JANUARY 1989 / $2.50

SPECIAL CONSTRUCTION ISSUE

NEW HAM RADIO

Winter Weekenders

ICOM

Dual Band Mobile & Handheld

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!

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First in Communications

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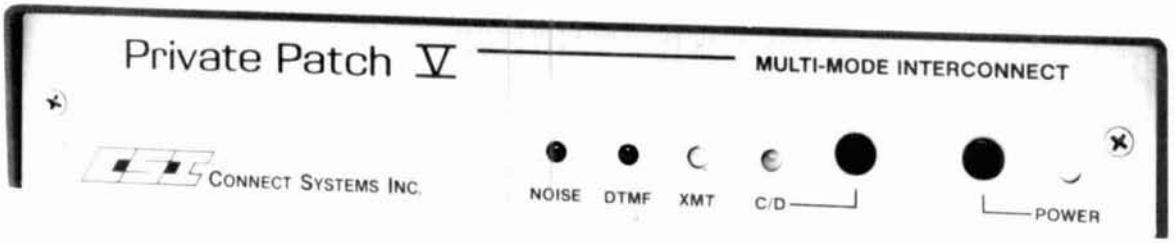
All stated specifications are subject to change without notice or obligation. All ICOM radios significantly exceed FCC regulations limiting spurious emissions. 321032AT588

FOUR user selectable operating modes and a 90 number autodialer make Private Patch V the ONLY choice!

NEW!



SELECT AN OPERATING MODE USING THE BUILT-IN KEYBOARD . . .

1. SIMPLEX SAMPLING PATCH

Private Patch V achieves a level of sampling patch performance unobtainable in any other product. Crucial to performance is the noise squelch filter. Compare our five pole filter to the competition's two pole filter. Advanced software algorithms perform noise correlation tests which result in greater useable range than the competition. Nine selectable VOX enhancement ratios allow you to vary performance from straight sampling to highly VOX enhanced. (sampling rate decreased while the land party is speaking). The mobile is in full control and can break-in at any time.

2. SIMPLEX VOX PATCH

VOX mode offers superb simplex operation with any radio, including synthesized and relay switched models. VOX mode has other advantages too. **1.** A linear amplifier can be used to extend straight simplex range. **2.** You can operate through any remotely located repeater to greatly extend range. **3.** If desired you can connect Private Patch V to the MIC and speaker jack of your radio. NO INTERNAL CONNECTIONS ARE REQUIRED. Control is maintained automatically with built-in dial tone detection, busy signal detection and fully programmable activity and time out timers. An optional electronic voice delay board eliminates first word clipping with slow switching radios.

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4. REPEATER CONTROLLER

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NEW!

Affordable DX-ing!

TS-140S

HF transceiver with general coverage receiver.

Compact, easy-to-use, full of operating enhancements, and feature packed. These words describe the new TS-140S HF transceiver. Setting the pace once again, Kenwood introduces new innovations in the world of "look-alike" transceivers!

- **Covers all HF Amateur bands with 100 W output.** General coverage receiver tunes from 50 kHz to 35 MHz. *(Receiver specifications guaranteed from 500 kHz to 30 MHz.)* Modifiable for HF MARS operation. *(Permit required)*
- **All modes built-in.** LSB, USB, CW, FM and AM.
- **Superior receiver dynamic range** Kenwood DynaMix™ high sensitivity direct mixing system ensures true 102 dB receiver dynamic range.

- **New Feature! Programmable band marker.** Useful for staying within the limits of your ham license. For contesters, program in the suggested frequencies to prevent QRM to non-participants.
- **Famous Kenwood interference reducing circuits.** IF shift, dual noise blankers, RIT, RF attenuator, selectable AGC, and FM squelch.

- **M. CH/VFO CH sub-dial.** 10 kHz step tuning for quick QSY at VFO mode, and UP/DOWN memory channel for easy operation.
- **Selectable full (QSK) or semi break-in CW.**
- **31 memory channels.** Store frequency, mode and CW wide/narrow selection. Split frequencies may be stored in 10 channels for repeater operation.
- **RF power output control.**
- **AMTOR/PACKET compatible!**
- **Built-in VOX circuit.**
- **MC-43S UP/DOWN mic. included.**

Optional Accessories:

• **AT-130** compact antenna tuner • **AT-250** automatic antenna tuner • **HS-5/HS-6/HS-7** headphones • **IF-232C/IF-10C** computer interface • **MA-5/VP-1** HF mobile antenna (5 bands) • **MB-430** mobile bracket • **MC-43S** extra UP/DOWN hand mic. • **MC-55** (8-pin) goose neck mobile mic. • **MC-60A/MC-80/MC-85** desk mics. • **PG-2S** extra DC cable • **PS-430** power supply • **SP-40/SP-50B** mobile speakers • **SP-430** external speaker • **SW-100A/SW-200A/SW-2000** SWR/power meters • **TL-922A** 2 kW PEP linear amplifier (not for CW QSK) • **TU-8** CTCSS tone unit • **YG-455C-1** 500 Hz deluxe CW filter, **YK-455C-1** New 500 Hz CW filter.

TS-680S

All-mode multi-bander

- 6m (50-54 MHz) 10 W output plus all HF Amateur bands (100 W output).
- Extended 6m receiver frequency range 45 MHz to 60 MHz. Specs. guaranteed from 50 to 54 MHz.
- Same functions of the TS-140S except optional VOX (VOX-4 required for VOX operation).
- Preamplifier for 6 and 10 meter band.

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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HAM RADIO

JANUARY 1989

volume 22, number 1

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HAM RADIO Magazine is published monthly by Communications Technology, Inc. Greenville, New Hampshire 03048-0498 Telephone: 603-878-1441

subscription rates

United States:
one year, $22.95; two years, $38.95; three years, $49.95
Europe (via KLM air mail), $40.00
Canada, Japan, South Africa and other countries (via surface mail), one year, $31.00; two years, $55.00; three years, $74.00

All subscription orders payable in U.S. funds, via international postal money order or check drawn on U.S. bank

international subscription agents: page 100

Microfilm copies are available from Buckmaster Publishing Mineral, Virginia 23117

Cassette tapes of selected articles from *HAM RADIO* are available to the blind and physically handicapped from Recorded Periodicals, 919 Walnut Street, Philadelphia, Pennsylvania 19107

Second-class postage paid at Greenville, New Hampshire 03048-0498 and at additional mailing offices
ISSN 0148-5989

Send change of address to *HAM RADIO* Greenville, New Hampshire 03048-0498

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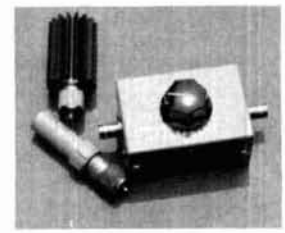

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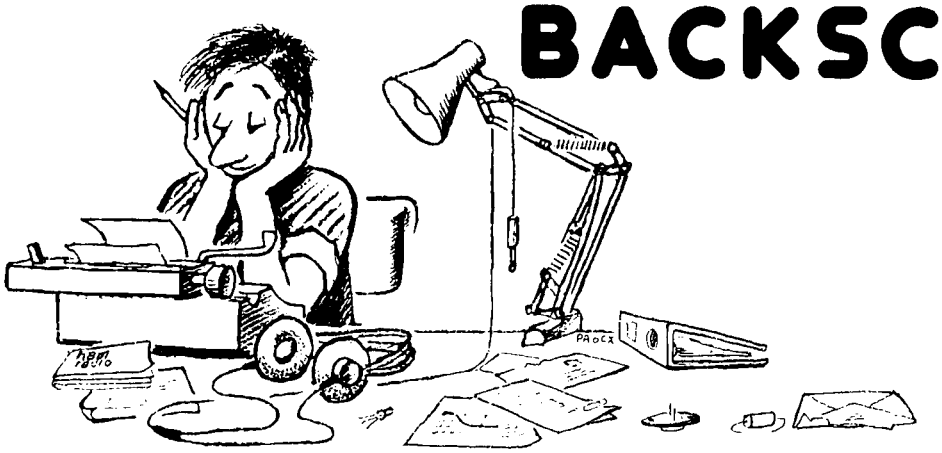

RADIO SPECTRUM POLLUTION

A recent editorial in the *Boston Globe* about radio spectrum pollution and its effects on the field of Radio Astronomy hit a very familiar chord. Radio spectrum pollution is a problem that is shared by far more than those in the field of Radio Astronomy. Almost all users of the radio waves, both passive (those who listen) and active (those who transmit a signal) have suffered from noise pollution of one form or another.

Due to the very nature of their science, Radio Astronomers are far more susceptible to noise problems. The signals that they are receiving are so weak, that it's nearly impossible to describe to the layman the technology that must be used. It may be hard to believe, but a car passing a receiving point at the wrong time could invalidate weeks of work.

The *Globe's* editorial suggested that the solution to the problem would only cost a few dollars. That is, unfortunately, incorrect. It went on to say that Congress should explore whether legislation may be necessary to encourage, or even require, manufacturers to install filters that would reduce the noise pollution caused by electrical equipment of all kinds.

Interference problems have plagued Radio Amateurs and other radio users for years. Studies conducted by a number of trade organizations have shown, time and time again, that interference caused to home TVs, radios, and VCRs, is caused by poor design in these devices and a lack of simple, easy-to-install filters! The manufacturers have been unwilling to incorporate changes due to the cost — a $1 fix times millions of devices totals up to millions of dollars — that the consumer will ultimately pay for. To me, the thought that they will install "noise filters" to protect Radio Astronomers is ludicrous.

Radio Amateurs spend hundreds of dollars engineering their stations to meet FCC specifications. Even so, they are still blamed for interference to consumer electronic devices — a problem that is created in the unit itself. Attempts by Radio Amateur lobbyists to get FCC or Congressional relief, have so far been unsuccessful.

While I would like to believe that there is a simple solution to the problem, it will be far more difficult to effect. The utopian view that Congress can solve all problems is just a dream. The answer lies, instead, in proper design and manufacturing techniques, along with firm standards of performance for consumer electronic devices mandated by the FCC.

J. Craig Clark Jr., N1ACH

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THE FIRST 144/220 MHz Dual Bander!

Double Take!

ACTUAL SIZE FRONT PANEL

TM-621A/721A

144/220 and 144/450 MHz FM Dual Banders

Once again, Kenwood brings you another Dual Bander First! The TM-621A is the first 144/220 MHz FM Dual Bander. The Kenwood TM-621A and TM-721A (144/450 MHz) re-defines the original Kenwood "Dual Bander" concept. The wide range of innovative features includes a dual channel watch function, selectable full duplex operation, 30 memory channels, extended frequency coverage, large multi-color dual digital LCD displays, programmable scanning, and more!

- **Extended receiver range** (138.000-173.995 MHz) on 2 m; 70 cm coverage is 438.000-449.995 MHz; 1-1/4 m coverage is 215-229.995 MHz. (Specifications guaranteed on Amateur bands only. Two meter transmit range is 144-148 MHz. Modifiable for MARS/CAP. Permits required.)
- **Separate frequency display for "main" and "sub-band."**
- **Call channel function.** A special memory channel for each band stores frequency, offset, and sub-tone of your favorite channel. Simply press the CALL key, and your favorite channel is selected!
- **30 multi-function memory channels.** 14 memory channels and one call channel for each band store frequency, repeater offset, CTCSS, and reverse. Channels "A" and "b" establish upper and lower limits for programmable band scan. Channels "C" and "d" store transmit and receive frequencies independently for "odd splits."
- **45 Watts on 2 m, 35 watts on 70 cm. 25 watts on 1-1/4 m.** Approx. 5 watts low power.
- **Automatic Band Change (A.B.C.)** Automatically changes between main and sub-band when a signal is present.
- **Dual watch function allows VHF and UHF receive simultaneously.**
- **Programmable memory and band scanning, with memory channel lock-out and priority watch function.**
- **Balance control and separate squelch controls for each band.**
- **Dual antenna ports.**
- **TM-621A has auto offset.**
- **Full duplex operation.**
- **CTCSS encode/decode selectable from front panel** or UP/DWN keys on microphone. (Encode built-in, optional TSU-6 needed for decode.)
- **Each function key has a unique tone for positive feedback.**
- **Illuminated front panel controls and keys.**
- **16 key DTMF mic. included.**
- **Handset/remote control option (RC-10).**
- **Frequency (dial) lock.**
- **Supplied accessories:** 16-key DTMF hand mic., mounting bracket, 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.

TM-721A shown with optional RC-10.

Optional Accessories:
• **RC-10** Multi-function handset/remote controller • **PS-430** Power supply • **TSU-6** CTCSS decode unit • **SW-100B** Compact SWR/power/volt meter • **SW-200B** Deluxe SWR/power meter • **SWT-1** 2 m antenna tuner • **SWT-2** 70 cm antenna tuner • **SP-40** Compact mobile speaker • **SP-50B** Deluxe mobile speaker • **PG-2N** DC cable • **PG-3B** DC line noise filter • **MC-60A, MC-80, MC-85** Base station mics. • **MA-4000** Dual band 2 m/70 cm mobile antenna (mount not supplied) • **MB-11** Mobile bracket • **MC-43S** UP/DWN hand mic. • **MC-48B** 16-key DTMF hand mic.

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COMMENTS

Challenge your knowledge

Dear HR

I've been a HR subscriber since my return from Vietnam in late 1968. You have always given me the kinds of technical articles that were on the leading edge of technology. Both in my hobby (ham radio) and in my former occupation (junior college teacher), I have been able to draw upon your magazine for a source of ideas, challenges to my expertise, and enjoyment in the challenging field of electronics. I like the idea of "Elmer's Notebook" to help newcomers discover what some (or most) of us internalized long ago.

To use a worn, trite phrase, "keep up the good work."

Richard B. Bridges, WB5GSA,
APO New York 09757

Technical competence compromised

Dear HR:

For the past several days the Cable News Network has been showing interviews with and comments about a survey of Americans concerning their knowledge of geography. Almost nobody knew the locations of Central America or Massachusetts. Very, very few knew the population of the United States. The terrible ignorance is appalling and immediately brings the politicians to their rostrums, snarling, "We MUST do something about this!"

And now I see more letters whining about being given MORE beneficial communication handouts. Could it be that the one, basic and fundamental reason that these people cry for easier examinations (or none at all) is that there is a provable and colossal ignorance loose in the land? Is it necessary to have easier test standards because hardly anyone can sucessfully pass an examination that used to be routinely given to high school teenagers thirty years ago? When I passed my Class B examination and thirteen word per minute code test 41 years ago, was I more intelligent than some college level student of today? Perhaps.

Let me point out that Amateur Radio is not a service to the average person on the street. Amateurs are licensed "in the public interest" and let us not allow the same word-twisting go on here as happens with the First Amendment. We assist in fire and flood, tornado and earthquake — we do not order pizzas or pass the word to your secretary that you've decided to have that extra martini. By all means, get a cellular telephone — that's just what they are for. The FCC experiment on 27 Megacycles to allow the citizenry to have access to their own, unmolested HF communications speaks loudly for itself. Those of you who believe that the future of Amateur Radio stands in harm's way are probably right. But is the answer to heap the spectrum with electronic effluvium in an attempt to disguise a little bit of communication knowledge — or to raise the level of technical competence to a point where it can be recognized and rewarded?

I don't believe that one would have to hire the best market survey company in the country to discover that a majority of amateurs find $2500 a rather steep price for a piece of ham gear — entrance level or not! I started out with a single 6L6 and a surplus crystal. But not today! Your kid doesn't want a Model-A, he wants a Mercedes Benz! The makers of soldering irons are going the way of the buggy whip manufacturers. Change the motherboard! It's much more of a challenge to break laws, social and moral — and all of us tired old people sit and wonder why the young people aren't just flocking to join the Amateur Radio ranks. Better start a stamp collection, brudder.

Joe Weite, KH6GDR,
Makakilo, Hawaii 96706

Latest issue... Great!...but..

Dear HR:

Hey guys! Great new September issue, but...I can't read the parts list on page 20 or LOTUS information on page 32 (fig. 2 and 3). Any chance of seeing it in larger print?

Thanks and good luck.

Sam Popkin, K2DNR,
Tucson, Arizona 85747

Full size copies of programs and parts lists are available for an SASE.
Ed.

Is zone 29 rare in contests?

Dear HR:

I enjoy giving zone 29 to United States stations during contests where zones count as multipliers.

However, over the past few years during each contest I have noticed that nearly every time I call a strong W station, by the time I give my callsign, he is calling CQ contest again, without having made a contact.

Perhaps my Australian drawl or accent puts stations off?

Honestly, most stations do not allow time for me to give my callsign.

If I do make a contact, most U.S. stations are very happy to have zone 29 as a new multiplier and they say so. So, please all you contest stations look out for the VK6 and leave enough time between calls.

By the way, there are only about 900 VK6 stations altogether and probably 4 or 5 active contesters!

Graham Rogers, VK6RO,
Ferndale, Western Australia

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NOW Four to choose!

Four to Go!

TM-221A/321A/421A/521A

144/220/450/1300 MHz

The Hottest Selling Compact FM Mobile Transceivers

The all-new TM-221A, TM-321A, TM-421A and TM-521A FM transceivers represent the "New Generation" in Amateur radio equipment. The superior Kenwood GaAs FET front end receiver; reliable and clean RF amplifier circuits, and new features all add up to an outstanding value for mobile FM stations! The optional RC-10 handset/control unit is an exciting new accessory that will increase your mobile operating enjoyment!

- **TM-221A receives from 138-173.995 MHz.** *This includes the weather channels!* Transmit range is 144-148 MHz. Modifiable for MARS and CAP operation. (MARS or CAP permit required.)
- **TM-321A covers 220-224.995 MHz, TM-421A covers 438-449.995 MHz, and the TM-521A covers 1240-1300 MHz.** (Specifications guaranteed for Amateur band use only.)
- **Built-in front panel selection of 38 CTCSS tones.** TSU-5 programmable decoder optional.
- **Simplified front panel controls**—makes operating a snap!
- **16 key DTMF hand mic., mic. hook, mounting bracket, and DC power cable included.**
- **Selectable frequency steps** for quick and easy QSY.
- **TM-221A provides 45 W. TM-321A 25 W, TM-421A 35 W, and TM-521A 10 W.** All models have adjustable low power.
- **Packet radio compatible!**
- **Programmable band scanning with memory scanning and memory channel lock-out.**
- **New amber LCD display.**
- **Kenwood non-volatile operating system.** All functions remain intact even when lithium battery back-up fails. (Lithium cell memory back-up, est. life 5 yrs.)
- **14 full-function memory** channels store frequency, repeater offset, sub-tone frequencies, and repeater reverse information. **Repeater offset on 2 m is automatically selected.** There are **two channels** for "odd split" operation.
- **Super compact:** approx. 1-1/2"Hx5-1/2"Wx7"D.
- **Microphone test function on low power.**
- **High quality, top-mounted speaker.**
- **Rugged die-cast chassis and heat sink.**

RC-10 Remote Controller

For TM-221A/321A/421A/521A. Optional telephone-style handset remote controller RC-10 is specially designed for mobile convenience and safety. All front panel controls (except DC power and RF output selection) are controllable from the RC-10. One RC-10 can be attached to **a combination of two transceivers** with the optional PG-4G cable. When two transceivers are connected to the RC-10, **cross band, full duplex repeater** operation is possible. (A control operator is needed for repeater operation.)

Optional Accessories:

- **RC-10** Multi-function handset remote controller
- **PG-4G** Extra control cable for second transceiver
- **PS-50/PS-430** DC power supplies
- **TSU-5** Programmable CTCSS decoder
- **SW-100A** Compact SWR/power/volt meter (1.8-150 MHz)
- **SW-100B** Compact SWR/power/volt meter (140-450 MHz)
- **SW-200A** SWR/power meter (1.8-150 MHz)
- **SW-200B** SWR/power meter (140-450 MHz)
- **SWT-1** Compact 2 m antenna tuner (200 W PEP)
- **SWT-2** Compact 70 cm antenna tuner (200 W PEP)
- **SWC-4** 1200 MHz Directional coupler.
- **SP-40** *Compact mobile speaker*
- **SP-50B** Mobile speaker
- **PG-2N** Extra DC cable
- **PG-3B** DC line noise filter
- **MC-60A, MC-80, MC-85** Base station mics.
- **MC-55** (8-pin) Mobile mic. with gooseneck and time-out timer
- **MA-4000** 2 m/70 cm dual band antenna with duplexer (mount not supplied)
- **MB-201** *Extra mobile mount*

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

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MFJ multi-mode data controller

9 modes for only . . . $249.95

Amateur radio's most versatile multi-mode data controller -- the MFJ-1278 -- lets you join the fun on Packet, AMTOR, RTTY, ASCII, CW, Weather FAX, SSTV, Navtex and gives you a full featured Contest Memory Keyer mode . . . you get 9 modes . . . for an affordable $249.95.

Plus you get MFJ's new **Easy Mail**tm so you and your ham buddies can leave messages for each other 24 hours a day.

You'll find it **the most user friendly of all multi-modes.** It's menu driven for ease of use **and** command driven for speed.

A high resolution 20 LED tuning indicator lets you *tune in signals **fast** in any mode.* All you have to do is to center a single LED and *you're precisely tuned in to within 10 Hz* -- and it shows you which way to tune!

Plus you get 32K RAM, KISS for TCP/IP, high performance HF/VHF/CW modems, software selectable dual radio ports, AC power supply and more.

All you need to join the fun is an MFJ-1278, your rig and any computer with a serial port and terminal program.

You can use the MFJ Starter Pack to get *on the air instantly.* It includes computer interfacing cable, terminal software and friendly instructions . . . everything you need to get on the air fast. Order MFJ-1282 (disk)/MFJ-1283 (tape) for the C-64/128 and VIC-20; MFJ-1287 for Macintosh; MFJ-1284 for the IBM or compatible, $19.95 each.

Packet

MFJ's new generation packet mode gives you genuine TAPR software and hardware plus many MFJ enhancments like Easy Mail tm.

A new Kiss interface makes the MFJ-1278 TCP/IP compatible.

Extensive tests published in **Packet Radio Magazine** ("HF Modem Performance Comparisons")prove the TAPR designed modem in the MFJ-1278 gives better copy with proper DCD operation under all tested conditions *than the other modems tested.*

New AMTOR mode!

Now the MFJ-1278 has a new AMTOR and Navtex mode, making it the only controller to feature **nine** digital modes.

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AN NE602-BASED QRP TRANSCEIVER FOR 20-METER CW

By **Rick Littlefield, K1BQT**, Box 114, Barrington, New Hampshire 03825

A complete QRP station that slips into your coat pocket

I've recently seen several small projects using the Signetics NE602 Gilbert Cell mixer.[1,2] I first used the NE602 in the "Micro-20 Receiver," a simple 20-meter superhet.[3] Additional experience and helpful feedback from other builders encouraged me to carry my exploration a bit further. Here's a complete QRP 20-meter transceiver which presses the NE602 into service as a transmit mixer.

Three modules contain the transceiver circuitry. The 3.25″ × 1.7″ receiver board is a new version of my original "micro-20" project, with several refinements for improved performance. The transmitter board is the same size as the receiver and is designed to deliver the QRP "legal" limit of 5-watts output. Other transmitter features are: high-Z keying, semi-QSK T/R switching, and provisions for adjustable CW off-set and sidetone monitoring. A CW filter board narrows receiver i-f and audio passbands for serious CW work. All of this fits into a 1.75″ × 4.0″ × 4.0″ Ten-Tec TG-type cabinet.

Receiver description

The receiver schematic is shown in **fig. 1**. This is a conventional single-conversion design incorporating some of the more desirable aspects of past projects.[4] The theory of operation has been presented elsewhere, but several refinements deserve mention. First, RF bandpass filter L1, L2 has been changed to improve out-of-band rejection. Second, the i-f was changed from 9 to 10 MHz. This lets you use inexpensive computer-clock crystals for the i-f filter and BFO. I added an optional BFO modification to ensure sufficient BFO tuning range when these crystals are used.

In the audio/AGC section, I dropped S-meter circuitry in favor of adding a trimpot for AGC threshold. Along the same line, I adjusted AGC drive to eliminate overshoot on extremely strong signals. Good AGC performance is important because receive circuitry remains "live" during transmit to monitor the CW signal.

The NE602 operating voltage was reduced slightly to improve operating characteristics, and VFO tank L3 was changed to resonate in the required 4.0-MHz range. Finally, I reconfigured the VFO tuning to cover only the bottom 100 kHz of the band.

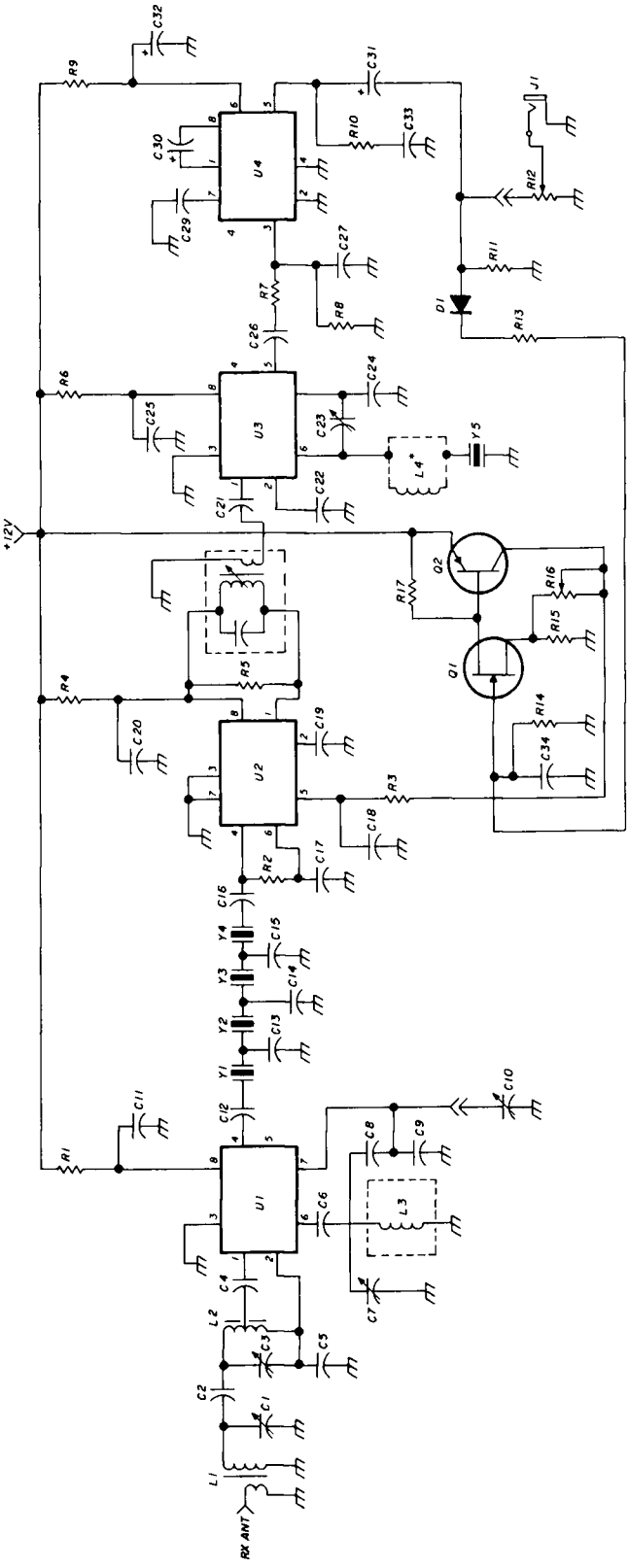
Transmitter description

Figure 2 shows the transmitter module. This board contains RF circuitry and switching for semi-QSK operation. Transmit mixer U1 samples the 4-MHz VFO signal generated in the receiver and mixes it with an internal 10-MHz oscillator to produce 14-MHz output. Transmit-offset is set by netting the 10-MHz LO. This arrangement eliminates the need to shift receiver BFO frequency during transmit and allows the receiver to be used as a sidetone monitor.

Keying is accomplished by switching the 12-volt supply line to U1. This is done by Q1, a DC switch which also activates relay controller Q2. Q1 presents a high-Z load to the handkey or keyer. Q2 functions as an FET relay driver for K1. An RC circuit on the gate of Q2 sets semi-QSK hold time. The values specified provide a delay of about 1 second. They can be adjusted if you wish. K1 supplies + 12 volts Vdc to Q3 and Q4 during transmit, and switches the antenna.

Q3 functions as a tuned-output buffer/driver which boosts U1's output to the required level for driving Q4. Class-C final amplifier Q4 delivers 4.5-5.0 watts output into a 50-ohm load with a Vc of 12 volts (somewhat

FIGURE 1



Schematic of transceiver receiver section. Component values are given in the receiver module parts list.

PARTS LIST

Receiver module

Capacitors (all monolithic capacitors are 50 volt)

C1,C2,C23	60 pF trimmer
C2	2.2 pF NPO
C4,C21	0.001 μF monolithic
C5,C6,C11, C17,C19,C20, C22,C25,C29, C33	0.1 μF monolithic
C7	8 pF NPO trimmer
C8,C9	330 pF NPO
C10	50 pF variable, VFO main tuning
C12-C16	(5) 100 pF/100 volt silver mica
C18	0.01 μF monolithic
C24	47 pF NPO
C26,C34	1 μF monolithic or electrolytic
C27	0.068 monolithic or equivalent
C30	10 μF/12 volt tantalum dip or electrolytic
C31,C32	100 μF/12 volt electrolytic

Inductors

L1	20 turns no. 28 on T30-2, 1-turn link on cold end
L2	20 turns no. 28 on T30-2, tap 7 turns from cold end
L3	57 turns no. 36 on 1/4" form (no slug) in 13-mm can
L4	(optional) 10 or 15 μH miniature choke
T1	10.7-MHz 10-mm i-f transformer, green core

Resistors (all 1/4-watt)

R1,R6,R7	2.2k
R2	390
R3,R5,R17	10k
R4	100
R8	47k
R9	22
R10,R11	15
R12	500-ohm linear pot with switch
R13	33k
R14	2.2 meg
R15	1k
R16	10k miniature trimpot

Semiconductors

U1,U3	NE602
U2	MC1350P
U4	LM386
Q1	MPF-102
Q2	2N3906
D1	1N914
Y1-Y5	10.000-MHz series resonant (100-Hz match)

greater output with a Vc of 13.8 volts). The PA collector tab is mounted to the transceiver case for cooling. T1, a 4:1 balun, transforms the output of Q4 to 50 ohms. Harmonic filtering is provided by a 5-element low-pass filter.

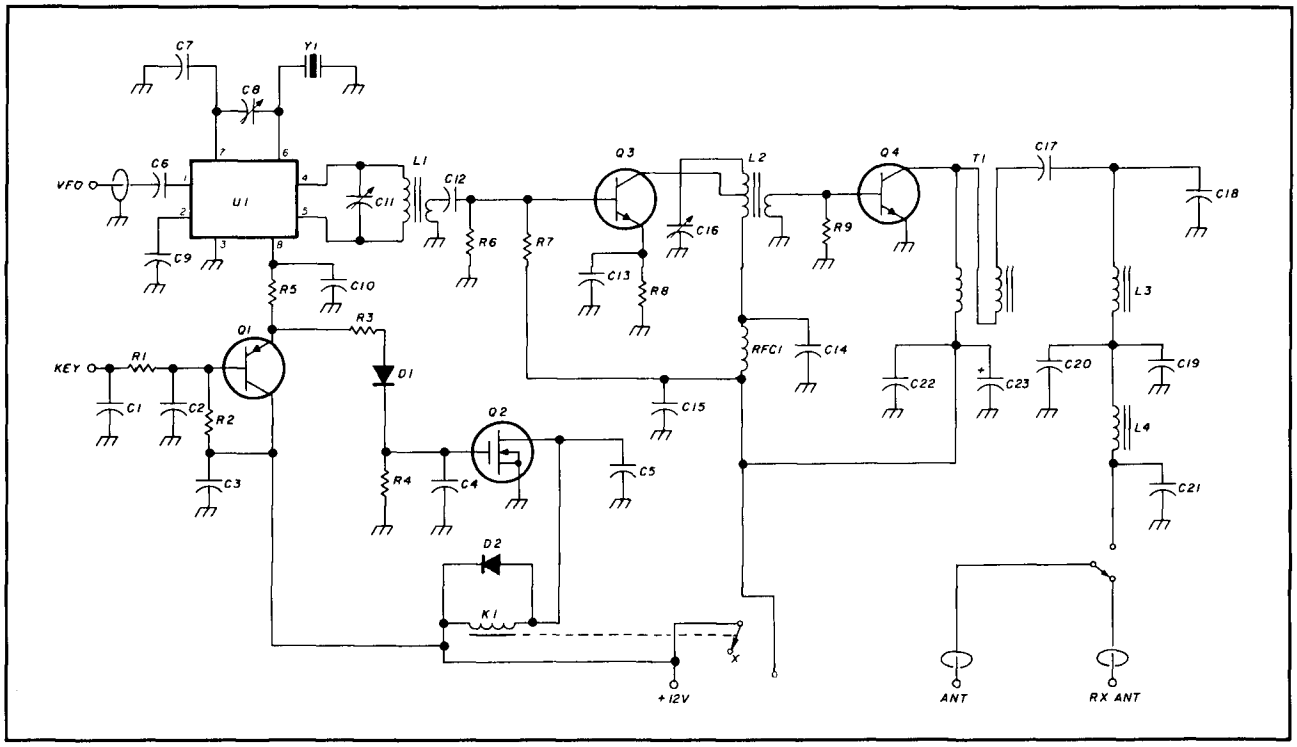
Filter description

The CW filter module, shown in **fig. 3**, actually houses two discrete circuits. The first is a 4-pole Cohn crystal bandpass filter identical to the one prescribed for the receiver. This connects in place of C21 on the receiver board and acts as a "post filter" for the i-f amplifier. The second element is a two-stage 700-Hz active bandpass filter installed between the product detector and audio amplifier (in place of C26). Distributing filtering throughout the system this way increases selectivity and, at the same time, reduces broadband noise generated in each stage. It also reduces the opportunity for ringing. The result is a very quiet and tight receiver — two important qualities for chasing serious DX, or pulling fellow QRP operators through noise and QRM.

Construction

Because this project employs two identical four-pole Cohn bandpass filters, your first task is to obtain eight 10.000-MHz crystals that resonate near the same frequency. Design bandwidth for the filter is about 1 kHz, so your matched set should resonate within 100 Hz of each other in a test oscillator (tolerance is 1/10th the desired bandwidth.)[5] The exact frequency of oscillation isn't critical, as long as the crystals you select cluster

FIGURE 2



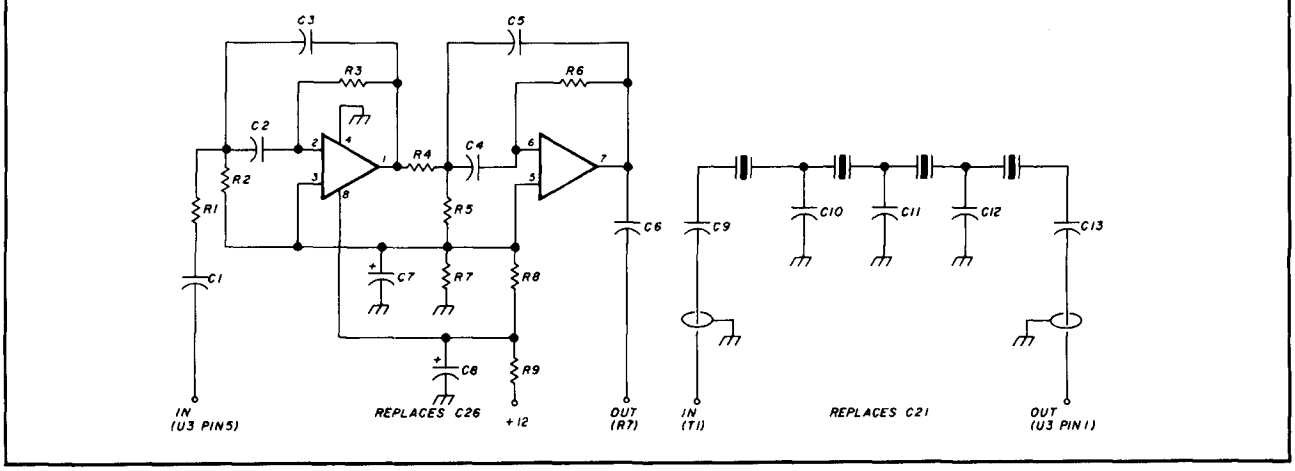
Schematic of transceiver transmitter section. Component values are given in the transmitter module parts list.

around *some* center frequency. It's my experience that 20 crystals from the same batch will yield eight close enough to do the job. If your crystals are spread over a wider range, the filters will work — they'll just be a bit broader.

All board layouts assume 1/4-watt resistors and monolythic bypass capacitors with 0.1" lead spacing. Board layout is tight, but construction is straightforward. If you have the proper tools plus some experience working on contemporary solid-state equipment, you should have no trouble building this rig. It's good practice to dope all toroid inductors and secure them to the board with glue. Double-check part locations and component polarities.

The receiver parts layout is shown in **fig. 4**. The most difficult job is winding VFO inductor L3; no. 32 wire is thin, and may break if pulled too tightly. I wound this coil on a 0.25" plastic form (FM receiver type) with the slug removed. It helps to mount the form before winding, and to secure windings in place immediately with clear nail

FIGURE 3



Schematic of transceiver CW-filter section. Component values are given in the CW-filter module parts list.

PARTS LIST

Transmitter module

Capacitors	
C1,C2,C3, C5,C9,C13, C14,C15,C17, C22	0.1 µF/50 volt monolithic
C4	1 µF/50 volt monolithic
C6	15 pF NPO
C7	47 pF NPO
C8,C11,C16	60 pF trimmer
C10,C12	0.01 µF, monolithic
C18,C19,C20, C21	220 pF silver mica
C23	10 µF/12 volt tantalum dip or electrolytic
Inductors	
L1	20 turns no. 28 on T30-2, 2-turn link on center
L2	20 turns no. 28 on T30-2 center tapped, 2-turn link on cold end
L3,L4	12 turns no. 24 on T37-2, spread over 80 percent of form
T1	10 turns bifilar no. 24 on FT37-61
RFC1	12 turns no. 28 on FT23-43
Resistors (all 1/4-watt)	
R1	47k
R2,R3	10k
R4	330k
R5	1.8k
R6	470
R7	2.7k
R8	47
R9	33
Semiconductors	
U1	NE602
Q1	2N3906
Q2	BS-170 (Radio Shack)
Q3	2N2222A
Q4	MRF-476 (Motorola)
D1,D2	1N914 switching diode
Y1	9.9985-MHz series resonant, 0.2" lead spacing
Miscellaneous	
K1	DPDT flat-pack 12 volt relay (Radio Shack)
	TO-220 insulated mounting kit (Q4)

polish. There are mounting holes for a CirKit 13-mm shield can (0.5″ × 0.5″ × 0.75″), but other shields will work.

You must install two jumpers on the back side of the receiver board. Fabricate TP-1 (test pin) from any discarded lead end. It's good practice (though not essential) to tie the cases of Y1-Y4 together with a common ground lead once they are soldered in place. Remember to omit C20 and C26 if you plan to install the external CW filter before initial testing.

Figure 5 shows the transmitter layout. A cutout is nibbled in the board to permit access to Q4's tab mount. To install Q4, first nip off the center lead (collector), then mount the device on the back side of the board as shown. Next, temporarily install a solder lug on the collector tab. This will help when you mount T1.

Install four jumpers on the back side of the module. Omit the jumper from K1 to C23 if you plan to run the PA directly off a 13.8-volt power source (Q4 is a class C stage, so Vc can remain connected during receive). Also, note that R9 is tack-soldered to the back side of the

PARTS LIST

CW Filter Module

Capacitors	
C1,C6	1 µF/50 volt monolithic or 1 µF/12 volt electrolytic
C2-C5	(4) 0.001, 1 percent 100-volt mylar film or equivalent
C7	10 µF/12 volt tantalum dip or electrolytic
C8	47 µF/12 volt electrolytic
C9-C13	(5) 100 pF/100 volt silver mica
Resistors (all 1/4-watt, 5 percent)	
R1,R4	680k
R2,R5	24k
R3,R6	1.8 meg
R7,R8	22k
R9	1k
Semiconductors	
U1	1458 (op amp)
Y1-Y4	(4) 10.000-MHz series resonant (100-Hz match)

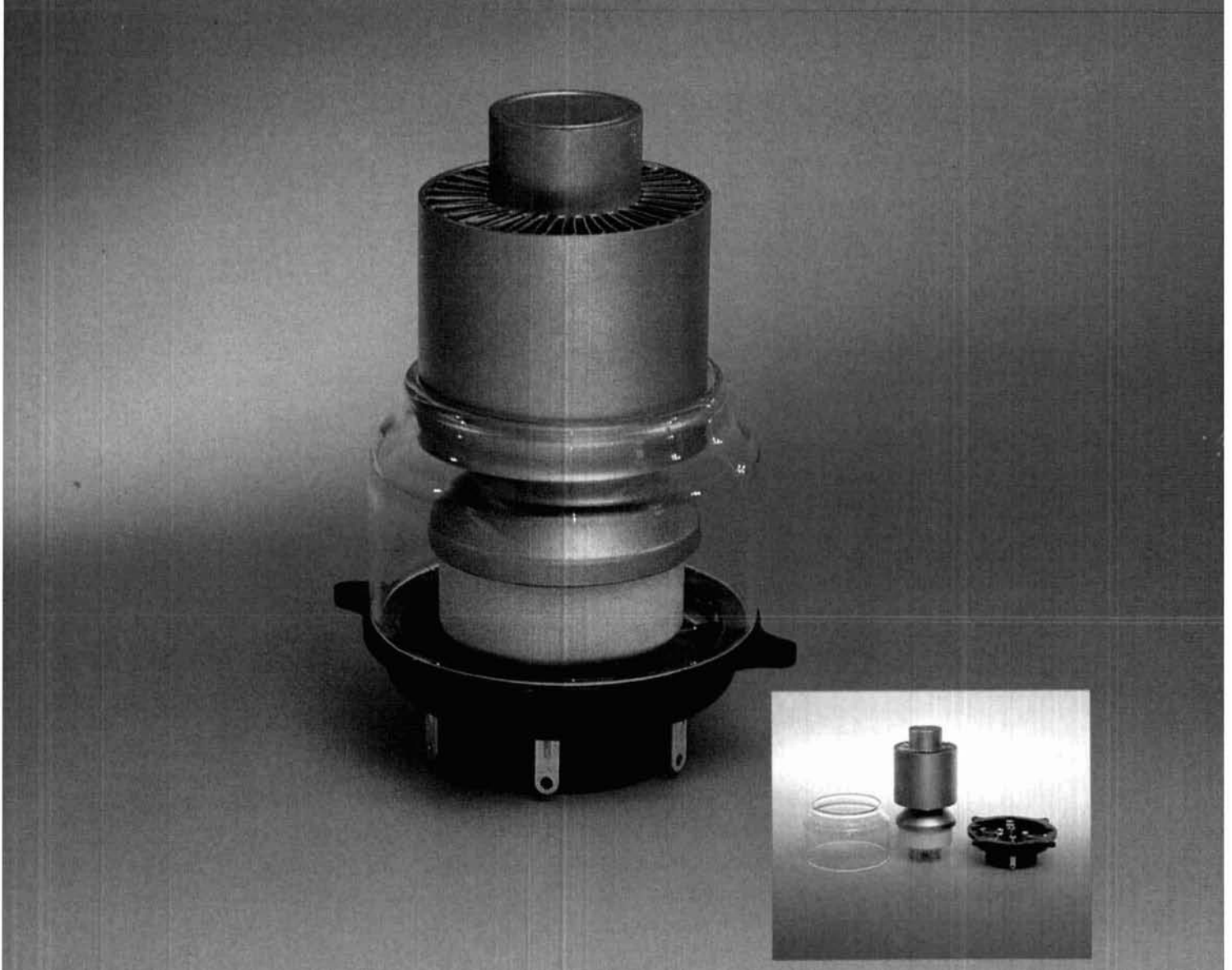


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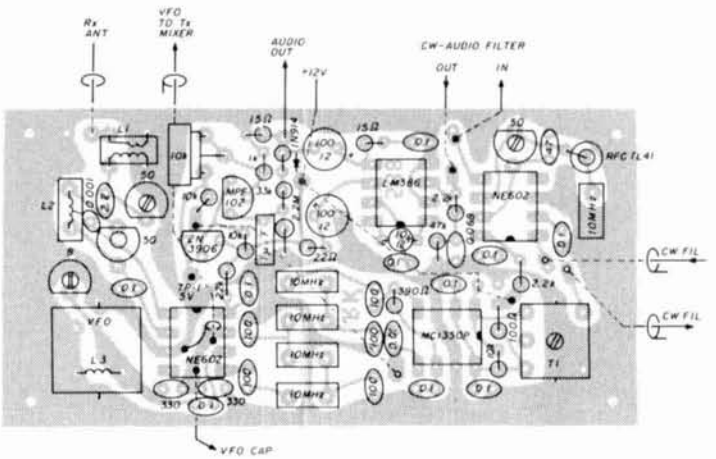
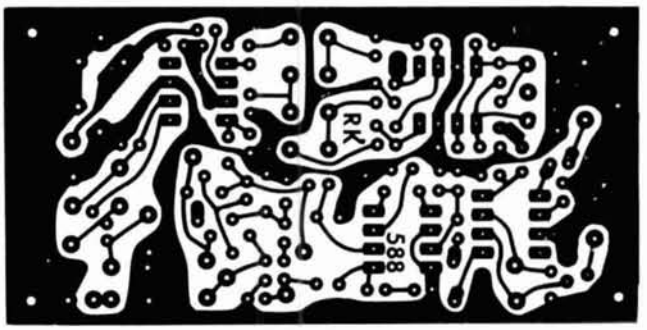
FIGURE 4





Component placement and pc board layout for the receiver.

board. Because the VFO line connects to the front side of the board, you must install a pin in the hole next to C6.

Constructing the CW filter module is easy — just follow the parts layout in **fig. 6**. If you substitute something other than 1 percent mylar-film precision capacitors for C2-C5, it is *critical* that you screen them with a capacitance bridge and select four values within 1 percent of each other. C9-C13 must be 100-volt silver micas; larger 500-volt types won't fit on the board.

Packaging

Any box can be used to house the transceiver. I built mine into a Ten-Tec TG box; **fig. 7** shows the layout. My first prototype sported several switches for various functions, had an S-meter, plus an array of status LEDs. While these options were simple to add, I found they contributed little to operation and needlessly complicated internal wiring. For my final layout, I opted for utter simplicity — a volume control and a tuning knob. One of my prototypes does have a small speaker built into the top. This is nice for casual listening, but when I settle in for some serious operating, the 'phones go on!

Choosing the right VFO tuning capacitor is important; it's the control you'll use most. Radiokit[6] sells a 50-pF ball-bearing capacitor with a built-in 6:1 drive perfect for QRP projects like this one. You can attach a simple pointer or concentric dial plate to the inner shaft for a frequency indicator. I recommend installing this — and all cabinet-mounted components and parts — before mounting the boards. Also, wire the 7812 voltage regulator.

Mount the transmitter module to the back panel of your cabinet with 3/16″ spacers and no. 4-40 hardware. This provides sufficient clearance for the MRF-476 to seat between the board and back panel. Six mounting points (with four in the PA section) ensure a respectable RF ground for the single-sided pc board. Mount the receiver to the bottom of the case on similar spacers. Leave enough room on the right-hand side for mounting the CW filter module. This is positioned vertically and held in place by a stiff solder lug bent to form a 90-degree bracket. Note the location of the 7812 regulator — all heat-generating components are kept as far from VFO circuitry as possible to ensure stability.

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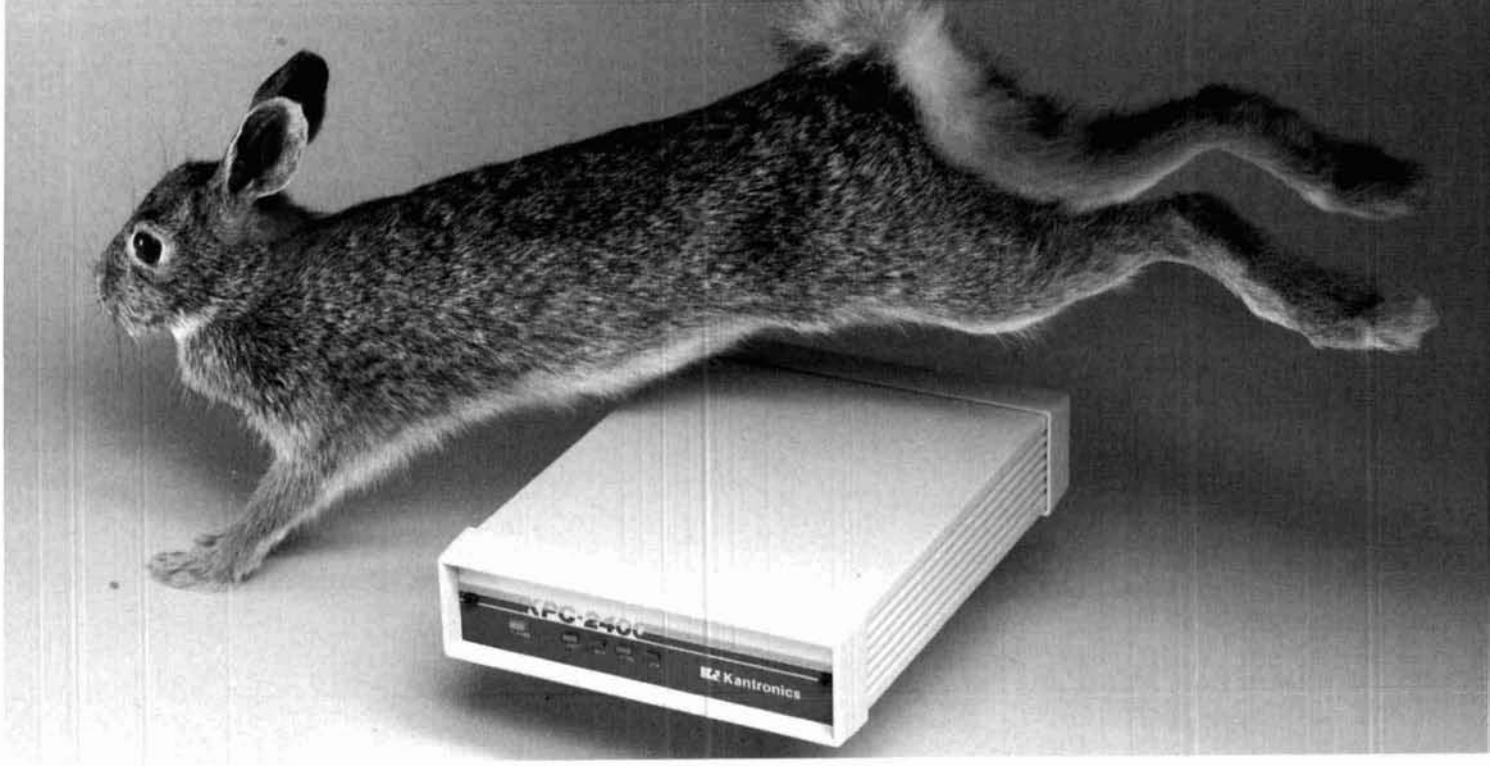

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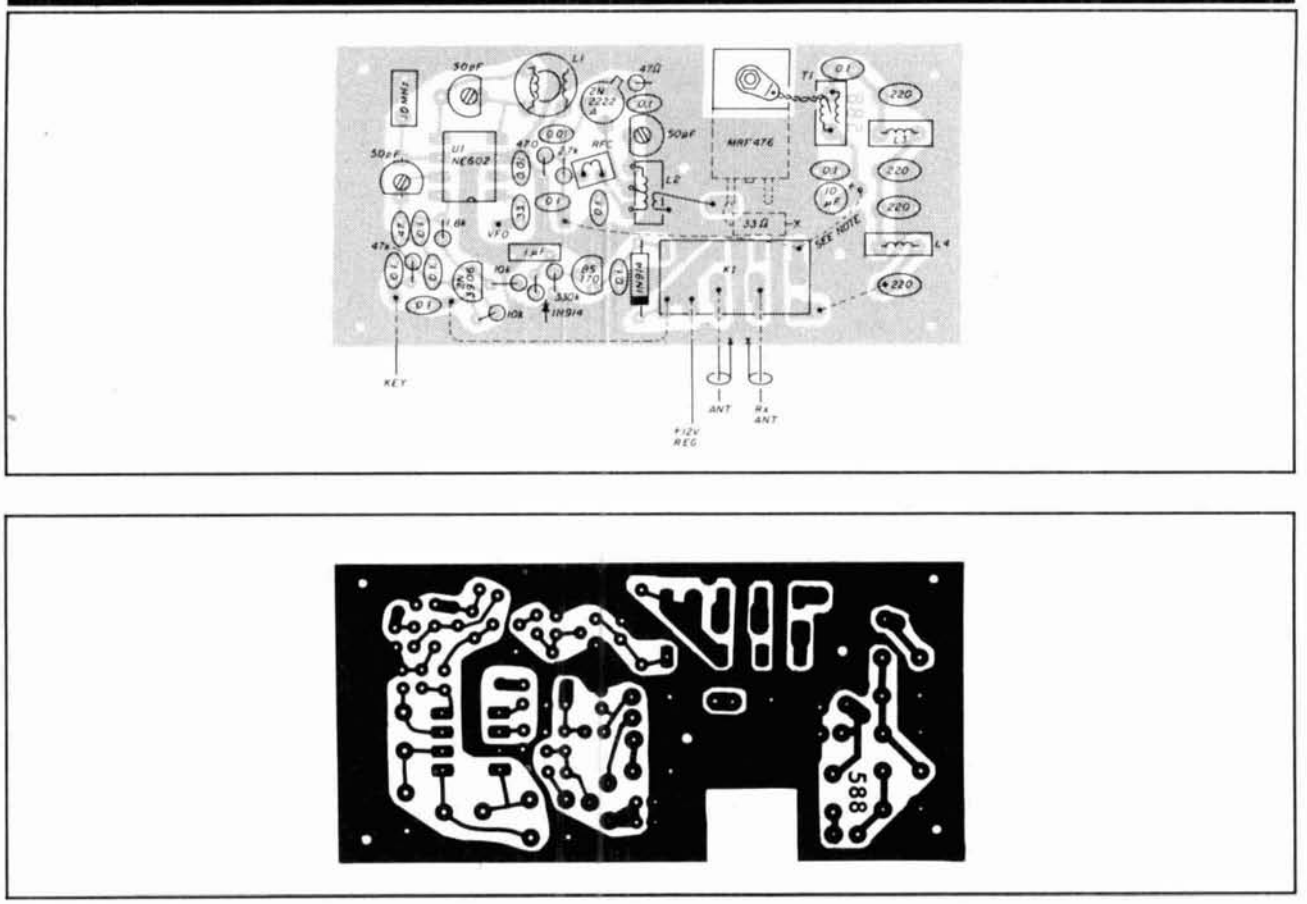
FIGURE 5



Component placement and pc board layout for the transmitter.

Interconnections carrying RF or i-f signals use miniature shielded cable. (Spiral-wound lavalier microphone cable is especially easy to work with.) *Remember to ground shields at one end only.* The shielded lead between the receiver VFO and transmit mixer adds capacitance to the VFO's LC circuit. Keep this as short as possible (ground shield at the receiver end). The keying line and all audio lines are unshielded. Use stiff bus wire to connect the receiver module to the VFO capacitor.

Alignment

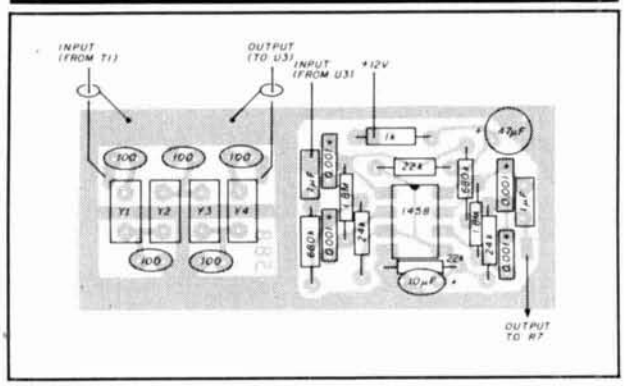
Set up the receiver. Connect a voltmeter to TP-1, and set trimpot R16 for a reading of 5 volts. Next, check the VFO and BFO for oscillation (using a general coverage receiver or counter). Adjust VFO calibration (C7) to cover from 4.0 MHz to between 4.070 and 4.1 MHz (20-meter CW range). To obtain this, you may need to substitute or add fixed capacitance. Set the BFO (C23) for 9998.5 — about 1.5 kHz below the filter's center frequency. This ensures acceptable rejection of the unwanted sideband. When the BFO is set, adjust T1 for an audible peak in background noise. Finally, connect an antenna or terminated signal generator, and peak C1 and C3 for maximum sensitivity.

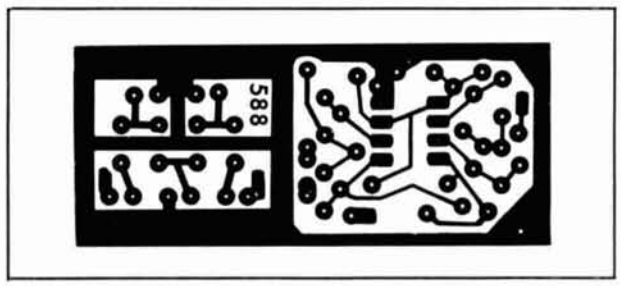
To tune the transmitter, connect a power meter and dummy load, and key the transmitter. Set C8 for an audible sidetone of around 1.5 kHz. Finally, adjust C11 and C16 for maximum output. Tuning should be smooth and sharp, without erratic peaks or other indications of instability.

Now make one final adjustment. In theory, offset should equal the audible sidetone frequency (i.e., the beat between the two 10-MHz LOs). In fact, the NE602 VFO has a habit of pulling a few hundred Hz during transmit — probably due to a load change when the circuit is keyed. Although unsettling, this effect is apparently harmless — there's no audible chirp. To compensate for the shift, send a string of dashes on your station transceiver and tune it in on the QRP rig (700 Hz note). Then key the QRP rig and adjust C8 for a corresponding 700-Hz note on the station transceiver. My sidetone note is around 1.5 kHz with offset adjusted to 700 Hz.

Before concluding, I should add a word about filter terminations. Theoretically, Cohn filters must be terminated at their characteristic impedance to provide optimal response. In practice, I find the impact of a mismatched port often looks worse on the scope than it sounds on the radio. By way of illustration, one of my

FIGURE 6





Component placement and pc board layout for the CW filter.

transceivers has resistively terminated filters and the other doesn't. In side-by-side comparisons, I can't hear the difference. Nevertheless, if you wish to go the extra step, here's how. First, take two 470-ohm resistors and carefully solder a 0.01 monolithic capacitor in series with each. On the back of the receiver board, tack-solder one of these from pin 4 of U1 to ground. On the CW filter board, tack the other from the output side of the filter to ground. Now, take a third 470-ohm resistor and tack it from the input side to ground. That's all there is to it.

Conclusion

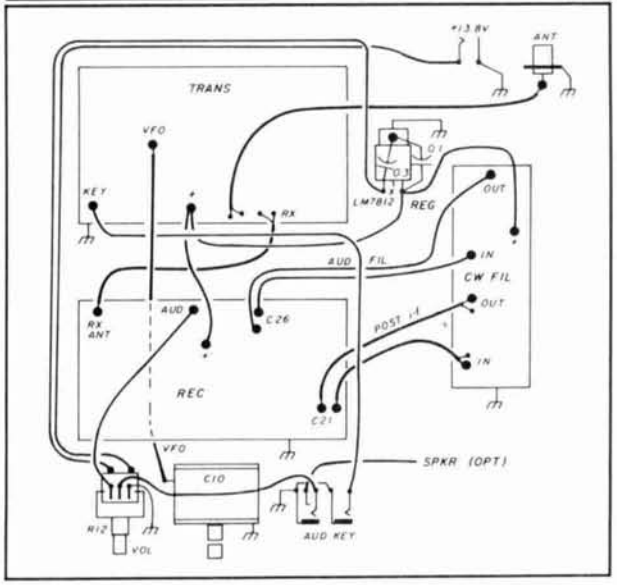
I owe special thanks to several builders who have written and shared their experiences with the NE602. Ed Pacyna, W1AAZ, deserves special credit for some of the information offered in this article. I also want to thank Radiokit for their ongoing support and encouragement.

Although billed as a double-balanced mixer, be aware that the NE602 is not "state of the art" for HF applications. It's a high-Z device with lots of gain and a third-order intercept of only −15 dBm, so it's prone to stray pick-up and occasional symptoms of intermodulation distortion. On the other hand, the NE602 has many attributes. It has a very low noise figure, needs no external LO circuitry and a minimum of external parts, comes in a small package with low power consumption, and is inexpensive. For the QRP microphile, these are very attractive pluses!

When it comes to actual operation, the rig itself is a lot of fun to use. Interference caused by overload is minimal and rarely a problem. I especially like having the built-in creature comforts of a good AGC, CW filter, sinewave sidetone, and semi-QSK switching (as opposed to full QSK). On the transmit side, running a full "QRP gallon" (5 watts output) ensures plenty of action. (My first on-air test landed a QSO with Nick, UV3DN, just outside of Moscow.) Best of all, the transceiver's small size means you can set it up anywhere. I presently have one in the office (a benefit of owning the company). My business partner refers to it as "the magic paperweight we use to talk to the Russians." People think he's kidding.

A complete parts kit (including pc boards and enclosure) is available from Radiokit for $124.95. A set of pc boards is $8.95. Ed.

FIGURE 7



Board placement within the enclosure.

References

1. Cliff Klinert, WB6BIH, "Build a Packet-portable SSB Receiver," *ham radio*, November 1986, page 55.
2. John Dillon, "The Neophyte Receiver," *QST*, February 1988, page 14.
3. Rick Littlefield, K1BQT, "The Micro-20 Receiver," *73*, February, 1988, page 28.
4. Rick Littlefield, K1BQT, "Compact 20-meter Travelradio," *ham radio*, June 1987, page 29.
5. Wes Hayward, "Designing and Building Simple Crystal Filters," *QST*, July 1987, page 24.
6. Radiokit, Box 973, Pelham, New Hampshire 03076.

Article A **HAM RADIO**

America's Communications Leader Presents Its All-New 10-Meter SSB/CW Mobile Transceiver

Realistic, America's premier brand of scanners, CB radios and satellite TV systems introduces the HTX-100, the perfect first rig for a beginning Ham and a superb 10-meter mobile radio for any amateur. It's compact, yet loaded with "big rig" features.

Pushbutton Memory Tuning

An easy-to-program memory stores 10 favorite frequencies and mike-mounted pushbuttons permit safe and easy up/down frequency selection while you drive. A front-panel lock control prevents accidental frequency changes. You can fine-tune reception with the ±1.5 kHz RIT control. Coverage is 28.0 to 29.6999 MHz, USB or CW. Convenient semi break-in keying and CW sidetone are built in.

Ultracompact and includes everything you need for underdash installation

Selectable Power Output

You can select 25-watt or 5-watt QRP power output from the front panel. The HTX-100 has a backlit LCD frequency display with mode and tuning-step indicators. You also get a 5-step LED signal/RF power meter, noise blanker, hefty 3-watt audio output, high-quality built-in speaker, front-panel headphone jack and a rear-panel jack for adding an external speaker.

Join the Action on "10"

With improving band conditions and new Novice voice and digital privileges, the 10-meter fun is just beginning. Be a part of it with this affordable, top-quality transceiver! Only $259.95 and in stock today at our store near you.

Exclusively at

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The Technology Store™
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FREE 184-Page Radio Shack Catalog! Write Dept. 375, 300 One Tandy Center, Fort Worth, TX 76102

THE WEEKENDER

Going digital

Like many hams, I'd been eyeing the numerous articles and gadgets designed to lead us into the modern century and go digital. Upgrading to digital involved spending a considerable sum of money, because I really couldn't do it at all without a computer and a terminal node controller (TNC). My engineering training drove me to research the abundant literature, try out each potential choice, and then look for the best price.

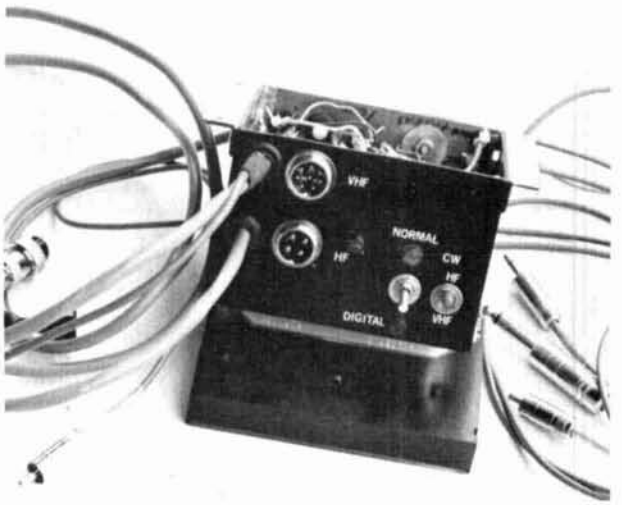
COMPUTER SHOPPER Magazine offered the widest possible selection of inexpensive computers, usually IBM clones. Armed with this information, I made a foray into the numerous computer stores in Silicon Valley and found exactly what I needed at a surprisingly low price.

A display at a recent ARRL convention featured all of the TNCs operating side by side. For various reasons, I liked the AEA PK 232 PAKRATT best and bought it.

Back home I was anxious to hook up the thing to my VHF and HF rigs and get on the air. As it turned out it's not like hooking up a toaster. You have to acquire or fabricate an RS-232 cable to connect the PAKRATT to the serial port of your computer. In the instruction book, AEA explains that only 10 of the available 25 pins in the socket/cable should be connected. You also have to make up the two special cables that link the two rigs. There are plugs for the TNC end, but simply bare wires on the other.

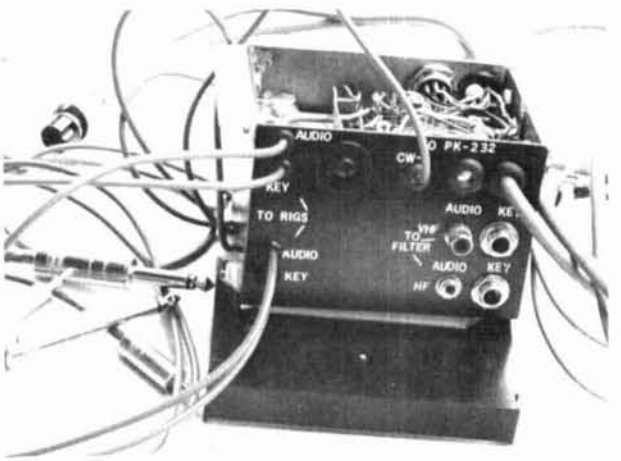
By William Schreiber, NH6N, 73-4327 Imo Street, Kailua-Kona, Hawaii 96740

PHOTO A



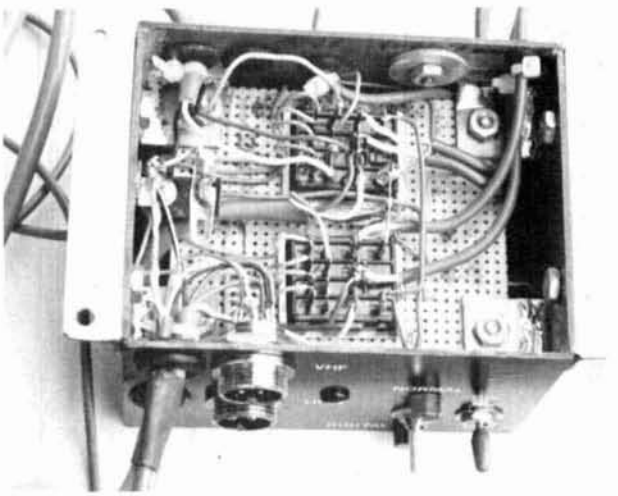
Front view—interface box.

PHOTO B



Rear view—interface box.

PHOTO C



Inside, bottom view—interface box.

PHOTO D

Interface box and rigs.

The PAKRATT, in its latest configuration, comes with a special "Communications Program" on a floppy disk. Two EPROMs inside the box allow you to boot up and use the system.

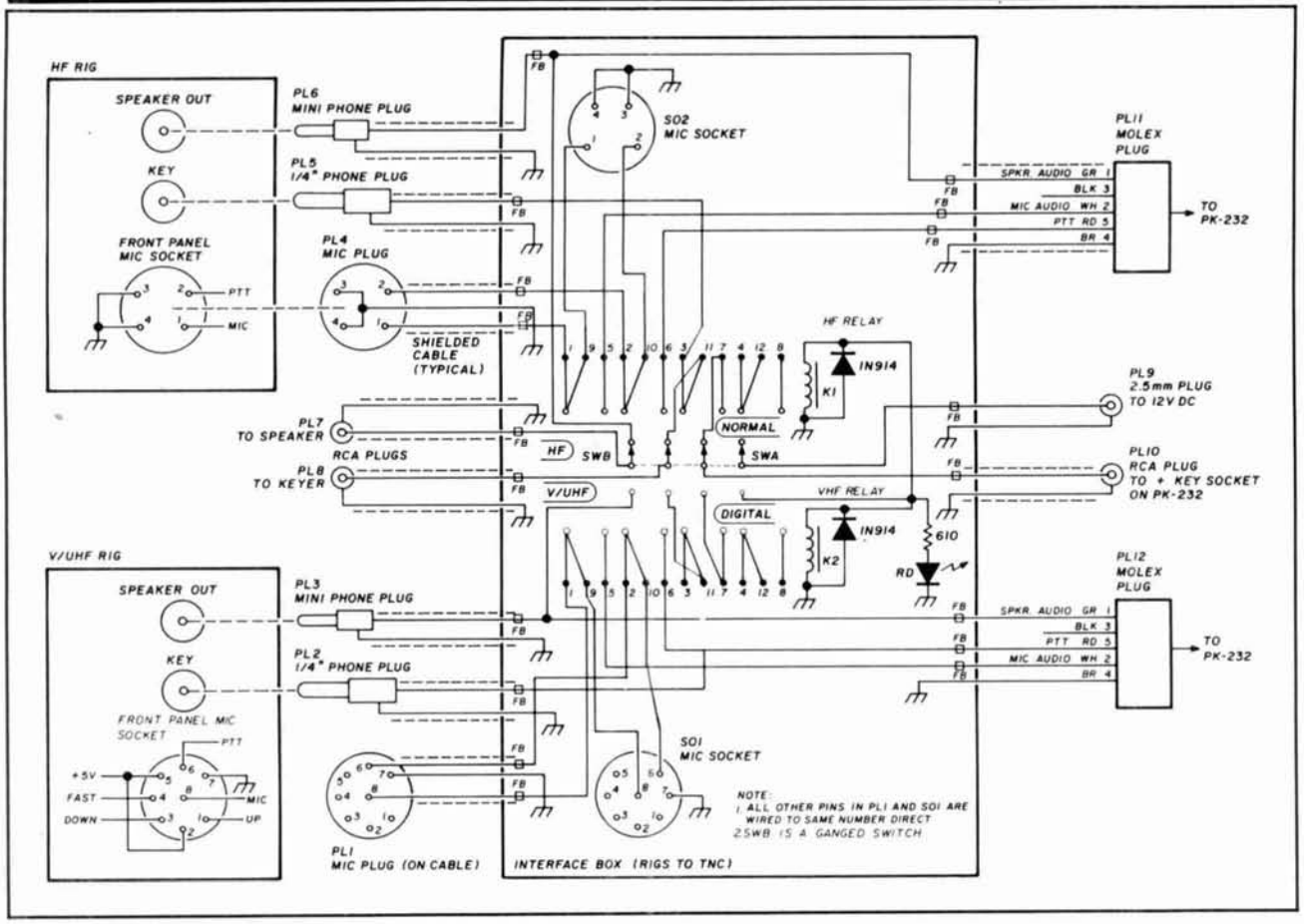
I finally had the whole thing connected and fired up the VHF rig. It worked like a charm, except when I used my Heath keyer on CW. (More on that later.) Unfortunately, the HF rig didn't work at all in any mode. After several calls to AEA, I concluded that the SSB crystal filter in my KENWOOD TS 180 was rolling off the audio at too low a frequency for the mark and space signals to reach the 232.

For several years I've been using the various ham satellites — mostly on CW where possible. But the uplink for OSCAR 10 and 13 is VHF and, as I said, I couldn't get CW out of the PAKRATT using my keyer. This TNC has a single CW output plug; I had it connected to the HF rig. Obviously, I had to do something to permit CW operation from either rig without having to disconnect cables.

A similar problem arises when the rigs are connected to the TNC in the approved manner, which involves using their microphone input plugs. If you want to shift back to normal mike usage, you have to disconnect the cables to the TNC. The idea of having to connect and disconnect cables and plugs didn't thrill me. I like things to be as convenient as possible, so I designed a simple interface box. This permits me to have everything permanently connected, and also lets me change from normal rig(s) operation to the new digital mode at the flip of a switch.

All it takes are two relays, a couple of toggle switches, and a slew of plugs and cables. The interface box ends up looking like a spaghetti factory gone wild — as you can see in the front view (**photo A**) and the rear view (**photo B**). **Photo C** shows an inside bottom view. The container was built from double-sided circuit board soldered together. Dimensions were 4″ × 2.75″ × 3″. Its

FIGURE 1



Schematic of the interface box.

PARTS LIST

Item	Reference designator	Radio Shack	All
2 each relays 4 PDT	K1, K2	275-214	RLY 124 PC
2 each socket relay	K1, K2	275-221	SRLY 4P
1 each switch SPDT	SW A	275-603	MTS-4
1 each switch 4 PDT	SW B	NA	NA *
2 each 1/4-inch phone plugs	PL 2, PL 5	274-1544	PHP 170
2 each mini phone plugs	PL 3, PL 6	274-1547	MMP
1 each 4-pin mic socket	SO 2	274-002	NA
1 each 4-pin mic plug	PL 4	274-001	NA
1 each 8-pin mic socket	SO 1	NA	NA **
1 each 8-pin mic plug	PL 1	274-025	NA
3 each RCA plug	PL 7, 8, 10	274-339	MPRP
1 each 3.5-mm plug	PL 9	274-1568	PCLID
2 each 5-pin Molex plug	PL 11, 12	NA	NA ***
10 feet 10-conductor shielded cable		NA	10 OC/522
1 each DB 25 S socket		276-1548	DB-25S
1 each DB 25 P plug		276-1547	DB-25P
2 each hoods DB25 shielded		276-1536	DB-25H
10 feet 5-conductor shielded cable		NA	5C/524
50 feet 2-conductor shielded cable		NA	2C/225
2 each 1N914 diodes		276-1520	NA
1 each LED red		276-041	LED-1
1 each LED socket		276-079	HLDCL-R
18 each ferrite beads	FB 73-2401	NA	NA ****

* Orvac Electronics, Orangethorpe Avenue, Fullerton, California
** Local Ham Store
*** Part of AEA kit supplied with PK 232
**** Amidon Associates, 12033 Otsego Street, No. Hollywood, California 91607
All Electronics, POB 567, Van Nuys, California 91408
Radiokit, Box 973H, Pelham, New Hampshire 03076

placement in regard to my rigs and assorted ancillary devices is shown in **photo D**.

Figure 1 is the schematic. *Note that I used ferrite beads on all wires entering or leaving the box.* Before I did this, all sorts of strange things took place. They were caused by RF getting into the wrong places via the interface box.

Parts for this project are available from ALL Electronics or Radio Shack. See the parts list for more information.

All things considered, it was a challenge to "go digital." But once I'd finally gotten through a string of digipeters and was connected, I had a feeling of satisfaction that I'd never encountered in my "normal" ham activities!

Note: Depending upon your radio, you may need to make some changes in the microphone connections. You can also adapt this idea for use with other TNCs. Ed.

Article B **HAM RADIO**

A TWO-LOOP 10-HZ STEP 40-70 MHZ SYNTHESIZER

By Luiz C. M. Amaral, PY1LL, Rua Dom Casmurro, 51, Jacarepagua, Rio de Janeiro, 22753, Brazil, and Carlos Alexandre C. Mathias

Achieve good image rejection without sacrificing resolution, tuning speed, locktime, and stability

Using a 40-70 MHz local oscillator is generally accepted as a means of achieving good image rejection in modern HF design. The frequency stability and accuracy of such an oscillator is achieved through synthesis. Often contradictory design requirements are high resolution, tuning speed, low noise output, spectral purity, low power consumption, small volume, and low price.[1-4] Most of the designs use many loops to obtain small step resolution. This article shows a method to overcome this difficulty.

The algorithm

Normally, unless special techniques are employed, the step size is equal to the reference source frequency. **Figure 1** shows a block diagram of such a loop. You must use a low reference frequency to provide high resolution. However, with step sizes less than 1 kHz, locking time and close-in noise are degraded. For instance, to achieve 10-Hz resolution in the 40-70 MHz range, it is usually necessary to use four or five loops.

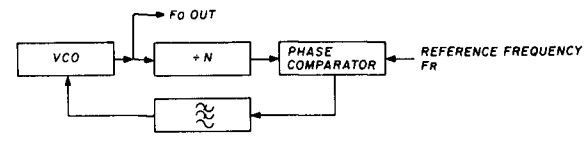
Figure 2 illustrates a two-loop block diagram that meets the combined requirements. To achieve short locking times and low noise output it is necessary to use substantially high reference frequencies — e.g., 10 kHz. If we put $Fr_1 = 9.99$ kHz and $Fr_2 = 10$ kHz in **fig. 2**, we can rewrite **eqn. 1**, $F_o = F_2 - F_1$, from **fig. 2** as:

$$F_o = (M \times 10 - N \times 9.99)\,\text{kHz} = [10 \times M - (10 - 0.01) \times N]\,\text{kHz} = [10 \times (M - N) + 0.01 \times N]\,\text{kHz} \quad (2)$$

where N and M are as defined in **eqn. 1**

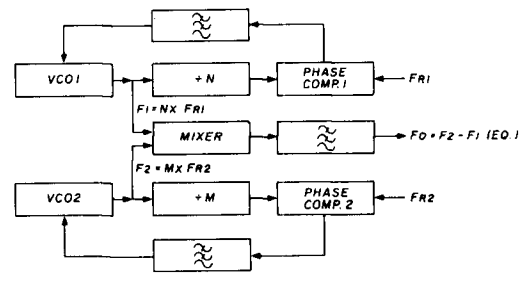
To make 10, 100, or 1,000-kHz steps (or their multiples), change only the divider, M. For steps of 10, 100, or 1,000

FIGURE 1



Loop diagram for simple one-loop synthesizer.

FIGURE 2



Algorithm for present synthesizer.

Hz (or their multiples), you have to change the values of N amd M to maintain M − N unchanged.

For instance, if you need a step 30 Hz up, increase N by 3 (3 × 0.01 = 30 Hz) and M by 3. So,

$F_{initial} = [10 \times (M - N) + 0.01 \times N]$ kHz

$F_{final} = [10 \times (M + 3 - (N + 3)) + 0.01 \times (N + 3)]$ kHz

Step = $F_{initial} - F_{final}$ = 0.03 kHz = 30 Hz

Derivation of design equations

One of the problems of 40-70 MHz synthesis using one loop is the rather high relative range: 30 MHz in a 40-MHz VCO. One of the advantages of the present method is that you can use two VCOs in a higher VHF band, making the relative range a minor problem. (In our units we have used F1 at 160-200 MHz and F2 at 120-130 MHz, both single loops.)

Now let's derive the design equations for these arrangements. Remembering that the output frequency is a seven-digit decimal number (e.g., 47,936.42 kHz), put:

$F_o = 10{,}000 \times A6 + 1{,}000 \times A5 + 100 \times A4 + 10 \times A3 + A2 + 0.1 \times A1 + 0.01 \times A0$ (in kHz).

Similarly the division factors N and M may be written, as they are integers:

(F_1 and $F_2 < 1{,}000$ MHz, so Mi = Ni = 0 for i > 4).

$N = N0 + 10 \times N1 + 100 \times N2 + 1{,}000 \times N3 + 10{,}000 \times N4$

$M = M0 + 10 \times M1 + 100 \times M2 + 1{,}000 \times M3 + 10{,}000 \times M4$

Using **eqn. 2** you have:

$10{,}000 \times A6 + 1{,}000 \times A5 + 100 \times A4 + 10 \times A3 + A2 + 0.1 \times A1 + 0.01 \times A0 = 10 \times [M0 - N0 + 10 \times (M1 - N1) + 100 \times (M2 - N2) + 1{,}000 \times (M3 - N3) + 10{,}000 \times (M4 - N4)] + 0.01 \times (N0 + 10 \times N1 + 100 \times N2 + 1{,}000 \times N3 + 10{,}000 \times N4)$

Equating the corresponding terms you have:

a) M4 − N4 = 0
b) M3 − N3 = A6
c) M2 − N2 = A5
d) M1 − N1 + N4 = A4
e) M0 − N0 + N3 = A3
f) N2 = A2 **(3)**
g) N1 = A1
h) N0 = A0

Because the Ai are given numbers, you have eight equations with ten unknowns to determine Ni and Mi. This gives you two degrees of freedom to locate the ranges of F_1 and F_2. (You must establish values for two parameters, so choose N4 at first.) If the values you choose for N4 (and M4) are too high, the dividers (which can be preset) may fail to operate and the noise performance will be poor because of the great division factor. But if N4 is too small, you'll have problems with the relative range of the VCO. In the present case, a good choice will be 1 for N4 (and M4).

The range of F_1 (N loop) is ≈ 10 MHz because, to cover 9.99 kHz (the maximum step not covered by the M loop alone) in steps of 10 Hz, we have 1,000 channels with 9.99 kHz of reference frequency, which gives 10 MHz. So, the F_2 (M loop) range is 10 MHz + 30 MHz (range of the output) = 40 MHz.

The other degree of freedom permits you to fix the value of N3. Choose 2 for this (meaning that with N4 = 1, for ≈ 10-MHz range, we have F_1 ranging from 120 to 130 MHz, and, consequently, F_2 ranges from ≈ (120 + 40) = 160 to ≈ (130 + 70) = 200 MHz. These frequencies are convenient enough for the dividers and relative ranges of the VCOs.

Now rewrite the expressions of N and M using **eqn. 3** and the chosen values for N3, N4, and M4:

$N = 10{,}000 \times N4 + 1{,}000 \times N3 + 100 \times N2 + 10 \times N1 + N0$ or,

$N = 12{,}000 + 100 \times A2 + 10 \times A1 + A0$ **(4)**

$M = 10{,}000 \times M4 + 1{,}000 \times M3 + 100 \times M2 + 10 \times M1 + M0 = 10{,}000 + 100 \times (A6 + 2) + 100 \times (A5 + A2) + 10 \times (A4 - 1 + A1) + (A3 - 2 + A0)$ or,

$M = 11{,}988 + 1{,}000 \times A6 + 100 \times (A5 + A2) + 10 \times (A4 + A1) + (A3 + A0)$ **(5)**

As the output ranges from 40,000.00 to 69,999.99 kHz, the value of A6 may be 4, 5, or 6. A5, A4, A3, A2, A1, and A0 may be 0 to 9. Now it's possible to calculate the exact ranges of N, M, F_1, and F_2:

a. Minimum N: A2 = A1 = A0 = 0.

From **eqn. 4**: $N_{min} = 12{,}000$.

b. Minimum F_1: (**fig. 2**) $F1_{min} = 9.99 \times N_{min} = 119{,}880$ kHz.

c. Maximum N: A2 = A1 = A0 = 9.

From **eqn. 4**: $N_{max} = 12{,}999$.

d. Maximum F_1: (**fig. 2**) $F1_{max} = 9.99 \times N_{max} = 129{,}860.01$ kHz.

e. Minimum M: A6 = 4; A5 = A4 = A3 = A2 = A1 = A0 = 0.

From **eqn. 5**: $M_{min} = 15{,}988$.

f. Minimum F_2: (**fig. 2**) $F2_{min} = 10 \times M_{min} = 159{,}880$ kHz.

g. Maximum M: A6 = 6; A5 = A4 = A3 = A2 = A1 = A0 = 9.

From **eqn. 5**: $M_{max} = 19{,}986$.

h. Maximum F_2: $F2_{max} = 10 \times M_{max} = 199{,}860$ kHz.

For example, suppose that you want to synthesize an output of 56,721.98 kHz. Then A6 = 5, A5 = 6, A4 = 7, A3 = 2, A2 = 1, A1 = 9 and A0 = 8.

ASTRON CORPORATION
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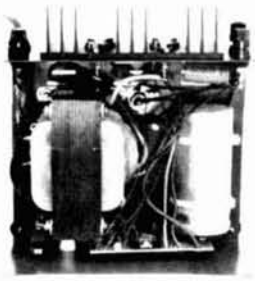


INSIDE VIEW — RS-12A

ASTRON POWER SUPPLIES

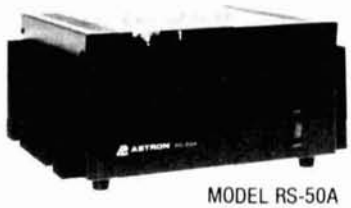
• HEAVY DUTY • HIGH QUALITY • RUGGED • RELIABLE •

SPECIAL FEATURES

- SOLID STATE ELECTRONICALLY REGULATED
- FOLD-BACK CURRENT LIMITING Protects Power Supply from excessive current & continuous shorted output
- CROWBAR OVER VOLTAGE PROTECTION on all Models **except RS-3A, RS-4A, RS-5A.**
- MAINTAIN REGULATION & LOW RIPPLE at low line input Voltage
- HEAVY DUTY HEAT SINK • CHASSIS MOUNT FUSE
- THREE CONDUCTOR POWER CORD
- ONE YEAR WARRANTY • MADE IN U.S.A.

PERFORMANCE SPECIFICATIONS

- INPUT VOLTAGE: 105-125 VAC
- OUTPUT VOLTAGE: 13.8 VDC ± 0.05 volts (Internally Adjustable: 11-15 VDC)
- RIPPLE Less than 5mv peak to peak (full load & low line)
- **Also available with 220 VAC input voltage**

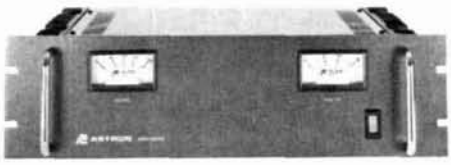


MODEL RS-50A

MODEL RS-50M

MODEL VS-50M

RM SERIES



MODEL RM-35M

19″ × 5¼ RACK MOUNT POWER SUPPLIES

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H × W × D	Shipping Wt. (lbs.)
RM-12A	9	12	5¼ × 19 × 8¼	16
RM-35A	25	35	5¼ × 19 × 12½	38
RM-50A	37	50	5¼ × 19 × 12½	50
• Separate Volt and Amp Meters				
RM-12M	9	12	5¼ × 19 × 8¼	16
RM-35M	25	35	5¼ × 19 × 12½	38
RM-50M	37	50	5¼ × 19 × 12½	50

RS-A SERIES

MODEL RS-7A

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H × W × D	Shipping Wt. (lbs.)
RS-3A	2.5	3	3 × 4¾ × 5¾	4
RS-4A	3	4	3¾ × 6½ × 9	5
RS-5A	4	5	3½ × 6⅛ × 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

RS-M SERIES

MODEL RS-35M

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H × W × D	Shipping Wt. (lbs.)
• Switchable volt and Amp meter				
RS-12M	9	12	4½ × 8 × 9	13
• 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

VS-M AND VRM-M SERIES

MODEL VS-35M

• Separate Volt and Amp Meters • Output Voltage adjustable from 2-15 volts • Current limit adjustable from 1.5 amps to Full Load

MODEL	Continuous Duty (Amps) @13.8VDC	@10VDC	@5VDC	ICS* (Amps) @13.8V	Size (IN) H × W × D	Shipping Wt. (lbs.)
VS-12M	9	5	2	12	4½ × 8 × 9	13
VS-20M	16	9	4	20	5 × 9 × 10½	20
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						
VRM-35M	25	15	7	35	5¼ × 19 × 12½	38
VRM-50M	37	22	10	50	5¼ × 19 × 12½	50

RS-S SERIES

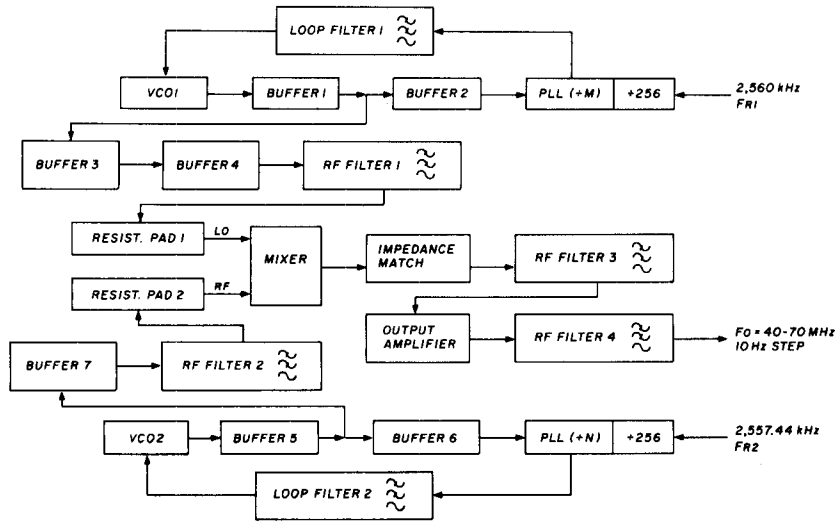
MODEL RS-12S

• Built in speaker

MODEL	Continuous Duty (Amps)	ICS* Amps	Size (IN) H × W × D	Shipping Wt. (lbs.)
RS-7S	5	7	4 × 7½ × 10¾	10
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

*ICS—Intermittent Communication Service (50% Duty Cycle 5min. on 5 min. off)

FIGURE 3



Block diagram for the present synthesizer.

Using **eqns. 4** and **5** you have:
$N = 12{,}000 + (100 \times 1) + (10 \times 9) + 8$ or, $N = 12{,}198$
and
$M = 11{,}988 + (1{,}000 \times 5) + (100 \times (6 + 1)) + (10 \times (7 + 9)) + (2 + 8)$ or,
$M = 17{,}858$
So, $F_1 = 9.99 \times 12{,}198 = 121{,}858.02$ kHz and $F_2 = 10 \times 17{,}858 = 178{,}580$ kHz.
It works because $F_o = F_2 - F_1 = 56{,}721.98$ kHz.

The algorithm shows that this is a type of synthesis which is convenient to implement with microprocessor control. The calculations become even more involved when two-modulus prescalers are used within the loops.

The complete design

Our particular assembled unit has been built according to the block diagram in **fig. 3**. The PLL blocks each include one two-modulus prescaler. We used MC-12016[5], 40/41 type); we have built them with MC-145156[6] PLLs. However, if you use the MC-145158, the reference frequency problem may be easier to solve by entering only one reference in both loops (e.g. 9,990 MHz — and programming the reference dividers with 999 for the M loop and 1,000 for the N loop). We've used the PD phase detector output (from the phase comparator of the PLL) to avoid operational amplifiers in the control lines. The resulting reference rejection has been better than 60 dB down.

Now let's analyze each block of **fig. 3**:
a. VCO 1 and 2: Because their frequencies fall in the VHF range, the low noise J-FET, like the U-310 (or the plastic J-310 family), is a convenient transistor choice.[7,9] If you don't plan to pretune, take care in your layout and choice of components to permit VCO 1 to cover its 40-MHz range.
b. Buffers 1, 2, 3, 6, and 7 may employ bipolar transistors like the BFY-90 for low noise, high isolation, and broadband operation. Buffer 5 may be a dual-gate MOSFET — try the MFE-521 or 3N-211[7]. For buffer 4 use a high output level broadband linear transistor (a BFW-16A) to get a suitable signal power for the mixer LO input.
c. We chose an SRA-1 bridge diode double-balanced mixer from Mini Circuits to get a very low spurious response. This is very dificult to obtain using other types of mixing devices. For this purpose we've had to "clean" both LO and RF port signals concerning harmonic content with RF filters 1 and 2. Two resistor pads have been used to couple both signals to the mixer under correct resistive impedance (50 Ω).
d. A BFY-90 stage presents the correct resistive load to the mixer (50 Ω). Its output passes a third RF filter to block the harmonic power (now generated by the mixer itself) and drives the final (BFW-16A) amplifier stage through another BFY-90 stage. This gives a high-level power (≈ 12 dBm) to the first mixer of the receiver. RF filter number 4 maintains the output free from harmonics.

Final comments

This article presents an algorithm rather than a circuit design. The synthesizer itself may be built using all the standard techniques for low noise operation, like in-loop mixing for lowering the division factors, low noise phase comparators (HEF-4750[8] series from MULLARD), and pretuned systems to get quieter varactor control. All these techniques are fully described in the literature[2,3] so we won't discuss them here. The only point we'd like

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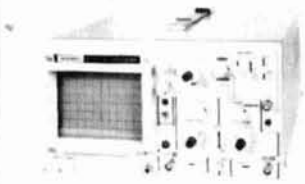

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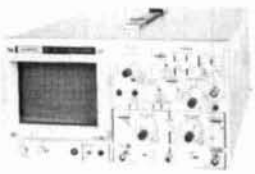

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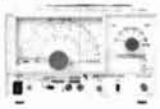

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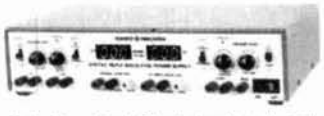

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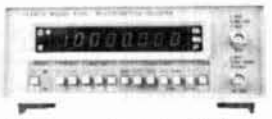

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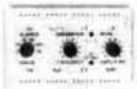

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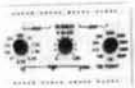

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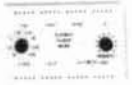

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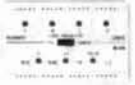

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to emphasize is that the higher the division factors, the poorer the close-in noise, because the noise from reference is multiplied by a greater number and we have a worse signal-to-noise ratio at the phase comparator. So, without in-loop mixing (or another equivalent technique to diminish N and M), special care must be taken with crystals and crystal oscillators to minimize in-band noise.[9]

Concerning stability and accuracy, note that 10 Hz in 200 MHz means 0.05 ppm, so that the use of simple "non-mastered" reference sources doesn't seem to make sense.

Conclusions

We've presented a method to synthesize three million 10-Hz channels (40-70 MHz) with a reference-to-step ratio of 1,000 by using only two loops. We have used the frequency difference between the two loops, but the sum may be used in the same manner as long as you take care that the spurious and harmonic signals don't fall within the output band region.

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Article C **HAM RADIO**

NOVEMBER WINNERS

Congratulatiqns to Alan Unangst, WC7R, our November sweeps winner and L.B. Cebik, W4RNL, author of November's most popular WEEKENDER — "Improving Operation with the MFJ 989 Transmatch." Both will receive a handheld radio. To enter for January's drawing, send in the evaluation card bound into this issue, or submit a WEEKENDER project. You could be our next winner! *Ed.*

Correct address

The address given for Hal Silverman, W3HWC, in the October 1988 issue (page 63) is incorrect. If you wish to contact Hal, his current address is: 14004 Harrisville Road, Mt. Airy, Maryland 21771.

THE HAM NOTEBOOK

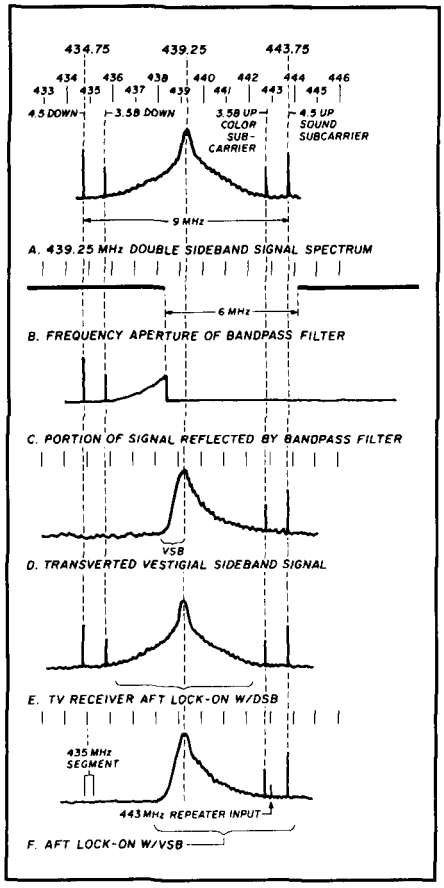
Clean ATV the modern way

Why do Amateur TV signals cause interference, while the interference from million-watt commercial TV stations is insignificant? Commerical TV stations use highly efficient transmitting systems, because any interference would be devastating to many other services and expensive in terms of power wasted. Most hams use the double-sideband method shown in the spectrum of **fig. 1A**. This method conforms to the lastest trend of using a small self-contained package, with few "bells and whistles".

In the past, ATV enthusiasts would heap together a mixture of homebrew and surplus equipment from TV stations. Their shacks looked as if 747s had crashed into them — twice. That was enough to keep many of us from getting involved. Today with VCRs, cameras, and computers in almost every home (and TV sets in half the rooms), you don't need to add much to receive and transmit state-of-the-art signals.

Modulators that generate a vestigial sideband signal (VSB) at low VHF frequencies are readily available and inexpensive.[1] The output has the color and sound sidebands "locked in" at a low RF level. When transverted upward to UHF, the lower sidebands are inserted again by way of the mixing process. This signal is still below 1 watt and can now be filtered, using helical resonators,[2] for the final cleanup. Compare

FIGURE 1



Simplified television spectra.

fig. 1A with **fig. 1D**. When a filter is used to remove the lower sideband of a high-power UHF signal, both insertion loss and losses from SWR can be quite high. That, coupled with the additional connector losses, can cause undue strain on the final amplifiers. The most obvious benefit of the VSB method is that the AFT in the average TV set locks on. Sound and color also lock in on strong or weak signals.

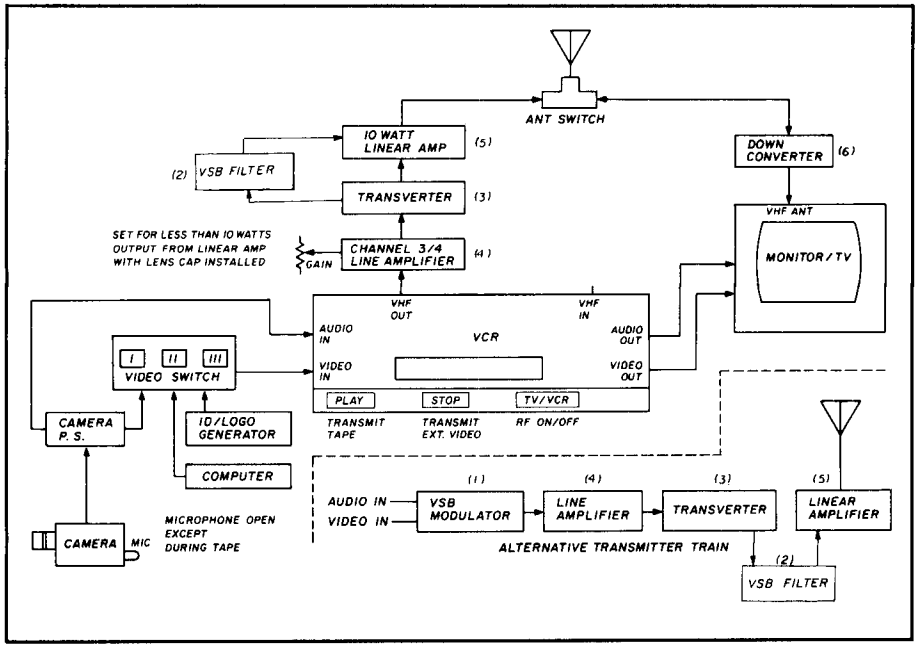
With a double-sideband signal (unless it's quite strong), you must tune out the picture to hear the sound. **Figures 1E** and **1F** show brackets whose width represents the 6-MHz ideal bandwidth of a TV set, and how the AFT will (essentially) center on the energy of the signal. Real sets are much narrower. **Figure 1F** also shows the 435-MHz satellite segment that may suffer interference from a 439.25-MHz double-sideband signal. This information is extremely important if you choose 421.25 MHz for the carrier; there is danger of transmitting out of the band.

A VCR has a modulator that transmits a fairly good VSB signal. The output can be the channel 3 or 4 signal required by the transverter.[3] The VCR makes a perfect control point for your ATV station. Although the operating format varies from model to model, all operations are accessible on the VCR. A separate video selector switch that feeds the VCR's VIDEO-in jack can connect any desired source. Many transverters and amplifiers idle with little current drain when excitation is removed; this simplifies transmitter switching. However, you must switch your antenna separately.

Figure 2 shows a comprehensive ATV station using a transverted VSB signal. I've also shown an alternative transmitting system that uses only a modulator. But, try using a VCR if you have one; it's a valuable video source. The VHF amplifier brings the 0.3-μW (5 mV) VCR output signal up to the 1 mW level required by the transverter. You can use a channel amplifier (for feeding apartment houses), or one or more of the multiset driver units called rabbits.[4]

Some of the control buttons are shown at the bottom of the VCR block. The names appearing on the

FIGURE 2



A comprehensive ATV station using a transverted VSB signal.

front of the VCR are inside the block. The actual functions, as they relate to ATV system operation, are listed below the block. The format for my unit, a Toshiba, allows VHF excitation control from the VHF-out jack using the TV/VCR or PLAY switch. In VCR mode (indicator lit), the internal modulator is energized and fed video from a tape — or whatever is fed to the VIDEO-in jack. A running tape overrides external video until you push the stop button.

To stop transmitting, push the TV/VCR switch again. The indicator light will go out. In this mode, a sufficiently strong signal from a downconverter entering the VHF-in jack, could pass throuh the VCR, and excite the transverter. When used in this way, with proper filtering, the VCR can become a repeater — but it requires two antennas. To be more specific, VHF-out follows VHF-in when in TV mode, and follows tape (or VIDEO-in) in VCR mode. However, VIDEO-out follows a tape if one is running; if a tape isn't playing, it follows VIDEO-in.

I've used a Hamtronics transverter for both 432-MHz sideband and ATV. It worked well in both situations, but I had some difficulty with the tune-up. Then I found a note that recommended tuning the UHF amplifier section with an accurate signal generator fed in through the coupling capacitor at the mixer output. Do this before tuning the local oscillator train to prevent mistaking the wrong output from the mixer — or the local oscillator frequency itself — for the desired one. If you don't have access to a reliable signal generator, order a completely wired and aligned board. If a high-power channel 3 or 4 station is close by, opt for a crystal on the channel that you don't have in your area. This will minimize interference. Also, don't mistake oscillations in the VHF line amplifier for trouble in the transverter.

With the great wealth of video devices available today, there's no lack of interesting material to transmit. Keep family home movies to a minimum and remember that copyrighted tapes are taboo. There are many interesting events, in Amateur Radio and other hobbies, to tape and present. Of course, there are so few of us skilled in the art of presentation that it would be rare to find a tape warranting over five minutes of air time. Though NASA and USWS material is (in a way) owned by the public, you usually need to contact them for a letter of authorization. Music is still illegal in Amateur Radio transmissions and should be edited out of any tapes you show.

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John Shelley, WA1IAO

Article D **HAM RADIO**

COLLECTOR MATCHING NETWORKS

By Mark Bacon, KZ9J, 2205 File Drive, Decatur, Illinois 62521

Tips for designing matching networks

For many, access to Computer Aided Design (CAD) software packages has rekindled interest in designing matching networks and filters for specific applications. Some years ago, I was involved in comparing the frequency response — bandwidth and stopband attenuation — of collector matching networks commonly used in bipolar transistor PAs. For the single HF bands, a lot of Amateur designers choose a narrowband common-emitter amplifier which couples RF through matching networks at the input and output of the active device; it's still the favorite for VHF.

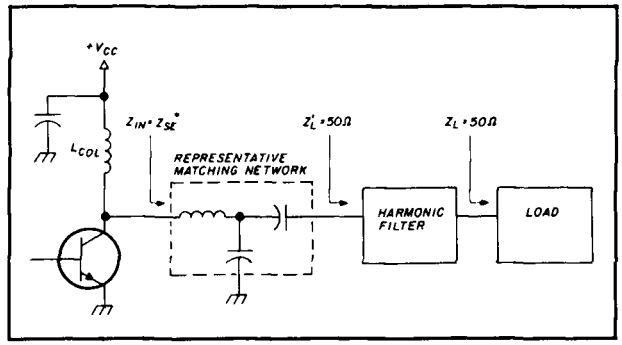
Power and attentuation

One way to find the response of a matching network is to compute the input impedance Z_{in} of the network (or network-harmonic filter combination) at regular (or logarithmically spaced) frequency steps. Many CAD programs (including mine) simplify the matching network step by step to the simplest series-equivalent circuit (R_{in} and X_{in} in series) and evaluate $Z_{in} = R_{in} + jX_{in}$. This sort of analysis (known as network reduction) is tedious when done by hand, but is well suited to a computer. Using Z_{in}, calculate the current flowing into the network which leads to the response and the relative power dissipated in the load. This approach doesn't require a lot of computer memory and is suitable for small programmable calculators. Several years ago I wrote programs for a TI 58; it still handles my matching network calculations.[1]

In the following algorithm, the relative power P_L drawn by the load of a PA is

$$P_L(dB) = P_T + IL \qquad (1A)$$

FIGURE 1



Partial circuit of an amplifier showing output circuit impedances at the operating frequency.

$$P_T(dB) = 10 \log \frac{4R_{se}R_{in}}{(R_{se} + R_{in})^2 + (X_{se} + X_{in})^2} \qquad (1B)$$

Where P_T is the relative power output of the PA (drawn at the network input) and IL is the dissipative insertion loss of the network (or network-harmonic filter combination). Since IL is negative, P_L is less than P_T by the amount of dissipative loss. The series-equivalent collector output impedance is $Z_{se} = R_{se} + jX_{se}$ and $Z_{in} = R_{in} + jX_{in}$ is the series-equivalent input impedance of the collector matching network. The impedance relationships are shown in **fig. 1**. Maximum output power (0 dB relative power) is drawn when $Z_{in} = Z_{se}^*$, the complex conjugate of the collector output impedance. The bandwidth of the amplifier is defined as the frequency interval for which the relative power holds within −1 dB of maximum. Many designers consider −1 dB a practical limit for the power curve. This limit corresponds to a return loss at the collector of −8.0 dB or a VSWR of 2.32.

A number of CAD programs include the IL of the net-

work or filter, some at a considerable level of sophistication.[2] Below 30 MHz, you can approximate IL by placing the loss resistances R_{loss} in series with the inductors. (Capacitor losses can generally be neglected at HF.) Then $R_{loss} = X_L/Q_u$, where X_L is the inductive reactance and Q_u is the unloaded Q of the coil.

The collector output resistance R_{se} is a large-signal parameter. Use the DC collector voltage and the desired output power for calculations below 30 MHz.[3] Many PA transistor manufacturers supply data for both R_{se} and X_{se} (often in parallel-equivalent form). R_{se} is small in high-power transistors (usually less than 5 ohms), and X_{se} is usually capacitive below 100 MHz.

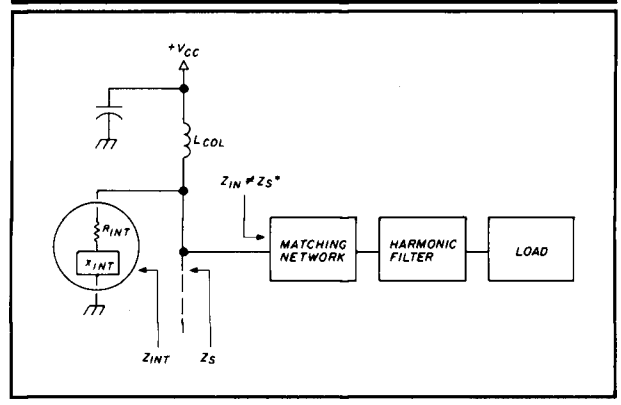
The computer program used for power output also lends itself to the analysis of the stopband attenuation of the collector matching network (or network-harmonic filter combination). The attenuation at the load is A_L(dB) = A_m + IL, where A_m (the mismatch attenuation) is computed with an equation of the same form as **eqn. 1B**, with the source impedance Z_s replacing Z_{se}. $Z_s = R_s + jX_s$ is made up of the internal impedance of the transistor in parallel with the bypassed collector choke, as shown in **fig. 2**. The internal resistance R_{int} is largely a function of operating parameters, although transistor characteristics play a role. As the operating conditions become increasingly nonlinear, the transistor operates more in a saturated condition (maximum possible collector current). As a result, collector current is drawn at lower average collector voltages and R_{int}, by Ohm's law, drops lower. R_{int} is several kilohms or higher in the unsaturated, linear classes (A and AB), a few hundred ohms in class C, and a few ohms or less in the saturated, switching classes (D and E).

For maximum output power, the collector matching network is designed to transform the load impedance Z_L to the conjugate of the collector output impedance Z^*_{se} rather than the true source impedance Z^*_s. Consequently, the collector matching network has a mismatched input because it really sees Z_s. In network/filter vernacular, the network (and harmonic filter if used) are single terminated. A mismatched input usually causes the frequency response of the network (or network-filter combination) to differ substantially from the ideal response with both ends terminated.

Matching network Q

For a 3 (or more)-element network, you can specify the desired network Q or relative half-power bandwidth. The Q is usually determined by a parameter called the design or loaded Q (Q_L). For narrowband transistor PAs the Q_L of the output network is generally 4 to 6. Many Amateur designers confuse Q_L with the circuit Q or operating Q (Q_{op}) of the network — the Q which the network exhibits in an actual circuit. Q_{op} reflects the loading on both ends of the matching network, whereas Q_L is fixed by the loading on only one end.[4] Determine the operating Q by dividing the frequency for which the network is tuned by the calculated (or measured) −3 dB bandwidth of the network.

FIGURE 2



Representation of a common-emitter PA to illustrate the source impedance.

Besides the Q, the 4-element collector matching network adds the shape of the passband. For example, if your goal is a PA with a large bandwidth (perhaps for 2-band coverage), you can tailor a 4 (or more)-element network for a Butterworth (maximally flat) or a Chebyshev response with a 1-dB passband ripple. I'll show how it's done later.

The amplifier

To determine bandwidth and stopband attenuation, you need to "design" an amplifier which will yield realistic numbers for the collector output impedance Z_{se} and the source impedance Z_s. The amplifier I chose operates class AB and uses a Motorola MRF422 transistor rated at 150-watts PEP output to 30 MHz; it loafs at 75-watts PEP at 7 MHz in this PA.

Estimate the collector output impedance using the graphs on the MRF422 data sheet.[5] You'll need the output resistance R_{out} versus frequency and the output capacitance C_{out} versus frequency. The data are in parallel-equivalent form for 150-watts PEP. At half the rated power, R_{out} about doubles and C_{out} drops from 4200 pF to an estimated 2600 pF at 7 MHz.[6] R_{out} is scaled by a factor of ×2 and C_{out} by 2600/4200 or ×0.619. Fortunately, these factors are nearly independent of frequency. For power calculations, C_{out} is converted to X_{out} by $X_{out} = -1/2\pi fC_{out}$, and the parallel-equivalent output impedance $Z_{out} = R_{out} + jX_{out}$ is transformed to the series-equivalent output impedance $Z_{se} = R_{se} + jX_{se}$. This is done by first inverting R_{out} and X_{out} to give the conductance G_{out} and the susceptance B_{out} ($B_{out} = -1/X_{out}$. Note the sign change). Then $Y_{out} = G_{out} + jB_{out}$ is inverted to give $Z_{se} = 1/Y_{out}$. W7DHD has a BASIC routine which performs the complex inversion by dividing Y_{out} into 1 + j0.[7] Z_{se} = 4.66 −j4.18 ohms for 75-watt MRF422 PA at 7 MHz, including the contri-

bution of the 3-μH collector choke (which causes a 6.6 percent increase in R_{se}). I know a 3-μH collector choke for a 7-MHz PA may raise a few eyebrows, but I chose a low inductance to avoid low-freqency resonances with output network capacitance which can lead to instability.[8] The choke reactance, over 130 ohms at 7 MHz, doesn't cut into the output power significantly. With Z_{se} (and Z_{in}) calculated at regular frequency steps above and below the frequency for which the PA is tuned, you can use **eqn. 1** to compute a power curve and -1 dB bandwidth.

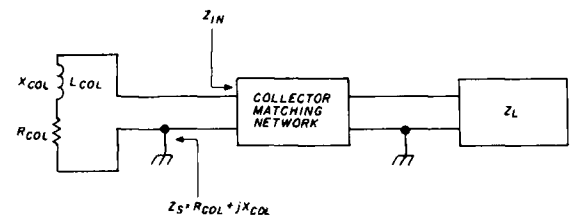
To determine the stopband response, you'll need a simple, tractable model to calculate the source impedance Z_s. As I mentioned, the internal collector resistance R_{int} in an AB class PA is in the kilohm range. In fact, R_{int} is so much higher than the collector choke resistance that R_{int} can be considered invisible. This leaves the bypassed collector choke as the source impedance (see **fig. 3**). That is, $Z_s = Z_{col} = R_{col} + jX_{col}$, where the series-equivalent loss resistance of the choke is $R_{col} = X_{col}/Q_u$. With the 3μH, $Q_u = 100$ collector choke, the choke impedance at 7 MHz is $Z_{col} = 1.319 + j131.9$ ohms, because $X_{col} = 2\pi fL_{col}$ and $R_{col} = X_{col}/Q_u$. Since R_{col} and X_{col} are directly proportional to the frequency, the impedance can be easily scaled to any frequency. For example, R_{col} and X_{col} at the second harmonic are just twice their values at 7 MHz. Now determine the stopband response with Z_s in place of Z_{se} in **eqn. 1**, just as you determined the power curve.

Designing the matching networks

The low-pass collector matching networks designed for the MRF422 PA are shown in **figs. 4A** through **4E**. (The capacitive voltage divider, **fig. 4D**, actually has a pseudo-bandpass response.) These networks transform the 50-ohm load impedance to $Z_{in} = 4.66 + j4.18$ ohms at 7 MHz. The 3-element networks come from formulas in Hayward and DeMaw's *Solid State Design*[9] and the *ARRL Handbook*.[10] These formulas assume a pure (nonreactive) input resistance, and lossless coils and capacitors. First, component values are calculated giving $R_{in} = 4.66$ ohms at 7 MHz with a 50-ohm resistive load and a loaded Q of 4. Next, the network input reactance is adjusted to $+j4.18$ ohms to compensate for the output reactance of the active device, $X_{se} = -j4.18$ ohms. The adjustment involves adding 4.18 ohms to the calculated reactance of the series inductances in **fig. 4A** through **4C**. The capacitive voltage divider (CVD, **fig. 4D**) has a shunt input capacitor. Here it's easier to use the parallel-equivalent output capacitance (2426 pF for the MRF422 with the effect of L_{col} included) and subtract 2426 pF from the calculated value of the shunt input capacitor at 7 MHz.

If you're not interested in insertion loss, you're finished with the 3-element designs. To observe the effect of imperfect coils (as I did), you need to input the

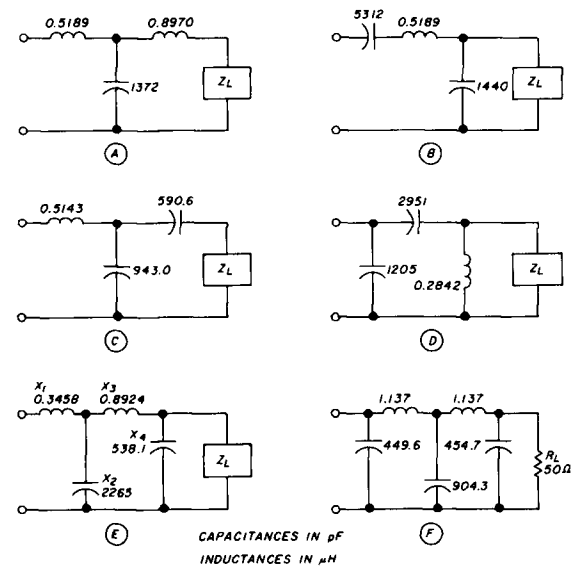
FIGURE 3



Equivalent circuit of the source impedance Z_s seen by the collector matching network of a class AB common-emitter amplifier.

$X_{col} = 2\pi fL_{col}$, L_{col} is the collector choke. $R_{col} = X_{col}/Q_u$.

FIGURE 4



Collector matching networks. (A) symmetrical T (LCL), (B) controlled-Q L (CQL), (C) unsymmetrical T (LCC), (D) capacitive voltage divider (CVD), (E) tandem L (TL). Element values are to match a 50 ohm load to the MRF422 collector load impedance, 4.66−j4.18 ohms at 7 MHz. Design Q is 4 for the 3-element networks, 3.55 for the TL. (F) A half wave low-pass filter (HWF). Q_u = 175 for all coils.

unloaded Q of the coil(s) and the other network parameters into the analysis program. I used coils with a Q_u of 175 for the networks in **fig. 4**. Imperfect coils will throw off the design Z_{in}. I use a repetitive procedure of systematically adjusting element reactances and recomputing input impedance until I obtain the desired Z_{in} again. Don't change the input series coil or shunt capacitor — the elements you already modified for collector output reactance. These elements are also determined by the chosen Q_L of the network. Changing the remaining two elements will always regenerate the desired Z_{in}.

You need to take a different tack when designing the 4-element tandem-L network (TL, **fig. 4E**). There aren't

any simple, exact formulas which allow you to independently choose the bandpass shape and the design Q. Fortunately you can calculate the end elements X_1 and X_4 for any desired bandpass and Q, and this leads to preliminary values for the inner elements X_2 and X_3.

The TL network in **fig. 4E** was designed for an optimally flat (Butterworth) response with a constant voltage (zero output resistance) source — a reasonable approximation for a transistor with an output resistance of a few ohms, like the MRF422. If the input-end Q of the TL is defined as $Q_{in} = X_1/R_{in}$ and the load-end Q is $Q_{load} = R_L/X_4$, the parameter indexing a maximally flat response is $Q_{in}/Q_{load} = 2$.[11] The design Q for this network is $Q_{in} + Q_{load} = 3.55$. These two conditions are solved for Q_{in} and Q_{load}, from which X_1 and X_4 are calculated. A ratio Q_{in}/Q_{load} between 1 and 2 gives a broader hammock-shaped response, if some passband ripple is allowable. For TL networks with a Q_{in}/Q_{load} of 2 or less, $X_2 \simeq -X_1$ and $X_3 \simeq -X_4$. (Watch the signs!) Now add 4.18 ohms to X_1 to compensate for the MRF422 output capacitance, and compute the input impedance with the preceding network elements. Systematically adjust X_2 and X_3 to steer Z_{in} to the design value, 4.66 + j4.18 ohms for the MRF422.

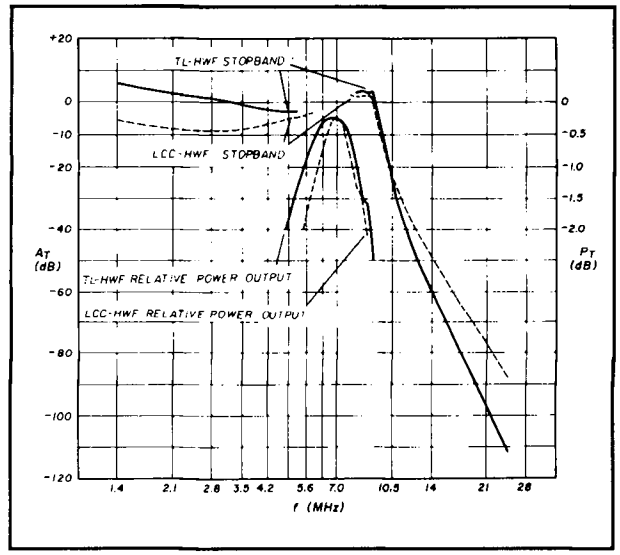
Figure 4F shows a half-wave harmonic filter which yields $Z_{in} = Z_{load} = 50 + j0$ ohms at 7 MHz and reduces harmonics 20 dB or more. The name half wave is derived from the impedance characteristics of the filter.[12] Like a half wavelength of transmission line, the half-wave filter reproduces at its input (with a 180-degree phase delay) whatever load impedance is coupled into it at the design frequency.

Frequency response curves

Both the relative power output of the PA and the stopband attenuation of the output circuits are referenced to 0 dB at the frequency for which the PA is tuned, and plotted versus frequency on the same graph. This combined power and attenuation curve (which I call a composite response curve) yields information at a glance on the width and shape of the power curve (assuming constant drive level and device gain), and harmonic rejection.

Figure 5 illustrates two composite response curves for the MRF422 PA. One is for a 3-element matching network (LCC, **fig. 4C**) and the other for the 4-element TL network of **fig. 4E**. Both matching networks are tied to the half-wave harmonic filter. These curves show clearly the large increase in harmonic attenuation when going from the low to the high-frequency edge of the 0, −1 dB power curve. For example, in the LCC-HWF response, the second harmonic attenuation A_2 corresponding to the low-frequency edge at 6.15 MHz, is only −40 dB (at 12.3 MHz). A_2 corresponding to the high-frequency edge at 7.9 MHz is 18 dB greater at −58 dB. Allowing for a second harmonic level of −12 dB in the amplifier

FIGURE 5



Composite response curves for TL-HWF and LCC-HWF PA output network-harmonic filter combinations. Amplifier is a 75-watt class AB MRF422 tuned for 7 MHz. Expanded P_T scale for relative power output is at right.

itself,[6] these A_2s reflect harmonic outputs of −52 dB and −70 dB. Although −52 dB is within FCC regulations, from my experience with interference I consider −60 dB the maximum harmonic output from a 75-watt or larger PA that assures peace with neighbors and nearby Amateurs. So, the net harmonic rejection of the output circuits should be −60 dB − (−12 dB) = −48 dB. This rejection specification moves the lower frequency limit for the PA with an LCC-HWF output circuit from 6.15 to 6.9 MHz, defining an operating range of 6.9 to 7.9 MHz.

According to the −48 dB criterion, the operating range of the MRF422 PA with a TL-HWF circuit is 6.2 to 8.1 MHz. The relative width of this range is 27 percent — sufficient to cover the whole 75/80-meter band, or to bridge two adjacent bands between 14 and 30 MHz. (We're assuming that the response doesn't change drastically when the amplifier is tuned for a different frequency — an assumption I have found to be generally true.) With the TL-HWF combination, the power curve is at least 37 percent wider, while the harmonic rejection is several dB better than with the 3-component networks.

The main features of all of the composite responses are summarized in **table 1**. The −1 dB bandwidth decreases as the operating Q increases, while the insertion loss and harmonic attenuation increase. If Q_{op} instead of Q_L is fixed for the various 3-component networks, the apparent differences in bandwidth and filtering ability practically vanish. For example, in addition to the CQL, the LCL, LCC, and CVD matching networks with $Q_{op} = 4.9$ in the MRF422 PA all have a second harmonic attenuation A_2 of −21 dB and an A_3 of −32 dB.

TABLE 1

Properties of collector output circuits for a 75-watt class AB MRF422 PA tuned for 7 MHz. Q_{design} and Q_{op} are explained in the text.

Matching network or matching network low-pass filter	Figure	Qdesign	Qop	Passband response (0,-1 dB MHz)	IL(dB)	A_2(dB)	A_3(dB)
LCL	4(A)	4	5.4	6.1-7.6	−0.143	−25.7	−40.0
CQL	4(B)	4	4.9	6.2-7.8	−0.123	−21.1	−32.4
LCC	4(C)	4	4.6	6.1-7.9	−0.122	−18.4	−29.2
CVD	4(D)	4	3.2	6.2-8.1	−0.098	−12.8	−18.3
TL	4(E)	3.55	6.9	4.9-8.1	−0.128	−29.7	−49.8
LCL-HWF	—	—	—	6.3-7.5	−0.242	−46.4	−88.5
CQL-HWF	—	—	—	6.2-7.8	−0.221	−49.4	−77.3
LCC-HWF	—	—	—	6.1-7.9	−0.221	−48.9	−77.6
CVD-HWF	—	—	—	6.2-8.0	−0.197	−41.4	−63.7
TL-HWF	—	—	—	5.5-8.0	−0.226	−59.9	−97.3

(The attenuation of the TL network depends on the passband width as well as the Q.)

Conclusion

Which collector matching network is best for an MRF422 PA? Because the composite responses of the 3-element networks are much the same for a given operating Q, the choice hinges on practical concerns like the ease of tuning and component values and ratings. Some networks — notably the CQL and CVD — are less suitable for medium- and high-power PAs. The series leg capacitors are 3000 pF or larger because of the large impedance transformation, and must carry a large current (3.5 amperes in the CQL). These networks are better suited to PAs in the 10 to 15-watt range, where both capacitance (for a given Q) and current are lower. The other networks, the LCL, LCC, and TL, are workhorses for PAs in the MRF422 class. Of these, the LCC is perhaps the most popular. It has only one coil and built-in DC blocking. The TL network is more difficult to tune (a spectrum analyzer and tracking signal generator are usually required to achieve the desired bandpass curve).

Even a modest programmable calculator can be used to design and analyze matching networks in conjunction with reactive sources and loads. I hope this article piques your interest in this important area.

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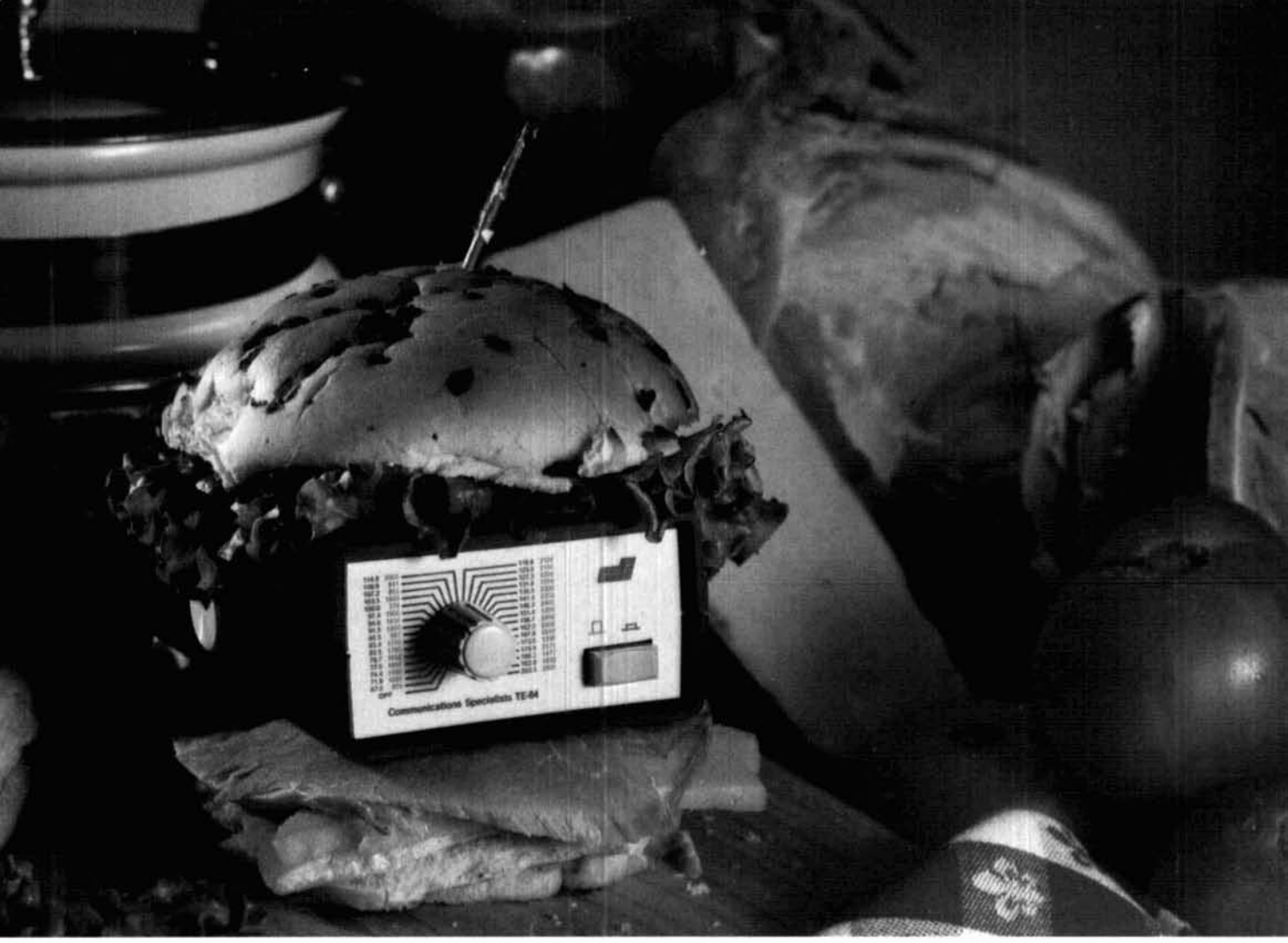

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By **Joseph J. Carr, K4IPV,** P.O. Box 1099, Falls Church, Virginia 22041-1099

While advertisers are the lifeblood of a magazine, and editors (and other staff) are the internal organs, the sinew and muscle are the non-staff freelance writers who contribute material to the magazine. That writer could be you! In this article I'm going to share some of what I've learned in the two decades since an Amateur Radio publication accepted my first article.[1]

First, let's get one matter straight right away. Technical writing is only a skill, and it's a skill that can be learned by almost anyone who has the brains to get an Amateur license. It is **not** an arcane art practiced by some specially talented mystical elite, but rather it's an attainable skill. And, you don't have to be an English major to do a good job (I made a "D" the first semester of college English 101 and flunked the third semester flat). I've written more than 50 books and 300 magazine articles, many of them for *Ham Radio*.

Slant

Not all articles are suited to all publications. The difference is what the trade calls "slant." This term refers to the point of view taken by the article in reference to the type of readers who buy the magazine. The same topic can sometimes be sold to several different magazines if the slant is different, the timing is different, and the magazines aren't generally in competition with each other.

The slant is merely your effort to aim the article at the readers of a particular magazine. Every editor can tell you something about his readers. You can also get a good idea of the readership by studying recent issues of the magazine. Using this information, you can "home in" on the types of article the magazine will buy. Although a few editors issue "want lists," most of them will tell you that they don't know what they want "but I'll recognize it when I see it."

Article format

There are several types of articles that appear in this magazine. Some are technical tutorial pieces, some are construction projects, and some are "how-to" pieces. Let's take a look at the basics of the how-to article. The common denominator for all how-to articles is that they offer instruction and advice. This definition covers a lot of territory, including most practical technical articles. There is no fixed universal format for all how-to pieces; almost any format will work some of the time. But there is one format that almost always works, so if you're a new writer, you might want to follow it until you have a little experience. The format, which I learned both at a writer's conference and from the editor of another Amateur publication, is called the "Tell-'Em-Cubed" method. Just follow this outline:

Tell 'em what you're gonna tell them.
Tell them.
Tell them what you told them.

The first "tell them" should be no more than about three paragraphs, and may be only one short paragraph. This "tell 'em what you're gonna tell them" segment must grab — and hold — the reader's attention, and convince him to continue reading. The main body of the article is the "tell them" portion and should occupy the bulk of the space. Finally, there's the "tell them what you told them" section for a quick (one to three paragraphs) summing up. Use it to highlight the main points, especially those that should be remembered.

For electronics articles there is a modified "Tell-'Em" format (which I call the "Ham Writer's Eight-Fold Way"):

Tell 'em what you're gonna tell them.
Tell what it's gonna do for them.
Tell them how it works.
Tell them how to build it.

Tell them how to test it.
Tell them how, when, and where to use it (as appropriate).
Tell them how to modify or adapt it for other applications.
Tell them what you told them.

Of course, not all of these elements need be included in every article, but it does represent a stylistic shopping list.

Writing the piece

Most successful authors prepare at least an informal outline for the article. This road map needn't be as formal as one for an English class; it's simply a guide to ensure that all bases are covered — and are covered in logical order. The outline keeps you on the right track.

Each major topic in your article deserves at least a paragraph. A major mistake novice writers make is to mix several topics in the same paragraph. If your outline is written to the paragraph level, you probably won't fall into this trap and your article will flow more naturally.

Another common mistake is to include too many topics in a single article. A magazine article is a capsule of information on a specific, usually quite narrow, topic. After my initial success in a ham magazine, I sent a manuscript to Jay Phipps, the editor of *Electronic Servicing*. Jay apparently saw something good in that mess of a manuscript, because he took the time to write a four-page bit of fatherly advice (not something one learns to expect from busy editors). He pointed out that there were at least four different articles in that one nine-page manuscript. When I finished rewriting the piece, it actually had five buried topics. Jay bought all five, just in time for Bonnie and me to get married.

How long should your article be? The quick-draw response is "long enough to tell the story," but (while true) that's not the practical answer. Take a look at the articles in *HR*. Most of them fall into a relatively narrow range of lengths that fits their format. In general, an article should be 5 to 10 double-spaced, typewritten pages with 2 to 6 illustrations. *HR* publishes longer pieces, and certainly some shorter pieces, but in general those that are bought fall in the mid-range. If you feel strongly that an article needs a long treatment, write to the editor and make a proposal for either a long article or a multipart one. If the topic strikes the editor's fancy, you might get a no-obligation "speculative" go-ahead.

Preparing the manuscript

When you prepare the manuscript for your article, keep in mind that a real, live, warm-blooded editor must read and work with your piece. Prepare the manuscript to make his job easier. I've seen a lot of potential writers over the years who'd get fewer rejection slips if they did a better job of manuscript preparation. If an author is too sloppy to do the mechanical job correctly, the editor might get the idea that he's a little sloppy with the facts as well.

Editors require typewritten manuscripts, so don't even think about sending in a handwritten piece. Your typewriter or computer printer should be in good repair, and print well. If you don't have access to a typewriter or computer, there are secretarial services that can do the job. Dot-matrix submissions are accepted by most publishers, but only if they are easily readable. An editor spends a lot of time every day reading, so a washed-out, low-resolution dot-matrix submission might just go unread. A "near letter quality" dot-matrix printer with a fresh ribbon will produce an acceptable product.

Type the final manuscript on 8-1/2 x 11 inch plain white 20# paper. Don't use colored paper, or paper with rules. If you're sending a computer printout, be sure to use a middle to high grade of paper. The cheap stuff (which costs only a little less than the good stuff) leaves a coarse, ragged edge that annoys editors.

Don't send a manuscript that includes a lot of hand corrections. In general, most professional writers will retype a page if more than three minor corrections appear on it — and even then only if they use a typewriter instead of a personal computer word processor. Most editors don't mind if a typewritten submission has a few legible hand corrections, but don't overdo it.

When the manuscript is finished, bind the pages together with a single paper clip, not a staple. Also paper clip the illustrations to the text. In a technical article, the pictures are as much a part of the manuscript as the text, so don't forget them. Send the manuscript flat in a large manila envelope; don't bend it over and force fit it into a standard no. 10 business envelope.

[Note: A little word of advice for new writers. If you want to hear Terry Northup scream in anguish all the way from New Hampshire, just forget to place a list of captions on the illustrations package!]

Illustrations

"A picture is worth a thousand words" says an old cliche. That old saw might be true in some cases, but when you're being paid on a per page basis, a picture is worth about 200 words. The real value of the picture, however, is that it enhances the article and makes it easier to follow. In fact, for technical articles, the picture might make it possible in the first place. A picture, in that case, isn't worth a thousand words — it's priceless.

Your illustrations don't have to be drawn profession-

ally. Pencil drawings are acceptable, but must be done in a way that can be interpreted by the magazine's artist. Use some sort of coarse grid graph ("quadrilled") paper, or an engineering sketch pad for your drawings. The latter are green or yellow tablets that are blank (with border) on one side and gridded on the other. The grid lines show through to the blank side enough to guide you in making the sketch, but do not appear on the picture.

The basic requirement for illustrations is that they be understood by the editor and the artist. The line drawing should be neatly done and contain all necessary information. For schematics, that requirement includes component values and semiconductor device type numbers. Keep in mind that there are different drawing practices in effect at different magazines. For example, *HR* uses "CR1" for the first diode in a circuit, not "D1." Also, they use the chassis ground symbol unless an actual earth ground is intended. Study *HR* illustrations to see which symbols they use.

Photographs are also very useful for illustrating the technical article. There are some general guidelines for taking photos. Don't use low-cost 110 or disk format films. Use 35-mm or larger (e.g., 120 or 220 size) film, even if you have to borrow a camera. The old 126 cartridge film (basically a form of 35-mm film in an *Instamatic®* cartridge) is useful if you have a good quality camera. Use black and white film like: *Verichrome Pan*, *Panatomic-X*, *Plus-X*, *Tri-X* or their equivalents. *Do not use color print film*. Some magazines can sometimes use slides, but check with the editor before you hang your piece on a color transparency. A photo laboratory can make a black and white print from your slide by shooting a black and white internegative from your transparency.

The print should be glossy, with borders (you may have to ask for them), and be either 4×5, 5×7, or 8×10 inches. Keep in mind that 35-mm negatives may not reproduce well as 8×10s. Place your photo in a celluloid "page protector." These are available at office supply stores for about 50 cents each. Tape the photo to the inside paper in a way that keeps the tape off the print. (See why you need to order bordered prints instead of the borderless type that's now standard?)

The "standard" lens that comes with most 35-mm cameras has a fixed focal length on the order of 48 to 55 mm. It's almost useless for anything but snapshots without an add-on device like a macro (close-up) lens, close-up bellows, or close-up rings. I use several different lenses for my pictures: a 28-80 mm Zoom Macro, a 70-210 mm Zoom Macro, a 50-mm "snapshot" lens fitted to a close-up bellows for really close-up shots, and 105-mm Macro lens. What's a "Macro" lens? Basically, it's one that lets you do close-up photography, that's all. While photographers may have a more rigorous definition, the point of owning a Macro lens is to allow you to focus closer than the standard 2-3 feet common on non-Macro lenses.

Conclusion

There are any number of reasons why you might want to write a technical article: it pays money, it brings recognition, it helps the Amateur Radio hobby, and it's a heckuva lot of fun. And guess what? YOU CAN DO IT!

Reference

1. Joe Carr, K4IPV, "Kill That Mobile Noise," *QST*, July 1968, page 36.

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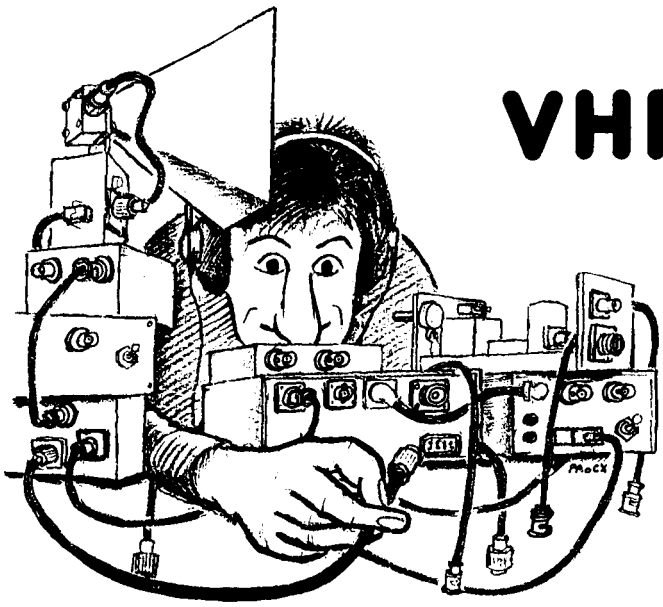

VHF/UHF WORLD

Joe Reisert, W1JR

DX records on 50 MHz and above

Many HFers have worked all the current DXCC countries. Some DXers have even worked and confirmed all current countries on the ARRL DXCC list on 20 meters. Eventually someone will work all current countries on all HF bands; the radio propagation is available.

Several Amateurs presently operating on 50, 144, and 432 MHz claim DXCC totals of 50 to 95 countries on these bands. One day, perhaps in the next few years, 6 and 2-meter DXCC will become a reality using a combination of F2, TE, E_S, and EME propagation.[1-4] But it probably won't be possible to work all current DXCC countries on 50 MHz or above — at least not in a normal lifetime. Even EME has its limitations!

There are many reasons precluding this achievement. Each IARU region has different and often incompatible frequency assignments above 29.7 MHz. The main impediment to working "long-haul" DX above 50 MHz is that the propagation modes required for DX are seldom available, except via EME. Those Amateurs that operate above 50 MHz have had to establish a different "yardstick" to measure performance against their peers.

For many years North American VHF/UHFers worked hard to attain a WAS or WAC award. "Locators" were sought in Europe. The ARRL VUCC (VHF/UHF Century Club) award has been a standard since 1983.

Yet even these awards are not a good measurement of an Amateur's capabilities on the frequencies above 50 MHz. Your actual location on the earth has a great bearing on your maximum DX possibilities. Tables were compiled of the longest DX worked on each Amateur band above 144 MHz. This worked up to a point, but soon became ineffective once someone worked across a special exclusive propagation path (i.e., from California to Hawaii, across the Mediterranean Sea, or the Great Australian Bight).

I started publishing a table with a different twist — one that recognized DX achievements in North America, based on the "suspected" propagation mode used.[2] I also developed similar worldwide and EME tables.

This new table first appeared in "VHF/UHF World" in 1985 and has changed many times. It's been improved and expanded with each new frequency, propagation mode, and claim. I've also added six-digit grid squares. The latest update appeared in "VHF/UHF World" of June 1988.[3]

Why the emphasis on VHF DX?

Many Amateurs move up to the VHF frequencies to improve local coverage; they do it to ragchew, or pass traffic with little or no QRM. These operators want to avoid DX and all its trappings! Still others enjoy the vast networks of VHF/UHF packet and FM repeaters, especially for wide area mobile coverage and emergency traffic.

Many 2-meter and above users are often unaware that they can work DX on these bands. They think that working beyond line-of-sight (LOS), or perhaps over 50 miles, isn't possible except in rare instances — and then only with an enormous antenna and lots of experience.

Those Amateurs who operate the VHF/UHF frequencies seriously know that coverage is possible out to several hundred miles at almost any time of the day or night using CW or SSB, moderate power (50-100 watts), a Yagi with an honest gain of greater than 10 dB, and a receiver with a low noise figure (less than 3 dB).

VHF/UHF DX must be quantified. On 6 meters there are several propagation modes not commonly available on 2 meters and above. The mode of propagation is often difficult to determine because many contacts involve a "mixed" propagation mode (combinations of F2, E_S, TE, MS, or backscatter).

Long-path contacts have been reported during the rare times when F2 propagation is present on 6 meters. In

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these contacts, the direction of propagation between stations is reversed and the signals cover distances exceeding half the earth's diameter or 12,430 miles (20,000 km). Because of their rarity, claimed 6-meter records (excepting EME) aren't included in most record tables.

So why the emphasis on DX on VHF and above? The reasons are many but the old saw still applies: "Because it's there." But that's not enough of an answer.

There are many other reasons to "seek out" DX on the higher frequencies. Successful record-breaking VHF/UHF DXing requires a unique knowledge of radio propagation and a certain amount of luck. But even the routine fallouts of VHF and above DXing are tremendous. A few that come to mind are:

- Discovering new modes of radio propagation.
- Determining the maximum capabilities of each propagation mode. (This includes the optimum times, days, and years and the necessary weather conditions, if applicable.)
- Choosing the optimum transmission mode (CW/SSB/FM, etc.) for each mode of propagation.
- Finding operating techniques that maximize data throughput.
- Unearthing equipment improvements like more stable local oscillators, lower noise weak signal receivers, efficient higher gain antennas with low side/grating lobes, and more efficient transmitters.

References 1 through 6 describe most of the known radio propagation modes available above 50 MHz. By familiarizing yourself with these references you can determine the capabilities and limitations of each mode, and try to expand upon them.

Determining the optimum equipment, operating techniques, and transmission mode greatly improves DXing results. For instance, CW is still the best weak signal technique — especially where only low data rates (like EME) are required. CW was used in the early days of meteor scatter propagation, but SSB is now widely used because it improves productivity by increasing the data rate.

In the "good old days" Amateurs used FM to great advantage on microwave LOS communications. Schemes like polaplexers circumvented the need for high stability oscillators.[7] State-of-the-art (SOA) improvements in local oscillator technology have increased the popularity of CW and SSB, and microwave records are falling like stones.

Most improvements resulted from the hard work of VHF and above weak signal DXers who wanted to develop the SOA in equipment, increase propagation knowledge, and set new DX records. We now have Amateurs using CW and SSB all the way up through 47 GHz[8]!

How are DX records broken?

This isn't a simple question. In most cases it's quite a challenge to break an existing DX record, and that takes a serious effort. You may need new equipment with greater capabilities than are presently available. Special locations and weather may also be required.

In other cases, an existing VHF and above DX record has actually been broken by accident, sometimes without the knowledge of either one or both of the new record holders! The fallout in this case may be great, as a new propagation mode or method is discovered to extend an existing record.

If you decide to challenge a DX record, examine carefully the existing records shown on the tables in this column. Study the characteristics of the particular propagation mode and record you expect to challenge. Finally, develop a plan of attack.

Each VHF and above DX record is listed by frequency and propagation mode with the callsigns of the record holders, grid locator, date, mode, and the actual DX attained in miles and kilometers. The DX shown is calculated using the best available information.

The distance shown on the tables is based on a "spherical" earth model. This is by far the most common distance determination method used by Amateurs because it employs simple mathematics and straightforward computer programs.

Spherical earth calculations have some inaccuracies depending on whether one or both of the stations are near the earth's equator or poles. The greater the distance involved, the greater the inaccuracies — but they probably never exceed about 44 miles (70 km) worst case.

In the future, I expect to convert the DX record tables to a different mathematical formula using an "ellipsoidal" earth model. This will improve record accuracy, but I doubt if anyone will lose or gain a claim!

I haven't converted to this more accurate method because few Amateurs seem to have used, or have access to, these more sophisticated models. A changeover at this time could cause confusion, and make it difficult to compare records.

In the meantime, if you'd like to try it, *The Radio Amateur's World Atlas*[9] describes a computer program for determining ellipsoidal earth distances. I can't testify to it s accuracy at this time, but hope to do so shortly.

My DX record information comes from the VHF/UHF/SHF Record Verification Forms you submit. (The form was shown on **table 4** of last June's "VHF/UHF World" column.[3]) I retain all claim forms for my record file. The grid locator shown on the records is derived from this information. This means the DX shown may not be the same as what you'd calculate using some of the new computer programs based on the center of center DX between two grid squares.

It's very important that all record information you send be as complete as possible. Accuracy is the key.

I try to include as much new information as possible on each new DX record submitted at the end of each "VHF/UHF World" column. This helps new record challengers gain

insight into the required equipment and parameters. More on this shortly.

New DX records

Generally speaking, it's rare when more than two VHF and above DX records are broken in a single month. Usually it's easy to summarize the new ones at the end of the column. But, so many DX records have been broken lately that it's been tough to keep up with the influx of telephone calls and paperwork. In the last few months, some of the same records have been broken three or more times! I finally decided that the fair thing to do was devote this month's column and the next to those records that have arrived recently, and have been fully documented.

This record DX activity is a great testimonial to the interest in and health of the VHF and above frequencies, as well as the challenges and advancement in the SOA. Who says we aren't utilizing our present frequencies adequately?

New ionospheric records

I've tried to find some way to arrange this new record material in an orderly fashion, but it's difficult. New records are coming in faster than I can get them out to you. I decided to break the new records into four separate categories: ionospheric, tropospheric, EME, and light waves.

144 MHz. For many years the North American 2-meter sporadic-E DX record was a "single-hop" contact. In the early 1980s there were probable "double-hop" contacts with some ducting. Then, in the June 1987 VHF contest, the first clear double-hop 2-meter contact was made in North America[4].

Now I've authenticated a new record that extends the 1987 one considerably. On June 6, 1988, at about 0230 UTC, stations in Alabama were working Colorado stations on 144.2-MHz SSB. Then, at about 0235 UTC, John Howard, KB4WM, Childersburg, Alabama (EM63TG) worked Merle Cox, W7YOZ, Kirkland, Washington (CM87VR) for a new DX record of approximately 2106 miles (3,389 km). At 0237 UTC KB4WM broke his own record by working Larry Logan, NF7X, Everette, Washington (CN87VX) for an approximate distance of 2111 miles (3,397 km). This was followed at 0250 UTC by Dale Peterson, WA4CQG, Auburn, Alabama (EM72FO) who jumped on frequency, worked W7YOZ, and extended the record even further. So, unless I hear to the contrary, the latest 2-meter sporadic-E record stands at 2172 miles (3495 km).

Both WA4CQG and W7YOZ were running about 400 to 500 watts on SSB with four 16-element and one 14-element Yagis, respectively. Signals were Q5, but only around the S4-5 level.

Remember that these contacts were still not coast to coast. A further extension, perhaps by as much as 500 miles, is still possible. Any challenges to this great opening?

220 MHz. Now let's look at the meteor scatter records. The first case involves 135 cm. This band is usually devoid of meteor scatter activity, except during the Perseids meteor shower. This year was no exception.

This year's Perseids shower was generally rated as poor — surely poorer than last year — by most 135-cm aficionados. This didn't dampen anyone's enthusiasm, but it did decrease longer distance contacts. They were few and far between.

But, after five years of trying to work each other, W1JR, Chelmsford, Massachusetts (FN42HN) finally completed a meteor scatter contact on 220.1-MHz SSB with Ron Roche, KØALL, Fargo, North Dakota (EN16OU) between 0500 and 0700 UTC on August 13, 1988 during one of several marathon sessions. We completed the contact by piecing together many short and relatively weak SSB bursts, none lasting more than a single call set at my end.

Both stations were running 600 to 1000 watts with single long boom Yagis. KØALL was also on one end of the previous 135-cm meteor scatter record. Ironically, we increased the dis-

tance over that record by only one mile!

If you examine the table in reference 3, you'll note a peculiar difference. The new record appears to be shorter than the previous one. But, before you suspect collusion, note that KØALL's grid square has changed.

When Ron rechecked his latitude and longitude after our contact he found out that they were listed incorrectly in the past. Anyway, the distance from KØALL to W1JR is still one mile further than the distance from KØALL to K1WHS, the previous record. This points out only too clearly the importance of verifying your longitude and latitude with the greatest of care. Enough said.

432 MHz. After several years of trying, I've finally verified the exact location of WØLER who was on one end of the longest documented 70-cm meteor scatter contact. As a result, that record distance has increased about two miles and will be reflected in the updated table.

Tropospheric records. Warmer weather typically brings good tropospheric propagation in North America. It also encourages lots of expeditions to the seacoast and the mountaintops. Expect to see lots of record attempts during these months.

This year was no exception. In fact, I think I was aware of more record attempts this past summer than a year ago — despite the fact that it's getting more difficult to find a record to break. Many of these expeditions were successful.

220 MHz. The tropospheric record on this band stood for a long time but it has now been broken. On September 9, 1988 there was some peculiar tropospheric ducting from Arkansas to some of the mountaintop stations in New England. Those of us who live at lower elevations in New England listened carefully, but the signals were going right over our heads!

At the same time hurricane Florence was whirling around just south of New Orleans, Louisiana. This apparently contributed to the very high barometric pressures in the Northern and East-

ern United States, and fed lots of warm moist air northward from the Gulf of Mexico.

At 0340 UTC Dave Olean, K1WHS, West Lebanon, Maine (FN43MK) and Rick Roderick, K5UR, Cabot, Arkansas (EM35WA) worked on 2 meters with good signals. Then they moved up to 220 MHz and quickly worked each other on CW at 0346 UTC with 559 to 579 signals.

The distance, 1267 miles (2039 km), is an extension of 85 miles over the previous record. Dave was running 1500 watts to four 17-element "Boomers" stacked vertically; Rick was running about 135 watts to a single Yagi of the same type.

3456 MHz. When you move up into the microwave bands, especially above 2450 MHz, it takes lots of luck to find a distant station at a record distance. Expeditions are usually organized to break the DX records. On August 7, 1988 Loren Libby, KXØO/Ø, traveled up to the top of Pike's Peak, Colorado (DM78KU) at 14,110 feet above sea level (see **photo A**)! At 1700 UTC he completed a CW contact on the 9-cm band with Dan Osborne, WB5AFY, Vernon, Texas (EM04ID) for a new DX record of 455.5 miles (733 km). Signals were 8 to 12 dB out of the noise in a 2-kHz bandwidth. Loren was running 13.5 watts into a 32-inch diameter dish and Dan was running a TWT at 250 watts to a 6-foot dish.

5760 MHz. Jim Crew, WA5ICW, and Larry Nichols, W5UGO, were also out traveling. In July, they were in the South Central states working portable on the 5-cm band. They regularly use 4-foot dishes for record attempts, but this time they decided to think big. Both brought along 10-foot dishes on trailers!

On July 9, 1988, Jim set up near Boise City, Oklahoma (DM86SR) and contacted Larry operating near Sand Springs, Oklahoma (EM16WD) on 5760 MHz using SSB — a new record distance of about 351 miles (564 km). The power was 5 watts with 10-foot dishes at each end. Signals were 30 dB over S9, despite a thunderstorm near the midpoint between their stations.

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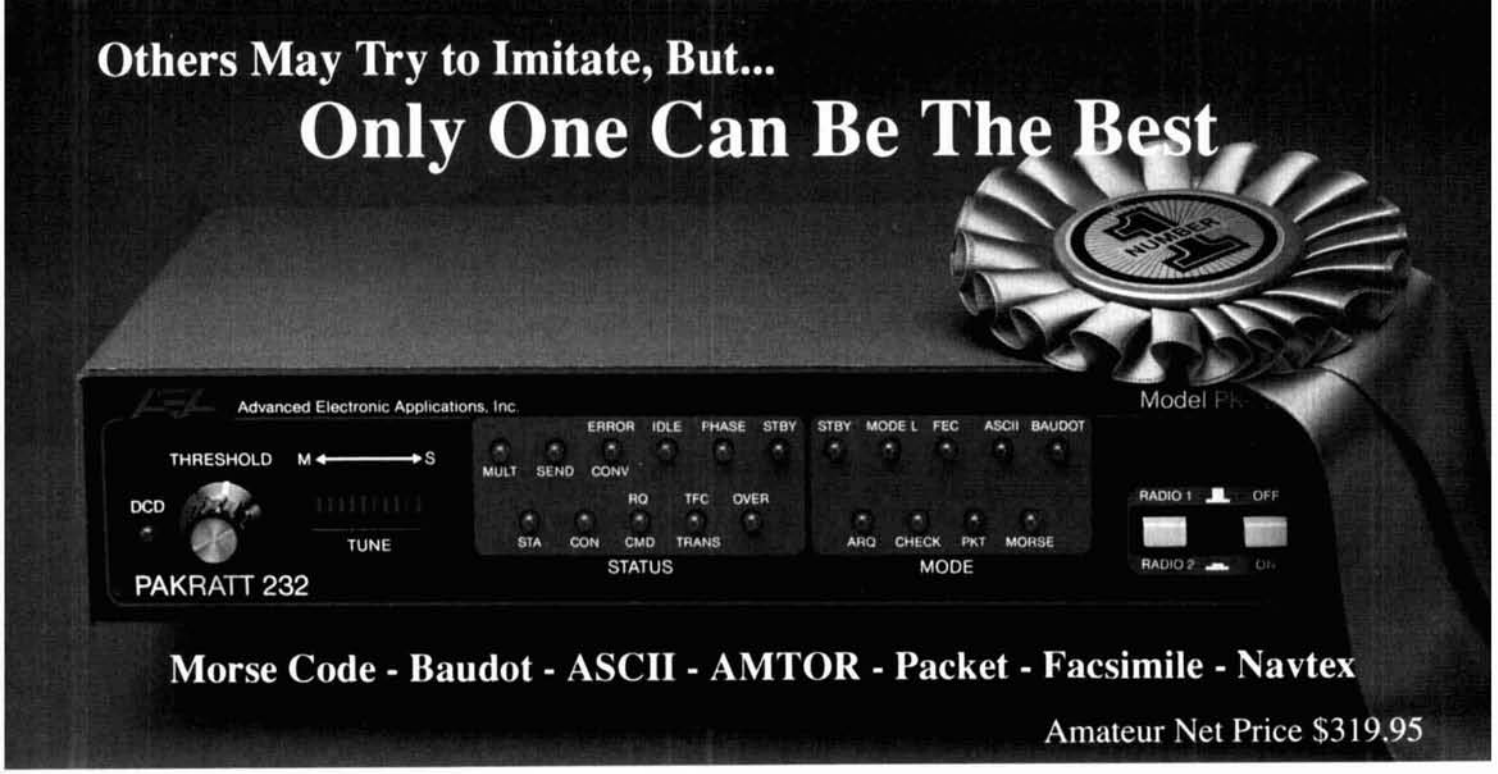

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PHOTO A

This photograph shows Loren Libby, KX0O, operating from the top of Pike's Peak near Colorado Springs, Colorado while setting the new 3456-MHz DX record.

PHOTO B

One of the participants in the new 5760-MHz DX records was WA5ICW using his 10-foot "portable" dish setup near Moses, New Mexico.

PHOTO C

The 10- and 4-foot dishes setup by W5UGO near Sand Springs, Oklahoma.

PHOTO D

N5JJZ and a 4-foot dish setup near Broken Arrow, Oklahoma.

Not satisfied with their record and the strong signals, Jim drove further westward to a location near Moses, New Mexico (DM86LR). Then about 1200 UTC on July 10, 1988, he worked Larry again for another new DX record at a distance of about 377.4 miles (607 km). Signals were 30 dB over S9. Larry then tried a 4-foot dish and signals dropped to 10 dB over S9. Still not satisfied, Larry changed his antenna to a small test horn and signals were still S9!

Then at 1256 UTC Jim broke the new record once more. This time he contacted Scott Brillhart, N5JJZ, Broken Arrow, Oklahoma (EM26CB) — a new record distance of 404 miles (650 km). Signals were S9 on SSB. Scott has a 4-foot dish and runs 5 watts. **Photos B, C, & D** show some of the setups used to make these new DX records.

10 GHz. Meanwhile, 3-cm expeditions were operating on both the Eastern and Western United States coasts. On July 10, 1988, a group of San Diego microwavers set out to break a new DX record using wideband FM (WBFM) on 10.250/10.280 GHz. The southern end of the path was operated by N6CW/XE2GDK, K9VV/XE1FUX, WA5LIG/XE2GBO, K6JYO, and N6XQ operating at various locations on Baja California Sur, Mexico (DM10/DM11).

Operating under the callsign XE2GDK and running at only 10 mW of WBFM into a 4-foot dish, they worked W6OYJ at 80 miles, WB6NOA at 176 miles, W6KGS at 216 miles, N6CA at 265 miles, and W6CPL at 280 miles.

Next XE2GDK operated from San Quinton, Mexico (DM20), and worked N6CA/6 just north of Santa Barbara, California (DM04) at a distance of 356 miles. A few minutes later XE2GDK worked their longest DX, Gary Field, NN6W/6, located about 10 miles northwest of Santa Barbara (also DM04) at a distance of 358 miles. NN6W/6 was running 15 mW into a 19-inch dish.

All the stations in these tests were operating Gunnplexers® full duplex using 30-MHz i-fs. While these contacts weren't DX records, they were WBFM records and came pretty close

to the narrowband record. Stay tuned; there's more to this story.

Other California 3-cm narrowband enthusiasts were out trying to extend the 1987 mountaintop records. On August 6, 1988 at 1156 UTC (4:56 AM PDT!), Bruce Erickson, WBØHLC/6, operating from Frazier Mountain, California (DM04MS) — one end of the previous DX record — completed a CW contact with Lynn Rhymes, WB7ABP/P on Bonanza King Mountain, California (CN81QB). This set a new North American DX record of 479 miles (770 km). At 1300 UTC the signals were strong enough that they used SSB.

Bruce was running about 700 mW to a 32-inch diameter dish and Lynn was running the same power into a 48-inch one. Bruce reports that he now has an FSK (1100 Hz shift) beacon on 10.36802 GHz in operation atop Mt. St. Helena, CM88QQ. The beacon runs 10-mW ERP to a vertical omni antenna and 120-watts ERP to a 12-inch dish with horizontal polarization aimed at a 142-degree heading intercepting the Diablo, Pinos, and Frazier Mountains to the south.

During early August, several stations in the Northeastern United States were trying long-haul coastal tropo on 3-cm using narrowband systems. One station was set up on Cape Cod, Massachusetts (near FN51AQ) looking to the southwest down the Atlantic coastline. Unfortunately the ducts didn't cooperate, so they were unable to work beyond about 200 miles. Others may try this path shortly.

During the September VHF contest, several members of the San Diego microwave group I mentioned earlier decided to try another attempt for the 3-cm DX record. This time one group traveled further south and operated from a site at 750-feet ASL near Guerrero Negro, Baja California Sur, Mexico (DL27VL). You can spot this location easily on the ARRL grid map[8] — it juts way out from the peninsula.

On September 10, 1988, at about 1545 UTC, XE2GFH (N6XQ and WA5LIG, operators) worked Chip Angle, N6CA/6 at Palos Verdes, California (DM03TS) for a new North American 3-cm DX record of about 498 miles. Both stations used 4-foot dishes and WBFM Gunnplexers at 80 and 10 mW, respectively. Shortly thereafter, AA6Q, WA7CGR, and WA6MEM joined Chip at Palos Verdes, and also worked XE2GFH with 10 to 50 mW and antennas as small as a 17-dB gain horn!

Not to be outdone, Chip then moved north to Beverly Hills, California (DM04SC) to an elevation of 2000 feet ASL and tried to extend his record. At 2200 UTC the record was extended to 522 miles! Signals were up to 25 dB out of the noise on peaks.

Meanwhile, Gary Field, NN6W/6 was operating near Santa Ynez Park, California (CM94XM) at a 3000-foot elevation and heard XE2GFH most of the day. However, XE2GFH couldn't copy him well enough on voice to complete a contact.

Finally at 0004 UTC on September 11, they made a complete contact using MCW for a new 3-cm DX record of 595.3 miles (958 km). Gary was running 15 mW with a 30-inch dish.

These primarily over water extended contacts bring up an important point. For some time I've been wrestling with a few critics about the differences in my designation of ducting and tropo as shown on the North American records table between 144 and 1296 MHz.

I feel strongly that contacts that are at least 75 percent over water have an unfair advantage on 2 meters and above, because low-attenuation ducting is often present (not to mention the normal superior refraction index over large bodies of water).[6] The path from California to Hawaii is the principal example. For this reason, I have treated over-water contacts as a separate category to avoid discouraging or competing directly with overland tropospheric records.

To further clarify this point, I'll be modifying the tables slightly. The tropo records previously shown will remain, but they'll be reclassified as Tropo OL (over land). Those contacts shown as ducting (which are at least 75 percent over water), will now be designated as Tropo OW (over water).

This, in effect, will open up a new category for records on all bands above 1300 MHz. But, in order to qualify for the tropo OW record, you'll have to exceed the distance of the tropo OL record on the respective band. Fair enough? I invite your comments.

47 GHz. Meanwhile, during the ARRL UHF contest, the microwavers up in the Northwestern United States were also active and trying to beat their own 47-GHz record. Tom Hill, WA3RMX/7, set up at Crater Lake, Oregon (CN82VW) and the Tektronix Radio Club operating as K7AUO/7 (W7ADV, K7RUN, and WA7GFP, operators) was on Mt. Ashland, Oregon (CN82PB). Both stations were at approximately 7300 feet ASL.

At first there was cloud cover at Mt. Ashland and no signals were copied. However, at 2145 UTC on August 6, 1988 the clouds lifted, the path was visually clear, and CW reports were exchanged. Shortly thereafter, the signals increased in strength and SSB communications were used.

The equipment involved was all designed and built by Tom Hill using a combination of surplus, new, and homebrew components and converters. At Crater Lake the power was 3.5 mW to a 28.5-inch dish. At Mt. Ashland the power was 4.3 mW into an 18-inch dish. Both stations operated on 47.040035 GHz (USB).

This new DX record is quite an achievement. The distance is 65.4 miles (105.2 km) — a significant increase over the previous one. In addition, this record exceeded the old worldwide record by about 25 percent. The contact was made using narrowband systems and on SSB. It's probably the highest frequency where two-way communication has ever been conducted using SSB, especially at this distance.

Summary

This month I've discussed how VHF/UHF and above DX records are made, along with their relative impor-

tance to Amateur Radio and the SOA. I also reviewed some of the most recent record-breaking contacts using ionospheric and tropospheric propagation.

Next month's column will discuss recent EME and light wave DX records. At the conclusion of February's column, I'll give you the latest updated DX record tables.

Final notes: Some important matters such as "band plans" and the restructuring of our 220 to 225-MHz band have recently occurred, but will have to wait until later. In the meantime, please examine the present ARRL band plan for the 220 to 225-MHz band (shown in recent *ARRL Repeater Directories).*[10]

You'll notice that I reserved the spectrum from 222.0 to 222.3 MHz when I chaired the writing of this band plan back in 1978! In the event that the FCC does remove the 220 to 222-MHz portion of the band, and if no Amateurs violate the existing band plan, 222 to 222.3 MHz would still be available for "protected" weak signal operation away from FM repeaters.

Feedback: In the October 1988 column of "VHF/UHF World" two graphs were mistakenly reversed, changing the meaning of the information that followed. To correct this, interchange graphs "C" and "D" in **fig. 1** on page 72.

Important VHF/UHF events:

December 21	*± 1 month. Winter peak of sporadic-E propagation*
December 22	*Predicted peak of the Ursids meteor shower at 0330 UTC*
January 4	*Predicted peak of the Quadrantids meteor shower at 0030 UTC*
January 6	*New moon*
January 10	*EME perigee*
January 14-16	*ARRL VHF sweepstakes contest*

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ELMER's NOTEBOOK

Tom McMullen, W1SL

Transistors and how they work

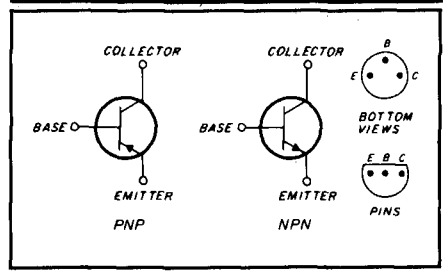
Transistors have been with us long enough that almost everyone has had some exposure to them in electronic equipment of one type or another. Almost any piece of radio gear around today contains some of these devices. Many new Amateur transceivers are totally dependent upon some transistors or semiconductors for their operation. When these devices first became commercially feasible, many articles were published explaining how the tiny bits of metal and plastic worked and what was inside their miniscule packages. I won't go into the "conventional" explanation involving holes, electron pairs, valence bonds, and all the rest — we're not interested in building transistors, just understanding how they work.

Transistor types

Transistors are divided into two basic classes: bipolar and field effect. I'll stick with bipolar types for this month, and look at field-effect transistors some other time. (There are several variations on these themes — devices called MOSFETs, IGFETs, junction transistors, unijunction transistors, mesa transistors, planar transistors, etc. I'll just cover the basic types here.)

In the bipolar transistor category, there are two types once again: NPN and PNP. These type designations reflect the makeup of the layers of semiconductor material in the transistor. **Figure 1** shows the schematic symbols for NPN and PNP transistors, plus the most common pin arrangements for either type. Knowing which is which can help when you're troubleshooting a piece of equipment without a schematic. I've always used a couple of trick phrases to identify them and note the appropriate polarity of their supply voltage.

FIGURE 1



Schematic symbols for NPN and PNP transistors, along with the most common pin or lead arrangements for either type.

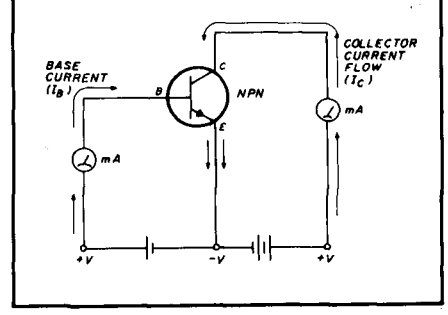
Look at **fig. 1**. There is an arrowhead drawn on one of the lines inside the symbol. This represents the emitter of the transistor. I use this arrowhead as the clue to the transistor type: **N**ot Pointing i**N** tells me that is an NPN transistor. Pointing i**N** Positively indicates a PNP transistor. These type designations (NPN and PNP) also give a clue to the voltage polarity that is applied to the collector. Use the center letter of the type designation as the indicator — n**P**n tells you that the collector is connected to the Positive (+) side of the supply (through resistors, transformers, RF chokes, etc.). In the other type — p**N**p — the collector is connected to the Negative (−) potential. (This, too, can be through transformers, resistors, RF chokes, or whatever.)

How do they work?

Bipolar transistors are current-amplifying devices. This means that a current made to flow into their input terminal (see base current in **fig. 2**) will directly affect the flow of current in the output circuit (the collector and associated components). Both base and collector currents flow through a common element, the emitter. The names of the emitter and collector elements describe what they do — the emitter emits electrons, and the collector collects them. But what in the world is a "base?"

This term comes from an early transistor design in which a base layer of semiconductor material was deposited

FIGURE 2



Base current (abbreviated I_B) through the base/emitter circuit causes a greater current (I_C) to flow through the collector/emitter circuit.

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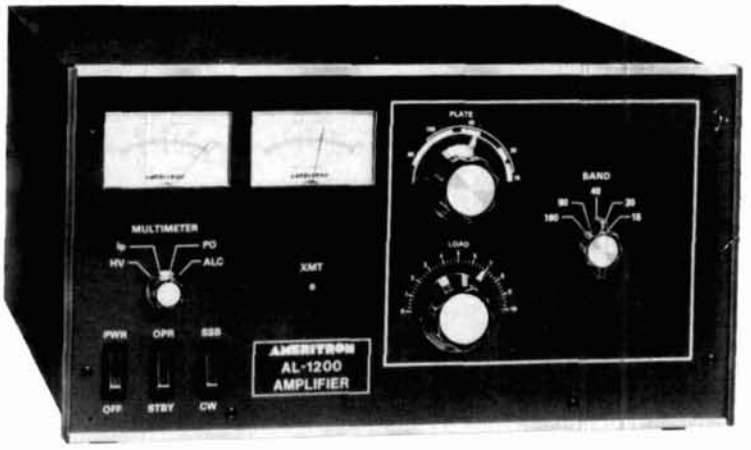

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AL-1500 LINEAR AMPLIFIER

8877 TUBE

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on some type of insulator, and then a slightly different type of material was deposited on the base layer to form the emitter and collector. The emitter and base layers function very much like a diode — in fact, some applications use the diode action of these two layers as part of a circuit design. One that comes to mind is a temperature-compensating circuit that maintains the correct bias in a power-amplifier circuit.

Transistors are low-impedance devices because they operate on current flow. This may be a new experience for those familiar with the old vacuum-tube technology. The input to the grid of a tube is high impedance, usually in the thousands of ohms. It's not unusual for the input impedance to a power transistor circuit to be in the single digits, or even less than 1 ohm. Even low-power amplifiers for audio or RF signals can have input impedances in the range of tens to hundreds of ohms.

This is where circuit designers earn their keep. Instead of a simple parallel-resonant circuit, you need a series-resonant circuit with a low-impedance output, or a combination of L/C networks that will provide impedance matching and selectivity at the same time. Considering the savings in space and power consumption, it's a very good tradeoff.

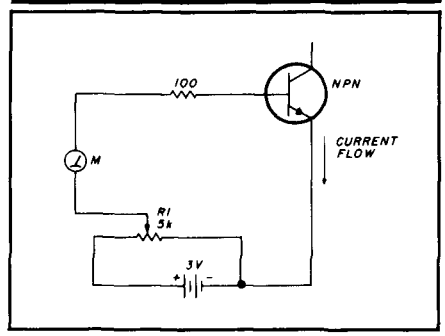
An experiment

All this looks good on paper, but what happens when you hook one of these devices up? I decided to try a simple experiment to find out. (I did the same thing with Ohm's law years ago. I found a precision 1-ohm resistor and hooked it to a 1-volt supply to see if Georg was right. He was!)

The transistors I used are garden-variety types available from flea-markets, supply houses, or mail-order firms in plastic packs of 10 or 20 for $1. My package was marked "2N2222 equivalent." I used common AA cells as the power source, along with a couple of milliammeters and a handful of clip leads.

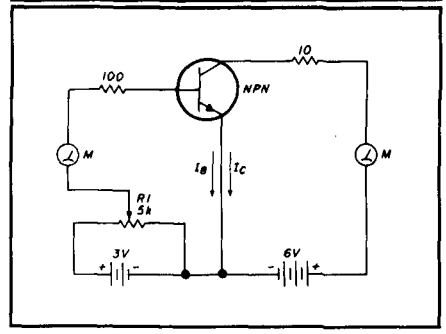
I first tried to see if the emitter/base part of a transistor was really a diode. Using the hookup shown in **fig. 3**, I measured the current flow with the positive voltage connected to the base through a 100-ohm current-limiting resistor. Sure enough, a small current began to flow as I changed the value of R1 to place voltage on the base. The current was approximately 20 μA at 0.45 volt and increased with voltage up to the point where 0.7 volt produced 2 μA of current. I stopped there rather than risk burning out the base/emitter junction. I then reversed the voltage polarity; the current flow was almost nonexistent. Increasing the voltage up to the full 3 volts of the supply produced only 30 μA. Diode action was confirmed. (You can perform this same experiment using an ohmmeter if you're sure which lead of the meter has the positive (+) voltage.)

FIGURE 3



The base/emitter junction can be tested with this setup. For most small transistors, the meter can be 0–100 μA. Check for reverse leakage by reversing the polarity, just as in a diode.

FIGURE 4



Setup used for checking collector current versus base current. The base-current meter was 0-100 μA, and the collector-current meter was a switchable VOM on the 0-10 and 0-100 mA ranges.

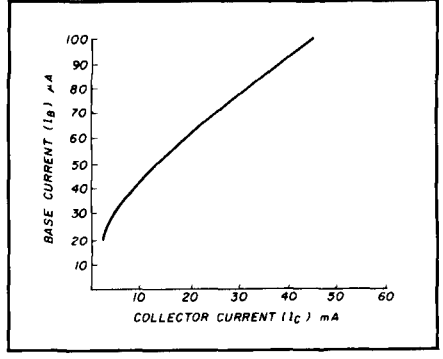
Now that you've explored the base/emitter theory, it's time to try the rest of the device. It takes a few more clip leads, a second milliammeter, and another resistor. The setup is shown in **fig. 4.** (I always use current-limiting resistors or fuses when experimenting — major meltdowns on the workbench are messy and the smoke sets off alarms all over the house!)

I found that increasing the current through the base by varying the value of R1 does indeed cause current to flow in the collector circuit. Two mA of collector current flowed with 20 μA of base current. Increasing the base current up to 100 μA caused a collector current of 45 mA. I stopped at that point because the transistor was getting warm to the touch. **Figure 5** is a graph of base current versus collector current.

Once again, the theory seems to fit what the experiment has shown. (Or is it the other way around?) — Bipolar transistors are current-manipulating devices. Where does the name "bipolar" come from? There are two kinds of material in the makeup of the transistor: P-type and N-type. The arrangement of those two types in the "sandwich" determines whether the device is PNP or NPN.

I performed the same experiment on an equally unknown PNP transistor and, once again, it worked just as the theory said it would. I had to reverse

FIGURE 5



A plot of base current and collector current measured using the setup of *fig. 4*. Be aware that some exotic UHF or low-noise transistors can't stand this type of test. If you experiment, use inexpensive or surplus devices. *(continued on page 100)*

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A 3456 MHz LINEAR TRANSVERTER

By Dave Mascaro, WA3JUF, RD 1 Box 467, Ottsville, Pennsylvania 18942

Over the past few years Amateur microwave activity in the United States has increased dramatically. Many operators active on 1296 MHz have put their stations on the 2304-MHz band. Stations work 10-GHz SSB/CW, as well as wide-band FM with Gunnplexers®There's more commercial equipment available for all bands up to 10 GHz. Homebrewers are using surplus TV receive only (TVRO) and outdated commercial equipment to build up to the next higher band, 3456 MHz.

As with other bands up to 2304 MHz, the main modes of communications on 3456 MHz are CW and SSB. There are many ways to generate RF power on this band — both CW and linear. Frequency multipliers with step recovery diodes (SRD) and active multipliers are used for CW, FM, beacon transmitters, and local oscillators. You can use linear transverters for SSB/CW and all other modes, just like on the 50 through 2304 MHz bands.

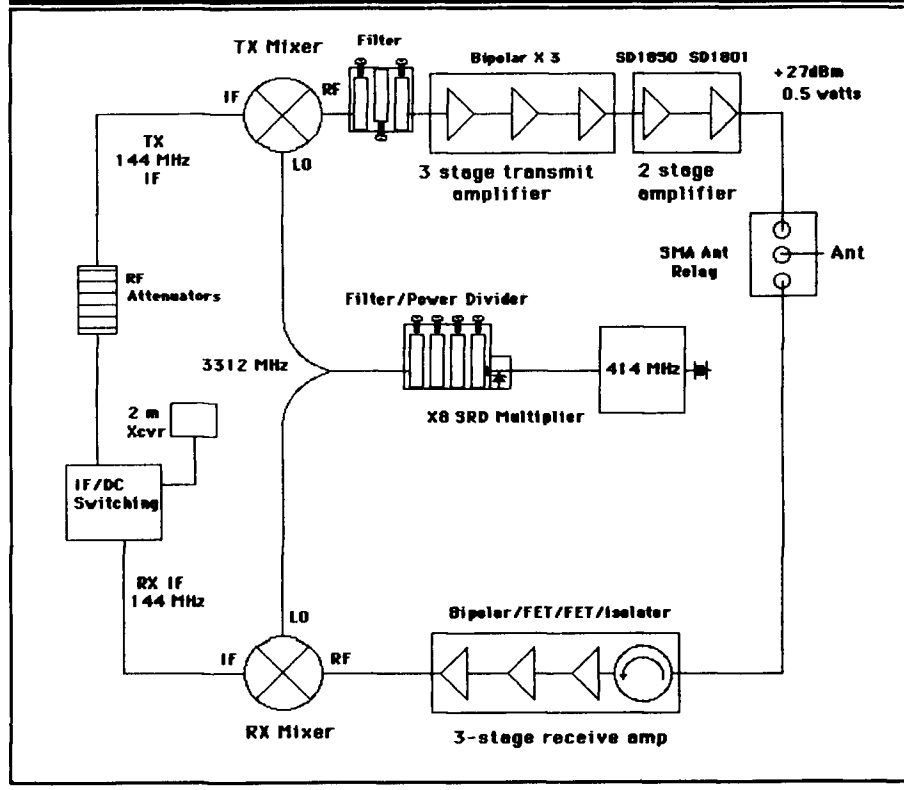
Figure 1 shows the block diagram of a 144 to 3456-MHz transverter. The transverter transmit and receive mixers use a common local oscillator at 3312 MHz. The 144-MHz transmit i-f is mixed with the local oscillator to produce 3456-MHz transmit signals. During reception, the 3456-MHz receive signals are mixed with the local oscillator to produce the 144-MHz receive i-f signals. A 2 or 3 section interdigital filter follows the transmit mixer to attenuate out the local oscillator and image frequencies.[1,2]

I didn't use a 144-MHz i-f post amplifier after the receive mixer. Unlike the 28-MHz "front end" in an HF transceiver that is normally used for a transverter, modern 2-meter transceivers have good front ends with plenty of gain. A post amplifier only makes the resting S-meter readings higher. The system noise figure is established in the 3456-MHz LNA.

Receive portion

Receive signals from the antenna relay are amplified by one-half of a modified TV receive only low-noise amplifier (TVRO LNA). The other half is used in the transmit portion of the transverter. My first modification involved installing an SMA antenna connector in place of the waveguide antenna input.[3] Normally a scalar-type feed horn is attached

FIGURE 1



Block diagram of a 144-MHz to 3456-MHz linear transverter.

directly to the LNA when used in a satellite receiving system. A feedthrough cap is also installed to bring + 15 Vdc into the LNA housing without using an external bias-T attached to the output "N" connector.

Split TVRO LNA

The greater than 50-dB gain LNA is modified again to make two separate three-stage amplifiers. The amplifier I use is the Amplica model ACD 305331 (90 degree) LNA. The 305331 LNA has two GaAsFET stages followed by four bipolar stages and a filter. **Figure 2** shows the "split-in-half" LNA. The transmit amplifier portion provides greater than 20-dB gain. There is greater than 30-dB gain and a 2-dB system noise figure in receive mode.

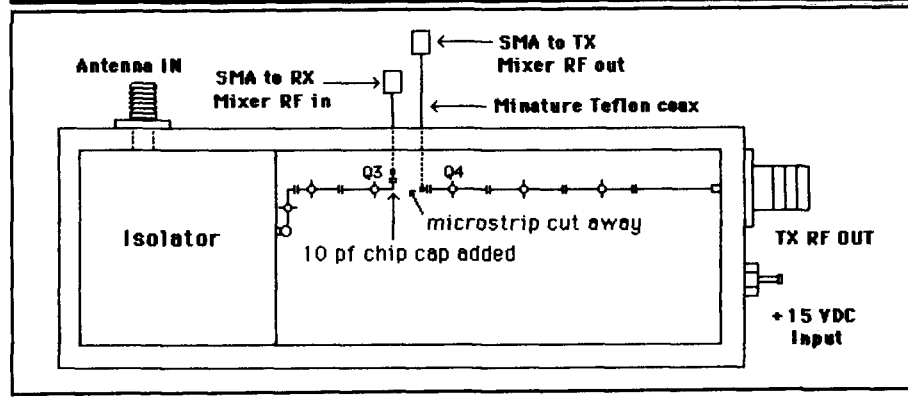
I modified the LNA by wiring two miniature 50-ohm Teflon® coax cables fitted with SMA male connectors into the amplifier between the third (Q3) and fourth (Q4) stages. The two coax cables should be long enough to go from inside the LNA and connect to the receive and transmit mixers in your transverter. Cut away the microstrip at the interstage DC blocking capacitor to create a gap in the line. Solder a 10-pF chip cap to the output line of stage Q3. This becomes the receive amplifier output. The existing DC blocking chip capacitor becomes the input of the transmit amplifier chain.

Open the other compartment of the LNA. Drill two holes and run the miniature coax through the holes into the compartment. Now drill two small holes in the pc board beside each of the two DC blocking capacitors to pass the coax cable center conductors. Solder the center conductors to the blocking chip caps and solder the shield of each cable to the ground plane at the point where the cable goes through the pc board. The shield relieves strain on the cable, so the chip caps don't break. Apply a dab of RTV or silicone bathtub seal where the cables go through the housing to increase the strain relief and moisture proof the LNA.

You now have two separate amplifiers. The stability of the receive front end is maintained because the input isolator is still intact. It's okay to leave the + 15 Vdc applied to the LNA; the front end won't oscillate into the open antenna relay during transmit. The LNA has an on-board 7812 voltage regulator, so you can use input voltages from 15 to 28 Vdc.

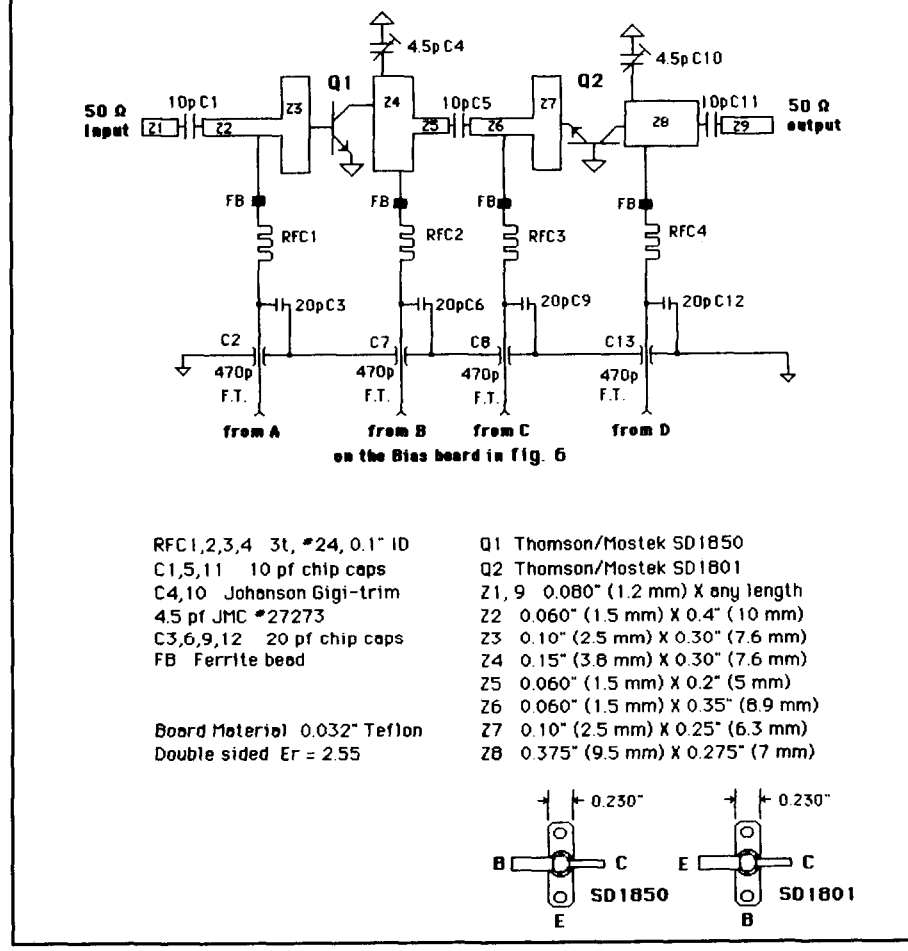
The receive amplifier output feeds the RF port of the receive mixer. The Mini-

FIGURE 2



A split TVRO LNA showing two separate 3-stage amplifiers.

FIGURE 3



RFC1,2,3,4 3t, #24, 0.1" ID
C1,5,11 10 pf chip caps
C4,10 Johanson Gigi-trim
4.5 pf JMC #27273
C3,6,9,12 20 pf chip caps
FB Ferrite bead

Board Material 0.032" Teflon
Double sided Er = 2.55

Q1 Thomson/Mostek SD1850
Q2 Thomson/Mostek SD1801
Z1, 9 0.080" (1.2 mm) X any length
Z2 0.060" (1.5 mm) X 0.4" (10 mm)
Z3 0.10" (2.5 mm) X 0.30" (7.6 mm)
Z4 0.15" (3.8 mm) X 0.30" (7.6 mm)
Z5 0.060" (1.5 mm) X 0.2" (5 mm)
Z6 0.060" (1.5 mm) X 0.35" (8.9 mm)
Z7 0.10" (2.5 mm) X 0.25" (6.3 mm)
Z8 0.375" (9.5 mm) X 0.275" (7 mm)

The 2-stage 3456-MHz linear amplifier.

Circuits ZFM-4212 and ZAM-42* are suitable mixers because they are fitted with SMA connectors. The pc board mounted PAM-42 is also a good 3456-MHz mixer. I used the Anzac MD-169 (normally pc board mounted). I enclosed it in a homemade brass housing fitted with SMA connectors.

You can peak the receive amplifier in a noise figure set-up by tweaking the miniature trimmers mounted throughout the LNA. Gain can be maximized at 3456 MHz.

Another application for a split LNA in a transverter involves using one half to amplify the very low output of a 3312-MHz schottky diode multiplier for the local oscillator, and the other half to amplify the transmit mixer SSB output. Try using a second modified 50-dB gain TVRO LNA for the receive amplifier. This approach worked very well for me.

Transmitter stages

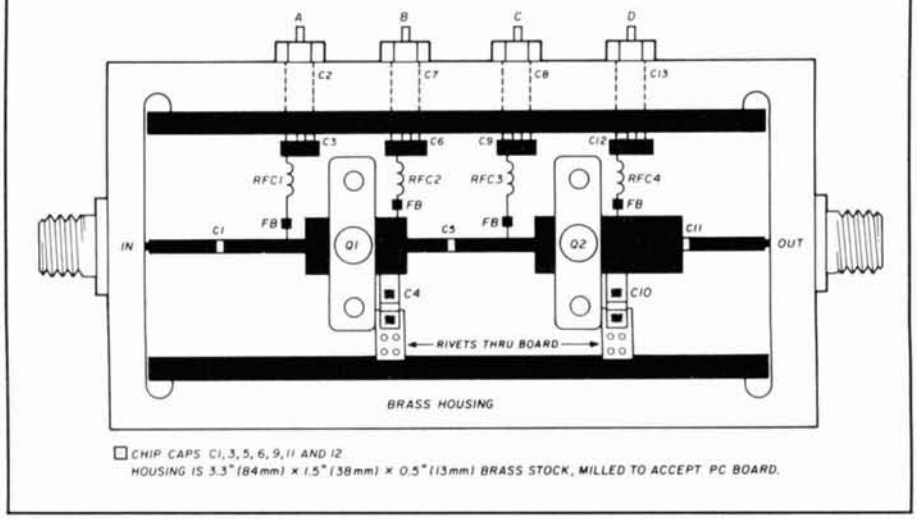
You can use the same type of mixer for the transmitter as you did for the receiver. I used the MD-169. The output of the transmit mixer (usually −10 dBm or so) is amplified by the second half of the split LNA, which provides +10 dBm (10 mW) output. The three bipolar stages and filter provide an excellent linear amplifier for low-level signals.

Two-stage linear amplifier

A two-stage linear amplifier, providing 20-dB gain and +27 dBm (500 mW) power output at 1-dB compression, follows the modified TVRO amplifier. The amplifier is shown in **fig. 3**. It was built into one enclosure to eliminate two SMA connectors, and to reduce its overall size. The amplifier is built on 1/32″ Teflon double-sided pc board (Er = 2.55), using microstrip matching networks (see **figs. 4** and **5**). Although the two stages are etched on one pc board and housed in the same enclosure, you can build two separate amplifiers. The DC blocking capacitor (C5) is mounted in a 50-ohm line; the two stages could be separated at this point. Use DC blocking capacitors on the input and output of both stages.

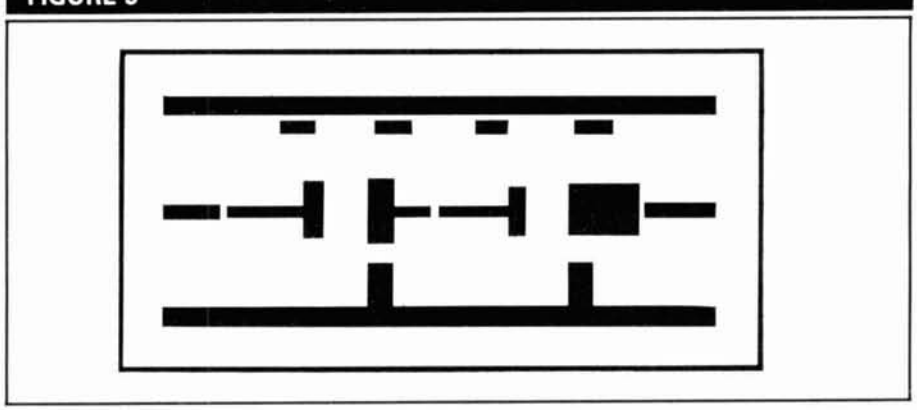
*Mini-Circuits, P.O. Box 166, Brooklyn, New York 11235, (718) 934-4500.

FIGURE 4



Component placement of the 2-stage 3456-MHz amplifier. All components mount on the trace side of the pc board.

FIGURE 5



Full scale artwork for 2-stage amplifier on 1/32″ Teflon® double-sided pc board. Er = 2.55. Opposite side (ground plane) is unetched.

Make all DC and RF grounds low inductance paths through to the ground plane side of the Teflon pc board. Do this by putting multiple rivets through to the ground side. Another method is to cut small slits into the board with an Xacto® knife, and insert and solder strips of copper foil on both sides.

All the amplifiers I build for 1296 MHz and up are constructed from milled-out brass housings. I solder the Teflon pc board into the brass enclosure, and mill two slots in the brass housing to accomodate the flanges of the two transistors. The bypass capacitors and tuning trimmers are mounted on the pc board close to the board edges. This allows direct connection to the brass housing and provides good DC and RF grounding. Holes drilled in the brass box enable you to externally tune the unit with a plastic tuning tool.

The input and output connectors of an amplifier should also be soldered to the ground plane side of the pc board. In my amplifier, I attached the two SMA connectors to the brass box with 2-56 screws and then soldered them permanently. I performed this step on a hot plate when I soldered the pc board in place. You could also solder the connectors on the ends of the pc board in a "launcher" configuration with the center pins of the connectors mounted and soldered parallel to the microstrip.

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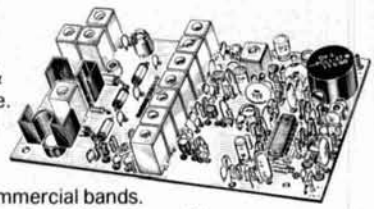

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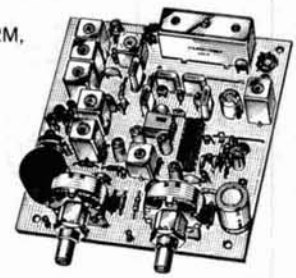

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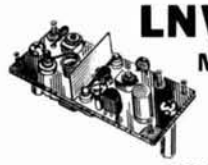

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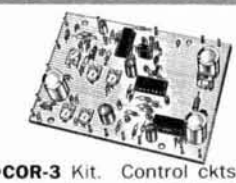

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		222-224	28-30
UHF MODELS		432-434	28-30
Kit with Case	$69	435-437	28-30
Kit less Case	$49	432-436	144-148
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105	117	129	141	153	165	177	189	201	213	225	237	249	261	273	285	297	309	321	333	345
106	118	130	142	154	166	178	190	202	214	226	238	250	262	274	286	298	310	322	334	346
107	119	131	143	155	167	179	191	203	215	227	239	251	263	275	287	299	311	323	335	347
108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288	300	312	324	336	348
109	121	133	145	157	169	181	193	205	217	229	241	253	265	277	289	301	313	325	337	349
110	122	134	146	158	170	182	194	206	218	230	242	254	266	278	290	302	314	326	338	350
111	123	135	147	159	171	183	195	207	219	231	243	255	267	279	291	303	315	327	339	
112	124	136	148	160	172	184	196	208	220	232	244	256	268	280	292	304	316	328	340	

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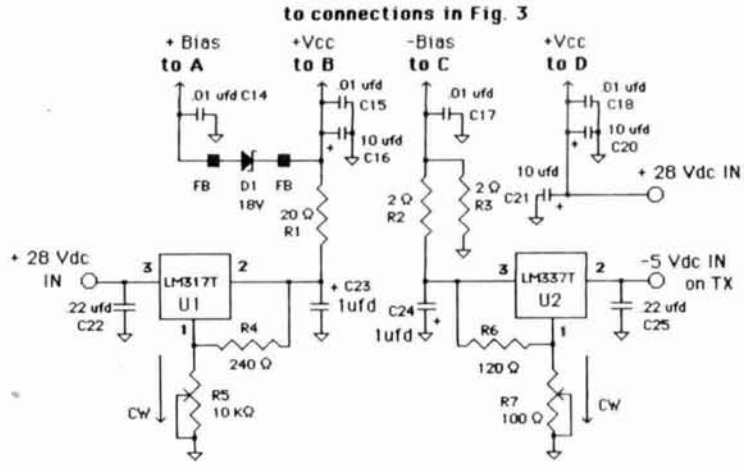
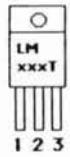
FIGURE 6



Resistors are 1/4 watt except where noted

C16,20,21 10 ufd/35 Vdc electrolytic
C23,24 1 ufd/35 Vdc Tantalum
D1 1N5248B 18 V/500mw zener diode
R1 20 Ω 1/2 watt
R2,3 2 Ω 1/2 watt
R5 10 KΩ minature pc mount pot
R7 100 Ω minature pc mount pot
U1 LM317T Positive regulator
U2 LM337T Negative regulator
FB Ferrite beads



LM317T
1-adjust
2-Vout
3-Vin

LM337T
1-adjust
2-Vin
3-Vout

Bias sources for the 2-stage 3456-MHz linear amplifier. Both regulators are mounted on a heatsink with mica insulators, shoulder washers, and heatsink compound.

Amplifier biasing

The first amplifier stage (Q1) is a common emitter Thomson SD 1850 transistor,* operated as a Class A amplifier. The SD 1850 can be used as a 150-mW Class A linear amplifier from 432 to 3456 MHz. Q1 uses standard zener diode biasing. The second stage (Q2) is a Thomson SD 1801 transistor (a 1 to 2 watt/1 to 3 GHz CW transistor). Q2 is a common base transistor (operating Class AB), and requires a negative voltage for bias in addition to the 28-Vdc collector supply.

I have forward biased many common base devices in the past — many are being used on 1296 and 2304 MHz. In most cases linearity is as good as with a common emitter amplifier. Because microwave power output is at a premium, Amateurs running common base linear amplifiers usually run them closer to power saturation (P_{sat}), rather than in the linear region. This is why the amplifier may sound slightly rough. Other than a few local SSB ragchews, most communications on 2304 and 3456 MHz are on CW.

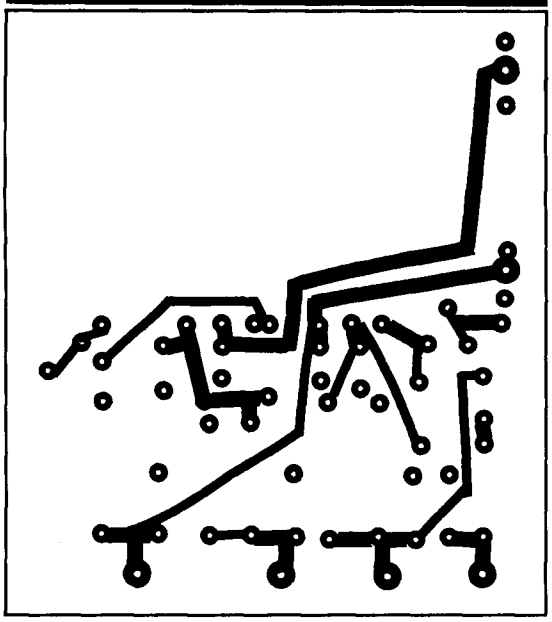
Low-power devices like the 1-watt SD 1801 are easy to bias linearly. Higher power devices like an SD 1597 transistor** require a little more care and a higher current bias source. A common base linear amplifier requires mainly that the bias source be of very low impedance. This is true for the −5 Vdc supply, as well as the associated components of the LM337T regulator. Use an LM337K for higher power common base amplifiers. The regulator in a TO-3 style case is capable of higher power dissipation.

The two bias sources in **fig. 6** were made on an etched G-10 double-sided pc board (shown in the **figs. 7** and **8**). All

*SGS-Thomson Microelectronics, Commerce Drive, Montgomeryville, Pennsylvania 18936, (215) 362-8500. All Thomson transistors are available through: RF Gain, Ltd., 100 Merrick Road, Rockville Centre, New York 11570, (516) 536-8868 and (800) 646-2322.

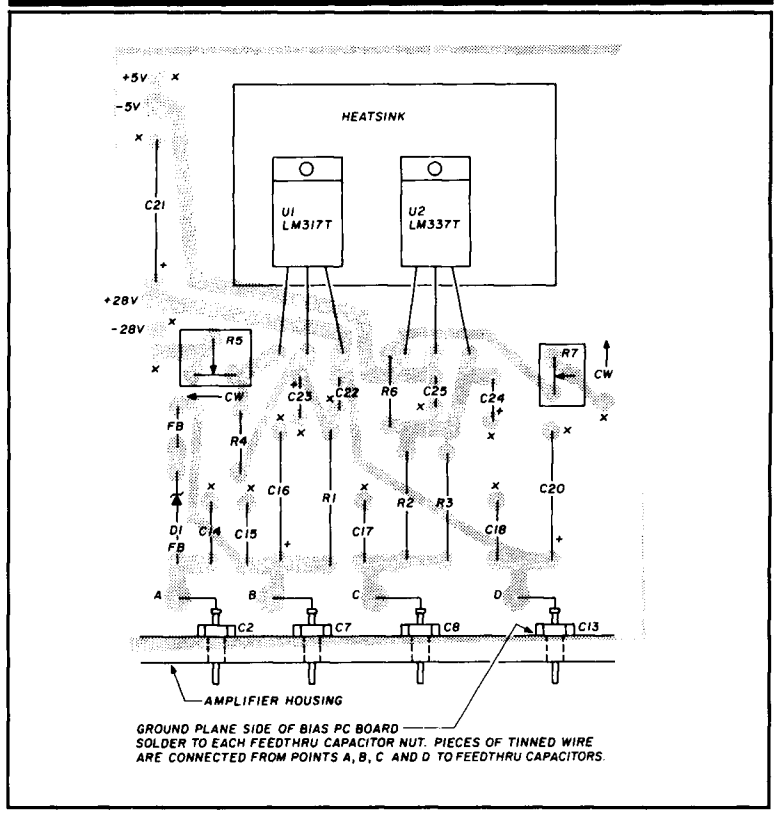
**The SD1597 is a Thomson 25 watt/1296 MHz transistor for Amateur applications.

FIGURE 7



Full-scale artwork of bias board. Etched side shown. Opposite side is the ground plane and is unetched. Board material is 1/16" (1.6 mm) G-10 double sided.

FIGURE 8



Component placement on the bias board, showing x-ray view of the traces. Parts are mounted on the ground plane side of the pc board, which is unetched. Clear all nonground holes on this side of the board. Solder all grounds on both sides of the board of points "x".

non-ground holes must be "cleared" on the unetched side to prevent component shorting. Begin by drilling the non-ground holes. Remove the copper by counterboring the holes with an oversized bit. Set the depth of the hole to about half the pc board thickness. Drill the ground holes last to prevent confusion about which holes get cleared. Solder components or wiring connected to ground on both sides of the board, as indicated by an "x" in **fig. 8**.

Solder the ground plane side of the pc board directly to the ground posts of feedthrough capacitors C2, C7, C8, and C13 as shown in **fig. 8**. Do this so that the bypass capacitors C14, C15, C16, C17, C18, and C20 will be close to the amplifier (where they will bypass RF most effectively). Use small-gauge tinned wire to connect the bias board to the feedthrough capacitors.

Two power-supply voltages (+28 Vdc and −5 Vdc) are supplied to the board. You can also build a power supply that provides all the positive voltages for a complete transverter (including this bias board).[4] An LM317T (U1) supplies a variable collector voltage for Q1. Adjust the collector voltage without power input (P_{in}), until the 18-Vdc zener diode conducts and biases on Q1. Set the optimum current while tuning the amplifier for power output.

I used an LM337T (U2) as the negative bias source for the output stage (Q2). The output voltage of U2 is halved by voltage divider R2-R3, because 1.2 Vdc is about as low as a three-terminal regulator will go. Note that the −5 Vdc supply must have a floating negative terminal. Peak the idling current while tuning for power output. The −5 Vdc is applied to the amplifier bias board during transmit only. This minimizes heating and possible oscillations into the open antenna relay during receive.

If maximum rather than linear power output (for a rover rig, for example) is a requirement, you could operate the second stage Class C with greater than 1-watt power output. This would eliminate the negative power supply (possibly a 6-volt Gel cell or lantern battery). You'd ground the emitter of Q2 by connecting RFC2 to ground. The microstrip dimensions would stay the same and the stage would be tuned up in the same manner as a linear one.

Tune-up

While I was tuning my amplifier, the two piston trimmer capacitors peaked at minimum capacitance. To bring the trimmers into range, I had to trim off some of the microstrip capacitors with an Xacto knife. I'd used the microstrip dimensions for some single amplifiers that I designed and built earlier. Not going out to 50-ohm connectors interstage produced slightly different impedance matching. Other than this, the amplifier came right up to power and gain expectations. The artwork in **fig. 5** reflects the microstrip dimension changes.

To tune this amplifier and most of others I've built, I used the following equipment: a Wavetek 2005 RF generator, HP435B power meters, and an HP spectrum analyzer (part of an RF test

station at Thomson). You'll need an RF generator and a "real" power meter to check linearity. Do this by changing the P_{in} in 1-dB steps, while looking for the same change in the output. Use the spectrum analyzer to check gain and linearity. Also look for spurious responses.

Now, set the quiescent current (idling current without power input). Attach a 50-ohm load to both the input and output connectors. Adjust both bias adjust pots (R5 and R7) for minimum voltage as measured on the output of U1 and U2. Do this before making connections to the amplifier, to prevent transistor damage. Adjust the Q1 collector current to 80mA with a current meter connected in series with the 20-ohm resistor (R1). Next, adjust the collector current of Q2 to 50 mA with a current meter in series with the collector supply feedthrough capacitor (C13).

Apply 5 mW of 3456-MHz RF to the amplifier input, with a power meter and spectrum analyzer attached to the output. Adjust the two trimmers (while looking at the analyzer and power meter) for maximum output.

The two-stage amplifier will produce maximum power output with 10 to 12 mW of drive. You can readjust the idling current on each stage slightly, under power output conditions for either maximum gain or maximum power output. It's possible to adjust the idling current of Q1 for 80 to 110 mA, and for Q2 up to 65 mA, for proper operation. The total current at 28 Vdc will be 200 to 250 mA when the two-stage amplifier is running at maximum power output.

My two-stage amplifier performed as follows:

Power output at 1 dBc +27.6 dBm (580 mW)/Gain = 19.8 dB

P_{sat} +29.3 dBm (850 mW)/Gain = 18.9 dB

Local oscillator

The local oscillator is probably the most important part of a transverter. It sets the transverter's frequency stability. The i-f frequency is usually very stable and accurate, because it's almost always a commercially made transceiver. Of course, all we're really interested in is the short-term stability. The actual frequency operated on at 3456 MHz can vary many kHz over normal temperature ranges. If you need the exact frequency (i.e., for schedules), use a frequency counter. If a 3.5-GHz counter is unavailable, measure a lower frequency stage of the local oscillator chain on a UHF counter. The 3312-MHz local oscillator frequency will give the 3456-MHz transmit/receive frequency.

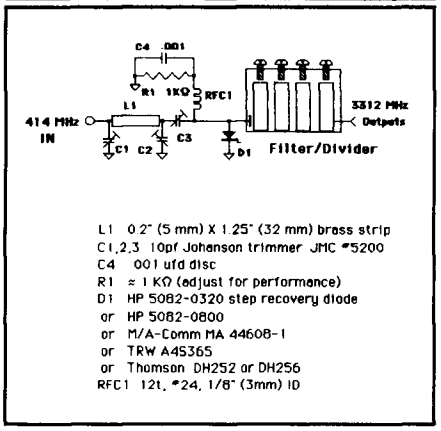
The local oscillator chain in my transverter starts out with a surplus 400-MHz telemetry transmitter strip, which uses a temperature-compensated crystal oscillator. You can find surplus crystal-controlled strips at flea markets; they make stable microwave local oscillator sources.

Step recovery diode multiplier

The 400-MHz module (crystalled up for 414 MHz) drives a X8 step recovery diode (SRD) multiplier (**fig. 9**). The multiplier functions as follows: A pi-network input circuit is used between the 414-MHz module and the SRD, to provide some impedance matching into the diode at 414 MHz. The output of the pi-network (C3) connects directly to the input of the SRD holder. The SRD provides a comb output, consisting of many harmonics of the 414-MHz driving signal. The RF is coupled into the 4-pole comb filter, which filters out the wanted signal (3312 MHz). Dual SMA connectors on the filter output provide the local oscillator signal to both mixers in the transverter.

Most SRDs are packaged without wire leads and require special clamp-type holders for mounting and heat sinking. You can make a brass housing to hold the SRD and provide output coupling into the 4-pole comb filter that follows. **Figure 10** shows the SRD holder. Clamp the step recovery diode between part no. 4 (the RF input/output connection) and part no. 6 (a 1/4-20 brass set screw). Use a dab of heat sink compound where the SRD mounts into part no. 6; this aids thermal conduction to the main housing. I made the brass diode holder on a milling machine to fit into the input end of the comb filter. You can make a functional unit with ordinary hand tools.

FIGURE 9



X8 SRD frequency multiplier and filter.

Depending on the SRD, you can make the 1/4-20 brass set screw (part no. 6) with the appropriate mounting hole. Some SRDs have 3-48 UNC threaded posts that would screw into part no. 6. You could use a glass-packaged SRD by making a Teflon spacer with the glass diode mounted in the center. Fold the wire leads over at both ends and clamp the Teflon spacer into the diode holder.

Attach the SRD holder to the comb filter as in **fig. 11**. It's possible to use an interdigital filter, but a comb filter is easier to mount and tune up because the tuners are on one side.[1,2] A comb filter uses the same dimensions as an interdigital type, but is configured with all the tuning elements on the same side. I used all brass construction. The end walls are 1/4" thick brass stock. Drill holes for the four filter poles, and on the opposite side for the four tuning screws. Solder two SMA connectors to the sheet brass covers. Attach the two covers with 2-56 × 3/16" screws to hold the filter together while soldering all joints on a hot plate.

After you've built the filter, attach the SRD holder to it with 2-56 × 3/16" screws. Use a small piece of sheet brass as a mounting platform for the pi-network input circuitry. Attach this assembly to the filter so the SRD input connection (part no. 3) is in close proximity to the trimmer capacitor (C3) of the input circuitry.

Apply the 414-MHz RF to the SRD/filter assembly. Adjust the input network and the filter for maximum power output with a power meter attached on one output port, and a 50-ohm load and spectrum analyzer on the other. Use a spectrum analyzer during tune-up to ensure a clean local oscillator output. Adjust the output coupling probe by threading it in or out of part no. 4. First loosen part no. 3, then tighten it up after the output coupling is optimized. You'll need to adjust the 414-MHz drive for proper output at 3312 MHz (5 to 10 mW at each output connector). The two outputs will be within 1 dB of each other — more than sufficient to properly supply a local oscillator signal to the two transverter mixers. You can change the 414-MHz drive using an LM317T voltage regulator which supplies an adjustable collector voltage to the 414-MHz output stages. In my transverter, power input at 414 MHz was 500 to 600 mW. I made no attempt at optimum input/output matching of the SRD; power at UHF is easy to come by.[5,6]

I provided two outputs on the comb filter instead of using a 3-GHz power divider to split the local oscillator for the two mixers (see **fig. 11**). This is a very simple power divider and you can use it on any comb or interdigital-type filter. You can take two different levels off the filter (for use in a duplex system) if one output uses capacitive coupling. For example, the center pin of an SMA connector provides coupling ≈ 15 dB down from a normally connected output.

There are a number of combinations for the local oscillator chain. In addition to what's shown in the block diagram, you could also generate 3312 MHz using a 1-GHz local oscillator strip (crystalled for 1104 MHz) driving an active tripler to 3312 MHz. There are a few sources for stable crystal-controlled 1-GHz local oscillator chains.*

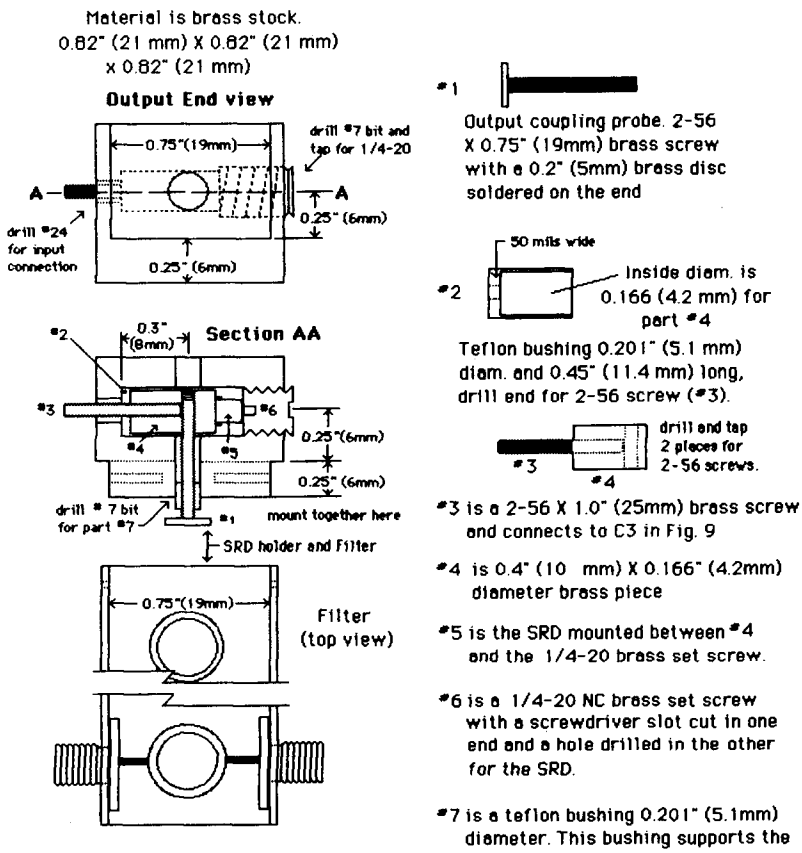
Active frequency multiplier

Figure 12 shows the ×3 to 3312 MHz multiplier. The active device is an SD 1801 transistor (Q1). The multiplier is built on 1/32″ Teflon double-sided pc board (Er = 2.55) and mounted in a brass carrier (shown in **fig. 13**). The multiplier is connected to a five-section interdigital filter.[1,2] I used an SMA connector on the input instead of the SRD holder. The input connector is tapped at 0.25″ from the cold end of the input pole.

The multiplier and filter are connected in the transverter with a small piece of UT-141 semi-rigid coax. The exact length of the cable seems to have an effect on the performance of the multiplier. Try different lengths of intercon-

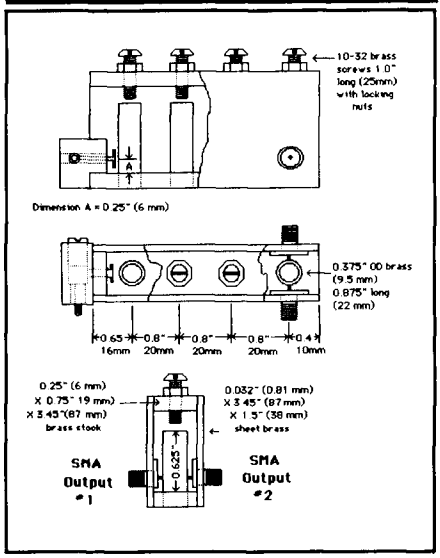
*Down East Microwave, Box 2310, RR #1, Troy, Maine 04987, (207)948-3741. (W3HQT sells the LMW Electronics, model ULO, Universal Local Oscillator kit.) SSB Electronics, 152-MHz Local oscillator chain for their 2304 MHz transverter, crystalled and retuned to 1104 MHz.

FIGURE 10



3456-MHz SRD holder and output coupling detail.

FIGURE 11

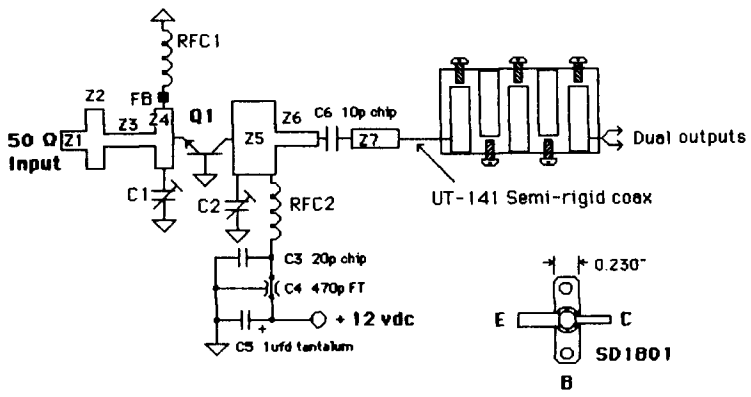


The SRD/Filter/Power divider assembly. At top, the SRD holder is shown mounted to the 4-pole filter. The middle is a cut-away view showing the position of the SRD output probe and dual local-oscillator outputs. The bottom is the end view filter/power divider. Connector input-output taps are 0.25″ (6 mm) from the cold end.

necting cable to provide the best match into the filter. The multiplier and filter are effectively one stage and are tuned as such. Again, a power meter is attached to one output, and a 50-ohm load and spectrum analyzer to the other. After tuning the filter for maximum power output at 3312 MHz, you can adjust the 1104-MHz drive level to provide the proper level outputs for the two mixers.

Here's how the multiplier operates. The input of Q1 is tuned to 1104 MHz (or 1152 MHz in a 3456-MHz beacon transmitter). The output is tuned to 3312 MHz (or 3456 MHz). An interdigital filter removes the fundamental and second harmonic frequencies and also provides two outputs for the two transverter mixers. The typical performance of the tripler and filter with one output is 30-mW power input at 1104 MHz (or 1152), which produces 40 to 60 mW output. P_{in} of 50 mW produces greater than 100 mW. When running the multiplier on 15 Vdc, I've seen +23 dBm (200 mW) out of one of these units. You could use this for a beacon transmitter. The 3312-MHz (3456 MHz) outputs are very clean; all unwanted harmonics are down greater than 45 dB and all non-harmonically related signals are down greater than 60 dB.

FIGURE 12



Board material is 0.032" Teflon double-sided
Er = 2.55

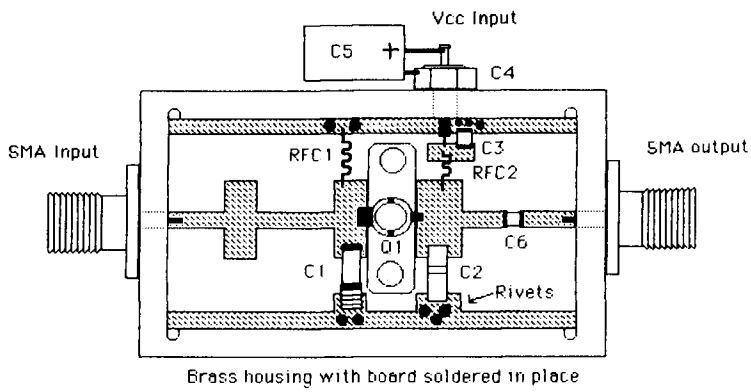
C1 3.5 pf Johanson piston trimmer, JMC #5801 or 5802
C2 4.5 pf Johanson Gigi-trim cap, JMC #27273
RFC1 6t, #26, 0.1" (2.5 mm) ID
RFC2 3t, #24, 0.1" (2.5 mm) ID
FB Ferrite bead

Q1 Thomson/Mostek SD1801

Z1,7 0.080" (2 mm) X any length 50Ω line
Z2 0.150" (3.8 mm) X 0.30" (7.6 mm)
Z3 0.060" (1.5 mm) X 0.35" (9 mm)
Z4 0.150" (3.8 mm) X 0.30" (7.6 mm)
Z5 0.200" (5.0 mm) X 0.30" (7.6 mm)
Z6 0.060" (1.5 mm) X 0.20" (5.0 mm)

X3 Multiplier to 3312 or 3456 MHz with a 5-section interdigital filter on the output.

FIGURE 13



Brass housing with board soldered in place

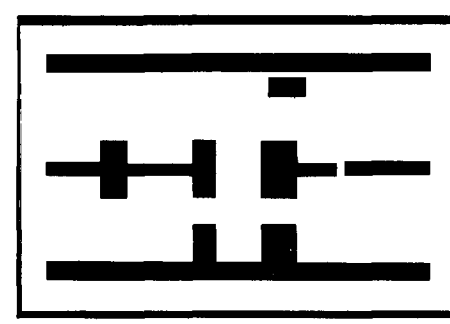
Parts placement on the X3 multiplier and full-scale artwork below. Trace side shown. Opposite side is unetched.

I-F and DC switching

It's necessary to have some means of switching the i-f transmit and receive lines when connecting the 2-meter transceiver to the 3456-MHz transverter. You'll also need a keying circuit to control the transmit/receive of the transverter. This requires one of two different hookups — depending on whether the 2-meter i-f will be a transceiver or another transverter (an MMT-144/28, for example*).

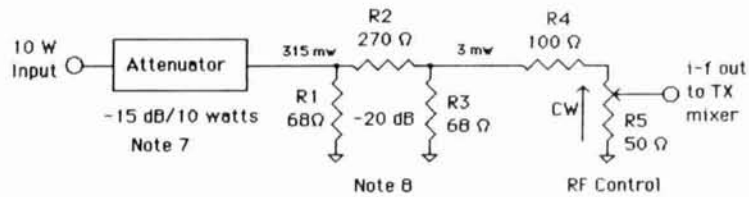
Two-meter transverter as an i-f

Separate receive and transmit connectors are available on the MMT-144 transverter. The i-f output of the receive mixer is connected to the 144-MHz receive port on the 2-meter transverter. On the transmitter side, you must insert an attenuator between the transmit output (nominally 10 watts) of the 2-meter i-f and the 3456-MHz transmit mixer (see **fig. 14**). Adjust the i-f drive level to the



*Microwave Modules Ltd., Liverpool, England, makes a complete line of VHF/UHF transverters.

FIGURE 14



all resistors are 1/2 watt carbon

R5 = 50 Ω minature pc board type pot

I-f attenuator and adjustable RF control.

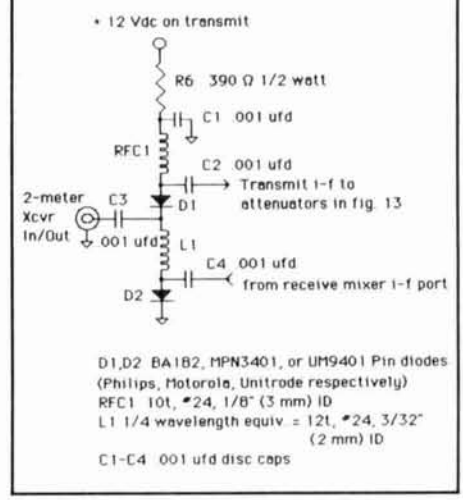
transmit mixer as follows: Turn the RF control (R5) CCW (maximum attenuation). Attach a power meter to the output of the 3456 transverter. Put the 3456-MHz transverter into the transmit mode and apply the 10 watts of drive. Adjust the RF control (R5) for a maximum power output at 3456 MHz. Reduce the 2-meter RF; it should show a decrease in the 3456-MHz output. If there's no reduction in power output, the mixer is being overdriven and you must insert additional attenuation in front of the RF control.

It's important that the i-f radio be operated at its normal output level, and not with the gain or CW control turned down. The RF control in the transverter is adjusted to match the i-f level, **not vice versa**. This ensures that the transverter will never be overdriven, even when the i-f radio's gain controls are adjusted improperly. The procedure is correct for any transverter system.

Two-meter transceiver for the i-f

Figure 15 shows a Pin diode RF switch that provides switching for the 2-meter i-f during transmit and receive. The i-f transceiver is connected to the Pin diode switch; this gives two separate ports similar to the outputs of the 2-meter transverter described earlier. The RF attenuators* and RF control are also used in this installation. The i-f drive adjustment is the same as if you were using a transverter. Don't make changes in the RF drive with the 2-meter transceiver in the "low power" position or you'll be asking for trouble.

FIGURE 15



D1,D2 BA182, MPN3401, or UM9401 Pin diodes (Philips, Motorola, Unitrode respectively)
RFC1 10t, #24, 1/8" (3 mm) ID
L1 1/4 wavelength equiv. = 12t, #24, 3/32" (2 mm) ID
C1-C4 .001 ufd disc caps

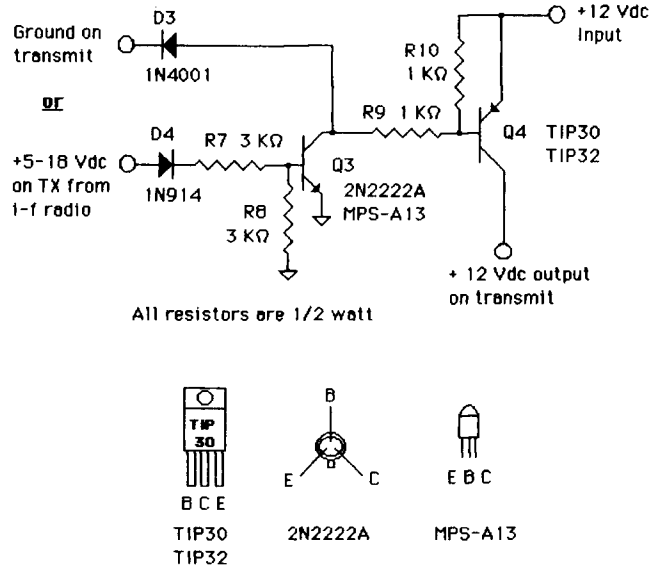
Pin diode RF switch.

DC control circuits

Control the 3456-MHz transverter with "hard keying." Use RF sensing *only* as a last resort. Hard keying is simple. Take a transmit voltage off the i-f radio — either via an accessory jack, or by going inside and soldering a wire to a resistor lead. You just need a voltage between 5 and 18 volts on transmit at a few milliamps of current. Check your radio's schematic to determine where to look with a voltmeter. **Figure 16** shows a DC switching circuit that provides 12 volts on transmit to control the Pin diode switch in **fig. 15**. The 12 volts will also key your 3456-MHz transverter control circuits and power supply[4].

*Microwave Modules RF Attenuator Models: MMR 3/25 = 3dB/25 watt, MMR 7/3 = 7dB/3 watt, MMR 15/10 = 15dB/10 watt

FIGURE 16



DC switching circuit, controlled by the i-f transceiver in the transmit mode.

Antenna relays

You can use antenna change-over relays manufactured by Transco Products, Inc. (and other manufacturers) at 3456 MHz. Look for surplus relays at flea markets. Some have specially made connectors designed for the military. Unfortunately, matching connectors usually aren't available. I use a Transco latching-type relay, P/N 82132-909C. It cost me $5.00 at a flea market. The connectors resembled an SMA female jack, but had male center pins. I removed the threaded-in connectors and installed female SMA connectors. Insertion loss, measured at 3456 MHz, is 0.1 dB; isolation is greater than 60 dB. Surplus relays manufactured by Electronic Specialty Company are usually good for 3456 and 5760 MHz.

Conclusion

The design for this transverter is relatively simple. A few basic components are all you need to build a "bare-bones" unit for mountaintop work. Besides the local oscillator, two mixers and the "split" TVRO LNA will get you on the air. You can use manual transmit-receive change-over (moving a coax cable between RF ports) with good results, as speed isn't usually a requirement. Microwatt transmitters and diode receivers are adequate for most line-of-sight communications. You can always add fancy switching and higher power output later.

You can use some of the component designs for other microwave projects. For example, the SRD multiplier is suitable for a beacon transmitter. The HP 5082-0320 diode is capable of much more power output at 3456 MHz than is used in this transverter. It's possible to find other 1 to 5-watt SRDs that will fit into the same holder. Try using the active multiplier for the output or driver of a beacon transmitter. Adjusting the collector voltage and RF power input for maximum yields 200 to 300-mW power output.

This transverter is one of many possible designs.* Microwave enthusiasts in other parts of the country are using surplus phase-locked sources for their local oscillators. TVRO mixers are also in service. GaAsFETS and surplus tube-type amplifiers are being used for the transmitters. There's also an assortment of TVRO, surplus, and homebrew GaAsFET receivers at work.

The majority of activity on this band comes from mountain-topping stations and local QSOs. Many stations will soon be on the 3.4-GHz band, and QSOs similar to 2304 MHz will be commonplace. Besides the parabolic antennas normally used on the microwave bands, the loop Yagi is becoming a popular antenna for 3456 MHz.**

*The ARRL Handbook

**Down East Microwave, Box 2310, RR #1, Troy, Maine 04987, (207) 948-3741 sells loop Yagi antennas for all bands 902-3456 MHz.

References

1. Bob Atkins, KA1GT, "The New Frontier," *QST*, May 1984, page 77.
2. R. Fisher, W2CQH, "Interdigital Filters," *QST*, January 1974.
3. Bob Atkins, KA1GT, "The New Frontier," *QST*, August 1987, page 59.
4. Dave Mascaro, WA3JUF, "Transverter Switching Display and Universal Transverter Power Supply," *QEX*, August 1987, page 8.
5. Hewlett-Packard Application Notes no. 913 and 920, May 1967.
6. R.E. Winkelman and E.G. Cristal, *Microwaves and RF*, September 1970, page 34.

Article I

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YAESU
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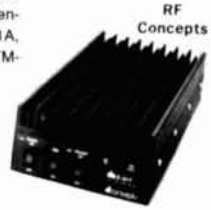
FT-2/1/709R/H
FT-1903/1123
FTH-2005/7005

ICOM
IC2AT/12AT
ICO2AT-32AT
IC2/4GAT
IC-A2/U16
IC-448A

Landmobile HT's
ICOM: U16, H16, V100, U400
MAXON, MOTOROLA,
YAESU: FTH 2005/2007
UNIDEN, REGENCY, KING, TAD
MARINE ICOM: M5, M55, M700
AVIATION ICOM: A20 H T.

PRIVATE PATCH V, Duplex 8000

RF Concepts



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Soldering Station 48 Watts $68.

AR 900 Hand Held Scanner 100 ch. Covers 27-54, 108-174, 406-512, 800-950 MHz $299

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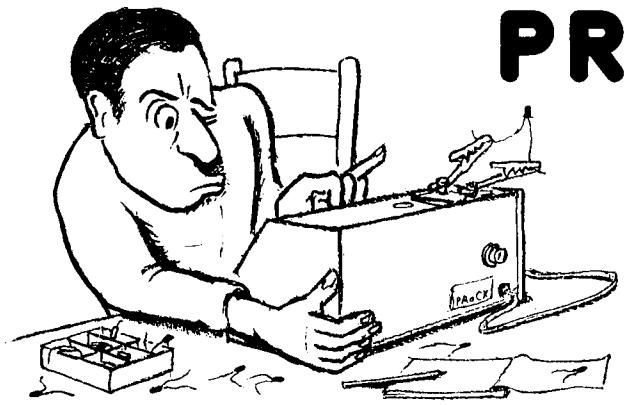

PRACTICALLY SPEAKING

Joe Carr, K4IPV

Parts for antenna tuners and linears...plus a correction

One of the delights of writing for a magazine like *Ham Radio* is receiving reader mail. Sometimes I get brickbats either for not covering a pet topic, or covering it in a way that someone doesn't like. I also get kudos and congratulations for covering a topic well, or covering one that other magazines seem to overlook. But let me make a mistake, and my mailbox fills up in a hurry — *HR* readers are a sharp lot! Fortunately, most of the "eagle eyes" simply point out the error and let me off the hook easily. Others...well, others...I won't tell you about them, except to state that for some people columnists' mistakes are mortal sins.

One error turns out to be not an error at all, merely an oversimplification. In one column I warned you to be careful of NPO capacitors because they are not really zero temperature coefficient. Most of them are 0 ± 30 ppm. Although I prefer silvered mica capacitors, some of you don't like them because they seem variable with respect to tempco (despite the rating). It turns out that I was right after all, but so were those of you who wrote. The selection of the low tempco capacitor is a lot more complicated than I (or any other Amateur Radio writer) have shown. I am researching the issue, and may write a column about it in the future. If you have information or opinions, write to me at the address at the end of this column.

Tuner/linear parts

Antenna tuners and linear-amplifier RF tuned circuits are popular Amateur Radio construction projects. That old saw, offered by scores of doomsayers, that hams don't build anymore is belied by my mailbag. Many people have written me (more than 60 in response to the spectrum analyzer column) on construction projects. A common question regards the class of parts used for tuners and linear amplifiers. When a schematic shows a variable capacitor, the capacitor could be a screwdriver-adjusted trimmer or a mighty vacuum variable. I'll take a look at a couple of different types of components this month.

Another question I see frequently concerns supply sources. Hamfests are traditional places to find linear/tuner parts, but those events are either drying up or people are asking an arm and a leg for parts. I saw a corroded (really scuzzy) transmitting-type variable capacitor at a hamfest; the owner wanted only $3 less than the price Radiokit was asking for a brand new one! Although hamfest bargains (and reasonable deals) still abound, you might contact some of the vendors shown in **table 1** for mail order purchases, or to locate a dealer who can help you.

TABLE 1

List of suppliers

Radiokit, POB 973, Pelham, New Hampshire 03076, (603) 635-2235
Barker & Williamson, 10 Canal Street, Bristol, Pennsylvania 19007, (215)788-5581
Fair Radio Sales, 1016 East Eureka Street, POB 1105, Lima, Ohio 45802
Nevada Communications, TELECOMMS, 189 London Road, North End, Portsmouth, PO2 9AE, England
Unadilla/Antennas Etc., POB 215 BV, Andover, Massachusetts 01810-0814, (617)475-7831
Van Gorden Engineering, POB 21305, South Euclid, Ohio 44121
SPI-RO Manufacturing, Inc., POB 1538, Hendersonville, North Carolina 28793
Alpha Delta Communications, Inc., POB 571, Centerville, Ohio 45459 (513)435-4772

Let's take a look at the types of parts that are suitable for building antenna-tuning units or the RF output deck of a linear, or class-C, RF power amplifier.

Photos A and **B** show a pair of high-voltage variable capacitors suitable for use in high-power applications. The capacitor in **photo A** is a 250-pF model about 10 inches long, with wide spacing between plates to accommodate the high voltage. In the model shown, the shaft has a nylon end piece

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Low pass probe, audio use	16.95
Direct probe, general purpose use	13.95
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Nicad pack for CT-70, 90 & 125	8.95

MODEL	FREQ RANGE	SENSITIVITY	ACCURACY	DIGITS	RESOLUTION	PRICE
CT-70	20 Hz-550 MHz	<50 mv To 150 MHz <100mv To 550 MHz	1 PPM	7	1 Hz, 10Hz, 100Hz	139.95
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 OV-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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TR-1, RF sensed T-R relay kit **6.95**

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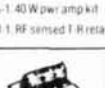
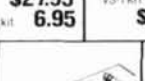
FM WIRELESS MIKE
Transmits up to 300 to any FM broadcast radio, uses any type of mike. Runs on 3 to 9V. Type FM-2 has added sensitive mike preamp stage.
FM-1 Kit **$3.95**
FM-2 Kit **$4.95**

SIREN
Produces upward and downward wail. 5 W peak audio output, runs on 3-15 volts, uses 3-45 ohm speaker.
Complete kit, SM-3 **$2.95**

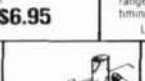


SUPER SLEUTH
A super sensitive amplifier which will pick up a pin drop at 15 feet! Great for monitoring baby's room or as general purpose amplifier. Full 2W rms output, runs on 6 to 15 volts, uses 8-45 ohm speaker.
BN-9 kit **$5.95**

60 Hz TIME BASE
Runs on 5-15 VDC. Low current (25ma) 1 min/month accuracy.
TB-6 Kit **$5.50**
TB-6 Assy **$9.95**



TELEPHONE TRANSMITTER
Low cost with professional performance. Features include: self phone line powered, tunable from 76 to 100 MHz, polarity antisensitive, compact size (1" x 1½"), easily installs anywhere on the phone line or inside the instrument itself.
PB-1 KIT **$14.95**



FM RECEIVER
For built-in applications or hobby experimentation. Full fledged superheterodyne receiver, microvolt sensitivity, 10.7 MHz IF, Integrated Circuit detector. 50 mw audio amplifier, 9V external power source, operation on standard FM broadcast band as well as large portions on each side, compact (6" square), for bug detection or reception.
FR-1 KIT **$14.95**

FM MINI MIKE
A super high performance FM wireless mike kit! Transmits a stable signal up to 300 yards with exceptional audio quality by means of its built in electret mike. Kit includes case, mike, on-off switch, antenna, battery and super instructions. This is the finest unit available.
FM-3 kit **$14.95**
FM-3 Wired and Tested **19.95**

NEW

MICROWAVE INTRUSION ALARM
A real microwave doppler sensor that will detect a human as far as 10 feet away. Operates on 1.3 GHz and is not affected by heat, light or vibrations. Drives up to 100 ma output, normally open or closed, runs on 12 VDC.
Complete Kit, MD-3 **$16.95**

NEW

SPEECH SCRAMBLER
Communicate in total privacy over your telephone or radio. This scrambler kit features full duplex operation using frequency inversion. Runs on a 9 volt battery. Both mike and line or speaker output/inputs. Easy to connect to any radio—telephone use requires no direct connection! Easy to build, uses IC DEM circuitry. Can also be used to descramble most com. scramblers.
Complete kit, SS-7 **$29.95**
Case kit, CSS-7 **12.95**

TERMS: • satisfaction guaranteed • examine for 10 days: if not pleased, return in original form for refund • add 6% for shipping and insurance to a maximum of $10.00 • foreign add 15% for surface mail • COD add $2.50 (COD in USA only) • orders under $20.00 add $1.50 • NY residents add 7% sales tax • 90 days parts warranty on all kits • 1 year parts & labor warranty on all wired units.

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RAMSEY ELECTRONICS, INC., 2575 Baird Rd., Penfield, N.Y. 14526

ALL NEW KITS

Complete kit, SG-7 **$89.95** **PERSONAL SPEED RADAR**

New low cost microwave doppler radar kit "clocks" cars, planes, boats, horses, bikes, baseballs, models, runners or virtually anything that moves. Operates at 2.8 GHz with over 1/4 mile range. LED digital readout displays speeds in miles per hour, kilometers per hour or feet per second! Earphone output permits listening to actual doppler shift. Uses two 1 lb coffee cans for antenna (not included) and runs on 12 VDC. Easy to build—all microwave circuitry is PC stripline. Kit includes deluxe ABS plastic case with screened graphics. Included are machined aluminum knobs for a well-finished professional look. A very useful and full-of-fun kit.

RADIOS

40 & 80 METERS HAM RECEIVERS

Sensitive all mode, AM, CW, SSB receivers for 3.5—4.0 or 7.0—7.5 MHz. Direct conversion design using NE602 IC as featured in QST and ARRL handbooks. Less than 1 μv sensitivity, varactor diode tuned, 50 mw audio output. Runs on 9VDC, has RF gain control. This kit is very easy to build, lots of fun and educational—ideal for the beginner or the old pro. The optional matching case kit features a rugged ABS plastic case with screened graphics. Included are machined aluminum knobs for a well-finished professional look.

40 Meter receiver kit, HR-4 **$24.95** 80 Meter receiver kit, HR-8 **$24.95** Receiver case kit, CHR **$12.95**

QRP TRANSMITTER KITS, 40 & 80 METERS

Operate a mini-ham shack. These little CW rigs are ideal mates to our 40 and 80 meter receivers. Features include smooth variable tuning, one watt output and excellent keying characteristics. Runs on 12 VDC and is VSWR protected. See how far you can stretch your signal with one of these mini rigs. Optional ABS cases are available.

40 meters QRP rig, QRP-40 **$24.95** 80 meters QRP rig, QRP-80 **$24.95** Case kit, CQRP **$12.95**

AIRCRAFT RECEIVER KIT

Hear exciting aircraft communications—picks up planes up to 100 miles away. Receives 110—136 MHz AM air band, varactor tuned superhet design with AGC, ceramic filter and adjustable squelch. Runs on 9V battery, 50 mw audio output, 1 μv sensitivity. Optional matching ABS plastic case lets you take it anywhere, features screened graphics and machined aluminum knobs for a real professional look. Compact—great for airshows or for just plain hanging around the airport.

Complete kit, AR-1 **$24.95** Receiver case kit, CAR-1 **$12.95**

SHORTWAVE RECEIVER KIT

A fantastic receiver that captures the world with just a 12" antenna! Receives 4—11 MHz in 2 MHz bands, varactor tuned, superhet design with AGC, RF gain control, and 50 mw audio output. Uses new Signetics mixer chip for less than a microvolt sensitivity, runs on 9V battery. This is a fascinating scout, school or club project, and will provide hours of fun even to the most serious DXer. Add the optional case kit and you have a real nice looking shortwave set.

Complete kit, SR-1 **$24.95** Receiver case kit, CSR-1 **$12.95**

PACKET RADIO

Commodore C64/128 packet radio interface. Uses famous German Digicom software. Features EXAR IC chip set for reliable operation—runs HF or VHF tones. Includes FREE disk software, PC board, all necessary parts and full documentation.

Complete kit, PC-1 **$49.95**

FM COMMUNICATIONS/2 METER RECEIVER

Sensitive superhet FM receiver tunes any 5 MHz segment from 135—175 MHz. Listen to 2 mtr ham operations, high band police calls, weather or mobile phone calls! Easy to build receiver features varactor tuning, IC mixer stage, ceramic IF filters and dual conversion design with adjustable squelch. Less than 1 μv sensitivity, runs on 9 V battery, with 50 mw audio output. Optional ABS case with screened graphics and machined aluminum knobs provide a nice professional look.

Complete kit, FR-7 **$29.95** Receiver case kit, CFR-7 **$12.95**

NEW MINIKITS—NEW MINIKITS

BROADBAND PREAMP

A sensitive all purpose preamp, ideal for scanners, TV sets, VHF, UHF rigs, counters, etc. Features low noise, 4 db NF, 20 db gain, 100 KHz—1 GHz operation. Runs on 9—12 VDC, 50 ohms input.

Complete kit, SA-7 **$12.95**

LIGHT BEAM COMMUNICATORS

Transmits modulated infrared light up to 30 feet without lenses, up to 1/4 mile using lenses. Uses 30 KHz carrier for hum-free operation, transmits thru windows, etc. Ideal for "bugs" or listening to IR remote controls. Transmitter has sensitive mike input, receiver uses PIN detector and drives speaker output. Units operates on 9—12 VDC.

Transmitter kit, LB-6 **$8.95**
Receiver kit, LB-5 **$9.95**

HIGH POWER FM WIRELESS MIKE

A high power unit that will transmit up to 1/2 mile to any FM broadcast radio. Sensitive input accepts any type of mike, will pick up normal voices 10 feet away using the available mini-electric mike cartridge. Operates on 9—12 VDC.

FM-4 kit **$9.95**
Sensitive microphone cartridge **$2.95**

2 MTR & 220 BOOSTER AMP

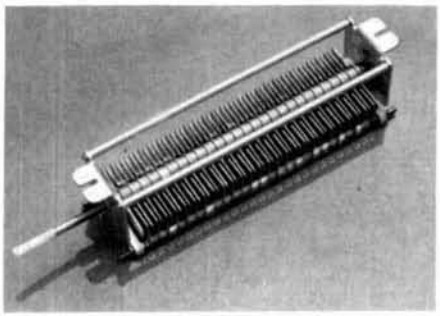
- **30 WATTS OUTPUT**
- **LOW NOISE PREAMP**
- **LOW COST**
- **RUGGED CAST ALUMINUM CASE**
- **ONE YEAR WARRANTY**

Here's a great booster for any 2 meter or 220 MHz hand-held unit. These power boosters deliver over 30 watts of output allowing you to hit the repeaters full quieting while the low noise preamp remarkably improves receptions. Ramsey Electronics has sold thousands of 2 mtr amp kits but now, we offer completely wired and tested 2 mtr as well 220 MHz units. Both have all the features of the high priced boosters at a fraction of the cost.

PA-10 2 MTR POWER BOOSTER (10 X power gain) Fully wired & tested $59.95

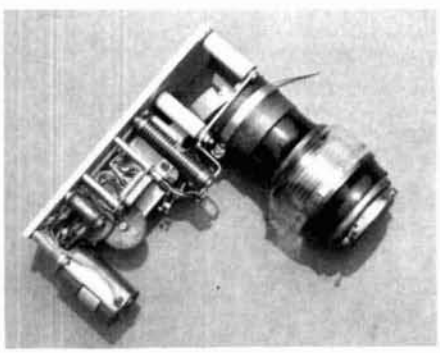
PA-20 220 MHz POWER BOOSTER (8 X power gain) Fully wired & tested $59.95

PHOTO A



High-voltage, air-dielectric variable capacitor.

PHOTO B



Motor driven 1000-pF vacuum variable capacitor.

that permits the stator plates to be at high voltage (where necessary) without placing the operator at risk. This particular capacitor (as well as the inductor in **photo C**) is part of the antenna-tuning unit kit offered by Radiokit (see **table 1** for address).

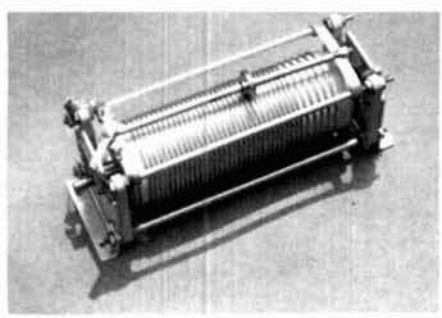
The capacitor in **photo B** is a 1000-pF vacuum variable. This model is surplus, and was obtained from Fair Radio Sales in Lima, Ohio. The surplus capacitor cost considerably less than the new vacuum variables, and a lot less than some hamfest "tailgate specials" I've seen in recent years. In this case, a motor drive mechanism is supplied allowing the user to set the capacitance by applying a +12 Vdc source to the motor control. Microswitches at the limits of travel can be used either to provide warning to the operator that the limit is reached, or automatically turn off the power to the motor and reverse the direction of travel. I plan to use this capacitor in an outdoor (remotely tuned) antenna-tuning unit.

Photos C and **D** show a pair of inductors used for antenna-tuning units. The version in **photo D** is a fixed coil made from B&W 3029 stock. There are three methods for connecting leads to the coil. One is to use an alligator clip. Press down a short section of alternate turns to allow the clip to be attached without shorting adjacent turns. Another is to simply solder a wire to a turn of the coil. Finally, sources like Radiokit sell special coil clips that screw onto the coil stock. Use either a manual attachment or an RF switch to select the required inductance.

The inductor shown in **photo C** is a rotary inductor. This one selects inductances from about 1-28 μH. A rotary shaft on the front end of the coil sets the inductance.

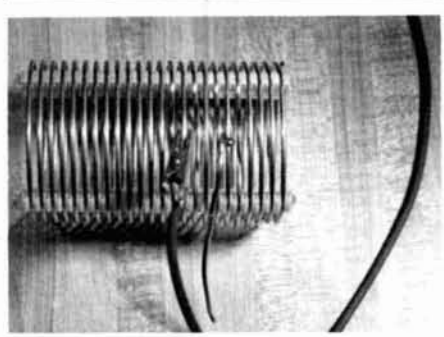
Photo E shows an antenna-tuning unit from Nevada Communications in England. I ordered this instrument through the mail (Nevada can accept most of the major charge cards familiar to United States customers).

PHOTO C



Roller or rotary inductor.

PHOTO D



Fixed inductor made from B&W miniductor stock.

Nevada also sells the individual components. One capacitor (shown on the right) is a 250-pF variable; the other is a dual-section 250-250 pF model. It can be used as either a dual capacitor in a Transmatch circuit, or can be connected in parallel to form a 500-pF unit.

Dummy loads

A dummy load is a substitute antenna for making measurements and tests. In fact, British radio engineers often refer to dummy loads as "artificial aerials." There are several uses for these devices. Radio operators should use dummy loads to tune up on crowded channels, and only then transfer to the live antenna.

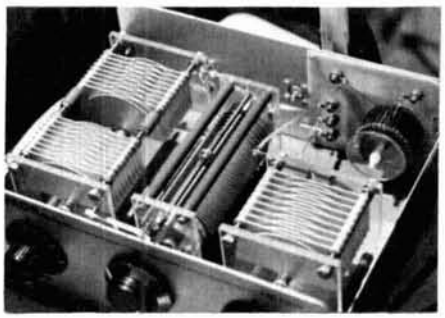
Dummy loads can also be used when troubleshooting antenna systems. Suppose you have a system in which the VSWR is high enough to affect the operation of the transmitter. You can disconnect each successive element and connect the dummy load to its output. If the VSWR goes down to the normal range, then the difficulty is downstream (i.e., towards the antenna). You'll eventually find the bad element (which is usually the antenna itself).

Several commercial dummy loads are shown in **photos F** through **H**. **Photo F** is a Drake DL-1000. This dummy load is usable throughout the HF region, and will handle 1000 watts for short periods. A long, high-power, noninductive resistor element inside the DL-1000 is rated at 50 ohms, and can dissipate 1000 watts for several minutes. If you anticipate longer times or higher powers, apply forced air cooling by adding a blower to one end of the cage.

I modified my DL-1000 by adding a BNC signal sampling jack. Connect this jack internally to either a two-turn loop made of no. 22 insulated hookup wire, or to brass rods positioned alongside the resistor element. It will then pick up a sample of the signal so that it can be viewed on an oscilloscope, or used for other instrumentation purposes. I'll discuss this modification in a future column.

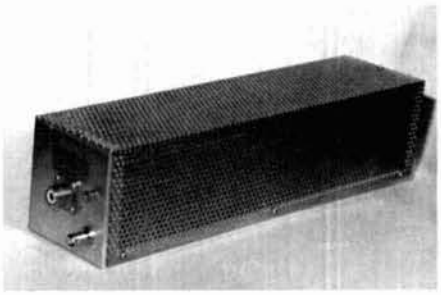
Photo G shows a small collection of my low-power dummy loads. The small gray load in **photo G** is a 5-watt model, and is typically used in Citizen's Band servicing. The resistor is mounted directly on a PL-259 coaxial connector. These loads typically work to about 300 MHz, although many are not really useful over about 150 MHz. I have successfully used it to service a 2-watt, 2-meter handheld. A higher power version of the same type is also shown in **photo G**. This device works to the low VHF region, and dissipates up to 50 watts for short times, even though it is rated at 15-watts continuous power. I have used this dummy load for servicing high-VHF landmobile rigs, VHF-FM marine rigs, and low-VHF landmobile rigs — as well as Amateur Radio rigs.

PHOTO E



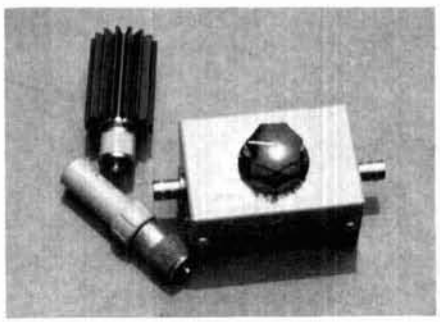
Nevada antenna tuner unit.

PHOTO F



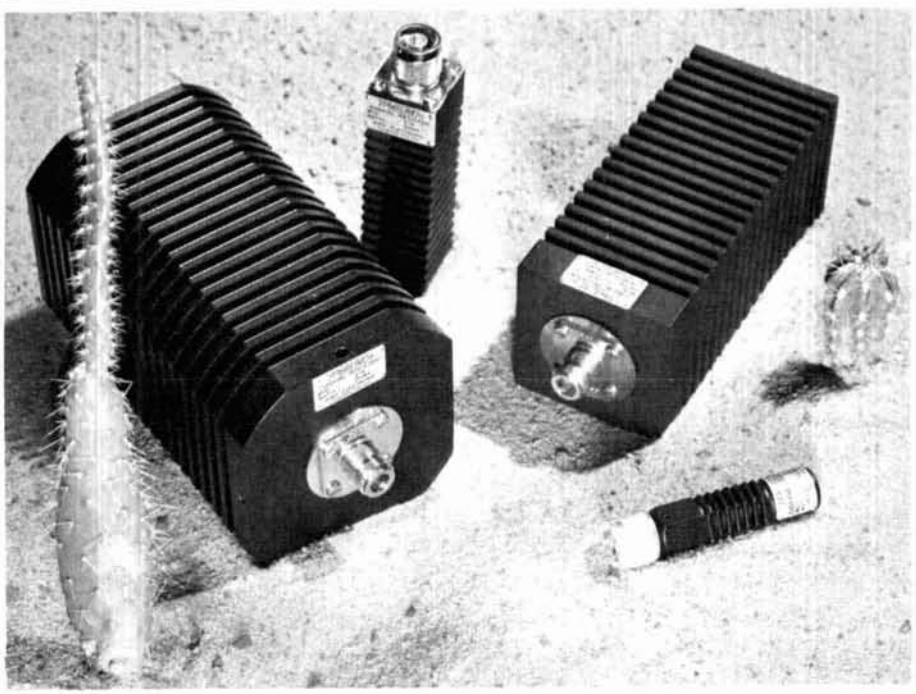
Drake DL-1000 dummy load for HF bands.

PHOTO G



Collection of small dummy loads.

PHOTO H



Commercial dummy loads made by Bird Electronics, Inc.

The load box shown in **photo G** is a homebrew device containing ten different 2-watt, carbon composition, *noninductive resistors. Also included* are a zero-ohm switch position (shorted to ground) and an open position (which requires an external load, or produces an "infinite" impedance). I used this dummy load to produce the photos in a past column on time domain reflectometry methods.

Photo H shows a small collection of 8000-series Termaline® dummy loads produced by Bird Electronics, Inc. These are professional instruments and are rated very conservatively. If you plan to service a lot of equipment or go into business, then it's probably a good idea to buy one or more of them. Even Amateurs with a modest workshop may want one of these professional loads.

I can be reached at POB 1099, Falls Church, Virginia 22041; I'd like to have your comments and suggestions for this column.

Article J **HAM RADIO**

THE WEEKENDER

A simple signal source for 903 MHz

Circuit testing is probably one of the most difficult problems you'll encounter when building equipment for the higher frequency Amateur bands. It's even harder on a new band, because you may have no operational equipment to use as a starting point. I've built a simple reference-signal generator for the 903-MHz band that can be operated without any other RF test equipment. Try using it as the reference point for adjusting antennas and equipment.

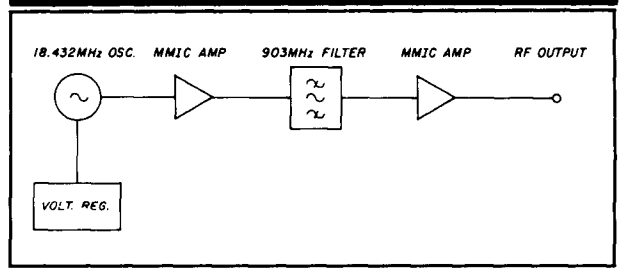
Circuit description

The idea for this test-signal generator came to me while I was looking through a catalog of standard TTL crystal oscillators. These oscillators, intended for use in digital computer equipment, are inexpensive and fairly accurate signal sources. One commonly available oscillator operates at 18.432 MHz and has a convenient 49th harmonic of 903.168 MHz. It's very near to the 903.1-MHz calling frequency — certainly close enough to be useful in testing and tuning equipment for the entire 33-cm band.

Once I realized that this oscillator's harmonic falls on a useful frequency, I started wondering how to use it to build a signal generator. The block diagram in **fig. 1** came to mind. The crystal oscillator's output is amplified and its harmonic level enhanced. A sharp, pretuned filter rejects most of the undesired harmonics and another amplifier increases the level of the 903-MHz signal. It requires no adjustments or external calibration.

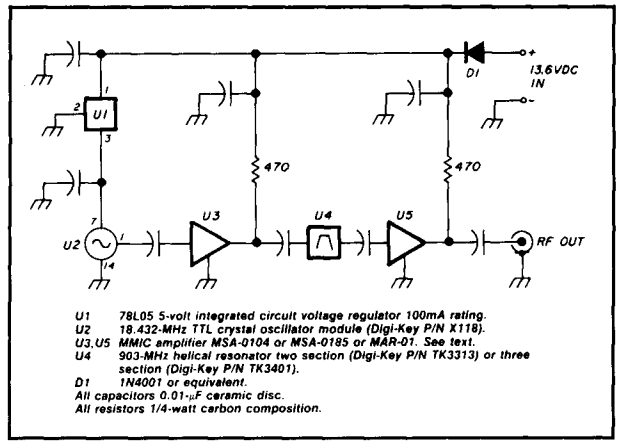
By Jerry Hinshaw, N6JH, 10 Acorn Circle, #101, Towson, Maryland 21204

FIGURE 1



Block diagram of the signal generator.

FIGURE 2



Detailed schematic diagram and parts list of the circuit.

The schematic diagram in **fig. 2** shows each of the subsystem "blocks" in detail. The first stage to the left is the oscillator. It needs a 5-volt supply and ground to provide a stable output. This voltage regulator reduces the 13.8-volt supply to 5 volts, and its regulation helps prevent "pushing" (frequency shifts caused by power supply variations).

The stage after the oscillator is an MMIC amplifier; it serves two functions. First, it isolates the oscillator from output impedance changes which would alter the oscillator frequency (a phenomenon sometimes called "pulling"). The MMIC amplifier, with its low reverse gain (S_{12}), acts as a buffer and shields the oscillator from load changes. It also isolates the oscillator from the filter's high VSWR at frequencies outside the passband. Second, the amplifier enhances the oscillator's harmonic output. (After all, it's the 49th harmonic that falls in the desired band — not the fundamental.) Use an amplifier which has a low output compression point for this function, so that it's driven into saturation by the oscillator's signal. When saturated, the amplifier operates nonlinearly and produces more harmonic power (since harmonics are distortion products produced by nonlinear amplification). This MMIC stage has considerable gain from HF to above 1 GHz, covering the fundamental of the oscillator at 18.432,

the desired harmonic at 903.168, and all points in between.

There are a number of silicon MMIC amplifiers which will work well here. As I mentioned before, the main requirement is for gain saturation when driven by the oscillator. I used an Avantek MSA-0104, biased with a resistor to about 15mA collector (output lead) current. Other possible choices are the MSA-0185 (the same device in a smaller plastic package) or the Mini-Circuits MAR-1 (which appears to be the Avantek MSA-0185 device sold under a different label). The slightly higher power Avantek MSA-02 (Mini-Circuits MAR-2) would probably work well enough, although the output level might be a bit lower due to its lower gain. The MSA-06 (MAR-6) would also be a good choice. It's similar in many ways to the MSA-01, except for its lower collector voltage and lower noise figure. The latter is of little merit in this application.

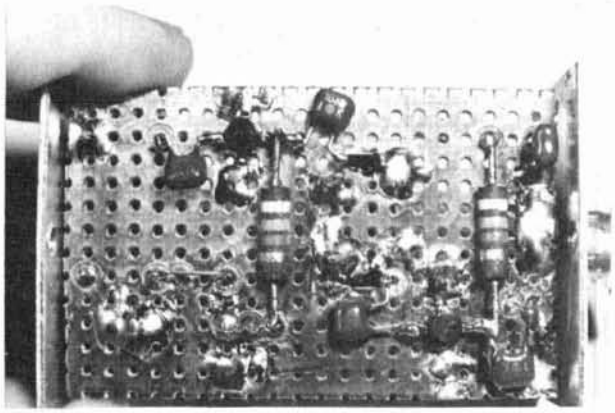
The next stage is the filter. The ideal filter would have no loss at 903 MHz, and infinite loss at all other frequencies. In practice, we want as much rejection as possible. The undesired harmonics are unfortunately close to the desired spectral line, only 18.432 MHz above and below the output at 903.168 MHz. This signal generator's circuit architecture is not ideal for rejection of undesired harmonics because the multiplication order is so high — the price you pay for such simplicity. Still, if the filter can reject the adjacent harmonics (numbers 48 and 50) by 10 to 20 dB relative to the harmonic at 903 MHz, the output will be quite useful.

Commercially available helical resonator filters are a good choice for this application. They are narrowband, have sharp rejection skirts, and low insertion loss at their center frequency. The Toko company manufactures a line of helical resonator filters with two or three resonator sections. Some even come pretuned. Either the two or three- section filter will work, but the three-section one gives a cleaner output spectrum due to its greater attenuation of the adjacent harmonics. The Toko filters available in the 900-MHz region have passband widths of about 10 to 15 MHz, measured at the −3 dB points, and losses of about 4 dB at the center frequency. They are packaged in small metal cans with radial leads at the bottom. You'll need good grounding to make them work, but otherwise they're trouble free.

A second MMIC amplifier after the filter increases the signal level of the 903-MHz line — the strongest harmonic at this point in the circuit. Here the signal level is low, so a high gain MMIC amplifier with a low compression point is again suitable (though for somewhat different reasons than for the stage ahead of the filter). Any one of the MMIC amplifiers mentioned before will work.

In summary, the test-signal generator is a chain consisting of an oscillator followed by a multiplier/amplifier, a narrow filter centered at the output frequency, and an output amplifier. There are only four stages, few components, and no adjustments.

PHOTO A



Details of the prototype's circuit board. The crystal oscillator's four leads are seen at the upper left. The first MMIC amplifier is at the top, and the bandpass filter is near the center. The output MMIC is at lower right.

Construction details

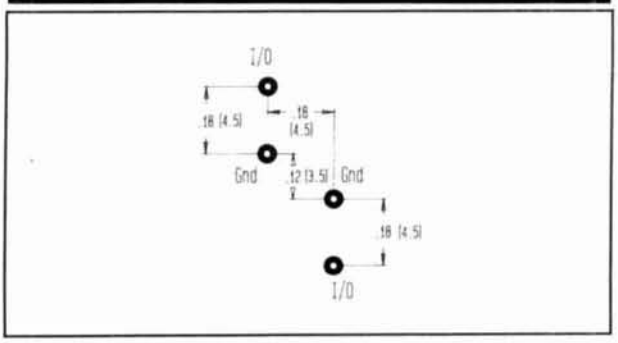
There's little need for a printed circuit board for a simple project like this; the usual Amateur methods work well. I used a copper-clad perfboard for the prototype. The oscillator DIP and the helical filter sit on the unclad side of the board while the smaller RF parts solder directly onto the copper-clad side. You can see many of the construction details in **photo A**.

The crystal oscillator's leads protrude through the holes in the perfboard. Two of the leads (the DC power lead and the RF output) are isolated above ground, so I cleared away the copper with a pad cutter. The other two leads are soldered to the copper foil, which is the ground plane for the circuitry.

Install the MMIC amplifiers by bending their two ground leads flush to the package and soldering them to the copper ground foil, as close as possible to the MMIC package. This gives them low-impedance ground connections. Leave the input and output ribbon leads suspended in the air; they are both short and stiff so no other support is needed. Solder the input and output coupling capacitors and the output bias resistor directly to the MMIC leads. Make the connections as short as practical, as is the practice in the "hot" portions of UHF circuitry. Short leads increase the mechanical strength of the assembly.

The hardest part is mounting the helical resonator filter, because its leads aren't on the perforated circuit board's 0.1-inch grid pattern. This means that you must drill special holes for at least some of the leads. **Figure 3** shows the pin connections and spacings for

FIGURE 3



Mechanical pin outline drawing of the two-section filter. Dimensions are inches (millimeters).

the two-section filter. Bend the metal mounting tabs on the filter flat and solder them to the board's copper ground foil.

The test oscillator can easily be built inside a 2″ × 1.5″ × 1.5″ box. A shielded box is preferable. It allows for the cleanest possible output, because only the filtered signal is permitted to exit the box by way of the output connector. **Photo B** shows my version, mounted in the ubiquitous "Bud" box. The output connector is a BNC type. It's a lossy choice at this frequency, but convenient, widely available, and inexpensive. DC power for the circuitry comes in through banana jacks.

Operation and test results

Once the circuit board is fully assembled (it took me about 90 minutes), it's ready for operation. No tuning is needed, and in fact none is possible. (The helical filters have screw adjustments which could be tuned for better response, but that's probably not a good idea without a spectrum analyzer.) The test oscillator should draw about 100 mA at 13.6 volts. Each of the MMIC amplifiers should have about 4 volts at the output tab, and about 1.6 volts at the input lead. There should be 5 volts at the output of the voltage regulator supplying the oscillator. If all of these voltages are correct and present, the signal generator should be operating.

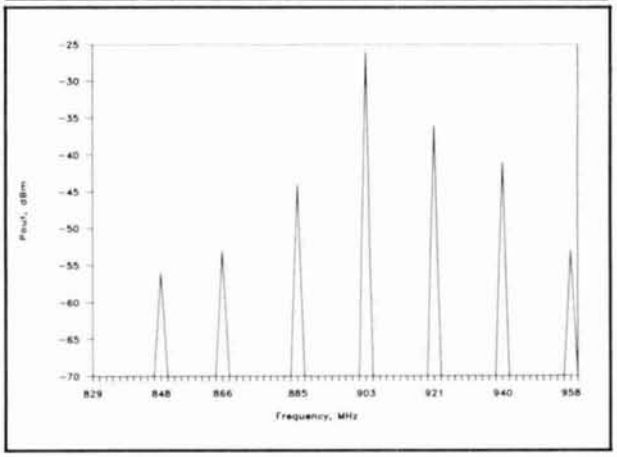
As soon as I applied DC power, the prototype worked and produced a strong signal at about 903.2 MHz. The audio note was fairly pure — quite pleasingly so for a crystal oscillator that was not designed for low phase noise and multiplied 49 times. (The phase noise of an oscillator is increased during frequency multiplication.)

On a spectrum analyzer, the output signal measures −26 dBm (2.5 μW) at the circuit board. This is not a huge signal by transmitter standards, but plenty large for testing even insensitive receivers. The spectrum appears fairly "clean" and the adjacent harmonic lines

PHOTO B

External view of the signal generator installed in a small metal box. The RF output is via the BNC connector to the right; DC power connects to the Banana jacks on the left.

FIGURE 4

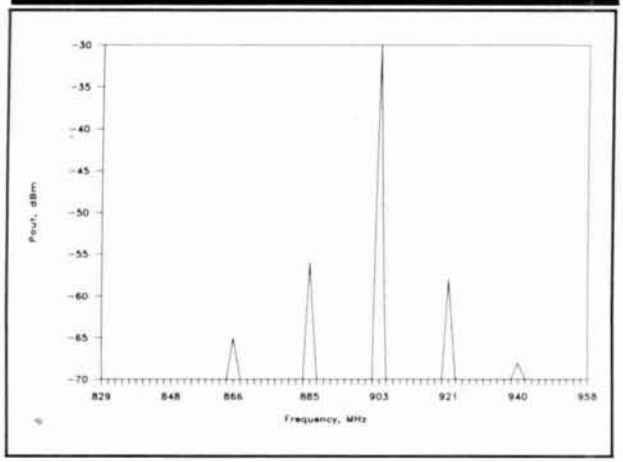


Spectral plot of the test oscillator's output. The main signal at 903.17 MHz is at about −26 dBm; all other harmonics are at least 10 dB below that.

are down more than 10 dB below the desired output. This is acceptable for a tuning indicator, and is good for a crystal reference. A spectrum plot is shown in **fig. 4**. You can see that the adjacent harmonics are rapidly attenuated away from the desired 903 center. All of the harmonics below 800 MHz and above 1 GHz are at least −70 dBm.

When a three-section helical resonator is used in place of the two-section model, the results should be even better — as indicated in **fig. 5**. I made the prediction that appears in **fig. 5** from the vendor's test data of filter attenuation of the three-resonator filter. Of course the three-section filter is more expensive, but the output purity is considerably better. The three-section filter is generally a good idea; for antenna testing (where the signal is radiated in space) the better filtering is probably essential. Building the test generator should be no different with the more selective filter, except for the necessary change required in the mechanical layout due to the filter's slightly larger size.

FIGURE 5



Predicted spectral plot for a signal source using a three-section helical resonator in place of the two-section filter used in the prototype.

Summary

This simple project provides a useful tool for aligning filters, amplifiers, and receivers and also for antenna testing. Because it can be built and used without needing alignment, it's a good starting point for work in the 903-MHz band. Use a similar approach with a different crystal oscillator and the proper filter to make a test generator for frequencies from at least 200 MHz up to 1200 MHz. You can assemble a "quick and dirty" version in less than one hour; a carefully constructed version — including packaging — shouldn't take more than three or four hours.

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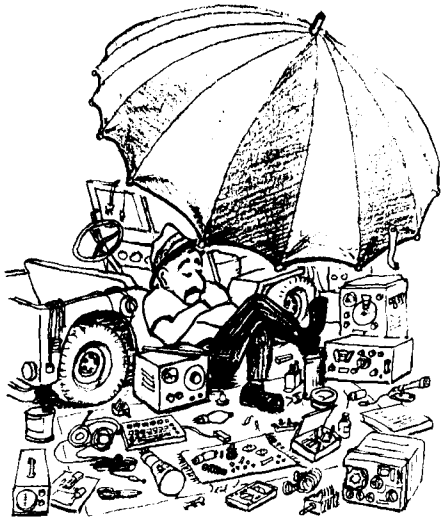

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INDIANA: January 7. South Bend Hamfest Swap & Shop, first Saturday after New Year's Day, Century Center downtown on US 33 Oneway North between Trustcorp Bank Building and river. Four lane highways to door from all directions. Tables: $5/5 ft. round; $15/8x2.5 rectangular; $20/8 ft. wall locations. Talk in freq: 52-52, 99-39, 69-09, 34-94, 145.29. K9IXU (219) 233-5307.

WISCONSIN: January 14. 17th annual Midwinter Swapfest sponsored by the West Allis Radio Amateur Club, Waukesha County Exposition Center Forum, Highways J & FT, Waukesha. 8 AM to 3 PM. Admission $2/advance; $3/door. Reserved 4' tables $3.00; at door $4. Free coffee and donuts until 9 AM. Amateur exams. Packet Radio meeting. Send SASE to WARAC Swapfest, POB 1072, Milwaukee, WI 53201

MASSACHUSETTS: January 14. MMRA, Minuteman Repeater Association, Flea Market, Westborough Senior High School. Admission $2. Tables $10/advance; $13/door. Doors open to sellers 8:30 AM. Talk in on MMRA's 146.01/.61 repeater. For tables contact Scott Bullock, KA1CLX 26 Willis Street, Apt 21, Framingham, MA 01701 (508) 872-4961 or Andrew Morrison, N1BHI (508) 481-3878.

LOUISIANA: January 21. SELARC Hamfest, South Eastern LA University Rec. Center. Exams, tables and fun. Wheelchair accessible. Joe Farris, 390 Piney Woods, Ponchatoula, LA 70454. (504) 386-8393.

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FLORIDA: January 29. The Sky High ARC's 9th annual Citrus County Hamfest, New Location—National Guard Armory, Seven Rivers Drive, Crystal River. Doors open for exhibitors 7 AM. General public 9 AM. Admission $3 advance, $4 door. Talk in on 146.355/955. SHARC Hamfest, 5334 S. Forest Terr, Homosassa, FL 32646 for tickets, tables or further information.

LONG ISLAND, NY. February 5. LIMARC Hamfest, Electricians Hall, 41 Pinelawn Road, Melville. 9 AM to 3 PM. Admission $4.00 all ages. $3.00 after 11:30 AM. 4x6 tables $12. Your own $1.50 per ft. Advance registration only. Talk in on 146.85. Mark Nadel, NK2T, 22 Springtime Lane East, Levittown, NY 11756 (516) 796-2366 or Hank Wener, WB2ALW (210) 694-1811.

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MASSACHUSETTS: February 18. Electronics Flea Market sponsored by the Algonquin ARC. Marlboro Middle School Cafeteria, Union Street off Rt 85, Marlboro. 10 AM to 2 PM. Sellers 8 AM. Admission $2.00. Tables $8/advance; $10/door. Wheelchair accessible. Talk in on 146.01/61 and 146.52. For more information Dan, KB1WW (617) 481-1587 or write AARC, Box 258, Marlboro, MA 01752.

MICHIGAN: March 19. The South Eastern Michigan Amateur Radio Association's 31st annual Hamfest/Swap & Shop, Grosse Pointe North High School, 707 Vernier Rd, Grosse Pointe Woods. 8 AM to 2 PM. Advance $2.00; at the door $3.00. Tables $8.00 and $10.00. ARRL and DX forums, Packet Radio demo. Talk in on W8FWC Repeater 146.74/14. For information write SEMARA Swap, PO Box 646, St. Clair Shores, MI 48080. Please SASE or phone N8HLY (313) 526-9498 after 6 PM.

THE MIT UHF REPEATER ASSOCIATION and the MIT Radio Society offer monthly HAM EXAMS. All classes Novice to Extra. Wednesday, January 18, 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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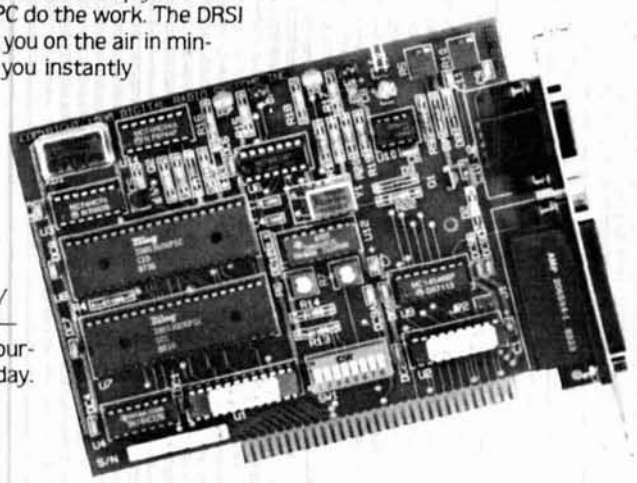

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DX FORECASTER

Garth Stonehocker, KØRYW

Better DXing in 1989

Now that the new year's begun, take time to consider ham radio DXing. It should be a new kind of year for this activity. The sunspot number will climb to very near maximum by the end of 1989, so now's the time to evaluate how your station performs on the higher frequency bands. The maximum usable frequency (MUF) for December 1989 is expected to reach 27.5 MHz at midlatitudes. MUF's nearly twice those in recent sunspot minimum years are expected. And, since the last sunspot maximum, we are allowed to use two new bands that we didn't have at the last sunspot maximum. These are 12 meters (usable now) and 17 meters (available July 1, 1989).

If you need a new rig to cover these bands, you may want a more powerful one. But the new bands (particularly 12 and 17 meters) are up where signal absorption isn't usually a great problem. However, you may want to evaluate your antenna's ability to put the signal where you want to DX. The signal increase you'll gain from coupling the antenna to the ionosphere to work your favorite DX area is well worth the effort. Choose the antenna that best increases your station's signal strength by homebrewing or selecting one of the many on the market. Directional antennas are highly recommended and not too difficult to build on 12 meters. A horizontal antenna can be placed high enough (60 feet) to give a signal takeoff angle of 10 degrees for general Dxing, but you'll need to determine the height that gives you the best angle to put the signal at the correct distance. While they are inherently low-angle radiators, vertical antennas need good ground radial systems and correct array phasing to put the best signal at the needed distance and place.

Last-minute forecast

Expect the first and second weeks to have openings in the higher frequency bands (10 to 30 meters). This is due to higher solar flux. Some openings may provide excellent signals to southern countries in the late afternoon and evening. Ionospheric disturbances could enhance these openings near the 5th, 11th, and 18th. Paths to Japan and Europe may have fluctuating signals and lower MUF's during these disturbed periods. Conditions will be favorable for winter absorption anomaly openings 3 to 4 days after the disturbance around the 18th. Check WWV for the STRATWARM announcement, along with the position of the poor signal area and its 180-degree partner. The strong signal openings are at positions in between. These openings are usually for the lower frequency bands near the evening, but do extend into the higher bands.

Lunar perigee is on the 12th; the full moon appears on the 22nd. An intense but short-duration (a few hours) meteor shower — the Quadrantids — will occur between January 2 and 4.

Band-by-band summary

Ten and 12 meters, the highest daylight-only DX bands, are nearest the MUF for Southern Hemisphere paths. They will be open during the 3 to 5-hour period centered on local noon most days when the solar flux is above 150. These bands open on paths toward the east and close toward the west. The paths are up to 4000 km (2400 miles) in single-hop length, and will double on occasion during evening transequatorial openings.

Fifteen and 17 meters daylight-only DX bands (open most of each day) have lower signal strengths and greater multipath variability than 10 and 12 meters. Propagation will be best when the MUF is resting just above these bands, up until the time it drops below them. This transition period occurs soon after sunrise and just before sunset. Transequatorial openings will occur with distances similar to 10 and 12 meters.

Twenty, 30, and 40 meters are both daytime and nighttime DX bands. Twenty is the maximum usable band for DX in the northern directions during the day and, in combination with 30 meters, provides nighttime paths for the day-only bands. Forty meters becomes the main over-the-pole DX daytime band, with some hours covered by 30 meters. This path and east-west paths may be affected by 10-20 dB of anomalous absorption during a few days of the month.

Eighty and 160 meters, the night-only DX bands, exhibit short-skip propagation during daylight hours and then lengthen at dusk. These bands follow the darkness path, opening to the east just before local sunset, swinging more to the north-south near midnight, and ending up in the Pacific areas for a few hours before dawn.

Article L

JANUARY

WESTERN USA

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

MID USA

MST	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00
ASIA FAR EAST	30	20	20	30	30	30	40	40	40	40	40	40	40	30	20	20	30	30	40	40	40	40	40	40
EUROPE	30	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
S. AFRICA	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
S. AMERICA	12	12	15	15	15	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
ANTARCTICA	12	12	15	15	15	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
NEW ZEALAND	10	12	12*	12	12	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
OCEANIA AUSTRALIA	10	20	15	20	20	20	20	30	30	30	40	40	40	40	40	40	40	40	40	40	40	40	40	40
JAPAN	15	20	20	20	20	20	20	20	30	30	40	40	40	40	40	40	40	40	40	40	40	40	40	40

EASTERN USA

EST	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00
ASIA FAR EAST	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
EUROPE	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	30	30	30
S. AFRICA	15	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
CARIBBEAN S. AMERICA	15	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
ANTARCTICA	15	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
NEW ZEALAND	10	12	12	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
OCEANIA AUSTRALIA	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
JAPAN	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next **higher** band for possible openings.

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83-822	PL-259 Teflon, Amphenol	1.50
PL-259/ST	UHF Male Silver Teflon, USA	1.50
UG-21D/U	N Male RG-8, 213, 214, Amphenol	2.95
UG-21B/U	N Male RG-8, 213, 214, Kings	4.00
9913/PIN	N Male Pin for 9913, 9086, 8214 fits UG-21D/U & UG-21B/U N's	1.50
UG-21D/9913	N Male for RG-8 with 9913 Pin	3.95
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(continued from page 64)

the polarity of both batteries and the milliammeters. The results were much the same (although the actual numbers were different because the transistor had different characteristics). There was a small amount of leakage current (collector current flow when there was no measurable base current), but the collector current increased smoothly in response to changes in R1.

JFETs operate on a different principle; I'll get into that next month. Until then, why don't you grab a couple of old transistors and see what you can find out?

Article H **HAM RADIO**

REVIEW

New high performance Yagi

Cushcraft's 12-4CD is the latest in the line of high performance HF mono-band Yagis. The 12-4CD, scaled from the popular 10-4CD, is designed to cover the new 12-meter ham band. The latest entry into the Skywalker family includes: computer-aided design-optimizing forward gain and maximizing sidelobe attenuation; the 50-ohm Reddi-match feed system (which allows direct connection to 50-ohm coax through a UHF PL-259 connector); rugged construction of heavy-wall, heat-treated 6063-T832 aluminum tubing; and stainless steel hardware. The 12-4CD is designed to cover the entire 100-kHz band segment with a SWR of less than 1.2 to 1, and is rated at 2000 watts PEP.

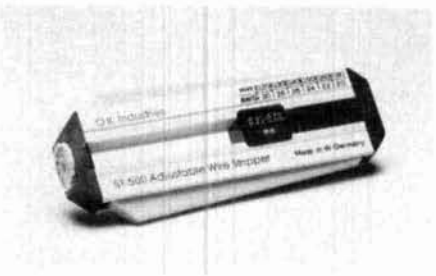
Antenna assembly was straightforward and simple with Cushcraft's updated instruction sheet. A concise, step-by-step, illustrated instruction manual showed the easiest way to final set-up. To put the antenna together you need a standard straight-blade screwdriver, a small adjustable wrench, and a measuring tape. I put all the parts together in a little more than an hour. After I had assembled the 12-4CD, it took me about 15 minutes to install it on a crank-up tower. The antenna is a delight to work with on towers. It weighs just 21 pounds and has a surface area of 3.9 square feet. It can be easily installed by one person.

Performance of the 12-4CD is what you'd expect from a high-performance 4-element monoband Yagi. Tuning from band edge to band edge indicated a maximum SWR of 1.3 to 1, with resonance at the center of the band. Although the higher bands (i.e. 12 and 10 meters) have been marginal at best through the summer months here in the Northeast, I was able to make several stateside contacts — all with excellent reports. Owing to the newness of the 12-meter band, and the relative lack of commercial antennas it, I didn't run comparative A-B tests. But from contest experience with Skywalker 10-4CD and 15-4CD beams, I believe this antenna will be a hot performer on 12 meters in the coming years. If you're looking to enjoy DX on 24 MHz and take advantage of our increased spectrum, this antenna will make your signal loud on 12 meters!

NB1H

New precision tool stripping wire

OK Industries Inc. has introduced a new adjustable precision wire stripper, the ST-500. The ST-500 strips 20 to 30 AWG wire with four specially hardened blades that handle all types of wire insulations — including Teflon. Simply turn the adjustment wheel to the appropriate wire diameter, put the wire through the hole, squeeze the handle, and turn the tool slightly to withdraw the wire.



The ST-500 also includes an adjustable wire stop, which ensures consistent wire strip lengths.

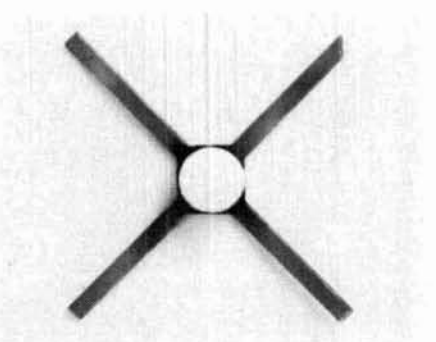
The ST-500 lists for $29.95 and is ex-stock.

For more information about the ST-500 or OK Industries full range of Bench Tools contact: OK Industries Inc., 4 Executive Plaza, Yonkers, New York 10701.

Circle #301 on Reader Service Card.

Low cost, high gain hetero-junction FET

California Eastern Laboratories announces the NE32084 low noise, hetero-junction FET. Low noise and high associated gain make the device suitable for LNA, gain stage, and OSC applications in DBS, TVRO, and other low cost, high volume products.



The performance features are as follows:

NF: 1.5 dB MAX (1.3 dB TYP) at 12 GHz
GA: 9.0 dB MIN (10.0 dB TYP) at 12 GHz

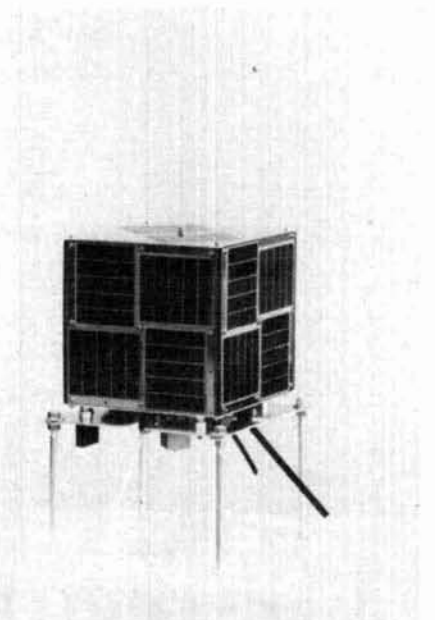
Samples and mass production quantities are available now from California Eastern Laboratories, the exclusive sales agent in North America for NEC RF and microwave semiconductors. For further information contact California Eastern Laboratories, Inc., 3260 Jay Street, Santa Clara, California 95054.

Circle #302 on Reader Service Card.

Consortium pioneers new satellite class

A consortium of Amateur Radio groups (AMSAT-NA, AMSAT-LU, and BRAMSAT — Brazil AMSAT) and Weber State College, Ogden, Utah are working together to construct and launch a new class of ultra-compact "microsatellites" so small they can be launched on virtually any launcher. The Tucson Amateur Packet Radio (TAPR) organization is providing initial financial support and ARRL is assisting with design and construction support.

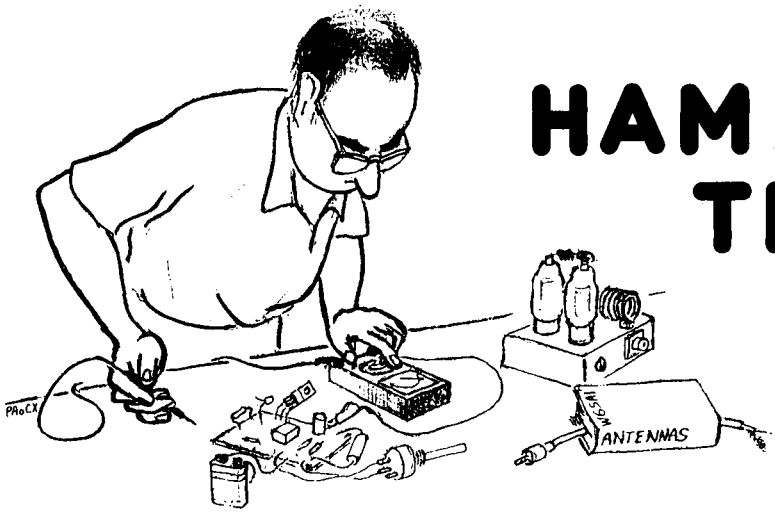
Each satellite consists of a common design bus. Each bus carries a mission-specific payload. AMSAT-NA and AMSAT-LU payloads are packet radio transponders. BRAMSAT's payload is a voice synthesizer transmitting easily-heard



VHF FM downlinks. The Weber State College payload is an earth-looking CCD camera.

The most unique characteritic of each satel-

(continued on page 106)



HAM RADIO TECHNIQUES

Bill Orr, W6SAI

A balun for 10 meters

More so than the lower frequency bands, 10 meters is a hostage to the sunspot cycle. When the sunspot count is low, the band is dead. Only spotty, occasional DX shows up as a result of sporadic E or other chancy forms of propagation.

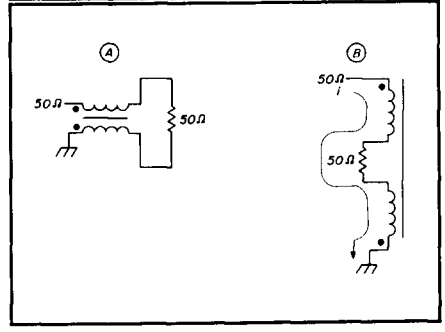
However, when the sunspot cycle is comfortably high the 10-meter band is a DX operator's paradise. Signals boom in from all parts of the world, often with astounding strength. Many recently licensed Amateurs have never had the thrill of 10-meter DX. But after a false start last spring 10 meters is jumping once again, and there's great interest in 10-meter antennas and antenna accessories.

Judging from my mail and conversations with newly licensed hams, the antenna balun is a confusing topic. I hear these questions: What is a balun? What does it do? Do I need one?

How the balun works

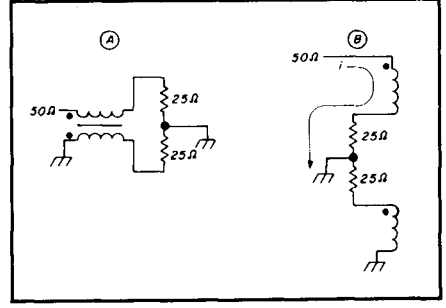
Let's look at the workings of the balun first. The word "balun" stands for "balance-to-unbalance". This implies that a balun provides two equal and opposite-phase voltages with respect to ground when driven from an unbalanced source, like a coax line with one conductor at ground potential. The balun is an ideal device for connecting a balanced antenna (such as a dipole) to a coax line.

FIGURE 1



(A) One-to-one, two-conductor balun matches ungrounded load. (B) Equivalent circuit shows magnetizing current (i) flowing through windings and load.

FIGURE 2



(A) Two-winding balun connected to grounded, balanced load. (B) Equivalent circuit shows magnetizing current (i) no longer flows equally in the windings and the load.

From another point of view, the balun provides isolation between the coax outer shield and the half of the dipole connected to it. If the balun were not present, some of the current flow in the coax shield would be present on the outside of the shield — not the inside. The current on the outside of the shield can radiate into space, making the coax line part of the antenna.

In the case of a beam, outer shield current can ruin an otherwise good front-to-back ratio, cause loading difficulties, and even lead to TVI and RFI problems. It can also cause erroneous SWR readings regardless of antenna type.

Some beam antennas and dipoles come with baluns, others don't. You can buy or build a balun if you want one. Building a balun isn't difficult, especially for 10 meters.

The 1:1 balun

There are many forms of baluns; the most popular Amateur type is the 1:1 design. This implies that when the balun is used with a 50-ohm coax line, it provides a balanced 50-ohm termination. Amateurs have found that this simple balun works well with balanced antennas having a feedpoint

impedance as low as 20 ohms, or as high as 80.

The simplest form of 1:1 balun is a choke coil made of coax line. The line is wound into a multi-turn coil about ten times the diameter of the coax. Most designs specify six to eight turns (**fig. 1A**). The electrical equivalent of this balun is shown in **fig. 1B**. The balun may be either air wound, or wound on a ferrite or powdered-iron core. (More about the core material later.)

If the balun is connected to a balanced and "floating" load (one that is not grounded), the balun will do the job. The magnetizing current (the current that creates the magnetic field in the core) is balanced in the windings and doesn't upset the balanced output voltages. You can see this in **fig. 1B**.

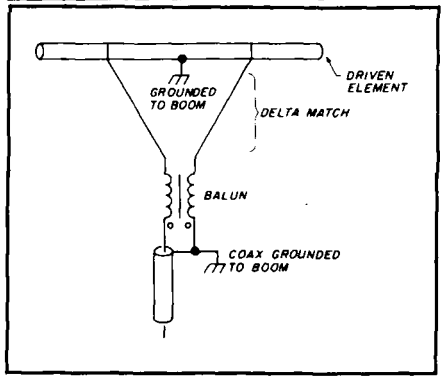
There's no guarantee that the driven element of the antenna is really balanced in an electrical sense. The degree of balance depends upon physical and electrical characteristics (mounting technique, parasitic capacitances, proximity of coax line, etc.) that you can't measure or control. One solution to this problem is to physically ground the center point of the antenna (**fig. 2A**). The load is no longer floating to ground, but the magnetizing current no longer flows equally in the windings and the load! It's shorted to ground by the ground point of the antenna (**fig. 2B**).

Here's an example. Some beam designs employ a balun and delta-match feed system with the driven element grounded to the boom of the array (**fig. 3**). Intuition tells you the design is practical, but the illustration in **fig. 2B** clearly shows that half of the feed system isn't working; the magnetizing current isn't flowing through one balun winding. The two-winding balun isn't doing the job it's supposed to do.

The three-winding balun

In many cases the two-winding balun (coax line wound up into a coil) feeding an ungrounded, floating dipole is adequate. A better solution is the three-winding balun shown in **fig. 4A**.

FIGURE 3



Two-winding balun (coax balun, for example) is shorted out when coax shield and center of driven element are grounded to boom of antenna.

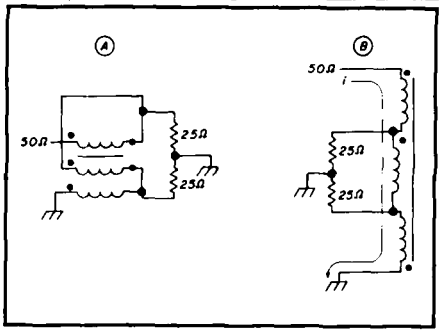
The third winding provides a path for the magnetizing current around the load, regardless of whether the load is floating or not (**fig. 4B**). Note that the polarity of the third winding is reversed. This is the ideal solution to the problem. The majority of 1:1 baluns on the market are made in this configuration. The simple coil-type coax balun can be readily converted into a three-winding balun. I'll tell you how in the next section.

A homemade balun for 10 meters

Figure 5 shows a simple and inexpensive air-core three-winding coax balun you can build. The balun is usable over the range of 14 to 30 MHz. You'll need a 25-1/2 inch length of RG-8A/U, a PL-259 plug and 3 feet of plastic covered no. 12 single conductor wire, available from most hardware or home improvement stores.

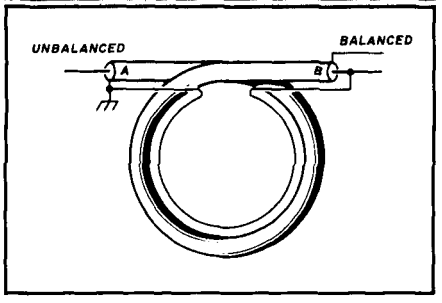
First place the PL-259 on one end of the coax cable. Next, remove 2 inches of the outer jacket of the opposite end of the line. Unbraid the outer braid and twist it into a pigtail. Now remove about an inch of the inner insulation. Place large soldering lugs on the two conductors. You'll attach these to the terminals of the driven element. The exposed joint needs to be carefully covered later with CoaxSeal™ Radio Shack Connector Sealant 278-1645, or equivalent to make sure water doesn't enter the coax cable.

FIGURE 4



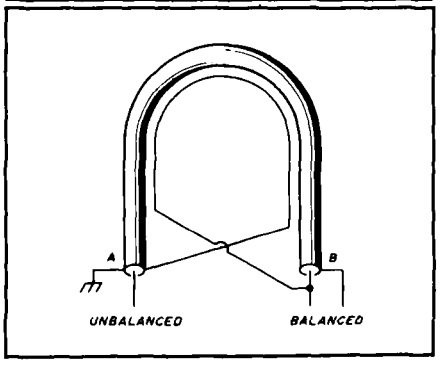
Three-winding balun (A) can feed either grounded or ungrounded load and maintain magnetizing current (B).

FIGURE 5



Coax balun performs properly when third winding is added. Extra winding is cross connected to coax at the ends. (Actual balun has two turns.)

FIGURE 6



Simplified balun drawing showing cross connections.

Winding the balun

Next, wind the coax into a two-turn coil; leave about two inches of coax free on each end. Do this by manipulating the size of the coil. The coax plug and pigtails should lie very close to each other on the same side of the coil. Hold the coil in position with bits of vinyl tape.

Now add the third winding to the coil. Carefully wind the plastic-covered wire in parallel with the coax. This is easy because there are only two turns to the coil. Smooth the wire up against the coax and tape it in place every few inches. When you've finished, the wire will be running closely parallel to the coax and you can tape the coil completely.

Finally, attach the wire to the coax winding. If the coil size is right, there will be about 2 inches (or less) of coax free of the coil at each end. The wire winding is cross-connected at the ends of the coax. (See **fig. 6**.) The end of the wire nearest end A of the coax is connected to end B of the coax. Do this by soldering one end of the wire to the shell (not the ring!) of the PL-259 and the other end of the wire to the free center conductor lead, just before it enters the soldering lug. Trim the ends of the wire as you proceed so that no loose wire is left at either end of the coil. After everything's in place, wrap the complete coil again with vinyl tape and waterproof the wires at one end of the balun with the coax tape.

That's all there is to it! The power rating of the balun is the same as that of the coax line.

You can also make a smaller, lighter balun for low-power applications by substituting RG-58B/U coax for the RG-8A/U. A PL-259 plug and UG-175 reducing adapter are used at one end of the balun; otherwise, all is as described earlier.

Modifying the balun for wideband use

The three-winding coax balun can be modified for lower frequency use. If you use three turns instead of two for both windings, the operating range of the balun is 7 to 30 MHz; with five turns, the range is 3.5 to 18 MHz. A six-turn design didn't work very well as it was difficult to hold the wire coil in close proximity to the coax coil.

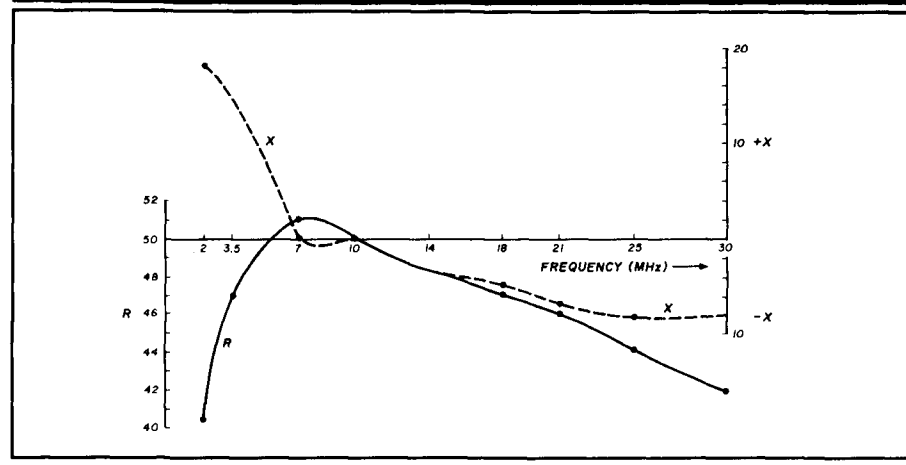
The ferrite-core balun

The air-core balun I've described is somewhat limited in low-frequency response. Even the five-turn design wasn't too good at the low-frequency end of the 80-meter band. You can extend the low-frequency limit by adding turns to the balun, but it's difficult to make an air-core balun that's electrically unbalanced function properly on the 80-meter band.

The solution is to use a higher permeability core. Both ferrite and powdered-iron cores that will do the job are available. The core can be a rod or a toroid. At the higher frequency end of the spectrum the core is almost "invisible," but the core is most important as the frequency of operation is lowered. At 80 meters, the entire balun field is contained within the core. Some manufactured baluns must be derated on 80 meters to prevent the core from running too hot. Many of them won't function at all on 160 meters. But the need for a balun on the lower bands is questionable; few highly directional antennas are used at these frequencies. In the case of a simple antenna like a dipole, current flow on the outside of the coax is no big deal. If the coax line is made an odd multiple of a quarter wavelength (1/4, 3/4, etc.), and an effective ground is used on the transmitter, current flow on the outside of the coax will be at a minimum.

The perfect balun really exists only in the laboratory; practical low-cost baluns work, but exert some influence on antenna resonance. Wideband, Amateur-style ferrite-core HF baluns usually have a design frequency of about 10 MHz and are useful over the 3.5-30 MHz range. Air-core coax-wound baluns have about the same design frequency, but are useful only down to about 4 MHz. In either case, above or below the design frequency, the balun appears as a reactive load and introduces its own SWR anomaly into the picture. **Figure 7** shows the SWR response of a typical wideband balun working into a 50-ohm load. The balun is good, but not perfect. The reactive effect of the balun, when you're operating with an antenna, is to move the resonant frequency of the antenna either higher or lower. A beam cut to 14,150 kHz, for example, may seem to be resonant at 14,220 kHz and "look like" 48.5 ohms when checked through a 50-ohm balun.

FIGURE 7



Ferrite-core trifilar balun shows good response between 6 and 25 MHz. Performance is poor at 80 meters (3.5-4.0 MHz) and 10 meters (28-30 MHz). Balun is terminated in 50-ohm noninductive load.

Dial cards for the TL-922A amplifier

I was working Bob, KL7DJI, in Fairbanks, Alaska the other day; he gave me a great idea for tuning charts for a linear amplifier. I made up a set, and they have proved invaluable for quick band changes (**fig. 8**).

The idea is simplicity itself. Cut a dial card from heavy paper. (I used index cards to make mine.) Slot the card to

(continued on page 109)

NEW products

lite is its volume and mass. Only 23 cm (9 inches) on a side, each cubical spacecraft will weigh in at less then 10 kg (22 lbs.). The small mass and volume make it feasible to launch these spacecraft inexpensively.

AMSAT officials say this new class of satellites uses advances in microminiaturization, advanced RF devices, and modular construction to pioneer a new niche in performance/mass/volume for satellites.

AMSAT-NA has contracted for an early 1989 launch for the first four satellites. The four satellites will be launched into a polar, low earth orbit by Arianespace early next year. The primary payload will be the French SPOT-II mission.

For more informantion, contact AMSAT Information Officer, Vern Riportella, P.O. Box 177, Warwick, New York.

Circle #303 on Reader Service Card.

Free catalog of tools and test equipment

Jensen Tools Inc. offers a free catalog of tools and test equipment. Illustrated in full color, the 160-page catalog lists many new products.

The catalog features over 50 tool kits. Other major categories include: hand and power tools (English and metric), tools and accessories for fiber optics and wire/cable systems, static control products, soldering/desoldering supplies, lighting and optical aids, circuit board accessories, test cables, carrying cases and shipping containers.

For your free catalog, write or call Jensen Tools Inc., 7815 S. 46th Street, Phoenix Arizona 85044. (602)968-6231.

Circle #304 on Reader Service Card.

New computer interface option

Advanced Computer Controls, Inc. announces the new computer interface option for the RC-850 Repeater Controller. The interface opens up remote control, programming and information access to FM repeater systems from a home computer or terminal via telephone modem or packet TNC.

The user interface resembles a packet BBS. It's menu driven with lots of on-line help.

Information that can be downloaded from the controller includes a "front panel display," command log, metering information, activity information, and the contents of the programmable memory. All controller commands may be entered through the remote terminal with text responses displayed on the terminal screen. Programmable speech and Morse code messages stored in the controller may be viewed directly as text. They can be reprogrammed by typing the letters and words directly, without referring to vocabulary codes.

Two additional Touch-Tone decoders on the Computer Interface board offload the main shared decoder for full-time coverage of links and remotes, and the telephone line.

A Vocabulary Expansion Option increases the

size of the synthesized speech vocabulary to 530 words.

The price of the Computer Interface Board is $350; the Vocabulary Expansion Option is $75. For additional information, contact Advanced Computer Controls, Inc., 2356 Walsh Avenue, Santa Clara, California 95051. Or call 1-408-727-3330.

Circle #305 on Reader Service card.

MFJ-986 3 KW differential-T antenna tuner

MFJ Enterprises, Inc. has introduced the new MFJ-986 3 KW Roller Inductor Differential-T Antenna Tuner. This unique design uses a single differential capacitor in place of two variable capacitors. It covers 1.8 to 30 MHz continuously, including MARS and all the WARC bands.

The differential capacitor makes tuning easier because you get minimum SWR at only one setting and have only two controls to adjust. It also gives you a broadband response that eliminates constant retuning.

A three-digit turns counter plus spinner knob gives precise inductance control for instant return to a favorite frequency.

The compact 10-3/4″ × 4-1/2″ × 15″ aluminum cabinet has plenty of room to mount the silver-plated roller inductor away from metal surfaces for highest "Q" and maximum power into your antenna.

A lighted two-color peak and average reading Cross-Needle SWR/Wattmeter lets you read forward and reflected power and SWR at a glance. It also has a new directional coupler that gives more accurate SWR and power readings over a wider frequency range.

A six-position antenna switch lets you select two coax lines and/or random wires (direct or through tuner), balanced line and external dummy load.

A new current balun for balanced lines reduces feedline radiation, field pattern distortion, and TVI. Ceramic feedthrough insulators for balanced lines withstand high voltages and temperatures.

The new MFJ-986 3 KW Roller Inductor Differential-T Antenna Tuner is priced at $239.95 and comes with MFJ's one-year unconditional guarantee.

For more information or your nearest MFJ dealer contact MFJ Enterprises, Inc., P.O. Box 494, Mississippi State, MS 39762, or order toll free at 800-647-1800.

Circle #306 on Reader Service Card.

QD-2 Quick Disconnect

Hustler, Inc. announces a new and improved Quick Disconnect, Model QD-2. The QD-2 is similiar to the original model QD-1 but features a new design for the lower half. The QD-2 is milled from a solid piece of stainless steel and comes with a 2-year warranty. For further information contact the Sales Department, Hustler, Inc., 1 Newtronics Place, Mineral Wells, Texas 76067.

Circle #307 on Reader Service Card.

CELEBRATE

the 75th anniversary of ARRL with a new Handbook!

1989 marks the 75th anniversary of the founding of the League. There's no better way of celebrating this momentous occasion, than with the new *1989 ARRL Handbook for the Radio Amateur*!

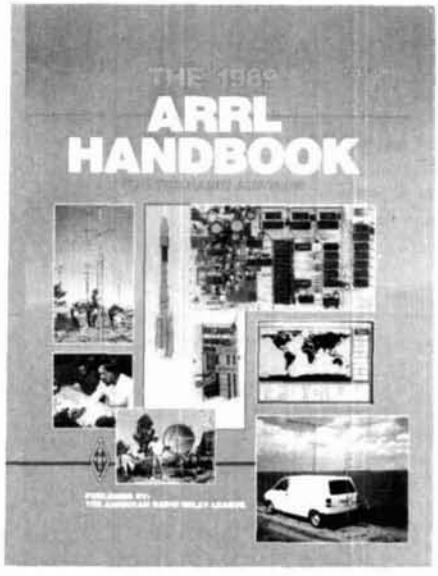
The 1200-page sixty-sixth edition contains over 2100 tables, figures and charts. The new *Handbook* is better than ever with revised information on phase noise measurement, direct frequency synthesis and spread spectrum communication techniques. The section on repeaters has been updated including a new CW identifier circuit. You'll find new spectrum analyzer and oscilloscope material, as well as several new projects in the test equipment chapter.

As always, we've added a host of new construction projects to this new edition. Just some of the new projects include: A 500-MHz frequency counter, 160 through 10 meter legal limit amplifier, simple CMOS keyer project, digital audio memory keyer and a L/Q meter for measuring coil inductance.

But that's not all. You'll find many other popular construction projects that can be built in a weekend such as power supplies and VHF/UHF preamps. For the more ambitious builder there are projects like the 1.8 MHz QSK transverter (there are VHF/UHF transverter projects too) and there are many amplifier designs to suit your needs from HF through microwaves.

The Handbook has always been famous as a reference for component data and you will find an entire chapter devoted to everything from transmitting tube and transistor specifications to aluminum tubing sizes. Satellite enthusiasts will find that the digital TR sequencer will add operating convenience to your station. Of course, you'll find the most up-to-date information on digital techniques, and the video communications chapter is packed with information not only on SSTV, ATV and FAX but Weather FAX as well. QRP enthusiasts will find the famous "Cubic incher" transmitter; not much bigger are the QRP SWR indicator and QRP Transmatch. There is also a VXO-controlled 6-watt CW transmitter for your favorite band between 80 and 15 meters. There are a number of useful station accesories that you can build like DTMF encoders and decoders, PIN-diode TR switch, digital PEP wattmeter and SWR calculator, Transmatches and dummy loads.

For $21, *The ARRL 1989 Handbook for the Radio Amateur*, remains an exceptional value for a hardcover technical publication. The price outside the US is $23. For postage and handling, add $2.00 (or $3.50 for insured mail or UPS — please specify)



Here is a description of what is covered in the Handbook:
The first 5 chapters serve as an introduction and cover: basics of Amateur Radio, electrical fundamentals, radio design technique and language, and solid state fundamentals. Vacuum tube principles as they pertain primariliy to high power amplifier design are also presented in these introductory chapters. There are 12 chapters devoted primarily to these radio principles: power supplies, audio and video, digital basics, modulation and demodulation RF transmitters, receivers, transceivers, repeaters, power amplifiers, transmission lines and antenna fundamentals. Another 4 chapters cover voice, digital, image and special modulation techniques. The RF spectrum, propagation and space communications are covered in 2 chapters. The construction and maintenance section has 12 chapters of useful projects ranging from power supplies and antennas through digital equipment. You'll find up-to-date component data that the Handbook is famous for. The final 5 chapters cover how to obtain your license, station design and operation, interference, monitoring and direction finding. An abbreviations list, huge index and etching patterns make up the balance of the book.

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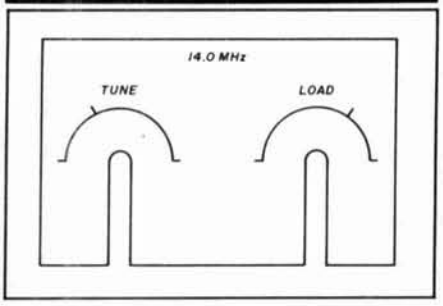
The American Radio Relay League, Inc., 225 Main St., Newington, CT 06111 USA

(continued from page 105)

FIGURE 8



Dial card for TL-922A amplifier. Cursor marks enable fast tuning. One card is made for each band.

drop down behind the "tuning" and "loading" panel controls. You'll need one card for each band.

Tune and load the amplifier and transfer the dial settings to the card. Just mark a line on the card that corresponds with the line indicated on the dial. Then, when you retune, slip the proper band-dial card in place and readjust the dials to the marks. This idea also works well with the various transceivers that have adjustable tuning and loading controls.

The "Dead Band" contest

Aha, you Couch Potatoes! I really caught you with my second quotation quiz! The cable:

STORY TRUE. AWAIT ME ALGIERS. BURROUGHS

is the beginning of *Pellucidar*, by Edgar Rice Burroughs. This is the transatlantic cable sent by Burroughs to Cogdon Nestor, who had found the telegraph line laid by David Innes connecting the Sahara Desert to Pellucidar — 500 miles below the earth's surface.

To date (late August), the only sharp-eyed readers who identified the famous cable are: Bob Clarke, N1RC; John Brown, GØGJB; and Bill Lathan, AK5K. Good work! My condolences to WØTDH, NW2V, W9VE, and W5OWS who came close.

Thanks to the following detectives who correctly identified the quote from Sherlock Holmes: Gerry Skloot, KE2N; Howard Tooker, W3TL; Ben Richardson, WB1CUA; Louis Axeman, Jr., N8LA; Dan Deckert, WA6FQC; Mike Mahoney, WA1KNO; Chris Kirk, KA1RSV; Dave Fordham, KD9LA; Peter Chadwick, G3RZP; Charles Rhine, AAØM; Cliff Watkins, KB7ADF; Jeff Rahmel, KA8ZAW; John Peak, KE6HS; Don Murray, W9VE; Jim Josenhans, WB2LEH; Bob Clarke, N1RC; John Nagle, K4KJ; and Dale Hunt, WB6BYU. Congratulations to all!

This month's "Dead Band Quiz" is an easy one. Name the book and author. If you don't know, ask your XYL or girl friend: "Last night I dreamt I went to Manderley again."

If you think you can identify this quotation, drop me your answer on a QSL card: Box 7508, Menlo Park, California 94025. Good luck!

Article M **HAM RADIO**

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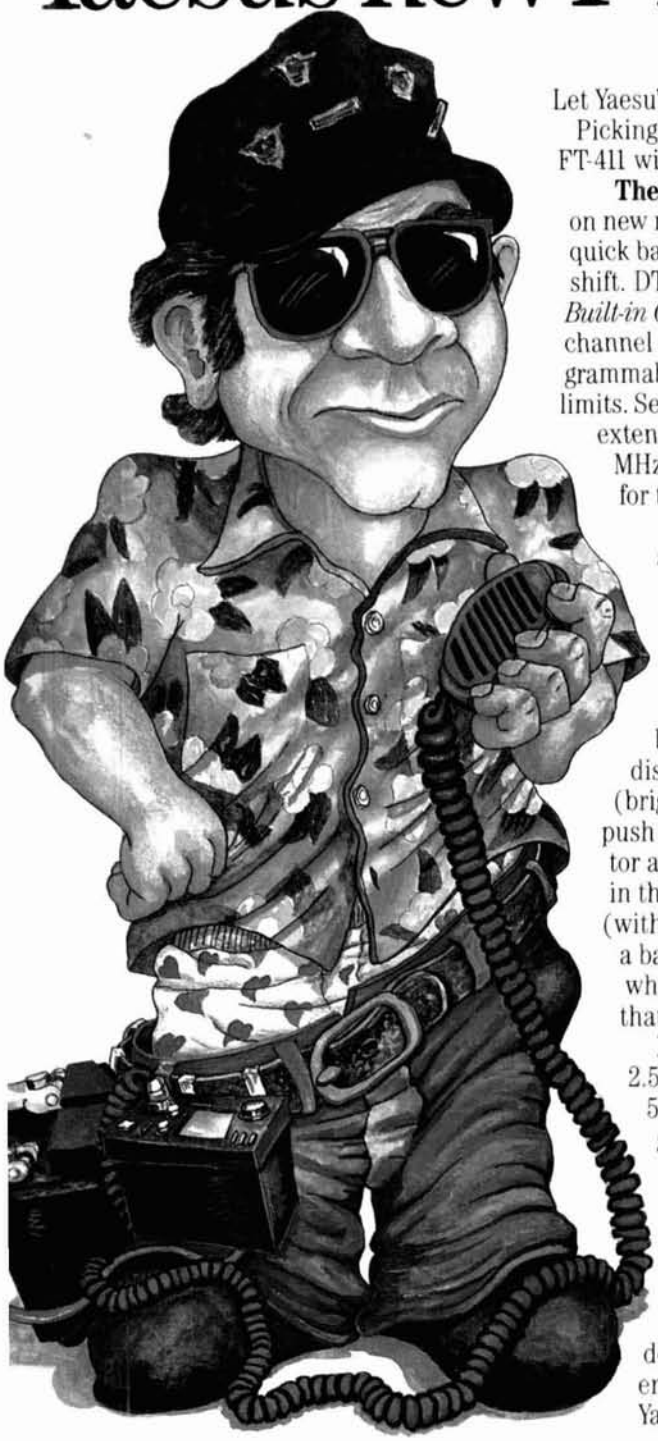

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Not bad for a handheld measuring just 55(w) x 32(d) x 139(h) mm (the same size as our FT-23R Series HTs)!

Friendly operation. For operating convenience, the FT-411's keypad features a "do-re-mi" audible command verification. Both the display and keypad can be backlit (brightly!) for night operation at the push of a button. A rotary channel selector allows fast manual tuning. Or key in the frequency directly. Operate VOX (with YH-2 headset option). Plus you get a battery saver to conserve power while monitoring. And a (defeatable) automatic power-off feature that shuts down your radio if you forget to turn it off!

High power capability. The FT-411 comes equipped with the 2.5-watt, 600-mAh FNB-10 battery pack. Try our optional FNB-12 5-watt, 500mAh pack or tiny FNB-9 2.5-watt, 200-mAh pack. Or get 6 watts output by applying 13.8-volts DC from an external power supply.

Swap options with Yaesu's FT-23R Series. Our rugged best-seller's chargers, batteries, and microphones are fully compatible with the FT-411. The FT-23R is the perfect companion for the FT-411, and at a great price!

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TS-940S—the standard of performance by which all other transceivers are judged. Pushing the state-of-the-art in HF transceiver design and construction, no one has been able to match the TS-940S in performance, value and reliability. The product reviews glow with superlatives, and the field-proven performance shows that the TS-940S is "The Number One Rated HF Transceiver!"

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- First with a full one-year limited warranty.
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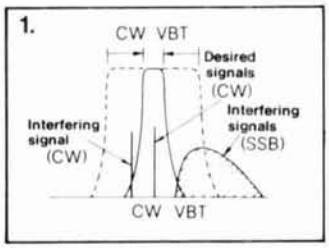

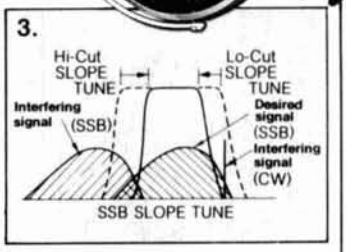

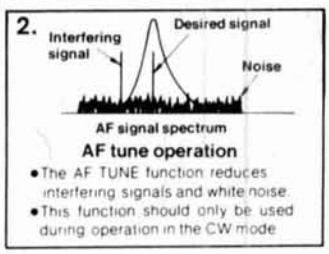

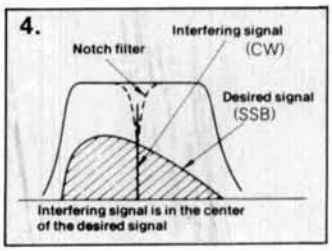

1) CW Variable Bandwidth Tuning. Vary the passband width continuously in the CW, FSK, and AM modes, without affecting the center frequency. This effectively minimizes QRM from nearby SSB and CW signals.

2) AF Tune. Enabled with the push of a button, this CW interference fighter inserts a tunable, three pole active filter between the SSB/CW demodulator and the audio amplifier. During CW QSOs, this control can be used to reduce interfering signals and noise, and peaks audio frequency response for optimum CW performance.

3) SSB Slope Tuning. Operating in the LSB and USB modes, this front panel control allows independent, continuously variable adjustment of the high or low frequency slopes of the IF passband. The LCD sub display illustrates the filtering position.

4) IF Notch Filter. The tunable notch filter sharply attenuates interfering signals by as much as 40 dB. As shown here, the interfering signal is reduced, while the desired signal remains unaffected. The notch filter works in all modes except FM.

- Complete all band, all mode transceiver with general coverage receiver. Receiver covers 150 kHz-30 MHz. All modes built-in: AM, FM, CW, FSK, LSB, USB.
- Superb, human engineered front panel layout for the DX-minded or contesting ham. Large fluorescent tube main display with dimmer; direct keyboard input of frequency; flywheel type main tuning knob with optical encoder mechanism all combine to make the TS-940S a joy to operate.
- One-touch frequency check (T-F SET) during split operations.
- Unique LCD sub display indicates VFO, graphic indication of VBT and SSB Slope tuning, and time.
- Simple one step mode changing with CW announcement.
- Other vital operating functions. Selectable semi or full break-in CW (QSK), RIT/XIT, all mode squelch, RF attenuator, filter select switch, selectable AGC, CW variable pitch control, speech processor, and RF power output control, programmable band scan or 40 channel memory scan.

Optional accessories:
• AT-940 full range (160-10m) automatic antenna tuner • SP-940 external speaker with audio filtering • YG-455C-1 (500 Hz), YG-455CN-1 (250 Hz), YK-88C-1 (500 Hz) CW filters; YK-88A-1 (6 kHz) AM filter • VS-1 voice synthesizer • SO-1 temperature compensated crystal oscillator • MC-43S UP/DOWN hand mic. • MC-60A, MC-80, MC-85 deluxe base station mics. • PC-1A phone patch • TL-922A linear amplifier • SM-220 station monitor • BS-8 pan display • SW-200A and SW-2000 SWR and power meters • IF-232C/IF-10B computer interface.

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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