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10-GHz TRANSCEIVER
for amateur microwave communications
At Henry Radio, we are proud that amateurs not only in the United States but throughout the free world look to us as their pre-eminent supplier of fine communications equipment. For fifty years this has been our principal business and it still is.

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In recent months there has been rising concern about the possible harmful effects to living tissue due to heating by radio-frequency energy at 10 MHz and above. The weekly CBS TV news magazine, 60 Minutes, devoted a segment to this topic several months ago, numerous “rf radiation” stories have been published in newspapers and magazines, and now there is a best-selling book on the subject: The Zapping of America, by Paul Brodeur. Although much of Brodeur’s book is devoted to what he calls the “deadly risk of microwave radiation” and its “cover-up” by the government, he apparently doesn’t know the difference between high-power radar or TV transmitters and high-frequency amateur and CB equipment. He would have you believe that little or no research has been done on the dangers of electromagnetic radiation; if your neighbors believe him, you may find your radio activities squelched by local citizens who are afraid of being “zapped” by your amateur transmitting equipment.

Contrary to what Brodeur says, microwave engineers have been aware of rf radiation hazards for 30 years or more, and the scientific community has spent thousands of man hours investigating its effects and establishing safety standards. It is known, for example, that the internal body organs are susceptible to damage from heating caused by high-power radio energy in the range from 150 to 1200 MHz, and that the eye is especially prone to damage from radiation above 1000 MHz. More importantly, it is known that power levels which cause damage are much higher than those found in the average ham shack. Kilowatt transmitters on the amateur uhf bands (432 MHz and above) are potentially hazardous, but if they are completely shielded they are not dangerous to your health. On the lower frequencies there is practically no danger, even if you’re running 2000 watts PEP.

Based on present knowledge, which is extensive, various government agencies have established rf radiation safety standards with recommended exposure limits referred to as Radiation Protection Guide Numbers (RPGN). The accepted RPGN value is 10 milliwatts per square centimeter of body area, the standard set by the Occupational Safety and Health Administration (OSHA). Although there are some scientists who disagree with this standard, most agree that rf power levels one-half the OSHA standard (5 mW/cm²) have little effect on the human body, and practically no one objects to a standard of 1 mW/cm². Note that this is based on continuous exposure.

If your transmitter is well shielded, and you use coaxial transmission line, the only possible danger is radiation from your antenna. Assuming a kilowatt linear with 65% efficiency and no feedline loss places about 650 watts at the antenna; what is the minimum safe distance? This depends on the directivity of your antenna, but for a half-wavelength dipole it equates to a distance of about 3 meters (10 feet) for a power density of 5 mW/cm². If you’re running less than a kilowatt, of course, the safe distance is less. Since most amateur dipoles are installed at least 8 meters (25 feet) above the ground, they obviously pose no radiation threat.

What about multi-element Yagi beams and stacked arrays? Since most of the power is concentrated in front of the beam, there is little danger above or below the antenna. Even with 650 watts input, the beam must have at least 15 dBi gain before the power density reaches 5 mW/cm² in the center of the forward lobe, 10 meters (30 feet) in front of the antenna. Few amateur antennas have this much gain, and those that do are used on uhf where it’s impossible to generate 650 watts into the antenna and stay within the legal power limit.

On the high-frequency bands, if your beam is on a tower at least 10 meters (30 feet) high and not pointed into a building less than 10 meters away, there is absolutely no hazard at legal amateur power levels. Keep this in mind if you start getting grief from your neighbors.
ICOM's New IC-280

ICOM introduces its new 2 meter mobile radio with the detachable microprocessor control head, the IC-280. Bright, easy to read LED's and a new style meter grace the brushed aluminum “new look” front panel of the detachable control head, which provides memory and frequency control for the remotely mountable main section.

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With the microprocessor head the IC-280 can store three frequencies of your choice, which are selected by a four position front panel switch. These frequencies are retained in the IC-280’s memory for as long as power is applied to the radio. Even when power is turned off at the front panel switch, the IC-280 retains its programmed memories; and when power is completely removed from the radio, the ±600 KHz splits are still maintained!

Frequency coverage of the IC-280 is in excess of the 2 meter band; and the new band plan (144.5 - 145.5 MHz repeaters) can easily be accommodated, since it was included in the IC-280’s initial planning by the ICOM design team.

The main section of the IC-280 puts you up to the minute with the latest state of the art engineering. The new IC-280 includes the latest innovations in large signal handling FET front ends for excellent intermodulation character and good sensitivity at the same time. The IF filters are crystal monolithics in the first IF and ceramic in the second, providing narrow band capacity for today and tomorrow’s crowded operating conditions. Modular PA construction with broad band tuning provides full rated power across the full 2 meter band (plus a little).

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Specifications subject to change without notice.

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The above discussion is derived directly from a consideration of the field cell concept and of field maps for the transmission lines. It also follows that a line of any shape can be either calculated from a map or measured very simply with an ohmmeter and resistance paper as described on page 492 of Electromagnetics by J. D. Kraus and K. R. Carver (McGraw-Hill, New York, 1973).

John Kraus, W8JK
Director, The Ohio State University Radio Observatory

bandspreading techniques

Dear HR:
I read with interest Mr. Leonard Anderson's excellent article on bandspreading techniques in February, 1977, ham radio. I would like to propose an alternate to his standard capacitor. By using a 3-wire guarded circuit, as shown in fig. 1, the cable length will not cause the standard to read in error. This is due to the shield of the coax acting as a shield between the two leads from the capacitor. This method is used quite frequently by GenRad and other companies when measuring very accurate capacitance values. The main disadvantage of the guard circuit is that the capacitor must be isolated from ground.

Robert Heider, W6EJO
Glendale, Missouri

antenna noise bridges

Dear HR:
I found the recent article on RX noise bridge measurements very interesting. As the developer of the original antenna noise bridge I would like to point out that two basic models were developed. The TE701 used a similar output circuit to the one shown in the article and worked well to over 100 MHz. The Model TE702 used a variation and worked to over 250 MHz. The bridge circuit was as follows:

Ted Hart, W5QJR
Richardson, Texas

*W5QJR is the inventor of the Antenna Noise Bridge, and holds the patent on this very useful device. Readers who are interested can obtain copies of the patent (number 3,531,717, dated September 29, 1970) for 50 cents from the Commissioner of Patents, Washington, DC 20231. Editor
The evolution of the MLA

When the MLA-2500 was first introduced it was a new concept in high performance amplifiers. Low and sleek yet powerful enough for the military. Some wondered . . . needlessly.

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Convinced? Isn't it time you owned the amplifier that powered Clipperton and thousands upon thousands of radio stations throughout the world?

MLA-2500 B $899.50.
CB'S THREAT TO 220 MHZ is far from dead, as indicated by an in-depth study just published by the FCC. "Alternatives for Future Personal Radio Services" is a two-volume set produced by the Commission's Office of Plans and Policy following a 20-month study by the Personal Radio Planning Group. After weighing all possible factors, the study concludes that 220-225 and the 900-MHz land mobile reserve bands are the best spots for a new CB service, and economics, performance, timing, and possible medical considerations all lean toward 220 MHz.

One Factor That Shouldn't be overlooked is that this study was done when Carlos Roberts headed the Office of Plans and Policy — and he's now head of the Safety and Special Services Bureau which includes Personal Radio Services (Amateur Radio and CB) among its Divisions.

THE FCC'S BAN ON 10-METER LINEARS was upheld in June by the Commissioners by a 5-1 vote despite a significant shift in FCC staff support. This time the Safety and Special Services Bureau joined the Chief Engineer's office in opposing the ban on legitimate Amateur linears, but the Field Bureau stated they found the ban to be very effective and the Commissioners went along.

AMATEUR RADIO WASN'T involved in FCC's discussion of interconnects (Docket 20846) in June, but the tone of the meeting was that commercial systems resembling Amateur autopatch repeaters were "dangerously close" to being common carriers and would be undergoing careful scrutiny in the near future. The implications for Amateur Radio are far from clear at this time, but Amateur repeater users and operators alike would be wise to be very careful in the operation of their systems.

AMATEURS REQUESTING CALLSIGNS not currently available (lx2s for Extras or "counterpart" lx3s for oldtimers switching call areas, for example) may find themselves stuck with a new callsign they really didn't want. So many Amateurs have been making improper requests that it's caused a serious backlog, about 8500 at last count. So, in the future, such applicants won't be asked whether they want one of the new callsigns, instead of what they'd requested, but will simply be issued one.

Amateurs Who Upgrade must request a callsign change in the FCC Field Office at the time of the exam — later requests for a new callsign (except by Extras) will be returned without action.

FCC'S EX PARTE COMMUNICATIONS rules, which severely limit Commission people's ability to discuss pending Notices of Proposed Rule Making, is now the subject of a Notice of Inquiry (General Docket 78-167). Until it acts on that NOI, the Commission has adopted an interim policy requiring outsiders planning to discuss a pending issue with the Commission to submit beforehand a memo for the record describing what they plan to discuss (according to current interpretations, the limitations on informal discussions do not apply to Petitions for Rule Making or Notices of Inquiry).

Comments On The NOI are due August 9, and Reply Comments by August 23.

"MEDIUM BANDWIDTH" ATV on 10 meters has been okayed by the FCC for a two-year test period starting June 16. The five stations receiving the Special Temporary Authority will be permitted the use of AS or FS with a maximum bandwidth of 35 kHz from 29.0 to 29.3 MHz. The five involved are W9NTP, W3BFG, W8LMD, W6N1V, and WB9LV1 — the STA was in response to a request from the ARRL.

THE PROPOSED REVISION OF THE 1934 Communications Act unveiled in June held no surprises for Amateur Radio, though it would abolish the FCC in favor of a "Communications Regulatory Commission" and delegate frequency allocation to the "National Telecommunications Agency." The only obvious effect on Amateurs would be the increase in license terms to 10 years, and reintroduction of license fees. Passage of the revised act is a long way off, however.

ALIEN AMATEURS SEEKING permission to operate in the United States should now send their Form 610-A applications direct to Gettysburg (FCC, Box 1020, Gettysburg, Pennsylvania 17325) instead of to Washington as in the past. Part 97.305 (b) of the Rules has just been revised to permit the change, which accelerates processing.

420-450 MHZ BAND USERS may be in for severe interference problems when the Air Force's "PAVE PAWS" radar goes into operation in the next year or so. The very-long-range system has an average ERP of about a billion watts, and one estimate says that when it's aimed at the moon the reflected signal would illuminate an entire hemisphere of the earth with a 10-20-microvolt signal. The main beam could also bum up a receiver front end 15 km away.

First Operational Site for PAVE PAWS is Cape Cod (Massachusetts) and a second installation is slated for Beale Air Force Base in California. PAVE PAWS has the potential for doing real damage to the Amateur satellite program as well as other weak-signal work on the 70 cm band. Both AMSAT and the ARRL are carefully studying the problem.
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10-GHz transceiver
for amateur microwave communications

Construction of a complete 10-GHz Gunnplexer transceiver with 30-MHz i-f and automatic frequency control

A little over a year ago Microwave Associates introduced a new component for amateurs which greatly simplifies the construction of a 10-GHz transceiver for operators who are interested in microwave communications but don’t have experience with microwave construction techniques. Without special knowledge or an extensive test setup amateurs can now use a Microwave Associates MA-87127 Gunnplexer to operate on the 3 cm (10 GHz) amateur band. No special mechanical work is required. The Gunnplexer is a complete transceiver which consists of a varactor-tuned Gunn diode rf source, a ferrite circulator which decouples the transmit and receive functions, and a Schottky mixer diode for the receiver signal. A diagram of the basic Gunnplexer system is shown in fig. 1; a block diagram of the complete transceiver is shown in fig. 2.

The Gunn diode oscillator requires a regulated 10 Vdc source which is capable of supplying 200 mA. The rf output power is approximately 20 mW;* a 17 dB gain horn antenna is available from Microwave Associates. The frequency of the Gunn diode can be tuned with the built-in varactor diode over a frequency range of 60 MHz minimum (100 MHz typical). The required varactor bias is +1 volt to +20 volts and should be controlled by a good quality multi-turn potentiometer.

The Gunnplexer can be easily frequency modulated with a small modulating voltage (mV range) which is superimposed on the varactor’s dc bias supply. Since a very small modulating voltage is required, the

*Three models are available: the 15-mW MA-87127-1, the 25-mW MA-87127-2, and the 40-mW MA-87127-3. Units are stocked by Glen Whitehouse, Newbury Drive, Amherst, New Hampshire 03031, and in Europe by Microwave Associates, Munich.

By Klaus H. Hirschemann, DJ700, Reger Strasse 4, 6500 Mainz 31, West Germany
amplification factor of a single-transistor microphone amplifier is sufficient.

**i-f amplifier**

To complete the 10-GHz transceiver, an i-f amplifier is required. Because the antenna and Gunnplexer and its antennas are normally physically separated from the operating position (for roof or tower mounting), an i-f amplifier with a low noise figure should be connected directly to the Gunnplexer’s mixer diode. A noise figure of 1.5 dB or less and a good impedance match \((Z = 200 \text{ ohms} \text{ at } 30 \text{ MHz})\) is required to obtain an overall system noise figure of 12 dB or better. With careful design, a system noise figure of less than 10 dB can be achieved.

The coaxial connection between the i-f preamplifier and the post amplifier/receiver at the operating position is not critical; a proven design is presented later in this article. When considering the noise figure of a Gunnplexer system it’s important to remember that the receiver has no preselection so the two receiver sidebands (carrier plus and minus the i-f) contribute equally to the overall noise figure.

Standardization of a single i-f system is essential for the operation of a 10-GHz system among a large group of amateur microwave enthusiasts. A 100-

fig. 1. Basic Gunnplexer system showing the varactor-tuned Gunn-diode oscillator, ferrite circulator, and Schottky mixer diode. A portion of the rf power from the oscillator is coupled to the mixer through the circulator. The i-f output impedance at 30 MHz is 200 ohms; a 4:1 transformer is required to provide a good match to 50 ohms (see fig. 2).

MHz i-f has been recommended by several German amateurs, but this is useful only if communications between two fixed stations is all that you want. The result is a full duplex system without transmit-receive switching where the Gunn oscillator operates simultaneously as a receiver local oscillator and frequency-modulated transmitter. Each partner operates at a different frequency, which results in the intermediate frequency as shown in fig. 3.

In most cases, however, amateurs want to contact as many other 10-GHz stations as possible. This requires that each station must be able to transmit and receive on either frequency. Since the varactor diode provides a maximum frequency tuning range of only 60 MHz, the use of a 100-MHz i-f would require mechanical tuning of the Gunn oscillator. Mechanical tuning of the Gunnplexer provides a tuning range of \(+100 \text{ MHz minimum}\), but this would unduly complicate a two-way communications set-up. By choosing a 30-MHz i-f, however, you can switch frequencies with a simple voltage change on the varactor diode.

In the Rhein-Main area in West Germany various Gunnplexers are operated at 10350 MHz (transmit) with \(+4\) volts of varactor bias; with \(+10\) volts on the varactor the transmit frequency is 30 MHz higher at 10380 MHz. If an operator knows whether the other station is using the lower (10350 MHz) or higher (10380 MHz) frequency, it is only necessary to tune the receiver over a small range of frequencies.

The instability of the self-oscillating Gunn diode requires wideband frequency modulation; a transmit bandwidth of 75 kHz and an i-f bandwidth of 200 kHz gives satisfactory results.

Construction of the 30-MHz receiver designed by DJ700. At the bottom left is the mosfet input stage, followed by the 40.7 MHz local oscillator and mixer. TDA1047 f m i-f strip, and TAA611 audio power amplifier. The two potentiometers are for squelch and audio gain.
fig. 3. Duplex operation of the 10-GHz Gunnplexer system, showing the oscillator frequencies for 100-MHz and 30-MHz intermediate frequencies. As discussed in the text, a 30-MHz i-f is preferred because of the 60-MHz tuning range provided by the varactor; the use of a 100-MHz i-f would require mechanical tuning of the Gunnplexer.

i-f post-amplifier

The 30-MHz i-f post-amplifier and receiver shown in fig. 4 was developed by the Zweite Deutsches Fernsehen amateur group. More than fifty of these receivers have been built and used on the air, and all operate well.*

The first 30-MHz amplifier stage uses a dual-gate BF900 MOSFET transistor (similar to the RCA 40673). The self-oscillating mixer is based on a Siemens SQ42P IC and translates the 30-MHz input signal down to the 10.7-MHz i-f. The parallel tuned circuit (L1-C1) resonates at 40.7 MHz, the frequency of the third-overtone crystal. Without inductor L1 in the circuit the oscillator has a tendency to run at the crystal’s fundamental at approximately 13.56 MHz; this can result in unwanted modulation products (13.56 + 10.7 = 24.26 MHz).

The Murata SFW10.7MA ceramic filter determines the i-f response characteristics of the receiver; the 3 dB bandwidth is 220 ± 40 kHz. The Siemens TDA1047 IC, which was developed for fm broadcast radios, is used as an amplifier and fm demodulator; it has excellent limiter capabilities and includes a built-in squelch circuit - its symmetry guarantees trouble-free operation.

An S-meter is connected to pin 14 of the TDA1047

* Kits to build your own 30-MHz post-amplifier are available from Elektronik Laden, Wilhelm-Mellies-Strasse 88, D4930 Detmold 18, West Germany; the price is 89 DM ($45) postpaid.

fig. 2. Block diagram of the complete 10-GHz Gunnplexer transceiver described by DJ700. In Germany these transceivers have been used to provide reliable communications up to 180 km (112 miles) or more. The 4:1 transformer consists of 18 turns slightly twisted no. 28 (0.3 mm) wire on an Amidon T50-6 toroid core; remove the protective diode installed across the mixer output before connecting the transformer.
L1 15 turns, 28 AWG (0.3mm) unsupported, closewound on 4 mm (5/32 inch) diameter mandrel
T1 Primary, 3 turns; secondary, 18 turns
T2 Primary, 18 turns; secondary, 5 turns
T3 Primary, 18 turns; secondary, 5 turns
T4 8 turns

All transformers wound with no. 32 AWG (0.2mm) wire on Vogt D41-2520 forms.

fig. 4. Schematic diagram of a broadband 30-MHz i-f post-amplifier/receiver which features a MOSFET input stage, S042P self-oscillating mixer, 10.7-MHz ceramic filter, TDA1047 amplifier/demodulator, and TAA611 audio power amplifier. The complete receiver is built into a package measuring 14.7 cm long, 7.4 cm deep, and 2.9 cm high (5.8 x 2.9 x 1.1 inches). A kit is available.
The successful operation of various 10-GHz amateur stations in the Rhein-Main area, operating with the equipment described here, has proved the system's feasibility and reliability. The use of 17-dB horn antennas at both ends of the link allows communications up to 60 km (35 miles) or more. The 3-dB beamwidth of the horn antenna is approximately 30 degrees, so antenna alignment is not particularly critical.

Some stations are using home-built 23 dB horn antennas or 2 meter (6 foot) parabolic reflectors, so there have been many 10-GHz contacts in the range...
of 100 to 200 kilometers (60-120 miles). Since a pair of Gunnplexers with these high-gain antennas has a calculated systems range of at least 400 km (240 miles), we could work over distances greater than 200 kilometers (120 miles) if we could find a non-obstructed path that long.

When setting up the Gunnplexers it's helpful to have a secondary link on 144 or 432 MHz, but many contacts have been achieved without it. The operation of a microwave transceiver with the aid of a map and compass is a new challenge and hobby for many amateurs in Germany.

Activity on 10 GHz in Europe has now reached the point that a 10-GHz bandplan has been approved by amateur groups in Germany, Holland, and Switzerland. In addition to providing space for communications between individual amateurs, the bandplan accommodates beacons, repeaters, and narrowband modes (CW, RTTY, SSTV, and single sideband).

Trial runs with higher gain antennas, narrower i-f bandwidths, and phase-locked loop circuitry for frequency stability are presently going on (reference 3, which describes a phase-locked Gunnplexer system devised by WA6EXV, is available from Microwave Associates).

I would especially like to thank DJ6RW, DJ3KM, DK2DRX, DJ8QL, and DJ8CY for their help in the construction and planning of this equipment.

references

*A+ 10 volt regulated power supply recommended for use with the 10 GHz Gunnplexer transceiver. The BC107B transistors may be replaced by any small-signal NPN silicon transistors such as the 2N4124. The MJ2955 may be replaced by a 2N3789 or similar 10 amp PNP device.*
THE GUNNPLEXER SYSTEM

The fascination of amateur microwave application is unique. First of all, microwave systems have an 'exotic' ring to them. Until the appearance of the Gunnplexer, getting into microwaves required either a six foot rack of surplus gear or a friend on the inside of a microwave hardware supply company. The Gunnplexer has changed all of that; you can hold the whole thing in the palm of your hand and you don't need any friends in the microwave business (in fact it may be better if you don't have any prior microwave knowledge because the Gunnplexer pretty much throws away the book on standard microwave design practices!)

An equal fascination is the wide band capability of the microwave region. The 10 GHz assignment, for example, has spectrum-space for 111 simultaneous video (4.5 MHz wide) channels. Try that even using SSTV in the 20 meter assignment. The bottom line on microwaves is simply that it will do much more communicating than you might first suspect.

DESCRIPTION

The MA-87127 series of frequency modulated transceiver "front ends" using Gunn oscillators and Schottky mixer diodes has been specially designed to operate in the amateur 10.0 to 10.5 GHz band.

The rear portion of the unit consists of a Gunn oscillator which directly converts DC to RF energy. The oscillator is delivered pre-set at 10.250 GHz (oscillators pre-set to other frequencies are available on special order 10.0 - 10.4 GHz). Mechanical tuning is available to shift the center frequency ±100 MHz. A tuning varactor is mounted close to the Gunn diode which will deviate the fundamental frequency typically 60 MHz when the proper tuning voltage is applied. FM, including both audio and video, can be applied to the tuning varactor input. The receiver noise figure is approximately 12 dB depending on auxiliary equipment used. A ferrite circulator has been integrated into the waveguide mount to isolate the transmitter and receiver functions.

TWO-WAY COMMUNICATIONS

The primary application of the Gunnplexer "front end" is for 2-way communications. Two units, one a transmitter and the other a receiver down converter, are used with their carrier frequencies off-set to provide a reasonable IF (30 MHz or higher). Applications range from linking remote receivers to VHF repeaters, transmitting color video, linking homemade computers, full duplex mountain top DXing or over water duct DXing. A separate power supply and simple FM modulator must be provided, the MA-86551 (17 dB) horn antenna (shown here) is suggested.

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The actual usable range is a function of characteristics such as output power, frequency stability and noise figure. Generally, it's desirable to deviate the FM signal so that the available IF bandwidth is completely filled. The graph in Figure 1 below indicates the maximum achievable range vs. IF bandwidth at threshold with the signal defined as the beginning of intelligible speech. Higher gain antennas will obviously greatly increase range.

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16 August 1978 More Details? CHECK-OFF Page 126
frequency-lock loop

Oscillator stability can be improved by applying this simple but effective frequency-lock loop

One of the main considerations in the design of radio communications systems is frequency stability. The objectives in the amateur radio service, however, are often quite different from those of other hf services. Amateurs have band allocations, while most other users have spot frequencies to work on, and consequently the vfo is usually our preferred primary frequency source. There are three basic frequency generation techniques in common use at the present time. The vfo is the oldest, offering simplicity and the very real asset of continuous tuning, but it is difficult to achieve high stability, especially in the long term. The crystal-controlled oscillator is also simple and very stable, but offers little flexibility, although such variations as the vxo and the “Rock-Mixer” have offered some help in this direction. Finally, there is the synthesizer, based on the phase-locked loop. At the expense of some complexity, this method offers excellent stability and can be very flexible. However, it is inherently a noncontinuously-tuned device, and, therefore, not as well suited to amateur applications — especially on the hf bands.

The vfo, in all respects except stability, offers what we need. It seems a pity to throw away all the results of the continuing development which have made the vfo as good a piece of equipment as it is, and start all over again with the synthesizer. On the other hand, the approach I have taken with the frequency-lock loop (FLL) takes advantage of the positive points of the vfo and adds to it the stability of the crystal oscillator. Moreover, you can readily add an FLL as an outboard unit to an existing vfo without major modification to your equipment.

basic principles

If you have a good frequency counter with a readout down to 1 Hz, you can, by manual tuning adjustments made suitably often, keep the vfo on the required frequency indefinitely. The stability in the medium to long term is that of the counter’s clock. The function of the FLL is to automate this operation.

The frequency-lock loop consists of a simplified counter with a crystal derived clock, an error detector and latch circuit, a filter section, and a controlled reactance to compensate for drift in the vfo tank circuit. The error detector may be compared with the operator’s recognition of a significant change in frequency, the filter his decision on the magnitude of the correction, and the controlled reactance the action of his hand on the vfo tuning knob.

counter

The purpose of the counter in the FLL system is not to display frequency, but to control it. And, as there is no reason to operate in the decimal or BCD modes, the simple binary counter is used. Comparing the FLL with the manual control, it should be obvious that there is no need to consider the most significant digits of the count. It is hoped that the vfo will not drift so much that the tens and hundreds of kHz would ever change, and surely not the MHz! So, for compensation of drift instabilities, only a small portion of a counter is required, and that can be in binary form.

The gate period is also of fundamental importance.

By Crawford MacKeand, WA3ZKZ, 115 South Spring Valley Road, Greenville, Delaware 19807
I originally decided on an updating frequency, based on my feelings for drift rate, of once every 3 seconds, (clock 4.2 Hz), arguing that no significant drift would occur in a gate period of 2.8 seconds. Although this is true, I have changed to a higher clocking frequency of about 420 Hz and a gate of 28 mS. The longer period works fine, but the device takes so long to decide what to do next that the user rapidly loses patience with it.

The counter gate logic is a modification of that presented by MacLeish. The crystal oscillator and dividers can be any arrangement that supplies the correct clock frequency, provided that it has the requisite stability. The counter preamplifier is also a standard circuit for sampling the output of the controlled oscillator.

error detector and latch

At the end of each count period the counter will be in a state which is dependent on the frequency of the controlled oscillator. If the frequency does not vary, neither will the counter’s state at that instant. I initially felt that I would need to devise a circuit which would provide an output indicating whether the controlled oscillator was too high or too low in frequency. The obvious way to do this was by the use of a binary logic comparator such as the 7485. However, this would entail the use of switched inputs to cover all the 256 possible states of the counter. Of course, one point of the 256 is available without any comparator at all: when the final stage of the 8-bit counter makes a transition, either 1 to 0 or 0 to 1. This means that during the period the gate was open some multiple of 128 cycles of the input frequency has been counted (256 cycles if you are only looking at the 1 to 0 transition). Therefore, without any further circuitry, the basic FLL shown in fig. 1 would indicate whenever the input frequency would satisfy these conditions. Assuming that we consider only 1 to 0 transitions, two successive frequency groups are related by:

\[ f_n - f_{n-1} = \frac{k}{12} f_c \]  

where 

- \( k \) = counter total
- \( f_c \) = clock frequency in Hz

To complete the error detector, I used a latch to hold the output from one count to the next. The output of the latch is a TTL signal; one state indicates that the input frequency is too high and the other state indicates that the input frequency is too low.

filter

If the latch output were applied directly to the controlled reactance, the output frequency of the vfo would constantly be pulled one way and then the

fig. 1. Partial schematic diagram of the basic frequency lock loop circuit. At this point, interpolation within the 256 cycle groups has not been taken into account.

fig. 2. Timing cycle of the basic FLL system.

fig. 3. Timing cycle of the frequency lock loop system with interpolation. The 74121 is used to shorten the count period, permitting resolution within a 256 cycle group.
other. However, the mean frequency would be correct. Intuitively, it seems that some smoothing is required. The FLL is very similar to a “bang-bang” servo, and can be readily stabilized by a first order filter or integrator composed of a single RC stage. The optimum filter is probably worth some investigation; nonlinear circuitry may also offer some advantages (a possible approach is described in reference 5).

The filter time constant $t_f$ should be long enough to reduce the fm on the vfo to an acceptable amount, and yet not so long as to make the balancing time excessive. My experiments in this area seem to indicate that somewhere in the region of 50 to 100 seconds is a good starting point.

**voltage-controlled reactance**

The obvious choice for the controlled tuning reactance is a voltage-variable capacitor diode (varactor...
fig. 6. Circuit board layout for the frequency lock loop. Shown above is the back side of the board, with most of the interconnecting wiring; drawing on next page shows the top side of the board and the parts placement diagram. Although not included in fig. 5, this board contains an additional 7490 which is one of the input dividers from the oscillator. Also not shown in fig. 5 are the numerous 0.1-µF bypass capacitors included on the board.

or varicap). Its application is dependent on the design of the vfo which is to be stabilized. The filter output has a useful range of about +1.5 to 3.5 V dc, although it would be a simple matter to include an op amp if a greater swing were required. The varicap should be connected to the oscillator tank so that it produces, with this voltage range, a frequency variation greater than the drift which is to be corrected.

In my Hammarlund HQ215 receiver I have been able to stabilize the high-frequency oscillator by coupling into a diode frequency shifter, which is provided for resetting the calibration when changing modes from USB to CW to LSB. Many transceivers have RIT circuits which provide similar access to the oscillator tank, while most transmitters and vfos can easily be modified as if you were providing for FSK operation.

interpolation

The basic FLL of fig. 1 will stabilize a vfo at discrete fixed frequencies, based on a fixed count period determined by the counter clock. The first method of interpolation I considered was that of varying the clock-oscillator frequency, using a vxo as the clock oscillator. With this arrangement I found that

\[ \frac{\Delta f_a}{f_a} = \frac{\Delta f_x}{f_x} \]  

where

- \( f_a \) is the basic clock oscillator frequency
- \( \Delta f_a \) is the change produced by pulling the vxo
- \( \Delta f_x \) is the resulting change
- \( f_x \) is the controlled frequency
This places another constraint on the design, in that $\Delta f_r$ must be at least as large as $f_n - f_n^-$, the difference between successive discrete stabilizing frequencies. But $\Delta f_r$ is limited by the design of the vxo. Because of this factor, and also the decreased stability of a vxo compared with a regular crystal oscillator, this method was set aside for future consideration in favor of an alternative which permitted the use of a fixed-clock frequency.

The basic timing cycle is shown in fig. 2. It should be obvious that if the total counting period could be varied, by at least the time required to count one group of 256 cycles, then the problem of interpolation would be solved. A non-retriggerable one-shot multivibrator is used to create a noncounting period.

The new timing diagram incorporating the interpolating one-shot is shown in fig. 3; the schematic diagram shown in fig. 4.

operation

The lock switch, S1, is initially set to FREE. In this position the oscillator will be at its nominal calibrated frequency, because R1 and R2 have forced the tuning voltage to its center value. The LED indicator will show the latch's output state. As the oscillator is tuned across its operating range, the LED will cycle on and off every time the frequency changes by $f_n - f_n^-$. If we now choose an operating frequency, the interpolation control is adjusted until the LED flickers, showing that the FLL is ready to lock. The lock point may be either at a 1 to 0 or a 0 to 1 transition as the frequency increases. At this point S1 is moved to either LOCK A or LOCK B. You will know if you've selected the wrong one because the oscillator will rapidly drive off frequency. Initially it is useful to establish a rule such as: clockwise rotation of pot, lights the LED, S1 to LOCK A. After this is established, when you select S1, you're on frequency to stay. Minor frequency adjustments can be made with the potentiometer.

A steady flashing of the LED is a good indication of continuing operation. Meter M1 is valuable in the lock mode to show how far you have drifted and how much corrective capacity you have left. While in the FREE position, it can be used to show which lock
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References

Position to use and also which way to move the interpolation pot.

Performance

In this system almost all of the stability is derived from the crystal clock, with the remainder determined by the RC product in the interpolator. Using the constants discussed, on 80 meters, this amounts to one group out of about 400. In other words, during the total gate period, about 400 groups of 256 cycles are passed, and therefore, only one four-hundredth of the period is dependent on the one-shot's stability. If this is as good as 0.1 per cent, the overall stability is close to one part in 400 000. There is, however, an interesting series of trade-offs between the various constants and values selected. A short-gate period makes the job of the filter easier and reduces the FM effect caused by ripple on the control voltage. A long-gate period, on the other hand, makes the unit difficult to use, but reduces the dependence of the overall stability on the one-shot. Having decided on the gate period, the frequency difference \( f_n - f_{n-1} \) is a function of the total count \( k \). If \( f_n - f_{n-1} \) is too small, jumping from one stable point to another could presumably occur.

There are a number of points which can be further refined if greater stability were required, but I have found, for instance, that the present design has made it possible to operate unattended on 3600 kHz RTTY autostart, where a stability of \( \pm 10 \) Hz is desired. My actual achieved stability, as shown in fig. 5, is closer to \( \pm 5 \) Hz, which seems to indicate little drift in the one-shot.

Conclusion

The frequency-lock loop provides a simple and effective way of improving the stability of a VFO, effectively competing with a crystal oscillator. Equipment modifications are minimal and can be largely outboard. The components of the FLL itself are all TTL, readily available and inexpensive, while the control system is easy to use and has no tricky components or adjustments. Construction follows normal TTL practice and the simple double-sided layout shown in fig. 6 is suggested for the main board.

References

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Locating and correcting the source of TVI is perhaps one of the most difficult tasks facing a radio amateur, one which must be performed methodically if satisfactory results are to be obtained. Much has been learned and written about transmitter harmonic radiation and TV receiver overload, but often very little is said about another prevalent and frustrating source of TV trouble, nonlinear rectification TVI.

Rectification TVI is caused by poor or intermittent contact between two conductors in the radiation field of a transmitting antenna. No amount of filtering or shielding at either the transmitter or TV set will correct the problem, since the interference is generated in the TV spectrum as direct harmonics of the transmitter’s fundamental frequency.

In January, 1953, a fine article by Mack Seybold, W2RYI, was published in QST, but I have seen nothing of a concrete nature on this particular problem since that time.

How do I know I have it

Rectification TVI can be suspected when suddenly there is TVI on one or more channels where there was none before, and no changes have been made in transmitter operation. Any metallic discontinuity can cause rectification TVI. In 1947, when I was living in a small town and in the days before the blessings of TV, my next-door neighbor said he heard voices coming from his bathtub drain. Another neighbor heard voices coming from her electric kitchen range. Both voices were caused by detection of my 75-meter a-m kilowatt rig. These two phenomena, no doubt, were caused by rectification.

The strength of the TVI will depend on the efficiency of the rectifier, the length of the “antenna” connected to the nonlinearity, the distance from the transmitting antenna, and the transmitter output power. Two signals on widely separated frequencies can also combine to produce a signal at a third frequency — the faithful $2A \pm B$, or intermodulation products. For example, if two hams live near each other, and one is on 21 MHz and the other on 28 MHz, interference can be caused on channel 4 ($2x21 + 28 = 70$ MHz) or channel 5 ($2x28 + 21 = 77$ MHz), or both, if a nonlinear discontinuity exists in the area. These two signals, of course, will exist only when both stations are transmitting. Also, each signal alone can cause TVI on channel 2 ($2x2), channel 3 ($2x3), and channel 6 ($2x3$ and $2x4$).

Visible TVI can be caused by an interfering signal as weak as 40 dB below the video carrier, depending on the frequency of the interference. A 1000 $\mu$V video signal, which is an adequate signal, can be interfered with by a 10 $\mu$V harmonic. If the amateur transmitter is running one-kW input, this does not leave much margin for harmonic generation.

All 14-MHz harmonics through the sixth can cause trouble, but the greatest problem is caused by the odd harmonics, the third and fifth. Table 1 shows the harmonic relationships of the 14, 21, and 28 MHz amateur bands with respect to the TV channels. The worst interference is caused at or near the video carrier, 1.25 MHz above the lower TV channel edge. With all stations using color, however, a particularly vicious interference is caused by a harmonic falling or near the color subcarrier frequency, 4.8 MHz above the lower TV channel edge.

By John E. Pitts, W6BD, 1068 Eden Bower Lane, Redwood City, California 94061
This effect was noted at W6BD on channel 4 when operating near 14.2 MHz. The interference appeared as wide diagonal color (rainbow type) bars on the screen. The fifth harmonic of the fundamental fell within 200 kHz of the color subcarrier at 70.8 MHz. Operation in the CW portion below 14.1 MHz caused no interference. Substitution measurements with a calibrated signal generator showed that color bars were caused by an interfering signal at 71.0 MHz with a signal strength of less than 300 pV. The desired channel 4 signal was 1500 pV. The cause was eventually traced to rectification TVI and was located by the methods presented here.

the fix for the hex

The harmonic chaser used in this hex-pedition (an expedition to find the hex) is simple to construct, easy to use, and will rapidly locate the source of the harmonic radiation. It is also, by today's standards at least, inexpensive. In this instance, the whole system was constructed and tested and the TVI source found in one weekend, so the work involved in the project is not great.

**table 1. Amateur-band harmonic relationships to low-frequency TV channels. All frequencies are in MHz.**

<table>
<thead>
<tr>
<th>fundamental</th>
<th>28</th>
<th>21</th>
<th>14</th>
<th>harmonic band</th>
<th>TV channel number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>4</td>
<td>56</td>
<td>54 - 60</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>63</td>
<td>70</td>
<td>60 - 66</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>70</td>
<td>84</td>
<td>66 - 72</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>76 - 82</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>82 - 88</td>
<td>6</td>
</tr>
</tbody>
</table>

Since the harmonic strength will be a relative measurement, a narrow-band receiver, tuned to the harmonic frequency, will be used. The easiest approach is to use a TV tuner whose i-f output is in an amateur band. This allows the selective station receiver to become the i-f amplifier and detector.

There are generally two types of tuners used for replacement purposes, the turret type and the wafer type. Due to the coil arrangement of the wafer-type tuner, it is unsuited for this purpose because the tuner's oscillator frequency must be changed. The most easily modified is the turret type, because the coils

---

**fig. 1.** Schematic diagram of the Sarkes-Tarzian tuner and power supply. The coil marked CC is tuned for maximum signal into the receiver. You should not use more than about 60 cm (2 feet) of cable between the tuner and the receiver, otherwise the tuner may not cover the desired output frequency range.
for each channel are mounted on an easily removable bar. Present-day tuners have an i-f of 41.25 to 47.25 MHz, out of the range of most ham receivers. The widest high-frequency amateur band is 28 to 29.7 MHz. Therefore, the oscillator frequency needs to be lowered only about 10 to 12 MHz to produce an i-f output at 29.0 MHz.

The tuner used is a replacement type, Sarkes-Tarzian MFT-1 preset replacement tuner (see fig. 1). It is housed, with a small power supply, in an LMB 12.7 x 11.4 x 19.1 cm (5 x 4-1/2 x 7-1/2 inch) W-2F chassis cabinet. Except for the tuner and cabinet, which cost about $27, all parts came from the junk box. Purchasing everything, and with a little horse trading and typical ham ingenuity, the entire cost should not exceed $40.

construction

The original cut-and-try coil modification was performed using a frequency counter. A counter is not absolutely necessary, but if one is available, the job is much easier. If not, a reasonably accurate grid-dip oscillator (GDO) can help set the tuner’s oscillator to the required frequencies. The oscillator was tuned to the high side of the desired signal because it did not want to oscillate on the low side. Therefore, as shown in table 2, the 10-meter receiver tunes backwards.

The only coil to be rewound is in the oscillator, the coil with the fine-tuning screw slug. Remove the snap-off shield from the tuner chassis. The channels to be modified are 2 through 6, since 7 and above are not normally subject to rectification TVI. Channel 5 doesn’t have to be modified, since no discrete amateur-band harmonic normally falls in this channel. Citizens band harmonics, however, do fall in channel 5.

Rotate the shaft until the bar with the greatest number of coil turns (channels 2 through 6), starting with the bar adjacent to the uhf strip, can be pulled out with the long-nose pliers. The uhf strip has no oscillator coil. The bars are easily removable, but use caution, as they can be broken. Pull at the pressure-finger point, the end with the tuning screw.

Remove all turns from the oscillator coil and clean the soldered portion of the contacts. Use care not to get solder on the switch contact portion of the terminals. Rewind the coils as shown in table 2; number 28 (0.32mm) AWG or number 30 (0.25mm) AWG enameled wire can be used. Wind on the number of turns indicated for each channel, observing the same winding direction as used on the other coils on the bar. Wind the turns close-wound, starting at the slug end. If necessary, the turns can be spaced later for the proper frequency range. Unscrew the fine-tuning screw about five turns out from full in. This will provide adjustment range later for the oscillator. Screwing the slug into the coil raises the oscillator frequency, and therefore raises the intermediate frequency to which the receiver is tuned. After each coil is rewound, return the bar to its original position in the turret to prevent mixing their positions.

Install and wire the power supply, jacks, and splitting filter as shown in fig. 1. Jacks and power supply may be whatever you have on hand in the junk box. Plate voltage for the tuner may be anything between 110 and 140 volts dc. The bias voltage is obtained from a rectifier on the 6-volt ac filament winding. The values shown for the resistors give a minimum of -0.8 volt and a maximum of about -4 volts. Normal operation is at full negative, but, if desired, the bias may be permanently set at -3 volts by selection of appropriate resistor values.

Install the tuner in the cabinet, mounting it with screws and spacers to the panel. Three of the front holes (near the shaft) will conveniently accept a 6-32 (M3.5) tap or a number 6 sheet-metal screw. For ease of fine-tuning adjustment, a piece of lucite (Plexiglas) — cut to 5.7 cm (2-1/4 inches) in diameter by a circle cutter — forms a good control wheel, similar to the fine-tuning control on a TV set. The center hole is sized for a force fit on the fine-tuning shaft, which is 9.5 mm (3/8 inch) in diameter. Mark the plastic shaft and then cut it to length with a hacksaw, after which the fine-tuning wheel may be forced onto the shaft.

Mark the length required on the selector shaft, cut it with a hacksaw, and smooth with a file. Rotate the

Interior view of the tuner section. Loop-antenna input connector is at the left rear, i-f output jack to the receiver in the center, and audio from the receiver is at the extreme right. The 4:1 balun, to match the 75-ohm line to the 300-ohm input, can be seen just below the type-F connector.
The base of the loop is fastened to the shell of an SO239 uhf jack, with screws and nuts holding two soldering lugs onto which the loop wires are soldered.

A 50-pF trimmer is soldered to the wires at the top of the loop. A piece of number 12 (2.6 mm) AWG or number 14 (1.6 mm) AWG copper wire is soldered to the inner terminal of the SO239 jack, formed to the contour of the loop with 6- to 9-mm (1/4-to-3/8-inch) separation, and soldered to the loop 13 cm (5 inches) up its circumference.

Using appropriate connectors and a very small metal box, the splitting filter is constructed for the earphone or telephone connection at the base of the loop. When connecting the filter to the antenna, observe the connections shown in the figure. If connected backwards, the loop will work, but no sound will be heard in the phones.

**tuning**

Connect the tuner and station receiver together as shown in fig. 3. Temporarily connect the harmonic-producing network (fig. 4) between the tuner and transmitter output. Place the tuner on channel 2; tune the receiver to 29 MHz and the transmitter to 28.000 MHz or 14.000 MHz. Only very low output is necessary, just enough to make the diode conduct, producing harmonics. Turn the transmitter on, and also the receiver bfo. Very slowly, rotate the fine-tuning control until the transmitter harmonic at 56 MHz is heard. Verify this frequency by using the GDO as a signal generator. If no signal is heard, tune the receiver between 28 and 30 MHz and adjust the fine-tuning control until the 56 MHz harmonic is received. Do not confuse the desired signal with the fundamental or second harmonic of the transmitter output, bypassed around the tuner. Then jockey the receiver tuning and fine-tuning control on the tuner until the second harmonic of 28 MHz or the fourth harmonic of 14 MHz (56 MHz) is at 29 MHz on the receiver. Look up the signal frequencies for the various TV channel video and sound carriers in table 2. If channel 2 exists in your area, it can easily be heard when an antenna is connected to the tuner input and the

**table 2. LO coil winding and i-f frequency output data for TV tuner modification. All frequencies are in MHz.**

<table>
<thead>
<tr>
<th>channel</th>
<th>LO coil number of turns</th>
<th>LO frequency</th>
<th>TV video receiver i-f</th>
<th>TV sound receiver i-f</th>
<th>receiver dial frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>16</td>
<td>85</td>
<td>55.25</td>
<td>59.75</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
<td>92</td>
<td>29.75</td>
<td>25.25</td>
<td>55</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>99</td>
<td>61.25</td>
<td>65.75</td>
<td>62</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>113</td>
<td>30.75</td>
<td>29.75</td>
<td>56</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>57.25</td>
<td>68.75</td>
<td>66</td>
</tr>
</tbody>
</table>
receiver is tuned to the indicated i-f frequency. In my test set-up, a 3 μV signal on any of the converted TV channels could easily be heard in the receiver.

Repeat the tuning procedure for the other channels and amateur bands according to the table. Note that the video or sound carrier can be used as check points if they're within the tuning range of the station receiver. I use my old Hammarlund HQ129X. The video carrier is a strong signal with 15.75 kHz sidebands extending several hundred kHz each side. The sound carrier has distorted modulation, since it is fm.

The loop is connected to the tuner via a convenient length of RG-58 or RG-59 cable equipped with suitable connectors. The most inexpensive connectors are F-type, used for TV cable connections. In my case, in order to reach the source of the rectification, 60 meters (200 feet) of cable was required. If you use F-type connectors, note that they are designed for coax with a solid center conductor.

The loop antenna operates as a radio direction finder to locate the source of signal rectification causing generation of harmonics. In order to hear the effect of loop rotation on the signal, the audio output of the receiver is sent via the coax cable to headphones or a telephone carried by the loop-antenna operator. While slowly rotating the loop about its vertical axis, a distinct null, about 2 or 3 degrees wide, is easily heard.

Although a loop is normally bidirectional, in this case, due to the tapped feed point, it exhibits about 10 dB of front-to-back ratio when properly tuned. With the operator looking through the loop, he is facing the signal when the deepest null is heard with the feed tap on the left side of the loop. Rotating the loop about its horizontal axis will indicate, by a deeper null, the angle of elevation of the incoming signal. For maximum directivity, the trimmer capacitor must be tuned for maximum signal at the frequency of interest.

Loop operation can be verified by tuning it and the

---

fig. 3. Interconnection diagram of the loop, tuner, and receiver. The earphone and microphone of each handset are connected in series. The battery is not required if the earphones alone are used.
receiver to a TV station and observing the effect of rotation. This test may be invalid if many echoes exist from pipes, ducts, or other large metal surfaces. This same effect must be considered when looking for TVI.

finding the hex

Set up the equipment as shown in the block diagram, fig. 3. Tune the TV set to the channel having interference. Turn on the transmitter and verify that it is causing interference, then turn the tuner to the same channel. Use only sufficient transmitter power to cause TVI. Tune the receiver to 29 MHz and find the harmonic. Note that table 2 is based on the lower edge of the 14-, 21-, and 28-MHz bands. Also note that the receiver, used as an i-f amplifier, tunes backwards. For example, if 21 MHz interferes with channel 3, the third harmonic is at 63 MHz and is tuned on the receiver at 29 MHz. If the transmitter is tuned to 21.3 MHz, the third harmonic is at 63.9 MHz and will fall at an i-f frequency of 28.1 MHz on the receiver dial.

Set the receiver controls for CW operation, and tune the harmonic so that its detected audio frequency is about 1 kHz. It will be necessary to retune the receiver from time to time since the oscillator will drift slightly. Therefore, an operator should be at the receiver for periodic tuning, and to key the transmitter on request. If two telephone handsets or operator’s headsets are available, constant communication between the antenna and receiver operators is possible.

Go outside the house and take a preliminary bearing on the interference source. Note the direction (a rough sketch or map may be helpful). Go to a second location and take a second bearing. In all but the most elusive cases of interference, two or three bearings will suffice. Rotating the loop axis vertically, rather than horizontally, will indicate the elevation of the source above ground level.

Under certain conditions, it may be advantageous to turn off the receiver agc and have the receiver operator control the signal level with the receiver’s rf gain control. When nearing the interference source, or when using the probe as a “sniffer” for harmonics radiating from equipment, a coax plug fitted with a few centimeters of stiff wire will serve as a probe antenna.

Due to the attenuated response of the loop antenna at the normal amateur frequencies, a highpass filter of the TV type was not found necessary. If one is used, it must be located after the splitting filter in the tuner, or the telephone extension will not work.

where to look

Many things can cause a rectification-harmonic problem. Some of these are rain gutters, downspouts, roof flashing (the metal under shingles), corroded TV antennas, rusty TV masts, poor (unsoldered) splices in TV feedlines (or in the station antenna system both transmitting and receiving), poor electrical conduit joints and other metal junctions of this nature, all transistorized equipment, intercoms, pipes, telephones, concrete reinforcing bars — the list is almost endless. Any two touching pieces of metal more than a few centimeters long in the field of the transmitting antenna are suspect. The obvious solution to the problem is to permanently bond the two pieces, or, if no electrical continuity is necessary, to permanently insulate them.

Three cases have been found and corrected at my location, galvanized-tin roof flashing and corroded TV antennas on two adjacent houses being the cause. In the latter case, good relations have always been maintained with the neighbors, so no problem existed in correcting the situation. In fact, one case resulted in a very nice Christmas gift as an expression of gratitude. The tin flashing problem was fixed by permanently connecting the two pieces with sheet metal screws and anti-corrosive grease, permanent separation being impractical. The corroded TV antennas were scraped clean at the connection points and then painted with an anti-corrosive grease.

About eight years ago, long before this equipment was built, I found a source of rectification in my own TV antenna so severe that a 75-watt transmitter on 3.5 MHz feeding a dummy load caused TVI. A friend and I found the cause, wholly by accident, after a prolonged search. With the equipment described here, it would have been found in minutes. Now that you have the tools, good hunting, and may all your hexes be easy ones.

reference

a dream realized:
the ultimate antenna array

A 7-element quad on 40 meters? You’d better believe it!
Here’s an account of how one DXer solved the problem of big antennas

Most of us at one time or another have fantasized about having the ultimate array: the antenna to make you king of the band; the supergain bone crusher. Usually these dreams are dashed away by the reality of circumstances, but sometimes someone will succeed in getting one of these monsters up. Although, generally, this supreme achievement will go unnoticed by most, the rewards of the labor are still collected in abundance by the ambitious amateur who undertakes the challenge and succeeds.

The following account isn’t meant to be a construction project but is presented with the hope that some of the ideas will convince others that, first, you don’t need a lot of money to build a large array; and, second, some dreams can come true with a little applied ingenuity.

how it all began

Having been one of those few fortunates who’ve had the pleasure of operating at a large multi-multi station during DX contests, I’ve become appreciative of the merits of high-gain antennas. One day in early 1973 I was discussing various antennas with Jerry, WA7KYZ, when the subject of 40-meter arrays came up. Since 40 meters is generally considered to be the transition between wire dipoles and rotatable beams, we decided to experiment with some high-gain fixed-wire antennas on that band. Fortunately, we had a sizable piece of land on which to work. This property was dotted with 46-meter (150-foot)-high Douglas fir trees.

initial attempts

The first antenna we tried was a full-size four-section 8JK beam. On paper it looked really simple, but it turned out to be a real monster. We had to resort to using 2.6 mm (no. 10) copper-plated steel wire for the elements and 17-foot-long 1x6s (5 meters x 25 x

By Paul Kiesel, K7CW, 3522 N.E. 115th Street, Seattle, Washington 98125
152 mm) for the spreaders. We finally got the thing up in the air by pulling up the ends with a pickup truck.

The antenna worked reasonably well. It seemed to have a low angle of radiation, as it was supposed to, and it definitely had gain. But it performed well in only two directions. It had a very narrow beamwidth. Additionally, we had a problem that we hadn’t contemplated: we had to keep untangling the open-wire feedlines. Also, we had to use a transmatch, which made things even more cumbersome. The antenna eventually came down when an ambitious ten-year-old neighbor untied one of the support ropes at the base of the tree. We had mixed feelings about the array’s demise.

the grand experiment

We fiddle-fumbled around for some time before we came up with the ultimate solution, the utopian array. It was to be a multi-element delta-loop quad. We decided to go with seven elements aimed at Europe. Every amateur in Washington state who works DX knows that the European path is the toughest nut to crack, because we have to battle the northern auroral zone. The east-coast guys have the same problem working into Japan. So we had to have a lot of gain; however, we didn’t want to narrow the pattern of the array too much. We could have put three times as many elements on the thing, since the supporting wire was 137 meters (450 feet) long! We couldn’t use the 2.6-mm (no. 10) wire for all the elements and support because it would have made the antenna much too heavy, so we used 0.8-mm (no. 20) brass wire for the elements. Sounds flimsy, all right, but it works fine for a temporary effort. We really lucked out on the element wire. I picked up 1220 meters (4000 feet) of it at a surplus place for $4.00. We used 9 kg (20-lb) nylon fishing line to pull out the corners of the loops. Jerry picked up some 75-ohm coax remnants from the local cable television company, so we used some of this for the feedline.

up she goes

Now, back to the support wire. Our two support trees were 137 meters (450 feet) apart. We couldn’t afford polypropylene or similar rope, so we decided to use some of the 2.6-mm (no. 10) wire left over from the 8JK project. We used no insulators to separate the loops from the support wire as they were unnecessary. As soon as the array was secured, we checked the swr to find that it was only about 1.5:1. We used 0.2-wavelength spacing between elements and the customary formula for loop dimensions. We kept all directors the same size. We found that the array would sway freely but not excessively with the breeze.

I wanted to photograph our antenna for posterity, but this proved impossible. All that was visible in the photos was a 137-meter-long (450 feet) wire, two trees, and a piece of coax reaching up into the air and seemingly terminating into nothing. There are definite possibilities here for those who need to display as little antenna as possible.
It took Jerry, my brother, John (K7TU, ex-WA7OTT), and me about a day and a half to build the antenna from scratch. As we secured each element, we pulled up the support wire a bit. We used a small butane torch to solder the loops to the supporting wire. To support the coax so it wouldn’t pull the loop out of shape, we ran a nylon cord down from the supporting wire to the feed point (fig. 1).

performance

I only use published gain figures as a ballpark method for deciding what kinds of array to consider, and I never tried to measure the gain of this antenna with respect to another antenna because of the many variables involved. My method of evaluation is to just get on the air and see how well the array works by communicating.

With the antenna connected to the rig, we tuned through the CW band and came across several UA1s and UA3s. (Remember — this was on the 40-meter band.) Their signals were so weak the S-meter didn’t move, but all were solid copy. The only other signals on the band were some rag-chewing W6s. It doesn’t sound too impressive until I mention that this first check was carried out at 12 o’clock noon.

A couple hours later we were able to work into Europe with consistent S4-S6 signals using only a barefoot T4X exciter. Later on that evening we were getting consistent 599 reports from all over Europe. The Europeans we worked were all solid copy. Our antenna was turning out to be a great performer.

further experiments

When we found out how well our antenna was performing, we decided to erect three more of similar type. We had enough material to erect three elements centered on the Caribbean/South America region, four elements on Japan, and four elements on the VK/ZL/Europe long path (fig. 2). By now we knew how to go about constructing the antennas, and the three new ones only took another day to erect. Upon trying them out we found that all three new antennas performed very well also.

sidelights

At this point a small anecdote relative to our antennas is appropriate. Soon after we got the four arrays up I was stringing JAs at about 9 o’clock in the evening when Gordy, W7SFA (now W7FU), broke in. He wanted to know how well I was hearing Japan. I told him that signals were moderate. This revelation must have surprised him, because he asked me what kind of antenna I had. I told him I was using a 4-element quad and that it was working quite well. Upon being asked by him if I could rotate my quad, I replied that I could and told him to stand by. At that point I paused and flipped the antenna switch over to the European 7-element job, which just happened to be pointing directly at him. I hit the key again and asked him how it sounded. I won’t repeat his reply here. And, quite frankly, his signals came up so much with the switch of antennas that their strength almost blasted me right out of my chair. Whew!

As flimsy as the antennas appeared, they proved to be very durable. They remained erect through several storms and during both weekends of the CQ WW DX Contest. In fact they were still in the air when the location had to be vacated a couple of months later.

Although we couldn’t use the antennas on a permanent basis, they were still well worth the effort. I’ll never forget how much fun it was to tell the Europeans on 40 meters; “The antenna here is a 7-element quad.”

ham radio

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The **HEATHKIT HW-2036A**
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higher frequency resolution
for an hf synthesizer

A unique method for obtaining 10-Hz increments from an hf synthesizer using a dual vco system

The advent of low cost phase-locked-loop frequency synthesizers has had considerable impact on vhf amateur radio equipment. Unfortunately, the frequency synthesizer is most adaptable to channelized systems, consisting of a finite number of discrete operating frequencies. Typical high-frequency amateur activity consists of tuning an analog-oscillator controlled radio to a clear frequency and making a call. To answer such a call, with single-sideband equipment, you must tune to within 50 Hz of the originating station’s frequency for near natural voice reproduction. This means that a practical, synthesized, hf ssb transceiver must be capable of continuously tuning in 100 Hz steps, and requires an internal, loop-reference frequency of 100 Hz in a conventional configuration. The loop filter cut-off frequency required to effectively eliminate reference frequency sidebands from the synthesizer’s output increases the loop lock-up time to several seconds after each frequency change. The ideal amateur CW receiver, equipped with narrowband i-f or audio filters, must be continuously tunable in 10-Hz steps, and this would have ten times longer lock-up time between frequency changes.

This article briefly describes a less common approach to an hf synthesizer which offers 10-Hz frequency steps from a 10000 Hz reference, and therefore offers 1000 times faster recovery after frequency excursions. In addition, less rugged mechanical construction of system oscillators is possible because of loop correction of low-frequency fm due to vibration.

Fig. 1 is a functional block diagram of a conventional PLL frequency synthesizer. The phase detector supplies correction pulses to the vco, through a low-pass filter, at a frequency equal to the reference frequency, until the vco is locked at a frequency equal to N times the reference frequency. A lower reference frequency requires a lower filter cut-off for a given attenuation of the ac component of the reference frequency. The filter is part of the closed loop and its response determines the maximum rate of vco frequency correction.

Fig. 2 is a functional block diagram of a two-part synthesizer, offering 10-Hz steps with the advantages of a 10 kHz reference frequency. Note the use of two reference frequencies, 10.000 kHz and 9.990 kHz. The output frequency is actually the difference frequency between two phase-locked oscillators. To change the output frequency by 10 Hz, we move the first oscillator 10.00 kHz; next, we move oscillator number two 9.99 kHz in the same direction. The difference between the oscillators’ frequencies has only changed 10 Hz.

In the following example, I have made provisions for high-side LO injection in a super-heterodyne application, employing a 9.0 MHz i-f system. Also, sample calculations are shown for bfo/carrier frequencies of 8998.5 kHz for lower sideband and 9001.5 kHz for upper sideband (remember the sideband inversion with high-side local oscillator injection). The actual operating carrier frequency is programmed in BCD into the circuit’s adders. Functionally, the circuit is divided into two major sections. Section two covers a range of approximately 50 to 60 MHz, with section one covering approximately 59 to 99 MHz.

To run section two at approximately 50 MHz, a divide ratio (programmed vco 2 offset) of 5005 is initially chosen for divider 2. To the resulting frequency

![fig. 1. Block diagram of a conventional PLL synthesizer.](image)

By William E. Coleman, N4ES, E-Systems/ECI Division, Box 12248, MS 11, St. Petersburg, Florida 33733
(49999.95 kHz) is added the bfo frequencies of 8998.5 kHz and 9001.5 kHz, producing the initial vco 1 frequency. This procedure allows us to calculate the final required programmed offsets for dividers 1 and 2 (fig. 3).

Therefore, for a programmed operating frequency of 00000.00 kHz, divider 1 must divide by 6744 for lower sideband, and 6045 for upper sideband as shown in fig. 1. Vco 1 will then operate at 67440 kHz for LSB and 60450 kHz for USB (fig. 4).

And, for a programmed operating frequency of 00000.00 kHz, divider 2 will divide by 5850 for LSB and 5150 for USB. Vco 2 will operate at 59441.5 kHz for LSB, and 51448.5 kHz for USB (fig. 5).

With a sample operating frequency of 14307.96 kHz USB programmed into the synthesizer's data input, divider 1 would divide by 8271. Vco 1 would operate at 82710 kHz (fig. 6A).

Divider 2 would divide by 5946, and vco 2 would operate at 59400.54 kHz (figs. 6B and 6C).

The i-f offset is implemented by separating the divide cycle of each programmable divide chain into

fig. 3. The initial frequency for vco 2 is determined by assuming there is no programmed input frequency (00000.00 kHz). For the vco to be at its proper lower frequency limit, the divider would have to have an initial divide factor of 5005, producing a 49999.95 kHz output. Vco number 1 will also start with the same frequency, except with the added offset required for either LSB or USB.

operate at 82710 kHz (fig. 6A). Divider 2 would divide by 5946, and vco 2 would operate at 59400.54 kHz (figs. 6B and 6C).

The i-f offset is implemented by separating the divide cycle of each programmable divide chain into

fig. 2. Functional block diagram of a high frequency synthesizer capable of 10-Hz steps, with a 10-kHz reference.

fig. 2. Functional block diagram of a high frequency synthesizer capable of 10-Hz steps, with a 10-kHz reference.
fig. 4. As seen in fig. 2, the data from the three most significant digits is added to the data from the fourth through the sixth significant digits. This number is then the final number which is used to control the programmable divider number one. (B) shows the same divider calculation, except for USB instead of LSB. The divider then controls vco 1 in 10 kHz steps.

two subcycles. During the first subcycle, the chain is loaded from and divides by the number programmed in a diode ROM (i-f offset data for the sideband in use). For the second subcycle, the chain is loaded with and divides by the data presented to the BCD frequency-select input lines. After both subcycles are completed, one pulse is sent to the phase comparator, and the entire cycle repeats. This approach may also be applied to single-divider PLL systems.

The reference frequencies are derived by dividing a 9.99-MHz crystal oscillator's output by 1000 and 999 to obtain outputs at 9.99 kHz and 10.00 kHz, respectively. An oven is recommended if the synthesizer's 10-Hz resolution is to be used to full advantage.

Vco 1 and vco 2 are combined in a mixer, which supplies the difference-frequency output through a 50-MHz lowpass filter. The mixer is image terminated through a highpass filter to reduce any unwanted intermodulation products which would result from an impedance mismatch at the vco sum frequencies.

Both filters must employ T-input sections so they appear invisible to the mixer in their cutoff regions.

Because the high-reference frequencies used in this synthesizer allow loop correction of vco microphonics below about 1 kHz, this circuit is ideal for mobile applications where vibration would otherwise require the use of extremely rugged oscillator enclosures.

This approach may be expanded to yield 1 Hz steps, or to utilize a 100-kHz reference, but either change would require a ten times greater frequency range of vco 2, and that much additional range added to the upper frequency limit of vco 1.

A recommended frequency programming scheme would incorporate thumbwheel switches to set the MHz range, with smaller frequency divisions being continuously tunable by an optically coupled, tuning-knob-controlled, up-down counter with readout. The high speed of this synthesizer makes it an ideal candidate for use in an automated, microprocessor-controlled station, in which case tuning could be implemented with the computer's ASCII keyboard, or even remote controlled via a modem. Wouldn't it be nice to have a remote 20-meter transceiver atop a 150-meter (500-foot) building?

I would like to thank Fred Studenberg, W4CK, and Chuck Jackson for their technical advice and constructive criticism of this article.
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* This model tuned for European fm bands. See your dealer for price details.

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automatic noise-figure measurements — fact and fancy

One of the major attractions at the regional vhf/uhf conferences is the noise figure measurement session. Everyone with a new converter or preamp, and especially anyone who does not possess or have access to calibrated noise-figure measuring equipment, anxiously awaits the measurement results. The session becomes a contest of sorts, in which you find out how your latest endeavor or purchase compares with the best of show.

Invariably these measurements are made using automatic noise-figure equipment because of the simplicity and speed with which measurements may be accomplished. Given any one test setup, the comparisons among the various units under test may be valid, in that the relative noise figures for each unit can be determined, as can the difference in noise figure between any of the units. But what about a preamp whose measured noise figure was 1.5 dB at the West Coast Conference and another which yielded 1.7 dB at the East Coast Conference? Is this a valid comparison, or going one step further, is either measurement really accurate? The discussion which follows will, I hope, provide these answers.

In addition, this article becomes another in the series devoted to the use and application of available surplus test equipment. Automatic noise-figure meters, such as the Hewlett-Packard models 340A, 340B, and 342A, and the AILTECH* types 74A and 75, are typical of those in general use. Noise sources which are usable from 10 MHz to 5 GHz, and which may be used with one or more of these instruments, are the Hewlett-Packard models 343A, 345B, and 349A, and the AIL types 7006, 7010, 7011, and 7012. Tables 1 and 2 list the pertinent specifications for the noise-figure meters and noise sources, respectively.

With the exception of the AIL 75, which is probably too new to show up on the surplus market, all of these noise-figure meters and noise sources are available from time to time. Oftentimes a solid-state noise source also becomes available. If it is one of the AIL series 76, it is compatible with the AIL 75 noise-figure meter; if it is manufactured by another company, it may be adaptable to one of the aforementioned noise-figure meters, but detailed information must be obtained from the manufacturer. However, because of their relative scarcity and the fact that they may not be truly compatible with most of the available noise-figure meters, no coverage can be provided in this article for any solid-state noise source.

As noted in Table 1, many of the Hewlett-Packard instruments have been special versions which accept one or more input frequencies different from those in the standard models. This should present no problem to the potential user, even if none of the instrument input frequencies corresponds to the output frequency from his converter. Either the converter output can be heterodyned to the noise-figure meter input frequency, as explained later, or the noise-figure meter can be modified. This modification involves nothing more than retuning or replacing coils in the instrument’s tuned amplifier, and is described in the appendix.

noise-figure equations

Before we can analyze the operation of automatic noise-figure equipment, we must understand a little about noise figures. The Hewlett-Packard model 340B Noise Figure Meter can be used with either a gas-discharge noise source or a temperature-limited diode source. Models 340A and 342A are similar in appearance (courtesy Hewlett-Packard Company).

*AILTECH, a Cutler-Hammer Company, was formerly Airborne Instruments Laboratory. Throughout this article, AIL will be used to identify equipment manufactured under either name.
noise-figure meters, it is necessary to understand the mathematical definition of noise figure insofar as it applies to the noise-figure meter. I will skip the basic mathematical derivation, since this has been covered extensively in references 1 through 5. Instead, I will start with a mathematical definition of noise figure and proceed to derive the relationships which permit the automatic noise-figure meter to function.

To eliminate any confusion between noise figure expressed as a numerical ratio and the logarithmic equivalent expressed in dB, I will limit the use of the term noise figure \((NF)\) to the logarithmic version and call the numerical ratio noise factor \((F)\).

The noise factor of a receiver is defined as the input signal-to-noise power ratio divided by the output signal-to-noise power ratio, and is expressed as

\[
F = \frac{S_i/N_i}{S_o/N_o} \tag{1}
\]

where \(S_i\) is the input signal power, \(N_i\) is the noise power at the input, \(S_o\) is the output signal power, and \(N_o\) is the output noise power.

If a broadband noise source is used at the receiver input

\[
S_i/N_i = EN = \frac{T_2 - T_o}{T_o} \tag{2}
\]

where

- \(EN\) = excess noise power (generally expressed in dB, but the equivalent numeric ratio in this case)
- \(T_2\) = equivalent absolute temperature of noise source when on, in °K
- \(T_o\) = °K

If we designate the output power from the receiver when the noise source is off as \(N_f\), and the receiver output power when the noise source is on as \(N_2\), the output signal power, \(S_o\), can be expressed as

\[
S_o = N_2 - N_f \tag{3}
\]

and since

\[
N_o = N_f \tag{4}
\]

\[
\frac{S_o}{N_o} = \frac{N_2 - N_f}{N_f} = \frac{N_2}{N_f} - 1 \tag{5}
\]

Rewriting eq. 1 by substituting eqs. 2 and 5, we get

\[
F = \frac{T_2 - T_o}{T_o} \left(\frac{N_2}{N_f} - 1\right) \tag{6}
\]

Converting eq. 6 to the equivalent noise figure, where \(NF = 10 \log F\),

\[
NF = 10 \log \left(\frac{T_2 - T_o}{T_o}\right) - 10 \log \left(\frac{N_2}{N_f} - 1\right) \tag{7}
\]

Since the first term in eq. 7 is the logarithmic equivalent of eq. 2, it is equal to the excess noise ratio \((ENR)\), in dB, of the noise source. Therefore eq. 7 can be rewritten

\[
NF = ENR - 10 \log \left(\frac{N_2}{N_f} - 1\right) \tag{8}
\]

The ratio \(N_2/N_f\) is often designated the \(Y\)-factor, so that an equivalent expression for eq. 8 is

\[
NF = ENR - 10 \log (Y - 1) \tag{9}
\]

Thus we have arrived at an expression for noise figure in which the only variable is \(Y\) when a noise

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**Table 1. Automatic noise-figure meter specifications.**

<table>
<thead>
<tr>
<th>model</th>
<th>NF ranges and accuracy</th>
<th>input frequencies (MHz)</th>
<th>bandwidth (MHz)</th>
<th>sensitivity (dBm)</th>
<th>agc range (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hewlett-Packard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>340A, B</td>
<td>0-15 dB: ± 0.5 dB, 3-30 dB: ± 0.5 dB from 10-25 dB, ± 1.0 dB from 3-10 dB, ± 1.0 dB from 25-30 dB</td>
<td>30, 60</td>
<td>1 (min.)</td>
<td>-60</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Same as 340A, B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hewlett-Packard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>342A</td>
<td>0-25 dB: ± 0.5 dB, 23-36 dB: ± 1.0 dB</td>
<td>30, 60, 75, 105, 200</td>
<td>1 (min.)</td>
<td>-60</td>
<td>50</td>
</tr>
<tr>
<td>AIL 74A</td>
<td>0-15 dB: ± 0.15 dB from 0-3 dB, ± 0.25 dB from 3-6 dB, ± 0.15 dB from 3-6 dB, ± 0.25 dB from 6-9 dB, ± 0.15 dB from 6-9 dB, ± 0.25 dB from 9-12 dB, 12-27 dB: ± 0.5 dB from 12-18 dB, 18-33 dB: ± 1.0 dB</td>
<td>30 (other options available)</td>
<td>5 (min.)</td>
<td>-73</td>
<td>65</td>
</tr>
<tr>
<td>AIL 75</td>
<td><strong>One of the following:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10, tunable 20-60</td>
<td>2</td>
<td>-67</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>6</td>
<td>-73</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30, tunable 40-180</td>
<td>2</td>
<td>-67</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>6</td>
<td>-67</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Standard input frequencies are listed; many special models were manufactured with one or more different input frequencies.

**Depends on if amplifier installed in noise-figure meter.
source of known ENR is used. Furthermore, since \( Y \) is the ratio of \( N_2/N_1 \), we need only measure this ratio, without regard to absolute power levels, in order to obtain the receiver noise figure.

**automatic noise-figure meters**

Now that we have a simplified noise-figure equation, let us investigate the actual method by which noise figure is measured automatically. Fig. 1 shows a simplified block diagram of a typical Hewlett-Packard noise-figure meter. The external noise source and receiver under test are included in the diagram so as to close the loop.

The noise source, powered by the noise-figure meter, is connected to the antenna input of the receiver under test, and the i-f output from the receiver is connected to the input of the noise-figure meter. A switching circuit in the noise-figure meter gates the tuned amplifier, meter integrator, agc, and noise source (via its power supply) on and off at a low audio-frequency rate. As shown in fig. 2, the noise source is gated on and approximately one-quarter cycle thereafter the tuned amplifier is gated on and the agc gate is opened. During this “on” time the receiver output, \( N_2 \), consists of the amplified power from the noise source plus the amplified receiver noise. This is used to establish a standard reference level through agc action.

After the noise source is gated off, the amplifier is again gated on, as is the meter integrator. During this time the receiver output, \( N_1 \), consists only of the amplified receiver and input termination noise, which is detected and integrated, and applied to the meter. Since the noise-source ENR is known, and \( N_2 \) is always amplified to a standard reference level, the only variable in eq. 8 is the metered value of \( N_1 \). The meter can therefore be calibrated to display noise figure directly, as a function of \( N_1 \).

The tuned amplifier is gated on for only one-half of the noise-source on and off periods in order to be certain that the output from the noise source has reached its maximum level or has fallen to its quiescent level.

The AIL noise-figure meters function in a similar manner, although there are differences in the actual circuits used to achieve the resulting indication.

**noise sources**

Although both coaxial and waveguide noise sources are available for use with automatic noise-figure meters, this discussion will be limited to the coaxial types, since waveguides presently have limited amateur use.

The Hewlett-Packard model 343A VHF Noise Source provides a wideband noise spectrum from 10 to 600 MHz and has a source impedance of 50 ohms. It generates an excess noise ratio of 5.2 to 6.6 dB, depending on the measurement frequency, at its specified current of 3.31 mA; refer to table 2. The noise source employs a special temperature-limited

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**fig. 1. Simplified block diagram of the Hewlett-Packard model 340A or 340B Noise Figure Meter.**
vacuum-tube diode (similar to the Sylvania 5722) whose plate and filament voltages are supplied by the Hewlett-Packard 340A, 340B, or 342A noise-figure meter. The noise output of a saturated temperature-limited diode is a function of plate current, which is set to an established value by means of a control on the noise-figure meter.

The Hewlett-Packard model 345B IF Noise Source produces an excess noise ratio of 5.2 dB from any one of four switch-selected source impedances: 50, 100, 200, or 400 ohms. Since tuned circuits within the noise source limit its spectrum to either 30 or 60 MHz, also switch-selected, it has limited amateur application and can be dismissed without further discussion.

Also usable with any of the Hewlett-Packard noise-figure meters are several 5722 noise generators whose construction has been described in references 6 through 8. It should be noted that most, if not all, of these homebrew noise sources suffer from impedance mismatch problems when used above 400 MHz. However, it is possible to build a noise source which compares favorably with the Hewlett-Packard 343A to at least 450 MHz; its construction will be described in a future article.

For receiver frequencies above 450 MHz, a noise source using a gas-discharge tube is generally used. Coaxial noise sources of this type may also be used at frequencies as low as 200 MHz. The Hewlett-Packard model 349A UHF Noise Source and the AIL Type 7010, 7011, and 7012 Coaxial Noise Generators all employ an argon-filled gas-discharge tube coaxially mounted in a helical transmission line. These noise sources produce excess noise ratios of 15.2 to 15.7 dB over their specified frequency ranges, as shown in table 2.

A simplified diagram of a coaxial gas-discharge tube noise generator is shown in fig. 3. The tube is alternately turned on and off by the switched power supply in the noise-figure meter. When a high-voltage pulse is applied between the anode and cathode of the tube, the argon gas ionizes and noise is generated. The noise is coupled into the helix and appears at the two coaxial connectors. One connector is used

<table>
<thead>
<tr>
<th>model</th>
<th>frequency range (MHz)</th>
<th>excess noise ratio (dB)</th>
<th>operating current (mA)</th>
<th>output vswr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hewlett-Packard</td>
<td>10-600</td>
<td>5.2 ± 0.2 from 10-30 MHz</td>
<td>3.31</td>
<td>10-400 MHz: 1.2 max.</td>
</tr>
<tr>
<td>343A</td>
<td></td>
<td>5.5 ± 0.25 at 100 MHz</td>
<td></td>
<td>400-600 MHz: 1.3 max.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.8 ± 0.3 at 200 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.05 ± 0.3 at 300 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.3 ± 0.3 at 400 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.5 ± 0.5 at 500 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.6 ± 0.5 at 600 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hewlett-Packard 345B</td>
<td>30 or 60,</td>
<td>5.2</td>
<td>0.41 to 3.31</td>
<td>50, 100, 200 or 400 ohm (± 4%) source impedance, switch selected</td>
</tr>
<tr>
<td></td>
<td>switch selected</td>
<td></td>
<td></td>
<td>200-2600 MHz: 1.35 max. fired</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5 max. unfired</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.6-3.0 GHz: 1.5 max. fired</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5 max. unfired</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.0-4.0 GHz: 2.0 max. fired</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.0 max. unfired</td>
</tr>
<tr>
<td>Hewlett-Packard</td>
<td>400-4000 (usable to 200)</td>
<td>14.6 ± 0.6 at 220 MHz</td>
<td>150</td>
<td>1.2 max.</td>
</tr>
<tr>
<td>343A</td>
<td></td>
<td>15.6 ± 0.6 from 400-1000 MHz</td>
<td>1.15 (nominal) fired</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>15.7 ± 0.5 from 1.4 GHz</td>
<td></td>
<td>1.3 (nominal) unfired</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5 (nominal) fired</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.0 (nominal) unfired</td>
</tr>
<tr>
<td>AIL 7006</td>
<td>10-250</td>
<td>15.2 ± 0.5</td>
<td>33.1</td>
<td>1.2 max.</td>
</tr>
<tr>
<td>AIL 7010, 7011</td>
<td>200-2600</td>
<td>15.2 ± 0.3</td>
<td>175</td>
<td>1.15 (nominal) fired</td>
</tr>
<tr>
<td>AIL 7012</td>
<td>2-5 GHz</td>
<td>15.5 ± 0.2</td>
<td>175</td>
<td>1.3 (nominal) unfired</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5 (nominal) fired</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.0 (nominal) unfired</td>
</tr>
</tbody>
</table>
for the noise output, while the other must be terminated by a precision 50-ohm load.

**connecting the noise source to the noise-figure meter**

Obviously each manufacturer supplies noise sources which are compatible with his own noise-figure meters. There is nothing, however, other than the problem of physically interconnecting the source and noise-figure meter, which precludes using one manufacturer’s gas-discharge source with another’s noise-figure meter.

The same interchangeability is not true for diode noise sources. The AIL type 7006 noise diode can be used only with the AIL 74A noise-figure meter, and the Hewlett-Packard diode noise sources can only be used with the Hewlett-Packard noise-figure meters. But, as previously mentioned, there are several 5722 noise generators which can also be used with the Hewlett-Packard noise-figure meters.

All of the Hewlett-Packard noise-figure meters discussed in this article originally included an interconnecting cable for that manufacturer’s gas-discharge noise sources. Unfortunately, the cable is invariably missing when the instrument reaches your local surplus emporium. On the other hand, the interconnections are rather simple, so that with the information which follows, you should be able to solve all of your interface problems.

To connect the Hewlett-Packard 349A coaxial (or any of the Hewlett-Packard 347-series waveguide) gas-discharge noise source to any Hewlett-Packard noise-figure meter, a 6-foot (1.8-meter) type 340-16A cable was originally furnished. You can buy a replacement directly from Hewlett-Packard, but the price was $100 the last time I checked. A good alternative is to make your own cable, as shown in fig. 4. If you want to connect a Hewlett-Packard gas-discharge source to either the AIL 74A or 75 noise-figure meter, it will be necessary to modify the captive cables on the AIL instrument, as follows.*

1. Cut the high- and low-voltage cables at a point at least 20 inches (51 cm) back from the connector ends.

2. Wire the cables from the noise-figure meter as shown in fig. 5A.

3. Wire the cable ends with the connectors attached as shown in fig. 5B.

The instrument cables, now terminated in a single multipin connector, will plug into the connector on the Hewlett-Packard noise source. An AIL noise source can still be used by connecting the multipin connector on the instrument cables to the mating connector on the now separate cable assembly shown in fig. 5B, thereby restoring the original configuration.

Fig. 6 shows the cabling needed to connect an AIL 7010, 7011, or 7012 noise source to any of the Hewlett-Packard noise-figure meters. The high-voltage connector required to mate with the anode connector on the AIL 7010 or 7012 is not available except as a part of the AIL 7003 cable set. Therefore it must be fabricated by using brass tubing of the appropriate size and suitable high-voltage insulating material.

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(teflon, polystyrene, etc.) between the inner high-voltage and outer ground conductors. WARNING: the anode lead and connector must be insulated for up to 5 kV; USE EXTREME CARE.

The Hewlett-Packard 343A and 345B noise sources each have a captive cable and connector to mate with the Hewlett-Packard 340B and 342A noise-figure meters. If you intend to use any of the previously referenced 5722 noise generators, the appropriate connector wiring is shown in fig. 7. The 5722 filament draws between 1.5 and 2 amperes, so be sure to use wire that is large enough to minimize the voltage drop between the tube and the noise-figure meter.

Connecting any of the commercial or homebuilt diode noise sources to the Hewlett-Packard 340A noise-figure meter requires somewhat more discussion. The diode panel connector on the 340A was originally a 3-pin connector, rather than the 5-pin Cannon WK-5-31S connector used on the later 340B and 342A models. (It was intended to mate with the long obsolete 345A noise source.) However, Hewlett-Packard Service Note 340A-1A* described how to replace the old 3-pin connector with the later 5-pin connector, and virtually everyone who had a 340A made the change. In fact, I have never seen an instrument with the old connector still in place.

If a new connector has been installed and you are going to use a homebuilt 5722-type noise source, the wiring information in fig. 7 applies. If the old connector is still on the instrument, you will have to be lucky enough to find a mating connector or else change the connector on the instrument. The filament connections on the old 3-pin connector are pins 1 and 2; pin 3 connects to ground.

The Hewlett-Packard 343A noise source can only be used with the 340A if the 5-pin connector has been installed. Before trying to use it, however, check the internal wiring to the connector to be sure that there is a connection to pin 4. If there is no wire on pin 4, run one from that pin to the black center-tap lead of transformer T101. (The transformer may be identified by tracing the leads from pins 1 and 2 of the connector, which are wired to the green and yellow leads, respectively, of T101.)

measurement techniques

We can now discuss the procedures and techniques of measuring noise figure with an automatic noise-figure meter. Because the actual operating procedures vary, depending on the instrument being used, no attempt will be made to describe the detailed operational steps. These appear in the instruction manual for the specific instrument, available from the manufacturer at nominal cost. In general, operation of the noise-figure meter consists of the following steps:

1. Connecting the receiver under test as shown in fig. 8. For the purposes of this discussion, the term “receiver” means any receiver or portion thereof (such as a converter, mixer, etc.) which provides an output signal at the input frequency of the noise-figure meter.

*Available from Hewlett-Packard Company, 1820 Embarcadero Road, Palo Alto, California 94303.
2. Energizing the noise-figure meter and establishing the fixed agc reference level.

3. Setting the noise-source operating current.

4. Calibrating the noise-figure meter to the noise-source ENR. (This step is not applicable to Hewlett-Packard noise-figure meters.)

5. Reading the receiver noise figure on the meter, and correcting for noise-source characteristics and/or loss-pad attenuation.

Although this generalized procedure sounds almost too simple to be true, it is just about as easy in practice. Any adjustments on the receiver can be made while it is under test by merely tuning for the best noise figure. Compare that to measuring noise figure by the manual twice-power method!

Let us now examine fig. 8 block by block. Most important, there should be a direct connection between the noise-source output connector and the loss pad, and between the pad and the receiver. This means no cables, and a minimum of adapters.

The use of a loss pad between the noise source and the receiver is an absolute necessity when using a gas-discharge source, and is highly recommended for diode noise sources. One of the disadvantages of gas-discharge noise sources is that they require a high-voltage ionizing pulse, typically several kilovolts. Because of capacitive coupling between the tube and the helix, this pulse appears as a spike in the noise output. Although the pulse is attenuated, the amplitude of the spike may still be several volts, which may be enough to destroy your expensive low-noise transistor. Therefore, a 6- to 10-dB pad must always be used with a solid-state receiver to attenuate the spike. Even with a 10-dB pad, there may be sufficient spike voltage to destroy certain GaAs fets.

A solid-state noise source should be used to check devices of this type.

The use of a loss pad with a diode noise source is not absolutely essential, but can minimize several problems. First of all, most receivers (remember the general use of this term) do not present a 50-ohm input when optimized for a noise match. Because the rated ENR of a noise source is based on a 50-ohm load, there will be an indeterminate mismatch loss if the receiver vswr is greater than 1.0:1. A 3- to 6-dB pad will not eliminate the mismatch loss, but may reduce it somewhat.

A second reason for using a loss pad is to ensure a 50-ohm source impedance for the receiver, since the vswr of the noise source also is not a perfect 1.0:1.

Any tendency of the receiver to "take off" when looking into an impedance of other than 50 ohms will be reduced by use of a pad.

Both of these reasons apply equally to gas-discharge noise sources, but are automatically realized by the absolute necessity of using a loss pad to protect the receiver. In either case, the attenuation of the pad must be known to a fair degree of accuracy; remember that the loss, in dB, must be subtracted from the reading obtained on the noise-figure meter, since any loss ahead of a receiver adds algebraically to the receiver noise figure.

In addition to providing an output at a frequency which is compatible with the noise-figure meter, the receiver must also provide enough gain to amplify the noise input to a level which exceeds the sensitivity of the noise-figure meter. However, the difference in the receiver output levels with the noise source on and off must not exceed the agc range of the instrument and overload it. This means that the output from the receiver, when the noise source is off, should be only slightly above the sensitivity level of the noise-figure meter. This can be determined by...
the use of the variable attenuator shown in fig. 8. The amount of attenuation which is introduced should be 6 to 10 dB less than the value which causes the receiver output to fall below the threshold required to establish the reference level.

Conversely, if the receiver has insufficient gain, it will not be possible to establish a signal reference level in the noise-figure meter. In that case, a post-amplifier must be substituted for the variable attenuator to provide sufficient overall gain.

receiver configuration

Thus far we have imposed two conditions which the receiver must satisfy — its gain must be compatible with the sensitivity requirement and agc range of the noise-figure meter, and its output frequency must match that of the noise-figure meter input. We have already discussed the first of these, and can proceed to the second.

The typical vhf or uhf receiving converter provides an output which is applied to a communications receiver used as a tunable i-f amplifier, detector, and audio amplifier. This output can fall anywhere in the entire hf, vhf, or even uhf spectrum. On the other hand, the input to the noise-figure meter must be at a specific frequency which may not correspond to the output from the converter. The combination of a 30-MHz amplifier in most of the noise-figure meters and most receiving converters with a nominal 28-MHz output has sufficient bandwidth to permit meaningful measurements.

For other converter output frequencies which do not correspond to the noise-figure meter input, an external mixer and signal source can be used to convert the output frequency of the receiving converter to the input frequency of the noise-figure meter. Fig. 9 shows the connections for such a frequency conversion. Any type of mixer can be used, although a packaged double-balanced mixer with coaxial connectors will prove to be the most convenient and versatile. These are available commercially;* a less expensive mixer can be packaged as described by Paul Shuch.10

The signal source functions as a local oscillator for the mixer, and may be anything which generates a relatively stable unmodulated output, such as a signal generator or vfo. The sum of the converter and signal-source frequencies, or the difference between them, must result in the input frequency required by the noise-figure meter. It makes no difference whether the sum or difference frequency is used; however, the signal source must not be set to a frequency which is close to or is a subharmonic of the noise-figure input frequency.

For example, if the receiving converter output is 14 MHz and the noise-figure meter input is 30 MHz, a signal-source frequency of either 16 or 44 MHz would provide the proper output frequency from the mixer. In this case, the 16-MHz choice should be avoided because its second harmonic at 32 MHz may appear at the mixer output and fall within the passband of the noise-figure meter. This, of course, will render any measurements meaningless, since the noise-figure meter cannot distinguish between the receiver signal and the spurious mixer output.

If a signal generator is used as the signal source, it can function indirectly as the variable attenuator shown in fig. 8. Varying the signal-generator output will vary the conversion loss of the mixer and permit

*Available from Mini-Circuits Laboratory, Merrimac Industries, Anzac Electronics, Hewlett-Packard, Cimarron, and others.
INTERSTAGE LOSS (dB) + 2ND STAGE NOISE FIGURE (dB)

fig. 12. The system noise figure ($N_{F,N}$) can be found from these curves when the first- and second-stage noise figures, first-stage gain, and interstage losses are known (courtesy Daico Industries, Inc.).

cascaded stages

The overall noise figure of any receiver depends primarily on the noise figure of the first stage. However, the noise generated by succeeding stages will contribute to the overall noise figure and, if the gain of the first stage is not over 20 dB or so, have a significant effect. Since low-noise preamps seldom have gains in excess of 15 dB, taking the noise contribution of the following stages into account is of major importance in determining the preamp noise figure.

The general equation for the noise factor of networks in cascade is

$$F_3 = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_1 - 1}{G_1 G_2} + \ldots$$  \hspace{1cm} (10)

where

$$F_3 = \text{system noise figure}$$

$$F_1, F_2, F_3 = \text{noise factor of first, second, third stages}$$

fig. 13. Excess noise ratios for Hewlett-Packard and AIL coaxial noise sources which utilize gas-discharge tubes. The curve for the Hewlett-Packard 349A is subject to the ENR tolerances listed in table 2; those for the AIL noise sources are typical and take into account the gas-tube-variations and hot-cold insertion losses.

control of the mixer output level. A post-amplifier has been shown in fig. 9 because the receiving converter gain, less the mixer conversion loss, will generally be insufficient to provide the necessary signal level into the noise-figure meter. This post-amplifier can be any type, such as a surplus i-f strip or a broadband amplifier, which will amplify the desired mixer output frequency. The mixer image frequency will be rejected by the tuned amplifier in the noise-figure meter.

The configuration shown in fig. 9 will result in valid noise figures only if the gain of the receiving converter is 20 dB or more. If the converter gain is less than 20 dB, the indicated noise figure will be worse than the actual noise figure because of the noise contribution of the external mixer. The actual noise figure must then be calculated, as explained later.

preamplifiers

In order to measure the noise figure of a preamplifier, the test setup of either fig. 8 or fig. 9 is used, with the preamp inserted between the loss pad and the receiver. To prevent any possible instability of either the preamp or the converter, in the event that either is not unconditionally stable, it is wise to use an additional loss pad between the preamp and the converter, directly at the converter input. This pad should provide about 3 dB loss; the exact value is not critical nor need it be known accurately. Its effect will be incorporated into the measured noise figure of the receiver (without the preamp), since this measurement is necessary to calculate the true noise figure of the preamp, as explained in the following section. If only an overall system noise figure is of interest, then the second loss pad should not be used.

A major consideration in the measurement of preamp noise figure is that of image response and the effect of filters on that response. It is mentioned here as a preliminary precaution only, and will be covered in detail under the heading image response error.
$G_1$, $G_2$ = power-gain ratio of first, second stages

The system noise figure, $NF_s$, is derived from the expression

$$NF_s = 10 \log F_i$$

(11)

It can be seen from eq. 10 that the numerical value of the second and succeeding terms is a function of the first-stage gain; the higher the gain, the lower will be the values of those terms. If all stages are active amplifiers, only the second-stage noise will be of importance, and only the first two terms of eq. 10 need be used in the calculation. However, if any of the early stages in the receiver has a gain of 1 or less (e.g., mixers and loss pads), three or even four terms of the equation may have to be taken into account.

As an example, refer to the test setup shown in fig. 10. Assume that the preamp gain ($A_1$) and the converter gain ($A_2$) have been measured at 12 dB and 20 dB respectively; the measured converter noise figure ($NF_2$) is 4 dB; and the measured mixer noise figure ($NF_3$) is 7.5 dB. The system noise figure indicated on the noise-figure meter is 8.65 dB. What is the preamp noise figure ($NF_1$)?

First, we must subtract 6 dB from the noise-figure meter reading, since that is the increase in noise figure caused by the 6-dB pad. Therefore the actual system noise figure ($NF_s$) is 2.65 dB. Second, we must convert the noise figures and gains (in dB) to noise factors and numerical gain ratios, as follows:

$$F_1 = \text{antilog} \frac{NF_1}{10} = \text{antilog} \frac{2.65}{10} = 1.841$$

$$F_2 = \text{antilog} \frac{NF_2}{10} = \text{antilog} \frac{4}{10} = 2.512$$

$$F_3 = \text{antilog} \frac{NF_3}{10} = \text{antilog} \frac{7.5}{10} = 5.623$$

$$A_1 = \frac{12}{10} = 1.2$$

$$A_2 = \frac{20}{10} = 2$$

$$G_1 = \text{antilog} \frac{A_1}{10} = \text{antilog} \frac{12}{10} = 15.849$$

$$G_2 = \text{antilog} \frac{A_2}{10} = \text{antilog} \frac{20}{10} = 100$$

By rearranging eqs. 10 and 11, and substituting the above values,

$$NF_1 = 10 \log \left( F_1 - \frac{F_2 - 1}{G_1} - \frac{F_3 - 1}{G_1 G_2} \right)$$

$$= 10 \log \left( 1.841 - \frac{2.512 - 1}{15.849} - \frac{5.623 - 1}{15.849 \times 100} \right)$$

$$= 10 \log (1.841 - .095 - .003)$$

$$= 10 \log 1.743 = 2.41 \text{ dB}$$

(12)

It can be seen from inspection of the above example that the third term is insignificant and can be ignored. However, suppose that the configuration shown in fig. 11 is being used to check out the same preamp, using the same mixer and a post-amplifier with a measured noise figure of 10 dB. Now the mixer is the second stage, so that $F_2 = 5.623$. Since, in a stage having a gain of less than 1, the noise figure is equal to the loss, the converse must be true. Therefore, the mixer loss ratio is also 5.623, making the gain ($G_2$) the reciprocal of 5.623, or 0.178. The post-amp noise figure of 10 dB results in $F_3$ being equal to 10 (the antilog of 10 divided by 10). In this case, the receiver noise figure reading on the noise-figure meter is 13.2 dB. Subtracting 6 dB for the loss pad, we obtain an actual noise figure ($NF_s$) of 7.2 dB, or a noise factor ($F_s$) of 5.248.

Again substituting the measured noise factors and gain ratios in eq. 12, we arrive at the following:

$$NF_1 = 10 \log \left( \frac{5.248 - 5.623 - 1}{15.849} - \frac{10 - 1}{15.849 \times .178} \right)$$

$$= 10 \log (5.248 - 5.623 - 10 \times .178)$$

$$= 10 \log 1.766 = 2.47 \text{ dB}$$

This is approximately the same noise figure as was calculated in the previous example, taking into account rounded-off numbers. Note that in this case the third term of the equation contributes significantly to the overall system noise figure, which leads to the conclusion that a low-noise post-amplifier should always follow a mixer when there is only one stage of amplification ahead of the mixer. If the post-amplifier noise figure were reduced to 1.0 dB, the system...
noise figure would improve from 7.2 to 3.3 dB. To paraphrase many textbooks, the calculation of this improvement is left as an exercise to the reader.

An interesting graphical representation of the relationships expressed in eq. 12 is shown in fig. 12. If the various stage noise figures, gains, and losses are known in dB, the difference between the system and first-stage noise figures can be read as $\Delta$ directly from the curves, which is added to the known first-stage noise figure to obtain the system noise figure.

For instance, let’s use the same preamp and mixer, and the 1-dB post-amplifier from the preceding example. The first-stage gain plus noise figure is 14.4 dB, and the interstage (mixer) loss plus second-stage (post-amplifier) gain is 8.5 dB. The curves of fig. 12 show that $\Delta$ is 0.9 dB at the intersection of these two values. Thus, the system noise figure is equal to the preamp noise figure plus 0.9 dB, or 3.3 dB.

### noise-source ENR corrections

In our discussion of the noise-figure equations which govern the operation of automatic noise-figure meters, we established that the only variable in eq. 8 was the ratio $N_2/N_1$, and that the $ENR$ term in that equation was a fixed value determined by the noise source. It follows, therefore, that the noise-figure meter calibration must be based on a known or predetermined $ENR$.

In the case of the AIL noise-figure meters, the operating procedures entail calibrating the instrument to the $ENR$ of the noise source. For the AIL 7006 diode noise source used with the AIL 74A noise-figure meter, the $ENR$ is $15.2 \pm 0.5$ dB when the diode current is set to 33.1 mA. If a gas-discharge noise source is to be used with either the AIL 74A or 75 noise-figure meter, the instrument is calibrated for the $ENR$ of the source at the frequency of measurement. Fig. 13 shows typical values for the AIL noise sources and the nominal $ENR$ for the Hewlett-Packard 349A for frequencies between 200 and 5000 MHz.

The meter scales of the Hewlett-Packard 340A, 340B, and 342A noise-figure meters are based on a fixed $ENR$ of 5.2 dB from a diode noise source and a fixed $ENR$ of 15.2 dB from a gas-discharge noise source. There is no adjustment for other values of $ENR$; if the noise-source $ENR$ is different from the value upon which the calibration is based, a correction factor must be applied to the noise-figure reading. If the $ENR$ exceeds the noise-figure meter calibration design value, the “excess” $ENR$ must be added to the noise-figure readings. If the $ENR$ is less than the calibration design value, the difference be-

![fig. 16. Simplified test setups for noise-figure measurements, using an untuned pre-amp and bandpass filters. The positions of the filters in each test setup are different. All configurations, except that at D, yield valid system noise figures.](image)
between the two values must be subtracted from the noise-figure readings.

An examination of table 2 reveals that the only noise sources which match either of the Hewlett-Packard design values are the Hewlett-Packard 343A, only when used below 30 MHz, and the Hewlett-Packard 3458, which has little amateur application. This means that whenever the 343A is used above 30 MHz, the indicated noise figure must be increased by the difference between 5.2 dB and the noise-source ENR at the frequency of use. If the measurements were being made at 400 MHz, for instance, the indicated noise figure would be too low, requiring a corrective addition of 1.1 dB to the meter reading.

Fortunately, in the case of the 343A, there is a simpler method which allows use of the noise-figure meter readings without correction. This involves reducing the diode current from its specified 3.31-mA value to one which maintains a nominally constant 5.2-dB ENR. Fig. 14 is a plot of the diode current versus frequency, which provides this compensation.

Varying the current in a gas-discharge noise source has little effect on its ENR, typically only 0.005 dB/mA. Therefore, the Hewlett-Packard noise-figure meter readings must be corrected if the noise-source ENR is not 15.2 dB at the frequency of measurement. See fig. 13 to determine the difference between the ENR and 15.2 dB; remember that the difference is added to the noise-figure readings if the ENR exceeds 15.2 dB, and is subtracted if the ENR is less than 15.2 dB.

If measurements are being made with a Hewlett-Packard noise-figure meter at one or only a few frequencies, as is the usual case for amateur receivers, the need for making corrections to the noise-figure readings can be eliminated by the use of a selected loss pad. The graduations on the two scales of the Hewlett-Packard instrument meters correspond, differing by exactly 10 dB. Therefore, if the noise-source ENR were exactly 15.2 dB, and a precision 10-dB pad were used between it and the receiver under test, the noise figure could be read directly on the meter diode scale, which is based on an ENR of 5.2 dB. Since the noise-source ENR is not 15.2 dB, a pad must be selected so that its loss is algebraically equal to the difference between 5.2 dB and the ENR shown in fig. 13. Thus for the 349A noise source, the use of a 10.35-dB pad at 432 MHz, or a 9.5-dB pad at 220 MHz, will allow direct readout of noise figure on the diode scale of the noise-figure meter.

**Image-response error**

Noise figure, as we have been using the term, is more correctly designated as the single-sideband noise figure. This has nothing to do with ssb as a method of modulation; it refers to the fact that any superheterodyne receiver has both a signal and an image sideband (channel), and that we are interested in measuring the noise figure in only a single (the signal) sideband.

The image response of a system consisting of wideband amplifiers followed by a heterodyne receiver (converter) can be an important factor when measuring noise figure. The image-channel signal adds to the signal-channel signal and results in a measured noise figure which is lower than the true noise figure. The noise-figure error is a function of the receiver gain at the signal and image frequencies, as expressed by the following equation:

\[
\text{Error}_{NF} \ (\text{dB}) = 10 \log \left( 1 + \frac{G_i}{G_s} \right) \tag{13}
\]

where \(G_i\) is the image-channel gain ratio and \(G_s\) is the signal-channel gain ratio. It can be seen that, for
equal signal- and image-channel gains, the error will be equal to $10 \log 2$, or 3 dB.

Fig. 15 is a graphical representation of eq. 13, and shows the amount by which the measured noise figure must be increased. It is apparent that the noise-figure error is negligible if the receiver image rejection is greater than 20 dB. However, the corrections, especially when measuring low noise figures, can be significant at image rejections under 20 dB.

Which brings us back to the measurement of low-noise preamp noise figure. The prevailing concept in the design of low-noise amplifiers is to have untuned input and output circuits, and to rely on a separate high-Q filter ahead of the preamp to discriminate against unwanted signals. This is a valid design concept, but may lead to serious errors in the measurement of noise figure, especially at the aforementioned vhf/uhf conferences.

Fig. 16 illustrates, in simplified form, the four possible configurations of measuring preamp noise figure, using a receiving converter and a noise-figure meter with a 30-MHz input. In the examples shown, measurements are to be made at 432 MHz, and both the noise source and the preamp are assumed to be flat from 372 to 432 MHz. The bandpass filters can be of any type — tuned circuits, cavities, stub tuners, etc. — and may actually be part of the input or output circuits of any of the individual blocks. However, the absence of a filter indicates that it does not exist, either separately or as a part of any circuit; thus, in fig. 16B, the preamp has no filter in either its input or output circuit, and the converter has no filter at its input. The converter output circuit has no effect on this discussion, and is assumed to be tuned to 30 MHz.

In fig. 16A, bandpass filters at the input and output of the preamp limit the overall system response to 432 MHz. This is the normal communications configuration, and yields valid noise-figure measurements. In fig. 16B, both filters have been eliminated, so that the preamp accepts noise inputs from 372 to 432 MHz and, in addition, contributes its internal noise over the same frequency range. Since the converter produces a 30-MHz output from the noise power at both 372 and 432 MHz equal to $2N_2/2N_1$, the ratio remains the same as from one channel only, resulting in a valid noise figure.

Fig. 16C shows a test configuration in which a filter is used only between the preamp and the converter. It can be seen from the frequencies indicated on that diagram that only the 432-MHz noise signal reaches the converter, so that it too is a valid method of measuring noise figure. (It is equivalent to using an untuned preamp with a normal, tuned-input converter.)

In fig. 16D, the filter position has been changed from the output to the input of the preamp. Notice that in this arrangement the noise input to the preamp is limited to 432 MHz. However, this amplified noise plus the internal noise generated by the preamp at both 372 and 432 MHz are converted to the 30-MHz input of the noise-figure meter. Therefore, the noise-figure reading will be erroneous. The conclusions to be drawn from this discussion are that meaningful noise figures will be obtained if no filters are used, or if a filter is used following the preamp, but in no case should a filter be used ahead of the preamp without an equivalent filter at the output.

**temperature error**

In the derivation of the noise-figure equations, $T_a$ is equal, by definition, to 290°K and represents the noise temperature of the noise source when de-energized. It is therefore apparent that if the noise source is at a temperature other than 290°K (17°C or 62.6°F), an error will be introduced. Although such errors are of relatively small magnitude, especially over a limited ambient temperature range, it may be necessary to take them into account when measuring very low noise figures. Fig. 17 shows the noise-figure correction, as a function of measured noise figure and temperature, for a typical gas-discharge noise source. It can be seen that if a noise-figure measurement of 2.0 dB were made in a room where the temperature was 80°F (approximately 27°C or 300°K), a correction of −0.1 dB should be made,
making the corrected noise figure 1.9 dB. Extended use of a gas-discharge noise source also raises the cold temperature, so that the source should be allowed to cool down to room ambient when accurate measurements are required.

The temperature-correction curves for the Hewlett-Packard 343A diode noise source appear in fig. 18. Since the diode heat will cause the termination temperature inside the noise-source housing to be somewhat higher than the ambient, this factor should be taken into account when establishing a corrected noise figure.

Noise power obeys all power-transfer laws, but because noise is random in phase, mismatches cause ambiguous errors rather than known power losses. Because an automatic noise-figure meter measures the ratio \( N_2/N_1 \), a mismatch affecting both of these powers has no effect on accuracy, since the ratio remains unchanged.

The major consideration in matching involves the excess noise power available from the noise source. The ENR of any of the noise sources discussed in this article, excluding the Hewlett-Packard 345B, is based on developing the noise power in a 50-ohm resistive load. If the load is not 50 ohms, the ENR will be indeterminate.

The mismatch error must be calculated for each system by considering that noise power follows the power-transfer laws. A typical plot of error limits for a receiver SWR of 2:1 is shown in fig. 19; the actual error can fall anywhere between the limits indicated.

**transmission-line (insertion loss) error**

This error is a function of the coupling of the gas-discharge tube to the helical transmission line (see fig. 3) and the attenuation of the transmission line, and always reduces the noise-source ENR. In fig. 13, this error has been taken into account in determining the excess noise ratios of the AIL noise sources. It has not been considered in the ENR curve for the Hewlett-Packard 349A, but according to the published data, the error is less than 0.25 dB. This is well within the ENR tolerances specified in table 2.

**cumulative errors**

If all errors are in decibels, they accumulate additively. Therefore, the total possible measurement error will be the sum of the following:

1. Noise-figure meter accuracy
2. Noise-source accuracy, corrected for frequency
3. Receiver image-response error
4. Temperature error
5. Mismatch error
6. Transmission-line (insertion-loss) error, if a gas-discharge noise source is used.

This is an imposing list, and could total well over 1.5 dB if all errors were of the same algebraic sign. However, many of these errors will cancel because of opposite signs, and generally the accuracy of the test equipment is far better than the limits of its specifications. Nevertheless, these possibilities of error are very real and cannot be ignored except for comparative measurements using the same equipment at one particular time. And even then, the mismatch errors between the noise source and the different receivers under test still exist.

**summary**

We have seen how automatic noise-figure measurements are accomplished, and have discussed their limitations and areas of inaccuracy. We can therefore answer the questions posed at the beginning of this article. A difference of 0.2 dB, or even 0.5 dB, in the noise figures of two different preamps measured at two different times on two different test setups is meaningless. Furthermore, the accuracies of such measurements, especially outside of a labor-

---

**fig. 19.** Typical errors for several possible conditions of mismatch between the noise source and receiver (courtesy Hewlett-Packard Company).
atory environment, are subject to rigorous examination. This is not a criticism of those amateurs who spend many hours at VHF/UHF conferences performing the tests; they know the limitations of their methods and equipment. Rather it is meant to warn those who accept noise figures as gospel that such is not the case.

The same warning applies equally to the "typical noise figure" specifications on some transistor data sheets. Unless an accurately calibrated hot-cold noise source is used to determine the noise figure of the device (and I personally know of cases where this was not done), the published figures may be no more accurate than you or I could obtain with surplus equipment – caveat emptor.

The automatic noise-figure meter can also be used to measure noise figure by the twice-power or y-factor methods. However, since this article was intended to cover only the automatic mode of measurement, no attempt has been made to discuss manual operation. Gain measurements may also be made, in a clever application described by Paul Shuch.11

I sincerely hope that this article has taken some of the mystery out of automatic noise-figure measurements. More important, I hope that it will dispel any idea that you know your receiver or preamp noise figure to within a tenth of a dB.

appendix

To change the input frequency of a Hewlett-Packard noise-figure meter, only the frequency-determining circuits in the instrument's tuned amplifier need be changed to the desired frequency. If the new frequency is relatively close to one already established in the instrument; it may be possible to make the change merely by retuning the variable inductors in the tuned circuits. Otherwise, the coils will have to be modified or replaced.

The Hewlett-Packard models 340A and 340B employ a four-stage tuned amplifier. The front-panel input frequency switch selects one of two coils in each stage of the amplifier. In the standard models, these coils and their inductance ranges are as follows:

<table>
<thead>
<tr>
<th>Input frequency (MHz)</th>
<th>model 340A</th>
<th>model 340B</th>
<th>Inductance (nH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>L1, L3, L5, L7</td>
<td>L6, L8, L10, L12</td>
<td>1.2 - 1.75</td>
</tr>
<tr>
<td>60</td>
<td>L2, L4, L6, L8</td>
<td>L5, L7, L9, L11</td>
<td>0.27 - 0.41</td>
</tr>
</tbody>
</table>

Regardless of whether the standard model, having the above input frequencies, or a special model having different input frequencies, is involved, the coil designations will be the same.

The coils resonate with approximately 20 pF. If the existing coils have sufficient inductance range to permit retuning, the procedure is simple. Set the METER FUNCTION switch to NOISE FIGURE and turn the INF CALIBRATION potentiometer fully clockwise. Then, using a signal generator, feed an unmodulated signal at the new frequency into the input of the noise-figure meter. Keep the signal level low enough so that the meter is never at full scale, and adjust the appropriate coils for maximum meter reading. If the meter reaches full scale, reduce the input signal before continuing the adjustments.

If new coils are required for the desired input frequency, select four adjustable coils whose mid-range inductance will resonate with 20 pF at the new frequency. Coils in the Miller 4300 series or Cambion 556-3338 series will replace those in the instrument without any mechanical modifications. After replacing the existing coils in the noise-figure meter with the new ones, retune the amplifier as described above. If the new frequency is 30 MHz or lower, a 3300-ohm composition resistor can be connected across each coil to broaden the amplifier response.

The Hewlett-Packard model 342A has provisions for five input frequencies. Instead of switched coils throughout the tuned amplifier, a fixed-tuned 30-MHz i-f amplifier is used in conjunction with a mixer and local oscillator circuit, which heterodynes four of the five input frequencies to 30 MHz. The fifth input frequency is 30 MHz, which is fed through the mixer with the oscillator disabled. In the standard model 342A, the following coils and frequencies are used in the mixer-oscillator circuit:

<table>
<thead>
<tr>
<th>Input frequency (MHz)</th>
<th>Mixer coil L10</th>
<th>Oscillator coil L14</th>
<th>Oscillator frequency (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0.32 - 0.55 pF</td>
<td>0.196 - 0.228 pF</td>
<td>140</td>
</tr>
<tr>
<td>60</td>
<td>0.32 - 0.456 pF</td>
<td>0.196 - 0.228 pF</td>
<td>100</td>
</tr>
<tr>
<td>70</td>
<td>0.32 - 0.465 pF</td>
<td>0.196 - 0.228 pF</td>
<td>100</td>
</tr>
<tr>
<td>105</td>
<td>0.32 - 0.456 pF</td>
<td>0.196 - 0.228 pF</td>
<td>75</td>
</tr>
<tr>
<td>200</td>
<td>0.32 - 0.442 pF</td>
<td>0.196 - 0.228 pF</td>
<td>170</td>
</tr>
</tbody>
</table>

Special versions of the 342A will have one or more input frequencies which differ from those listed above. Therefore the coil inductances may also be different, but the designations will be the same.

To change any of the input frequencies except the 30-MHz input, either retune the coils associated with the input switch position to be changed, or use new adjustable coils whose mid-range inductance will resonate with 14 pF at the required frequencies. The mixer coil obviously must be tuned to the input frequency. The oscillator coil must be tuned to a frequency which is 30 MHz above or below the input frequency; be sure that the oscillator frequency and its harmonics are well removed from the 30-MHz intermediate frequency.

Set the local oscillator on frequency by means of a frequency counter or a dip oscillator. Then adjust the oscillator and mixer coils (but not the coils in the i-f stages) as previously described for the model 340A or 340B, using a signal generator at the new input frequency.

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This project grew out of a desire to design an electronic Teletype keyboard which would permit handicapped people to communicate with others. I took an initial design suggested by Ed Brown, WØEPV, determined that it was feasible, and developed the circuit shown in this article. The keyboard itself would generally have to be custom designed for each particular individual; for amateur use any surplus keyboard with a simple, closing-type contact will be sufficient.

**circuit description**

The heart of the circuit is a set of eight shift registers, composed of four 7474 ICs (see fig. 1). During static conditions, the Q outputs of the shift registers are all high, forcing the 7430 NAND gate low. This low disables the clock, while also enabling the pulse generator. When a particular key is actuated (key line taken low), the pulse generator is discharged through the respective cores. For example, if the Y line went low, the pulse generator would be discharged through cores T1, T3, T5, T6 and T7. The pulse from each core sets its respective shift register, causing the Q output to go low. Now that one of the inputs of the 7430 has been driven low, its output will change states, both enabling the clock and disabling the pulse generator.

Prior to the change in the 7430, the magnet driver was held in a mark condition by the action of U2.

By L. A. Stapp, WØPHY, 2903 Ash Street, Hays, Kansas 67601
With both inputs to U2A now low, U2 pin 8 will go high, forcing the magnet driver into the space condition. Since the clock has now been enabled, it will put out a pulse after 21 ms, moving the contents of the shift register down one increment. Each low state, on the Q line, will create a mark, while a high forms a space.

With the clock free running, as long as there is a low into U1, the shift register will receive pulses and move the data one increment for each clock pulse. After 8 shift operations, the registers will be clear and their high outputs will cause U1 to change states again, completing the character.

**construction**

Building this electronic keyboard is extremely straightforward with the use of TTL circuitry. Before operation, R5 should be adjusted with U1 pin 8 high, to provide 1.6 volts on pin 6 of the NE555. If

*A copy of the circuit board layout and parts placement diagram is available by sending a self-addressed, stamped envelope to ham radio, Greenville, New Hampshire 03048.

---

fig. 1. Schematic diagram of the electronic keyboard. Each toroid is an Indiana General CF-102, 0-6, wound with a 10-turn primary. The wires from the pulse generator are fed through the appropriate core to form the mark periods for each character.

fig. 2. This power supply will provide voltages for both the keyboard plus the Teletype loop. The transformer is a Stancor 8626.

the keyboard is to be used at 60 words per minute, R1 should be adjusted so the 555 oscillates at 45 Hz; for 75 words per minute, use 61 Hz.

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improved grounding for the 1296-MHz microstrip filter

Construction techniques for improving the performance of the three-pole 1296-MHz bandpass microstripline filter

The 1296-MHz microstripline bandpass filter discussed in a previous article has allowed dozens of uhf experimenters to "clean up their act" on the 23-cm band. As shown in fig. 1, the filter consisted of three top-coupled parallel-resonant circuits with grounded microstripline inductors. The filter is easy to assemble and tune, but several amateurs who have built it experienced difficulties caused by erratic stripline grounding. The new design presented here eliminates those difficulties and provides lower insertion loss and steeper skirts that will not tend to degrade as the filter is used.

The grounding of the microstriplines in the original design was accomplished by wrapping a thin brass or copper strap around the edge of the PC board, soldering it to the stripline on one side of the board and the groundplane on the other. Although this method of grounding worked well in the prototypes, the stripline inductance is a function of the placement of the grounding strap. Furthermore, the strap's placement on the edge of the board makes it extremely susceptible to physical damage, especially when installing or removing the filter board from its box. A third difficulty with wraparound grounding is that it forces the end of the microstripline inductor to extend to the edge of the board, where stray coupling can cause the tuning of the filter to change when the unit is placed inside an enclosure.

All of these difficulties can be easily eliminated by placing the grounded end of the microstripline inducers somewhat away from the edge of the board and drilling through the board for the installation of a grounding wire or post. With the ground connection running through (rather than around) the board, its mechanical integrity is assured, and the groundstrap inductance is more nearly constant from one filter to the next, especially if the diameter of the grounding wire or post is specified.

By H. Paul Shuch, N6TX, Microcomm, 14908 Sandy Lane, San Jose, California 95124

60 August 1978
Although a short length of number 18 (1.0 mm) tinned copper wire makes an acceptable through-board ground connection, maximum grounding effectiveness and mechanical integrity, I have found, can be achieved by installing small electronic eyelets through the board, setting them with a press, and soldering both sides. The eyelets I use are made of thin brass, measuring 0.47 inch (1.2 mm) diameter by 0.093 inch (2.5 mm) long. They look something like tiny rivets. The eyelets are available from a number of vendors* and can be easily set using a center-punch (or sharp nail) and hammer.

**grounding the trimmer capacitors**

Another area of difficulty encountered by several readers is the grounding of the piston trimmer capacitors. The capacitors I originally used were designed for chassis mounting, so it was necessary to modify them for circuit-board use by adding a bus-wire loop around the terminal nearest the adjusting screw (see fig. 4 of reference 1). It would have been better to use a trimmer specifically designed for PC use, with legs installed for grounding the rotor end through the circuit board. One such capacitor is the R-Triko 202-

![fig. 2. Full-size printed-circuit layout for the three-pole 1296-MHz bandpass filter. Etched on double-clad 1/16" (1.5 mm) fiberglass-epoxy circuit board; the etched side serves as a ground plane.](image)

08M, a German ceramic piston trimmer available in the required 1-to-5-pF range.* I find filters using this capacitor easier to tune up, although I caution the builder against repeated adjustments because the tuning mechanism loses spring tension and becomes erratic after a couple dozen adjustments. The best procedure is to set the filter on frequency once, and then place a dot of nail polish, epoxy paint, or Loctite on the tuning screw as a reminder to leave it alone!

**assembling the modified filter**

Fig. 2 is a full-size printed circuit layout for the 3-pole bandpass filter, modified for through-board grounding. The board should be etched from double-clad 1/16-inch (1.5-mm) fiberglass-epoxy printed-circuit stock, with one side left unetched to serve as a ground plane. The board should be drilled in the same manner as the template in fig. 3 and the three eyelets installed at the bottom end of the microstrip-lines.† Don't forget to remove a bit of ground plane

![fig. 3. Full-size drilling template for the bandpass filter board.](image)

them for circuit-board use by adding a bus-wire loop around the terminal nearest the adjusting screw (see fig. 4 of reference 1). It would have been better to use a trimmer specifically designed for PC use, with legs installed for grounding the rotor end through the circuit board. One such capacitor is the R-Triko 202-

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*One acceptable eyelet is part number F-4703-B, available from International Eyelets, Inc., 528 Santa Barbara Street, Santa Barbara, CA 93101.

*These capacitors are available in the United States through Stettn-Trust, Inc., 67 Albany Street, Cazenovia, NY 13035.

†Completely etched, drilled, and plated printed circuit boards, with the three eyelets installed, are available for $4.50 postpaid within the U.S. and Canada, $5.00 elsewhere, from Microcomm, 14938 Sandy Lane, San Jose, CA 95124. Completely assembled, tuned, and tested filters are also available. Send a stamped, self-addressed envelope for details.
Fig. 4. Effect of the bandpass filter on a 1296-MHz local oscillator chain. Spectrum display at top shows the various spurious outputs of a poorly designed LO. Spectrum at bottom is the result of passing the LO signal through a three-pole bandpass filter of fig. 1. The worst remaining spurious component is suppressed 25 dB. (Both displays: dc - 1.8 GHz sweep; horizontal scale, 200 MHz/division; vertical scale, 5 dB/division.)

Fig. 5 shows the results when the filter is used to clean up the output of a previously published transmit balanced mixer. Notice that the i-f feedthrough signal and its harmonics, the LO feedthrough, the

Fig. 4. Effect of the bandpass filter on a 1296-MHz local oscillator chain. Spectrum display at top shows the various spurious outputs of a poorly designed LO. Spectrum at bottom is the result of passing the LO signal through a three-pole bandpass filter of fig. 1. The worst remaining spurious component is suppressed 25 dB. (Both displays: dc - 1.8 GHz sweep; horizontal scale, 200 MHz/division; vertical scale, 5 dB/division.)

filter performance

Reference 1 included a swept response curve for the original bandpass filter, as measured on a network analyzer. The response curve for the modified filter design shows slightly reduced insertion loss (on the order of 0.5 dB) and slightly steeper skirts. Perhaps the most realistic indication of filter performance is not its swept response, but the filter's behavior in an actual system. Fig. 4 shows the effect of installing the bandpass filter behind an extremely spurious local oscillator chain. Note that the numerous spurious components are all significantly suppressed, with the worst remaining spur reduced from -5 dB to about -25 dB, relative to the desired output.

Fig. 5 shows the results when the filter is used to clean up the output of a previously published transmit balanced mixer. Notice that the i-f feedthrough signal and its harmonics, the LO feedthrough, the

metallization from around the center-pin holes for the input and output coaxial connectors so the signal isn’t grounded out. A 1/8-inch (3-mm) twist drill, used as a deburring tool, works well for this operation.

Connectors J1 and J2 are installed next, soldering the center pin to the input and output microstrip lines, and running a bead of solder around the connector body on the ground-plane side of the board. The trimmer capacitors are installed last. If you use the recommended Triko trimmer, be sure to bend the two mounting legs nearest the adjusting screw down against the ground plane before soldering. The photograph of the completed filter will assist you in assembly.
C1 1-9 pF piston trimmer (Triko 203-09M or equivalent)
C2, C3 1-5 pF piston trimmer (Triko 201-01M or equivalent)
CR1 Step recovery diode (H-P 5082-0180)
J1, J2 SMA coaxial connector (E.F. Johnson 142-0298-001 or equivalent)
L1, L2 Microstripline inductors (see fig. 2)

fig. 6. Circuit and construction details for a local-oscillator multiplier which provides 0.5 mW at 1200 MHz from a 5 mW 400-MHz drive signal. This circuit uses the same printed-circuit layout as the bandpass filter (see fig. 2). Output spectrum of this circuit is shown in fig. 7.

image signal, and the intermodulation products are all suppressed below the dynamic range of the spectrum analyzer.

local-oscillator multiplier

In a previous article I described a diode multiplier for developing local-oscillator injection for a 1296-MHz converter. As this multiplier used a microstrip-line output filter, it seemed reasonable to assemble a similar multiplier on the bandpass filter PC board, thus allowing one PC artwork to do the job of two. The circuit, which makes a rather nice low-level tripler, is shown in fig. 6. Note that the microstripline previously associated with the first filter pole is now used to support the multiplier diode and its input matching circuit. Do not install a grounding eyelet on this first stripline if you are building the multiplier! The other two filtering poles help reject the many other harmonic components generated by the step-recovery diode, as shown in the spectrum analyzer display of fig. 7. When driven by the 5-to-10 mW signal from my uhf LO chain, this multiplier provides about 0.5 mW of third-harmonic output. This power level can be easily buffered in a 1296-MHz preamp, applied to a 3-pole filter for additional spurious rejection, and used to drive the LO port of a transmit or receive balanced mixer.

I should point out that the circuit of fig. 6 provides no dc return for the anode side of the multiplier diode. A dc return is necessary for the diode to properly develop self-bias; in my system this dc path is provided at the output of the uhf LO. If the driving stage does not offer dc continuity to ground, it will be necessary to install a dc return circuit on the multiplier board. This can be most readily accomplished by adding a small (0.33-μH) rf choke to ground at the location normally occupied by the first trimmer capacitor when this board is used as a filter.

summary

The printed-circuit layout can be used to fabricate high-quality bandpass filters and diode multipliers for the amateur 23-cm band. The designs are based upon previous articles, but the addition of through-board eyelet grounding significantly improves performance and reliability. Further details on construction, tune-up and testing, and system application are discussed in reference 1.

references


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- 0.4 µV for 20 dB quieting FM sensitivity
- 10 watts RF output on SSB, FM, CW
- 3 watts on AM
- 1 watt FM low-power switch
- 0.25 µV for 10 dB (S+N)/N SSB/CW sensitivity
- 0.4 µV for 20 dB quieting FM sensitivity.

The TS-700SP shown with the matching VFO-700S and SP-70. Also shown is Kenwood's new MC-30 noise cancelling hand held microphone, HS-4 headphone set and the MC-50 dynamic microphone.
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fm signal reports

How often have you heard, "'You're 40 per cent quieting but Q5 copy,'" and wondered how the operator on the other end arrived at the 40 per cent figure? He must have been good at guessing, had a super trained ear, or maybe trying to be friendly.

When I became interested in two-meter fm I was very much confused with per cent quieting signal reports (especially if I had to give one). The transceiver I used was an ICOM IC20 and it did have a relative strength S-meter. While working simplex, whatever the meter indicated would be the report I gave. However, working through repeaters presented a whole new ball game. Unlike simplex, repeaters may come slamming into your location, but the signal on the input side may be quite weak. Under such circumstances the S-meter reading is invalid for a report, but a monitor scope would immediately show the per cent noise quieting into the machine. One day while working on a circuit and using my old EICO model 460 scope, I saw the light for a per cent quieting indicator.

operation

After examining the IC20 schematic for a good signal pickoff point, I decided the best place would be at the output of the discriminator stage (at TP3) and ahead of the audio control circuit (see fig. 1).

fig. 1. Pickoff point in a typical amateur 2-meter transceiver for connecting a monitor scope. In this case it's at TP3 in the popular ICOM model IC20. The pickoff point should be made at the receiver discriminator output, but ahead of the audio control circuit.

Several advantages would be obtained by doing this: 1) I'd see the noise figure as it appeared, unaffected by audio and squelch-control settings; 2) I'd see peak deviation (modulation); 3) by connecting directly from the discriminator output to my scope's dc vertical input I'd be able to measure the dc voltage produced by the received-signal carrier. Most fm transceivers (or receivers) have a test point at the location mentioned for alignment purposes. Your manual or schematic should indicate if this point is available.

connection

Modification and wiring of the transceiver was simple (fig. 1). Connection to the outside world was made using a small-diameter, single-conductor, shielded cable from the discriminator circuit to a

By Ed Spadoni, W1RHN, 91 Tower Street, Dedham, Massachusetts 02026
rear-panel-mounted phono connector (Radio Shack No. 274-346) designated J4 in fig. 1. The shield was wired to J4 ground lug only. Next my scope was connected through a suitable length of shielded cable, with a male phono plug on the end, to mate with J4.

**calibration**

Scope control settings will vary depending on the types of scope used. My EICO 460 control settings were as follows: Vertical attenuator in the DC-X1 position, horizontal sweep at 100 Hz, and sync on INTERNAL. With the transceiver tuned to an inactive channel, adjust the vertical gain for 51 mm (2 in.) p-p noise level (fig. 2). The noise as seen on the scope indicates the total passband of the rig's receiving section. My IC20 has a passband of better than 16 kHz, which allows me to see signals ±8 kHz from the passband center with reasonable accuracy. At present I can read 1 kHz = 2.5-mm or 0.1-in. division on the scope with good linearity to ±8 kHz.

It's essential to have your receiver properly aligned and your receiving crystals adjusted to the passband center. If you're synthesized, be sure the receive oscillator is also properly adjusted. I've found that a very convenient frequency reference source is a repeater output signal. By tuning in several machines you can see if things are properly adjusted by noting if the repeater signals are located in the passband center. If not, a little trimming must be done.

Working someone with a synthesized or vfo rig can prove very helpful in determining the linear portion of your receiver and its frequency limits. After determining the useful reading range of your transceiver-scope combination, you should be able to read signals to ±1 kHz of your receiver passband center.

**using your scope**

Here are some samples of the more important waveforms observed while monitoring both simplex and repeater signals.

1. 100 per cent noise quieting signal, either simplex or repeater, with a pause in modulation:

2. 50 per cent noise quieting signal, either simplex or repeater, with a pause in modulation:

3. Normal signal showing deviation (modulation). Most transceivers and repeaters have their deviation set for a nominal peak of 5 kHz:

4. 100 per cent quieting repeater signal received at your location with a weak and noisy input signal. Horizontal sweep adjusted for expanded one or two speech waveforms:

5. Repeaters normally produce equal swings of deviation, in both up and down directions, with most input signals. If a new station comes into the machine and produces the pattern shown below, this means that the new signal's carrier frequency is off and higher than the repeater passband center. The opposite would be true with a low-frequency carrier signal into the machine:

---

**fig. 2. Scope presentation for calibration. Peak-to-peak noise should occupy the entire scope face, which represents the total passband of the receiver on noise.**
6. Hum accompanying signal. Frequency and ratio of hum to modulation can be determined. Hum frequency is referenced to 60 Hz.

\[ \text{Per cent of hum} = \frac{\text{hum } p-p}{\text{deviation } p-p} \times 100 \]

7. Power supply whine accompanying the received-signal carrier has a constant amplitude and frequency. Mobile alternator whine is similar, except the amplitude and frequency will change as the vehicle is accelerated or decelerated. Whine appears as a high-frequency modulated carrier with or without voice modulation:

8. Upper-channel interference from a strong simplex or repeater station. Many hams have experienced this condition and termed it (in error) intermodulation. Lower-channel interference is similar, except that the baseline would appear on the lower side of the passband with audio transients shooting upward:

9. Checking and adjusting Touch-Tone signals. Preferably, use a simplex channel and have the operator close-talk into the microphone at a normal voice level. (Note the peak deviation.) Next, have the operator switch in the TTP, push buttons 1 and 2 or 1 and 4, and observe the peak amplitude. Peak deviation and amplitude should be the same for both; if not, adjust TTP output level. Then have the operator push all buttons to see if all levels are the same. When a single button is pressed a dual frequency is generated and is a normal function for a TTP, as shown below. Each button produces its own set of different frequencies:

10. Frequency measuring. Using a scope with your transceiver gives you a limited-range frequency meter, allowing you to read up to ±8 kHz per channel on 2 meters. The range is restricted only by the passband capability of your transceiver.

final comments

You can leave the scope in the circuit without affecting transceiver performance. If you have separate receive-transmit capability, the scope can also be used to monitor your own transmitted signal. The waveforms illustrated are those most often encountered and are therefore the most important.

Scopes aren’t difficult to come by. Try surplus houses, auctions, or build one from a kit. A monitor scope beats the cost of frequency counters and you see much more. Making this simple modification to your radio and adding a scope will allow you to keep watch over other rigs (your hand-held; repeater output), especially the transmitted signals. The combination becomes unbeatable when used with synthesized transceivers or those with ±5-kHz offset or with transceivers having a VFO and 1-kHz readout.
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single-tone decoder
for vhf fm
Design and construction of a false-free device using a single tone to alert you on two-meter fm

A single-tone decoder is adequate for many applications on vhf fm, but very little practical information on these devices has been published. Several years ago K2OAW described the use of a 741 op amp as a carrier-operated relay (COR) and tone decoder, but I didn’t know what a COR was at that time. So I read the part about the tone decoder, and within 15 minutes I was at the junk box struggling to put a reasonable facsimile together to see whether or not all that was claimed for this circuit was true. The claims were that the decoder would not trigger on noise, speech, or even singing but would activate immediately in response to the chosen tone. Beyond that, the decoder bandwidth was not supposed to get any broader as the input amplitude increased. Also, the decoder was not supposed to trigger on the selected tone if that tone were accompanied by any other tone or noise.

This article describes a single-tone decoder with hints on how to set it up. It has the advantage of being free from falsing while coming on quickly enough to stop a scanner on the frequency where the tone was transmitted. An appropriate encoder, small enough to fit in most hand-held transceivers, is also described.

In those days I had two CB hand-held transceivers with built-in tone encoders for mutual noise making on 11 meters. I wanted to use the decoder (if it worked) with these units. Fortunately I had all I needed on hand to make the circuit on a perf board. When I was finished, lo and behold, it worked! It was so selective that it wouldn’t false, even on channel 11 with the band open; when my tone came through, the decoder came right on.

I put it all together in a box with a speaker and some jacks and used it that way for several years until I got on 2-meter fm. I then discovered some problems and shortcomings that needed solutions. Over the years I came up with a modified circuit that filled my needs and has been working well ever since. Before going any further, let me explain why I used a single-tone decoder rather than Touch Tones, sequential tones, or some other type of selective decoding device. It’s not really the decoder but the encoder that makes the difference. A stable, single-tone encoder can be easily and inexpensively built to fit into a hand-held transceiver, and that’s exactly what I did.

operation

The radio is on at all times and tuned to a repeater frequency, but a relay directs the audio to a 10-ohm, 2-watt resistor and the decoder input. When the desired tone is received the audio is directed through a 7-second timer to both a local and an extension speaker. (The extension speaker, in my case, is located in the kitchen.) After seven seconds the unit resets, and the audio is removed from the speakers. My wife (the technician in the house) then goes to the shack and operates a toggle switch that defeats the decoder, disconnects the extension speaker, and supplies the audio at a conversational level to the

By Steve S. Kraman, MD, WA2UMY, 29018 Candlelight Way, Lexington, Kentucky 40502
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local speaker. After two-way communications are completed, the same switch returns the unit to normal operations. Nothing need be disconnected from the rig at any time.

The original circuit is reproduced here (fig. 1) to demonstrate its operation. I'll dispense with a detailed description of how the decoder works. Briefly, the incoming signal is separated into two components — the desired component and all others. The two voltages so derived are rectified and fed respectively to the positive and negative inputs of the 741 op amp. The voltage at the positive input must exceed that at the negative input for the 741 to turn on. The bandwidth is set by R7, which determines the op amp bias. (A complete description of the circuit can be found in the original article.)

**modified decoder**

Fig. 2 shows the modified circuit. C1, the frequency-determining capacitor, is replaced by seven capacitors and a seven-pole, single-throw switch on a 14-pin DIP. (This is only a convenience to allow easy frequency change.)

**choosing capacitors**

Be sure to use only NPO capacitors for C1; that is, capacitors whose values do not change with temperature, otherwise you may find, as I did, that on warm or cool days the decoder will not respond to your tone. A drift of only a few hertz can prevent the decoder from working. If you're not sure of your capacitors but have access to a capacitance bridge, connect the chosen capacitor across the bridge, take a reading, and then cool the capacitor with freeze mist and take a second reading. If the change is more than slight (say about 10 per cent), don't use it. You'll find that most disk ceramics will change value by as much as 50 per cent under these conditions. Mylar or tantalum capacitors are usually good.

My unit is set up to decode frequencies between 300-600 Hz using a 150-μH toroid; an 88-μH toroid, as originally described, is fine. Experiment with values of C1 to see where you are and work up or down from there. If you have a low-band rig, connect the audio output to the decoder and use the crystal calibrator to generate a test signal. Of course, an audio signal generator may be used, but remember that the amplitude must be similar to that of an audio power amplifier since these are the conditions under which the decoder was designed to work.

**adjustment and tests**

If the decoder doesn't operate at first, test the frequency determining components by placing a dc voltmeter across the 741 positive and negative inputs. Sweep an audio-frequency generator over as

---

**fig. 1.** Original circuit of the single-tone decoder, which forms the basis of the modified system. (From 73, July, 1972.)

**fig. 2.** Modified decoder featuring easy frequency change using 7 NPO capacitors and a 7-pole, single-throw switch on a 14-pin dual in-line package. Unit decodes frequencies from 300-600 Hz. The universal 741 op amp does the work; bandwidth is set by resistor R7.
wide a band as possible. The voltage will peak at one frequency and remain negative at all others. Play around with the bandwidth while you are doing this.

The 555 timer is set to keep the speakers on for about seven seconds, but you can substitute a pot for R2 to give different lengths of time.

The meter across K1 is used to adjust the encoder to the decoder frequency. The meter will read highest at the decoder's most sensitive frequency. The meter is also useful for quick checks and adjustments. Almost any sensitive meter can be used with the appropriate series resistor to keep it in range. I used a tape recorder VU meter.

encoder

I tried several circuits as an encoder, but by far the best is the "Twin-T Oscillator" taken from the Radio Amateur's VHF Manual. While the output amplitude is low and must be fed into the transmitter mike input, the frequency is completely independent of the supply voltage over its operating range. When NPO capacitors are used, a very stable source of oscillation results, which is mandatory if the encoder-decoder pair are to work reliably. It's best to set up the encoder with an oscilloscope to try to achieve a near-perfect sine wave. Other waveforms contain harmonics, which will tend to desensitize the decoder. Keep this in mind when you operate through a repeater. The repeater's audio shaping, or your own overdeviation, may cause tone distortion.

suggested improvements

This unit has worked well for several years, but, for still further usefulness, the following may be done. A scanning board can be added to the receiver and connected so that the decoder, when coming on, will inhibit the scanner and lock the receiver onto the tone frequency. This may be accomplished by a second 555 timer set to lock on for about one minute. The manual defeat switch would also inhibit the scanner. This setup will allow you to use whichever repeater or simplex frequency is most convenient at the time, especially if your favorite repeater happens to be down just when you want to make the call. The decoder can be used in this way because it triggers almost instantly on the appropriate tone. Other single-tone decoders using the 567 chip require a prolonged tone to achieve freedom from falsing. A scanner would pass by too fast to decode the tone in this case. Other modifications will come to mind I'm sure. I hope you find this project useful and fun.

reference

When the FCC acted we reported:

**HR REPORT**

Amateur Radio's
WEEKLY NEWSLETTER

prepared by the editors of Ham Radio Magazine

Number 201 May 12, 1978

EX-NOVICE LICENSEES whose licenses expired less than a year ago will be eligible to apply for reinstatement just like any other Amateur Licensees under the FCC's recent rules change making Novice licenses non-renewable (HR 195). This means any good for five years and renewable (HR 195). This means any
geroner whose license expired after May 15, 1977, can submit a Form 610 on or after this May 15, but within one year of his original expiration date, when the new provisions become effective, and regain his license for a full five years - without retaking an exam. Present Novice license holders must realize the new five year license terms are not retroactive - their licenses still expire in two years on the expiration date they bear and must be renewed with Form 610, available from Ham Radio for $2.50.

THE RUSSIAN "RS" AMATEUR satellites are now reported due to be launched before the end of this year and are to be inserted into "high altitude" orbits.

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reprinted from HR Report, May 12, 1978
Two excellent articles have appeared in the amateur literature dealing with electronic bias switching (EBS) for high-power linear amplifiers. Why electronic bias switching? It's a great saver of tube life. It reduces tube dissipation, ambient noise, and your power bill. EBS, in general, is a way to make your amplifier operate more efficiently in whatever mode you choose, ssb or CW.

The EBS method described here may be used by those amateurs interested in CW only operation or by those using ssb with or without signal processing. Using the basic circuits described in references 1 and 2, a very efficient EBS circuit can be built into the popular Henry 2K4 or 3KA linear amplifier. The circuit can be adapted to your home-brew linear with a little ingenuity.

Henry rf decks

First of all, for those not knowing it, the rf decks in the 2K4 and the 3KA amplifiers are almost identical. The only difference is the use of wider-spaced loading variable capacitors in the 3KA (two 350 pF instead of two 500 pF, plus three additional 100-pF, 5-kV doorknob fixed capacitors). A 2K4 rf deck can easily be modified to a 3KA rf deck by simply changing these components. Of course, the 3KA uses higher plate voltage (3.6 instead of 2.8 kV). A 2K4 can be driven to 2 kW PEP with 100 watts rf, while the 3KA needs at least 150 watts of rf drive to run at its full rated output.

The EBS circuit will not be dealt with in detail. The referenced articles discuss the principles of operation of the circuit. The circuit components can be mounted on the aluminum panel covering the compartment that houses the swr bridge, zener diode, etc.

fig. 1. The bias and transmit-receive switching circuits in the Henry 2K4/3KA linear amplifiers. Dashed line (upper right) shows a 50k resistor added to the circuit through a +50-100-volt power supply to effect complete amplifier cutoff during receive mode.

Fig. 1 shows the original bias plus transmit/receive switching circuit as used in the 2K4 and 3KA amplifiers. During receive, R21 is switched into the cathode circuit, whereby the tube is biased to a point very near cutoff. Simply adding a 50-k resistor (fig. 1) and connecting it to a +100-volt supply (50-150 V) will improve the circuit; the tube will then be completely cut off during reception (+100 volts on the cathode).

By Michael James, W1CBY
improved bias circuit

Fig. 2 shows the EBS circuit as developed especially for the 2K4 and 3KA linears. R1 through R4 are well over-dimensioned resistors (in wattage), where a parallel combination is used for added safety (if one resistor opens, the system will still function on the remaining resistor). These resistors can be mounted on the bottom side of the cover plate. The Darlington transistor and the thyristor can be bolted to the plate using mica washers. All other components should be wired point-to-point on wiring strips. The rf choke (2.5 mH) in the integrator circuit between the Darlington transistor collector and base was necessary to prevent rf from getting into the base circuit and being rectified. This was the case with one particular unit in which the circuit functioned even without rf applied to the diode rectifier from the exciter input. Installing the rf choke cured the problem.

operation on cw

If you’re a CW-only man, the time constants on the make and break side of the switch can be made much shorter. Change the 0.47-µF capacitor to 0.047-µF and the 20-nF to 2 nF. This will turn the amplifier on and off much faster and still further reduce tube dissipation between dots and dashes. Closing S1 allows you to run the amplifier in its original condition; that is, without the EBS circuit. It also allows you to check tube idling current.

operation on ssb

Using signal processing. One general disadvantage of running a great amount of clipping (10-20 dB) is the objectionable background noise that may occur between words, especially if you have some noisy fans or if room acoustics are not the best.

First it’s essential that, when using speech proces-
wattmeter, is at least 25 dB down from your steady “Aaa...” (3.2 watts versus 1000 watts).

4. Open S1, without changing any setting to your transmitter or processor. If the background noise (at —25 dB or better) trips the EBS circuit (meaning that if you see the background on the scope or output meter, or if your plate meter does not drop to zero) then the EBS-circuit input sensitivity is too high. Increase the value of the 22k resistor until you find a value where the background noise just does not trip the EBS circuit. This value should be such that a drive of a little higher than —25 dB (say 5 watts or —23 dB in our example) turns on the EBS circuit.

If, when first switching on the EBS circuit, your —25 dB background noise does not trip the EBS circuit, reduce the value of R9 (22k), and determine the value where a —25 dB signal will not trip the EBS circuit, while a —23 dB signal does.

Once you’ve determined the correct value of R9, you’ve not only installed a good working power saver but have achieved total elimination of all bothersome background noise, while running 15 or 20 dB of processing in a noisy environment. Nobody (especially the locals) will hear the blowers and accuse you of running excessive power!

Ssb using no signal processing. Using the EBS circuit with a value of R9 as determined above but driven by a nonprocessed ssb drive signal will result in too-low sensitivity of the input circuit. This will cause the circuit to switch on syllables. The result will be a distorted signal (similar to a vox dropping in and out while you talk because of too-short vox delay).

To work properly, the value of R9 must be decreased until switching does not occur between syllables. The best way to find out is to listen to your own signal using headphones and adjust R9 until the breaking up on syllables disappears. A value of 1.5 - 3.3k seems to be a good starting value.

If you want the EBS circuit to be fully flexible for both ssb modes (processed and nonprocessed ssb drive signals), a small switch (S2) or relay can be installed, which switches a second resistor in parallel with R9 to reduce its value when operating with a nonprocessed drive signal.

references

bibliography

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2. PPM LONG TERM With a spec. of ± 1 PPM per six months, your additional error would only be 145Hz when measuring 145MHz, six months after calibration.

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august 1978
rejuvenating transmitting tubes with thoriated-tungsten filaments

Many amateur high-powered linear amplifiers are designed around the popular Eimac family of tubes, such as the 4-250A, 4-1000A, and the 3-500Z. All these tubes use thoriated-tungsten filaments. All other things being equal, the life of these tubes depends on the filament, which should be treated with care if you expect your tubes to last.

Filament emission is a complex process. As the chemical composition of the filament changes, the electron emission changes. As soon as the tube is turned on, it starts to lose electron emission, which finally drops below a value determined to be the “end-of-life” point. This process generally takes several thousand hours.

Once the end-of-life point is reached, the filament’s chemical composition is so changed that nothing can be done by the user to restore the filament emission. The tube is then said to be “decarburized.” The ditungsten carbide on the filament surface has thus evaporated or has combined with residual gas, and the carbide surface layer on the filament is gone.

Theoretically, it’s estimated that a four per cent increase in filament voltage will result in a 20K increase in temperature, a 20 per cent increase in peak emission, and a 50 per cent decrease in life because of filament carbon loss. This, of course, also works the other way. For a small decrease in temperature and peak emission, life of the filament carbide layer, and hence the tube, can be increased substantially.

For the Eimac 4-1000A and other tubes of this filament voltage, broadcast stations run the tube at 7.2 volts instead of 7.5 volts. The reason is extended life. The 3-500Z filament should be run at 4.8 volts instead of 5.0 volts, and so on. The filament voltage should be checked with a 1 per cent meter to achieve these values.

If the tube filament is contaminated, or if electron emission is otherwise inhibited (perhaps a grid has been overheated and has liberated gas, or filament chemistry has been upset by running the filament at a very low voltage), the tube can be rejuvenated by increasing the filament voltage by about 15 per cent and running it for a time at this over-voltage (filament power only; no other voltages on the tube elements). This filament overvoltage action will cause emission material in the filament to “boil” out from the filament interior and form a new emissive surface.

The “cooking” time depends on the filament condition — the time may be only a few minutes or it may be longer. The only way to tell is to test the tube at intervals for emission. If the tube has been cooked properly, and the filament is in the right condition chemically to begin with, normal electron emission will be restored.

If you have a power tetrode or triode tube that has lost filament-emission (evidenced by decreased power output), it’s certainly worth a try to get the tube back to near-new condition. Make sure that you meter the “cooking” circuit properly and that adequate cooling for the tube envelope and filament connectors is allowed.

These large tetrodes are expensive to replace, and you haven’t anything to lose by cooking the filament of one that’s lost emission. However, don’t expect miracles. If your linear has used tubes, you probably don’t know the history of the tube’s operation and the cause of filament emission loss. It’s worth a try, though, and you may be pleasantly surprised.

Alf Wilson, W6NIF

audio rolloff

Many people find that their external Touch-Tone® encoder will not access some systems. Many times, this is not the fault of the radio or the encoder, but actually the interface between the two units. What often occurs is that the signal from the encoder is connected into the audio input. Most radios incorporate a small-value capacitor (0.001 to 0.0033 µF is typical) between the microphone input and the first audio IC. This capacitor rolls off the low frequencies from the Touch-Tone encoder, yet passes the high frequencies relatively unattenuated.

One possible solution to this problem is to change the value of the input capacitor to 0.1 µF. If this is not practical, another remedy would be to directly inject the signal from the encoder into the input of the first audio IC. In this case, connect a 0.01 µF capacitor between the encoder and the IC. The capacitor should be mounted as close to the circuit board as possible to preclude any problems with rf getting into the audio stage.

Joe Olivera

*Touch-Tone® is a registered trademark of the American Telephone and Telegraph Company.
tester for 6146 tubes
Since many popular exciters and transceivers use 6146 tubes, and since it is not easy to find a tube tester to accommodate this tube, there is a need for a simple tester to evaluate the condition of 6146 transmitting tubes. This is particularly important when speech processors are used — they tend to raise the average power input, thus shortening tube life. The circuit shown in fig. 1 uses junk box parts, but will provide a very acceptable 6146 tube tester.

In this tester an ac bias for the grid is provided from the filament winding. It must be polarized. It must be polarized properly, i.e., the grid must be going positive as the plate is going positive. To check this, reverse the filament connections. Choose the one which yields the greatest plate current. The tester is then ready for use.

A good tube will draw 115 mA or more as indicated on the meter. Note that this meter indication is the average of half-wave rectified current. Tubes providing 90 mA or less should be discarded or, at most, kept for emergency spares. The tester is also useful for balancing pairs of tubes.

Gary Liegel, W6KNE

programmable accessory for electronic keyers
Since completing the programmable accessory for electronic keyers, August, 1975, *ham radio*, I’ve struggled to get it operational with my WB4VVF keyer, achieving only intermittent success. The problem has always centered around the memory address and the READ/ WRITE control line.

As I’ve discovered, the READ/ WRITE line of the memories does not have to be synchronously pulsed with the address locations, merely taking the R/W line to +5 volts during the READ is sufficient.

Therefore, since it turned out that the clock pulse from Q2’s collector will directly drive U9A, both U8 and U11A are no longer required. The READ/WRITE switching is still done with S3 as seen in fig. 2.

Another problem was that the output pulse from U11B was fast enough to feedthrough the first binary counter in U12 and trigger the second binary counter simultaneously. This prevented full address of the memories. Bypassing pin 4 of U11B with a 1000 pF capacitor cured the problem.

Since programmable memory address was not required, 7493s were substituted for 74193s. Additionally, sockets must be changed from 16 pin to 14 pin. The 7493 is somewhat cheaper and more available from suppliers.

John M. Korns, K9WGN/W0USL

simple frequency counter
The frequency counter described by K4JIU in February, 1978, *ham radio*, page 30, has proven to be a simple, but useful, design. Unfortunately, after building the counter on the board supplied by Mr. Bordon, the counter wouldn’t operate above about 30 MHz on the 50-MHz range, or above 300 MHz on the 500-MHz range. Discussions with the author indicated that the problem probably revolved around the waveform presented to the 7208. The Intersil data sheet stated that the optimum input waveform should have a 50 per cent duty cycle. This is the case in the 5-MHz range. But, when using the 74196 prescaler, the QD output has an 80 per cent duty cycle.

One possible cure is to use the QC output from the 74196 to drive the counter. This will give a duty cycle of 60 per cent. This change also requires that the nonscaled 5-MHz input be loaded through Data Input C instead of Data Input D. The change is accomplished by cutting the foil runs at pins 12 and 13 of U3 and using pieces of insulated wire to connect the foils to pins 2 and 3 respectively. After the change, there will be no connections to pins 12 or 13.

Carroll Hamlet, W2QBR

Dear HR:

In regard to VK2ZTB’s article summarizing ssb phase shift networks in the January, 1978, issue, several comments are in order. First, a review of the many existing broadband audio phase-shift networks is fine, but the underlying theory common to each should also be presented.

In general, the type of networks employed are called all-pass filters (the attenuation is constant, and the phase changes monotonically with respect to frequency, over the entire frequency band of interest). All-pass filter characteristics:

The $Q$ of both filters is chosen to be 0.2252. $\omega_o$ of all-pass filter 1 is $2\pi$ (428 Hz); $\omega_o$ of all-pass filter 2 is $2\pi$ (2104 Hz).

Note that even though the phase shift of each filter changes with frequency, the phase difference between the two outputs is 90 degrees over a wide band of frequencies.

No active filter examples were included in the article (VK2ZTB’s fig. 11 uses op amps, but there are no RC networks in the feedback path). Why not use the more state-of-the-art active filter approach? One realization of this type of circuit uses two Steffen all-pass filters.

The general transfer function for the Steffen circuit is:

The resulting audio phase shift network for ssb generation (300 to 3000 Hz) is as follows:

Tom Apel, WB9YEM
Madison, Wisconsin
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The EMI-ACE, while not offered as part of the kit, can be obtained separately for use with fuel pumps, windshield wiper motors, cooling or heating blowers, and the like. The ACE may not be necessary in all cases.

For more information on the EMI Power Purifier Pack and other Marine Technology products, write to Marine Technology, 2780 Temple Avenue, Long Beach, California 90806; or use ad check on page 126.

new Heath wattmeter

Heath Company, the world's largest manufacturer of electronic kits, has released a new wide-band Bi-directional Wattmeter. Called the IM-4190 (or SM-4190 in an assembled version), it is a self-contained unit that measures transmitted radio power up to 300 watts and reflected power up to 30 watts. It covers the 100-MHz to 1-GHz spectrum, and is an ideal tool for two-way radio service and repair, or for the amateur-radio enthusiast.

The IM-4190 is capable of withstanding full power overloads on its lower scales without damage to the meter movement. A single 9-volt battery powers the IM-4190, so it may be used while portable. N-type coaxial connectors are used for low insertion loss. Adaptors are included for use with UHF-type connectors.

The IM-4190 kit retails for $114.95 and the SM-4190 assembled version $195.00 (mail order from Benton Harbor). For more information on the IM/SM-4190, write Heath Company, Department 350-630, Benton Harbor, Michigan 49022.

VIZ wattmeters

The Test Instruments Group of VIZ Manufacturing Company has introduced two new easy-to-use wattmeters that are ideal for testing VHF, FM, and even UHF transmitters as well as popular high-frequency and CB units.

The WV-551A dummy-load RF wattmeter has a broad frequency range — from 1.9 to 512 MHz. Its power range is 0.5 to 15 watts with full-scale accuracy better than 5 per cent. Input impedance is 50 ohms, and VSWR is less than 1.15:1 at 500 MHz. It is simple to use: the transmitter output line is connected directly to the unit and readings are taken from the scale on a taut-band meter. The user price for the WV-551A is $60.

The WV-552A in-line RF wattmeter is a dual unit used to measure both forward and reflected power — especially useful in matching and adjusting antennas, or for tuning transmitters for maximum output. Readings are taken from the two easy-to-read meters.

Measurements with the WV-552A are possible over three selectable frequency ranges: 20-40 MHz, 40-100 MHz, and 100-230 MHz. The meter's power ranges are 0-20 watts and 5-100 watts (forward), and 0-5 watts and 1-20 watts (reflected); full-scale accuracy is better than 5 per cent. The VSWR is less than 1.15:1 over the entire frequency range, and input impedance is 50 ohms.

Both wattmeters are supplied with type M connectors; M-to-N and M-to-BNC adapters are available.

The user-price is $150. For further information and data sheets, contact Bob Liska, VIZ Test Instruments Group, VIZ Manufacturing Company, 335 East Price Street, Philadelphia, Pennsylvania 19144; telephone (215) 844-2626.

Palomar Electronics hand-held transceiver

The Test Instruments Group of VIZ Manufacturing Company has introduced two new easy-to-use wattmeters that are ideal for testing VHF, FM, and even UHF transmitters as well as popular high-frequency and CB units.

The new Palomar Mini-I VHF-FM transceiver is about the same height as a dollar bill — yet it's a giant in performance. The transmitter output is one watt, with a total of 18 channels available in the 144-148-MHz band. The channels are obtained by using up-down split, down-up split, or simplex, all with only six crystals.

With the Auto-Patch option, the Palomar Mini-I can access a repeater and communicate through the telephone system as well.

Dimensions of the Palomar Mini-I are 152 mm high by 67 mm wide by 46 mm deep. Its compact size makes it exceptionally convenient as a means of portable communications.
For more information about the Palomar Mini-I VHF transceiver, write to Palomar Electronics, 655 Upper Street, Escondido, California 92025.

Hamtronics converters

Hamtronics, Inc., announces a new series of low-cost vhf and uhf converters for use in receiving Oscar and other exciting signals on your present high-frequency receiver. At prices of $34.95 for the kit (or $54.95 wired and tested), they're quite a bargain for the enjoyment you'll get from listening to the ever-increasing activity on these bands.

The converters are small in size: only 7 x 11 x 2.5 cm (2-3/4 x 4-1/2 x 1 in). They can be constructed and tested in only a few hours. Built-in test points make alignment simple. The converters feature new high-Q coils, compartmental shielding, and ferrite-bead decoupling.

Any 2-MHz segment in the vhf and uhf range can be covered, using the 10-meter band on your existing receiver. Standard models are listed below, and other rf and i-f ranges are available on special order at the same price. An attractive extruded aluminum case kit is available as an option for $12.95 additional.

standard converters for 28-30 MHz i-f

<table>
<thead>
<tr>
<th>model</th>
<th>input range</th>
</tr>
</thead>
<tbody>
<tr>
<td>C50</td>
<td>50-52 MHz</td>
</tr>
<tr>
<td>C144</td>
<td>144-146 MHz</td>
</tr>
<tr>
<td>C145</td>
<td>145-147 MHz</td>
</tr>
<tr>
<td>C146</td>
<td>146-148 MHz</td>
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<tr>
<td>C220</td>
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<td>220-MHz band</td>
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<tr>
<td>C432-2</td>
<td>432-434 MHz</td>
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<tr>
<td>C432-5</td>
<td>435-437 MHz</td>
</tr>
<tr>
<td>C432-7</td>
<td>427.25 (61.25 MHz i-f)</td>
</tr>
<tr>
<td>C432-9</td>
<td>439.25 (61.25 MHz i-f)</td>
</tr>
</tbody>
</table>

To order, or to request a free 40-page catalog on vhf and uhf transmitters, receivers, preamps, and accessories, call 716-663-9254; or write Hamtronics, Inc., 182F Belmont Rd., Rochester, New York 14612.
R-X Noise Bridge

All Palomar Engineers products are made in U.S.A. Since 1965, manufacturers of Amateur Radio equipment only.

- Learn the truth about your antenna.
- Find its resonant frequency.
- Adjust it to your operating frequency quickly and easily.

If there is one place in your station where you cannot risk uncertain results it is in your antenna.

The Palomar Engineers R-X Noise Bridge tells you if your antenna is resonant or not and, if it is not, whether it is too long or too short. All this in one measurement reading. And it works just as well with ham-band-only receivers as with general coverage equipment because it gives perfect null readings even when the antenna is not resonant. It gives resistance and reactance readings on dipoles, inverted Vees, quads, beams multiband trap dipoles and垂直s. No station is complete without this up-to-date instrument.

Why work in the dark? Your SWR meter or your resistance noise bridge tells you only half the story. Get the instrument that really works, the Palomar Engineers R-X Noise Bridge. Use it to check your antennas from 1 to 100 MHz. And use it in your shack to adjust resonant frequencies of both series and parallel tuned circuits. Works better than a dip meter and costs a lot less. Send for our free brochure.

The price is $49.95 and we deliver postpaid anywhere in the U.S. and Canada. California residents add sales tax.

Italy write i2VTT, P.O. Box 37, 22063 Cantu. Elsewhere send $52.00 (U.S.) for air parcel post delivery worldwide.

Fully guaranteed by the originator of the R-X Noise Bridge. ORDER YOURS NOW!

artwork transfer film for PC boards

Printed Circuit Products Company, of Helena, Montana, has produced a film that can be used to pick up artwork from printed pages and used for etching sensitized board. Called PCP Type-A, the film is easy to use. A protective backing is peeled off, then the clear film is pressed in place over the desired artwork. A blunt instrument is used to burnish the film into firm contact with the paper, and to remove all air bubbles. The combination is soaked in water until the paper softens and can be removed by rubbing, leaving the "print" on the film.

After the film has dried, the artwork is ready for use. Simply apply it over the surface of any sensitized pc board material in the normal manner, and expose, develop, and etch your own printed circuits.

The Type-A film eliminates the many phototographic processes that usually accompany transferring artwork from the printed page to a form useful in etching boards. Note, however, that the artwork does not change form in the process — it remains either negative or positive, just as it is printed.

PCP Type-A film can also be used to create custom decals for your equipment, relabel meter faces, dials, or panels. For more information and prices, write to Printed Circuit Products Company, P.O. Box 4034, Helena, Montana 59601.

Touch-Call encoder

Standard Communications has announced the availability of their new TT-1A Touch-Call encoder which can be mounted on the front of SCC Model C146A, C730L, and C830L hand-held transceivers. The unit uses the dual-tone multiple frequency (DTMF) system to enable the user to place remote telephone calls, obtain access to repeater systems, activate decoders in other transceivers, or to
perform other remotely controlled operations.

The tones generated are compatible with both the Bell and RCC radiotelephone requirements. The unit is solid state and generates two simultaneous audio tones between 600 and 1700 Hz. The digitally synthesized frequencies generated are nonharmonic and provide high immunity to falsing. The TT-1A requires 7.5 to 15 Vdc for operation, which is obtained from the battery pack in the hand-helds. These encoders may be used with the commercial versions of SCC's hand-helds, which cover 450 to 512 MHz or 148 to 174 MHz and the amateur radio 144 to 148 MHz model. See your Standard dealer or write Standard Communications Corporation, P.O. Box 92151, Los Angeles, California 90009.

Multicore Solder products

Multicore Solders, a leading worldwide supplier to aerospace, electronic, and industrial manufacturers has introduced a line of selected, professional-quality solders and soldering accessories specifically packaged for the technician, service man, home owner, hobbyist, and do-it-yourselfer. Included in the product line are multiple-core wire solders in a variety of alloys and/or flux formulations, solid wire solder, solder creams, an emergency solder, flux pastes, and a line of desoldering wick.
Among the different solder alloys offered are those for electronic, general-purpose electrical, and a number of nonelectrical applications including sheet-metal work, plumbing, aluminum, and even a solder specifically formulated for stainless steel and silver jewelry.

The packaging for each of the products has been carefully designed to provide the user with a functional and practical choice, depending on the quantity he plans to use as well as storage requirements. All packaging is printed with complete application and instructional data, and is color coded according to alloy for quick identification. Complete information on all these products is available from Multicore Solders, Westbury, New York 11590.

Whitehouse parts catalog
A new catalog is available from G. R. Whitehouse & Co. of Amherst, New Hampshire. It lists many of the parts for amateur projects which have been described in *Ham Radio*, *Ham Radio Horizons*, and other amateur literature.

A scan through the pages reveals such items as a kit of parts for noise bridges, transmatches, and computing SWR indicators. There are several pages of individual component listings, such as toroid coils, ferrite beads and rods, and an assortment of cores for the experimenter.

A number of Barker & Williamson items are carried by Whitehouse, including coaxial switches, air-wound coils, multi-band plate circuits for high-power final amplifiers, and attenuators and filters.

The catalog shows a good selection of variable capacitors, including those made by E. F. Johnson, James Millen, and some Cardwell and Hammarlund types. Another section displays Jackson Brothers dials and drives, James Millen knobs and shaft couplers, and aluminum cases.
There is also a large section listing the J. W. Miller inductors and the Cushcraft line of antennas and accessories.

To obtain your copy of this free catalog, write to G. R. Whitehouse & Co., 16 Newbury Drive, Amherst, New Hampshire 03031.

MAX-100 frequency counter

A new state-of-the-art LSI counting technology has enabled Continental Specialties Corporation to offer a competent frequency counter at a very good price. The counter, called MAX-100, delivers an accurate 8-digit display of frequencies from 20 Hz to 100 MHz. The crystal-controlled timebase features 3 ppm (parts per million) accuracy, and the counter updates the display every second.

The counter input includes a preamplifier which allows it to work with as little as 30 mV of signal. Diodes protect the input up to 200 Volts. Although it is a low-profile unit, the MAX-100 features large, bright, 15-mm (0.6-in.) digits. No range switch is necessary, because the least significant digit always represents 1 Hz. Leading zeroes are blanked, and over-range signals cause the most significant digit to flash.

The MAX-100 can be operated on internal alkaline or nickel-cadmium cells; or from automotive or 115-Vac power by using a battery charger or eliminator. All 8 digits flash to indicate a low battery condition, which permits extended battery life.

The input impedance of the counter is 1 megohm, shunted by 56 pF. Sine-wave sensitivity is rated at 30 mV RMS from 10 Hz to 50 MHz, 100 mV RMS to 80 MHz, and 300 mV RMS above. A number of accessories are...
Handymen! Hobbyists! DO-IT-YOURSELVERS!

Let Kester Solder aid you in your home repairs or hobbies. For that household item that needs repairing — a radio, TV, model train, jewelry, appliances, minor electrical repairs, plumbing, etc. — save money — repair it yourself. Soldering with Kester is a simple, inexpensive way to permanently join two metals.

When you solder go "First Class" — use Kester Solder.

For valuable soldering information send self-addressed stamped envelope to Kester for a FREE Copy of "Soldering Simplified".

ICOM programmablevhf marine radio

ICOM has announced a new addition to its Marine VHF radio line by introducing the ICOM M25D — similar in appearance and features to ICOM’s popular 25-channel M25. A key advantage of the ICOM M25D is its 25-channel diode-programmable system. The diode matrix in the M25D can be “programmed and re-programmed” to any 25 of the commercial, pleasure, or international Marine VHF channels, thus eliminating the need to buy expensive crystals when additional channels are required.

ICOM enjoys an industry-wide reputation for producing one of the most thoroughly sealed and weather-protected Marine VHF units on the market. Like the M25, the M25D features a unique single-piece, molded-aluminum-base construction, incorporating a series of O-ring seals and gaskets around the switches and case covers to provide the maximum protection of the internal electrical components. The speaker is protected from rain and moisture by a tough, water-resistant membrane. The transceiver also features safety memory to channel 16, automatic start on 16, pushbutton selection for both weather and channel 16, a locking mounting system, a 5-watt audio system, an automatic nighttime dimmer system, and a provision for external speakers.

The ICOM M25D, like the M25, is FCC certified under both Parts 81
and 83, as well as Canadian DOC certified for pleasure vessels and compulsory equipped commercial vessels. Learn more about the ICOM M25D by writing for a free brochure to: Icom-East, Suite 307, 3331 Towerwood, Dallas, Texas 75234; or in the western U.S., Icom-West, Inc., 13266 Northrup Way, Suite 3, Bellevue, Washington 98005.

**CW speaker system**

Skytec is offering a loudspeaker unit designed expressly for CW. Employing a unique, acoustic-chamber resonator, the Skytec CW-1 combines good single-frequency selectivity with a nice tone shaping characteristic.

By filtering right at the audio output, the unit suppresses hum, hiss, ringing, and miscellaneous noises left in the audio by most communications receivers. The CW-1 adds a remarkable degree of selectivity to any CW receiver, and it gives the best of receivers the most pleasant, "just right" bandpass for long contacts, net operating, and band scanning.

Priced at $19.95, the 8.9 x 16.55 cm (3-1/2 x 6-1/2 inch), 0.9 kg (2 pound) unit is shipped with a connecting cable. A front switch provides for bypassing the audio to the regular station speaker for other than CW reception. Skytec's ordering address is Box 535, Talmage, California 95481, or for more information contact Jim Bowles, W6DLO, at 707-462-6882.
quantities of quality

SOMETHING TO MAKE LIFE EASY: We carry AP test clips for both 14 pin and 16 pin ICs. Gold plated wiping action; sturdy pins for scope probes; also removes ICs from sockets without damage. Model TC-14 (14 pin), $2.40. Model TC-16 (16 pin), $4.75. We also carry the A.C.E. 201K breadboarding kit (with 1,032 solderless plug-in tie point capacity) for only $24.95.

SEMICONDUCTORS FOR THE EXPERIMENTER

<table>
<thead>
<tr>
<th>Component</th>
<th>Price</th>
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<tbody>
<tr>
<td>LM377</td>
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<td>LM666</td>
<td>$1.75</td>
</tr>
<tr>
<td>LM686</td>
<td>$1.85</td>
</tr>
<tr>
<td>UA706</td>
<td>$0.75</td>
</tr>
<tr>
<td>PET-1 DUAL NJFET, VN107HF, 1,000 units, $1.60</td>
<td></td>
</tr>
</tbody>
</table>

RF TRANSISTORS

(All specs for the following taken at 25 degrees C at 2 GHz)

#2NRF1 (3.45) $2 GHz power transistor. Pd max 3.5W, Pout minimum 1.0W, Pin 300 mW, efficiency 30%. Similar to RCA 2N5470.

#2NRF2 (5.55) $2 GHz power transistor. Pd 7.5W, Pout 2.5W, Pin 300 mW, efficiency 33%. Similar to RCA 2N5470.

#2NRF3 (8.85) $2 GHz power transistor. Pd 2W, Pout 5.5W, Pin 1250 mW, efficiency 33%. Similar to RCA 2N5470.

#2NRF4 (7.95) $2 GHz power transistor. Pd 2W, Pout 7.5W, Pin 1.5W, efficiency 33%. Factory selected prime 2N2936.

RF ICs

The “MAGICOM” RF processor module provides up to 6dB increase in output with smooth, clean, undistorted audio and more penetration for those pile-ups. Price $27.50

ENDORSED BY W6TOG AND BIG GUN DXers WORLD WIDE

Satisfaction Guaranteed or Money Refunded
All prices postpaid in Calif. add 6% sales tax - Mastercharge and Visa accepted

IT’S MAGIC—IT’S “MAGICOM” PROCESSOR MODIFICATION KIT

IMPROVES AUDIO PUNCH • IMPROVES PROCESSED SPEECH QUALITY

Converts TS-820 speech processor from RF compressor to RF clipper

The “MAGICOM” RF processor module provides up to 6dB increase in output with smooth, clean, undistorted audio and more penetration for those pile-ups. Price $27.50

ENDORSED BY W6TOG AND BIG GUN DXers WORLD WIDE

Satisfaction Guaranteed or Money Refunded
All prices postpaid in Calif. add 6% sales tax - Mastercharge and Visa accepted

uhf mobile antennas

A line of 5-dB gain uhf mobile antennas covering the 3/4 meter (420 MHz) frequency range and featuring simplified field tuning requirements has been introduced by Antenna Incorporated of Cleveland, Ohio.

Most 420 MHz antennas require the whip to be cut from the top and bottom for exact tuning. The Antenna Incorporated antennas feature a top sleeve which slides to adjust the upper portion of the whip, so only the bottom portion of the antenna needs to be cut for tuning.

These uhf antennas feature plated stainless-steel whips to make the antenna more conductive for reduced power loss, stainless-steel shock springs, and 17 feet (5 meters) of coaxial cable. They are available in 100- and 150-watt versions; the 150-watt models are supplied with Antenna Incorporated’s high-power cable which has electrical characteristics similar to RG-8/U but in a size similar to RG-59/U.

These antennas are available in a variety of mounting configurations, including hole mount, trunk-lip mount, cowl mount, and a mount which adapts to existing Motorola mounts. The 100-watt versions also are available with a spring-clip gutter mount.

“The simplified tuning process means there is less chance for error...
when the antenna is field-cut to exact frequencies,” sales manager Fried-
berg said. “Add to this the variety of mounting configurations we offer,
and these antennas are the fastest and simplest antennas to install.”

Further information on the new antennas, and the complete line of Antenna Incorporated communica-
tions antennas and accessories, is available from Antenna Incorporated,
26301 Richmond Road, Cleveland, Ohio 44146.

MFJ rf noise bridge

MFJ Enterprises has a new rf
noise bridge, model MFJ-202, which
allows quick adjustment, for maxi-
mum performance, of any antenna,
whether a single or multiband dipole,
inverted vee, beam, vertical mobile
whip, or random-wire system. It
indicates resonant frequency, radiation
resistance, and reactance of these
antennas, and also whether to short-
en or lengthen the antenna for mini-
mum swr over any portion of a band.

The MFJ rf noise bridge has a re-
sistance range of 250 ohms and a
wide capacitance range of ±150 pF
for reactance measurements. Included
is a unique range-extender that
shunts large unknown impedances
down to within the measuring range
of the noise bridge. In addition to
measuring antenna characteristics,
the noise bridge can be used to
tune transmatches, adjust tuned cir-
cuits, and measure inductance and
the rf impedance of amplifiers, baluns,
transformers, and other rf circuits. It
can also be used to determine elec-
trical length, velocity factor, and
impedance of coax cable. With a trans-
match and dummy load, it can syn-
thesize rf impedances for test pur-
poses.

MFJ provides a 30-day money back
trial period and a one year uncondi-
tional warranty.

The MFJ-202 RF Noise Bridge is
available from MFJ Enterprises for
$49.95 plus $2.00 shipping and han-
dling. To order call toll free 800-647-
8660 or mail order to MFJ Enter-
prises, P.O. Box 494, Mississippi
State, Mississippi 39762.

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waves, antennas, FM and plenty more. 490 pages. $1976.
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plains everything about OSCAR from concept to actual use.
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Radio newcomers with basic information on receivers, tran-
smitters, and antennas. It also explains how to obtain a British
amateur license. 118 pages. $1978.
- RS-GAR Softbound $3.95

RSGB MEMBERSHIP AND RADIO COMMUNICA-
TION (A monthly column) Become a member of the famous
Radio Society of Great Britain and you'll receive Radio Com-
- RS-RC Softbound $15.50

Information on MFJ Products now available from
Radio's Communications Storehouse
Greenville, NH 03048
REPEATER USERS — Stay in Touch — with DSI

UNIVERSAL TOUCH-TONE® ENCODERS

The Data Signal TTP Series of keyboard encoders is used to generate the standard 12 or 16 DTMF digits. The encoders provide fully automatic transmitter keying and feature a delayed Transmit Ready light, an interdigit timer, and a built-in audio monitor. Features also include all solid-state, crystal-controlled, digitally-synthesized tones and an optional internal mount Automatic Number Identifier (ANI).

TTP-1 (12-digit) $59.00
TTP-2 (16-digit) $69.00


*Touch-Tone is a registered trade name of AT&T.

SUB-MINIATURE ENCODERS

MODEL SME — Smallest available Touch Tone Encoder. Thin, only .05" thick; keyboard mounts directly to front of handheld portable; sub-miniature tone module fits inside. This keyboard allows use of battery chargers. Price SME (less keyboard) $24.00.

AUTOPATCH — Ready to go!

A Complete Autopatch facility that requires only a repeater and a telephone line. Features include single-digit access/disconnect, direct dialing from mobile or hand-held radios, adjustable amplifiers for transmitter and telephone audio, and tone-burst transponder for acknowledgement of patch disconnect.

RAP-200 P. C. Card $199.50
RAP-200R Rack Mount $249.50

You can't go wrong with a Mobile 2.

With 5/8 wave ready, all we left out was a high price. Now available in both 5/8 and 1/4 wavelengths, the Mobile 2 antennas are great for 2 meters, 220 MHz or 440 MHz bands.

The original Mobile 2 mounts to your trunk lid. The Mobile 2 magnetic grabs on almost anywhere, and stays put. Even when passing big trucks. Both antennas come with all cable, connectors and hardware in one package. Either way, you can't go wrong with a Kantronics Mobile 2.

magnetic $19.95
trunk $11.95

KANTRONICS The Lightweight Champs.

1202 East 23rd Street
Lawrence, Kansas 66044
Phone 913.842.9745
We accept Visa, Master Charge, check and money orders.
This new instrument has taken a giant step in front of the multitude of counters now available. The Opto-8000.1 boasts a combination of features and specifications not found in units costing several times its price. Accuracy of ±0.1 PPM or better — Guaranteed — with a factory-adjusted, sealed TCXO (Temperature Compensated Xtal Oscillator). Even kits require no adjustment for guaranteed accuracy! Built-in, selectable-step attenuator, rugged and attractive, black anodized aluminum case (.090" thick aluminum) with tilt bail. 50 Ohm and 1 Megohm inputs, both with amplifier circuits for super sensitivity and both diode/overload protected. Front panel includes "Lead Zero Blanking Control" and a gate period indicator LED. AC and DC power cords with plugs included.

**SPECIFICATIONS:**
- **Base—TCXO ±0.1 PPM GUARANTEED!**
- **Frequency Range**—10 Hz to 600 MHz
- **Resolution**—1 Hz to 60 MHz; 10 Hz to 600 MHz
- **Decimal Point**—Automatic
- **All IC's socketed (kits and factory-wired)**
- **Display**—8 digit LED
- **Gate Times**—1 second and 1/10 second
- **Selectbale Input Attenuation**—X1, X10, X100
- **Input Connectors Type**—BNC
- **Approximate Size**—3\'-\' x 7\'\'w x 6\'\'d
- **Approximate Weight**—2 1/2 pounds
- **Cabinet**—black anodized aluminum (.090" thickness)
- **Input Power**—9-15 VDC, 115 VAC 50/60 Hz or internal batteries
- **OPTO-8000.1 Factory Wired $299.95**
- **OPTO-8000.1K Kit $249.95**

**ACCESSORIES:**
- **Battery-Pack Option—Internal Ni-Cad Batteries and charging unit $19.95**
- **Probes:**
  - P-100—DC Probe, may also be used with scope $13.95
  - P-101—LO-Pass Probe, very useful at audio frequencies $16.95
  - P-102—High Impedence Probe, ideal general purpose usage $16.95
- **VHF RF Pick-Up Antenna-Rubber Duck w/BNC #Duck-4H $12.50**
- **Right Angle BNC adapter #RA-BNC $ 2.95**

**FC-50 — Opto-8000 Conversion Kits:**
Owners of FC-50 counters with #PSL-650 Prescaler can use this kit to convert their units to the Opto-8000 style case, including most of the features.
- **FC-50 — Opto-8000** Kit $59.95
- **FC-50 — Opto-8000F** Factory Update $99.95
- **FC-50 — Opto-8000.1 (w/TCXO)** Kit $109.95
- **FC-50 — Opto-8000.1F** Factory Update $149.95
- *Units returned for factory update must be completely assembled and operational*

**TERMS:** Orders to U.S. and Canada, add 5% to maximum of $10.00 per order for shipping, handling and insurance. To all other countries, add 10% of total order. Florida residents add 4% state tax. C.O.D. fee: $1.00. Personal checks must clear before merchandise is shipped.
HRCB's new LOG BOOK is here — and it is unquestionably the finest one you'll ever use. 80 big, double-sided pages of clear, legibly ruled stock, all spiralbound to lie flat for easy writing. More than 2000 entries give you twice the space for less money than the log book you are probably using now. Order yours today!

8-3/8" x 10-7/8", 80 pages.

ONLY $1.50 each (plus 40c shipping)

Send check, money order or charge card information:
Ham Radio's Communications Bookstore, Greenville, NH 03048
TEN-TEC CENTURY 21 GOES DIGITAL!

Century 21, the exciting 70-watt, 5-band CW transceiver that surprised everyone with its super performance and low cost, has another surprise for you. A second model with digital readout (and a mod kit for those who would like to convert their dial model). Both Models 570 and 574 have the same unique circuitry that has won raves from everyone — both have the same fine features:

- **Direct Frequency Readout (Model 574):** 5 red LED digits, 0.3" high, accurate to nearest 1 kHz. Model 570: marked in 5 kHz increments from 0-500 kHz. MHz markings for each band displayed, tuning rate typically 17 kHz per tuning knob turn.
- **Full Break-In:** Full Band Coverage on 3, 5, 7, 14, 21 MHz Bands, 1 MHz on 28 MHz Band.
- **70 Watts Input:** Total Solid-State. Receives SSB and CW. Receiver Sensitivity 1 µV. Instant Band Change. No Tune-up. Offset Receiver Tuning. 3-Position Selectivity. Adjustable Sidetone Level.

**THE RECEIVER:** Double-Direct-Conversion. Easy tuning. Just select the frequency and set the audio level. Excellent cross-modulation characteristics. Offset tuning so you can tune either side of zero beat to reduce QRM. Front panel control selects one of 3 selectivity curves: 2.5 kHz for SSB reception, 1 kHz for normal CW, and 500 Hz for when the QRM gets rough. Plus separate AF and RF controls, headphone jack, and built-in speaker.

**THE TRANSMITTER:** Total solid-state. Push-pull Class C final amplifier. Individual low-pass filters are switched into the antenna line to reduce unwanted radiations, minimize TVI. No tune-up needed when changing frequencies or bands. And full break-in allows incoming signals to be heard between transmitted characters. Now CW is real conversation!

**THE VFO.** Common to receiver and transmitter. Permeability tuned. Linear scale on model 570; 5-5.5 MHz basic frequency is crystal-mixed to the desired frequency so bandspread and stability are the same on all bands (crystals included for 3.5, 7, 14, 21, and 28-28.5 MHz segment of the 10 meter band).

**THE POWER SUPPLY.** Built-in, AC operated, and regulated. Monitors current demand, shuts down automatically when necessary for protection. Lighted input current meter shows proper Drive setting.

**MATCHING ACCESSORIES.** Model 277 Antenna Tuner/SWR Meter. Model 670 Electronic Keyer, 6-50 wpm, self-completing characters. Model 276 Calibrator for markers at every 25 and 100 kHz. Model 273 Crystal for 28.5-29 MHz. Model 1170 12 VDC Circuit Breaker for mobile operation of models 574 and 570.

574 Century 21 Digital Transceiver $399.00
570 Century 21 Non-Digital Transceiver $299.00
277 Antenna Tuner/SWR Meter $85.00
670 Century 21 Keyer $29.00
276 Century 21 Calibrator $29.00
273 Crystal for 28.5-29 MHz $5.00
274 Digital Mod. Kit for Model 570 $90.00
1170 DC Circuit Breaker $8.75

See both Century 21 surprises at your TEN-TEC dealer — or write for full details.

THE SECOND SURPRISE OF THE CENTURY: DIGITAL

![TEN-TEC CENTURY 21 DIGITAL TRANSCEIVER](image)
The Frequency-Agile FL-1 system is totally unique in that it will automatically scan the 280-3000 Hz audio spectrum, and when sensing interfering heterodynes, CW or RTTY signals, rejects them up to 40 dB.

### NOTCH-MODE OPERATION
During your SSB/SSTV operations, the Frequency-Agile FL-1 automatically scans, locks, and tracks interference within the 280-3000 Hz spectrum, and in a second or two reduces QRM up to 40 dB.

For CW/RTTY usage, fully INDEPENDENT control of bandwidth and center frequency provides rejection of interfering signals up to or greater than 40 dB.

### PEAK-MODE OPERATION
The SSB/SSTV operator, using the fully INDEPENDENT controls of the FL-1, can precisely tailor the audio response: reducing or eliminating adjacent channel splatter or SSTV QRM. The CW/RTTY operator can adjust bandwidth down to 25 Hz rejecting virtually all interference to the desired signal. Often, the AUTOMATIC and AFC features of the FL-1 are desirable when in this mode.

**$179.95**
- Made in England
- 1 full year warranty
- VISA/MasterCharge accepted

### GENERAL SPECIFICATIONS
- Size: 8" W, 3" H, 5.5" D
- Requires 9-16 VDC from either internal battery or external supply (not included)
- Installs easily in your audio line between your receiver and speaker
- Highest quality construction - 2 glass circuit boards, 8 ICs, 6 Transistors, 8 Diodes, 2 LEDs

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**THE PROFESSIONALS’**

**NEW MODEL COUNTERS**

**NEW**

- **CTR-2A**
  - 500 MHz
  - & 1 GHz

**NEW Period Measurement**

- 1 us to 1 sec.

The New Model CTR-2A Series Counters are designed and built to the highest standards to fulfill the needs of commercial communications, engineering labs and serious experimenters. With an accuracy of +0.0005% (oven option) the CTR-2A can handle the most critical measurements and is about half the cost of other commercial counters.

If you need a reliable counter at an affordable price, the CTR-2A is the answer.

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- TCXO Std. ± 2 ppm
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- 05) 10 sec. Time Base $5.00
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70 KHz to 160 MHz

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This Month's Special

BEARCAT 210... $249

SAY Electronic Power Supplies
Completely Regulated 13.8 to 20 volts dc, variable. Separate volt and amp meters. Dual protection against
over voltage and over current.

4 amp ......... $59.95
8 amp ......... $109.95
20 amp ....... $159.95

16 ELEMENTS — F9FT — 144 MHz

The 'Tonna' You've been hearing about

144/146 MHz SWR ≤ 1.2:1
17.8 dBi Wt. 4.4 kg.
50 ohms Horiz./Vert.
length 6.4 m. F/B ratio 22 dB
Side lobe attenuation >60 dB
Horizontal aperture 2 x 16° (-3 dB)
Vertical aperture 2 x 17° (-3 dB)

$55.95

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SPECIAL ORDERS WELCOME

TERMS: All prices FOB Houston. Prices subject to change without notice. All items Guaranteed. Some items subject to prior sale. Send letterhead for Amateur dealers price list. Texas residents add 5% tax. Please add postage estimate.

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17.8 dBi Wt. 4.4 kg.
50 ohms Horiz./Vert.
length 6.4 m. F/B ratio 22 dB
Side lobe attenuation >60 dB
Horizontal aperture 2 x 16° (-3 dB)
Vertical aperture 2 x 17° (-3 dB)

$55.95

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flea market

Electronic equipment hotline is a new classified advertising format for buying and selling professional, industrial, and surplus electronic equipment. Subscriptions $9/year, add $5 per word. Reproduction fee: 10c per word. Include return postage. Deadline October 19, 1978. Electronic Equipment Hotline, P.O. Box 4768, Panorama City, CA 91402.


Wanted: Hallicraft SX115 and Heath CW SSB filters. Andre, VE2BIT, 456 Route 138, St. Augustine, Quebec, Canada, GOA 3EO.

Porta Pak the accessory that makes your mobile really portable. $67.50 and $88.00. Dealer inquiries invited. P.O. Box 67, Somers, West, 53171.


Ham Radio Horizons, a super new magazine for the Beginner, the Novice and anyone interested in Amateur Radio. What it's all about, How to get started. The fun of ham radio. It's all here and just $10 per year. HURY HURY! Ham Radio Horizons, Greenville, NH 03048.

Free catalog of new merchandise. Resistors, capacitors, IC's, semiconductors, and more. Send to: Key Electronics, Box 356464, Schenectady, New York 12303.


Motorola HT220, HT200, and Pageboy service and modifications performed at reasonable rates. WA4FRR (602) 445-4389, evenings.

Authorized Dealer for Dentron, KLM, Larsen, Bearcat, etc. Big Catalog 201 962-4695 Narwad Electronics, 61 Belt Road, Ringwood, NJ 29546.

Reconditioned test Equipment for sale. Catalog $5.00. Walter, 2697 Nickel, San Pablo, CA 94806.

Teletypewriter parts wanted: for all machines manufactured by: Kienischmidt, Corp., Teletype Corp. and Mite. Any quantity, top prices paid send list for my quote. Phil Rickson, W4LWN, Rt. 6, Box 1173G2, Brooksville, FL 33512.


Osl cards 500/10, 400 illustrations, sample. Bowman Printing, Dept. HR, 743 Harvard, St. Louis, MO 63130.

Homebrewers: Stamp brings component list. CPO Surplus, Box 189, Braintree, Mass. 02184.

We may not have a toll-free number, but we'll save you more $$$ in the long run! This month's special: CMC Ham Heavy-Duty rotor for only $114.95, prepaid anywhere in the Continental United States! We are also factory-authorized dealers for Yaesu, Drake, Kenwood, Ten-Tec, ICOM, Denon, and many more. For the best deal around on the HF or VHF gear of your choice, write or call us today for our low quote. Try our personal, friendly Ham Service and become one of our many happy and satisfied customers. HOOSIER ELECTRONICS, P.O. Box 201, Terre Haute, Indiana 47802. (812) 236-1456.

Wanted - Millen I's 455 kc and 1600 kc - $61455 $61600 several needed. Also schematic for Mixers Dream Rec, Owen Laughlin, 1310 Pinecrest Dr., Eden, MI 48022.

Authorized distributor F9/FT Antennas, Microwave Modules, RFx Products' new temporal reflector, 19 element, 425 MHz Yagi - Radio Clinic - N2MB (formerly WA2BIT) (213) 327-8992.

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Quantech 303 Wave Analy $445

Tek65 Dual beam 10MHz scope less plug ins ... 625

Tek6580 80MHz gen ver scope less plugs $445

URAM25 Stand Sgn Gen 10kHz 50MHz calib attn ... 225

For complete list of all test equipment send stamped, self-addressed envelope.

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Specializing in used test equipment.
# Antenna Sale!

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<thead>
<tr>
<th>HY-GAIN</th>
<th>Regular</th>
<th>Special</th>
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<tbody>
<tr>
<td>TH6-DXX Super Thunderbird</td>
<td>$249.95</td>
<td>$209.95</td>
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<td>TH3-MK3 3 ele. 10, 15, 20 Mtr. beam</td>
<td>199.95</td>
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<td>Hy-Quad 2 ele. Quad 10, 15, 20 Mtr.</td>
<td>219.95</td>
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<td>TH3-Jr. 3 ele. 10, 15, 20 Mtr. beam</td>
<td>144.50</td>
<td>129.95</td>
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<tr>
<td>18 HT Hy-Tower 10-80 Mtr. Vertical</td>
<td>279.95</td>
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<td>14AVQ/WB 10-40 Mtr. Trap Vertical</td>
<td>67.00</td>
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<td>18AVT/WB 10-80 Mtr. Trap Vertical</td>
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<td>203 3 ele. 2 Mtr. beam</td>
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<td>205 5 ele. 2 Mtr. beam</td>
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<td>208 8 ele. 2 Mtr. beam</td>
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<td>214 14 ele. 2 Mtr. beam</td>
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<td>Classic 33 3 ele. 10, 15, 20 Mtr. beam</td>
<td>232.50</td>
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<td>Classic 36 6 ele. 10, 15, 20 Mtr. beam</td>
<td>310.65</td>
<td>249.95</td>
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<td>TA-33 3 ele. 10, 15, 20 Mtr. beam</td>
<td>206.50</td>
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<td>TA-36 6 ele. 10, 15, 20 Mtr. beam</td>
<td>335.25</td>
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<td>TA-33 Jr. 3 ele. 10, 15, 20 Mtr. beam</td>
<td>151.85</td>
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<td>TA-40KR 40 Mtr. add on</td>
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<th>CUSHCRAFT</th>
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<td>ATB-34 4 ele. 10, 15, 20 Mtr. beam</td>
<td>259.95</td>
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<tr>
<td>ARX-2 2 Mtr. Ringo Ranger</td>
<td>36.95</td>
<td>32.95</td>
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<tr>
<td>A147-20T 2 Mtr. Twist</td>
<td>59.95</td>
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<td>A144-10T 10 ele. Twist 2 Mtr.</td>
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<td>32.95</td>
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<td>A144-20T 20 ele. Twist 2 Mtr.</td>
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<th>HUSTLER</th>
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<td>4BTV 10-40 Mtr. Trap Vertical</td>
<td>99.95</td>
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<td>RM-75 75 Meter Resonator</td>
<td>15.50</td>
<td>13.50</td>
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<tr>
<td>RM-75s 75 Meter Super Resonator</td>
<td>30.00</td>
<td>26.50</td>
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<tr>
<td>G6-144-A 6 db. 2 Mtr. Base Collinear</td>
<td>67.55</td>
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<td>System One 5 ele. 10, 15, 20 Mtr. beam</td>
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<td>239.95</td>
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<td>System Two 4 ele. 10, 15, 20 Mtr. beam</td>
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<th>CDE ROTORS</th>
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<tr>
<td>Ham III</td>
<td>$125.00</td>
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<tr>
<td>T2X Tail Twister</td>
<td>$249.00</td>
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<tr>
<td>CD-44</td>
<td>$105.00</td>
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If you'd like to become a member of our amateur radio design team, if you'd like to have the satisfaction of knowing you designed the rig that the OM on the other end of the QSO is so proud of — if you'd like to become one of the hams at Heath — then we'd like you to contact us. We're looking for graduate EE's who have specialized in HF and VHF Communications equipment design, with from one to four years of practical, proven design experience behind them. If this is the kind of opportunity you've been looking for, send your resume and salary history to Ken Smith, Professional Employment, at:

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Coming Events

ALASKA: ARRL Convention, Anchorage, August 26, 27. Write: ARRL Alaska Convention 76, Anchorage ARC, P.O. Box 1987, Anchorage, AK 99510.

WIMU (Wyoming, Idaho, Montana, Utah) The 46th Annual WIMU Hamfest is scheduled for August 4, 5, and 6, 1978 at Mack's Inn. Idaho; 25 miles South of West Yellowstone, Montana. Talk-in 146.34/94 and 3935. Advance registration: $6.00 for adults and $2.00 for children, before July 15th. Pre-registration registration: $7.00 and $2.50. SPECIAL PRIZE DRAWING FOR PRE-REGISTRATION. Please send pre-registration to: WIMU Hamfest, 3845 Vaughn Street, Idaho Falls, Idaho 83401. Phone (208) 522-9566.

ILLINOIS: Fox River Radio League Hamfest Sunday, August 27, 1978 Kane County Fairgrounds Exhibition Hall, St. Charles. 8:00 AM - 5:00 PM. Commercial exhibits & sales, used equipment market, raffle drawing; 1st prize: Kenwood TS-520 S Transceiver; 2nd prize: Midland 13-500 Transceiver. Door prizes. Motorhome camping. Admission — Raffle Ticket $1.00 advance, $2.00 gate. For information & Tickets Contact: Don Berridge WBPAP — 2303 Deerfield Way, Geneva, IL 60134. Telephone: (312) 232-8093. Talk-in frequency — 146.94 Simplex (7:00 AM to 3:00 PM).

NEW JERSEY — The 550 Amateur Radio Club annual flea market Saturday, August 26, 1978 9:00 AM to 5:00 PM American Legion Hall, Oak Street, Oakland, N.J. Admission $1.00, tables $3.00, tailgate $2.00. Talk-in WR2AHD 147.49/146.49 or simplex 146.52. Dealers invited. Refreshments. For information or table reservations, write 550 ARC, P.O. Box 364, Oakland, N.J. 07436, attention Mark Kirschen — WA2HL (201) 337-3259.

IOWA: 75 Meter Net's annual Potluck picnic and hamfest Sunday, August 20, Riverside Park, Marshalltown. Awards and prizes. Love, L0BBFF.

INDIANA: The Delaware Amateur Radio Association hamfest 8:00 AM until 5:00 PM, Saturday, August 12, Springwater Park, east of Muncie on Country Club Road. Hourly prize drawing from 10:00 AM until 4:00 PM, grand prize drawing at 4:00 PM. Flea market. Admission $1.50 8:30-10:00 AM; $2.00 10:00-12:00; $2.50 12:00-1:30. Talk-in on 147.25.50 simplex. Tickets $1.50 advance, $2.00 gate. Send check and SASE to: P.O. Box 3021, Muncie, IN 47303.

SPECIAL EVENT: Miss America Pageant, Atlantic City, N.J. Station K2BR. Dates: Sep. 1 to 10, 1978; Approx. frequencies: CW, 3555, 3055, 14055, 21055; Phone: 3935, 7235, 14280, 21380; Novice: 3730, 71730, 21130. QSL Info to K2BR. Operation from Atlantic City Convention Hall. Traffic to and from Contestants will be welcome. This station is sponsored by the Southern Counties Amateur Radio Association.

MICHIGAN: Hamfest! Aug. 6, Saline Fairgrounds — table and trunk sales, food, prizes. Talk-in 146.3797 and 146.52. General info, advance tickets, table reservations — write Arrow, Box 1972, Ann Arbor, MI 48106.

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Famous "W2AU" Balun

MODEL 1: $14.95
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Yes, we are amateurs personally. But no, we're definitely not amateurs when it comes to engineering the most sophisticated, most dependable amateur transceivers, antennas and accessories available.

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FOX RIVER RADIO LEAGUE HAMFEST New Location: indoors at Kane Co. Fairgrounds, St. Charles, IL. Sunday, August 27th. Tickets: $2.00 at gate - $1.50 advance. Contact: Don Berndt W9BAP, 2303 Deerfield Way - Geneva, IL 60134.

MANSFIELD, PA - The Tioga County PA ARC Hamfest will be held Saturday, August 28th starting at 8:00 AM at the Tioga Co. Fair Grounds on Rt. 6 between Wellsboro and Mansfield, PA. The $2 admission is good for all special programs and the XYL and children are free. In addition to the usual Flea Market and displays a bingo table and other items of interest will be available for the ladies and the PA Grand Canyon is within a short distance. Talk-in on 19/75, 52 Sim., and CB 5. For more information write to Dennis Voorhees, WA3FWQ, RD #2 - Box 117A, Millerton, PA 16936.


CONN. WELI ARC 2nd Annual Flea Market & Auction Sunday, August 29 from 8:00 AM - 4:00 PM at Farmington Golf Club, 70 Farmington Road, Farmington, CT. Admission $5.00 for adults, $2.00 for under 12. Contact: John McQuilken, W1EF, 1 Frisbee Rd., Transco, MA 01376.

NORTH ALABAMA HAMFEST Sunday, August 20, 1978 at The Mall in Huntsville, AL. Prizes, catalog, ARRL forum, MARS meetings, ladies activities. Hamfest supper on Saturday night. For more information: N.A.H.A., P.O. Box 423, Huntsville, AL 35804.


INDIANA: LaPorte County Summer Hamfest, Sunday, August 27, LaPorte County Fairgrounds, LaPorte. Dealers 9:00 AM. Public 8:00 AM. 5 miles southeast of Chicago on Indiana #2. Talk-in on 01/61, 31/76 and 52 simplex. Donation $2.00 at gate. For more information: LFARC, P.O. Box 30, LaPorte, IN 46350.

PENNSYLVANIA: The Beaver Valley Amateur Radio Association's first annual hamfest Saturday, August 19, 9 AM to 5 PM at Brady's Run Park, 5 miles north of Rochester, PA on Route 31. Tickets: advance $3.00 or $3.50 at the door. 2:30 PM Gala Dinner tickets $4.50. For more information write to David B. W8NR, 2401 Linda Ln., Beaver, PA 15009.

PENNSYLVANIA: South Hills Brass Pounders and Modulators 41st Hamfest. Saturday, August 6, noon to dusk, Mt. Pleasant, PA. For more information write to Melvin K. W2QZ, 415 Old School Rd., Mt. Pleasant, PA 15666.

ELMIRA, NEW YORK HAMFEST - September 30th from 9-5. Door prizes, grand prize, Flea Market, tech talks, and more. Contact: W2KU, John Breslin, 340 West Avenue, Elmira, New York. 14903 for tickets and info.

OHIO: 21st Annual Warren ARA Hamfest. Sunday, August 20, Trumbull KS Campus, Ohio Rd. 45 at Warren. Dealers 7 AM - 5 PM, Public 8 AM - 5 PM. Contact Don Smith, WA1RTH, 324 East Warren St., Warren, OH 44481.

ARKANSAS: Little Rock Ham-A-Rama, August 5-6, Arkansas State Fair Grounds, Little Rock. Air conditioned building. Flea market. Hourly door prizes, grand prize for $1.00 registration. Registration $2.00. Contact: Don Gough, WB8STK, P.O. Box 2844, Little Rock, AR 72203.

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NEW YORK: Mt. Beacon ARC 5th Annual Hamfest, Saturday, August 19th, 9AM to 5PM at Stewart Field, Newburgh. Talk-in 3789 and 52. Admission $2.00. Dealer box $2; under 12 free. Additional information: Ron Perry, WA2GZA, RD 1, Glen Ave., Fishkill, N.Y. 12542.

VIRGINIA: 2nd Annual Bristol ARC Hamfest, August 19 and 20, 9AM to 5PM at Washington County Fair Grounds, Route 11, Abingdon. Admission $1.00, flea market $2 extra. Talk-in 01-61 and 07-67. For info send SASE to WD4ECL Bowery, 77 Bondwine Rd., Bristol 24000, (703) 689-3086.

OHIO: 42nd Annual Cincinnati Hamfest — Sunday, September 17, 1978 at Stricker’s Grove on State Route 128, one mile west of Ross (Venice) Ohio. Exhibits, Prizes, Good Food, Refreshments, Flea Market (radio related products only) Music. Good Fellowship, Hidden Transmitter Hunt and Sensational Air Show. No increase in cost, same as last year — $7.50 in advance. For further information: Lillian Abbott, KBCKI, 1424 Main Street, Cincinnati, Ohio 45210.


PENNSYLVANIA: 3rd Annual York County Hamfest, September 15, US 220 Exit at Thomsen Airport. 10 mile drive, 1 mile west of York. 8:00 AM to 6:30 PM. Registration $3.00. YLs and children free. Tailgate $1.00 per space extra. Talk-in 146.375, 146.525, 147.833. Fly-ins to site. Self-contained campers. Display tables under roof by advance registration. Caterer: Contact Leroy Frey, KSPGR, 175 S. Albemarle St., York, PA 17403. (717) 954-1203.

INDIANA: Tippecanoe Area Hamfest, Sunday, August 20, Tippecanoe County Fairgrounds, Lafayette, 18th Street at Teal Road (Indiana Highway 25). Flea market setups after 6:00 PM Saturday. Sunday gates open at 8:00 AM. Camping on grounds. Unlimited electricity, Friday through Sunday night. Major pre-registration and attendance prizes. Tickets $2.00 — mail or gate. Talk-in 146.375. More info — Bill Zins, WA2OHT, 3327 S. Albermarle St., York, PA 17403.

KENTUCKY: The Lexington Bluegrass Amateur Radio Club Annual Hamfest Aug. 13th starting 8:00 AM at the National Guard Armory near Bluegrass Field. Talk-in on 146.5 MHz. Large indoor exhibit area, outdoor flea market. Major prizes, forums, refreshments, free parking. Advance tickets $2.50, $3.00 at door. Flea market space $1.00 extra. For information: Paul Heflin, WA4PAB, 43 Potomac Dr., Lexington, KY 40503. Phone: (606) 278-0646.

WEST VIRGINIA: Jackson County ARC's 2nd Annual Hamfest, West Virginia FFA/FHA Conference Center, Ripley, Sunday, August 13. Just off interstate 77 at Ripley. For information: Robert D. Morris, WA8CTO, JCARC, 628 Church St. South, Ripley, West Virginia 25271.

NEW JERSEY: South Jersey Radio Assn Hamfest is Sept. 10, 1978 rain or shine at Ellingsbury Shopping Center, Cherry Hill N.J, at intersection of routes 41 and 70. Family registration $2.00 Flea market, auction, & activities. Many prizes. Talk-in 52. Contact K2KA, Box 2726, Cherry Hill, N.J. 08002. Tel: (609) 429-0832 for info.

HAMEFFEST 4TH ANNUAL PINDIC & HAMMUCK HAMFEST, Sunday, August 13, 1978 at Santa Fe Park, 31st and Wolf Road, Willow Springs, Illinois, Southwest suburb of Chicago. Exhibits for OM's and XYL's. FAMOUS SWAPPERS TMRD and 100 vendors. Start time 8:00 AM. Advance tickets $2.00. For Hamfest info or Advance Tickets (send check or money order — SASE appreciated) to Bob Hayes W9KXW, 19837 Cedar Ave., Country Club Hills, IL 60417.

FLORIDA: Five Flags ARA's Annual Ham-A-Rama, September 3, University of West Florida field house, Pensacola. Write: FFARA, P.O. Box 17343, Pensacola, FL 32522.

OHIO: Union County ARC Hamfest, Sunday, August 27, Plain City Fairgrounds, Plain City. Tickets: $1.50 advance, $2.00 at door. Refreshments, free flea market, overnight camping Saturday, inside tables for dealers. Talk-in on 146.55. NEW! Fee: Gene Kirby, WRB5Z. Sec'y, 13813 U.S. 36, Marysville, OH 43040. SASE please.

MINNESOTA: Central States VHF Contest, August 17, 18, and 19 at 20, 1978 at the Midway Motor Lodge, Rochester, Minnesota. Antenna gain measurements, speakers, entertainment, banquet, and prizes. Plus much more that you cannot afford to miss. Send registration immediately to: Terry Van Benschoten, W5VB, 2326 NW 111th, Safari, Minnesota 55601. FHA Tours reservations call (507) 386-8696. For information, call Ed, (507) 265-2604 (home) or (507) 253-3090 (work); and Terry (507) 386-1496 (home) or (507) 286-0568 (work). Central States VHF NET Sunday night 8:30 Central time on 3818 kHz. Rochester repeater on 146.622.

FLORIDA: Jacksonville Hamfest, August 5th and 6th at the Jacksonville Beach Municipal Auditorium. Doors open 8:00 AM. Advanced registration $25.00, $5.00, Ladies and children with registered amateur admitted free. Activities include commercial exhibits. ARRL forum, QWA meeting, DX forum, antenna forum, computer seminar and much more that you must see to believe! For more information, write: Jacksonville Hamfest Association, 911 Rio St. Johns Dr., Jacksonville, Florida 32211. Telephone (904) 744-9501.


CALIFORNIA: Microcomputer Net on W6KCV (146.2688) Mt. Oso, Sunday nights at 900. Listen for N6HF. Beginners welcome.

OHIO: Cleveland Hamfest; come for the fun on September 9th from 800 AM to 6:00 PM at Canton Fairgrounds, Berea, Ohio. Talk-in on 146.52 simplex: $2 admission. Write to: Cleveland Hamfest Association, P.O. Box 27211, Cleveland, OH 44117.


ILLINOIS: Rockford ARA Hamfest and ARRL State Convention, September 10, 1978, Winnebago County Fairgrounds, Pecatonica, 10 miles west of Rockford on U.S. 20. Low cost camping, inside tables available $3. Snack bar (free camping (electrical hookup $4). Prizes, microcomputer seminar, ARRL technical discussion, OSCAR presentation, contest talk, Midwest Country Cousins meeting, many others. Come one, come all for FUN! Talk-in on 146.0681 and 146.52 simplex. Tickets $1.50 advance, $2 at door. SASE to Rockford Amateur Radio Association, P.O. Box 500, Rockford, Illinois 61110.

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<td>$301 - $1000</td>
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NEW TOLL FREE PHONE 800-528-1417
Now phone in your orders no charge (minimum phone order $15.00)
Or mail in your order — no minimum on mail orders

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We DO NOT sell surplus, retests or other low quality parts. Make up your order from this AD and our current catalog and phone it in today — Operators on duty 9 AM to 6 PM MST.

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7404 .18 CD4011 23
7406 .18 CD4012 39
7410 .30 CD4016 45
7412 .18 CD4017 70
7414 .25 CD4020 90
7416 .79 CD4023 23
7418 .50 CD4025 45
7420 .35 CD4026 90
7423 .35 CD4029 90
7425 .65 CD4046 .125
7429 .39 CD4049 .45
7430 .39 CD4050 .45
7432 .39 CD4051 .70
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7404 .18 CD4011 23
7406 .18 CD4012 39
7410 .30 CD4016 45
7412 .18 CD4017 70
7414 .25 CD4020 90
7416 .79 CD4023 23
7418 .50 CD4025 45
7420 .35 CD4026 90
7423 .35 CD4029 90
7425 .65 CD4046 .125
7429 .39 CD4049 .45
7430 .39 CD4050 .45
7432 .39 CD4051 .70
7434 .45 CD4069 .23
7436 .45 CD4071 .23
7439 .79 CD4081 .23
7440 .79 CD4511 .95
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7443 .69 MC14410 9.28
7444 .69 MC14419 3.26

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7404 .18 CD4011 23
7406 .18 CD4012 39
7410 .30 CD4016 45
7412 .18 CD4017 70
7414 .25 CD4020 90
7416 .79 CD4023 23
7418 .50 CD4025 45
7420 .35 CD4026 90
7423 .35 CD4029 90
7425 .65 CD4046 .125
7429 .39 CD4049 .45
7430 .39 CD4050 .45
7432 .39 CD4051 .70
7434 .45 CD4069 .23
7436 .45 CD4071 .23
7439 .79 CD4081 .23
7440 .79 CD4511 .95
7441 .70 CD4518 .85
7442 .70 MC14409 9.95
7443 .69 MC14410 9.28
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Finally! Superior 8-Pole CW Selectivity for Drake TR-4, TR-4A, TR-4C
SST T-1 RANDOM WIRE ANTENNA TUNER

All band operation (160-10 meters) with any random length of wire. 200 watt output power capability—will work with virtually any transceiver. Ideal for portable or home operation. Great for apartments and hotel rooms—simply run a wire inside, out a window, or anywhere available. Efficient toroid inductor for small size: 4-1/4" x 2-3/8" x 3", and negligible loss. Built-in neon tune-up indicator. SO-239 connector. Attractive bronze finished enclosure.

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THE ORIGINAL Random Wire Antenna Tuner... in use by amateurs for 6 years

SST T-2 ULTRA TUNER

Tunes out SWR on any coax fed antenna as well as random wires. Works great on all bands (80-10 meters) with any transceiver running up to 200 watts power output. Increases usable bandwidth of any antenna. Tunes out SWR on mobile whips from inside your car.

Uses efficient toroid inductor and specially made capacitors for small size: 5-1/4" x 2-1/4" x 2-1/2". Rugged, yet compact. Negligible line loss. Attractive bronze finished enclosure. SO-239 coax connectors are used for transmitter input and coax fed antennas. Convenient binding posts are provided for random wire and ground connections.

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Matches 50 ohm coax to the lower impedance of a mobile whip or vertical. 12-position switch with taps spread between 5 and 50 ohms. Broadband from 1-30 MHz. Will work with virtually any transceiver—300 watt output power capability. SO-239 connectors. Toroid inductor for small size: 2-3/4" x 2" x 2-1/4". Attractive bronze finish.

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1 watt input gives you 15 watts output across the entire 2 meter band without re-tuning. This easy-to-build kit (approx. 1/2 hr. assembly) includes everything you need for a complete amplifier. All top quality components. Compatible with all 1-3 watt 2-meter transceivers. Short and open protected—not damaged by high SWR.

Kit includes:
- Etched and drilled G-10 epoxy solder plated board.
- Heat sink and mounting hardware. All components—
  including pre-wound coils.
- Top quality TRW RF power transistor.
- Complete assembly instruction with details on a
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only $29.95

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GUARANTEE

All SST products are guaranteed for 1 year. In addition, they may be returned within 10 days for a full refund (less shipping) if you are not satisfied for any reason. Please add 82 for shipping and handling. Calif. residents, please add sales tax. COD orders OK by phone.

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<thead>
<tr>
<th>State</th>
<th>Dealer Name</th>
<th>Address Details</th>
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<tr>
<td>Iowa</td>
<td>BOB SMITH ELECTRONICS</td>
<td>RFD #3, HIGHWAY 169 and 7 FT. DODGE, IA 50501</td>
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<td>For an EZ deal.</td>
</tr>
<tr>
<td>Kansas</td>
<td>ASSOCIATED RADIO</td>
<td>8012 CONSER P. O. B. 4327 OVERLAND PARK, KS 66204</td>
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<td>Amateur Radio’s Top Dealer. Buy — Sell — Trade</td>
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<td>Kentucky</td>
<td>COHOON AMATEUR SUPPLY</td>
<td>HIGHWAY 475 TRENTON, KY 42286 502-886-4535</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yaesu, Ten-Tec, Tempo, DenTron. Our service is the BEST.</td>
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<td>Maryland</td>
<td>THE COMM CENTER, INC.</td>
<td>9624 FT. MEADE ROAD LAUREL PLAZA RT. 198 LAUREL, MD 20810 301-792-0600</td>
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<td>R.L. Drake, Ten-Tec, Icom, Wilson, Tempo, DenTron, Mosley, Cushcraft</td>
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<td>PROFESSIONAL ELECTRONICS CO., INC.</td>
<td>1710 JOAN AVENUE BALTIMORE, MD 21234 301-661-2123</td>
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<tr>
<td></td>
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<td>A professional place for amateurs. Service-sales-design.</td>
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<td>New Jersey</td>
<td>ATKINSON &amp; SMITH, INC.</td>
<td>17 LEWIS ST. EATONTOWN, NJ 07724 201-542-2447</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ham supplies since &quot;55&quot;.</td>
</tr>
<tr>
<td>Nevada</td>
<td>COMMUNICATIONS CENTER WEST</td>
<td>1072 RANCHO DRIVE LAS VEGAS, NV 89106 800-634-6227</td>
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<tr>
<td></td>
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<td>Kenwood, Yaesu, Drake and more at discount prices.</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>ECONOMIC DISTRIBUTORS</td>
<td>1960 PECK STREET MUSKEGON, MI 49441 616-726-3196</td>
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<td></td>
<td></td>
<td>Dealer for all major amateur radio product lines.</td>
</tr>
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TOWN & COUNTRY CONVENTION CENTER

1978 ARRL NATIONAL CONVENTION, SAN DIEGO, CALIF. SEPT. 22-24, 1978

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NAME ........................................... CALL ............
STREET ............................................
CITY ............................................. STATE............ ZIP ............

MAKE NAME BADGES AS BELOW

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ADVANCE REGISTRATION WITH BANQUET (Ladies & Regular) ........................................ $19.00
ADVANCE REGISTRATION ONLY ...................................................................................... $6.00
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3.900 MHZ
146.04-.64 MHZ
147.75-.15 MHZ

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TOWN & COUNTRY HOTEL
500 HOTEL CIRCLE
SAN DIEGO, CA 92108 (714) 291-7131

NOTES: Only a limited number of banquet tickets will be sold at the door. Be sure to state you are attending the ARRL Convention when requesting hotel reservations. Cut off date for guaranteed reservations is Sept. 7, 1978. Please check your preference for breakfast Sunday, Sept. 24: //DX// QCWA//WCARS//FM//MARS//TRAFFIC//WPSS. Breakfast tickets will be sold Sat., Sept. 23 in the registration area. Breakfasts and prices will be controlled by the sponsoring group. Breakfasts held will depend on sponsors and your interest. Requests for refunds must be postmarked prior to Sept. 15, 1978.

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**ALLOW 4 TO 6-WEEK DELIVERY ON PRE-BUILT UNITS**

In the past when your YAESU or KENWOOD dealer said the CW filter for your set was optional you had a choice. Buy one of his standard units — or do without.

**NO LONGER!**

Now FOX-TANGO not only offers filters similar in bandwidth to those supplied by your set's manufacturer, but also sharp eight-pole, 250 Hz bandwidth filters with superior shape factors at an unbeatable price — some similar units are being advertised for $100! And even so, they are not as sharp.

**BUT THAT'S NOT ALL!**

Yaesu's CW filters for the FT-101, FR-101 and FT-301 Series have a bandwidth of 600 Hz. Most hams feel 600 Hz is too wide for today's conditions, but that's not the only reason they find the going rough when the band is crowded. Not only are our filters eight-pole, but they have a superior shape factor and 500 Hz bandwidth. Ideal for tuning ease, yet sharp and selective enough to cut through all but the heaviest QRM. And for the Kenwood CW enthusiast FOX-TANGO now offers, in addition to the sharp eight-pole 250 Hz units for the TS-520, R-569, and the TS-820 Series, new eight-pole 400 Hz filters with characteristics superior to those of the regular Kenwood 500 Hz units.

**SOME REAL OPTIONS**

But talk about FREEDOM OF CHOICE! Inexpensive, easily installed diode-switching boards are now available for all the above sets which permit the addition of up to two crystal filters in addition to those for which the manufacturer provides space. For example, if you have no CW filter at present or are just buying your set (which never comes with the filter factory-installed) you can select either of our superior units, secure in the knowledge that you can add the other later if you wish. Or if your rig already has a standard CW filter installed, you can add our sharp unit so that either can be switch-selected often using existing front panel controls. Just imagine! Null your rare DX with the standard-type filter and cut out the crud and crowd with the flip of a switch. Now that's OPERATING!

**HOW WE DO IT!**

Some hams have wondered how we can offer superior filters at such a low price. And they are superior, not only on the basis of laboratory tests but according to members of the International Fox-Tango Club who have used them in their rigs for many months. The answer to the "low price" question is that these filters are made for us in Japan by a concern with almost a quarter-century of experience in the design and production of these units, among others, for use in the best-known and most respected brands of both amateur and commercial gear. In the past their filters were sold exclusively to manufacturers. Now they are being offered at retail for the first time — and at introductory prices — through our organization only.

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Our Filters are sold on a Money-back Guarantee Basis.

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**DIODE SWITCHING BOARDS** permit easy mounting without drilling up to two crystal filters of any type in addition to those for which the manufacturer provides space. These boards will accommodate any of the filters listed below and other types planned for the future. They include one stage of amplification to compensate for filter insertion losses, if desired. Complete instructions.

**SPECIFY**

Set with which board is to be used. $15 with purchase of any filter $20 without filter. Airmail Ppd. US & Canada. Overseas add $1.

**ALL TYPES**

| Only $50 | Airmail Ppd. US & Canada. Overseas add $1 |

**Circle type desired.**

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<td>State</td>
</tr>
<tr>
<td>MC 4 digit no.</td>
<td>Zip</td>
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I enclose $ (Make checks payable to FTC)

I prefer to charge my 

Florida residents add 4% Sales Tax.

More Details? CHECK — Off Page 126
**Famous Hamtronics Preamps**

Let you hear the weak ones!

Great for OSCAR, SSB, FM, ATV. Over 10,000 in use throughout the world on all types of receivers.

<table>
<thead>
<tr>
<th>Kit</th>
<th>Price</th>
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<tr>
<td>P9 Kit</td>
<td>$12.95</td>
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<tr>
<td>P14 Wired</td>
<td>$24.95</td>
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**F9 Kit**

Deluxe VHF model for applications where space permits.

- 1-1/2 x 2" covers any 4 MHz band
- 12 Vdc
- Ideal for OSCAR
- Diode protection
- 20 dB gain

**Other frequencies available**

- VX2-5 28-29 = 145-146
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**New VHF & UHF Converter Kits**

let you receive OSCAR signals and other exciting SSB, CW, & FM activity on your present HF receiver.

either one

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Including crystal

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Build up your own gear for OSCAR CW, HF repeaters, control links

- Professional sounding audio
- Free of spurs
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- Built-in testing aids

**VHF/UHF FM RCVR Kits**

- New generation receivers
- More sensitive
- More selective (70 or 100 dB)
- Commercial grade design
- Easy to align with built-in test kits
- Lower overall cost than ever before

**RF Power Amplifier Modules for Above**

- No tuning
- VSWR Protected
- Wired and Tested
- Rated for Continuous Duty
- Great for Repeaters

<table>
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<tr>
<th>Model</th>
<th>RF Range (MHz)</th>
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<td>C50</td>
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<td>28-30</td>
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<td>C146</td>
<td>146-148</td>
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<td>C110</td>
<td>Aircraft</td>
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</tr>
<tr>
<td>C220</td>
<td>220 band</td>
<td>28-30</td>
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<tr>
<td>Special</td>
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- Completely Stable
- Built-in testing aids

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Hamtronics, Inc.

182-C Belmont Rd; Rochester, NY 14612
ALL-MODE VHF amplifiers

FOR BASE STATION & REPEATER USE

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<thead>
<tr>
<th>MODEL</th>
<th>INPUT</th>
<th>OUTPUT</th>
<th>PRICE</th>
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<td>V135</td>
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<td>V180</td>
<td>8-15W</td>
<td>180-200W</td>
<td>$525</td>
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Universal 19" Rack Mount $25

• 143-149 MHz No Tuning
• AM - FM - CW - SSB
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- Antenna Impedance: 50 ohms unbalanced
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- DC 13.8 Volts, negative ground

Power Consumption: AC Receive 30 VA
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- DC Receive 1.2 Amps Transmit 6.5 Amps

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- Weight: Approximately 9 kg

Receiver
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- FM 0.35 uV for 20dB QSB
- AM 1.0 uV for 10dB S/N
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