuit, you have a "built-in" resonance. Most likely this will occur on the higher-frequency coils (40 to 200 MHz) if lead lengths are too long or if nonresonant bypass capacitors were used.

calibration

Finally, check the dial calibration by beating the oscillator against a good communications receiver. Calibration may be a bit off if stray capacitances of the new circuit vary from the original. While most dippers are only approximately calibrate, you'll want to maintain reasonably accurate calibration. Loosening the dial-locking screw and readjusting its position relative to the tuning capacitor will take care of most cases. However, if the calibration error exceeds this method of correction, or if the error occurs only on certain coils, the following tips will help.

Sliding a one-half inch strip of aluminum foil over two or three turns of the coil will lower its frequency. Conversely, a single shorted turn of wire placed around the form will increase the coil's frequency as you slide it toward the coil. **Fig. 5** illustrates these methods. After calibration has been adjusted, the shorted turn or foil strip may be permanently cemented in place.

references

1. L. G. McCoy, W1ICP, "A Field-Effect Transistor Dipper", *QST*, February, 1968.

2. Calvin Sondergoth, W9ZTK, "Transistor Oscillators," *73*, March, 1969.

3. J. R. Fisk, W1DTY, "Designing Transistor Oscillators," *73*, August, 1969.

4. "Transistor Oscillators," *The Radio Amateur's Handbook*, ARRL Staff, 1968, Chapter 4, p. 87.

5. Rufus P. Turner, "How To Use Grid-Dip Oscillators," John F. Rider, Inc., New York, N.Y., 1960.

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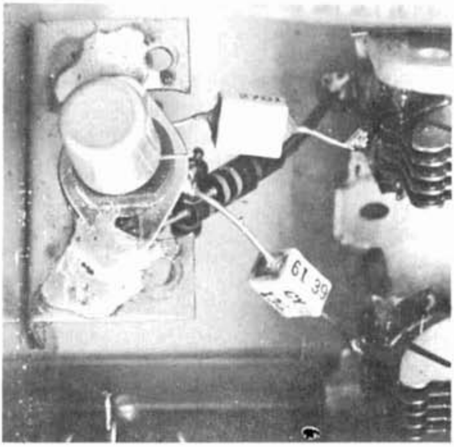
Method of mounting transistor in the GD-1B gdo.



integrated audio filter-frequency translator for cw reception

A sharp audio filter combined with a keyed audio oscillator— using economical ICs

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Many amateurs like to use an audio filter to improve selectivity when receiving cw signals. Such a filter requires no internal modifications to a receiver, and the filter can be switched in or out of the circuit as desired. However, when using an audio filter you must accept the fact that the cw signals will have the same tone. This can become tiresome over a long period, because the audio tone has no harmonic content to provide a more pleasing musical quality.

An audio filter should have sharp response to be effective. Really sharp audio filters within the useful audio-frequency range are expensive, except for some surplus types such as the FL-8. Also, since filter response must be in the 800-1400 Hz range, many good bargains in very sharp filters, such as the teletype units, must be disregarded.

the audio keyer

An audio keyer has been the classic solution to the problems of (a) varying the tone frequency of the *audio selective* device and (b) allowing the use of filters of almost any audio frequency. The keyer operates as follows.

Receiver audio is passed through an audio filter whose output activates a keyer circuit. The keyer circuit switches the output of an audio oscillator at the same speed as the received signals. The audio oscillator tone can be varied without affecting the received signal.

Several audio-activated keyers using vacuum tubes have been described. Unfortunately, because of the components then available, these keyers were quite bulky (almost the same size as some complete receivers) and expensive. Although their advantages were recognized, it's doubtful if many amateurs attempted to build them.

Simple integrated circuits now available allow an audio-activated keyer to be constructed very compactly and inexpensively. In fact, an audio keyer can be made to fit inside the spare space in many audio filter enclosures. The IC keyer to be described doesn't have all the refinements of the vacuum-tube unit, but it satisfies most operational needs.

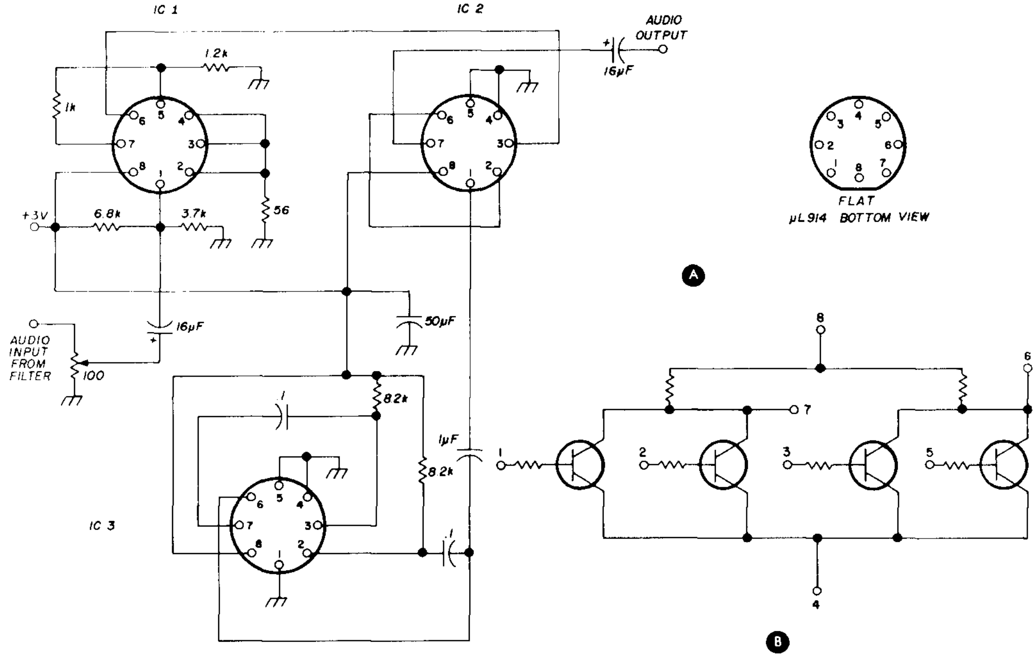

fig. 1. Schematic of the frequency translator-keyer, A, using Fairchild μL914 IC's. The μL914 internal circuit is shown in B.

circuit functions

Fig. 2 is a block diagram of an IC frequency translator-keyer. The circuit differs slightly from the vacuum tube concept. Whereas the tube unit uses relay driver stages and relays for control, the IC keyer employs a wave shaper and a gating circuit.

The block functions are as follows: the squarer stage accepts the output of the audio filter, which is fed from the receiver audio output. The squarer converts the filter's sine-wave output into a square wave of the same frequency. (The squarer may be considered as a hard limiter stage.) The squarer stage output is fed into an enable gate, which controls the audio oscillator signal to the audio amplifier. When a square wave is present at the squarer output, the audio oscillator signal is gated to the audio amplifier. Thus, the audio oscillator follows input-signal keying to the audio filter.

Noise can also activate the stages, so a level control for the squarer is included. The time constants for coupling to the stage can be chosen to further increase noise immunity. A bypass switch is included to disable the keyer when scanning a band. It's easier to find signals without audio selectivity; also false triggering from noise and interference is avoided.

Audio filters have rather high attenuation, so the audio signal should be taken from the receiver speaker terminals rather than from the headphone jack. A transformer may or may not be required to match the audio filter input, depending on its impedance. The filter can peak at almost any frequency as far as the keyer circuit is concerned. However, because of the restricted i-f, bfo and af response of most receivers, it's advisable to choose an audio filter in the 300- to 400-Hz range. This range is broad enough to include most audio and teletype filters described in amateur publications.

circuit description

Fig. 1 shows the keyer circuit using three μL914 IC's. Design has been kept as simple as possible. The input unit, IC1, is the sine-to-square wave converter. The input level potentiometer is shown as 100 ohms, but its value should be close to the audio filter output impedance. The coupling capacitor from the potentiometer arm to terminal 1 of IC1 was chosen to provide optimum performance and to avoid false triggering on noise.

IC2 is the enable gate. If the internal connections of IC2 are followed **(fig. 2A)**, it will be seen that when terminal 3 is at a positive level, the transistor associated with this terminal switches its collector to near ground potential. This places the emitter-collector resistance of the transistor associated with terminal 2 at a high level, which allows signal flow from terminal 1 to 7. When terminal 3 is not positive, the base-emitter forward bias on the transistor associated with terminal 2 rises to about the same value as the supply voltage, and terminal 7 is shorted to ground.

IC3 is a simple multivibrator audio oscillator similar to those used as monitors in electronic keyers. The components shown will provide a fundamental signal, high in harmonic content, of about 1 kHz. The resistors can be replaced by a dual 20 kilohm or 50 kilohm potentiometer if a variable tone is desired. This is especially recommended for those who like to change the receiver bfo pitch when receiving signals without an audio filter.

IC2's output is at a very low level. In general, it can be only directly coupled and used with sensitive headphones. No additional audio amplifier circuits are shown, as individual circumstances will dictate what is necessary. Any phone-type transistor amplifier can be used to boost the output of IC2.

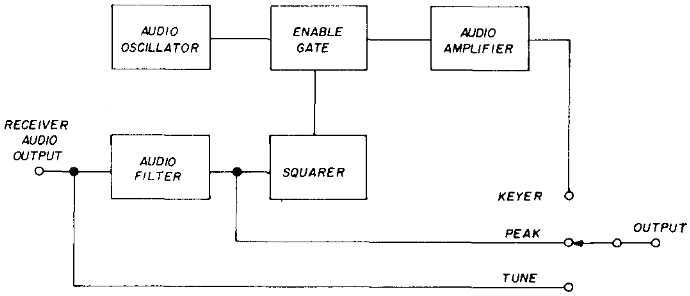

fig. 2. Block diagram of the IC frequency translator-keyer.

construction

There's nothing critical about the construction or wiring. Leads should be kept reasonably short, and the wires to terminals 3 and 7 of IC2 should be separated from each other and from the connection to terminal 1.

The circuit of **fig. 1** is mounted on a vector board. Sockets aren't used. The μL914 IC's are soldered in place.

Supply voltage of 3-3.5 volts can be obtained from either two size-C cells in series or from a well-filtered (minimum 1,000 μF output capacitance) source within the receiver.

operation

Tuning is done with the audio filter and keyer out of the circuit. When a desired station is found, the mode switch is set for the audio filter output (peak position), and the receiver bfo is varied to peak the signal within the audio filter passband. Then the keyer output is chosen, and the audio oscillator frequency is varied to obtain the desired tone.

With some practice, varying receiver audio output level and keyer input level will reduce the effects of false triggering. However, if good noise immunity can't be obtained, even when using a noise limiter, the input stage (IC1) can be converted to a Schmitt trigger as shown in **fig. 3.**

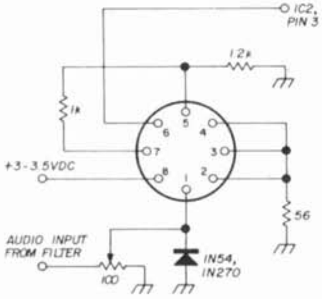

fig. 3. Schmitt trigger circuit modification for the IC1 stage of fig. 1A involves only a simple bias change at terminal 1. The diode may also improve operation.

Unlike the simple squarer circuit, which reacts to low-level signals, the Schmitt trigger will produce an output signal only when the input level exceeds a certain value. Thus, selection is provided against low-level noise (low in the sense of being some value less than the triggering level). The output signal will drop to zero only when the input signal falls below the triggering level.

The Schmitt trigger circuit should be used only when the noise can't be handled by the simple squarer circuit. Also, the Schmitt trigger should be used with cw agc, since large variations in audio output level between cw characters can cause the trigger to lock on or off faster than the keyer input-level control can be adjusted.

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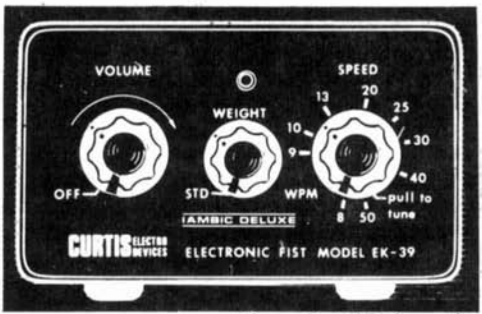

rf power detecting devices

What to expect from bolometers, barretters, and thermistors in measurement applications

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Devices for detecting electromagnetic energy have been around since the early 1900's. These include the early electrolytic detector, carbon coherer, Fleming valve, and galena-catwhisker combination. Detectors similar to the latter are still in use. Modern materials and packaging, however, have improved their performance and reliability.

In this article I'll discuss various detectors and compare their advantages and disadvantages as applied to rf power measurement at amateur frequencies.

basic detectors

Two types of detector are in common use. The first depends on unidirectional resistance between elements. This type includes all semiconductor diodes and their vacuum-tube counterparts. The second type changes resistance when it absorbs rf energy. Examples of this detector are bolometers, barretters, and thermistors.

Both detector types have many applications in detection and demodulation of rf energy.

definitions

Many take for granted that detection and demodulation are one and the same thing. This is not the case. Radio-frequency energy doesn't have to carry modulated intelligence to be detected. An example is the simple diode wavemeter, which has an indicator that reveals the presence of an unmodulated rf carrier.

demodulation

Demodulation is a byproduct of the detection process. Demodulation translates modulated intelligence, riding on the detected carrier, into a form that can be displayed aurally or visually. An example of demodulation is when an rf carrier, modulated by a 1-kHz tone, appears as a 1-kHz voltage at the detector's output.

Common diode detectors are used to convert rf energy to dc voltages and modulated rf energy to ac voltages that can be measured with orginary test equipment. Thus, rf voltages, current, or power can be quantified by using rf detectors and the proper readout device.

the diode detector

Diode detectors have characteristics that affect their accuracy in rf-measuring applications. An understanding of their drawbacks as well as their advantages is essential to using them effectively.

Diodes have a high impedance between their elements when reverse biased, **fig. 1A**, and a low impedance when biased in the forward direction, **fig. 1B**. This resistance characteristic allows the current to flow in only one direction, resulting in dc pulses flowing in the load.

The resistance characteristic is nonlinear. It obeys a square-law function, which occurs when the diode's output is proportional to the square of the input (assuming constant input impedance for a given range of input levels).

equivalent circuit

Another characteristic is that the resistance is directly proportional to the power dissipated. The square-law characteristic is due to the physical properties of the junction, **fig. 2**. In this circuit, C is the barrier capacitance due to charge storage in the barrier region. R represents the nonlinear barrier resistance, which is about 5k ohms at low current levels and falls rapidly with increasing current. The barrier-spreading resistance, r, is due to the construction of current paths in the barrier region. Its value will be as high as 50 ohms in point-contact diodes, decreasing to tenths of an ohm in diffused-junction types.

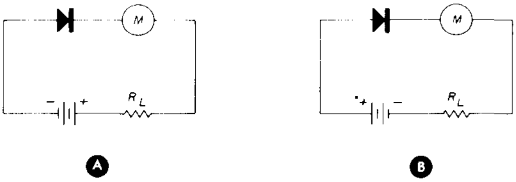

fig. 1. Reverse- and forward-biased diode junctions. Meter response is a function of diode junction resistance, which is high when reverse biased, A, and low when forward biased, B.

measurement errors

Most power and vswr meters are calibrated in terms of the square-law function. However, if too much power is applied to the diode, a readout error can result.

The diode's square-law region is typically limited to input levels between 0.25 and 1 mW. Above 1 mW, the diode's output will deviate in excess of 10 percent from the square-law response. In terms of dB error,

$$E = 10 \log (1 + d)$$

where E is the error in dB and D (100) is the percent deviation from the square-law function.

Crystal diode sensitivities of the order of 5k μV/mW are readily obtained at frequencies below 1 GHz. By proper choice of detector load resistance, the square-law range (5 percent deviation-error band) can be optimized to allow power ration (attenuation) measurements over a range of 36-38 dB with errors of the order of 0.2 dB. If the diode is overdriven, errors of 1 dB or more can occur. This is a considerable error at microwave frequencies in some applications.

bolometers

These detectors **(fig. 3)** use fine platinum wires (known as Wollaston wires) as active elements. The active elements are small compared to a wavelength at the measurement frequency. Their changes in resistance, however, are sufficiently large for accurate measurements with small changes in input power.

Bolometers are used with a specific "bias" current, which activates a bridge circuit. Typically, a bolometer presents 200 ohms to the bridge, although this may range from 50 to 400 ohms. The bolometer generally presents a 50-ohm resistance to its input. Excitation currents are of the order of 4.5 to 4.7 mA. A simplified bridge circuit is shown in **fig. 4.**

sensitivity

Bolometers are less sensitive than diodes. Normal sensitivities range from 4 to 10 ohms per mW of rf, depending on the temperature coefficient of the resistive elements. In terms of voltage, this works out to about 21 μV/mW.

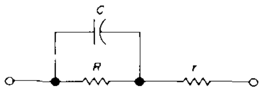

fig. 2. Equivalent circuit of forward-biased semi-conductor diode junction. Functions of circuit constants are discussed in the text.

Bolometers are preferable to diodes

when overdriving and burnout is a problem. At powers over 1 mW, bolometers deviate about 10 percent from square-law response due to convective cooling of the resistance element. However, this deviation is nearly linear with power level and is easily compensated in measurements.

This deviation from square-law response falls to less than 2 percent at 200 mW; thus bolometers can be used for relative power and attenuation measurements over a 53-dB range with less than 0.2-dB error (5 percent square-law deviation). This is approximately 15 dB more power range than is available with diodes.

The dynamic range numbers (dB) are given on the assumption that signal-to-noise ratios are at least 10, which is an acceptable value for accurate results with most instruments.

Unlike diodes, bolometers are not affected by overload up to about 32 mW, including 15 mW bias power.

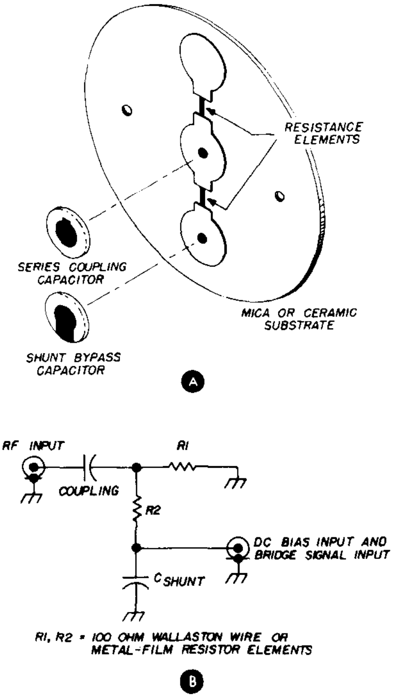

fig. 3. Schematic, B, and physical representation, A, of bolometer. Input resistance is 50 ohms nonreactive; bias input to bridge is typically 200 ohms.

barretters

Barretters are a type of bolometer employing a single Wollaston wire element, **fig. 5.** Usually they're used as shunt elements, **fig. 6**, and are packaged to replace crystals in applications where wider measurement range and greater power-handling capability are desired, and where a decrease in sensitivity can be tolerated.

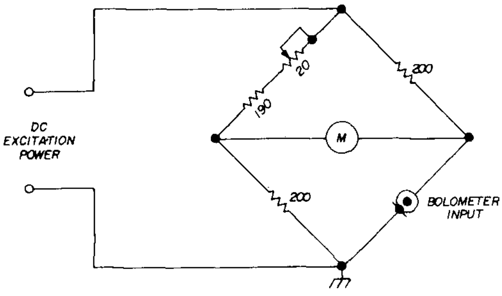

fig. 4. Simplified bolometer or thermistor bridge circuit.

thermistor detector

A thermistor is another important rf detector. Thermistors are resistance elements made from one of several metallic oxides such as oxide of manganese, nickel, titanium and zinc. All exhibit a negative temperature coefficient. The slope of resistance versus temperature of thermistors is much greater than that of bolometers. Thus, thermisiors have improved sensitivities that range from 50 to 100 μV/mW of rf input.

Like bolometers, thermistors require a bias current. This is usually adjusted to provide a "zero power" resistance of 100 to 200 ohms. Thermistors also have a large overload capability and the widest dynamic range of all the rf detectors. This makes them ideally suited for accurate, steady-state power measurements. However, thermistors have disadvantages that limit their applicability. The prime limitation *is their relatively slow time constant.* Ranging between 1 and 3 seconds, it prevents the thermistor from measuring peak pulsed or peak ssb power. Additionally, audio-frequency modulated signals can't be demodulated with a thermistor, as its resistance changes too slowly to follow an audio signal. Another disadvantage is its sensitivity to ambient temperature changes. This tends to make long-term stability a serious problem. Most thermistor rf detectors use dual elements that tend to compensate each other for drift.

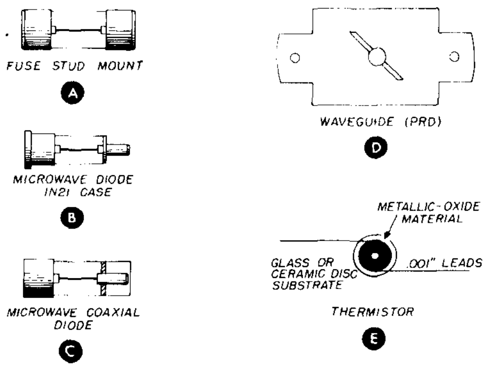

fig. 5. Packaging of barretters and thermistors. A, B and C use Wollaston-wire elements.

Unlike diodes and bolometers, thermistors are insensitive to overload and can be exposed to fairly high-level rf inputs for short periods without damage. The output characteristic of thermistors, although opposite in polarity, is similar in slope to the curve of bolometers and will permit a measurement range from approximately 50 µW to 5 mW.

rf detector readouts

In many amateur applications, only a relative indication of rf power is needed. This requires only a milliammeter and a potentiometer for a sensitivity adjustment. In many other applications such as measuring transmitter efficiency, antenna gain, feedline or filter losses, or low level injection powers, it's desirable or even necessary to get a quantitative figure in watts or dB. In these cases more sophisticated circuitry must be employed. For best accuracy and repeatability, the null-balance measurement system is usually employed. Usually a variation of the Wheatstone bridge provides high accuracy especially at low power levels. Temperature stability and dynamic range are a problem with these units. Many techniques have been imployed to eliminate these problems.

self-balanced bridge

Practical measurement bridges differ from the simple Wheatstone circuit of **fig. 4.** Usually some sort of a "self- balancing" circuit is employed.[1] Shown in **fig. 7,** the self-balancing bridge is direct reading and is much less sensitive to ambient temperature variations. With the proper bias adjustments, it can be used with all types of bolometer, barretter and thermistor detectors for input powers up to 100 mW depending on the type of detector employed. In the self-balancing circuit, the Wheatstone bridge forms a coupling network in the feedback loop of a high-gain audio amplifier. The resulting audio oscillator automatically adjusts its output voltage to maintain a balanced condition in the bridge network. When the bridge is unbalanced by an rf input, an equal amount of audio power is removed from the bridge, restoring balance. This is read out in terms of voltage by the audio voltmeter **(fig. 7)** whose scale is calibrated directly in terms of rf power.

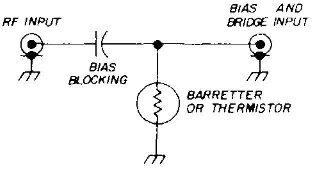

fig. 6. Barretter or thermistor mount circuit.

attenuators and filters

The power range of all detectors may, of course, be greatly extended by calibrated attenuators[2] and directional couplers.[3] Most ham-type swr bridges use a crude form of directional coupler to sample relative rf power on a *transmission* line. Where fairly accurate results are desired, precision couplers are employed, sometimes with calibrated attenuators when even more power reduction is required. For amateur use, attenuators can be made from carbon composition resistors or from calibrated lengths of RG-58/U coax (at vhf).

Measurement errors due to improper detector use are varied. Some are of little significance in amateur applications. For amateurs, most problems result from gross overdrive of the detector. This results in destruction of the unit through burnout, or a serious departure from the idealized square-law output curve with a resultant measurement error. Errors due to this can be reduced by using attenuators and by knowing the input parameters of the detector.

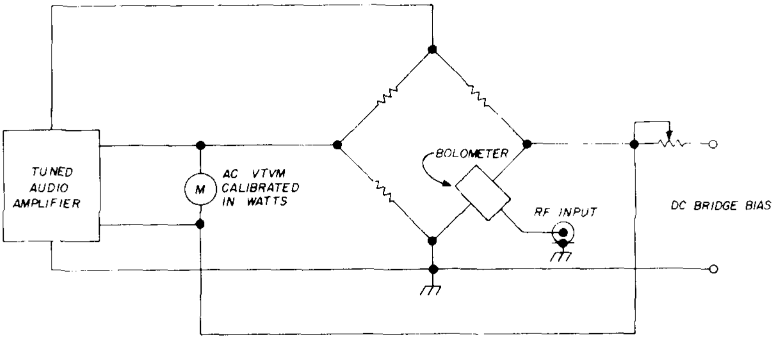

fig. 7. Self-balancing bridge and power meter. This circuit is much less sensitive to temperature changes than the simple Wheatstone bridge.

Another common error resulting in amateur rf detector applications is also of importance. All rf detectors described in this article are untuned; that is, they have no inherent selectivity and will accept power over a wide frequency range. Therefore, when measuring power sources with high harmonic content, the detector will sum the power in the desired frequency as well as that in its harmonics. This results in nonexistent and colossal "efficiency." What's worse, it can cause operation on an undesired or spurious frequency.

When measuring output power from sources containing harmonics, some type of *selective filter with a calibrated insertion loss* should be used to reject the unwanted power before it reaches the detector.

Representative filters are described in the references. Further details on rf power detectors are contained in Henney's "Radio Engineering Handbook," 1959 edition.

I hope this discussion will provide a better understanding of this basic measurement tool and encourage its use in amateur applications.

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design criteria for ssb phase-shift networks

How to minimize network errors for effective sideband suppression — an analysis of Norgaard and Dome circuit

A.I.H. Wade, G3NRW, 11 Daubeney Close, Harlington, Dunstable, Bedfordshire, England

Phase-shift networks in amateur phasing-type exciters consist of passive elements arranged to produce two equal-amplitude signals in phase quadrature. Two networks are required: one operates at audio and the other at radio frequency.

The rf network operates at a single frequency, whereas the af network must pass a band of voice frequencies. The rf network is fairly simple to adjust, but the af network is more critical as to construction and adjustment. This applies not only to the network, but to its associated circuits as well.

theory

Two popular audio networks are analyzed: Norgaard and Dome. Design-center conditions are considered first. Then network errors are discussed in terms of their effect on carrier suppression in a practical system. A brief treatment of the rf phase-shift network is also given.

Four areas are considered:

1. The ideal case.
2. Network phase errors.
3. Network amplitude errors.
4. The general case (combined effects of phase and amplitude errors.

ideal case

A lower-sideband signal, for example, requires a voltage of the form

$$V_o = A \cos(\omega c - \omega m)t \qquad (1)$$

where

V_o is the lower-sideband voltage

A is the signal amplitude

ωc is the carrier frequency ($\omega = 2\pi f$)

ωm is the audio-signal frequency

Two networks are required to produce this voltage, one each for the audio and carrier frequency. Each network has two outputs whose phase difference is 90°; thus four signals are produced:

a. $V1 = A \sin(\omega m\ t)$ (2)

b. $V2 = A \sin(\omega m\ t + \pi/2)$ (3)

c. $V3 = B \sin(\omega c\ t)$ (4)

d. $V4 = B \sin(\omega c\ t + \pi/2)$ (5)

where A and B are amplitudes of the audio and carrier signals respectively.

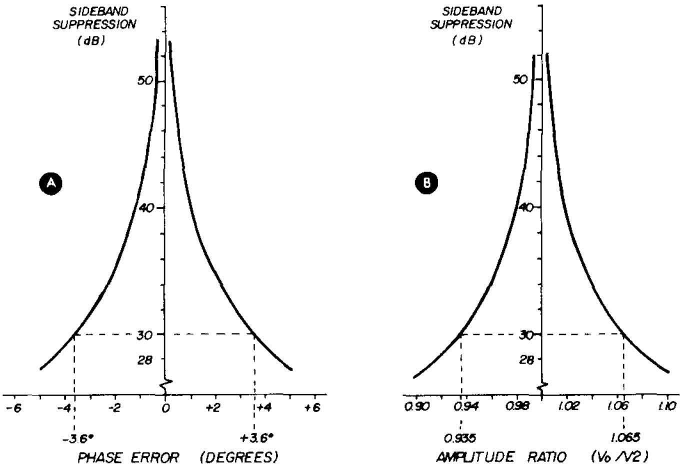


fig. 1. Sideband suppression as a function of phase error, A, and amplitude unbalance, B, assuming ideal conditions. For 30-dB attenuation, errors must not exceed ±3.6° and 6.5 percent respectively.

If signals a and c are applied to the input of one balanced modulator, the modulator's output will be of the form

$$V_a = \frac{A}{2}\left[\cos(\omega c - \omega m)t - \cos(\omega c + \omega m)t\right] \qquad (6)$$

Similarly, if signals b and c are applied to another balanced modulator, its output will be

$$V_b = \frac{A}{2}\left[\cos(\omega c - \omega m)t + \cos(\omega c + \omega m)t\right] \qquad (7)$$

The phasing system of producing ssb signals hasn't been too popular. As the author points out, the audio networks are tricky to adjust and the degree of sideband suppression depends on how well the networks are designed to limit phase and amplitude errors.

Phase-shift network theory is presented here in terms of system equations. Realizing that mathematical articles don't appeal to many readers, *I feel this one is appropriate because of* the renewed interest in phase-shift techniques for direct-conversion receivers. The phasing method is also interesting for vhf ssb work. This article presents essential data for those wishing to avoid the pitfalls associated with phasing networks. With an understanding of their basic concepts, the networks can be tailored to produce quite acceptable results.

Although not included because of space limitations, an appendix accompanying the manuscript derives the equations in the text. Interested readers may obtain a copy from *ham radio* for $1.00. **editor**

At the output of each balanced modulator is a signal that contains components of both upper and lower sidebands (the carrier has, in both cases, been balanced in the modulators).

The outputs of the two balanced modulators are combined:

$$Vo = Va + Vb = A \cos(\omega c - \omega m)t \quad \textbf{(8)}$$

The upper sideband has now been cancelled leaving only the desired lower-sideband signal.

phase errors

In the previous discussion it was assumed that each network shifted the phase through precisely 90°. This can't be done in practical networks, so phase error terms ϕ and θ must be introduced into **equation (3)** and **(5)** to account for this. It can be shown that the lower and upper sideband amplitudes will then become $A \cos(\phi - \theta)/2$ and $A \sin(\phi + \theta)/2$ respectively. That is, an unwanted upper sideband has been generated whose amplitude is a function of the *sum* of the phase errors of the two networks. The unwanted sideband can be eliminated if the phase errors are exactly equal in magnitude but of opposite sign. In practice, this can't be obtained over the frequency range in which the networks must operate.

Note that, if the rf network has no phase error, θ becomes zero, and the amplitudes of the two sidebands reduce to $A \cos(\phi/2)$ and $A \sin(\theta/2)$.

Defining the sideband suppression, S, as the ratio (in dB) of the lower-to-upper sideband,

$$S \text{ (in dB)} = 20 \log_{10} \cot \phi/2 \quad \textbf{(9)}$$

This is plotted in **fig. 1A**. Taking the minimum acceptable value of suppression as 30 dB, the maximum phase error that can be tolerated is of the order of ±3.6°. This assumes, however, that the rest of the system is perfect. In practice this number must be reduced.

amplitude unbalance

In eqs. 2 and through 5, it was assumed that the af quadrature signals were of equal amplitude, A, and the two rf signals were of equal amplitude, B. Again, in practice, this condition won't be met exactly, thus requiring a further change to the four equations. To simplify matters, however, assume that the rf network can be adjusted to produce two equal-amplitude signals, and the two outputs are of magnitudes A and nA, where n is approximately unity.

An unwanted upper sideband is again generated which is of amplitude $A/2\ (n - 1)$. Its suppression is

$$S \text{ (in dB)} = 20 \log_{10} (n + 1)/(n - 1) \quad \textbf{(10)}$$

This dependence of sideband suppression on the value of n is shown in **fig. 1B**. As n approaches unity, the suppression tends to infinity; and to satisfy the limiting condition of 30 dB, n must be between 0.935 and 1.065. That is, the amplitudes of the two audio signals must not differ by more than 6.5 percent.

general case

Up to this point we've examined separately the effects of phase errors and amplitude unbalance in the network outputs. To illustrate what happens in the general case, these effects must be combined. In this case, the sideband suppression is

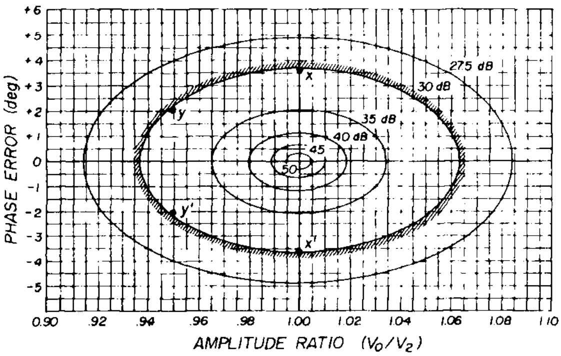


fig. 2. Combined effects of network amplitude and phase errors. Errors must lie within shaded area for acceptable sideband suppression.

$$S \text{ (in dB)} = 10\log_{10}\frac{1+n^2+2n\cos\phi}{1+n^2-2n\cos\phi} \qquad (11)$$

From this equation the curves of **fig. 2** are plotted: the suppression may be read directly once the phase error and amplitude unbalance are known. The curve corresponding to the suppression limit of 30 dB is shaded; for acceptable operation, the audio phase-shift networks errors must not lie outside this area at any frequency. For example, a phase error of ±3.6° is acceptable only with perfect amplitude balance (points X); if the amplitudes differ by, say, 5 percent, the phase error can't exceed ±2.2° (points Y).

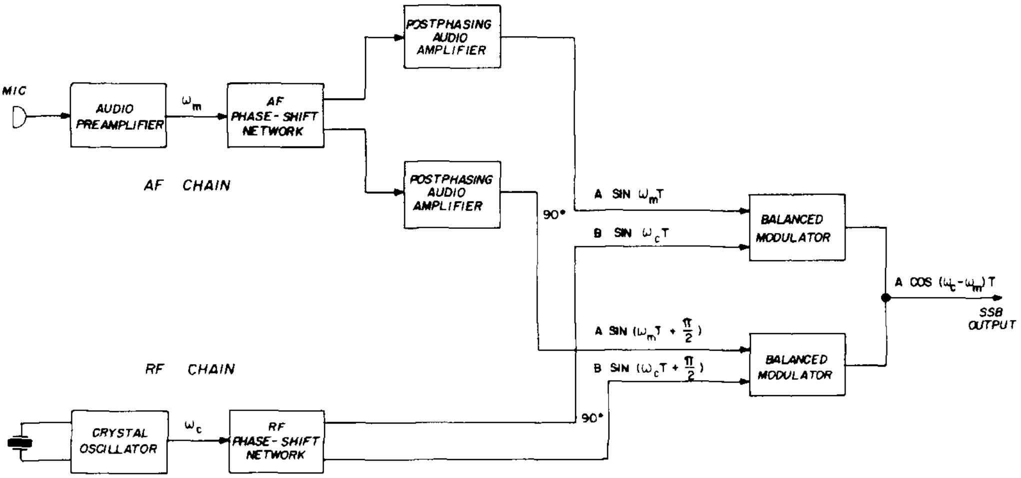


fig. 3. Typical phasing-type ssb exciter.

From the foregoing we can consider the requirements of an ssb phasing exciter, a block diagram of which is shown in ***fig. 3***. The amplifiers in the audio frequency chain are considered first.

audio preamplifier

The audio preamplifier must

1. Amplify the low-level output of the microphone.

2. Overcome the insertion loss of the audio phase-shift network which follows it.

3. Tailor the frequency response so that frequencies outside the range of 300 to 3000 Hz are attenuated.

The first two requirements are easily met if usual precautions are taken to minimize distortion. For the third requirement, filtering must be used in the preamplifier because the signals presented to the phase-shift network must be restricted to the frequency range mentioned. The reason is that practical networks exhibit increasing phase errors outside this range, producing poor sideband suppression.

postphasing amplifiers

Each audio phase-shift network output drives an audio amplifier. The amplifiers buffer the network outputs from the modulator inputs and offer the correct terminating impedance to the networks.

Optimum phase-shift network performance requires correct output terminating impedance, which is usually high and must be constant. The amplifiers must introduce no phase or amplitude errors in addition to those produced by

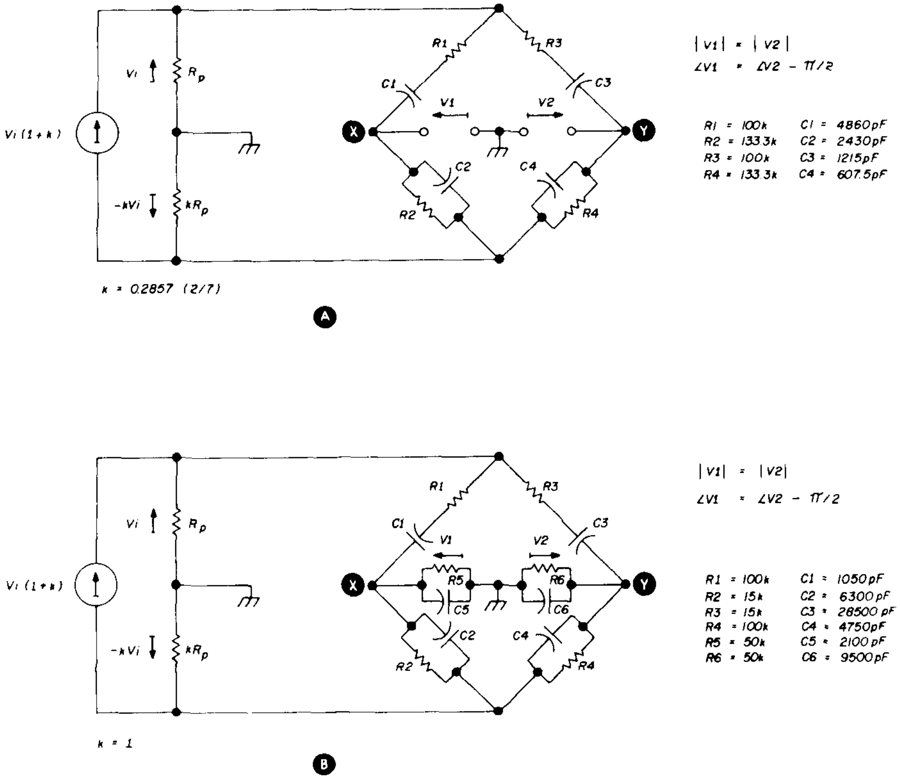


fig. 4. Norgaard network, A, and Dome network, B. Input drive floats in both circuits. Equal-amplitude outputs are taken from points X and Y.

the phase-shift network. These amplifiers must have a wide frequency response and minimum amplitude distortion.

rf circuits

The rf chain of an ssb exciter functions similarly to the audio chain, but at a fixed, comparitively low frequency. This simplifies its design because

1. The oscillator frequency may be accurately maintained by crystal control.

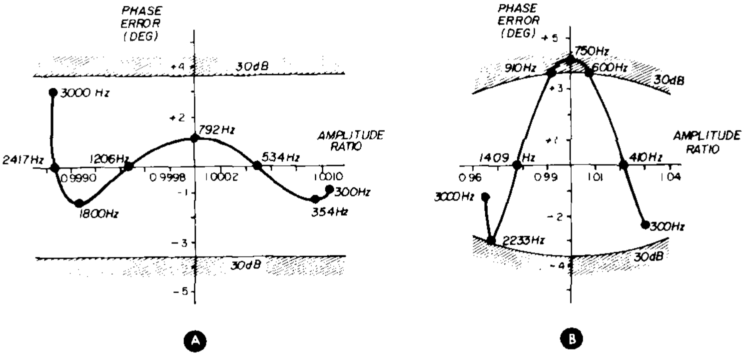


fig. 5. Error response of Norgaard network, A, and Dome network, B. Suppression with the Dome network falls below 30 dB between 600 and 910 Hz.

2. The rf phase-shift network operates at only one frequency, so it's simple to design, construct, and adjust.

Crystal frequency is determined by operating frequency and unwanted mixer products. The final operating frequency is obtained by mixing the ssb output of the exciter with a heterodyned frequency.

detailed network analysis

The Norgaard and Dome audio phase-shift networks have the following characteristics:

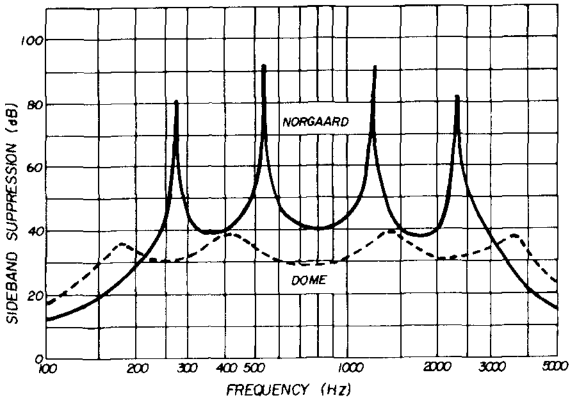


fig. 6. Sideband suppression as a function of frequency. Note marginal performance of the Dome network around 750 Hz.

1. The Norgaard **(fig. 4A)** is a bridge network designed to be terminated in an infinite impedance. Its input requires two antiphase signals whose amplitudes are in the ratio 2:7.

2. The Dome is shown in **fig. 4B**. It is a full lattice network. Outputs are developed across a finite, complex impedance. Its input requires two antiphase signals of equal amplitude.

Each network operates on the differential phase principle. The phase angle with respect to the input of *each* output increases with frequency, but the phase difference between the outputs remains constant at 90°.

The amplitude and phase response of the Norgaard and Dome networks are shown in **fig. 5A** and **5B**. In both cases *ideal* component values, input drive ratios, and terminating impedances are assumed. The arrows on the curves indicate the direction of increasing frequency; several spot frequencies are also shown.

amplitude response

In the Norgaard network, the amplitude ratio of the two outputs remains very close to unity; worst-case unbalance is of the order of only 0.1 percent. The suppression curves are quite flat in this region, so amplitude unbalance has negligible effect on the final suppression value.

In the Dome network, maximum error is approximately 3 percent. Amplitude unbalance is therefore responsible for degrading maximum obtainable suppres-

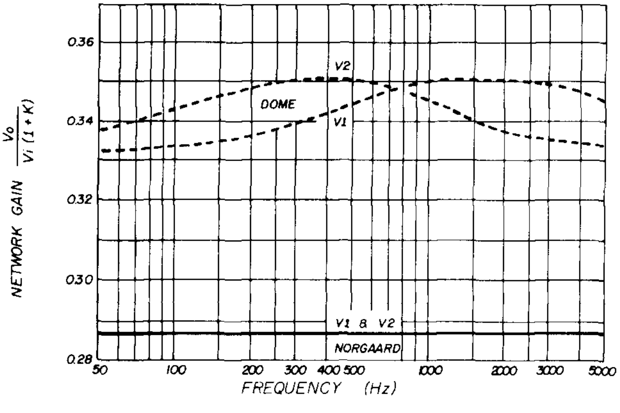


fig. 7. Insertion loss of Norgaard and Dome phase-shift networks.

sion by several dB.

phase response

The maximum phase error produced by the Norgaard network is +2.9° at 3000 Hz. The phase error is primarily responsible for limiting sideband suppression.

Fig. 6 compares the two networks over a wider frequency range. Note sideband suppression at line frequency. The Norgaard network suppresses the unwanted sideband 7.5 dB at 60 Hz, increasing to 15 dB at 120 Hz. This means that the audio preamplifier must be designed to attenuate these frequencies on the unwanted sideband.

The Dome network phase error ranges from -2.9° to 4.2°. Unwanted sideband suppression decreases to 28.8 dB at 750 Hz.

network gain

If the amplitudes of the two antiphase input signals are Vi and kVi, where k is the ratio of the appropriate network (i.e., 2/7 or 1), and Vo is the output signal amplitude, then network gain is

$$G = \frac{V_o}{V_i\,(1 + k)} \qquad (12)$$

This plotted versus frequency for each network **(fig. 7)**. Note that little variation in insertion loss is evident for either network. Expressing the gain at 1 kHz (by taking Vo as the mean of the nearly equal otuputs), the Norgaard and Dome networks exhibit -13.1 and -15.2 dB respectively.

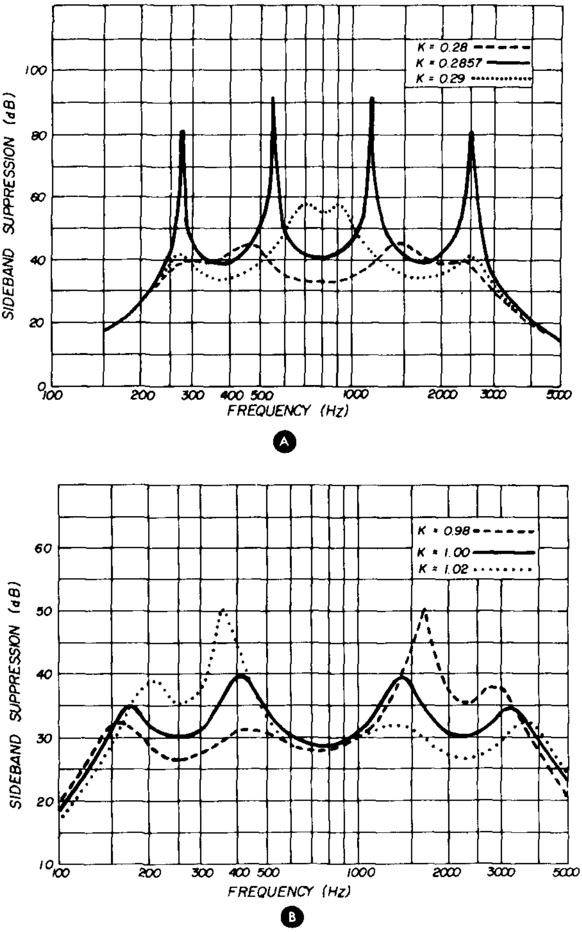
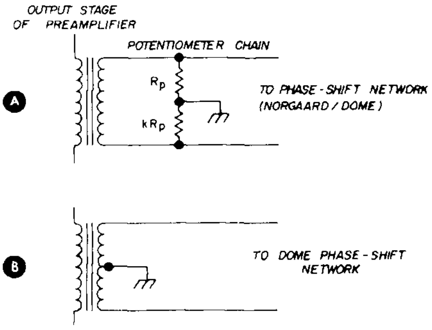


fig. 8. Effect of drive-ratio errors (i.e., incorrect values of k). Norgaard network response is shown in A; Dome network in B.

fig. 9. Usual method of coupling audio preamp to either network, A. Center-tapped transformer should be used for the Dome network, B.



incorrect drive ratio

As mentioned previously, the correct drive ratios for the Norgaard and Dome networks are 2/7 and 1. Even very small deviations from these values will result in degraded performance **(fig. 8)**. Allowing for other imperfections in the system, the drive ratio for the Norgaard network should be kept within ±2 percent, or within the range 0.28 to 0.29. The Dome network is similarly affected, but to a greater extent. In this case the maximum tolerable error is about 1 percent of optimum.

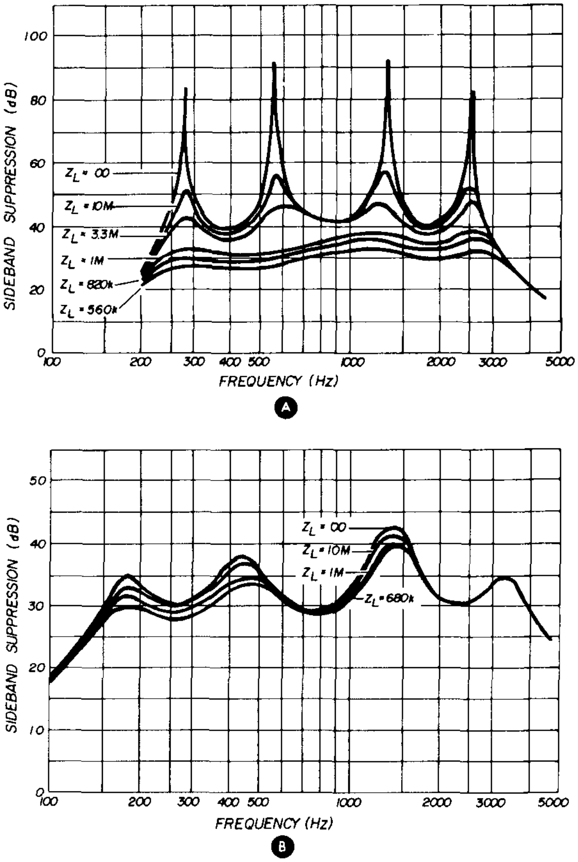


fig. 10. Effect of terminating outputs of Norgaard network, A, and Dome network, B, in a finite impedance.

practical considerations

Input signals to the network are usually transformer coupled from the audio preamplifier. Amplitude ratio is obtained by resistive divider **(fig. 9A)**.

The voltage ratio of the phase-shift networks is extremely critical. Common practice is to include a preset potentiometer across the transformer secondary to adjust this ratio. A potentiometer just doesn't have the long-term stability to maintain a *fixed* and *accurate* ratio of the two input signals. The tapped resistor network should be considered as part of the phase-network. The same care should be used in choosing its components as those of the phase-shift network.

The actual values of the resistors in **fig. 9A** are not important provided they are in the correct ratio. They should be comparatively low in value and consistent with drive capability and terminating resistance of the audio preamp. This will minimize unwanted phase shift due to stray capacitance.

Regarding the Dome network, the resistive divider should not be replaced with a center-tapped transformer **(fig. 9B)**, because the voltage amplitudes across the two halves of the winding won't be within 1 percent of each other over the passband.

terminating impedance

So far I've discussed network performance under ideal conditions (infinite terminating impedance). It is instructive to consider performance when the networks are terminated in a finite impedance.

The Norgaard and Dome circuits are compared in **fig. 10**, in which each is terminated in an infinite impedance and several values of finite impedance.

A 10-megohm load doesn't seriously affect sideband suppression of the Norgaard network (fig. 10A). However, a 1-megohm termination makes quite a difference. For even lower values, the curves flatten at the low-frequency end and are shifted further downward. Suppression is less than 30 dB over much of the passband with load impedances below 500k.

Load constraints on the Dome network are even more critical **(fig. 10B)**. Terminating impedance for this configuration should be of the order of 10 megohms.

transistor applications

With both networks, minimum acceptable terminating impedance is very high compared to the input impedance of conventional transistor amplifiers. Probably fet's should be used here. It might be possible to replace output resistors R5 and R6 (Dome network) with transistor amplifiers that have an input impedance equal to the resistors. Care must be taken in amplifier design to ensure constant imput impedance.

capacitive loading

When the Norgaard circuit is used with tubes, resistors R2 and R4 (**fig. 4A**) also function as grid-leak resistors, this eliminates any additional loading. Stray capacitance across the network output must be considered in this application, however.

The solid curve of **fig. 11** shows the suppression of the Norgaard network when each output is terminated in a complex impedance, consisting of a parallel combination of 20 pF and 10 megohms. Such a small value of capacitance has negligible effect at the low-frequency end of the passband; but as the frequency is increased, the suppression peaks are lower and shift slightly lower in frequency. Performance is still satisfactory, however, because the suppression doesn't fall below 38 dB except at the extreme high-frequency end of the passband.

The Dome network also may be used with the output resistors acting as grid-leak resistors, but stray capacitance will have negligible effect because the outputs incorporate large shunt capacitors (C5, C6 in **fig. 4B**).

audio preamp frequency response

When followed by the Norgaard network the preamplifier's frequency response should be as shown in **fig. 12**. From 300 to 3000 Hz the response is flat as is taken as the reference level of zero dB. The suppression of the unwanted sideband over this range is always better than 30 dB, and the network's amplitude response is quite flat (**fig. 7**). Below 200 and above 3000 Hz, preamplifier frequency response follows the curve of **fig. 6**.

Frequency response of the preamplifier followed by the Dome network is similar, except that the curve dips slightly at mid-band. The curve of **fig. 12** shows the overall response of the preamplifier. This is determined by coupling capacitor values and transformer response, in addition to the contribution of a filter. The response curve's slope at the extreme ends of the passband is about 15 dB/octave.

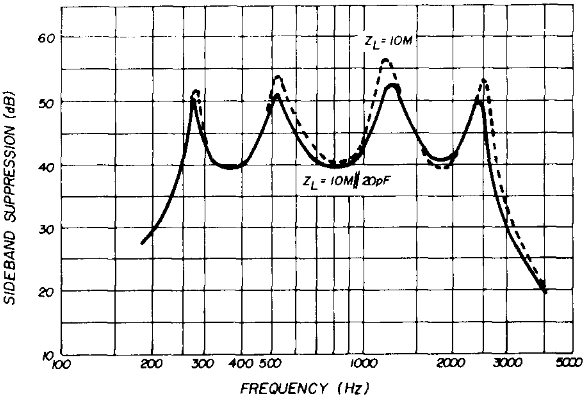
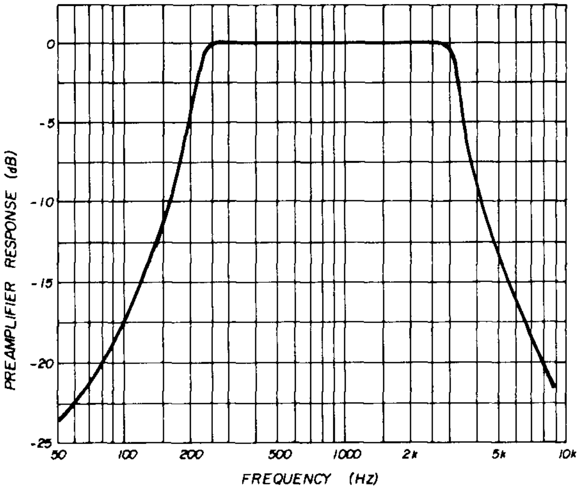


fig. 11. **Performance degradation due to stray capacitance in Norgaard network. Large capacitances shunting Dome networks eliminate this problem.**

fig. 12. **Audio preamplifier frequency response. A slope of about 15 dB/octave is required at each end of the passband to ensure 30-dB sideband suppression.**



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electronic keyer oscillators

A basic oscillator circuit does double duty as a clock and sidetone generator in this application of ICs

John G. Curtis, WA6JNJ, Box 4090, Mountain View, California 94040

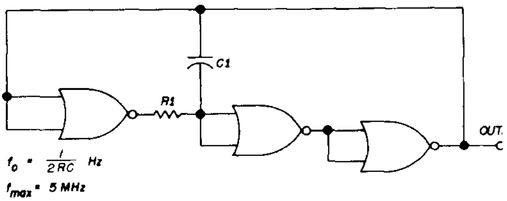
If you are a cw operator you've probably seen the large number of electronic keyer articles published in the amateur literature during the past few years. So many have appeared that all circuits seem to look alike. In general, however, most of the designs have a few interesting features worth noting.

The oscillator described here uses a special kind of integrated circuit, the LU380A, made by Signetics. The oscillator is used in an electronic keyer known as the Electronic Fist.* The logic form of the IC, called Utilogic, is neither DTL, TTL, nor RTL. Although not too well known in amateur circles, Utilogic is widely used in industry. The distinguishing feature of this IC is that the NOR and OR gates have inputs at the transistor bases. This means that the input impedances are fairly high, on the order of 15-25k ohms. Because of this high input impedance, the devices can be used in multivibrators and oscillators.

---

*The IC and keyer are available from Curtis Electro Products, Box 4090, Mountain View, California 94040. The IC is $1.34 plus 50c handling and mailing. The keyer is $49.00 (kit form) or $56.00 (wired and tested).

fig. 1. Basic oscillator used in the "electronic fist" keyer. Three NOR gates plus timing constants R1, C1 form this simple circuits.



keyer oscillators

Two oscillators are used in the electronic keyer mentioned above. One, the clock, forms the dots and dashes; the other is a sidetone generator. Both oscillators are of the form shown in **fig. 1**. Each uses three-quarters of a quad two-input NOR gate, the LU380A. The oscillator consists of three NOR gates arranged in a ring. The only other components in the basic circuit are a timing resistor and capacitor. The rings consists of an odd number of inverting gates; thus it has no stable state and tends to oscillate at a frequency determined by C1 and R1. The frequency is roughly equal to 1/(2RC), where frequency, R, and C are in Hz, ohms and farads. The maximum obtainable frequency is about 5 MHz. The output is a pretty fair square wave at the lower frequencies.

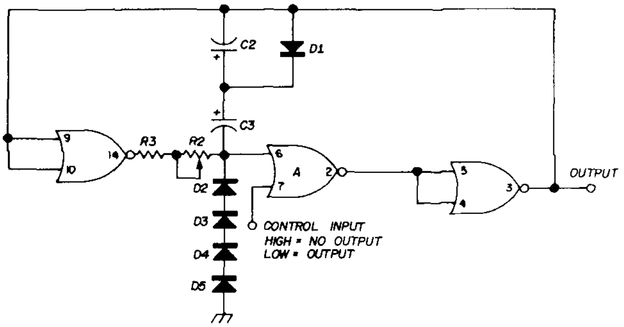


fig. 2. Clock oscillator circuit.

clock oscillator

For the clock oscillator, we use the circuit shown in **fig. 2**. The keyer is designed to operate at 8 wpm for the lower end of the speed range. Using readily available components, and trying to keep the value of R2 + R3 fairly low for linearity of adjustment, we find that a value of 25 µF for C2 and C3, 5k for R2, and 1k for R3 will yield a frequency of 3.3 Hz. Even though C2 and C3 are in series, they effectively yield their individual capacitance values. It turns out that 3.3 Hz works out to 7.92 wpm. This is based on:

Code speed (wpm) = 2.4 x dot frequency in Hz

The origin of this formula is obscure, but it correlates closely with the other rule-of-thumb, which is:

Code speed (wpm) = no. of dashes in 5 seconds

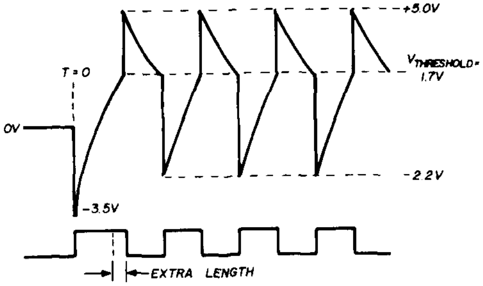
Tests show that the calculated value is very close to that measured.

To find the upper end of the speed range when R2 is cranked down to zero resistance, we find the theoretical upper speed is 47.52 wpm. This, again, agrees closely with the value found in practice. In the actual keyer, R3 is selected to meet the 50 wpm mark exactly.

operation

Diode D1 shunts reverse bias around

fig. 3. Timing diagram showing effect of eliminating gate input clamp.



Utilogic is a registered trademark of the Signetics Corporation.

C2 when the keyer is idling. Otherwise, the capacitance of C2 would slowly disappear due to its reverse polarity. The best choice for the capacitor would be a nonpolarized type, but it would be as large as the whole keyer. C3 needs no protection, since it has a very low duty cycle of reverse bias.

Diodes D2 through D5 are a negative clamp on the gate input to ensure that the first cycle of the oscillator is close to the same length of succeeding cycles. **Fig. 3** shows the clock waveform without these diodes. The first cycle starts with the input of gate A resting near ground potential, but subsequent cycles start at the threshold point of the gate. The error, in any case, is not great and can be discerned only with instruments; and the resulting cw sounds fine either way.

Fig. 4 shows the error after correction. It also shows the high degree of dot/space ratio accuracy obtainable with this simple circuit.

The control input of gate A inhibits oscillation when it is held at logic state 1. When the control input is lowered to logic state zero, the oscillator starts generating the first character. I found this instant-starting clock much simpler to use than the free-running variety, which tends to force spacing between letters.

sidetone oscillator

The sidetone oscillator, **fig. 5**, is of the same form as the clock. Sidetone oscillator frequency, normally 800 Hz, is adjustable by R4. The output is gated by NOR gate B, which drives the base of a 2N404 through current-limiting resistor R5. An ordinary output transformer, with a 500-ohm center tapped primary and 8-ohm secondary driving a 2-inch speaker, completes this simple monitor circuit.

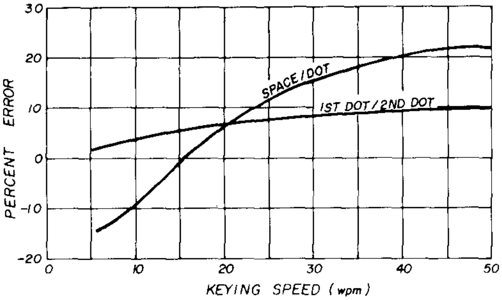


fig. 4. Timing accuracy of the clock circuit after correction. Note high degree of dot/space ratio.

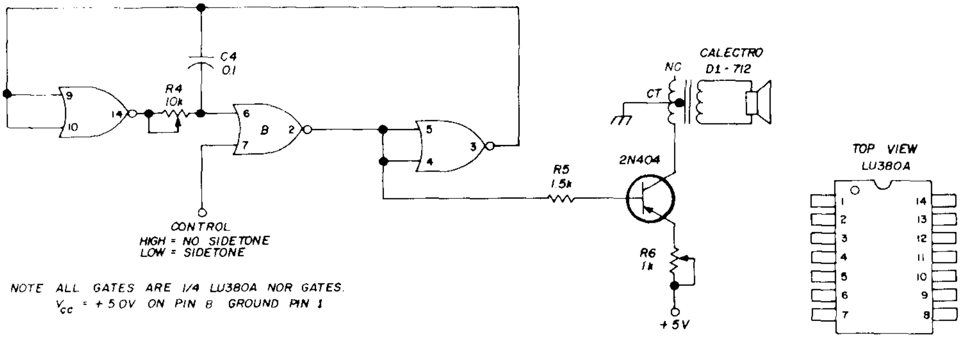


fig. 5. The sidetone oscillator. Frequency is adjustable by R4; output level by R6.

The output level, controlled by R6, is adequate for a roomful of people. Fairly high efficiency is obtained, since the 2N404 operates near class C.

reference

1. L. Brock, "Utilogic NOR and OR gate Applications," Signetics Corporation Applications Memo 97, June, 1969.

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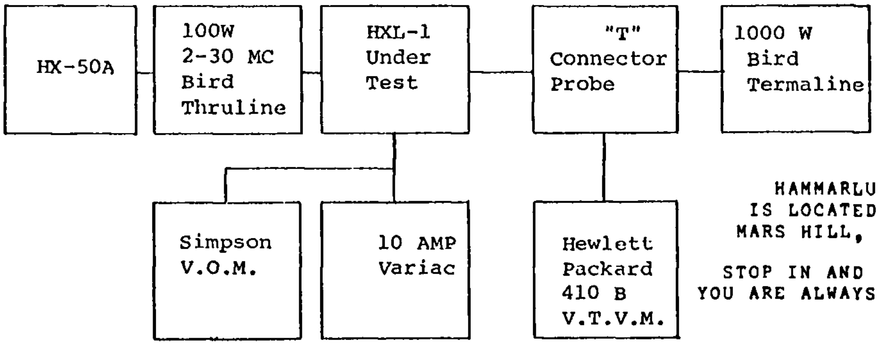

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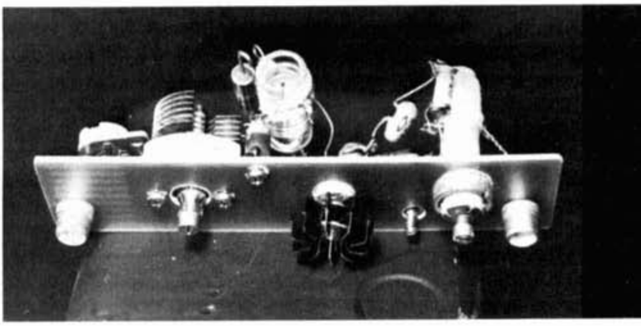

transistor frequency multipliers

Selecting transistor frequency-multiplier circuits for maximum efficiency and output

Frank C. Jones, W6AJF, 850 Donner Avenue, Sonoma, California 95476

The circuit board in the photograph was put together to try out different circuits for frequency doubling from 14 to 28 MHz; a high-output signal generator provided the 14-MHz drive. A wattmeter across the output provided readings for comparing the relative efficiencies of different multiplier circuits.

The transistor used for nearly all the tests, the 2N5188, is an inexpensive npn transistor rated at 4 watts maximum dissipation at 25° C; this indicates a maximum dissipation of 2 watts or so with a moderately sized heat radiator slipped over the transistor case. Typical cutoff frequency for the 2N5188 is 325 MHz. Selected 2N5188's can be used in class-C rf service up to about 150 MHz—at lower frequencies nearly all units give equally good results without special selection.

An rf voltmeter was connected from base to ground (or emitter) to make sure the maximum base-to-emitter breakdown voltage of 5 volts peak was not exceeded during tests. The proper value for the base-bias resistor in frequency multipliers ranges from 100 to 5000 ohms. If the base-bias resistance is too great the tran-

sistor may be damaged by high rf drive since the 5-volt rating is easily exceeded. In most of these tests a 1000-ohm bias resistor was used, and the rf drive adjusted to 3 volts rms maximum.

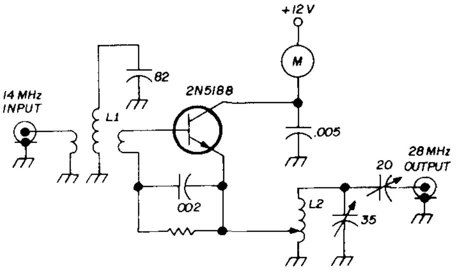

fig. 1. This circuit is essentially the same as fig. 3 although the transistor collector is at rf ground.

The 2N706, 2N2711 and 2N222 provide moderately good efficiencies when operated as frequency multipliers up to about 1/5 of their cutoff frequency. The 2N4427, 2N3866, 2N3553 and similar power transistors provide more output on two meters than the 2N5188, but they cost several times as much. Two 2N5188 stages—one as a frequency multiplier providing 0.1 to 0.3 watts output and the other as a buffer with 0.5 to 1 watt output—offer an economical way of building a two-meter transmitter. The more expensive power transistors can then be used as power amplifier stages for a few watts of fm or cw.

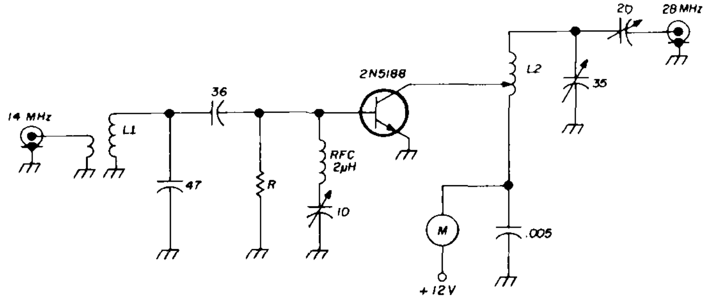

fig. 2. This circuit provides a low-impedance path from base to emitter and effectively connects the collector-to-base feedback capacitance across the output.

practical circuits

Four practical frequency-doubler circuits are shown in **fig. 1** to **4**. Although the circuit of **fig. 3** is the one usually seen in the literature, the circuits of **fig. 2** and **fig. 4** proved to be far superior. The circuit of **fig. 1** is a little unusual in that its collector is grounded for rf, but it is basically the same as **fig. 3** (and actually performed about the same). **Fig. 1** has slightly less rf radiation loss since the collector is connected to the case—the construction used for most transistors that are rated at more than 0.5 or so. However, in the 14-to-28 MHz frequency doubler tests the rf loss wasn't high enough to warrant the use of the common-oscillator layout over the more usual grounded- or common-emitter circuit.

The reason the circuits in **fig. 2** and **fig. 4** gave twice as much output as the others is quite simple: the transistor has a relatively high feedback capacitance between collector and base, so any appreciable impedance from base to emitter—even a single-turn link—causes degeneration; the series-tuned 28-MHz circuit in **fig. 2** provides a very low impedance path from base to emitter and effectively connects the collector to-base feedback capacitance across the output. This eliminates degeneration and increases output by 1.5 to 3 times in doubler, tripler and quadrupler stages.

The series-trap circuit also provides excellent efficiencies at vhf and uhf but it requires careful adjustment. The disadvantage of the circuit in **fig. 2** is that it will break into self-oscillation if the series-resonant circuit is incorrectly tuned; it also requires an additional adjustment in the frequency multiplier.

The advantage of the series-tuned circuit is that it can be applied to an existing frequency multiplier in a vhf or uhf converter or transmitter to obtain more output. Usually a small moderately high-Q rf choke coil can be selected which will resonate with a 5- or 10-pF piston capacitor to the desired *output* frequency. With this simple modification tripler and quadrupler stages really come to life as far as rf output is concerned.

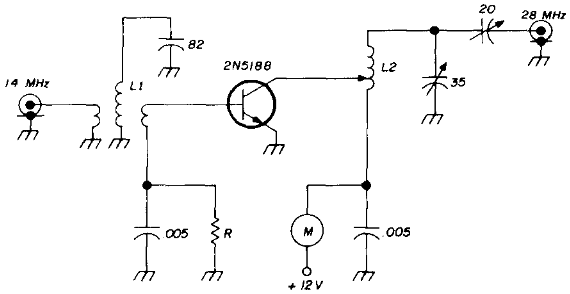

fig. 3. This is the frequency-multiplication circuit usually seen in the literature.

The frequency-multiplier circuit in **fig. 4** is my favorite for doublers, triplers, or quadruplers—at high or low power. It provides a low-impedance path from base to emitter if C2 is large enough to provide a reactance of only a few ohms at the output frequency; if the reactance is below 10 ohms excellent results can be obtained. The ratio of C2 to C1 should be between 5:1 and 10:1.

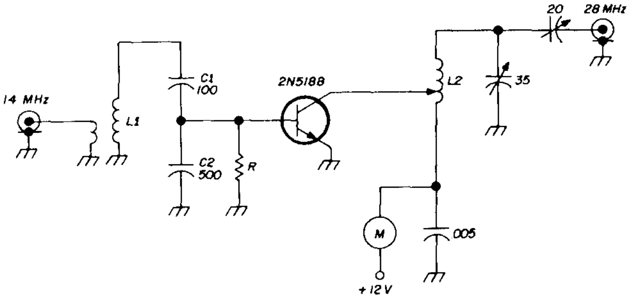

fig. 4. This circuit is W6AJF's favorite for frequency-multiplication service.

In most small-power frequency-multiplier circuits the collector must be connected to a tap on the output tuned circuit to obtain a reasonable impedance match. To minimize undesired harmonic output the tuned circuit should have an operating Q of at least 15. In usual designs the collector tap is located 1/6 to 1/2 the total number of turns from the cold end.

Low-power frequency-multiplier circuits, such as those used in vhf receiving converters, can be designed with the collector connected to the hot end of the tuned circuit if the tuned circuit has a resonant impedance in the range of 1000 to 3000 ohms. If the circuit doesn't tune sharply it indicates low circuit Q and poor harmonic suppression, and may mean the collector load or external load is too heavy.

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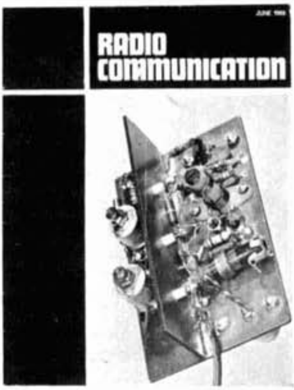

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rtty frequency-shift meter

This instrument will measure rtty shift as well as small frequency differences in any audio filter

Jim Goding, VK3ZNV, 15 Yarrabee Court, Mount Waverly, Victoria, Australia

One of the problems confronting the rtty operator is measuring the correct frequency shift between mark and space signals.

This article describes a direct-reading indicator with which you can measure these frequencies from your receiver output. By offsetting the mark frequency to zero and increasing meter sensitivity, the difference between mark (2125 Hz) and space (2295 or 2975 Hz) can be accurately measured.

the circuit

The circuit consists of an input amplifier, Schmitt trigger, monostable multivibrator, averaging amplifier, and meter amplifier **(fig. 1)**. The input amplifier has an input sensitivity of about 100 mV. The Schmitt trigger squares the input signal, which is then differentiated by the 300-pF capacitor. The negative pulses are clipped by a diode, and the positive pulses trigger the monostable (one-shot). Thus a series of rectangular pulses is produced whose repetition rate is equal to the signal frequency. Pulse amplitude and length are respectively 3.6 V and 80 microseconds.

The averaging amplifier produces a steady negative dc voltage proportional to the average voltage of the waveform at the one-shot's output which is, in turn,

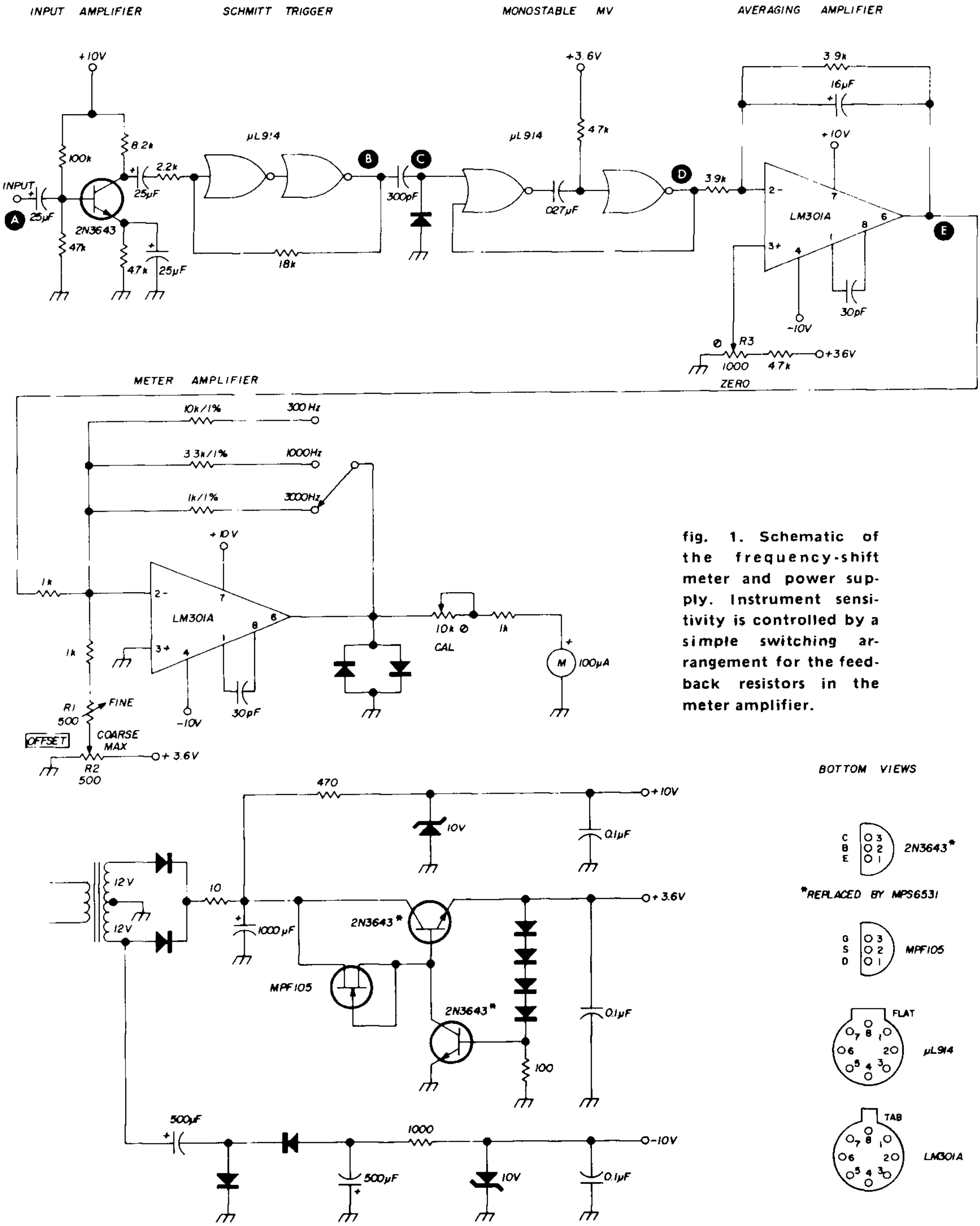


fig. 1. Schematic of the frequency-shift meter and power supply. Instrument sensitivity is controlled by a simple switching arrangement for the feedback resistors in the meter amplifier.

proportional to input frequency. Typical waveforms are shown in **fig. 2.**

Instrument sensitivity is selected by switching the feedback resistors in the meter amplifier. The meter amplifier will have a gain of 1, 3.3 or 10 corresponding to 3000, 1000 and 300 Hz respectively. Potentiometers R1 and R2 allow a small current opposite in polarity to the signal current to be applied to the meter amplifier; thus the meter indication is fully adjustable.

calibration

An accurately known audio frequency is required for calibration. With no input to the instrument, set offset controls R1 and R2 to zero and the range switch to 300 Hz. Adjust R3 for a zero indication on the meter. Set the range switch to the appropriate range for the calibrating frequency; i. e., the range that gives the highest reading without pinning the meter. Next apply the calibrated signal, and adjust the calibration control for the correct meter indication.

If 1 percent resistors are used as shown, only one range need be calibrated; the others will be automatically correct. Zero-set and calibration controls may be preset screwdriver-adjustment pots located on the back of the instrument.

shift measurement

To use the instrument, set the range switch to 3000 Hz and apply the mark frequency to the input. The meter should indicate the mark frequency. Set the meter to zero, *with the mark frequency still applied to the input.* Then switch the meter to the 1000-Hz range for 850-Hz shift, or to the 300-Hz range for 170-Hz shift. The zero point might need readjustment with the fine offset control. Now apply the space frequency to the input. The shift may then be read on the meter.

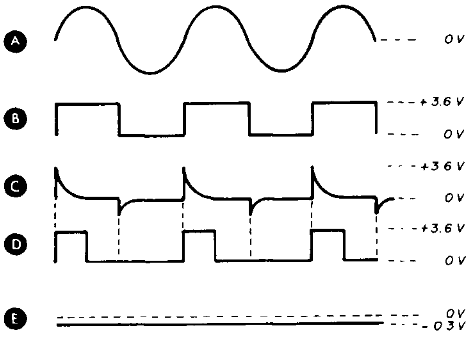


fig. 2. Typical waveforms. These will appear at similarly labeled points in the schematic.

meter protection

While the circuit is virtually foolproof, it's possible to pin the meter in the forward direction if the input signal's frequency is too high. The meter can be pinned in the reverse direction when no input is applied with the offset control advanced. Therefore, the diodes in the meter amplifier output are included to protect the meter from possible high overload levels.

noise response

If noise is on the signal to be measured, as when measuring the shift of a weak signal, errors may result because the Schmitt trigger will fire on noise pulses as well as on signal. The error may be reduced by using the minimum audio signal that will give a steady reading. Errors due to noise will be no problem, of course, when setting your transmitter's shift by monitoring its signal on your receiver.

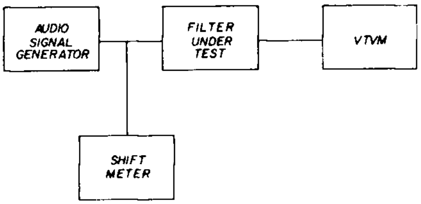


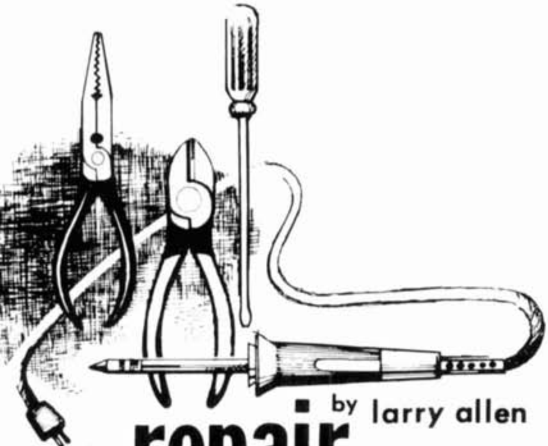
fig. 3. Application of the circuit for adjusting small differences in audio filter output frequency.

other uses

The instrument is also useful in adjusting audio filters for rtty and other uses. A typical test setup is shown in **fig. 3.**

While most audio signal geneators have good *absolute* accuracy, their calibration is seldom good enough for measuring small differences in output frequency. In setting up many filters, particularly for rtty, filter bandwidth is often more important than center frequency.

ham radio



by **larry allen**

the repair bench

curing trouble in mobile power supplies

Remember the days when only three things could go wrong with a mobile power supply? A sticky vibrator, a bad buffer capacitor, and—if things were really bad—a transformer.

It wasn't hard to figure out which it was; they all blew the fuse. A done-in transformer spewed was and varnish, and a worn-out buffer made even a new vibrator sound ragged. And substituting a new vibrator was a sure way to bring the output voltage back up to normal if the old vibrator was shot.

Nowadays when a fuse pops, it all happens so quietly you hardly think anything's wrong at all. The buzzing vibrator has been replaced by transistor switches. The frequency they flip-flop at is audible but so quiet you can't usually hear it. And when one of the transistors goes—it generally goes completely. There's no bounce, rattle, or noise. Just thump! and the fuse or circuit breaker pops open.

the heavy demands

A lot is expected of the mobile power supply. Take the one pictured in **fig. 1**. It's big enough to operate an ssb linear from a 12-volt car battery. It can furnish up to 500 mA at 2 kV, if it has to. Typically, it runs about 2.1 kV with an average load of 180 mA. It also supplies -110 volts at 60 mA, for bias.

The switching transistors in a supply like this must be heavy ones. Likewise the transformer and rectifier diodes must be rated to withstand lots of voltage and current. Input wiring and components must carry the heavy battery-current drain of a supply like this—as much as 30 or 35 amps.

Running a unit like this on the repair bench requires the same kind of care you'd use installing it. Heavy wiring from the dc supply is a must. No ordinary battery eliminator today can handle the load, so you'll need a storage battery. A charger across it will keep it at full power.

An ideal bench setup brings the 12-volt battery cables up to ¼-inch bolt terminals at the back of the bench. A 4-foot cable is made up from two No. 6 awg wires terminated at one end in soldered-on eye terminal lugs; the holes in the lugs fit over the terminal bolts. The other end of the test cable has a heavy-duty Jones female plug to fit this power supply. Other cables can be made up for other power supplies.

A 60-amp cartridge fuse (Buss FRN-60) in the battery-cable line protects the battery. It doesn't take long for a dead short to ruin battery plates and burn the insulation right off the cable wires. If you set up your bench like this, occasionally spin the cartridge fuse in its holder; that keeps the contact clean and cool.

the switched inverter

The basic input circuit of the Heath

Heathkit HP-13 dc supply, their newest model, is designed for mobile operation of the SB-101, SB-110A, HW-100 and Heath Single Banders.

mobile supply is diagramed in **fig. 2**. A 40-amp breaker protects the car battery. An input relay is necessary because no ordinary switch could carry the power for this supply. A switch on the transmitter closes the relay. A choke and capacitor decouple the input dc line, so no hash from the dc-to-ac inverter can affect other accessories.

fig. 1. Heathkit HP-14 power supply, although no longer marketed, is an example of a high-voltage mobile power supply that can be used with a 1-kW PEP linear amplifier. Switching transistors are heavy-duty types, and heavily heat sinked. (Two are out of sight on other sides of the unit.)

When the input relay closes, 12 volts positive is applied to the emitters of both transistors through a short portion of the transformer winding. The collectors are grounded, making them negative with respect to emitter. That's the first requirement for operation of pnp transistors.

At the same time, the rest of each winding half is feeding the positive voltage to the bases and to resistors R1 and R2. The voltage at the base of each transistor is less positive (thus more negative) than that reaching the emitter, because the winding drops some of it (R1 and R2 are dividers with the winding resistances). With base negative (to the emitter) the pnp transistors can conduct.

However, the transistors are not perfect matches. One conducts more than the other. Heavy electron current flows in one (for this example, let's say it's Q1). The path is from ground through collector to emitter, through a short portion of the transformer winding to the center tap, and out to the positive battery terminal.

As this current builds up, it develops a magnetic field in the winding. That field applies a negative-going rise to the base of Q1, adding to the negative bias already there. The transistor conducts even more.

Meanwhile, the same magnetic field is backward-biasing the other transistor. The portion of transformer winding between Q2's base and emitter applies a

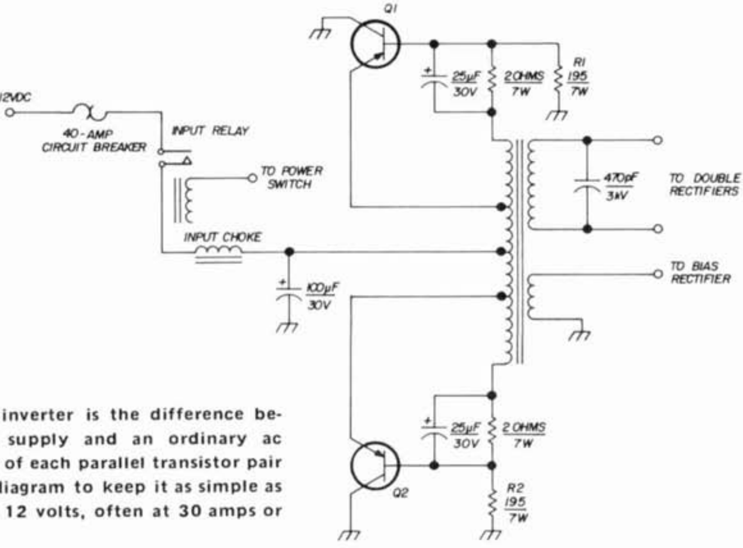


fig. 2. Dc-to-ac inverter is the difference between a mobile supply and an ordinary ac supply. Only one of each parallel transistor pair is shown in this diagram to keep it as simple as possible. Input is 12 volts, often at 30 amps or more under load.

positive-going voltage to the base, which cuts that transistor off. No current can flow in the collector/emitter/winding circuit of that transistor.

Sooner or later, the transformer saturates. That is, even though current in Q1 keeps increasing, the magnetic field doesn't. Then, no more extra base bias for Q1 is developed by the transformer winding. Q1 current suddenly begins dropping off.

As the magnetic field collapses, the whole process reverses itself. Suddenly, Q2 gets the go-ahead bias it needs to start conducting. And it does. The more it does, the more its end of the transformer winding forward-biases it. It takes off like Q1 did earlier. Current goes way up. And all this time, Q1 is being cut off like Q2 was earlier.

This goes on till the transformer saturates at the Q2 end. Then again the process reverses and Q1 takes over. The transistors keep switching back and forth, generating more or less of a square wave. There's a photograph of how it looks on the oscilloscope in **fig. 3**. Notice how transformer saturation tapers the voltage off gradually until suddenly the other transistor takes over. Then the waveform has straight sides till full voltage is reached in the other polarity.

Another factor that rounds the trailing corner of the output waveform (and causes the overshoot at the leading corner) is the capacitor across the high-voltage secondary. Without it, transient overshoots and preshoots could generate large counter-emf's that might damage the transistors. In this respect, the 470-pF capacitor acts like the buffer capacitor in old vibrator supplies.

A resistor-capacitor network in the base circuit of each transistor is further protection; they absorb any transient spikes that might zap the base junctions of the transistors.

trouble in the switcher

The most likely trouble is a shorted transistor. As mentioned on the schematic, each transistor is actually a pair; there are four transistors, with heat sinks. If a transistor shorts, the switcher quits. Usually, the breaker opens—from the short or from overcurrent in the two opposite transistors.

To test the shorted one, you have to disconnect the base and emitter leads. Usually, the leads have tips that slip down over the pins. If the wires are soldered, don't overheat the pins disconnecting and reconnecting them.

Use your ohmmeter. Clip the common test lead to the collector (grounded in this example). The ohmmeter should read open or extremely high to both pins. Next clip the ohmmeter common to the base pin and touch the probe to the emitter. Then reverse them. You should get a low reading (but well above zero) one way and a high reading the other. If you get an infinite reading both ways, the transistor is open. If you get zero or a very low reading both ways, the transistor is shorted.

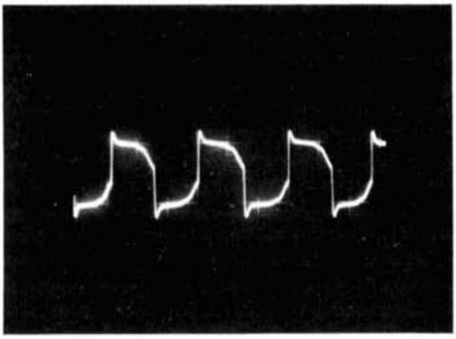


fig. 3. Waveform developed by dc-to-ac inverter. This shaped square wave is what is fed to the rectifier doubler circuit by the transformer secondary.

Be cautious replacing the transistor. Be sure it's the right type. If it opens, the others overload and may go. Position the new one carefully. Sometimes the mounting holes are sloppy and the base or emitter can touch chassis ground. If it's the base, goodbye new transistor!

If a transistor blows, also check the base resistors and electrolytic capacitors (with one end loose). It only takes a few minutes. A poor electrolytic may let transmitter keying transients damage the transistors. If so, a new transistor may soon go the way of the old one.

If you have a capacitor checker with a power-factor test, use that. Also measure capacitance. If not, use your ohmmeter. Make sure both electrolytics charge up quickly and don't show a resistance below 50k. If they charge slowly, power factor is too high. You can measure resistors directly.

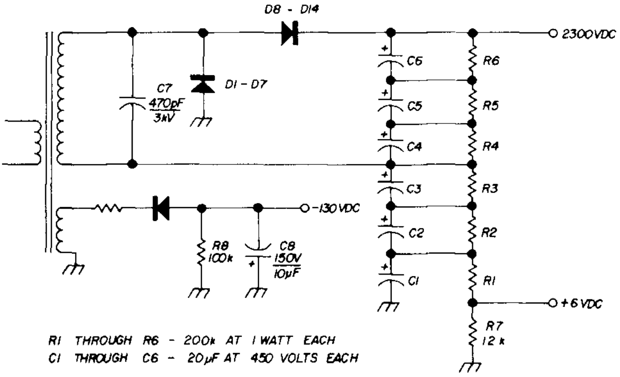


fig. 4. Dc output section of typical mobile hv supply. Diodes in series increase voltage rating without expense of hv diodes. Circuit is full-wave doubler. Bleeders distribute voltage among capacitors, which are also in series for higher voltage rating.

the high dc side

You can have trouble with the dc circuits of a mobile supply, too. That consists of rectifier diodes, filter capacitors, and bleeder resistors.

The output of a supply in this example is diagramed in **fig. 4**. The transformer is the one you see in **fig. 2**, but only the secondary is drawn here.

The transformer steps up the voltage of the primary waveform, which is only about 10 volts peak to peak (p-p) at the emitter of the transistors. There's about 1000 volts p-p across the secondary winding and C7.

Diodes in series give a rating to withstand such high voltage. There are seven diodes in each leg of the voltage-doubler circuit.

The doubler is a simple full-wave type. On one half-cycle, diodes D8–D14 charge capacitors C4–C6. One the next, diodes D1–D7 charge capacitors C1–C3. The charges across the two strings of capacitors add, and the output is double the input.

The bleeders, R1 through R7, have a number of purposes. For one thing, they're a safety factor. They drain off any charge on the capacitors, and on any capacitor in the transmitter, when the supply is shut down. Also, connected as they are, they equalize voltage distribution across all the electrolytic capacitors. Without them, one capacitor might develop too much voltage and break down.

Also, R7 is a small-value divider resistor in series with the six main bleeders. It develops a 6-volt positive dc. This output is ordinarily for automatic level control (ALC) bias.

The bottom winding develops about 125 volts p-p. That's rectified in a diode connected with anode to output. A filter capacitor and bleeder resistor keep the output at a negative 130 volts dc (-130 V dc). That's bias for the linear amp. In one Heath linear, it also operates the antenna relay.

dc output troubles

Some troubles in a supply like this can be diagnosed from the symptoms.

Low output, for example, can be the result of an open diode. That leaves only half the doubler working, and no-load dc output is reduced to half or less.

An open bleeder can cause the parallel capacitor to be damaged. If output drops drastically with even slight load, check each output resistor and capacitor. You may have to disconnect one end of each capacitor to get a meaningful ohmmeter or checker reading.

Whenever you find an open bleeder resistor, always replace its capacitor too. It has taken an overdose of voltage. Even if it seems healed, its ability to form a dielectric may be impaired.

A shorted diode in a series string like this doesn't show up immediately. Later, another may go, then another. Eventually, one will probably burn open. Some may develop backward leakage that will eventually damage others. So, when *any* diode trouble is found check all the others in that series string. Just check them one at a time with your ohmmeter; you don't even have to disconnect them. One direction should read less than 100 ohms (actual amount depends on the ohmmeter battery). The other direction should read open.

It's a good idea to check the bleeders periodically. Just watch a voltmeter connected to the dc output. Turn the supply on, *with no load* connected. Then turn it off. The meter should drop to zero volts in a matter of 1 or 2 seconds. If not, BEWARE. The bleeder is open.

An open R7 shows up in other ways, too. Most notably, the ALC output voltage (6 volts) rises to practically the full dc output voltage. The linear couldn't take that. If the ALC diode in the linear blows, first thing to check is the ALC-bias bleeder in the power supply. An easy was is by the bleeder test just described.

Troubles in the -130 volt bias supply are ordinary. If output is very low under load, R9 or the diode is probably the culprit. If it's low even without a load, the capacitor (C8) is probably bad. Be sure to connect any replacements with proper polarity. Check the 100k bleeder, too. A meter on the output, with no load, should drop to zero as fast as the meter pointer will allow, when you turn the supply off.

caution—high voltage

You've got to be careful around these supplies. Never assume the bleeder is okay. A jolt of 2000 volts, when current capability is 500 mA, can cool you for good. It only takes 8 or 9 mA to make your heart fibrillate, if you don't get aid within a very few minutes the damage is permanent. Dead permanent. Even a couple of milliamps can hurt an already weak heart, or weaken a good one.

I never work around one of these except with two things: a 1-meg 2-watt carbon resistor I know is good, and a jumper lead. The resistor goes across the output before I turn on the supply the *first time. It stays there until the last test* is run and I'm sure the internal bleeders are working. Besides that, I always keep a jumper clipped across the high-voltage output except when I'm firing up the supply for a live test. When I turn it off, back on goes the jumper. This may seem like trouble, but so are funerals.

Whenever possible, I do my troubleshooting with tests that don't require me to fire up the unit. That takes some of the danger away. (I wrote about that kind of troubleshooting in this department in August 1968, page 52; November 1968, page 62, and January 1969, page 52.)

what's ahead in repair bench

Solid-state equipment is now the rule more than the exception. With it comes the old fear of not being able to keep the gear operating. More specifically, hams worry about how to track down trouble in a solid-state receiver or transmitter.

Most hams can do pretty good deciding what section or stage is fouled up. But their unfamiliarity shows through when they get down to troubleshooting the circuits inside the stages.

Next month, I'll show you a sure-fire approach to servicing transistors. I won't make a super-speed technician out of you, but when you get through reading next month's column you'll know how to find out what's working and what isn't.

ham radio

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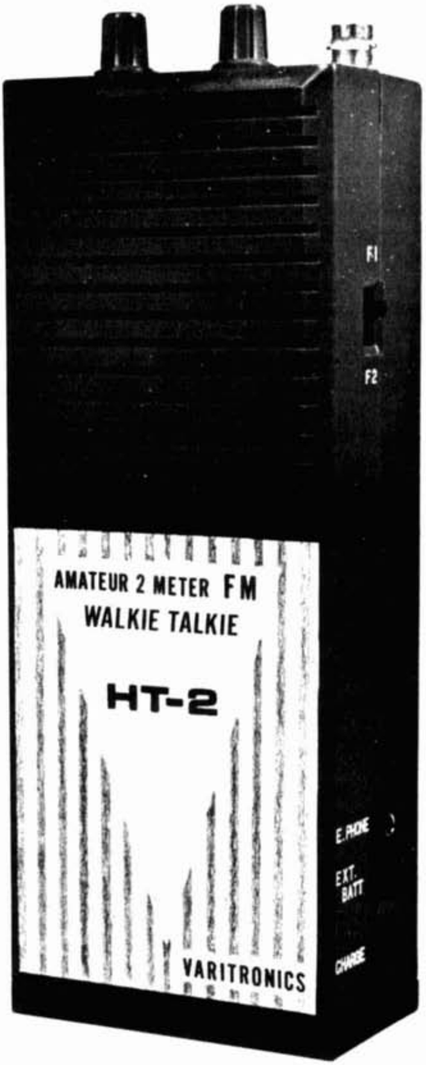

VARITRONICS INCORPORATED

Arizona Interstate Industrial Park
2321 East University Drive
Phoenix, Arizona 85034

knight-kit two-meter transceiver

Jim Fisk, W1DTY

If you've been shopping around for a little two-meter rig, you've probably seen the ads for the Knight-kit TR-108 transceiver. This little unit covers the entire two-meter band, and combines a sensitive double conversion receiver with fifteen watts input and a built-in 117-Vac/12-Vdc power supply. All you need to get on the air is an antenna and a crystal for your favorite two-meter frequency (an optional vfo kit is available if you want to move around the band a bit). Also, if you want to go mobile, an accessory mobile mount is available.

receiver

The first stage of the two-meter receiver section is a 6HA5 grounded-grid rf amplifer. This stage provides adequate gain and noise figure for the maximum range that can be expected with the TR-108. The crystal-controlled oscillator/tripler that feeds the first mixer uses a third-overtone crystal cut to 37.883 MHz—a 6CW4 serves as the oscillator and the triode section of a 6GJ7 as the tripler. The pentode section of the 6GJ7 is used as the first mixer with a resulting output of 30.35 to 34.35 MHz. Since the converter section has a 4-MHz bandpass, each coil must be properly peaked to maintain the broadband characteristics. The converter section is the most critical part of the whole transceiver, and is prewired and aligned by the factory for maximum performance. Sensitivity is 0.5 μV for 10 dB signal-plus-noise to noise ratio.

The output from the converter chassis is fed into the second mixer through a coaxial cable. The triode section of a 6EA8 is used as a tunable oscillator to provide injection for the second mixer; the second mixer is the pentode section of the same 6EA8. The oscillator circuit is a temperature-compensated shunt-fed Hartley circuit that tunes from 32 to 36 MHz; output from the second mixer is at 1650 kHz.

The 1650-kHz i-f strip in the TR-108 transceiver uses two high-gain 6BZ6 amplifiers and three double-tuned i-f transformers. The double-tuned i-f transformers provide a simple way to obtain narrow bandwidth. The selectivity is 6 dB down at the 8-kHz points. Image rejection is rated at 55 dB and i-f rejection is better than 50 dB.

The dual-diode 6AL5 used in the detector/automatic noise limiter stage is very sensitive to low-level signals. The first diode section of this tube functions as a standard a-m detector. The agc voltage is derived from this section, filtered and fed back to the control grid of the i-f amplifier stages.

The second-diode section of the 6AL5 is used as a series-gate noise limiter. This type of noise limiter introduces negligible distortion, even under strong-signal conditions with high-level modulation—most limiters distort the desired signal when limiting begins. The series-gate circuit is self-adjusting over a wide range of signal levels so the limiting level is compatible with the amplitude of the incoming signal.

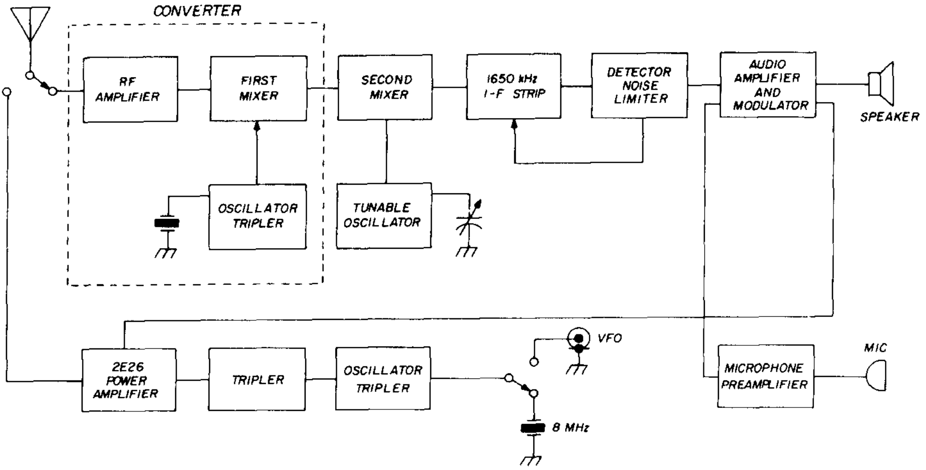

fig. 1. Block diagram of the TR-108 two-meter transceiver.

One triode section of a 12AX7 is used for the audio amplifier to drive the 6L6 audio power stage; the other triode section of the 12AX7 serves as a microphone preamp. The audio output transformer has one primary and two secondaries; the primary is matched to the 6L6 audio power amplifier. In the receiver mode, one of the secondary windings is used to drive the speaker. A front panel jack allows headphone operation or an external speaker. The second audio-transformer secondary winding is used for modulation. The frequency response of the audio stage is engineered to cover from 300 to 3000 Hz, the speech range required for maximum intelligibility.

transmitter

The transmitter may be crystal controlled with crystals in the 8-MHz range, or an external vfo may be used. The Knight-kit V-107 vfo is designed to go along with the TR-108 and its six-meter cousin, the TR-106. The 6CL6 oscillator/tripler stage is operated as a Colpitts oscillator with the plate circuit tuned to the third harmonic of the grid circuit. For vfo operation, the tube serves as an amplifier/buffer and tripler. Excellent vfo isolation is provided by the pentode.

The output from the 6CL6 drives a 6BQ5 tripler stage. This small beam-power tube drives the 2E26 power amplifier to its full capacity. The compact 2E26 stage runs at 15 watts input. The output circuit is a conventional pi network designed to work into 30 to 90 ohms with a vswr less than 3:1.

The Knight-kit engineers gave harmonic generation very careful consideration when they designed the TR-108 in an effort to eliminate problems with harmonic radiation. A double-tuned transformer is used to couple energy from the 6BQ5 tripler to the final; this reduces harmonics and provides adequate drive over the complete two-meter band. The output pi network furnishes further harmonic suppression and the wrap-around case shields the entire unit so undesired radiation is minimized.

power supply

The power supply is one of the most interesting circuits in the transceiver since it is designed to operate from either 117 Vac or 12 Vdc. Switching from one power source to the other is automatically accomplished by using the proper power plug.

In the dc-to-dc-converter mode, the supply uses a two-transistor oscillator to switch the primary 12-volt dc power on and off at about 90 Hz: the resultant ac is stepped up by the transformer. In the ac mode, the transformer functions as a normal step-up type. The high voltage dc is provided by a voltage-doubler circuit across the transformer secondary. Power for an external vfo is available on the back panel.

summary

The transceiver is fairly easy to assemble and with the excellent instructions furnished with the kit, only a few evenings work is required to do the job. Plenty of lineup and tuneup instructions are provided as well as hints for operating on the vhf bands. The instruction manual also includes information on building a simple antenna, mobile installation and mobile noise suppression, as well as some excellent dope on television interference and how to cure it.

Performance is right up to the manufacturer's rating. You're not going to work any moonbounce or meteor scatter with 15 watts input, but with a good antenna and patience, you may be able to work a little DX when the band opens up. In the meantime, the little TR-108 is great for local ragchews, DX nets and a-m repeaters. The receiver is more than sensitive—the 15-watt input rating of the transmitter is the limiting factor as far as maximum range is concerned. You can be sure you'll hear the other guy if he can hear you.

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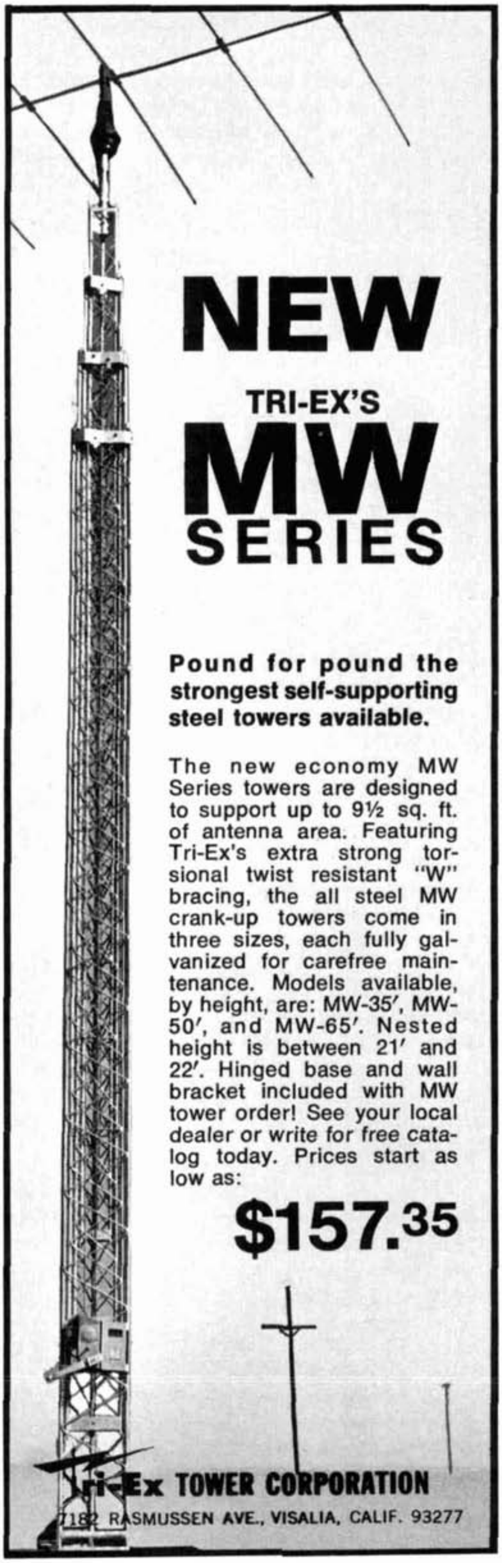

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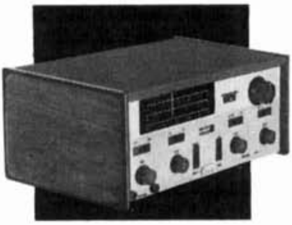

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SPECIFICATIONS	PM 3 / PM 3A	PM 2 / PM 1
Frequency range	(Band) 40 meters (Range) 7.0-7.4 MHz 20 meters 14.0-14.8 MHz	(Band) 40 meters (Range) 7.0-7.3 MHz 80 meters 3.5-4.0 MHz
Finish	Baked enamel. End panels, walnut wood grain.	(same)
Power Required	12 volts DC 30 ma. to receive 450 ma. to transmit	12 V. DC. 20 ma. to receive 200 ma. to transmit
Semi-conductor Devices	1 dual-gate MOSFET, 1 integrated circuit, 8 silicon transistors	1 dual-gate MOSFET, 1 integrated circuit, 4 silicon transistors
Types of Reception	CW-SSB-AM	CW-SSB-AM
Selectivity	2 KHz at 6 db down points	(same)
Sensitivity	Less than 1 uv	(same)
Antenna output impendence	Pi Network	50-75 ohms. Fixed Link
Audio	Output impendence 1000 ohms. Frequency response ± 3 db 200-2500 Hz	(same)
Frequency Stability	Less than 100 Hz drift. No warm up	(same)
Power Input	Approximately 5 watts	Approximately 2 watts.
Front panel controls	On-off, 40-20 band switches (3), transmit-receive, volume, receiver peak, tune-operate, tune, load. Metered amplifier. Head phone tip jacks.	On-off, 40-80 band switches (3), transmit-receive, volume, VFO/crystal, receiver peak, oscillator tuning and amplifier tuning. Metered amplifier. Head phone tip jacks.
Tuning	Slide-rule dial. Flywheel tuning	(same)
Size	HWD 4½", 10⅜", 6⅝"	(same)
Shipping weight	3 pounds	2¾ pounds

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repairing broken coax connectors

The insulation in SO-239 coax chassis connectors sometimes breaks and falls out after a period of use. While a new connector costs only 59c, it is often far easier and quicker to repair a broken one than replace it. Set the piece of gear on the bench so the connector is upright. With a pair of long nose pliers squeeze the four parts of the inner connector sleeve together and fill the inner part with melted candle wax. Epoxy resin is used to replace the original broken and lost insulating material. After the epoxy hardens overnight remove the candlewax with a small screwdriver or with a 5/32" twist drill, and the SO-239 will be permanently repaired.

Robert B. Kuehn, WOHKF

antenna dimensions

Here's a chart of antenna dimensions that should be handy if you're getting ready to put up a new sky wire. This is part of a computer listing I ran that covered the spectrum from 3.5 to 30 MHz with readouts for each 50 kHz change in frequency.* The first column of the chart, **table 1**, is the operating frequency in MHz. The following six columns give the dimensions of 5/8 wavelength, 1/2 wavelength, 1/4 wavelength, the length of one side of a cubical quad, the length of an inverted vee, and the proper radial length for a ground-plane antenna, all lengths given in feet. To convert from hundreths of feet to feet-and-inches use the chart in **table 2.**

Jim Barcz, WA9JMY

*A copy of the complete computer printout, from 3.5 to 30 MHz in 50 kHz steps, with dimensions to six decimal places, is avaiable from *ham radio* for $1.00.

table 2. Conversion chart from hundredths of feet to inches. From table 1 an inverted-vee antenna on 3.9 MHz is 118.974 feet long. This is equivalent to 118 feet, 11.64 inches (after rounding off to 118.97 feet).

	0	1	2	3	4	5	6	7	8	9
0	0.00	0.12	0.24	0.36	0.48	0.60	0.72	0.84	0.96	1.08
0.1	1.20	1.32	1.44	1.56	1.68	1.80	1.92	2.04	2.16	2.28
0.2	2.40	2.52	2.64	2.76	2.88	3.00	3.12	3.24	3.36	3.48
0.3	3.60	3.72	3.84	3.96	4.08	4.00	4.32	4.44	4.56	4.68
0.4	4.80	4.92	5.04	5.16	5.28	5.40	5.55	5.64	5.76	5.88
0.5	6.00	6.12	6.24	6.36	6.48	6.60	6.72	6.84	6.96	7.08
0.6	7.20	7.32	7.44	7.56	7.68	7.80	7.92	8.04	8.16	8.28
0.7	8.40	8.52	8.64	8.76	8.88	9.00	9.12	9.24	9.36	9.48
0.8	9.60	9.72	9.84	9.96	10.08	10.20	10.32	10.44	10.56	10.68
0.9	10.80	10.92	11.04	11.16	11.28	11.40	11.52	11.64	11.76	11.88
1.0	12.00	12.12	12.24	12.36	12.48	12.60	12.72	12.84	12.96	13.08

table 1. Antenna dimensions; length in feet

frequency (MHz)	length (feet)					
	5/8 λ	1/2 λ	1/4 λ	quad side	inverted vee	radials
3.50	167.143	133.714	66.857	71.714	132.571	68.571
3.55	164.789	131.831	65.915	70.704	130.704	67.606
3.60	162.500	130.000	65.000	69.722	128.889	66.667
3.65	160.274	128.219	64.110	68.767	127.123	65.753
3.70	158.108	126.486	63.243	67.638	125.405	64.865
3.75	156.000	124.800	62.400	66.933	123.733	64.000
3.80	153.947	123.158	61.579	66.053	122.105	63.158
3.85	151.948	121.558	60.779	65.195	120.519	62.338
3.90	150.000	120.000	60.000	64.359	118.974	61.538
3.95	148.101	118.481	59.241	63.544	117.468	60.759
4.00	146.250	117.000	58.500	62.750	116.000	60.000
7.00	83.571	66.857	33.429	35.857	66.286	34.286
7.05	82.979	66.383	33.191	35.603	65.816	34.043
7.10	82.394	65.915	32.958	35.352	65.352	33.803
7.15	81.818	65.455	32.727	35.105	64.895	33.566
7.20	81.250	65.000	32.500	34.861	64.444	33.333
7.25	80.690	64.552	32.276	34.621	64.000	33.103
7.30	80.137	64.110	32.055	34.384	63.562	32.877
14.00	41.786	33.429	16.714	17.929	33.143	17.143
14.05	41.637	33.310	16.655	17.865	33.025	17.082
14.10	41.489	33.191	16.596	17.801	32.908	17.021
14.15	41.343	33.074	16.537	17.735	32.792	16.961
14.20	41.197	32.957	16.479	17.676	32.676	16.901
14.25	41.053	32.842	16.421	17.614	32.561	16.842
14.30	40.909	32.727	16.364	17.552	32.448	16.783
14.35	40.767	32.613	16.307	17.491	32.334	16.725
21.00	27.857	22.286	11.143	11.952	22.095	11.429
21.05	27.791	22.233	11.116	11.924	22.043	11.401
21.10	27.725	22.180	11.090	11.896	21.991	11.374
21.15	27.660	22.128	11.064	11.868	21.939	11.348
21.20	27.594	22.075	11.038	11.840	21.887	11.321
21.25	27.529	22.024	11.012	11.812	21.835	11.294
21.30	27.465	21.972	10.986	11.784	21.784	11.268
21.35	27.400	21.920	10.960	11.756	21.733	11.241
21.40	27.336	21.869	10.934	11.729	21.682	11.215
21.45	27.273	21.818	10.909	11.702	21.632	11.189
28.00	20.893	16.714	8.357	8.964	16.571	8.571
28.10	20.819	16.655	8.327	8.932	16.512	8.541
28.20	20.745	16.596	8.298	8.901	16.454	8.511
28.30	20.671	16.537	8.269	8.869	16.396	8.481
28.40	20.599	16.479	8.239	8.838	16.338	8.451
28.50	20.526	16.421	8.211	8.807	16.281	8.421
28.60	20.444	16.364	8.182	8.776	16.224	8.392
28.70	20.383	16.306	8.153	8.746	16.167	8.362
28.80	20.313	16.250	8.125	8.715	16.111	8.333
28.90	20.242	16.194	8.097	8.685	16.055	8.304
29.00	20.172	16.138	8.069	8.655	16.000	8.276
29.10	20.103	16.082	8.041	8.625	15.945	8.247
29.20	20.034	16.027	8.014	8.596	15.890	8.219
29.30	19.966	15.973	7.986	8.567	15.836	8.191
29.40	19.898	15.918	7.959	8.537	15.782	8.163
29.50	19.830	15.864	7.932	8.508	15.729	8.136
29.60	19.764	15.811	7.905	8.480	15.676	8.108
29.70	19.697	15.758	7.879	8.451	15.623	8.081

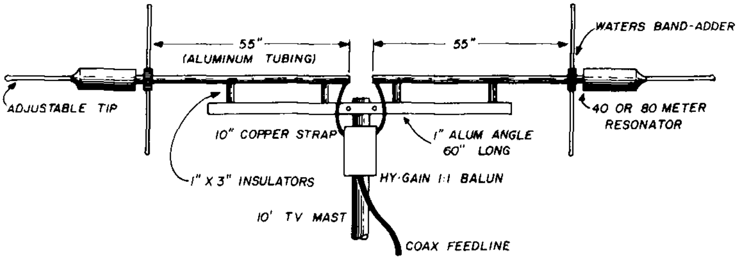

fig. 1. Multiband dipole designed for wooden boats by W2INS. This antenna would also be suitable for portable and apartment stations.

portable all-band antenna

Although the antenna shown in **fig. 1** was designed primarily for operation on large wood boats, it looks ideal for any amateur with limited space. Vertical antennas are virtually unmanageable on large non-metal boats, and must be constantly retuned, matched and re-resonated; this all-band miniature dipole is relatively non-critical, easy to tune and easily matched. Although it can be rotated to take advantage of any inherent directivity, most users don't go to the trouble. The antenna is tuned up on the lowest band of operation (either 40 or 80 meters) with a grid dipper and antennascope. Operation on the higher bands is provided by the two Waters Mobile Band-Adders. The original design of this antenna is attributed to W2INS, and it has been built by a number of boat enthusiasts with excellent success.

elmac chirp and drift

Even though the Elmac AF-67 is fifteen years old, it still has many fine attributes. In fact, I just bought one. It worked fine on a-m, and it's tailored speech characteristics are as desirable today as when it originally was designed. However, in its original form it had two serious flaws that limited it's usefulness: a chirpy cw signal and unacceptable drift on 15 and 20 meters.

The chirp was cured in my unit by regulating the supply to the buffer/multipler stages. A 420-ohm dropping resistor and a 10k bleeder along with an OB2 regulator in series with an OA3 provide the proper operating voltages (see **fig. 2**). Keying with the new regulated supply is clean and chirpless.

Frequency drift was noticed only on 15 and 20 meters. A 35-pF variable capacitor, C15, is unique on these bands, so it was suspect. Sure enough, when it was replaced with an ordinary 35-pF trimmer the drift disappeared. I mounted the trimmer on the bottom plate of the vfo module because the original position was almost inaccessible.

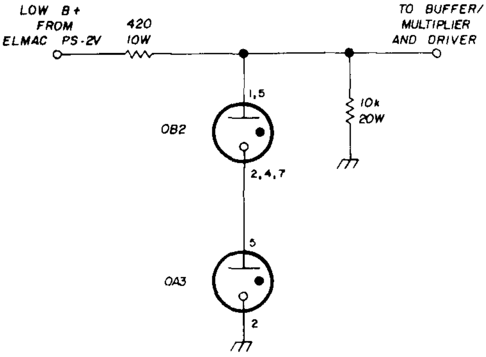

fig. 2. Regulated supply eliminates chirpy cw signal from Elmac AF-67.

I carefully examined the faulty capacitor and found that only one leaf of the rotor shaft contact spring was soldered in place—the other leaf maintained electrical contact through pressure. I suspect that some type of diode action was occuring between the pressure spring and the mounting nut, but because of the inaccessibility of the original mounting position, I didn't put the unit back in the transmitter to run further tests.

George Hirshfield, W5OZF

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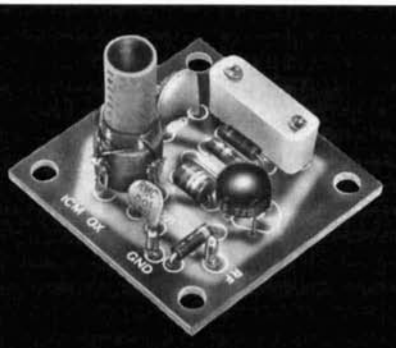

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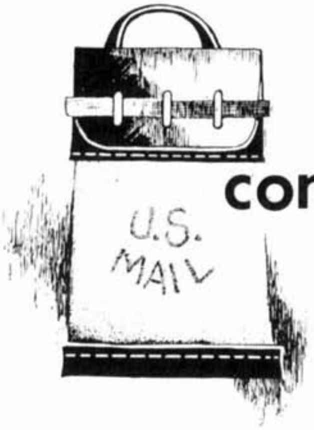


comments

multiband antennas

Dear HR:

First, allow me to congratulate you for a fine magazine. Through it many valuable and useful data become available to those of us who otherwise have no access to it; e.g. specifically practical design data for semiconductor high-frequency applications. If you're not employed in the business, as I'm not, such information is hard to come by. Although a poor schoolteacher can hardly afford to do much with it yet, I do find it invaluable in maintaining a modern perspective in electronics.

However, I do have reservations about some things I read in your magazine. Take for instance Mr. Orr's, "Simple Dual-band Antennas" in the March issue. Now, far be it to deny Mr. Orr's technical veracity; I have long found his writings both stimulating and correct. But, on the basis of some grassroots antenna experience I'd like to challenge the practical radiating efficiency of his half-wave radiator, folded-into a quarterwave space. I don't think that he or anyone else can do it.

Living as I do in one of those relatively small-lot suburban areas this business of getting up a good antenna for the 80-meter cw band is a live, pragmatic issue. In facing this issue at my own place, and that of my friends, I have found that a doublet-type antenna with a total *radiating* length of about four-tenths of a wavelength (100-foot wire on 80 meters, or about fifty feet on 40 meters) is the very minimum length that will produce satisfactory practical communication results. This, of course, assumes a means of resonating the wire to the operating frequency. Furthermore, this is independent of the feeding technique providing it is properly done.

Now, it's a plain fact that *any* unshielded conductor carrying appreciable RF current will radiate. James Clerk Maxwell told us as much back in 1870 or so. But to merely radiate, and to radiate *effectively* under typical amateur conditions in a ham's backyard, represent two different things.

Let's not talk microvolts per meter or things like that—I'll define "effective radiation" from an antenna as occurring when a typical fifty-watt (dc input) amateur station in the cw portion of the band can successfully compete with normal QRM conditions, achieving at least fifty percent "comebacks" on calls properly made under any but contest conditions. Unless Mr. Orr's location is considerably better than mine I'll respectfully bet him a drink that his antenna described in **fig. 2**, page 19 (March, 1970 issue) will *not* meet this test consistently unless his antenna is more than thirty feet above "dirt." (Most of my friends and myself have to work with antennas considerably lower than this.)

Mr. Orr makes much of the satisfactory swr he achieves with his antenna. This is nice, I suppose, but he could achieve an swr of unity very easily merely by hanging a 50-ohm, non-inductive resistor across the far-end of his RG-8/U. So what? Swr near unity is a desideratum, no doubt, but it is no guarantee of a good signal as any experienced radioman knows. What counts is, "stirring up the ether" as we used to say back in the pre-relativity days.

If Mr. Orr would take the wires he "folds back," and drop them vertically down to within five feet of the ground at each end (to make the total *wire* length at least 100 feet), then couple a *good* open-wire line to the center instead of that pretty but lossy coax I'll bet he would stir-up the ether much more. Of course, he'll need a good antenna tuner at the bottom end of his feedline but that's no problem for a good man. He can then run a short piece of coax to his antenna relay. Then he'll be in business for blood instead of kicks. Furthermore, if he makes the tuner coils plug in he can tune his antenna for other higher frequency bands too with remarkably good results. (Why are so many "modern" radiomen apparently allergic to the good old tuned, open-wire line? What's so sacred about coax?)

Let me put results where my mouth is: last winter I was interested in some QRP work with a small 8-watt (input) transmitter on 80-meter cw. My first attempts were with an approximately quarter-wave-long doublet. I made a contact or two but not much fun. Then I hung about fifteen feet of wire on each end of the doublet. One would think that I had jacked up the eight-watter and put a hundred watter in its place! I soon worked all districts with my pipsqueak and had *many* long, solid ragchews. Lots of fellows thought I was kidding them when I told them my input was only eight watts. So, who is correct here, James Clerk Maxwell, Mr. Orr, or yours truly? Probably all of us somehow or other. But I hope I've stirred-up a little thought—and maybe an anti-coax revolution.

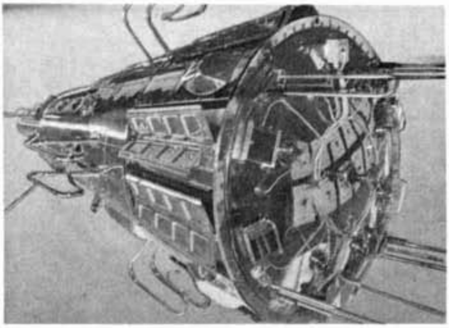
C. R. Rockey, W9SCH/W9EDC
Deerfield, Illinois

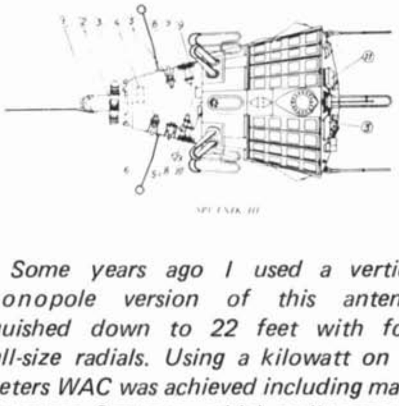
make mine canadian club

Of course, Mr. Rockey is correct. And so are James Clerk Maxwell and I. All practical antennas are a series of compromises. The finesse comes into play in selecting compromises available to best fit the situation.

The antenna in question, a compact folded dipole, works. As my first witness, enclosed is a photo and drawing of the Russian Sputnik III space satellite which bristles with folded monopoles (eight in all). A similar form of antenna is often used for glide-slope detection on jet aircraft (see Antenna Engineering Handbook, *first edition by Jasik, McGraw Hill, N. Y., section 27-5).*

Personally, I've used an 80-meter sixty-five foot folded dipole about 20 feet in the air for local skeds (up to 500 miles or so using 180 watts PEP input). No difficulty was experienced in laying down a strong signal with the abbreviated antenna.





SPUTNIK III

Some years ago I used a vertical monopole version of this antenna squished down to 22 feet with four full-size radials. Using a kilowatt on 80 meters WAC was achieved including many European Contacts—which really separate the men from the boys on the West Coast (antennawise).

Finally, I take mild issue to Mr. Rockey's claim that a 100 foot antenna is the very minimum length that will produce satisfactory results on 80 meters. Look about at the eight-foot antennas that are used every day: they are called mobile whip antennas. *(You can use two of them back to back for a pretty good sixteen foot dipole, too!.)*

I demur from entering the coax-versus open wire line discussion. Using open *wire line, in my opinion, is like washing your feet with your socks on.*

On second thought, I'll reserve that drink offer until I meet Rock. He sounds like a great guy. Maybe we'll get together some day for a chat and I'll order two CC on the rocks. Bottoms up!.

William I. Orr, W6SAI

a-m modulator

Dear HR:

In reference to Mr. Hall's article "A Different Approach to Amplitude Modulation," (*ham radio,* February, 1970) it should be pointed out that some undesirable aspects are associated with this type of approach. Although this modulation technique does eliminate the modulation transformer and the conventional class-B modulator transistors, it is interesting to examine the trade-offs involved.

Basically, the method described consists of modulating the power supply series regulator transistor. The problem arises from the unusually high dissipation this system requires of the regulator transistor. Unlike conventional modulation where the rf amplifier collector current flows through the low resistance secondary of the modulation transformer, this method requires that the entire rf amplifier current flow through a regulator transistor which must have a voltage drop across it greater than the supply voltage to the rf amplifier. This means that the average regulator transistor dissipation will always exceed the entire input to the transmitter rf amplifier.

Although the article makes reference to the fact that efficiency is low, the figures quoted are somewhat misleading because they are bases on 100% sine-wave modulation. In practical use involving voice modulation and normal pauses between words, the quiescent dissipation becomes more significant from a heat producing standpoint. Since the idling current for conventional class-B modulator transistors is quite low, Mr. Hall's method would require nearly twice the input power in the quiescent state. This is a situation similar to running the modulator transistors of a conventional system in class A.

Although the regulated power supply would probably be used with either method, with conventional a-m the modulator would not normally be supplied from the regulated output. Therefore, the regulator transistor dissipation would be modest since the power transformer voltage would be selected such that only a few volts are dropped across the regulator transistor.

The fact that this amplitude modulation method requires twice the normal supply voltage and, therefore, consumes twice the amount of power (idling) would probably preclude its use with battery operated equipment. The choice of this circuit for ac operated (or mobile) equipment should be quided by whether it is practical to dissipate the additional heat produced. The space savings facilitated by eliminating the modulation transformer and transistors may conceivably be offset by the additional heat sink area required to satisfy regulator transistor temperature requirements.

Jerry Manikowski, W9JGV
Hanover Park, Illinois

In reply to Mr. Manikowski's remarks about my article, I wish to thank him for bringing up the fact that the efficiencies mentioned in the article are misleading because they are based on 100% sine wave modulation. His point is well taken, and I am guilty of an oversight there.

The "usually high dissipation" required of the regulator transistor is the price that must be paid for elimination of the conventional modulator. It was not my intention to imply that this modulation approach offered something for nothing; rather, it is presented for its novelty and because it requires no modulation transformer. It is hoped that some builders will find the scheme useful in some applications, as indeed one has.

Courtney Hall, WA5SNZ
Dallas, Texas

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Common abbreviations:

MHz	megahertz	V	volt
acc	accessories	T-Power	Transistor Powered
w/acc	with accessories	6/12V	is NOT the same as 6V or 12V
W	watt		

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new products

instrumentation amplifier

A low-cost self-powered IC signal conditioner with continuously variable voltage gain from one to greater than 1000 has been announced by Integrated Controls, Inc. Input impedance is greater than 100 megohms on the lower gain ranges, and the input overvoltage capability is ±30 Vdc continuously. The output is short-circuit proof, and current limits at 20 mA. The gain-bandwidth product is 700 kHz, low-frequency noise is typically 10 μV, and gain stability is typically better than 100 ppm/°C. Operating temperature range is zero to +70° C. The mercury battery pack provided permits greater than 1000 hours of continuous operation exclusive of transducer excitation. $85 from Integrated Controls, Inc., P. O. Box 17296, San Diego, California 92117.

general-coverage receiver

The new Knight-Kit model R-195 solid-state communications receiver kit tunes the international and domestic shortwave bands, marine weather and navigational beacon bands plus the standard a-m broadcast band. (Frequencies are 200-420 kHz, 550-1800 kHz, 1.8-12 MHz.) The receiver includes a tuned rf stage for high sensitivity and low noise, and the large illuminated slide-rule tuning dial makes tuning easy.

Field-effect transistors are used in the front end for high sensitivity with low cross modulation, and ceramic i-f filters provide selectivity and interference rejection. Sensitivity is better than 2 μV for 10 dB signal-plus-noise to noise. Selectivity is 4.5 kHz at the 6 dB points. Other features include series-gate automatic noise limiter, avc, built-inbfo and product detector, remote receiver muting connections, built-in speaker and headphone jack.

The R-195 receiver kit is priced at $89.95. Knight-Kit's new modular concept makes assembly of this kit easy even if you've never built a kit before. Most parts are already soldered to the printed-circuit boards, and all critical adjustments have been made at the factory. All the builder has to do is follow the detailed step-by-step instructions and solder the connections between circuit boards. Full description of this new receiver can be found in Allied 1970 catalog, sent free on request from Allied Radio Corporation, 100 N. Western Avenue, Chicago, Illinois 60680.

test equipment catalog

A new 44-page test equipment catalog from Tucker Electronics describes over 2000 different test instruments and microwave components for sale or rent. Most of the listed items are either new-surplus or used-reconditioned; all are calibrated to the manufacturer's original specifications by a calibration laboratory (traceable to N.B.S.). Included in the catalog are voltmeters, transfer standards, signal generators, oscilloscopes plus many others; manufacturers include Dumont, Fluke, General-Radio, Hewlett-Packard, Polarad, Tektronix and others. For a copy of catalog no. 18, write to Tucker Electronics Company, P. O. Box 1050, Garland, Texas 75040.

communication receiver

The new Drake SPR-4 communications receiver is an all solid-state unit that may be programmed to suit your present and future interests. The front-end of this new receiver uses a dual-gate mosfet that provides signal-handling characteristics that are said to be superior to the best tube receivers. The all solid-state design, of course, has the advantages of low power consumption, mechanical and thermal stability and reliability.

The SPR-4 can be programmed with accessory crystals for 23 ranges (each tuning a 500-kHz band) from 0.5 to 30 MHz plus 150 to 500 kHz. Crystals supplied with the receiver allow coverage on these ranges: 150-500 kHz, 0.5-1.0 MHz, 1.0-1.5 MHz, 6.0-6.5 MHz, 7.0-7.5 MHz, 9.5-10 MHz, 11.5-12 MHz, 15-15.5 MHz, 17.5-18 MHz and 21.5-22 MHz. These ranges cover the most popular short-wave listening frequencies and include aircraft radio and weather, marine ship and shore stations, high-frequency communications, WWV standard time signals, foreign broadcast, CB and amateur radio.

This new receiver features avc on a-m, cw and ssb with time constants selected for optimum effectiveness on each mode. Audio output is held constant within 3 dB over a 100-dB range of input signals. Sensitivity on ssb and cw is 0.25 μV for 10 dB signal-plus-noise to noise ratio. Hum and noise are more than 60 dB below rated output. Accessories include a matching speaker, crystal calibrator, noise blanker, loop antenna, and transceive adapter that allows full transceive operation with Drake T-4B and T-4XB transmitters. The model SPR-4 is priced at $379.00. For more information, or the name of your local dealer, write to R. L. Drake Company, 540 Richard Street, Miamisburg, Ohio 45342

eimac application bulletin

The new Eimac 4CX600 family of ceramic-metal tetrodes is designed to meet the demands of modern communications systems. These new tubes are ruggedized, compact, radial-beam tetrodes for use up to 890 MHz. Closely controlled parameters plus state-of-the-art assembly and testing permit an extremely high-gain bandwidth product and low intermodulation distortion level to be achieved simultaneously.

Eimac's Application Bulletin number 14 covers these tubes in detail and includes circuits for a tunable 140-250-MHz stripline amplifier, a 432-MHz cavity amplifier, a 150-MHz class-B amplifier, as well as many others. This bulletin, which normally sells for $1.50, will be available free of charge to the first 100 readers of *ham radio* who write to Bill Orr, W6SAI, Advertising Manager, Eimac Division of Varian, 301 Industrial Way, San Carlos, California 94070

vhf fm transceiver

The new Varitronics IC-2F fm transceiver for two meters (and IC-6F for six meters) provides a full 20 watts input with 12 or more watts out. New innovations in these units include APC (automatic protection circuit) which consists of an swr bridge and two dc amplifiers that bias the power-amplifier and driver transistors off if the unit sees high vswr in the transmit mode. This saves the transistors from possible damage. In addition, direct access is provided to the discriminator so an outboard zero meter can be used, and all switching is done electronically, eliminating problems with relays. These new transceivers also include a dc input filter that does away with alternator hash, a squelch circuit that uses thermistors to eliminate temperature-induced squelch drift, a hinged chassis for easy servicing, test points brought up from boards for easy voltage, current and frequency checks, a low-pass output filter, and zener-regulated supply voltages for all oscillators.

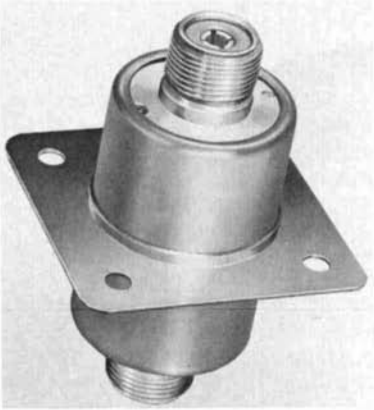
The receiver features a quiet fet front end with ceramic filters and integrated-circuit i-f stages. Actual sensitivity is below 0.2 μV for 20 dB quieting.

Units are supplied complete with crystals, microphone, mounting bracket, plugs and dc cabling. The only accessory is the ac power supply (IC-3P). This power supply incorporates a sensitive zero-type discriminator meter, and is designed to provide a stand for the transceiver. Hardware is provided to mate the transceiver and the ac power supply into one neat compact unit, if desired. For more information on the new IC-2F and IC-6F, write to Varitronics Incorporated, 3835 North 32nd Street, Suite 6, Phoenix, Arizona 85018.

decoder/driver ic

Motorola's new BCD-to-decimal decoder/driver, the MC9860/9760, converts a four-bit complementary BCD code into a one-of-ten output with sufficient voltage to drive a neon-filled display tube. The high-voltage output transistors in the ICs allow direct operation of the display tube without background glow. With the MC9860/9760 decoder/driver, MC867/767 quad latch and MC880/780 decade up counter, designer can build a completely integrated readout system that is smaller, faster, and less expensive than conventional systems. Supplied in the 16-lead dual in-line plastic package, the MC976OP sells for $5.55 in small quantities. For more information, write to Technical Information Center, Motorola Semi-conductor Products, Inc,. Box 20924, Phoenix, Arizona 85036.

lightning arrestor



A lightning arrestor originally developed for protecting military communications equipment is now available to radio amateurs. This new arrestor, the Dale Electronics LA-8A4C, provides permanent protection from lightning damage to your radio equipment. This arrestor has

TAKE YOUR PICK

These units will replace the 100 kHz calibrator built into most receivers. Using your 100 kHz crystal this unit will provide sharp accurate markers with readouts at 100 · 50 · 25 · 10 and 5 kHz usable thru 50 MHz. Keep your receiver calibrated at all times, locate sub bands, MARS frequencies and band edges.

or

Frequency marker, less cabinet and switch

Specifications: Glass Epoxy Board. Adjustment to zero beat with WWV. Uses 100 KHz crystal (not supplied). 3 to 4 VDC. Compact — 1.75 x 3.75 inches. Install anywhere!

Complete easy-to-assemble kit $16.50 Wired and Tested $19.95

SWITCH $1.00 CRYSTAL ONLY $3.50
with purchase of any of above

SELF-CONTAINED UNIT

The TBL 1 Marker is a complete unit including the circuit board shown at left and powered with 3 "C" type flashlight batteries. Merely connect to your receiver antenna — no internal wiring necessary. A front panel control allows zero beat with WWV.

Special introductory price Less crystal and batteries $29.95

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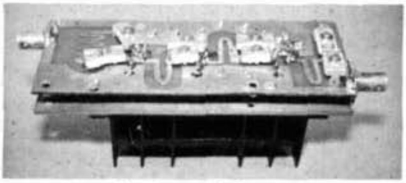
been proven so reliable that Dale Electronics will pay you $2000 if a properly-installed LA-8A4C fails to protect your equipment from lightning damage. The ultra-reliable LA-8A4C can withstand five direct strokes of lightning, eliminates heavy static buildup and installs easily in any 52- or 72-ohm coaxial feedline. $19.95 is the standard price for the arrestor–the added protection of the $2000 warranty policy costs you nothing. Dale Electronics, Inc., P.O. Box 609, Columbus, Nebraska 68601.

fm transceiver

Galaxy Electronics has announced a new two-meter fm transceiver, the FM-210. This new solid-state unit features a high-performance fet-front-end transceiver and 3-channel crystal-controlled independent transmit/receive selected by front panel controls, highly effective squelch system and a speech compressor for optimum intelligibility under adverse operating conditions. The FM-210 is designed for operation from 12- to 14-Vdc supplies; an optional power booster provides higher power operation from either 12-14 Vdc or 117 Vac. Total power drain in the receive mode, with the audio squelched, is 60 mA; during transmit the current drain is 500 mA.

Receiver sensitivity is 1 uV for 12 dB quieting; 0.5 uV for 12 dB SINAD. On transmit the unit runs 5 watts input (3 watts out), and with the optional power booster, 10 watts input (6 watts out). The power booster is actually a dc-to-dc converter that provides 24 Vdc to the final power amplifier transistor. The transceiver also includes adjustable bandwidth, 2 to 20 kHz, and an adjustable clipping filter that provides up to 30 dB clipping. The FM-210 is normally configured for wideband operation; narrow band is available on special order.

For more information on this new unit, write to Galaxy Electronics, 10 South 34th Street, Council Bluffs, Iowa. The transceiver is priced at $299.95; the optional power booster is $39.95.



short circuits

Conversion of the Hallicrafters SR-160 to an SR-500 (to gain greater power output), *cannot* be done as described on page 66 of the February, 1970 issue. The biggest problem lies in the filament circuit—the 8236 tubes have 6-volt heaters and will be immediately zapped if the SR-160's 12-volt filament circuit isn't changed.

high-frequency converter

The crystal oscillator stage in the high-frequency mosfet converter shown on page 30 of the January, 1970 issue is incorrect. Each of the crystals should be returned to the base of the 2N4124 oscillator stage, *not* to ground. Also, the unlabeled capacitor across L5 in the mixer drain circuit should be 170 pF.

varactor modulator

In the frequency-modulated crystal oscillator in **fig. 10**, page 18 of the September, 1969 issue, the MV-833 varactor is installed backwards. The diode must be reverse biased for correct operation.

432-MHz ssb converter

The B+ supply to the crystal oscillator in **fig. 1**, page 50 of the January, 1970 issue should come directly from the positive terminal of the OC5 voltage-regulator tube. Also, the oscillator B+ lead should be bypassed with a uhf-type feedthrough capacitor, and the cathode bias resistor in the 6J4 grounded-grid amplifier stage should be 56 ohms.

ic noise blanker

The 47k resistor in the emitter circuit of the Schmit trigger in **fig. 3**, page 54 of the May, 1969 issue should be 47 ohms. The circuit will not trigger reliably unless this resistor is less than 150 ohms.

ham radio

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High performance 9 MHz xtal filters for SSB, FM, AM & CW applications. Perfectly suited for miniaturized solid-state equipment.

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Filter Type		XF-9A	XF-9B	XF-9C	XF-9D	XF-9E	XF-9M
Application		SSB-Transmit.	SSB	AM	AM	FM	CW
Number of Filter Crystals		5	8	8	8	8	4
Bandwidth (6dB down)		2.5 kHz	2.4 kHz	3.75 kHz	5.0 kHz	12.0 kHz	0.5 kHz
Passband Ripple		<1 dB	<2 dB	<2 dB	<2 dB	<2 dB	<1 dB
Insertion Loss		< 3 dB	< 3.5 dB	< 3.5 dB	< 3.5 dB	< 3 dB	< 5 dB
Input-Output	Z_t	500 Ω	500 Ω	500 Ω	500 Ω	1200 Ω	500 Ω
Termination	C_t	30 pF	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	(6:60 dB) 1.8	(6:40 dB) 2.5
			(6:80 dB) 2.2	(6:80 dB) 2.2	(6:80 dB) 2.2	(6:80 dB) 2.2	(6:60 dB) 4.4
Stop Band Attenuation		> 45 dB	> 100 dB	> 100 dB	> 100 dB	> 90 dB	> 90 dB
Price		$21.95	$30.25	$32.45	$32.45	$32.45	$23.00

Matching HC-25/U crystals: 8998.5 (USB), 8999.0 (BFO), 9000.0 (carrier), 9001.5 (LSB), $2.75 each.

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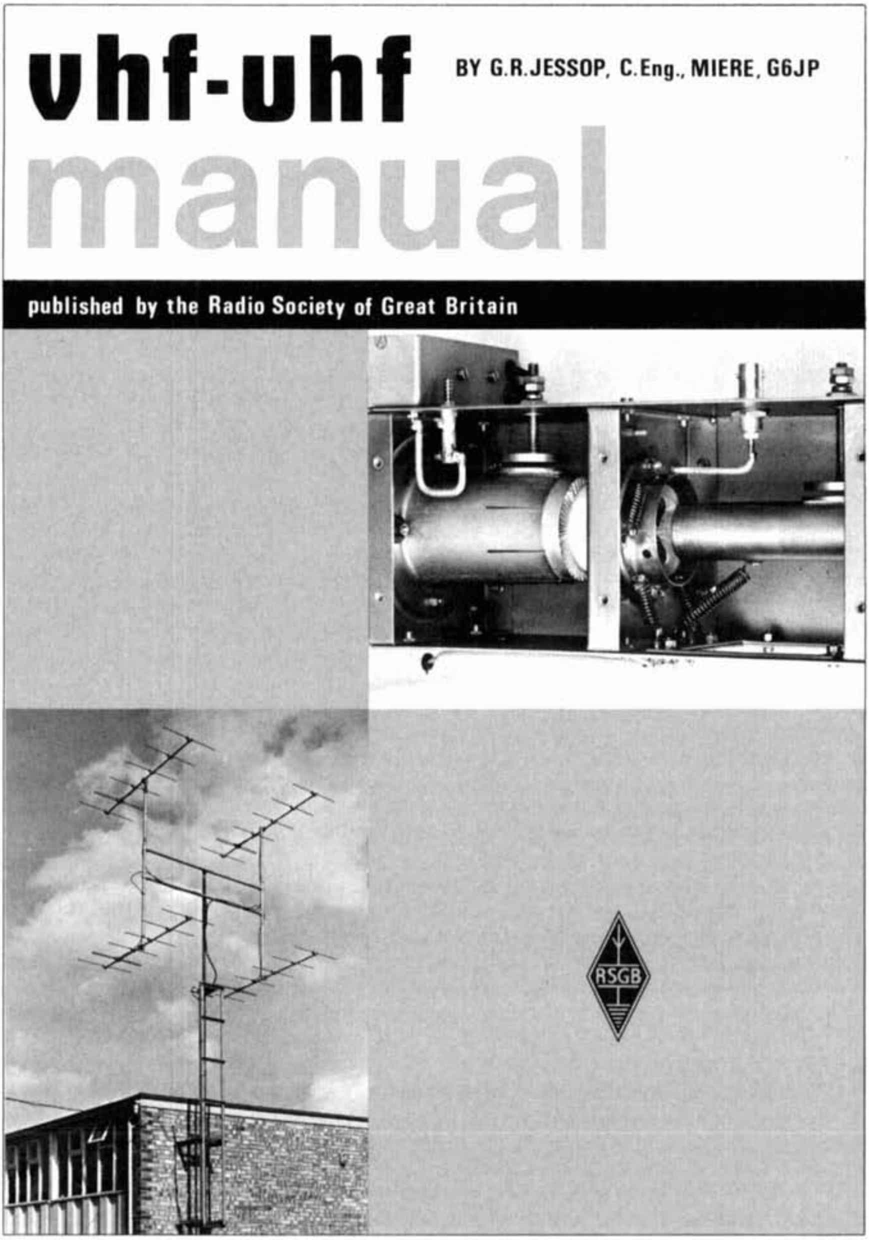

vhf-uhf manual

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published by the Radio Society of Great Britain

If you have any interest in the frequencies above 30 MHz then you need this book. It is probably the most comprehensive work of its kind ever produced, ranging from advanced material to simple circuits for the beginner to vhf. An attractive layout and clear style make the VHF/UHF Manual a most worthwhile addition to your library.

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TRADE 28KSR, 19, TYPING REPERFORATOR, TT/L-3, for 28ASR, 60 cycle supply or motor for mite. David G. Flinn, 10 Graham Road West, Ithaca, N.Y. 14850.

TOUCHTONE DIAL equivalent from Denmark. Ten button, convertible to all twelve with data included. State color: beige or black, limited number green. 12VDC required for oscillator operation. $16.00 postpaid USA. J. O'Brien, W6GDD, 6606 5th Street Rio Linda, CA 95673.

PLYMOUTH (ENGLAND) RADIO CLUB announces an Official Mayflower Certificate to be awarded during the period of the Mayflower Celebrations, from March, 1970 to November, 1971. Qualifications are: One QSO with GB2USA, or any THREE members of Plymouth Radio Club, or any THREE Plymouth **CITY** Stations; SWL's — Reports of similar nature to above. Cost of Certificate will be 2 IRC's (2/- in stamps for UK Stations). No QSL's are necessary to verify QSO's, just log extracts which will be checked at PRC. Send qualifications to A. Baker, G3KFN, 74 Travistock Road, Stoke, Plymouth, Devon., England.

ON-THE-AIR HAM RADIO facilities will be provided by the U. S. Navy's Washington voice in amateur radio, K4NAA, operating daily from the Sheraton Park Hotel in Washington, D. C. during the three days of the Armed Forces Communication and Electronics Association Convention in June. AFCEA delegates with amateur licenses are invited to take advantage of the Navy's ham station during the convention on June 2, 3, and 4. K4NAA fixed portable will be operational from 0900 to 2200 EDST with CW, SSB, and RTTY on the 10, 15, 20, 40, and 80 meter bands. A specially designed QSL card is available to amateurs who are invited to make contact during the AFCEA convention.

QSLS. Second to none. Same day service. Samples 25¢. Ray, K7HLR, Box 331, Clearfield, Utah 84015.

EVANSVILLE, IND. HAMFEST, 4H Grounds (Highway 41 North 3 miles) July 12, 1970. Air conditioned, Swappers/Hams/Families welcome.

FOR SALE: HW-12 with calibrator, $80. HW-22, $70. Globe King 500A (500W, a-m and CW), $125. Gonset 913A 500-watt 6M linear, $200. Gonset 910C 6M Sidewinder (a-m, CW and ssb) with ac and dc supplies, Laff 100W linear plus many extras, $360. Gonset 2M 100W linear w/spare 826s, $90. Gonset Communicator III 6M, $115. 6M Ameco Preamp, $10. Eico 720 90W CW transmitter, $55. Tecraft 6M converter with supply (7-11 MHz out), $35. Knight R-100A gen'l coverage receiver, $60. Heath vfo VF-1, 10-160M, $15. Eico 23-channel CB transceiver, $75. Heath HX-30 6M transmitter (a-m, CW and SSB), $140. Heath HA-20 175W 6M linear, $110. Factory-sealed Ameco PT preamp, $55. Heath Sixer, w/crystals and mike, $35. Ameco 6M converter with power supply, $15. Swan 14C dc module, $50. Drake factory-sealed DC-4 12 Vdc supply, $105. Factory-sealed Ameco OCMW monitor, $12. Westcom noise blanker for Swan 250, $20. Gonset 6M G-50, $160. Ham-M rotator, $105. Factory-sealed 24-hour Pennwood clock, $14. All items fob. Tom Dittrich, WB2LZD, 605 Broad St., Endicott, N. Y. 13760.

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

WORLD QSL BUREAU — see ad page 88.

FOLLOWING EQUIPMENT has been stolen: KWM-2A Transceiver w/136B-2 Noise Blanker, S#16922; KWM-2A Transceiver w/136B-2 Noise Blanker, S# 16942; 312B-4 Cabinet Speaker, S#63314; 312B-4 Cabinet Speaker, S# unknown; 516F-2 Power Supply, S#58705; 516F-2 Power Supply, S#58521; 30L-1 Linear Amplifier, S#27604. Anyone having information is asked to contact Dave Leopard, Texas Instruments, Inc., 13500 North Central Expressway, Dallas, Texas 57222.

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

COMMERCIAL LICENSE EXAMS: Second $18.00: First $24.00; Sample questions; Price list $1 refundable. Ebco Enterprises, P. O. Box 432, Sparks, Nevada 89431.

DRAKE R4A/T4 combo with MS-4 and AC supply, $495. K4CWW, 217 Milton Drive, Carrboro, N. C.

FOR SALE 3-element Gotham tri-band beam. Brand new never used. $45. You pick up or will ship collect. Steve Perry, WB2ESN, Rocky Point, N. Y. 11778.

OVER 10,000 SEMICONDUCTORS, New, Name-Brand — At consistent Savings. Hard-to-get, R.F. Power, Microwave, A.F., etc. Send for Semiconductor and Parts Catalog today. K. & J.B. Electronics, Dept. E-3, 3805 New Haven Avenue, Fort Wayne, Indiana 46803.

THE TRI-STATE AMATEUR RADIO SOCIETY announces its Twenty-third Annual Hamfest to be held Sunday, July 12, 1970, at the 4-H Youth Rural Center on Highway 41 North. Advance registration $1.50 and $2.00 at the door. For details contact Jack Young, K9LAU, P. O. Box 492, Evansville, Indiana 47703.

SOMERSET COUNTY HAMFEST — The 5th SCARC Annual Hamfest will be held Sunday, June 7 at the Casebeer Grove 4 miles north of Somerset, Pa. on US Route 219. Registration starts at noon. Rain or Shine — Free tables indoors for swap-shop. Write K3YVS, 719 Division Street, Berlin, Pa. 15530.

TELEGRAPH KEYS WANTED: Wire, wireless, Spark or CW. Related books. Ted Dames, W2KUW, 308 Hickory St., Arlington, N. J. 07032.

SQUEEZE KEY, the ultimate electronic Keyer. Integrated circuits, silicon transistors throughout. Built-in double lever key, monitor speaker, relay. Beautiful import. SASE for brochure. Dave Kennedy, W9DL, R.R.#1, Box 295-B, Elburn, Illinois 60119.

HEATHKIT TS-4A Sweep Generator, covers 3.6 to 220 MC. Mint. Original cost $69.95. CIE N-515T Electronic Slide Rule. Best offer takes. S. J. Stansfield, 131 W. Race St., Leslie, Michigan 49251.

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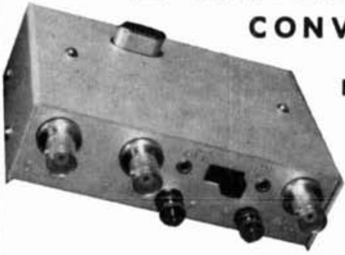

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A full description of this fantastic converter would fill this page, but you can take our word for it (or those of hundreds of satisfied users) that it's the best. The reason is simple – we use three RCA dual gate MOSFETs, one bipolar, and 3 diodes 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.

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THE ATLANTA RADIO CLUB'S 43rd Annual Hamfest will take place June 13-14 at the North Dekalb Shopping Center, Atlanta, Georgia. Location is at Interstate 285 and the Lawrenceville Highway. Main prize drawing at 2 p.m. Prizes include Swan 500 C w/AC Power Supply, Color Television, Ham M Rotator, Classic 33 Beam. Dinner-Dance on June 13 at 8:30 p.m. in the S and S Cafeteria, Lenox Square. Special drawing this night is an HW-12. For reservations call K4ZYK or K4YID on Atlanta Radio Club Net every Saturday at 5 p.m. on 3975 khz.

WANTED: CUSTOMERS, No experience necessary. Write or call "HOSS TRADER ED MOORY" for the best deal on new or used equipment. USED EQUIPMENT BARGAINS: Guaranteed: 75A-4, $299.00: KWM-2, $695.00: 30L-1, $385.00: R4-A, $279.00: 2B, $169.00: Galaxy 5, $229.00: HT-37, $179.00: HQ-170AC, $209.00: SX-96, $99.00: HX-10, $169.00: NC-303, $199.00: NCX-3, $155.00: Swan 350, $275.00: Swan 500, $339.00. Write for "Free" List. Contact us for Special Deals on Brand new Equipment in factory sealed cartons with full factory warranty and Special Prices on New Tower and Beam Packages. Ed Moory Wholesale Radio Co., Box 506, Dewitt, Ark. 72042. Phone (501) 946-2820.

NOVICE CRYSTALS: 40-15M $1.33, 80M $1.83. Free flyer. Nat Stinnette Electronics, Umatilla, Florida 32784.

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MAYFLOWER 70 AWARD has been instituted by the Committee governing The Cheshire Homes Amateur Radio Network Fund, to commemorate the 350th Anniversary of the Sailing from Plymouth of The Pilgrim Fathers for America. The object of this Award is to continue our efforts to provide Amateur Radio Equipment to the Homes which care for the incurable sick and permanently disabled. All profits from this Award will be devoted to this purpose, no Member of the Committee will receive payment or reward for his services. The Award is open to all Amateur Radio Operators and SWL's throughout the World from January 1, 1970. No time limit. Any Band or Mode. No QSL Card required. But a certified copy from Log Book must be sent. Operators in the U.S.A. must submit proof of ONE contact with an Amateur Radio Station operating from Plymouth, England. SWL's as above but Reception of ONE Amateur Station. The cost of Certificates is ONE DOLLAR which includes Postage by surface mail. Forward all claims to: W. M. Clarke, G3VUC, Fillace Park, Horrabridge, Yelverton, Devon. PL20-7TE, England.

TECH MANUALS — R-390/URR, R-390A/URR, BC-639A, $6.50 each. Many others. List 20¢. S. Consalvo, 4905 Roanne Drive, Washington, DC 20021.

FOR SALE H W 32-A mint condition, $75.00. Max Holland, W4MEA, Hiwassee College, Madisonville, Tennessee 37354.

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THE MILLIWATTER is a non-profit monthly QRPP (5 watts or less) newsletter. Operating news, QRPP construction projects, technical info, low power WAS standings, etc. For sample copy send address and stamp to Mike Czuhajewski, WA8MCQ, Route 3, Paw Paw, Mich. 49079.

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

FOR SALE: 32S1, 516F2, 75S1, 312B4, $725. 32S3, 516F2, $600. KWM2, 516F2, $675. 312B5, $265. Electrocom FSC-250, TK-100, Filters BPF-1275A, 2125A, 2975A; ready to go with the Collins "S-Line", $250. 75S3, $400. Variac, 220V/31 amp, $50. Model "B" slicer, $35. KW matchbox, meter, $135. Clegg "66'er", $125. Collins 302C-3 wattmeter, $70. HT-32, $175. HT-32B, $250. HT-33A, $250. SW-350C, 117-XC, Shure #450 mike, $425. Transformers: 12.6/1.0 A, $1.50; 12.8/20 A, $7; 2880 VCT/500 ma, $15; 1300 V/3.0 A, $20; 6.3 VCT/20 A, $7; 5 VCT/30 A, $8; HA-410, mike, antenna, $85. TA-33, $60. Classic-33, $85. AR-22 indicator, $25. Ham-M, $85. SR-46-A, HA-26, $150. 75A-2, vernier knob, Model "B" Slicer, $195. HRO-50-T1, spkr, calibrator, Model "B" Slicer, $175. TR-3 (Drake reconditioned Apr. '70), AC-3, MS-4, $400. T4X (Drake reconditioned Aug. '69), epoxy cabinet, AC-3, $395. Squires-Sanders SS-1R, SS-1V, SS-1S, (factory reconditioned, Mar. '70), $575. HA-1 keyer, Vibrokey, $70. Eldico EE-3 keyer, $45. HW-32-A, HP-23-A, mike, $140. Collins F455Y-60 (for 75S1/75S2), $23. 30L-1, $350. 30L-1 (factory sealed), $450. Prop-pitch motor (converted), transformer; $25. SR400, HA20, PS500AC, PS500DC, new mobile mount; $850. HA20 (new), $125. Linear-Systems #350-12 (sealed carton), $85. HX500, $250. TRADE for late Ham-Gear: Nikon "F" (f 1.4 50 mm lens) with carrying-case, Bell & Howell #200EE 16 mm movie camera, carrying-case, and 5 cartridges Kodachrome. James W. Craig, 29 Sherburne Avenue, Portsmouth, N. H. 03801.

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WANTED — DONATION of low band FM equipment and accessories, such as GE Progress Line, both mobile and base for rescue squad. Send to Bill Dunn, Winchester Rescue Squad, Winchester, Va. 22601.

CAMPOREE — Brandon Amateur Radio Society's Second Annual Camporee will be held at Florida Camplands June 12, 13, 14. Contact WA4YNW.

HAVE FEW 5894 tubes see 432 Amplifier April Ham Radio, trade/sell $5, list VHF/UHF SASE. W4API, Box 4095, Arlington, Virginia 22204.

ANNUAL HAMFEST of the Champlain Valley Amateur Radio Club will be held on July 19 starting at 10:30 a.m. EDT, at the club shack on the Akey Road, Cadyville, N. Y. (7.2 miles west of Plattsburgh on Route 3). Food and beverages available on the grounds, talk-in on 146.34-146.94 FM (W1KOO) and 3925 KC. SSB. Send advance registrations ($1.50) to CVARC, Box 241, Cadyville, N. Y. 12918. Fun and prizes for all ages.

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THE IOWA 75 METER phone net annual picnic will be held on the second Sunday in August — August 9, 1970 — at Anson Park in Marshalltown, Iowa. All amateurs and their families are cordially invited. Each should bring a covered dish and his own service. Festivities will begin around noon. Prizes will be offered and a swap table will be available.

THE WASHINGTON STATE HAMFEST will be July 11th and 12th this year. This event will again be sponsored by the Radio Club of Tacoma, and will be held at the Sportsmens' Chateau, 164th and Canyon Road, south of Tacoma. Activities include CW Awards Program, QLF and QAS contests, mobile judging and mobile efficiency contests, technical meetings, technical displays, QCWA display, manufacturers' displays, 75 and 10 meter mobile hunts, swap shop, hole-in-one contest, womens' and childrens' activities, after dinner program, many fine prizes, etc., etc. Camping space available on the grounds — $1.00 per night with free electrical hookup. 3970 KHz, 50.5 MHz, and 146.76 MHz FM will be monitored for arriving mobiles. $5.00 includes Saturday evening dinner and registration; children under 12 $1.50 for dinner only. Logger's breakfast served by the club Sunday for only $1.25. Snack bar open both days. All dinner reservations must be made in advance. For information, Hamfest tickets, or motel reservations, contact John Austin, K7CZF, 8478 Eastside Drive, N.E., Tacoma, Washington 98422.

EARLY VACATION? Then tear up that ticket to Tahiti. There'll be more fun at the ARRL Hudson Division Convention. October 17-18. Hilton Motor Inn, Tarrytown, N. Y. Exhibits, Lectures, Contests, Gabfests, New York sightseeing, Fun. OSL Hudson Amateur Radio Council, c/o Larry Strasser, 3591 Bainbridge Avenue, Bronx, N. Y. 10967. No charge for a suntan.

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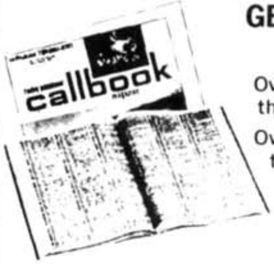

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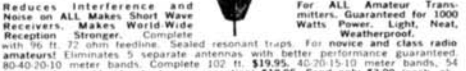

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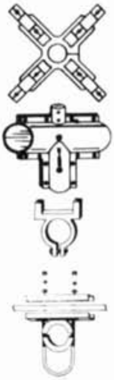

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Fibre optic face plate lens from Starlight scope. Just released from gov't security wraps. Cost to gov't $80.00. An unusual mystifying optical device. .... **#SL $3.50**

COHERENT ROD $1.00

Fibre optic coherent rod approx. 3 inches x 0.07 conducts images.

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Solid clad rod, light enters one end, comes out the other. May be bent in flame.
#CR 8 inch pieces 25¢ ea. 5/$1.00

FIBRE OPTIC LIGHT PIPE

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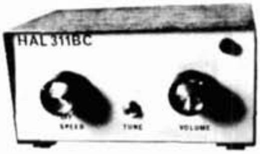
HAL DEVICES



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Requires 100 KHz signal and 3 vdc
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For the DBM in March 1970 Ham Radio
7/8x2" G10 glass PC board
4 HP 2800 hot carrier diodes matched by **HAL**. 2 Indiana General CF102-Q1 toroids.
Instructions included. $5.50 postpaid.

Hot Carrier Diodes: HP2800. . . . . . . .90¢, 12/$10.00 Matched by **HAL** . . . .4/$4.25

IC's: f μ L 900, 914. . . . . .60¢ f μ L 923. . . . . .90¢
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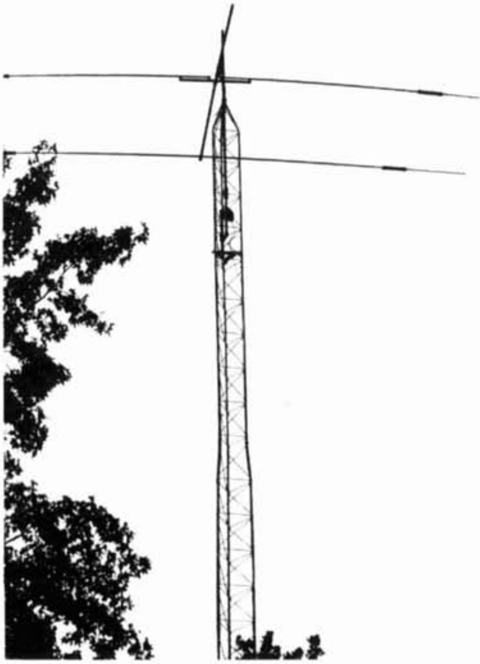

When Drake Dimitry commenced manufacturing towers he did so with two overwhelming purposes in mind. He wanted to prove that a light weight aluminum tower had substantial advantage to tower users and he wanted to design a series of towers which provided exactly the mechanical strength and height necessary for most installations.

Conventional towers are usually ordered without regard for the individual's specific requirements and chosen on the basis of price versus height for the most part. Drake felt that there was a great deal of waste in such cases and that towers could be provided which fit more particularly the individuals requirement and which could then be expanded as need be to fit ever changing load requirements of the average American ham.

The concept developed by Mr. Dimitry is the answer to such a requirement. It is sensible beyond compare and while this page does not offer means of illustrating the detail by which all of the facts can be made clear, we, nonetheless, have available a rather nice set of literature which we can send out to all hams who ask for it.

The principle advantages of the Heights tower are the facts that no maintenance is required, that the tower can be expanded at will, it can be erected quickly and easily by one man and when soundly chosen will provide adequate strength for typical 80 mph winds without the tower being guyed or house bracketed at any point. Moreover, if the tower is ordered with a hinged base it is most unlikely that the tower will ever have to be climbed.

Heights was number one with us last year and we expect it to be number one this year as well. Practically priced and quickly delivered the Heights aluminum tower is very likely your answer to an improved ham installation.

I would like the chance of proving this to you and suggest that if you are in the market for a new set up that you give us the chance to quote on your entire tower antenna package. We are the distributors for all standard brands and maintain the largest tower beam inventory in the country. Obviously our prices have to be right too.

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These days, when you think of Japanese-built products, think of Nikon, or Sony, or Toyota. And Yaesu. Our transceivers are state-of-the-art engineered and carefully hand-assembled. They're so solid, stable and reliable we guarantee them for one year. Yaesu is quite likely the best transceiver made anywhere in the world today.

The complete Yaesu story is a long one. So we've compiled a comprehensive information packet that gives you the complete picture. Including things like comparative detail photos, a schematic, and a comparison chart that shows you the FTdx 560's superiority over rigs you're more familiar with. Once you've looked over the FTdx 560 literature we think you'll agree that the amateur operator's impossible dream has become an incredible fact.

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