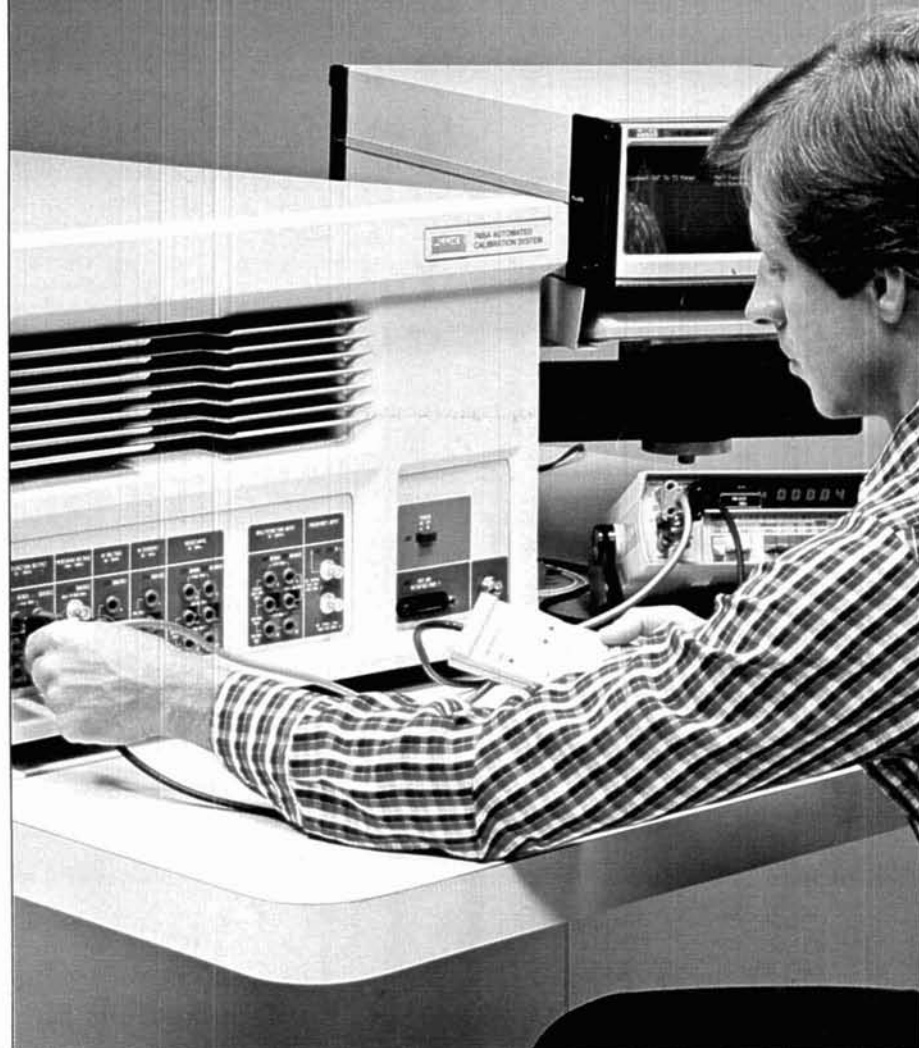


# *ham radio* magazine

- amplifying your ht
- vacuum tube substitution
- 1750 meter operation
- rf synthesizers
- vertical phased arrays
- hybrid types explained

*BACK TO BASICS:  
DEFINING AMPS, VOLTS, AND OHMS*



**hr**

focus  
on  
communications  
technology

# ICOM IC-45A

## Compact 440 — 449.995 MHz Mobile



**IC-45A**  
440-449.995 MHz Mobile  
10 Watts

**10 watts / 5 memories / 2 scanning systems in a 2"H x 5½"W x 7"D size / optional tone encoder / touchtone® microphone make the IC-45A the most popular 440-449.995 MHz mobile transceiver.**

**Dual VFO's.** Dual VFO's give an extra stored frequency for scanning (memory scan scans 5 memories plus 2 VFO's) and each VFO has a different tuning rate for easy QSY.

**Optional Encoder.** Plug-in to allow easy access. Field programmable.

**5 Memories.** Instant access to most used frequencies. VFO A information is transferred to the selected memory by pushing the W/CK button.

**Priority Channel.** Any memory channel may be monitored for activity on a sample basis, every 5 seconds, without disruption of a QSO conducted on a VFO frequency.

**LED Bar Meter.** Shows strength of received signal as well as relative transmitter

output from the fully protected final RF amplifier. APC (automatic power control) is used to detect SWR and adjust the power output to a safe level.

**Simplex/Duplex Operation.** Standard 600KHz offset initializes into radio at turn on. Offset may be changed by pressing the priority button while in VFO mode. Rotating the main tuning knob will now change the offset up or down and the offset will be displayed on the frequency readout.

**Adjustable Power Levels.** Pulling the squelch knob out places the unit into low power. Both the high and low power may be independently set to accommodate your simplex/repeater requirements or amplifier input characteristics.

**Nor/Rev Capability.** Use of the W/CK button in the duplex mode, allows one touch monitoring of the repeater input frequency. If simplex operation is possible you will know instantly.

**Scanning.** Pushing the S/S button initiates the scan

circuitry. With the mode switch in a memory position the unit will scan all 5 memories plus the 2 VFO frequencies.

With the mode switch in a VFO position, the unit will scan the band defined by memories 1 and 2. Full band scan or program band scan is selected internally.

The IC-45A has internally switched scanning choices of adjustable delay period after a carrier is received then resume scan, or resume on carrier drop.

**A Compact FM Mobile.** Fits in the smallest of places. Stacking, matching Mobile Mounts for UHF and VHF units make a complete mobile communications system for your car.

**Memory Backup.** When the optional IC-BU1 backup power unit is installed on the back of the IC-45A, memory will be maintained while transferring the unit from power source to power source. If the unit is not removed from power, it will maintain memory even when turned off with or without the IC-BU1.



**IC-RP3010**  
FM Repeater

Now a 10 watt 440Mhz FM repeater from the leader in VHF communications. The IC-RP3010 features high stability crystal controlled channels, CTCSS system, ID'er, remote control through a DTMF decoder and microprocessor controlled circuitry.

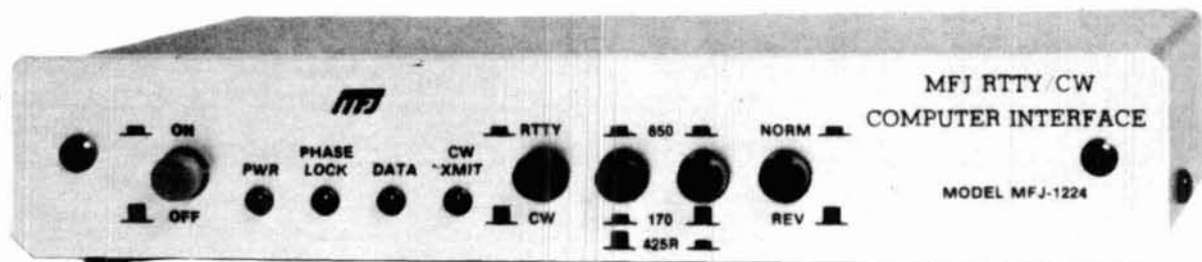


# ICOM

## The World System

# MFJ RTTY / ASCII / CW COMPUTER INTERFACE

Lets you send and receive computerized RTTY/ASCII/CW. Copies all shifts and all speeds. Copies on both mark and space. Sharp 8 Pole active filter for 170 Hz shift and CW. Plugs between your rig and VIC-20, Apple, TRS-80C, Atari, TI-99, Commodore 64 or most other personal computers. Uses Kantronics software and most other RTTY/CW software.



- Copies on both mark and space tones.
- Plugs between rig and VIC-20, Apple, TRS-80C, Atari, TI-99, Commodore 64 and most other personal computers.
- Uses Kantronics software and most other RTTY/CW software.

**\$ 99<sup>95</sup>**  
**MFJ-1224**

This new MFJ-1224 RTTY/ASCII/CW Computer Interface lets you use your personal computer as a computerized full featured RTTY/ASCII/CW station for sending and receiving.

It plugs between your rig and your VIC-20, Apple, TRS-80C, Atari, TI-99, Commodore 64, and most other personal computers.

It uses the Kantronics software which features split screen display, 1024 character type ahead buffer, 10 message ports (255 characters each), status display, CW-ID from keyboard, Centronic type printer compatibility, CW send/receive 5-99 WPM, RTTY send/receive 60, 67, 75, 100 WPM, ASCII send/receive 110, 300 baud plus more.

You can also use most other RTTY/CW software with nearly any personal computer.

A 2 LED tuning indicator system makes tuning fast, easy and positive. You can distinguish between RTTY/CW without even hearing it.

Once tuned in, the interface allows you to copy any shift (170, 425, 850 Hz and all shifts between and beyond) and any speed (5 to 100 WPM on RTTY/CW and up to 300 baud on ASCII).

Copies on both mark and space, not mark only or space only. If either the mark or space is lost the MFJ-1224 maintains copy on the remaining tone. This greatly improves copy under adverse conditions.

A sharp 8 pole active filter for 170 Hz shift and CW allows good copy under crowded, fading and weak signal conditions. Uses FET input op-amps.

An automatic noise limiter helps suppress static

crashes for better copy.

A Normal/Reverse switch eliminates retuning while stepping thru various RTTY speeds and shifts.

The demodulator will even maintain copy on a slightly drifting signal.

A +250 VDC loop output is available to drive your RTTY machine. Has convenient speaker output jack.

Phase continuous AFSK transmitter tones are generated by a clean, stable Exar 2206 function generator. Standard space tones of 2125 Hz and mark tones of 2295 and 2975 Hz are generated. A set of microphone lines is provided for AFSK out, AFSK ground, PTT out and PTT ground.

FSK keying is provided for transceivers with FSK.

High voltage grid block and direct outputs are provided for CW keying of your transmitter. A CW transmit LED provides visual indication of CW transmission. There is also an external hand key or electronic keyer input jack.

In addition to the Kantronics compatible socket, an exclusive general purpose socket allows interfacing to nearly any personal computer with most appropriate software. The following TTL compatible lines are available: RTTY demod out, CW demod out, CW-ID input, +5 VDC, ground. All signal lines are buffered and can be inverted using an internal DIP switch.

For example, you can use Galfo software with Apple computers, or RAK software with VIC-20's. Some computers with some software may require some external components.

DC voltages are IC regulated to provide stable

AFSK tones and RTTY/ASCII/CW reception.

Aluminum cabinet. Brushed aluminum front panel. 8x1 1/4x6 inches. Uses 12-15 VDC or 110 VAC with optional adapter, MFJ-1312, \$9.95.

## RTTY / ASCII / CW Receive Only SWL Computer Interface



**\$ 69<sup>95</sup>**  
**MFJ-1225**

Use your personal computer to receive commercial, military and amateur RTTY/ASCII/CW traffic.

The MFJ-1225 automatically copies all shifts (850, 425, 170 Hz shift and all others) and all speeds.

It plugs between your receiver and VIC-20, Apple, TRS-80C, Atari, TI-99, Commodore 64 and most other personal computers.

It uses Kantronics software which features CW receive 5-99 WPM, RTTY receive 60, 67, 75, 100 WPM, and ASCII receive 110, 300 baud, plus more.

An automatic noise limiter helps suppress static crashes for better copy, while a simple 2 LED tuning indicator system makes tuning fast, easy and positive.

In addition to the Kantronics compatible socket, a general purpose socket provides RTTY out, RTTY inverted out, CW out, CW inverted out, ground and +5VDC for interfacing to nearly any personal computer with most appropriate software.

Audio in, speaker out jacks. 4 1/2x1 1/4x4 1/4 in. 12-15 VDC or 110 VAC with adapter, MFJ-1312, \$9.95.

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## TS-830S

"Top-notch"...VBT, notch, IF shift, wide dynamic range

The TS-830S has every conceivable operating feature built-in for 160-10 meters (including the three new bands). It combines a high dynamic range with variable bandwidth tuning (VBT), IF shift, and an IF notch filter, as well as very sharp filters in the 455-kHz second IF.

### TS-830S FEATURES:

- LSB, USB, and CW on 160-10 meters, including the new 10, 18, and 24-MHz bands. Receives WWV on 10 MHz.
- Wide receiver dynamic range. Junction FETs in the balanced mixer, MOSFET RF amplifier at low level, and dual resonator for each band.
- Variable bandwidth tuning (VBT). Varies IF filter passband width.
- Notch filter high-Q active circuit in 455-kHz second IF.
- IF shift (passband tuning).
- Noise-blanker threshold level control.
- Built-in digital display, (fluorescent tube), with analog dial.
- 6146B final with RF negative feedback. Runs 220 W PEP (SSB)/180 W DC (CW) input on all bands.
- Built-in RF speech processor.
- Narrow/wide filter selection on CW.
- SSB monitor circuit.
- RIT and XIT (transmitter incremental tuning).

### Optional accessories:

- SP-230 external speaker.
- VFO-230 external digital VFO with five memories, digital display.
- VFO-240 external analog VFO.
- AT-230 antenna tuner.
- YG-455C (500 Hz) or YG-455CN (250 Hz) CW filter for 455 kHz IF.
- YK-88C (500 Hz) or YK-88CN (270 Hz) CW filter for 8.83 MHz IF.
- KB-1 deluxe heavyweight knob.



## TS-530S

"Cents-ational"...IF shift, digital display, narrow-wide filter switch

The TS-530S SSB/CW transceiver covers 160-10 meters using the latest, most advanced circuit technology, yet at an affordable price.

### TS-530S FEATURES:

- 160-10 meters, LSB, USB, CW, all amateur frequencies, including new 10, 18, and 24 MHz bands. Receives WWV on 10 MHz.
- IF shift tunes out interfering signals.
- Built-in digital display (six digits, fluorescent tubes), with analog dial.
- Narrow/wide filter selector switch for CW and/or SSB.
- Built-in speech processor, for increased talk power.
- Wide receiver dynamic range, with greater immunity to overload.
- Two 6146B's in final, allows 220W PEP/180 W DC input on all bands.
- Advanced single-conversion PLL, for better stability, improved spurious characteristics.
- Adjustable noise-blanker, with front panel threshold control.
- RIT/XIT front panel control allows independent fine-tuning of receive or transmit frequencies.

### Optional accessories:

- SP-230 external speaker with selectable audio filters.
- VFO-240 remote analog VFO.
- VFO-230 remote digital VFO.
- AT-230 antenna tuner/SWR/power meter.
- MC-50 desk microphone
- KB-1 deluxe VFO knob.
- YK-88C (500 Hz) or YK-88CN (270 Hz) CW filter.
- YK-88SN (1.8 kHz) narrow SSB filter.



## TS-660

The TS-660 "QUAD BANDER" covers 6, 10, 12, 15 meters.

- FM, SSB (USB), CW, and AM
- Dual digital VFO's
- Digital display
- IF shift built-in
- 5 memories with memory scan
- UP/DOWN microphone
- All-mode squelch
- Noise blanker
- CW semi break-in/sidetone
- 10 W on SSB, CW, FM; 4 W on AM.

### Optional accessories:

- PS-20 power supply
- VOX-4 speech processor/VOX
- SP-120 External speaker
- MB-100 Mobile mount
- YK-88C, YK-88CN CW filters
- YK-88A AM filter.

# KENWOOD

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1111 West Walnut, Compton, California 90220

# ham radio

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# REFLECTIONS REFLECTIONS

## “The Old Man” lives

**I don't know how many of you remember “T.O.M.”** I'm not old enough myself to have read the column when it first came out (1916-1932?) but I sure became another avid fan of his while pouring through old volumes of *QST*. For those of you who have never had the pleasure, let me introduce you to one of the greatest cynical voices of Amateur Radio to have ever existed.

“T.O.M.” was a pseudonym assumed by an individual who was gutsy enough to call it as he saw it. He recognized situations for what they were and freely voiced his opinion. Usually the subjects were associated with either poor operating techniques or poorly functioning equipment. The comments in the form of a letter to the magazine would mysteriously appear on the editor's desk without any knowledge of who wrote it or where it had come from. There are those who believe it was written by Hiram Percy Maxim himself. In honor of the fine gentleman, whoever he may have been, I dedicate the following short piece and actively solicit comments.

**Rotten operating.** At the top of my list are *LISTS*. *Hate is a strong word, but it sure approaches how I feel about self-appointed “gods” who believe it is their inalienable right to “manage” a DX station's callers when they themselves have a hard time understanding the DX station because of low signal level at their location or a language “barrier.”* A case in point is a well known French-speaking DX station on 20 meters who puts an excellent signal into the East Coast at least. *One of the MC's in this case had a hard time hearing and understanding the station while others were copying him Q5. What sense does it make to take a list of 100 calls when the band is dropping out? What sense does it make to have two or three MC's trading off calls on the same frequency while the DX station just waits? I'm not talking just seconds — I'm talking many minutes — precious minutes as the vagaries of propagation does its thing.*

In defense of list operation there are those who say that the DX station requested help and couldn't handle the ensuing pile-up alone. I used to feel that way. But come on, folks! What is the real value of that contact if your call has been retransmitted by a more powerful station and perhaps even your signal report? *It cheapens the process and product. (Incidentally, what is the product? I won't get into that now. I'm not done with list operation yet.)*

**Dear “rare” DX station:** If you have a hard time sorting out the horde and want to use an MC, why don't you tell him to repeat the following: *“The DX station requests all callers to listen carefully, keep all calls short and only answer if your letters are acknowledged.”* Listen to Arild, 3X4EX, some day and see how he handles pile-ups — extremely effectively, I might add. If the DX station must have an MC, how about interspersing the list operation with “free” periods during which anyone NOT on the list may call in? The DX station just might be very surprised to see how many more stations he can work and also gain some confidence in the process. By the way, DX station, if there is some persistent Amateur calling out of turn and you just want to get him off your back, acknowledge him and just forget to log the contact, or more directly, *say so at the time.* (That'll either straighten everyone up or create pandemonium.)

I have to admit that on the lower bands there's more of a temptation to assist a friend or “twenty friends.” (I've done it myself and have been helped also.) But I've tried to do it right in as rapid fire a manner as possible, not retransmitting calls, and I have been extremely sensitive to even one dissenting voice on the frequency.

There, I've said it. There are many other areas of rotten operating that I can and will address as the need arises. Remember folks — this is our hobby — with a stress on the word *hobby*. Let's go back to basics, recalling that it's a privilege to use the frequencies and try to communicate a little more.

**Rich Rosen, K2RR**  
Editor-in-Chief

P.S. You still have an opportunity to express *your* opinions. Just grab your copy of the September issue, find the survey on the editorial page and go for it. Preliminary returns have been fantastic. I know it's impossible, and too much to wish for, but if everyone could just take the time to fill out the survey what a well-rounded poll that would make. It would help us provide to you the best ham radio magazine of the 80's.

# NEC

## Linear Power Bipolars

### NEL1300

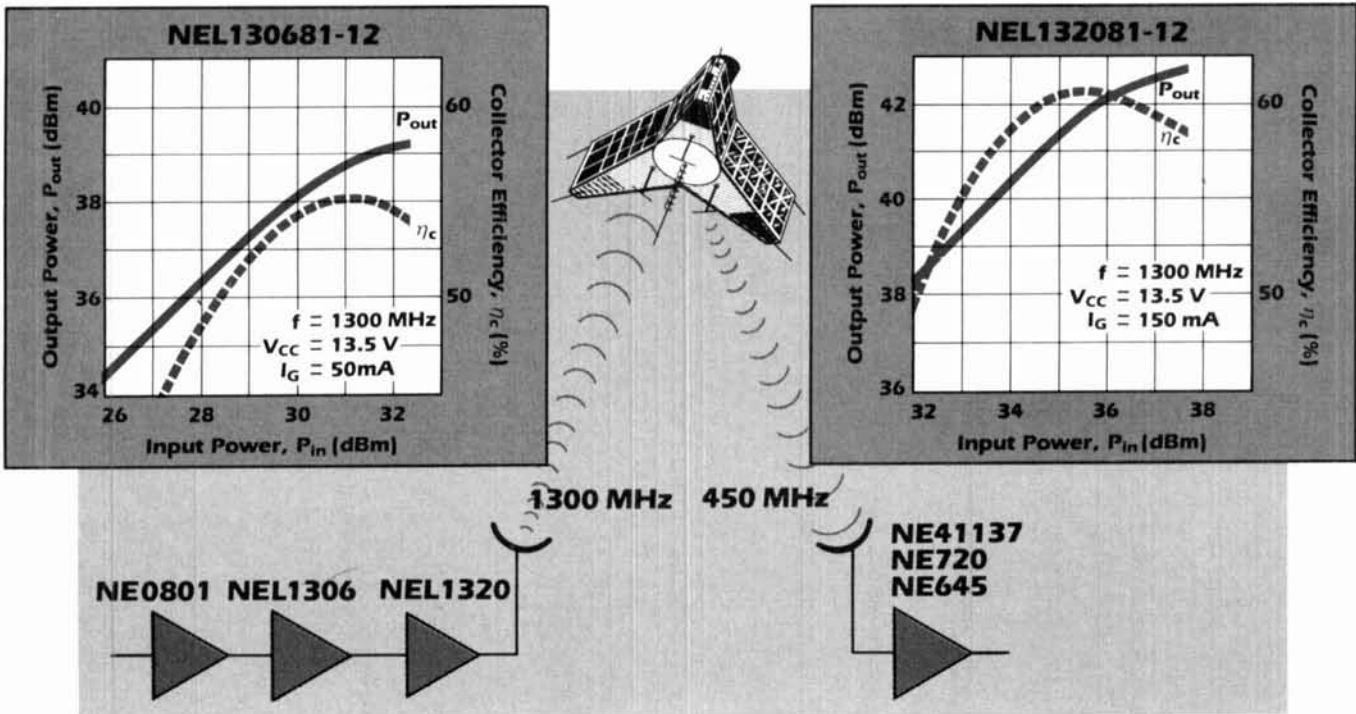
- High linear power and gain

NEL1306  $P_{1dB} = 38 \text{ dBm typ.}$   
 $G_{1dB} = 7.5 \text{ dBm typ.}$

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 $G_{1dB} = 6.0 \text{ dB typ.}$

- 13.5 volt operation
- Pt-Si/Ti/Pt/Au metallization system
- Emitter ballasting
- Silicon nitride passivation

From our latest line of NPN epitaxial power transistors, NEC now introduces the NEL1300 range of linear power bipolar devices. The series is available in a low cost metal-ceramic stripline package offering linear power output levels of 6 watts and 20 watts. Designed primarily for mobile and base station operation in the 1300 MHz band, the series is compatible with single sideband and other popular modulation modes requiring high linearity combined with high output power and gain.



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AMATEUR RADIO-CABLE TV CONFRONTATION CONTINUES TO HEAT UP, with the ARRL filing a Motion for Expedited Action on its previous petition to have cable channels E (2 meters) and K (220 MHz) taken away from the cablecasters. That earlier petition, RM-4040, was filed in January, 1982, and cited numerous problems Amateurs throughout the country were having with cable system leakage. Attempts to resolve the problem through discussions with the National Cable TV Association have met with frustration, hence the latest League action to push the Commission toward a workable solution. The NCTA received an extension of time to file comments on the League's petition, so its response wasn't available at press time.

Excessive Leakage Will Cost A California CATV Firm a \$3000 fine, according to the FCC. Times-Mirror Cable Television was cited for leakage problems with its Encinitas (near San Diego) system, which was found to have high signal leakage on many frequencies including the Amateur bands. That system had been investigated previously by the FCC, but had claimed to have cleared up its leakage problems.

OCTOBER 28 IS THE NEW DATE FOR STS-9'S LAUNCH with W5LFL/Space/Mobile aboard, after delays in checking out some of the mission systems. W5LFL's hand-held is a custom-built Motorola, which passed NASA's rigorous compatibility checks after a minor interference problem with a telemetry system was found to be due to cable routing.

W5LFL's Primary Transmit Frequency Will Be 145.550 MHz, with 145.250, 145.530 and 145.570 as back-ups. He'll listen on 144.650, 144.700-144.850 (25-kHz channels), 144.910-145.090 (20-kHz channels), plus 145.350 and 145.450. The 25-kHz channel spacing is to conform with 2-meter usage in other parts of the world. In all cases he should specify the frequencies to which he'll be listening, as well as any special instructions such as call areas or states he's looking for, during his "even minute" transmit period.

EXTENSION OF AMATEUR LICENSE TERMS TO 10 YEARS should be the first Commission action for Amateur Radio following the August recess. Present licenses would not be extended, but all new licenses and renewals will be for the longer period. It's also expected that the present five-year grace period for renewal after expiration will be trimmed to two years.

Some Other Pending FCC Actions May Be Delayed, however, since the Commission has been reduced by law to five commissioners and only four are presently serving, following Anne Jones' departure. Few controversial issues are likely to be resolved until another Commissioner is on board, to avoid the possible stalemate of a two-two split.

OSCAR 10'S MODE B TRANSPONDER WORKS BEAUTIFULLY following turn on August 6. Users from all corners of the world appeared in the first few days, leading to comments that the downlink sounded more like 20 meters than 2—complete with pileups! Signals have improved steadily, and with the final position tweaking at the end of August, it's possible to work through OSCAR 10 well, with an ERP well under 100 watts.

Some Excessively Strong Signals Have Been Noted, as much as 20 to 30 dB above the beacon. Such signals cut down transponder gain, knocking weaker signals out completely. Users are asked to limit power so their downlink signals are no stronger than the beacon.

ARRL CW Bulletins Are Now Carried On OSCAR 10, 145.840 downlink. Both the AMSAT Tuesday night net and Westlink have also been relayed by the new bird.

Mode L Tests Are Set For Early September; listen for the 70 cm downlink signals Thursdays and Saturdays (GMT) + one hour from OSCAR 10's orbital apogee.

AMSAT's 1983 Annual Meeting Will Be November 12 near Laurel, Maryland. An excellent space symposium is planned; call AMSAT at (301) 589-6062 right away if you want to attend.

Two Russian Satellites, RS-4 and RS-5, are no longer being heard and appear dead.

ARRL WILL ADMINISTER "NO-CODE" LICENSE EXAMS if the FCC adopts no-code and the ARRL becomes the exam program administrator. Responding to questioners at the Pacific Division Convention, League President W4KFC also stated that membership status and privileges of no-code Amateurs would be decided by the League membership.

BEACON POWER HAS BEEN INCREASED TO 100 WATTS OUT in an addendum to the FCC's recent revision of the rules on Amateur power. Beacons had been limited to 100 watts input.

BELGIAN AMATEURS FACE LOSS OF MANY MICROWAVE BANDS if a bill proposed for the Belgian Parliament becomes law. According to G3WDG, 432-434 MHz plus the 23, 13, 9 and 6 cm bands are all involved. ON6AT/RTT solicits messages of support from other Amateurs.

LOG-KEEPING IS NO LONGER REQUIRED OF CANADIAN AMATEURS, after their Department of Communications deleted that part of its rules in a surprise move. However, a log showing CW activity will still be required in applying for some license endorsements.

NO MORE REPEATERS WILL BE COORDINATED ON TO 2 METERS in southern California. Following the lead of the Northern Amateur Relay Council, which recently ended its attempts to coordinate 2 meters due to overcrowding, the 2-Meter Area Spectrum Management Association (TASMA) agreed that the band could accommodate only a few limited coverage repeaters in remote areas. Any uncoordinated machines that appear could be subject to the sanctions against intentional interference cited by former FCC Private Bureau Chief Jim McKinney.





# HF, VHF, UHF, Across the spectrum. VARIAN EIMAC.

Ham operators know that EIMAC started in power tube development with the 150T in 1934. While the 150T is now a collector's item, EIMAC, a division of Varian, still holds leadership in power tube design with its 4CX250B, 8874, 3-500Z, 8877 and 3CX400U7; modern examples of EIMAC's continuing, innovative solutions to tough communication requirements.

EIMAC's proven power tubes are used in amateur service for heavy-duty, reliable performance in traffic; RTTY; SSTV; DX operation; VHF/UHF work; moonbounce, and exploration of the outer limits of communication techniques across the spectrum.

High quality and long life make EIMAC tubes the favorite choice of operator and equipment builder, amateur and professional alike.

For communication and research worldwide, choose EIMAC. For information on VARIAN EIMAC power tubes, call or write today. Or contact the nearest Varian Electron Device Group sales office.

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Tel: (042) 31 66 55  
Telex: 845-78789





## comments

### fan letter

Dear HR:

In regard to the heatsink cooling fan suggested by Ed Marriner, (*ham radio*, Ham Notes, July, 1983), perhaps a better scheme to minimize losses and unnecessary heating would be to substitute a 1- or 2- $\mu$ F capacitor for the dropping resistor.

This provides a use for the old "bathtub" capacitors (600V) which otherwise seem to end up in the trash barrel.

**Fred J. Norvik, W2GH**  
Albany, New York

### repeater etiquette

Dear HR:

The spectacular growth in the number of repeaters has resulted in operating practices we can all be proud of — as usual, the self-discipline of Amateur Radio operators has made itself evident. (A few minutes spent listening to the radio services that do not have stringent licensing standards will convince anyone that Amateurs are doing a good job.)

Some aspects of repeater use could use improvement; consider, for example, the following:

*Overuse and underuse of call signs.* Once every ten minutes and at the beginning and end of a QSO does the trick. Some Amateurs are beginning to use call abbreviations — typically, omitting the prefix and using only the body of their call. This is certainly unlawful and confusing to the listener.

*Non-substantial communications* — some repeaters are monopolized by Amateurs who talk by the hour and say very little. They usually break politely when asked to by a "call please" request but return to their meaningless gabbing as soon as the interruption has cleared. Another problem occurs when people continuously update each other on their whereabouts without apparent reason. In one case overheard recently, this type of never-ending QSO involved a man and wife who continually embellished their conversation with expressions of endearment.

The foregoing applies doubly to phone patch conversations. This is an important privilege; it should be guarded carefully.

It should be apparent that we are judged by what we say. I have two non-Amateur associates who ride to and from work with me. Their comments on conversations we overhear suggest what the public thinks. If we expect the public's support in matters of tv, rfi, and antenna erection, we must at least convince them that we use our privileges meaningfully. There are hundreds of acceptable subjects for discussion, both related to and not related to Amateur Radio; before you push the microphone button, ask yourself if you really have something to say!

*Inconsiderate operation* — how many times have you heard a station break into a QSO and take over, ignoring one or more of the original participants? I was testing an antenna not long ago with the help of another very cooperative station. Without any warning, a friend of the other operator broke in and interrupted the tests for several minutes. He signed off as if I were not even there. Eventually the tests were completed. Remember, when you are impolite, a lot of people are listening and forming their opinion of you (and Amateur Radio).

There are those who talk only to a fixed group and make the newcomer feel he did something wrong by just trying to say "hello." Single-purpose repeaters and nets and closed repeaters may have to be accepted. How-

ever, those who use repeater time and exclude others for no good reason ought to think twice: none of us has the exclusive right to any Amateur frequency.

On the whole, in my opinion, repeater operation deserves a very high mark. With a little more effort, it could get itself into the "straight A" class!

**George A. Wilson, Jr., W1OLP**  
Walpole, Massachusetts

### high spirits

Dear HR:

I don't know when I ever enjoyed *ham radio* as much as I did the May, 1983 issue on antennas. I'm in the process of mounting a vertical atop a 70-foot tower; I don't know how well it will work, but I'll try.

The article on "Log-Yagis Simplified" was really great; it was a big help to me. I just had to write and let you know about it.

Keep the good articles coming. I'll be looking for one soon on vertical antennas mounted above the beams on a tower.

**Fred Jones, WA4SWF**  
Louisa, Kentucky

### free QSL's

Dear HR:

Help! My poor secretary is being buried in a pile of coupons from *ham radio* readers who've requested the free QSL cards offered in our August advertisement.

We're making every effort to fill all requests as quickly as possible. But because of the tremendous response to our offer, some hams will have to wait.

If you've requested QSL cards but not yet received them, please be patient; we'll mail yours as soon as the next print order is received.

Thanks.

**Tom Bluesteen**  
Advertising Manager  
RCA Government  
Communications Systems  
Camden, New Jersey 08102

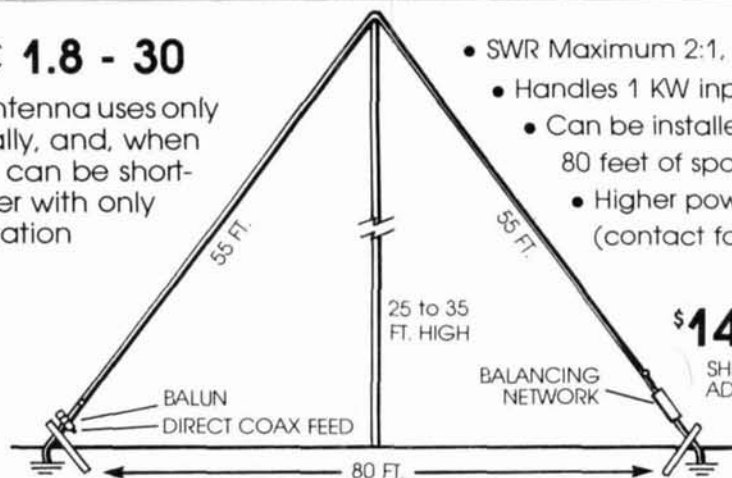
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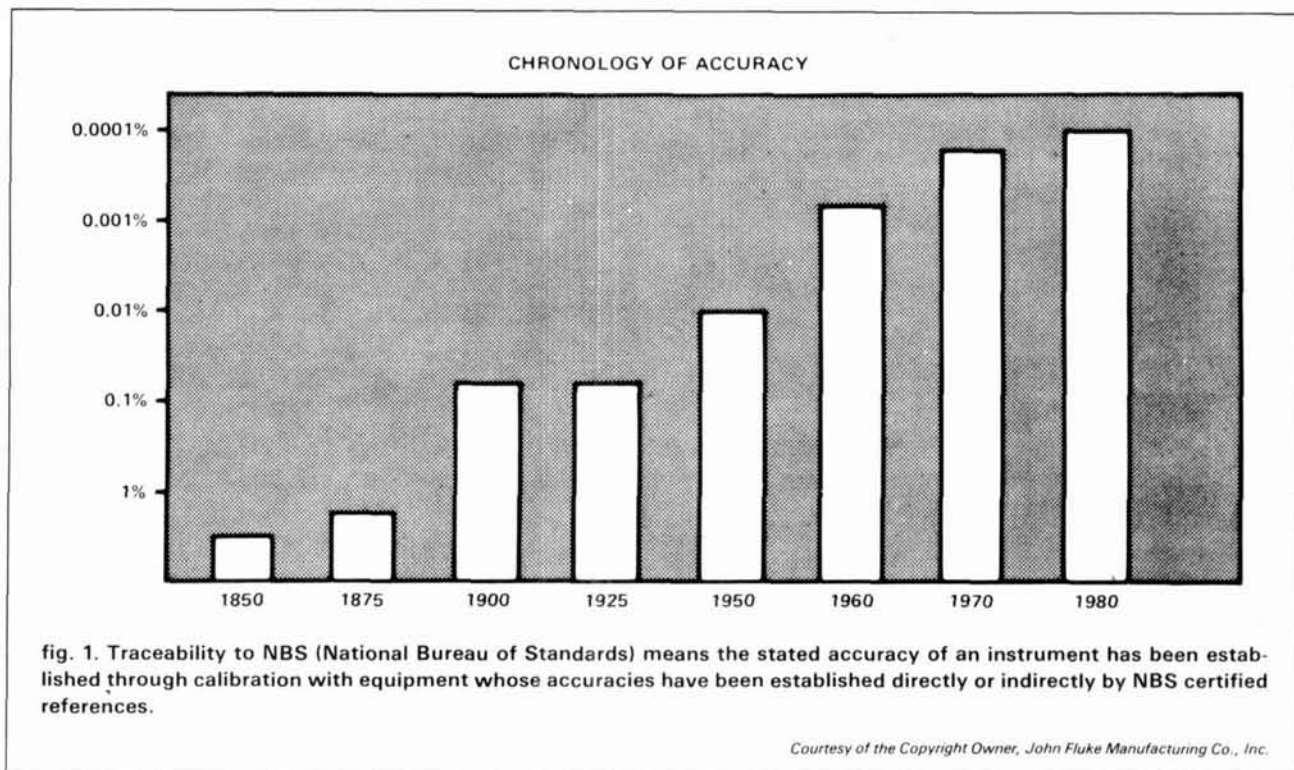
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Back to basics:  
the fundamentals  
of measurement

## electrical calibration standards



**Calibration** — whether it be checking the butcher's scales or fine tuning in a radio station — always involves certain principles and goals. These are to achieve accuracy and precision and to permit interchangeability in mass-produced items. Along with metrology, the science of measurement, calibration gives us confidence in the units of measure we use daily.

Before delving into the specifics of determining the five basic electrical quantities (the farad, ampere, volt, henry, and ohm), let's discuss and define some calibration philosophies. Calibration is the process of comparing the readings obtained on test and measurement instruments to those of carefully defined

references or standards of usually far greater accuracy in order to determine and then correct any deviations in the instrument. Two benefits result — uncertainty about the particular instrument under test is minimized and the instrument meets the requirements for traceability.

"Traceability" means that measurements can be traced back to the National Measurement System. (See **figs. 1** and **2**.) It exists on seven levels, all traceable to the NBS (National Bureau of Standards):

**By Vaughn D. Martin**, 114 Lost Meadows, Cibolo, Texas 78108

The *Tertiary Level* includes instruments used for production work, quality control, maintenance, and general measurement purposes.

*Local Secondary Standards* are used for calibration work and as references in certain production and engineering areas.

*Transfer and Inter-laboratory Standards* maintain or represent the basic electrical units locally and are sometimes referred to as Local Primary Standards.

*NBS Working Standards* are used to calibrate and certify local standards.

*NBS Secondary Standards* include Transfer, Check, and Scaling Standards. They are used to compare NBS Working Standards to the Legal Electrical Reference Units, the values of which are embodied in the NBS Primary Standards.

*NBS Primary Standards* are derived from the basic "SI" Units.

The *International System of Units (SI)* is the "glue" that holds the whole structure together.

### what is a standard?

It is possible to build a rugged platinum and iridium standard, but that standard would change, over time, as it became affected by its environment. While a standard could be arbitrarily defined without regard to the physical environment, such a standard would never be more than arbitrary. We could say that it was a standard derived or based upon a previous standard, or carefully examine the physical properties and elements of nature and advantageously base the standards on these properties. In actuality, the determination and derivation of each of the various standards employs some or all four of these techniques.

Consider this. The two most basic units of measurement, length and time, are derived as follows:

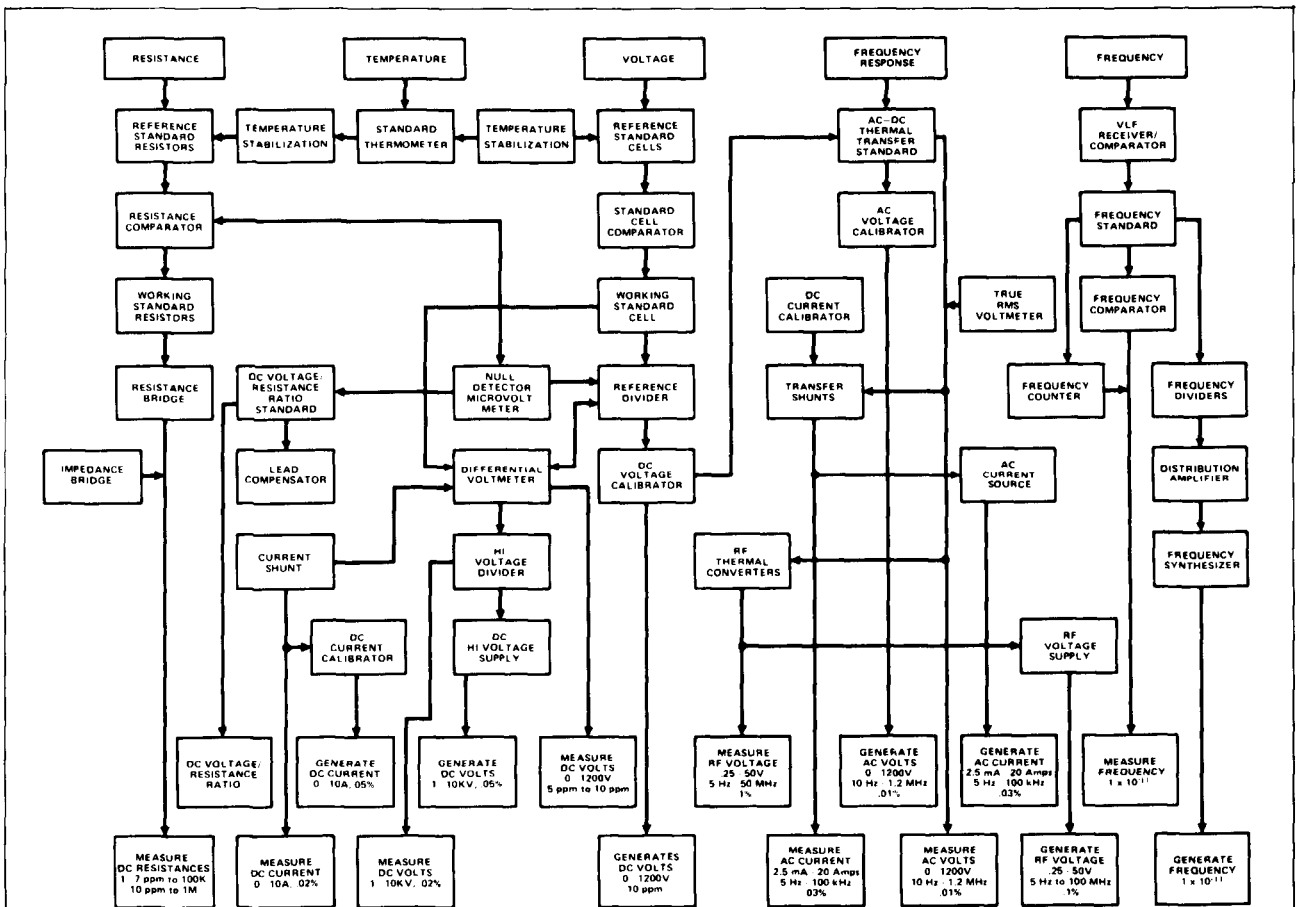


fig. 2. All measurements can be "traced" back to NBS National Measurement System.

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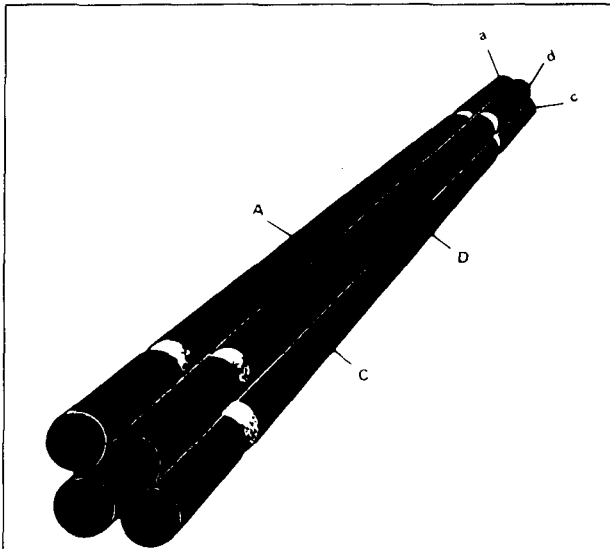


fig. 3. Basic structure of the first operating calculable capacitor, built at NBS in 1960. The calculated "cross capacitor" is the average of the capacitance (per meter of length) of the capacitor formed by rods A and C and that formed by B and D. When the "guard" sections a, are kept at the same voltage as A b, b at the same voltage as B, etc., then A, B, C, and D are very nearly as if parts of infinitely long rods.

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length is based on the meter, which is a set number of wavelengths of radiation of the Krypton 86 atom. Measurement of time is based on the second, which is defined as a certain number of cycles of radiation of the Cesium 133 atom in the NBS atomic clock.

In electronic communications, one of the most vital concerns is with the propagation of electromagnetic waves, the maximum velocity of which is limited only by the speed of light. Now that we know the exact value of length and time, it is possible — through the use of Maxwell's equations in electrodynamics and electrostatics — to precisely realize the relationships existing between permeability and permittivity of free space.\* We can now derive one electrical standard from another (a technique mentioned earlier), and we do precisely this in the definition of the farad, the standard of electrical capacitance. Once we define the farad, all other electrical parameters fall into place.

### defining the farad

The farad was really not very precisely defined until 1956 when two Australian physicists, Thompson

\* $c$  (velocity of light) =  $\frac{1}{\mu_0 \epsilon_0}$  where  $\mu_0 \epsilon_0$  equals free space permeability and permittivity, respectively. Editor

and Lampard, contrived a technique of precisely measuring the lengths of two parallel metal rods in a special configuration, measuring the speed of light, and then calculating the value of the permittivity of free space. (See figs. 3 and 4.) Extensive work at the NBS followed, and these techniques were refined to the point where we now know the value of a farad to within  $\pm 2$  ppm (parts per million). Now that the farad, the unit of capacitance, is known, determination of all other electrical units can follow. Impedance to the flow of AC is based on capacitive reactance formulas, and other electrical parameters such as current can be defined from this.

It is known that a quadrature or four-element bridge is an electronic circuit that can be used to compare the impedance of capacitors, inductors, and resistors. (Refer to the lower left portion of fig. 5.) A stable source of known ac frequency is all that is left to power the bridge. Since frequency is the inverse of time and since time is quite well defined by the atomic clock in the NBS facility in Boulder, Colorado, we are home free. Realizing also that there is one frequency, called the resonant frequency, at which inductive and capacitive reactances cancel one another, we can now define the henry from the farad, since the farad is already known. In addition,

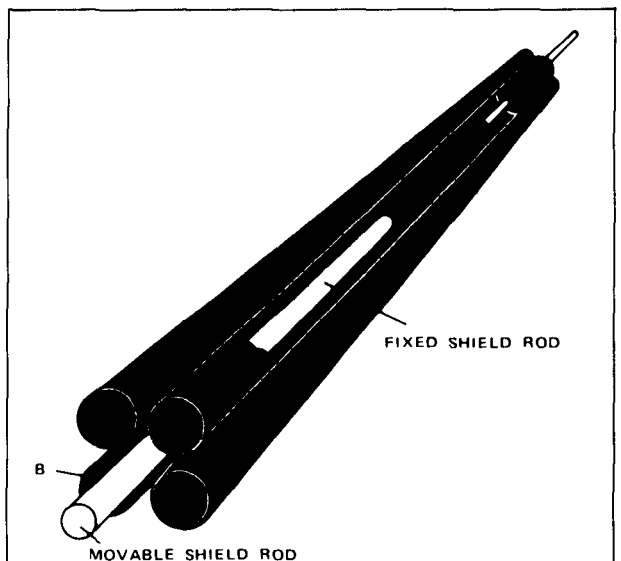
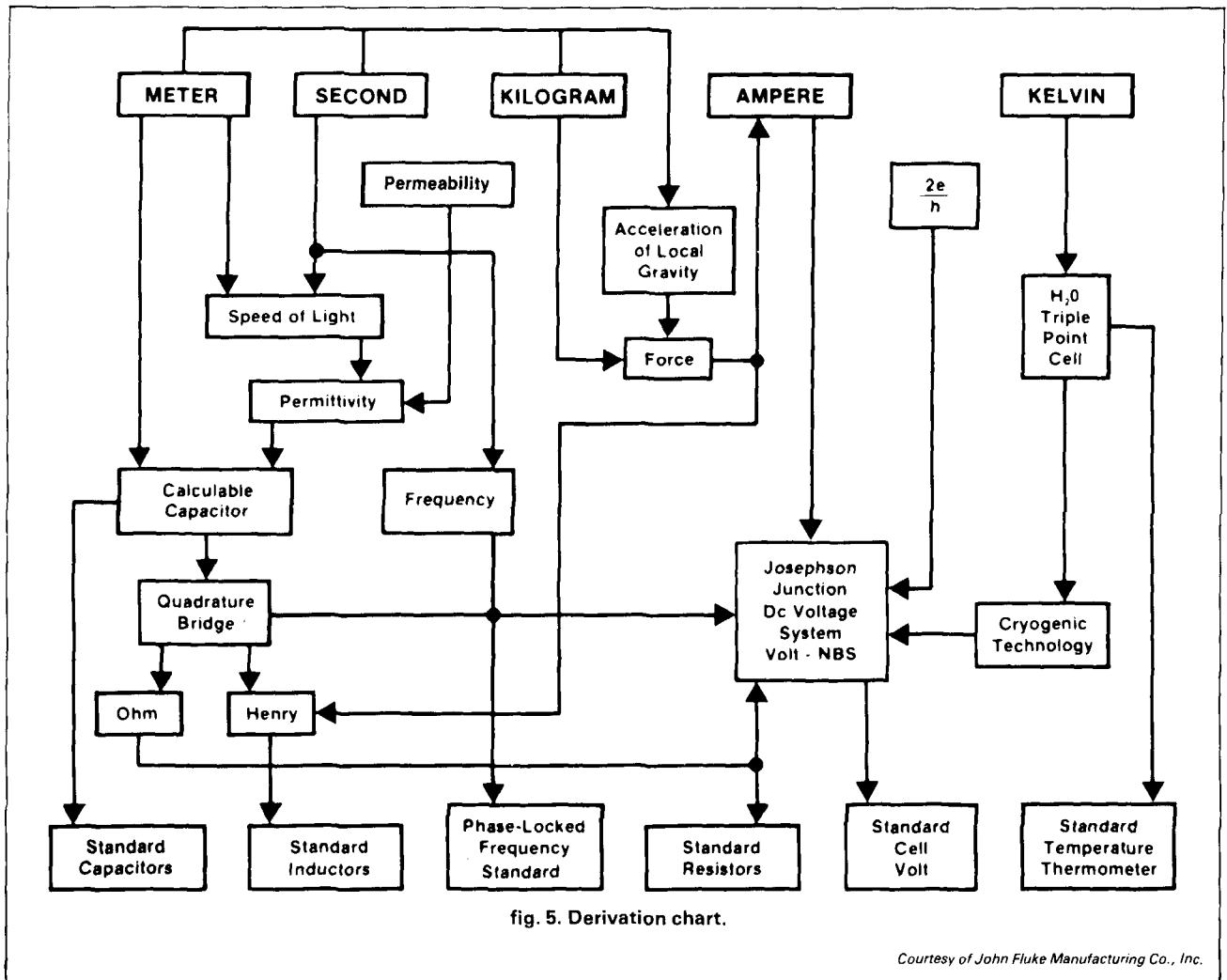


fig. 4. Basic structure of the variable cross capacitor used as standard of farad and ohm. The capacitance calculated is the change in cross capacitance when the movable shield rod is displaced through a measured distance along the axis. (Most of the rod D has been removed so the shield rod can be better seen. Note that the variable cross capacitor does not need guard sections. Omitted from this and the preceding figure is the metal shield that encloses the entire device.)

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through an AC-DC transfer technique, the ohm has been defined to better than  $\pm 0.06$  ppm. In other words, the ohm was derived by calculating the inductance of a carefully designed coil, taking into account all physical dimensions and the number of turns and type of wire used.

An ac source was then applied to the coil, and by knowing its frequency and being able to calculate the coil's inductance, the third quantity in the formula for inductance reactance (the resistance in ohms) was then derived.

### the ampere

In Ampere's equation, current and its conductors are defined with respect to magnetic force. But first — in this hair-splitting business of defining absolute standards — *force itself* has to be very well defined. You will recall from physics that force is equivalent to *mass times acceleration*. The mass standard in the form of a kilogram bar of iridium and platinum al-

ready exists (in the BPIM, the French equivalent to our NBS). Next, we concern ourselves with acceleration — a special kind of acceleration, or the acceleration at local gravity at the site of the experiment. We derive acceleration by performing a drop test and measuring the distance traveled and the time elapsed.

Having now established force and inductance from previous work on the quadrature bridge arrangement as a result of first knowing capacitance and time, we can proceed in defining the ampere absolutely by placing one free coil inside a fixed coil and attaching the free coil to the arm of a balance. Current is run through the coils; this counterbalances the gravitational force, attracting a known mass which has been placed on the other arm of the balance. By opposing the downward force of local gravity on our known mass with magnetic fields resulting from the solenoid or magnetic "pulling" of our two coils and through Ampere's equation, an absolute determination of the unit of current, the ampere, is made.

## the volt

The last unit to determine in the set of electrical standards is the volt. This unit can be determined in one of two ways. First, a very precise one-ohm resistor could have one ampere of current passed through it; as a result of Ohm's law, a one-volt drop would exist across this one-ohm resistor (see fig. 6). This very precisely determined volt would then be compared to some standard saturated cells and the results of this comparison would then be the nominal mean value assigned to this reference group. By having a number of standard saturated cells, the drifting of one cell to a few millionths of a volt above an actual volt would be offset by another cell drifting a few millionths of a volt in the other direction and collectively averaging all readings, a mean or average would then be obtained. But there are two problems with this technique, which the NBS used until most recently. First, the cells drifted; and second, since the volt was defined as a result of first determining the ampere, the problem was compounded by the practice of precisely redetermining the ampere only once or twice per decade.

The second method of determining the volt was much better and resulted from the work of a British physicist, Brian Josephson. In 1962, he published a paper entitled "Possible New Effects in Superconductive Tunneling" and won a Nobel Prize for what was later to be known as the "AC (alternating current) Josephson Effect." This discovery offers the computer industry semiconductor switching speeds approaching the speed of light and probably more importantly, offers a means by which the absolute volt can be very accurately determined.

To understand this wonderful discovery, let's first examine what a Josephson junction is and how it is used. In its simplest terms, the Josephson junction is a frequency-to-voltage converter. The frequency/voltage ratio is precisely equal to two times the elementary electron charge divided by Planck's Constant. The NBS places a resonant thin-film tunnel junction in an environment approaching absolute zero (0 degrees Kelvin or -273.15 degrees C) (see fig. 7). The result is a superconductor. Next, they interface the Josephson junction to an external voltage comparator which is connected to a Reference Standard Cell and then apply a stable dc supply voltage to the junction. This junction is irradiated with microwave energy from a Klystron tube that is phase-locked or precisely tuned by being locked to WWVB, the radio station at the NBS in Boulder, Colorado, that broadcasts the atomic time signals. (The atomic clock's quartz crystal oscillator is extremely accurate, with a short-term frequency stability of 1

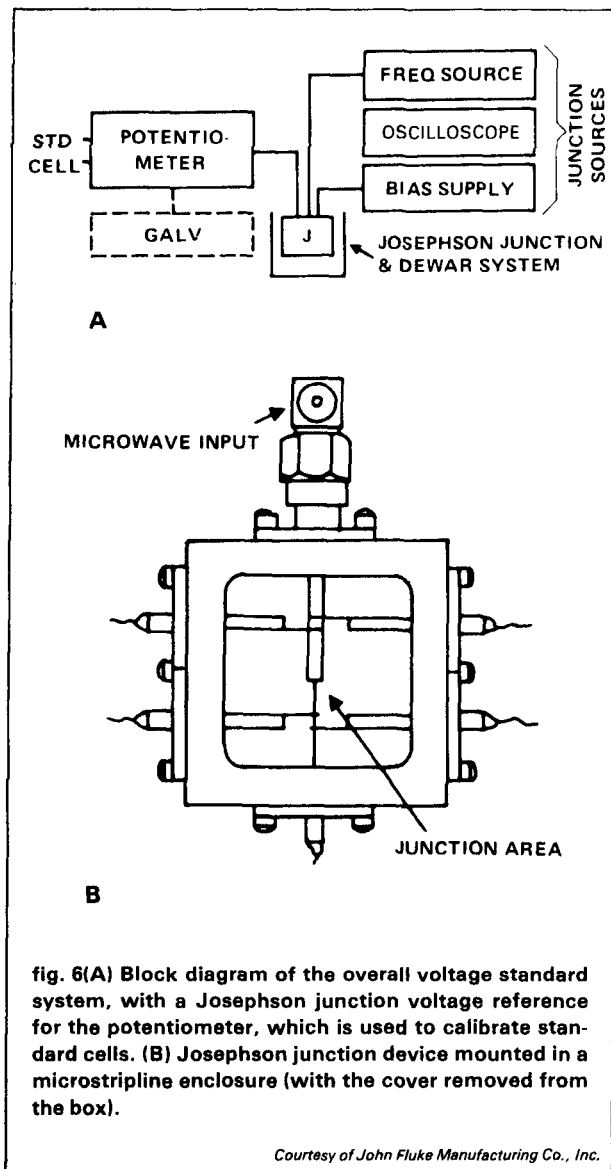


fig. 6(A) Block diagram of the overall voltage standard system, with a Josephson junction voltage reference for the potentiometer, which is used to calibrate standard cells. (B) Josephson junction device mounted in a microstripline enclosure (with the cover removed from the box).

Courtesy of John Fluke Manufacturing Co., Inc.

part per  $10^9$ .) The Josephson junction then generates a DC voltage between 1 and 10 millivolts, depending on the microwave frequency. The beauty of the system is that the resulting DC voltage has an accuracy approaching that of the Atomic Time Standard; furthermore, this can be reproduced anywhere in the world where WWVB or its equivalent can be received by radio and then processed for phase-lock control. The total system uncertainty in this voltage determining scheme is less than five parts per  $10^8$ .

The resulting junction voltage is transferred up to the 1-volt level and then used as a check standard on a reference group of saturated cells. This small group then serves as a check on the working standards used for the Bureau's voltage calibration services.

**ham radio**



# Morse Keyers & Trainers by AEA

AEA produces the finest Morse keyers and trainers in the world. All AEA keyers operate with any standard keyer paddle and offer selectable monitor tone, selectable dot and dash ratios, full weighting and selectable dot and/or dash memory. In addition, all our keyers offer full, semi-automatic or straight key modes. The keyers and trainers are keypad controlled which significantly reduces the complexity of operation for all the features offered. Each keyer has separate + and - keyed outputs for keying any modern transmitter. All keyers and trainers operate from 12 VDC (or 117 VAC with optional model AC-1 wall adaptor) which makes them ideal for portable operation. AEA microcomputer-based products are all subjected to a full burn-in and test prior to shipment, as well as being designed for maximum R.F. immunity.

## NEW BT-1



The **BT-1 Basic Trainer** is a hand-held computerized unit which teaches the code one character at a time at 18 or 20 words per minute. The BT-1 contains a self-paced training program that allows serious students the possibility of learning Morse to 20 wpm in as little as one month! Each character represents a separate practice session in which the character is first introduced by itself, and then presented 50% of the time along with all previously learned characters. There are no tapes to memorize, wear out, or break. No programming skills are necessary; the BT-1 is very easy to use. The tone oscillator can also be keyed for sending practice. An earphone jack is provided for private listening. The BT-1 will go as high as 99 WPM in 1 WPM increments. A battery operated version, the BT-1P, is available with wall charger and internal NICAD batteries.

The **KT-3 Keyer-Trainer** unit uses the teaching program used in the BT-1 trainer. In addition, the KT-3 features a full function Morse automatic keyer for keying any modern transceiver, or for sending practice. Speed range is 18-99 wpm for transmitting and 1-99 wpm for training.

The **KT-2 Keyer-Trainer** is a computerized keyer with all the features shown above, plus a Morse proficiency trainer. It is designed to increase your existing code as quickly as possible. The unit can be set for beginning practice speed, ending practice speed, and duration of practice. The microcomputer does all the rest by gradually increasing the speed during the practice time selected. You can even select between fast code (Farnsworth) or slow code methods. The characters are sent in 5 letter groups, or random word lengths. Two levels of difficulty can be selected; common Morse characters or all English Morse characters. A 24,000 character answer book is provided for the 10 separate starting positions. There is also random practice mode for which no answers are available.

## NEW KT-3



The **CK-2 Contester™ Keyer** is the lowest cost automatic keyer available featuring an automatic serial number generator for contesting. The CK-2 keyer features a large 500 character message memory that can be soft-partitioned into as many as 10 sections. An exclusive AEA edit mode makes it possible to correct mistakes made while entering messages or to insert words into previously established messages. Two different speeds can be set for fast recall in addition to a stepped variable speed control. The CK-2 features an automatic message repeat mode with variable delay-before-repeat for automatic CQ transmissions or TVI testing.

## CK-2 Contester™



## MM-2 MorseMatic™



The **MM-2 Morsematic Keyer** represents the most sophisticated paddle keyer ever designed and features two powerful microcomputers. The Morsematic incorporates virtually all the features (except the preset and stepped variable speeds) of both the CK-2 and KT-2 shown above. In addition, the MM-2 offers an exclusive automatic beacon mode which is invaluable for meteor scatter, moonbounce scheduling, or beacon operation.

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# rf synthesizers for hf communications: part 3

## Design and build a 5 to 5.5 MHz synthesizer

The first two parts of this series discussed the basic PLL. This third section applies the developed theory to the design and construction of a 5.000 to 5.500 MHz synthesizer that steps in 1 kHz increments, demonstrates synthesizer design, and provides some solutions to problems that may occur in synthesizer design.

### synthesizer specifications

Loop performance specifications in a communications application such as an LO in a receiver or transmitter are phase noise, spurious content, and lock time. The best phase noise performance can be obtained with multi-PLL synthesizers<sup>1</sup> if space, complexity, and design time are not a problem. But because a simple single-loop synthesizer can be made more inexpensively and compactly than a multi-PLL synthesizer, design and construction of a simple single-loop synthesizer will be discussed here.

As a receiver LO, any spurs around the carrier can create spurious responses in the audio output. These spurs usually appear as reference feedthrough, power line (and harmonic) modulation of the VCO, and spurious oscillations in the VCO itself. Spurious oscillations in the VCO and power line modulation of the VCO are prevented by proper oscillator design, which includes good shielding and filtering. Reference feedthrough is largely a product of proper choice of loop parameters ( $f_n$ ,  $\xi$ , etc.) and type of phase detector.

In the design loop,  $-70$  dBc was chosen as a reasonable reference feedthrough limit, and  $-40$  dBc for any spurs created by power line 60 Hz (and harmonics). Since spurs at 60 Hz (and odd harmonics) originate largely from the power lines coupling into the VCO, shielding is an effective technique for reducing them. 120 Hz spurs are usually the result of

power supply ripple modulating the VCO and can be suppressed by filtering.

Lock time happens to be not only a function of loop bandwidth, but of frequency step size as well as the amount of frequency error, the designer considers acceptable for the "lock" state. Lock time for frequency synthesizers is usually specified as to within some  $\Delta f$  of the desired frequency before some specified time. Our loop must be within 1 Hz in less than 100 ms with a 1 kHz step in VCO frequency. A very rough equation for lock time for much less than 1 percent frequency error (relative to frequency step taken) is:

$$t_{LOCK} = 10/f_{\beta}$$

which is about 100 ms for a loop bandwidth of 100 Hz.

### the phase detector

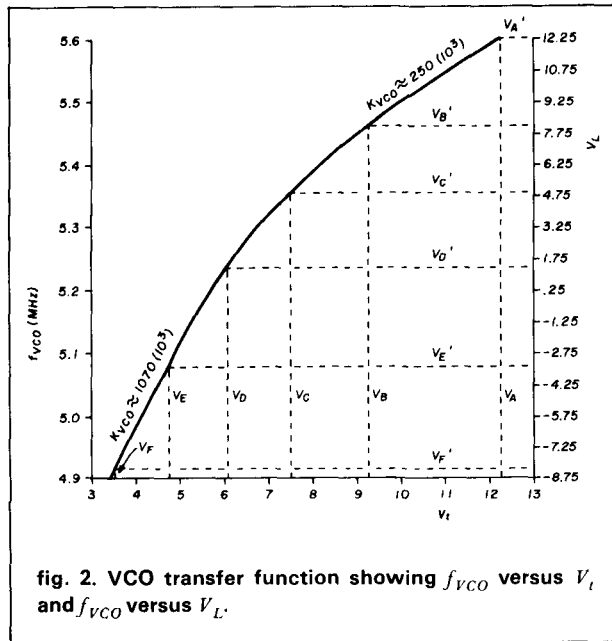
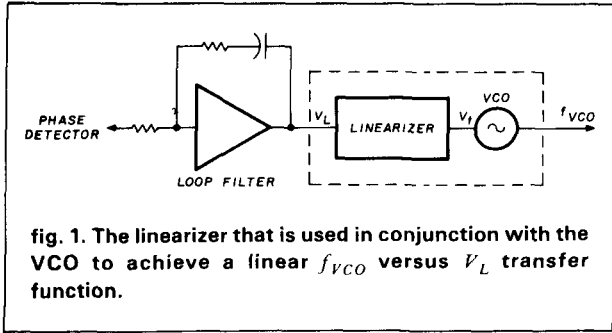
The design loop with an  $f_{REF} = 1$  kHz requires a very narrow bandwidth to reduce reference feedthrough, while a wide loop bandwidth is required for a fast lock time. This design uses a relatively wide loop bandwidth ( $f_{\beta} = 100$  Hz) for rapid lock time. To achieve the  $-70$  dBc reference feedthrough requirement, a sample and hold (or an approximation of it) phase detector was used.

The phase detector is part of Motorola's MC145151 PLL IC. This phase/frequency detector goes tri-state (open circuit) with zero phase error at its inputs. As long as zero phase error is maintained, there will be no reference feedthrough. However, there is always a small amount of reference feedthrough, since zero phase error cannot be maintained indefinitely because of VCO drift, etc., which causes the phase detector to generate occasional corrective pulses (at an  $f_{REF}$  pulse rate).

### programmable divider

The MC145151 PLL IC contains a programmable divider usable to at least 15 MHz at a supply voltage of 5 volts and a signal voltage of 500 mV peak-to-peak. The maximum division ratio is 16,383. It uses a straight binary input (not BCD), which facilitates linking to a computer, though not thumbwheel switches.

By Craig Corsetto, WA6OAA, 4312 Marlowe Drive, San Jose, California 95124



## the VCO

In this narrow-loop bandwidth synthesizer design low spurious content and good phase noise performance directly relate to the VCO physical and electrical design. In addition it is also important that the VCO has a low frequency drift rate (to reduce reference feed-through), linear transfer function (to keep loop bandwidth and damping reasonably constant), and be well filtered and shielded (to reduce modulation of the VCO by power supply ripple and induced 60 Hz from power wiring).

VCO frequency drift can increase reference feed-through by forcing the phase detector to generate correction pulses (which are not completely filtered by the loop filter) which in turn modulate the VCO. This is especially important when the reference frequency is close to the loop bandwidth, as is the case in this loop. Common contributors to frequency drift are the varactor diodes, toroidal core inductors in the resonator (if used), or excessive power in the resonator (unfortunately one of the requirements for a high signal-to-noise floor ratio for the oscillator).

Because a short lock time is required and  $f_{REF}$  is close to the loop bandwidth, then  $K_{VCO}$  must be fairly constant across the VCO frequency range in order to hold the loop bandwidth close to its designed value (and therefore reference feedthrough). Usually all that is required is to use the most linear section of the VCO tuning curve; its size dependent upon an acceptable value of nonlinearity. If the section of the VCO tuning curve used is small, this means a higher  $K_{VCO}$ , and the VCO will be more sensitive to unwanted signals on its tune line. The approach chosen here is to use a linearizer in combination with the VCO (fig. 1) to very closely approximate a linear VCO tuning curve (constant  $K_{VCO}$ ).

## the VCO linearizer

Fig. 2 shows the tuning curve for the VCO used in the design loop, with its 4.3:1 variation in  $K_{VCO}$ . Since this is significantly more than the 1.1:1 variation in  $K_N$ , (across the synthesizer frequency range) the effects of  $K_N$  on loop gain can be neglected in the following analysis.

With  $K_{VCO}$  the major cause of loop gain variations, its effects on  $f_n$  and  $\xi$  can be calculated:

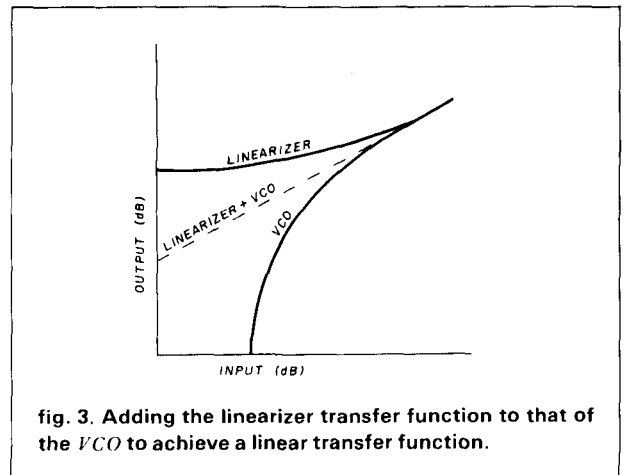
$$\Delta_K = \sqrt{\frac{K_t(MAX)}{K_t(MIN)}} = \sqrt{4.3} = 2.07 \quad (1)$$

Assuming that the loop bandwidth is 100 Hz and the damping factor equals 2 when the loop gain is greatest (i.e.  $K_{VCO}$  is at its maximum), then the effect of the 4.3:1 variation of  $K_{VCO}$  can be calculated:

$$f_n = \frac{f_\beta}{\sqrt{2\xi^2 + 1 + \sqrt{(2\xi^2 + 1) + 1}}} = 100/4.25 = 23.53 \text{ Hz} \quad (2)$$

$$\text{And } f_n(MIN) = f_n(MAX)/\Delta_K = 23.53/2.07 = 11.37 \text{ Hz}$$

$$\xi(MIN) = \xi(MAX) / \Delta_K = 2/2.07 = 0.97$$



$$f_{\beta} = f_n \sqrt{2\xi^2 + 1 + \sqrt{(2\xi^2 + 1)^2 + 1}}$$

$$= 11.37 \text{ Hz} (2.44) = 27.74 \text{ Hz} \quad (3)$$

which results in a 100/27.74 (3.6:1) change in loop bandwidth with its resulting effect on lock time.

The linearizer is designed to have a response that is the inverse of the VCO (nonlinear) transfer function so that when the linearizer is added to the VCO it will have the effect of producing a linear VCO tuning curve with constant  $K_{VCO}$  (fig. 3).

The linearizer is implemented (fig. 4) using resistor/diode sections<sup>2</sup> and a voltage divider network in order to individually modify the slope of the linearizer transfer function as each resistor/diode section is forward biased. (As  $V_L$  decreases, successive diodes are turned on modifying the slope of the  $V_L$  versus  $V_t$  curve).

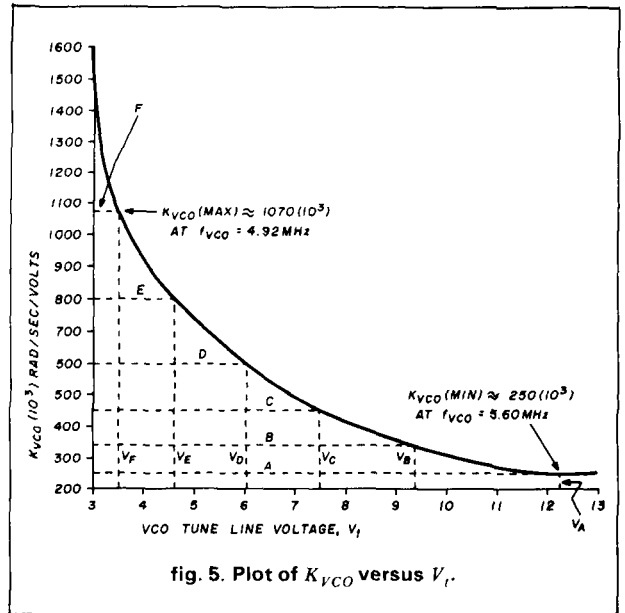
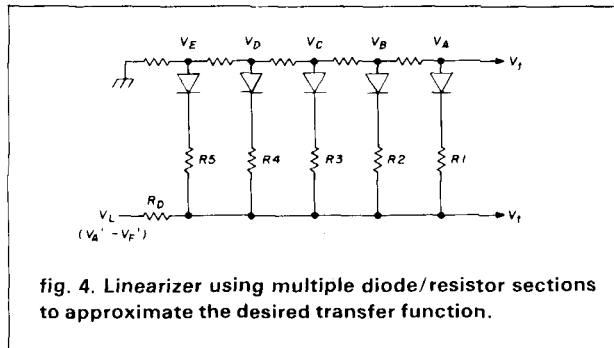
The method used to design the linearizer required the following steps:

1. plotting  $K_{VCO}$  versus  $V_t$  and then determining the VCO range to be linearized,
2. calculating the quantity of resistor/diode sections required for the maximum allowed variation in  $K_{VCO}$  (realizing that this is only a segmented approximation of the required transfer function to achieve a linear VCO tuning curve),
3. calculating the voltages for the voltage divider,
4. calculating the resistor values for the resistor/diode sections.

The VCO frequency range to be linearized is roughly 4.92-5.6 MHz which allows for some drift in frequency. The  $K_{VCO}$  at these two frequencies are  $1070 (10^3)$  and  $250 (10^3)$  rad/sec/volt. The number of resistor/diode sections needed for the linearizer are approximately:

$$n \approx \frac{\log \frac{K_{VCO} (MAX)}{K_{VCO} (MIN)}}{\log \Delta K_{VCO}} \quad (4)$$

where  $\Delta K_{VCO}$  is the allowed variation in  $K_{VCO}$  after it is linearized. For the design loop, it was decided that  $K_{VCO}$  will be allowed to change by only 30 percent so



$\Delta K_{VCO} = 1.3$ . (Once again, neglecting  $K_N$ , if  $K_{VCO}$  is the only source of loop gain variation, it varies only by 30 percent, then  $f_n$  and  $\xi$  will vary only by the square root of this, or 14 percent. This is acceptable.)

Therefore the number of resistor diode pairs needed are:

$$n = \frac{\log \frac{1070 (10^3)}{250 (10^3)}}{\log 1.3} = 5.54$$

It is decided to use 5 resistor/diode pairs instead of 6 even though this means a slightly higher error. This error is approximately:

$$\Delta K_{VCO} = 10 \frac{\log \frac{K_{VCO} (MAX)}{K_{VCO} (MIN)}}{n}$$

$$= 10 \frac{\log 4.3}{5} = 1.337 \quad (5)$$

Knowing  $\Delta K_{VCO}$  the voltage divider voltages can be calculated. In fig. 5 a mark for every 33.7 percent increase in  $K_{VCO}$  (starting at the low end of the  $K_{VCO}$  plot, or  $250 (10^3)$  in the example) corresponds to a voltage on the VCO tune line,  $V_t$ . If all the calculations are computed correctly, then the last computed point should correspond to the maximum  $K_{VCO}$  of the range over which the linearizer was designed to work ( $1070 \cdot 10^3$ ).

$$K_{VCO} (B) = 1.337 K_{VCO} (A)$$

$$= 1.337 \cdot (250 \cdot 10^3) = 334.25 \cdot 10^3$$

$$K_{VCO} (C) = 1.337 K_{VCO} (B)$$

$$= 1.337 \cdot (334.25 \cdot 10^3) = 446.89 \cdot 10^3$$

$$K_{VCO} (D) = 1.337 K_{VCO} (C)$$

$$= 1.337 \cdot (446.89 \cdot 10^3) = 597.5 \cdot 10^3$$

$$K_{VCO}(E) = 1.337 K_{VCO}(D)$$

$$= 1.337 \cdot (597.5 \cdot 10^3) = 798.8 \cdot 10^3$$

and for a check

$$K_{VCO}(F) = 1.337 K_{VCO}(E)$$

$$= 1.337 \cdot (798.8 \cdot 10^3) = 1068 \cdot 10^3$$

which is very close to  $1070 \cdot 10^3 = K_{VCO}(MAX)$ .

The corresponding trip voltages (where the resistor/diode combination starts conducting) are:

$$V_A = 12.25 \text{ volts} \quad V_D = 6.05 \text{ volts}$$

$$V_B = 9.35 \text{ volts} \quad V_E = 4.60 \text{ volts}$$

$$V_C = 7.70 \text{ volts} \quad V_F = 3.50 \text{ volts}$$

The voltage divider component values are chosen such that the current through them is much higher than the maximum current through the diodes to keep the voltages  $V_A$  through  $V_E$  constant.

To calculate the resistor values  $R_1$  through  $R_5$  and  $R_D$ , the voltage  $V_L$  that corresponds to the voltage  $V_t$  (especially at the trip voltages  $V_A$  through  $V_E$ ) must be determined. This is done by letting  $V_A'$  equal  $V_A$  and then linearly scaling the voltages  $V_B'$  through  $V_F'$  such that these voltages are always less than their corresponding voltages  $V_B$  through  $V_F$  (fig. 2). This means that  $V_L$  will swing through a larger range of voltages ( $-9.25$  to  $12.25$ ) than  $V_t$ , ( $3.5$ - $12.25$ ) as detailed below:

$$V_{A'} = 12.25 \quad (V_{A'} = V_A)$$

$$V_{B'} = 8.2 \quad (V_{B'} < V_B)$$

$$V_{C'} = 4.9 \quad (V_{C'} < V_C)$$

$$V_{D'} = 1.4 \quad (V_{D'} < V_D)$$

$$V_{E'} = -3.25 \quad (V_{E'} < V_E)$$

$$V_{F'} = -9.2 \quad (V_{F'} < V_F)$$

By assuming perfect diodes (i.e., no forward voltage drop), resistors  $R_1$  through  $R_5$  can be determined. To keep the current through the diodes at a minimum  $R_D$  should be fairly high (46.4k chosen here). By knowing what voltage the linearizer requires at its input ( $V_L$ ) to generate a corresponding voltage at the output, ( $V_t$ ) (fig. 2) resistors  $R_1$  through  $R_5$  can be calculated (fig. 6).

Power supply ripple is kept off the VCO tune line by using a Darlington transistor with a large RC time constant in its base that buffers the voltage to the linearizer voltage divider.

Ideally, the linearizer provides a perfectly constant  $K_{VCO}$  across the VCO tuning range. Because the linearizer is synthesized using linear segments (and these linear segments are really nonlinear due to the imperfect diodes), there will still be a non-constant  $K_{VCO}$  (non-linear VCO tuning curve), though vastly improved. Fig. 7 shows the measured  $K_{VCO}$  versus  $V_L$  using the linearizer and is compared to fig. 5 to show the improvement. The error appears to be very close to the calculated value of 33.7 percent.

## loop filter

With  $K_{VCO}$  almost constant and  $K_\phi$  and  $K_N$  defined, the loop filter components can now be determined. Looking at fig. 7, the minimum and maximum values for  $K_{VCO}$  are:

$$K_{VCO}(MAX) = 250 \cdot 10^3$$

$$K_{VCO}(MIN) = 190 \cdot 10^3$$

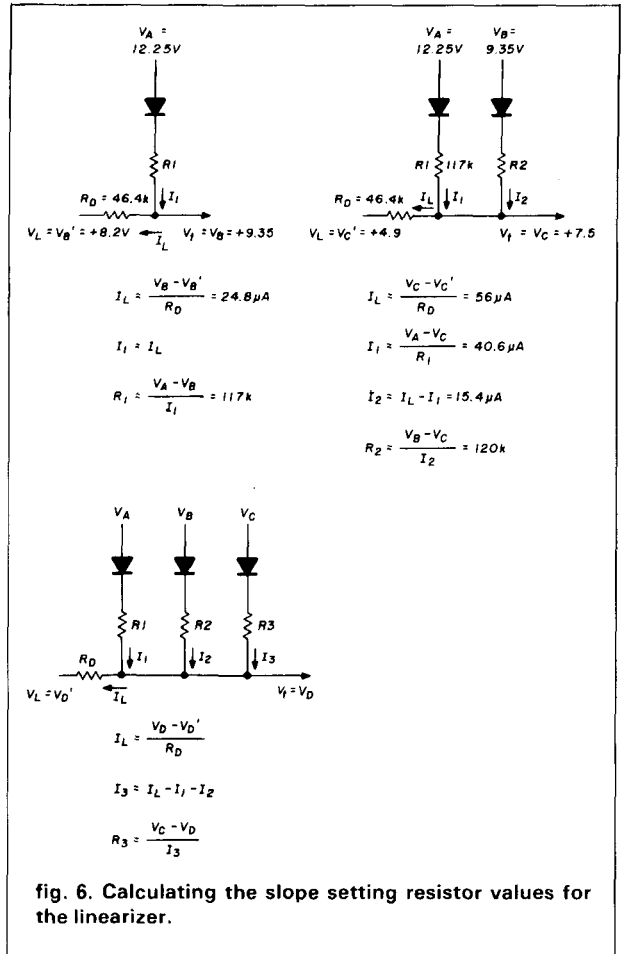


fig. 6. Calculating the slope setting resistor values for the linearizer.

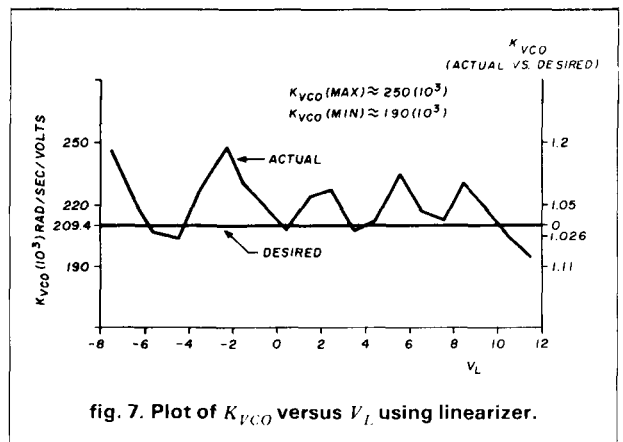


fig. 7. Plot of  $K_{VCO}$  versus  $V_L$  using linearizer.

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BALUN: ..... 4:1,2KW	ELLIPTICITY: ..... 3 dB Max.
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The values for  $K_N(MAX)$  and  $K_N(MIN)$  were as stated before:

$$K_N(MAX) = 200 \cdot 10^{-6}$$

$$K_N(MIN) = 181.82 \cdot 10^{-6}$$

$$K_\phi = 0.398 \text{ volts/radian}$$

Assuming  $K_{VCO}(MAX)$  occurs at  $K_N(MAX)$  and  $K_{VCO}(MIN)$  at  $K_N(MIN)$  (for worse case open loop gain variation) then:

$$K_t(MAX) = 19.9$$

$$K_t(MIN) = 13.75$$

Variations in  $f_n$  and  $\xi$  are:

$$\Delta_K = \sqrt{\frac{19.9}{13.75}} = 1.2$$

It was decided to have a damping factor of approximately one, but since it will vary by  $\Delta_K = 1.2$  the lower value of  $\xi$  will be set at  $\xi = 0.95$  and the maximum value will then be  $\xi = 0.95 (1.2) = 1.14$ , which, as discussed before, corresponds to the maximum loop bandwidth of 100 Hz. Using this information both  $f_n(MAX)$  and  $f_n(MIN)$  can be calculated:

$$f_n(MAX) = \frac{f_\beta(MAX)}{\sqrt{2\xi^2 + 1} + \sqrt{(2\xi^2 + 1)^2 + 1}}$$

$$= 100/2.708 = 36.92 \text{ Hz}$$

and

$$f_n(MIN) = f_n(MAX)/\Delta_K = 36.92/1.2 = 30.77 \text{ Hz}$$

With maximum values of damping, loop natural frequency, and loop gain known, the two time constants for the loop filter can now be determined.

$$t_1 = \frac{K_t}{(\omega_n)^2}$$

$$t_2 = \frac{2\xi}{\omega_n}$$

At  $f_{VCO} = 5.00 \text{ MHz}$  the loop gain is at its maximum corresponding to maximum values for  $f_n$ ,  $f_\beta$ , and  $\xi$ . Using these maximum values the time constants are:

$$t_1 = \frac{19.9}{(2\pi 36.92)^2} = 369.8 \mu\text{s}$$

$$t_2 = \frac{2(1.14)}{2\pi 36.92} = 9.828 \text{ ms}$$

Using minimum values of  $K_t$ ,  $f_n$ , and  $\xi$  should produce the similar results:

$$t_1 = \frac{13.75}{(2\pi 30.77)^2} = 367.8 \mu\text{s}$$

$$t_2 = \frac{2(0.95)}{2\pi 30.77} = 9.83 \text{ ms}$$

Although the loop filter components could now be

calculated using  $t_1$  and  $t_2$ , there are two areas that will restrict the values of R1 and C1 and should be examined (fig. 8). These areas are leakage currents and phase detector output current.

With the loop in lock the phase detector is in an open-state mode and does not "source" or "sink" current to the integrator, thereby allowing the integrator to hold its charge. Therefore the voltage out of the loop filter is constant. However, leakage currents will either add or subtract charge from the integrator capacitor causing the loop filter output voltage to the VCO to vary, changing its frequency. The loop then corrects for this frequency shift during the next reference frequency clock cycle. This means that a signal, at a frequency equal to the reference frequency and of an amplitude dependent on the leakage current, will be on the VCO tune line and thus modulate it (reference feedthrough).

Given the equation for the integrator:  $\Delta V_{OUT} = I/C (\Delta t)$ , where I is the leakage current,  $\Delta t = 1/f$ , and C is the integrator capacitor (C1), C is really the only variable available to the designer. ( $f_{REF}$  is fixed, and I is the leakage current of both the phase detector in its open circuit mode and the bias currents of the (LF-356) op-amp used in the integrator. The leakage current for the phase detector is 1 nanoampere and for the op-amp is about 10 pico ampere. The phase detector leakage predominates and so the op-amp leakage can be neglected.)

With maximum acceptable spur level of  $-70 \text{ dBc}$ , and knowledge of  $K_{VCO}(MAX)$ , the maximum reference feedthrough voltage on the VCO tune line can be approximated, then the smallest value of C1 for that reference feedthrough voltage can be calculated (given the leakage current).

$$V_L (p-p) = \frac{P_{SSB}^{20}}{8\pi f_m 10^{20} K_{VCO}(MAX)}$$

$$= \frac{8\pi (1\text{kHz}) 10^{-70}}{250 \cdot 10^3}$$

$$= 31.8 \mu\text{V}(p-p) \approx 32 \mu\text{V}(p-p)$$

where  $V_L = (p-p)$  reference feedthrough signal voltage

$P_{SSB}$  = single sideband spur level in dBc

$f_m$  = reference feedthrough signal frequency

The minimum value of C1 is:

$$C1(MIN) = (I) \frac{\Delta t}{\Delta V} = (I) \frac{1/f_{REF}}{\Delta V_L}$$

$$= 1 \text{ nA} \left( \frac{1 \text{ ms}}{32 \mu\text{V}} \right) = 0.031 \mu\text{F}$$

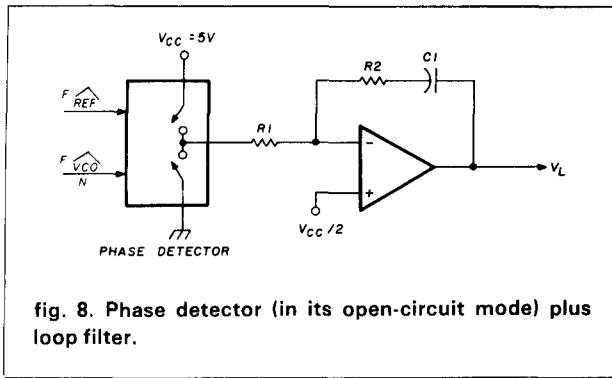


fig. 8. Phase detector (in its open-circuit mode) plus loop filter.

$$R1(MIN) = (5 - 2.5) / 500 \mu A = 5000 \text{ ohms}$$

The loop filter components can now be calculated by letting  $R1 = 5000$  and solving for  $C1$ :

$$C1 = t_1 / R1 = 367.8 \mu s / 5000 = 0.0736 \mu F$$

which fortunately happens to be greater than the minimum value for  $C1$  calculated before. Letting  $C1$  take on a more practical value,  $C1 = 0.068 \mu F$ ,  $R1$  can be recalculated:

$$R1 = 367.8 \mu s / 0.068 \mu F = 5410 \text{ ohms}$$

Calculating for  $R2$ :

$$R2 = t_2 / C1 = 9.83 \text{ ms} / 0.068 \mu F = 144.5K$$

or 147K, a common value in 1 percent resistors. Both  $R1$  and  $C1$  are within the desired limits.

For prefiltering ahead of the loop filter  $R1$  is split into two series resistors and a capacitor is tied between their common points and ground.

A unity gain inverter using a low noise op-amp follows the loop filter for required signal inversion

where  $I$  is the leakage current and  $V$  is the calculated reference feedthrough voltage for a  $-70$  dBc spur level.

The smallest value of  $R1$  is determined by the maximum current the phase detector can develop which, for the MC145151 is about  $500 \mu A$ . With the maximum phase detector voltage of approximately  $+5V$  and the other extreme at (a virtual)  $2.5V$  then:

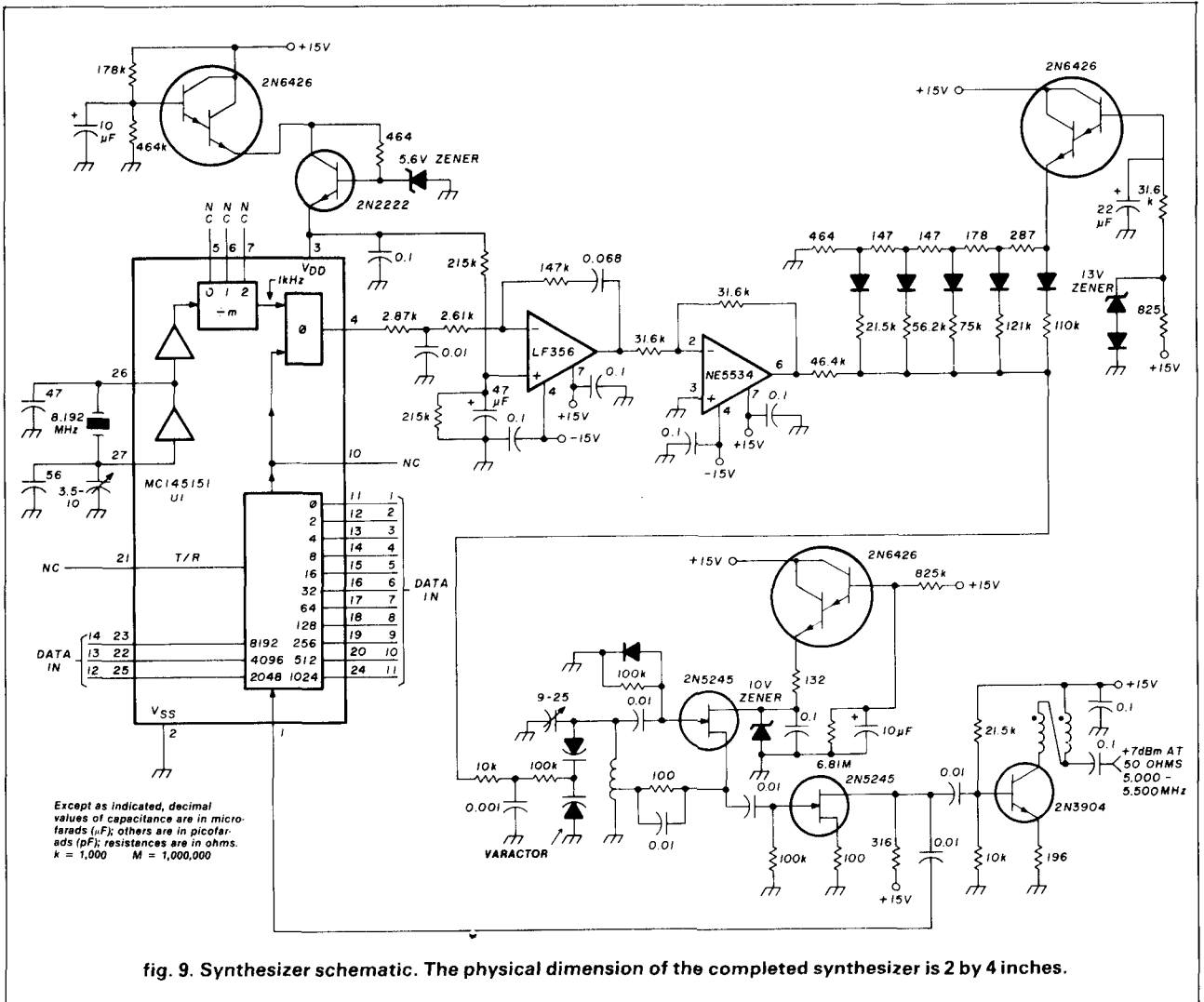


fig. 9. Synthesizer schematic. The physical dimension of the completed synthesizer is 2 by 4 inches.

for negative feedback in the phase-locked loop. Another filter pole is added to the loop by the addition of a 0.01  $\mu\text{F}$  capacitor across the inverters' feedback resistor. Like the pre-filter ahead of the loop filter, this pole is located at a frequency well outside the loop bandwidth.

### loop performance

This synthesizer (fig. 9) performed according to specifications immediately after completion. The only problem was excessive 60 Hz (and its odd harmonics) spurs which were solved with proper shielding. A Hewlett-Packard HP8568 spectrum analyzer was used to measure phase noise and spurious responses. Fig. 10 uses a wide-frequency sweep to show the general "cleanliness" of the synthesizer output for large frequency offsets from the carrier. The noise pedestal around the carrier is that generated by the spectrum analyzer.

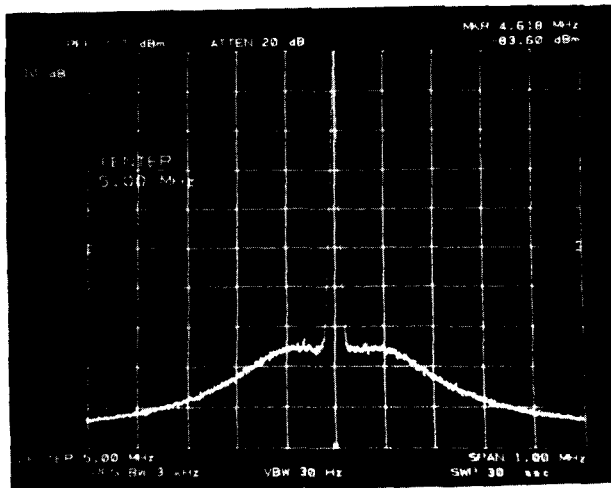


fig. 10. Phase and amplitude noise spectrum of the synthesizer for large offset frequencies ( $\pm 500$  kHz).

Fig. 11 is a SSB phase (and amplitude) noise plot of the synthesizer output using a 5-kHz linear sweep. The spurs are caused by the phase detector; examined closely, they can be seen to be two noise peaks centered around where the reference feed-through spur should be. Upon close examination the reference feed-through was greater than  $-70$  dBc, as designed. Unfortunately temperature effects on phase detector leakage current were not taken into account (as well as the variations in leakage current among MC145151's) and the  $-70$  dBc spur requirement is exceeded as the MC145151 heats.

Fig. 12 is a narrow spectrum view of the synthesizer using a 500 Hz sweep. This shows what reasonable shielding and filtering can do to minimize spurs. The 60 Hz spurs, originally only  $-30$  dBc,

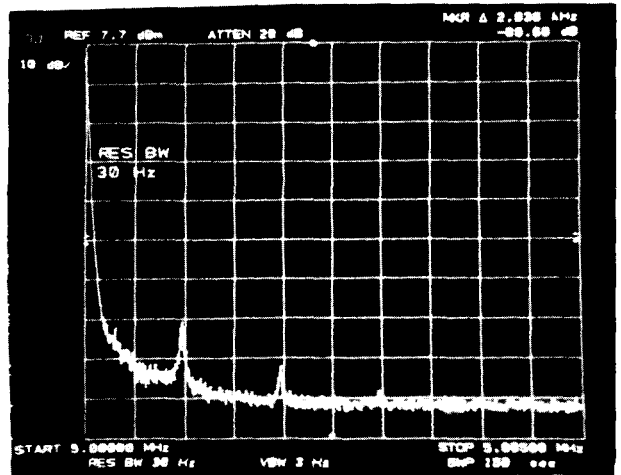


fig. 11. SSB phase and amplitude noise spectrum for up to 5 kHz offset. Spurs are actually two noise peaks centered around the reference feedthrough spur.

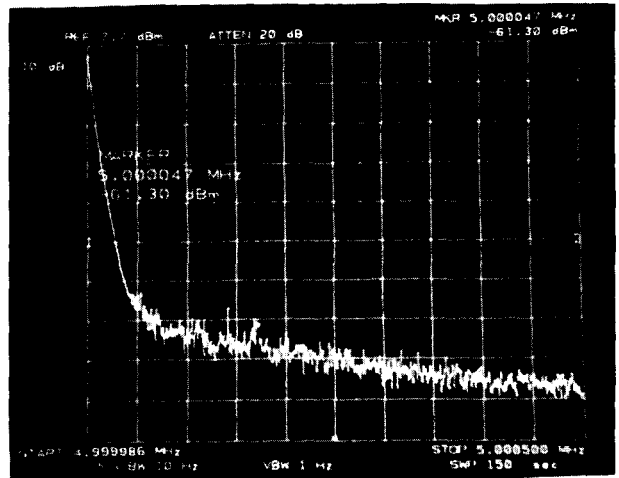
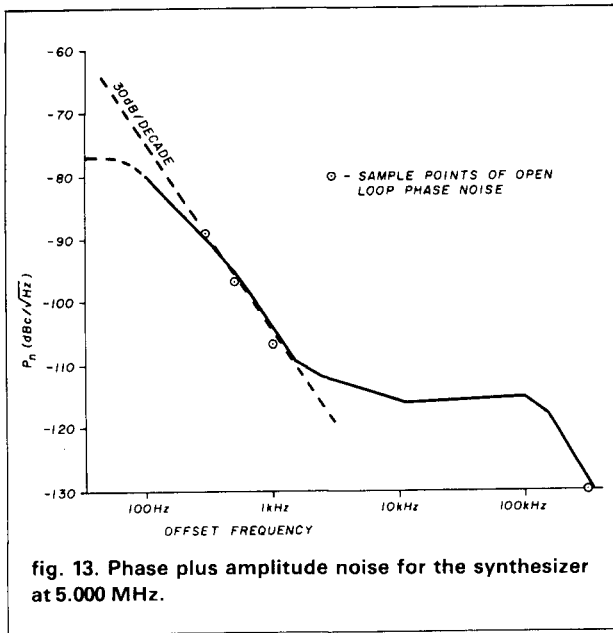


fig. 12. Close in phase and amplitude noise spectrum of synthesizer showing no perceptible 60 Hz or harmonic related spurs.

were reduced an additional 15 dB by optically shielding the varactor diodes, and by more than 30 dB through magnetic shielding of the synthesizer. The 120 Hz spurs were taken care of by using a Darlington transistor as an active filter for supply lines to sensitive parts of the synthesizer (i.e., VCO, linearizer, etc.).

Fig. 13 is a phase noise plot of the synthesizer at 5 MHz. Since the phase noise past the loop bandwidth (offset frequencies greater than  $f_{\beta} = 100$  Hz) is equivalent to that of the open loop VCO, while loop bandwidth and damping are held fairly constant, then the phase noise plot taken at any other frequency within the synthesizer range will be essentially identical.

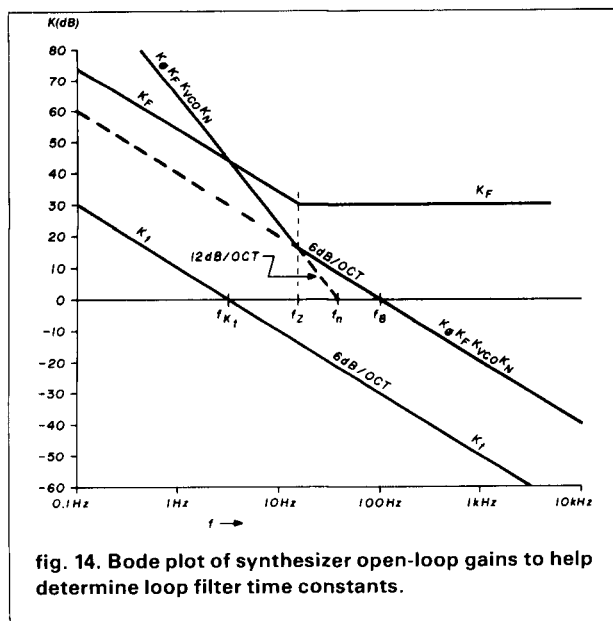
The lock time was examined by changing the programmable divider by one ( $\Delta f_{VCO} = 1$  kHz) and measuring the voltage settling time at  $V_L$  for a



roughly 1 percent frequency error. This turned out to be about 30 ms, much less than the  $10/f_\beta$  calculated (which shows just how rough an estimate of  $10/f_\beta$  is).

### using the Bode plot

Another method used in designing the loop filter, as well as a check and debugging aid, is by using the Bode plot. This is done by plotting the transfer function of  $K_t = K_\phi K_{VCO} K_N$ , then plotting the desired transfer function of  $K_\phi K_F K_{VCO} K_N$ . Subtracting the two gives the required transfer function of the loop filter from which the time constants for it can be derived.



In the example loop,  $K_t = 19.9$  (at  $f_{VCO} = 5.0$  MHz). A plot of  $K_t$  would have a 6 dB/octave slope crossing zero at a frequency of:

$$f = K_t/2\pi = 19.9/2\pi = 3.2 \text{ Hz}$$

The desired open-loop response,  $K_\phi K_F K_{VCO} K_N$  (fig. 14) crosses the desired bandwidth  $f_\beta = 100$  Hz with a 6 dB/octave slope at unity gain, then intersects and assumes the 12 dB/octave slope of a line that crosses unity gain at:

$$f_n = \frac{f_\beta}{\sqrt{2\xi^2 + 1} + \sqrt{(2\xi^2 + 1)^2 + 1}} = 39.4 \text{ Hz}$$

where the desired value of damping is one.

Subtracting  $K_t$  from  $K_\phi K_F K_{VCO} K_N$  (the desired total open-loop response) gives  $K_F$  as shown in fig. 14. The 6 dB/octave slope of  $K_F$  levels off at  $f_z$  at  $A = 30$  dB. The resistor ratios for the loop filter (fig. 8) are:

$$R2/R1 = Y = 10^{A/20} = 10^{+30/20} = 31.62$$

The time constants are:

$$t_2 = 1/(2\pi f_z) = 1/(2\pi 15.5 \text{ Hz}) = 10.27 \text{ ms}$$

$$t_1 = t_2/Y = 10.27 \text{ ms}/31.67 = 324.2 \mu\text{s}$$

As expected, these are very close to the earlier designed values.

This plot could further include all poles and zeros in the loop to spot potential problems (i.e., too much phase shift where it may cause loop instability).

### conclusion

This synthesizer should work fairly well as an LO for a receiver or transmitter if a 1 kHz step is small enough. For a synthesizer requiring smaller frequency steps a different configuration may be used, in-loop mixing with a VXO being a good choice.

It is important to realize that this synthesizer wanted a fast lock time with low reference feed-through, and paid a rather high price — i.e., inclusion of the linearizer — for it. If a longer lock time is acceptable (lower  $f_\beta$  to accommodate variations in loop gain), the linearizer can be left out of the circuit, simplifying the design. However, in the application for which this synthesizer will be used (frequency scanning), a rapid lock time is desirable. It also must be mentioned that as  $f_\beta$  decreases, the loop will have increasing difficulty in tracking mechanical vibrations, and even its own VCO drift.

### references

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2. William Egan, *Frequency Synthesis by Phase Lock*, pages 55-58, John Wiley and Sons, 1981.

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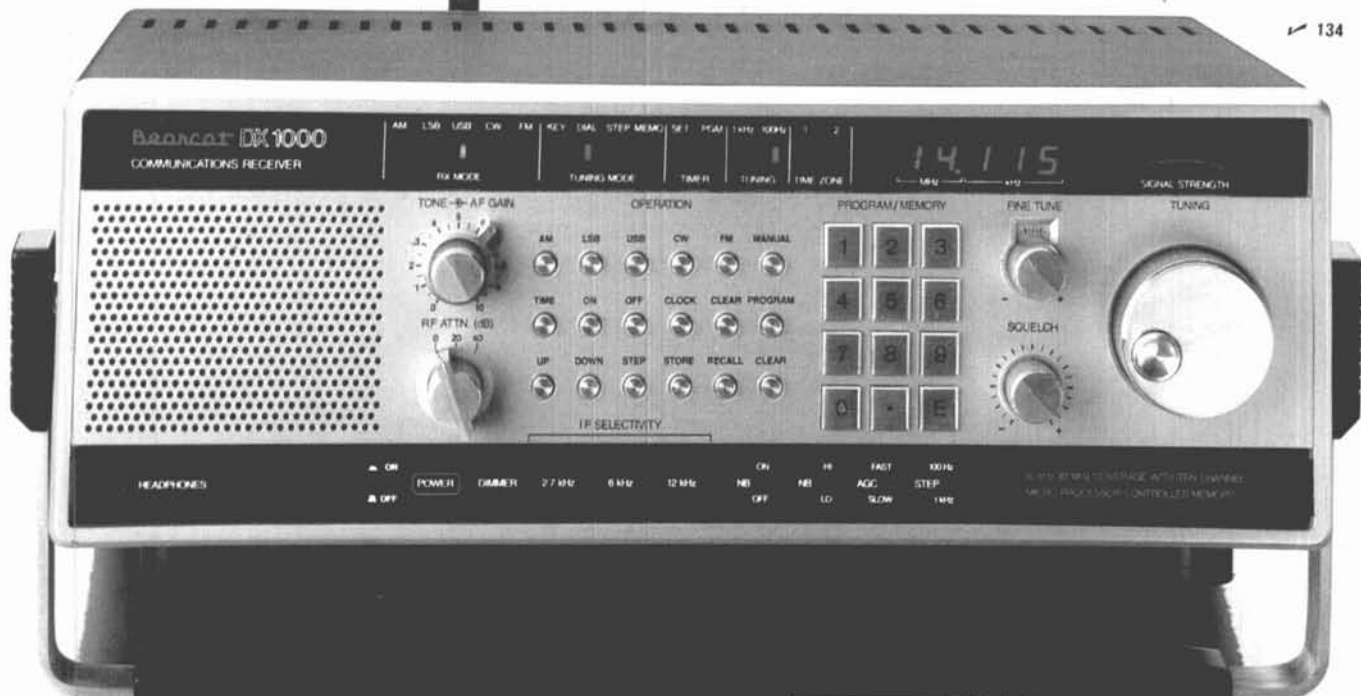
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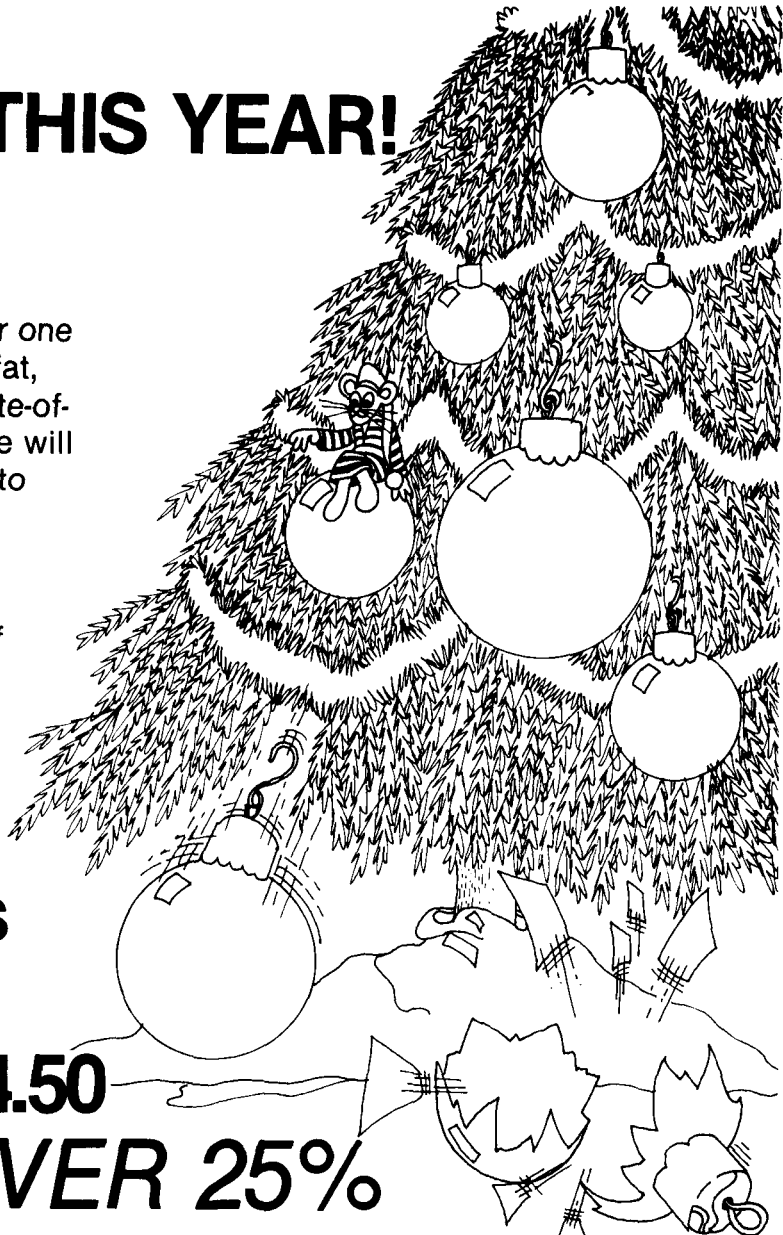
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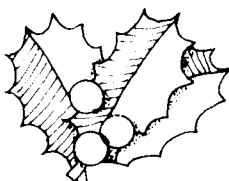
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# vertical phased arrays: part 4

## Feed network design using L-match circuits, $\pi$ and tee coax-equivalent circuits

**Previous articles of this series** on vertical phased arrays<sup>1,2,3</sup> concentrated on the design of the physical aspects of arrays: element length, radius, spacing and ground planes. The latest article<sup>3</sup> dealt with electrical measurements of the arrays and calculation of driving-point impedances. Knowing the required drive current amplitude and phase for each element of the array pattern selected, and knowing the measured values of self- and mutual impedances, we can calculate the driving-point impedance of these elements. The importance of this cannot be over-emphasized; because of mutual impedance effects between elements, driving-point impedances of elements in an array are not fixed entities. Each element's driving-point impedance depends upon the amplitude and phase of the drive currents — not just upon its own drive current, but upon the amplitude and phase of the drive current of every element in this array. A change of the current amplitude or phase to any element results in a driving-point impedance change of every element together with a change in all current amplitudes and phases. Examination of the set of simultaneous equations defining these driving-point impedances illustrates this relationship:

$$\begin{aligned} Z_1 &= E_1/I_1 = Z_{11} + I_2Z_{12}/I_1 \\ &+ I_3Z_{13}/I_1 + \dots + I_nZ_{1n}/I_1 \quad (1) \\ Z_2 &= E_2/I_2 = I_1Z_{12}/I_2 + Z_{22} \\ &+ I_3Z_{23}/I_2 + \dots + I_nZ_{2n}/I_2 \end{aligned}$$

$$\begin{aligned} Z_n &= E_n/I_n = I_1Z_{1n}/I_n + I_2Z_{2n}/I_n \\ &+ I_3Z_{3n}/I_n + \dots + Z_{nn} \end{aligned}$$

where  $Z_1, Z_2, \dots, Z_n$  are element driving-point impedances

$E_1, E_2, \dots, E_n$  are element impressed voltages

$I_1, I_2, \dots, I_n$  are element drive currents

$Z_{11}, Z_{22}, \dots, Z_{nn}$  are element self impedances

$Z_{12}, Z_{13}, Z_{23}, \dots, Z_{1n}, Z_{2n}, Z_{3n}$  are mutual impedances between pairs of elements

(All terms can be complex.)

For example, suppose the drive current  $I_2$  to element 2 changes. Since  $I_2$  appears in the equation for every element, all driving-point impedances, currents and voltages are affected. The self and mutual impedances do *not* change, even though it is the mutual impedances that cause this interaction.

An array is a coupled system, automatically adjusting to any change with a new set of currents and phases, which again simultaneously satisfies all the equations. There is an infinite number of such solutions, but *only a few* result in useful array patterns. A feed network must be designed that when connected to the terminals of each element, applies the proper voltage amplitude and phase, causing the required drive currents to flow. If this condition is met, then all conditions are met. (It may now be clearer why I have been emphasizing the importance of physical and electrical symmetry of the elements.) As the array direction is switched, each port of the feed network continues to "see" the same driving-point impedance it was designed for, even though each port is now feeding a different element. Exact symmetry is probably the most difficult condition to meet in practice because it depends upon more than just simple duplication of physical elements; it also depends on duplication of the environment adjacent to each element: for example, ground planes or other nearby conductors that might act as antennas.

**By Forrest Gehrke, K2BT, 75 Crestview Road,  
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## feed networks

Just as there are an infinite number of solutions to the set of equations defining the driving-point impedances of an array, there are almost as many ways to design networks fitting the one solution required. Some designs are better than others, resulting in more bandwidth for usable F/B (front-to-back) ratio or low SWR. As a general rule, the simpler (that is, the fewer stages in the network), the better, but there are exceptions.

*For superior F/B performance, for all network designs, the designer must know the driving-point impedance of each element.* In this respect, vertical phased arrays are more critically affected by element variations than Yagis are by height variations. For multiple-element arrays, cookbook recipe duplication attempts are almost guaranteed to miss optimum current drive conditions by 10 percent. *This is enough to reduce the F/B performance by 50 percent or more.*

## basic design objectives

Some basic design decisions must first be made: what type of circuit elements should be used? Should the design have the objective of a 1:1 SWR match to the array feedline? Feed networks may be devised using coaxial cables as circuit elements. Although simple in construction, there may be technical and cost drawbacks. Series or stub coaxial cable sections, provided one has a wide enough selection of different characteristic impedances and lengths, could be used for a network that matches to the feedline. The cost would be high and bandwidth narrower than the array's intrinsic F/B capability.

As a special case, for arrays operating with 90-degree current phase multiples and equal current amplitude ratio element pairs,<sup>3</sup> an approach suggested by W7EL<sup>4</sup> makes use of the unique characteristic of a 1/4-wavelength line to produce a constant 90-degree phase displacement between input voltage and output current, independent of the load termination. If two such lines are connected to a common feedpoint, equal current will flow into the loads regardless of their termination impedances. The current phase displacement between the two loads is 0 degrees, but this may be changed to 180 degrees by insertion of a 1/2-wavelength line in series with one of the lines. (The phase displacement of a 1/2-wavelength line also is independent of the load impedance.) A 90-degree current phase displacement, as was pointed out earlier in this series,<sup>1</sup> cannot be obtained by insertion of a 1/4-wavelength line when the termination is reactive. Therefore, instead of inserting an additional 1/4-wavelength line, a lumped-constant phase correction circuit based upon the calculated driving-point impedances is inserted. It pro-

vides a drive current phase of 90 degrees and the correct amplitude at the element(s). The input voltage amplitude and phase to the correction circuit must be designed to be the same as that of the common connection point of the array. SWR of the array can be minimized by proper choice of the characteristic impedance of the coaxial cable feeder lines but cannot be designed for a 1:1 condition. This approach, based upon this unique characteristic of 1/4-wavelength lines, which are also the element feedlines, is limited to arrays where this length is able to physically reach the directional switch. If not possible, a further 1/2-wavelength line has to be added to each feedline to maintain the basis of the design concept.

*This article provides sufficient information to enable the reader to design a feed network for any conceivable array. There are no restrictions on array spacings, current amplitude ratios or phase displacements. The elements must be alike, but they need not be resonant. Conventional or not, if the array you've been able to fit onto your property has a useful pattern, a feed network can be designed to drive it at the needed conditions.* Such versatility requires complete design freedom — freedom to use any characteristic impedance, to transform to any input resistance, regardless of reactive load impedances. Coax is an excellent means for transmission of RF energy between physically separated points. If it also fills a role as a specific circuit element, so much the better. But as a circuit element where the physical spacing does not require it, coax is confining; with only two characteristic impedance choices commonly available (there are perhaps two more, but neither is easy to find), one is constantly making compromises and designing around this limitation. Furthermore, ease of circuit adjustment is not notable. On the other hand,  $\pi$  and tee coax-equivalent lumped-constant circuits may be designed for any exact characteristic impedance or any electrical length, whether lagging or leading phase, and are easily adjusted. And surprisingly, low impedance lumped constant circuits of the same levels as coaxial transmission lines display comparable characteristics, even when designed for fairly large single increments of phase displacement. **Table 1** compares coaxial cable with a 45-degree  $\pi$  circuit cascaded with a 45-degree tee circuit operated as a 1/4-wavelength transformer. Off-frequency phase variation and development of input reactance compares very favorably with coaxial transmission line.

Rounding out the list of network building blocks are the shunt and series input L-match transforming circuits. Included are the two special cases of this circuit, where the series or shunt branch is absent, which I will call a Parallel and a Series impedance circuit, respectively. **Figs. 1A** through **1F** are schematics of all of these circuits.

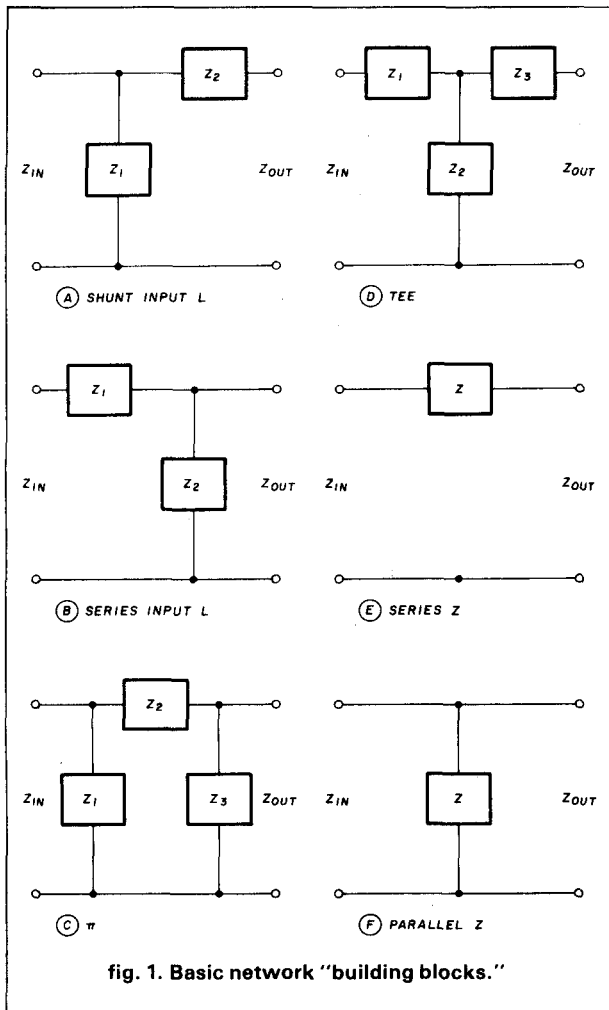


fig. 1. Basic network "building blocks."

## why a 1:1 SWR?

For multi-element arrays the objective of a 1:1 match to the array feedline does not stem from an obsession with SWR. *A low SWR provides no significant measure of an array's efficiency or usable F/B bandwidth.* Designing for an SWR of 1:1 simplifies network design calculations and electrical tests. However, the real value is the instant array condition conveyed every time an SWR measurement is made. A failing relay in a directional switch or a network malfunction is quickly detected, even if this circuit is to an element requiring very little power. Such a failure may raise the SWR from 1:1 to 1.1:1, for example, while the same failure in an array normally showing 2:1 will not be noticed. At "smoke" test time it removes uncertainty; a 1:1 SWR represents an unambiguous confirmation of the accuracy of array measurements, network design, and construction.

As an illustration of the step-by-step design procedure for an array feed network, I will use the popular 2-element array. The same array will be used to show the error that arises in many 2-element ver-

tical array feed arrangements. From Part 3 of this series,<sup>3</sup> the driving-point impedances of two 1/4-wavelength resonant elements spaced 1/4-wavelength apart with unity current ratio and 90 degree phase displacement, are:

Element 1	Element 2
$Z_1 = 21.4 - j15$	$Z_2 = 51.4 + j15$
$I_1 = 1 \angle 0^\circ$	$I_2 = 1 \angle -90^\circ$

Assuming 50 ohm 1/4-wavelength feedlines, using a Smith Chart or by calculation, the element driving-point impedances rotated to the input ends of the feeders are:

$$Z_1 = 78.3 + j54.91 \quad Z_2 = 44.82 - j13.08$$

At element drive conditions of 1 ampere with a phase displacement of  $-90$  degrees between elements, the voltages and currents that must be applied to the inputs of these feeders in polar form are:

$$I_1 = 0.52 \angle 55.0^\circ \quad I_2 = 1.07 \angle 16.3^\circ$$

$$E_1 = 50 \angle 90^\circ \quad E_2 = 50 \angle 0^\circ$$

Notice that the current phase change in the two equal 1/4-wavelength feeders are 55 degrees and 106.3 degrees (90 degrees + 16.3 degrees). Next a 1/4-wavelength 50-ohm delay line is added to the feedline from element 2. Rotating the impedance to the end of the delay line we find these conditions:

$$Z_2 = 51.4 + j15$$

$$I_2 = 1 \angle 90^\circ$$

$$E_2 = 53.54 \angle 106.3^\circ$$

These are the conditions that must exist at the input ends of the feeders from each element for the assumed drive conditions. The current phase delay through the delay line is less than 90 degrees, (90 degrees - 16.3 degrees, or 73.7 degrees, the difference between the input and output angle). Observe that the input voltage amplitudes and phases are not alike at the input ends of the coaxial lines from the two elements. But these two terminals are normally connected together; clearly two different voltages can't coexist here. Since the difference is fairly small, the actual drive conditions that result if connected anyway will be acceptable, though the F/B ratio will diminish. The choice of 1/4-wavelength element feeders just happened to provide this fair agreement. I estimate the actual phase displacement between elements to be about 115 degrees and the current amplitude ratio about 1.15. The 1/4-wavelength delay line didn't produce a 90-degree delay and the delays in the two equal length feeder lines were unequal; these are all quite different results from what is often assumed to occur.

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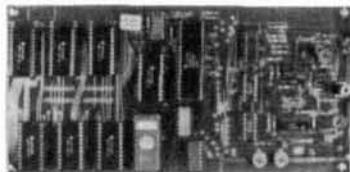
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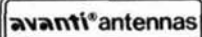
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length feeders as long as lengths are kept equal. Let's see how we fare following this advice using 3/8-wavelength 50-ohm feeders for the same array:

Element 1	Element 2
$Z_1 = 21.4 - j15$	$Z_2 = 51.4 + j15$
$I_1 = 1 \angle 0^\circ$	$I_2 = 1 \angle -90^\circ$
$E_1 = 26.13 \angle -35.03^\circ$	$E_2 = 53.54 \angle -73.73^\circ$

135° Feeder	135° Feeder
$Z_1 = 63.58 - j53.98$	$Z_2 = 37.43 + j2.67$
$I_1 = 0.58 \angle 148.56^\circ$	$I_2 = 1.17 \angle 51.66^\circ$
$E_1 = 48.39 \angle 108.22^\circ$	$E_2 = 43.97 \angle 55.75^\circ$

1/4 wavelength delay line
$Z_2 = 66.46 - j4.75$
$I_2 = 0.88 \angle 145.75^\circ$
$E_2 = 58.60 \angle 141.66^\circ$

Note: all impedances, voltages, and currents are input conditions — that is, looking towards the load.

Using 3/8-wavelength feeders, the input voltages required to be applied to each chain are very different. If these terminals are tied together the drive conditions to the elements will be far from intended. Conclusion: element feeders are an integral part of the feed network for a phased array; their circuit characteristics must be taken into account.

### designing for optimum drive

While it is possible to solve for the undesirable drive conditions that would result from making this connection, why bother? It is better to start with the correct design. While doing so, suppose a 1:1 SWR match to a 50-ohm array feedline is included. This would require that the paralleled input impedances of the networks from each element be 50 ohms pure resistance. Assuming lossless conditions, we can go

back to the resistive components of the element driving-point impedances for this determination. These are 21.4 and 51.4 ohms, respectively. At 1 ampere to each element the total drive power is the sum of the  $I^2R$  inputs, or 72.8 watts. Using the relationship  $E^2/R = W$ , and substituting 50 ohms (the characteristic impedance of the array feed-line) for  $R$ :

$$E^2 = 50(72.8), \text{ or } E = \sqrt{3640} = 60.33 \text{ volts}$$

Having established the array feedline voltage amplitude for this drive power, we can calculate the required resistive inputs for each element's network. Rearranging,  $R = E^2/W$ :

$$R_1 = 3640/21.4 = 170.09 \text{ ohms}$$

for network, No. 1 input

$$R_2 = 3640/51.4 = 70.82 \text{ ohms}$$

for network, No. 2 input

As a check on calculations it is useful to do the parallel conductance calculation:

$$1/R_1 + 1/R_2 + \dots + 1/R_n = 1/Z_0 \quad (2)$$

Starting again at the end of the 3/8-wavelength feeder to element 1, one possibility is an L-match network, transforming directly to 170.09 ohms pure resistance. L-match circuit component calculations involve a square root extraction, guaranteeing at least two solutions. (Under certain circumstances, there may be four solutions.) While all solutions produce the intended transformation, they do so with differing phase displacements, with at least one of those displacements being a leading phase. Remembering that element 2 is starting 90 degrees behind the first, fewer stages in the network usually result if a leading phase L-match is chosen for element 1.

Shown in **table 2**, beginning with the driving-point impedances and working forward to the common

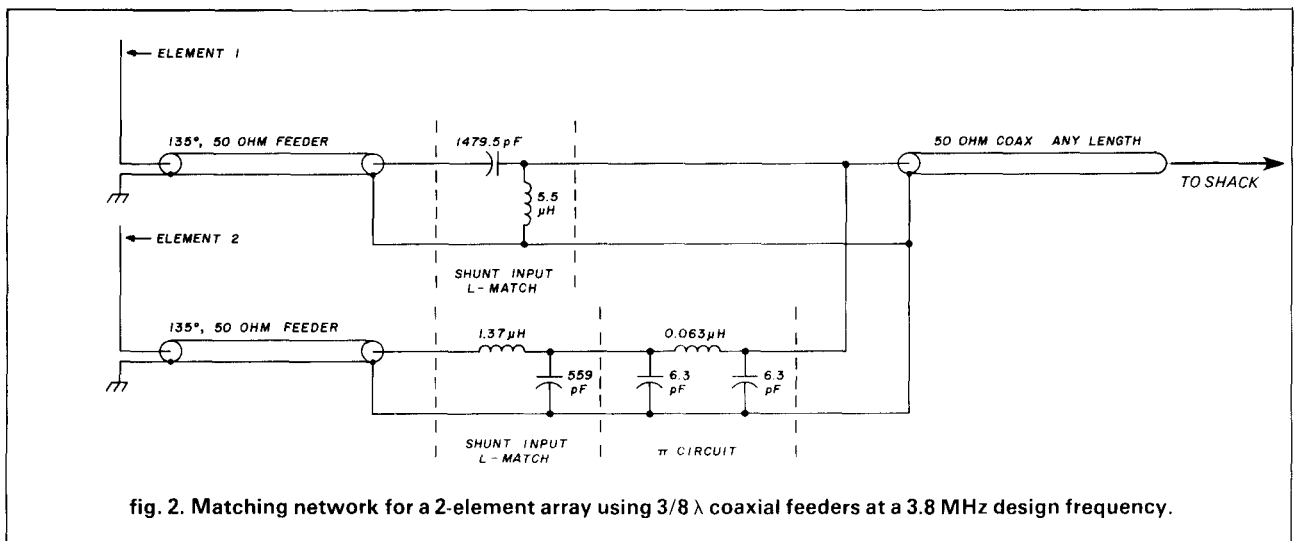


fig. 2. Matching network for a 2-element array using 3/8 λ coaxial feeders at a 3.8 MHz design frequency.



connection of the array, are the input parameters of each circuit. Fig. 2 shows the schematic and component values at the design frequency of 3.8 MHz.

At the inputs of each network chain,  $E_1$  and  $E_2$  are equal in amplitude and phase; the two inputs may be connected together without disturbing drive conditions. Their paralleled resistive inputs represent a 50-ohm resistive load, as designed. The  $\pi$  coaxial-equivalent network was added to the element 2 chain only to show how this type of network circuit is used to match the voltage phase at the common connection of the array network. In this example the agreement that happened to be achieved at the input to the 2 element shunt L-match is sufficient; the  $\pi$  network can be omitted.

**4-terminal networks.** The design procedure for producing exact matching at the required array conditions has been demonstrated. Before proceeding with other examples, the design equations for these circuits are presented. All network circuit components are reactances and assumed to be lossless. Subscript **a** denotes the series load termination components,  $R_a + jX_a$ , instead of the more commonly used  $R_L + jX_L$ , to avoid any confusion with  $jX_L$ , as an inductive reactance.

**L-match circuit.** This circuit can take two forms (see fig. 1A and 1B), termed *Shunt Input* and *Series Input* L-matches. Though this circuit consists of only two components, its analysis is relatively complex. The calculations for either form include a square root extraction, resulting in two possible sets of components for any desired impedance transformation. Either set works; one set often has a leading phase angle, while the other may lag. The absolute value of the angles are not necessarily equal nor always of opposite sign! The component set may have the same reactance sign; that is, both may be inductive (+) or both capacitive (-). The circuit is sometimes referred to as an L-C match, but it could also be an L-L or C-C match. A more apt description is L-match, taken from the similarity of its schematic representation to the letter "L".

**Shunt input L-match.** The series arm component  $X_2$ , must be calculated first, since its value is used in the calculation for the second component:

$$X_2 = -X_a \pm \sqrt{R_a(R_{in} - R_a)} \text{ ohms} \quad (3)$$

$$X_1 = - \left[ \frac{R_a^2 + (X_2 + X_a)^2}{X_2 + X_a} \right] \text{ ohms} \quad (4)$$

where  $R_a$  and  $X_a$  are the series equivalents of the load termination and  $R_{in}$  is the desired input (pure) resistance.

Close attention must be paid to signs. A positive result indicates an inductance, while a negative sign is a capacitance.

**Series input L-match.**  $X_2$  must be calculated first. Note that  $X_2$  is the shunt arm of this circuit, however.

$$X_2 = \frac{-R_{in}X_a \pm \sqrt{R_{in}R_a(R_a^2 + X_a^2 - R_{in}R_a)}}{R_{in} - R_a} \text{ ohms} \quad (5)$$

$$X_1 = \frac{-X_2[R_a^2 + X_a(X_2 + X_a)]}{R_a^2 + (X_2 + X_a)^2} \text{ ohms} \quad (6)$$

Which form should be used? Usually, the shunt input L-match is the only form possible if  $R_{in}$  is equal to or greater than  $R_a$ . Besides, the arithmetic is easier! The series input L-match is used when  $R_{in}$  is less than  $R_a$ . There is a set of circumstances, however, in which the series form can be used even if  $R_{in}$  is greater than  $R_a$ . Inspection of the equation for the series form calculation of  $X_2$  will show this case when  $R_{in}$  is greater than  $R_a$  and when  $(R_a^2 + X_a^2 - R_{in}R_a)$  is equal to or greater than zero. Four solutions, two series and two shunt L-matches, then result. These additional options, if available, are often useful, allowing a smaller phase displacement or more (physically) realizable set of components as a result.

**$\pi$  coaxial-equivalent circuit (fig. 1C).** The  $\pi$  circuit and the shunt input L-match will be found to be the most frequently used circuits for vertical phased array feed networks. The type used here is set up as a reversible network — that is, the input and output can be interchanged without affecting operation, just as with coaxial cable. Reactances  $X_1$  and  $X_3$  are always equal and if capacitive, then  $X_2$  is inductive. At the design frequency this particular configuration shows the same properties as coax. As the frequency is varied, the phase displacement starts differing from that obtained with coax, the difference being larger the greater the equivalent "length" of the circuit. If, instead, multiple sections, each an equal increment of the total phase displacement, are cascaded, the combined network approaches coaxial cable characteristics. This should be expected since the equivalent circuit of coax is a series of infinitesimally small  $\pi$  sections. The design equations are relatively simple:

$$X_2 = Z_0 \sin \theta \text{ ohms} \quad (7)$$

$$X_1 = X_3 = - \frac{Z_0 \sin \theta}{1 - \cos \theta} \text{ ohms} \quad (8)$$

where  $Z_0$  is the required characteristic impedance  
 $\theta$  is the electrical length in degrees

A positive sign indicates an inductance while a negative sign indicates capacitance.

If a *leading* phase, say 30 degrees, is desired, this would be equivalent to 330 degrees in electrical

length if coaxial cable were used. Substituting 330 degrees in these equations causes  $X_2$  to be negative and  $X_1$  and  $X_3$  to be positive; the appropriate capacitance and inductances can then be calculated from the relations:

$$C = 1/\omega X \text{ and } L = X/\omega \quad (9)$$

where  $\omega = 2\pi f$ ,  $f = \text{frequency in Hz}$

Half-wave section (180 degree electrical length)  $\pi$  circuits are taboo, since the calculated circuit values are physically unrealizable. At the least, two separate 90-degree sections are suggested to achieve this "electrical length."

**Tee coaxial-equivalent circuit (fig. 1D).** This circuit is used in the same applications as the  $\pi$  circuit. Alternated with  $\pi$  networks in equal increments of electrical length, network characteristics can be made to equal or exceed coax (assuming coax of the same characteristic impedance is available for comparison). For applications requiring a leading phase displacement only one inductance (for the shunt arm) is necessary, sometimes simplifying construction. The design equations are:

$$X_2 = -Z_0/\sin \theta \text{ ohms} \quad (10)$$

$$X_1 = X_3 = \frac{Z_0(1 - \cos \theta)}{\sin \theta} \text{ ohms} \quad (11)$$

where  $Z_0 = \text{required characteristic impedance}$   
 $\theta = \text{electrical length required in degrees}$

As with the  $\pi$  network, a positive sign indicates inductive reactance and a negative sign, capacitive reactance. Also, 180 degree sections cannot be physically realized and require at least a 2-section cascaded network to achieve that displacement.

**Series impedance circuit (fig. 1E).** This circuit is used when  $R_{in}$  is equal to  $R_a$  and the load has a reactance  $X_a$ . The series matching impedance is simply the reactance of the opposite sign.

$$X = -X_a \text{ ohms} \quad (12)$$

**Parallel impedance circuits (fig. 1F).**

$$X = - \left[ X_a + \frac{R_a^2}{X_a} \right] \text{ ohms} \quad (13)$$

The parallel matching reactance has the opposite sign of the parallel equivalent reactance of the load. The series and parallel circuits can be thought of as a shunt input L-match — with one of its circuit branches either equal to infinity or zero impedance, respectively.

These conditions occur when  $R_{in} = R_a$  or

$$X_a = \sqrt{R_a(R_{in} - R_a)}$$

Either circuit should be considered, particularly when the load has a relatively large reactance compared to its resistive component. The circuit is simple, and cascaded with a following L-match circuit, results in a broader bandwidth network.

## design limitation and other considerations

Some design hints may be helpful to understanding the use of these circuits:

1. The L-match circuits first require selection of the input resistance wanted, transforming from any output impedance. Phase displacement, however, cannot be pre-defined, though the direction, lead or lag, may be chosen.

2. Single L-match impedance transformation ratios exceeding 5-to-1 should be avoided. Above that ratio, expect to see increased frequency sensitivity and resultant reduction in bandwidth. For high ratios, consider transforming in step increments of resistance using several L-matches or combinations of L-match and  $\pi$  or tee circuits (the latter as 1/4-wavelength transformers).

3. In this particular application,  $\pi$  and tee circuits are always designed for pure resistance terminations. These circuits are designed to act as a 1/4-wavelength transformer, or as a specific coaxial-equivalent length, leading or lagging, of transmission line. Choose any characteristic impedance, but keep in mind that large (more than  $\pm 90$  degree) increments of angular displacement, especially at high impedances, reduce bandwidth.

4. Cascaded circuits may each have a capacitor at their common connection points, which are then in parallel. For example, see fig. 3 showing a 567 pF and 392 pF capacitor at a common connection point. The two values may be added and a single capacitor placed at that junction. However, until the network has been tested, it is useful to keep the circuits independent for separate adjustment.

## designing networks for multi-element arrays

Armed with the design equations for simple 4-terminal networks, we can now examine feed networks for arrays consisting of several elements. If the array is one requiring a phase angle multiple, for example, 0, 90, and 180 degrees, or 0, 100 and 200 degrees, and all feedlines are equal in length, the simplest network may result if the middle element is treated as if it were the reference element of the array. The respective networks for the array end elements are designed to lead and to lag the middle element. Then neither has to be designed to span a large angular displacement, and fewer stages result.

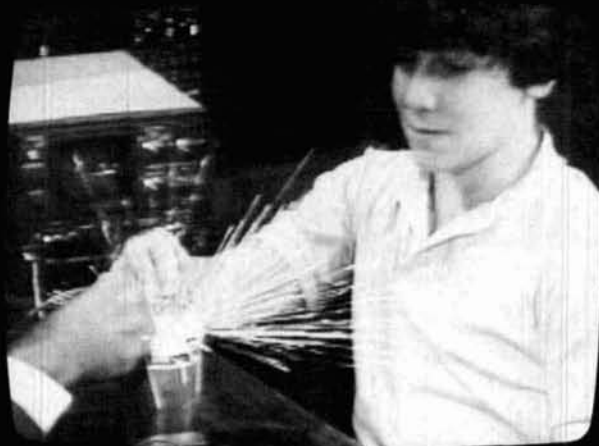
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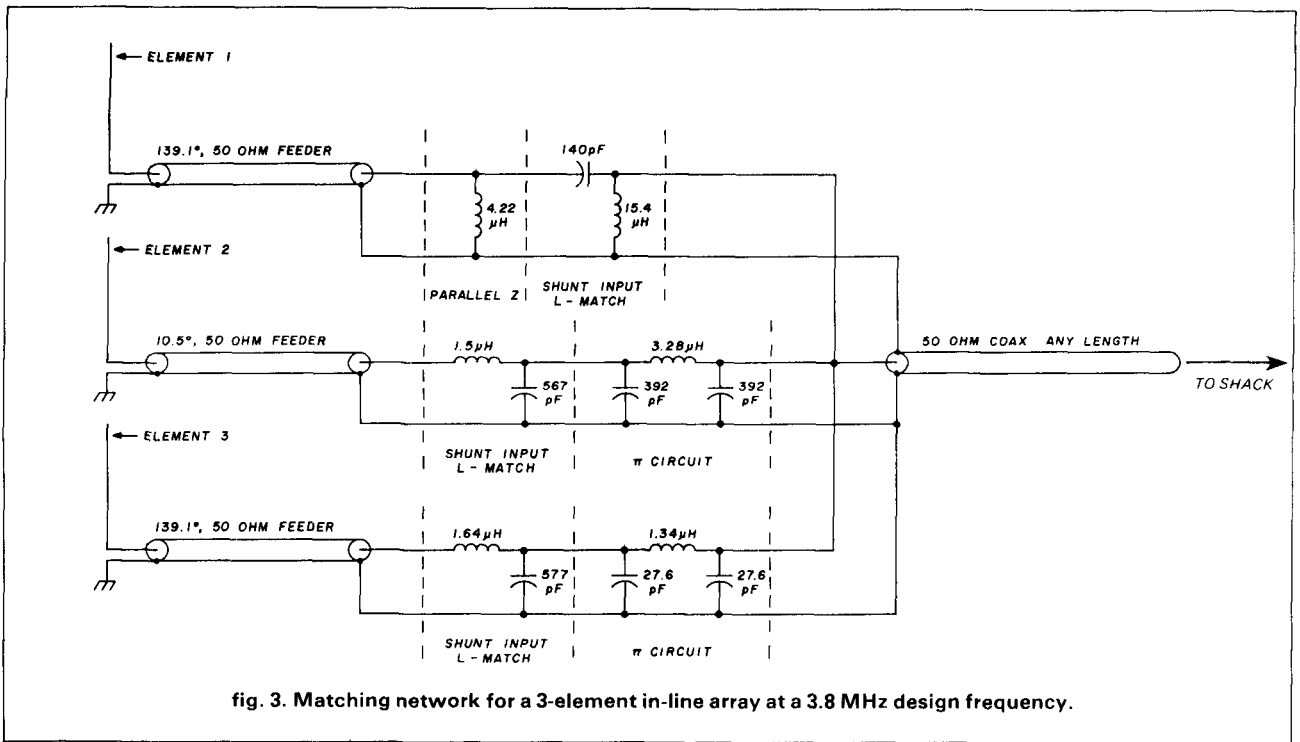


fig. 3. Matching network for a 3-element in-line array at a 3.8 MHz design frequency.

**3-element in-line array.** This array has a particularly deep F/B ratio extending over a wide azimuthal sector. We should be especially interested in taking advantage of this capability. Since the middle element has the same drive-point impedance regardless of array direction, there is no need to make its feeder equal in length to other feeders. Assuming the directional switch is located five feet from the middle element, equal length end element feeders are brought to the center area. At 3.8 MHz, using 0.66 velocity coax, these are 66 feet (139.1 degrees) and for the center element, 5 feet (10.5 degrees) with a  $Z_0$  of 50 ohms. Assuming an array of 3 resonant 1/4-wavelength elements, spaced a quarter-wavelength apart, with current amplitude ratios of 1,2,1 and phase relationships of 0, -90, and -180 degrees, respectively, the driving point impedances are  $Z_1 = 15.4 - j17$ ,  $Z_2 = 36.2 + j0$  and  $Z_3 = 75.4 + j43$ . (Part 3 showed these values incorrectly).<sup>5</sup> As was done with the 2-element array example, the feed network is matched to the 50-ohm array feedline. The sum of the  $I^2R$  input power terms, assuming 1 ampere to the first and third elements and 2 amperes to the middle element, is 235.6 watts. Using the  $E^2/R = W$  relationship, this establishes an amplitude of 108.54 volts at the array feedline connection. At that point the input impedances for each element's network are the pure resistances:

$$Z_1 = 764.94 + j0$$

$$Z_2 = 81.25 + j0$$

$$Z_3 = 156.23 + j0$$

The sequence of input parameters at each junction of the networks is shown in **table 3**.

The resulting network is shown in **fig. 3**. Illustrated in this example is the application of the parallel circuit and the use of leading and lagging phase L-match circuits. Here, element 1 is used as the reference element of the feed network. A parallel impedance circuit is used to transform the impedance seen at the input end of the feeder to a pure resistance. This is then transformed to the pure resistance required for the chain with a shunt input L-match chosen to produce a leading phase change. The resulting input voltage then becomes the objective for the other two network chains.

**Triangular array.** The triangular array feed network demonstrates still another technique for simplifying a feed network. Since elements 2 and 3 operate at identical conditions, the inputs of their transmission line feeders may be paralleled and fed from a common network. **Fig. 4** shows the two feeders connected to a shunt input L-match, and being transformed directly to a resistive input. This is then cascaded with a tee circuit having a sufficiently leading phase displacement to equal the voltage amplitude and phase of the element 1 network. The array termination is designed to match a 50-ohm transmission line. Part 3 incorrectly showed the driving-point impedance of element 1. The correct impedance is  $Z_1 = 20.4 - j10$ . **Table 4** shows the sequence of input parameters at each network junction.

**4-square array.** The 4-square array obviously requires a more complicated drive network. The look-



**table 1. Comparison of impedance, voltage and current phase, and SWR variations with frequency, of 90 degree length of coax and a cascaded 45 degree  $\pi$  circuit and 45 degree tee circuit, both acting as a 50-ohm characteristic impedance 1/4-wavelength transformer. Load termination is 75 ohms pure resistance; the center design frequency is 3.75 MHz.**

frequency MHz		coax	$\pi$ and tee
3.55	$Z_{in}$	33.46 - j2.33	33.45 - j1.86
	$I_o/I_i$	0.67 $\angle$ -86.8°	0.67 $\angle$ -86.33°
	$E_o/E_i$	1.49 $\angle$ -82.82°	1.50 $\angle$ -83.15°
	SWR	1.5	1.498
3.65	$Z_{in}$	33.37 - j1.16	33.36 - j0.91
	$I_o/I_i$	0.67 $\angle$ -88.4°	0.67 $\angle$ -88.15°
	$E_o/E_i$	1.5 $\angle$ -86.4°	1.5 $\angle$ -86.58°
	SWR	1.5	1.5
3.75	$Z_{in}$	33.33 + j0	33.33 + j0
	$I_o/I_i$	0.67 $\angle$ -90°	0.67 $\angle$ -90°
	$E_o/E_i$	1.5 $\angle$ -90°	1.5 $\angle$ -90°
	SWR	1.5	1.5
3.85	$Z_{in}$	33.37 + j1.16	33.36 + j0.88
	$I_o/I_i$	0.67 $\angle$ -91.6°	0.67 $\angle$ -91.88°
	$E_o/E_i$	1.5 $\angle$ -93.6°	1.5 $\angle$ -93.39°
	SWR	1.5	1.5
3.95	$Z_{in}$	33.46 + j2.33	33.45 + j1.72
	$I_o/I_i$	0.67 $\angle$ -93.2°	0.67 $\angle$ -93.79°
	$E_o/E_i$	1.49 $\angle$ -97.18°	1.5 $\angle$ -96.74°
	SWR	1.5	1.498

Note:  $I_i, E_i$  equal input current and voltage, respectively.  $I_o, E_o$  equal output current and voltage, respectively.

network can be designed to reduce this tendency is a question. Perhaps the best alternative is to set the design center frequency on the low end of the intended operating range, recognizing that the optimum F/B bandwidth is a narrow frequency band of about 2 to 3 percent.

Using the driving-point impedances from Part 3 for a 4-square consisting of 1/4-wavelength resonant elements, spaced a quarter-wavelength apart, and phased 0, -90, -90, -180 degrees with current amplitude ratios 1,1,1,1, respectively, input parameter sequences of a suggested drive network are

**table 5. Network input parameters for a 4-square array.**

element 1	element 2	element 3	element 4
$Z_1$ 3.4 - j12	$Z_2$ 39.4 - j17.5	$Z_3$ 39.4 - j17.5	$Z_4$ 63.4 + j47.5
$I_1$ 1 $\angle$ 0°	$I_2$ 1 $\angle$ -90°	$I_3$ 1 $\angle$ -90°	$I_4$ 1 $\angle$ -180°
$E_1$ 12.47 $\angle$ -74.18°	$E_2$ 43.11 $\angle$ -113.95°	$E_3$ 43.11 $\angle$ -113.95°	$E_4$ 79.22 $\angle$ -143.16°
<b>100° coax</b>	<b>100° coax</b>	<b>100° coax</b>	<b>100° coax</b>
$Z_1$ 403.97 + j387.1	$Z_2$ 62.39 + j22.57	$Z_3$ 62.39 + j22.57	$Z_4$ 22.73 - j11.37
$I_1$ 0.09 $\angle$ 46.88°	$I_2$ 0.79 $\angle$ -12.43°	$I_3$ 0.79 $\angle$ -12.43°	$I_4$ 1.67 $\angle$ -74.97°
$E_1$ 51.33 $\angle$ 90.66°	$E_2$ 52.73 $\angle$ 7.46°	$E_3$ 52.73 $\angle$ 7.46°	$E_4$ 42.44 $\angle$ -74.97°
<b>elements 2 &amp; 3 paralleled</b>			
<b>L-match</b>	<b>L-match</b>	<b>L-match</b>	<b>L-match</b>
$Z_1$ 2141 + j0	$Z_2, Z_3$ 92.39 + j0	$Z_4$ 114.83 + j0	
$I_1$ 0.04 $\angle$ -17.37°	$I_2, I_3$ 0.92 $\angle$ 42.04°	$I_4$ 0.74 $\angle$ 15.2°	
$E_1$ 85.32 $\angle$ -17.37°	$E_2, E_3$ 85.32 $\angle$ 42.04°	$E_4$ 85.32 $\angle$ 15.2°	
<b><math>\pi</math> circuit</b>		<b><math>\pi</math> circuit</b>	
$Z_1$ 2141 + j0		$Z_4$ 114.83 + j0	
$I_1$ 0.04 $\angle$ 42.04°		$I_4$ 0.74 $\angle$ 42.04°	
$E_1$ 85.32 $\angle$ 42.04°		$E_4$ 85.32 $\angle$ 42.04°	

**table 2. Network input parameters for a 2-element array.**

element 1	element 2
$Z_1$ 21.4 - j15	$Z_2$ 51.4 + j15
$I_1$ 1 /0°	$I_2$ 1 /-90°
$E_1$ 26.13 /-35.03°	$E_2$ 53.54 /-73.73°
<b>135° coax feeder</b>	<b>135° coax feeder</b>
$Z_1$ 63.58 - j53.98	$Z_2$ 37.43 + j2.67
$I_1$ 0.58 /148.56°	$I_2$ 1.77 /51.66°
$E_1$ 48.39 /108.22°	$E_2$ 43.97 /55.75°
<b>shunt input L-match</b>	<b>shunt input L-match</b>
$Z_1$ 170.09 + j0	$Z_2$ 70.82 + j0
$I_1$ 0.36 /96.25°	$I_2$ 0.85 /95.03°
$E_1$ 60.33 /96.25°	$E_2$ 60.33 /95.03°
	<b><math>\pi</math> circuit</b>
	$Z_2$ 70.82 + j0
	$I_2$ 0.85 /96.25°
	$E_2$ 60.33 /96.25°

**table 3. Network input parameters for a 3-element in-line array.**

element 1	element 2	element 3
$Z_1$ 15.4 - j17	$Z_2$ 36.2 + j0	$Z_3$ 75.4 + j43
$I_1$ 1 /0°	$I_2$ 2 /-90°	$I_3$ 1 /-180°
$E_1$ 22.94 /-47.83°	$E_2$ 72.4 /-90°	$E_3$ 86.80 /-150.3°
<b>139.1° Coax</b>	<b>10.5° Coax</b>	<b>139.1° Coax</b>
$Z_1$ 47.42 - j67.6	$Z_2$ 36.71 + j4.35	$Z_3$ 27.77 + j20.68
$I_1$ 0.57 /159.27°	$I_2$ 1.98 + /-82.33°	$I_3$ 1.65 /-36.83°
$E_1$ 47.06 /104.32°	$E_2$ 73.49 /-75.59°	$E_3$ 56.98 /-0.25°
<b>parallel Z</b>	<b>shunt input L</b>	<b>shunt input L</b>
$Z_1$ 143.19 + j0	$Z_2$ 81.35 + j0	$Z_3$ 156.23 + j0
$I_1$ 0.33 /104.32°	$I_2$ 1.33 /-34.59°	$I_3$ 0.69 /28.24°
$E_1$ 47.06 /104.32°	$E_2$ 108.54 /-34.59°	$E_3$ 108.54 /28.24°
<b>shunt input L</b>	<b><math>\pi</math> circuit</b>	<b><math>\pi</math> circuit</b>
$Z_1$ 764.94 + j0	$Z_2$ 81.35 - j0	$Z_3$ 156.23 + j0
$I_1$ 0.14 /40.01°	$I_2$ 1.33 /40.01°	$I_3$ 0.69 /40.01°
$E_1$ 108.54 /40.01°	$E_2$ 108.54 /40.01°	$E_3$ 108.54 /40.01°

given in table 5 with the schematics shown in fig. 5.

Reaching the center area of a 4-Square array whose elements are spaced 1/4 wavelength with 1/4 wavelength feeders is a problem. Coax with a velocity factor greater than 0.71 is required. Unfortunately, most foam dielectric cables have velocity factors around 0.71, allowing little or no slack for placement of and connections to a directional switch and the feed network. Since a lumped-constant network imposes no restriction on element feeder lengths, I have chosen 100° for these feeders (at 3.8 MHz, 47.45 feet), which is more than sufficient.

The input ends of the feeders to the two middle elements are paralleled and a shunt input L-match is used to transform this combined load directly to the desired pure resistance at the common connection to the array. The input voltage for this chain is the design objective for the networks feeding the remaining elements. Consequently, after transforming the other elements to their required pure resistances (equalling 50 ohms when all networks are paralleled), coax-equivalent  $\pi$  circuits are used to match the voltage phase required at the common connection of the array.

### coming soon

In a forthcoming article in this series I shall cover in detail a method of calculating simple 4-terminal networks based on matrix algebra. As with many mathematical procedures, application of the procedures to the solution of problems doesn't necessarily depend upon a complete understanding of the underlying theory. It is a tool simplifying what is otherwise a tedious process. The calculation procedures are struc-

**table 4. Network input parameters for a triangular array.**

element 1	element 2	element 3
$Z_1$ 20.4 - j10	$Z_2$ 78.4 + j4	$Z_3$ 78.4 + j4
$I_1$ 1 /0°	$I_2$ 0.5 /-90°	$I_3$ 0.5 /-90°
$E_1$ 22.72 /-26.11°	$E_2$ 39.25 /-87.08°	$E_3$ 39.25 /-87.08°
<b>90° Coax</b>	<b>90° Coax</b>	<b>90° Coax</b>
$Z_1$ 98.81 + j48.43	$Z_2$ 31.81 - j1.62	$Z_3$ 31.81 - j1.62
$I_1$ 0.45 /63.89°	$I_2$ 0.79 /2.92°	$I_3$ 0.79 /2.92°
$E_1$ 50 /90°	$E_2$ 25 /0°	$E_3$ 25 /0°
<b>shunt input L</b>	<b>elements 2 &amp; 3 paralleled shunt input L</b>	
$Z_1$ 146.08 + j0	$Z_2, Z_3$ 76.02 + j0	
$I_1$ 0.37 /29.22°	$I_2, I_3$ 0.72 /65.70°	
$E_1$ 54.59 /29.22°	$E_2, E_3$ 54.59 /65.70°	
	<b>tee circuit</b>	
	$Z_2, Z_3$ 76.02 + j0	
	$I_2, I_3$ 0.72 /29.22°	
	$E_2, E_3$ 54.59 /29.22°	

fering equations for matrix values), making it ideal for programmable calculators or small computers. For the same reason, the procedure easily lends itself to chained calculations, allowing fast analysis of a cascade of networks.

### reference

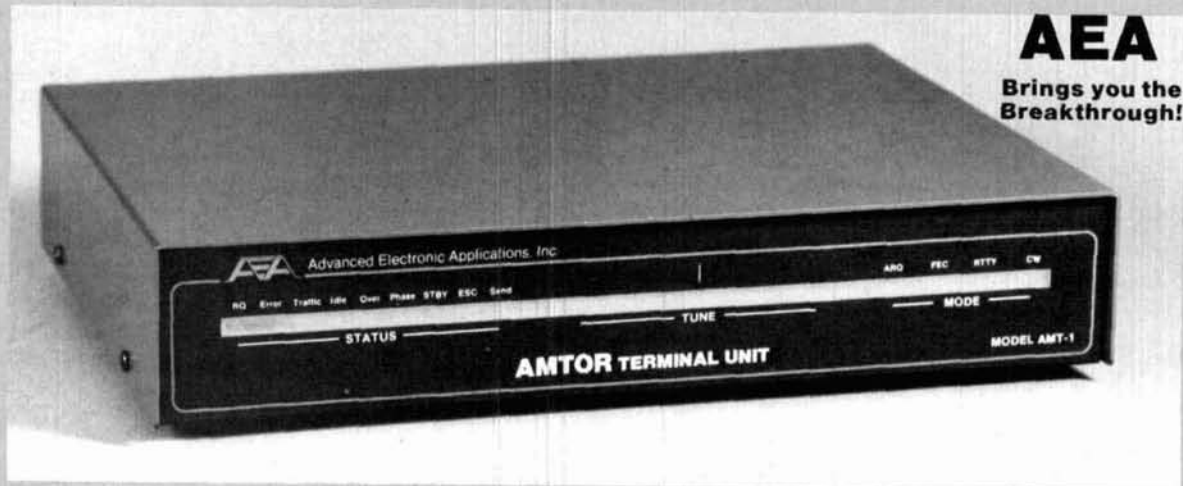
1. Forrest Gehrke, K2BT, "Vertical Phased Arrays, Part 1," *ham radio*, May, 1983, page 18.
2. Forrest Gehrke, K2BT, "Vertical Phased Arrays, Part 2," *ham radio*, June, 1983, page 24.
3. Forrest Gehrke, K2BT, "Vertical Phased Arrays, Part 3," *ham radio*, July, 1983, page 26.
4. Roy Lewallen, W7EL, private communication. Contact K2BT for further information.
5. See "Short Circuits," *ham radio*, October, 1983.

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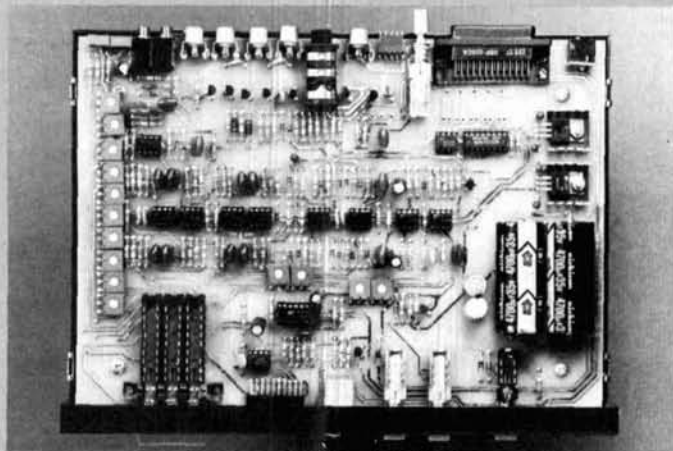
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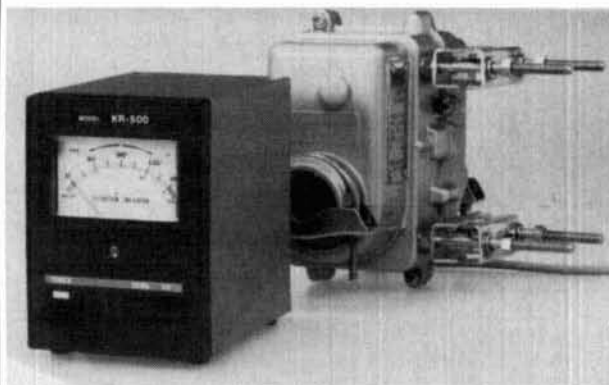


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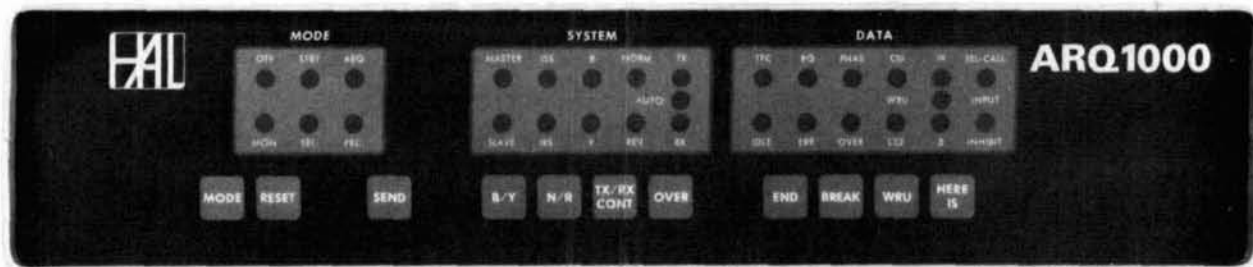
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## evolution of the amplifier

I've never seen an amplifier design that is quite what I needed to meet these design requirements: 1-watt drive for full output (30 to 40 watts), low cost, ease of construction, and long-term reliability. I decided to build one based on a two-transistor circuit.

The 2N6080 and MRF238 transistors were readily available at low cost. This particular combination provided an excess of drive power between stages; however, this helps make the amplifier wideband, and ensures continued operation near rated output under low-battery conditions. The power consumption consequently is slightly higher than necessary, but still much less than that of an equivalent tube-type radio.

To make the amplifier easy to duplicate and tune, I decided to use printed-line inductors instead of discrete coils. The next step was to calculate the impedance-matching networks. Motorola's excellent application notes<sup>1</sup> were used to do this. Once calculated, the networks were verified using "The Electronic Breadboard."<sup>2</sup> Data for the inductors was obtained from references 3 and 4. Once built, the matching networks were modified empirically.

The resulting circuit is shown in fig. 1. The input-matching network consists of  $C_1, C_2, C_3, C_{13}$ , and  $L_1$ . The interstage network uses  $C_4, C_5$ , and  $L_2$ , and the

output network is made up of  $L_3, C_6, C_7, C_8$  and  $C_{14}$ . Power-supply decoupling is very important and is achieved by  $C_9-C_{12}$ , RFC2, RFC4, and feed-through capacitor  $C_{15}$ .

The 1N540 diode serves two functions. It protects the amplifier by clipping inductive spikes from things like starter motors. It also protects the amplifier against reverse polarity of the power supply, by causing the line fuse to blow.

Once the amplifier was constructed and working, some means of transmit/receive switching was needed. PIN diodes are state-of-the-art and small, but not readily available. The alternative was to modify an open-frame relay, as described in reference 5. The relay circuit is actuated by RF from the exciter. Its driver circuit is shown in fig. 2.

## construction

Once the design is completed, the circuit board must be constructed. I used a 9-1/4 × 2-3/4 inch (23.5 × 7 cm) piece of G-10 board with copper on both sides. Orr<sup>6</sup> highly recommends short, direct paths, and this philosophy was followed. The inductor and RF-transistor connecting pads must be laid out first. It is important to realize that these are printed inductors and not transmission lines; therefore, the copper material on the reverse side of the board must be removed under the inductors. If this is not done, the amplifier will not work.

Although straight-line inductances are shown in fig. 3, this is not mandatory. The important parameters are average path length and the path width. Next, lay out the power-supply line — remember it carries several amperes and must not have any appreciable resistance. Finally, allocate an area for the modified T/R relay and its driver circuit, and lay this out. The layout that I used is shown in fig. 3.

This layout is simple enough to reproduce directly on the board, using ordinary electrical tape and trimming it to size with a sharp blade. After the layout is completed and verified, etch the board using standard techniques. (I used ferric chloride.)

By James A. Sanford, WB4GCS, 509 Forest Drive, Casselberry, Florida 32707

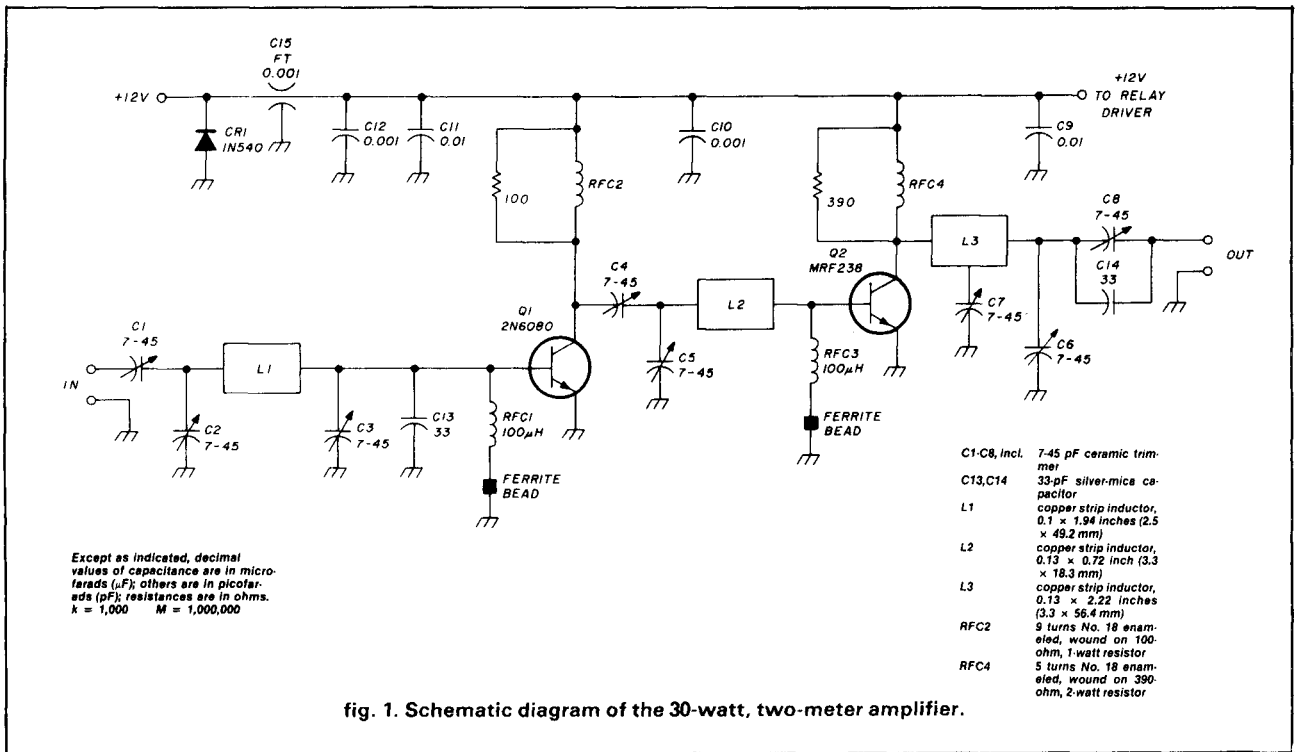


fig. 1. Schematic diagram of the 30-watt, two-meter amplifier.

After the board is made and drilled, mount it to the heatsink using 1/8 inch (0.32 cm) spacers 5/16 inch (0.79 cm) in diameter. Mount the RF transistors to the heatsink, using a thermal compound to ensure good heat transfer. If a torque wrench is available, torque the hardware to six inch pounds (0.68 Ntm). Otherwise, tighten it until a moderate resistance is felt, using a wrench no longer than three inches. Make sure you hold the stud to prevent it from moving. Avoid overtightening the stud on the transistors or they could be damaged. Also, be sure that the top and bottom ground planes are connected together in at least six places.

After the transistors are mounted to the heatsink, solder them to the PC board. The transistors are mounted before soldering to avoid excessive (damaging) stresses on the leads during mounting to the heatsink.

Next, mount the capacitors and chokes, keeping the lead lengths as short as possible. Follow the parts layout in fig. 4. Mount the relay, using either metal hardware or epoxy glue. Wire the input and output coax lines to the relay, and then install the relay-driver components. The input and output coax connectors can be mounted directly on the PC board, or made part of the cabinet and connected by short lengths of coax. This completes the actual construction.

Carefully check the wiring against the circuit diagram. Pay close attention to transistor orientation and placement of the variable capacitors. The amplifier is now ready for a "smoke test."

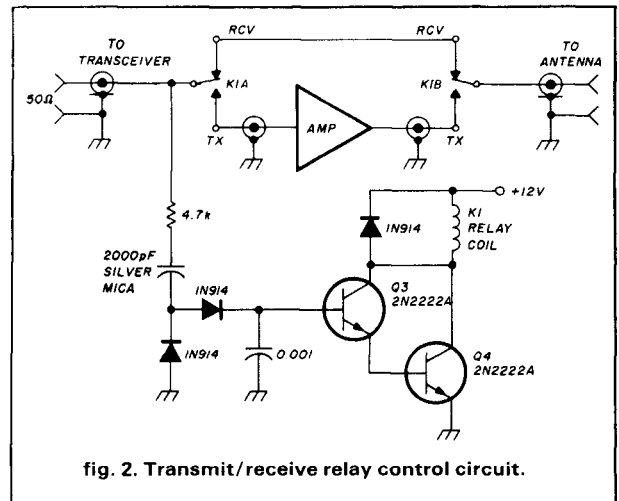


fig. 2. Transmit/receive relay control circuit.

## testing

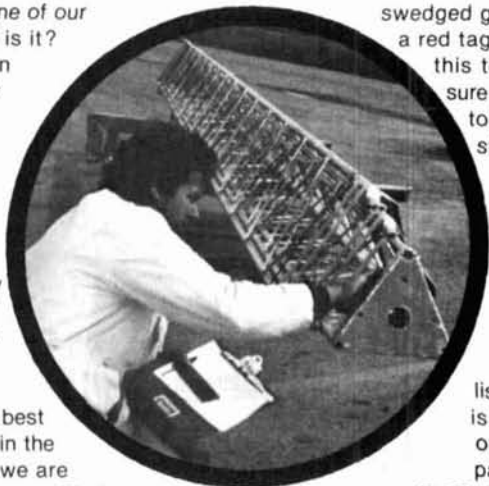
Connect the amplifier to a 12-volt source through a fuse of 10 amperes, a 50-ohm load, and a driver. Apply power and monitor the idling current — it should be low (a few mA). With some means of measuring output to the load, apply drive to the amplifier. The relay should switch to the transmit position. If it doesn't, check the relay-control circuit and try again.

Once the relay transfers, you should see some RF output. If not, adjust the input tuning until you see some low value of output. Then peak the output network for maximum output. Next, peak the interstage and input networks for maximum output. Repeat the entire procedure until no further increase in output

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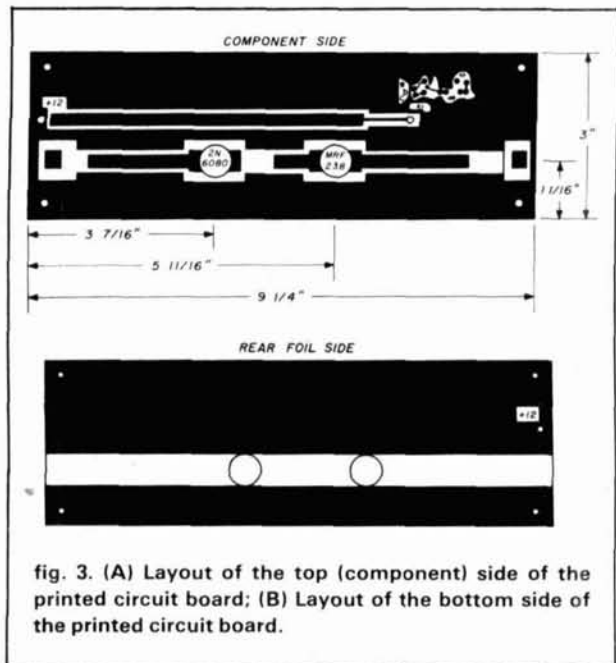


fig. 3. (A) Layout of the top (component) side of the printed circuit board; (B) Layout of the bottom side of the printed circuit board.

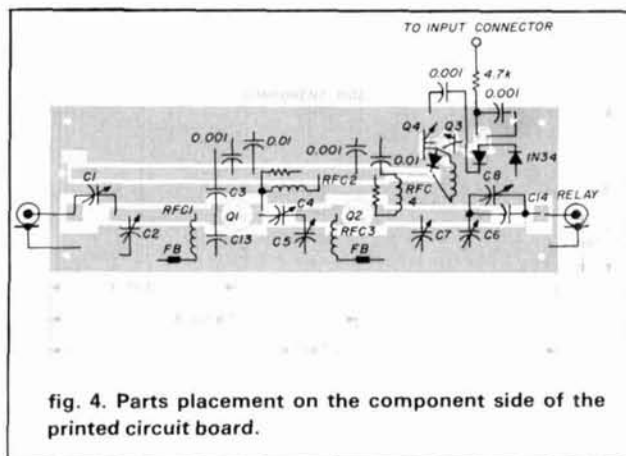


fig. 4. Parts placement on the component side of the printed circuit board.

can be seen. The output should be between 30 and 40 watts, depending on drive level and power-supply voltage. The input SWR should be very close to 1:1. Measure the power supply current, which should be between 4 and 6 amps. Keep in mind that the duty cycle should be kept low until the tuning has been completed. Pay close attention to transistor temperatures — they will get warm, and excessive temperature can result in catastrophic failure.

### final assembly

The enclosure is up to you. I soldered together double-sided circuit board to make a simple, cheap, and RF-tight enclosure. After the amplifier is placed in the enclosure, recheck the output — there should be little change.

Amateurs often ignore a basic fact of heat transfer and fluid flow: hot air rises. The heatsink needs to be mounted in such a way that the hot air can flow un-

impeded. This means that the fins must be vertical. I have seen far too many installations where heatsink fins are horizontal, reducing efficiency. The obvious benefit of doing this right is increased reliability and long life.

### results

I installed the amplifier in my car and it has been working well for several months. Output power and gain as a function of frequency are shown in fig. 5. Though not perfect, the bandwidth is certainly acceptable for use on the two-meter band. During several months of operation, no degradation in performance or change in tuning has been noted. This attests to the long-term stability and reliability of the amplifier.

One aspect all too often neglected by Amateurs is that of spurious outputs. This amplifier was checked on a spectrum analyzer with gratifying results. There were no measurable outputs other than the one desired. As close as could be measured, the output was a faithful reproduction of the input. When modulated with a single tone, the TR-2400-and-amplifier combination exhibited textbook response, clean and symmetrical, with no hint of instability or distortion. The insertion loss in the receive mode is negligible.

The total time needed to build and test this amplifier was less than one weekend, including fabricating the circuit board. The final product was a reliable 30-watt amplifier capable of being driven to full output by a 1-watt hand-held transceiver.

### parts

One of my pet peeves is people who describe equipment that is very nice to build, but uses hard-to-find, or outrageously expensive, custom-manufactured components. This amplifier uses readily available components, and I will cite my sources for non-

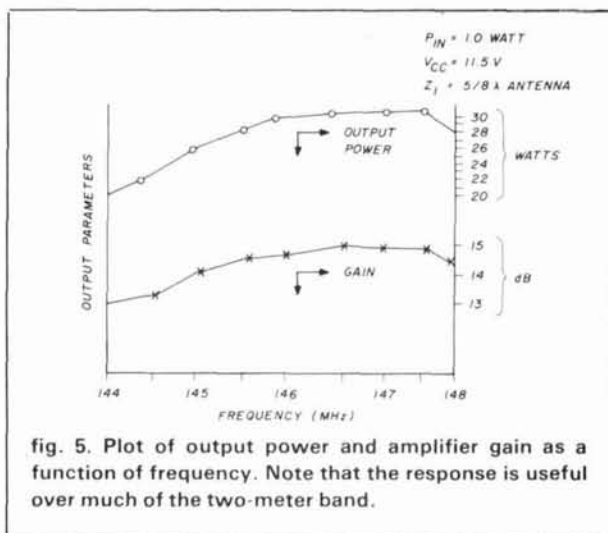


fig. 5. Plot of output power and amplifier gain as a function of frequency. Note that the response is useful over much of the two-meter band.

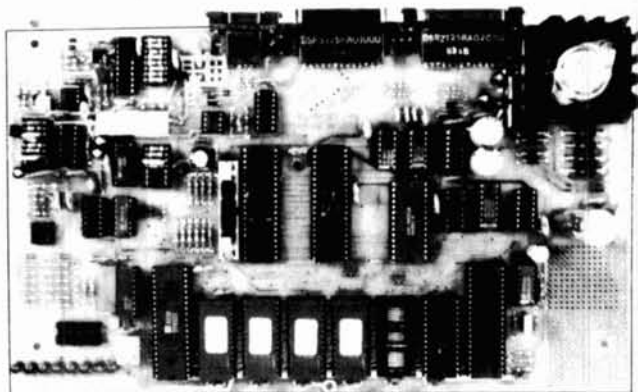
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junk-box parts. The transistors came from Semiconductor Surplus. I obtained the circuit board and ceramic trimmers from a local surplus outlet, but these are seen at every hamfest and in the advertising pages of *ham radio*. The chokes came from the junk box and are not critical. The ferrite beads are available from Amidon and others, and also at hamfests. I have modified several types of junk-box relays, and all worked well in this circuit.

You can make some substitutions. The chokes are not critical; just be sure to use ferrite beads to lower the *Q* and prevent low-frequency oscillations. I used ceramic trimmer capacitors, although compression or piston types would probably also work. Whatever type is used, it must be capable of withstanding the rf currents involved. This is especially important in the output circuitry. If you have access to a good capacitance meter, you can build the amplifier using various capacitors, and then substitute fixed-value chip capacitors, such as those made by Unelco. This will provide maximum reliability.

The most critical part is the heatsink — if it is not adequate, the transistors will not survive. I used one 6 × 3-3/4 inches (15.24 × 9.83 cm). If you have a bigger one, so much the better. The more area available for heat transfer, the cooler the transistors will run.

To ensure adequate cooling in the hot Florida sun, I placed a fan on the heatsink to help keep temperatures low. This may not be necessary, but is good insurance to help the amplifier last. To date there have been no thermal problems, even with temperatures inside the car higher than 100 degrees F.

### acknowledgements

Several people contributed in different ways to the success of this project. I am grateful for the assistance of W4MJJ, W4RJV, WA4HSY, and WD4LWL.

### conclusion

I would welcome any comments or suggestions. Please include an SASE if a reply is desired. Printed circuit boards may be available. Contact the author for details.

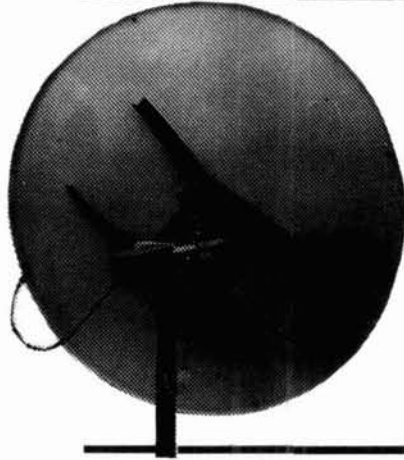
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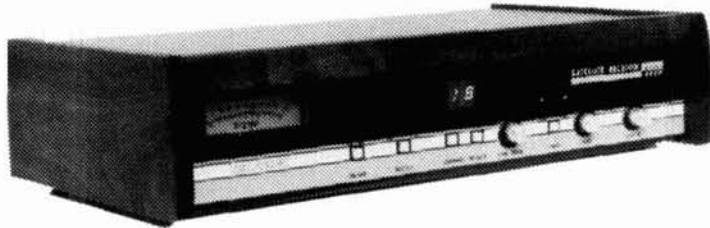


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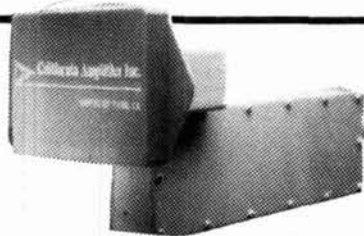
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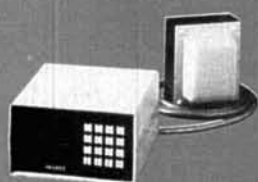
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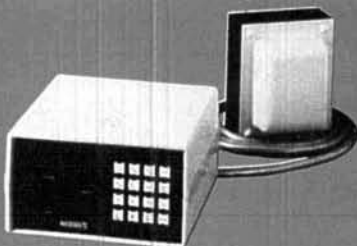
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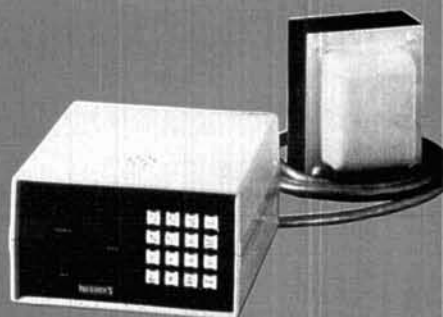
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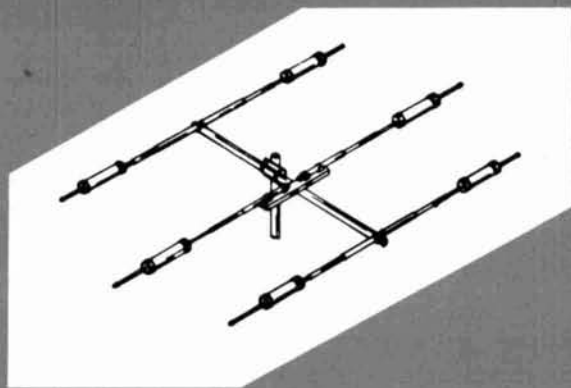
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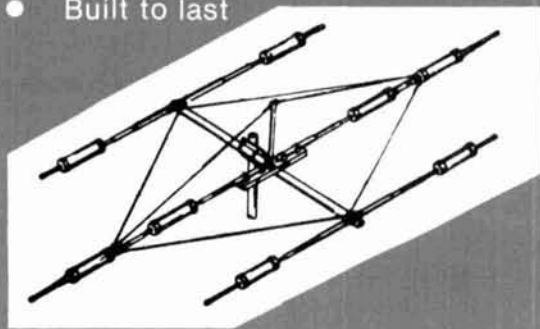
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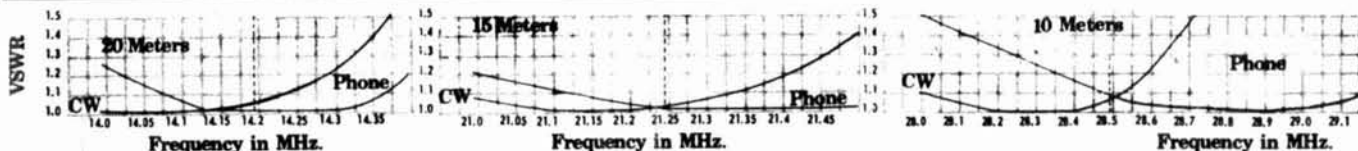
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# vacuum tube substitution

## Using one tube in place of another saves time, trouble

**Radio Amateurs always keep** a supply of spare parts and vacuum tubes on hand, but when a vacuum tube fails and an exact replacement is unavailable, the Amateur has two choices: either to buy a new tube — which may be expensive or scarce — or find a substitute.

Because a substitute tube may be cheaper than the original, and perhaps easier to obtain, this article discusses tube substitution in general and rectifier tubes in particular.

Unfortunately, tube substitution handbooks aren't always very useful. This would not be so if most of the substitutes were listed, but this is seldom the case. For some tubes, no substitutes are listed; for others, suggested substitutes denoted by suffixes such as *G*, *GT*, and *GTA* may differ only slightly from the original and be as costly or as difficult to obtain. Sometimes substitutes may be as hard to find as the originals themselves. (Receiving tube manuals may be more helpful in that they list many tubes which have identical base diagrams and are thus interchangeable if they have similar or superior characteristics.)

Tubes with the same kind of base but with different terminal diagrams require only minor changes in socket wiring for substitution. Tubes with the same kind of base and known terminal diagrams, but different filament or heater voltage, may also be used; a higher voltage requires a different filament transformer or secondary winding, and a lower voltage requires a dropping resistor in series with either one of the two socket terminals. The resistance of the drop-

ping resistor is determined by Ohm's law: the drop in voltage is divided by the current in amperes. The power rating must exceed the product of these factors, or  $E \cdot I$  watts. Current differences are seldom important.

If a substitute tube has a different base than the original, it requires a very different socket unless a suitable adapter is available. It is both difficult and impractical to change bases on old tubes; the absence of separate bases permits only socket rewiring for substitution.

### tube-base history

Early vacuum tubes were often baseless or had only bases for filaments. Candelabra bases, Edison medium screw bases, and Edison bases were common. From 1915 to 1927 various 4-pin bases and sockets were tried, with varying success. In 1923 the famous UV199 and UV201A triodes were introduced. Their UV bases had solder-filled brass pins which made butt-end contacts with flat socket contacts. The solder tips often corroded badly, so some tips were gold-plated and later, in 1925, UV bases were superseded by UX bases with long pins for side-wiping contacts with ordinary metals.

In 1927 the 27-triode detector-amplifier was introduced to avoid hum in new AC receivers. It had a unipotential or heater-type cathode and required a 5-pin base. The then-new 24A screen-grid tube or tetrode, also of heater-type, needed a 5-pin base and a top cap for connection to the control grid. The advent of pentodes, beam power tubes, and multifunction tubes led to 6- and 7-pin bases and often top caps. The use of 4- to 7-pin bases practically ended in 1935 when octal-base tubes were introduced.

Most tubes required no more than seven active

By Carleton F. Maylott, W2YE, 279 Cadman Drive, Williamsville, New York 14221

pins, but the 6L7 pentagrid mixer required all eight pins plus a top cap, for a total of nine connections. Miniature baseless tubes, which began to replace octal tubes in about 1950, are usually 7-pin or 9-pin types. Some multi-unit tubes have ten or twelve pins.

The first vacuum tube rectifiers on the market were the half-wave UV216 in 1921, (replaced by the UX216B in 1925), and the full-wave UX213 in 1925, which was superseded by the UX280, (now simply 80), in 1927. These tubes, sold by RCA, were developed by GE and Westinghouse, respectively. Unlike other types, rectifier tubes largely survived the trend to more than 4-pin bases from 1927 to 1935. Octal-base rectifier tubes have endured over the years, as

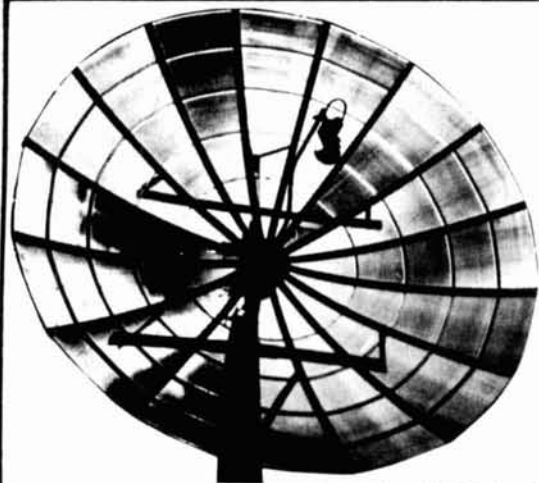
demonstrated by the presence of approximately fifty rectifier tubes in the octal-base list (table 1). Notable exceptions to the 4-pin and 8-pin rectifier preference are the 5-pin 84/6Z4, which had a heater-type cathode, and the 6-pin 25Z5, which had a heater, two cathodes and two plates, and provided doubler operation. Half-wave rectifiers need only three connections, of which two are for filament and one is for plate — usually a top cap, so only two base pins are wired. Full-wave filament-type rectifiers need four pins — two for filament and two for plates.

### rectifier type substitution

There are several good reasons why rectifier tubes are usually the first tubes to fail or weaken. They sup-

table 1. Rectifier tube base diagrams. Commas signify common connections. Column K dashes signify filament/heater-only type tubes, with no cathode employed; column K numbers indicate cathode element pin connection(s). (M) signifies mercury vapor; TC, top cap plate connections (half-wave).

pins	diagram	tube type	F or H	K	P	
4	4AB	2X2A, 2Y2	1 + 4	—	TC	
	4AD	83V	1 + 4	4	2 + 3	
	4AT	872A/872 (M)	2 + 4	—	TC	
	4B	2Z2/G84, 866 Jr. (M)	1 + 4	—	2	
	4C	5X3, 5Z3, 80, 82 (M), 83 (M)	1 + 4	—	2 + 3	
	4G	6Z3	1 + 4	3	2	
	4P	3B28, 816, 836, 866A, AX, B(M)	1 + 4	—	TC	
	5	5D	84/6Z4	1 + 5	4	2 + 3
		6E	25Z5	1 + 6	3 + 4	2 + 5
	7 (none)					
8	3C	1G3GTA/1B3GT, 1K3A/1J3	2 + 7	—	TC	
	5DA	5AR4/GZ34, GZ32-34-37, R52, U54, U70	2 + 5	5	3 + 4	
	5DE	3DG4	1 + 3	—	5 + 7	
	5L	5AT4, 5V4GA, 5Z4, GZ32	2 + 8	8	4 + 6	
	5Q	5X4G, 5Y4G-GA-GT	7 + 8	—	3 + 5	
	5T	5AS4A, 5AW4GT, 5AZ4, 5R4GB, 5R4GY, 5T4, 5U4GB, 5V3A/5AU4, 5W4GT, 5Y3GT, 5Z10, GZ30-31, RJ2, U50-51-52, WTT102	2 + 8	—	4 + 6	
	6AD	35Z5GT, 45Z5GT	Midtap 3, 2 + 7	8	5	
	6S	6AX5GT, 6X5GT, 6ZY5G, EZ35	2 + 7	8	3 + 5	
	8EZ	3A3C, 3CZ3A	2 + 7	7	TC	
	8KS	5DJ4	1, 7 + 2, 8	—	3, 4 + 5, 6	
	8MK	3CU3A	2 + 7	—	TC	
	8MU	2CN3A, 3CN3B	2 + 7	7	TC	
	8MX	3DB3/3CY3, 3DJ3	2 + 7	1, 7	TC	
	8MY	3DA3/3DH3	3 + 5	8	TC	
	8MZ	3DC3	2	1, 3, 5, 7	TC	
	7 min.	5BQ	35W4	Midtap 6, 3 + 4	7	5
		5BS	6BX4, 6X4, 12X4, EZ90, EZ900, HZ90, U78, U707, VZM70, 6202	3 + 4	7	1 + 6
	9 min.	9BS	12DF5	4 + 5	3 + 8	1 + 6
		9CB	6AF3, 6AL3	4 + 5	TC	9
9DJ		6BW4	4 + 5	9	1 + 7	
9DT		3A2A	2, 5, 8	1, 4, 6, 9	TC	
9M		6CA4, EZ4, U709, UU12	4 + 5	3	1 + 7	
9NT		5BC3	1 + 3	—	5 + 9	
9QT		5BC3A	1 + 2, 3	—	5, 6 + 8, 9	
9U		1V2	4 + 5	—	1, 9	
9Y		1X2A, B, C	2, 5, 8	—	TC	



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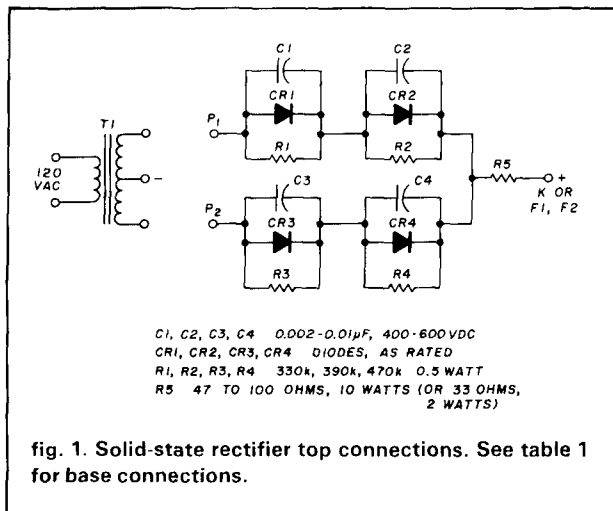


fig. 1. Solid-state rectifier top connections. See table 1 for base connections.

ply DC plate power for other tubes in radio receivers and for much electronic equipment. They also frequently sustain severe transients and momentary overloads. While many suitable substitutes are available, many of these require changes in socket wiring, as evident in **table 1**, which lists about fifty rectifier tubes among fifteen octal-base diagrams. **Table 1** includes both foreign and domestic half-wave and full-wave rectifier tubes. It will assist in substituting one tube for another as well as substituting solid-state equivalents for rectifier tubes.

### solid-state rectifier substitution

It is unnecessary to substitute tubes or to change socket wiring or sockets if solid-state parts are mounted in an old vacuum-tube base or a similar plug foundation. (The bases of defunct tubes are easily removed by hack-sawing them about midway or by crushing the glass in a vise. A cloth wrapper will help prevent the hazard of flying glass particles.)

Each leg of a full-wave rectifier circuit must withstand a peak inverse voltage of 1.4 times the RMS voltage to center-tap of the transformer secondary. This voltage usually exceeds the PIV rating of a single diode, so two or more diodes must be used in series. Each diode should be shunted by a small capacitor in order to minimize voltage spikes, and by a resistor to equalize PIV drops. Capacitors should be rated at 400 to 600 volts and 0.002 to 0.01  $\mu$ F capacitance. Resistors should be rated at one-half watt minimum and 500 to 1000 ohms per volt of PIV. Values of 330k, 390k, and 470k, are suitable at 200 to 400 volts per diode.

These parts should be chosen carefully and connected properly, according to the diagram of **fig. 1** and the pin numbers of **table 1**. The two anode or plate leads (P1 and P2) and one cathode or filament

lead (K or F) must be connected to three specific pins in the desired tube base. Solder in the base pins must be melted so as to pass the leads, which may be No. 18 solid copper wire; the pins must then be resoldered.

It is seldom necessary to use diodes in parallel because their current ratings usually exceed those of rectifier tubes. If two or more diodes must carry the load current, each diode should be in series with an equalizing resistor of about 33 to 47 ohms and 2 watts minimum rating. Without series resistors, one of several nonlinear devices in parallel may take most of the current and burn out.

A limiting resistor of at least 10 watts and 47 to 100 ohms rating may be connected in series with a rectifier output or a transformer center-tap connection. The resistor may burn out under overload conditions, but it will protect the diodes and cost less to replace. A well-chosen fuse may be used instead of, or in addition to, the resistor.

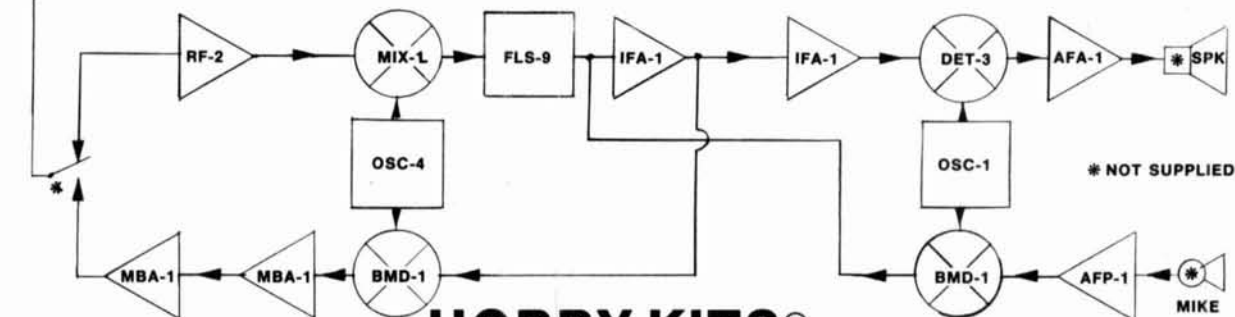
### rectifier design data

The following facts deserve consideration in rectifier design:

1. Half-secondaries of plate transformers usually have about 50- to 200-ohms resistance, and power-line inputs to transformerless rectifiers have negligible resistance.
2. Choke-input and resistive input filters usually have more than 100-ohms input resistance, and capacitor-input filters have negligible input resistance until the capacitors are charged.
3. Vacuum-tube diodes usually withstand high peak currents caused by short circuits and starting transients because their plate resistance exceeds 500 ohms and their plate current is limited by filament emission and space charge. Solid-state diodes, on the other hand, may fail because they usually have less than 100 ohms resistance and no current-limiting saturation phenomena.
4. Peak current in all rectifiers may be limited to safe values by adding series resistance of high enough value to make the total resistance adequate but low enough value to avoid an excessive voltage drop under normal load.
5. In order to avoid abnormally-high peak currents and peak inverse voltages, as well as poor ripple reduction, in choke-capacitor filters, the product of the choke inductance in henrys and the capacitor capacitance in microfarads must be greater than the resonant value of 7.08 for a half-wave filter (60 Hz ripple) and 1.77 for a full-wave filter (120 Hz ripple).

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# ham radio TECHNIQUES

Bill Orr  
W6SAI

Today's popular all-solid-state transmitters's would make yesterday's old timers' eyes pop out. What fun to work a modern rig with all the bells and whistles!

Owners of today's transmitters, however, find that many of them require matching to an antenna with an SWR less than 2:1. This is no problem on the higher bands, since most antennas meet this requirement, but 80 meter operators discover that they cannot cover the whole band with a single simple antenna and are therefore restricted to operating within a small portion of the band.

Some heroic attempts have been made to solve this problem<sup>1,2,3</sup> but the "broadband" 80-meter antenna solution still seems in doubt — or has it already been solved?

## let's not reinvent the wheel

The basic 80 meter, center-fed dipole, mounted in close proximity to ground, has a feedpoint resistance in the neighborhood of 30 ohms. I say "in the neighborhood" advisedly, as the measured resistance varies with height above ground, the conductivity of the soil in the vicinity of the anten-

na and the degree of coupling between the antenna, the outer shield of the feedline and any other conductors (such as house wiring, telephone lines, etc.) in the vicinity of the antenna.

As a result of these variables, SWR measurements made on one 80-meter dipole may vary considerably from those made on an identical antenna at a different location.

Because of the antenna environment, some "lucky" 80-meter operators find their dipole has an extremely broad frequency response and they can operate their solid-state transmitter over nearly the whole band! But their buddy across town with the same antenna is limited in operation to a small segment of the band, since the SWR quickly departs from low values when he operates his antenna away from the design frequency.

Improving ground conductivity is a difficult task.<sup>2</sup> An extensive ground screen is called for in the case of vertical polarization and it is not known if such a ground installation would be cost-effective with horizontal polarization. I would doubt it, myself. [It would, at the minimum, better define the "array" (antenna plus image) elevation pattern. — Editor]

## decoupling the antenna from the environment

Meaningful SWR measurements are difficult to achieve when the transmitting antenna is coupled to nearby conducting objects. In my case, the SWR measurements on an 80-meter dipole changed radically when I turned on the ceiling light fixture in the living room. The dipole was parallel to the wires leading from the utility box at one end of the house to the light fixture. Placing a 0.01, 1.6-kV ceramic capacitor across the connections of the fixture seemed to detune the house wiring sufficiently so that meaningful SWR numbers could be obtained.

The first step was to determine if the dipole was coupled to the outside of the outer shield of the coaxial feedline. This was tested by adding an extra length of line at the station end and noting if the SWR reading changed from the original measurements at different frequencies.

Since I knew there was unwanted coupling, I was not surprised when I was able to plot a new SWR curve that had only a vague resemblance to the old one after my line-splicing experiment. It looked as if I could move

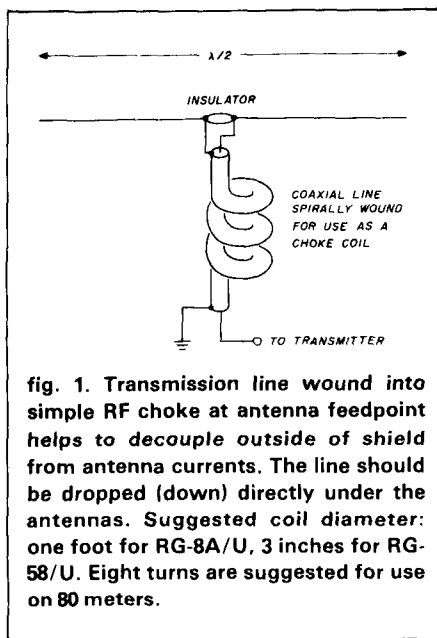


fig. 1. Transmission line wound into simple RF choke at antenna feedpoint helps to decouple outside of shield from antenna currents. The line should be dropped (down) directly under the antennas. Suggested coil diameter: one foot for RG-8A/U, 3 inches for RG-58/U. Eight turns are suggested for use on 80 meters.

the resonant frequency at will within the band by merely changing the length and position of the coaxial line with respect to the dipole!

The second step was to bring the coaxial line directly down to the surface of the ground under the center of the dipole and run it along the ground to the station. Before, it had looped through the air at about a 45 degree angle to the dipole.

Repeating the SWR measurements showed that by varying line length the SWR changed but not nearly as much as in the previous situation. It looked as if I were proceeding in the right direction.

The next step was to try to decouple the outer shield of the coax a bit more. I wound the line up into a choke coil just under the center of the antenna (fig. 1). This helped, but it seemed as if more isolation were required. Luckily, I had a 2.5 MHz to 15 MHz air-wound balun available (fig. 2). I placed this device at the dipole feedpoint and was successful in decoupling the coaxial shield from unwanted antenna-induced currents.

### a balun transformer for 80 and 160 meters

The balun design shown in fig. 2 is useful for both 80 and 160 meters.

Since it has an air core, it will not saturate at a high power level as the ferrite core design might do; and because the windings have more turns (inductance) than the more common design, this balun performs better at the lower frequencies.

The balun is wound on a plastic (PVC) form 3-1/2 inches (9.0 cm) in diameter. The design consists of 10 trifilar turns on No. 14 Formvar™ (or enamel) insulated wire. The ends are held in place by 4-40 hardware. The windings are interconnected by short lengths of wire run between the appropriate terminals. The common connection of two of the windings is used as the ground point at one end of the balun and is attached to the coaxial shield. When completed, a plastic bottle is cut to fit over the balun as a rain shield. The balun is attached directly to the center insulator of the dipole and the coaxial line dropped down directly beneath it.

Take care that the top end of the coaxial line is sealed from moisture. Water can seep into the line by capillary action of the shield but a good coat of sealant (RTV, for example) will waterproof the end of the line. (Make sure your sealant does not contain acetic acid, or it will corrode the copper wires of the coax. Read the label before you buy.)

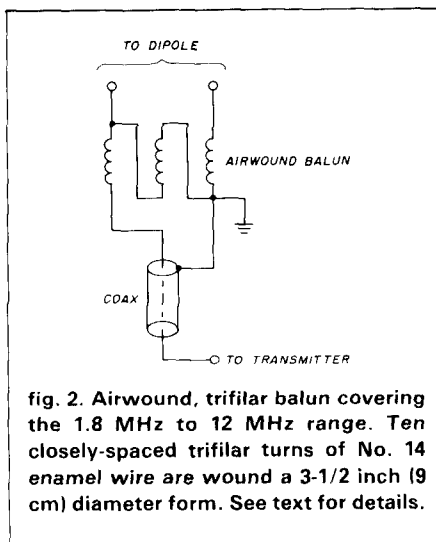


fig. 2. Airwound, trifilar balun covering the 1.8 MHz to 12 MHz range. Ten closely-spaced trifilar turns of No. 14 enamel wire are wound a 3-1/2 inch (9 cm) diameter form. See text for details.

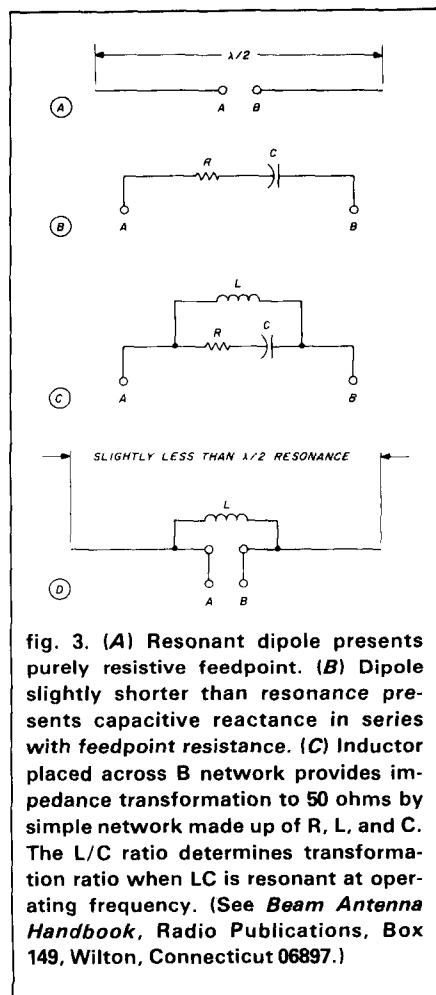


fig. 3. (A) Resonant dipole presents purely resistive feedpoint. (B) Dipole slightly shorter than resonance presents capacitive reactance in series with feedpoint resistance. (C) Inductor placed across B network provides impedance transformation to 50 ohms by simple network made up of R, L, and C. The L/C ratio determines transformation ratio when LC is resonant at operating frequency. (See *Beam Antenna Handbook*, Radio Publications, Box 149, Wilton, Connecticut 06897.)

### matching the antenna to the line

I was now in a position to make a meaningful SWR measurement of the antenna. As expected, a minimum of 1.56:1 occurred at resonance corresponding to an antenna impedance of 32 ohms. The easiest way to achieve a better match between antenna and line is to make the antenna form a portion of a network whose input impedance over a small range is 50 ohms (fig. 3). If the antenna is cut slightly shorter than its resonant length, its terminal impedance will have a capacitive reactance term. A compensating inductor placed across the antenna terminals would then provide a tuned network whose total impedance can be made to match the coaxial line impedance. For an antenna (radiation) resistance of 32 ohms,

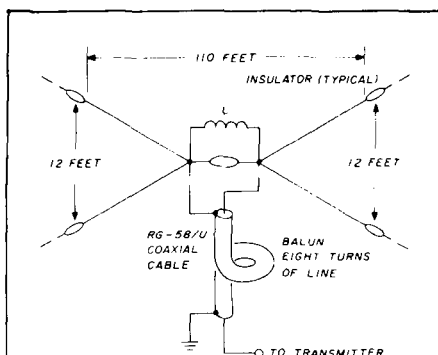


fig. 4. Broadband fan dipole for 80 meters. Wires may be either in horizontal or vertical plane. See fig. 3 for data on coil L.

points? Alas, the correctly-designed dipole still will not cover the whole 80-meter band, falling within the desired SWR ratio limits over only about 220 kHz. But this exercise provides a clue that may help solve the bandwidth problem.

### broadband dipoles

The previous discussion illustrates a method of feeding and matching a centered 80-meter antenna system. It applies equally well to a broadband antenna as to a conventional antenna.

The fan dipole shown in fig. 4 provides good bandwidth on 80 meters when properly matched to the transmission line. It is only 110 feet (33.53m) long at resonance (3.75 MHz). When the length of the arms and the center matching coil are properly adjusted, the antenna exhibits an SWR of less than 2:1 over the complete 80-meter band.

A second broadband antenna design similar to the fan dipole is shown in fig. 5. This scheme consists of two parallel-fed dipoles placed at right angles to each other. The dipoles are cut for opposite ends of the band. (I

haven't tried this idea, but I am waiting for a report from someone who has.<sup>3</sup>) The dipole's SWR follows a V curve with points of minimum SWR occurring near the band edges. The dipoles have to be physically separated by at least 60 degrees; otherwise, the broadband response is lessened.

Again, as in the case of the simple dipole, the input impedance of the antenna is quite low and a matching coil has to be placed across the feed-point to provide a step-up transformation to 50 ohms.

The idea looks like a good one and with sufficient separation between the dipoles, it should work.

### the W6TC two-frequency dipole

George, W6TC, wrestled with the problem of using a dipole across the 80-meter band and finally came up with a classic solution so simple that I wish I had thought of it myself!

George's idea is shown in fig. 6. This illustrates a dipole cut for 3800 kHz and used for SSB operation. To

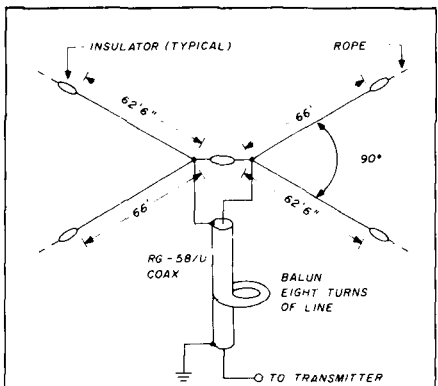


fig. 5. Parallel-fed dipoles placed at right angles to each other provide wideband response. Dipoles are cut for opposite ends of the 80-meter band. See fig. 6 for coaxial balun data. (Note: Dipoles are in horizontal plane.)

the shunt coil (L) should have a reactance of about 64 ohms. For the 80-meter band, this turns out to be about 2.7  $\mu$ H. A coil of 8-1/2 turns of No. 12 wire, 2 inches in diameter and 2 inches long will do the job. The antenna is trimmed six inches at a time until unity match is achieved at the desired operating frequency of the antenna.

### antenna bandwidth

After this task is completed, what will the operating bandwidth of the antenna be between the 2:1 SWR

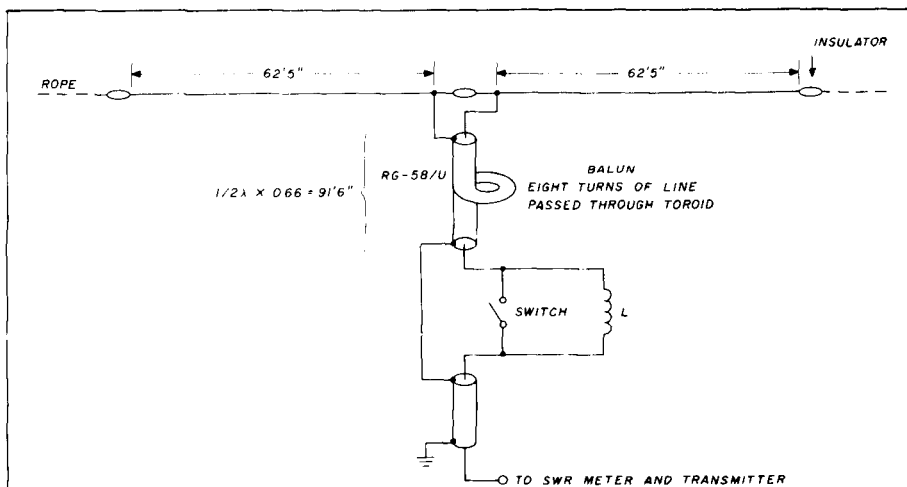


fig. 6. The W6TC two-frequency dipole for 80 meters. Antenna is cut for resonance at high frequency end of band. A single loading coil for operation at the low frequency end of the band is placed an electrical half-wavelength down the transmission line. The line is decoupled from the antenna by a simple balun placed directly at the antenna insulator. Toroid is powdered iron material T-200 (2" OD) (1.25" ID), 2-mix (red,  $\mu = 10$  (Amidon T-200-2), or equivalent.

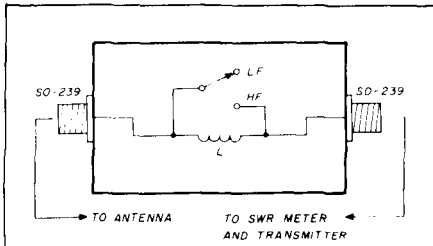


fig. 7. Remote loading inductor is placed in shielded box at operating position. Coil is approximately 11 turns No. 12 wire, 2" diameter and 2-1/4" long. (About 3.75  $\mu$ H). Switch is surplus ceramic unit.

operate at 3500 kHz, George first placed a single loading coil in series with one leg of the dipole. The unbalance caused by not splitting the coil and putting half of it in each leg was unnoticeable.

Now, the problem is that the dipole has to be raised and lowered to insert or remove the loading coil for a QSY from one end of the band to the other. George solved this problem by moving the coil a half-wavelength down the coaxial feedline, placing the loading coil right at the operation position.

Physically, the coil is placed in a box as shown in fig. 7. A ceramic switch is connected across the loading coil and instant QSY between the ends of the band is possible — right from the operating position. The two SWR curves for the antenna are shown in fig. 8.

### another easy way

In microwave antennas, a device known as a "double-stub tuner" can be used to reduce the SWR on a feed system. Simpler versions of this tuner have become known as "line flatteners" and one that will work on 80 meters is shown in fig. 9.

Using the line flattener, an 80-meter dipole cut for one portion of the band can be made to work anywhere in the band with near-unity SWR presented to the transmitter.

Under the worst of circumstances, the SWR on the line could go as high as 5:1 if a dipole cut for one end of the band were used at the opposite end of the band. Even so, the line flattener can readily take care of the problem. In most instances, the dipole is cut for some frequency within the band and maximum SWR excursions run closer to 3:1 at the band edges. No matter, the line flattener does the job.

The device is easy to adjust. The capacitors and inductors are adjusted until the SWR at the transmitter is unity. If you run out of capacitance range in one unit, a 1250 working volt mica capacitor placed in parallel with the fully meshed capacitor will help.

### any ideas from the field?

Well, I've heard of the scheme of making the 80-meter dipole out of steel wire to introduce a little loss and thereby lower the circuit Q and improve the bandwidth. And it might work, but I don't have feedback from anybody who has tried the idea.

But I would like to hear from those who have any original thoughts on an 80-meter broadband antenna system that will show a low value of SWR to the new solid-state rigs.

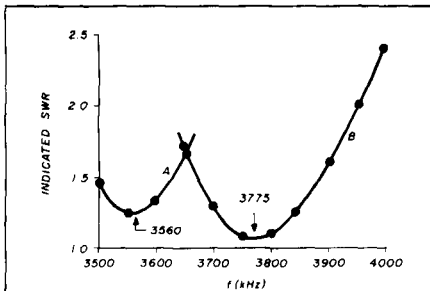


fig. 8. The W6TC two-frequency dipole. Curve A shows resonance at 3560 kHz with a remote loading inductor in the circuit. Curve B shows resonance at 3775 kHz with inductor shorted out. Resonance curve B can be shifted by changing length of antenna; curve A can be shifted by changing the value of the loading inductor.

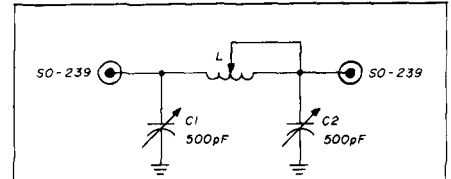


fig. 9. A coaxial "line flattener" for 80 and 160 meters. Capacitors may be shunted with 1250 volt mica units to increase range. (As much as 2000 pF may be required on 160 meters.) Inductor can be tapped or switched. No. 16 bare or tinned copper wire is recommended as a starter (12 turns per inch). Surplus rotary inductor would be useful.

### computermania!

In my April, 1983, column I discussed short, loaded dipole antennas and showed a simple computer program that would aid in the fast design of a short dipole for any Amateur band. Missing from the program was the section required to design the impedance matching coil. The program was modified by Dick, W6EDE, for a TRS-80 (II), and has been further refined by John McComic, K4KAJ (fig. 5). John's program covers the complete antenna design, plus matching coil, for any frequency. The result is a half-length dipole, perfect for cramped locations.

A copy of the missing section of the program is available directly from *ham radio*. Be sure to enclose a stamped (20¢) business-size envelope (9-1/2 x 4-1/8) with your request.

(My thanks to the following who also provided interesting and useful antenna programs: Lloyd Phillips, WB6WCA; Warner Thompson, N7WT; and I. L. McNally, K6WX.)

### references

1. William I. Orr, W6SAI, "Ham Radio Techniques," *ham radio*, August, 1982, page 42. (See Snyder 80-meter antenna product review in this issue. Editor)
2. Jerry Hall, K1TD, "The Search for a Simple Broadband 80-Meter Dipole," *QST*, April, 1983, page 22.
3. Mason A. Logan, K4MT, "Stagger-Tuned Dipoles Increase Bandwidth," *ham radio*, May, 1983, page 22.

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LNA 432	380-470		1.0 dB	18 dB	\$44.95

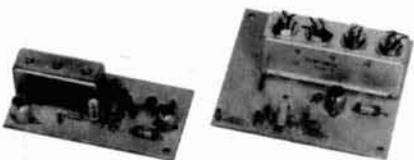
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	144-148	50-54
	220-222	28-30
	220-224	144-148
	222-226	144-148
	220-224	50-54
	222-224	28-30

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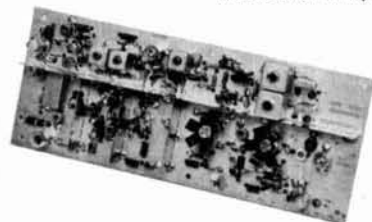
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28-30	220-222*	
50-54	220-224	
144-146	50-52	
50-54	144-148	
144-146	28-30	

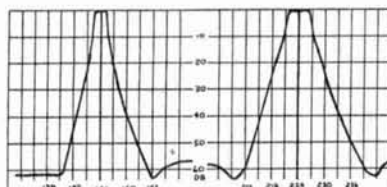
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28-30	435-437	
50-54	432-436	
61.25	439.25	
144-148	432-436*	

\*Add \$20 for 2M input

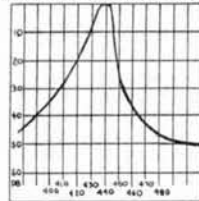


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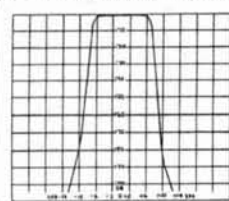
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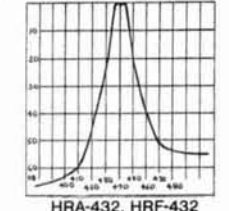


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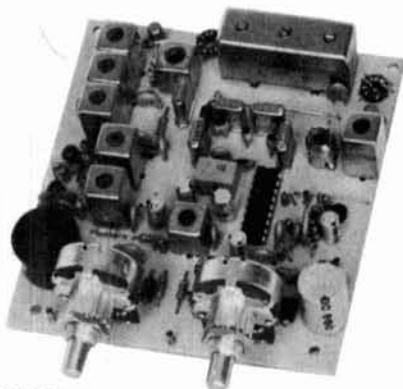
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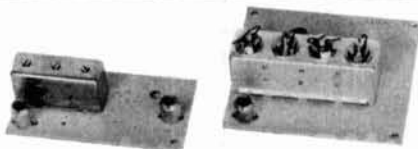
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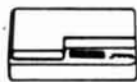


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## short circuits

### vertical phased arrays

The following corrections should be made to part 3 of K2BT's article, "Vertical Phased Arrays" (July, 1983):

Eq. 3 (p. 30) should read:

$$Z_{12} = \pm \sqrt{Z_{22}(Z_{11} - Z_1)}$$

The polar notation in the upper left-hand column of page 32 should include the angle symbol and read:

$$20.4 \angle 132.2^\circ$$

The following lines identifying the driving point impedances in table 3 (page 33) should be corrected as indicated.

3-element in-line array,  $\lambda/4$  spacing:

$$Z_1 - 6.6 - j21 \text{ should read } 15.4 - j17$$

$$Z_2 \ 51.4 + j0 \text{ should read } 36.2 + j0$$

$$Z_3 \ 79.4 - j39 \text{ should read } 75.4 + j43$$

triangular array,  $0.289\lambda$  spacing:

$$Z_1 \ 28.4 - j10 \text{ should read } 20.4 - j10$$

### panoramic adapter

The following corrections should be made to "Design Notes on a Panoramic Adaptor/Spectrum Analyzer" by Rick Ferranti, WA6NCX, (February, 1983):

In fig. 4 (page 30), the connection shown between the transistor's collector and the 3.3k resistor is erroneous. The collector lead is still attached to T1.

In reference to the 31 MHz band-pass filter in fig. 8 (page 31) the notation "space coils 1/2 inch apart . . ." refers to the distance between T<sub>1</sub> and T<sub>2</sub> (centers); the 2-turn windings on the coil should be over the 12-turn windings on each form at the cold end.

A small variable capacitor across the 4.7k resistor was deleted from fig. 9 (page 32), but not from the text. Because the capacitor pulled the oscillator only slightly in frequency, it is not necessary in this circuit.

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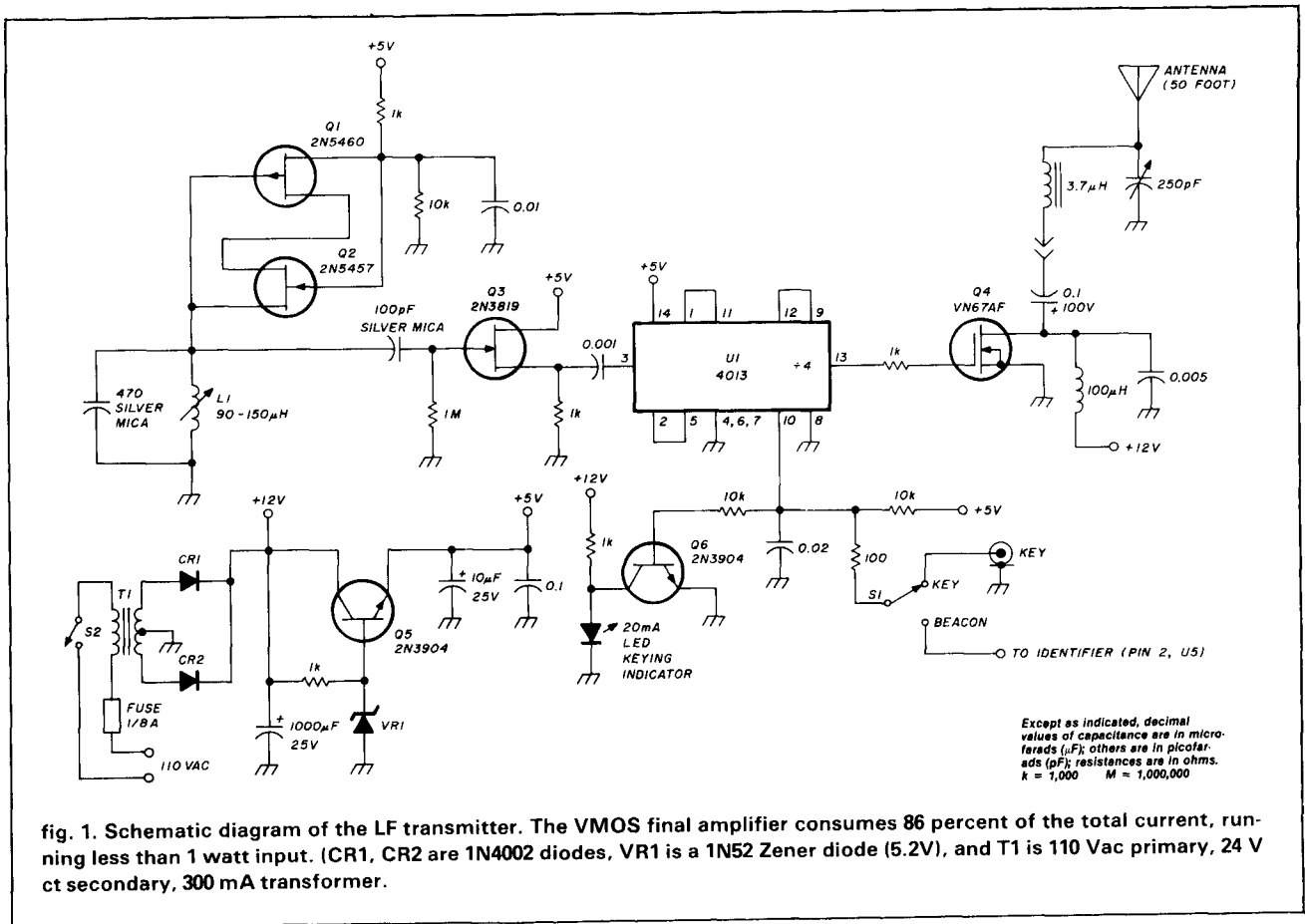


fig. 1. Schematic diagram of the LF transmitter. The VMOS final amplifier consumes 86 percent of the total current, running less than 1 watt input. (CR1, CR2 are 1N4002 diodes, VR1 is a 1N52 Zener diode (5.2V), and T1 is 110 Vac primary, 24 V ct secondary, 300 mA transformer.

## VMOS on 1750 meters

### A CW or beacon transmitter for 160 kHz

Many interesting experiments and enjoyable QSOs can be your reward for operating on the 1750-meter band. No license is required to use the slice of radio spectrum between 160 and 190 kHz, and it requires only simple equipment to provide the legal maximum of 1-watt input to the transmitter. Enthusiasts have made contacts over distances of 700 miles in spite of the antenna-size limit of 50 feet.

I've used my VMOS transmitter to make a contact from East Haven, Connecticut to Owings, Maryland — a span of 250 miles. It can be done consistently as long as very noisy conditions do not exist. Many

schedules have successfully been kept with stations in New Jersey, New York, Maryland, and Massachusetts. My beacon signal has been heard as far north as New Hampshire and as far south as Maryland. Receiving equipment for this band is not at all difficult to build.<sup>1</sup>

D-layer reflection and groundwave propagation modes dominate the band and best results are obtained by installing a good ground system and by keeping antenna coupling-losses low. Radiation resistance for the 50-foot antenna is on the order of 0.02 ohms and the radiation efficiency is therefore very low. Nevertheless, a few milliwatts of effective radiated output does give you usable communications.

By S. J. DeFrancesco, K1RGO, 17 Jeffrey Road, East Haven, Connecticut 06512

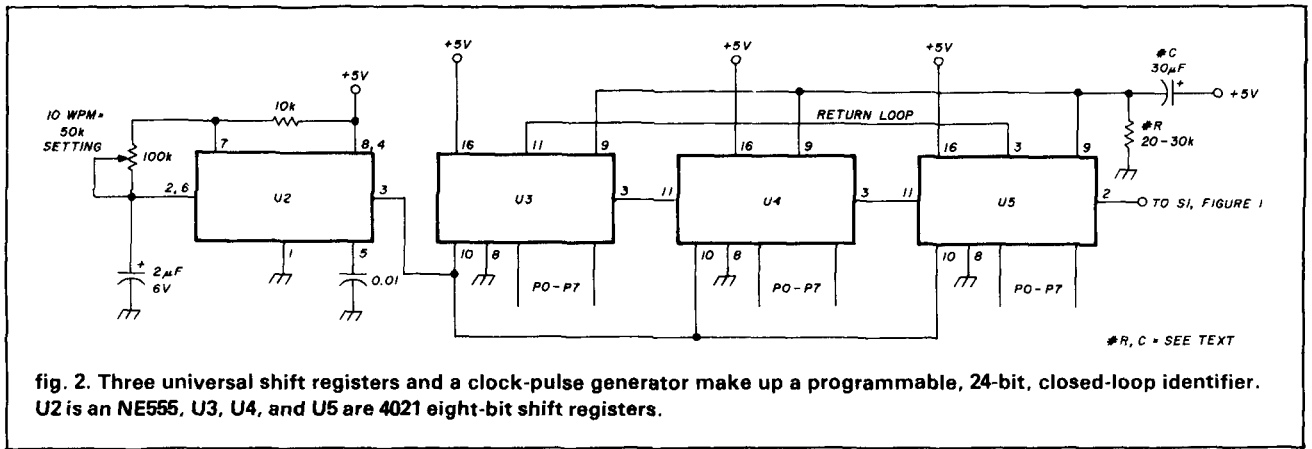


fig. 2. Three universal shift registers and a clock-pulse generator make up a programmable, 24-bit, closed-loop identifier. U2 is an NE555, U3, U4, and U5 are 4021 eight-bit shift registers.

### the transmitter

The transmitter circuit diagram shown in **fig. 1** uses a 600-800 kHz negative-resistance oscillator consisting of Q1 and Q2. L1 is a variable inductor of 90-150 µH. The 470 pF capacitor can be made variable, and an old BC loop stick can be used for L1 instead. Stability is excellent — only a few hertz of drift were observed one hour after the unit was turned on. Isolation is provided by Q3, a source-follower circuit which drives U1. U1 is a CMOS 4013 type-D dual flip-flop used to divide the 600-800 kHz from the oscillator down to 150-200 kHz. The output of U1 drives the VMOS amplifier. The output of Q4 is coupled to the antenna tuning network through a 0.1 uF capacitor. The antenna tuning network consists of a 250 pF variable capacitor and a 3.7 mH coil wound on a ferrite rod. This high Q L/C arrangement resonates the 50-foot vertical antenna to 160-190 kHz.

Transmitter keying is accomplished by gating U1 on and off at pin 10. Q6 is an LED driver connected to indicate keying. S1 is set to key position for manual

CW operation, or BEACON position for continuous-message operation.

### identifier

Three 4021 CMOS universal eight-bit shift registers are used in the identifier for minimum power consumption. In **fig. 2**, U3, U4, and U5 clock inputs are connected in parallel. U2 is a square-wave clock-pulse generator which drives the other ICs. The 100k potentiometer can be adjusted to obtain the desired code speed. The P0-P7 parallel inputs are programmed to provide identification. R\* and C\* are somewhat critical and should be selected for the code speed used. R\*, shown in **fig. 2**, is 30k for 15 wpm or less, or 20k for 20-30 wpm. C\* is 30 µF for this same range of code speeds.

When power is first turned on, P0-P7 parallel inputs are loaded in serial with pin 9 on U3, U4, and U5 in a logic-high state. As C\* equalizes, and pin 9 goes low, the serial-loop mode is activated and the program is stored. It then circulates in a continuous loop. The output (pin 2 of the U5) pulse train is fed to

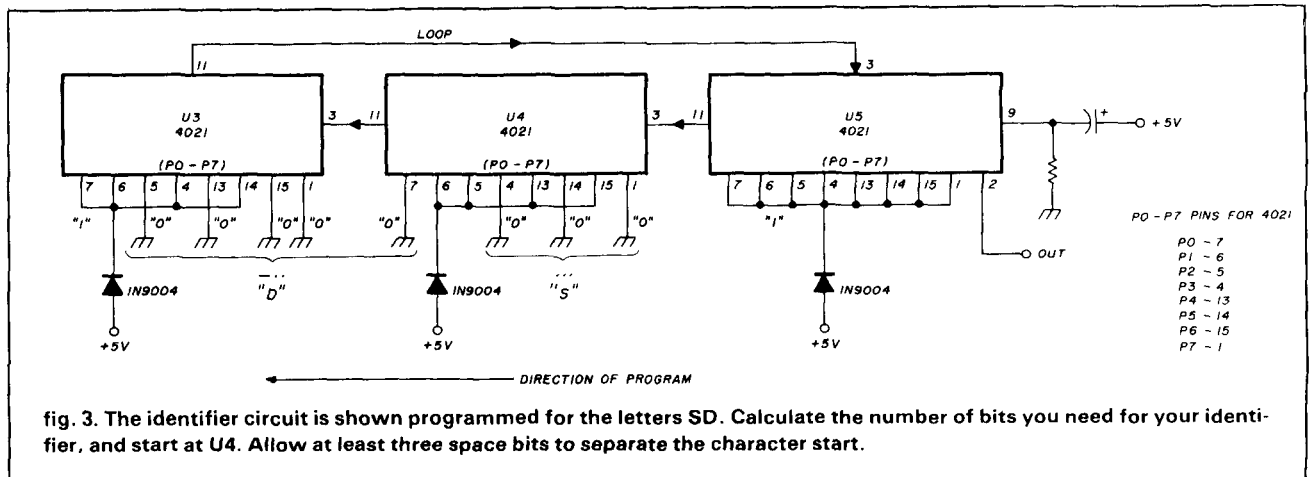


fig. 3. The identifier circuit is shown programmed for the letters SD. Calculate the number of bits you need for your identifier, and start at U4. Allow at least three space bits to separate the character start.

U1 in the transmitter, providing CW transmission in the beacon mode. Code speed is varied by changing the output frequency of U2.

### programming

A dash is equal to three bits (zero) and a dot is equal to one bit (zero). Spacing between dots and dashes to form a character is one bit (zero). Spacing between characters is two bits (1). The identification I use is "SD," consisting of fourteen bits with ten bits to spare. The program is shown in fig. 3, using the P0-P7 parallel inputs. A 0 is an on bit and a 1 is an off, or space, bit. Once the program is wired in, no other preprogramming is needed. If your program appears to drop a bit or two, shut off the power for a few seconds and then switch it back on again; this will reset the program.

### operation

I monitored the transmitter on an RBA-5 low-frequency receiver, and adjusted the VFO to the desired frequency (185 kHz). When I keyed the transmitter, I heard very little key clicking, and a nice, chirp-free signal was generated. I tuned the output capacitor for maximum indication on my field strength meter. An NE-2 neon bulb glowed brightly when touched to the antenna terminal. I then tuned the 250-pF loading capacitor and found that no shift in frequency was being caused by the antenna tuning. I turned the switch to the BEACON mode to evaluate the IDer, and it worked fine.

This system has run twenty-four hours at a time and has been very reliable. Total current drain is 100 mA, of which 86 mA is used by the VMOS power amplifier. Input to the final is around 1 watt, the legal unlicensed limit.

### construction notes

The complete unit can be made very small, including the power supply — it is possible to fit everything except the antenna loading circuit into a 2 × 4 × 2-inch (50 × 103 × 50 mm) Minibox.

The 3.7 mH antenna coil can be air core or low-loss ferrite core. I close-wound 138 turns of No. 26 wire on an old 5/8-inch diameter broadcast-band ferrite core. A 250 or 365 pF variable capacitor can be used with this inductor to resonate the 50-foot vertical antenna. Experimentation with various cores and coils to improve efficiency in the antenna circuit can be evaluated by field-strength readings.

### ham radio

### references

1. DeFrancesco, S.J., K1RGO. "A Fixed-Tuned LF Converter," *ham radio*, January, 1983, page 19.

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74LS05	.24	74LS190	.88
74LS08	.27	74LS191	.88
74LS09	.28	74LS192	.78
74LS10	.24	74LS193	.78
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74LS12	.34	74LS195	.68
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74LS21	.28	74LS241	.98
74LS22	.24	74LS242	.98
74LS26	.28	74LS243	.98
74LS27	.28	74LS244	1.25
74LS28	.34	74LS245	1.45
74LS30	.24	74LS247	.74
74LS32	.28	74LS248	.98
74LS33	.54	74LS249	.98
74LS37	.34	74LS251	.58
74LS38	.34	74LS253	.58
74LS40	.24	74LS257	.58
74LS42	.48	74LS258	.58
74LS47	.74	74LS259	2.70
74LS48	.74	74LS260	.58
74LS49	.74	74LS266	.54
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74LS157	.64	74LS683	3.15
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74LS161	.64	74LS688	2.35
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2797	58.95
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8T28	1.84
8T95	.88
8T96	.88
8T97	.88
8T98	.88
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DP8304	2.24
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DS8836	.98

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78M05C	.34	7908T	.84
7808T	.74	7912T	.84
7812T	.74	7915T	.84
7815T	.74	7924T	.84
7824T	.74	7905K	1.44
7805K	1.34	7912K	1.44
7812K	1.34	7915K	1.44
7815K	1.34	7924K	1.44
7824K	1.34	79L05	.78
78L05	.68	79L12	.78
78L12	.68	79L15	.78
78L15	.68	LM323K	4.90
78H05K	9.90	UA78S40	1.90
78H12K	9.90		

C, T = TO-220      K = TO-3      L = TO-92

## DIP SWITCHES

4 POSITION	.84
5 POSITION	.89
6 POSITION	.89
7 POSITION	.94
8 POSITION	.94

## IC SOCKETS

	1-99	100
8 pin ST	.12	.10
14 pin ST	.14	.11
16 pin ST	.16	.12
18 pin ST	.19	.17
20 pin ST	.28	.26
22 pin ST	.29	.26
24 pin ST	.29	.26
28 pin ST	.39	.31
40 pin ST	.48	.38
64 pin ST	4.20	call

ST = SOLDER TAIL

8 pin WW	.58	.48
14 pin WW	.68	.51
16 pin WW	.68	.57
18 pin WW	.98	.89
20 pin WW	1.04	.97
22 pin WW	1.34	1.23
24 pin WW	1.44	1.30
28 pin WW	1.64	1.44
40 pin WW	1.94	1.75

WW = WIREWRAP

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ZIF = TEXT TOOL (Zero Insertion Force)

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2.4576	3.90
3.2768	3.90
3.579535	3.90
4.0	3.90
5.0	3.90
5.0688	3.90
5.185	3.90
5.7143	3.90
6.0	3.90
6.144	3.90
6.5536	3.90
8.0	3.90
10.0	3.90
10.738635	3.90
14.31818	3.90
15.0	3.90
16.0	3.90
17.430	3.90
18.0	3.90
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32.0	3.90

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## pacemakers and RFI: safety first

We read Edwin M. Hollis's letter (Technical Forum, June, 1983) concerning the use of transmitting equipment by a ham with an implantable cardiac pacemaker.

There is a general misconception that everyone with a pacemaker will "expire" when exposed to an RF field or a microwave oven. The twenty-five or more manufacturers of pacemakers worldwide are concerned about the response of their products to electromagnetic interference and do extensive testing on the products before release. These tests are done by the manufacturer and by independent testing organizations. Virtually all manufacturers include filters and/or shielding of the electronic circuit.

Pacemakers are prescribed for patients who have some abnormality in the normal electrical activity of the heart. Without this normal electrical activity, the heart will slow down or skip beats entirely. The pacemaker monitors this activity and generally puts out a stimulating impulse only when needed. The stimulating impulse "shocks" the heart muscle,

causing the muscle to contract and the heart to beat.

The circuit that monitors the heart activity also looks for interfering signals (EMI, RFI, etc.). If interfering signals are detected, the pacemaker's stimulating pulses will be turned on, instead of shutting off completely. There is a remote possibility of the pacemaker's being inhibited (turned off) if the field is intense. (This warning is included in the patient handbooks and physician manuals.) If this were to occur, the patient might experience dizziness or fainting spells. As soon as the interfering signals were removed, the pacemaker would return to normal operation. No permanent damage would be done to the pacemaker's electronic circuit.

In recent literature, there have been no reported deaths due to RFI exposure of patients with implanted pacemakers. There have been reported cases of patients experiencing fainting spells or dizziness with older pacemaker models that are no longer manufactured.

If a patient is concerned about exposure to RF fields, the pacemaker manufacturer should be contacted.

The address and phone number are printed on the permanent plastic I.D. card given to all pacemaker patients.

Any Amateur with a pacemaker should follow these general rules:

1. Make sure transmitting equipment is in good working order.
2. Maintain a good ground on all equipment.
3. Avoid working on equipment with cover or shields removed.
4. Do not stand near antenna systems radiating power, especially in front of directional arrays.

If you must do any of these things, have someone else nearby to turn off transmitting equipment if any dizziness or fainting spells are experienced. Electrical shock hazard is not increased because of the pacemaker. There is no technical reason why an Amateur Radio operator with an implantable cardiac pacemaker cannot continue to enjoy the hobby by simply exercising a few cautionary measures.

**John W. Bixler, K3EAS**

**Field Program Coordinator**

**William L. Johnson, K3FOW,**

**Electronics Manager**

**Donald A. Henry, W3FE, Engineer**

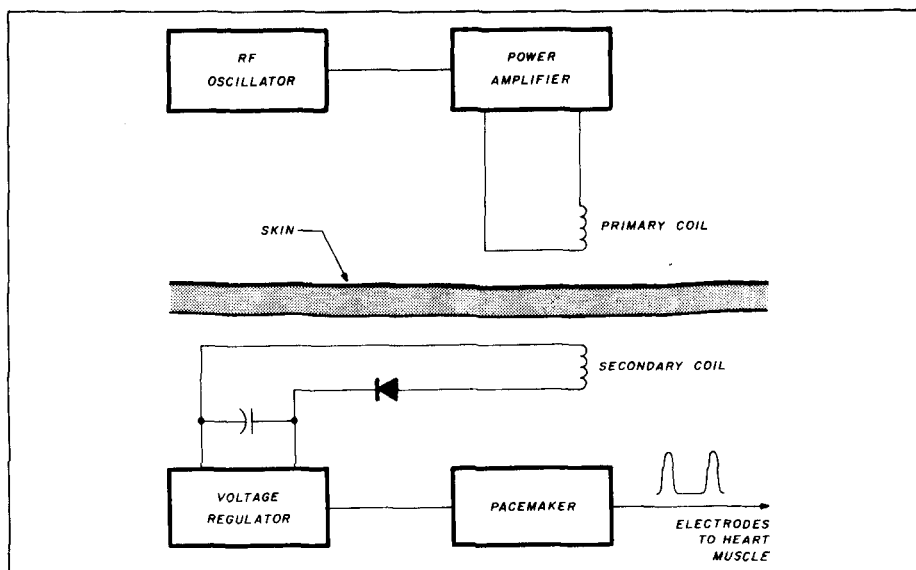
**Cook Pacemaker Corporation**

**Leechburg, Pennsylvania 15656**

## concern at high levels

I have some information for Ed Hollis, K4CN, on the effects of RFI on pacemakers (Technical Forum, June, 1983).

It depends on the type of pacemaker. Some are RFI powered externally (fig. 1); in these, a secondary coil rectifies the induced voltage to power the pacemaker. There are also nuclear-powered long-term pacemakers, employing a shielded radioactive source, which are implanted in the patient. The most popular pacemakers at present contain a lithium



battery which can last up to ten years.

Basically, a pacemaker simulates the periodic electrical pulse which stimulates the heart muscle to a state of contraction. Its circuitry can be a monolithic multivibrator or a blocking oscillator of either the asynchronous or the more complex-demand type used in synchronous pacemaker. The latter depends on ventricular contractions' return pulses which automatically adjust the pulse rate with variations in physical activity. The pulse width for pacemakers varies from 0.5 to 2 ms with amplitudes of 5 to 9 volts.

In the normal ham shack you need not worry about any disruption of the pacemaker operation. *But very high levels of RFI can override the pulsed output*, especially affecting the demand type synchronized pacemaker, which is controlled from the heart muscle. Avoid standing under a broadcast station antenna (running kilowatts), stay away from high ERP microwave dishes, and when adjusting your beam antenna's gamma match, *shut your transmitter off.* — **Salvatore J. DeFrancesco, K1RGO**

## heartwarmer

Dear HR:

I can think of no adequate way of thanking *ham radio* for printing the item "pacemakers and RFI" for me in your June issue (Technical Forum, page 98). The response to the item has been just overwhelming; the value of information gained from the data and letters cannot be adequately measured. The many letters describing personal experiences and offering technical advice were incredible.

It proved several things: first of all, that a lot of Amateurs subscribe to *ham radio*; and what is more important, they read it. If one ever did have any doubts about the type of person the Amateur is, such a response from so many who have taken their time and money to inform another ham (who they never even knew) about a subject which might make the differ-

ence between life or death was heartwarming, to say the least.

From the mail I received it is apparent that the pacemaker, along with other forms of medicine and electronics, has come a long way in the past few years. Even though an Amateur himself is not wearing one of the gadgets, it is nice to know that he will not be endangering a neighbor who might come too close to a transmitting antenna, causing an unexpected problem . . . please thank all the readers who spent their time and money to respond to my question.

The tremendous response to the item also proves without a doubt that there has been and just may still be a vital problem in this area. I'm sorry if I gave the impression that the experience I had in the hospital was recent. It was, in fact, quite some time ago and I have been convinced that many changes have been made since then, as well one could expect. In spite of that I found many not convinced as to the reliability of pacemakers in the presence of RFI; I was also unable to find a recent schematic, which is understandable.

**Edwin M. Hollis, K4CN**

*ham radio* has prepared a list of recent articles on possible RFI interference with pacemaker operation. We would be happy to make that list available to concerned readers or their physicians. Address requests to: PACEMAKERS, *ham radio magazine*, Greenville, New Hampshire 03048. (Enclose large SASE.) — Editor

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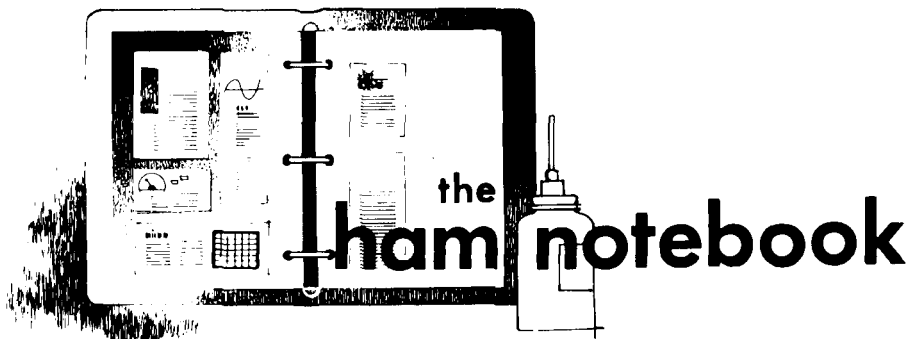


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## zero-beat indicator for RTTY

I built the ST-5 demodulator described in *ham radio*<sup>1</sup> but had difficul-

ty finding the zero beat of the incoming signal on my receiver. The ST-5 has a meter for tuning. When the meter reading is identical for MARK and SPACE, the Model 19 machine

provides solid print. However, I found it quite difficult to tune in the signal so that the meter would indicate this condition.

Dave, N2DS, our local solid-state wizard, suggested I make a device using the LM3914 chip\* with its ten-LED output. The LM3914 has ten positions for the LEDs, and the resistors for them are built into the chip. The LM3914 is known as a "bar analog generator."

I developed a plan to have two vertical columns of ten LEDs each. One column would be for MARK and one for SPACE. Required were two LM3914s, a 5-volt regulated power supply, twenty red LEDs, and two resistors, R1 and R2 (fig. 1).

Resistor R1 is 1.21k. I made this resistor using 1k, 200 ohms, and 10 ohms in series (watch tolerances). Resistor R2 is 3.83k. I used a 3k resistor plus an 800-ohm and a 30-ohm resistor in series. You'll need two R1 and two R2 resistors.

Turning this idea into a construction project resulted in a nice visual device to tune in an RTTY signal. The circuit is more economical and better than an oscilloscope with the high voltage involved and its many controls.

## construction

Only three wires are needed to connect the zero-beat indicator to the ST-5. The control circuit (fig. 1) can be built on perf or PC board, which is mounted inside the ST-5 cabinet.

Mount the following components onto the control board: two 2N3904s, two 5k trim pots, two 1k ¼-watt resistors, two 1N4148 silicon diodes, and two 0.068-μF disc ceramic caps. Mount the control board in the ST-5 demodulator so that you can adjust

\*Radio Shack part #276-1767. LEDs are part #276-1622.

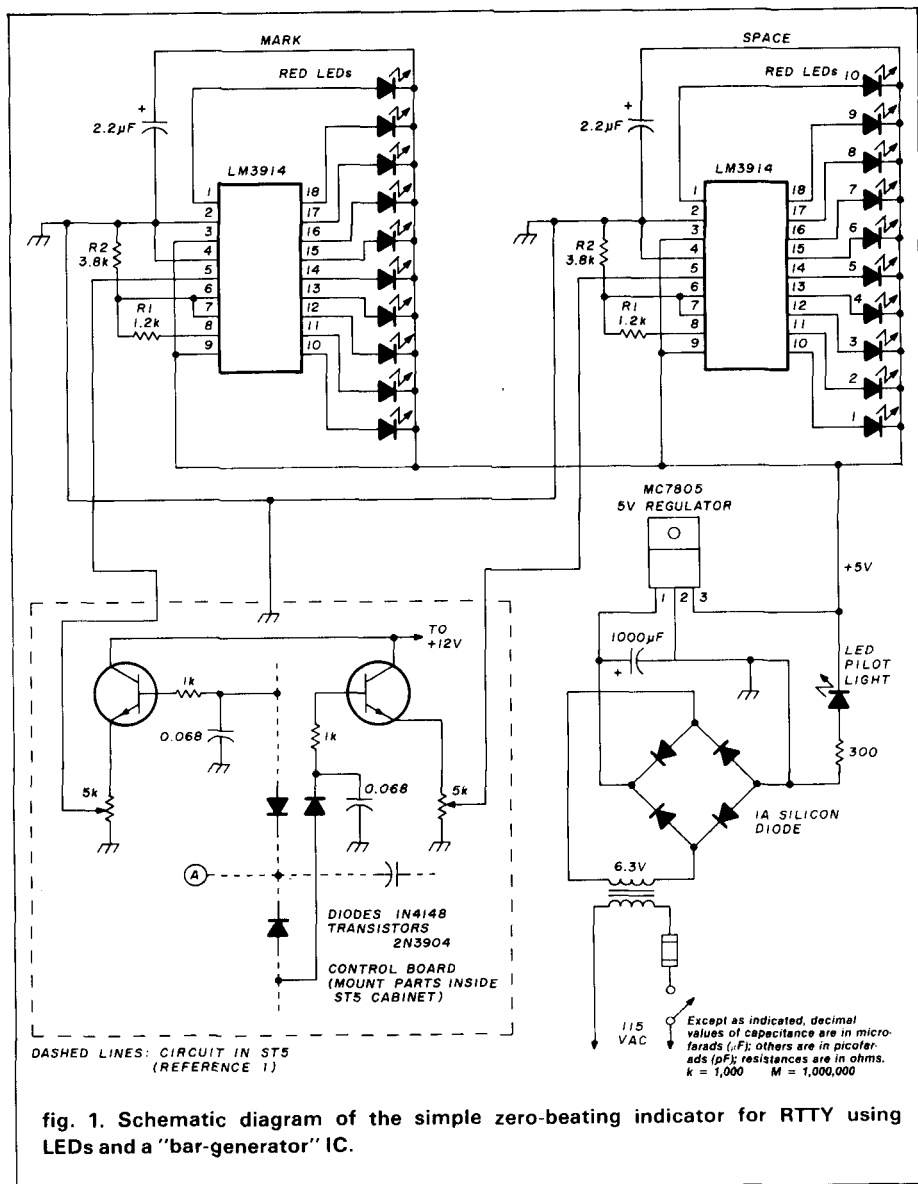


fig. 1. Schematic diagram of the simple zero-beating indicator for RTTY using LEDs and a "bar-generator" IC.



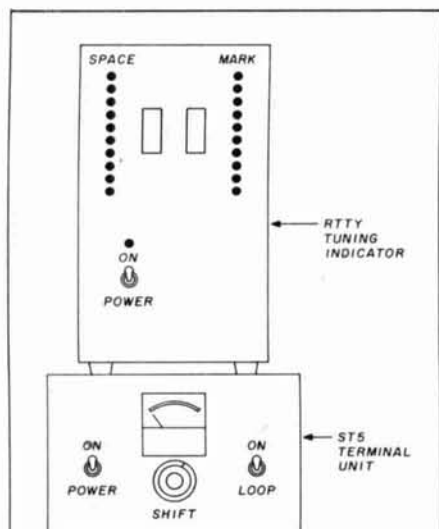


fig. 2. Author's zero-beat indicator mounted on the ST-5 demodulator. Other physical arrangements are possible. Use your ingenuity.

the trim pots easily. In fig. 2 you'll note that I've mounted the LM3914 chips between the vertical columns of LEDs. No big deal. Perhaps you would like to have the LEDs running horizontally. In any event, if you want to use the vertical display, a better way of mounting the LM3914s is to the left of the LEDs, as shown in fig. 1. This makes for easier wiring.

### adjustment

With an input signal, adjust the MARK trim pot so that eight of the ten MARK LEDs light up. Then, with a SPACE signal, adjust the SPACE trim pot so that eight of the SPACE LEDs light. Another method is to tune in W1AW on 3625 kHz. Then make your adjustments, as you'll have a good MARK and SPACE signal. Be sure you get the first 15 minutes of W1AW's transmission; it changes to ASCII during the second 15 minutes.

I'd like to thank Dave Schmarder, N2DS, for his help in completing this project.

### reference

1. Irvin M. Hoff, W6FFC, "The Mainline ST-5 RTTY Demodulator," *ham radio*, September, 1970, page 14.

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# hf hybrids: a second look

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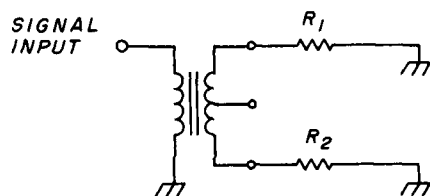


fig. 1A. 180 degree hybrid equivalent circuit.

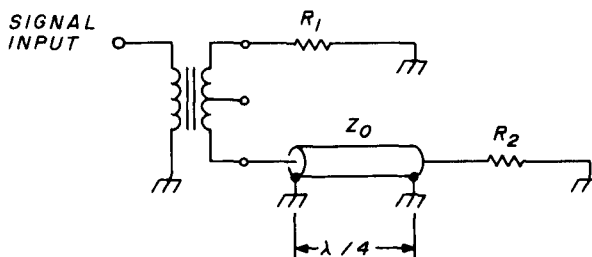


fig. 1B. Quadrature hybrid equivalent circuit.

Hybrids are generally four-port devices used in UHF and microwave designs, where they are easily fabricated as part of stripline or microstrip assemblies. They usually fall into one of two general classes: the 90 degree or quadrature hybrid, and the 180-degree hybrid. Examples of the quadrature type are the side-coupled directional coupler, the branch coupler, and capacitively coupled hybrid.<sup>1</sup> The 180-degree type is probably best exemplified by the ring or "rat race" coupler.

As one might imagine, the quadrature hybrid divides its signal between two outputs which are 90 degrees out of phase with respect to each other. The rat race, on the other hand, provides two outputs which are in phase opposition.

A major difference between the two classes, other than the phase relationship of their output signals, is that in order to obtain a null at the fourth port, the quadrature hybrid requires that the two loads must both match the impedance level for which the device was designed. The 180 degree variety, on the other hand, requires only that the two output loads match each other.

## why?

If we replace our hybrid with yet another and simpler form, a center-tapped transformer, with loads on opposite ends of the secondary coil, (fig. 1A), then as long as the two loads are equal, no signal is present at the center tap, which becomes our fourth port. But suppose we require a quadrature

phase relationship between the two output signals. We then introduce a quarter wavelength of line between one output and its load. This quarter wavelength of line inverts the impedance of that load, so that unless both loads match the impedance of that section of line, no balance will exist, and a signal will appear at the center tap (fig. 1B).

This simple exercise demonstrates why quadrature hybrids must match the loads to the design impedance, while 180 degree hybrids need only to match one load against the other.

The transformer form of hybrid is found to have numerous applications in the high-frequency range. With appreciable power levels, the signal may be introduced into the center tap of the transformer. Dividing into two paths, with opposing magnetic fields, saturation of a ferrite core would be avoided, while the other coil (now the secondary), will show, at its output, any unbalance between the two loads.

The use of such transformer-type hybrids in the high-frequency range has not been generally exploited, but would seem to offer much for compact power dividers, combiners and phase shifting devices.

## reference

1. Henry S. Keen, W2CTK, "High Frequency Hybrids and Couplers," *ham radio*, July, 1970, page 57.

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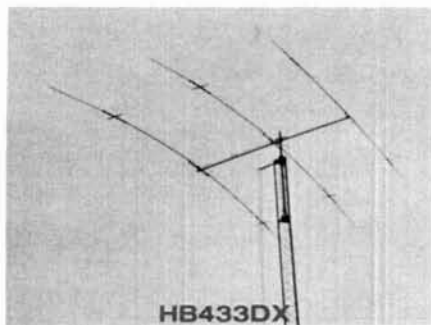
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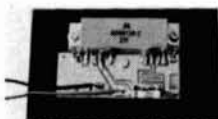
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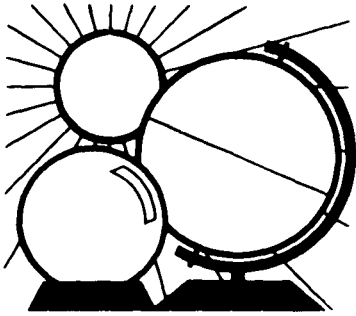
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# DX FORECASTER

Garth Stonehocker, KØRYW

## trans-equatorial DX

The autumnal equinox — with its promise of winter DX conditions to come — also signals the return of trans-equatorial openings, with their 5000 to 7000 mile (8000-11,200 km) paths.

A cross-section representation of the ionosphere along the 75-degree west meridian is shown in fig. 1. Data for this drawing was obtained by ionosonde returns off the bottom half of the ionosphere. Note a concentration of contour lines near the center and right (southern latitude) side. The thick line is a ray of energy transmitted from the earth at 20 degrees north with a low take-off (elevation) angle. This ray just grazes the middle maximum and does not return through the lower ionospheric layers or earth bounce before it grazes the second southern maximum; it then bends enough to return to the earth at 30 degrees south. This layer-to-layer reflection accounts for less signal loss

(10-15 dB) than the "normal" intermediate earth reflection type transmission. This low loss makes trans-equatorial propagation very effective in providing excellent DX QSOs with our southern friends.

The maximums are located on both sides of the geomagnetic equator ( $\pm 20$  degrees). The electrons drift-diffuse up the geomagnetic field lines each afternoon until about 2200 local time, mainly during the winter half of the year. Geomagnetic disturbances tend to enhance the electron upward drift from the trough just south of the auroral zone. The dotted lines in the drawing are representative geomagnetic field lines.

Although lower MUFs are now being experienced because of the diminishing solar cycle, one can still expect the 15- and 10-meter bands to have some trans-equatorial propagation openings this winter during the high solar flux days in which geomagnetic disturbances occur. Listen

to WWV on 2.5, 5, 10, 15, or 20 MHz at 18 minutes after the hour for solar flux, geomagnetic A and K indices, as well as for the solar activity and geomagnetic condition report and forecast. If the solar flux exceeds 150 and A is greater than 30, with K greater than 4, expect very good trans-equatorial openings.

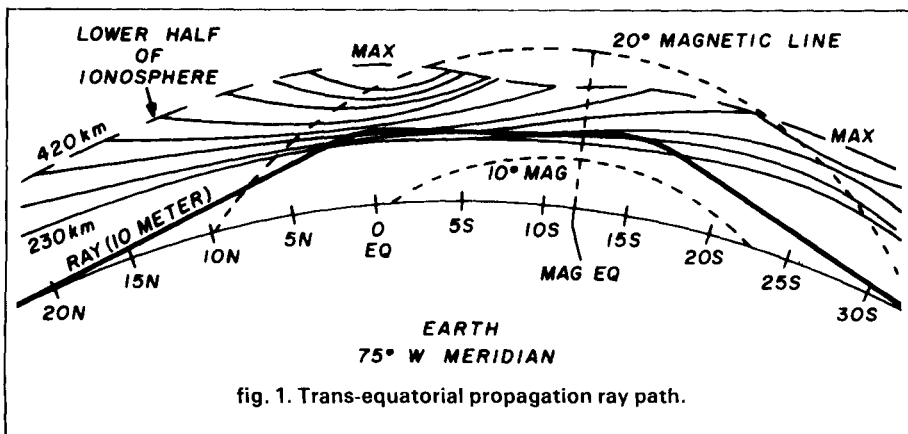
## last-minute forecast

On the higher frequency bands (10-30 meters) DX conditions should improve with rising solar flux and flare activity during the two middle weeks of the month. This leaves the first and last weeks for operation on the improving lower bands (30-160 meters). Both night and day DX should be very good this time of the year.

Expect disturbances during the following days in October: 1st, 2nd, 9-15th, 19-21st, 24-30th. This is still the equinox period when the solar wind particles are very effective in producing ionospheric effects and still within those years of maximum solar coronal holes to feed the solar wind. All in all, that's a double dose of interesting DX conditions.

In October the Orionid meteor showers are visible from the 15th to the 25th. The maximum rate will be between ten to twenty per hour on the 20-21st of the month. The moon is full on the 21st and perigee occurs on the 4th of the month.

In most parts of the country, October represents the last opportunity of the year for antenna repair and maintenance. How are your antennas? Are



GMT	PDT	WESTERN USA																
		N	NE	E	SE	S	SW	W	NW	ASIA FAR EAST	EUROPE	S. AFRICA	S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN	
0000	5:00	20	20	15	10	15	10	10	10	10	20	20	20	20	10	10	10	20
0100	6:00	20	20	15	10	15	10	10	10	10	20*	20	20	20	10	10	10	20*
0200	7:00	20	20	15	10	15	10	10	10	10	15	20	20	20	10	10	15	15
0300	8:00	20	30	20	10	15	10	10	10	10	10	15	20	20	10	10	15	15
0400	9:00	20	30	20	10	15	10	10	10	10	10	10	15	20	10	10	10	15
0500	10:00	20	30	20	15	15	10	10	10	10	10	10	15	20	10	10	10	15
0600	11:00	20	30	20	15	20	15	15	15	15	15	15	15	20	10	10	10	20
0700	12:00	20	30	20	15	20	15	15	15	15	15	15	15	20	10	10	10	20
0800	1:00	20	30	20	20*	20	20*	20	20*	15	20*	20*	20*	20	10	10	10	20
0900	2:00	20	30	20	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1000	3:00	30	30	20	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1100	4:00	30	30	20	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1200	5:00	30	30	20	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1300	6:00	30	30	20*	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1400	7:00	30	20	15	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1500	8:00	30	20	15	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1600	9:00	30	20	15	15	15	15	15	15	15	20	20	20	20	10	10	10	20
1700	10:00	30	20	10	15	15	15	15	15	15	20	20	20	20	10	10	10	20
1800	11:00	30	20	10	15	15	15	15	15	15	20	20	20	20	10	10	10	20
1900	12:00	40	20*	10	15	15	15	15	15	15	20	20	20	20	10	10	10	20
2000	1:00	30	20*	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20
2100	2:00	30	15	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20
2200	3:00	20	20*	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20
2300	4:00	20	20	15	10	10	10	10	10	10	10	10	10	10	10	10	10	20

GMT	MDT	MID USA																
		N	NE	E	SE	S	SW	W	NW	ASIA FAR EAST	EUROPE	S. AFRICA	S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN	
0000	6:00	30	20	15	10	15	10	10	10	10	20	20	20	20	10	10	10	20
0100	7:00	30	20	15	10	15	10	10	10	10	20	20	20	20	10	10	10	20
0200	8:00	30	30	15	10	15	10	10	10	10	15	20	20	20	10	10	10	15
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0400	10:00	40	30	20	15	15	10	10	10	10	10	10	15	20	10	10	10	15
0500	11:00	30	30	20	15	15	10	10	10	10	10	10	15	20	10	10	10	15
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0900	3:00	30	30	20	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1000	4:00	20	30	20	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1100	5:00	20	30	20	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1200	6:00	20	30	20	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1300	7:00	20	30	15	20	20	20	20	20	20	20	20	20	20	10	10	10	20
1400	8:00	20	30	15	20	20	20	20	20	20	20	20	20	20	10	10	10	20
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2100	3:00	20	20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20
2200	4:00	20	20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20
2300	5:00	30	20	15	10	10	10	10	10	10	10	10	10	10	10	10	10	20

GMT	EDT	EASTERN USA																
		N	NE	E	SE	S	SW	W	NW	ASIA FAR EAST	EUROPE	S. AFRICA	CARIBBEAN S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN	
0000	8:00	30	20	15	10	15	10	10	10	10	20	20	20	20	10	10	10	20
0100	9:00	30	20	15	10	15	10	10	10	10	20	20	20	20	10	10	10	15
0200	10:00	30	30	15	10	15	10	10	10	10	15	20	20	20	10	10	10	15
0300	11:00	30	30	20	10	15	10	10	10	10	10	15	20	20	10	10	10	15
0400	12:00	40*	30	20	15	15	10	10	10	10	10	10	15	20	10	10	10	15
0500	1:00	30	30	20	15	15	10	10	10	10	10	10	10	15	15	15	15	20
0600	2:00	30	30	20	15	20	15	15	15	15	15	15	15	15	15	15	15	20
0700	3:00	40	30	20	15	20	15	15	15	15	15	15	15	15	15	15	15	20
0800	4:00	30	40	20	20	20	20	20	20	20	20	20	20	20	20	20	20	30
0900	5:00	30	40	20	20	20	20	20	20	20	20	20	20	20	20	20	20	30
1000	6:00	20	40	20	20	20	20	20	20	20	20	20	20	20	20	20	20	30
1100	7:00	20	30	20	20	20	20	20	20	20	20	20	20	20	20	20	20	30
1200	8:00	20	30	15	20	20	20	20	20	20	20	20	20	20	20	20	20	30
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1400	10:00	20	20	15	20	20	20	20	20	20	20	20	20	20	20	20	20	30
1500	11:00	20	20*	10	15	15	15	15	15	15	20	20	20	20	20	20	20	30
1600	12:00	20	20*	10	15	15	15	15	15	15	20	20	20	20	20	20	20	30
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1900	3:00	20	20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20
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2100	5:00	30	20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20
2200	6:00	30	20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20
2300	7:00	30	20	15	10	10	10	10	10	10	10	10	10	10	10	10	10	20

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides the MUF during 'normal' hours.  
 \*Look at next higher band for possible openings.

they in sufficiently good condition to last through winter? Do they need to be custom-tailored to your specific DX operating goals? Now's the time to check.

### band-by-band summary

Ten to thirty meters will be open for the entire twenty-four hour period on most days of the month. The bands should peak in all directions just after local sunrise, and again toward the east and south during late evening hours. During darkness, the bands will peak toward the west, in a south-west-northwest arc that will encompass the Pacific area.

Forty and eighty meters will be the most usable nighttime DX bands. Most areas of the world will be workable from dusk until sunrise. Hops shorten on these bands to about 2500 miles for 40 meters and to 1500 miles for 80 meters, but the number of hops can increase since signal absorption in the ionosphere's D region is low during the night. The path follows the direction of darkness across the earth, similar to the way the higher bands follow the sun. Vertical antennas over good ground systems give the lowest take-off angles for long skip on these bands during darkness.

One-sixty meters will be similar to 80 meters, providing good working conditions for enthusiastic DXers who like to work the night and early morning hours. In terms of QRN, this band will be quieter now.

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RG62A/U 96% shield mil spec 93 ohm	12'/ft
RG174/U min. 50 Ω mil spec	10'/ft
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MRF450A	12.50	28.00	MRF492	20.00	43.00
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MRF240	(S)	40W	145-175	15.00	
MRF245	(F)	80W	130-175	27.00	
MRF247	(F)	80W	130-175	27.00	
MRF492	(F)	70W	27-50	20.00	
SD1416	(F)	80W	130-175	29.50	
SD1477	(F)	125W	130-175	37.00	
SD1441	(F)	150W	130-175	83.50	
2N6081	(S)	15W	130-175	7.75	
2N6082	(S)	25W	130-175	9.75	
2N6083	(S)	30W	130-175	9.75	
2N6084	(S)	40W	130-175	12.00	
2SC1955	—	1W	130-175	15.00	
2SC2289	—	5W	130-175	20.00	
MRF641	(F)	15W	430-470	21.50	
MRF644	(F)	25W	430-470	24.50	
MRF646	(F)	45W	430-470	24.50	
MRF648	(F)	60W	430-470	33.50	

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- Add \$5 for shipping and handling (Cont. U.S.). Calif. residents add applicable sales tax.
- Specifications/price subject to change

MODEL	FREQUENCY	OUTPUT POWER	INPUT POWER	SUGG. PRICE LESS TAX
	(MHz)	(W)	(W)	\$
1410	144	160	10	225
1410G	144	160	10	265
1412	144	160	30	199
1412G	144	160	30	239
2210	220	130	10	225
2210G	220	130	10	265
2212	220	130	30	199
2212G	220	130	30	239
4410	440	100	10	225
4410G	440	100	10	265
4412	440	100	30	199
4412G	440	100	30	239

1. Models with G suffix have GaAs FET preamps. Non-G suffix units have no preamp.
2. Covers full amateur band.

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by Jim Rafferty, N6RJ

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product

# REVIEW

## Cushcraft 32-19: 19-element 2-meter Boomer

If you've been paying attention to the results of VHF/UHF antenna gain contests, you'll know that the Cushcraft Boomer has been a pretty successful design. In a few instances, Boomers have been able to walk away with top honors for each band in which they were entered.

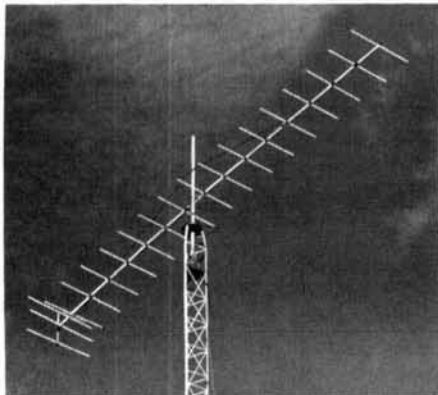
Using the latest in computer design techniques, Cushcraft engineers optimized spacing and element length to ensure maximum performance. (See **table 1.**) The Boomer also uses a T-match driven element with a 1:1 coaxial balun to provide coaxial decoupling and a low VSWR. One unique new feature on the Boomer is the Trigon three-element reflector assembly. The Trigon design enhances the front-to-back ratio and gives the antenna a sharper forward pattern.

**table 1. Cushcraft 19 element 2-meter Boomer.**

range	144-146 MHz
forward gain	16.2 dBd
front/back	24 dB
weight	12 pounds (5.44 kg)
length	22 feet (6.71 m)
turning radius	11 feet (3.5 m)
wind load	3.5 square feet (0.33 square m)

Assembling this antenna is a very easy job taking less than two hours to complete. All of the elements are measured and pre-cut for ease of assembly. Fasteners are stainless steel to eliminate the problems caused by corrosion. Since the Model 32-19 uses such a long boom (22 feet) Cushcraft has added a supporting truss to provide an extra measure of mechanical stability and to keep the antenna level. All of the aluminum used is a special heat-treated tubing that is designed to take the strongest of storms without damage and keep on performing.

As many of you know, my interest in ham radio has been, for many years, 160 meters. But using the 2-meter Boomer during this June's VHF contest was a real joy. I couldn't help comparing operation on the two different bands; as I carefully and patiently pieced together the calls of stations I worked (there was fading and other propagation anomalies) I felt that my time spent ferreting calls out of the



muck on 160 meters had been excellent preparation for two-meter contesting. It was a relief not to have to fight any thunderstorm QRN. I had a lot of fun during the contest and was able to take advantage of the excellent Aurora Sunday night, June 12. Being limited to just 10 watts hurt; plans are now underway to get at least 100 watts cooking in time for the next contest. For information, contact Cushcraft, P.O. Box 4680, Manchester, New Hampshire 03108. RS#301

N1ACH

## the Snyder antenna: model FB 75/80

The best way to describe this 80-meter broadband wire antenna is *simple*. For those who want to operate anywhere between 3.500 and 4.000 MHz without having to adjust wire lengths or a tuner, this 80-meter version of the Snyder product line is an answer.

From the moment of unpacking to final installation, less than 15 minutes is involved. (This assumes that a skyhook at 45 or more feet is available and the coaxial cable is already dressed.) At my location, a heavily wooded area of New Hampshire (for those of you who don't live here, it's *all* heavily wooded), a tree limb at 45 foot height was used as the support. However, telescoping masts, towers, tall poles can all serve that same function.

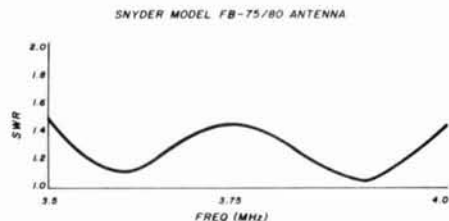
How does the antenna achieve broadband operation without tuning? It uses a patented technique that achieves this performance by combining a sealed center unit that weighs about one pound (0.45 kg) and contains no reactive elements, according to Snyder, with a middle cable assembly (that looks like a sleeve) and outer lengths of copperweld wire.

### installation

Installation proceeds smoothly if you follow the instructions. In my installation I attached the supporting rope to the convenient small bracket on the center assembly and raised it five feet off the ground. After the coaxial cable

was connected and sealed, and stress relieved (45 feet of RG-8 weighs a bit), I unfurled the middle cable assemblies and payed them out. I attached ropes to the six-inch long end insulators and raised the antenna to its final height while securing the copperweld ends, which I left for last. (Those of us who have worked with copperweld — haven't we all? — can appreciate the small additional amount of time and care required in handling this spring wire. *Unwind only the section of cable that you're working with.*)

The FB 75/80 makes an attractive, sturdy installation as an inverted vee. It can be secured in other configurations as a horizontal dipole, sloping dipole, or as an element in an array. It is highly recommended that if used as a horizontal dipole a center support be provided to bear the weight of the feedline and center insulator.



### performance

This antenna has an SWR curve that has the shape of the letter W (see **fig. 1**). Feeding a small amount of power into this antenna at every 25 kHz from 3.5 to 4.0 MHz and using a Bird thru-line wattmeter basically confirmed the manufacturer's specifications. This antenna "wants" to be in the clear away from all large conducting and dielectric objects or obstructions to provide best performance.

On the air comparisons between this antenna in an inverted-vee configuration and a 50-foot apex high sloping delta loop revealed the expected results. Using a rapid switching arrangement it compared favorably (same report) with the Delta loop antenna for most U.S. contacts. The sloping delta loop has the edge for Europe and longer paths. In all fairness it must be mentioned that the sloping delta loop performs as well as my full size 80-meter Bobtail curtain in its favored directions.

### conclusion

The Snyder Antenna Company has accomplished its goal in providing Amateurs with a non-tune broadband basic antenna. It is a pleasure to install and operate with any transceiver and especially complements any of the modern "instantaneous" frequency change solid-state units. In addition to base station use, it is well suited for portable operation be it emergency, field day, or DXpedition. For information about Snyder products, contact the company at 250 East 17th Street, Costa Mesa, California 92627. RS#303

K2RR

# 10GHz GUNNPLEXER transceiver

## BBC Metrawatt model MA3E multimeter

There's no doubt about it: digital readouts are definitely in vogue. So it came as some surprise when an analog multimeter appeared on my desk for review the other day.

BBC Metrawatt entered the American market fairly recently when it introduced a rather complete line of both digital and analog meters. Model MA3E represents a moderately-priced unit that offers a number of appealing features.

My first impression was that this is a very European unit, with its gracefully curved lines in a very neat and functional design. (No wonder — its unique case was designed by Porsche.) To protect the meter when not in use, the unit folds together to make a convenient, easy-to-transport package. The high-impact plastic case is built to withstand industrial use or abuse without compromise in performance.

The MA3E incorporates an electronic amplifier providing a combined total of 35 measuring ranges that include 18 for AC and DC voltages up to 1000 volts; 12 for AC and DC currents up to 10 amperes; and five resistances up to 20 megohms, including a battery check — all while providing a constant input resistance of 10 megohms.

All measuring ranges are manually selected by use of a switch located on the main frame. The viewing angle of the meter can be varied to meet the needs of the user.

The unit operates from an internal 9-volt battery or from an external power supply. Low power consumption ensures long battery life.

The test leads are recessed into the meter and specially shielded to prevent accidental shorting while plugged into the meter. The leads are also threaded to accept alligator clips and other accessories.

The MA3E measures approximately 5-3/4 x 4-1/2 x 1-3/4 inches (146 x 118 x 44 mm) and weighs less than one pound (0.45 kg), without battery.

Luckily the MA3E arrived for review while we were rebuilding WB1AHV, the ham radio Amateur station. While crawling up and down connecting power lines and antenna leads, I found the MA3E to be a real joy to use. The adjustable meter made reading voltages or determining continuity a snap. Being a bit ham-fisted, I accidentally knocked the meter off the operating table, but the rugged case wasn't damaged at all, to my relief.

This is a useful meter that, at under \$200, should find wide acceptance in both Amateur Radio and industrial applications.

Detailed information on the MA3E and other models in the product line are available from BBC-Metrawatt, 6901 West 117th Avenue, Broomfield, Colorado 80020. RS#302

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by Bill Pasternak, WA6ITF

Comprehensive handbook covers just about every facet of FM operation in a simple, easy to understand manner. 45 chapters put all kinds of FM and Repeater topics within easy reach. You get a solid background in FM theory, control devices for repeaters, how to build a repeater, ATV and RTTY application ideas and more. This huge, fact-filled repeater book is a must for anyone interested in FM communication. ©1980. 536 pages, 1st edition.

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## TIDBITS

### MORSE CODE, BREAKING THE BARRIER

by Phil Anderson, WØXI

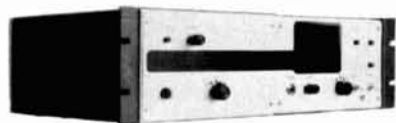
Learning the Morse Code does not have to be the painful experience many folks make it out to be. This little booklet is chockfull of helpful and highly recommended hints and tips on how to learn the Morse Code. Uses the high/low method to eliminate the dreaded 10 wpm plateau. ©1982, 1st edition.

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**RTTY/CW terminal**

The new Flesher Corp. TU-470 RTTY/CW terminal unit receives up to 300 baud on all three shifts and provides TTL and RS-232 compatible I/O, including bi-polar CW and PTT outputs, for complete remote control and isolation of computer level I/O keying.

Each TU-470 RTTY filter board is a high-sensitivity, high Q, 3 stage, 6 pole active bandpass filter said to provide excellent stability and sharpness. A signal balance restorer circuit has been incorporated to allow reception of non-standard RTTY shifts on mark only. The CW filter/demodulator has a 3 stage, 6 pole filter centered at 750 Hz for CW reception.

The unit also provides crystal controlled AFSK, FSK, 170 Hz narrow preselector filter, built-in 20 or 60 mA loop supply, autostart, threshold control, 5 LED indicators, bar graph tuning, scope outputs, reverse receive, reverse transmit, and much more.



The TU-470 RTTY/CW terminal unit is available wired and tested for \$499.95.

For more information, contact Flesher Corporation, P.O. Box 976, Topeka, Kansas 66601. RS#304

**lightning protector**

The new IS-RCT from PolyPhaser relies on fast 50 nanosecond three-element crowbar gas tubes to provide effective protection from lightning for the hamshack rotor control box.

Designed to be mounted on a ground pipe or grounded tower leg, with terminals down to keep snow and rain off connectors, the unit is housed in a heavy duty stabilized plastic case. All grounding hardware is stainless steel.

**WARNING**

**SAVE YOUR LIFE OR AN INJURY**

Base plates, flat roof mounts, hinged bases, hinged sections, etc., are not intended to support the weight of a single man. Accidents have occurred because individuals assume situations are safe when they are not.

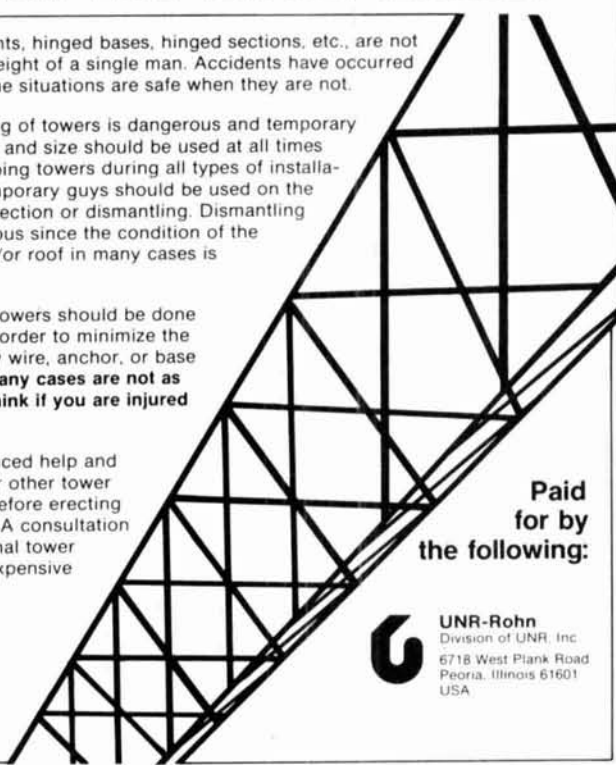
Installation and dismantling of towers is dangerous and temporary guys of sufficient strength and size should be used at all times when individuals are climbing towers during all types of installations or dismantlings. Temporary guys should be used on the first 10' or tower during erection or dismantling. Dismantling can even be more dangerous since the condition of the tower, guys, anchors, and/or roof in many cases is unknown.

The dismantling of some towers should be done with the use of a crane in order to minimize the possibility of member, guy wire, anchor, or base failures. **Used towers in many cases are not as inexpensive as you may think if you are injured or killed.**

Get professional, experienced help and read your Rohn catalog or other tower manufacturers' catalogs before erecting or dismantling any tower. A consultation with your local, professional tower erector would be very inexpensive insurance.

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For information, contact PolyPhaser Corporation, 1500 West Wind Boulevard, Kissimmee, Florida 32741. RS#305

## keyer trainer

The AEA Basic Trainer Model KT-3 is a computerized Morse code instructor. Character speeds are given at 20 WPM with a three-second interval between letters or letter groups. This method of learning helps eliminate the plateau so many Morse code students encounter between 10 and 12 WPM. This system does not encourage the student to learn a "dot-dot-dash-dot" for F, but rather one cohesive sound of dididahdit (at the character speed of 20 WPM). As a result, the student does not have to unlearn bad habits such as counting dots and dashes in order to copy code.

Because the sound of any given letter does not change from 0 to 20 WPM, it is easier for the student to increase copying speed if he or she has learned code at a rate of 20 WPM. To facilitate this learning technique, the minimum programmable speed on the Basic Trainer is 18 WPM character speed. After learning the code, the user can progress up to 99 WPM with the KT-3. Each character is taught separately by repetition. The student progresses only after he is confident he knows the letters being presented by the KT-3.

After the first letter (F, in this case) is learned, a student may progress to the letter K. After learning K, the student activates the computer to present the letters F and K in random sequence at a 20 WPM character speed. This technique continues as the student learns each subsequent letter in the alphabet.

Easy to operate, the KT-3 requires no computer programming skills. An earphone monitor jack is provided for private practice sessions. The KT-3 operates from 12 Vdc (or 117 Vac with optional AC-1 Wall Adaptor).

For details, contact Advanced Electronic Applications, Inc., 2006-196th St. SW, Lynnwood, Washington 98036-0918. RS#306

## six-band high-frequency vertical

Hustler has announced the availability of its new 6-BTV six-band trap vertical for the high-frequency ham bands.

Based on the popular 4-BTV, the new 6-BTV offers full band coverage of 10, 15, 20, 30, and 40 meters with a VSWR of under 1.6:1 at band edges and up to 100 kHz on 75 or 80 meters.

According to the manufacturer, fiberglass reinforced high Q traps, extra-strength aluminum components, and stainless steel hardware combine to make the new 6-BTV the most rugged, high performance, high-frequency vertical available.

The 6-BTV lists for \$199.95. For additional information, contact Hustler, Inc., 3275 North B Avenue, Kissimmee, Florida 32741. RS#307

## fm dual band

Trio-Kenwood has announced the release of a compact new combination 2-meter and 70-centimeter FM radio, model TW-4000A. Among its features are a large, easy-to-read LCD display, ten channels of memory with offset recall, lithium battery memory back-up, dual digital VFO's, priority watch, common channel, programmable memory scan, band scan, and a full 25 watts of rf output on each band.

An optional accessory available for use with the TW-4000A is the VS-1 voice synthesizer unit that announces the operating frequency,



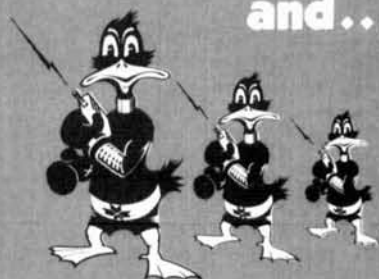
VFO "A" or "B", repeater offset, and the memory channel number when the unit is turned "ON", when another frequency is selected, or when a memory is recalled. The VS-1 is designed to be easily installed inside the TW-4000A.

Additional information is available from Trio-Kenwood Communications, 1111 West Walnut Street, Compton, California 90220.

## AMTOR terminal

The ARQ1000 is a full send-receive terminal for the AMTOR ARQ code. All features of the CCIR 476-2 Recommendation are supported. Modes include: ARQ, FEC, SEL-FEC, and MONITOR. The ARQ1000 may be used with the HAL DS3100 and ST6000, CT2200, CT2100, or CRW6850 terminals or any ASCII or Baudot terminal at baud rates from 45 to 300 baud. Non-volatile keyboard-programmable

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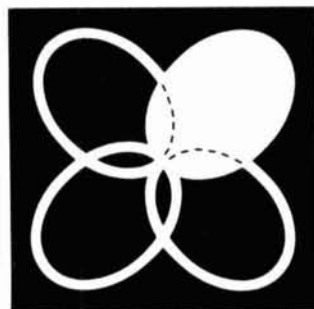
Make this the year where you hear and are heard! The sun spot number is dropping fast and there is still time to install your new INSTANTARRAY™ system before the temperature dives. Order now and "own" your frequency during the fall CQ WW tests. Run JA's on 80 in the late afternoons this December and join them for breakfast the next AM. Achieving the 80 & 40 portions of the 5BWAZ & DXCC awards should be fun, not a chore!

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ARQ access code, SEL-CAL code, and WRU answer-back codes are included. The ARQ1000 is housed in a cabinet that matches the CT2200 and CT2100. Available options include the DM170 internal demodulator and ARQX10 encryptions module.



For more information, contact HAL Communications Corporation, P.O. Box 365, Urbana, Illinois 61801. RS#311

### single chip code-practice processor

The world's first single chip code-practice processor, the CPP1, is a true 8-bit microcomputer containing all the tables and timing necessary to learn Morse code. By adding a simple dot clock and tone generator to this processor, it is possible to practice Morse code at rates from 1 WPM to over 100 WPM.

The CPP1 is said to eliminate the frustrations of trying to learn code by tape, and promises to put an end to searching for a particular practice group, stopping and rewinding, and having to learn at whatever speeds the tape offers.

For further information, contact Micro Digital Technology, P.O. Box 1139, Mesa, Arizona 85201. RS#309

### base station transceiver

ICOM has announced the introduction of a new base station transceiver for 2 meters, the IC-271A. Covering the entire 2 meter ham band, it features fm/upper sideband/lower sideband and CW modes, has a 25 watt output standard, with an optional built-in power sup-

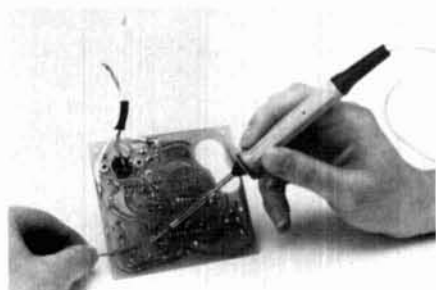


ply available. It has 32 full function memories. Built-in sub-audible tones selectable from the main tuning dial provide ease of operation. Frequencies, modes, tones and offset may be written into each memory. Scanning is possible with the IC-271A; either the whole band, memories or selected modes may be scanned. The IC-271A features ICOM's new high contrast, two-color display, showing frequency digits in white and control functions in red.

For further information, contact ICOM America, Inc., 2112-116th Ave., NE, Bellevue, Washington 98004. RS#310

### miniature soldering iron

An industrial grade precision miniature soldering iron that heats up quickly, has a non-



melt handle and is suited for students, hobbyists, and professionals is available from M.M. Newman Corporation.

The Antex Model G Soldering Iron features a wide range of slide-on tips. Designed for delicate circuitry, the tips are directly grounded and heat up in only 45 seconds. Compact and fully portable, the Antex Model G Soldering Iron weighs only 3/4 ounce without cord. Built for continuous or intermittent use, the tip slides directly over the heating element and heats up to 700-750 degrees F. Complete with a premium grade pretinned 3/32 inch tip, the Model G sells for \$15.95.

For more information, contact M.M. Newman Corporation, 7 Hawkes Street, P.O. Box 615A, Marblehead, Massachusetts 01945. RS#312

### multi-outlet panel

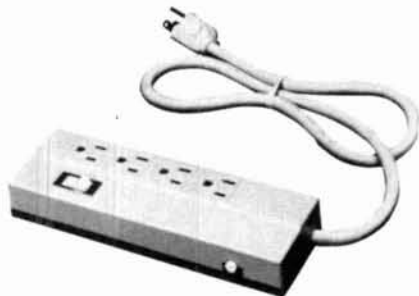
A new multi-outlet panel from Flexiduct provides four circuit-breaker-protected outlets for safe use where too few electrical outlets exist.

The new outlet-extender panel features 4 grounded outlets, an on/off switch, a circuit breaker with a push-button reset (to protect from overloads) and a double-insulated cord with a three-prong end plug. It is rated at 15 amps, 125 volts, 1875 watts and is UL listed.

Other Flexiduct safety products include 4 and 6 outlet multi-outlet strips, a plug-in surge suppressor, a multi-outlet surge suppressor,



lay-flat power extensions, over-the-floor cord cover and products for use with telephones.



Information on Flexiduct safety products is available from Winders & Geist, Inc., P.O. 83088, Lincoln, Nebraska 68501. RS#313

## two more Kulduckies

Larsen Electronics has added two new antennas to its Kulduckie line. Both the Helical Quarter Wave and the Stout are designed to work with most hand-held radios.

The Helical Quarter Wave antenna combines the best features of the helical and full quarter wave antenna. It is said to deliver better performance with a shorter, more stable antenna than a full quarter wave VHF. The Stout antenna series features a slightly larger diameter helix with a closer pitch for applications in which space is a problem. Both new antennas are available in VHF frequencies 136-142, 142-150, 150-162, and 162-174 MHz.

For more information, contact Larsen Electronics, P.O. Box 1799, Vancouver, Washington 98668. RS#314



## new dish

A satellite TV antenna made by an entirely new method of production has been announced by Total Television, Inc.

The design of the 12 foot diameter dish consists of a heavy-duty expanded aluminum mesh reflective surface supported by twenty-four injection molded ribs connected to an injection molded main support.

The material from which the dish structure is molded is a sophisticated plastic formulated to endure all kinds of weather. Products molded from the plastic material have been used for nearly twenty years to replace concrete in exterior and underground applications. The manu-

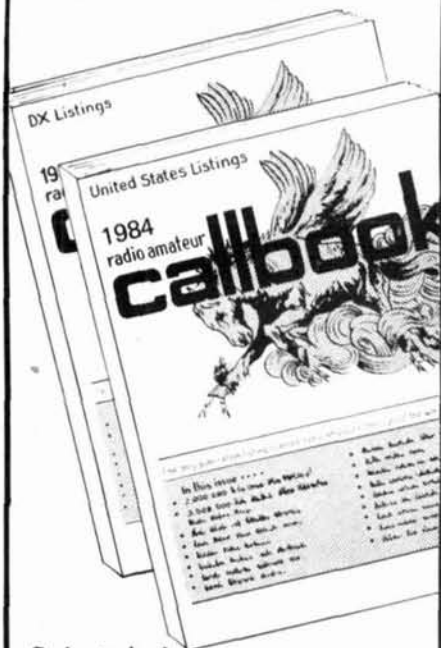
# 40 - 80 - 160 VERTICALS

Our verticals include a 1 5/8" x 5' pre-drilled galvanized mounting pipe, a base insulator, slotted sections of aluminum tubing marked for easy assembly, SS hose clamps and all SS bolts, washers, etc. The 1-40 radiator @ \$99 is self supporting and rises 33' above the insulator. The 1-80 radiator uses a unique tilt-up base insulator that allows the assembled 57' radiator weighing circa 35 lbs. to be easily erected. The 1-80 is supplied @ \$217 with two sets of low-stretch, UV resistant mylar insulating guys which attach to the radiator at two levels by SS washers nicopressed through three 6' sections of wire to the mylar to provide electrical loading. 160 kit @ \$48. #16 awg copper radial wire @ \$26/M. Prices FOB Carlisle, MA.



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manufacturer says that the material, Structuralite,™ will be unaffected by temperatures ranging from minus 55 degrees to plus 255 degrees F. grees F.

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For further information, contact Total Television, Inc., 17537 N. Umpqua Highway, Roseburg, Oregon 97470. RS#315

### dipole

The new KT5B multi-band dipole antenna from Kilo-Tec is designed for use on the 1.8 MHz through 30 MHz amateur radio bands. It uses no loading coils or traps and will handle 2 kW PEP. The price is \$59.95.

For further information, contact Kilo-Tec, P.O. Box 1001, Oak View, California 93022. RS#316



## plate frames

License plate frames personalized with individual call signs are now available from BHC, Incorporated. Molded from black ABS plastic — the same material used for trim on many new cars, a set of HAM-TAGS consists of two



black frames with white, permanent vinyl letters in the large imprint area. (License plates differ from state to state so drivers would have to check their plates to see if their calls would go at the top or bottom of the frame.) In states that issue only one plate, BHC will furnish a frame for the rear and a plate for the front. HAM-TAGS are \$12.95 per set plus \$1.50 shipping; information is available from BHC, Incorporated, 1716 Woodhead, Houston, Texas 77019. RS#317

## scaleable ac voltmeter

The Slimline II ac voltmeter from Nationwide Electronic Systems, Inc., (NES), scales ac voltage input signal to any desired unit, mounts quickly, and features a large (0.9 inch) LED display which can be easily scaled to read out directly in engineering units. The Slimline will accept the output from a voltage transformer, ac tach generator, or any device with an ac voltage output.

Examples of use include scaling 34.52 Vac from a potential transformer to read directly as 1.726 kV; 0.825 Vac from a current-to-voltage transformer to read directly as 165 ac amps; and 43.5 Vac from ac tach generator to read directly as 783 rpm.

All adjustments and controls for this meter are accessible under the flip-up door located beneath the display. Models are available for ranges from 0 to 200 Vac.

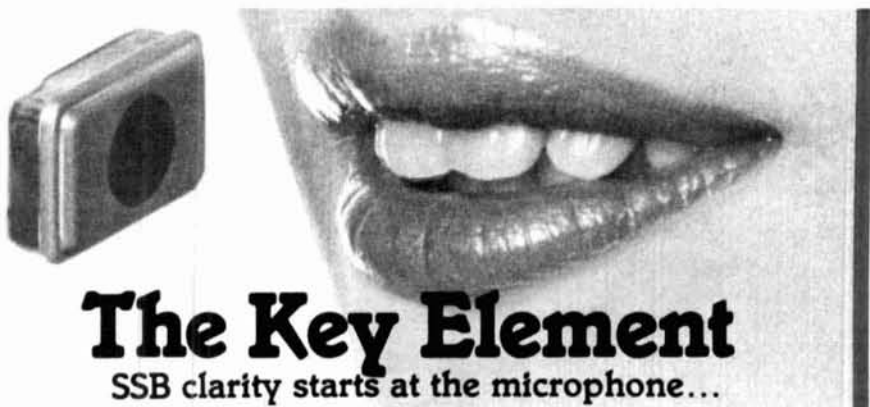
Also available from NES are scaleable dc voltmeters, scaleable ammeters, clocks, counters, process meters, and the unique ASCII Bustle® (BCD/ASCII converter). All NES products are backed by a solid 3-year warranty.

For more information or a copy of the NES Condensed Catalog, contact NES, Inc., 1536 Brandy Parkway, Streamwood, Illinois 60103. RS#318

## field-strength element

An extremely sensitive relative field-strength element, Model 4030, expands the usefulness of the thousands of Thru-line wattmeters in the field by helping to optimize the radiated signal of any transmitter from 2 to 1000 MHz.

Model 4030 employs modern broad-band circuitry instead of the highly reactive resonant networks of most field-strength meters, which



# The Key Element

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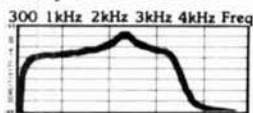
Heil Sound, the company that pioneered proper audio equalization techniques for major performing groups and communicators, invites you to be part of one of the biggest advancements in Single Sideband transmission since the 'Donald Duck' vs. AM days.

If you are not satisfied with the "sound of your station"—it's no wonder—most "communications" microphones used today were designed for "public address" use, not for sophisticated SSB techniques.

No one microphone can be all things to all Hams, so this new HC-3 element and HM-5 mic were developed only for maximum clarity on SSB transmissions.

The response of this tiny ceramic element rolls off sharply under 350 Hz and above 3100 Hz with a peak at 2400 Hz for high articulation in the speech range.

Hams who care about maximum results in getting over, around and through DX pile-ups now have another weapon in their arsenal... The Key Element!



You can easily install this small, advanced HC-3 element, with its broad-range impedance-matching characteristics, into virtually any microphone case you own, or purchase the custom HM-5 mic with HC-3 installed.

"...Have not yet heard an FT-101 sound any better than when used with The Key Element..." —Paul, G3AWP

"...I now have a comfortable feeling that my audio is better than the rig was originally capable of..." —Ken, W9UBS

"...Thank you for the fine report, All reports to date have been excellent..." —Lee, W1SE

For those who desire the ultimate audio into and out of your transmitter/transceiver, consider the ideal combination of the Heil EQ-200 audio equalizer and HM-5 microphone.



For more information, or to order the HC-3 cartridge element at \$19.95 the HM-5 SSB microphone at \$54.95, or the EQ-200P at \$59.95, contact Heil Ltd., Marissa, IL 62257. 618-295-3000.



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149

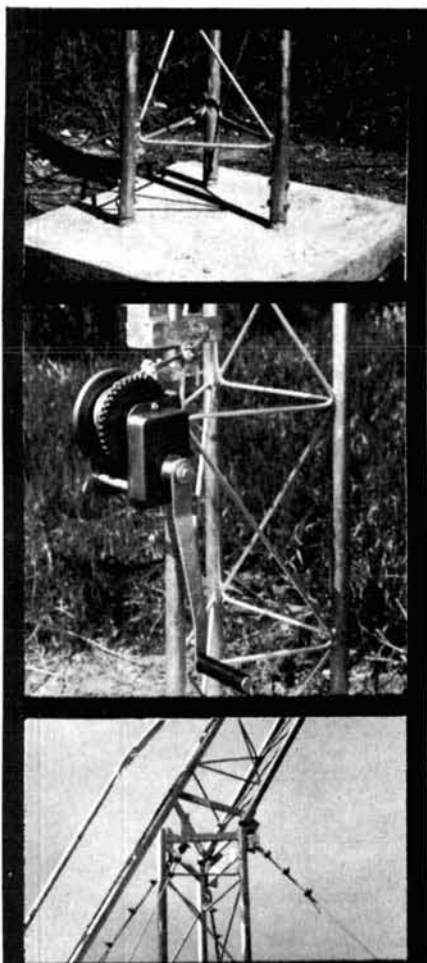
limit their utility. The element consists of a flexible receiving antenna, a single high-pass network and a variable gain rf amplifier/detector. A battery-saving feature turns everything off when the element is removed from the wattmeter. Typically full scale deflection is obtained from a one watt CW source at 150 MHz through a quarter wave antenna 8 feet distant. Dynamic range is at least 30 dB and battery life is 100 hours or more.

For more information, contact Bird Electronic Corporation, 30303 Aurora Road, Cleveland (Solon), Ohio 44139. RS#319

## "affordable" repeaters

A new line of repeaters in several frequency ranges is available from International Telecommunications Systems Florida Inc. Ranges include 30-50 MHz, 132-174 MHz, 200-240 MHz, 380-480 MHz, or any band combination. The power output is 30 watts; the unit operates from 13.6 VDC or 115/220 Vac and costs \$499.

For further information, contact International Telecommunications Systems Florida Inc., 8416 N.W. 61st Street, Miami, Florida 33166. RS#320



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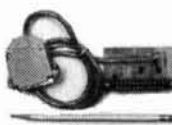
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## handheld DMM

Keithley Instruments, Inc., has introduced the Model 132 Handheld DMM as their top of the line 3-1/2 digit meter. The unit combines the field service capabilities of Keithley Handheld DMM's with the two most often required additional measurement capabilities, TRMS ac and temperature.



The 132 features unique characteristics: according to Keithley, it is the only handheld DMM which incorporates TRMS and TEMP; carries the lowest price of any handheld TRMS DMM available; and is the only one with an integral TC connector and full probe selection.

Available in both a degree F version (132F) and a degree C version (132C), the 132 has a complete dc voltage range from 200 mV to 1000V with 0.25 percent accuracy, current ranges from 2 mA to 2 A and resistance ranges from 200 ohms to 20 megohms. The 132C measures temperature from -20 degrees to 1370 degrees C, the 132F from 0 degrees F to 2000 degrees F using optional type K thermocouple sensors or probes.

For complete information, contact Keithley Instruments, Inc., 28775 Aurora Road, Cleveland, Ohio 44139. RS#321

## fm transceivers

Amateur-Wholesale Electronics has announced the new PCS-4000 series of FM transceivers. The familiar PCS-4000 covers the 2-meter band plus adjacent CAP and MARS frequencies, from 142 to 149.995 MHz, with 25 watts output. Three new units are now available for 10 meters, 6 meters, and 70 centime-

ters. The PCS-4800 covers 28 to 29.99 MHz in steps of 10 or 20 kHz. The PCS-4500 covers 50 to 53.995 MHz in steps of 5 or 10 kHz. The PCS-4300 covers 440 to 449.995 MHz in steps of 5 or 25 kHz. A 220-MHz unit will soon be available.

The new PCS-4800, PCS-4500, and PCS-4300 employ the same advanced microcomputer chip found in the PCS-4000, providing the versatility and ease of operation found in the 2-meter Azden transceiver. Standard repeater splits, 16 memory channels in two separate banks, up to eight odd splits, dual memory scan, dual programmable band scan, free and vacant scanning modes, and frequency reverse are but some of the features. Each unit has 10 watts or 2 watt selectable output, discriminator scan centering, a digital S/RF meter, busy-channel and transmit LED indicators, and a full 16-key autopatch pad (except for the PCS-4800).

All units come with dynamic remote-function microphone, built-in speaker, mobile mounting bracket, remote speaker jack, and all hardware. The size is 2 inches high by 5-1/2 inches wide by 6-3/4 inches deep. The bright green LED frequency display and illuminated keyboard provide visibility under a variety of ambient conditions. All are designed for mobile or fixed station use.

For further information, contact Amateur-Wholesale Electronics, 8817 S.W. 129 Terrace, Miami, Florida 33176. RS#322

### SSTV/RTTY/CW/FAX tuner

The new "Blinky" Model 959 is a SSTV tuning unit consisting of an op-amp limiter amplifier and six active precision tuned, temperature stable bandpass filters, providing a visual blinking LED indication when a received SSTV, RTTY, FAX, or CW signal is perfectly tuned. The

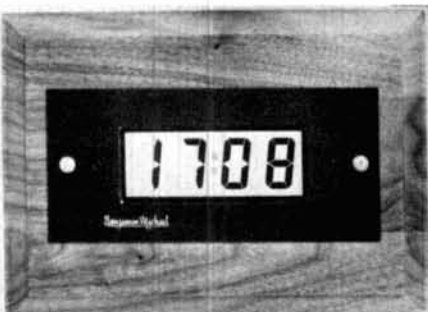


user simply tunes until all six LED's are blinking at the same time and the SSTV is tuned. For RTTY, FAX, or CW, the user tunes until the first two LED's are blinking (low tones) or the last two LED's (high tone).

"Blinky" Model 959 is made in the United States and sells for \$99.95. For more information, contact TimeKit, P.O. Box 22277, Cleveland, Ohio 44122. RS#324

### digital military time clock

The Model 193A Digital Military Time Format Wall Clock from Benjamin Michael Industries, Inc., features a 1-inch digital display for excel-



lent visibility. It also features quartz accuracy, total immunity to power line failures and disturbances, and all solid-state construction. The clock will operate for well over one year on a single AA battery.

Housed in a hand-made solid walnut case, the model 193A is priced at \$129.95 plus \$3.00 shipping. For more information, contact Benjamin Michael Industries, Inc., 65 East Palatine Road, Prospect Heights, Illinois 60070. RS#323

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**WANTED:** 4-124A, 4D21, 2E26, 6146A tubes, GE 4EP4A3 P/S. W4BUZ, 1703 Verdun Drive, Rt. 11, Greensboro, NC 27410.

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**FOR SALE:** Swap 240, 3 band transceiver. AC and DC supply \$225.00. WA0CKH. R.L. Thompson, 817 Colorado S.W., Huron, SD 57350.

**VLF-LF** preamps, coupler, Loran-C boards. SASE. Burhans Electronics, 161 Grosvenor St., Athens, Ohio 45701.

**SPARK KEYS** wanted for my collection. Also large or unusual radiotelegraph keys, sideswipers, military/spy keys, foreign keys and pre-1950 bugs. K5RW, 1128 Midway, Richardson, TX 75081.

**WANTED:** Kenwood TS-700SP transceiver and MARS-7600 adapter. C.T. Huth, 146 Schonhardt, Tiffin, OH 44883.

**WANTED:** Manuals all precision noise figure indicator 74a, also noise generators 7006, 7010 and 7052. Original or photocopy. Offer to H. Troess, Ostertalstr. 33, D 6680 Neunkirchen, West Germany.

**PRE-1946 TELEVISION SETS** wanted for substantial cash. Finder's fee paid for leads. Also interested in spinning disc, mirror in-the-lid, early color sets, 9AP4 picture tubes. Arnold Chase, 9 Rushleigh Road, West Hartford, Conn. 06117. (203) 521-5280.

**TAPETONE** 6 meter converter with power supply Model XC-50 \$60. Lewis F. Good, 25 Harris Ave., Wellesley, Mass. 02181.

**MUSEUM** now open for radio historians and collectors. Free admission. Old time Amateur (WZAN) and commercial station exhibits, 1925 replica store and telegraph displays. 15,000 items. Write A.W.A. for details: Bruce Kelley, W2ICE, Holcomb, NY 14469.

**COLLECTOR PAYING** cash for Gonset equipment, catalogs, manuals, etc. — unmodified only. State condition and price. F.T. Marcellino, 13806 Parkland Dr., Rockville, MD 20853.

**MOBILE IGNITION SHIELDING.** Estes Engineering, 930 Marine Dr., Port Angeles, WA 98362.

**SELL RCA 7094** tubes, new, your price, make offer. Jim, W4IW, 5012 Perrine Drive, Jacksonville, FL 32210. Tel. (904) 771-3462.

**CABLE CONVERTERS, decoders.** Catalog \$1 refundable. APS, POB 263 HR, Newport, RI 02840.

**TRADE H.P. 208-B** oscilloscope for set of machinist tools from retired machinist or toolmaker. Also have KW Custom built 4-400-A Linear amplifier with vacuum variables, three meters, rack mounted 19" panel, built by Sperry Rand engineer. Like Swiss watch quality. Sell my collection of thirty years receiving tubes, boxed, dollar each. Send me your list of needs for availability and quantities required. W5QJT, P.O. Box 13151, El Paso, TX 79913. Tel. (915) 581-2017.

**IBM-PC RTTY & ASCII.** SASE for full details. E. Alline, NE5S, 773 Rosa, Metairie, LA 70005.

**BUY-SELL-TRADE** Twice monthly publication. SASE for free issue. The Ham Boneyard, 364 Kilpatrick Ave., Port St. Lucie, FL 33452.

**RTTY-EXCLUSIVELY** for the Amateur Teleprinter. One year \$7.00. Beginners RTTY Handbook \$8.00 includes journal index. P.O. Box RY, Cardiff, CA 92007.

**SATELLITE TELEVISION SYSTEM.** Order the 2-year warranted Dexcel/Gould 1100-01 receiver/L.N.C. with precision 9' spun aluminum antenna and ball-bearing polar mount at our call-for-current lowest price (approximately \$1598.00) and we'll complete the system with a Chaparral Polarotor/Control, hook-up assembly, 125' line and installation instructions and assistance. Videosat, Inc., (602) 445-0383, Box 449, Prescott, Arizona 86302.

**HAM HOLIDAY** Sri Lanka. Write to Spangles Travels, 84

Templers Road, Mount Lavinia, Sri Lanka. Enclose 5 IRCs.

**RECEIVERS.** National NC-300 \$95; Hammerlund HQ 100A \$85; Lafayette HR-600 \$35; Knight Star Romer \$30; Hallicrafters HT-18 TX \$25. K6KZT, 2255 Alexander, Los Osos, CA 93402.

**APPLE COMPUTER OWNERS** — Announcing "The Logger" — A very sophisticated, full-featured disk-based log book for ham radio operators. "The Logger" manages over 1900 log entries per standard DOS 3.3 diskette with sixteen separate functions including personalized QSL cards for less than 2 cents each! Unlocked program diskette and User's Guide \$35. pd. U. S. Large SASE for more information. Bob Jackson, Dept. HR, Box 57304, Webster, TX 77598.

**FULL FEATURED,** all speed Baudot and ASCII for your IBM-PC. SASE to: Emile Alline, 773 Rosa, Metairie, LA 70005.

**RS303/U AND FERRITE BEADS** for W2DU's balun (QST March '83) HF \$8, VHF \$6 ppd. Copperweld™ 30% - 18 ga 3c, 14 ga 6c. All Amateur wire and cable (Belden & generic); Larsen, Unadilla, Janel, custom QSL's, crystals. All from Certified Communications. "the CB to 10 meter people", 4138 S. Ferris, Fremont, MI 49412.

**TRADE** Hewlett Packard Oscilloscope Model 120-B for set of machinist tools from retired toolmaker or machinist. Sell collection of 30 years receiving tubes at only a dollar each. Send list of your needs for availability and quantities. W5QJT, P.O. Box 13151, El Paso, TX 79913.

**HALLICRAFTERS \$\$\$** Serious collector needs Hallicrafters and other Ham equipment manufactured before 1940 for restoration and eventual museum exhibit. Need Hallicrafters, National, Hammarlund, Patterson, RCA, RME, Grebe, etc. Condition not important. Also need QST mags Vols. 1 & II and old tubes. All letters answered. Write Dave Medley, WA5YXA, 6621 Duffield Drive, Dallas, Texas 75248.

**LCR BRIDGE** wanted. Prefer one that reads capacitance and inductance reactance in ohms, 0 to 1000 ohms, thru 150 MHz. What have you? W5LCB, Box 54415, Oklahoma City, Okla. 73154.

**WANTED:** Schematics-Rider, Sams or other early publications. Scaramella, P.O. Box 1, Woonsocket, RI 02895-0001.

**SURPLUS ITEMS FOR SALE.** Specific Products standard time and frequency receiver, Model WYYC. Used only 1 yr. Excellent condx. This has a built-in scope. \$385. Lewis F. Good, 25 Harris Ave., Wellesley, Mass. 02181.

**WANTED:** Cash paid for used Speed Radar equipment. Write or call: Brian R. Esterman, P.O. Box 8141, Northfield, Illinois 60093. (312) 251-8901.

**WANTED:** Old RCA, Western Electric tubes. (713) 728-4343. Maury Corb, 11122 Atwell, Houston, Texas 77096.

**WANTED:** Early Hallicrafter "Skyriders" and "Super Skyriders" with silver panels, also "Skyrider Commercial", early transmitters such as HT-1, HT-2, HT-B, and other Hallicrafter gear, parts, accessories, manuals. Chuck Dachs, WD5EOG, The Hallicrafter Collector, 4500 Russell Drive, Austin, Texas 78745.

**COLLINS KW-1** parts wanted. Chuck, Box 766, Dahlgren, Virginia 22448.

**RUBBER STAMPS:** 3 lines \$4.50 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

**HEATH HR-1680** ham band receiver. 80-10 meters, solid-state, speaker, excellent condition. Great for backup receiver or Novice. \$145. Call Ken at 616-375-6300 work. 616-372-3116 nights or weekends. WB8IKJ.

**RADIO WEST!** High quality coverage communications receivers with Collins filters and other DX modifications! Catalog 50¢ (refundable). Radio West, 3417 Purer Rd., Dept. HR, Escondido, CA 92025. (619) 741-2891.

**ATARI OWNERS** — Amateur Radio software. Dupesheet program with fast machine language search and storage routines, easy to understand manual. Prints, lists, saves and retrieves call signs. 16K tape (2000 calls) \$16.95, 48K disk (5000 calls) \$20.95, ppd. SASE for catalog. Richard M. Donnelly, 2309 McClendon, Houston, TX 77030.

**VERY in-ter-est-ing!** Next 4 issues \$2. Ham Trader "Yellow Sheets", POB356, Wheaton, IL 60189.

**WANTED, MILITARY SURPLUS RADIOS.** We need Collins 618T, ARC-94, ARC-102, 718F-1/2, MRC-95, MRC-108, RT-980/GRC-171, RT-712/ARC-105, RT-804A/APN-171, ARC-114, ARC-115, RT-823/ARC-131 or FM-622, RT-857/ARC-134 or Wilcox 807A, ARC-159, ARC-164, RT-858/APX-72, APN-153, ANTENNA COUPLERS 490T, CU-1658A,



CU1239/ARC-105, CU-1669A, ARC-105, Sperry Rand 3226A1, 3226B1, 690D1, 490B-1. Top dollar paid or trade for new Amateur gear. Write or phone Bill Slep, 704-524-7519, Slep Electronics Company, Hwy. 441, Otto, NC 28763.

**SUPER CQWW CONTEST** programs. TRS-80 Model I, III, (IV in III mode) Completely machine language. Logs 3200+ contacts per band. Automatic identification of country and zone from call letters. Dupe Speed 12000+ contacts per second. Screen displays zones still needed, total points, zones, countries, etc. Automatic cw generator with 2 buffers. Log Print program prepares logs and dupe sheets. \$39.95 Log Preparation program for hand logs. Similar features to above. \$29.95 Free fact sheet and sample printouts. K4SB, 3496 Velma Dr., Powder Springs, Georgia 30073.

## Coming Events ACTIVITIES "Places to go..."

**CONNECTICUT:** The Tri-City ARC Auction, St. James Parish Hall, Poquetanuck, October 29. Setup 9 AM, auction 10 AM until sold out. Admission free. Food available. Talk in on 146.73, 67 or 94 repeaters. For information call WA2RYV (203) 848-9670.

**GEORGIA:** The Alford Memorial Radio Club's 11th annual Hamvention, November 5 and 6, Stone Mountain Park, Stone Mountain. 9 AM to 5 PM Saturday and 9 AM to 3 PM Sunday. FCC exams, seminars, dealers, gigantic flea market, free parking. \$3.00 admission fee includes Saturday night family cookout and variety entertainment. Camping and other amusements at the park. Talk in on 146.16/146.76. For further details: SASE to Lew Howard, W4LHH, 4132 Creek Stone Court, Stone Mountain, GA 30083 or (404) 292-5469.

**INDIANA:** The Allen County Amateur Radio Technical Society will hold their 11th Fort Wayne Hamfest, Allen County Memorial Coliseum, November 13. OSCAR, FSTV/SSTV, Audio and computer forums. Tickets \$2.50 advance (SASE). \$3.00 at door. Children under 12 free. Parking \$1.00. Deadline for advance tickets November 1. Tables \$6.00. Premium tables \$20.00. Talk in .88 and .52. For information: Hamfest Chairman, AC-ARTS, Inc., P.O. Box 10342, Fort Wayne, IN 46851.

**INDIANA:** The Hoosier Hills Ham Club's 22nd annual Hamfest, Sunday, October 9, Lawrence County 4-H Fairgrounds, U.S. 50, Bedford. Admission \$3.00; swap shop \$2.50 with own tables. Gates open 10 AM Saturday, October 8, for flea market setup and campers. Free fish fry, campfire, entertainment, coffee, Saturday night. Talk in on 146.13-73 on 3910 kHz. For information: KA9JTZ, Dick Reistter, Hoosier Hills Ham Club, Box 891, Bedford, Indiana 47421.

**LOUISIANA:** The Twin City Ham Club's Hamfest, Saturday, November 12, West Monroe Convention Center, 8 AM to 5 PM. Dealers — Swap Tables — Fellowship. Talk in 25-85 and 52-52. For information: AE5V, Benson Scott, 107 Contempo, West Monroe, LA 71291.

**LOUISIANA:** Amacom '83, the New Orleans Hamfest-Computerfest, October 15 and 16, Delgado Community College's City Park campus. Sponsored by the Jefferson ARC, Greater New Orleans ARC, the Delta DX Association and the New Orleans VHF Club. Demonstrations, speakers, awards, flea market and commercial exhibits. FCC exams. Admission \$5 advance (incl. two tickets) or \$5 at door (no tickets). Talk in on Jefferson ARC's repeater W5GAD/R on 147.285/885 or 449.0/444.0. For details and reservations: Amacom '83, P.O. Box 73665, Metairie, LA 70033 or call Bill Bushnell, WASMJM, Chairman, at (504) 887-5022. Reservations should be made before October 5.

**MARYLAND:** The Columbia Amateur Radio Association's 7th annual Hamfest, Sunday, October 23, 8 AM to 3:30 PM, Howard County Fairgrounds, 15 miles west of Baltimore. Admission \$3.00. Indoor tailgating and tables \$6.00 additional. Outdoor tailgating \$3.00 additional. Talk in on 147.735/135, 146.52/52. For reservations and information: Ed Wallace, K3EF, 9905 Carillon Drive, Ellicott City, MD 21043.

**MASSACHUSETTS:** The Framingham Amateur Radio Association's 9th annual Fall Flea Market, the largest indoor flea market in New England, Sunday, October 30. We will again be at the Framingham Civic League Building, 214 Concord Street (Route 126) in downtown Framingham. Doors open 10 AM; sellers setup 8:30 AM. Admission \$2.00. Tables \$10.00 (preregistration required). Radio equipment, computer gear, bargains galore! Talk in on 75/15 and 52 direct. For information/reservations: Ron Galka, K1YHM, 3 Driscoll Drive, Framingham, MA 01701.

**MASSACHUSETTS:** The Wellesley Amateur Radio Socie-

ty's annual Fall tailgate flea market, Wellesley High School, Rice Street, Wellesley. Starts 9 AM. Admission \$1.00 for buyers or sellers. Talk in on 147.63/03. For information: Nels Anderson, K1UR, (617) 872-5259.

**MASSACHUSETTS:** The 1983 New England DXCC Dinner, November 5, Concord Lodge of Elks, Baker Avenue, West Concord. DX talk and slide programs, auction begins at 2 PM. Afternoon session \$2.00. Cocktail hour 6 PM followed by a 7-course roast beef dinner. Banquet speaker VK0C/W. Cost for the evening \$14.95. Reservation forms will be mailed in September. Contact Jim Dionne, K1MEK, 31 DeMarco Road, Sudbury, MA 01776.

**MICHIGAN:** The Central Michigan Amateur Radio Club and Lansing Civil Defense Repeater Association will hold their annual Ham Fair, Sunday, October 9, 8 AM to 3 PM, Grand Ledge High School 7 miles west of Lansing. Swap shop, demonstrations, antennas, computers and handcrafted items. Donation \$2.50 adults. Tables 75¢/foot. For information: Rowena Eirod, KA8OBS, 111 Lancelot Place, Lansing, MI 48906, (517) 372-5462; or write Ham Fair '83, P.O. Box 18044, Lansing, MI 48901.

**MICHIGAN:** Electronic Flea Market, Sunday, October 23, Kalamazoo County Fairgrounds, 10 AM to 4 PM. Dealer setup 9:30 AM. Tickets \$2.00 advance; \$2.50 at door. 4 ft. table rental \$2.50 advance; \$3.00 at door. For table reservations and tickets SASE with check to: Ham 10 FM Club of Kazoo, Ken Coasey, KA8RUA, 2825 Lake Street, Kalamazoo, MI 49001.

**NEW ENGLAND:** The Hosstraders will hold their annual autumn swapfest, Saturday, October 8, rain or shine, Deerfield, New Hampshire, Fairgrounds. Admission \$1.00, tailgating included. Friday night camping for self-contained rigs, after 4 PM. Profits benefit Shriners' Boston Burns Hospital. Last May's donation \$2,702.00. For information/map SASE to Norm, WA1IVB, RFD Box 57, West Baldwin, ME 04091; or Joe, K1RQG, Star Rt. Box 56, Bucksport, ME 04416; or Bob, W1GWU, 105 Walton Rd., Seabrook, NH 03874.

**OHIO:** The Northwest Ohio Amateur Radio Club's 9th annual Lima Hamfest, Sunday, October 9, Allen County Fairgrounds (exit 125/126, 1 mile from I-75). Gates open 6 AM. Tickets \$3.00 advance; \$3.50 at gate. Tables \$6.00; half table \$3.50. Free camping, electrical hookup \$7.00. For information/reservations (please enclose check): N.O.A.R.C., Box 211, Lima, OH 45802. Talk in on 146.07/67, 147.63/03, 146.52/52.

**OHIO:** The Marion Amateur Radio Club will hold its 9th annual "Heart of Ohio" Ham Fiesta, Sunday, October 30, 0800 to 1600, Marion County Fairgrounds Coliseum. Tickets \$3.00 advance, \$4.00 at door. Tables \$5.00. Check in on 146.52 or 147.90/30 or 223.34/224.94. For information, tickets or tables contact: Paul Kitzer, W8GAX, 393 Pole Lane Road, Marion, Ohio 43302. (614) 389-5573.

**PENNSYLVANIA:** The R.F. Hill Amateur Radio Club's annual "Winterfest" Amateur Radio Flea Market, Sunday, November 13, Sellersville National Guard Armory, Route 152, Sellersville. Indoor space available \$4.00. Outdoor tailgating \$3.00. Buyers \$2.00. Refreshments on site and nearby. Flying hams land at Pennridge Airport, Perkasie. Talk in on 144.71/145.31 Almont. 146.28/146.88 Souder-ton and 146.52 simplex in local area. For information: P.O. Box 29, Colmar, PA.

**PENNSYLVANIA:** The Irwin Area ARA's Swap & Shop, Saturday, October 15, Circleville V.F.D., off U.S. 30, 3.5 miles west of Penn. Turnpike, exit 7. Flea market, vendors, refreshments, free parking. Talk in on 146.925/325 and 146.52 MHz. For information: Rick Jackson, N3DAA, 39-D Lower Boone Drive, Turtle Creek, PA 15145. (412) 829-1953.

**PENNSYLVANIA:** The Red Rose Repeater Association and SERCOM, Inc., will sponsor a Computerfest, Sunday, October 23, 9 AM to 4 PM, Guernsey Sales Pavilion, east of Lancaster, Rts. 30 and 896. Admission \$3.00. XYL's and children under 14 free. Featuring computers and Amateur Radio equipment. Tailgating \$2.00. Inside tables available by reservation. Talk in on 147.615/015, 146.01/61 and 146.52 simplex. For information: The Computerfest Committee, P.O. Box 5029, Lancaster, PA 17601.

**TENNESSEE:** Hamfest Chattanooga and the State ARRL Convention, October 22 and 23, Chattanooga State Technical Community College, Amnicola Highway, Chattanooga. Forums, contests and non-ham activities. College cafeteria will be serving breakfast and lunch both days. A hospitality party will be held Saturday, October 22, at the Ramada Inn. Phone (615) 894-6110 for reservations and ask for special "Hamfest Chattanooga" rates. Inside dealer and indoor/outdoor flea market spaces available. For information: Hamfest Chattanooga, P.O. Box 3377, Chattanooga, TN 37404 or phone N4DON (404) 820-2065.

**AMSAT** will hold an Amateur Radio Satellite Symposium in conjunction with its annual meeting, Saturday, November 12, Johns Hopkins University Applied Physics

Laboratory, off I-95 between Baltimore and Washington. Program includes tracking OSCAR 10, a report on the W5LFL space shuttle operation, PACSAT and more. Free admission but reservations are required. Contact: AMSAT, P.O. Box 27, Washington, DC 20044 or (301) 589-6062.

## OPERATING EVENTS "Things to do..."

**OCTOBER 1:** The Jackson (TN) Amateur Radio Club will operate special events station K4EP from the historic Casey Jones' Railroad Museum to help celebrate heritage week in Jackson. Operation will be on the lower 25 kHz of the General class phone bands on 80, 40, 20 and 15 meters. All QSL's will be answered with a unique commemorative card. Please SASE. Hams wishing to visit the home of the famous railroader use 147.21 up 600 for information and directions.

**OCTOBER 8 AND 9:** Columbus Day Special Event. Open to Radio Amateurs worldwide. Columbus hams work non-Columbus. Non-Columbus hams work as many Columbus hams as required for certificate. Saturday, October 8, 1400Z to 2400Z, 10 meters phone, 28.6 MHz ± 10 kHz. Sunday, October 9, 1400Z to 2400Z, 15 meters phone 21.4 MHz ± 10 kHz. Exchange name and RST. Score one point for each contact (excluding WBTO). Six points for a WBTO contact. A final score of ten must be submitted within 120 days to be eligible for certificate. Please include SASE. Requests for certificates: Radio Station WBTO, Special Event Coordinator, 280 East Broad St., Columbus, Ohio 43215.

**OCTOBER 8 AND 9:** The Peninsula Radio Operators Society (P.R.O.S.) will operate special event station KB3QV on the grounds of Salisbury State College, Salisbury, Maryland, to help celebrate the Delmarva Folklife Festival. 1600Z to 2100Z both days. Frequencies: 10 through 80 meters General phone bands. QSL information: SASE to P.O. Box 2315, Salisbury, MD 21801.

**OCTOBER 11, 12 AND 13:** The Colquitt County Ham Radio Society will operate club station WD4KOW from the site of the sixth annual Sunbelt Agricultural Exposition, 0900 to 1700 EDT each day. Operations will be in the General portion of the HF bands. Members will be listening for visiting hams on local repeater 146.19/79. Visiting hams are welcome to the Amateur booth at the Expo and to operate the Amateur station. For a special QSL card, please SASE to Colquitt County Ham Radio Society, P.O. Box 813, Moultrie, GA 31768.

**OCTOBER 15 AND 16:** Jamboree on the Air. 0001Z Saturday to 2400Z Sunday. The 26th annual Scouting-ham radio event sponsored by the World Scout Bureau, Geneva, Switzerland. Scouts of all ages are welcome to participate. The World Bureau station, HB9S, the BSA station, K2BSA, and many others will be operating. Exchange friendship greetings, scout talk and experiences. For certificate SASE to Boy Scouts of America, International Division/JOTA cards, 1325 Walnut Hill Lane, Irving, TX 75062-1296. A special pocket patch is available for \$1.00 each pp, any quantity. Send check/M.O. to BSA, International Division/JOTA patch, same address. Frequencies: CW — 3.590, 7.030, 14.070, 21.140, 28.190 MHz. Phone: 3.940, 7.290, 14.290, 21.360, 28.990 MHz plus Novice, RTTY and SSTV frequencies.

**OCTOBER 22 AND 23:** QRP Amateur Radio Club International Fall QSO Party. 1200 UTC Saturday, to 2400 UTC Sunday. Maximum operating time 24 hours. Exchange RS(T), state/province/country and QRP ARCI membership number. Non-members give RS(T), state/province/country and power output. Frequencies: CW — 1810, 3560, 7040, 14060, 21060, 28060, 50360 kHz. SSB — 1810, 3985, 7285, 14285, 21385, 28885, 50385 kHz. Novices and Technicians: 3710, 7110, 21110, 28110. Call CQ QRP de (call sign) CQ QRP Contest etc. Certificates awarded to highest scoring station in each state/province/country with two or more entries. All entries considered for Triple Crowns of QRP award. Send full log data plus separate worksheet showing details, time off the air. None returned. For results and scores include large SASE and one ounce of U.S. postage or IRCs. Logs must be received by November 20, 1983. Send to QRP ARCI Contest Chairman, William Dickerson, WA2JOC, 230 Mill Street, Danville, PA 17621.

**OCTOBER 28:** Suffolk County Radio Club will operate W2DQ from 0000Z, October 28 to 2400Z October 30 to celebrate Suffolk County's 300th birthday. Frequencies: Phone 15 kHz up from lower 40-15 meter General class band edges. Novice 21.135. For a special certificate send large SASE to AC2P.

**OCTOBER 30:** Navy Week Special Event Station. The Laurel, Maryland, ARC will operate K3LDE on board USF Constellation, 1200-2200 UTC. Frequencies: primary 7225, 14225 and 21400 per band cond. Request 3 first-class stamps to cover mailing tube and specially designed certificate to Box 259, Annapolis Junction, MD 20701.

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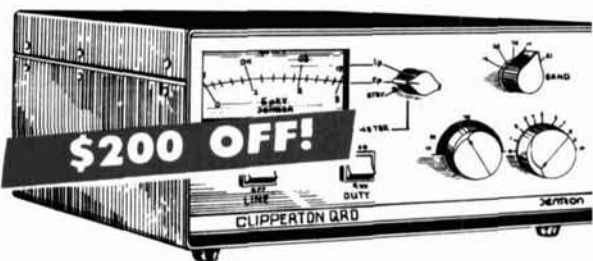
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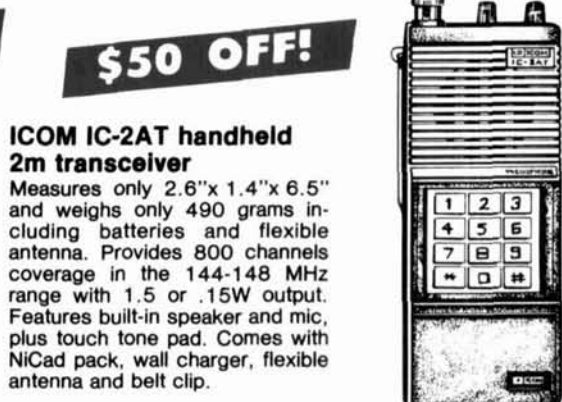
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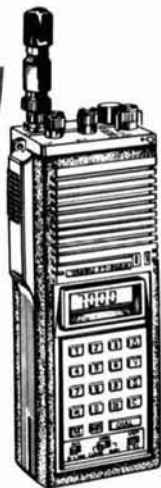
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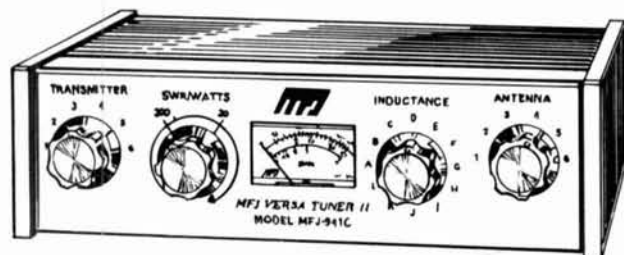
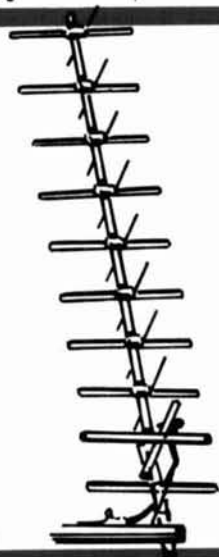


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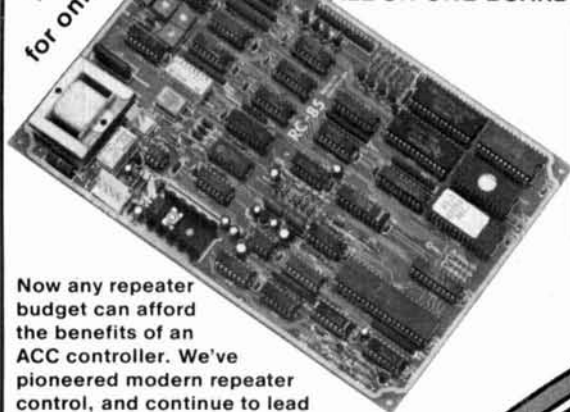
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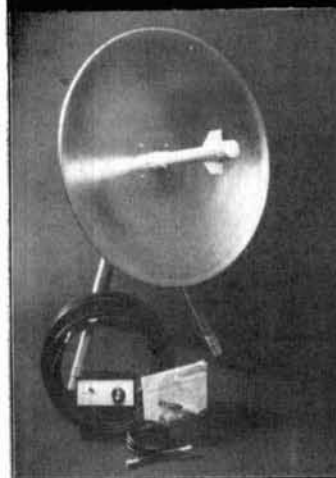
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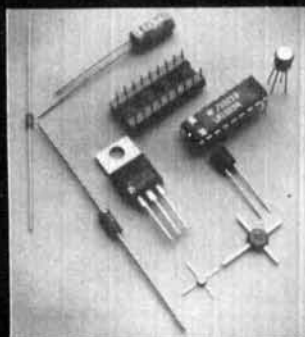
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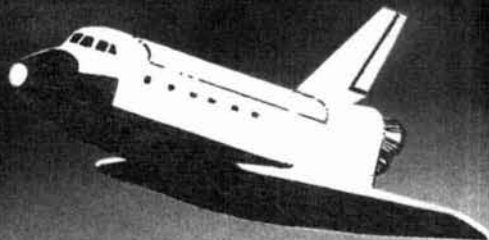
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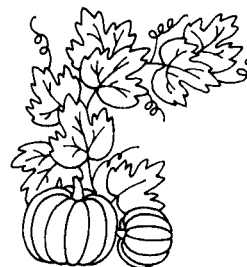
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# Introducing the **hy-gain**® **EXPLORER 14**

## Remarkably Compact, High Performance Broadband Tribander with Quad-Band Option

### New Para-Sleeve Design

The Explorer 14 is a new antenna design we call PARA-SLEEVE which uses an "open-sleeve" dipole optimized for maximum bandwidth and directivity. Here is the concept. A central dipole, driven directly by the transmission line, has a 1/2 wave resonance on the lowest operating frequency. Two shorter sleeve elements, tightly coupled to the central dipole, modify its impedance to create a 1/2 wave resonance to the highest operating frequency. This para-sleeve system is expanded by the addition of 15 meter traps and 20 meter element tips. A revolutionary new concept for HF tribanders. So unique, we've applied for a patent.

### Broadband Performance

The Explorer 14 will load solid state transceivers to maximum output with VSWR below 2:1, eliminating the need for an antenna tuner. You'll have edge to edge broadband

performance on 20, 15 and 10 meters with gain and front-to-back ratio competitive to giant tribanders that cost twice as much or more. You'll be able to work stations you cannot even hear with a dipole antenna. And, the Explorer 14 handles maximum continuous legal power with a respectable safety margin.

### Short Boom Save Space and Money

If your space or budget was too limited for a long boom tribander, chances are the Explorer 14 will fit both. The boom is only 14' (4.3 m) long and the turning radius requires only 17'3" (5.3 m). The compactness of the Explorer 14 reduces its overall weight and windload surface so you can mount it on a roof tripod, a mast or a tower. For example, the Hy-Gain CD-45II rotator and HG52 tower are a perfect match for the Explorer 14. This saves you the cost of an extra heavy duty rotator and tower.

### Superior Construction

The Explorer 14 includes passivated stainless steel hardware and heavy gauge, pre-formed element and mast brackets. High grade 6063-T832 thick wall swaged aluminum tubing is used throughout. A BN86 balun is included and a new Beta Multi-Match provides DC ground to reduce lightning hazard and precipitation static. It's a rugged, easily assembled antenna that survives winds to 100 mph (160 km/h).

### Quad Band Option

You can add a fourth band, either 30 meters or 40 meters to the Explorer 14 with the QK-710 kit. A kit that attaches to the central dipole and is easily adjusted for either 30 meters (WARC) or 40 meters at minimal extra cost.

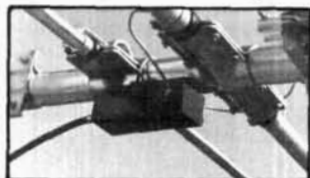
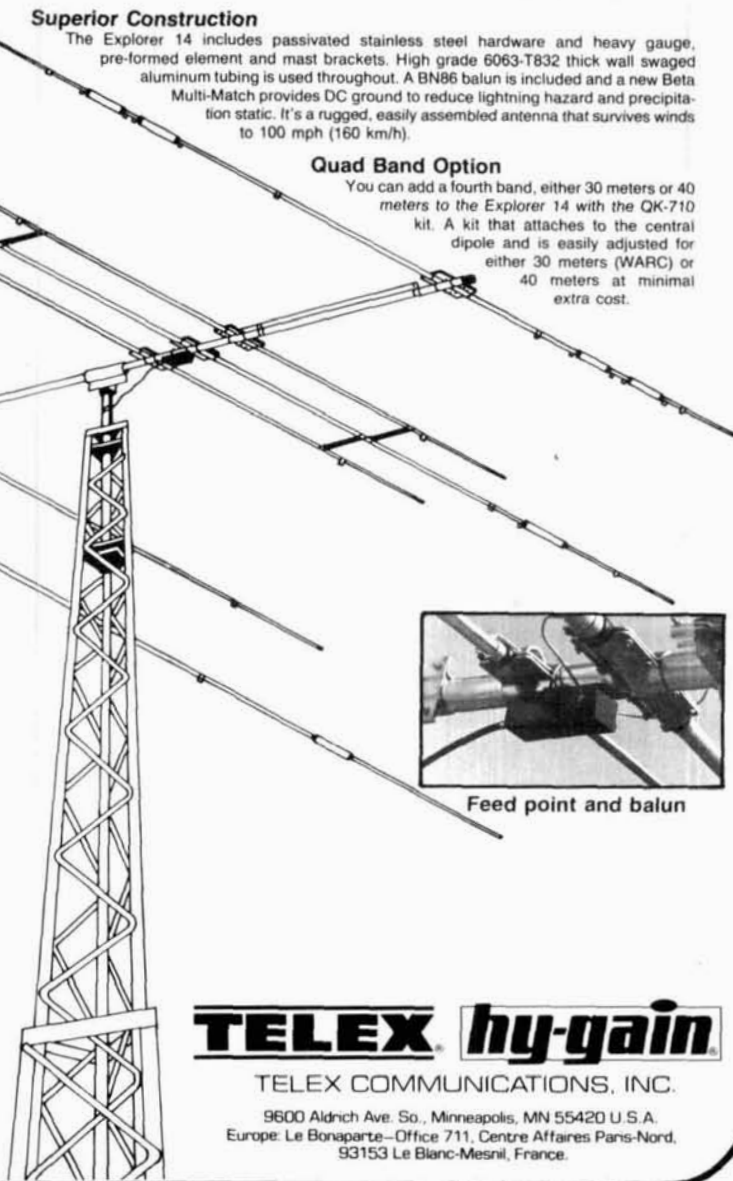


Lew McCoy, WIICP, is among the most authoritative writers in amateur radio. For over 30 years he served on the ARRL technical staff with his last position as assistant senior technical editor. Presently he is the technical writer for CQ magazine. Here is what he had to say about the Explorer 14:

"In my opinion, with Explorer 14, Hy-Gain produced a truly high gain, high performance antenna in a small package. The "para-sleeve" design provides the amateur a whole new ball game, particularly in the area of broadbanding. I was really surprised when I actually verified the gain, front-to-back and bandwidth during my recent visit to the Hy-Gain labs and antenna range in Lincoln, Nebraska. The Explorer 14 is a winner."

### Specifications:

Frequencies of operation:	Electrical		
	20M	15M	10M
Under 2:1 VSWR (MHz)	14.0-14.35	21.0-21.45	28.0-29.7
Maximum F/B Ratio (dB)	27	27	21
Maximum Gain (dB)	7.5	8.0	8.0
Maximum Power	Maximum Legal DC Ground		
Mechanical			
Boom Length	14'1 1/2" (4.3 m)		
Turning Radius	17'3" (5.3 m)		
Net Weight	43 lbs. (19.5 kg)		
Wind Surface Area	7.5 sq. ft. (.69m <sup>2</sup> )		



Feed point and balun

## TELEX hy-gain

TELEX COMMUNICATIONS, INC.

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- Two VFOs for quick QSY across the band.
- Ten memory slots for storage and recall of favorite channels.
- Selectable synthesizer steps (5 kHz or 10 kHz) in dial or scanning mode.
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- Unique VFO/Memory Split mode for covering unusual repeater splits.
- Up/Down band scan plus memory scan for busy or clear channel. Scanning microphone included in purchase price.

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- Optional synthesized CTCSS Encode and Encode/Decode boards available.
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FM Handheld  
2 Meters

FT-708R  
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70 cm



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SSB/CW/FM Portable

FT-690R - 6 Meters  
USB/CW/AM/FM Portable

FT-790R - 70 cm  
SSB/CW/FM Portable  
430-440 MHz

Price and Specifications Subject To  
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**YAESU**  
*The radio.*



482R

# FM "Dual-Bander"

**NEW**



**2 m & 70 cm in single compact package, LCD, 25 W, optional voice synthesizer.**

## TW-4000A

**KENWOOD's TW-4000A FM "Dual-Bander" provides new versatility in VHF and UHF operations, uniquely combining 2 m and 70 cm FM functions in a single compact package.**

### TW-4000A FEATURES:

- **2 m and 70 cm FM in a Compact Package**  
Covers the 2 m band (142.000-148.995 MHz), including certain MARS and CAP frequencies, plus the 70 cm FM band (440.000-449.995 MHz), all in a single compact package. Only 6-3/8 (161)W x 2-3/8 (60)H x 8-9/16 (217)D inches (mm), and 4.4 lbs. (2.0 kg).
- **Large, Easy-to-Read LCD Display**  
A green, multi-function back-lighted LCD display for better visibility. Indicates frequency, memory channel, repeater offset, "S" or "RF" level, VFO A/B, scan, busy, and "ON AIR." Dimmer switch.
- **25 Watts RF Power on 2 m/70 cm.**  
Hi/Lo power switch.
- **Optional "Voice Synthesizer Unit"**  
Installs inside the TW-4000A. Voice announces frequency, band, VFO A or B, repeater offset, and memory channel number.
- **Front Panel Illumination**

- **10 Memories with Offset Recall and Lithium Battery Backup**  
Stores frequency, band, and repeater offset. Memory 0 stores receive and transmit frequencies independently for odd repeater offsets, or cross-band operation.
- **Programmable Memory Scan**  
Programmable to scan all memories, or only 2 m or 70 cm memories. Also may be programmed to skip channels.
- **Band Scan in Selected 1-MHz Segments**  
Scans within the chosen 1-MHz segment (i.e., 144.000-144.995 or 440.000-440.995, etc.). The scanning direction may be reversed by pressing either the "UP" or "DOWN" buttons on the microphone.
- **Priority Watch Function**  
Unit switches to memory 1 for 1 second each 10 seconds, to monitor the activity on the priority channel.
- **Common Channel Scan**  
Memory 8 and 9 are alternately scanned every 5 seconds. Either channel may be recalled instantly.
- **Dual Digital VFO's**  
Selectable 5-kHz or 10-kHz for 2 m, and 5-kHz or 25-kHz for 70 cm. Depress "UP" or "DOWN" key on the front panel for band change in 1-MHz steps.
- **16-Key Autopatch UP/DOWN Microphone (Supplied)**
- **Repeater Reverse Switch**

- **High Performance Receiver/Transmitter**  
GaAs FET RF amplifiers on both 2 m and 70 cm, high performance MCF's in the 1st IF section, provide high receive sensitivity and excellent dynamic range. The high reliability RF power modules assure clean and dependable transmissions on either band.
  - **Rugged Die-cast Chassis**
  - **Optional Two-Frequency CTCSS Encoder**  
Easily mounted inside the radio, allows DIP switch programming of two different tone frequencies, for 2 m and 70 cm.
  - **"BEEPER" sounds through speaker.**
  - **Easy-to-Install mobile mount**
- TW-4000A accessories:**
- **VS-1 Voice Synthesizer**
  - **TU-4C Two-Frequency Programmable CTCSS Encoder**
  - **KPS-7A Fixed station power supply**
  - **SP-40 Compact mobile speaker**

More information on the TW-4000A and TS-780 is available from all authorized dealers of Trio-Kenwood Communications, 1111 West Walnut Street, Compton, California 90220.

# KENWOOD

...pacesetter in amateur radio

## All mode "Dual-Bander"

### TS-780

**2 m & 70 cm all mode, dual digital VFO's, 10 memories, scan, IF shift...**

### TS-780 FEATURES:

- USB, LSB, CW, FM all mode, covering the 2 m band (144.000-148.000 MHz) and the middle 70 cm band (430.000-440.000 MHz). UP/DOWN band switch.
- Dual digital VFO's with normal/tight drag switch. VFO steps in 20-Hz, 200-Hz, 5-kHz, or 12.5-kHz, plus "FM CH" channel-
- ized tuning. Split (cross) frequency operation possible. F. LOCK switch provided.
- 10 memories include band and frequency data, backed up by internal batteries (not supplied). Battery life exceeds one year. Memories 9 and 10 for priority instant recall.
- Band scan, with selectable 0.5, 1, 3, 5, and 10-MHz scan bandwidth.
- Memory scan selectable for all memories, or 2 m or 70 cm only.
- IF shift circuit rejects adjacent interference.
- High sensitivity and wide dynamic range • 7-digit

fluorescent tube digital display  
• 10 watt RF output • 2 m  $\pm$ 600-kHz TX offset switch with reverse switch • Tone switch for optional TU-4C two frequency tone

encoder unit • VOX and semi break-in CW built-in • FM center-tune meter • Noise blanker for SSB, CW.

Subject to FCC approval

