

HAM RADIO



Featured this month...

A Simple DC Amp for your Meter
The Battle of the Beams: Part 1
The N05H All-band Dipole

June Weekenders

Solid-State Switching the Midland 13-509
and
A Motorized Agitator for your PC Boards



Kim Bottles K7IM

DOUBLE YOUR PLEASURE DOUBLE YOUR BANDS

Dual Band Radios from ICOM!

Double your operating pleasure with Icom's new dual band IC-3210 mobile and IC-32AT handheld FM transceivers. Each unit incorporates a wealth of special features and options designed to move you into the forefront of today's expanded 2-meter and 440MHz activity. Icom dual banders: the FM enthusiasts dream rigs!

Wideband Coverage. Both the IC-3210 and IC-32AT receive 138 to 174MHz including all NOAA weather channels, transmit 140 to 150MHz including MARS/CAP, and operate 440 to 450MHz. Total coverage of today's hottest FM action!

Full Duplex Operation. Simultaneously transmit on one band while receiving on the other for incomparable dual band autopatching!

20 Memories. Store any combination of standard or odd repeater offsets and subaudible tones.

Powerful! The IC-3210 delivers 25 watts output on both bands. The IC-32AT is five watts output on both bands. Selectable low power for local use on both units.

Programmable Band and Memory Scanning. Includes easy lockout and recall of various memories. Exceptional flexibility!

Repeater Input Monitor Button. Opens the squelch and checks Tx offset simultaneously.

Priority Watch. Monitor any channel for calls while continuing operation on another frequency.

Optional Beeper. Monitors for calls with your subaudible tone, then gives alerting beeps.

Double Your Bands with Icom's dual band IC-32AT handheld and IC-3210 mobile, and double your operating pleasure on 2-meters and 440MHz.




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All stated specifications are subject to change without notice or obligation. All ICOM radios significantly exceed FCC regulations limiting spurious emissions. 321032AT688



Cards and plaque courtesy W6TC

EIMAC's new DX champion! The 3CX800A7.

Varian EIMAC continues to commit its development of reliable tubes for HAM radio.

The new, rugged 3CX800A7 power triode provides 2 kW PEP input for voice service or 1 kW cw rating up to 30 MHz. Two tubes will meet the new, higher power ratings authorized by the FCC.

Designed for today's low profile, compact linear amplifiers, the 3CX800A7 powerhouse is only

2½ inches (6.35 cm) high. Cooling requirements are modest and a matching socket, air chimney and anode clamp are available.

A data sheet and more information is available from Varian EIMAC. Or the nearest Electron Device Group sales office. Call or write today.

Varian EIMAC
301 Industrial Way
San Carlos, California 94270
Telephone: 415-592-1221



KENWOOD

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All-mode
tri-bander!

Warp Drive!



TS-790A Satellite Transceiver

The new Kenwood TS-790A VHF/UHF all-mode tri-band transceiver is designed for the VHF/UHF and satellite "power user." The new TS-790A is an all-mode 144/450/1200 MHz transceiver with many special enhancements such as Doppler shift compensation. Other features include dual receive, automatic mode selection, automatic repeater offset selection for FM repeater use, VFO or quick step channel tuning, direct keyboard frequency entry, 59 memory channels (10 channels for separate receive and transmit frequency storage), multiple scanning and multiple scan stop modes. The Automatic Lock Tuning (ALT) on 1200 MHz eliminates frequency drift. Power output is 45 watts on 144 MHz, 40 watts on 450 MHz, and 10 watts on 1200 MHz. (The 1200 MHz section is an optional module.)

- High stability VFO. The dual digital VFOs feature rock-stable TCXO (temperature compensated crystal oscillator) circuitry, with frequency stability of ± 3 ppm.
- Operates on 13.8 VDC. Perfect for mountain-top DXpeditions!
- The mode switches confirm USB, LSB, CW, or FM selection with Morse Code.
- Dual Watch allows reception of two bands at the same time.
- Automatic mode and automatic repeater offset selection.
- Direct keyboard frequency entry.
- 59 multi-function memory channels. Store frequency, mode, tone information, offset, and quick step function. Ten memory channels for "odd split."
- CTCSS encoder built-in. Optional TSU-5 enables sub-tone decode.
- Memory scroll function. This feature allows you to check memory contents without changing the VFO frequency.

- Multiple scanning functions. Memory channel lock-out is also provided.
- ALT—Automatic Lock Tuning—on 1200 MHz eliminates drift!
- 500 Hz CW filter built-in.
- Packet radio terminal.
- Interference reduction controls: 10 dB RF attenuator on 2m, noise blanker, IF shift, selectable AGC, all mode squelch.
- Other useful controls: RF power output control, speech processor, dual muting, frequency lock switch, RIT.
- Voice synthesizer option.
- Computer control option.

Optional Accessories:

- PS-31 Power supply • SP-31 External speaker
- UT-10 1200 MHz module • VS-2 Voice synthesizer unit • TSU-5 Programmable CTCSS decoder
- IF-232C Computer interface • MC-60A/MC-80/MC-85 Desk mics • HS-5/HS-6 Headphones
- MC-43S Hand mic • PG-2S Extra DC cable



Complete service manuals are available for all Kenwood transceivers and most accessories. Specifications, features, and prices are subject to change without notice or obligation.

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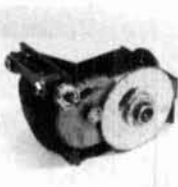
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APRIL WINNERS

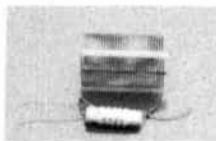
Congratulations to Kenneth L. Frank, WB5AKI, our April sweeps winner and Bryan Bergeron, NU1N, author of April's most popular WEEKENDER — "Easy Antenna Access For Urban Apartment Dwellers." Both will receive a copy of *The Radio Handbook* by Bill Orr, W6SAI.

Our WEEKENDER sweepstakes ends with our April winners. Thanks to everyone who sent in cards. Your comments have been invaluable to us!

Terry Northup, KA1STC



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Backscatter



VIEW FROM THE TOP

By the time you get this magazine, the 1989 Dayton Hamvention™ will be a distant memory. However, as I sit here and write today, Dayton is just a week away.

For those of you who've never been to Dayton, it's truly one of the most interesting experiences you'll ever have. Plan to go someday. You'll have the time of your life. The Hamvention is three jam-packed days of the best forums, displays, and opportunities to meet people from around the world. I've run across friends I haven't seen in twenty years, and connected faces to voices from far off DX locations.

If you didn't make Dayton this year, try to set aside time to go next year. It really is one of the most enjoyable events on the ham calendar!

NO-CODE SURVEY RESULTS An Even Split: 50% for, 50% against

WOW! Did we get a lot of mail.

March's editorial discussed the concept of a no-code license and asked for responses from you, our readers. Quite a few of you took the time to either pen a QSL card with a simple statement or write long thoughtful responses. From simple "Yes!" or "No!" answers, to four-page letters detailing your positions, you sure let us have it with both barrels.

Of the responses we received, there was an even 50-50 split of opinion. The last time no-code was discussed in 1983, the responses to our editorial ran 20 to 1 against a no-code license. What has changed in our hobby over the last few years and what does it mean?

First of all, no-code as a license class won't be the panacea for Amateur Radio's problems. It is, however, a step recognizing that not everyone who would like to be ham wants to learn the Morse code. As currently envisioned, a no-code licensee's privileges would be for bands above 50 MHz only. Many of you are under the impression that there would be a below 30 MHz no-code license. That is simply not the case.

A number of you feel strongly that CW acts as a "lid filter," or a way to weed out undesirable potential new hams. That's what they told me about pledging a fraternity in college — going through it would make a better brother out of me. I didn't buy it then and I don't today. Hazing has all but been eliminated from our society. Most of us recognize that it's better to stimulate a person with positive motivation than with "trials" and tests, or hurdles to overcome.

Several of you commented that there is already (for all intents and purposes) a no-code license — CB. However, CBers are not hams and are missing all of the benefits that we, as hams, share. Besides, CB radio was never intended to be an outlet for casual communications.

A significant number of letters commented on the fact that CW is fun. While I agree wholeheartedly, I know many good hams who hate CW and, after passing the General class exam, never want to see a key again.

On the pro no-code side, the general trend supported the realization that not everyone who wants to be a ham wants to learn the code. In this light, most felt that a VHF or UHF only no-code license would be a good idea. No one suggested that a no-code license be a freebie or giveaway ticket. Some suggested that the no-code exam be made harder than the current Extra exam, while others felt that a license on par with either the current Novice or Technician class license was in order.

So, what's next? There have been several very interesting developments. On March 16, 1989, the Space Coast Amateur Technical Group in Melbourne, Florida made a formal filing with the FCC for a no-code license. At almost the same time, the ARRL No-code Study Committee made a proposal to the Executive Committee for a new license class without a code requirement. The ARRL Board will discuss this step further at their July meeting. If it is adopted as policy, the Board may direct League counsel to draft and submit a proposal for a no-code license to the FCC by this fall.

The bottom line is that a no-code license won't result in an explosion in new Amateur Radio licenses. It will, however, provide another path for bringing people into the hobby. It then becomes incumbent upon us to get others interested in Amateur Radio.

One rap made by several writers was that no-code is nothing but an attempt by the Amateur Radio industry to increase the number of licensees in order to enhance their profit margins. Nothing could be further from the truth. The accusers fail to recognize that many of us in the business are long-time hams ourselves. While we may be in business to make a profit, that is not the sole force that drives us. Many of us are driven by our love for the hobby and our desire to ensure that there is a future for Amateur Radio. It's often very difficult to separate the emotional from the rational when it comes to Amateur Radio.

Time, the ARRL, the FCC, and the rest of us will determine whether or not there will be a no-code license. If you're currently against no-code, please ask yourself if you're being fair to those who want to be hams without learning the code. There are people out there with much to offer for whom the code would not be a vital communications skill. Who knows what benefits they could bring to our hobby if we were to encourage them?

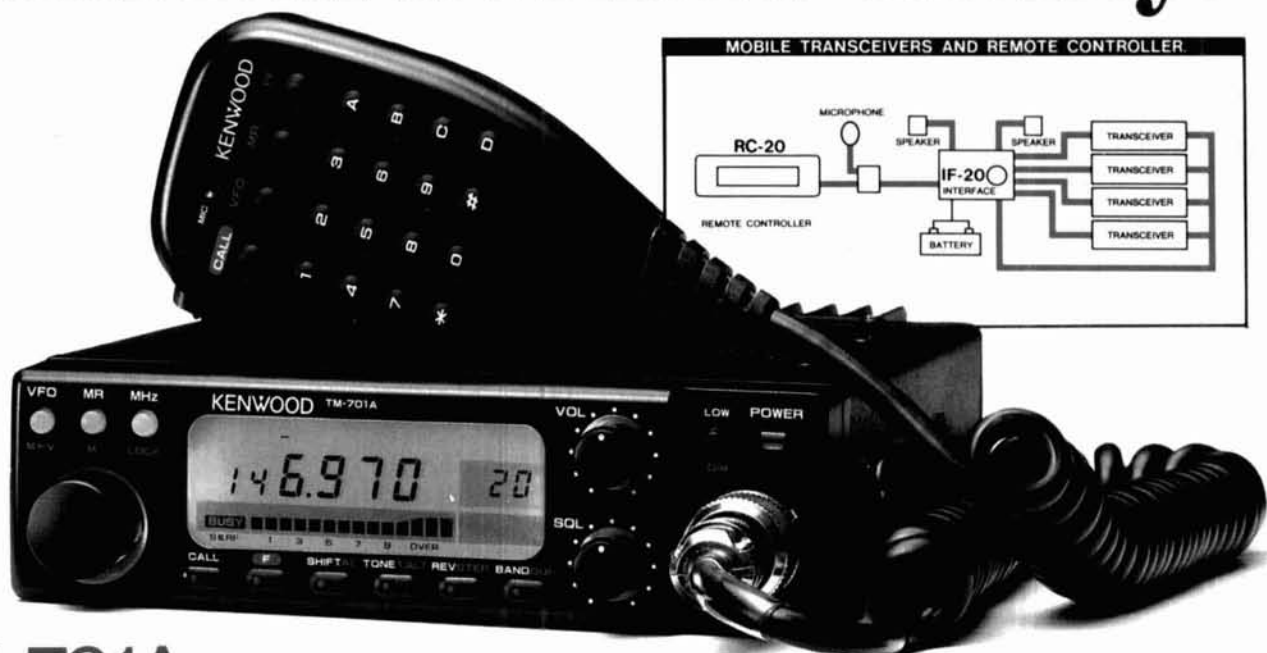
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KENWOOD

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Affordable
Breakthrough!

Dual Band Afford-ability!



TM-701A

Dual Bander

The TM-701A combines two radios into one compact package. You get 25 watts on 2 meters and 70cm, 20 memory channels, tone encoder built-in, multiple scanning, auto repeater offset selection on 2 meters, and a host of additional features!

- **20 multi-function memory channels.** 20 memory channels allow storage of frequency, repeater offset, CTCSS frequency, frequency step, and Tone On/Off status, CTCSS and REV, providing quick and easy access during mobile operation.
- **25W on 2m and 70cm.**
- **Selectable full duplex-cross band (Telephone style) operation.**
- **Easy-to-operate front panel layout.**
- **Multi-function DTMF mic. supplied.** Controls are provided on the microphone for CALL (Call Channel), VFO, MR (Memory Call or to change the memory channel) and a programmable function key. The programmable key can be used to control one of the following functions on the radio: MHz, T.ALT, TONE, REV, BAND, or LOW power.
- **Easy-to-operate illuminated keys.** A functionally designed control panel with individually backlit keys increases the convenience and ease of operation during night-time use.

- **Optional full-function remote controller (RC-20).** A full-function remote controller using the Kenwood bus line may be easily connected to the TM-701A and mounted in any convenient location. The new controller is capable of operating all front panel functions.
- **Built-in dual digital VFO's.**
 - a) Frequency step selection (5, 10, 15, 20, 12.5, 25kHz)
 - b) Programmable VFO
- **Programmable call channel function.** The call channel key allows instant recall of your most commonly used frequency data.
- **Programmable tone encoder built-in.**
- **Tone alert system—for true quiet monitoring.** When activated this function will cause a distinct beeper tone to be emitted from the transceiver for approximately 10 seconds to signal the presence of an incoming signal.
- **Easy-to-operate multi-mode scanning.**
 - a) VFO scan
 - Band scan, Programmable band scan.
 - b) Memory scan plus programmable memory channel lock-out
 - c) Dual scan
 - Dual call channel scan
 - Dual memory scan
 - Dual VFO scan
 - d) Scan stop modes
 - Time operated scan (TO)
 - Carrier operated scan (CO)

- e) Scan direction
- f) Alert

When the AL switch is depressed memory channel 1 is scanned for activity at approximately 5 second intervals.

- **MHz switch.**
- **Lock function.**
- **Repeater reverse switch.**

Optional Accessories

- **RC-20** Full-function remote controller
- **RC-10** Multi-function remote controller
- **IF-20** Interface unit handset
- **MC-44** Multi-function hand mic. with auto-patch
- **MC-48B** 16-key DTMF hand mic.
- **MC-55** 8-pin mobile mic.
- **MC-60A/80/85** Desk-top mics.
- **MA-700** Dual band (2m/70cm) mobile antenna (mount not supplied)
- **SP-41** Compact mobile speaker
- **SP-50B** Mobile speaker
- **PS-430** Power supply
- **PS-50** Heavy-duty power supply
- **MB-201** Mobile mount
- **PG-2N** Power cable
- **PG-3B** DC line noise filter
- **PG-4H** Interface connecting cable
- **PG-4J** Extension cable kit
- **TSU-6** CTCSS unit

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Comments



Self portrait

Dear HR

RE: the February issue, WHAT A GREAT COVER!!!!

I am a broadcast engineer, have been a ham for 36 years, and do a great deal of design and repair work. I am completely at home around electronics.

I recently bought a state-of-the-art rig, and my expression upon spreading out the circuit diagram was almost EXACTLY the same as the person depicted on the cover. With all my years of experience, it took me about an hour to figure out where the signal came in, and went out. I still haven't figured out much in between.

Keep up the good work on a good magazine.

**Walter Boller, W9OBG/7,
Olalla, Washington 98359**

Voice versus packet racket

Dear HR

An electronic plague has descended upon Amateur Radio. Long-standing nets and discussion groups have been pushed out of existence by the agonizing, screeching tide of packet racket. Large numbers of those who might well be the majority in our hobby now find it impossible to monitor their favorite frequency because a packet station has plopped down on it or near it. Who can stand that piercing sound that has been likened to that of fingernails on a blackboard?

A typical example is found when monitoring 144.9 MHz. This frequency has been used for fast-scan TV liaison for over thirty years. It is important for signal reports, homing-in antennas, and guiding transmitter/modulator adjustments. An S-9 packet signal on 144.905, while not even moving the meter on adjacent channels, breaks through and can be heard 10 kHz up and down. The worst part is that the

RF burst lasts longer and blocks all but the strongest voice signals on 144.9.

When I first read about packet in *QST*, it was described as the ultimate in space-age technology. Economy in use of the spectrum was the keynote in this discussion, due to its inherent speed and accuracy. This allows a large number of operators to be serviced by one system. What it really amounted to, in many cases, was a new justification for having spent hundreds of dollars on a computer that started gathering dust after the novelty had worn off. Although most Hams can talk well and many can even chew gum at the same time, this great store of wit and wisdom had to be digitized, dehumanized, and stored in libraries called bulletin boards. I guess it goes along with the inability to listen and write: a product of our "space-age" school systems.

In any case, the basic pleasures of Amateur Radio, hearing a voice from afar, sensing its emotions, its unique sounds, are being bittered. It is bad enough to lose frequencies to commercial interests, but it is much worse to have them rendered unlistenable by your own group. This could be the final assault in which Amateur Radio, like all the great empires, falls from within.

**John Shelley, WA1IAO,
N. Granby, Connecticut 06060**

Another viewpoint

Dear HR

Today I received my February 1989 issue of HAM RADIO, and I just completed reading AA6FW's comments concerning youth and ham radio. I am especially interested because I am the

author of the August 1988 letter that mentioned "gimmies and wanna be's..." you referred to.

I agree with several of your view points:

1. Yes, radio seems no longer to be a mysterious mechanism to most people.
2. Yes, perhaps many ham radio operators are senior citizens that clump to 80 meters and BS about nothing.
3. Yes, perhaps many hams do not appreciate growth.
4. Yes, incentive must come from more than the ARRL.
5. Yes, perhaps, a no-code license will be incentive for newcomers to ham radio.

However, I challenge many of the arguments used to support these viewpoints. My letter last summer expressed my concerns about the few numbers of younger people being licensed. I appreciate that my perspective will always be one-sided. Nevertheless, it's been my experience that incentive has to come from within.

This is apparent in the workplace and at home. I am an engineer with many years in the IC construction business. The latest craze in productivity is "taking ownership." That's great from the manager's position. My experience, with peers, subordinates, and business contacts, has been that this ownership *has* to already be in place and active; it cannot be forced. I can make someone own a project but I cannot (and do not) expect the same results I would get if that ownership were sincere.

The same is true with ham radio. This hobby has and always will provide technical challenges and satisfaction for those willing to move forward. The old saying, "You can take a horse to water but you can't make him drink," is appropriate. I worked with high school kids a few years in a program (Explorer's Group) involving them with the wonders of engineering and science. Either they are interested or they are not.

KENWOOD

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All New
Dual Bander!

Two in the Hand!

TH-75A

2m/70cm Dual Band HT

The new TH-75A Dual Band HT from Kenwood is here now! Many of the award-winning features in our dual band mobile transceivers are designed into one hand-held package.

- Dual Watch function allows you to monitor both bands at the same time.
- 1.5 watts on 2 meters and 70cm: **5 watts when operated on 12 VDC (or PB-8 battery pack).**
- Large dual multi-function LCD display.
- 10 memory channels for each band stores frequency, CTCSS, repeater offset, frequency step information, and reverse. A lithium battery backs up memories. Two memories for "odd split" operation.
- Selectable full duplex operation.
- Extended receiver range: 141-163.995 and 438-449.995 MHz; transmit on Amateur band only. (Modifiable for MARS and CAP. Permits required. Specifications guaranteed on Amateur bands only.)
- Uses the same accessories as the TH-25AT (except soft cases).
- Volume and balance controls, plus separate squelch controls on top panel.
- Super easy-to-use! For example, to recall memory channel, just push the channel number!
- CTCSS encode/decode built-in!
- Automatic Band Change (ABC). Automatically switches between main and sub band when signal is present.
- Automatic offset selection on 2 meters.
- Tone alert system for quiet monitoring. When CTCSS decode is on, the tone alert will function only when a signal with the proper tone is received.
- Four ways to scan, including **dual memory scan**, with time operated or carrier operated scan stop modes, and priority alert.
- Automatic battery saver circuit extends battery life.



- **Supplied accessories:** Dual band rubber-flex antenna, PB-6 battery pack, wall charger, belt hook, wrist strap, water resistant dust caps.

Optional Accessories

- PB-5 7.2 V, 200 mAh NiCd pack for 1.5 W output
- PB-6 7.2 V, 600 mAh NiCd pack
- PB-7 7.2 V, 1100 mAh NiCd pack
- PB-8 12 V, 600 mAh NiCd for 5 W output
- PB-9 7.2 V, 600 mAh NiCd with built-in charger
- BC-10 Compact charger
- BC-11 Rapid charger

- BT-6 6-cell AA battery case
- DC-1/PG-2V DC adapter
- HMC-2 Headset with VOX and PTT
- SC-22 and SC-23 Soft case
- SMC-30/31 Speaker mics.
- WR-1 Water resistant bag.

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Complete service manuals are available for all Kenwood transceivers and most accessories.

MFJ TUNERS

Here is the finest 3 KW PEP Tuner money can buy with roller inductor, dummy load, new peak reading meter, antenna switch, balun and more ...

The MFJ-989C is not for everyone. However, if you do make the investment you get the finest 3 KW PEP tuner money can buy - one that will give you a lifetime of use, one that takes the fear out of high power operation and one that lets you get your SWR down to absolute minimum.

The MFJ-989C is a compact 3 KW PEP roller inductor tuner with a new peak reading Cross-Needle SWR/Wattmeter. The roller inductor lets you get your SWR down to absolute minimum.

With three continuously variable components - two massive 6 KV capacitors and a high inductance roller inductor - you get precise control over



MFJ-989C \$349⁹⁵

SWR and the widest matching range possible from 1.8-30 MHz.

You get a new lighted peak and average reading Cross-Needle SWR/Wattmeter with a new more accurate directional coupler.

You get a giant two core balun wound with teflon wire for balanced lines and a 6-position antenna switch with extra heavy switch contacts.

Its compact 10³/₄x4¹/₂x15 inch cabinet fits right into your station.

You get a 50 ohm 300 watt dummy load for tuning your exciter, a tilt stand for easy viewing and a 3-digit turns counter plus a spinner knob for exact inductance control. Add \$10 s/h.

2-knob Differential-T™ Tuner



MFJ-986 The new MFJ-986 Differential-T™ 3 KW PEP 2-knob Tuner has a differential capacitor to make tuning foolproof and easier than ever. It ends constant retuning with broadband coverage and gives you minimum SWR at only one best setting. Covers 1.8-30 MHz.

The roller inductor lets you tune your SWR down to absolute minimum. A 3-digits turns counter lets you quickly return to your favorite frequency.

You get MFJ's new peak and average reading Cross-Needle SWR/Wattmeter with a new directional coupler for more accurate readings over a wider frequency range. It reads forward/reflected power in 200/50 and 2000/500 watt ranges. Meter lamp is front panel switched and requires MFJ-1312, \$9.95.

A new current balun for balanced lines reduces feedline radiation and forces equal currents into antenna halves that are not perfectly balanced for a more concentrated, stronger signal. Add \$10.00 s/h.

MFJ's Fastest Selling Tuner



MFJ-941D The MFJ-941D is MFJ's fastest selling 300 watt PEP antenna tuner. Why? \$109⁹⁵ Because it has more features than tuners costing much more and it matches everything continuously from 1.8-30 MHz.

It matches dipoles, vees, verticals, mobile whips, random wires, balanced and coax lines.

SWR/Wattmeter reads forward/reflected power in 30 and 300 watt ranges. Antenna switch selects 2 coax lines, direct or through tuner, random wire, balanced line or tuner bypass. Efficient airwound inductor gives lower losses and more watts out. Has 4:1 balun. 1000 V capacitors. 10x3x7 inches.

MFJ's Random Wire Tuner

MFJ-16010 \$39⁹⁵

You can operate all bands anywhere with any transceiver when you let the MFJ-16010 turn any random wire into a transmitting antenna. Great for apartment, motel, camping operation. Install a wire anywhere! Tunes 1.8-30 MHz. 200 watts PEP. Ultra small 2x3x4 in.



MFJ's Best 300 Watt Tuner



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I chuckled as I read the comments about not being able to find someone to talk to. With half a million hams in this country? My face flushed as I read about (you) not having much to say to such a person (as me) on the air because of my "wanna be's" letter. Oh well.

The expectations placed on kids today (from my very middle-class and former welfare-recipient position) are overpowering and sometimes unrealistic. Couple this with today's amazing feats that are taken for granted, along with life being taken for granted, and suddenly ham radio is uninteresting. However, incentive and support are the key ingredients to get more youth into ham radio. How about joining a club and getting involved with youth to show them examples of ham radio and its challenges.

**Lawrence Caracciolo, N3CCW,
Federal Way, Washington**

Thoughtful response

Dear HR

I would like to respond, in part, to the letter by Harry Helms, AA6FW, which was in the February issue.

To begin with, I can see that there has been a stagnation in membership in our fraternity. I agree that it is a good idea to take every opportunity to involve new people in Amateur Radio.

Mr. Helms complains that "Amateur Radio has been 'curmudgeonized.'" Then he says that he has a hard time finding anyone "stateside" with whom he can have a ragchew. May I submit that Mr. Helms has become somewhat of an elitist.

Why does he believe that those who defend the need for a code requirement should have an Extra class license? I freely defend the code requirement and recognize that it is a discipline, even though I dislike using CW intensely. Those who wish to upgrade should do that which is necessary. Others, such as myself, will occasionally use CW on the low bands, or not, as they desire.

I find offensive the implication that because I started in Amateur Radio with a conditional license, that license is tainted. My licenses cover a period of over twenty-five years. During that

time, I have assisted in a number of emergencies and tried to be helpful to other Amateurs.

I have never considered it my place to judge them.

**Jerome W. Silverstein, K3FKI,
Verona Pennsylvania 15147**

Reading the "small" print

Dear HR

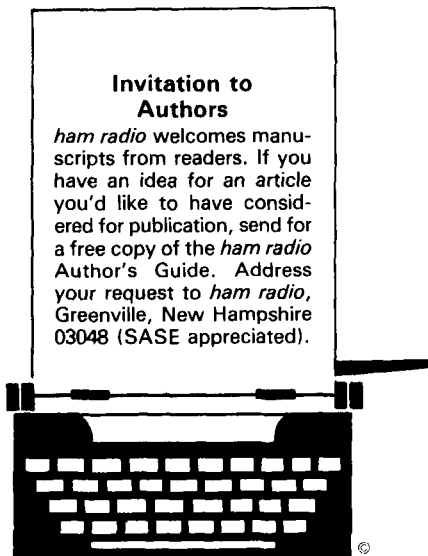
Please accept my compliments for your work with *Ham Radio*. I have gotten the magazine for many years and keep them all as a very valuable source of reference in most ham matters. There have through the years been some outstanding articles, like the series on Yagi Antennas by W2PV and now lately Ron Todd's "Pathfinder" (which gives me a lot of pleasure to operate and gave me a lot of fun to implement). "Pathfinder: Part 1" was easy as you printed the program with letters large enough for my 67 year old vision to see without a magnifying glass. The second part was tougher due to the "magnifying glass" print. But don't you worry also the sun has its spots (fortunately).

So thanks again for a fine job.

**Bo Stjernberg, SM6ASD,
Goteborg, Sweden**

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A SIMPLE DC AMPLIFIER FOR YOUR METER

By Yardley Beers, W0JF, 740 Willowbrook Road,
Boulder, Colorado 80302

By connecting a simple amplifier to one of those old meters you probably have in your shack, you can enjoy a device that gives a full scale deflection for a couple of millivolts or a few microamperes. You can assemble such an amplifier using a common op amp circuit and easily obtained components. If you are unfamiliar with op amps, building this amplifier can be educational as well.

A meter with this kind of amplifier has many uses in the shack. If you connect a diode between its terminals and use a foot or two of loose wire as an antenna, it becomes a sensitive field strength meter. You can improve the sensitivity by using an RF choke and bypass capacitor as shown in Figure 1, but these components aren't often required.

You might also find this meter helpful for adjusting QRP equipment. You need some deflection on your meter to know if your adjustments are making things better or worse. Adding this amplifier to your meter makes it possible to study leaks in shielding. When connected to a tuned circuit, it can be used to identify harmonics. The modified meter can also be used as a sensitive bridge balance detector.

This meter and amplifier arrangement can demonstrate a number of effects not usually part of Amateur experience. If you connect a diode in a transparent case to the meter, you'll often find that the diode is sensitive to light, while the meter deflection is of opposite polarity to that produced by RF. (The moral here is that circuit boards with such diodes should be shielded from light.) The meter can also be used to demonstrate thermoelectric effects using ordinary metals, even though there's a bad impedance mismatch between a thermocouple and the amplifier input. Take a piece of copper wire and a piece of aluminum wire and twist one end of each together. Connect the other ends to the amplifier input, with

the copper wire attached to the positive terminal. The meter will deflect when you heat the junction gently with a soldering iron. If you use special thermocouple wire, it's possible to get a deflection simply by pinching the junction between your fingers.

I have found these meters useful in working with my homemade QRP microwave demonstration setup.¹ The 1N34s and some surplus diodes have considerable response at 2.4 GHz, but not as much as microwave hot carrier diodes. The 1N914s aren't sensitive to this radiation, or to light. I don't have a microwave oven, but I believe a proper diode connected to one of these meters could detect leaks in the shielding.

The focus of this article is on the use of op amps as DC amplifiers. These amplifiers can also be used to amplify AC signals at millivolt levels. At higher levels the amplifiers overload, and the output approaches zero. They are especially effective when the signal source has a high impedance and the load has a low impedance. I connected a pair of 8-ohm headphones through one of them to the output of a broadcast band crystal receiver. With the amplifier turned off, I could hear nothing. With it on, I heard several stations with excellent volume.

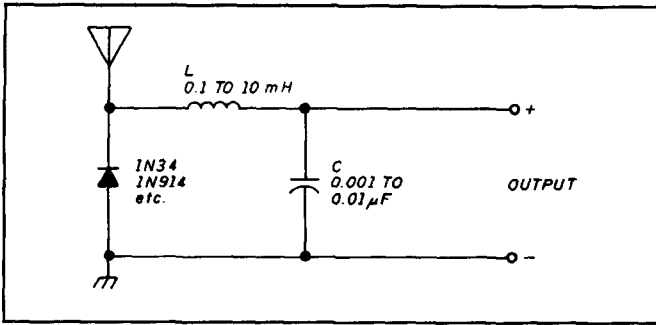
Op amp fundamentals

An op amp is a high-gain amplifier with two input terminals. (See Figure 2.) Voltage applied to the noninverting input terminal gives an output voltage of the same polarity. Voltage applied to inverting input terminal gives an output voltage of the opposite polarity. Internal negative feedback tries to make the voltage between the input terminals zero. The output voltage is proportional to the difference between the voltages that would occur between these terminals in the absence of this feedback.

In many applications, one of the input terminals is tied to ground and the input voltage is applied to the other input terminal. In the application used here the input signal is connected between the noninverting input and ground. External negative feedback is established by connecting a resistor (R_f) between the output and inverting input terminals and a resistor (R_s) from the inverting input to ground. If the open loop gain of the amplifier is very high the voltage gain is:

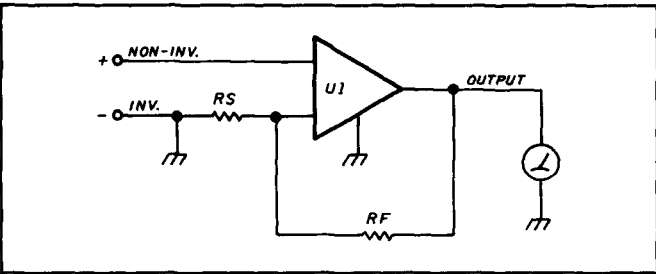
$$G = 1 + R_f/R_s \quad (1)$$

FIGURE 1



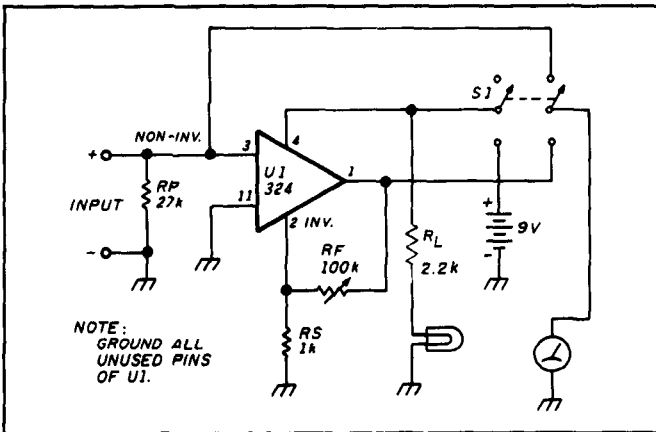
Diode detector circuit.

FIGURE 2



Basic circuit for operational amplifier.

FIGURE 3



Circuit for LM324 Operational amplifier.

If you use very large values of R_f , the amplifier becomes unstable. The maximum usable value depends a little on the input resistance. With $R_s = 1\text{ k}$, I find the maximum practical value for R_f in both circuits is about 100 k. This means the maximum theoretical value of G is about 100. The measured experimental values are close to this value.

In principle, the output voltage is zero when the voltage between the input terminals is zero — regardless of the resistance between these terminals. The LM324 amplifier in Figure 3 is designed to produce zero output under these conditions; the LM741 circuit in Figure 4 contains an adjustment for controlling this “zero offset.” In either case, the output voltage doesn’t remain zero for large input resistances and the amplifier may become unstable. Consequently, I’ve placed a resistor (R_p) in parallel with the input to prevent the meter

from going off scale when the input terminals are open circuited.

The input resistance looking into the op amp is very high — on the order of megohms. This means the resistance looking into the terminals of the circuits shown in Figures 3 and 4 is essentially that of R_p . The output resistance is very low (less than 1 ohm).

Moving coil meter fundamentals

The op amp’s performance depends on the properties of the meter it’s used with. I based my assumptions on a meter that has a full scale deflection for 1-mA input and a resistance of 200 ohms. This meter can measure current or voltage, depending on the values of the resistances present in the circuit to which it’s connected. In electronic circuits these values are in thousands of ohms, and it’s appropriate to connect the meter in series with some portion of the circuit and use it to measure current. In very low resistance circuits (like those composed of thermocouples), you may think of this meter as one for measuring voltage and requiring 200 mV for full scale deflection.

Power is the fundamental quantity determining the deflection. Replacing the moving coil with another coil having the same external dimensions but more turns of inner wire decreases the current required for full scale deflection. At the same time, it needs less voltage because the resistance is higher. Using the simplifying assumption that in both cases the space occupied by the insulation on the wire is negligible, you can see that the change in current compensates for the change in voltage while the power is exactly the same — 200 μW . Therefore, obtaining maximum meter deflection involves an impedance-matching problem.

Response time is one property of the meter that I’ve overlooked. Replacing the coil with one that has larger external dimensions increases the sensitivity. But because the coil contains more mass, the needle moves more slowly. An alternative is to replace the original spring with one that isn’t as stiff. This increases both sensitivity and response; but, the meter also becomes more sensitive to vibration.

Selecting a meter to use with the op amp

Meter selection isn’t terribly critical. A voltage gain of about 100 and a very low output resistance are central properties of the op amp. The meter can thus be considered a millivoltmeter. You’ll get the greatest sensitivity from a meter that requires the fewest millivolts for full scale deflection. However, the ICs have a rated maximum output current on the order of 20 mA, and it appears that a meter with a full scale deflection for a current of this size would be optimum.

I checked the millivolt calibrations of a number of different meters with full scale current ratings between 0.2 and 25 mA. Contrary to what I said before, there was very little difference. All the meters gave a full scale deflection at about 200 mV, within a factor of 2 or so. Apparently my previous assumptions don’t apply. Instead, it seems the manufacturers have adjusted the parameters of their meters to make this voltage difference a design objective. However, meters with lower current ratings can save battery drain.

You may wish to build two tip jacks into the unit and use a meter from your shack (a volt ohmmeter switched to a milliam-

pere scale, for instance). If you want a very compact instrument, you can use a surplus tuning meter.

Circuit for the LM324 op amp

The chip containing the LM324 op amp has four units. The circuit in **Figure 3** uses only one of them. This circuit is identical to **Figure 2** except for the inclusion of the input resistor R_p , the battery, and an on/off switch.

The LM324 offers you the simplicity of using a battery with one polarity and wide voltage flexibility. As I said before, it is supposed to be balanced so that it has zero output for zero voltage input — regardless of the external resistance connected to it. In practice this balance isn't perfect, and I've introduced the resistance $R_p = 27\text{ k}$ to keep the output voltage within reason. You might want to try other values. The input voltage for full scale output is about 2 mV. The corresponding current is this voltage divided by the value of R_p , or about $0.07\text{ }\mu\text{A}$. With the 1-mA, 200-ohm output meter this corresponds to a current gain of 14,000. The input power is $0.140\text{ }\mu\text{W}$, while output power is 0.2 mW. The power gain is 1,400,000 or about 61 dB.

This circuit is simpler than that of the LM741. You pay for that simplicity by giving up a good method of controlling the zero offset. The power and current gains are limited by the relatively low value of R_p . One way to control the zero offset would be to connect a variable bucking voltage in series with the input, dispensing with R_p . If this were calibrated, the meter could be used as a null indicator and the unknown voltage would be equal to the bucking voltage.

Circuit for the LM741 op amp

The LM741 requires power supply voltages of both polarities with respect to ground. I use a single 9-volt battery with a voltage divider (R_1 and R_2 in **Figure 4**). By making R_1 variable, I have incorporated a method for controlling the zero offset. (Another way is to connect a potentiometer to pins 1 and 5, which are not used in this circuit.)

The ability to control the zero offset makes it practical to use a higher resistance for $R_p = 1\text{ meg}$. With the same voltage gain value of 100, the current for full scale output is now $0.002\text{ }\mu\text{A}$, and the current gain is 10,000. The power input is $4\text{ }\mu\text{W}$, and the power gain is 50,000,000 or 77 dB.

Construction methods

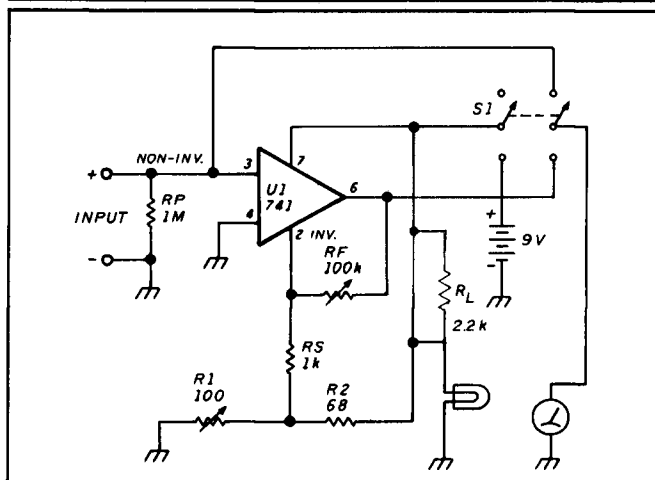
This project allows for great flexibility in construction methods. I've built two LM324 amplifiers and one LM741. One is housed in a meter case with a 3-inch meter. A second is in a $1\text{-}1/2'' \times 2'' \times 3\text{-}1/8''$ mini box with pin jacks for the meter. The third is mounted in a sardine can with tip jacks for the meter. (There's room to mount a surplus tuning meter.) All three contain 9-volt batteries.

The IC is hard wired into the circuit and supported from other components by its leads. You may want to mount a terminal strip in the box along with one or two insulated terminals in the LM324 circuit. Using the LM741 requires a terminal strip with four or five insulated terminals because of the voltage divider.

Calibration

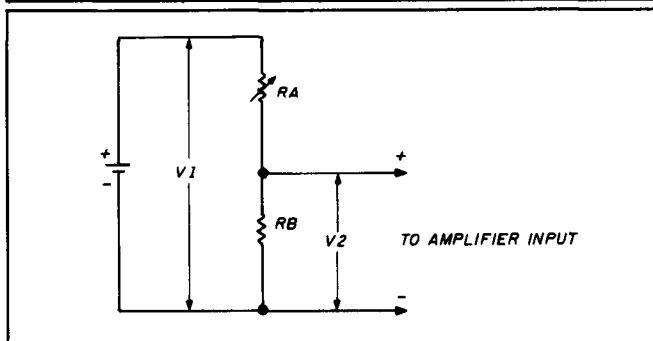
Accurate calibration isn't required in many applications. However, you can obtain a calibration by using the circuit

FIGURE 4



Circuit for LM741 operational amplifier.

FIGURE 5



Calibration circuit.

shown in **Figure 5**. In this circuit resistors R_a and R_b are in series across known voltage V_1 (conveniently supplied by a flashlight cell), and voltage V_2 is across R_b and applied to the input of the amplifier. R_b should be small (I use 1 ohm). R_a is adjusted to give a full scale reading. Find the value of R_a with an ohmmeter. The voltage at the input is: $R_b \times V_1 / (R_a + R_b)$. The same scheme can be used with the amplifier turned off for determining the millivolt calibration of the meter. The voltage gain is given by the ratio of the two values of R_a , if the value of R_b is small by comparison.

You can obtain the current calibration from the voltage calibration and the known value of R_p . You can also find it directly by using the voltage divider circuit. To do so, connect a known resistance R_m — on the order of megohms — between the voltage divider and the input of the amplifier; then adjust R_a for full scale deflection. Assuming that the voltage across the terminals of the IC is negligible when compared with V_2 , the current for full scale deflection is V_2 / R_m .

Refinements

I have given the details for a simple construction project which creates a compact instrument. There are a number of refinements you can add to make this device more useful.

- You can build the detector shown in **Figure 1** into the box that holds the op amp. It can be disconnected by an SPST switch in series with the diode. The presence of the choke

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and bypass capacitor aren't likely to affect the amplifier's use in other applications.

- **Figures 3 and 4** suggest that the feedback resistor R_f is a continuously variable resistor. There are times when you may want to reduce the gain, but have reproducible settings. I suggest using a tap switch with fixed resistors valued at 1 k, 3.3 k, 10 k, 33 k, and 100 k corresponding to approximately 10-dB changes in gain. If the switch has some extra positions, you might use one of them for a 220 or 330-k resistor.
- There's a gap in sensitivities with high-resistance input sources. With the amplifier off, the input is too small to give a detectable reading at some input levels. With the amplifier on, and with the lowest gain setting, the meter is off scale. For convenience, switch in some resistors in shunt with the amplifier input to bridge this gap. You'll have to experiment to find the specific values needed for a particular circumstance.
- You might want to add a reversing switch, especially if you plan to use the amplifier with inputs of both polarities. Add the switch at the input for the LM324 amplifier, and insulate both input terminals from ground. When the internal zeroing action is working correctly, the circuit won't respond to signals of the incorrect polarity. The meter refuses to deflect at all, rather than deflect backwards. If you're using the LM741 amplifier, place the reversing switch at the output, where it can be useful in adjusting the balance.
- As I suggested earlier, you might build a calibrated source of bucking voltage into the input of an LM324 amplifier.

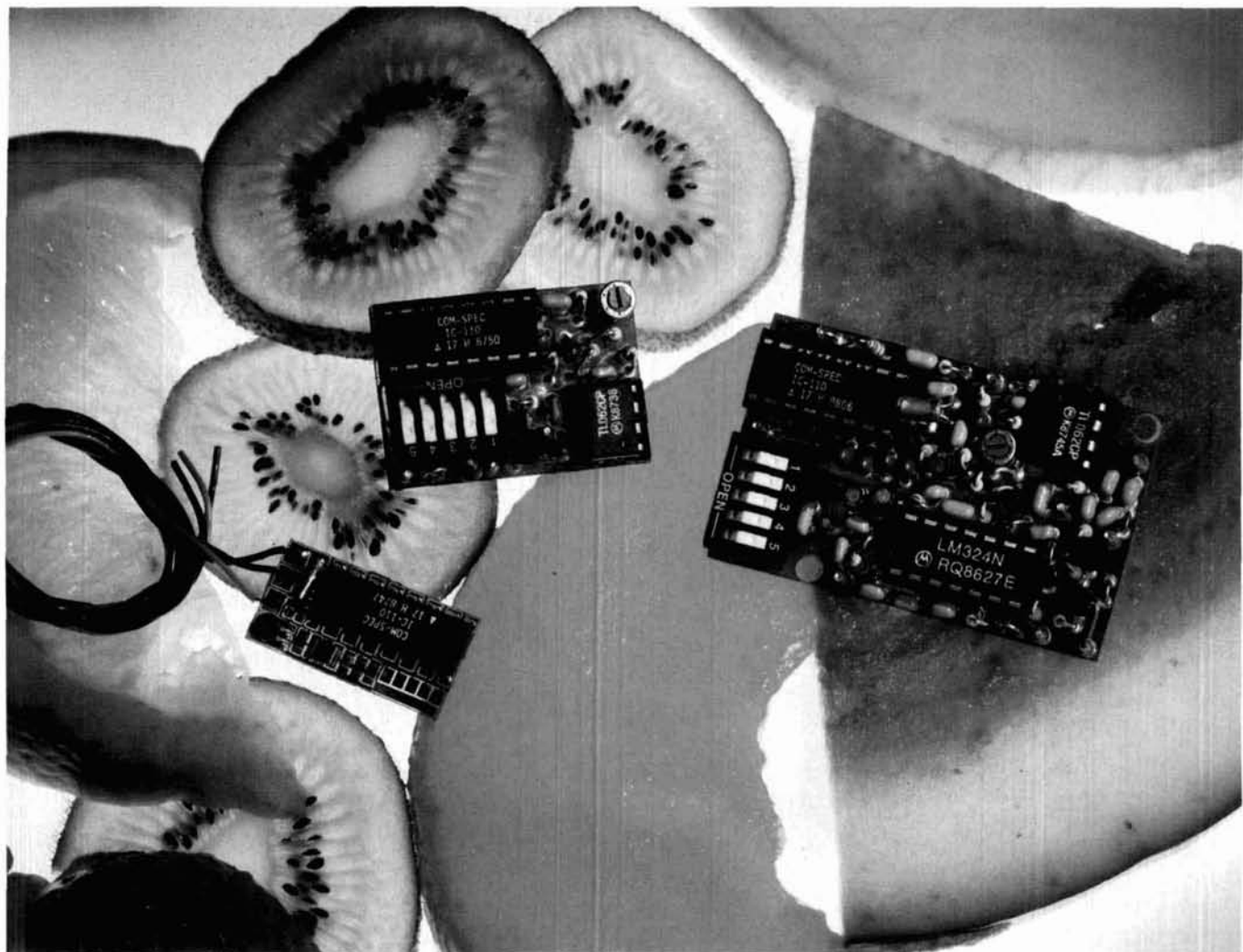
Conclusion

Beginners should find this article a helpful introduction to op amps. Op amps have wide applications. While they are most often used as some form of DC amplifier, they may also be used as AC amplifiers. Such amplifiers should have blocking capacitors. It's more feasible to cascade AC amplifiers because the zero offset of one stage is not amplified by the next. If you use feedback networks with capacitors, the op amp becomes a very effective filter.

These are topics discussed in many current magazine articles as well as the references given below^{2,6}. For beginners, I recommend **Reference 3**. For an advanced treatment read **Reference 5**. It contains internal circuit diagrams of the LM324 and LM741 amplifiers along with data on their ratings. For practical circuits using operation amplifiers in diverse applications, I suggest **Reference 6**. For a discussion of the zero offset problem and some of the improved op amp chips now available, see **Reference 7**. **Reference 8** and **9** are useful survey articles on op amps. 

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9. Joe Carr, K4IPV, "Practically Speaking: An Overview of Operational Amplifiers: Part 2," *Ham Radio*, December 1988, page 83



Choice Selection.

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SOLID-STATE SWITCHING THE MIDLAND 13-509

By Nick Ciarallo, VE2HOT, 85 Celtic Drive, Beaconsfield, Quebec H9W-3M6

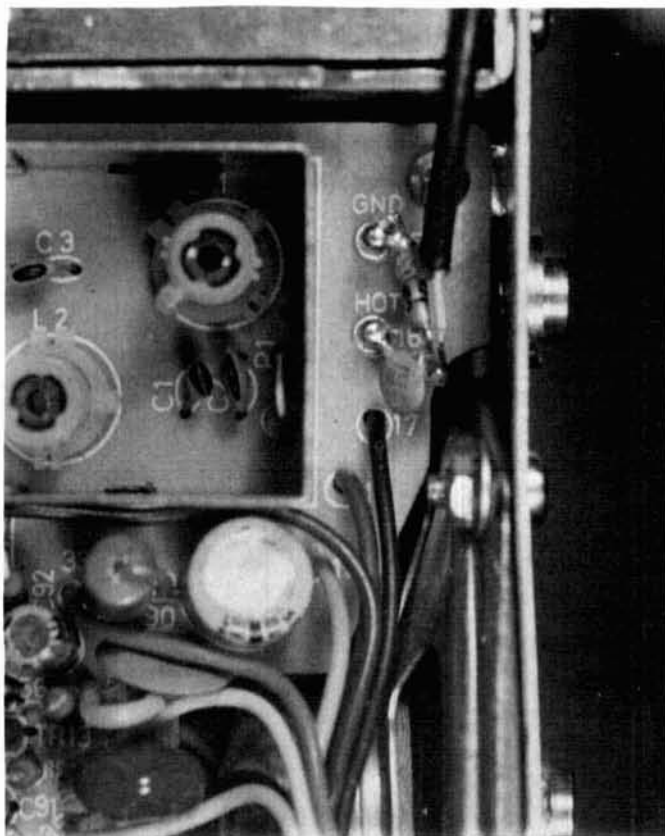
If you have a Midland 13-509, you might have the same problem I had. About two years ago, the TX/RX relay was on its way out and was driving me crazy! The radio transmitted intermittently, so I suspected the relay. It looked hopeless and I decided to trash it. I've seen articles on solid-state switching for other radios, but nothing for the famous 13-509. So, as they say, I had to "roll my own." Because I would be removing the relay, I had to make sure the circuit would do what the relay did. That is:

- Supply +12 volts to the transmitter and the PIN diode switch when keyed.
- Supply the receiver with +12 volts when unkeyed.
- Handle the RF switching.

How it works

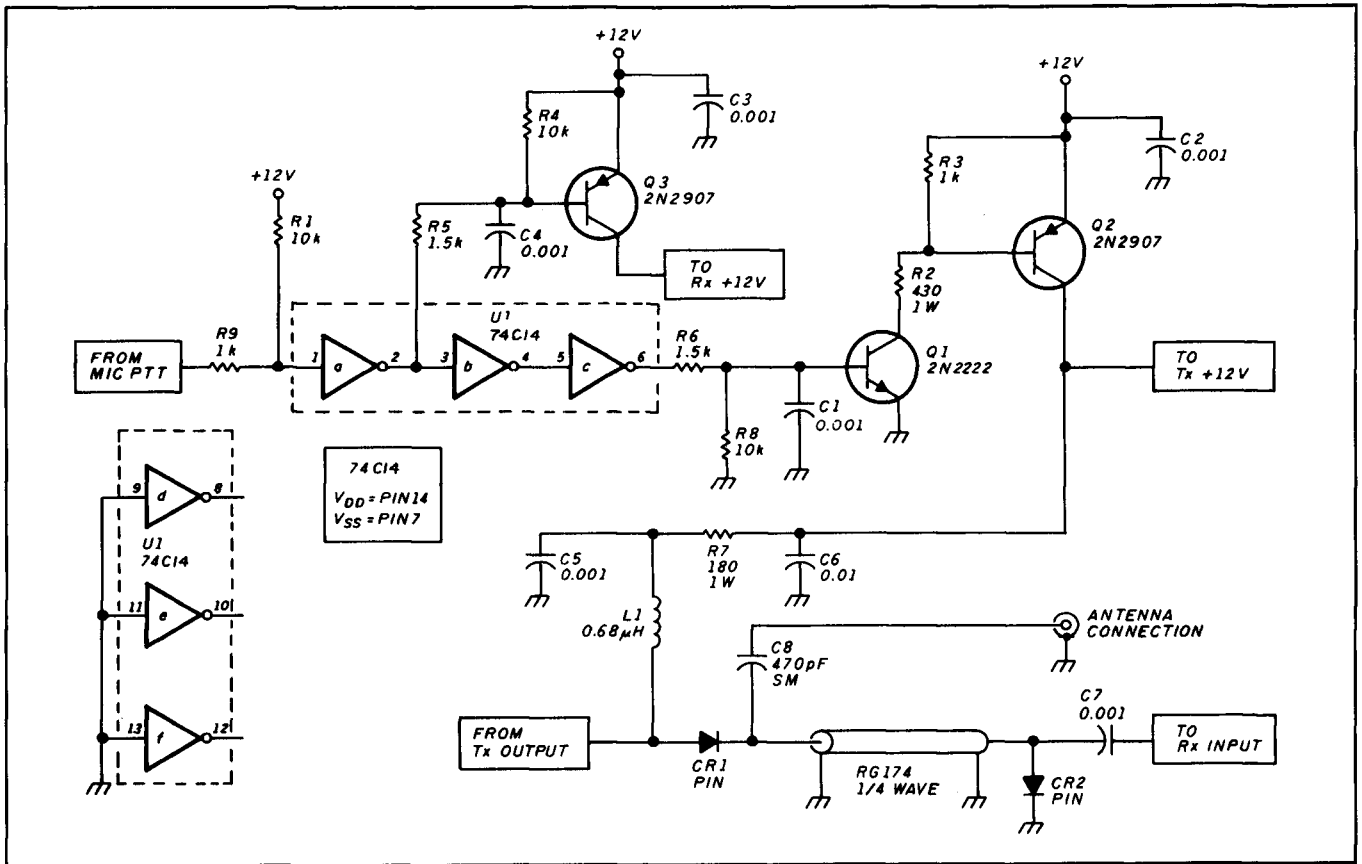
When the radio is keyed, the RF switch has to show the transmitter a short circuit (or something close to it) to the antenna. At the same time, the switch must isolate the receiver's sensitive front-end components from the transmitter's high-power signal. When the radio is keyed, both PIN diodes are turned on (see **Figure 1**). The first PIN (CR1) provides a low-impedance path for the transmitter to load into the antenna; the second PIN (CR2) is essentially a short circuit at the receiver input. The coax between the receiver and antenna acts like an impedance transformer because it's a quarter wavelength long at 223 MHz. This makes the short circuit caused by PIN diode CR2 at the receiver input look like a high impedance at the antenna. When you unkey the radio and put the switch in receive mode, both PIN diodes are removed from the circuit because they no longer have any bias current. The antenna now sees a high-impedance path to the transmitter and a short circuit to the receiver. Consequently, none of the received signal is

PHOTO A



Receiver PIN diode installation (CR2 in **Figure 1**). The PIN diode is located next to the word **HOT**. Note there is no excess length where the RG-174 makes its connection to the diode.

FIGURE 1



The 13-509 PIN diode switch schematic. Note the unused inputs of the 74C14 are connected to ground.

absorbed by the transmitter's output circuitry and there's no loss of receiver sensitivity. If you want to know more about PIN diodes and PIN switches, OA4KO/YV5 has written an excellent article on the subject.¹

The design

First, I removed the relay. Then I measured the current requirements for the transmitter and receiver. The switched 12-volt line that feeds the transmitter supplies everything except the driver and final. The current drawn by these stages is about 200 mA. The receiver draws 140 mA at full volume, unscquelled. The PIN diode switch requires 60 mA (a little less than the relay). Armed with this information, I was ready to design the DC switching circuit. The most convenient way to do the switching was to start with a hex inverter to provide the appropriate levels, and then buffer the outputs to supply the required current. I selected a 74C14. Because the current demands for the radio aren't very large, you can use small transistors. I used 2N2907s and they worked just fine. Empirically select the resistor that determines the bias current for the PIN diodes. The resistor you use depends on which diodes you choose. Almost any PIN diode will work; just make sure it can handle the power. Don't shy away from ones that look like 1N914s; they can probably handle a hundred watts. Check the specs!

The transformer

The coaxial transformer for 223 MHz is 8.75" long and

PARTS LIST

CAPACITORS

- 2 0.01 μF
- 5 0.001 μF
- 1 470 pF/SM

RESISTORS

- 1 180/1 watt
- 1 430/1 watt
- 2 1 k
- 2 1.5 k
- 3 10 k

INDUCTORS

- 1 0.68 μH

DIODES

- 2 PIN diodes (see article description)

SEMICONDUCTORS

- 1 2N2222
- 2 2N2907
- 1 74C14

MISCELLANEOUS

- 10" piece of RG-174 50-ohm coax perfboard

is made from RG-174 mini coax. Make sure the 50-ohm section is the proper length. If you cut a piece of coax that is 10" long and strip off and separate 1/2" from each end, the actual 50-ohm section will be 9 inches. The formula for determining the coaxial cable length is as follows:

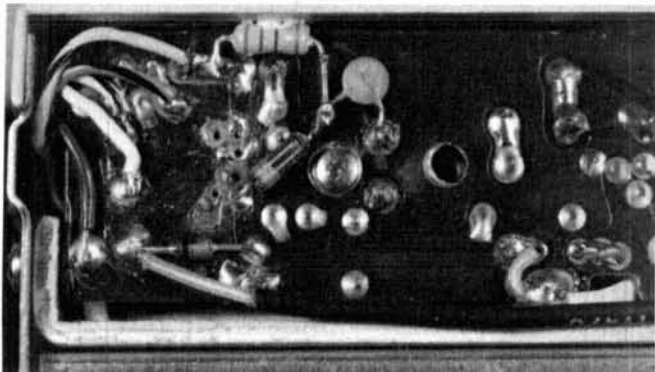
$$1946/F_o = L$$

where F_o is the frequency in MHz, and where L is the length in inches

for 66-percent velocity factor coax

example: $1946/223.0 = 8.73"$;

round off to 8.75"

PHOTO B

Transmitter PIN diode installation. There are "stripline" inductors for SWR protection circuit. Again, note there is no excess lead length where the RG-174 connects to the PIN diode.

Installation

I mounted the PIN diode and coupling cap for the receiver across the antenna input terminals on the receiver strip (see **Photo A**) and ran the quarter-wave coaxial transformer over to the antenna connection, where the relay used to be. I installed the PIN diode for the transmitter on the foil side of the board near the relay location, after the "stripline inductor" which couples RF to a second stripline inductor located next to it (see **Photo B**). These inductors are actually parallel traces on the pc board, used to couple RF to the diode that detects reflected power for the VSWR protection circuit. My last addition was a capacitor right at the antenna connector. I used a 470-pF silver mica unit. You must install this cap to prevent the +12 volt (TX) switched line from supplying the antenna with DC. In my tests, this capacitor didn't affect the performance of the radio in any way.

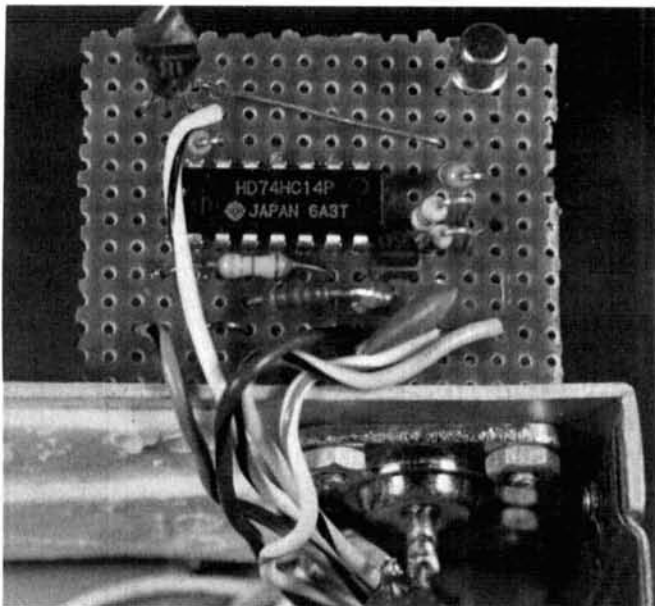
I built the logic circuit on a small piece of perfboard. The relay pads provide all the connections necessary for the solid-state switch. Make sure you tie **all** unused inputs of the 74C14 to ground and bypass the chip by placing a 0.01- μ F capacitor across its supply pins. Keep all RF connections as short as possible.

Photo C shows the solid-state switch just before installation. I used double-sided tape to mount the completed circuit in the compartment at the back of the radio where the relay used to be. **Photo D** shows the circuit mounted with double-sided tape.

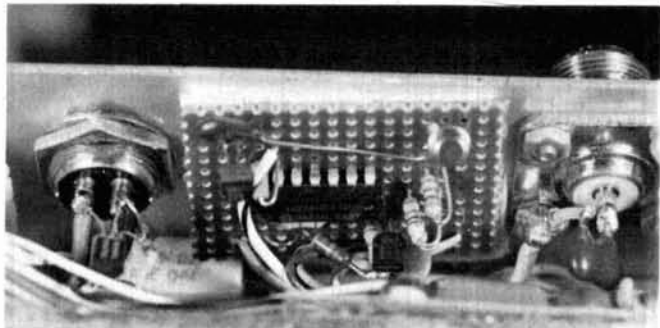
Results

Your radio will switch quickly after you make these modifications. I measured 20 ms to full power, which is an improvement on an already fast-switching radio. Receiver sensitivity improved and the radio is now quieter since I've removed what had become (in my radio, anyway) a very lossy relay. The same holds true for the transmitter.

The power output increased 4 watts. This 4-watt difference equates to the removal of about 1.6 dB of insertion loss! Since the RX/TX turnaround time is faster, you can use the radio for high-speed packet linking without worrying that the relay will die in mid-January at your remote repeater

PHOTO C


Completed circuit before installation. A 74HC14 was used in the original design; the 74C14 has been substituted due to greater availability.

PHOTO D

The PIN diode switch installed. The double-sided tape holds the complete PIN diode switch assembly securely.

site. After over two years of daily service with this modification installed, my radio hasn't given me any problems.

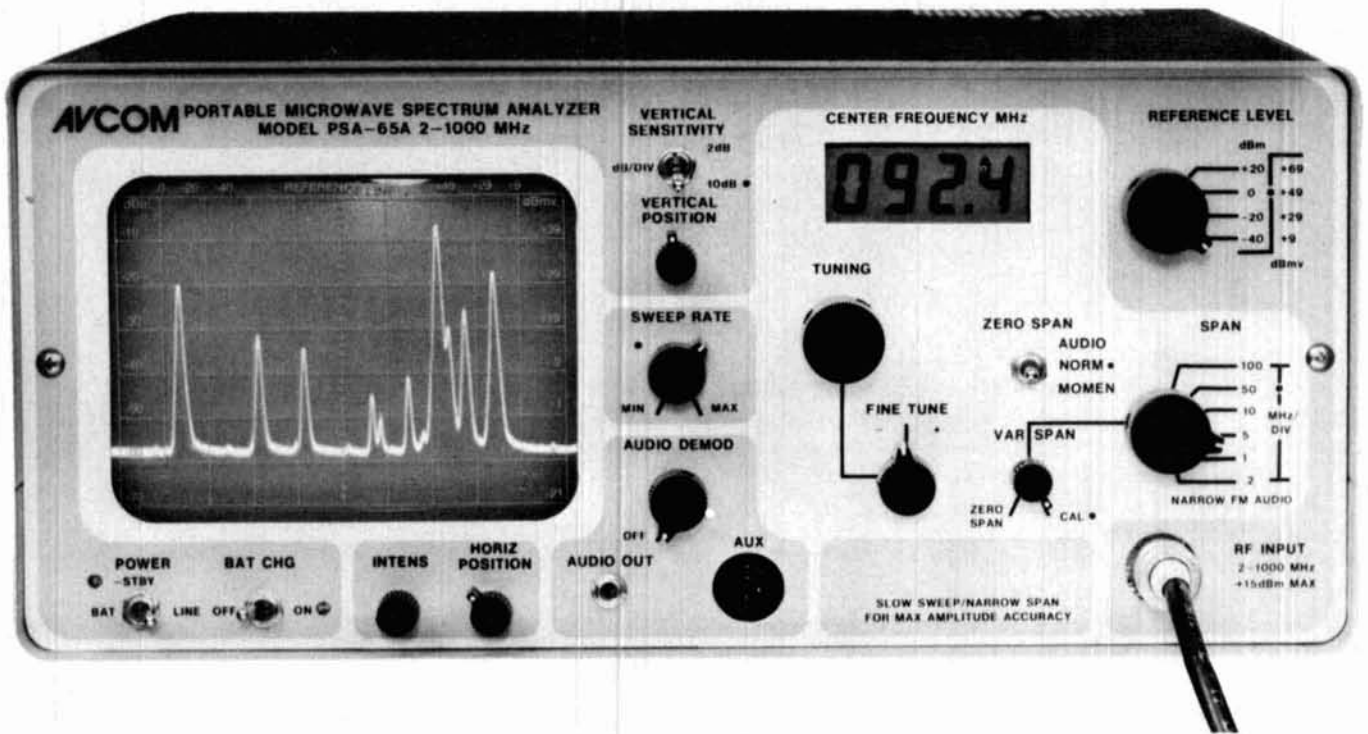
Final note

I'd like to hear from anyone with suggestions and/or modifications for this circuit. If you have questions about the circuit and its installation, send me an SASE and I'll try to answer you as fast as possible. I'd like to thank Jean-Guy Deschênes, VE2BEY; Henry Szczawinski, VE2BJR; Ben Soo; and Dino Moriello, VE2FSA, for their help in putting this article together. If you have a question that you feel can be answered on packet, I can be reached at NA2B. 

REFERENCES

1. Luis E. Suarez, OA4KO/YV5, "Make the Switch to PIN Diodes," 73, October 1986, pages 28-32.

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Ham Radio Techniques

Bill Orr, W6SAI

COAX REVISITED

We were jammed in the tail of the A-20 (Boston) attack bomber, electrical cables and steel control wires all around us. It was pitch black except for the beam of my flashlight. The noise was deafening. Herbie, W6KJT, leaned against me and shouted in my ear, "Feel the cable!" I did as he told me and found that the coax cable was very warm to the touch. I knew the cable was running hot because of the RF in it. I had just turned on the aircraft transmitter a few moments before and locked the key. Then we had crawled to the back of the fuselage to determine the condition of the coax feeding the antenna.

"That's only 100 watts in the cable," he yelled. "Come along with me!" We squirmed forward, dropped into the bomb bay of the fuselage, and slid to the cement floor of the factory. I turned off the transmitter on my way out of the aircraft.

The A-20 production line stretched, plane after plane, until it disappeared at the back of the Douglas Aircraft assembly plant. At the far end of the line, the skeleton frames of the A-20s were attacked by gangs of riveters whose tools made an ear-splitting din — like that of a thousand machine guns. As the planes progressed along the line, their wings, engines, landing gear, and other major parts were added. By the time an aircraft reached the point on the line where we were standing (next to the huge hangar doors) it was complete, loaded with radio and navigation equipment, and almost ready for flight testing.

It was mid-summer 1941 and the building was hot. Herbie dusted himself off and led me to the radio room at the side of the building. "Starting



right now, on plane number 386, we stop using this old copolene-insulated coax line and start using some new coax called WC-549. It has a brand-new polyethylene inner dielectric and is rated for use at 400-watts power up to 200 megacycles!"

Two hundred megacycles! I looked at the new coax, glistening in its black jacket. Just the thing for my post-war ham rig! W6KJT grinned as he read my thoughts. He pointed to a large box full of interesting devices. "New style coax plugs and receptacles! The military nomenclature is PL-259 for the plug and SO-239 for the socket. There's also a splice adapter. When all of this stuff gets on the market after the war, ham radio will never be the same again!"

I agreed. But how much would this new, efficient coax line cost? Maybe hams wouldn't be able to afford it!

The low-loss coax didn't become available for civilian use until 1946 when the military dumped miles of it on the surplus market (see **Figure 1**). It sold from two to five cents a foot,

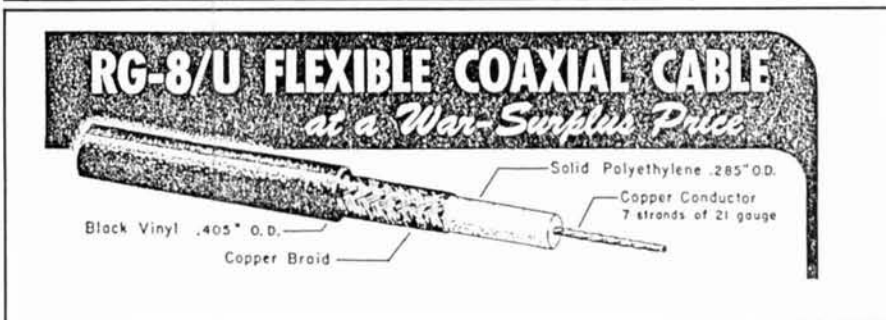
depending upon the quantity ordered. In the interim, the Army-Navy RF Cable Coordinating Committee had standardized the cable at 52-ohms impedance, defined its characteristics and had renamed it RG-8/U. (The nomenclature described it in the military cable procurement list: "RG" stood for "Radio Guide," the number "eight" indicated the serial number of the particular cable type, and the "U" stood for "Utility" service.)

A companion, smaller diameter, low-power cable (RG-58/U), was also manufactured during the war in vast quantities. It was available as surplus at a comparable low price. I was so carried away with enthusiasm that I bought a 500-foot roll of each cable type.

It was a whole new ball game for Amateur Radio. The transition from open-wire line to coax was difficult, but it paid important dividends once television became popular and we had to deal with TVI problems. The wartime development of the SWR meter also provided Amateurs with a quick and meaningful readout of antenna operation.

During the fifties, military coax sys-

FIGURE 1



Military surplus coaxial cable sold for from two to five cents in 1946.

tems underwent another major modification. HF and VHF systems were standardized on a 50-ohm impedance level. Because the venerable RG-8/U was a 52-ohm cable, it was obsolete and would be dropped from the military inventory to be supplemented by an equivalent 50-ohm line, RG-213/U. The smaller companion cable RG-58/U (53.5 ohms) was dropped in favor of the interim RG-58A/U (50 ohms) and the new RG-58C/U (50 ohms). That was the end of the matter, or so it seemed.

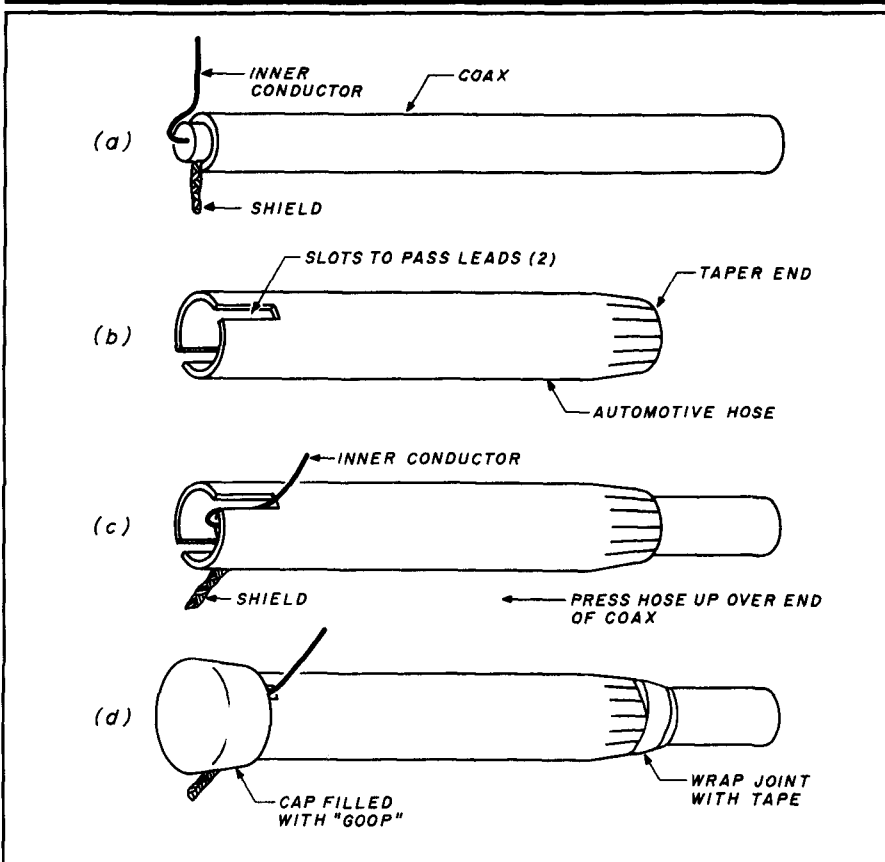
Today's coax confusion

The military cable change opened the door for the manufacture and sale of "RG-8 type" coax cable of questionable quality bearing a seemingly authentic military acceptance number. Any outfit with a secondhand cable-making machine could grind out cheap RG-8 type cable made to any specification. The unsuspecting purchaser, seeing the look-alike cable at an attractive price, was often conned into thinking he was getting a high-grade product. Not so! Some RG-8/U and RG-8A/U cables are still made to the old military specifications by reputable manufacturers, but a lot of today's RG-8/U isn't.

It's easy to make a cheap coax line. Copper creates the major material cost; the cost can be reduced when there is less than the optimum number of fine wires in the outer braid and the braid's weave is looser. The inner conductor can be made of smaller gauge wire, or can have less wires than in the approved coax. The inner insulation can be made of reclaimed or substandard material and the outer jacket can be made of inferior vinyl that has pinholes. The alignment between inner conductor and outer shield may be imperfect. Finally, the rigid inspection and testing given to approved cable types may be entirely absent.

You may not notice results of using cheap coax right away. The first thing you'll find is that it's difficult to place a PL-259 plug on the coax. Good coax has a 97-percent shield coverage. This means that only 3 percent of the shield area is open; the remainder is composed of small copper wires. Less expensive coax may have as little as 75-percent shield coverage, leaving 25 percent of the shield area open. This

FIGURE 2



Making the coax center insulator. See text for instructions.

plays havoc when you try to solder a coax plug on the cable. As soon as the shield wires are hot enough to solder, the polyethylene inner insulation melts and squirts out between the wire interstices, making soldering almost impossible.

It's okay to use this cheap cable at the lower frequencies (like 160 and 80 meters), providing you can solder on the coax fittings. Loss is low and overall shielding is adequate. It's not a good idea to use solderless coax plugs to overcome the soldering problem — but that's another story.

When copper is eliminated in a cheap cable, the cable characteristics change. The 75-percent shield coverage of the cable results in a characteristic impedance of about 60 ohms! Velocity of propagation is also higher and averages 78 percent, as contrasted with 66 percent for the approved line. This can get you into big trouble if you're cutting quarter-wave line sections to formula and not bothering to check line length with a dip meter.

In the VHF region, the cheap coax doesn't fully isolate the inner conductor from the outside environment. This diminishes the good electrical isolation quality of the cable.

How can you tell good coax from the cheap stuff? One way is to weigh 100 feet of the line. RG-213/U or good RG-8/U weighs about 11 pounds. The cheaper line may weigh as little as 8 pounds per 100 feet.

"Foam" coax

A new type of coax line appeared on the market in the fifties. The inner dielectric, called "cellular polyethylene," contains many tiny bubbles. The cable is slightly more flexible than an equivalent one with a solid dielectric, and has substantially less loss in the VHF region than common solid dielectric coax. Below 50 MHz, however, there's only a slight advantage in using foam coax for Amateur operations.

A lower loss cable for VHF/UHF use has inner insulation composed of a thick polyethylene insulating thread that wraps around the center conduc-

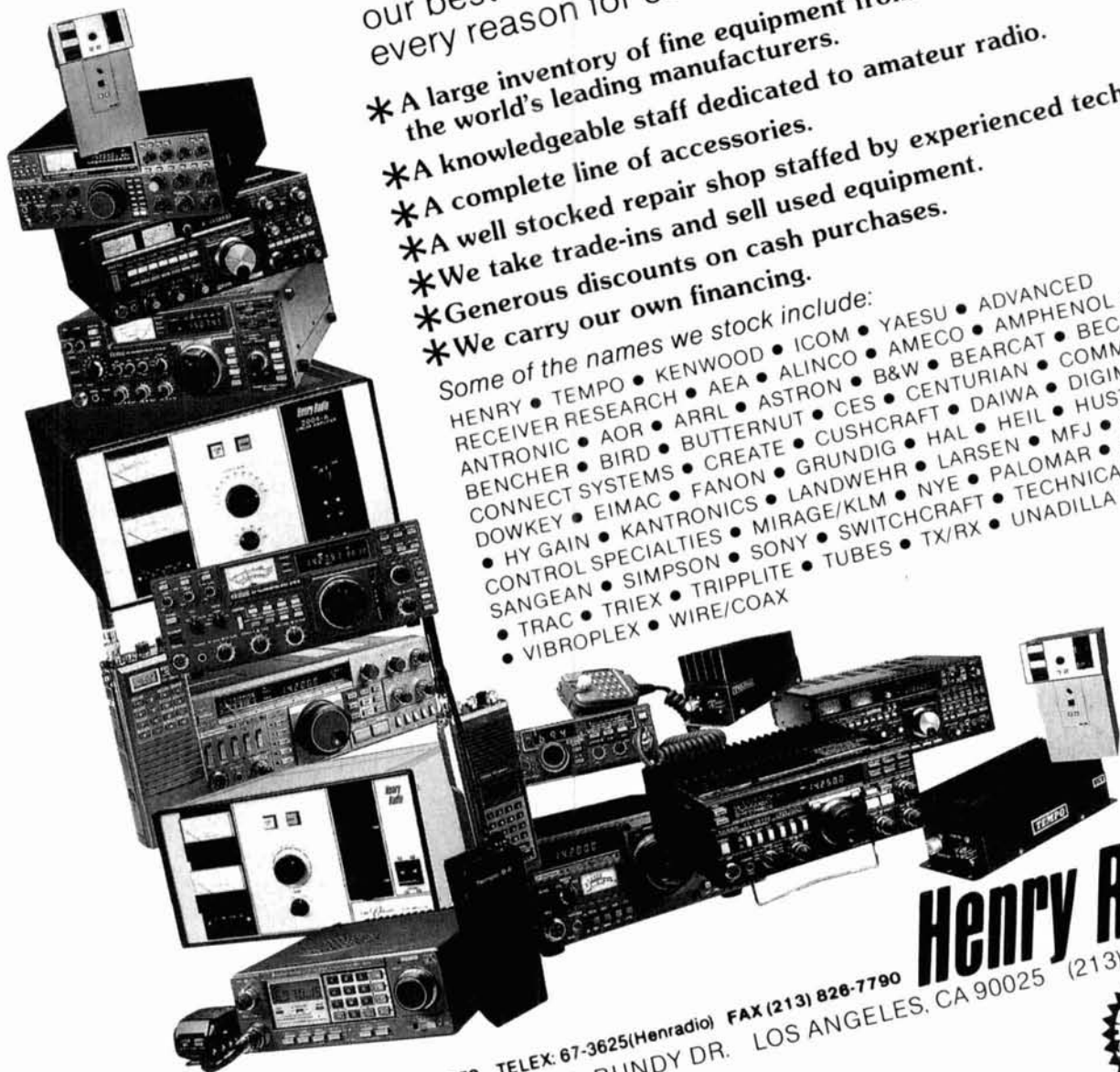
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TABLE 1

Popular types of "50-ohm" coax lines. Approximate weight is in pounds per 100 feet. The cable impedance is Z and the velocity of propagation is V.P. The Military Standard is given where applicable. The inner dielectric is either solid polyethylene (P) or cellular polyethylene (foam). The percentage of shield coverage is given.

Coax	Belden	Saxton	Weight per 100 ft	Z	V.P.	Conductor inner/outer		Mil. Std.	Dielectric
RG-8/U	8237	8282	11.5	52	66	A	G	JAN-C-17A	P
RG-8A/U	9251	1584	11.5	52	66	A	G	MIL-C-17D	P
RG-8/U type	8214	8284	11.0	50	78	B	G	—	F
RG-8/U type	9208	1583	8.5	57	78	A	H	—	F
RG-8X (mini)	9258	8315	4.1	50	78	C	J	—	F
RG-213/U	8267	8409	11.5	50	66	A	G	MIL-C-17D	P
RG-58/U	8240	8289	3.2	53.5	66	D	K	JAN-C-17A	P
RG-58/U type	9201	1589	2.9	53	66	D	L	—	P
RG-58A/U	8259	7290	2.9	53	66	D	L	JAN-C-17A	P
RG-58C/U	8262	1591	2.9	50	66	E	K	MIL-C-17D	P
RG-58C/U	9203	—	2.9	50	66	E	K	MIL-C-17E	P
RG-58/U type	8219	1600	2.9	50	78	F	M	—	F

The inner conductor is defined as:

- A—13 AWG 7 strands no. 21 solid copper
- B—11 AWG 7 strands no. 19 solid copper
- C—16 AWG 19 strands no. 29 solid copper
- D—no. 20 solid copper
- E—20 AWG 19 strands × 0.0071 diameter solid copper
- F—20 AWG 19 strands no. 32 solid copper

The outer shield is defined as:

- G—Bare copper, 97-percent shield coverage
- H—Bare copper, 80-percent shield coverage
- J—Bare copper, 95-percent shield coverage
- K—Tinned copper, 95 percent shield coverage
- L—Bare copper, 78-percent shield coverage
- M—Tinned copper, 96-percent shield coverage

tor. The outer shield is made up of two layers. The inner layer is a closed aluminum wrapping; the outer layer is a tinned copper braid that has 60 to 97-percent coverage. Either combination provides 100-percent cable coverage.

In addition to these common cables, you can purchase specialized cables for CATV use with a nominal impedance of 75 ohms. These have limited applications for general Amateur service.

I've summarized some useful cables for Amateur Radio operations in Table 1. The cables are cross-referenced to Belden and Saxton catalog numbers for your convenience.

A cheap and effective center insulator

Do you need an inexpensive center insulator for a Field Day dipole? You can buy several different makes, but here's a design you can build yourself

for just a few pennies. The idea originated with Lloyd Bensen, W9YCB. The device is light, waterproof, and made of easily obtainable materials (Figure 2). Lloyd uses his insulator on a beam because he had problems with water entering the line.

The heart of the assembly is a 4-1/2" length of 1/2" (inner diameter) automotive hose. Taper one end of the hose with a razor or sharp knife, and slot the other end to receive the wires of the coax cable. Slide the hose over the cable as shown, with the slotted end facing the end of the cable.

Prepare the cable by fanning out the braid and unbraiding about 2" with a pointed tool. Twist this portion of the cable into a tight pigtail. Now remove the inner insulation, leaving only a protective collar about 1/8" long between the inner conductor and the outer, braided pigtail.

Bend the coax conductors into the shape shown in the drawing and tin

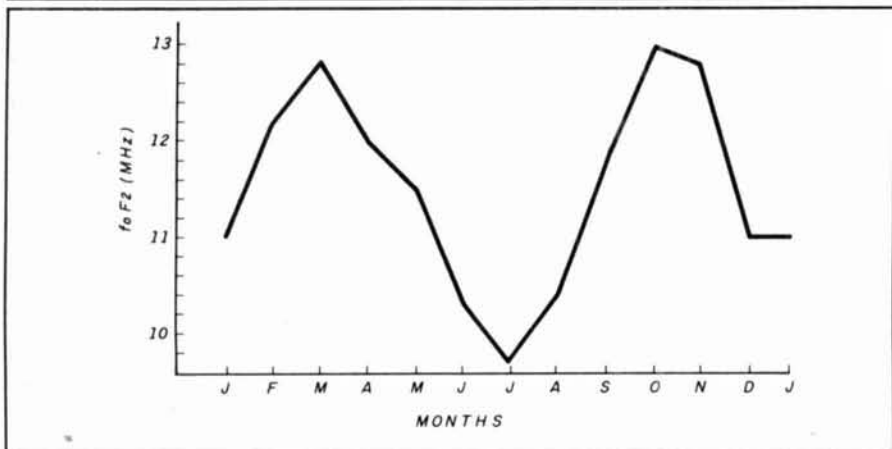
them. Extend the tinning back to the insulating material. Tin the exposed portion of the outer braid all around the cable. Finally, cut the conductors back leaving leads about 3/4" long.

Press the hose up so the tinned conductors drop into the slots you cut. Taper the slots slightly for a tight fit.

Now weatherproof the end of the cable. Lloyd recommends using a plastic cap from a hardware store or home service center. A cap with about 5/8" inner diameter slips nicely over the hose. Cover the end of the cable and the inside of the cap with semi-liquid insulation before attaching the cap. Lloyd used "Sportsman's Goop" from a sporting goods shop. (You could fill the cap with quick-setting epoxy instead.) Press the cap over the hose and the end of the cable and carefully wipe away any excess goop or epoxy around the conductors.

Wrap the tapered end of the hose with vinyl tape. Extend the tape an inch

FIGURE 3



Seasonal change in ionospheric reflection averaged monthly since 1946, as observed by KH6SB at the Maui (Hawaii) Ionospheric Station. Measurements were made during daylight hours (1100 to 1700 HST) on vertical angle of reflection. Maximum Usable Frequency (MUF) is about three times higher than measured reflection frequency (FoF2) shown. The MUF has been highest during months of March, October and November, regardless of sunspot cycle number. Low point of the MUF is reached in July. (Measurements taken mid-month intervals.)

or two down the coax line. This prevents moisture from entering the end of the hose and being drawn up into the coax by capillary action.

It takes almost as long to read this as it does to make the joint. Try one of these simple devices out on your next Field Day antenna!

Radio conditions getting better!

In my September 1988 column I discussed ionospheric readings made at the Maui, Hawaii Ionospheric Station by Steve, KH6SB. One of the charts shown depicted the average value of F2 reflection measured by a pulsing

technique on a vertical path. The chart was for a 24-hour time period, averaged each month since 1946.

Figure 3 shows the same measurements plotted over a 7-hour period, corresponding to the daylight hours. This provides a more realistic picture as the higher frequency bands are usually closed to F2 skip during the hours of darkness.

The chart is especially meaningful as the sunspot cycle continues to rise. It shows that DX conditions are at their best during mid-February through mid-May. A second period of good DX activity falls during the period of mid-September through mid-November.

DX conditions during the winter aren't bad, but they are limited by the short span of daylight. Summer DX conditions, on the other hand, are poor from mid-May through mid-September. If you want to take a vacation or work on your antenna, this is the time to do it!

The "Dead Band" contest

I want to express my appreciation to all who write me in regard to these little tests of expertise. I appreciate your support and kind remarks. I'm sorry I can't reply to each of you in person. I'd like to extend a hearty "thank you" to all who took the time to write.

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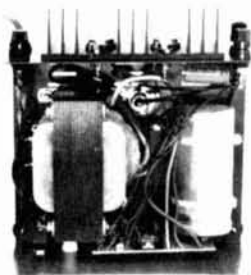
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RS-5A	4	5	3½ × 6¾ × 7¼	7
RS-7A	5	7	3¾ × 6½ × 9	9
RS-7B	5	7	4 × 7½ × 10¾	10
RS-10A	7.5	10	4 × 7½ × 10¾	11
RS-12A	9	12	4½ × 8 × 9	13
RS-12B	9	12	4 × 7½ × 10¾	13
RS-20A	16	20	5 × 9 × 10½	18
RS-35A	25	35	5 × 11 × 11	27
RS-50A	37	50	6 × 13¾ × 11	46

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• Switchable volt and Amp meter				
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• Separate volt and Amp meters				
RS-20M	16	20	5 × 9 × 10½	18
RS-35M	25	35	5 × 11 × 11	27
RS-50M	37	50	6 × 13¾ × 11	46

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VS-35M	25	15	7	35	5 × 11 × 11	29
VS-50M	37	22	10	50	6 × 13¾ × 11	46
• Variable rack mount power supplies						
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RS-10S	7.5	10	4 × 7½ × 10¾	12
RS-12S	9	12	4½ × 8 × 9	13
RS-20S	16	20	5 × 9 × 10½	18

Ham Notebook



A Big Video Monitor for Packet Demonstrations

Packet operators are often called upon to give demonstrations to public officials or Amateur Radio groups. Because of the small screen, everyone has to crowd around to see what's going on. Small computer screens create difficulties for sight-impaired hams as well.

There are large-screen (and even projection) TVs available, but most equipment designed for off-the-air television reception has only a 4.5-MHz video bandpass and is unable to display the "normal" 80 columns. (Commodore and Apple default to 40 columns because many people use ordinary television sets as monitors.) The serious computer user needs a monitor with a video bandpass of at least 12 MHz.

There is a family of excellent large-screen monochrome video monitors that meet the 12-MHz video bandpass requirement. These are the 19-inch Motorola M5000s and 23-inch Motorola M7000s made for use as flight annunciator displays at airports. Unfortunately, they are no longer manufactured, but service literature and parts are still available and the monitors do show up at computer and ham flea markets.

A frequently asked question is: "Will my computer have enough output to drive a large-screen monitor like that?" Luckily, this is no problem. A monitor requires two inputs, power and signal. While the power requirement may go up (these units require 110 watts), the signal requirement is independent of screen size.

The M5000 and M7000 require 117 volts AC and a "composite" video sig-

nal (the normal output from most computers like the Apple or Commodore). They are specified to have a horizontal sweep frequency of $15,750 \pm 500$ Hz with a vertical of 50 or 60 Hz.

It would probably be wise not to share this tip with our non-ham computer friends, or they'll dry up the entire supply, and there won't be enough left for us...

David McLanahan, WA1FHB

A Simple Infrared Detector

My house is full of remote gadgets. The TV, VCR, and other assorted goodies all respond to commands issued on invisible rays of infrared light. Even my ham shack hasn't been spared; optical interrupters have replaced multisection tuning capacitors in receivers and transceivers. For most of us, trouble-shooting these devices has been limited to changing the battery and hoping for the best.

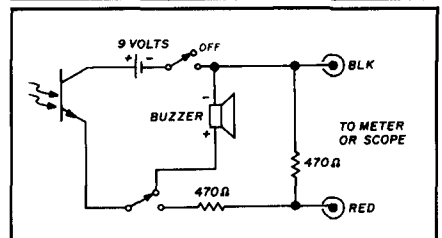
This project is designed to detect infrared light. It can be used in conjunction with a scope to verify that encoding information is present.

I enclosed my detector in a 4-3/4x2-1/2x1-1/16 plastic case, but the circuit is simple enough that you can breadboard it when the need arises. I found all the parts at the local Radio Shack for under \$15. Construction isn't critical; I mounted all of the components on the case's front panel and used point-to-point wiring.

The circuit is shown in Figure 1. To keep things portable, you can use a

piezoelectric buzzer in place of the scope for infrared detection. The encoded binary information emitted from a hand controller will modulate the buzzer's tone. I mounted the phototransistor in an LED bezel. You can also install it in the barrel of an old pen (with a length of RG-162 going back to

FIGURE 1



The circuit for the simple infrared detector.

PARTS LIST

Quantity	Description	Radio Shack part number
1	IR phototransistor	276-145
1	piezo buzzer	273-065A
2	SPDT switches	275-603
2	470 ohm 1/2 watt	271-019
1	9-volt battery	23-464
1	battery connector	270-325
1	battery holder	270-326A
2	binding posts	274-661
1	plastic case	270-222
1	LED bezel	276-080

the remaining circuitry) for probing around infrared sources in shaft encoders and other tight areas.

The detector saturates when used outdoors during the daytime. A small 3 or 4-inch tube placed in front of the phototransistor will reduce incidental pickup.

Peter J. Bertini, K1ZJH

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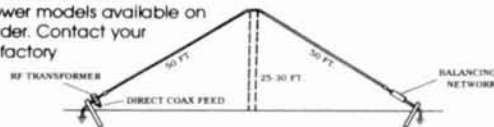
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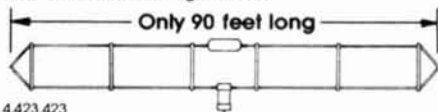
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THE BATTLE OF THE BEAMS

PART 1

By D. V. Pritchard, G4GVO, 55 Walker Dr., Leigh on Sea, Essex SS9 3QT, England

1940...Now, nearly 50 years from those near-disastrous days, how many of us remember (or even know of) the debt of gratitude owed to one man who confounded the radio experts and overcame officialdom to earn Churchill's praise as the man who "broke the bloody beams" — who went on to unravel the secrets of German radar and Hitler's "V weapons," the V1 pilotless flying bomb (the "doodlebug") and the V2 rocket?

Born in London in 1911, R. V. Jones was educated at St. Jude's, Herne Hill, and later at the Elementary School in Sussex Road, Brixton, where he won a scholarship to Alleyn's School, Dulwich. Awarded an Open Exhibition in 1929 to Wadham College, Oxford, he worked in the Clarendon Laboratory under Professor Lindmann (later Lord Cherwell and Winston Churchill's wartime Scientific Adviser), where he turned his talents to infrared detection — an interest he was to pursue for the next 30 years.

In 1939, he was appointed Scientific Officer to the Military Intelligence Service (MI6) to find out what the Germans were doing in the way of applying science to warfare. In early 1940, he came to believe that they had a radio-navigation system by which they hoped to bomb accurately at night.

Knickebein—the crooked leg

From captured documents found in crashed German aircraft he came across the word *Knickebein*, or "crooked leg." The Germans' code names were informative — this one even sounded like a beam. But what kind was it?

Then two prisoners of war were overheard to speak of something called *X-Gerät*, or "secret apparatus;" evidently it was something used in an aircraft, and involved radio pulses. A thriller could hardly have a more intriguing title, but what was *X-Gerät*— and was it the same as *Knickebein*? Deeply interested, Jones pressed his Intelligence sources for more information and in March was rewarded with the navigator's notes from a shot-down Heinkel. *Navigational Aid: Radio Beacons working on Beacon Plan "A."* Additionally from 0600hr

Beacon Dühnen. Light Beacon after dark. Knickebein from 0600hr on 315°.

Shortly afterwards, a cooperative prisoner said that *Knickebein* was a beam so narrow and exact that two of them could pinpoint a target with an accuracy of less than a kilometer. He also added that *Knickebein* was in some ways similar to *X-Gerät*, assuming that we were familiar with both systems!

From the wreck of another Heinkel, a diary was rushed to Jones. It read: *March 5. Two-thirds of flight on leave. Afternoon training on Knickebein, collapsible boats, etc.*

By this time, the cryptographers at Bletchley Park had performed a near miracle by breaking the German *Enigma* code. One of the intercepted messages from a German aircraft was sent to Jones: *Knickebein, Kleve, is confirmed at position 53°24' north and 1° west.* This meant that the aircraft had reported receiving the beam a few miles south of Retford in Nottinghamshire, and Kleve (where Anne of Cleves came from) was on the nearest German soil to England.

But, clearly, there had to be two beams: one along which the bomber flew, and another one — a marker beam — to tell the pilot when he was approaching his target. Evidence of this second beam arrived a few days later in yet more salvaged papers from a crashed Heinkel. *Long-range Radio Beacon: Knickebein (Bredstedt) 54°39', 8°57', Knickebein (Kleve) 51°47'5", 6°6'.*

So Bredstedt in Schleswig-Holstein was the source of the second beam!

Amateurs and experts

Obviously beams less than a kilometer wide at well over 300 km called for very high frequencies — possibly something in the centimetric region. And although this part of the spectrum was in some use at the time, the power generated by valves then available was very low. Certainly the German system suggested they had overcome the problem. (It was only later that we discovered that German radar had been operating on 50 cm since about 1930!)

However, Rowley Scott-Farnie, G5F1 (then a signals officer in RAF Intelligence), showed Jones a report by T. L. Eckersley (the country's leading propagation expert), in which Eckersley had computed the possible range of a 20-cm transmitter sited in the Hartz Mountains. If the calculations were correct, the signals would bend round the earth and might well be heard by a bomber at 20,000 feet over England. This

information, together with the evidence he had already collected, prompted Jones to alert Professor Lindemann to the possibility that the Germans had a narrow-beam system for bombing the country. Lindemann naturally countered with the objection that the frequencies they would have to use could not possibly bend round the earth, but Jones produced Eckersley's calculations and told him that indeed they could.

But how were the Germans doing it? Inspection of captured aircraft revealed nothing unusual and the radio equipment seemed perfectly normal — certainly nothing in the way of centimetric receivers. He pressed for yet more information, especially from the prisoner-of-war interrogation centers. Did their aircraft carry special receivers for beam reception? Had we missed something?

Quite correctly the prisoners admitted nothing. But at one center a prisoner was overheard to tell his friend that no matter how hard we looked for the equipment we would never find it. This startled Jones, for it implied that it was under our very noses and therefore we would never see it. Methodically he sifted through the captured equipment, but the only item that fit the bill was the receiver marked E Bl 1 (Empfänger Blind 1) — Blind Landing Receiver Type 1 — which was used by both the RAF and the Luftwaffe for blind landing on the Lorenz Beam System.

The Lorenz System, however, only had a range of about 8 km at best, unless the Germans had somehow dramatically increased its range. Knowing that Farnborough had evaluated the equipment, he inquired if there was anything unusual about the receiver.

"No," came the reply. "But since you mention it, the receiver is many times more sensitive than they would ever need for blind landing."

Could that be it! Dr. Jones spoke to Lindemann, who drafted a note to Churchill. He wrote: *"There seems some reason to suppose that the Germans have some type of radio device with which they hope to find their targets."*

Churchill initialed the note and sent it to the Air Minister, adding: *"This seems most intriguing and I hope you will have it thoroughly examined."*

A committee of inquiry was formed and Squadron Leader R. S. Blucke was put in charge of flying operations. Three Ansons were fitted with suitable receivers and flown by Lorenz-trained pilots. Rowley, G5FI, told Jones that the German preset frequencies were likely to be 30, 31.5, and 33.3 MHz, and sure enough a few days later a scrap of paper recovered from yet another crashed aircraft read: *Knickebein (Kleve) 31.5.*

On June 20 a Heinkel was shot down. The radio operator had bailed out, had torn his notes into shreds, and was actually burying them when he was captured. An Intelligence NCO unearthed them, gummed them together, and sent them to London: *VHF. Knicke 54°38'7"N, 8°56'8"E, 51°0'30"N, Eqms., Stollberg 30 mcs. Kleve 51°47'N, 6°2'E, 55°N, 2°Eqms., 31.5 mcs.*

This seemed to confirm the existence of another Knickebein installation at Stollberg and in Schleswig-Holstein. It also confirmed Scott-Farnie's guesses about the frequencies. Yet after two flights the Ansons failed to find the beams.

Was Jones wrong after all? Many thought so. Sir Henry Tizard was skeptical (and fell from Churchill's favor as a result), Air Chief Marshal Dowding was doubtful, and Air Chief Marshal "Bomber" Harris was scathing. Other military and scien-

tific brains looked askance at the young man who questioned established wisdom. Then, suddenly, Jones was summoned to a meeting at Downing Street.

Thinking the message was one of Scott-Farnie's practical jokes, he arrived half an hour late to find the meeting already in progress. A galaxy of talent confronted him. Churchill sat on one side of the table flanked by Lindemann on his left and Beaverbrook on his right. Facing them was Sir Archibald Sinclair (the Air Minister), Sir Cyril Newall (Chief of the Air Staff), Sir Henry Tizard, Watson-Watt, and Portal and Dowding (Commanders-in-Chief of Bomber and Fighter Commands). Breathing his apologies to the Prime Minister, Jones took his place at the end of the table. An argument was taking place — did the beams exist or didn't they? Soon Jones realized that nobody in the room knew as much about the matter as he did. Suddenly Churchill snapped a question at him, and feeling he couldn't answer it out of context Jones said, "Would it help, sir, if I told you the story right from the start?" Churchill seemed somewhat taken aback but then replied, "Well yes, it would."

For the next 20 minutes Jones outlined his evidence. As he later recalled *"...although I was not conscious of my calmness at the time, the very gravity of the situation somehow seemed to generate the steady nerve for which it called. Although I was only 28, and everyone else around the table much my senior in every conventional way, the threat of the beams was too serious for our response to be spoiled by nervousness on my part."*

When he had finished, an air of incredulity filled the room. Sir Henry Tizard demanded to know why the Germans should use a beam anyway, assuming such a thing was possible. Our own pilots found their targets very well by astro-navigation. (They didn't! *Author.*) Others round the table seemed doubtful. But Churchill was convinced and asked Jones what should be done.

"I told him that the first thing was to confirm their existence by discovering and flying along the beams for ourselves, and that we could develop a variety of countermeasures ranging from putting a false cross-beam for making the Germans drop their bombs early, to using forms of jamming ranging from crude to subtle."

With a typical "Let this be done at once!" Churchill then turned round and tore a strip off the Air Ministry for their tardiness.

And expert amateurs

Elated at having convinced the Prime Minister, Jones dashed away to attend a conference in the office of the Director of Signals, Air Commodore Nutting, to discuss the possibility that the Germans might exploit pulse techniques as navigational aids. T. L. Eckersley was to give evidence. However, because Eckersley disagreed with Jones's findings, the subject reverted to Knickebein.

But what about those propagation calculations? Oh, those! Eckersley pooh-poohed them; he didn't believe them himself. He was only trying to demonstrate how far the signals *might* go under certain conditions. He thought he had been stretching theory too far, and doubted if signals in the 30-MHz band would curve round the earth.

The Ansons had failed to detect the beams during their previous flights and another one was due that evening. In order to cancel it the Principal Deputy-Director of Signals,

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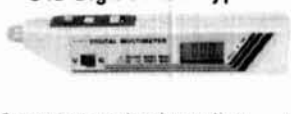


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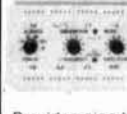
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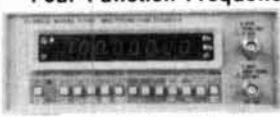


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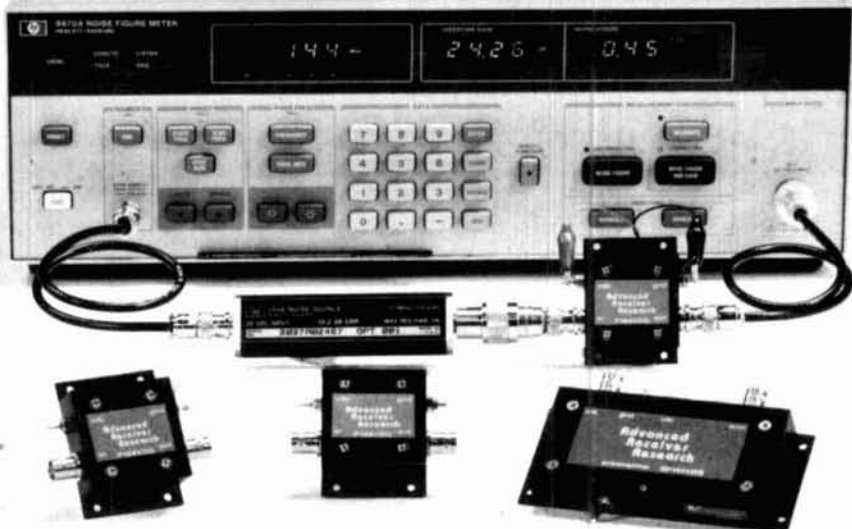
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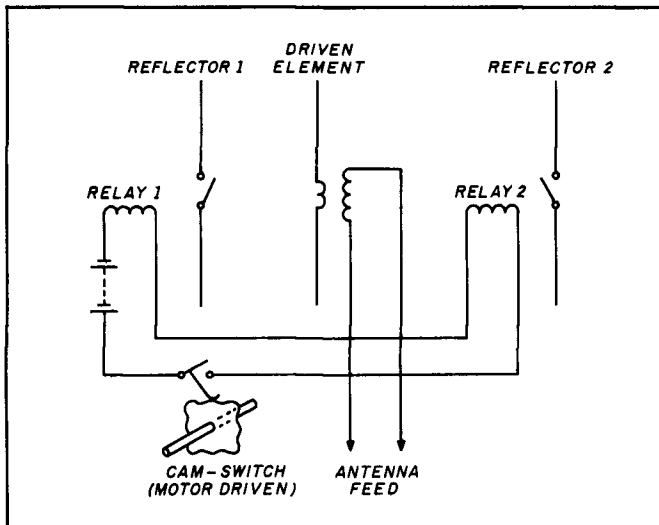
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FIGURE 1



The principle of the operating reflectors.

Group Captain O. G. Lywood, picked up the phone saying, "Well, we have here the greatest expert on radio propagation in the country and he says the beam theory is all wrong. We've wasted a lot of time and let's not waste any more. This evening's flight should be canceled!" But Dr. Jones stood his ground. Pointing out that Eckersley's evidence had neutralized itself because he had said one thing a few months before and now said something quite different, and that enough evidence already existed to convince him, he demanded that Eckersley's statement should be ignored. He also told Lywood that if the flight was cancelled he would "jolly well let the Prime Minister know who had countermanded his orders." Lywood backed down.

From the Chair, Air Commodore Nutting demanded: "And what do we do if we find the beams?" Quietly Jones whispered to Rowley Scott-Farnie, "Go out and get tight!"

Black night and bright dawn

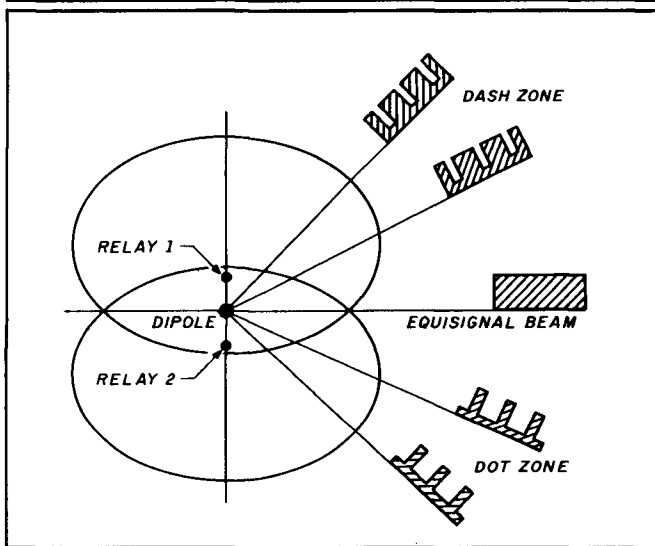
Dr. Jones went home to spend one of the most miserable nights of his life. "Had I, after all, made a fool of myself and misbehaved so spectacularly in front of the Prime Minister? Had I jumped to false conclusions? Had I fallen for a great hoax by the Germans? Above all, had I arrogantly wasted an hour of the Prime Minister's time when Britain was about to be invaded or obliterated from the air?"

It was a beautiful summer's night — the shortest night of a terrible year for Britain — when Flight-Lieutenant Bufton and Corporal Mackie climbed aboard their Anson and flew over the area between Huntingdon and Lincoln. Neither had been told the Knickebein story, but merely to search for beams with Lorenz characteristics. Suddenly on the Hallicrafters receiver they heard signals on 31.5 MHz. Dots!

The aircraft swung to the north. Still dots. Then a continuous note, and later, as expected, a zone of dashes. When the dashes ceased, Bufton and Mackie began intently to plot the beam. The following afternoon Bufton's report was on Jones's desk:

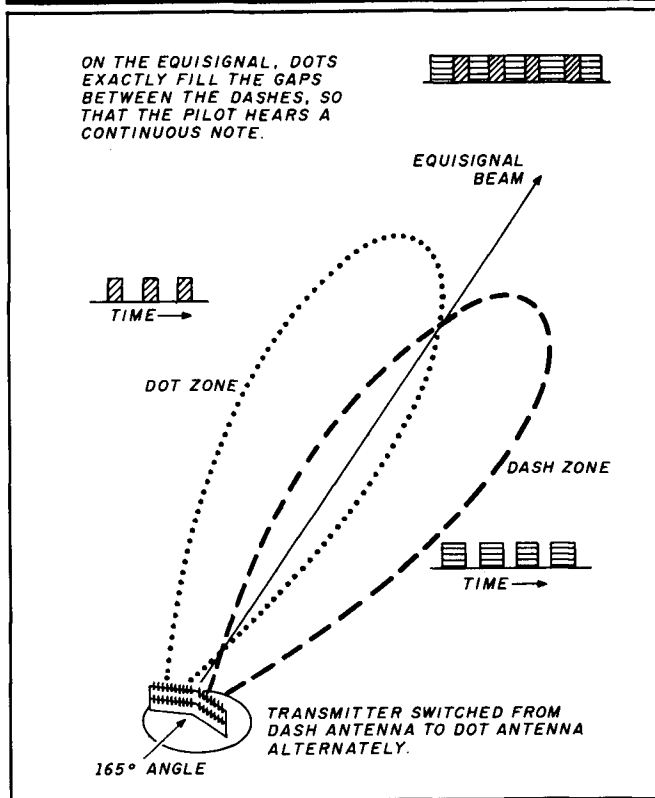
1. There is a narrow beam (approximately 400 to 500 yards wide) passing through a position 1 mile south of Spalding,

FIGURE 2



The principle of the Lorenz beam system.

FIGURE 3



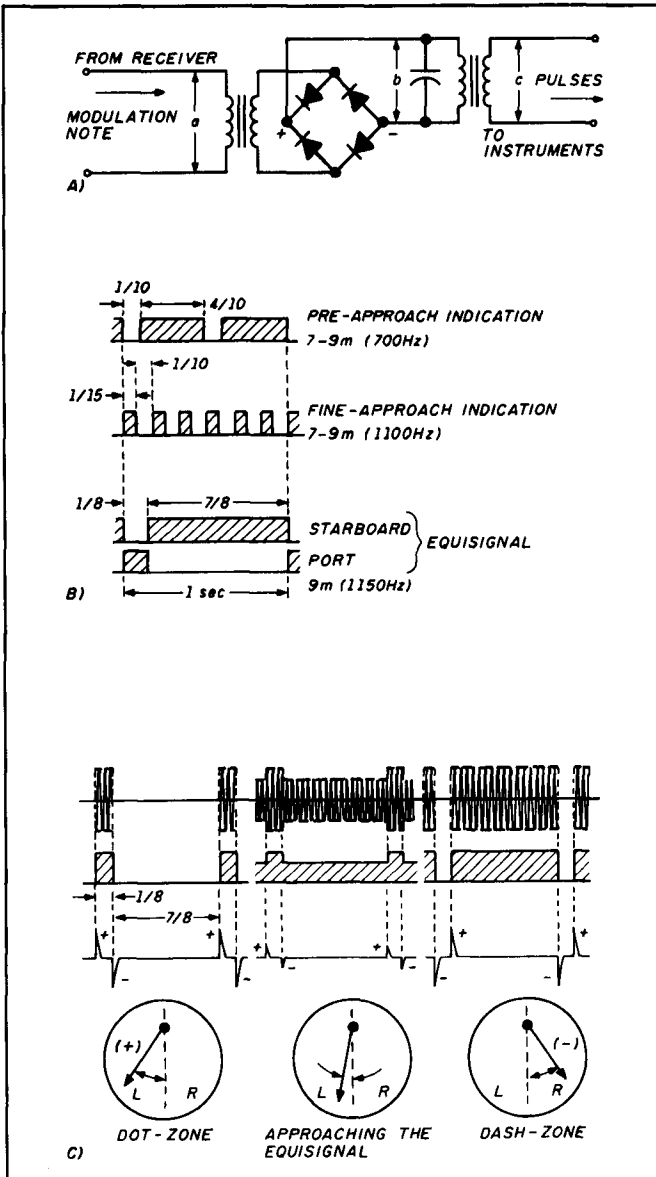
The principle of the Lorenz (Knickebein) beam.

having dots to the south and dashes to the north, on a bearing of 104°(284°T).

2. The carrier frequency of the transmissions on the night of 21/22 June was 31.5 mc/s, modulated at 1150 cycles and similar to Lorenz characteristics.

3. There is a second beam having similar characteristics but with dots to the north and dashes to the south synchronized

FIGURE 4



The target approach indication with the Knickebein system. (A) Pulse rectifying circuit. (B) Pulse rate timing — distances in meters, tones in hertz (for approach on flightpath). (C) Pulse rectification and waveforms, tone-modulated signal. At rectifying circuit and as final pulse.

with the southern beam, apparently passing through a point near Beeston on a bearing lying between 60°+ and less than 104°.

In other words the director beam was aimed at Derby where the Rolls Royce factory produced engines for the RAF — as Jones had suspected. The impact of Bufton's report on the meeting that afternoon may well be imagined. Jubilation was in the air. Even "Daddy" Nutting was skipping round the room in delight. All doubts were now dispelled and countermeasures could go ahead urgently.

In the midst of the revelry Scott-Farnie buttonholed Jones: "Remember what you said yesterday?"

So they bowled across to a pub to celebrate.

The Lorenz System

In 1932, Dr. E. Kramar of the German Lorenz Company began to develop a high-frequency blind landing system on pre-set frequencies between 30 and 33.5 MHz, continuous wave modulated at 1150 Hz. The beacon transmitter and its associated antenna system stood at the end of a runway and had a range of 3 to 5 km (sometimes more depending on conditions) even though the transmitter developed 500 watts. The output was fed to a single dipole, to the left and right of which and at a quarter-wave spacing was a single reflector cut at its center point. A relay was used to alternately close and open the reflector, as shown in Figure 1, whereupon a beam was generated at an angle left and right of the driven element composed of dots to one side and dashes to the other (see Figure 2). These alternating beams partially overlapped each other centrally to give a narrow zone of about 3° angle in which the dots and dashes were heard as a single note, telling the pilot he was on the correct approach (see Figure 3 and 4). A simple presentation unit was also provided in the cockpit which showed the course deviation on a meter; a form of range measurement was furnished by an S-meter arrangement.

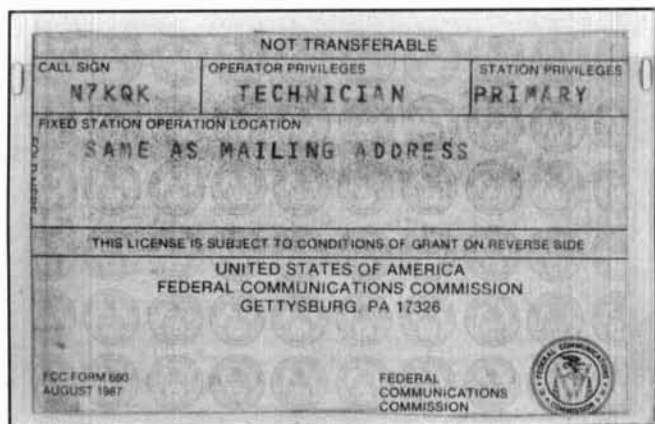
Two additional transmitters were employed to aid landing (Figure 5). At a point 3 km before the runway was an early-approach system on 38 MHz with a power of 5 watts, but having a slower keying rate and a lower modulation note. The second system was comprised of a transmitter at 300 meters before the runway, with a higher key rate and modulation tone. Both these systems operated a lamp on the presentation unit to give further visual indication.

The accompanying aircraft receiver was known as the EB 1 (Blind Landing Receiver 1), which was developed from the earlier EBE receiver. The system was made available to Lufthansa in 1934 and the aircraft were fitted with vertical rod antennas, usually quarter-wave whips. Later, the Luftwaffe produced a specification for what was to be called the Blind Landing System FuB 1, and which required two separate receivers — the EB 1 for signals in the range 30 to 33.3 MHz, and the EBL 2 for 38 MHz. All multi-engined aircraft of the Luftwaffe were fitted with these up to 1941.

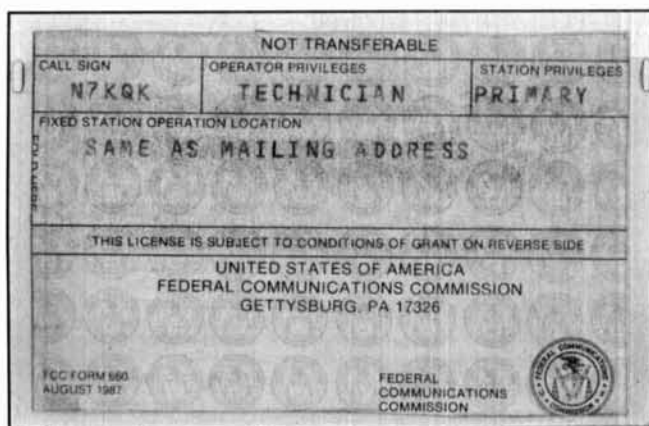
As war seemed inevitable, Dr. Lohmann of Telefunken developed a much larger system which was called FuS An 721 in 1938. This was an antenna array of metal girders 30 meters high and 90 meters long which revolved on a circular iron track. In the middle was a 50-watt transmitter for 30 to 33.3 MHz. The framework supported 16 vertical wire dipoles and reflectors and was arranged as an angle of 165° (looking down on the array), so that eight two-element antennas were in each leg of the framework. From this "broken neck" appearance, *geknickten* in German, came the code name Knickebein.

Details of the transmitters and receivers used are, unfortunately, no longer in existence. However, the antenna lobes were similar to those shown in Figure 6, except that the narrow equisignal zone was ±0.3° wide and the keying of the dash/dot system had a ratio of 1:7. The improved receiver, another mark of the EB 1 known as the Fu Bl 1, could receive the beam at a range of 500 km and a height of 6500 meters. The principle was that the main beam was directed at a tar-

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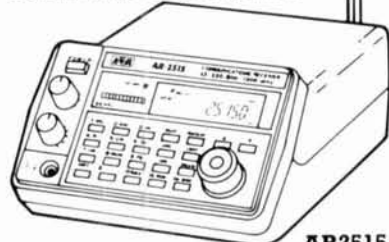
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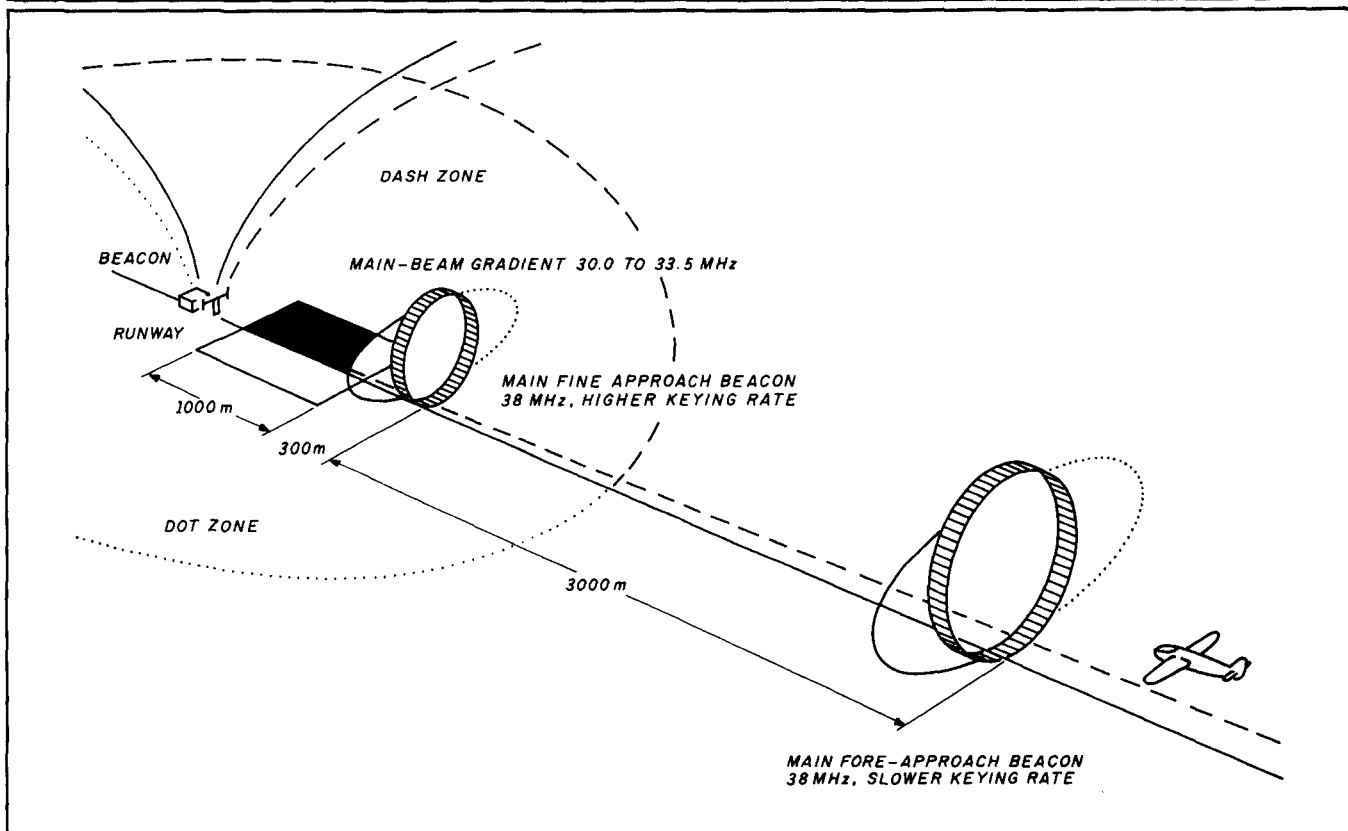
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FIGURE 5



The principle of the Lorenz blind landing system.

get, and the pilot knew he was on course when a continuous note appeared in the receiver. If he strayed to the left, a preponderance of dots was heard; a swerve to the right produced dashes.

By 1940, ten smaller versions of Knickebein had been built which required only a circular track of 45 meters in diameter. Each leg of the angled frame contained only four sets of vertical two-element arrays, which were broadbanded to tune between 30 and 33.3 MHz by construction from wide-diameter tubing. The range was almost the same in practice as the large Knickebein, although the main beam width was wider at $\pm 0.6^\circ$.

As already mentioned, when in use the main beam was directed at the target, and at a predetermined point some distance before the target was reached it was overlapped by a second beam on a different frequency. This told the pilot his distance in kilometers from his objective. Figure 6 shows the method in more detail.

Although no details remain of the receivers used, it is known that they were t.r.f. types and, as will be seen later, very susceptible to jamming. For this reason a Dr. W. Kloefer of Lorenz developed a superhet, the EBL 3 H, which needed only slight preparation as it used the same p.s.u. as its predecessor and fitted the same cabinet. This was tunable over a number of channels from 1 to 34 in the spectrum 30 to 33.3 MHz, and could receive the Knickebein transmissions at the same height and range as the earlier model.

Pulling the Crooked Leg

A special unit was set up to counter the beams (which were code named *Headaches*) under the command of Wing Commander E. B. Addison of No. 80 Wing at Radlett. The technical design of the countermeasures was the responsibility of Dr. Robert Cockburn of the Telecommunications Research Establishment at Worth Matravers. Both organizations were accorded the highest priority.

Receivers were placed on top of the masts of certain stations of the Chain Home RDF (radar) system, and the unlucky operators in these dizzy crow's-nests were connected by telephone with Fighter Command Headquarters at Bentley Priory.

Professor Jones records how he, too, spent a night on top of one of these towers — listening to the signals which Eckersley had said could not be heard even by a bomber at 20,000 feet over England. "When about dusk the German beams were switched on, the men in the towers would be able to pick them up and let us know, for instance, if a beam was going between tower 'A' and tower 'B.' That would give us a clue to the beam's position, and one of our chaps would go up in an Anson and fly back and forth until he picked up the beam, which could then be plotted."

The first jammers were diathermy sets used by hospitals to cauterize wounds. These were requisitioned and tuned to the Knickebein frequencies. Although they only emitted a mush

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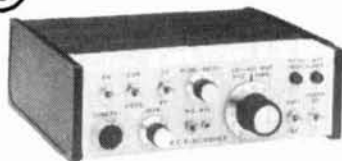
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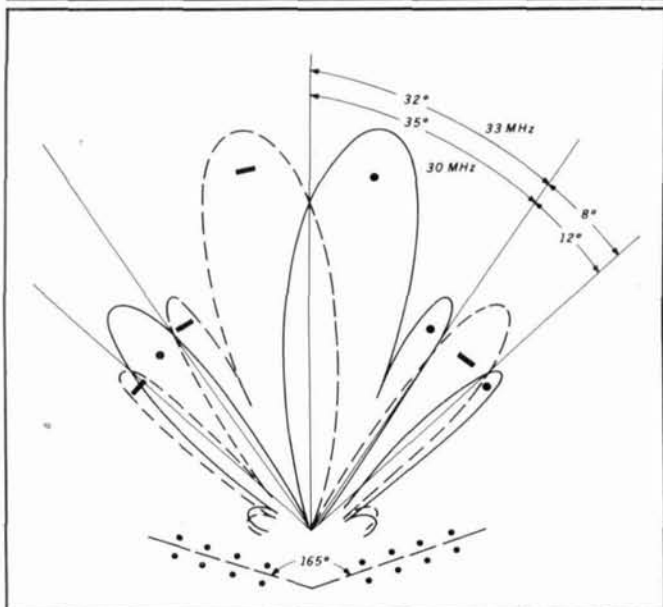
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FIGURE 6



The antenna pattern of the Knickebein array.

of signals, it was thought that they had some effect on the beams. Installed mainly in police stations, they were switched on when ordered by No. 80 Wing.

Fortunately we had acquired the Lorenz license before the war, so Lorenz transmitters were modified and strategically placed, as were "Meacons," or mock beacons. The Luftwaffe, with more than 80 radio beacons at their disposal in Germany and occupied Europe, began to find radio navigation an ever-increasing problem. But it was Cockburn's jammers (code named *Aspirins*) that were most effective. Immensely powerful, they flooded the beams with dashes and the German pilots, flying into their own dash zones, would steer to find the equisignal only to find Cockburn's dashes. They would continue turning until they found a dot zone (and Cockburn's dashes), which often synchronized into a false equisignal note. After they found themselves flying round in circles during bombing raids for a few weeks, they came to realize that we had found and jammed their system. We had, in fact, "pulled the crooked leg." An additional bonus lay in the fact that it was several months before the German pilots had the courage to tell Goering that Knickebein was useless.

Had the system worked successfully, a number of bombers could have put bombs every 17 meters into a selected target. As it was, our cities suffered severe mauling from the Luftwaffe. Who knows how much worse the loss of life and property would have been but for the efforts of a young physicist who refused to believe the experts, and courageously challenged his superiors.

Today one wonders how many Londoners and citizens of our other major cities have heard of Professor R. V. Jones.

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LINEAR TUNING WITH A WAR SURPLUS CAPACITOR

Precision dials based on frequency measurements

By John Pivnichny, N2DCH, 3824 Pembroke Lane, Vestal, New York 13850

Modern commercial transceivers have linear tuning scales. Whether these scales are analog or digital, each revolution of the main tuning knob covers a fixed number of kilohertz across the tuning range. Linear analog tuning is done with specially designed capacitors that aren't available to Amateur transceiver builders. I think a first-class homebrew design should have this capability, and this article explains how to add it inexpensively.

Capacitor fundamentals

Consider a variable capacitor constructed as shown in **Figure 1A**. Capacitance change is made by a horizontal movement rather than a rotary motion. As the movable plate slides to the right by an amount X , the capacitance at the terminals (C) decreases an amount ΔC from its value C_0 , which is present when the movable plate is at its left-most position (fully meshed).

In equation form:

$$C = C_0 - \Delta C \quad (1)$$

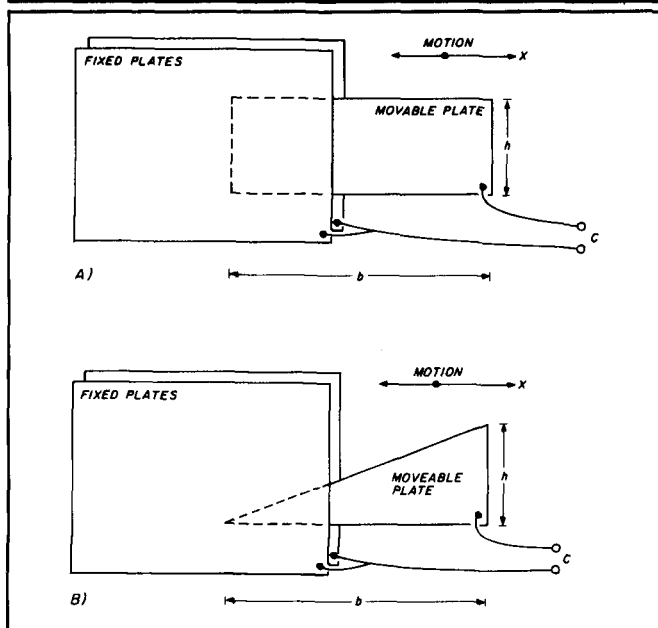
$$\text{or } C = C_0 - kX \quad (2)$$

The constant k represents the change in capacitance per unit movement in X . **Equation 1** is plotted in **Figure 2A** and:

$$k = \frac{C}{X} \quad (3)$$

The amount of change depends upon the size of the plates and the spacing. But because the movable plate has straight sides, the value of k is fixed across the whole tuning range. This

FIGURE 1



Capacitor plates are moved laterally to produce a change in capacitance. A and B are discussed in the text to show effect on capacitance with plate movement.

is linear capacitance and it's well known that it won't produce linear tuning. The high frequencies will be compressed at the right edge of the dial.

Obviously the capacitance is changing too quickly at the high-frequency end of the dial. **Figure 1B** shows an improvement. The rectangular movable plate has been replaced by a triangle of height h and base b . The terminal capacitance now depends upon the area of the meshed triangle. The triangle's base and the height change with horizontal motion X . In equation form:

$$C = 1/2 (b - X) (h - \frac{h}{b} X) \quad (4)$$

$$C = 1/2 (bh - 2hX + \frac{h}{b} X^2) \quad (5)$$

Equation 5 (plotted in **Figure 2B**) shows that the capacitance changes more slowly at the high-frequency end of the dial, due to the parabolic shape represented by **Equation 5**.

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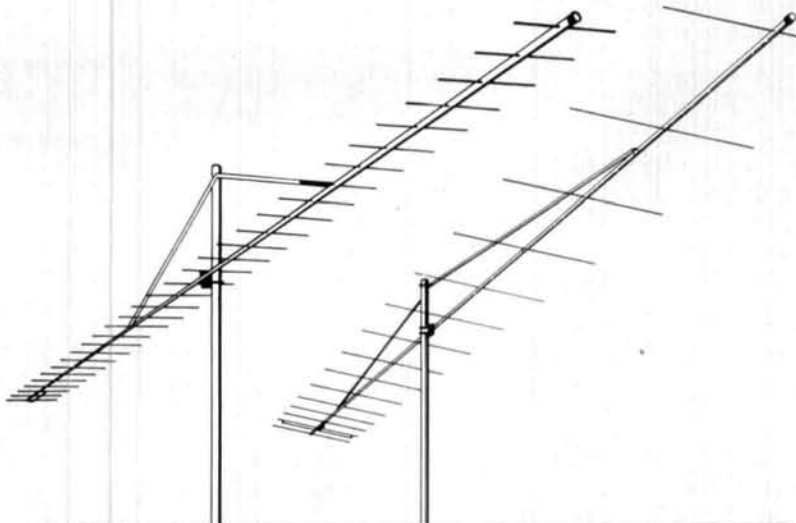
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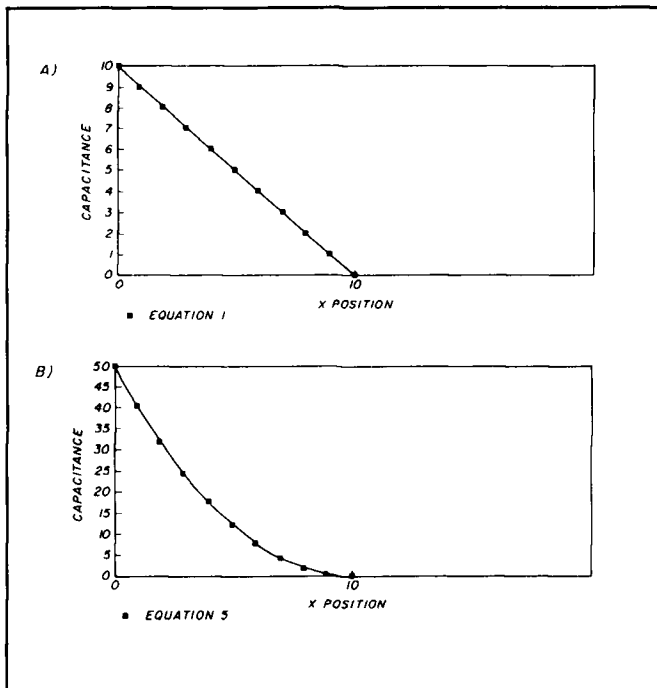


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FIGURE 2



Data for rectangular, A, and triangular, B, capacitor plates. Capacitance scale is arbitrary.

Unfortunately, this isn't exactly the curve necessary for a linear frequency scale, but now you have the background to get there.

Think of the top edge of the movable plate as representing an equation with the X axis starting at the right edge and going left. This reversal is necessary because frequency increases as capacitance decreases. The Y coordinate is given by the height of the variable plate at each X coordinate.

The equations are:

rectangle: $Y = h$ for $0 < X < b$ (6)

triangle: $Y = h - \frac{h}{b} X$ for $0 < X < b$. (7)

They are shown in Figure 3A and 3B and represent the plate shapes of Figure 1 — except for that of the X axis in its normal position (i.e., going right).

Figure 3 gives the slopes (actually the negatives of the slopes) of the data plotted in Figure 2. You can get the shape of the movable plate for any capacitance equation of Figure 2 by taking the slope, as shown in Figure 3.

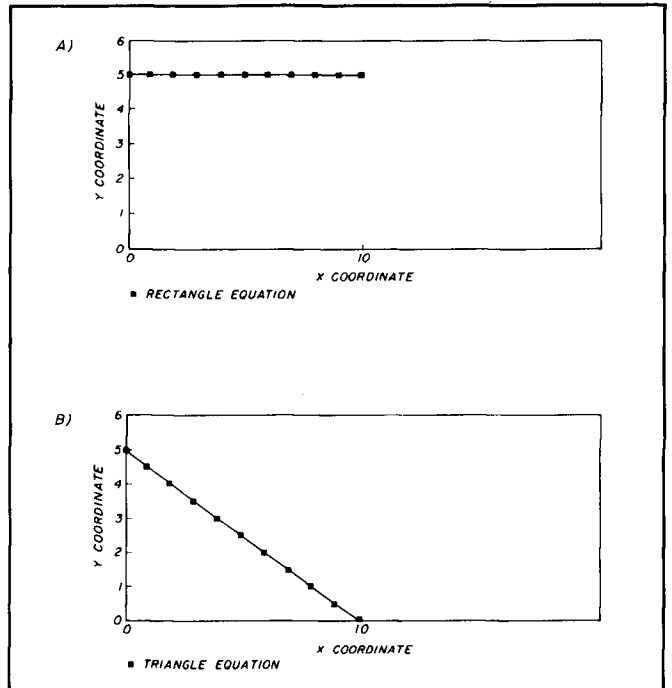
You want a capacitance equation that produces linear tuning. For a parallel LC-tuned circuit the resonant frequency is given by:

$$f = \frac{1}{2\pi\sqrt{LC}} \quad (8)$$

Solving for C: $C = \frac{1}{4\pi^2 L f^2}$ (9)

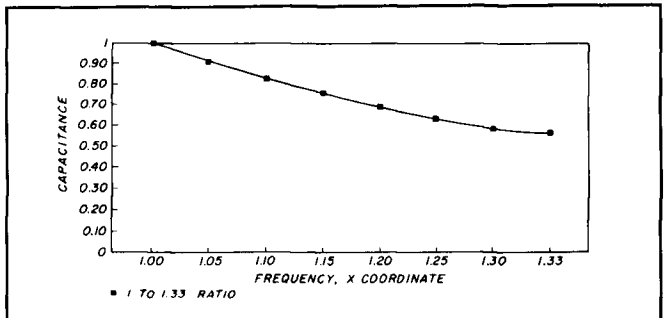
If the frequency increases linearly, the capacitance must decrease as the reciprocal of the square of the frequency. Suppose you want to cover the 3 to 4-MHz range. This is a 1:1.333 frequency ratio. Figure 4 shows how the capacitance

FIGURE 3



Equations 6 and 7 are plotted in A and B and represent capacitor-plate shapes of Figure 1. Shown are the negatives of the slopes of the data in Figure 2.

FIGURE 4



Required tuning capacitance as a function of frequency.

must change across the frequency range. Note the shape of the curve; the correct one will be the curve corresponding to Figure 2 for linear tuning over a 1:1.333 ratio.

The capacitance curve will be the same for any 1:1.333 tuning ratio. The exact range will be set by inductance L, whether it's 3 to 4 or 6 to 8 MHz. However, another tuning ratio will require a different Figure 4 curve.

This means that you can only build a linear frequency tuning capacitor for one frequency ratio. These types of capacitors are specified by their minimum and maximum capacitances and frequency ratios. But you may require a certain fixed capacitor in parallel with the tuning capacitor to achieve the correct curve from Figure 4. It's possible to design a linear frequency capacitor to allow for stray or feedback capacitance from the oscillator circuit.

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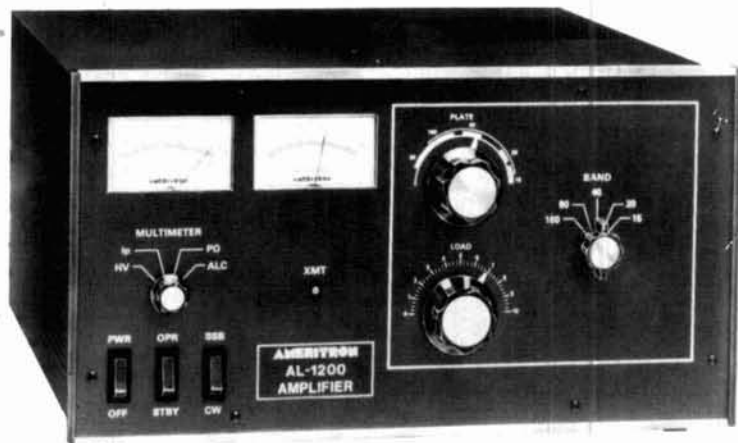
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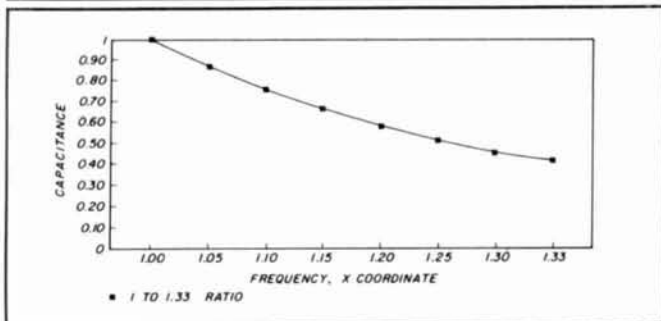
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FIGURE 5

Equation 10 data shows shape of capacitor plate to give capacitance curve of Figure 4.

To determine the plate shape needed to give the capacitance curve of Figure 4, take the derivative of Equation 9:

$$\frac{dC}{dF} = \frac{-I}{2\pi^2 L f^3} \quad (10)$$

The top edge of the capacitor must vary as the reciprocal of the cube of the frequency (ignore the negative sign).

This curve is plotted in Figure 5 for the 1:1.333 frequency ratio. The inductance is used to set the exact frequency range once again. The analysis gets more complex if you're removing a final amount of capacitance to allow for circuit capacitance. It can be done, but I won't discuss that process in this article.

You could trace Figure 5, place the tracing on a piece of sheet metal, cut out one or more plates, and use them to construct a linear frequency tuning capacitor with horizontal motion. I haven't tried this yet; maybe one of you will. What about a rotary capacitor? The mathematics are analogous using polar coordinates. I haven't included it here, but the principles are the same. Like the linear frequency tuning capacitor, a rotary linear frequency capacitor is good for only one frequency ratio. That ratio can be scaled to any range by inductance selection, and the variable capacitor may allow for a fixed external capacitance in the oscillator circuit.

Now that the background is out of the way, I'll describe how to build an oscillator using a precision variable capacitor available at little or no cost.

Tuning capacitor

The 35 to 150-pF main tuning capacitor from ARC 5 WWII command-set transmitters is one of the finest variable capacitors available to Amateurs. It is still listed in Fair Radio Sales catalogs.* You can buy the capacitor alone or purchase the whole transmitter (not all of them come complete). The same capacitor seems to have been used for the 2.1 to 3, 3 to 4, 4 to 5.3, 5.3 to 7, and 7 to 9.1-MHz models. Actually, the transmitters contain two similar capacitors. The only difference between them is that the front one, used for tuning the final amplifier, has a dial drive attached. Many old-timers may still have these caps in their junkboxes. The capacitor is shown in Photo A.

A worm drive with an anti-backlash gear moves the adjustable plates. Exactly 96 turns of the shaft take the capacitor through 360 degrees. Of course, you can only use a maximum of 180 degrees; I recommend slightly less to avoid errors at the beginning and end.

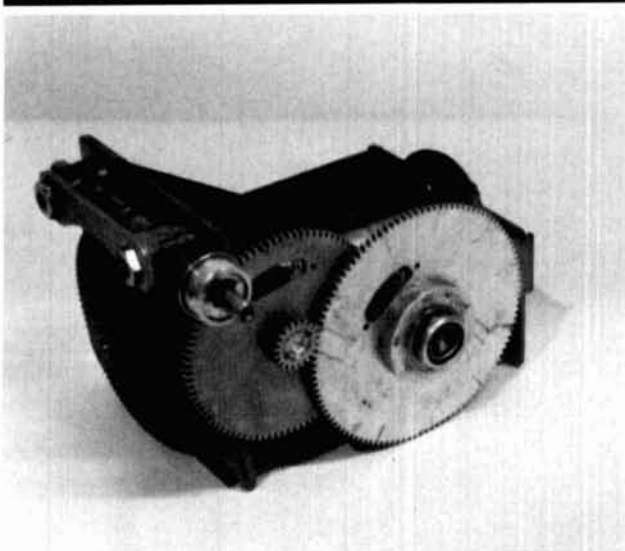
In capacitors with the dial drives, the worm drive moves the plates while another set of anti-backlash gears rotates the dial. Exactly 99 turns of the shaft move the dial through 720 degrees, or two revolutions. Because of this difference, you shouldn't rotate the capacitor 360 degrees. The dial will be off by three turns of the shaft after it revolves twice.

An examination of the dials shows that they're not linear. For example, 3.7 turns of the main shaft move the dial from 4 to 4.1 MHz, but 3.2 turns are needed to move it from 5.2 to 5.3 MHz. Photo B shows two representative dials.

Because these capacitors have excellent gear drives, I decided to determine just how far off they would be for typical Amateur tuning ranges. After all, 7.0 to 9.1 MHz is a pretty wide range for Amateur use. Even a capacitor with linear capacitance plates can give a fairly good approximation of linear frequency over a small frequency ratio. The plates on this capacitor are closer to linear frequency; there is a smaller radius at the high-frequency (minimum capacitance) end than at the low-frequency one.

Frequency error

I mounted a circular protractor on the dial drive in place of the surplus dial and took frequency measurements every 10 degrees from 0 to 300. The protractor was placed at the point

PHOTO A

Tuning capacitor.

PHOTO B

Two representative dials.

*Fair Radio Sales Company, P.O. Box 1105, Lima, Ohio 45802.

where the plates were fully meshed (330 degrees). I used a homebrew frequency counter to take readings to the nearest 5 kHz. The raw data is shown in **Table 1**.

The oscillator circuit is shown in **Figure 6**. I chose values and adjusted the inductance for the feedback capacitors, C_x , and coupling capacitor to cover a 4 to 5.3-MHz range.

The plot of frequency versus dial rotation shown in **Figure 7** looks good, but this kind of plot can be misleading. Very large, inherent errors of greater than 10 kHz are present. There are measurement errors based on how accurately the dial is positioned in reference to the 10-degree marker on the protractor scale. There's also a ± 2.5 -kHz error; I recorded the frequency only to the nearest 5 kHz when I could have taken it to the nearest Hz with this counter.

I used a curve-fit technique to minimize or average out the measurement errors. Drawing a straight line (mathematically) through the data points minimizes the frequency error between the raw data points and the straight line. This is referred to as linear least-square curve fitting because the sum of the squares of the errors is minimized.

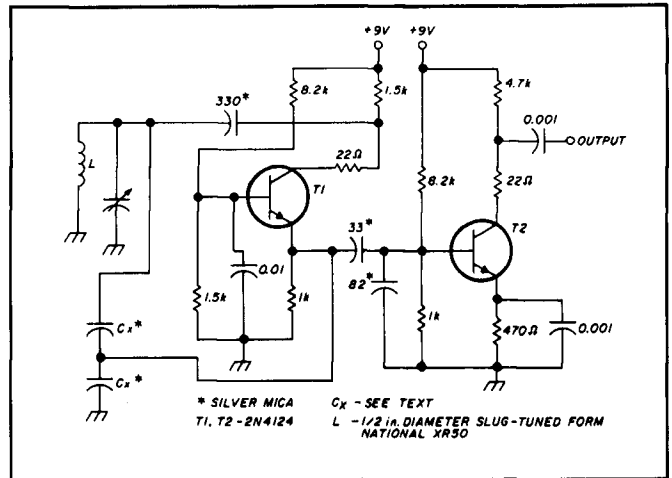
Using a straight line like this is the best way to match a linear dial over the frequency ratio selected. You can adjust the oscillator circuit's "fixed" capacitor and inductor to achieve the same deviation from a linear dial that you'd get from the

TABLE 1

Test data taken to determine dial position and frequency of a surplus WWII command-set capacitor.

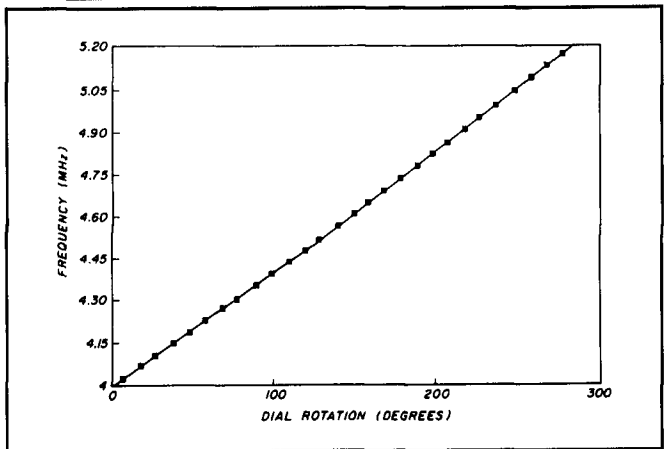
Dial Position (degrees)	Frequency (MHz)
0	4.0
10	4.03
20	4.07
30	4.11
40	4.15
50	4.19
60	4.23
70	4.27
80	4.31
90	4.355
100	4.40
110	4.44
120	4.48
130	4.52
140	4.565
150	4.61
160	4.65
170	4.69
180	4.74
190	4.78
200	4.825
210	4.87
220	4.91
230	4.96
240	5.0
250	5.05
260	5.09
270	5.14
280	5.18
290	5.23
300	5.27

FIGURE 6



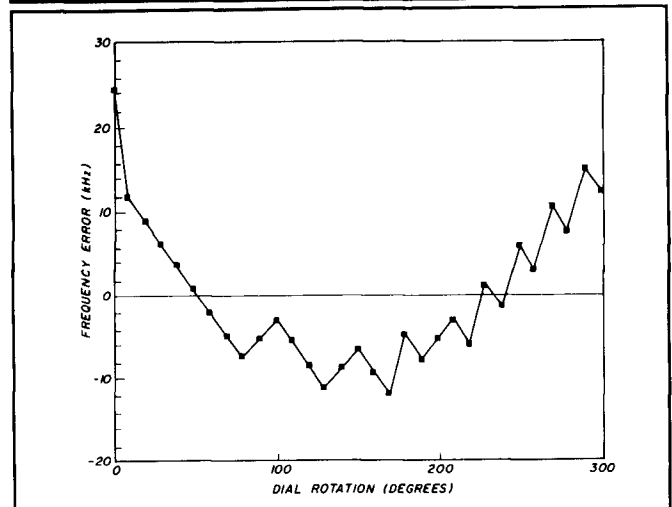
Oscillator circuit used for frequency-error measurements.

FIGURE 7



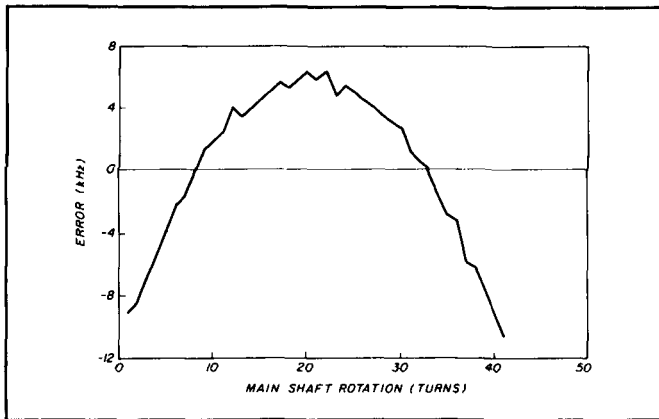
Plot of frequency versus dial rotation looks linear but can be misleading. Measurement errors are minimized using a curve-fit technique as in **Figure 10**.

FIGURE 8



Plot of frequency error versus dial rotation. A least-squares curve fit minimizes errors.

FIGURE 9



Error curve for a straight-line fit to the raw data of Table 2.

deviations between the measured data and the best straight-line fit. **Figure 8** shows a plot of the deviations for the 4 to 5.3-MHz range. It's easier to see how far off a linear dial will be with the plot in **Figure 8** than it is with the one in **Figure 7**.

At the low end of the dial the error starts off positive; that is, the actual frequency will be about 10 kHz higher than indicated on the dial. In the center the error is 10 kHz negative, and at the high-frequency end it's 10 kHz positive again. At two points the frequency will match the dial reading exactly. The parabolic nature of the error curve is rather ragged in appearance, undoubtedly due to the measurement errors indicated earlier.

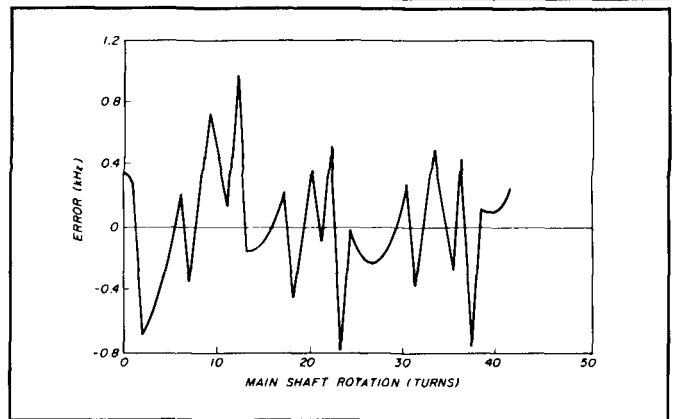
Numerous computer programs are available for curve-fit calculations. Some sophisticated calculators have this feature. You can do the calculations yourself using a simple calculator and the formulas from a math or statistics textbook. I recommend using a computer; even the smallest personal computer can handle the calculations. Some programs can also calculate higher order curves, in addition to straight-line fits.

I smoothed the ragged appearance of the error curve in **Figure 8** in two ways. For actual frequency measurements, I took more care in positioning the dial directly under a cross hair while recording the frequency to the nearest 1-kHz reading. In addition, I made a second-order curve fit to the raw data. Because the error curve seems to have a parabolic shape, a second-order curve (parabola) fits the raw data quite well.

Figure 9 shows the error curve for a straight-line fit to the raw data of **Table 2**. I took frequency readings to the nearest kilohertz for each single turn of the main shaft. I made 49 turns and selected the 42 center readings to eliminate errors at the ends of the capacitor range. My readings covered about 300 degrees of the main dial, including the 3746 to 4083-kHz range. **Figure 10** shows the plot of raw data versus a square fit (parabola), along with the resulting error. There's a less than 1-kHz error; the random scatter indicates the fit is as good as possible and is probably limited by measurement errors.

Using the smoothed raw data (parabola), I can find the best straight-line fit to determine the error from a linear dial. **Figure 11** shows the result of my calculation. Now compare **Figure 11** with **Figure 10** and you'll see that raggedness

FIGURE 10



Deviation from a parabola. Data shows less than 1-kHz error and random scatter indicates a good fit.

TABLE 2

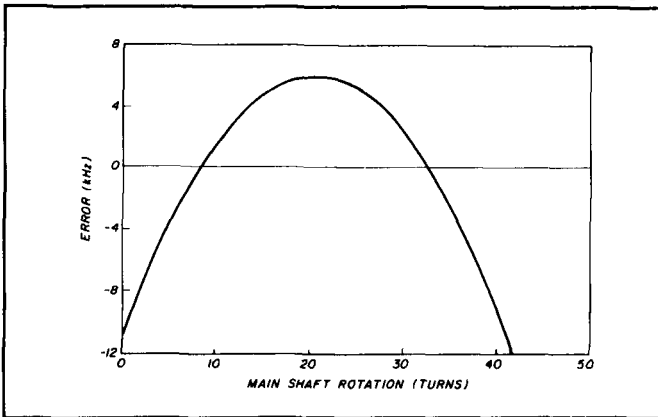
Frequency readings between 3746 and 4083 kHz taken to produce error as a function of capacitor shaft rotation in **Figure 10**.

Turning shaft (turns)	Frequency (kHz)	Tuning shaft (turns)	Frequency (kHz)
0	3746	26	3950
1	3750	27	3958
2	3756	28	3965
3	3763	29	3972
4	3772	30	3979
5	3780	31	3986
6	3789	32	3993
7	3798	33	4000
8	3807	34	4006
9	3816	35	4013
10	3824	36	4020
11	3833	37	4026
12	3842	38	4032
13	3850	39	4039
14	3858	40	4044
15	3867	41	4051
16	3874	42	4057
17	3882	43	4063
18	3890	44	4069
19	3898	45	4074
20	3906	46	4078
21	3913	47	4083
22	3921	48	4085
23	3929	49	4083
24	3936		
25	3944		

introduced by the measurement error has been removed; however, the basic error remains. This basic error results from the incorrect shape of the capacitor plates used over the particular frequency ratio in **Table 2**.

How does the error for this type of precision-tuning capacitor change with the frequency ratio covered? True straight-line frequency capacitors are designed for only one frequency ratio. Does this capacitor have a ratio where the error will be at its lowest?

FIGURE 11



Smoothed raw data (parabola) is used to find the best straight-line fit to determine the error from a linear dial.

More measurements

I tried a variety of tuning ratios using the procedure just described. I selected fixed capacitors from 50 to 500 pF and investigated frequency ratios from less than 1.1:1 to over 1.3:1. My tuning range was about 200 kHz to over 1300 kHz at the center dial frequency of 4.6 MHz. I calculated the percentage error by dividing the error at the dial center by the tuning range. As I mentioned previously, you can make the error small for almost any capacitor by restricting the tuning range. Calculating the percentage error, however, highlights the true error of the capacitor.

The results are shown in Figure 12. Note that the error is positive at the dial center for ratios below 1.25:1 and negative for ratios above. This reverses the parabolas of Figures 8 and 9. As it turns out, the best ratio is 1.25:1. The error here seems to be very close to zero. In fact it's less than 0.1 percent.

Practical use

With errors this small, you can construct high-performance linear tuning dials. For example, a 500-kHz range can be covered with less than 0.5-kHz error. You could also use the circular protractor degree markings to cover the 300 kHz from 1.2 to 1.5 MHz.

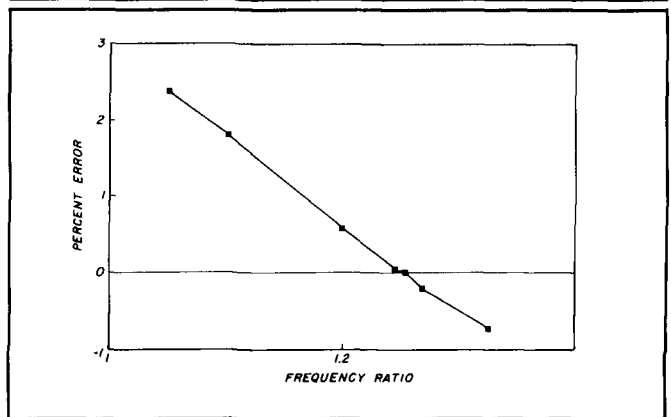
Transceiver builders are interested in the 4.8 to 6-MHz range. By using just the top 5.5 to 6 MHz, you can build a nice master VFO. It's also possible to make a remote VFO for use with the popular commercial transceivers. Precision linear dials are practical for Amateur measuring instruments like signal generators and R-X bridges. I'm sure you can find many more applications.

I have one suggestion that should make your transceiver front panel layout more attractive. Mount the capacitor at an angle so the main shaft is aligned directly below the center of the dial as shown in Figure 13.

Conclusion

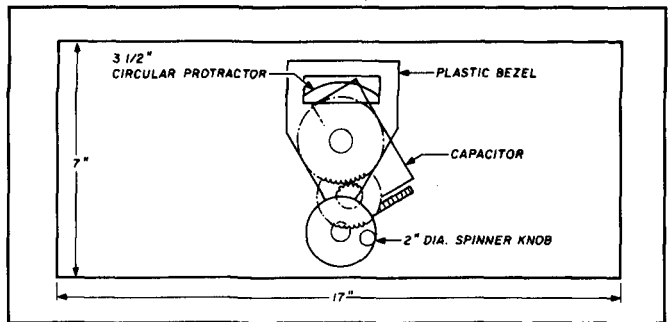
The theory of linear tuning capacitors led me to explore the use of surplus capacitors in Amateur applications. I've given construction details for practical precision dials. Remember that it's important to select a 1.25:1 frequency ratio for 300 degrees rotation of the main dial.

FIGURE 12



Percent error for a WWII tuning capacitor. Tuning range was about 200 to 1300 kHz at center dial frequency of 4.6 MHz.

FIGURE 13



Transceiver application.

I still don't know why the original dials from WWII gear are nonlinear. They appear to use a 1.32:1 frequency ratio. Was the capacitor designed for one ratio, but used with another? Was it a trial-and-error procedure that was put aside too soon? I'd like to hear from anyone who knows what happened. **77**

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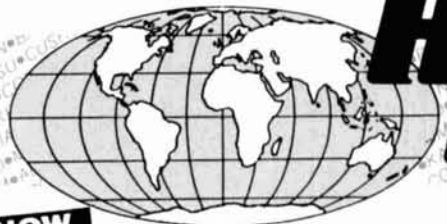
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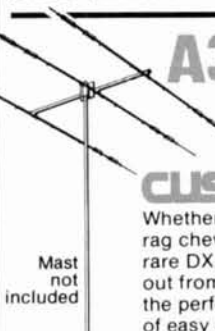
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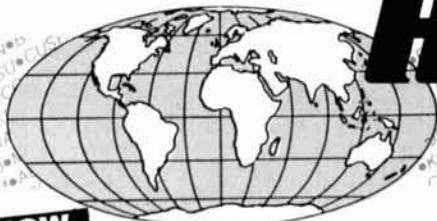
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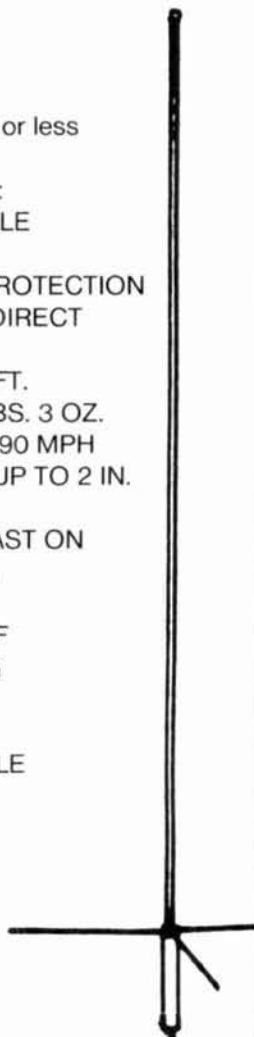
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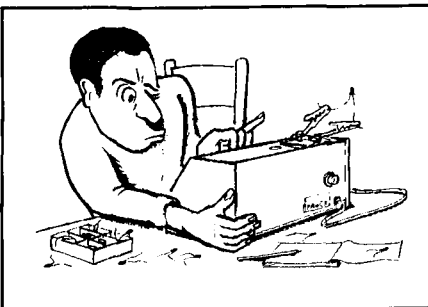
PART 1 HIGH-FREQUENCY DIPOLE ANTENNAS

Last month I discussed the basic ingredients of the dipole antenna. This antenna has acquired an undeservingly poor reputation in an era of multi-band beams and other costly antennas. When installed correctly (which is easy to do), the dipole turns in a credible performance. In fact, some poorly constructed (or designed) commercial three-element beam antennas perform only as well as a dipole at the same height. The dipole antenna performs well for the money, time, and brainpower invested. This month I'll take a second look at this antenna and discuss how you might go about tuning one. I'll also describe dipole variants like the broadbanded and loaded dipoles.

Tuning the dipole antenna

There are two issues to address when tuning an antenna (any antenna, not just the dipole): *resonance* and *impedance matching*. Although they are frequently treated in the literature as the same issue, they are not. In this article I'll deal primarily with the process of tuning the antenna to resonance. Not all antennas are resonant, but the dipole is.

There's a lot of misinformation on antenna tuning. Perhaps much of what is believed is a result of using VSWR as the indicator of both resonance and impedance matching. Many people honestly (but erroneously) believe that the VSWR can be "tuned out" by adjusting the feedline length. That myth probably derives from the fact that voltage or current-sensing instru-



ments are used for VSWR measurement, and these are affected by transmission line length. But the problem lies in the instruments; it's not a fact of radio physics. Another factor which leads to confusion is that varying the line length may provide an impedance transformation that matches the antenna to the transmitter, but doesn't address the point that the antenna is off resonance and therefore less efficient.

There's only one proper way to tune a dipole antenna — *adjust the length of the antenna elements*. You don't adjust the transmission line. As I mentioned when discussing construction methods last month, you leave the electrical connections at the center insulator unsoldered so you can make these adjustments.

The minimum point in the VSWR curve is the resonance indicator. **Figure 1** shows a graph of VSWR versus frequency for several different cases. Curve A represents a disaster — a high VSWR across the band. The actual VSWR value may be anything from about 3.5:1 to 10:1 (or thereabouts), but the cause is the same. The antenna is either open or shorted, or is so far off resonance that it appears open or shorted to the VSWR meter.

Curves B and C represent antennas that are resonant within the band of interest. Curve B represents a broadbanded antenna that's relatively flat across the band, and doesn't exhibit excessive VSWR until the frequency is

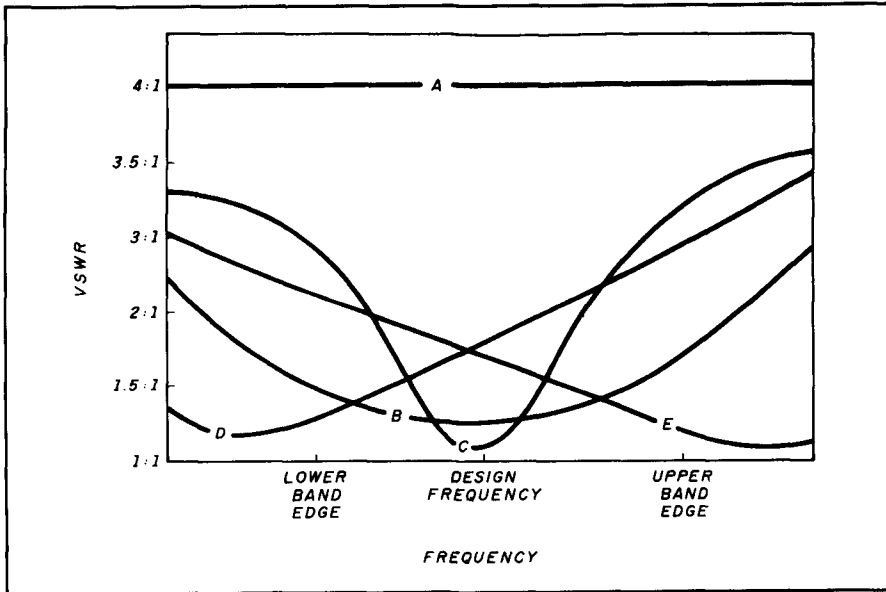
outside the band. Curve C is also resonant within the band, but this antenna has a lot higher Q than curve B. In the simplest sense the broadbanded antenna is best, but that statement is true only if broadness is not purchased at the expense of efficiency. Resistive losses tend to broaden the antenna frequency response but also reduce its effectiveness. The antenna is effectively "broadbanded," as seen by the transmitter, by the addition of the equivalent of a power-absorbing resistor at the feedpoint. Again, it's undesirable if this broadbandedness is purchased at the cost of increased loss.

Curves D and E in **Figure 1** are resonant outside the band of interest. The D curve is resonant at a frequency on the low side of the band, making that dipole too long. In this case you need to shorten the antenna to raise the resonant point inside the band. Curve E represents an antenna that's resonant outside the upper limit of the band; this antenna is too short and must be lengthened. Because the antenna is frequently too short, cut the elements longer than necessary at first.

How much you cut depends on two factors: how far the resonant point is from the desired frequency, and which band you're working on. The second requirement results from the fact that the "frequency per unit" length varies from one band to another. Let's look at an example of how to calculate this figure. The procedure is simple:

- Calculate the length required for the upper end of the band.
- Calculate the length required for the lower end of the band.
- Calculate the difference in lengths for upper and lower ends of the band.
- Calculate the width of the band in kilohertz by subtracting the difference between the upper frequency limit and the lower frequency limit.

FIGURE 1



VSWR versus frequency for several cases.

- Divide the length difference by the frequency difference; the result is in kilohertz per unit length.

Example

Calculate the frequency change per unit of length for 80 and 15 meters.

Solution:

For 80 meters (3.5 to 4.0 MHz):

$$L_{ft} = 468/4 \text{ MHz} = 117 \text{ feet}$$

$$L_{ft} = 468/3.5 \text{ MHz} = 133.7 \text{ feet}$$

Difference in length: $133.7 \text{ feet} - 117 \text{ feet} = 16.7 \text{ feet}$.

Frequency difference: $4000 \text{ kHz} - 3500 \text{ kHz} = 500 \text{ kHz}$.

Calculate frequency/unit length: $500 \text{ kHz}/16.7 \text{ feet} = 30 \text{ kHz/foot}$.

For 15 meters (21.0 to 21.45 MHz):

$$L_{ft} = 468/21.45 = 21.82 \text{ feet}$$

$$L_{ft} = 468/21 = 22.29 \text{ feet}$$

Difference in length: $22.29 \text{ feet} - 21.82 \text{ feet} = 0.47 \text{ feet}$.

Convert to inches: $0.47 \text{ feet} \times 12 \text{ inches/foot} = 5.64 \text{ inches}$.

Frequency difference: $21,450 \text{ kHz} - 21,000 \text{ kHz} = 450 \text{ kHz}$.

Calculate frequency/unit length: $450 \text{ kHz}/5.64 \text{ inches} = 80 \text{ kHz/inch}$.

The frequency change per foot at 80 meters is small, but even small changes can result in very large frequency shifts at 15 meters. You can calculate approximately how much to

add or subtract from an antenna under construction using this kind of calculation. If, for example, you design an antenna for the so-called "international net frequency" on 15 meters (21,390 kHz), but find the actual resonant point is 21,150 kHz, then the frequency shift required is $21,390 - 21,150$, or 240 kHz. To determine how much to add or subtract (as a first guess):

The factor for 15 meters is 80 kHz/inch, which is the same as saying 1 inch/80 kHz.

The required frequency shift is 240 kHz.

Therefore:

$$\text{Length change} = 240 \text{ kHz} \frac{1 \text{ inch}}{80 \text{ kHz}}$$

$$\text{Length change} = 3 \text{ inches}$$

Each side of the antenna must be adjusted by half the length calculated above, or 1.5 inches. Because the first resonant frequency is less than the desired one, you should shorten the length by 1.5 inches. Once the length is correct (as proven by the VSWR curve), solder the connections at the center insulator to make them permanent, and hoist the antenna back to operating level.

You can see the difference between resonance and impedance matching in the value of the VSWR minimum. While the minimum indicates the resonant point, the value of that minimum

is a measure of the relationship between the feedpoint impedance of the antenna and the characteristic impedance of the transmission line. Last month you learned that:

$$Z_o > R_r:$$

$$VSWR = Z_o/R_r \quad (1)$$

$$Z_o < R_r:$$

$$VSWR = R_r/Z_o \quad (2)$$

Where:

Z_o is the coaxial cable characteristic impedance.

R_r is the radiation resistance of the antenna.

Although knowing the VSWR won't tell you which situation is true, you'll know that there's a high probability that one of them is. Experiment to find which is the case. Of course, if the VSWR is less than about 1.5:1 or 2:1 then forget about it; the improvement isn't generally worth the expense and cost. When the transmission line is coupled to a transmitter that's equipped with a tunable output network (most tube-type transmitters or final amplifiers), it can accommodate a relatively wide range of reflected antenna impedances. But modern solid-state final amplifiers tend to be a little more picky about the load impedance. For these transmitters a coax-to-coax antenna-tuning unit (ATU) is needed.

Other dipoles

So far I've discussed classic dipoles with half-wavelength single conductor radiator elements connected to a coaxial transmission line. This type of antenna is most often installed horizontally a half wavelength above the ground (or wherever convenient if that's impossible). Next I'll take a look at other forms of dipoles. Some of these are equal in every way to the horizontal dipole; others are basically compensation antennas used when a proper dipole isn't practical.

Inverted-V dipole

The inverted-V dipole is a half-wavelength antenna fed in the center like a dipole. By definition, the inverted-V is merely a variation on the dipole theme. In this antenna (Figure 2) the center is elevated as high as possible above ground, but the ends droop very close to the surface. Angle

"a" can be almost any convenient angle greater than 90 degrees. Most inverted-V antennas use an angle of about 120 degrees. This antenna provides a compromise when a dipole can't be used. Many operators believe it's a better performer on 40 and 80 meters in cases where the dipole can't be mounted at a half wavelength (64 feet or so).

Sloping the antenna elements down from the horizontal to an angle (Figure 2) effectively lowers the resonant frequency. This means the antenna will need to be shorter than a dipole for any given frequency. There's no absolutely rigid equation for calculating the overall length of the antenna elements. Although the concept of "absolute" length doesn't hold for regular dipoles close to the ground, it's even less viable for the inverted-V. There is, however, a rule of thumb you can use for a starting point — make the antenna about 5 percent shorter than a dipole for the same frequency. Try cutting the antenna to the length required for a regular dipole on the same frequency and trim from there, using the tuning procedure.

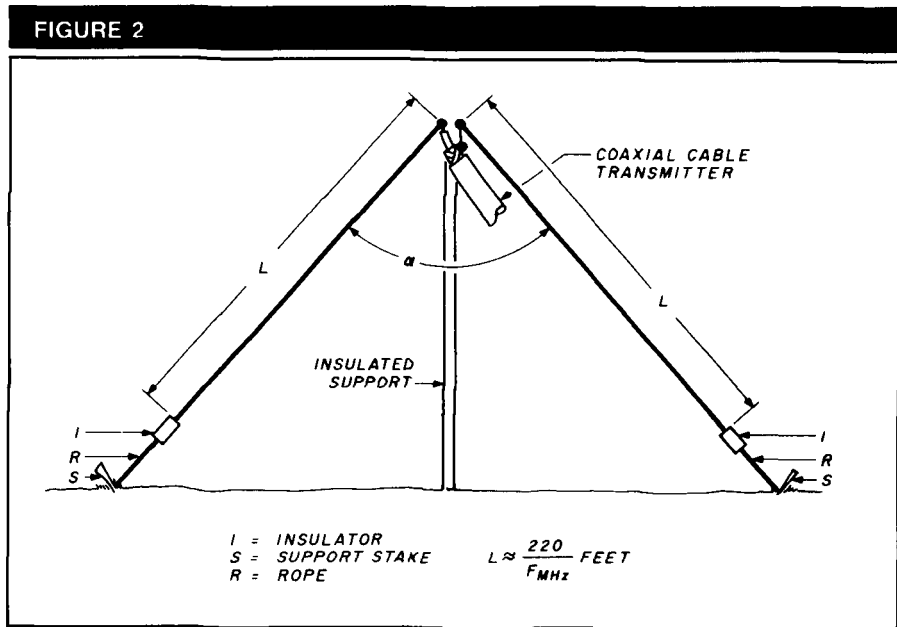
$$L = \frac{468}{F_{MHz}} \text{ feet} \quad (3)$$

After determining the approximate length, find the actual length with the same cut-and-try method used to tune the dipole in the previous section.

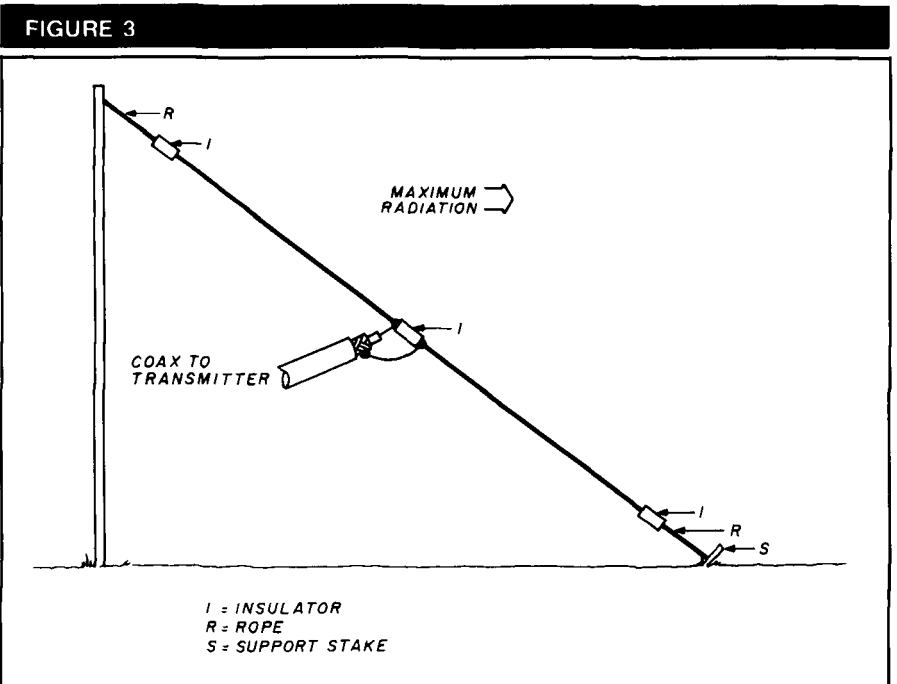
Sloping the elements changes the feedpoint impedance of the antenna and narrows its bandwidth. You'll need to make some adjustments as a result. You might want to use an impedance-matching scheme at the feedpoint, or an antenna tuner at the transmitter.

Sloping dipole ("sloper" or "slipole")

The sloping dipole in Figure 3 is popular with operators who need a low angle of radiation but don't have a large area for their antenna installation. Various texts call this antenna the sloper or the slipole. I use the term slipole to distinguish this antenna from a sloping vertical. But whatever you call it, it's a half-wavelength dipole with one end at the top of a support and the other end close to ground, fed in the center by coaxial cable.



Inverted-V dipole antenna.



Sloper dipole (also called "slipole").

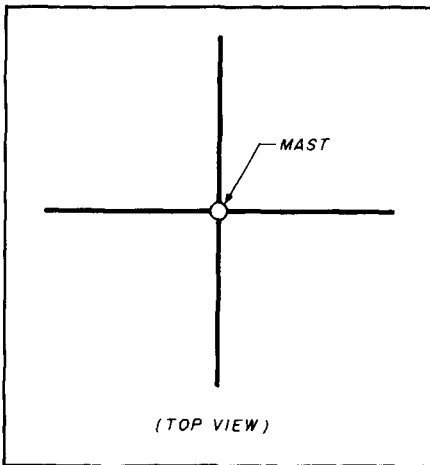
Some operators like to hang four sloping dipoles from the same mast pointing in different directions (Figure 4). A single four-position coaxial cable switch lets you switch a directional beam on different headings that favor various locations.

Broadbanded dipoles

It is rarely discussed that the length/diameter ratio of the conductor used for the antenna element is a fac-

tor in determining antenna bandwidth. In general, a large cross-sectional area makes the antenna more broadband. In some cases, using aluminum tubing instead of copper wire for the antenna radiator is advisable. Tubing is a viable solution on the higher frequency bands. Aluminum tubing is inexpensive, lightweight, and easily worked with common tools. You can make a rotatable directional dipole with ordinary aluminum tubing. But as

FIGURE 4



Several slopers supported from a common mast give directional characteristics.

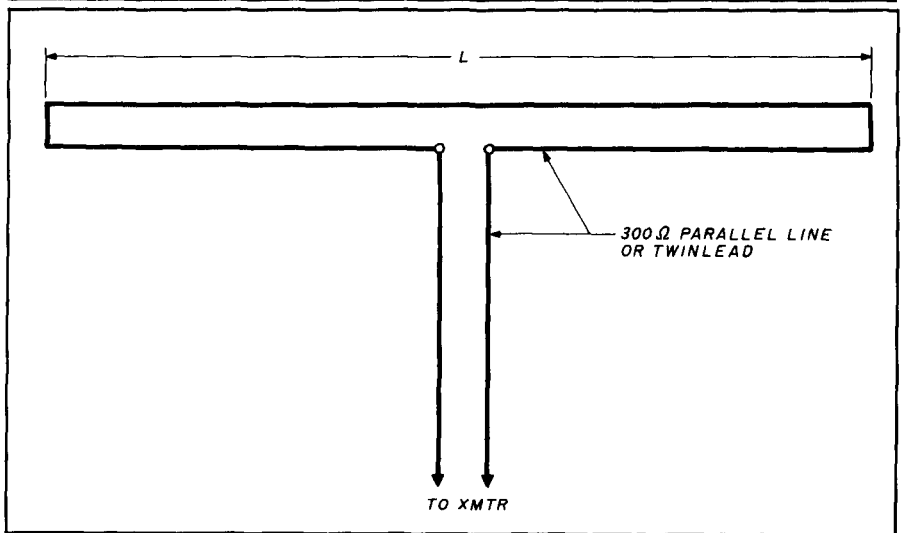
the frequency decreases, the weight becomes greater. This is because the tubing is longer and must be of greater diameter for structural strength.

Aluminum tubing is impractical on 80 meters and nearly impractical on 40. Yet it's at 80 meters that you find a significant problem (especially with certain older transmitters). The band is 500 kHz wide, and older transmitters often lack the tuning range for the entire band. Three basic solutions to the problem of wide bandwidth dipole antennas are: the *folded dipole*, the *bowtie dipole*, and the *cage dipole*.

Figure 5A shows the folded dipole antenna. It's basically two half-wavelength conductors shorted together at the ends and fed in the middle of one of them. The folded dipole is usually constructed from 300-ohm television antenna twin-lead transmission line. Because the feedpoint impedance is nearly 300 ohms, you can use the same type of twin lead for the transmission line. The folded dipole exhibits excellent wide bandwidth properties, especially on the lower bands.

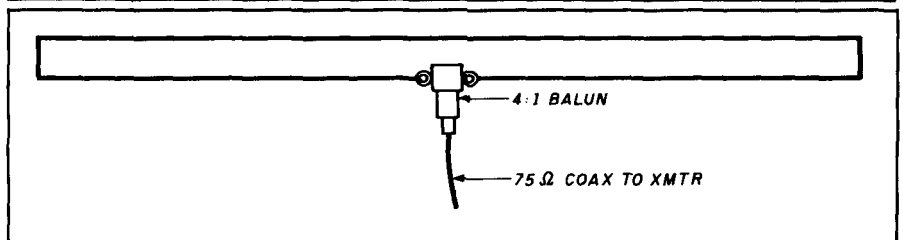
For a folded dipole the transmitter has to match the 300-ohm balanced transmission line, which is a disadvantage. Unfortunately, most modern radio transmitters are designed to feed coaxial cable transmission line. Although you can place an antenna tuner at the transmitter end of the feedline, it's also possible to use a 4:1 balun transformer at the feedpoint (Figure 5B). This arrangement makes

FIGURE 5A



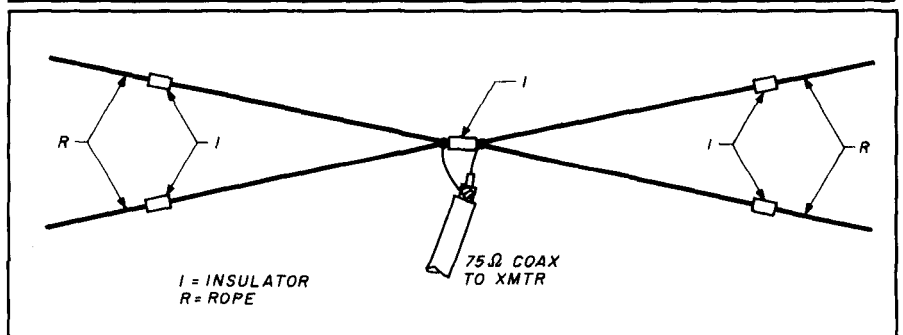
Folded dipole fed with twin lead.

FIGURE 5B



Folded dipole fed with coax and a 4:1 BALUN.

FIGURE 6



Broadbanded "bowtie" dipole.

the folded dipole a reasonable match to 52 or 75-ohm coaxial cable transmission line.

Another method for broadbanding the dipole is to use two identical dipoles fed from the same transmission line arranged to form a "bowtie," as shown in Figure 6. Using two identical dipole elements on each side of the transmission line increases the conductor cross-sectional area, so the

antenna has a slightly improved length/diameter ratio.

The bowtie dipole was popular in the 1930s and '40s; it was the basis for the earliest television receiver antennas. (TV signals are 3 to 5 MHz wide and require a broadbanded antenna.) This antenna was also popular during the 1950s as the so-called "Wonder Bar" antenna for 10 meters. Some are still in use, but the antenna's

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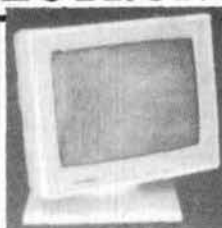


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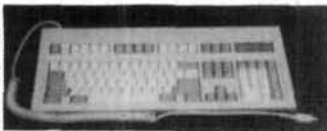
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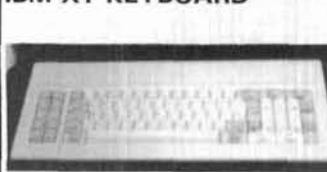
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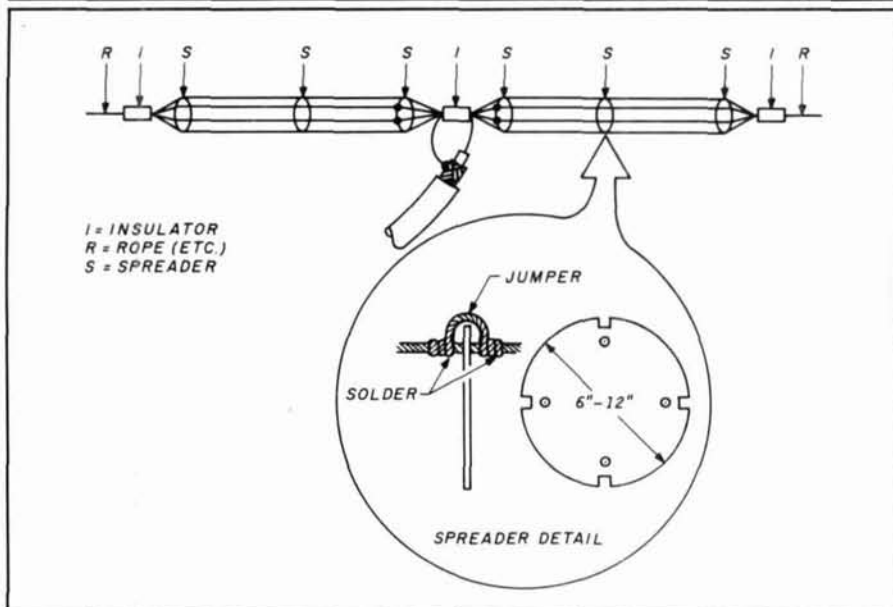
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FIGURE 7



Cage dipole.

popularity has faded. The ends are spread to approximately 11 percent of the total length.

The cage dipole (Figure 7) is similar to the bowtie in concept, if not construction. Again, the idea is to connect several parallel dipoles extending from the same transmission line in an effort to increase the apparent cross-sectional area. But with the cage dipole, spreader disk insulators keep the wires separated. The insulators can be built from Plexiglas™, lucite, or ceramic. They may also be made of materials like wood that's properly treated with varnish, polyurethane, or any other material that prevents water-logging. The spreader disks are held in place with wire jumpers (see inset

to Figure 7) soldered to the main element wires.

Some bowtie and cage dipole builders make the elements slightly different lengths. This "stagger tuning" method forces one dipole to favor the upper end of the band and the other to favor the lower end. The overall result is a slightly flatter frequency response characteristic across the entire band. On the cage dipole, with four half-wavelength elements, it should be possible to overlap even narrower sections of the band in order to create an even flatter characteristic.

Shortened dipoles

The half-wavelength dipole is too long for some applications — espe-

TABLE 1

Approximate inductance reactances as a function of the percentage of half wavelength represented by the shortened radiator.

Percent of half wavelength	Coils at feedpoint (ohms)	Coils at middle of radiators (ohms)
20	1800	2800
30	950	1800
40	700	1300
50	500	950
60	360	700
70	260	500
80	160	320
90	75	160
95	38	80
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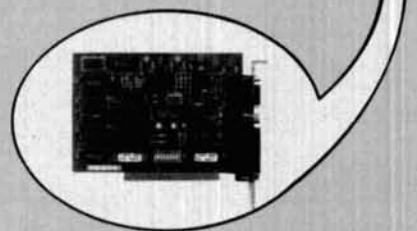
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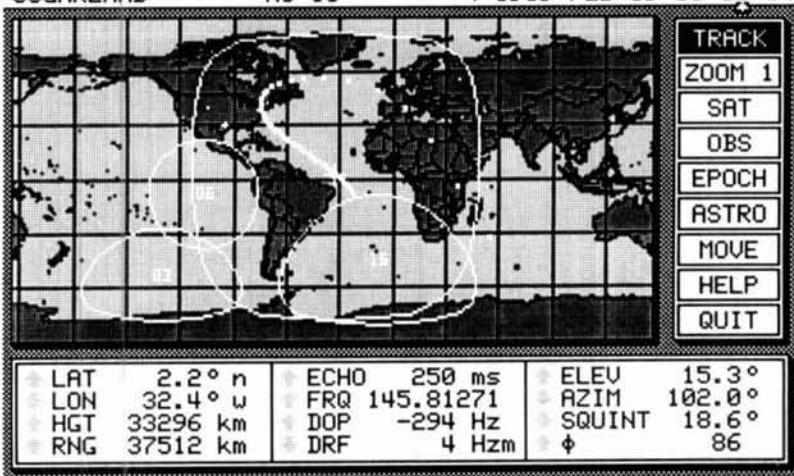
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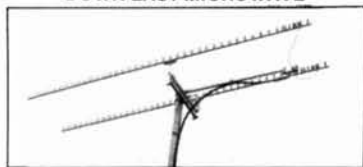
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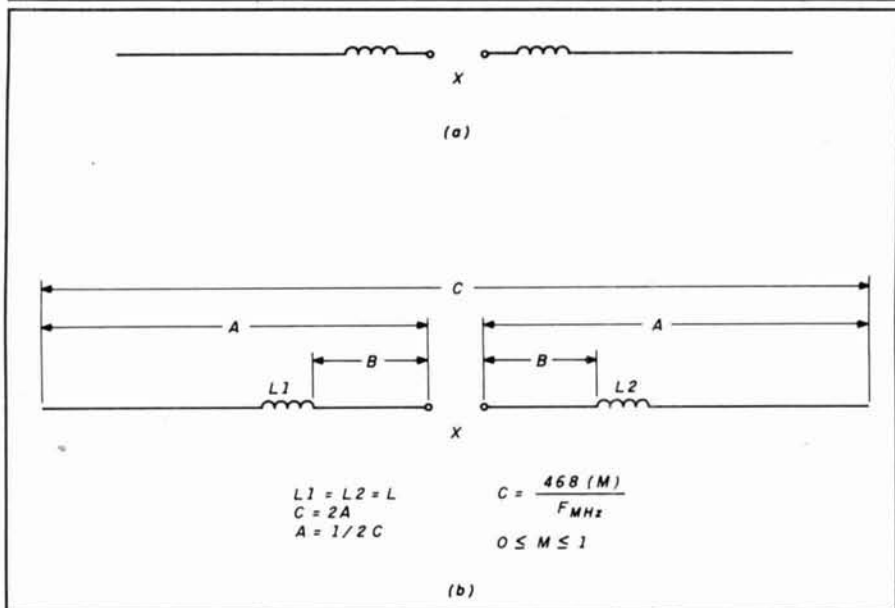
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FIGURE 8



Coil-loaded dipole: a) coils at feedpoint; b) coils at 50-percent point.

cially where real estate is at a premium. Many operators solve this problem by using a coil-loaded shortened dipole like the one shown in Figure 8. A shortened dipole (one which is less than half a wavelength) is capacitive, so it must have an in-line inductance to compensate for the inherent capacitive reactance. There's no reason why the loading coil can't be put at any point along the radiator, but in Figures 8A and 8B they are placed at 0 and 50 percent of the element length, respectively. This makes coil inductance calculations easier, and also represents the most common practice.

Table 1 shows approximate inductive reactances as a function of the percentage of half wavelength represented by the shortened radiator. It's likely that the percentage figure will be imposed on you by the situation, but the general rule is to pick the largest figure consistent with the available space. For example, suppose you have about 40 feet available for a 40-meter antenna that normally needs about 65 feet for a half wavelength. Because 39 feet is 60 percent of 65 feet, you can use this value as the design point for your antenna. In Table 1 you'll see that a 60-percent antenna with the loading coils at the midpoint of each radiator element wants to see an inductive reactance of 700 ohms. Rearrange the

standard inductive reactance equation ($X_L = 6.28 FL$) to the form:

$$L_{\mu H} = \frac{X_L \times 10^6}{6.28 F}$$

Where:

$L_{\mu H}$ is the required inductance in microhenries.

F is the frequency in hertz (Hz).

X_L is the inductive reactance calculated from Table 1.

Example

Calculate the inductance required for a 60-percent antenna operating on 7.25 MHz. The table requires a reactance of 700 ohms for a loaded dipole with the coils in the center of each element (Figure 8B).

Solution:

$$L_{\mu H} = X_L \times 10^6 / 6.28 F$$

$$L_{\mu H} = (700)(10^6) / (6.28)(7,250,000)$$

$$L_{\mu H} = 7 \times 10^8 / 4.6 \times 10^7 = 15.4 \mu H$$

The calculated inductance is approximate and may have to be altered by cut-and-try methods.

The loaded dipole antenna is very sharply tuned. Because of this, you must either confine operation to one segment of the band or provide an antenna tuner to compensate for the sharpness of the bandwidth characteristic. However, efficiency drops markedly far from resonance, even

with a transmission line tuner. The tuner overcomes the bad effects on the transmitter, but doesn't alter the basic problem. Only a variable inductor in the antenna will do that. (At least one commercial loaded dipole once used a motor-driven inductor at the center feedpoint.)

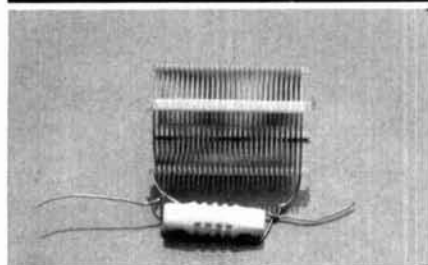
Photos A and B show two methods for making a coil-loaded dipole antenna. Photo A shows a pair of commercially available loading coils designed for this purpose. These coils are for 40 meters, but other models are also available. The inductor in Photo B is a section of B&W Miniductor connected to a standard end or center insulator. No structural stress is assumed by the coil; all forces are applied to the insulator.

PHOTO A



Commercial loading coils.

PHOTO B



Homebrew loading coil based on B&W Miniductor.

Conclusion

The dipole antenna is easy to design, easy to build, and well behaved enough that even novice builders can make it work successfully, and well. Go for it!

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Have you ever measured the amount of RF power going into a coax feedline at, say, 2 meters and then measured the amount of RF coming out the other end? I did and I was amazed! I had about half the power at the far end of a 100-foot length of RG-8 cable. When I tried RG-58 coax, I had a power loss of about 75 percent. I didn't really believe my measurements, so I went to the coax tables. The tables list 100 feet of RG-8 coax (silver-plated center conductor with silver-plated double-shield outer braid) as having a loss at 150 MHz of about 2.5 dB. If you add a little more, because of connectors or standing wave ratio, you can easily approach 3 dB. That 3 dB reduces the signal power by one-half. In other words, if you have a 3-dB loss and 100 watts going into the coax, the 3 dB will cause a loss of 50 watts in the line. This means that the remaining power going to the antenna is 50 watts. Quite a price to pay! The RG-58 is even worse. The tables list its loss factor as 6 dB. Your 100 watts would be reduced by half and then by half again (or 75 percent), leaving 25 watts to appear at the other end of the cable. This, of course, assumes there are no other losses.

At about the time I was making these measurements and checking my data, the local cable operator gave me a "tag end" of 3/4" hardline. I'd heard that aluminum hardline was superior to RG-8 coax. The tables show a 1/2 dB loss at 150 MHz, over a 100-foot length.

I wanted to know how to match my 50-ohm equipment to the 75-ohm hardline. I remembered that a quarter-wave matching transformer was a possibility and looked up the for-

mula for the impedance of the quarter-wave section. It was stated as follows:

$$Z_o = \sqrt{Z_1 \times Z_2} \quad (1)$$

where: Z_o = impedance of the line

Z_1 = the 50-ohm coax

Z_2 = the 75-ohm hardline

Solving for:

$$Z_o = \sqrt{50 \times 75} = \sqrt{3750} = 61.2 \text{ ohms} \quad (2)$$

In other words, you'd need a coax with an impedance of 61.2 ohms to make a quarter-wave matching transformer.

At this point I shrugged my shoulders and was about to look for some other solution, because 61.2-ohm coax isn't what you'd call a standard item. Then I remembered that several hams in our area use copper pipe to make transformers. I had heard that they were easy to build for VHF and UHF ham communications. Using the *ARRL Handbook*, I found the formula for calculating the sizes of the inner and outer conductors for air-dielectric coax.

Calculations

The basic formula for calculating the inner diameter of the outer conductor and the outer diameter of the inner conductor is listed as follows:

$$Z_o = 138 \text{ Log } D/d$$

where: Z_o = impedance of the line

D = inner diameter of the outer conductor

d = outer diameter of the inner conductor

Since you already know that Z_o is 61.2 ohms, you can rearrange the formula to solve for D , for example:

$$Z_o = 138 \text{ Log } D/d$$

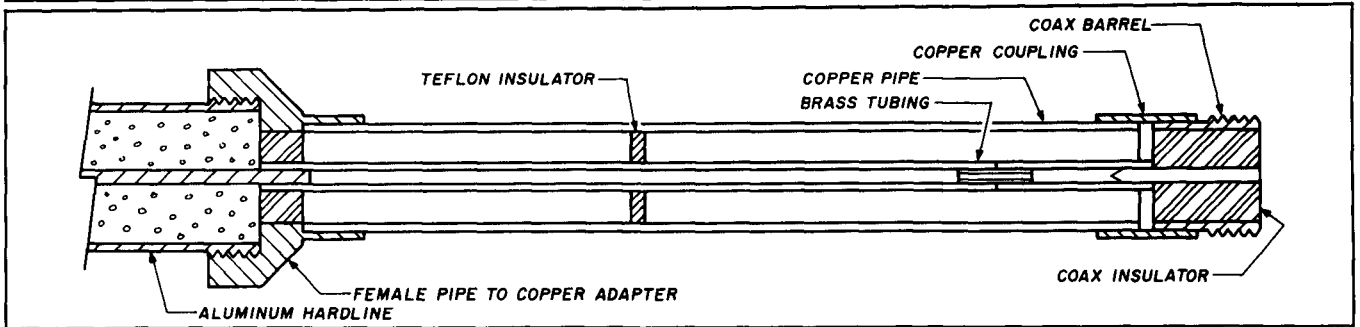
$$Z_o = 138 (\text{Log } D) - (\text{Log } d)$$

$$D = 10^{\left(\frac{Z_o}{138}\right) + \text{log } d} \quad (3)$$

Substituting the appropriate numbers you find:

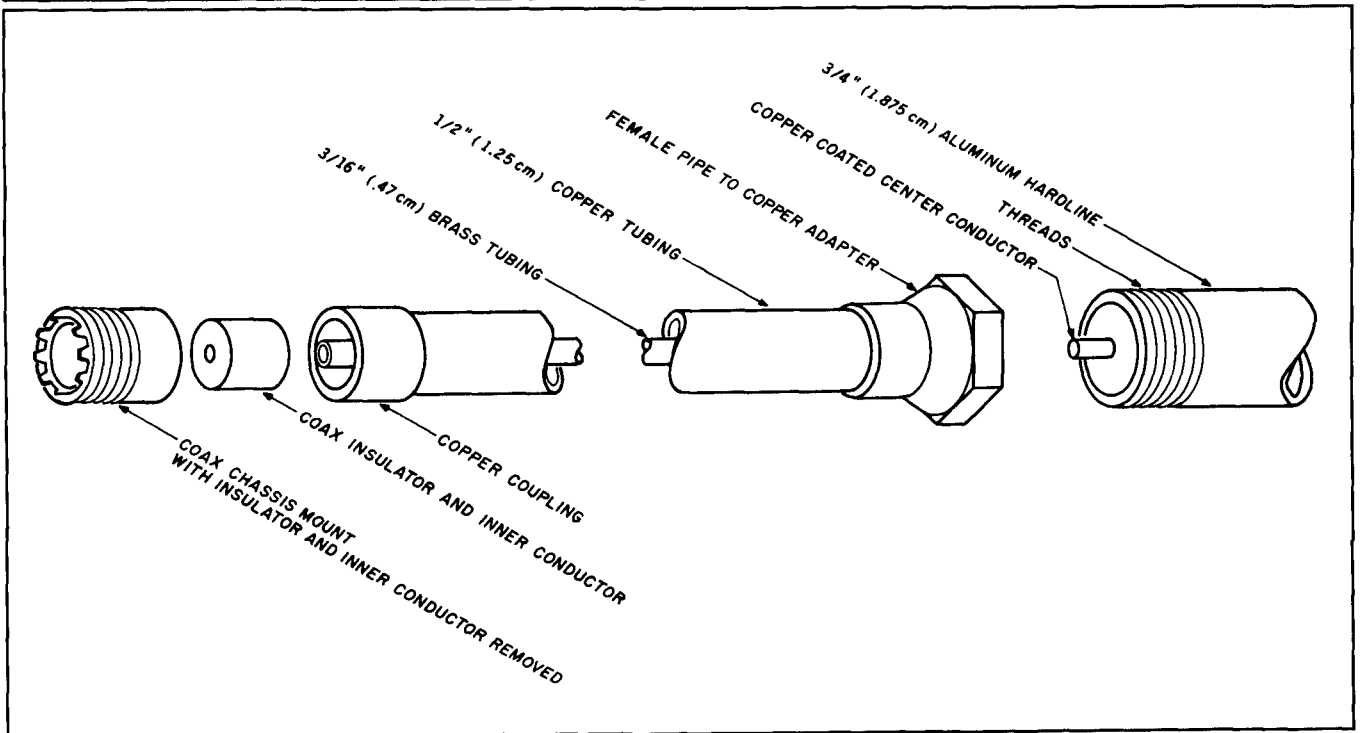
$$D = 10^{\left(\frac{61.2}{138}\right) + \text{log } d} \quad (4)$$

FIGURE 1



Detailed layout of the components used in the construction of a quarter-wave matching transformer for 75 to 50-ohm coax.

FIGURE 2



Expanded view of the quarter-wave matching transformer.

If you arbitrarily select 3/16" brass tubing (available at most hobby shops) for the inner conductor, you can solve for the larger conductor as follows:

$$D = 10 \left(\frac{61.2}{138} \right) + (-0.7270) = (0.4435) + (-0.7270) \quad (5)$$

$$D = 10(-0.2835)$$

$$D = 0.5205 \text{ or just over } 1/2".$$

This means that if you use 3/16" brass tubing for the inner conductor, you can use 1/2" copper pipe for the outer conductor. But what length should the transformer be? I wanted to use 147.225 MHz so I used the formula:

$$\frac{234}{\text{freq. MHz}} \text{ or } \frac{234}{147.225} = 1.589 \text{ feet or } 19 \text{ inches} \quad (6)$$

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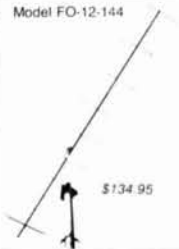
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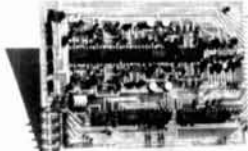
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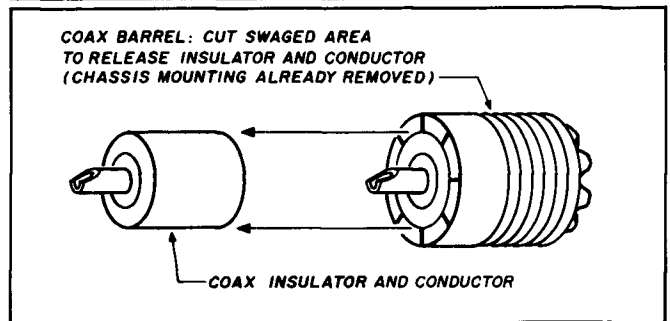
Construction

To begin, measure the exact size of the *inner* diameter of the *outer* conductor you'll be using. Consult **Table 1** to find the corresponding brass center conductor. The brass tubing at the hobby store is sized so that the next smaller one slides snugly into the larger size. This is ideal for lengthening the tubing from the 12" standard lengths to whatever length you need. When you purchase the four pieces of brass tubing for the inner conductor, be sure to purchase one length of the next smaller size. Then you can sweat solder small lengths inside the larger brass tubes to make them longer.

The parts list covers most of the major items needed to build two quarter-wave matching transformers. You'll want to construct one matching section for each end of the hardline. (See **Figure 1.**) Here's the procedure I used to build the transformers.

- Trim both ends of the hardline back so that approximately 1/2" of the center conductor extends beyond the outer sheath. Carefully clean any plastic foam residue from the center conductor. The center conductor is copper plated. Be sure to leave the copper plating intact or you'll be unable to sweat solder the brass tubing to the center conductor.
- Run a 1/2" pipe-threading die onto each end of the hardline. The threads won't be very deep because the hardline is a little under size.
- Select a coax chassis mount and turn it down in a lathe (or file it) to remove the flange. This lets the coax barrel fit snugly inside the 1/2" copper coupling. Make two of these. I use N-type coax fittings, but UHF types work well also.
- Carefully remove the center conductor from the coax barrels. Some of these are held in with split washers; others are merely "press" fit, and some are swaged. If swaged, cut the swaging so the inner conductor and insulator slide out of the barrel (see **Figures 1, 2, and 3**).
- Splice two pieces of the 3/16" brass tubing together using a 1" length of the smaller diameter brass tubing which slides inside this tubing. Sweat solder the joint; then fit the coax center conductor into one end of the 3/16" tubing. You might have to construct a bushing. Sweat solder this inner coax conductor to the brass tubing.
- Cut the other end of the brass tubing to the correct length. Measure from one end of the brass tube to the other. (Do not include the length of the coax center conductor in this measurement).
- Make a Teflon™ spacer to slide tightly over the tubing and inside the outer conductor (the 1/2" copper pipe). Sweat solder the brass tubing to the inner conductor of the hardline. See **Figures 1 and 2**.
- Temporarily thread the adapter onto the hardline. Cut a 1/2" copper pipe to approximately 20"; then slide one end into the adapter. Slide the copper coupling over the other end of the 1/2" copper pipe. Carefully measure the distance between the end of the brass tubing and the area in the coupling where the coax barrel will be placed. **Figure 1** shows how the coax barrel should fit into the copper coupling. The brass tube should be up against the plastic insulation on the hardline on one end, and the coax inner insulator properly located in the coax barrel at the other end. Trim the copper pipe to exact length at this time. Double

FIGURE 3



Details for making the coaxial barrel to fit in the end of the 1/2-inch copper tubing.

TABLE 1

Some close approximations for inner and outer conductor diameters.		
Inner Conductor		
Decimal	Fraction	Metric
0.15625	5/32	39 mm
0.1875	3/16	47 mm
0.21875	7/32	55 mm
Outer Conductor		
Decimal	Fraction	Metric
0.4340	7/16	108 mm
0.5205	33/64	130 mm
0.6071	19/32	152 mm

check to make sure everything fits together exactly as shown in **Figure 1 and 2**.

- Solder the copper pipe to the female pipe to copper adapter. Spread Noalox™ on the aluminum hardline threaded area and thread the adapter onto the hardline. Tighten the adapter on the hardline, being careful not to bend or otherwise distort the hardline. It's easy to strip the threads because they aren't deep. Be careful! Tape this connection to help keep moisture out of the joint.
- Assemble the copper coupling, coax insulator, center conductor, and coax barrel into final configuration. Sweat solder the copper coupling to the copper pipe and the coupling to the coax barrel.

This completes the transformer. As I said before, you'll need one of these assemblies at each end of the 75-ohm hardline.

When I checked the power going into the cable and compared it with the power coming out the other end, I couldn't detect more than about 2 watts of loss over the 100-foot length. This was a far cry from my earlier measurements. I've used the system for over four years with no deterioration.

It was worth the small effort it took to build these quarter-wave matching sections. The 75-ohm hardline is cheap and the transformer makes it usable with 50-ohm devices. I hope you'll have the same good results. If I can be of any help, please send an SASE.

I want to thank my friend Rob Mayer who helped me rearrange the basic formulae when I got into trouble with logs. **73**

A MOTORIZED AGITATOR FOR YOUR PRINTED CIRCUIT BOARDS

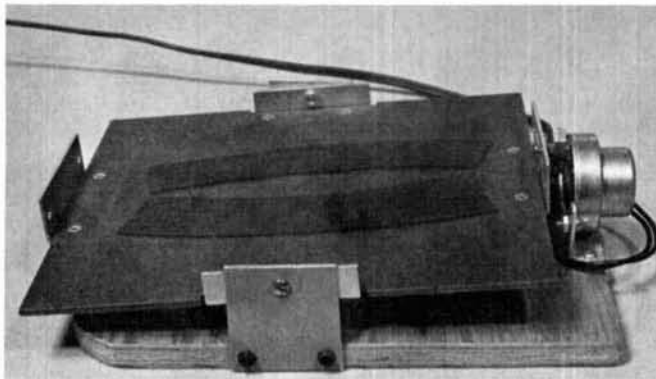
W. C. Cloninger, Jr., K3OF, 4409 Buckthorn Court, Rockville, Maryland 20853

When I first began making printed circuit boards, I placed the unetched board and etching solution in a glass container and agitated the contents by hand. Although the instructions for the ferric chloride etchant indicated a normal etching time of 15 to 20 minutes, I found that it took my boards considerably longer to etch completely — often as long as an hour.

There are three reasons for the extended etching time: (1) the thickness of the copper on the board, (2) the temperature of the etching solution, and (3) the fact that etching time increases noticeably as the etching solution nears the end of its useful life or point of exhaustion. I can't control the thickness of the copper, but I can control the other two variables. To increase the temperature of the etching solution, I place the glass container in a pan of warm water (approximately 100°F). I choose to be a little frugal with the etching solution, because I discard it immediately after use. The rule of thumb is to use 1 ounce of ferric chloride for each square inch of copper, but you can alter this rule depending on copper thickness.

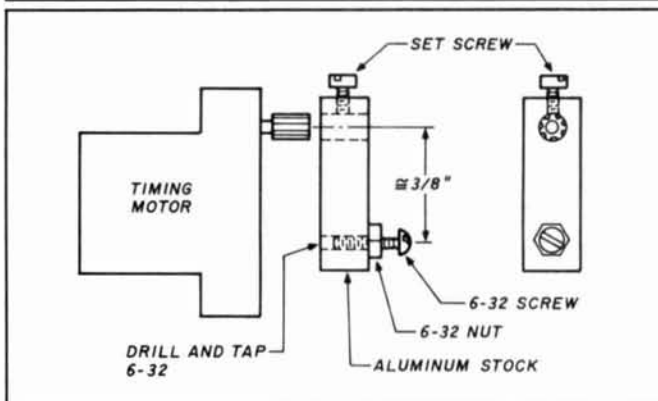
I suspect that my etching times are long because I like to get the maximum out of the etchant. I don't like to discard etchant that's only 50 percent exhausted. The long time required makes it quite a chore to agitate the boards and solution by hand. I mentioned in a previous article on making pc boards¹ that a motorized agitator was one of my next projects. The motorized agitator shown in **Photo A** is an easy, one-evening project. There's nothing difficult or fancy about its construction.

PHOTO A



Motorized agitator showing simple construction. Rubber inner-tube strips were glued to platform to keep container used for etching from slipping.

FIGURE 1



Details for making a simple crank for installation on the timing motor.

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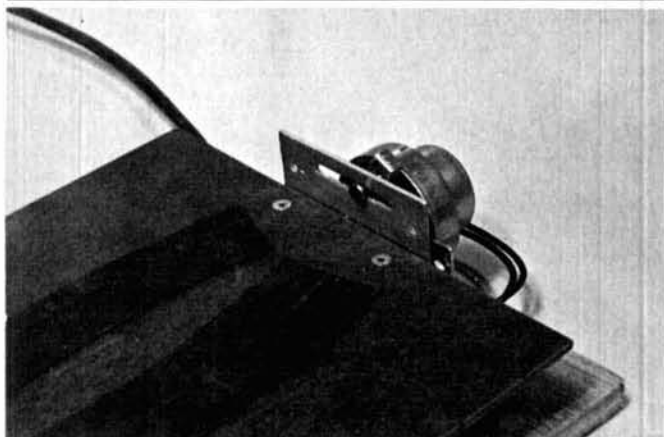
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PHOTO B



Closeup of crank and slot mechanism.

The heart of the project is the timing motor. I used a 4-rpm motor from my junkbox (an Olson Electronics special for about 79 cents). There are several suitable timing motors available from H & R Corporation, 401 E. Erie Avenue, Philadelphia, Pennsylvania 19134, for less than \$10. Another source is JERRYCO, Inc., 601 Linden Place, Evanston, Illinois 60202. Other hobby and surplus suppliers may have suitable low rpm motors. I don't think you want to go over about 6 rpm because you want to agitate the solution, not slosh it.

The motor is connected to a rocking platform by a crank and slot mechanism. Figure 1 shows how the crank was made and attached to the motor. Photo B shows how the crank is connected to a slotted bracket on the end of the rocking platform. I used aluminum angle stock for the ends and side brackets, and secured them to the masonite platform with pop rivets. A couple of rubber strips from an old inner tube added to the rocking platform keeps the tray or dish from slipping during agitation.

Using the agitator

I have found that it's important to change the position of the etchant container several times during agitation to prevent uneven or incomplete etching. You may also wish to keep the solution warm. I've found that a 100-watt bulb in a photographic reflector placed a few inches above the tray keeps the solution warm during agitation. A heat lamp positioned above the solution would be more than adequate.

This motorized agitator makes it easy to monitor the progress of the board etching, and saves a lot of tedious hand agitation. **h**

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1. W.C. Cloninger, K3OF, "EZ PCBs," 73, August 1987, page 43

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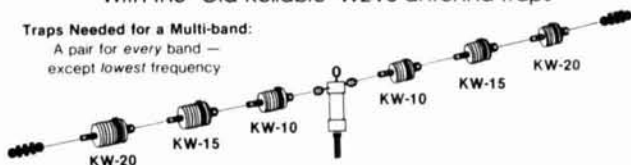
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ATV technology reaches new heights

William J. Brown, WB8ELK, 12536 T 77, Findlay, Ohio 45840

On June 4, 1988 at 8:58 a.m. CDT, W9PRD (Bob), WB9IHS (Chuck), and I launched a helium balloon Amateur Radio experiment from a grass airstrip 8 miles northwest of Greensburg, Indiana. The balloon package consisted of a 1-watt ATV transmitter (Wyman Research), a computer video I.D. generator with two graphics screens timed in sequence (Elktronics VDG-1), and a half-watt 2-meter FM transmitter sending out a CW I.D.

The balloon system was made up of a 6-foot weather balloon (Kaysam 105G), a recovery parachute, aluminum foil for FAA radar, and the 3-1/4 pound transmitter setup. The 2-meter antenna was a quarter-wave vertical whip; the ATV antenna was an omni-horizontal KS8J "beachball" antenna with two loops at right angles to each other.

The beachball antenna is somewhat directional and has a deep null off the back. As a result, there were deep fades in the ATV picture as the balloon and its cargo spun around. We determined the overall spin rate of the balloon package throughout the flight by observing these fades. The spin rate varied from one revolution every 20 seconds up to four revolutions per second. We plan to eliminate the fading in future flights by using a phasing line to feed one of the loops, making it a true omnidirectional antenna.

A combination of cold temperatures and battery failure caused a WB8ELK flight the previous August to stop transmitting at 70,000 feet, so we started a search for improved insulation and batteries. To better protect the equipment, we made a styrofoam package 2-1/2 inches thick and painted black to absorb solar radiation. Then, WB9IHS found some lithium cell batteries. These SAFT LX 2649 C cells are designed to withstand low pressure and low temperatures. We used ten cells

(two chains of five cells). After 8-1/2 hours of continuous drain at 700 mA they still had over 3 hours of life left!

Quite a few ATV'ers from central Indiana were on hand to help us launch the balloon. Larry, WB9YAJ, established a live linkup to the Indianapolis ATV repeater from the airstrip so that anyone within repeater range could view the launch activities. The weather was perfect. When we began inflating the balloon inside an aircraft hanger at 8:30 a.m., there was only a light wind and skies were crystal clear. Mother Nature didn't let us off that easy, however; the winds increased to over 20 mph just a few minutes before launch. Since the balloon was already fully inflated and the winds were fast approaching impossible launch speeds, we decided to send it up before the situation worsened. The balloon flailed around wildly, narrowly missing the hangar door, a telephone pole, and several other sharp objects as we carried our gear about 200 feet onto the center of the runway. Suddenly, the wind died down and the balloon floated straight up lifting the transmitter package off on its journey.

The Indianapolis "Fox Hunters" club had volunteered to be the ground tracking team. They filled six cars and headed off on a chase across southern Indiana, armed with all kinds of direction-finding gear for 2 meters and 70 cm. We were able to watch the balloon for 15 minutes as it headed quickly towards the southwest, rising about 750 feet per minute. Bill, WB9SBY, filmed the launch from a small chase plane for the first few minutes, but the balloon quickly gained altitude on them. We had hoped for some bigger chase planes, but they were all grounded with maintenance problems.

In York, Pennsylvania, WA3USG (Rick) chaired a 40-meter net on 7.155 MHz; N9CJD (George) ran an 80-meter net on 3.871 MHz. The nets received over 80 check-ins and reception reports during the flight. Stations in over nine states received the balloon signals which covered most of the Midwest and part of the South. Operators reported S-meters "pegged" out to nearly 300 miles in all directions. There were many reports of reception on handhelds and scanners over

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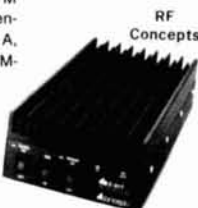
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the same area. W0RPK (Ralph) in Indianola, Iowa was the farthest station to report. He picked up the 2-meter signal at 450 miles. VE3JO and VE3ZK in London, Ontario observed sync bars and a brief, locked picture at a distance of 400 miles. At one point, WB0QCD (Mike) had a P3 to nearly P4 picture at 340 miles. W8YOS near Cleveland had a P2 at 334 miles. WA8KQQ reported a P5 during most of the flight from over 100 miles. In fact, we received several P5 reports from over 100 miles. WB8MSJ (Joe) received P4 signals in full color from 220 miles. Levels of P3 to P4 were seen over 250 miles away by KB9FO (Henry) and N9AB (Andy) in the Chicago area. A brief P5 report came in from K9MTE (Jim) from over 270 miles!

The balloon reached its maximum altitude of 115,000 feet about 2-1/2 hours into the flight. With the exception of an intermittent relay on the 2-meter transmitter, everything was still operating well. We took several internal temperature readings which indicated that the new insulation was working. The temperature was actually over 90° F inside and never seemed to drop below 60 degrees at any time during the flight.

The balloon burst at 11:27 a.m. CDT and started down. Our first indication of the plunge was the rapid fading and flutter on the ATV signal when the package started spinning. The most distant receiving stations started losing the signal rapidly. We estimate that in the near vacuum of 115,000 feet, the package probably dropped at speeds of nearly 700 mph until it was slowed by the parachute at around 50,000 feet. The balloon landed at 11:54 a.m. CDT, after falling for 27 minutes.


Because the jet stream was directly over southern Indiana, the chase team had a real challenge. At times the balloon had been speeding along at over 100 mph. In what might be their "ultimate" fox hunt, the tracking crews were nearly 30 miles from the balloon when it landed. The crews made a dedicated search across a large portion of southern Indiana; the three remaining cars finally got a good fix on the 2-meter signal at 4 p.m. They were about 10 miles north of their quarry when the 2-meter relay stuck again, killing the signal. But as they drove on through a small town, they heard a very weak signal on 439.25 MHz. After driving as far as he could down a dirt road, W9DUU (Paul) started on foot through some incredibly dense underbrush and thorns in the worst possible terrain for direction finding — dense woods and rolling hills! Worried that he might not find his way out again, Paul took one last reading after he'd hacked his way through nearly a mile of woods. At 5:20 p.m. he looked up and saw the balloon hanging 60 feet up in a large tree! The transmitter package was dangling about 20 feet off the ground, still sending out its ATV picture! Paul hooked it with a sapling and brought everything back intact. The balloon landed a mile east of English, Indiana, right in the middle of the Hoosier National Forest, a distance of 86 miles from the launch site!

Except for the fact that the beachball loop antenna now looks like a pair of coat hangers because of its tree landing, the transmitter package will be ready for a repeat flight with a live TV camera. A future flight will carry the first airborne ATV Repeater. The repeater will have a 434 MHz input and 910.25 MHz output; it has the potential of linking up two stations nearly 700+ miles apart!

Special thanks go to everyone who participated in this event. I'd like to thank W9NTP (Don), who let us use his lab very early in the morning on launch day to work on the transmitter package. Don also provided us with the "Mission Control" sta-

tion where NQ9Q (Brian) and I tracked the balloon. WB9IHS was a great help in choosing the battery system. He also provided up to the minute weather and wind forecasts from the weather bureau via the FAA radio club. Thanks to W9DUU and the Indianapolis Fox Hunters, and of course to W9PRD. His incredible optimism allowed him to predict months in advance that we would have a near perfect launch on June 4 at 9:00 a.m.

I hope these balloon flights will help to increase ATV activity and give us an idea of the possibilities for ATV aboard space shuttles or stations. And who knows, with the experienced launch team we've put together, maybe NASA will give us a chance to help launch the shuttle!

Editor's Note: On January 21, 1989, WB8ELK launched a fifth balloon which carried a small black and white Sony video camera and an Elktronics color video identifier. The balloon rose to a peak height of just over 100,000 feet sending live video pictures of the southern California desert and the curvature of the earth from the edge of space. Bill is considering making his next balloon flight a full ATV repeater! 

REFERENCES

1. Fred Maia, W5YI, *W5YI Report*, Volume 11, Issue #4, February 15, 1989, page 9

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AN RTTY CONVERTER

Almost instant gratification for radioteletype buffs

By Peter Doherty, W1UO, P.O. Box 7252, Greenville, North Carolina 27835

RTTY (radioteletype) has certainly changed in the past few years. Gone are the days of those monstrous mechanical machines, the Model 15, 19, and 28. How many remember the clickety-clack of the old model 15 as it copied the latest W1AW bulletin, sounding like the wire room of some major news network? Well, the whirring of gears and the printing of rolls of hard copy have been replaced by the silence of integrated circuits in the personal computer. Radioteletype has moved from the mechanical into the electronic realm.

One thing hasn't changed, though. The tones that are detected on your receiver can't key your computer directly, just as they can't key a Teletype® machine directly. Likewise, typing on your keyboard won't generate the tones your transmitter needs. As in years past, this is the job of the terminal unit (TU) or converter; MODEM (MODulator DEModulator) is the modern vernacular.

There are many classic TUs from the vacuum tube era. Old-timers will remember the W2PAT, W2JAV, and the Twin-City converters. How many of you built the one-tube converter and keyer (5763 and 6U8) that appeared in the *Radio Amateur's Handbook* for so many years? The vacuum tube TU has been replaced by integrated circuits that do a better job with less power. Two chips made by EXAR, the XR2206 and the XR2211, replace the 5763 and 6U8. Despite their simplicity, the chips do a surprisingly good job of generating and demodulating RTTY tones. This terminal unit is meant for the beginner or casual RTTY operator who doesn't want to spend a couple of hundred dollars on a little-used converter.

Transmitter converter

The transmitter converter is built with an EXAR monolithic function generator chip, the XR2206. The generator tone frequency is determined by C6 and R1 or R2 (see **Figure 1**). Depending on the state of pin 9 on the XR2206, R1 or R2 is part of the frequency-determining circuit. For instance, with pin 9 high, R1 is in the circuit and a 2295-Hz space tone is generated. With pin 9 low, R2 sets the mark tone to 2125 Hz. Potentiometer R4 sets the output level of the audio tones at pin 2.

U3a acts as a buffer and inverter between the outside world and the XR2206 chip. Inverters are handier than straight buffers in this application; they make it easier to invert logic signals so that tones and LEDs run "right side up." LED CR1 blinks in time with the incoming data from the computer. You can see when the computer has finished sending, so that you don't switch to receive prematurely. R3 sets the distortion of the chip to a nominal value. If you're a purist you may want to substitute a 500-ohm potentiometer and adjust it for minimum distortion on an audio analyzer. Then you can plug the audio tones into an HF SSB or VHF/FM rig.

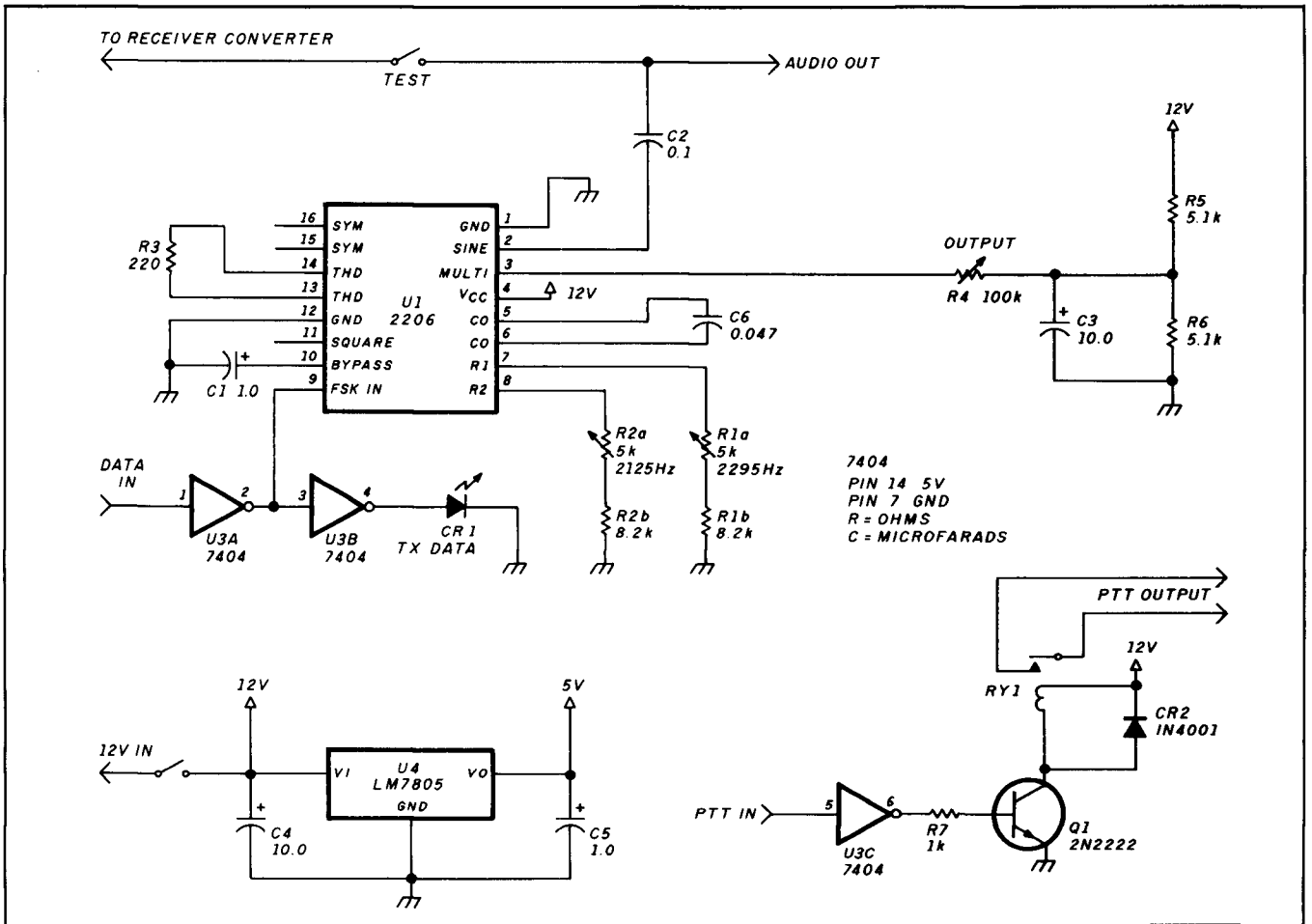
Figure 1 also shows a simple push-to-talk (PTT) interface for use between your computer and radio. PTT data from the computer is buffered and inverted by U3C and drives Q1 and RY1. I opted for a reed relay here because many rigs have different keying voltage requirements, and the reed relay will key just about any rig. If you find that your software is in the receive mode but the PTT relay is keyed, simply add another 7404 inverter in series with U3C to get the PTT signal right side up.

The converter is powered by a plug-in 12-volt DC supply. The 7805 IC regulates this voltage to 5 volts for use by the XR2211 and 7404.

Receiver converter

The receiver converter in **Figure 2** is designed around the EXAR XR2211 FSK (frequency shift keyer) demodulator chip. Audio from the receiver's speaker or phone jack is routed to pin 2 of the XR2211 through C7. Audio from the transmitter converter can also be applied to this point through a test switch to test the transmit/receive converter combination. C9 and R16 set the center frequency of the converter. For mark/space tones of 2125/2295 Hz the center frequency is 2210 Hz. Resistor R14 or R15 in series with R13 set the bandwidth of the

FIGURE 1



Schematic of the transmit converter portion of the circuit.

TABLE 1

Receiver modem calculations

2125/2295 Hz, 170-Hz Shift
 Center frequency
 $f_o = (2125 + 2295) / 2 = 2210$ Hz
 Choose value of R16
 $R_{16} = 20$ k (18 k + 5-k pot)

Calculate C9

$$C9 = 1 / (f_o \times R_{16})$$

$$= 1 / (2210 \times 20000)$$

$$= 0.0000000226$$

$$= 0.022 \mu F$$

Calculate Rshift (R13 + R14)

$$R_s = R_{16} (f_o / \text{FSK shift})$$

$$= 20000 (2210 / 85) = 520$$

$$= 20000 (2210 / 170) = 260$$

$$= 20000 (2210 / 425) = 104$$

$$= 20000 (2210 / 850) = 52$$

Calculate C12

$$C_{12} = C9 / 4 = 0.005 \mu F$$

All values are rounded to nearest standard component values.

Transmitter modem calculations

$F_1 = 2295$ Hz $F_2 = 2125$ Hz
 Choose a value for R1 and R2
 R_1 and $R_2 = 10$ k (8.2 k + 5-k pot)
 Calculate C6
 $C_6 = 1 / (R_1 \times f_o)$
 $= 1 / (10000 \times 2295)$
 $= 0.0000000044$
 $= 0.047 \mu F$ (standard value)

Check values of R1 and R2

$$R_1 = 1 / (C_6 \times f_o)$$

$$= 1 / (0.0000000047 \times 2295)$$

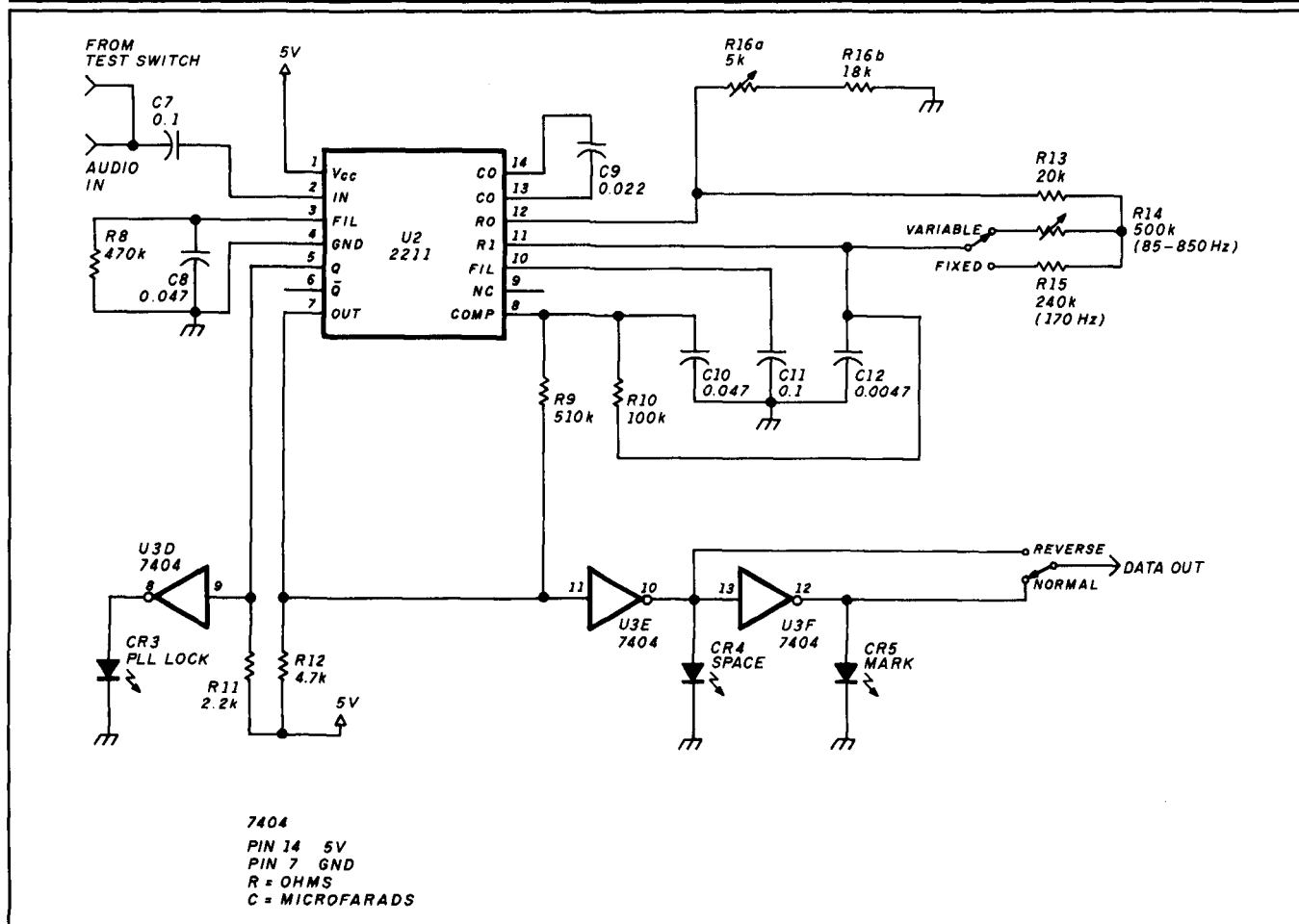
$$= 9.27$$

$$R_2 = 1 / (0.0000000047 \times 2125)$$

$$= 10.01$$

R_1 and R_2 fall within range of 8.2-k resistor and 5-k pot

FIGURE 2



Schematic of the receive converter portion of the circuit.

XR2211; hence the shift of the RTTY signal to receive. R15 copies a fixed shift of 170 Hz; potentiometer R14 allows you to copy shifts from 85 to 850 Hz. This comes in handy when you leave the Amateur bands to explore RTTY on the commercial bands. CR3 indicates if the phase-locked loop (PLL) is locked onto the RTTY signal, CR4 shows that a space signal is being received, and CR5 indicates the same for the mark signal. Data out is routed through a SPDT switch making normal/reverse data available. This is helpful on the commercial bands, as many stations use tones inverted with respect to the Amateur standard.

Design notes

It's easy to design the converter for other frequencies. Table 1 gives most of the necessary formulas. I've worked these calculations for frequencies of 2125/2295-Hz and 170-Hz shift. Just substitute the new audio tones and shift, and select the nearest standard component values. The potentiometers give you some leeway in the selection of the frequency-determining capacitors. Note that the signals to and from the converter are transistor-transistor logic (TTL) level; that is, 0 and 5 volts. If your computer uses different levels, like RS-232 (-12 and +12 volts), you must change these voltages before applying them to the converter. For the RS-232, a set of

1488/1489 line driver/receiver chips designed for this purpose will do the job. An even better choice would be the Maxim MX232, as this chip doesn't require an external negative bias supply. You can find information on using these chips in their data specification sheets.

Construction

All the components to build the converter are available from Radio Shack, Jameco, or Digi-Key. For the best frequency stability, choose polystyrene or some other stable type for frequency-determining capacitors C6 and C9. These are sometimes hard to find; check the flea markets. I have used Mylar™ capacitors with good results. R1a, R2a, and R16a should be ten-turn pots to allow precise setting of the tone frequencies. The backlash of a normal pot will drive you crazy!

I built my converter (see Photos A and B) on a Radio Shack prototype board and mounted it in one of their little metal cases. I mounted variable shift potentiometer R14 in the center of the front panel. Four LEDs, indicating lock, mark, space, and TX data are mounted on one side of the front panel. On the other side I put the four switches for power, normal/reverse, variable/170-Hz shift, and test. The wiring is audio level and not too critical. You may want to consider using ferrite beads or bypass capacitors, or both, on the computer leads to keep

PARTS LIST

	Description
CAPACITORS	
C1,C5	1.0- μ F tantalum
C2,C7,C11	0.1- μ F Mylar
C3,C4	10- μ F electrolytic
C6	0.047- μ F polystyrene or Mylar
C8,C10	0.047- μ F Mylar
C9	0.022- μ F polystyrene or Mylar
C12	0.0047- μ F Mylar
DEVICES	
U1	EXAR XR2206
U2	EXAR XR2211
U3	LM7404
U4	LM7805
CR1,CR3,CR4,CR5	LED, panel mount
CR2	1N4001
RESISTORS	
R1a,R2a,R16a	5-k ten-turn pc pots
R1b,R2b	8.2 k
R3	220
R4	100-k pc pot
R5,R6	5.1 k
R7	1 k
R8	470 k
R9	510 k
R10	100 k
R11	2.2 k
R12	4.7 k
R13	20 k
R14	500-k pot
R15	240 k
R16	18 k
MISCELLANEOUS	
Switches	
SPDT	two each
SPST	two each
RY1	Reed relay, 12 volt
Q1	2N2222A

the computer interference out of your radio and vice versa. I didn't find this necessary in my application.

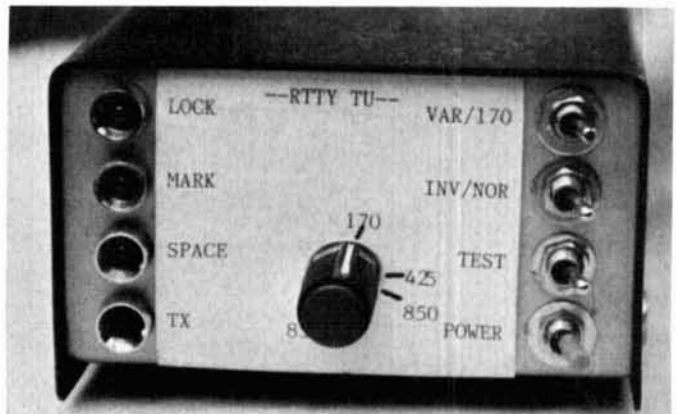
Lacking a better method, I typed the front panel label on heavy card stock and attached it to the front panel with wide, transparent packing tape. It's crude but effective. I just couldn't picture myself squeezing all those rub-on letters into such a small place.

Alignment

The easiest way to align the transmitter section is with a frequency counter. Connect pin 1 of the 7404 to 5 volts through a 1-k pull-up resistor (pin 9 of the XR2206 goes low) and adjust R2a for the mark tone of 2125 Hz. Ground pin 1 of the 7404 (pin 9 of XR2206 goes high) and adjust R1a for a space frequency of 2295 Hz. If your software has inverted mark/space tones, adjust R1a for the mark tone and R2a for the space tones.

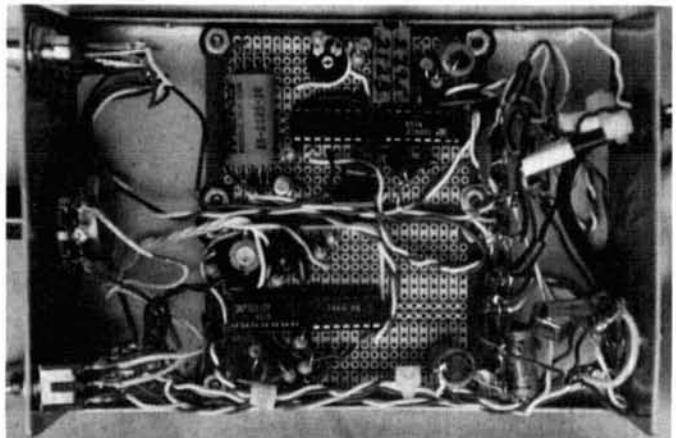
If you don't have a frequency counter, you can use an audio source of known calibration and an oscilloscope. A calibrated converter from a friend would be a good source. Feed the calibrated tone into the horizontal amplifier and feed the uncalibrated tone into the oscilloscope vertical amplifier. Now adjust the proper pot in the converter until the pattern

PHOTO A



The completed converter.

PHOTO B



Internal view of the converter.

becomes a perfect circle, indicating that the tones are the same frequency. Do this for the mark and then the space frequencies. (These oscilloscope patterns are called Lissajous figures; the technique is described in any radio handbook.)

To calibrate the receiver, first set the fixed/variable switch to the fixed position. Next, connect an ohmmeter to read the combined resistance of R13 and R14. Adjust R14 to full resistance (a combined total of 520 k) and mark the front panel knob for 85-Hz shift. Now adjust R14 for a total of 260 k and mark the panel for 170-Hz shift. A resistance of 104 k equals a shift of 425 Hz and a resistance of 52 k equals a shift of 850 Hz. These are the most commonly used shifts on the short-wave bands. (This adjustment isn't very important.) With the fixed/variable switch in the fixed position and no signal present, disconnect C8, short pin 2 to pin 10 of the XR2211, and attach a frequency counter to pin 3. Set the frequency to the center frequency (2210 Hz) with potentiometer R16a. Remove the short and reconnect C8. As before, if you don't have a frequency counter, feed a known RTTY signal into the input and adjust R16a for a clean copy on your computer.

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CT-90	10 Hz-600 MHz	< 10mV to 150 MHz < 150mV to 600 MHz	1 PPM	9	0.1Hz, 10Hz, 100 Hz	169.95
CT-50	5 Hz-600 MHz	LESS THAN 25 mV	1 PPM	8	1Hz, 10Hz	189.95
CT-125	10 Hz-1.25 GHz	< 25mV @ 50 MHz < 15mV @ 500 MHz < 100mV @ 800 MHz	1 PPM	9	0.1Hz, 1Hz, 10Hz	189.95
CT-90 WITH DV-1 OPTION	10 Hz-600 MHz	< 10mV to 150 MHz < 150mV to 600 MHz	0.1 PPM	9	0.1Hz, 1Hz, 10Hz	229.90

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Operation


Once the tones are adjusted in the transmit portion, the only other adjustment you need to make is to the output level. R4 takes care of this. Set your software into the transmit mode and feed the tones into the mic jack of your transceiver through the appropriate connector. You should be in LSB mode. Set R4 to midscale. Now adjust the mic gain on your rig, along with R4 for the proper RF output level on your transceiver. Remember that RTTY is a 100-percent duty cycle mode, and many transceivers are not designed for continuous output. You may have to back down on the output until you attain a safe level. In an FM radio you just have to adjust R4 until you reach the proper deviation without clipping in the mic circuit.

To tune in an RTTY signal, first check out the ham bands around 3.6 or 14.1 MHz where most signals will be operating 170-Hz shift. As you tune through an RTTY signal, the PLL lock, mark, and space lights will flicker. As you approach the center of the signal, the PLL lock light will suddenly glow with full brilliance. The mark and space lights should be flickering evenly. A slight adjustment of the VFO on your receiver will result in copy on your computer screen.

If the lock light is lit and the mark/space lights are flickering but you don't have clean copy, try the normal/reverse switch. If you are properly tuned to an RTTY signal that's not keying, the PLL lock and mark lights should be lit. If you're new to RTTY, it will take a while to get the hang of tuning in the signals. It may also take a while to get all the software and converter connections running right side up, using the proper options of your software and/or inverters in your converter. On FM, it's only a matter of adjusting R16a on the receiver converter until clean copy occurs while receiving an RTTY signal.

When you start cruising the shortwave bands in search of commercial stations, operation will take a little more savvy. Here are a few hints. You probably won't know the shift of the shortwave station. Tune in the signal until the tones sound "about right." Flip the fixed/variable shift switch to variable. Then rock the variable shift potentiometer until the PLL lock lights and the mark/space lights blink evenly. Odds are good that the station will be running one of the standard shifts marked on the front panel. Now it's time to try the normal/reverse switch and different speeds in your software. After a short time, you'll be able to recognize the shift, the speed, and whether the RTTY signal is in Baudot or ASCII simply by the sound.

Concluding remarks

If you're just interested in listening, it's not necessary to build the transmit section. The receive converter is a simple device. It won't rival a full-blown unit with separate mark and space filters. However, it does a good job on the crowded Amateur bands — as long as the interference isn't too severe. Commercial stations tend to operate on clear channels, so the results with these have been very good. Of course, the quiet environment of VHF/FM is the ideal situation for this converter. Despite the fact that an RTTY contest on 20 meters on a Sunday afternoon will probably crush the little converter, I've had many enjoyable QSOs on both 20 and 80 meters in less than clear channel situations. I have also used it to copy bulletins in ASCII from W1AW. I use this converter with a Commodore 64 and Kantronics Hamsoft Software. Gone is the mechanical thunder of the Model 15. 

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THE NO5H ALL-BAND DIPOLE

**Easy to build,
easy to move
antenna**

Gary L. Elliott, NO5H, 41200 Highway 933,
Prairieville, Louisiana 70769

My line of work requires that I move to a new location every four or five years. This means I'm continually taking down or putting up antennas. As a result of this, I am always looking for a wire-type antenna that's easy to construct and get working.

I enjoy working all the HF bands from 160 through 10 meters and do most of my operating on 160 and 40 meters. My goal was to design a coax-fed dipole antenna that was simple to build and fit into a 198-foot space.

Description

My antenna design is neither new nor unique. But I've never seen it written up in any of the Amateur publications.

I built a 3/2-wavelength dipole cut for the center of the 40-meter band and fed with 75-ohm CATV coax through a half-wave matching section of 300-ohm or open-wire line. Why a 3/2 antenna cut for 40 meters? I wanted an antenna that would operate on 160 meters as a dipole, and in an inverted "V" configuration. I didn't want to resort to traps or to tying the feeder wires together, as you would when using a short dipole as a "T"-type antenna. I wanted the advantage of a dipole, in a length shorter than full dipole size.

If the antenna I've described sounds like a G5RV-based design, it should. The G5RV is also a 3/2-type dipole, except that Louis Varney, G5RV¹ designed his dipole to a 3/2 wavelength at a frequency of 20 meters. Like the G5RV, my antenna is an all-band 160 through 10 design, but it has certain advantages because of the longer length of the dipole. This longer length allows full-dipole and/or long-wire performance on all bands from 160 through 10 meters; you don't need to tie the feeders together for 160-meter operation.

Operation

The NO5H antenna operates in the following configurations on the accompanying bands:

- shortened half-wave dipole on 160 meters
- two half waves in phase on 75 meters
- a 3/2-wavelength dipole on 40 meters
- two full waves in phase on 30 meters
- two long wires each 3/2 wavelengths long on 20 meters
- two long wires each 2 full wavelengths long on 15 meters
- two long wires each 5/2 wavelengths long on 12 meters
- two long wires each 3 full wavelengths long on 10 meters

All-band coverage (including the two usable WARC bands) is achieved easily with this simple antenna configuration.

Construction

The flat-top portion of the antenna is 203' long; each half of the flat top is 101'6" in length. The formula I used is:²

$$L = \frac{1451.4}{f \text{ (MHz)}} \quad (1)$$

The matching section is made from 53'6" of 300-ohm twin lead with a velocity factor of 82 percent (in my case). When the formula is used this way it becomes:³

$$L = \frac{468}{f \text{ (MHz)}} \times .82 \quad (2)$$

I used a run of 75-ohm CATV RG-6 coax to the antenna tuner in the station.

This antenna design has some unique features that set it apart from similar antennas. I use CATV RG-6 coax with 100-percent aluminum shield,* along with a long shank F-type cable connector at both ends of the coax. The F-type connector requires the use of a compound jaw crimping tool. The antenna is as simple to build as any other dipole, and using F-type connectors on the coax makes the assembly process even easier.

*Radio Shack, RG-6 CATV coax p/n 278-1324.

Once the 203' flat top is laid out and the center insulator installed, attach the 53'6" matching section by soldering it in place at the center insulator. I installed an SO-239 chassis connector at the other end of the matching section. One wire of the matching section is soldered to the center pin and the other to a solder lug bolted to one of the corner mounting holes. The connection needs to be sealed from the weather by whatever means you generally use. I installed a long shank F-type connector** on the end of the RG-6 coax and coiled the coax into a 6" diameter 11-turn choke coil. Then I attached a female F to PL-259 adaptor*** to the F connector on the RG-6 coax. This lets you run the coax to the station antenna tuner after the antenna is raised to its operating position. When you connect the coax at the station end it's good to allow a little extra; you may have to shorten the coax run a bit if you encounter a hard-to-load condition on one band. **Figure 1** gives dimensional details for the antenna.

Some of you may wonder why I used CATV-type RG-6 coax and F connectors for an Amateur antenna project. The better quality RG-6 has the same loss per hundred feet as RG-213 coax and lower loss than RG-8X coax at a cheaper price per foot than the others. RG-6 cable is also 100 percent shielded. The coax has an aluminum shield which is not intended to be soldered, and that's why I used the F connector. Using this connector at the 200-watt level hasn't presented a problem. In fact, using the crimp on the long shank F connector makes trimming the lead-in much easier if a loading problem occurs on one of the bands in use.

I think we all need to be more innovative when it comes to antennas and feed systems. Those who operate at VHF and UHF learned long ago to use CATV hardlines and cables because of the lower loss. Fifty ohms doesn't have to be the magic number for most applications. Many stations now use antenna tuners or rigs with built-in tuners to control the SWR that their solid-state rigs feed into. So don't be afraid to give other cables or connectors a try; you may find that they do make antenna projects easier and more fun.

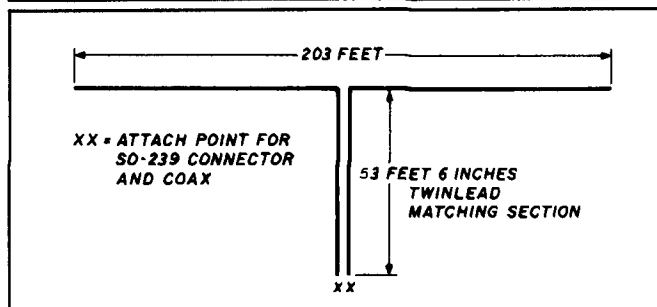
Conclusion

The antenna can be mounted either as a horizontal dipole or an inverted V. In my case, the antenna is in the inverted Vee configuration with the apex at about 50 feet and the ends of the antenna about 10 feet off the ground.


Does it work? Comparisons with my regular G5RV show improvements on all bands. The greatest are seen on 30 through 10 meters. On 40 and 80 meters I find that the improvement depends on the distance and propagation of the signal being received.

One thing I can't stress enough is that both this design and the G5RV require the use of an antenna tuner. Take time to read Louis Varney's comments on the G5RV design in the *ARRL Antenna Compendium, Volume One*.⁴ Even at the 3/2 design frequency with the half-wave matching section, the feedpoint impedance is still a little over 100 ohms. On the other

FIGURE 1



Dimensional details of the N05H all-band antenna.

bands the feedpoint impedance varies because of the complex loads presented by the antenna, resulting in the need for an antenna tuner. My design and the G5RV are efficient all-band antennas that can be coax fed. 

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2. Bill Orr, W6SAI, "Ham Radio Techniques: The G5RV Explained," *Ham Radio*, February 1985, page 59.
3. Louis Varney, G5RV, *ibid.*, page 89.
4. Louis Varney, G5RV, *ibid.*, pages 86-90.

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The weather station comes with a wind vane and speed sensor and all mounting hardware. Also included are two remote temperature sensors, a plug-in computer card, basic operating software, 12 volts AC power adapter, and complete documentation. The PCW's VLSI on-board microprocessor generates instant weather data on the computer screen. It shows current temperature (inside/outside); barometric pressure; wind speed, chill, gust, and direction; high and low temperature over a 24-hour period; and clock/calendar. An optional rain collector is also available.

The PCW has programmable alarm set points for time, high wind speed, and high and/or low temperature. When any set points are reached, the PCW card sounds an alarm (even when the computer is shut off) using its own power supply.

The optional PCWPRO software package, an advanced controller, makes the PCW weather station a sophisticated monitoring and data logging program. It can display each function in graphic form and saves data to disk on the hour and half hour. Both the PCW and the PCWPRO can be placed in the computer's background to allow use of your PC for other functions, such as logging QSO's or word processing. You can return to it by typing a user-selected key sequence.

The instructions were extremely easy to follow, explaining in simple terms how to configure the board to work with your PC. The PCW plug-in board accommodates different computer configurations.

The enhanced PCWPRO software is designed with open architecture and predefined system calls. User-written programs may be designed to interface the PCW Weather Station with other computer applications.

The PCW weather station sells for \$299, the PCWPRO enhanced software for \$99.95, and the optional RG-2 rain collector for \$49.95. All are available from Azimuth Communications, Corp., 11845 W. Olympic Blvd., Suite 1100, Los Angeles, California 90064.

de N1GCF

Circle #301 on Reader Service Card.

Ameritron RCS-4 and RCS-8V

Over the last ten years, the price of coaxial cable has jumped significantly due to the high cost of raw materials. Hams with long, multiple feedlines know how expensive several runs of coax can be.

However, Ameritron has two ways to overcome this problem. The RCS-4 will switch four antennas and doesn't require extra cabling to operate. The RCS-8V switches five antennas and requires an external control cable.

The RCS-4 is elegant in its simplicity. The relay box contains three relays that are switched by voltages fed through the coaxial feedline. With no voltage present, the antenna selected is no. 4. As you switch to the other antennas from the control box, either DC +, DC -, or AC is fed into the coax to turn on the appropriate antenna relay.

Three 0.01- μ F capacitors and a radio frequency choke isolate the station from the antennas at the control box and the relay voltages from the antenna lines. The three relays have 10-A contacts and are rated at 50-ms switching time. A small air spark gap is mounted on the relay box circuit board to bleed off any static charges that could accumulate. Additional lightning protection is recommended through coax loops on all feedlines.

To use the RCS-4, insert the control box into your shack's feedline just before it goes outside and connect the relay box to the end of the feedline. Connect your antennas to the relay box and you're ready to go! The antenna selector switch has red LEDs that indicate which antenna is selected. Make sure that the relay box is installed with the connectors down and that you do not attempt to further weatherseal the unit. Water will accumulate if you do, and eventually the unit will have problems. The relay box can be mounted anywhere that's convenient for you. Its rugged construction ensures you'll have minimal problems after installation.

Insertion loss is less than 0.05 dB under 30 MHz and the insertion VSWR is under 1.1:1 from 1.8 to 30 MHz. The unit is designed to handle 1500 watts and 2500 watts PEP maximum. One word of warning — never attempt to switch while transmitting! If you do, you risk losing the switch.

The RCS-8V gives you several advantages over the RCS-4. It will handle greater power, it's rated at 4 KW below 30 MHz (1 KW PEP at 148 MHz), and works from 1.8 to 220 MHz with negligible insertion loss and only a slight additional loss at 450

MHz. This greater flexibility is gained through use of an external control line to switch antennas.

You can use any wire to control the switch. As long as the conductor to ground return resistance is less than 80 ohms, the unit will operate normally. Five or 8-conductor rotor wire is usually the easiest to get and use. To set up the switch connect at least a 5-conductor control cable between the relay box and the control box in the shack. (Make sure that the wires are connected in proper sequence.)

The RCS-8V gives you the ability to select more than one antenna at a time. For instance, if you're running stacked beams, you can wire the switch to select either the upper or lower antenna or for additional gain, or both antennas at the same time. The switch can also be used to select either five antennas for one rig or five rigs for one antenna. Versatility is limited only by your needs.

The RCS-8V will switch in less than 50 ms and uses heavy-duty 10-A rated relays. The relays are isolated so that you can switch two antennas simultaneously. However, I recommended that you ground the antennas when they're not in use. Ameritron provides the information on how to modify your switch.

These two products are constructed from high quality rugged parts and will give years of service. The relay boxes for both the RCS-4 and RCS-8V are made from steel enclosures for 100-percent shield coverage and TVI/RFI protection. Whatever your needs, one of these two switches will work for you. See your local Ameritron dealer for more information.

de N1ACH

Circle #302 on Reader Service Card.

Cushcraft A4S four-element, HF Triband Yagi antenna

Looking for an antenna to maximize your signal on 20 through 10 meters? Cushcraft's A4S four-element tribander is more than up to the task.

In keeping with Cushcraft's history of high-performance HF Yagis, the A4S is a true winner. Offering triband coverage with three elements each on 10, 15, and 20 meters, the A4S has been optimized to provide excellent

(continued on page 86)

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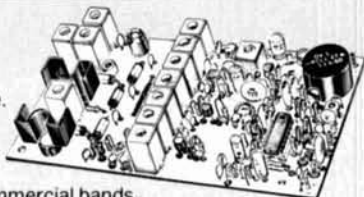
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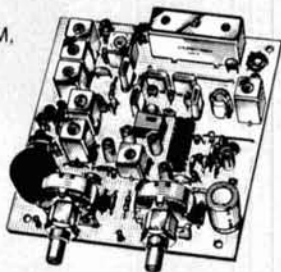
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	220-224	50-54
	222-224	28-30
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(continued from page 84)

bandwidth (greater than 500 kHz on 10 meters) and the maximum obtainable gain and F/B ratio. Cushcraft rates the antenna at a nominal 8.9 dBd of forward gain and 25 dB front-to-back ratio. The maximum power rating is 2000 watts PEP.

Construction of the A4S is simple and straightforward when you use the instructions included with the antenna. The 18-foot boom comes in three 6-foot sections. The stainless steel hose clamps and bolts provided to pin the sections prevent boom rotation. The elements are constructed of telescoping lengths

of aluminum, weatherproof traps, and stainless steel hardware for a rugged and durable installation. It took us just under an hour to put the antenna together.

Replacing HAM RADIO's 12-year-old antenna with the new A4S took only a half hour. The A4S weighs 37 pounds and can be handled easily by one person. A light and manageable antenna is always a joy for working on a tower and the A4S is no exception for ease of installation.

Cushcraft also has an add-on kit available for 40 and 30 meters. The additional traps

are installed at the end of the driven element. The kit is then set for either 40 or 30 meters.

Our old Cushcraft antenna had always held its own, both in DX pileups and in state-side QSOs. The new A4S has demonstrated that it is capable of maintaining the performance tradition. Band conditions permitting, I was effortlessly able to work anything I heard. If you are looking for good performance, the A4S is an excellent choice. Retail price is \$525.

de NB1H

Circle #303 on Reader Service Card.

NEW PRODUCTS

UI-7 FM module for IC-725 and noise-reducing power cord

The UI-7 is an FM module which allows AM transmit with the IC-725 transceiver. Suggested retail price is \$71.99.

Also available is the CP-11, a cigarette lighter power cord with a built-in noise reduction filter. Suggested retail price is \$18.99.

Contact ICOM America, Inc., 2380 116th Avenue N.E., PO Box C-90029, Bellevue, Washington 98009-9029.

Circle #304 on Reader Service Card.

New Software for MN and Yagi

The new MN (enhanced version of the U.S. Navy's MININEC) program for IBM-PC and compatible computers will analyze almost any antenna made of wire or tubing. MN computes antenna forward gain, front-to-back ratio, beam width, sidelobes, angle of radiation, current, impedance, SWR near fields, and far fields. Antennas may be modeled in free space or over real earth. It plots antenna radiation patterns in polar or rectangular form on CGA, EGA, or HGC graphics screens. Hard copies of the plots may be made for nearby antennas or structures, allowing detailed analysis of stacked arrays. The 5-1/4 inch MN disk contains over 100 files, including libraries of antenna and plot files, a file editor, and documentation. The program costs \$75 (\$80 in Canada and foreign countries).

YO Yagi Optimizer Software

The new YO program for IBM-PC and compatible computers automatically adjusts the element lengths and spacings of a Yagi design to maximize forward gain, optimize pattern, and

minimize SWR. Radiation patterns at the center and edges of a band, and a scale drawing of the antenna, are plotted on CGA, EGA, or HGC graphics screens during optimization. Hard copies of the plots may be made on dot-matrix printers. YO computes several trial designs per second for small Yagis, with an optional math co-processor chip installed. Yagis of up to 50 elements may be modeled. The YO design package includes models for gamma and hairpin matching networks, element tapering, mounting plates, and frequency scaling. A library of Yagi files and documentation are included. The program costs \$90 (\$95 in Canada and foreign countries).

These programs are available from Brian Beezley, K6STI, 507-1/2 Taylor Street, Vista, California 92084.

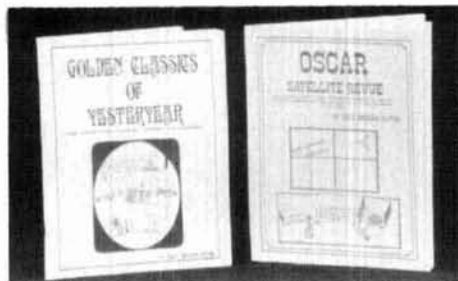
MFJ Offers Two New Books

MFJ offers two new books by Dave Ingram, K4TWJ.

In *Golden Classics of Yesteryear*, you'll find real-life tales, and information on transmitters, receivers, favorite circuits, telegraph keys, bugs, and other ham radio topics. It contains easy-to-build weekend projects from the 1920s, '30s, '40s and '50s.

K4TWJ even shows you how to build a classic "Tailender" — an early DX memory keyer that requires no power supply or other electronic parts and works like a champ. Ingram, a collector of classic radio gear, shows you how to collect, restore, and operate it.

OSCAR Satellite Revue is an anthology of CQ magazine articles about setting up and operating various types of OSCAR stations for working DX, as well as Japanese and Russian satellites. Each article is followed by an update and



ready-to-use frequency conversion charts for all satellite modes. There are tracking notes for OSCAR 13, OSCAR 10, Japanese JO-12, and Russian RS-10/RS-11.

K4TWJ even shows you how to work the Russian robot on RS-10 and exactly how to receive a QSL card confirming this rare DX!

There's a quick-start guide for newcomers and an equipment review section. Also included is up-to-date Keplerian data for computerized tracking programs.

For more information contact MFJ Enterprises, Inc., PO Box 494, Mississippi State, Mississippi 39762. Phone: (601)323-5869. To order call toll free (800)647-1800.

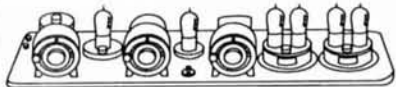
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SPORADIC E BASICS FOR 1989

What will the sporadic E propagation conditions be as the maximum of solar cycle 22 approaches? From May through September radiation from the nearly overhead sun generates high ion densities in the lower ionosphere that support short-skip propagation — including multiple short skips. The geomagnetic field clusters these ions into cloud-like patches known as sporadic E (E_s). These patches form a thin layer of intense ionization in the E region about 60 miles up. A patch gives a strong, mirror-like signal reflection over skip distances of 600 to 1200 miles. This lasts for perhaps an hour.

The frequency and magnitude of Sporadic E occurrences are functions of geographical location. The best locations for summer E_s openings are on either side of the geographic equator, at the point where the geomagnetic equator is farthest away. This condition occurs in the Northern Hemisphere in Southeast Asia (best) and the Mediterranean (next best). In the Southern Hemisphere it occurs in South America. The highest frequency propagated by E_s tends to occur at local noon. Since the E_s patch is embedded in the regular E layer, it tends to track the E maximum ion density throughout the day, season, and sunspot cycle. This summer you can expect an increase in the E layer as an E_s base for higher maximum usable frequencies (MUFs) over a 1200-mile hop. This increase will give base MUFs of 51 to 57 MHz this year, so 6-meter openings should be really good. The highest probability of occurrence is near sunrise and again around sunset.

These two E_s characteristics affect short-skip openings differently. Openings on the higher frequency bands occur around local noon; the lower bands tend to have openings near sunrise and sunset. This characteristic is nearly constant over the sunspot cycle so there should be the same number of low to midlatitude E_s openings, but the MUF is up for better DX. More about E_s next month.

Last-minute forecast

Openings on the higher frequency bands (10 to 30 meters) are expected to be best the last two weeks of the month. At the same time, signal strengths will be lower than normal. Both are conditions of the increased MUF from the 27-day solar flux maximum expected at that time. Solar flare geomagnetic disturbances are expected around the 19th and 27th; another disturbance may result from thin corona near the 9th. These will lower the MUF by 15 to 25 percent. Because these effects are worse on evening paths, the lower frequency bands will experience more fading and much lower signal strengths. Otherwise, the lower bands should be best the second week of June.


The moon will be full on June 19th and at perigee (its closest approach) on June 28th. Summer solstice is on the 21st at 1100 UTC. The Aquarid

meteor shower starts about the 8th, peaks around the 28th, and lasts until about August 7th. The maximum radio-echo rate will be 34 per hour.

Band-by-band summary

Six meters will provide occasional openings to South Africa and South America around noontime via short-skip E_s propagation. There will be long-skip conditions on 10 meters in the afternoon during the peak times of the 27-day solar cycle. Otherwise, look for sporadic E short-skip and multihop openings around local noon for DX on this band. (Evening transequatorial openings usually don't occur in the summertime.) Twelve, 15, and 17 meters (almost always open to some southern part of the world) will be the main daytime DX bands. Operate on 12 first and then move down to 15. DX is considered 5000 to 7000 miles on these bands. There may be some long, one-hop transequatorial propagation paths occurring early in the month.

Twenty, 30, and 40 meters will support DX propagation from most areas of the world during the daytime and into the evening hours on most days. DX on these bands may be either long skip to 2500 miles or short skip E_s to 1250 miles per hop. There are many good hours of DXing ahead because the days are longer.

Thirty, 40, 80, and 160 are all good for nighttime DX. Although the background thunderstorm noise will be noticeable, these bands are still quiet enough to provide good DX-working conditions. Sporadic E propagation may be a contributing factor toward enhanced conditions at local sunset, and will occur more often during the next three months. 

WESTERN USA

GMT	PDT	N	NE	E	SE	S	SW	W	NW
0000	5:00	12	17	15	10	12	10	10	12
0100	6:00	12	20	17	10	12	10	10	10
0200	7:00	10	20	17	12	15	10	10	10
0300	8:00	10	20	17	12	15	10	10	10
0400	9:00	12	20	17	15	20	10	10	10
0500	10:00	12	17	15	15	20	10	10	12
0600	11:00	15	15	12	15	20	10	10	12
0700	12:00	15	17	12	17	20	10	12	12
0800	1:00	17	17	15	17	20	10	15	15
0900	2:00	17	20	20	17	20	12	15	15
1000	3:00	20	20	15	20	20	12	20	15
1100	4:00	20	15	12	20	20	15	17	20
1200	5:00	30	15	12	15	30	15	17	20
1300	6:00	15	15	10	12	30	20	20	20
1400	7:00	15	12	10	12	30	17	20	17
1500	8:00	15	12	10	10	30	17	20	17
1600	9:00	15*	10	10	10	30	17	20	30
1700	10:00	17	10	10	10	30	15	20	20
1800	11:00	17	10	10	10	20	12	20	17
1900	12:00	20	10	10	10	15	10	10	15
2000	1:00	20	12	12	10	15	10	10	15
2100	2:00	17	12	12	10	12	10	10	12
2200	3:00	15	15	15	10	12	10	10	12
2300	4:00	15	17	15	10	12	10	10	12

MID USA

MDT	N	NE	E	SE	S	SW	W	NW
6:00	17	17	15	10	12	10	10	10
7:00	17	20	17	10	12	10	10	10
8:00	15	20	17	12	15	10	10	10
9:00	12	30	17	12	15	10	10	12
10:00	12	20	17	15	20	10	10	12
11:00	15	20	15	15	20	10	10	15
12:00	15	17	15	15	20	10	10	15
1:00	17	20	15	17	20	10	12	15
2:00	17	20	20	17	20	12	15	17
3:00	20	20	15	17	20	12	15	20
4:00	20	20	12	20	20	15	20	20
5:00	20	15	12	20	20	15	17	20
6:00	15	15	10	15	30	20	17	17
7:00	15	15	10	12	30	15	20	15
8:00	15	12	10	12	30	20	20	15
9:00	12	12	10	10	30	17	20	15
10:00	12	12	10	10	30	17	20	20
11:00	10	10	10	10	30	17	20	30
12:00	10	10	10	10	20	15	20	20
1:00	12	10	12	10	15	12	10	15
2:00	15	12	12	10	15	10	10	15
3:00	15	12	12	10	12	10	10	15
4:00	15	15	15	10	12	10	10	12
5:00	20	15	15	10	12	10	10	12
6:00	20	20	15	10	12	10	10	12

EASTERN USA

EDT	N	NE	E	SE	S	SW	W	NW
8:00	12	15	15	10	17	10	10	10
9:00	12	17	17	10	17	10	10	10
10:00	15	17	17	12	20	10	10	12
11:00	15	30	17	12	20	10	10	12
12:00	17	20	20	15	20	10	10	15
1:00	17	30	15	15	20	10	10	15
2:00	20	20	15	15	20	12	10	17
3:00	20	20	17	17	20	12	12	17
4:00	17	17	15	17	20	12	15	20
5:00	15	17	12	20	20	15	15	20
6:00	15	15	12	15	20	20	20	17
7:00	12	15	10	12	20	15	17	15
8:00	12	15	10	12	30	15	17	15
9:00	10	15	10	10	30	15	20	15
10:00	10	12	10	10	30	17	20	15
11:00	12	12	10	10	30	17	20	20
12:00	12	12	10	10	30	17	20	20
1:00	15	12*	10	10	20	12	20	17
2:00	15	12	10	10	17	10	20	15
3:00	17	12	12	10	15	10	10	15
4:00	20	12	12	10	17	10	10	15
5:00	20	12	12	10	17	10	10	15
6:00	20	15	15	10	12	10	10	12
7:00	17	15	15	10	12	10	10	12

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Elmer's Notebook

Tom McMullen, W1SL

PART 1 VISUAL AIDS — OSCILLOSCOPES

One of the most useful aids for determining how electronic circuitry works or troubleshooting faulty equipment is something which can be used to examine the signals present at various points. Signals and waveforms weren't very complex early in the electrical age, and one instrument used to "look" at waveforms involved projecting a beam of light. This "oscillograph" device used a tiny mirror affixed to an armature. A narrow beam of light was focused on the mirror. When the armature was excited by a waveform the light beam reflected from the vibrating mirror would trace a pattern on a ground glass screen, a nearby wall, or photographic film. The frequency response of this system was limited by the mechanical inertia of the armature and mirror.

When waveforms became more complex (as with higher audio and low-range radio frequencies), the mechanical device was useless. The oscilloscope picked up where the oscillograph left off. The heart of the oscilloscope is the cathode-ray tube (CRT) which, in addition to being an excellent test instrument, is also the basis for many other essential inventions — including radar "scopes," television sets, and most computer screens.

The oscilloscope's principle of operation is amazingly similar to the mirror-type device — except that the moving part is not a mirror, but electrons with no inertia to hamper the faithful reproduction of waveforms. As shown in **Figure 1**, the CRT can present information along three axes.

Before getting into a discussion about generating and deflecting the electron beam, I'd like to talk about how you can see the waveform on the front face (screen) of the tube even though the electron beam is invisible. The inside surface of the tube front is coated with a "phosphor" material



which emits light when electrons strike it. At first the phosphor emitted only green light, and that was the standard color of oscilloscope traces for years. White phosphors were eventually perfected and used in early black-and-white television sets. Some specialized yellow screens were popular in early radar "scopes." Some of these phosphors would glow long after the electron beam had moved on to another spot. This characteristic is called "persistence;" it's beneficial in some uses and detrimental in others. The technique of using phosphors that would glow red, green, and blue was also developed. These phosphors were the precursors of present-day color television receivers and multi-color computer monitors.

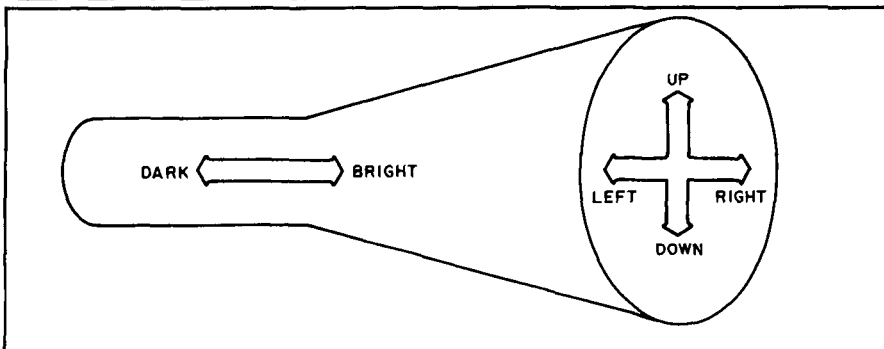
The electron gun

No, it's not the latest arcade game; it's the device that starts electrons on their path toward the screen of the tube. The interior of the CRT is a vacuum, so electrons can be pulled off the surface of a heated cathode by the charge on a nearby electrode — just

as they are in amplifier tubes used in other applications. One difference is that the first electrode has a small hole in it. While many electrons are pulled off the cathode and strike the electrode, others pass through the hole and continue toward the screen. The voltage on this first electrode (G1 in **Figure 2**) determines the intensity of the beam. Other electrodes (F1, F2, and F3 in **Figure 2**) accelerate and focus the beam of electrons so that it strikes the screen as a tiny spot. This whole assembly fits near the base, in the narrow neck of the tube, and is called the electron gun.

The glass shell of the tube flares out to support the screen of the CRT. This gives it a funnel-like shape. The inside surface of this flared part is usually coated with a conductive material connected to a high-voltage source of very low current capacity. This voltage keeps the electron beam tightly packed on its way to the screen and prevents electrons from "bouncing back" (secondary emission) when they hit the screen. Otherwise, stray electrons would distort the image. When used in an oscilloscope, the beam is almost always deflected by an electrostatic charge on the deflection plates, as shown in **Figure 2**. One pair of plates is mounted along the horizontal axis (HP1, HP2), and another pair along the vertical axis (VP1, VP2). For

FIGURE 1



The usefulness of an oscilloscope is greatly determined by the cathode-ray tube (CRT) and its ability to show signals in two axes, vertical and horizontal. The third axis, bright and dark, enhances its utility as a test instrument.



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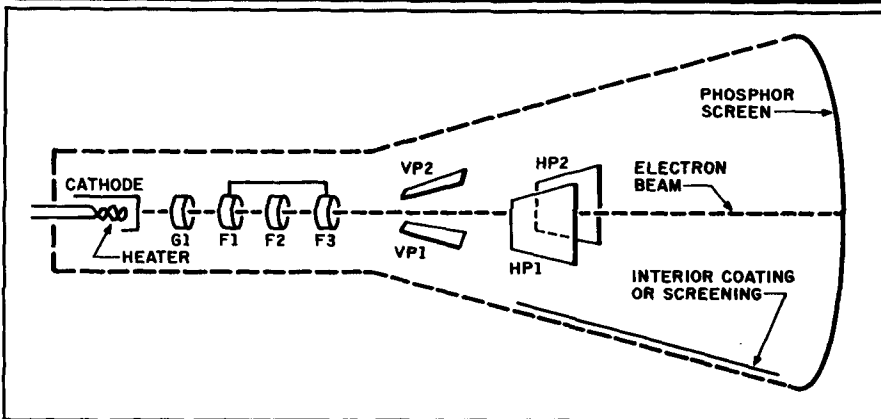
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FIGURE 2



The basic components of a CRT. It contains elements that change the intensity of the electron beam (G1), focus the beam (F1, F2, F3), deflect the beam (VP1, VP2, HP1, HP2), and help maintain the focus and intensity (the interior coating or screening).

line across the waveform you're looking at. This blanking voltage can also be modulated with a series of square waves, allowing you to break the waveform on the screen into dotted or dashed lines as an aid in determining time duration (or frequency) of the signal. This is also how the light and dark areas of a television image are produced on the screen. The beam is modulated by a complex video waveform that reproduces the image formed in the TV camera.

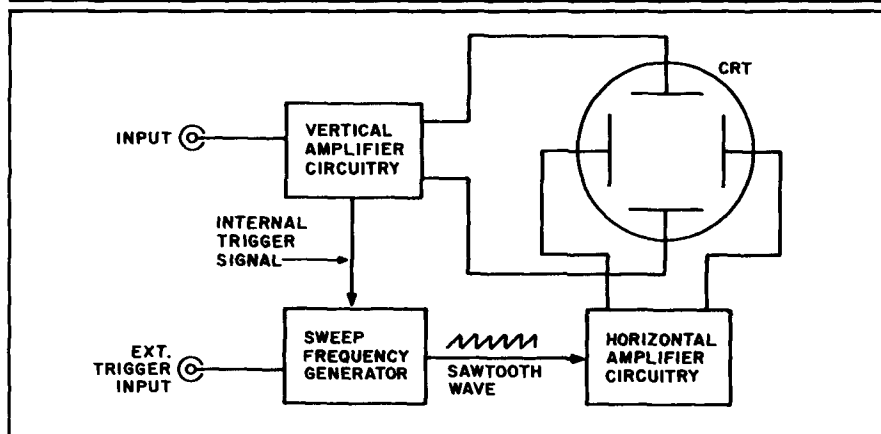
Electromagnetic (or just "magnetic") deflection of the electron beam is widely used in radar scopes and television receiver CRTs. Magnetic deflection has an interesting trait. The beam is deflected at right angles to the field between the coils. Therefore, the coils that deflect the beam right and left are mounted in a vertical plane. It's costly to mount electrostatic plates inside the tube and bring connections out through the glass wall. This is why television receivers universally use the relatively inexpensive electromagnetic deflection.

Other circuitry

A useful test instrument requires several circuits in addition to the basic CRT (see Figure 3). The voltage that deflects, or sweeps, the spot across the screen must be a waveform with a jagged shape like teeth on a saw — a sawtooth wave. Special oscillator and shaping circuits develop this waveform, and the frequency can be varied allowing different rates of sweep to look at a wide range of signal frequencies. The sweep can also be "triggered" on and off, allowing you to "catch" just one particular signal when it occurs. For example, perhaps you are looking at a 5 volts DC line, and want to see any noise or hum that rises to 5.5 volts. Set the trigger point to just below 5.5 volts, and any noise of that amplitude which appears on the line will cause the 'scope to start a trace and show the signal. This feature is often used when you take a photograph of the waveform on the screen. The trigger can be fired manually or automatically to produce just one sweep while the camera shutter is open.

An amplifier is usually required to boost any input signal up to a level that will deflect the beam vertically. This circuit, called a vertical amplifier or verti-

FIGURE 3



The horizontal and vertical circuits needed to drive a CRT. The amplifiers are quite complex; they must amplify signals from DC to several MHz, and do so without distortion or a decrease in gain.

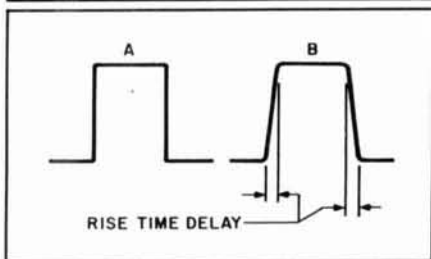
example, when a positive voltage is placed on the right plate and a negative voltage is placed on the left plate, the beam is deflected from left to right across the screen. The vertical plates function in the same manner. The signal from the vertical or horizontal amplifier circuitry is applied to the deflection plates 180 degrees out of phase, just as in a push-pull amplifier for audio or radio frequency use. This combination lets you control the position of the spot anywhere on the screen to trace even the most complex waveforms.

The third axis

An interesting new capability is added to the instrument when you start controlling a third variable — the brightness of the spot on the screen. By changing the voltage on the first

electrode after the cathode (G1), you can control the intensity of the electron beam. You can make the spot brighter or dimmer, or extinguish it altogether. Turning the beam off is called blanking, and is useful in getting rid of "retrace" lines. To illustrate what this does for you, try a simple experiment. Grab a sheet of paper and a pencil. Place the point of the pencil near the left edge of the paper and move it to the right. Make the line wavy as you go, and stop just short of the right edge of the paper. Now, without lifting the pencil off the paper, move it directly back to the starting point. This last line is the retrace line, created when the electron beam returns to its starting point after each trace across the screen. By turning the beam off when it starts its retrace, you avoid making a distracting

FIGURE 4



Distortion can be caused by poor vertical amplifier response. The original squarewave at A is degraded as shown at B. The poor response also causes the corners to be rounded when the horizontal portion starts or stops.

cal deflection amplifier, requires a very special design. It must amplify signals that range from a very few Hz up to several MHz, do so with almost no distortion, and have equal gain over the entire range. (Some circuits actually pass DC voltages so you can measure the signal by deflection from a base line.) This is no small trick, and was very difficult to do with vacuum tube amplifiers. Solid-state devices seem to handle the task easily when coupled with appropriate impedance-matching and bandpass circuitry. A garden-variety oscilloscope should be able to pass 20 MHz; one that's useful to over 50 MHz isn't too hard to find at reasonable prices. While 'scopes of this range will suffice for troubleshooting most Amateur equipment, you'll need something rated to near 100 MHz if you want to look at the pulses in digital equipment like computers. Unfortunately, this kind of equipment is significantly more expensive.

The importance of this vertical response frequency can be seen in Figure 4. Figure 4A shows an actual square wave; 4B shows the wave as it might appear on an average oscilloscope screen. The reason it doesn't look square on the screen is because of something called vertical response time or rise-time delay. When the flat (+) part of the square wave stops, the beam descends toward the negative (-) part. However, the beam is still sweeping from left to right, so the spot doesn't land directly below the end of the + bar. The same thing happens when the - part stops and the beam rises to the + level. The time it takes to get from - to + (and vice versa) is

called the rise time; the shorter that time is, the more like the true waveform the trace will be. How does this relate to frequency? A 100-MHz signal rises and falls 100 times faster than a 1-MHz signal. An amplifier with a rise-time response equal to 100 MHz will faithfully reproduce some pretty steep waveforms, while one that is only rated at 1 MHz will distort the waveform (see Figure 4B).

Some oscilloscopes incorporate a "Z" axis amplifier to control the brightness of the trace. This isn't often needed in general troubleshooting, but in some instances it can be used to impress external signals — like time markers (a bright "pip" every 100 milliseconds) or frequency markers (a pip every 1 MHz in a spectrum analyzer) — on the electron beam.

An oscilloscope requires various voltages for operation, and the power supply is accordingly complex. It must supply a range of positive voltages for the accelerating and focusing anodes, and for the brightness control. Positive voltage is required for the deflecting anodes, and a very high voltage is placed on the interior conductive coating. This voltage, sometimes called the "ultor anode" voltage, varies from near 2000 volts in common oscilloscopes up to 20,000 or 30,000 volts in some television receivers. The current is in microamperes and not directly lethal, but contact with it will usually cause severe muscle reaction which can result in physical injury.

As you can see, the oscilloscope is an extremely versatile instrument. A meter's pointer is a one-axis device which indicates amplitude, and that is exactly what the vertical axis of a CRT does. The horizontal sweep circuit in an oscilloscope introduces another axis which lets you look at a waveform over a specific period of time. The brightness control introduces a third axis that hides retrace lines, and lets you trace an image on the screen. In part 2, I'll look at another visual aid, the light-emitting diode (LED), and some of its uses.

For further reading:

If you'd like to learn more about the workings and uses of oscilloscopes, I recommend *Oscilloscopes*, by Rien van Erk, McGraw-Hill, 1978. It's an excellent, well-illustrated tutorial.

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WANTED: Ten-Tec QRP transceivers. Signalizer audio amplifier S20/S30 RX-10 receiver. Modules MX1 TX1 AA1 Argonaut and power supply. Russ Olmsted, 608 West Thompson Lane, Murfreesboro, TN 37129. (615) 893-5344.

COMMODORE-128 PROGRAM available to track the Amateur Satellites. Uses Keplerian data supplied by NASA free. Tracks up to 8 satellites simultaneously. Program also supports printing schedules and predictions for satellites. Use it to track MIR and talk to the Cosmonauts. SATRAK128, \$26.50 includes shipping. Other information on this or other programs for the C128, requires a business size SASE. Reid Bristol, WA4UPD, PO Box 0773, Melbourne, Florida 32936-0773.

WANT: 32S3 xmtr, 250TL and 304TL tubes. KF6WM, 45300 Royal, King City, CA 93930.

DXERS—CUSTOMIZED PRINTOUT of antenna headings calculated for your location. List includes over 650 worldwide locations. Send Lat/Long coordinates, name, call sign, check for \$12.95 U.S. Brian Henderson, VE6ZS, 23 Deermoss Pl SE, Calgary, Alberta, Canada T2J 6P5. (403) 278-2084.

HANDICAPPED NOVICE needs HF equipment donated—anything please. KA3OUE, (412) 531-7443 anytime.

OFFICIAL MILITARY-TYPE ID TAGS. ("Dog Tags")!!! Customized with your Call Letters, etc. 5 seven-teen space lines. 20" nickel plated chain included. \$4.29 postpaid. JPW ENTERPRISES, PO Box 353, Logan, Utah 84321

MAGAZINES WANTED: "Microwave Systems News" (MSN), "RF Design", "PCIM (Power Conversion & Intelligent Motion)" and "QEX" (1980-present). Call collect 519-742-4594 (Ontario) after 6 PM Eastern time.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14,280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

QUAD ANTENNAS 10-12-15 meters \$139.95. 10-15-20 meters \$199.95. Light weight fiberglass construction. Lightning Bolt Antennas, RD 2, Volant, PA 16156. (412) 530-7396.

"SOME UNPUBLISHED THEORIES AND MORE for The Radio Amateur" by Lymansson. Includes RF wattmeter, moni-match, balun etc. From R.L. Pfohl-Beeman, Publisher. \$10 p/d. POB 70, Loogootee, IN 47553.

BACK ISSUES OF HAM RADIO. Have most issues from 1969 to 1974. Mint condition. \$3.00 for single issues. WN0G, 319-377-3563.

HAM TRADER YELLOW SHEETS. In our 27th year. Buy, swap, sell ham radio gear. Published twice a month. Ads quickly circulate—no long wait for results. Send No. 10 SASE for sample copy, \$13 for one year (24 issues). PO Box 2057, Glen Ellyn, IL 60138-1057 or PO Box 15142, Dept HR, Seattle, WA 98115.

VHF-UHF-SHF. Large SASE. West Coast VHFer, POB 688, Holbrook, AZ 86025.

CHASSIS & CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Rd, Dover, PA 17315.

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RUBBER STAMPS: 3 lines \$5.00 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

"HAMLOG" COMPUTER PROGRAM. Full features, 17 modules. Auto-logs, 7-band WAS/DXCC. Apple \$19.95. IBM, CP/M, KAYPRO, Tandy, C128 \$24.95. HR-KA1AWH, POB 2015, Peabody, MA 01960.

WANTED: ARC-5 and SCR-274 equipment, parts and accessories, any condition. Ken, WB9OZR, 362 Echo Valley, Kinne-
lon, NJ 07405. (201) 492-9319.

WANTED: Ham equipment and other property. The Radio Club of Junior High School 22 NYC, Inc. is a nonprofit organization, granted 501(C)(3) status by the IRS, incorporated with the goal of using the theme of Ham Radio to further and enhance the education of young people. Your property donation or financial support would be greatly appreciated and acknowledged with a receipt for your tax deductible contribution. In Dayton, meet the crew from 22 and relax at our flea market tables, check in on 144.30 simplex. Please write us at: PO Box 1052, New York, NY 10002. Or call our round the clock hotline: (516) 674-4072. Thank you!

WANTED: Drake Linear Amp Model MN4439-1000W (2000 PEP), 1.8-30 MHz. Call Bruno Molino, VE2FLB, 26 Rue Des Anciens, Gatineau, Quebec J8T 3T2. (819) 561-3689.

RECONDITIONED TEST EQUIPMENT \$1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC. ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

May 21: ILLINOIS: Hamfest sponsored by the Kankakee Area Radio Society, Will County Fairgrounds, Peotone. 8-3. For information write KARS c/o Frank DalCanton, KA9PWW, RR 1, Box 361, Chebanse, IL 60922. (815) 932-6703 after 4 PM or (815) 937-2452 before 4 PM CST.

June 3-4: WASHINGTON: Hamfest sponsored by the Apple City ARC, Rocky Reach Dam, 7 miles north of Wenatchee. For information and registration Bob Lathrop, 919 N. Woodward Drive, Wenatchee, WA 98801.

June 3: NEW HAMPSHIRE: The Hosstraders Flea Market is back at the Deerfield Fairgrounds. Admission \$5 per person. Wheelchair accessible. Questions or map SASE to WA1IVB, RFD Box 57, West Baldwin, ME 04091.

June 4: NEW YORK: Hall of Science Hamfest, sponsored by the Hall of Science ARC, Hall of Science parking lot, Flushing Meadow Park, 47-01-111 Street, Queens. Starts 9 AM. For information Steve Greenbaum, WB2KDG (718) 898-5599 or Arnie Schiffman, WB2YXB (718) 343-0172.

June 4: PENNSYLVANIA: Firecracker Hamfest sponsored by the Harrisburg RAC, Bressler Picnic Grounds, Harrisburg. Starts 8 AM. Contact Dave Dormer, KC3MG. (717) 939-4957.

June 10: NORTH CAROLINA: 2nd annual Hamfest and Computer Electronics Fair sponsored by the Forsyth ARC, Dixie Classic Fairgrounds, Winston-Salem. 9 AM to 3 PM. For information contact Jim Rodgers, N1DRI, POB 11361, Winston-Salem, NC 27166. (919) 760-2493.

June 10: COLORADO: Superfest "XI", Larimer County Fairgrounds, South Railroad Avenue, Loveland. 8 AM to 4 PM. June 11: ILLINOIS: 32nd annual Hamfest sponsored by the Six Meter Club of Chicago, Santa Fe Park, 91st and Wolf Road, Willow Springs. Ticket Chairman, Mike Corbett, K9ENZ, 606 South Fenton Ave, Romeoville, IL 60441.

June 11: ILLINOIS: The 60th anniversary of EGYPTIANFEST, sponsored by the Egyptian ARC, at the Clubhouse, R13 at I-270, Granite City. Contact Egyptian ARC, PO Box 562, Granite City, IL 62040. (618) 931-1177 Thurs eves.

June 11: KENTUCKY: "Ham-O-Rama '89" sponsored by the Northern Kentucky ARC, Erlanger Lions Park. Gates open 8 AM. For more information or registration N40EB, NKARC, POB 1062, Covington, KY 41012. (606) 331-3258.

June 11: OHIO: The Goodyear ARC's 22nd annual Hamfest and family picnic, Wingfoot Lake Park near Akron. Flea market 8 AM to 4 PM. For tickets or information William F. Dunn, WB1FM, 4730 Nottingham Lane, Stow, OH 44224. (216) 673-8502.

June 16-17: MINNESOTA: Amateur Fair '89. NEW LOCATION—Aldrich Arena, Maplewood. 8-10 PM. For information, tickets write Amateur Fair '89, PO Box 290131, Brooklyn Center, MN 55429. (612) 653-9999.

June 16: ALBERTA: Annual Picnic sponsored by the Central Alberta Radio League, Burbank Campsite. Contact P. Fitzgerald, VE6QT (403) 746-2821 or D. Miller, VE6XF, (403) 886-4883. 2 FM 3.2
June 17: MICHIGAN: 14th annual Swap Shop sponsored by the Straits Area ARC, Petoskey. 8 AM to 1 PM. For information Irene, N8HBT (616) 539-8986 or Clark, KA8TIL (616) 582-6455.

June 17: NEW JERSEY: 18th annual Hamfest sponsored by the Raritan Valley Radio Club, Columbia Park, Dunellen. Starts 8 AM. For information Dave, KA2TSM (201) 763-4849 or John, WA2C (201) 96855070.

June 18: WISCONSIN: Hamfest sponsored by the Central Wisconsin Radio Amateurs, Student Center, University of Wisconsin, Stevens Point campus. Starts 9 AM. Free admission. For information Art Wysocki, N9BCA, 3356 April Lane, Stevens Point, WI 54481. (715) 344-2984.

June 18: MICHIGAN: Monroe Hamfest sponsored by the Monroe County Radio Communications Association, Monroe County Fairgrounds. Handi parking. All buildings wheelchair accessible. For information Larry Lindner, KB8AIZ, 2001 Ida-Maybee Dr, Monroe, MI 48161. (313) 587-3663.

June 18: MARYLAND: Father's Day Hamfest sponsored by the Frederick ARC, Frederick County Fairgrounds. 8 AM to 4 PM. For information Dave Durkovic, N3BKD, 7128 Limestone Lane, Middletown, MD 21769.

June 18: CALIFORNIA: Santa Maria Radio Swapfest, Union Oil Co Newlove Picnic Grounds, just south of Santa Maria. Gates open 9 AM. Talk in 146.94. For information Hank Korczak, W6PME, 917 West Anthony Way, Lompoc, CA 93436. (805) 736-1761.

July 2: PENNSYLVANIA: Murgas ARC Hamfest, Ice-A-Rama, Coal Street Sports Complex, Wilkes-Barre. Starts 8 AM. Contact Mike Benish, K3SAE, Box 214, RD #1, Pittston, PA 18643. (717) 338-6863.

July 8: WISCONSIN: Swapfest sponsored by the South Milwaukee ARC, American Legion Post 434, 9327 South Shepard Avenue, Oak Creek. 7 AM to 2 PM. For details South Milwaukee ARC, POB 102, South Milwaukee, WI 53172-0102.

July 8-9: INDIANA: 19th annual ARRL Division Convention and Hamfest, Marion County Fairgrounds, Indianapolis. Gates open 6 AM both days. For information (317) 356-4451.

July 9: PENNSYLVANIA: 4th annual Hamfest sponsored by the North Hills ARC, Northland Public Library, 300 Cumberland Road, Pittsburgh. 8 AM to 4 PM. For information SASE to Bob Ferrey, Jr, N3DOK, 9821 Presidential Drive, Allison Park, PA 15101. (412) 367-2393.

October 1: NORTH CAROLINA: JARSTEST '89, Benson American Legion Complex, 301 N. Benson NC 27504. 8 AM to 4 PM. For flyer SASE to Johnston Amateur Radio Society, PO Box 1154, Smithfield, NC 27577. (919) 934-0486, 894-5479.

OPERATING EVENTS

"Things to do . . ."

June 9: The East Pasco Amateur Society will operate a special event station AB4LN to celebrate the centennial of Dade City, Florida. Operation starts daily at 10 AM. Send QSL and business SASE for certificate to EPARS Centennial, AB4LN, PO Box 942, Dade City, FL 34297-0942.

June 10: The Tusco ARC, New Philadelphia, Ohio, will operate W8ZX 1700 UTC from New Towne mall to celebrate the 50th anniversary of the club and to promote public interest in Amateur Radio. For QSL SASE to W8ZX, PO Box 725, New Philadelphia, OH 44863.

June 17: Chicago. The Amoco ARC will operate special event station W9GT from 1300Z June 17 to 0100Z June 18 to commemorate the 100th anniversary of the incorporation of Amoco Corp. Phone, CW and packet 80-10m and VHF. For special QSL SASE to Amoco ARC, Mail Code 0802, 200 E. Randolph Drive, Chicago, IL 60601.

June 17: The Prince Georges Amateur Radio Emergency Service, Maryland, will operate a special event station at the Prince Georges Worldfest. 1500 UTC June 17 to 0200 UTC June 18. This year marks the 293rd anniversary of Prince Georges County. For a special QSL card send QSL card and SASE to PG-ARES, PG EOP, 7911 Anchor Street, Landover, MD 20785.

June 18: 1989 SMIRK Party Contest. 0000 UTC June 18—2400 UTC June 19. Send contest entries by July 6, 1989 to Lisa Lowell, KA0NNO, PO Box 547, Hugo, CO 80821.

July 1: Colorado Six Meter Invitational Net is sponsoring an activity day contest. Exchange callsign, name, grid square and SIN number on 50 MHz. Send logs by July 31 to N0AKI, 8529 Fenton St, Arvada, CO 80003. Please SASE.

July 4: High Plains ARC will operate KT7V at historic Fort Laramie from 0000Z July 4 to 0000Z July 5. For QSL send business SASE to KT7V, 111 Camino Del Rey, Torrington, WY 82240.

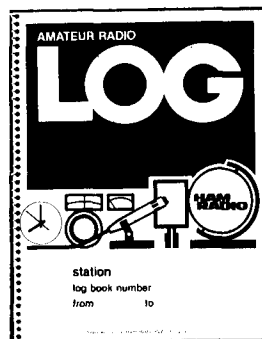
LAUREL ARC monthly (except December) Amateur exam sessions for all license classes. No fee is charged. Pre-registration is required. Call (301) 725-1212, Maryland Radio Center, 8576 Laurelale Drive, Laurel, MD 20707.

NORTH COAST ARC 1989 LICENSE EXAMS. 12:30 PM, Saturdays February 11, April 15, June 10, August 12, October 14, December 9. N. Olmsted Community Cabin, S of Lorain on W. Park. Novice thru Extra. Walkins allowed. Talk in 145.29 repeater. For information Dan Sarama, KB8A, 15591 Rademaker Blvd, Brookpark, Ohio 44142. 287-5083 or Pauline Wells, KA8FOE, Rick Wells, K8SCI, 777-9460/779-8999.

AMATEUR RADIO CLASSES: For those people interested in obtaining a Novice (basic level) Ham license or upgrading to Tech/General, the Chelsea Civil Defense, in cooperation with QRA Radio Club, will sponsor Amateur Radio Communications classes evenings at Chelsea High School starting MARCH 7, 1989. For more information write Frank Masucci, K1BPN, 136 Grove Street, Chelsea, MA 02150. Please enclose your telephone number.

THE MIT UHF REPEATER ASSOCIATION and the MIT Radio Society offer monthly HAM EXAMS. All classes Novice to Extra. Wednesday, JUNE 21, 7 PM, MIT Room 1-150, 77 Mass Avenue, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 484-2098. Exam fee \$4.50. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.

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A built-in SSB filter is standard. When an optional SSB filter (YK-88S or YK-88SN) is installed, **dual** filtering is provided.
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- AT-250 external auto. tuner (160 – 10 m)
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Complete service manuals are available for all Kenwood transceivers and most accessories. Specifications and prices are subject to change without notice or obligation.

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