

JULY 1988 / \$2.50

ham radio • July 1988

# ham radio

magazine



**hr**  
focus  
on  
communications  
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annual VHF/UHF issue

Hand built PA CX



# HOW DO YOU PACK 7 WATTS, 20 MEMORIES AND SCANNING INTO A HANDHELD?

**IC-2GAT: 7 Watts** Rx 138-174MHz, Tx 140-150MHz

**IC-4GAT: 6 Watts** 440-450MHz

**IC-32AT: 5 Watts** Rx 138-174MHz/440-450MHz,  
Tx 140-150MHz/440-450MHz

**A New Generation of Powerful, Versatile Handhelds.**

*Select a new "G Series" or dual band ICOM transceiver and enjoy full base station luxury in a portable unit designed especially for you!*

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- **Compatible Accessories.** All ICOM IC-2AT/02AT series battery packs, headsets and speaker mics are interchangeable.
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**IC-32AT**  
2 Meters and  
440MHz

**IC-2GAT**  
2 Meters

**IC-4GAT**  
440MHz



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All stated specifications are subject to change without notice or obligation. All ICOM radios significantly exceed FCC regulations limiting spurious emissions. 1H4488

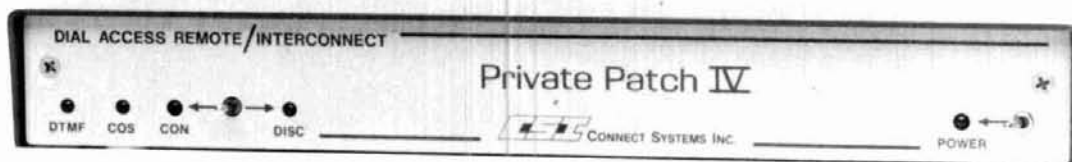
# THE ALL NEW PRIVATE PATCH IV BY CSI HAS MORE COMMUNICATIONS POWER THAN EVER BEFORE

- Initiate phone calls from your HT or mobile
- Receive incoming phone calls

NEW!

- Telephone initiated control . . .

- ✓ Operate your base station with complete control from any telephone
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- ✓ Selectively call mobiles using regenerated DTMF from any telephone
- ✓ Eavesdrop the channel from any telephone
- ✓ Use as a wire remote using ordinary dial up lines and a speaker phone as a control head.



The new telephone initiated control capabilities are awesome. Imagine having full use and full control of your base station radio operating straight simplex or through any repeater *from any telephone!* From your desk at the office, from a pay phone, from a hotel room, etc. You can even change the operating channel from the touchpad!

Our digital VOX processor flips your conversation back and forth fully automatically. There are no buttons to press as in phone remote devices. And you are in full control 100% of the time!

The new digital dialtone detector will automatically disconnect Private Patch IV if you forget to send # (to remotely disconnect) before hanging up. This powerful feature will prevent embarrassing lock-ups.

The importance of telephone initiated control for emergency or disaster communications cannot be overstated. Private Patch IV gives you full use of the radio system from any telephone. And of course you have full use of the telephone system from any mobile or HT!

To get the complete story on the powerful new Private Patch IV contact your dealer or CSI to receive your free four page brochure.

Private Patch IV will be your most important investment in communications.

✓ = NEW FEATURE

- ✓ \* /# or multi-digit connect/disconnect
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- Secret toll override code
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- ✓ Dialtone disconnect
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- Timeout timer
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- Ringout
- ✓ Ringout or Auto Answer on 1-8 rings
- Busy channel ringout inhibit
- ✓ Status messages
- ✓ Internally squelched audio
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- ✓ Separate CW ID level control
- ✓ 24 dip switches make all features user programmable/selectable.

- Connects to MIC and ext. speaker jack on *any* radio. Or connect internally if desired.
- Can be connected to any HT. (Even those with a two wire interface.)
- Can be operated simplex, through a repeater from a base station or connected directly to a repeater for semi-duplex operation.
- 20 minutes typical connect time
- Made in U.S.A.

## OPTIONS

1. ½ second electronic voice delay
2. FCC registered coupler
3. CW ID chip



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THE FIRST  
144/220 MHz  
Dual Bander!

## Double Take!



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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/remotè 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/remotè 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.

## KENWOOD

KENWOOD U.S.A. CORPORATION  
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# ham radio

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## contents

### 10 sporadic E and 50-MHz transatlantic propagation during 1987

Geoffrey H. Grayer, G3NAQ

### 38 VHF/UHF world: propagation update — part 3

Joe Reisert, W1JR

### 56 cheap and dirty 6-meter beam

Glen E. Zook, W5UOJ

### 60 ham radio techniques: line voltage and power tube life

Bill Orr, W6SAI

### 64 2-meter monitor

Rodney A. Kreuter, WA3ENK

### 72 practically speaking: non-ideal linear IC amplifiers typical problems and how to solve them

Joe Carr, K4IPV

### 78 a simple low-cost comb generator frequency calibrator

Larry Martin

### 90 Elmer's notebook: ten-meter skyware

Tom McMullen, W1SL

The Quad Antenna: part 3 by W4MB will appear  
in our August issue.

98 advertisers index

9 comments

83 DX forecaster

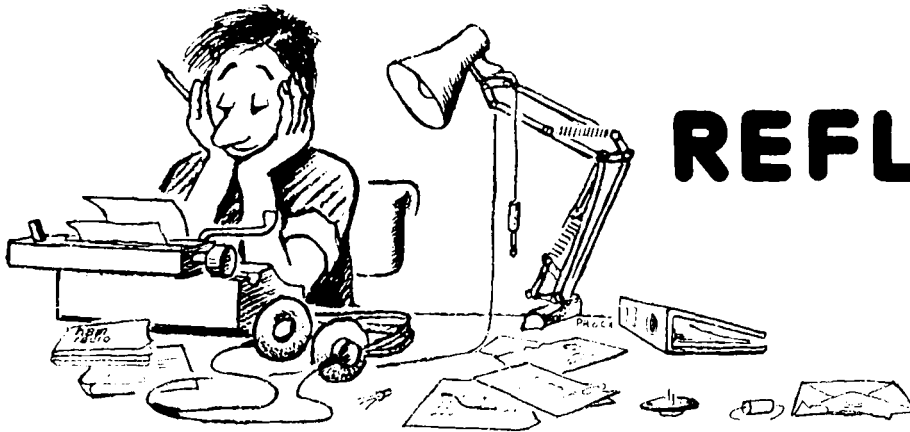
96 flea market

88 ham mart

71 new products

98 reader service

4 reflections



# REFLECTIONS

**No doubt about it folks** — we've got a mess on our hands.

Recent events in the repeater coordination area would lead a casual observer to believe that chaos is but one small step away. While it may be stretching a point, the reality may not be too far from chaos.

In several regions of the United States, groups who are dissatisfied with current coordinators have formed coordinating bodies of their own. The goals of these new groups may be either well placed or highly questionable, but the confusion they are creating is threatening irreparable harm to the hobby.

Because the events leading up to this situation have already been well reported, I won't go into specifics. I will say, however, that blame needs to be assigned to many. Some would call for the FCC to step in and solve the problem once and for all; in this era of government de-regulation it isn't going to happen. The FCC has neither the budget nor the manpower to step in. Anyway, remember what happened in the '70s when the FCC clamped down on repeaters with all kinds of new regulations and rules. Not too many of us were happy with that situation.

Who else could step in and help solve the problem? The ARRL.

After extensive discussion and planning, Steve Mendelson, WA2DHF, ARRL Hudson Division Director, made a suggestion to the FCC at the Dayton Hamvention FCC Forum that makes the most sense I've heard in a long time. Simply put, this suggestion is for the ARRL to conduct a national referendum of repeater trustees to ascertain which coordination group they support. The referendum results would then be certified to the FCC as a clear mandate of who the preferred regional coordinator is for the majority of repeater trustees. The FCC would then "certify" that group as the sole regional authority for frequency coordination.

I have talked to Mendelson at length and feel that his suggestion has tremendous merit. Mendelson has years of experience in the field of repeaters. He is an ex-president of the New York City Area Coordinating Group and has been actively involved in FM communications for many years.

There are a couple of hurdles that need to be cleared before this plan can be implemented. First, the plan is not a League plan — it is Mendelson's and needs to be proposed to the Board of Directors for their approval at the July Board meeting. Second, the proposal needs to be endorsed by the FCC. Without FCC approval, little will be done to solve the problem. In fact, because of the feelings of some of the participants in this struggle, it could further inflame the situation to the point of complete spectrum anarchy.

If ever there was a reasonable and intelligent suggestion to solve a very serious problem, this is it! I urge you to contact your League Director today and discuss this proposal with him. Notes to ARRL President Larry Price and Dave Sumner wouldn't hurt either. There are currently no alternative ideas; Mendelson's plan is well thought out and offers a good chance to solve the problem before it reaches crisis proportions.

Hopefully, the Board of Directors will agree. We can't afford to wait much longer.

**Craig Clark, N1ACH**  
Assistant Publisher

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All New  
Compact HF!

## “DX-citing!”

### TS-440S Compact high performance HF transceiver with general coverage receiver

**Kenwood's advanced digital know-how brings Amateurs world-wide "big-rig" performance in a compact package. We call it "Digital DX-citement"—that special feeling you get every time you turn the power on!**

• **Covers All Amateur bands**

General coverage receiver tunes from 100 kHz—30 MHz. Easily modified for HF MARS operation.

• **Direct keyboard entry of frequency**

All modes built-in USB, LSB, CW, AM, FM, and AFSK. Mode selection is verified in Morse Code.

• **Built-in automatic antenna tuner (optional)**

Covers 80-10 meters.

• **VS-1 voice synthesizer (optional)**

• **Superior receiver dynamic range**

Kenwood DynaMix™ high sensitivity direct mixing system ensures true 102 dB receiver dynamic range. (500Hz bandwidth on 20m)

• **100% duty cycle transmitter**

Super efficient cooling permits continuous key-down for periods exceeding one hour. RF input power is rated at 200 W PEP on SSB, 200 W DC on CW, AFSK, FM, and 110 W DC AM. (The PS-50 power supply is needed for continuous duty.)

• **Adjustable dial torque**

• **100 memory channels**

Frequency and mode may be stored in 10 groups of 10 channels each. Split frequencies may be stored in 10 channels for repeater operation.

• **TU-8 CTCSS unit (optional)**

• **Superb interference reduction**

IF shift, tuneable notch filter, noise blanker, all-mode squelch, RF attenuator, RIT/XIT, and optional filters fight QRM.

• **MC-43S UP/DOWN mic. included**

• **Computer interface port**

• **5 IF filter functions**

• **Dual SSB IF filtering**

A built-in SSB filter is standard. When an optional SSB filter (YK-88S or YK-88SN) is installed, **dual** filtering is provided.

• **VOX, full or semi break-in CW**

• **AMTOR compatible**



**Optional accessories:**

- AT-440 internal auto. antenna tuner (80 m—10 m)
- AT-250 external auto. tuner (160 m—10 m)
- AT-130 compact mobile antenna tuner (160 m—10 m)
- IF-232C/IC-10 level translator and modem IC kit
- PS-50 heavy duty power supply
- PS-430/PS-30 DC power supply
- SP-430 external speaker
- MB-430 mobile mounting bracket
- YK-88C/88CN 500 Hz/270 Hz CW filters
- YK-88S/88SN 2.4 kHz/1.8 kHz SSB filters
- MC-60A/80/85 desk microphones
- MC-55 (8P) mobile microphone
- HS-5/6/7 headphones
- SP-40/50B mobile speakers
- MA-5/VP-1 HF 5 band mobile helical antenna and bumper mount
- TL-922A 2 kw PEP linear amplifier
- SM-220 station monitor
- VS-1 voice synthesizer
- SW-100A/200A/2000 SWR/power meters
- TU-8 CTCSS tone unit
- PG-2S extra DC cable.

**Kenwood takes you from HF to OSCAR!**



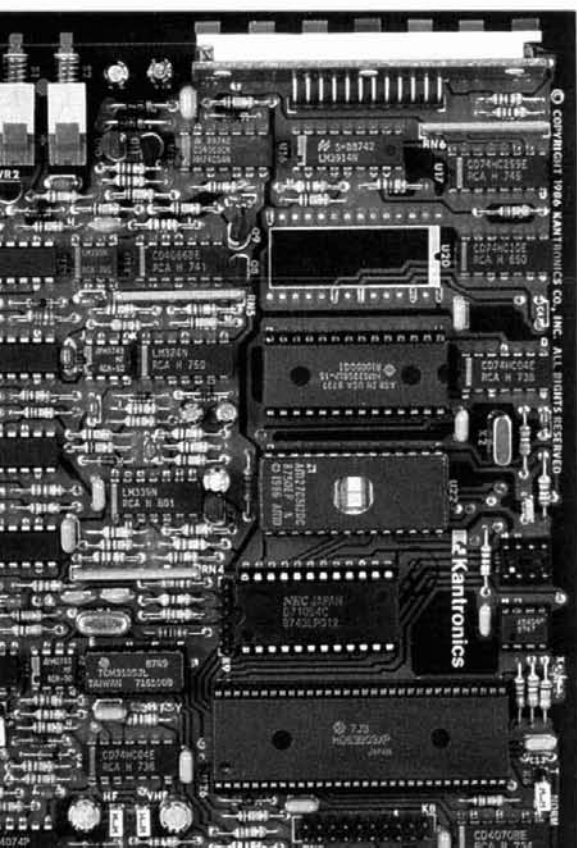
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You'll be the envy of the airwaves with all the modes and features KAM brings to your fingertips. In addition to Packet, ASCII, AMTOR,





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WEFAX, CW and Radioteletype, you'll have Dual-Port Operation (the only TNC offering this feature), Personal Packet Mailbox™, KA-NODE™, gateway, and digipeater operation.

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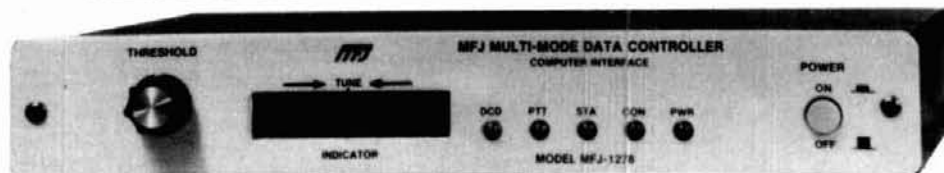
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# MFJ multi-mode data controller



**MFJ shatters the 6 mode barrier and the price barrier with the MFJ-1278 and gives you . . . Packet, RTTY, ASCII, CW, WEFAX, SSTV and Contest Memory Keyer . . . 7 digital modes . . . for an affordable \$249.95**

Amateur radio's newest multi-mode data controller -- the MFJ-1278 -- lets you join the fun on Packet, RTTY, ASCII, CW, Weather FAX, SSTV and gives you a full featured Contest Memory Keyer mode . . . you get 7 modes . . . for an affordable \$249.95.

Plus you get high performance HF/VHF/CW modems, software selectable dual radio ports, precision tuning indicator, 32K RAM, AC power supply and more.

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!

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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 or MFJ-1284 for the IBM or compatible, \$19.95 each.

## Packet

Packet gives you the fastest and most reliable error-free communications of any amateur digital mode.

With MFJ's super clone of the industry standard -- the TAPR TNC-2 -- you get genuine TAPR software/hardware plus more -- not a "work-a-like" imitation.

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

Hardware DCD gives you more QSOs because you get reliable carrier detection under busy, noisy or weak conditions.

A hardware HDLC gives you full duplex operation for satellite work or for use as a full duplex digipeater. And, it makes possible speeds in excess of 56K baud with a suitable external modem.

Good news for SYSOPs! New software lets the MFJ-1278 perform flawlessly as a WORLI/WA7MBL bulletin board TNC.

## Baudot RTTY

You can copy all shifts and all standard speeds including 170, 425 and 800 Hz shifts and speeds from 45 to 300

baud. You can copy not only amateur RTTY but also press, weather and other exciting traffic.

A high performance modem lets you copy both mark and space for greatly improved copy under adverse conditions. It even tracks slightly drifting signals.

You can transmit both narrow and wide shifts. The wide shift is a standard 850 Hz shift with mark/space tones of 2125/2975 Hz. This lets you operate MARS and standard VHF FM RTTY.

You get both the American Western Union and the international CCITT character sets. Autostart for unattended reception and selectable "Diddle".

A receive Normal/Reverse software switch eliminates retuning and Unshift-On-Space reduces errors under poor receiving conditions.

## ASCII

You can transmit and receive 7 bit ASCII using the same shifts and speeds as in the RTTY mode and using the same high performance modem. You also get Autostart and selectable "Diddle".

## CW

You get a Super Morse Keyboard mode that lets you send perfect CW effortlessly from 5 to 99 WPM, including all prosigns -- it's tailor-made for traffic handlers.

A huge type ahead buffer lets you send smooth CW even if you "hunt and peck".

You can store entire QSOs in the message memories, if you wanted to! You can link and repeat any messages for automatic CQs and beaconing. Memories also work in RTTY and ASCII modes.

A tone Modulated CW mode turns your VHF FM rig into a CW transceiver for a new fun mode. It's perfect for transmitting code practice over VHF FM.

An AFSK CW mode lets you ID in CW.

The CW receive mode lets you copy from 1 to 99 WPM. Even with sloppy fists you'll be surprised at the copy you'll get with its powerful built-in software.

You also get a random code generator that'll help you copy CW faster.

## Weather FAX

You'll be fascinated as you watch WEFAX signals blossom into full

fledged weather maps on your printer. Other interesting FAX pictures can also be printed -- such as some news photographs from wire services.

Any Epson compatible printer will print a wealth of interesting pictures and maps.

Automatic sync and stop lets you set it and leave it for no hassle printing.

You can save FAX pictures and WEFAX maps to disk if your terminal program lets you save ASCII files to disk.

Pictures and maps can be printed to screen in real time or from disk on IBM and compatibles with the MFJ-1284 Starter Pack.

You can transmit FAX pictures right off disk and have fun exchanging and collecting them.

## Slow Scan TV

The MFJ-1278 lets you exchange pictures with thousands of SSTVers all-over-the-world.

You'll not only see what your ham buddies look like but you can send your own pictures to them, too.

You can print slow scan TV pictures on an Epson compatible printer. If you have an IBM PC or compatible you can print to screen in near real time or from disk with the MFJ-1284 Starter Pack.

You can transmit slow scan pictures right off disk -- there's no need to set up lights and a camera for a casual contact.

You can save slow scan pictures on disk from over-the-air QSOs, audio tapes and other sources if your terminal program lets you save ASCII files.

The MFJ-1278 transmits and receives 8.5, 12, 24, and 36 second black and white format SSTV pictures using two levels.

## Contest Memory Keyer

Nothing beats the quick response of a memory keyer during a heated contest.

You'll score valuable contest points by completing QSOs so fast you'll leave your competition behind. And you can snag rare DX by slipping in so quickly you'll catch everyone by surprise.

You get iambic operation with dot-dash memories, self-completing dots and dashes and jamproof spacing.

Message memories let you store contest RST, QTH, call, rig info -- everything you used to repeat over and over. You'll save precious time and work more QSOs.

You get automatic incrementing serial numbering. In a contest it can make the difference between winning and losing.

A weight control lets you penetrate QRM with a distinctive signal or lets your transmitter send perfect sounding CW.

## More Features

Turn on your MFJ-1278 and it sets itself to match your computer baud rate. Select your operating mode and the correct modem is automatically selected.

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# comments comments

## carrier complaint

Dear HR:

I finally got around to thoroughly digging into my copy of your March issue.

Your "Reflections" column hit a very, very sore spot with me (if I may be excused for that old, old cliché). I agree with you that all lids who throw carriers on an occupied frequency should be hung by their thumbs (sorry Bob and Ray). I too have experienced trying to copy a weak DX station with the headset in place on my ears and the audio gain turned way up when some idiot sends me rolling off my chair in pain with an S-9 carrier.

I guess I'm not an aggressive DXer, but I do like to do some of it now and again when the bands are open. More often though, you'll find me chatting with some of my friends about our latest antenna experiments or other projects. It is on many of these occasions when I have had that famous urge-to-kill a few of your DXing friends. It's absolutely infuriating to have some lid, working split with a European on 40 meters, start screaming right on our frequency. Of course we can't inform this dumbbell that he is wiping us out because he is listening down below 7100 kHz. Did he ever think to check the frequency he intended to transmit on and/or ask if it was busy? Not on your life. More than once my friends and I have given serious consideration to dropping down on the DX station's transmitting frequency and start up a CW QSO. But we haven't gotten that mad yet...not yet. What is that old saying, "two wrongs never make a right?" So, my DXer friend, next time you get your eardrums blown out by some thoughtless tuner-upper...stop and think. Did

you have the same kind of consideration for the guys on 7.229 MHz when you were trying to make a contact with that EA5 operating split the other night?

Next time you get so frustrated you feel compelled to write an editorial on behalf of all of your DXing buddies, slip the shoe on the other foot and see if it fits.

Incidentally, I have prepared charts of settings for both my transmatch and my amplifier. These are kept handy at my operating position, and 99 percent of the time I can go on the air with transmatch and amp without any preliminary tuneup. If there happens to be a little error and the SWR is higher than I would like, I just touch it up while I'm transmitting my side of the QSO. Those amplifier settings were arrived at by tuning into a dummy load, and the transmatch settings were developed by transmitting low power into my antenna on bands which were closed during that part of the day. Once these settings are recorded and stuck on the wall behind my desk I never have to put a carrier on the bands again.

Hell of a fine publication. Enjoy every issue cover to cover. I admit a good many of the articles are over my head but then I would never learn anything if I read only that which I already knew and understood, would I?

**Harold P. (Phil) Morgan, WD0P,  
ex KAØRUM, Lake Lotawana,  
Missouri 64063**

## remedy for RFI

Dear HR:

Last week one of our local hams, WB6MBT, came to me for help on an RFI problem. Every time he keyed his transmitter, significant amounts of rf appeared at all of his ac outlets. TV reception was impossible. I loaned him a dummy load and suggested he determine if the radiation from his antenna was being coupled into the house wiring. My second suggestion was to check that the neutral ground wire was not connected to his radio chassis.

Finally, I suggested that he wind his line cord on a ferrite rod.

Today I received my March copy of *ham radio* and Bill Orr's column fully endorsed my approach.

I will include some comments on this subject extracted from articles in my RFI file.

"Ground Systems," I.L. McNally, *ham radio*, May 1970:

"Do not use the electric utility ground bus as that common impedance will introduce the noise and interference on that ground wire."

"Solving the Problems of RFI," John Labaj, W2YW, *ham radio*, September 1984:

"Better keep all grounds, especially ac and rf grounds separate. The feed-through of rf power to the ac line will be much greater from a common junction than the ac line would pick up from direct radiation."

"Power Line Grounding: Friend or Foe," WØTHM, *QST*, February 1985:

WØTHM discusses in detail the problems of unbalanced loads in the three wire distribution system. This results in high currents in the neutral wire and an induction field that penetrates throughout the house. Power line transients and power line hash cause serious interference to radio reception if the third wire neutral is connected to the radio chassis.

The first step toward noise reduction is a good earth ground (*ham radio*, May 1980). The second step is to remove the third wire neutral ground connection from the radio chassis. Third, use a good surge and RFI filters in the line supply using a separate earth ground.

The current article on "Radio Grounds" by Bill Orr in the March *ham radio* discusses the use of ferrite rod line filters to reduce the coupling of rf into the house wiring.

It appears that close attention to all of the remedies covered in these articles should go a long way in reducing noise coupling and rf coupling associated with the primary power distribution system.

**I.L. McNally, K6WX  
Sun City, California 92381**

# sporadic E and 50-MHz transatlantic propagation during 1987

Examines  
transatlantic openings  
on 50 MHz

**This article examines** transatlantic openings during 1987 from the United Kingdom on the new 50-MHz (6 meter) Amateur band. Data from ionospheric vertical sounders (ionosondes) on both sides of the Atlantic and a correlation with European DX on the same day supports conjecture that propagation is due to multi-hop sporadic E ( $E_s$ ). The geographical distribution of stations is consistent with the geometry of multiple hops at E layer height and the land distribution. The time behavior of transatlantic openings can be derived from that of European long distance contacts, which in turn is shown to be consistent with  $E_s$  on other bands. Thus  $E_s$  is now firmly established as being partly or completely responsible for transatlantic propagation on this frequency during solar minimum years.

## introduction

In February 1983 the 50-MHz band was released to a number of selected Radio Amateurs in Great Britain, following the termination of Band 1 television transmissions. Since then the band has been made available to both classes of licensees in the United Kingdom (with severe ERP restrictions), and also in certain other European countries. In addition, many Amateurs in countries which still do not allow transmission now have receiving equipment for cross-band contacts. Although the 50-MHz band was available in

pre-war Europe, the band has produced many surprises, perhaps due to advances in equipment and an increased number of stations. Recently there has been much discussion about the propagation mechanism responsible for the transatlantic openings which have been unexpectedly frequent during the present minimum in the solar cycle. It was obvious from the reported strength of the signals that propagation was due to a reflection (or more properly, refraction) mode rather than a scatter mode. Transatlantic openings coincided with the months during which intense ionization of the E layer is common and, together with other evidence, this suggested that multiple reflections from  $E_s$  were the most likely mechanism. I decided to study a few of these events in detail to see which characteristics could be understood using known  $E_s$  phenomenology. Apart from reports by operators of 50-MHz Amateur contacts or reception, data are included from ionosondes at a few MHz, and from observations of Amateur beacons on 28 MHz (10 meter) and of 144-MHz (2 meter)  $E_s$  events. A consistent picture is found throughout the spectrum making it possible to predict, simply but accurately, the time of day when a particular long distance path is likely to be open.

## $E_s$ : an overview

Sporadic E is the name given to a form of ionization which occurs at E layer heights (100-130 km, occasionally up to 170 km) and exhibits rapid changes in density, position, and height<sup>1</sup>. The characteristics of  $E_s$  in the equatorial region, and  $E_s$  connected with

**By Geoffrey H. Grayer, G3NAQ, "Bagatelle",  
3 Southend, Brightwalton, Newbury, Berks RG16  
0BE, England**



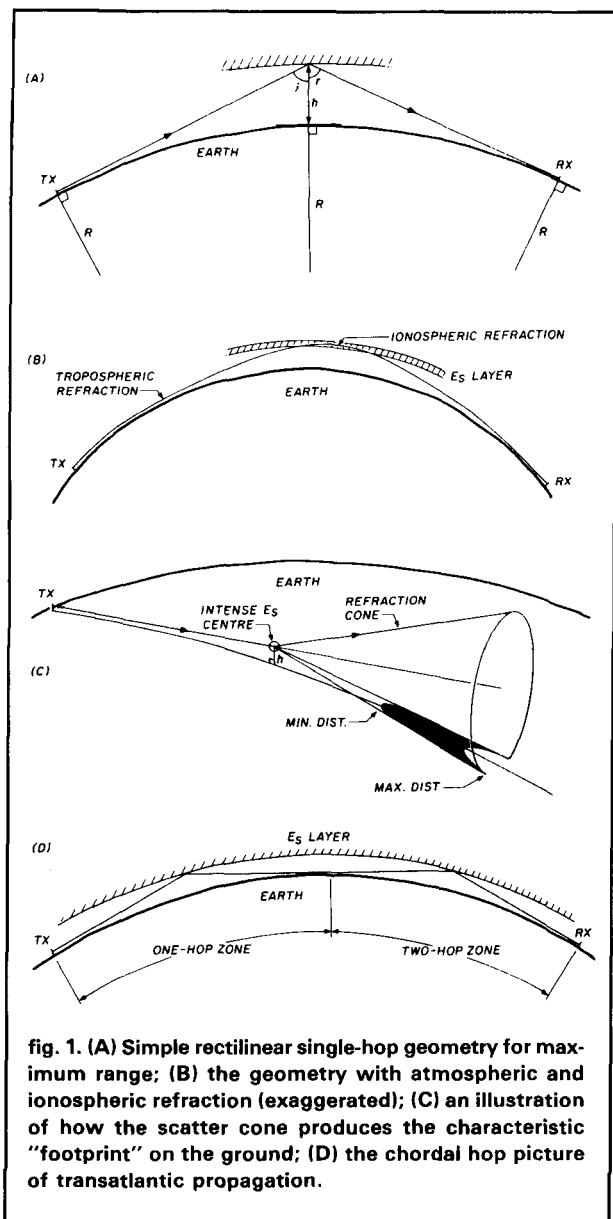


fig. 1. (A) Simple rectilinear single-hop geometry for maximum range; (B) the geometry with atmospheric and ionospheric refraction (exaggerated); (C) an illustration of how the scatter cone produces the characteristic "footprint" on the ground; (D) the chordal hop picture of transatlantic propagation.

auroral activity, differ from temperate zone  $E_s$  which is the type referred to here. A temperate zone sporadic E "layer" is characterized by being rather thin in depth (estimates range from a few km to less than 1 km)<sup>2</sup> and uneven in density.<sup>3,4</sup> It is often transparent enough for higher (normal E and F) ionospheric layers to be observed through it by ionosondes probing at vertical incidence. The frequency below which no penetration occurs is known as the *blanketing frequency*,  $f_b E_s$ . The lowest frequency which penetrates the  $E_s$  layer without any reflection is referred to as the *critical frequency*,  $f_o E_s$ . (The suffix "o" refers to the so-called "ordinary" component of the wave.)

The ionization density of the  $E_s$  layer is never great enough for the frequency  $f_o$  of waves reflected back at vertical incidence to reach 50 MHz. However, as

the angle of radio waves meeting the  $E_s$  layer moves away from the perpendicular (as is the case for point-to-point contacts) the upper frequency of waves which may be returned to earth increases. The highest reflected frequency  $f_{max}$  is normally related to  $f_o$  by  $f_{max} = f_o / \cos i = f_o \sec i$ , where  $i$  is the angle between the ray and the normal to the refracting layer (fig. 1). This relation, sometimes referred to as the *secant law*, is true for a boundary where there is a sudden change of electron density, and is also valid under certain conditions for a horizontally stratified layer<sup>5</sup>. The highest frequencies are reflected when  $\cos i$  is minimum and  $i$  is maximum, corresponding to reflection from an  $E_s$  layer on the horizon. In this case the range is near the maximum possible for the height of the reflecting layer; this range is evaluated later. Only if the layer is completely regular will the wave emerging from the layer be at the same angle to the normal — that is,  $r = i$ . As mentioned above, the layer is in fact usually very uneven in density, and the secant law also implies that regions where the ionization is most concentrated propagate the highest frequencies. These regions can be very small<sup>6</sup>, resulting in extremely narrow "beams" of propagation.

Let us imagine what the  $E_s$  layer looks like if we could see radio waves at any frequency we chose. At  $f < f_b$  (typically a few MHz) we would see the sky covered by a shiny, irregular reflecting surface. Propagation is general over a large area, and multiple hops are possible over the extent of the layer. As  $f$  increases through  $f_b$  to  $f_o$  and above, the patch overhead becomes translucent and then transparent, while the rest becomes increasingly lumpy in appearance. This transparent patch increases in size as the frequency is raised until it spreads to the horizon, but the "sky" remains hazy, as the irregular patches of ionization still scatter some of the waves.

Finally, only a few shiny clouds remain on the horizon. At the highest frequencies where there is still evidence of  $E_s$  (rarely above 200 MHz), only one or two very small concentrations with an ionization density sufficient to refract the radio wave back to earth will be visible. The  $E_s$  no longer looks like a layer, but rather a few small clouds. The waves undergoing maximum deflection from these concentrations of ions form the surface of a cone, filled with waves that are refracted less as they miss the core of ionization. The intersection of this narrow cone with the ground forms the long, narrow wedge-shaped zone of propagation (fig. 1C). The width of this track on the ground must subtend less than the cone vertex angle, and in the case of minimum angle to reach ground, it reduces to a line. In practice the refracting clouds are unlikely to be regular in shape, so the "cone" will also be rather irregular. Rays are refracted into a very small solid angle rather than being widely scattered, so signal

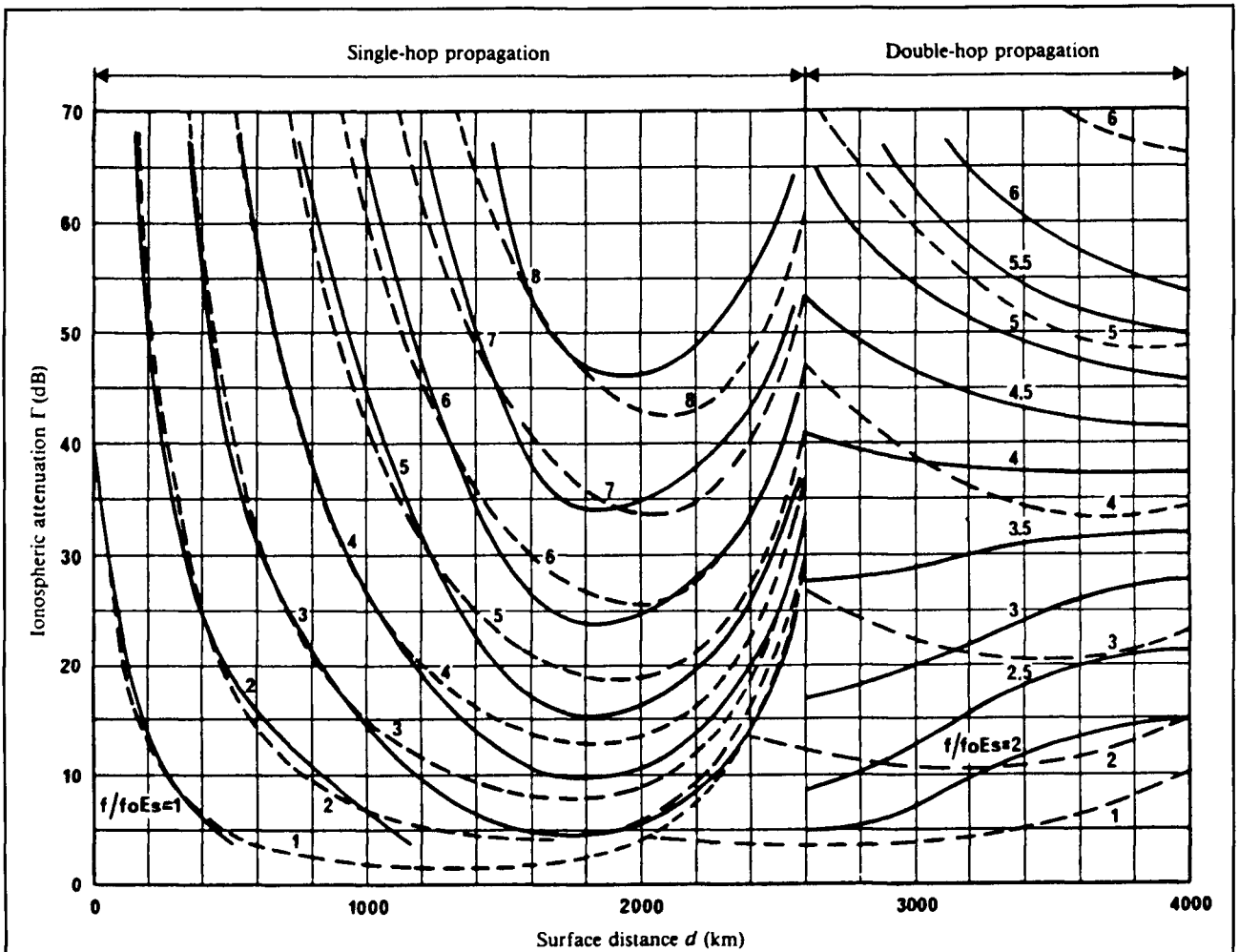


fig. 2. Path loss for  $E_s$  propagation as a function of distance with  $f/f_0$  as parameter. Continuous lines are observed values, dotted lines are from an empirical formula<sup>a</sup> (reproduced by permission of ITU).

reduction will be small. Because the grazing angle with the earth is very shallow, a small increase in bending angle will illuminate a long strip on the ground. Since the  $E_s$  clouds are not stationary, the area covered on the ground will also move, increasing the extent of the opening. This pattern is typical of the upper end of the  $E_s$  spectrum — for example, 144 MHz.

At lower frequencies like 50 MHz this situation will occur more frequently, and sometimes ionization densities will reach levels where the refracted cone grows quite large and skip distance shorter, so that the ground area covered is extensive. The rays in the cone which do not quite reach the ground can go on to encounter another  $E_s$  cloud. At 50 MHz there is still a sufficiently high probability of ionization reaching the necessary density for reflection, so an occasional second or third encounter should come as no great surprise. This can be deduced from the pattern of stations heard during suitable  $E_s$  conditions throughout the

frequency spectrum. The references already quoted also support this scenario.

Now let's consider the maximum critical frequency necessary for  $E_s$  propagation, using the simple rectilinear geometry shown in fig. 1A. The value of the angle  $i$  at maximum range (elevation angle at antennas being zero) is given by

$$i = \sin^{-1} \left( \frac{R_o}{R_o + h} \right) \quad (1)$$

where  $R_o$  is the radius of the earth, and  $h$  is the height of the reflecting layer. At a typical  $E_s$  layer height of 115 km, the resulting value of  $i$  is 79.2°. The secant law  $f_o = f_{max} \cos i$  gives 9.35 MHz as the critical frequency which must be exceeded for 50 MHz to be returned to ground. Because of the irregularity of the  $E_s$  layer described above, the secant law is only approximately true in its simple form. Weak propagation does take place by scatter mode above  $f_{max}$ , but



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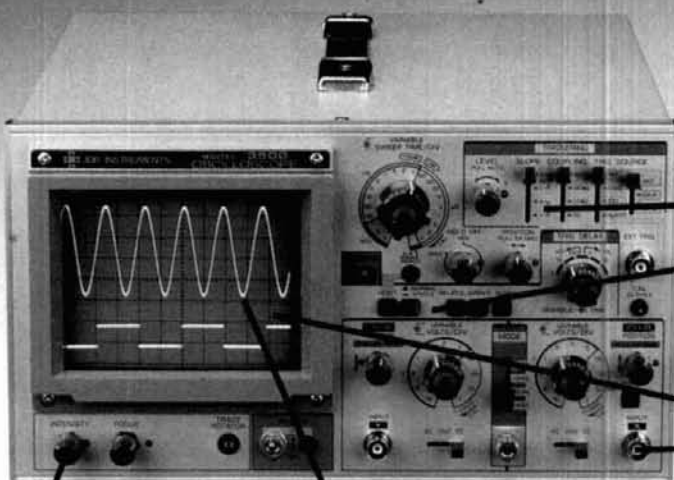
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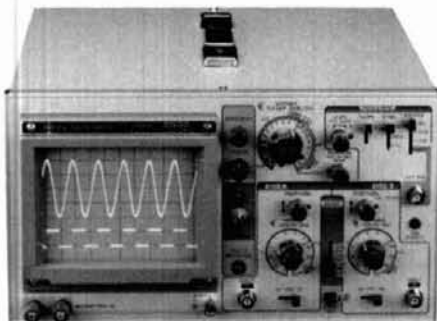
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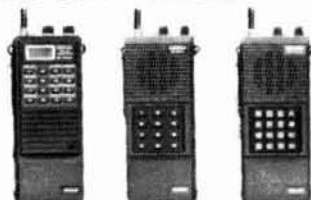
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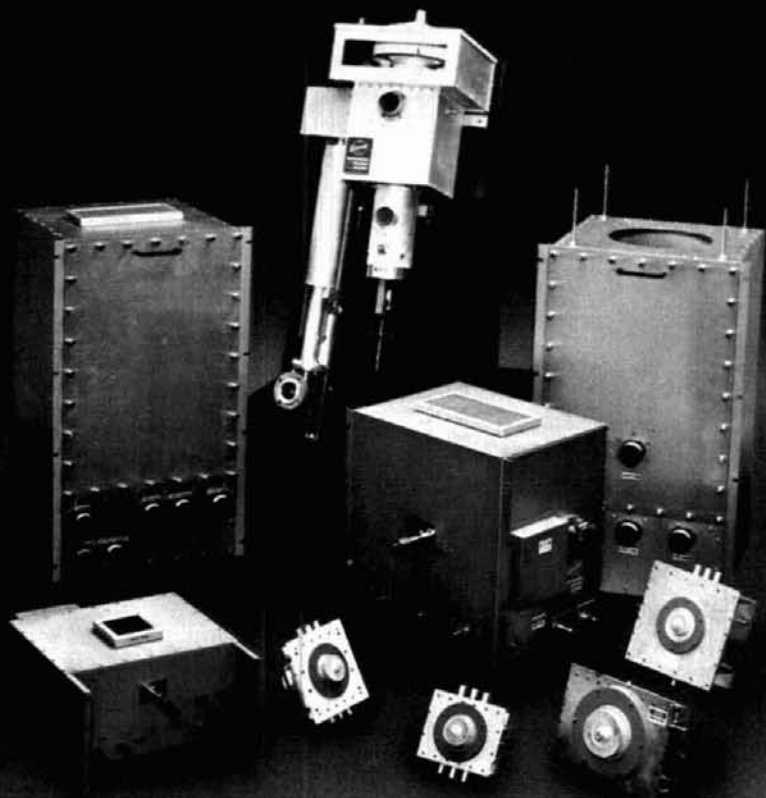


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CV-2250	3CX10,000U7	170-227	10 kW†
CV-2400	8874	420-450	300/1250 W*
CV-2800	3CX400U7	850-970	225 W
CV-2810	3CX400U7	910-970	190 W

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there is a rapid increase in signal strength near this frequency<sup>6</sup>. It has been found<sup>7</sup> that a better approximation is  $f_{max} = \epsilon f_o \sec i$ , where  $\epsilon$  normally lies between 1.2 and 1.3. For 50-MHz propagation it is probably sufficient that  $f_o$  exceeds 7.2 to 7.8 MHz, and the corresponding  $f_o$  for 144 MHz is 21 to 22.5 MHz. The observed path loss for sporadic E has been fitted<sup>8</sup> to an empirical formula as a function of  $f/f_o$  and distance, see fig. 2.

Next consider the maximum theoretical range. From fig. 1A, this is given by

$$D_{max} = 2 R_o \cos^{-1} \left( \frac{R_o}{R_o + h} \right) \quad (2)$$

This expression is a simpler form of that given by Kimbell<sup>9</sup>, and predicts the same maximum range of about 2400 km for reflection at a height of 115 km. The calculation assumes: no atmospheric refraction, a point reflection at a sharp ionospheric boundary, and both stations at zero height above ground. Corrections for each of these points will tend to extend the available range, as I will now describe.

In a "standard" troposphere at these frequencies the apparent horizon is 4/3 the distance of the visible horizon. In addition, forward scattering will increase the over-horizon range. In practice, on 144 MHz during summer conditions, a well-equipped station typically has a ground range exceeding 300 km, and low-angle rays go on to hit the ionosphere at some extended point. You would have to trace the ray through the actual atmosphere to find the increase of range obtained in each particular case. Note that the wave will be bent towards a more grazing angle of incidence, hence  $f_o$  does not need to be so high for reflection to occur. It is, however, a fact that tropospheric effects are less on 50 MHz than the higher frequency bands.

There is a second effect which tends to extend the range. The ray is returned to earth by refraction in an electron gradient rather than reflection at a surface, and this curved path itself extends the range by the distance

$$d = a \sin i \frac{f}{f_o} \ln \left( \frac{f_o + f \cos i}{f_o - f \cos i} \right) \quad (3)$$

where  $a$  is the "half thickness" of the ionized layer assuming a parabolic distribution of electrons<sup>5</sup>, the other quantities having been defined above. Similar penetration effects occur with vertical incidence ionosondes. It can be shown that with some assumptions<sup>10</sup> this extra distance is included in the recilinear model of fig. 1A if one uses the observed or "virtual" height  $h' = ct/2$ , where  $t$  is the time delay measured by the ionosonde and  $c$  is the velocity of light. This effect is such that if the true height  $h = 115$  km and the virtual height  $h' = 125$  km, the range is increased by 100 km.

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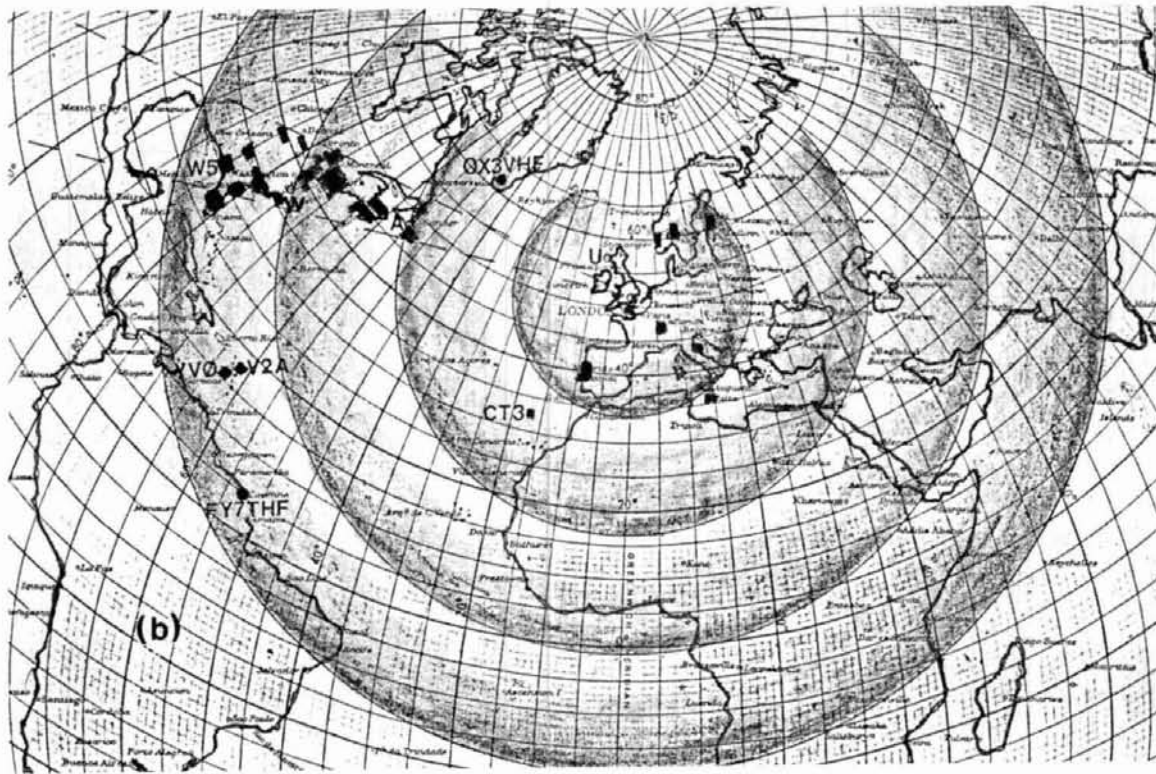
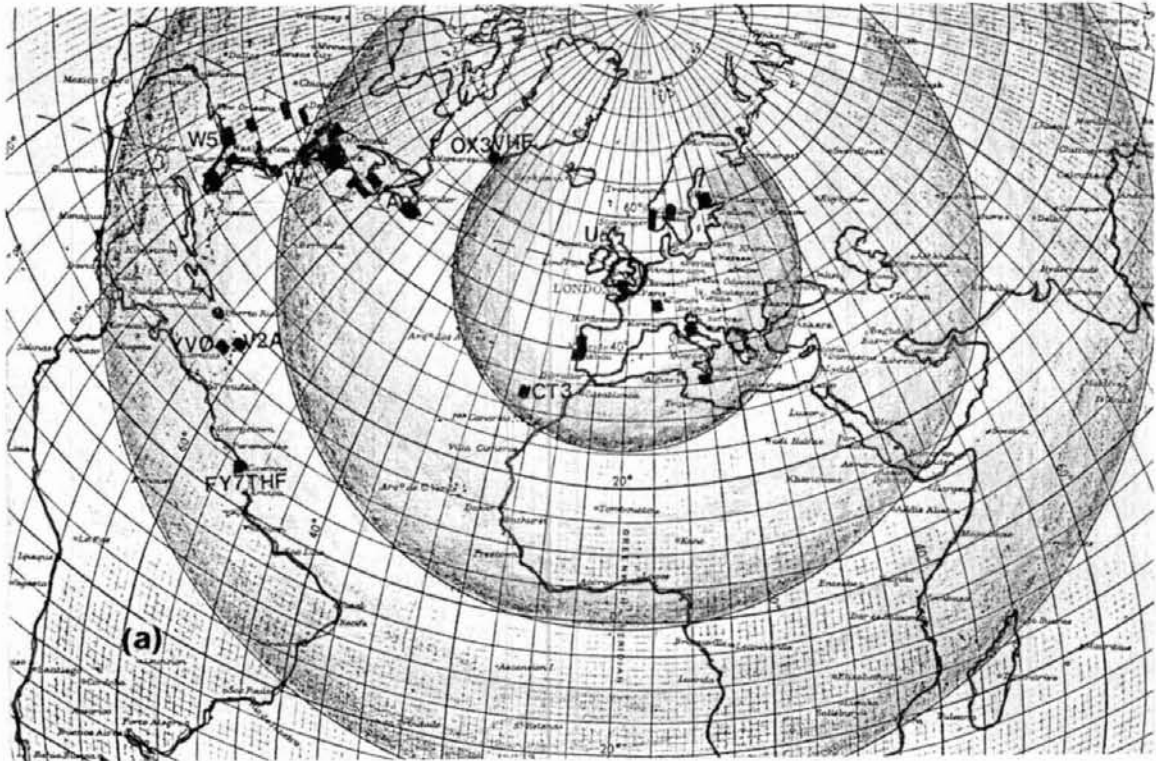


fig. 3. Distribution of 50-MHz propagation from England and Wales (black areas) during 1987 plotted on a Great Circle projection centered on Greenwich. The 50-MHz beacons OX3VHF and FY7THF are indicated, also the ionosondes on Wallops Island (W), Argentina (A), South Uist (U), and Slough (S). The shading shows the areas with highest probability of contact assuming: (a) Double hop transatlantic  $E_s$  propagation, (b) Triple hop transatlantic  $E_s$  propagation.

**Table 1. Summary of principal 50-MHz openings<sup>11</sup> during 1987 used in fig. 3. Callsigns and prefixes are in bold. †IARU World Locator System<sup>12</sup>.**

Date	Start	End	Locators† worked/heard
May 25	1605	1830	IN80, JN36
to	2012	2048	<b>FY7THF</b>
May 26	2220	0037	EN90, EM74, EM90, FM09, FM18, FM19, FM25, FN31, FN32, FN42, FN43, FN44, FN53, GN37
Jun 7	1253	1552	FN43, FN44, IN61, JM75, JN53, JN64, JO45, JO65, JO67, KM64
Jun 15	1643	2041	FK97( <b>V2A</b> ), IN53, IN60, IN61, JN02, KM64, KP01, JN36, JN87
Jun 15	2328	2343	EM94, FM04, FM15
Jun 17	2136	0042	EM70, EM79, FM09, FM18, FM19, FM29, FN20, FN31, FN32, FN42, FN43, FN44, FN53, GN37
Jun 18	1155	1211	EL96, EL97
	1610	1940	IO54, IP62, JN11, JN47, JN58, JN64, JO43, JO45, JO55, JO65, JO67
	2006	2040	FN44, FN74, GP60( <b>OX3VHF</b> )
	2134		<b>FY7THF</b>
Jun 19	1725		EN86, FM18, FM29, FN20, FN21, FN24, FN25, FN31, FN32, FN34, FN42, FN43, FN44, FN74,
		2002	GN37, <b>FY7THF</b>
Jun 21	1714		FM28, FM29, FN12, FN20, FN21, FN24, FN25, FN31, FN32, FN34,
		2200	FN41, FN42, FN43, FN44, FN74, FN84
Jun 24	1451		JM75
	1714	1830	FK85( <b>YV0</b> )
	1917	2034	IM59, JN11, JN12
Jul 10	1908	2116	GP60( <b>OX3VHF</b> ), JP61, KP01
Jul 17	1815		EN81, FN91, FM19, FM29, FN13, FN20, FN21, FN24, FN25, FN29, FN31, FN32,
		2200	FN41, FN42, FN43, FN44, FN51, FN53, FN84, FN86, JO67, JP61
Jul 19	0715	2010	IM12( <b>CT3</b> ), IM59, JN69, JO28, JO29, JO53, JO59, JO65, JP61
Jul 21	1645	1731	JN13, JN33, JP61
	1829	2250	FM15, FM28, FN20, FN31, FN32, FN41, FN42, FN43, FN44, FN53, FN74, FN84, GN37

Thirdly, stations at both ends of the path will in general have an advantage in height compared with the simple model, which assumes both stations at sea level, and thus a horizon at zero distance! For a height of 100 m, this geometric horizon becomes 35 km, increasing to 50 km at 200 m height. If stations on either end were situated at 200 m ASL with their horizon at sea level, their range (ignoring refraction effects) would be increased by 100 km. There is an effect counteracting this, however; ground reflection inclines the principal antenna lobes upwards by an angle depending on the radiation pattern, the antenna height, and the nature of the surrounding land.

To summarize, in the situation in **fig. 1B**, it should not be surprising if the maximum observed skip distances exceed that derived from the simple approach of Kimbell<sup>9</sup> by some hundreds of km.

### multiple hop $E_s$

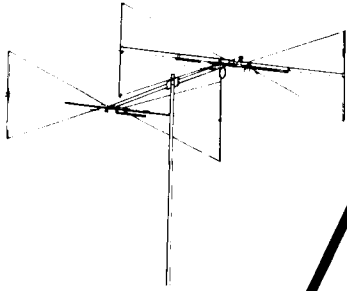
The locations of long distance stations heard or worked in the United Kingdom on 50 MHz during 1987 (**table 1**) are plotted on maps (**figs. 3A** and **3B**) centered on Greenwich, using a projection in which directions and distances are true globally along great circle paths measured from the central region (circled). The locations of the North American stations are shown separately and on a larger scale for a few major openings on **fig. 4**. Note that all times quoted in this article are UTC.

**Table 1** and **fig. 4** show that the majority of openings to the United States in 1987 had a similar pattern, most of the stations contacted being in a rather limited area. This is also one of the characteristics of  $E_s$  openings on the higher frequencies. The northerly limit is given by the region in which midlatitude  $E_s$  is normally found (**fig. 6**), and the southern extent is bounded by the sea. It is assumed that the most distant stations contacted correspond to the limiting case in terms of chordal hops, which do not quite touch the earth between  $E_s$  reflections (**fig. 1D**). As many authors<sup>13</sup> have noted, there is no need to invoke a reflection off the sea between ionospheric reflections; this would only decrease range and signal strength.

The outer limits of the zones shown in **fig. 3** are meant to indicate the maximum range normally found from  $E_s$  propagation. Obtainable range extends towards the observer with increasing ionization density, but the probability falls rapidly at the same time (indicated by the shading). Unusually intense ionization at one or more of the reflection points will fill in the intermediate areas, but its occurrence will be rarer. Maximum range is statistically the most probable, and chordal hops can occur at densities below that needed for ground-to-ground liaison. The outer zone limits represent the points of nearest approach to the earth for maximum range chordal hops. This does not mean to imply that multi-hop propagation has an intermediate ground reflection.



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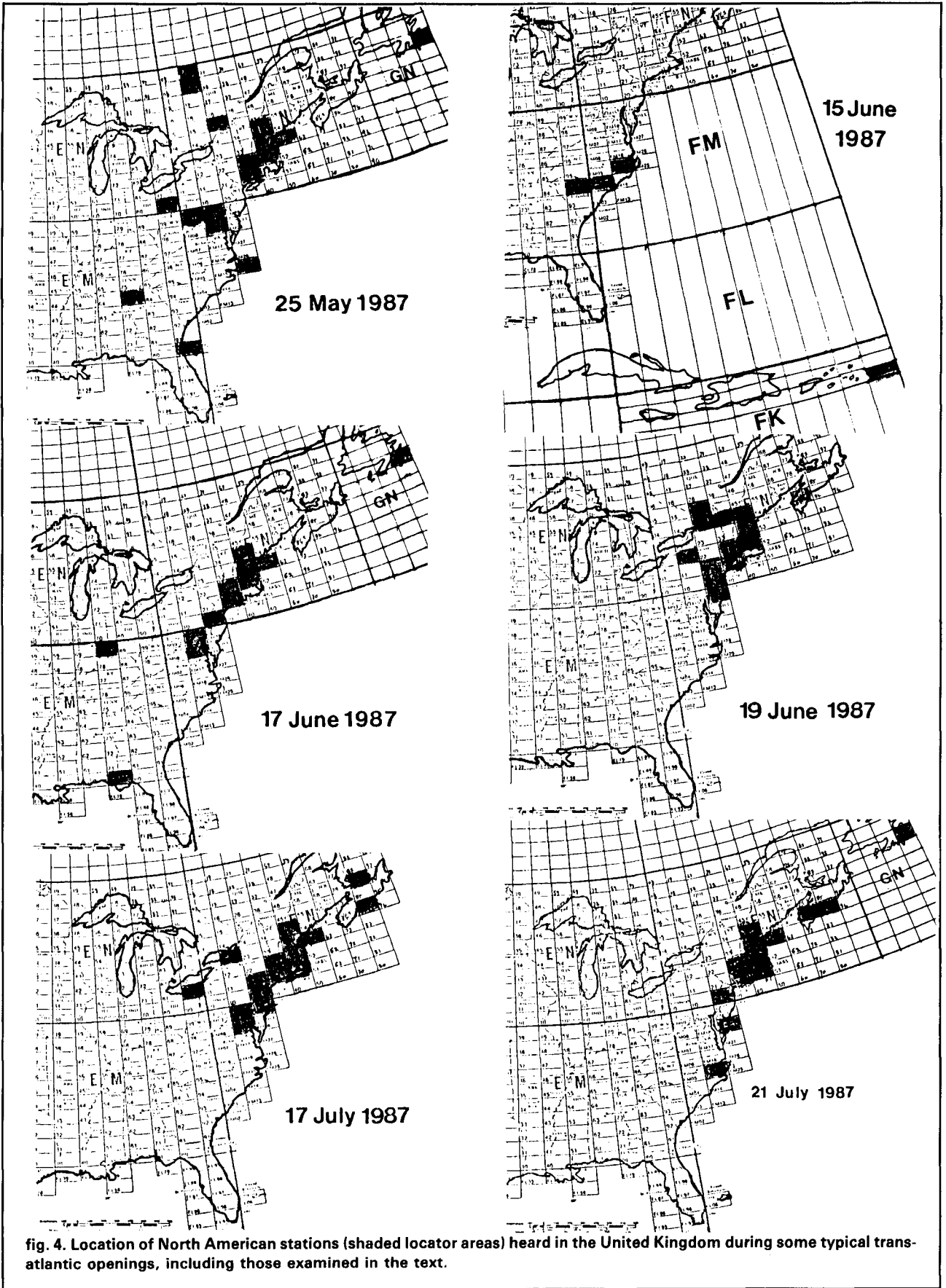


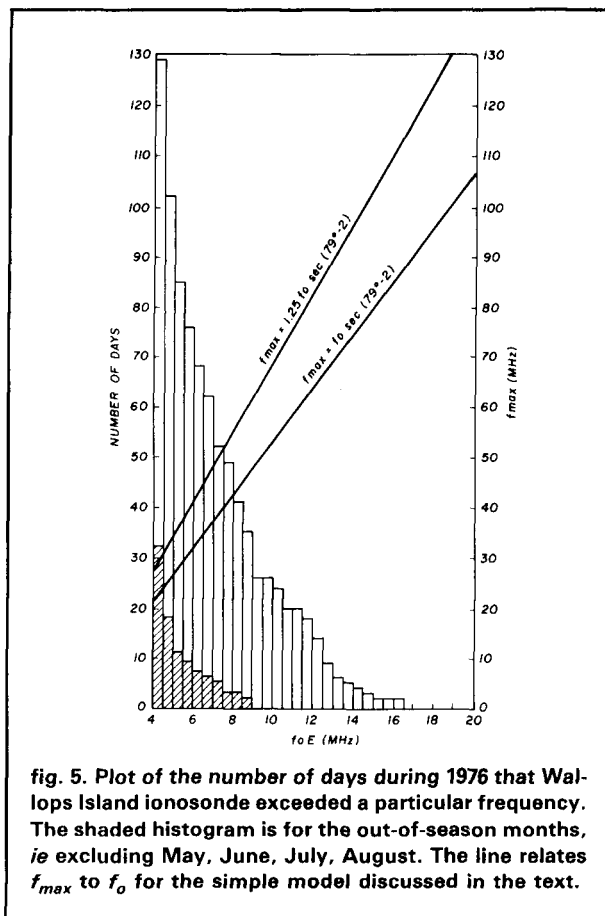
fig. 4. Location of North American stations (shaded locator areas) heard in the United Kingdom during some typical transatlantic openings, including those examined in the text.

**Figure 3A** illustrates two-hop propagation to the main area of North America, corresponding to a maximum skip distance of about 3000 km and a minimum of 2000 km, distances which are credible in view of the preceding discussion. Bands corresponding to one, two, and three hops have been drawn using these limits.  $E_s$  contacts at these distances on 144 MHz are very rare; contacts in the 1500 to 2000 km range are more common. The record distance for an  $E_s$  contact from the United Kingdom on 144 MHz is about 3475 km to Cyprus, while the world record  $E_s$  distance on 144 MHz is 3865 km from Lebanon to Portugal. These distances seem excessive to be single hop, even taking into consideration the previous arguments, but are consistent with twice the common-hop distance. Note that in each case the countries involved lie in a zone of high incidence of  $E_s$  (**fig. 6**), and double-hop propagation becomes more likely. In **fig. 3B** bands are shown corresponding to triple-hop propagation to North America, each hop being between 1350 and 2000 km which match the 144 MHz data well. **Figure 2** shows a minimum in this distance range for  $f/f_o < 7$  — that is, refractive propagation. The European 50-MHz contacts shown in **fig. 3** are also typically within this range.

No firm conclusion can be drawn at this stage as to whether **fig. 3A** or **fig. 3B** is the correct picture, but on balance the evidence suggests the latter. Although the reduced probability of finding a triple rather than a double coincidence of suitable  $E_s$  supports the two-hop case, it will be seen below that there are several instances of contacts indicating two hops between 1150 and 1500 km. It should be possible to infer the normal skip distance for multi-hop paths by examining logs of Amateurs in North America, where there are stations along the transcontinental east-west path, unlike across the Atlantic!

### estimate of probability

The principal objection to multiple hop  $E_s$  being accepted as the mechanism for transatlantic openings may be that the probability of suitable  $E_s$  "clouds" correctly positioned is too small. In Europe, this view seems to be based on experience of  $E_s$  at 144 MHz, forgetting the much more common propagation on 28 MHz. However, the time for which  $f_{max}$  exceeds a certain value decreases very rapidly with frequency. This is illustrated in **fig. 5** — a plot of the number of days during 1976 when a particular value of  $f_oE$  was exceeded at the Wallops Island ionosonde. These data were chosen for 1976 (one period previous in the solar cycle) because of the 15-minute sampling rate throughout the year; comparable data for 1987 was unavailable. Two lines are drawn in **fig. 5** showing the relation of  $f_o$  to  $f_{max}$ , assuming the secant law with



and without the correction factor  $\epsilon = 1.25$ . Note that  $f_{max} = 50$  MHz is exceeded on 52(26) days, compared with 128(76) days when  $f_{max} > 30$  MHz (uncorrected values are given in parentheses). Thus  $E_s$  is present at 50 MHz for 35 to 40 percent of the time it is found on 30 MHz.

I must point out the errors in using vertical ionosonde data in this way. A factor has already been introduced to correct the secant law. This factor was justified on account of the irregular nature of the  $E_s$  layer. The highest concentrations of ionization seem to be very small in extent, as is evidenced by the extremely limited areas of propagation on 144 MHz, and also by radar observations<sup>4</sup>. If the dimensions (in particular in the vertical direction, which is normally the minimum) become comparable with the wavelength (25 meters at 12 MHz), then an incident wave will be scattered rather than reflected, however concentrated the ionization. These patches may never be detected by ionosondes, providing a good justification for studies of point-to-point communication. In addition, the periods when the highest frequencies are propagated are very fleeting; at a sampling rate of 15 minutes, there is a good probability that these extreme excursions will be missed, either in time or in space.

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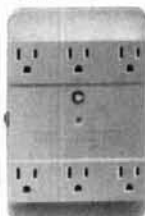
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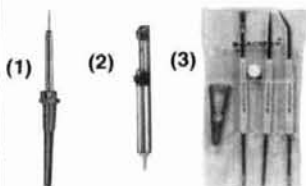
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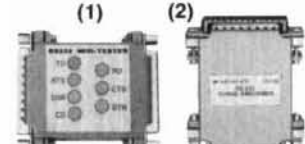
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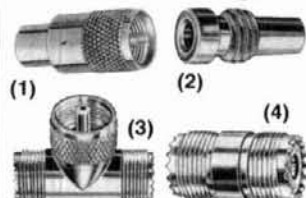


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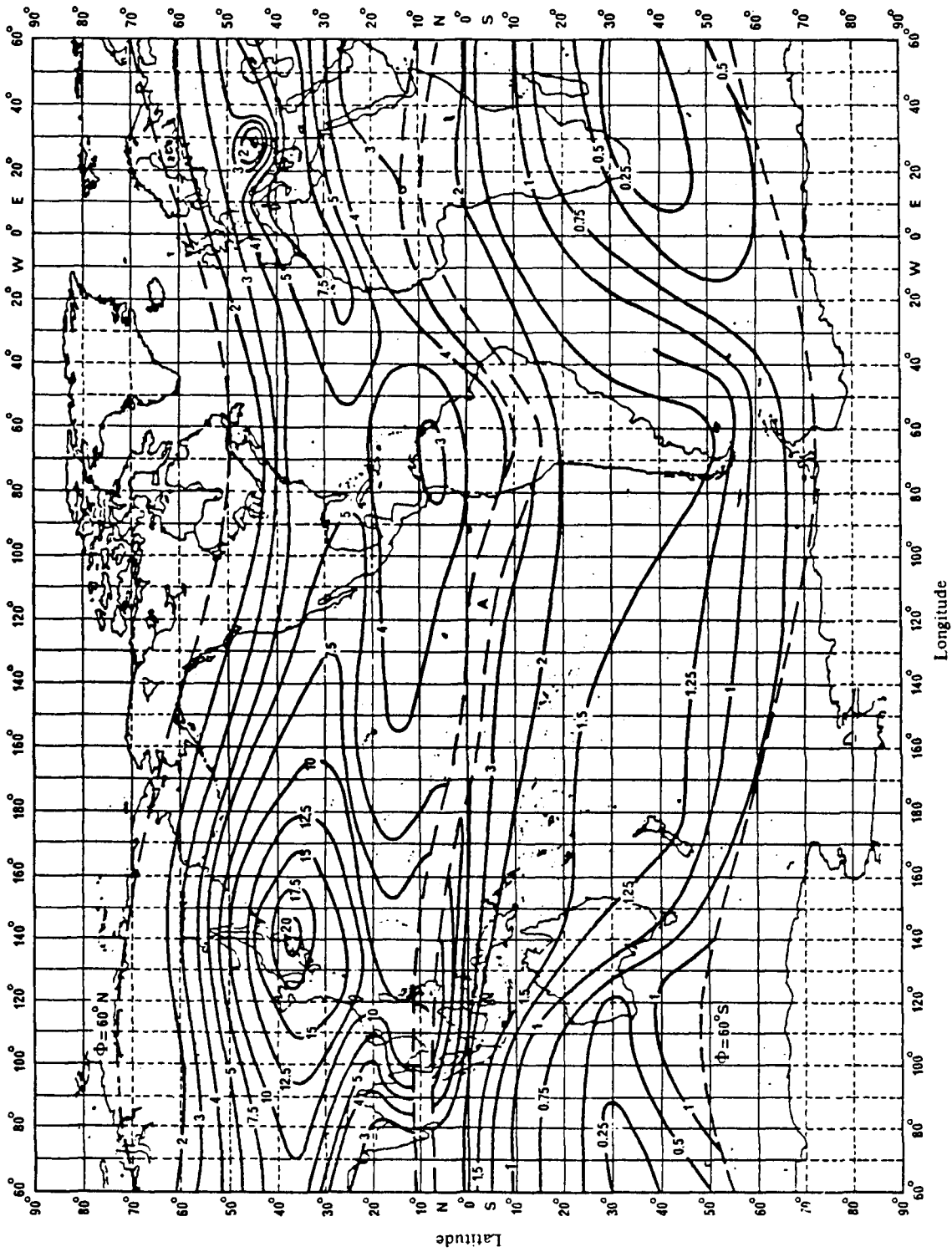


fig. 6. Map showing the percentage of time  $f_oE_s$  exceeds 7 MHz in the temperate zones between May and August (Northern Hemisphere) and between November and February (Southern Hemisphere)<sup>1</sup> (reproduced by permission of ITU).

So while the figures above are likely to be good estimates, the data cannot be extrapolated to 144 MHz, where **fig. 5** shows that an  $f_{max}$  of 144 MHz was never reached! The lack of appreciation of these factors has led a number of commentators in the past to disbelieve Amateur reports of 144 MHz  $E_s$ !

**Figure 5** was used to estimate the number of days on which 50-MHz propagation by  $E_s$  was possible. An estimate of the total time this was possible can be made from a CCIR document<sup>9</sup>. This gives for Region A (Europe and North Africa)  $f_oE_s$  exceeding 7.5 MHz, corresponding to  $f_{max} > 50$  MHz using  $\epsilon = 1.25$  for 2.5 percent of the time, or about 46 hours, in the period 0800 to 2300 UTC from May through August. The equivalent value for Region B (North America) is 3.5 percent, or 65 hours. Split between the 52 days on which  $f_{max} > 50$  MHz at Wallops Island, as evaluated above, this implies an average opening of more than one hour. From **table 1** it seems that the days when transatlantic communication occurred were those in which the  $E_s$  lasted much longer. These graphs unfortunately do not extend beyond  $f_oE_s = 12$  MHz, probably for reasons similar to those listed above, so again estimates cannot be made for 144 MHz.

### correlation between European and transatlantic propagation

There is no dispute that  $E_s$  is the propagation mechanism of 50-MHz contacts made over distances of 1000 to 2000 km during the summer months. From the United Kingdom, these were reported on no less than 40 days out of the 61 in June and July (66 percent). Compare this with the 52 days during 1976 when Wallops island ionosonde suggested that 50-MHz propagation was possible, estimated above from  $f_o$ . Transatlantic propagation was reported on 8 of these days (13 percent). The probability of both occurring on the same day if their origins are unrelated (that is, due to different mechanisms) is 66 percent  $\times$  13 percent = 8.6 percent, or 5.2 days. In fact, 7 (11 percent) out of 8 of the days when North American stations were heard had earlier produced European contacts. Although the difference of 2 days is hardly significant in a statistical sense, it could become so if this test were extended to months during which  $E_s$  occurred less frequently.

### ionosonde data at the time of 50-MHz openings

If  $E_s$  can be shown to be present on both sides of the Atlantic during transatlantic openings, this would constitute very strong circumstantial evidence for this mode of propagation. Unfortunately the current distribution of active ionosondes is significantly reduced compared with the IGY era. The four active and relevant to this investigation are shown in **fig. 3**. They are

located at Slough, southern England; South Uist, Outer Hebrides, Scotland; Argentia near St. John's, Newfoundland; and Wallops Island off the coast of Maryland, United States. A number of openings of special interest are described next.

### July 10, 1987

First consider the evidence for  $E_s$  propagation into the nearer zones of **fig. 3**. The Greenland 50-MHz beacon OX3VHF, situated just above 60 degrees North in latitude, is above the zone where  $E_s$  is prevalent (see **fig. 6**). But on July 10, 1987, this beacon was audible throughout the United Kingdom between 1945 and 2115 UTC (**table 1**), at distances between 2500 and 3000 km. At 2000 UTC the South Uist ionosonde, located near the great circle path (**fig. 3**), shows  $E_s$  with  $f_o = 10.2$  MHz, amply exceeding the minimum  $f_o$  for 50-MHz propagation. An hour earlier it had reached the highest value of  $f_oE_s$  recorded at this sta-

**Table 2.** Ionosonde data for July 10, 1987. The  $f_oE_s$  in brackets are the monthly median values for that time of day.

UTC	Slough		South Uist	
	$f_oE_s$ MHz	h' km	$f_oE_s$ MHz	h' km
1600	3.4(4.7)	110	3.2	105
1700	3.5(4.4)	110	3.2	105
1800	3.0(4.4)	110	3.8	125
1900	3.0(4.3)	115	12.1	120
2000	3.1(4.4)	110	10.2	110
2100	3.7(3.7)	105	8.4	110
2200	3.8(3.8)	110	2.5	120
2300	2.9(3.4)	115		

tion during the year, 12.1 MHz (**table 2**). This intense  $E_s$  to the north also gave short-skip  $E_s$  contacts into Norway and Finland (1140 to 1600 km). Considering the high values of  $f_o$  observed, the propagation of OX3VHF is consistent with two rather short hops of 1250 to 1500 km, or one of 2500 to 3000 km (**fig. 3B**).

### July 19, 1987

At the southerly end of this arc (there is only sea in between) on July 19, 1987, several stations contacted Madeira (marked CT3 in **fig. 3**) between 1600 and 1836 UTC at distances of 2300 to 2600 km. At the same time many stations were contacted in Portugal, ranging between 800 and 1500 km, so it seems highly probable that two hops of 1150 to 1300 km were responsible. At around 1800 UTC a contact between Norway and Madeira took place, a distance of 2600 km. Since Norwegian stations were audible in the southern United Kingdom at the time, it is possible this was a triple-hop contact. Both the Slough and South Uist ionosondes show  $E_s$  present during this

RUTHERFORD APPLETON LABS. REMOTE YY DDD HMM OUTPUT FRQUY CAB XLZT NRW HEIG PP  
 #051 SLOUGH, U.K. DIGISONDE 256 1987 170 1759 124410001A15 CCE 4151 324 8208 C1  
 H(KM) 100 150 200 250 300 350 400 450 500 550 600 650

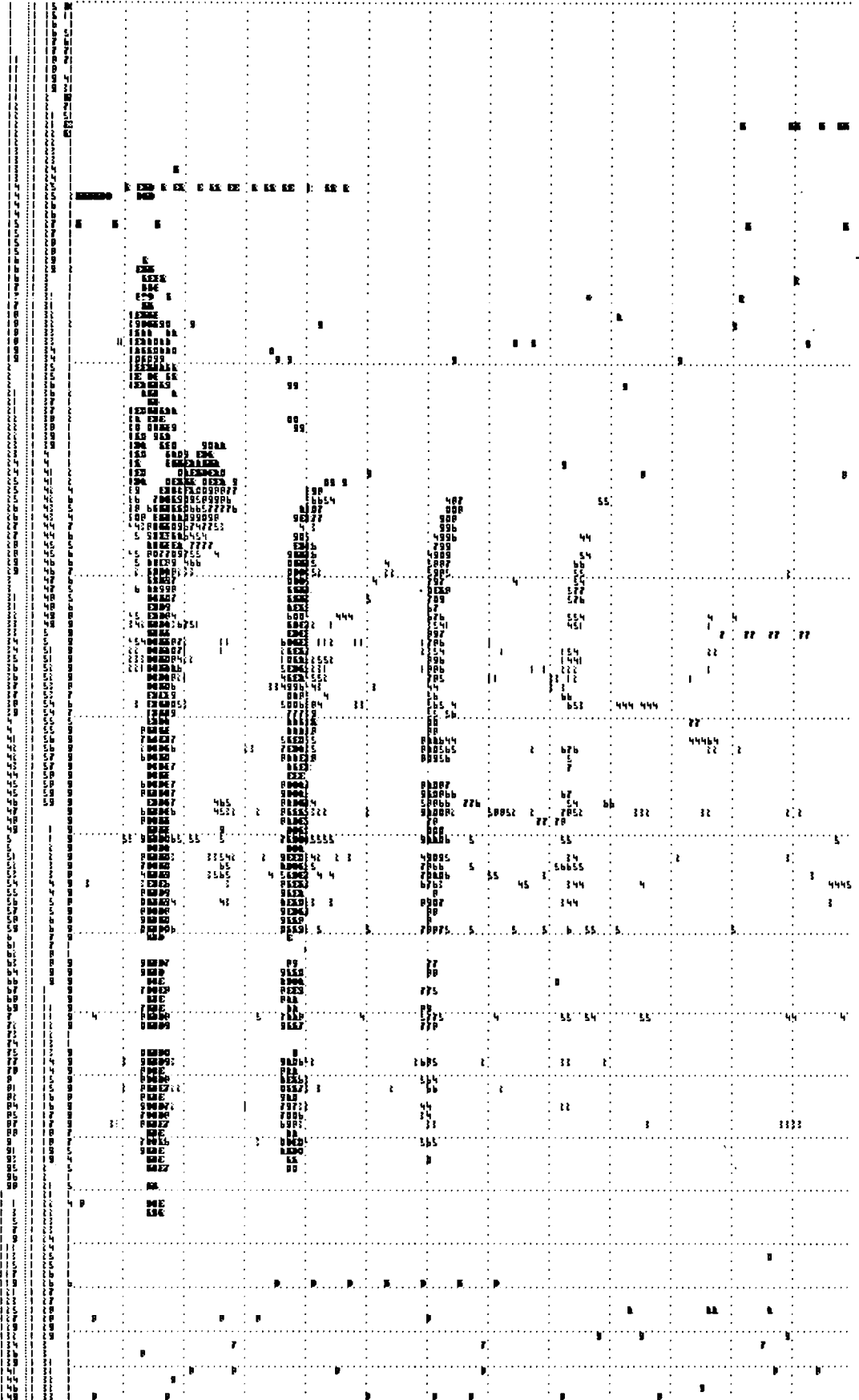


fig. 7. The ionogram recorded at Slough on June 19, 1987 at 1800 UTC. It shows at least four reflections from a blanketing  $E_s$  layer at a virtual height of 130 km.

**Table 3. Ionosonde data for July 19, 1987.**

UTC	Slough		South Uist	
	$f_oE_s$ MHz	$h' km$	$f_oE_s$ MHz	$h' km$
1500	5.5(5.0)	120	none	
1600	8.5(4.7)	115	4.7	130
1700	5.5(4.4)	120	3.2	105
1800	4.0(4.3)	120	4.5	105
1900	2.8(4.3)	125	3.5	135
2000	5.7(4.4)	115	2.65	180

time (table 3), though only one value (that for Slough at 1600 UTC) exceeds the  $f_o$  required for this skip at 50 MHz. Because the ionosonde samples only a very limited area once an hour, small high density clouds may not be observed. Transatlantic propagation was not recorded on either this or the next day, but July 21st produced a long list of North American stations heard in the United Kingdom.

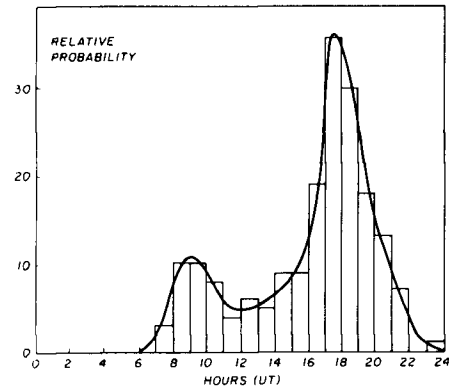
### June 19, 1987

Now let's look at the transatlantic opening of June 19, 1987 occurring between approximately 1725 and 2000 UTC (table 1). The areas heard in central and southern England and Wales shown in fig. 4 are typical of other openings shown in the figure. The Slough ionosonde (table 4) shows  $E_s$  increasing from 1600 UTC, and  $f_o$  exceeding 7.5 MHz sometime between 1700 and 1800 UTC. Figure 7 shows the appearance of the ionosonde trace at 1800 UTC. The lowest trace represents the first reflection of the  $E_s$  layer; the simi-

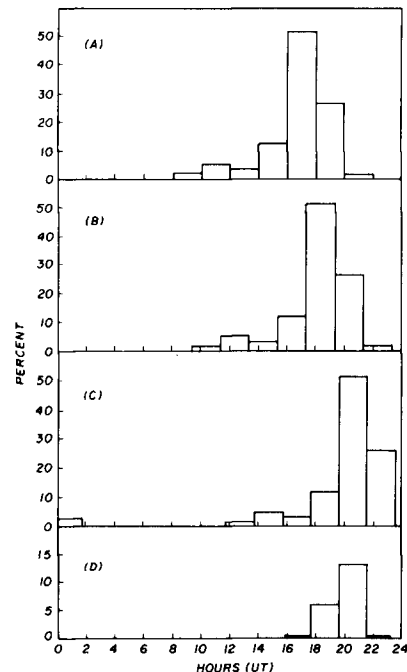
**Table 4. Ionosonde data for June 19, 1987.**

UTC	Slough		South Uist	
	$f_oE_s$ MHz	$h' km$	$f_oE_s$ MHz	$h' km$
1500	5.9(4.0)	120		
1600	3.6(4.1)	150	3.9	165
1700	6.7(5.0)	125	4.0	145
1800	9.9(4.0)	115	5.2	130
1900	10.1(5.0)	115	5.3	125
2000	8.7(3.3)	115	4.6	120
2100	1.6(3.2)	-	8.7	110

lar ones above are the second, third, and fourth reflections, with an intermediate ground reflection between each one. The apparent heights of these layers were  $2h'$ ,  $3h'$ , and  $4h'$ . There was no sign of an F layer, so the  $E_s$  layer blanketed up to the highest frequency. By 2000 UTC the  $E_s$  was less dense, and had almost disappeared by 2100 UTC. This behavior correlates with the times that transatlantic signals were recorded. Because the first ionospheric reflection takes place in a northerly region of low  $E_s$  probability, it might be



**fig. 8. Hours during which European  $E_s$  signals were reported on 50 MHz during summer of 1987. The curve is a freehand smoothing.**

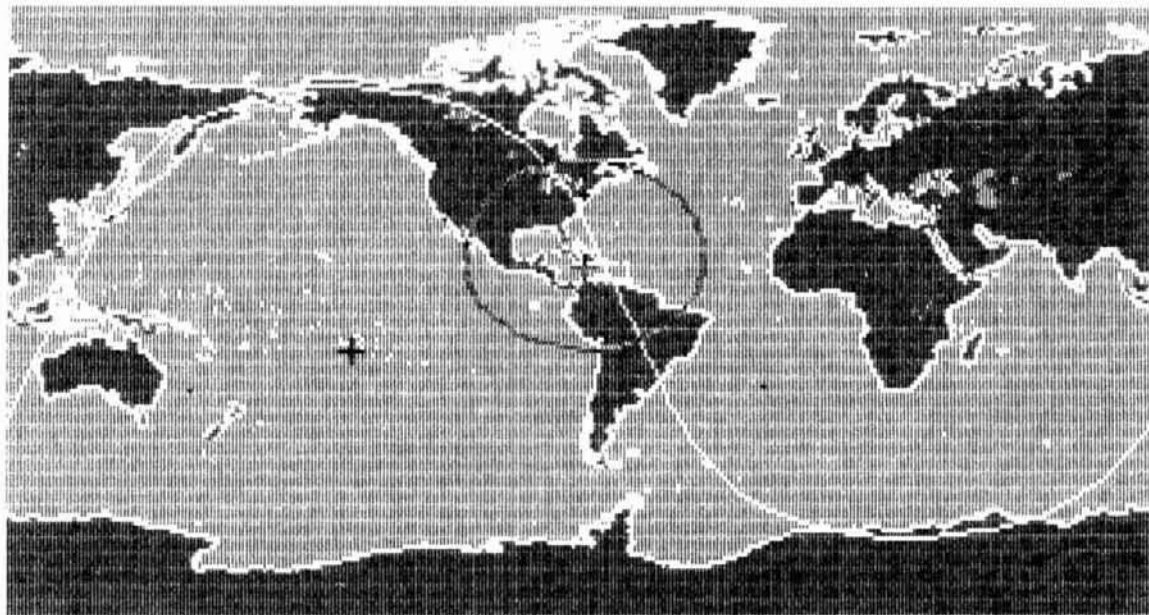


**fig. 9. (A) Distribution of 144-MHz  $E_s$  openings throughout the day binned in 2-hour intervals<sup>18</sup>; (B) and (C) the same distribution shifted to the position of the two ionospheric reflections on a transatlantic path; (D) the product of (B) and (C).**

expected that the presence of  $E_s$  in this region determines the path. The ionosonde at Slough, some 1200 km to the east, is the nearest. Unfortunately, the ionosonde at Argentia, Newfoundland, situated near the great circle path, was not operational at this time. But the Wallops Island ionosonde, some 2000 km to the southwest, does show the presence of  $E_s$ , though

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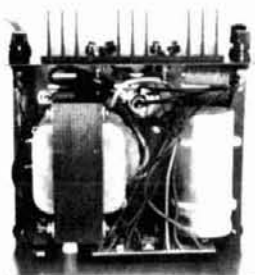
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RM-35A	25	35	5 1/4 x 19 x 12 1/2	38
RM-50A	37	50	5 1/4 x 19 x 12 1/2	50
• Separate Volt and Amp Meters				
RM-12M	9	12	5 1/4 x 19 x 8 1/4	16
RM-35M	25	35	5 1/4 x 19 x 12 1/2	38
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RS-4A	3	4	3 1/4 x 6 1/2 x 9	5
RS-5A	4	5	3 1/2 x 6 1/2 x 7 1/4	7
RS-7A	5	7	3 3/4 x 6 1/2 x 9	9
RS-7B	5	7	4 x 7 1/2 x 10 1/4	10
RS-10A	7.5	10	4 x 7 1/2 x 10 1/4	11
RS-12A	9	12	4 1/2 x 8 x 9	13
RS-12B	9	12	4 x 7 1/2 x 10 1/4	13
RS-20A	16	20	5 x 9 x 10 1/2	18
RS-35A	25	35	5 x 11 x 11	27
RS-50A	37	50	6 x 13 3/4 x 11	46

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RS-35M	25	35	5 x 11 x 11	27
RS-50M	37	50	6 x 13 3/4 x 11	46

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VS-12M	9	5	2	12	4 1/2 x 8 x 9	13
VS-20M	16	9	4	20	5 x 9 x 10 1/2	20
VS-35M	25	15	7	35	5 x 11 x 11	29
VS-50M	37	22	10	50	6 x 13 3/4 x 11	46
• Variable rack mount power supplies						
VRM-35M	25	15	7	35	5 1/4 x 19 x 12 1/2	38
VRM-50M	37	22	10	50	5 1/4 x 19 x 12 1/2	50

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RS-7S	5	7	4 x 7 1/2 x 10 1/4	10
RS-10S	7.5	10	4 x 7 1/2 x 10 1/4	12
RS-12S	9	12	4 1/2 x 8 x 9	13
RS-20S	16	20	5 x 9 x 10 1/2	18

not reaching particularly high values of  $f_o$  during the opening (table 4).

### July 17, 1987

The distribution of contacts on July 17, 1987 is much the same (fig. 4). This time all three ionosondes show a sporadic E layer at the time of the opening, and the  $E_s$  trace again disappears from the Slough data about the time the opening terminated (table 5). The critical frequencies recorded are not very high, but see the comments made for July 19th. Note that this opening finished two hours later than that of June 19th, and that the F2 layer was also evident on the ionograms at both Slough and Argentina. This is unlikely to be material for two reasons: the  $f_oF2$  was too low (5.7 MHz at 2200 UTC) and the F2 layer does not show the inhomogeneous structure of  $E_s$ , and the area of propagation is similar to the other events. For the F layer to span the range of stations contacted during this opening in a single skip would require (using

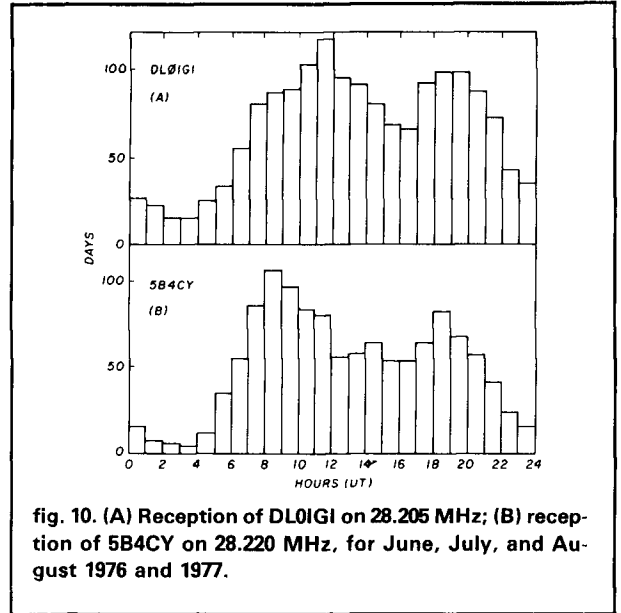


fig. 10. (A) Reception of DLØIGI on 28.205 MHz; (B) reception of 5B4CY on 28.220 MHz, for June, July, and August 1976 and 1977.

Table 5. Ionosonde data for July 17, 1987.

UT	Slough		Argentina		Wallops Is.	
	$f_oE_s$ MHz	h' km	$f_oE_s$ MHz	h' km	$f_oE_s$ MHz	h' km
1500	none					
1600	5.8	120				
1700	4.4	120				
1800	3.3	120				
1900	2.8	130				
2000	3.1	135	5.1	130	5.4	110
2100	2.8	120	4.2	120	4.2	110
2200	none		4.8	120	5.1	110
2300	none		3.7	120	6.1	110

the formula derived from fig. 1A) heights between about 350 and 800 km, and critical frequencies between 15 and 23 MHz — conditions certainly not observed on the ionograms!

### diurnal pattern of transatlantic contacts

It has been noted that the daily time distribution for 50-MHz transatlantic  $E_s$  contacts looks very different from that of typical European  $E_s$  openings<sup>9</sup>. I will show that the two are in fact strongly related. Figure 8 shows the hourly distribution of 50-MHz European DX during the summer of 1987.

This histogram was constructed by making an entry for each hour during which 6-meter continental European stations were logged by the stations contributing to table 1. This means that the same hour can appear several times in the histogram, making calibration in terms of probability difficult. The distribution obtained is typical of that found for  $E_s$ . A comparable plot for 144 MHz  $E_s$  given by Pasteur<sup>15</sup> is shown

in fig. 9A. Agreement with fig. 8 is good for the afternoon peak, while the morning peak occurs earlier on 50 MHz.

This double time structure is also found on the hf bands. Figures 10A and 10B show, for each hour of the day, the number of days that two 28-MHz beacons were observed at Keele, central England<sup>16</sup> during the months of June, July, and August 1976 and 1977, at a similar point in the solar cycle. Continuous observations were made using an automatic recorder. The distances imply that this propagation was either due to  $E_s$  or was exceptionally auroral; the latter was excluded on the basis of signal characteristics. Here the morning peak was the dominant one, and occurs somewhat earlier than on the higher bands. Now DLØIGI<sup>17</sup> at 3450 km must be double-hop propagation with the reflection taking place at around 13° and 24° E. Assuming that the pattern of occurrence moves with the sun, you can see that the peaks are shifted about the correct amount and in the correct direction (15° longitude is equivalent to 1 hour). Note also that

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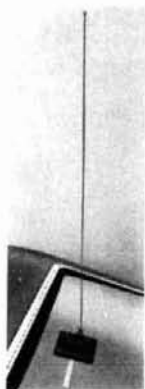
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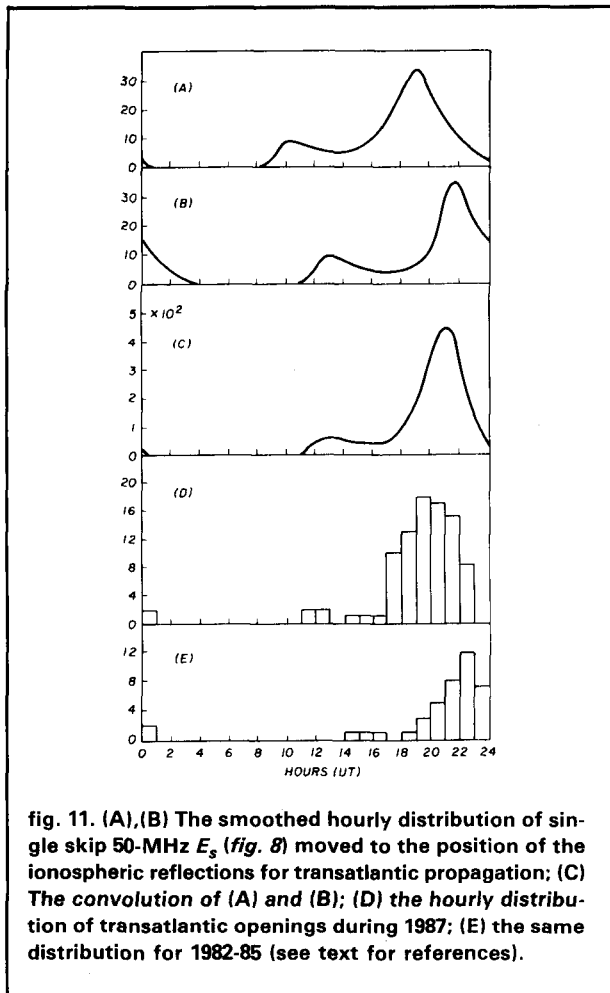


fig. 11. (A),(B) The smoothed hourly distribution of single skip 50-MHz  $E_s$  (fig. 8) moved to the position of the ionospheric reflections for transatlantic propagation; (C) The convolution of (A) and (B); (D) the hourly distribution of transatlantic openings during 1987; (E) the same distribution for 1982-85 (see text for references).

the single-hop beacon was audible for 1592 hours out of a total of 4416 hours, or 36 percent of the time, while the double-hop beacon was audible for 1222 hours, or 28 percent of the time. If the probability of the second reflection was equal to that of the first, the expected fraction of time when it would be audible is  $0.36^2 \times 100\% = 13\%$ . Obviously the occurrence of  $E_s$  at the two points of reflection was highly correlated, implying that the conditions for producing  $E_s$  on a certain day act over a considerable area. This has already been suggested from the correlation between European and transatlantic propagation on 50 MHz.

Returning now to the 50-MHz daily pattern — made up largely of contacts in the NNE and SSW directions to Norway and Portugal (as rather few other European countries are able to use this band) — it is assumed that the distribution correctly describes the relative probability of occurrence of 50-MHz  $E_s$  at the longitude of the United Kingdom. The following treatment assumes two-hop transatlantic propagation (fig. 3A), but the results are almost identical for three hops (fig. 3B) apart from lower probability introduced by requiring an extra reflection. Figure 11A shows the distri-

bution of fig. 8 corrected to the region of the first ionospheric reflection at about  $20^\circ$  W, a delay of 1 hour 40 minutes, and fig. 11B at the second around  $56^\circ$  W, a delay of 3 hours 45 minutes. The hourly pattern for the occurrence of simultaneous hops should then be the two distributions multiplied together hour by hour; this is shown in fig. 11C. Figure 11D shows the *actual* hourly distribution of transatlantic contacts, using the same observers to eliminate (as far as possible) personal bias. The agreement is remarkably good, except for a slight excess of late events. This distribution peaked significantly earlier (2 to 3 hours) compared with transatlantic openings<sup>9</sup> which occurred during 1982-1985 (see fig. 11E). It appears that during that period, following the solar maximum, transatlantic events could have originated from a different mechanism (possibly involving F layer propagation).

It can be assumed from the information above that the *short term* probability of  $E_s$  at the two locations is uncorrelated and the *daily* occurrence is highly correlated. The fact that the treatment works supports this assumption. This could give a clue to the originating mechanism of  $E_s$ .

A similar exercise was performed with the data of the reception of the 50-MHz beacon in French Guiana, FY7THF. This is located in the triple-hop zone of fig. 3A, but as the direction is more southerly the reflection points are at about  $14^\circ$  W (+1 hour),  $33^\circ$  W (+2 hours 12 minutes) and  $47^\circ$  W (+3 hours 8 minutes). Because they are close together in time there is a bigger overlap than for the North American path, which must compensate somewhat for the requirement of an additional reflection. Furthermore, fig. 6 shows that this path traverses a zone of much higher incidence of  $E_s$ . The three overlapping curves are shown in fig. 12A and their product in fig. 12B. The actual distribution<sup>9</sup> of reports of reception in Europe during the months of May, June, and July in the years 1979-1985 is reproduced in fig. 12C; again, agreement is very good. The few available reports of reception during 1987 are also consistent.

You should now be able to estimate, with the aid of fig. 6 and the construction of diagrams like fig. 12, the likelihood of a particular path "working", and the best time of day to try. Openings southward employing one or two hops to north and mid-Africa should be fairly frequent considering that they lie in the same time zone, have maximum overlap, and they traverse a zone of frequent  $E_s$ . Paths from the United Kingdom eastward towards Asia also look very favorable due to the high incidence of  $E_s$  over the European continent (fig. 6), although high ground reduces the effective skip distance. For example, the two-hop path to Bahrein reaches grazing incidence over the Black Sea, and a similar time analysis shows a good overlap around 1600 hours UTC (fig. 13).

The same treatment was applied to the transatlantic path using the hourly distribution of 144-MHz  $E_s$  (figs. 9A-D). An overlap is found between about 2030 and 2200 UTC, showing that transatlantic  $E_s$  contacts on 144 MHz may well be possible even if very infrequent. So, after a big  $E_s$  opening in Europe on 144 MHz, operators in Europe shouldn't just turn off and celebrate, but turn their beams west. If 50 MHz is open, try to set up a transatlantic contact on 2 meters!

### comments on the causes of $E_s$

The wind shear theory has become generally accepted as the explanation for the concentration of ions in a thin layer. The annual regularity and daily unpredictability of  $E_s$  remain as inexplicable as ever. On one day intense  $E_s$  can occur anywhere from central Europe to the mid-United States, indicating that whatever mechanism concentrates the ionizable material acts over a considerable fraction of the globe. For this reason thunderstorms, essentially local phenomena, can't play a major role as some have suggested. Indeed, the worldwide distribution of thunderstorms shows no correlation with the occurrence of  $E_s$ . Likewise stratospheric "jet streams" producing localized "plaques" of  $E_s$  do not seem consistent with the widespread simultaneous occurrence of  $E_s$  on a hemispheric scale. The annual pattern of meteor showers is very much like that of the occurrence of  $E_s$  in the Northern Hemisphere, peaking with many showers in the May to July period and a smaller peak from December to January. Meteors may originate the metallic material making up the  $E_s$  layer, but they can have no immediate influence. The peak  $E_s$  season occurs during the summer in the Southern Hemisphere, while maximum global meteor activity happens during the winter. From the success of the path time predictions, it can be seen that the sun clearly plays a decisive (though perhaps not unique) role in ionization. There are indications that the solar wind also plays some part, but this is a subject for another article!

### conclusion

The evidence indicates that the origin of the majority of 50-MHz openings listed in table 1 is multi-hop sporadic E reflections. The rarity of double-hop  $E_s$  on higher frequencies (144 MHz) can be explained by the very rapid fall-off of probability as the frequency increases, and also by the lack of suitably equipped and active stations in accessible regions. At the same time, I do not want to discount reports that lack an obvious explanation: apparent one-way propagation, long distance stations which don't appear on great circle beam headings, and the presence or absence of backscatter during these openings.

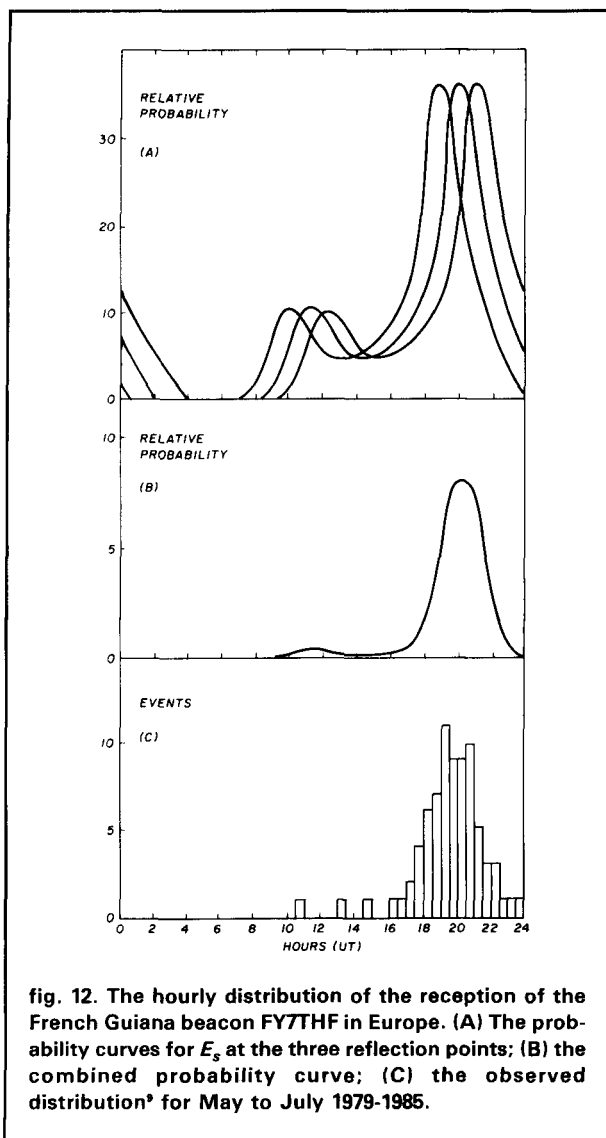


fig. 12. The hourly distribution of the reception of the French Guiana beacon FY7THF in Europe. (A) The probability curves for  $E_s$  at the three reflection points; (B) the combined probability curve; (C) the observed distribution<sup>9</sup> for May to July 1979-1985.

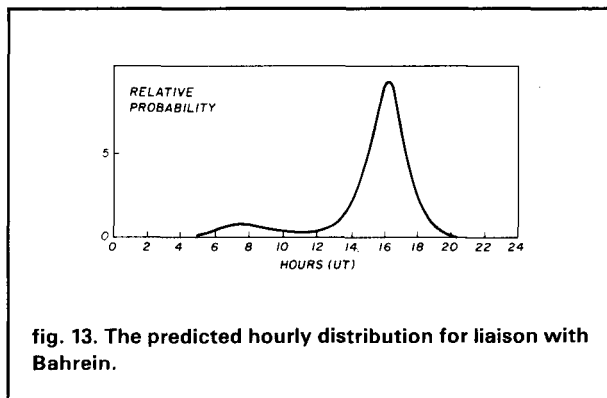


fig. 13. The predicted hourly distribution for liaison with Bahrain.

The localized directional properties of  $E_s$  make observations very difficult. Amateur service can be valuable for this kind of study; the 50-MHz band is very suitable for studying and collecting information on  $E_s$ .





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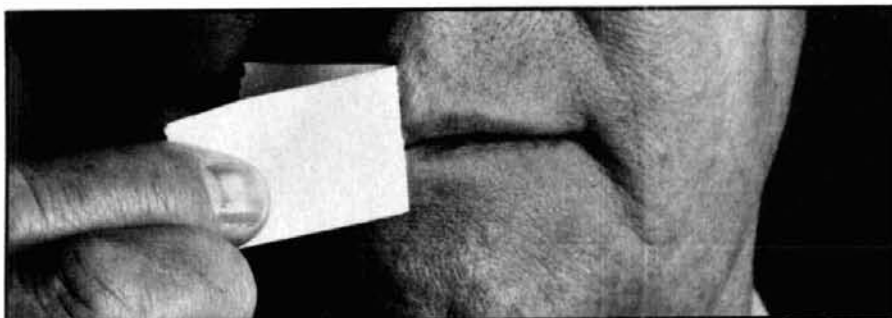


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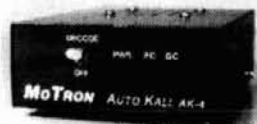
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## acknowledgments

I wish to thank Dr. Mike Hapgood and Rita Blake of the World Data Centre for Solar-terrestrial Physics, Rutherford Appleton Laboratory, for help with the ionosonde data; Ian White, G3SEK, Steve Cherry, G3SJK, and Jon Eastment, GW4LXO, for discussions; the Rutherford Appleton Laboratory for permission to reproduce the ionosonde data; and Radio Amateurs whose logs extracts have been included.

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18. 5B4CY is located at Zyyi, Cyprus at 34° 45' N. 33° 19' E.

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### about the author

Geoffrey H. Grayer, BSc, PhD, is an experimental physicist and was engaged in particle physics until 1986. His last experiment was the Nobel Prize winning UA1 at Cern, Geneva, where he was the senior resident physicist working on the experiment trigger. Dr. Grayer was the discoverer of the intermediate vector boson particles W and Z. For the last 18 months he has been involved in satellite experiments investigating lower energy particles found in solar wind. He has been published by the RSGB and works for Rutherford Appleton Laboratory in England. He has been involved in Amateur Radio since 1958.

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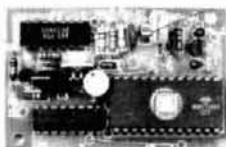
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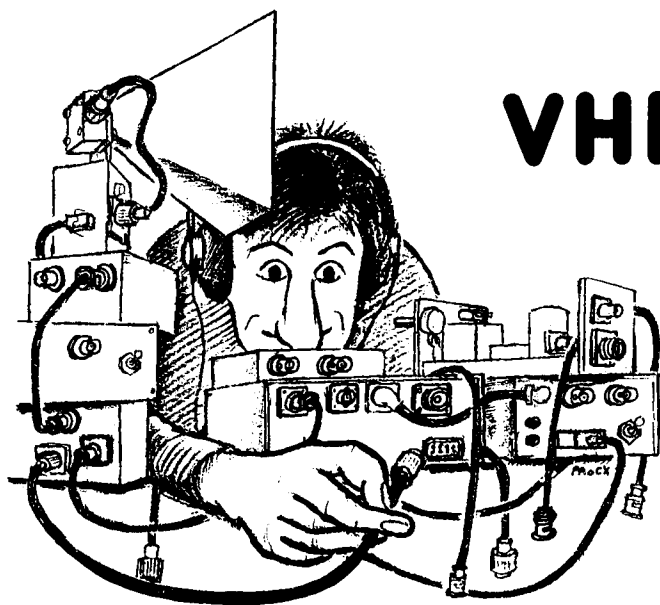
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# VHF/UHF WORLD

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## propagation update- part 3

In June we reviewed the latest VHF/UHF/Microwave DX records.<sup>1</sup> We also discussed the upcoming solar cycle and what effect it may have on some of the ionospheric modes of radio propagation like F2 and FAI. This month we'll discuss some of the other ionospheric modes; then we'll update tropo, EME, and other types of microwave and millimeter-wave propagation.

### midlatitude sporadic E

Sporadic E propagation, often referred to as "E skip" by VHFers, is truly the workhorse mode for 6-meter DX. Band openings can occur at any time of the day or year. In North America openings are most common and intense between mid-May and mid-August, with a minor peak  $\pm 1$  month around the winter solstice (December 22). They occur most often in the late morning or the late afternoon to early evening (local time).

Radio sonde observations show that the ionized cloud responsible for E skip is typically 0.6 to 2.5 miles (1-4 km) thick and is usually located at an altitude of 62 to 75 miles (100-120 km). Therefore, the typical propagation distance varies between about 500 and 1300 miles (800-2100 km), although distances as short as 300 miles (500 km) sometimes occur when there is very intense ionization. Multiple-hop sporadic E openings are most common during the summer, permitting North American stations to work coast to coast as well as CONUS to Hawaii and Europe.

It has long been known that sporadic E propagation was usable through 225 MHz, although openings on 2 meters and above are few and far between.<sup>2,3</sup> While studies have been conducted to see if there is any link between solar activity and sporadic E propagation, no definitive correlation has been proven. In fact, there seems to be a feeling that there may be some inverse relationship, because some of

the most intense openings have occurred during years when sunspot activity is low!

There is some possibility that a relationship does exist between sporadic E openings and the position of coronal holes on the surface of the sun. Research conducted by Sid Lieberman, WA2FXB, shows that most North American 6-meter sporadic E openings during June and July occur about 4 or 5 days after the occurrence of an MSB (magnetic sector boundary) crossing.<sup>4</sup>

For many years Amateurs have noticed the presence of lightning storms when sporadic E propagation is present. Sid's research also shows that meteorologists have noted an increase in lightning storms 4 or 5 days after an MSB crossing.

The MSB crossing can be determined from solar data available from WWV propagation reports at 18 minutes after each hour, or from the PRF (Preliminary Report and Forecast of Solar Geophysical Data) available from NOAA (National Oceanic and Atmospheric Administration).<sup>\*</sup> The MSB crossing tends to occur when the "K"

\*The PRF is published weekly and is available from NOAA, Space Environment Services Center, 325 Broadway, R/E/SE2, Boulder, Colorado 80303-328. Effective June 30, 1988, there is a \$26 per year charge to cover the actual cost of publication.



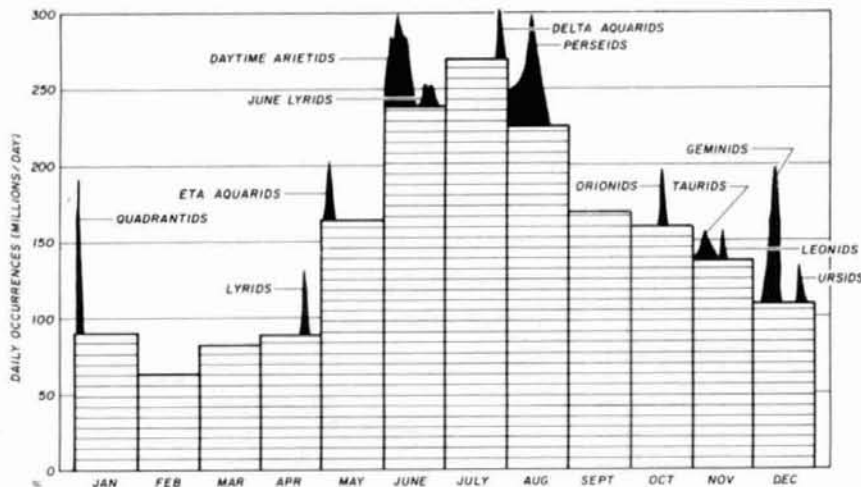


fig. 1. This chart shows the daily occurrence of random meteors. Superimposed on the tops are the major meteor showers at the approximate dates they occur.

index (a measure of magnetic activity) drops to a minimum for at least a few hours.

Dick Bolt, W1DGA, has taken up where Sid left off and studied many years of data on 6 and 2-meter openings. He noticed an increase in sporadic E openings 3 to 5 days after a coronal hole crosses the central meridian, the point on the sun's surface directly opposite the earth. However, he points out that because the surface of the sun is not solid, the rotational period is different between the sun's equator and its poles. Those coronal holes near the sun's equator tend to rotate on about a 25-day basis, while those at 45 degrees latitude take 28 or 29 days per revolution. The typical sporadic E openings will repeat statistically on an approximate 25-29 day basis, depending on the latitude of the coronal hole.

Unfortunately, Dick has not been able to pinpoint the place on the earth where the opening will occur but he's still trying. Stay tuned. This study may bear fruit in the not too distant future.

As has been widely reported in the literature and in references 2 and 3, one probable cause of sporadic E propagation is wind shear — a break in the vertical profile of the horizontal winds. The cause is still under speculation but lightning is definitely suspect. Lightning is most prevalent at the same time

of year that sporadic E propagation peaks.

It seems to me that meteors can also have a definite effect on sporadic E propagation. Looking at fig. 1 you'll see that the occurrence of random meteors tends to peak over 250,000,000 per day between June and August, the same time period when sporadic E propagation peaks. The minimum amount of random meteors occurs between mid-January and mid-April when sporadic E propagation is low.

Figure 1 shows that about half of the major yearly meteor showers occur during the same random meteor peak season. Another significant point about this time of year is that several of these same meteor showers occur during the daytime hours when sporadic E propagation is typically most prevalent. Also, the very dense Geminids and Quadrantids as well as the weaker Ursides showers occur near the winter sporadic E peak.

Finally, Swedish scientists have reported that the number of meteors tended to increase during sunspot minimums by up to a factor of 2 during 1963, as compared with the peak of solar cycle 19 in 1956-59.<sup>3</sup> The terminal point of meteors likewise was higher during these same minimum sunspot years.

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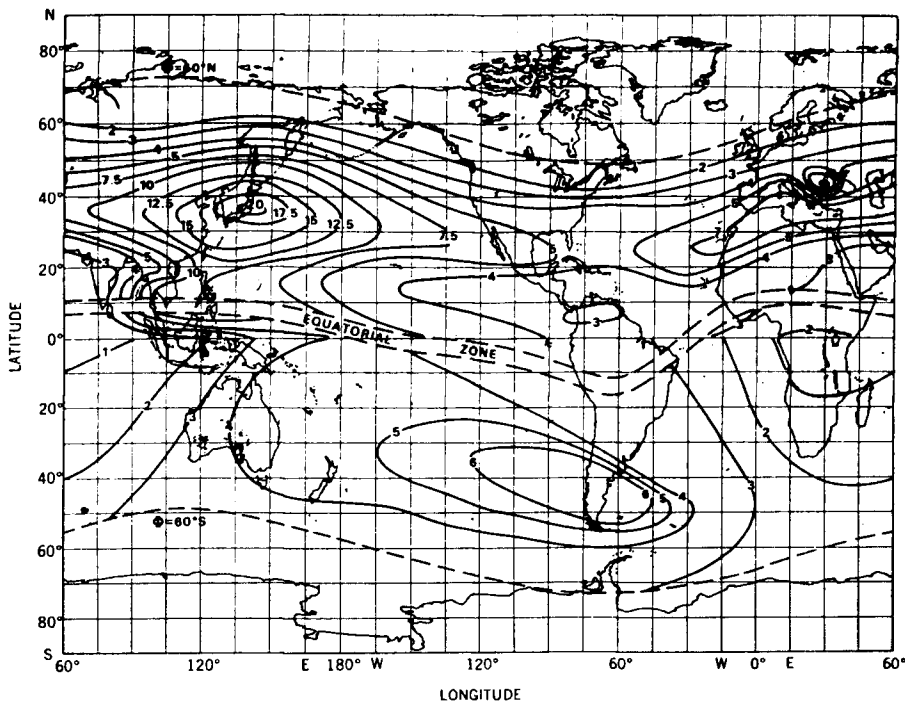


fig. 2. This map shows the percentage of time during the summer months when sporadic E ( $F_oE_s$ ) exceeds 7 MHz at vertical incidence. This corresponds roughly with the time when 6-meter sporadic E propagation is present.

sporadic E openings were reported almost daily somewhere in North America. Did meteor activity enhance this terrific sporadic E season in 1987 when the solar cycle was near its minimum?

Let's review some of the telltale signs of sporadic E propagation. It is most easily detected at hf by vertical-incidence ionosondes (ionospheric sounding stations). Typical sporadic E critical frequency, or  $F_oE_s$  as it is sometimes called, is first detected in the 5-10 MHz region but can go as high as 15-18 MHz when a very intense event is taking place. The higher the frequency of the vertical return, the higher the VHF MUF.

Probably the most interesting data to Amateurs is the  $F_oE_s$  summer months worldwide map assembled by Ernest K. Smith, N6HQK, and shown in fig. 2. These data are taken from ionosondes when the  $F_oE_s$  was about 7 MHz, a typical value to yield 6-meter and higher sporadic E propagation.<sup>5</sup>

Note in fig. 2 that the highest incidence of summertime sporadic E propagation is in the region around

Japan, Indonesia, and near the Mediterranean Sea. South Africa and the northern part of North America have much less. The southern portion of the United States will have about two to three times more openings than the northern states and southern Canada.

We've been discussing 6-meter sporadic E. As mentioned earlier and in reference 2, sporadic E propagation can extend beyond the 135-cm (220 MHz) Amateur band.

Most 2-meter openings occur when the skip distance on 6 meters drops well below 500-600 miles (800-950 km) or when there is noticeable backscatter on 6 meters.<sup>1</sup> The longest worldwide documented two-way sporadic E contact on 144 MHz took place on July 7, 1983 over a distance of 2402 miles (3865 km) between EA8XS (IL28GA) and HG0HO (KN07RU). The complementary North American record took place on June 14, 1987 at a distance of 1980 miles (3186 km) between KD4WF (EM92LA) and NW70/7 (DM25GV).<sup>1,6</sup>

Both contacts were probably dou-

ble hops where at least two E clouds were linked, presumably with a mid-path reflection from the earth as shown in fig. 3. Based on North American geography, coast to coast 2-meter contacts may be possible. However, the proper conditions will most likely favor stations in the southern United States and only take place if two clouds are very close to the optimum geometry (fig. 3).

## 2-meter and higher sporadic E

What does it take for 2-meter or 135-cm sporadic E propagation? This question involves much speculation. Obviously the E cloud must have a tremendous refractive index and be very smooth. Propagation on 6 meters should be "super" and some very short paths might be accessible.

Backscatter on 6 meters would probably also be present, along with evidence of co-channel interference on television channel 7 (174-180 MHz or higher). The conditions on 2 meters should be very good before attempting 135-cm contacts.

These conditions were present when the first 135-cm two-way sporadic E contact took place between K5UGM (EM12MS) and W5HUQ/4 (EM90GC) on June 14, 1987 over a

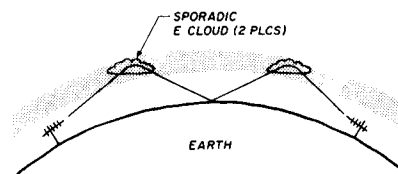


fig. 3. This sketch shows the approximate geometry required for "double hop" sporadic E propagation.

932-mile (1499 km) path.<sup>1,7</sup> Virtually the entire United States was experiencing 6-meter E skip. Some triple hop (and possibly quadruple hop) was noted as stations as far apart as Georgia to Hawaii and Europe to the central United States were making contacts! Numerous stations from coast to coast were making 2-meter contacts, some in both easterly and westerly directions at the same time.

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One normally expected sporadic E phenomenon was not present — the shortening of the 2-meter path distance. It had been widely speculated that the 2-meter distance would have to shorten significantly and that different Amateur bands would experience different optimum distances. In fact, the stations completing the first 135-cm contact were in contact on 2 meters at virtually the same time, and no real short distance 2-meter contacts were reported.

Is some rethinking necessary? Perhaps too much emphasis has been placed on the shortened path on the next lower band. If 2 meters is open, give 135 cm a whirl! The higher frequency path requirements are more precise; don't give up.

During the next few years we'll experience the peak of solar cycle 22. Sporadic E openings will probably be somewhat enhanced for the more northern stations as the upper air winds and weather change slightly. Increased interest in solar as well as lightning connections will be studied. The higher the altitude of the lightning strikes, the better the chance for a 2-meter or higher frequency sporadic E propagation opening.<sup>2,3</sup> In North America this tends to happen toward the end of July.

More 6-meter DX will be worked because the number of countries with 50-MHz operating privileges has been greatly expanded, especially in Europe and Africa. There is always a possibility of a 2-meter contact between the United States and Europe, but if it does happen it will probably be between the Azores and a lucky Amateur in the fourth call area (see fig. 2).

### sporadic F propagation?

Sporadic F propagation was recently broached in *Radio Communications*.<sup>8</sup> The discussion came about because some of the United Kingdom to United States openings were too long in duration, and the distances don't always match the typical sporadic E path distances across the continents.

The article references scientific data that verifies the presence of ionized regions up to 93 miles (150 km) above ground level in the normal F layer, and much higher than the typical sporadic E explained earlier in this column. These F layer ionized patches tend to drift slowly downward over a period of several hours until they settle in and dissipate around 65 miles above the earth, the typical height of sporadic E clouds. This is an interesting theory; advanced rockets should make a study possible. Does anyone have any further supporting data?

### aurora update

As the solar cycle heats up, so do the number of occurrences of auroral propagation. This mode of propaga-

1988 is particularly interesting. Even though only about one-quarter of 1988 is included, the number of aurora observed so far this year is already well ahead of the last two years. It looks as if there will be some very exciting auroral openings in the next year or two.

Although auroral propagation tends to favor stations in the northern latitudes, some of the strongest auroral occurrences have favored stations further south. The reasons for this are simple.

Lower latitude stations have a better reflection angle and can fully use their lower angle of radiation to direct most, if not all, of their signal directly at the aurora. Northern stations often "see" the aurora well above the maximum radiation angle of their antennas.

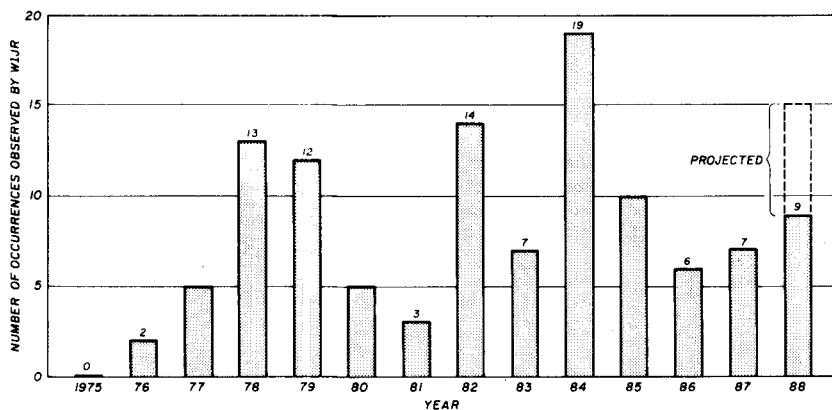


fig. 4. This histogram shows the number of times auroral propagation was observed at W1JR (FN42HN) since 1975. See text for further explanation.

tion should be very common in the next couple of years. While it will virtually wipe out hf propagation, it can yield some great VHF and UHF DX.

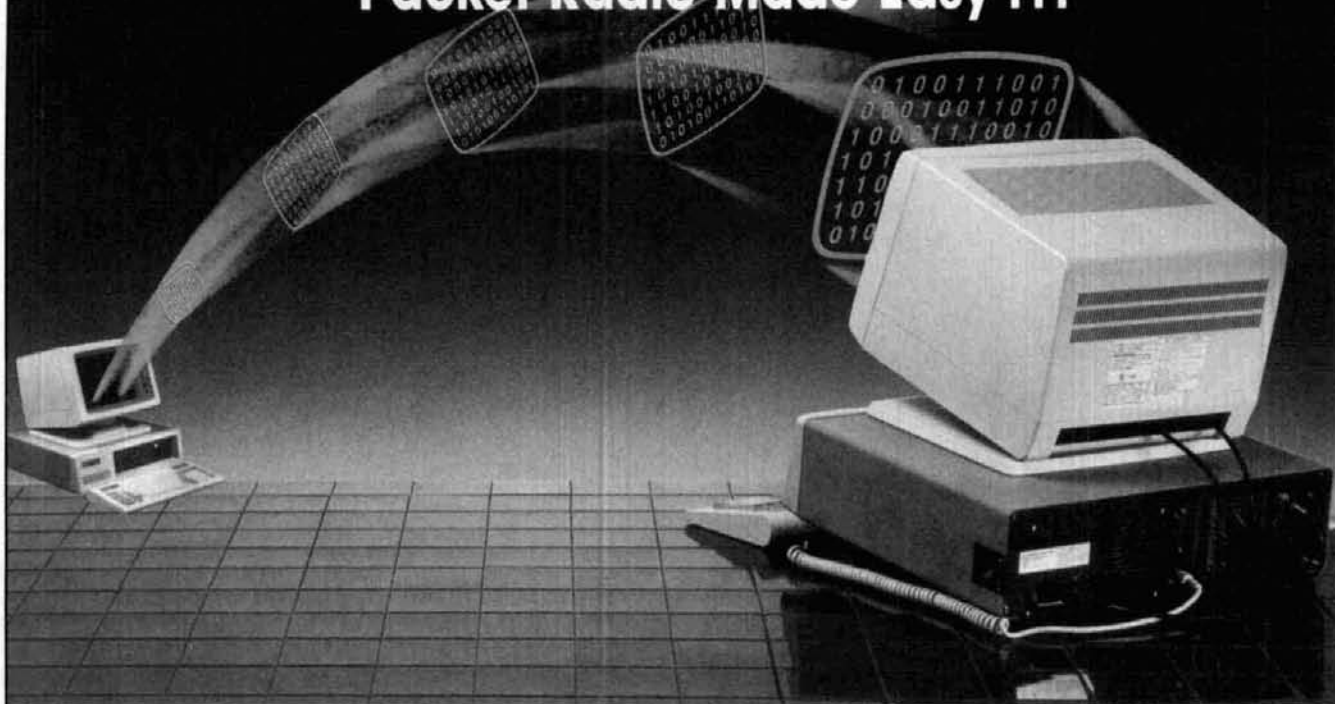
Reference 3 illustrates how auroral propagation tends to follow the rise and fall of each solar cycle. However, it's not too common near the solar minimum or at the peak of the solar cycle. To re-emphasize this point, I have updated the information in reference 3 to include the more recent auroras that I have observed here in New England.

Figure 4 clearly shows the trend of auroras just mentioned; the data for

To illustrate this point, stations in the northern United States had the auroral curtain directly over their heads during the now-famous aurora of February 7 and 8, 1986. During that same aurora the North American DX record was extended on both 144 and 432 MHz and equaled on 220 MHz.<sup>1</sup> In all but one case, one or both of the stations involved were below the 40th parallel.

Don't forget that auroras can occur at any time of the day. I've noted several recently that were in progress in the mornings (8-11 A.M. local) but were not productive because there

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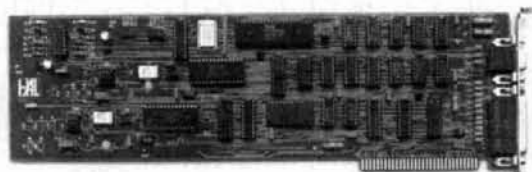
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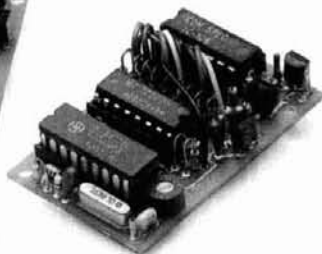


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was "no one around to talk to."

How was I sure that there was aurora present? There was a pronounced flutter noted on hf Amateur signals. I also heard the familiar "buzz" on some of the 6-meter Amateur beacons as well as television video carriers. If you hear these telltale signs, aim your antenna north and put out a call. You may get a surprise.

Most auroral openings occur in the spring and fall, and typically start in the late afternoon or early evening. Remember, the highest usable frequency during an aurora opening tends to occur shortly after the commencement of aurora. If you want to make 135 or 70-cm contacts, move up there quickly after discovering the presence of aurora on the lower VHF bands before the MUF drops too low. Don't give up if the aurora goes away. It often returns in an hour or so.

Knowing when an aurora is expected is not as difficult as predicting sporadic E propagation! Besides the clues noted above, the propagation bulletin on radio station WWV is a great indicator of aurora.

Auroras almost always occur within 30-48 hours after a major solar flare. Listen to WWV at 18 minutes past the hour for word of flares. Expect an aurora imminently whenever the K index announced on the station (it is updated every 3 hours) goes to 4 or higher. The higher the better!

Don't forget that auroras often repeat in 26 to 30 days. This can be ascertained ahead of time by checking the forecasted K index in the NOAA PRF, as mentioned earlier.

Reference 2 notes that aurora propagation is possible beyond 2500 MHz, although Amateurs haven't had any documented success above 450 MHz. However, as you go higher in frequency, the "hot spot" gets very narrow and lots of ERP (effective radiated power) is necessary. These are incompatible requirements since antenna gain will have to be high, making the beam width narrow and increasing the problem of locating the common reflection point.

For these reasons 1296 MHz may be

very difficult to conquer on aurora propagation. The signal will be very spread out in frequency and the doppler shift could reach 5 to 10 kHz! For this reason the new 903-MHz band offers some very interesting possibilities. I've tried 903-MHz schedules several times when 432 MHz was usable, but no success to date.

Finally, the doppler shift on aurora propagation is often greater than most Amateurs expect. For instance, I've seen shifts approaching 3-5 kHz at 432 MHz. If you use a transceiver, tune around only with RIT after you call a CQ. Don't forget that a station responding to your CQ doesn't expect you to shift frequency. Also check the range of your RIT. Many of the modern transceivers don't have sufficient tuning range to match the maximum doppler present.

Aurora propagation is a fun mode and a great way to work DX on a band when normal propagation modes won't support extended DX. The present claimed North American DX record on 2 meters is 1347 miles, with 1145 and 1182 miles on 220 and 432 MHz, respectively.<sup>1</sup> A recent claim in Europe would extend the worldwide 2-meter aurora record out to 1439 miles. That's real DX!

### auroral E<sub>s</sub>

Reference 2 mentioned this interesting form of radio propagation on 6 meters. Basically it resembles sporadic E and takes place a few hours after an auroral opening has faded away.

The problem with catching auroral E openings is that they tend to occur during the very early hours of the morning. They are most often discovered over weekends when someone strolls home from a late evening cocktail party!

Several W1 to W7 auroral E type openings were observed during the descending years of solar cycle 21 (1982-1986). Likewise, openings from Alaska to the lower 48 states and Canada have been reported. With the return of auroras, this could be a good way to increase your DX and VUCC grids.

### meteor scatter update

Interest is still high in meteor scatter communications, especially during the major showers like the Perseids and Geminids. Meteor scatter offers 800-1000 mile contacts up through 432 MHz (more on this shortly), and with a little luck out to 1400 miles.

Nowadays 2 and 6-meter meteor scatter contacts are sort of routine. They can be made almost daily using random meteors that typically peak between 5 and 8 A.M. local time. Use fig. 1 to determine the most optimum time of the year. Meteor showers offer more flexibility on schedule time, better reliability, and greater distances.

European Amateurs have been running meteor scatter schedules since the early 1960s and achieving success daily, even during the daytime on random meteors. What's their secret? They transmit for long periods, typically 1 to 5 minutes, at very high speed CW, usually 100-200 words or 500-1000 letters per minute! This way they only need a very short burst (not much longer than a ping!) to obtain an entire set of calls or reports.

You ask, "Who can copy CW at that speed?" The answer is "no one!" The Europeans' secret to success is to record the output of their receiver at a fast speed, and at the end of the receiving period slow down their tape and replay any recorded bursts at an easy to copy 15-25 words per minute<sup>9</sup>.

The European meteor scatter procedure is, in effect, a form of packet communication. Some Amateurs in North America would say this isn't a valid contact, but technology marches on! We now have an abundance of VHF packet communications on 2 and 6 meters. Just tune up to 145.010 MHz some evening and listen to all the strange sounds.

Can this technology be used to VHFer's advantage? The answer is a qualified yes. One problem is that present packeteers are using bandwidths of 15 kHz, 5 to 6 times that of normal 2-meter SSB communications. Using NBFM creates an additional 10 dB disadvantage in the signal strength

required for adequate detection signal to noise ratio.

If you run a packet system with typical antenna gains of 12-14 dBi, at least 500 watts, and the packet protocols presently in use, you incur about a 15-20 dB disadvantage over SSB. But many meteor bursts on 2 and 6 meters, especially during showers, are at least 30-40 dB out of the noise. Therefore, packet meteor scatter even using NBFM is definitely feasible.

The implementation of packet radio for DXing would be a big step forward and probably will be the next technology step. A great enhancement would be to implement one of the hf packet protocols at a lower baud rate (300 baud), using narrow receiver bandwidths that enhance signal to noise ratio. Packet meteor scatter DXing is a wide-open opportunity for DXing VHFers.

Meteor scatter contacts on 135 cm are still rather difficult even with high power and high gain antennas, and are almost entirely confined to the better meteor showers. Contacts on 70 cm, despite some push in the 1970s, are almost nonexistent in North America due to the extremely poor success rate and the apparently poorer results on the Perseids meteor shower of late. Europeans have had several successes on 70-cm meteor scatter lately, but they are all using the CW high-speed system. It looks as if 70-cm operators will have to wait until the Leonids peak in the late 1990s or discover new operating techniques!

Meteor scatter techniques and how to pinpoint shower peaks are discussed in detail in reference 10. Reference 11 stresses the importance of the scheduling time to attain proper meteor shower geometry along with recommended software. Reference 12 discusses the optimum times as well as the peak of the shower. For those interested in optimizing the shower peak, I'd suggest that you obtain a copy of the latest *Astronomical Calendar 1988*.\*

\* *Astronomical Calendar 1988* is available from Astronomical Workshop, Furman University, Greenville, South Carolina 29613 at \$12 plus \$3 for postage and handling.

## EME update

In the early days of EME communications, contacts were rare and usually involved large groups. Amateurs often used the latest and best equipment available, whether it be homebrew or borrowed from a commercial company. That has all changed. EME operation is now a proven communications technique used daily on 144 and 432 MHz. Two-way contacts have now been made on every Amateur band between 50 and 5760 MHz, as shown on **tables 1 and 3** in reference 1.

Six-meter EME is picking up. There are about five stations now active and many more in the advanced building stages. It still requires large antenna arrays and 1,000 watts, but receiver and feedline problems are minimal. Look for an increase in 6-meter EME to fill in the gap until F2 returns.

Most of the worldwide EME activity is concentrated on 2 meters. One station alone has contacted over 800 different stations but it has a gigantic antenna system capable of working anyone with at least 2,000 watts of ERP! Nowadays you can be an appliance operator and still join in on the fun. Everything you need to use is available commercially.<sup>13,14</sup>

EME activity on 135 cm is now very slow, due in part to the small number of stations with the required equipment. It hasn't been helped by recent attacks by commercial companies on the 220-222 MHz frequency spectrum. However, this is still an excellent band and requires an antenna system with much less physical size than 2 meters. So 135-cm EME really deserves more consideration. Typical equipment is described in reference 15.

EME activity on 70 cm is quite prevalent, with several stations having contacted well over 200 different stations. About 45 DXCC countries have been represented, as well as all continents and 50 states. Portable 70-cm EME operation is also popular using 20-foot dishes or arrays of four to eight long Yagis. Typical equipment requirements are described in reference 16.

Our newest UHF band, 33 cm (903 MHz), is just getting started on EME.

For a starter antenna a dish with a diameter of at least 12 feet should be sufficient, as long as you run at least 100-150 watts and a feed-mounted low-noise preamplifier. This band looks very exciting for EME in the near future, since only a modest setup is required.

Two-way EME got its start on 23 cm (1296 MHz) in 1960. It does require a more elaborate setup, but many stations with dishes as small as 8-12 feet in diameter are making contacts. Power is a problem and most operators now use two to six 2C39/7289 tubes in a cavity. Circular polarization is standard operating practice, so Faraday is no longer a problem! Many operators use SSB and contacts are now routine. The W2NFA/W2IMU notes are a good guide.\*

EME activity on 2304/2320, 3456, and 5760 MHz is much more specialized and beyond the scope of this month's column. Those who are active are using state-of-the-art antennas, and in most cases antenna-mounted preamplifiers as well as power amplifiers. It appears that 10.368 GHz EME will soon be a reality.<sup>1</sup> One of the biggest problems so far is antenna aiming and tracking the moon. Another problem, antenna cost, is being helped by the use of TVRO-type dishes. EME operation is alive and well, so stay tuned.

## other propagation modes

A lot of microwave activity is springing up, especially on 3 cm (10.368 GHz) with the commercial availability of solid-state transverters. The difference between a GunnPlexer® running 20 milliwatts and a low-noise transverter operating on CW or SSB with 200 milliwatts (both are typical equipment specifications) is over 36 dB, or an equivalent of 63 times improvement in DX! I'll bet some really serious record attempts will take place shortly on the 13-cm (2304 MHz) through 3-cm bands.

There are many propagation modes and developments and I try to include

\*Write Dick Turrin, W2IMU, Box 65, Colts Neck, New Jersey 07722 for further information.

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**Table 1. This quick reference table lists the most common types of North American VHF/UHF and above propagation. They are in no particular order. Optimum frequencies and a short summary of the typical characteristics are included.**

Propagation Mode	Frequencies	Remarks
1. Line of sight	50 MHz and up	Unobstructed path plus some bending extension.
2. F2	50 MHz	Requires high sunspot number, typically above 100 (solar flux > 150). Fall is best season.
3. Backscatter	50 MHz	Present during high sunspot activity like F2 or during an intense sporadic E opening.
4. Midlatitude sporadic E	50-225 MHz	Peaks between mid-May and mid-August and again between mid-November and mid-January. Best times are 0900-1200 and 1700-2000 local.
5. TE	50 MHz	Best at equinoxes $\pm 2$ weeks. Especially good when sunspot count is high. Optimum time is in late afternoon and early evening.
6. Equatorial FAI	50-450 MHz	Requires high number of sunspots. Should be located $\pm 10$ to 15 degrees of the geomagnetic equator. Other characteristics are same as TE.
7. Ionospheric scatter	50-150 MHz	Good from 800-1300 miles at midday in summer. Especially good during years with high sunspot activity. Path loss about 90 dB over free space at 6 meters and 115 dB at 2 meters. Requires high power.
8. Aurora	50-3000 MHz	Often occurs 24-48 hours after a solar disturbance. WWV K $\geq 4$ . Aim antenna to northerly direction.
9. Artificial aurora	50-450 MHz	Manmade ionospheric heating. Best when located near one of the heater installations. Very similar to aurora.
10. Auroral E	50 MHz	Similar to sporadic E. Usually occurs a few hours after an aurora has faded out.
11. Meteor scatter	50-450 MHz	Best on 2 and 6 meters for random meteors between 5-8 A.M. local time or at optimum direction and time during meteor showers. Above 225 MHz is very difficult.
12. FAI	50-450 MHz	Usually follows a sporadic E opening. Aim antenna slightly north of direct path. Has characteristics similar to aurora.
13. EME	50 MHz and up	High path loss (250-280 dB typical) depending on frequency. Requires very low noise figure receiver, high transmitter power, and high antenna gain (>20 dB).
14. Tropospheric scatter	50 MHz-20 GHz	Good up to 800 miles between stations having equipment similar to EME.
15. Tropospheric bending and super refraction	144 MHz and up	Best in spring and early fall, especially when there's a slow moving high barometric pressure (>30.0") and when a weather front is approaching somewhere along the path.
16. Tropospheric ducting	50 MHz and up	Similar to tropospheric bending. Best over water and flat land. Antenna elevation is important so you can couple into the duct.
17. Lightning scatter	144 and up	Sporadic. Both stations must aim into storm cell. Characteristics similar to meteor scatter.
18. Aircraft scatter	144 MHz up	Best when a large aircraft is at a high elevation and midway between stations. Usable up to about 500 miles.
19. Knife edge diffraction	1 GHz up	Best over a sharp edge such as a mountain peak especially when it is near one end of the path.
20. Obstacle gain	400 MHz up	Both stations must aim at obstacle such as a large building or mountain. Best when obstacle is near mid-point of path.
21. Rain scatter	5-25 GHz	Aim antenna into storm cell especially if it is elevated. Lots of signal distortion.

the latest record-breaking contacts at the end of each month's column. For those interested in microwave and millimeter-wave propagation, see references 17 and 18 which appeared in "VHF/UHF World" two years ago.

## how to find openings

By now you're probably wondering how to discover and use all this super propagation. To take full advantage you must understand the propagation modes available on all bands of interest and know when they are usable. **Table 1** shows most of the major propagation modes, the frequencies where they are most prevalent, and a few

words on their characteristics. It provides a quick reference guide.

There are many ways to find openings and just as many ways to miss them. For instance, there will always be a major opening when you least expect it or when you're "out of town!" It is surely a fact that we miss more openings than we catch. But this is rapidly changing with the increased use of calling frequencies (see **table 2**) and greater activity.

There is a problem with the 6-meter calling frequency (50.110 MHz) that has been used for many years. For the last decade it has been recommended as the DX calling frequency, with

50.200 MHz recommended for domestic operation. The latter never caught on. The popular 50.110 MHz is now so totally congested, especially during VHF contests, that DX can't break through the QRM. It has been suggested that all contest and routine activity on 6 meters take place above 50.125 MHz to allow room for the weaker DX near 50.110 MHz.

Another good way to detect openings is to monitor Amateur propagation beacons. They are most prevalent between 50-50.1, 144.05-144.06, and 432.07-432.08 MHz, with some scattered throughout the UHF and microwave bands.

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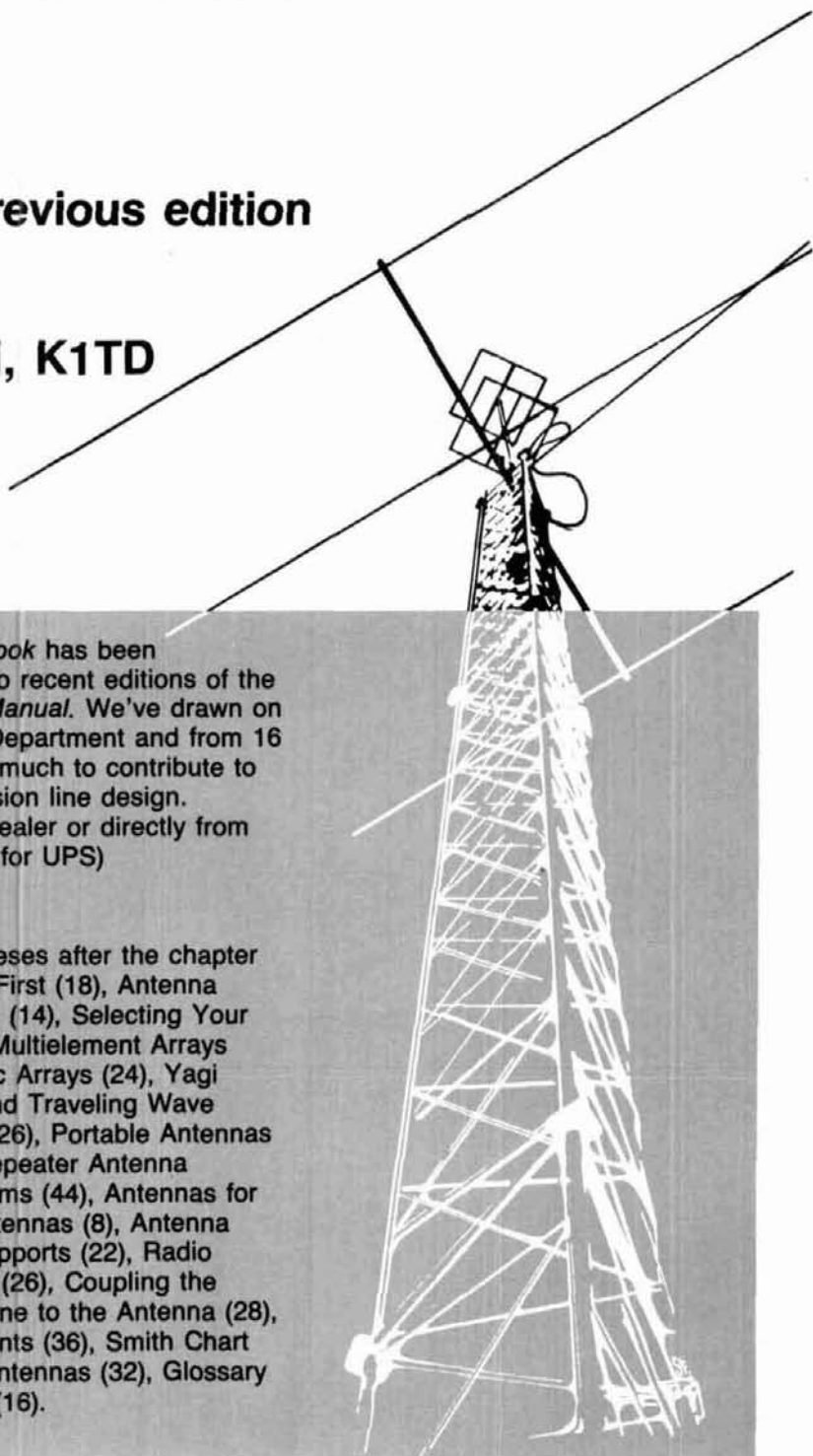
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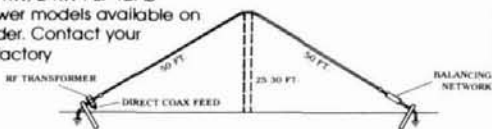
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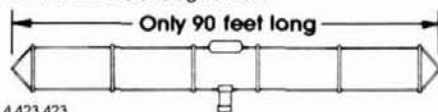
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The FCC regulates all automatic beacons (the most common types) on all frequencies below 450 MHz. In recent years, partially because of increased Amateur activity, beacons have sometimes caused interference with EME and other weak signal propagation. As a result, the ARRL VUAC is now soliciting comments on moving all beacons on 2 meters and higher to roughly 75-300 kHz above the present weak signal calling frequencies (rather than below, as is current practice). A note to the ARRL Membership Services Committee with your comments might help. Only after a consensus is found will the FCC be petitioned to approve any frequency changes for automatic beacons on the frequencies below 450 MHz.

The thousands of beacons outside the Amateur bands are rich sources of propagation indicators. Commercial stations like FM, television, and aircraft beacons are a few. Prime beacons to monitor for possible 6-meter openings to Europe are the video carriers of European television at 48.25 and 49.75 MHz.

Other good indicators of possible openings on 6 meters are the Amateur beacons between 28.2-28.3 MHz. Don't overlook above average and out-of-area Amateur activity between 28.3-28.5 MHz, the new Novice phone band.

**Table 2. This table shows the recommended weak signal calling frequencies on the VHF/UHF bands.**

Band	Frequency
6 meters	50.110 MHz DX *
	50.200 MHz Domestic *
2 meters	144.2 MHz
135 cm	220.1 MHz
70 cm	432.1 MHz
33 cm	903.1 MHz
23 cm	1296.1 MHz
13 cm	2304.1 MHz
9 cm	3456.1 MHz
6 cm	5760.1 MHz
3 cm	10.368 GHz

\* See text for explanation.

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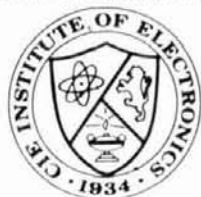
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2N4429	NPN	TO-18	5 for 75¢
2N4430	NPN	TO-18	5 for 75¢
2N4431	NPN	TO-18	5 for 75¢
2N4432	NPN	TO-18	5 for 75¢
2N4433	NPN	TO-18	5 for 75¢
2N4434	NPN	TO-18	5 for 75¢
2N4435	NPN	TO-18	5 for 75¢
2N4436	NPN	TO-18	5 for 75¢
2N4437	NPN	TO-18	5 for 75¢
2N4438	NPN	TO-18	5 for 75¢
2N4439	NPN	TO-18	5 for 75¢
2N4440	NPN	TO-18	5 for 75¢
2N4441	NPN	TO-18	5 for 75¢
2N4442	NPN	TO-18	5 for 75¢
2N4443	NPN	TO-18	5 for 75¢
2N4444	NPN	TO-18	5 for 75¢
2N4445	NPN	TO-18	5 for 75¢
2N4446	NPN	TO-18	5 for 75¢
2N4447	NPN	TO-18	5 for 75¢
2N4448	NPN	TO-18	5 for 75¢
2N4449	NPN	TO-18	5 for 75¢
2N4450	NPN	TO-18	5 for 75¢
2N4451	NPN	TO-18	5 for 75¢
2N4452	NPN	TO-18	5 for 75¢
2N4453	NPN	TO-18	5 for 75¢
2N4454	NPN	TO-18	5 for 75¢
2N4455	NPN	TO-18	5 for 75¢
2N4456	NPN	TO-18	5 for 75¢
2N4457	NPN	TO-18	5 for 75¢
2N4458	NPN	TO-18	5 for 75¢
2N4459	NPN	TO-18	5 for 75¢
2N4460	NPN	TO-18	5 for 75¢
2N4461	NPN	TO-18	5 for 75¢
2N4462	NPN	TO-18	5 for 75¢
2N4463	NPN	TO-18	5 for 75¢
2N4464	NPN	TO-18	5 for 75¢
2N4465	NPN	TO-18	5 for 75¢
2N4466	NPN	TO-18	5 for 75¢
2N4467	NPN	TO-18	5 for 75¢
2N4468	NPN	TO-18	5 for 75¢
2N4469	NPN	TO-18	5 for 75¢
2N4470	NPN	TO-18	5 for 75¢
2N4471	NPN	TO-18	5 for 75¢
2N4472	NPN	TO-18	5 for 75¢
2N4473	NPN	TO-18	5 for 75¢
2N4474	NPN	TO-18	5 for 75¢
2N4475	NPN	TO-18	5 for 75¢
2N4476	NPN	TO-18	5 for 75¢
2N4477	NPN	TO-18	5 for 75¢
2N4478	NPN	TO-18	5 for 75¢
2N4479	NPN	TO-18	5 for 75¢
2N4480	NPN	TO-18	5 for 75¢
2N4481	NPN	TO-18	5 for 75¢
2N4482	NPN	TO-18	5 for 75¢
2N4483	NPN	TO-18	5 for 75¢
2N4484	NPN	TO-18	5 for 75¢
2N4485	NPN	TO-18	5 for 75¢
2N4486	NPN	TO-18	5 for 75¢
2N4487	NPN	TO-18	5 for 75¢
2N4488	NPN	TO-18	5 for 75¢
2N4489	NPN	TO-18	5 for 75¢
2N4490	NPN	TO-18	5 for 75¢
2N4491	NPN	TO-18	5 for 75¢
2N4492	NPN	TO-18	5 for 75¢
2N4493	NPN	TO-18	5 for 75¢
2N4494	NPN	TO-18	5 for 75¢
2N4495	NPN	TO-18	5 for 75¢
2N4496	NPN	TO-18	5 for 75¢
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2N4498	NPN	TO-18	5 for 75¢
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### 10 AMP SOLID STATE RELAYS

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CONTROL  
Rated 5.5 to 10 Vdc  
will operate on 3-32 Vdc  
LOAD:  
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2 1/4" X 1 3/4" X 7/8"  
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coils etc. 100 parts.  
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directory. \* Other VHF publications are of interest and many are listed in reference 19. (I hope to publish a club list soon.)

There are net frequencies and special VHF activity frequencies on the hf bands that often help spot VHF openings. An example is 3818 kHz, the frequency of the Central States VHF Society net which is often used as an evening gathering place for VHFers, especially during meteor showers. EMEers meet on Saturdays and Sundays from 1600 to approximately 1900 UTC on 14.345 MHz. The 6-meter activity frequency is 28.885 MHz, which is often busy when 6-meter openings or crossband activity is expected.

How about a dedicated packet net for exchanging VHF/UHF information, activity, band openings, and beacon frequencies? Dxers in W1/W2/W6 (and perhaps other places) have such nets and bulletin boards near 144.95 MHz. These nets broadcast rare DX activity as well as WWW solar activity. They also allow interconnects between linked stations over a wide coverage area. This could be an invaluable source of information exchange for VHF and above enthusiasts. Imagine seeing a flash that ZD8MB is being heard in the states on 50.110 MHz or KH6HME is being heard in California on 1296 MHz! Why not give it a thought. Maybe the DXers would let us jump on their net until we can establish our own systems.

### summary

I hope this month's column has brought you up to date on all the latest propagation happenings on the frequencies above 50 MHz. Reviewing the references listed should help you understand the propagation opportunities available on these bands. Table 1 can be your mini propagation guide. Good luck on your search for new DX.

### notes

Per Amateur Satellite Report (AM-SAT newsletter), bulletin no. 171, March 21, 1988: Dr. Patrick MacIntosh, the Director of Solar Physics

\*Harry Schools, KA3B, 1606 S. Newkirk Street, Philadelphia, Pennsylvania 19145, \$8 for each directory.

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Research at NOAA's Space Environment Laboratory, Boulder, Colorado, reports that the peak of solar cycle 22 may be a lot higher and earlier than originally predicted. Let's hope he's right. Check WWV and the PRF.

Just a reminder. The latest accepted ARRL VUAC Band Plan as shown in the ARRL Repeater Directory lists the 33-cm calling frequency as 903.1 MHz with EME activity between 903.0 and 903.05 MHz. Using these frequencies will help reduce QRM from other services and bring interested parties together so they won't miss openings by being spread out in frequency.

### new records

On March 22, 1988 at 1300 UTC Gene Monk, W4ODW, Niceville, Florida (EM60SM) worked Al Ward, WB5LUA, McKinney, Texas (EM13QC) for a new extension of the 33-cm (902-928 MHz) tropo DX record. Gene was running only 10 watts on 903.1 MHz SSB while Al was running 150 watts to a single 47-element loop Yagi. Tropo was reported between the Florida Panhandle and Texas for a few days and signals were quite strong. The distance was 623 miles (1003 km). **Table 1** from last month's column is already obsolete! Congratulations to Gene and Al.

### acknowledgments

I would particularly like to thank Dr. Ernest K. Smith for sending me the copy of his  $F_0E_s$  maps article.<sup>5</sup> Thanks also to those who took the time to write with comments and suggestions for future columns.

### important VHF/UHF events

July 1	$\pm 1$ month. Look for USA to Europe openings on 6 meters
July 2	EME perigee
July 13	New moon
July 16-17	CQ VHF WPX Contest
July 20	$\pm 3$ weeks. Look for 2-meter sporadic E openings
July 21-24	Central States VHF Conference, Lincoln, Nebraska (contact WD0DGF)

July 28	Predicted peak of the Delta Aquarids meteor shower at 2100 UTC
July 30	EME perigee
Aug 6-7	ARRL UHF Contest
August 11	Predicted peak of the Perseids meteor shower at 1900 UTC
August 12	New moon
August 20-21	ARRL 10 GHz Cumulative Contest, first weekend
August 25-28	Microwave Update 1988 Conference Estes Park, Colorado (contact W0PW)
August 27	EME perigee

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18. Joe Reiser, W1JR, "VHF/UHF World: Microwave and Millimeter-wave Propagation-part 2," *ham radio*, August 1986, page 69.
19. Joe Reiser, W1JR, "VHF/UHF World: Keeping VHF/UHFers up-to-date," *ham radio*, March 1985, page 126.

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# cheap and dirty 6-meter beam

For over 40 years the Amateur Radio fraternity has used an antenna construction technique known as "plumber's delight". This method, based on the fact that the center of a half-wave antenna lies at a 0-voltage point, allows the center of the element to be grounded to the boom material and can make for easier rotary beam construction.

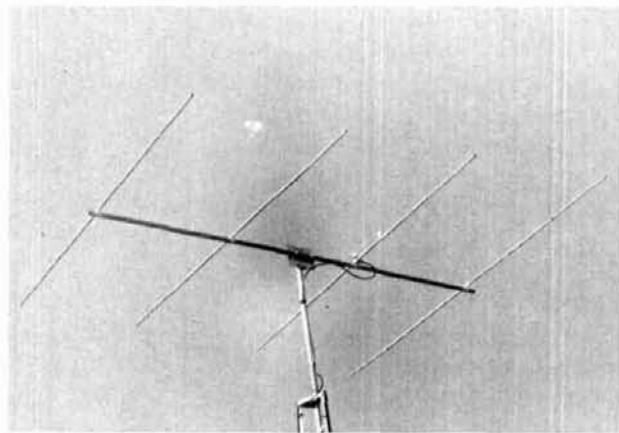
Many different ways of attaching elements to the boom have been tried over the years. Some have been as simple as a single "U" bolt with holes drilled in the element; others have been much more complicated. The beam construction method described here is simple and inexpensive. It cost me less than a dollar!

Several years ago, the local Amateur Radio club needed a 6-meter beam for Field Day operation. Not wishing to expend much in the way of funds, we made a quick search of the antenna graveyard. We found various pieces of aluminum but no way to attach the elements. Then it hit me; just use simple E.M.T. clamps (photo A)!

These clamps, often made of galvanized iron, are available from any well-stocked hardware store for as little as 7 cents apiece. Drill the element material to pass a No. 10 bolt and the clamp easily attaches to the element. Next, drill two 1/8-inch holes into the boom, through the clamp, to pass a No. 8 sheet metal screw. Viola! A "cheap and dirty" way to attach the elements to the boom.

This antenna worked great for Field Day, but was relegated to the antenna graveyard soon after. Over the next several years, the boom and other pieces found their way into other antenna projects and soon only the elements remained. I finally decided to resurrect the antenna, and the "Cheap and Dirty 6-meter Beam" was the result.

The beam consists of four elements on a 10-foot boom (antenna dimensions shown in fig. 1). The material used for the boom is two sections of Radio Shack heavy-duty mast that telescopes approximately 6



## Inexpensive way to attach elements

inches. The elements are made from 5/8-inch 6061-T3 aluminum, and the gamma match from 3/16-inch rod. You could probably use Radio Shack light-duty mast for the boom material, but the difference in cost is minor.

To build the antenna, cut the elements to length, drill them to attach to the E.M.T. clamps, and attach them to the boom. To attach the boom to the mast, drill a sheet of aluminum about 12 x 6 inches to accept "U" bolts. The model built at W5UOJ (see lead photo) uses Radio Shack TV-type "U" bolts for both the boom and mast. However, the actual "U" bolts used depend on the size of the mast and boom material.

The gamma match, shown in fig. 2, is straightforward; it's a piece of 3/16-inch rod approximately 14 inches long. Make a movable strap from a small piece of aluminum and attach it near the end of the material. A second strap attaches the rod to the variable capacitor. A small plastic enclosure can be used for weatherproofing; I didn't use one.

Instead of a plastic enclosure, the variable capacitor was set, then wrapped with a plastic bag and black plastic tape. This appears to work; the capacitor has

Glen E. Zook, W5UOJ, 410 Lawndale Drive,  
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Facsimile Screen Display

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Each package includes a terminal program with split screen display, QSO buffer, disk storage of received data, and printer operation, and a second program for transmission/reception and screen display of facsimile signals. The IBM programs are on 5-1/4" disk and the Commodore programs are plug-in ROM cartridges.

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made it through two separate ice storms so far. But, if in doubt, use a small plastic box.

You don't need stand-off insulators in the gamma match assembly — the gamma rod isn't long enough to need any and the aluminum strap gives enough support. By the way, the gamma capacitor used at W5UOJ was an old "APC" type, but you can use any variable with an appropriate value.

There are two methods of adjusting the gamma match for best SWR. The first is to mount the antenna directly on a tower, mast, or other suitable point and make the necessary adjustments. A simpler method is to take a wooden stepladder, prop the antenna on it pointing upward, and make your adjustments to the gamma match.

You don't have to use 6061-T3 for the elements; almost any aluminum tubing from 1/2 to 5/8 inch will work. The lengths are such that any droop is insignificant. The gamma rod can be made from aluminum ground wire, like the kind available from Radio Shack, but probably will have to be a couple of inches longer for the best match.

You'll probably have to use bolts about 1/2 to 1 inch longer than necessary when attaching the E.M.T. clamps to the elements because the clamps are a bit too short. But the bending that results from tightening the bolts firmly secures the elements to the boom.

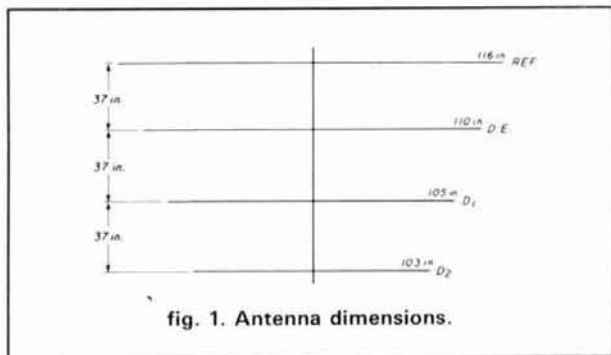


fig. 1. Antenna dimensions.

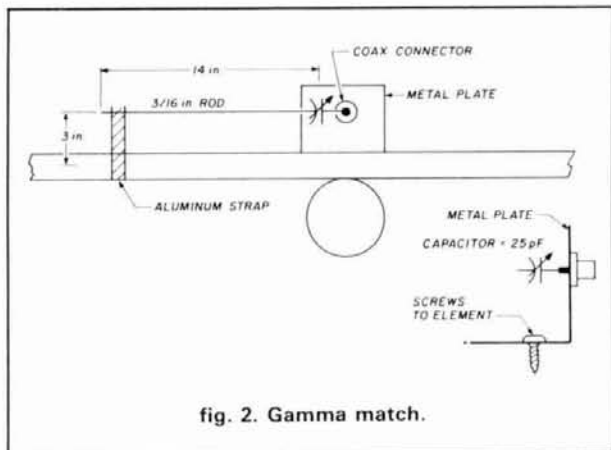


fig. 2. Gamma match.

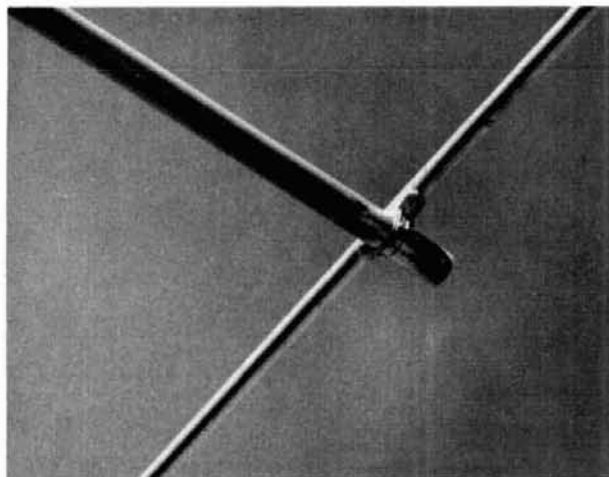


photo A. An E.M.T. clamp makes an excellent method of connecting the elements to the boom.

The extra bolt length can be cut off with a pair of sidecutters. Next, drill the clamp on each side and secure it to the boom with sheet metal screws.

The clamps used with the 1-1/4 inch boom material are for 1-inch E.M.T. For a 1-1/2 inch boom, use clamps for 1-1/4 inch E.M.T. Antennas built for higher frequency operation can use smaller clamps. Boom material 1-1/2 inches in diameter results in a stronger beam.

If you use Radio Shack boom material, make sure that the two boom halves do not turn. Put the two sections together and drill a 1/8-inch hole. Then, secure the boom material with a No. 8 sheet metal screw.

The same technique was also applied to a three-element 10-meter beam used for OSCAR 6 and 7 work. Here, however, I used boom material 1-1/2 inches in diameter along with the heavier clamps to secure the elements to the boom.

Obviously, there are other ways to secure elements to the boom in a "plumber's delight" Yagi. But I doubt you'll find any as inexpensive. Although I haven't tried it, there's no reason why E.M.T. clamps can't be used for 6-meter antennas with more than four elements, or smaller clamps for 2 meters and up.

While the actual performance of this antenna has not been checked on an antenna range, it compares favorably with commercially made four- and five-element beams used in this area. The total cost was less than \$15; the aluminum and the variable capacitor were surplus. You'll spend approximately \$25 to \$30 on this antenna if you buy all the parts. But, it's still cheaper than buying a beam and takes only a few hours to build.

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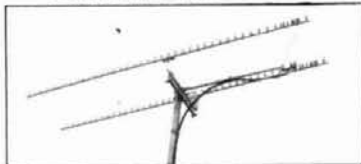
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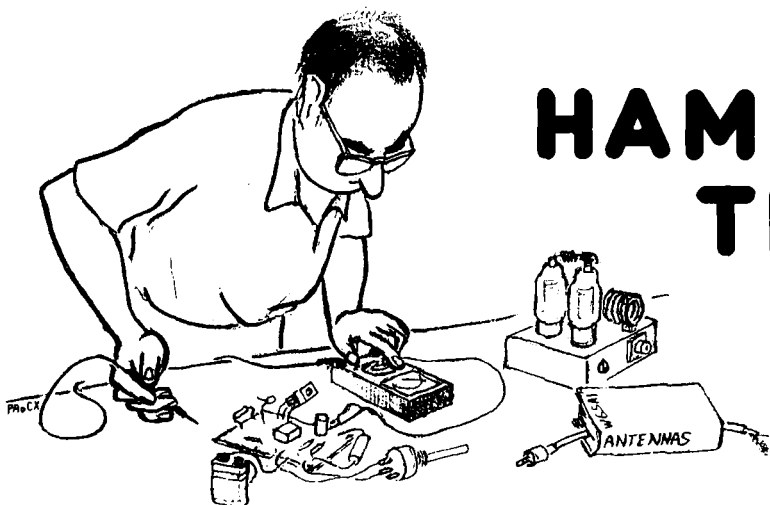
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# HAM RADIO TECHNIQUES

Bill Orr, W6SAI

## line voltage and power tube life

Have you checked the cost of a replacement power tube recently? Just like the cost of automobiles, houses, and other items, it has gone up over the years. Taking good care of the tubes in your linear amplifier will put money in your pocket in the long run.

Control of filament voltage is a main factor in determining vacuum tube life. Most power tubes specify filament voltage excursion limits — in most cases,  $\pm 5$  percent of a nominal value. The popular 3-500Z high- $\mu$  power triodes have a nominal filament voltage of 5.0 with limits of 4.75 and 5.25 volts.

Undervolting the filament will seriously limit the electron emission and the maximum plate current level; overvolting the filament will reduce the emission life of the tube. The voltage limits specified by the tube manufacturer strike an economical compromise between emission and filament life.

During World War II the 6C21 pulse tube was developed. It was a 450TH triode whose 7.5-volt filament was uprated to 8.2 volts. The tube had very high pulse emission for its size, but the

guaranteed tube life was derated to 200 hours.

## measuring filament voltage

Measure filament voltage at the tube socket so that the resistance of filament wiring or chokes does not degrade the reading's accuracy. Use a digital voltmeter or an iron-vane, d'Arsonval type rms-responding analog instrument. The latter can be identified by the nonlinear ac scale which is highly compressed at the low-voltage end. The old Weston model 476, 3-1/2 inch meter with a 0 to 8-volt scale is ideal for 5-volt tubes. It can often be found for a few dollars at a flea market. You can have the calibration checked at the electrical laboratory at a local college, or at a meter repair shop.

The popular digital voltmeter used for ac measurements is a peak-reading device, calibrated for an rms reading. It's acceptable, but accuracy is not as good as the iron-vane analog meter in cases where the power line harmonics are particularly high. In any case, both instrument types are satisfactory for general Amateur use.

The common volt-ohmmeter is not recommended for accurate filament voltage measurement. It has a dc meter movement with a series rectifier added for ac measurement. Calibration can change quickly if the rectifier is accidentally overloaded or slowly as the rectifier ages. In addition, any substantial harmonic content of the power line casts doubt on the indicated reading, even if the meter is accurately calibrated for 60 Hz use.

## meter accuracy

The accuracy of many small meters is  $\pm 2$  percent of the full scale reading. This doesn't leave much margin for error when you're trying to ascertain voltage limits of  $\pm 5$  percent. The solution is to have the meter calibrated as described earlier. My filament voltmeter was accurately calibrated at the 5-volt scale marking. I take good care of the meter and keep it in a safe place, away from bumps and jars.

## line voltage limitations

As the filament voltage limitations of the 3-500Z are  $\pm 5$  percent, the primary line voltage must be held within these

limits. In the thirties the nominal line voltage in the United States and Canada was 110 volts; in the forties it was raised to 115, and then to 117 just after World War II. By the late fifties the nominal line voltage was about 120 volts. Now, it may run as high as 125 volts in certain parts of the country.

Line voltage limits are set by the Public Utility Commission in each state. In California, the voltage limits are 115 and 125 volts, centered about 120 volts. This amounts to a plus or minus tolerance of about 4.5 percent, which is within the 5-percent voltage tolerance established for the 3-500Z. So, if the manufacturer of the amplifier using the 3-500Z designs his transformer to deliver the required filament voltage and current at a primary voltage of 120 volts, the filament voltage will remain within limits even if the line voltage varies within the proscribed excursions.

Most imported linear amplifiers are manufactured with a power transformer designed for the line voltage of the country where the amplifier will be used. Unfortunately, many of the amplifiers are designed around a 115-volt primary requirement, because this is a common line voltage in many countries. When such an amplifier is run on a nominal 120-volt line, the filament voltage often exceeds the upper limit specified by the manufacturer.

I have a popular imported amplifier using a pair of 3-500Z tubes. The instruction manual specifies a power source of either 120 or 240 volts. However, when checked with accurate meters, it was found that a line voltage of 120 resulted in a filament voltage of 5.22 volts at the tube socket — dangerously close to the upper limit of filament voltage excursion. Using a variable voltage transformer, I determined that a primary voltage of 115 provided the correct filament voltage. I then checked the results under the 240-volt condition and found that a line voltage of 230 provided the correct filament voltage.

Obviously, the power transformer of the amplifier had been designed for a 115/230-volt primary source. When

run on a 120/240-volt source, the amplifier requires an auxiliary primary circuit step-down transformer to achieve the correct nominal filament voltage (fig. 1).

### the correction transformer

Because I wanted to run the amplifier from the nominal 240-volt circuit, I had to reduce the primary voltage by 10 volts. Checking line voltage over a

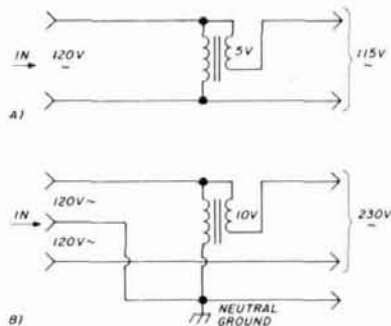


fig. 1. (A) 5-volt transformer "bucks" line voltage. Depending upon polarity of secondary, the transformer either boosts or reduces line voltage. (B) 115/120 volt transformer can be used as 240-volt circuit with primary connected between one side of line and neutral. Notes: Neutral ground is attached to chassis ground in most amateur equipment. Transformer secondary must carry full primary current of amplifier.

period of days showed that the average value ran close to 244 volts. This meant that a 14 volt, rather than a 10 volt, step-down transformer was required. According to the operating manual, the maximum primary current of the amplifier was about 14 amperes, so the transformer has to deliver 14 volts at about 14 amperes. An oddball!

Looking for a transformer like this in a catalog may be a waste of time. Even if you find one, it will be very expensive. A suitable transformer can often be purchased at a flea market. If the current capacity is OK, you may be able to run it from a variable-voltage transformer (like a Variac™ or Powerstat™) in order to hit the required voltage "on the nose" (fig. 2). The transformer can have either a 120 or 240-volt primary. Various hookups are shown in the illustration.

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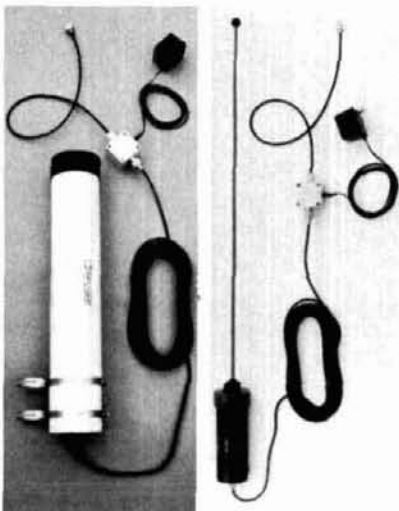
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## keeping track of filament voltage

In most cases it is not practical to attach a permanent filament voltmeter to the amplifier. An iron-vane meter connected across the primary circuit is helpful. I have one mounted in a small box that sits next to the SWR meter on my operating table. It didn't cost much and doesn't take up much space. But I feel very comfortable with it, especially when I contemplate the cost of replacement tubes for my amplifier!

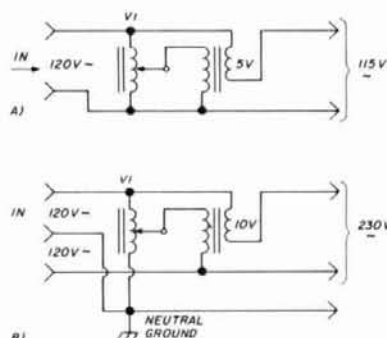


fig. 2. (A) Variable voltage transformer (V1) used on 120-volt circuit to adjust line voltage. (B) Variable voltage transformer (V1) on 240-volt circuit. Capacity of variable voltage transformer is equal to line current drawn by amplifier times difference in input and output voltages. For 2-kw condition ( $i = 14A$ ) capacity is  $14 \times 10 = 140$  watts.

## a "cheap and dirty" antenna current indicator

Remember those good old thermocouple rf meters of yesteryear? Just the thing for measuring antenna current! You can occasionally find one at a flea market, but if you can't, Jack Sobel, W0SVM, has a satisfactory substitute for all except nitpickers (fig. 3). Jack shunts a No. 47 pilot lamp with a 33-ohm, 1-watt resistor. This little assembly has copper alligator clips on it and he snaps it across a few inches of his feedline at his antenna tuner. He uses two of these gadgets for a two-wire line. Vary the tap spacing to accommodate your power level.

## the helix antenna revisited

The helix dipole seems to generate

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more heat than light. A lot of hams don't like them, but some who have used them are very happy with them. Bruce Muscolino, W6TOY, has used helix-wound antennas for some years.

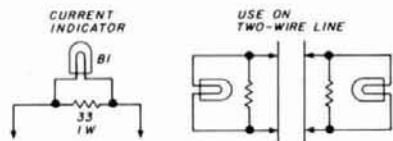


fig. 3. Inexpensive antenna current indicator. Clips are placed across a few inches at one feed wire. Vary resistance value to match line circuit. (Design shown is for two-wire line.)

One arrangement he found satisfactory was two HY-gain helically wound fiber glass CB antennas which he used back-to-back as a helical dipole, hung in his small attic. A hand-wound center coil resonated them to 20 meters with the aid of a dip meter. He fed the antenna with ribbon line and an antenna tuner. Running 100 watts, he made WAC over a period of several weeks. For those Amateurs who have landlord problems, a simple antenna like this may be the only compromise which permits them to get on the air!

### what to do when the band is dead

What do you do when the band is dead? Many times I hunker down with a good book and forget Amateur Radio. I have favorites that I have read repeatedly over the years. I bet you do too! Just to see how smart my readers are, I'm going to give you a quotation from one of my favorite books and see how many can identify it. No prizes, but I'll give the name and call in this column of the readers who send their QSL card to me (Box 7508, Menlo Park, California 94025) with the name of the book and the correct identification of the quote. Choice of the "winner" will be arbitrary-HI. OK? Here's the quote: "You have been in Afghanistan, I perceive."

(That was easy, wasn't it?)

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When's the last time you fired up the old soldering iron? A friend of mine once said, "Rosin is the grease paint of our industry and every now and then you've got to get out to the bench and remember what it is to smell some solder."

Thanks to a new product line from Motorola, which includes narrowband fm transmitters and receivers, this dual conversion tunable receiver is about as simple as a receiver can get.

### MC3362

The receiver is built around the new Motorola MC3362. Although there have been a few "receivers on a chip" (like the CA3089) for a few years, none comes close to the MC3362. Until now most ICs have included the i-f amplifiers, detectors (or discriminators), and audio pre-drive circuits. The MC3362 is a dual conversion receiver that starts at the antenna and ends at the audio output.

A basic block diagram of a dual conversion receiver is shown in **fig. 1**. Notice that the antenna feeds directly into the first mixer with no rf stage. This technique is more common than most people realize. RF amplifiers are included only in high performance rigs. If you

have a fully synthesized 2-meter rig it probably has one, but the difference in performance with or without an rf stage is minor. (Please, no letters from DX hounds with liquid nitrogen-cooled front ends!) Tests on the unit I built showed a sensitivity of about 1.5 microvolts — not fantastic but not bad either.

Except for the i-f filters, the crystal, the audio driver, some resistors, capacitors, inductors, and the speaker, the MC3362 has all of the circuitry shown in **fig. 1**. The MC3362 specifications are listed in **table 1**.

A functional block diagram and pinouts of the MC3362 are shown in **fig. 2**. Let's take a look at it block by block.

### first mixer

The first mixer has two inputs in case you want to use a balanced drive from a transformer. Motorola says this mixer is good to about 470 MHz. Input required at 49.7 MHz (the IC was built for the cordless telephone market) is typically 0.7 microvolt for an (S + N)/N of 20 dB. Gain is about 18 dB; Motorola says this increases to about 2 microvolts at 470 MHz.

### first LO

The first local oscillator can use an LC tank or crystal as its frequency determining element, or an external source. In the case of an LC tank, a varicap diode is included so that tuning can be accomplished by using a variable control voltage instead of a variable capacitor. If you need a wide tuning range, use a large inductor and small capacitor in your tank so that the varicap has more effect (the varicap range is about 10 to 20 pF). Coarse tuning can be accomplished by tuning the capacitor in the tank (pins 21, 22), fine tuning

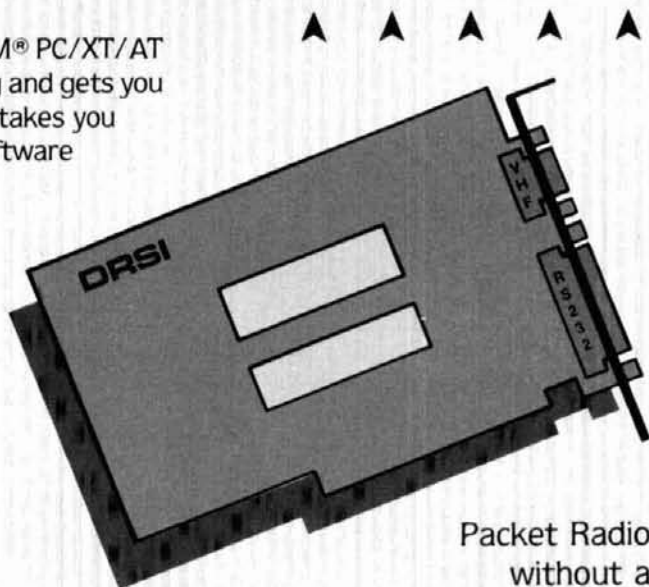
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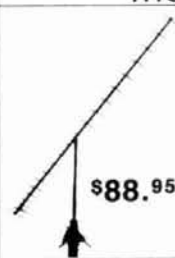
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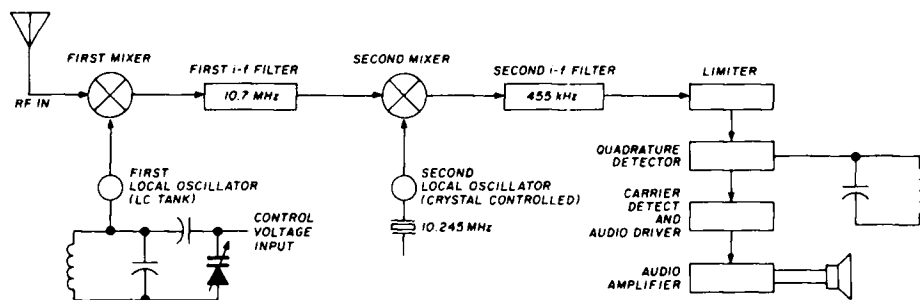


fig. 1. Block diagram of a typical dual conversion FM receiver.

Table 1. MC3362 specifications

First i-f	10.7 MHz
Second i-f	455 kHz
Power Supply	2 to 7 volts (regulated)
Current Consumption	4 mA
Sensitivity	0.7 microvolts (50 MHz)
Maximum Frequency	180 MHz (with internal LO) 470 MHz (with external LO)
First Mixer Input	690 ohms in parallel with 7.5 pF
Cost	\$1.86 in 100-piece quantity (Sept. 1987)

by using the varicap. Keep the control voltage between 1.2 volts and  $V_{CC}$ , the supply voltage. The oscillator quits below about 1.2 volts. If you don't use the varicap, tie pin 23 to  $V_{CC}$ .

Maximum frequency is about 180 MHz. Use a larger  $V_{CC}$  for higher frequency operation.

A buffered output is provided for this LO (pin 20), in case you want to phase lock it to an external source. *Be careful not to ground this pin* because it is the emitter of an emitter follower with no collector resistance.

### first i-f

The first i-f filter is external to the MC3362. A 10.7-MHz ceramic filter is recommended. The muRata filter that Radio Shack used to carry is satisfactory. Note that many different filters will work here: the main considerations are bandwidth, insertion loss, and cost. Be careful — some 10.7-MHz filters are not 10.7 MHz, but more like 10.63 MHz. Impedance should be 330 ohms. Typical parts are the muRata SFE10.7MA and Toko SK107M3-AO-10.

### second mixer

The second mixer also has two inputs, perhaps to accommodate a fancy 455-kHz crystal filter that requires transformer matching. The gain is about 21 dB; response is good to about 20 MHz.

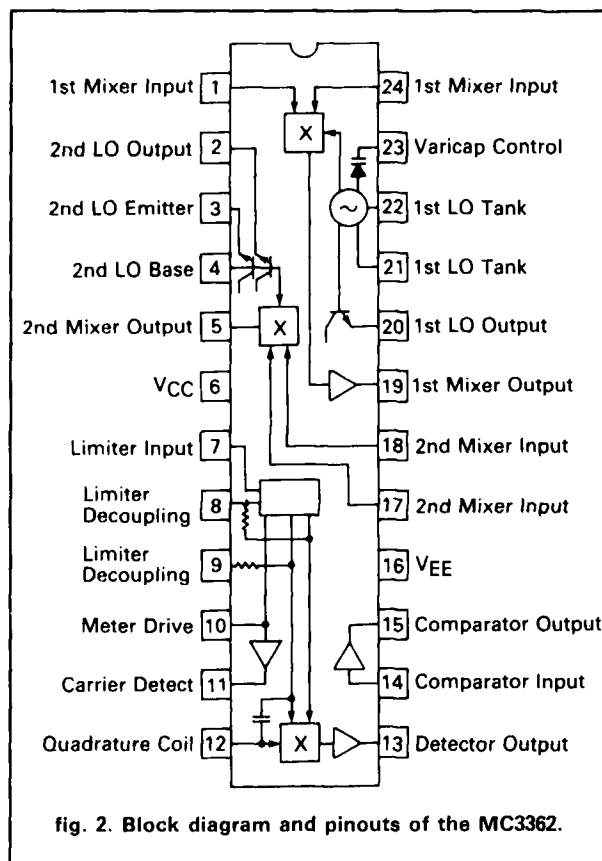


fig. 2. Block diagram and pinouts of the MC3362.

### second LO

The second local oscillator is designed to be crystal controlled at 10.245 MHz (10.7 MHz — 455 kHz). The crystal should be a fundamental type cut for a load capacitance of 32 to 40 pF. A buffered output is provided (pin 2).

### second i-f

The second i-f filter is external to the MC3362. A 455-kHz ceramic filter is recommended. The printed

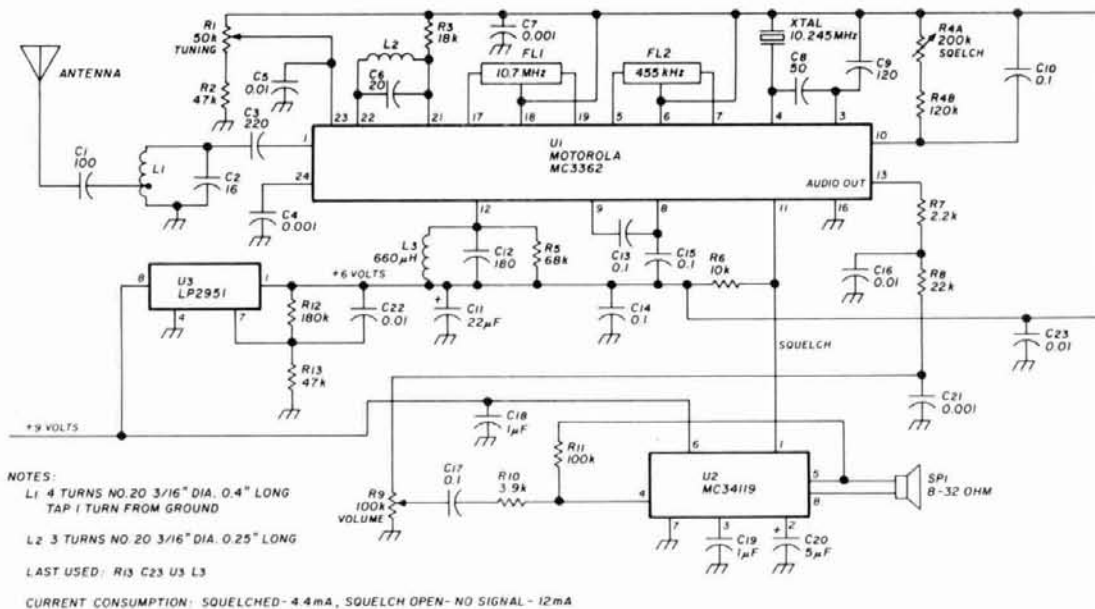


fig. 3. Motorola MC3362 IC is foundation for 2-meter receiver.

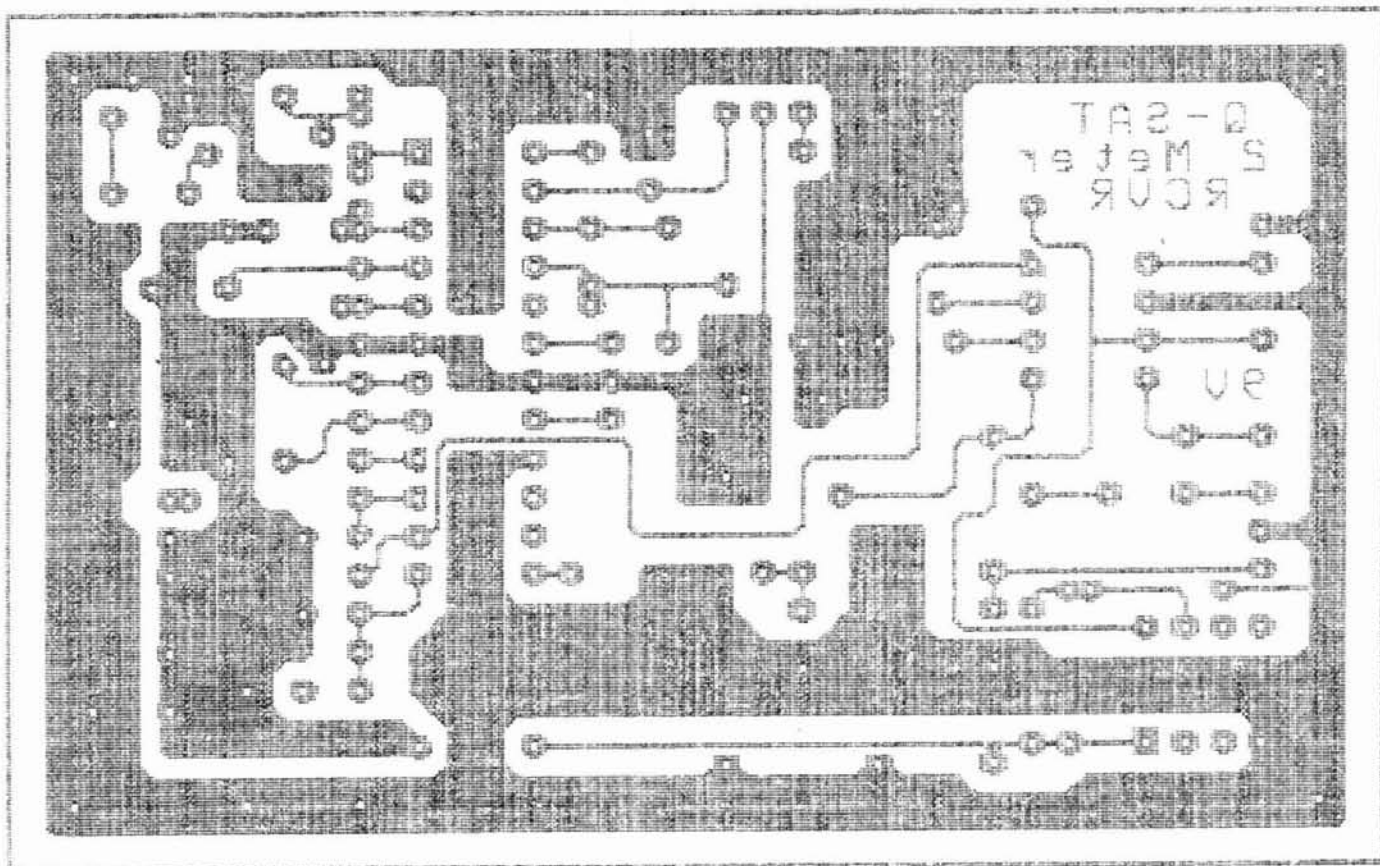


fig. 4. Printed circuit artwork; 2X size. Top view looking through the board.

parts list

C1	100 pF
C2	16 pF NPO or dipped silver mica (see text)
C3	220 pF
C4,C7,C21	0.001 $\mu$ F
C5,C16,C22,C23	0.01 $\mu$ F
C6	22 pF NPO or dipped silver mica (see text)
C8	47 or 50 pF
C9	120 pF
C10,C13,C14, C15,C17	0.1 $\mu$ F
C11	10 to 22 $\mu$ F, 10 volts
C12*	180 pF or RMC2A6597HK (see text)
C18,C19	1 $\mu$ F
C20	5 $\mu$ F, 15 volts
FL1*	10.7-MHz filter—SFE10.7MA (see text)
FL2*	455-kHz filter—SFU455A (see text)
L1	3/16 inches diameter 4 turns spaced to 0.4 inches tapped 1 turn from ground No. 20 wire
L2	3/16 inches diameter 3 turns spaced to 0.25 inches No. 20 wire
L3*	660 $\mu$ H or RMC2A6597HK (see text)
R1	50-k pot
R2	47 k (see text)
R3	18 k
R4	(see text)
R5	68 k
R6	10 k
R7	2.2 k
R8	22 k
R9	100-k pot (audio taper)
R10	3.9 k
R11	100 k
R12	180 k
R13	47 k
U1*	Motorola MC3362P
U2*	Motorola MC34119P
U3*	National LP2951CN
Crystal*	10.245 MHz (HC-18U style)
Printed Circuit Board*	

All capacitors should be as small as possible.

All resistors 1/4 watt.

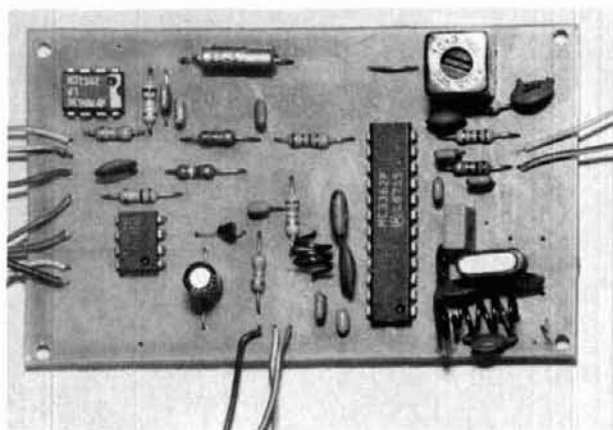


fig. 5. Closeup of 2-meter receiver showing parts placement.

circuit board is laid out to accept two different pinouts. The 455-kHz filters once sold by Radio Shack will work. As in the case of the 10.7-MHz filter, consider bandwidth, loss, and cost. Impedance should be 1.5 to 2 k. Typical parts are the muRata CFU455D and SFU455A, and the Toko LFC-455I.

A limiter is used to remove any a-m component from the signal. The limiter response is good to about 1 MHz.

A quadrature detector is provided to detect the fm signal. Output is dependent on the carrier "swing". Figure about 250 microvolts for narrowband fm.

A meter drive and a squelch circuit are provided.

Data detect is a comparator which is designed to detect zero crossings of FSK modulation data rates of 2000 to 35000 baud.

## construction

The basic receiver circuit is from a Motorola application note. It was so new that it didn't have an application note number. The schematic (modified from the application note) is shown in fig. 3.

Since the receiver is operating at 147 MHz, it is advisable to build the circuit on a pc board (fig. 4). Perfboard with a ground plane and some copper tape can be used; my original prototype was built on a Radio Shack board — the type with a ground plane on top.

If you duplicate the pc board presented here, please note that some capacitors have more than two mounting holes. Don't worry about the extra holes; just find the best fit (fig. 5). Be careful — it's crowded around L<sub>1</sub>!

Some things about this circuit may seem a little strange. For example, if you've ever used ceramic filters, you probably connected the middle lead to ground instead of to the V<sub>CC</sub> plane. Actually, at 150 MHz and with proper power supply bypassing, the V<sub>CC</sub> plane and the ground plane are both at the same ac potential, so it doesn't really make any difference. Also many components that you would normally see connected between the IC and ground are really connected to the V<sub>CC</sub> plane.

The voltage regulator (a National LP2951) used in this design is also a little different; it's a low dropout adjustable regulator. Believe me, I agonized over using this part because many people will have a hard time obtaining it. Why not just stick to a 7805? Most regulators require an input voltage at least 2 volts higher than the output. For example, imagine a standard 5-volt 7805 operating from a 9-volt NiCd battery. In the first place, a 9-volt NiCd is really 8.4 volts. Since the 7805 requires about 2 volts more than the output, this circuit will work until the battery output falls to about 7 volts. With the LP2951, the circuit will work until the battery falls to about 5.5 volts. (Battery life is extended by using the LP2951.)

The output may be trimmed to suit your power supply. Because Motorola suggests a slightly higher voltage for operation at 150 MHz, an adjustable regulator is recommended. The temperature performance of this particular part is better than almost anything else on the market. You probably can delete it (jumper pin 1 to pin 8) and get away with four AA batteries for a power supply, but I suggest a 9-volt NiCd and a regulator. Motorola warns that the first LO will drift with any change of the power supply.

The audio amplifier is a bit different, too. I've used

### Directory of component manufacturers

muRata-Erie 1148 Franklin Rd, S.E. Marietta, Georgia 30067	(404) 436-1300 coils, crystals, ceramic filters, crystal filters
Toko America Inc. 1250 Feehanville Drive Mount Prospect, Illinois 60056	(312) 297-0070 coils, ceramic filters, crystal filters, quadrature coils
Coilcraft 1102 Silver Lake Road Cary, Illinois 60013	(312) 639-6400 coils
Fox Electronics PO Box 1078 Cape Coral, Florida 33910	(813) 482-7212 crystals
GTE Sylvania Electronic Components Division 2401 Reach Road Williamsport, Pennsylvania 17701	(717) 326-6591 crystals
International Crystals P.O. Box 26330 Oklahoma City, Oklahoma 73126	(405) 236-3741 crystals
JAN Crystals P.O. Box 06017 Ft. Myers, Florida 33906	(813) 936-2397 crystals
Comtec 3300 East Sparrow Ave. Flagstaff, Arizona 86004	(602) 526-4123 crystals
Standard Crystal Corp. 9940 E. Baldwin Pl. El Monte, California 91731	(818) 443-2121 (800) 423-4578 crystals
Digi-Key Corp. P.O. Box 677 Thief River Falls, Minnesota 56701	(800) 344-4539 Toko coils and filters

For the National Semiconductor and Motorola parts, I suggest you contact your nearest sales office or try the following distributors: Hamilton—Avnet, Hallmark, Schewber, or Mil-Gray.

the LM386 in this type of application for quite a while, but I hate finding room for a 100- or 250- $\mu$ F output coupling capacitor. The MC34119 with a differential output and an enable pin is hard to beat.

Notice resistors  $R_{4A}$  and  $R_{4B}$ . If you want an adjustable squelch, use them both ( $R_{4A} = 200$  k;  $R_{4B} = 1$  k). If you'd rather have a fixed level, replace  $R_{4A}$  with a jumper and make  $R_{4B}$  about 120 k. The pc layout is set up for either configuration.

Inductor  $L_3$  and capacitor  $C_{12}$  can both be replaced by a Toko LC tank part number RMC2A6597HK (highly recommended). If the tank doesn't seem to want to go down far enough in frequency, put about 18 pF in parallel with it.

If you can't find nonpolarized capacitors for  $C_{18}$  and  $C_{19}$ , use polarized caps. In both cases the negative side will go to ground.

The only critical thing about this circuit is that you enjoy building it!

### tune-up

I suggest that you omit  $C_2$  and  $C_8$  at the start. In my first prototype I calculated the coils precisely and

allowed for input capacitance, strays, and the varicap. They weren't even close (10 MHz off). As an alternative, tack solder a trimmer (10-60 pF) temporarily to the bottom of the board. Tweak the tank using the trimmer; then take the tank out and measure it. Substitute the closest cap you can find.

Your tune-up can be done in a number of different ways. Some signal source will be necessary. A signal generator is best, but you can use a grid dip meter or an on-the-air signal like a busy local repeater. Start with the first LO tank ( $L_2$ ,  $C_6$ ). For now, you can tack a trimmer capacitor in place of  $C_6$ , or squeeze and stretch the coil until the oscillator is around 136 MHz. The buffered output and a frequency counter would be ideal. After you have trimmed the oscillator tank, you can tune the input coupling tank ( $L_1$ ,  $C_2$ ) using the same method. Now tune the quadrature coil  $L_3$ . Don't forget the tuning control  $R_1$  during all this. By the way, increasing  $R_2$  will give a smaller, less critical tuning range. Just don't go below 10 k or the control voltage will drop below 1.2 volts. A practical upper limit is probably about 100 k.

My prototype tuned 4.5 MHz (143.75 to 148.25

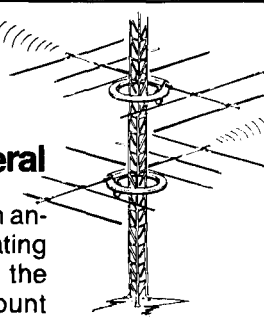


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MHz) with the parts called for in the parts list. For fine tuning add a 5-k pot between R<sub>1</sub> and R<sub>2</sub>, connected as a variable resistor; or better yet use a ten-turn pot for R<sub>1</sub>.

**modifications**

There is no reason that this receiver must work on 2 meters. Motorola doesn't specify the lower operating frequency, but I suspect it will go all the way down to the a-m broadcast band. Of course, a narrowband fm receiver isn't much good below 28 MHz. It was designed to operate on 49 MHz, and 6 meters should be no problem. (My prototype is also a good weather receiver on 162 MHz.)

Because tuning can be done using a control voltage, a scanner seems to be a natural. A ramp generator or even a counter with a D/A can be connected to pin 23. The squelch can be used to stop the scan. Remember not to allow the control voltage to go too low.

With a fixed crystal instead of an LC tank for the first LO, you could operate on the 75-MHz radio control band — if fm is allowed on that band. Motorola's data sheet covers operation with a fixed crystal oscillator, although it's a bit sketchy.

**more Motorola parts**

In addition to the MC3362, Motorola has three more ICs which should be of interest to hams. One is the MC3363 narrowband fm receiver. This receiver is much like the MC3362 but has an extra NPN transistor and an op-amp. It's available only in a 28-pin surface mount package.

The MC2831A, a low-power fm transmitter, includes a microphone preamp, fm modulator, rf buffer good to 30 MHz, a tone oscillator, and a low battery detector.

The MC2833 fm transmitter is the same as the MC2831A, but has no tone oscillator or low battery detector. It does have two undedicated NPN transistors which can be used as rf amplifiers or doublers/triplers. (24 MHz multiplied by 6M1 puts it on 2 meters.) It might make a nice transceiver with the MC3362.

**obtaining parts**

Parts seem to be a problem these days. The people at Motorola were nice enough to provide me with the lists of parts suppliers.

You can obtain a printed circuit board for \$6 plus \$1 postage and handling. A kit of "hard to find" parts (marked with an \* on the parts list) is also available for \$23 plus \$2 postage and handling from: Q-Sat, PO Box 110, Boalsburg, Pennsylvania 16827. (Pennsylvania residents please add 6 percent sales tax.)

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## new edition listeners catalog

Universal Shortwave has released a new edition of their listeners catalog. Catalog 88-03 has a full line of portable and communications receivers, antennas, headphones, books, and accessories. As always, a large section of the catalog is devoted to radioteletype and facsimile equipment.

Universal's Amateur Radio division has just published its first ham radio catalog. Catalog 88-02 features a full spectrum of Amateur equipment, representing all major manufacturers.

Both catalogs are now available for \$1 each (refundable) or free with any purchase from: Universal Radio, 1280 Aida Drive, Reynoldsburg, Ohio 43068.

Circle #301 on Reader Service Card.

## Kantronics Watchdog and Morse Tutor

Kantronics announces the Watchdog circuit that can be installed inside the KPC-1, KPC-2, and the KPC-400. The circuit monitors the push-to-talk line of the TNC. If the P.T.T. has been active for two minutes, the Watchdog will activate and the attached radio will un-key preventing a local area network from being disabled due to a "hung-up" TNC. After the circuit has been activated, a power on/off will restore the KPC to normal operation.

The Watchdog circuit retails for \$10, plus \$2.50 for shipping in the U.S. and Canada. International shipping is \$7.50.

The new Kantronics Morse Tutor for IBM compatible computers provides practice, quiz, and general information functions. It has alternate learning sequences and variable character speeds to sound like hand-sent code. No memorization of commands is required to operate.

The Morse Tutor is priced at \$19.95, plus \$2.50 for shipping in the U.S. and Canada. International shipping is \$7.50.

For more information contact Kantronics, Inc., 1202 East 23rd Street, Lawrence, Kansas 66046.

Circle #302 on Reader Service Card.

## satellite tracking, propagation software

Randy Stegemeyer, W7HR, has developed a new satellite tracking software package for Macintosh computers with at least 512K RAM and an 800K drive. MacTrak offers tabular data output for tracking and scheduling, and "windows" to selected locations. Graphics capabilities include world map, polar, and great circle

displays. A view mode presents the earth as seen at any time from the satellite. The real-time mode displays data as it changes and, when used with the KLM/Mirage Tracking Interface, follows satellites as they pass within range. The program also tracks the sun and moon and would be useful for EME applications.

A propagation prediction package is included which provides an estimate of Maximum Usable Frequency (MUF) to any point, calculates sunrise and sunset times, bearings and distances, and displays the "gray line".

The program is priced at \$49.95. For complete details contact the author at PO Box 1590, Port Orchard, Washington 98366.

## new version 4.4 software for CS64S

Engineering Consulting has introduced new 4.4 software for the Super Comshack 64 Model CS64S for the ham shack or hilltop repeaters.

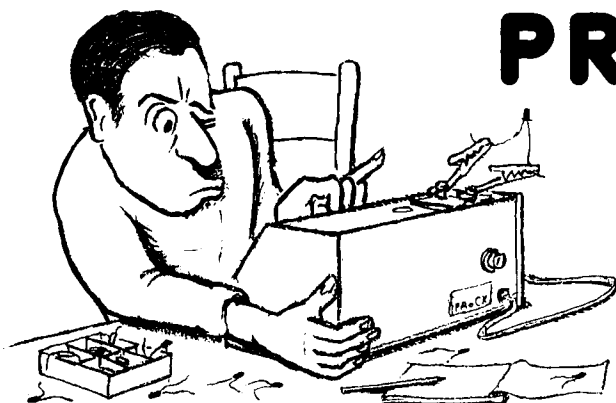
Each user may be assigned a unique access code which the Super Comshack 64 recognizes. The control operator can then allocate access privileges on various levels of system control. The Super Comshack system "speaks" the call-sign of each station requesting access to a function such as autopatch, remotes, or system commands.

The new version 4.4 software supports up to 300 users and up to 1,020 18-digit telephone numbers which can be assigned to individuals in banks. New users may be added to the system at any time. The system can be reprogrammed remotely to switch over to nine sets of parameter files, each containing unlimited system variables. A complete printout of user assignments and all parameters can be made at any time.

The control operator can adjust the speed and pitch of the voice synthesizer. The new software has the capability to pronounce all words in the English language. Verbal messages can be entered from the parameter files or from touchtones; emergency messages can be created from touchtone strings which represent letters.

The version 4.4 software can be used with any REV 4 CS64S board. It is available from Engineering Consulting, 583 Candlewood Street, Brea, California 92621 for \$59.95, which includes the manual and 90-day free revision upgrades.

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# PRACTICALLY SPEAKING

Joe Carr, K4IPV

## non-ideal linear IC amplifiers typical problems and how to solve them

**Operational amplifiers** and other linear IC devices are widely used in communications equipment; this includes Amateur equipment. Unfortunately, the textbook circuits are based on ideal devices — amplifiers that are perfect in every way. That little ploy makes the equations work, but is somewhat naive for the real world. When you go to the electronics parts store (or mail-order catalog), the kind of op-amps you'll find fall short of the ideal type in the textbooks. Here's a dose of reality — and the medicine needed to correct the problems that these amplifiers exhibit.

We'll consider two major problems. The first is dc offsets on the output resulting from any of several defects, the different forms of offset, and several means for eliminating them. Second, we'll discuss the problem of frequency response. This problem is twofold, involving gain bandwidth product (which affects the maximum frequency response of the circuit) and excess frequency response. The latter can lead to oscillation and ringing in the output circuit.

### dc offset problems

A dc output offset is a dc voltage

that appears on the output terminal, but not in response to any input signal. It's an output voltage that exists when it shouldn't (i.e., when  $V_{in} = 0$ ). There are several sources of output offset voltage in real-world op-amps.

**Input Offset Current.** One cause of the output offset voltage is input offset currents. **Figure 1** shows the typical input stage used in bipolar op-

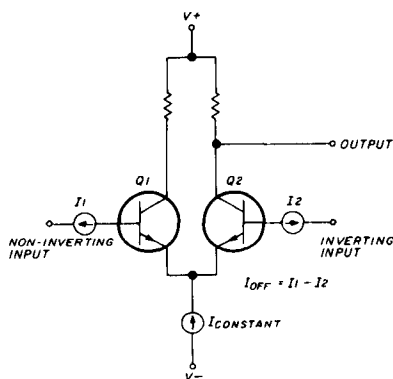


fig. 1. Differential amplifier input stage.

amps. Transistors Q1 and Q2 form an NPN differential pair. The inputs of ideal op-amps neither sink nor source current, but real op-amp inputs are transistors — and transistors need to be biased. If this were an ideal world the two currents would be equal and cancel out. But real op-amps use transistors that are mismatched ever so slightly. The differential input bias current forms an input offset current:

$$I_{off} = I_1 - I_2 \quad (1)$$

The offset current ( $I_{off}$ ) can produce an output voltage offset equal to the product of the current and the gain of the op-amp. While a low-gain op-amp circuit may not exhibit a large output offset from the input offset current, high-gain circuits almost invariably suffer such problems.

The severity of the problem depends in part upon the design of the op-amp. While certain old-fashioned types (like the 741) have rather significant offset currents, certain new types have the current reduced to a point where it is all but negligible. Especially low-input bias currents are found in op-amps that use either MOSFET or JFET transistors for input transistors Q1 and Q2 (fig. 1). These devices are called BiMOS and BiFET op-amps, respectively.

One problem with input offset currents occurs when a feedback network is used to set the gain of the op-amp (including both inverting and noninverting followers). The current flows in both input resistor (R1) and feedback resistor (R2), and produces an input offset voltage equal to the product of the current and the parallel combination of R1 and R2. By Ohm's law, this voltage is equal to:

$$V = \frac{(I_{BI} \cdot R1 \cdot R2)}{(R1 + R2)} \quad (2)$$

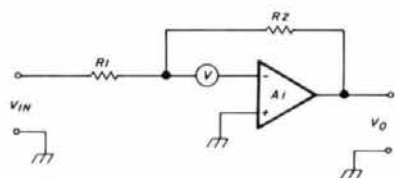


fig. 2. Input offset voltage.

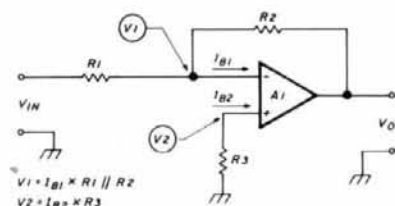


fig. 3. Use of compensation resistor.

A method to cancel this voltage in practical circuits by using a compensation resistor in series with the other (noninverting) input follows.

**Input Offset Voltage.** The ideal op-amp has no voltage sources in series with either input, except those external sources that supply signal. Real op-amps, however, have an internal voltage source in series with one or both inputs. The input offset voltage **fig. 2** is defined as the voltage required to force the output voltage to zero when the input signal voltages are zero. There are usually independent voltages in series with each input, but unless they are exactly equal (in which case they cancel each other), we can model the input offset voltage as a single voltage source in series with one of the two differential inputs. The output voltage offset produced by the input offset voltage is given by:

$$V_{out} = \frac{(V)(R1 + R2)}{R1} \quad (3)$$

Where:

- $V_{out}$  is the output offset voltage at  $V_o$  in **fig. 2**
- $V$  is the input offset voltage
- $R1$  is the input resistance
- $R2$  is the feedback resistance

### corrections for dc offset problems

Both input offset current and input offset voltage produce an output off-

set voltage that can adversely affect amplifier operation. There are several ways to eliminate the output offset voltage.

**Figure 3** shows an inverting follower circuit that uses a compensation resistor ( $R3$ ) to eliminate the output offset voltage caused by the input offset current. The input bias current flowing from the inverting input ( $IB1$ ) will create a voltage drop ( $V1$ ) across  $R1$  and  $R2$ . This voltage was defined in **eqn. 2**. Voltage  $V1$  is seen by the op-amp as a valid dc signal voltage. If the value of  $R3$  is equal to the parallel combination of  $R1$  and  $R2$ , then the voltage drop across it ( $V2$ ) will be the same as the voltage applied to the inverting input. In other words,  $V1 = V2$ . This situation occurs because the two bias currents are almost equal in the majority of op-amps. The value of  $R3$  is the parallel combination of  $R1$  and  $R2$ , or:

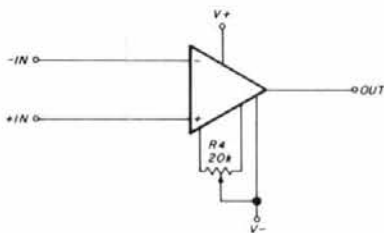
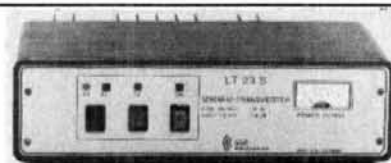


fig. 4. Use of offset null terminals on some op-amps.

$$R3 = \frac{R1 \cdot R2}{R1 + R2} \quad (4)$$

**Figure 4** shows the use of built-in offset null terminals found on some op-amps (typically pins 1 and 5, or 1 and 8). This circuit can eliminate output offset voltages from any source. The offset null potentiometer is connected between the offset null terminals, while the potentiometer wiper is connected to the negative dc power supply ( $V-$ ). This method is preferable where the offset voltage is within the normal range of the offset null terminals.

The variant circuit in **fig. 5** is used on the LM-101, LM-201 and LM-301 op-amps. In this circuit the potentiom-



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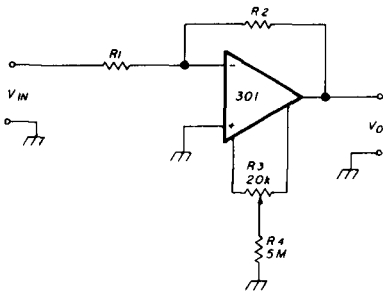


fig. 5. LM-101/LM-301 offset null terminals.

eter is connected across the offset null terminals as before, but the potentiometer wiper is connected to ground through a 5-megohm resistance (R4).

You should select a ten to twenty-turn trimmer potentiometer for any of these offset null circuits. This type of part allows maximum adjustability. The usual offset potentiometer is screwdriver operated, but if you use a shaft operated type you can use the same control as a position control for oscilloscopes, strip chart recorders, and other purposes where an offset is intentionally selected.

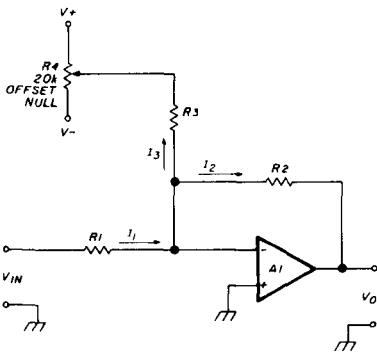


fig. 6. "Universal" offset null circuit.

Figures 6 through 9 show offset null circuits that can be used with any op-amp whether or not it possesses offset null terminals. The method shown in fig. 6 is, perhaps, the most commonly seen. In this case, cancel the output offset voltage by inserting a counter current (I3) into the summing junction. When V1 is the voltage at the wiper of the offset null potentiometer the output voltage, due to the adjustment of R4, is:

$$V_o = V_1 \cdot \frac{-R_2}{R_3} \quad (5)$$

The idea is to adjust potentiometer R4 to obtain an output voltage that exactly cancels the output offset. For example, if the output offset potential is +1.5 volts, select a value of V1 that makes eqn. 5 equal to -1.5 volts. In many cases, this involves making R3 = R2, so the voltage at the wiper of potentiometer R4 (i.e., V1) should be equal to the output offset voltage that it cancels.

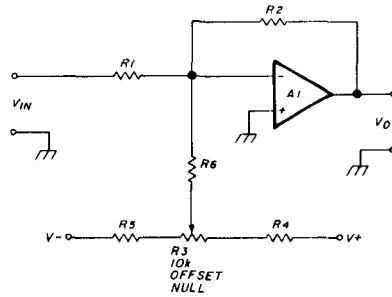


fig. 7. High resolution offset null circuit.

Figures 7 and 8 are variations on the same theme that permit better resolution adjustments of the offset voltage. These circuits are often used in high-gain amplifier circuits with small signals. Those applications typically have very low level signal inputs. The version in fig. 7 places two resistors in series with the arms of the potentiometer (R4 and R5). The value of R3 is usually smaller than the combined values of R4 and R5, and also R4 = R5. The fig. 8 version uses a pair of

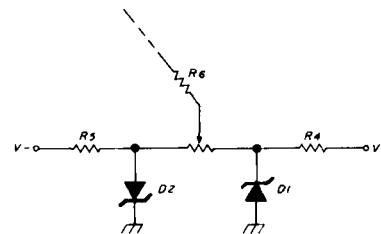


fig. 8. Alternate high resolution offset null circuit.

zener diodes to place the ends of the potentiometer at lower potentials than the V- and V+ voltages that operate the amplifier. In most cases the zener potentials of D1 and D2 are equal, giv-

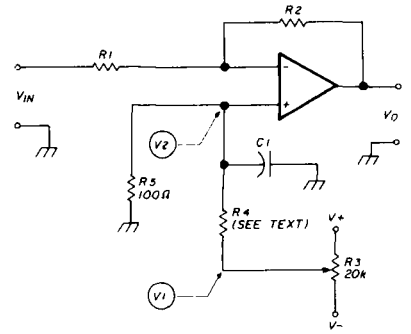


fig. 9. "Zero null" circuit.

ing a symmetrical range of offset voltages that can be canceled. There is no reason why different values can't be used if that is the situation of the specific circuit.

Figure 9 shows a final offset null circuit. In this case, apply the counter-voltage to the noninverting input rather than the inverting input. A small value resistor (R5) is connected between the noninverting input and ground. A resistor from the potentiometer wiper (R4) acts with R5 to form a resistor voltage divider. The voltage applied to the noninverting input (V2) is:

$$V_2 = \frac{V_1 \cdot R_5}{R_4 + R_5} \quad (6)$$

or, given the value of R5:

$$V_2 = \frac{100 \cdot V_1}{R_4 + 100} \quad (7)$$

The output voltage produced by V2 acting on the op-amp's noninverting input is:

$$V_o = V_2 \frac{R_2}{R_1} + 1 \quad (8)$$

Because of the gain of the circuit, make V2 a very small value. Use the equations above to select the values for V1 and R4 required to cancel out the offset voltage.

The capacitor used between the inverting input and ground is optional in most cases. C1 sets the noninverting input at ground potential for ac signals, while keeping it at a non-zero value of V2 for dc. The value of C1 is such that it has a capacitive reactance of 10 ohms at the lowest frequency of oper-



ation. This capacitor can be used only in relatively low gain circuits because capacitors to ground from inputs increase the noise output from the circuit. In low-gain circuits, however, the benefits may outweigh the noise problems.

## frequency compensation problems

Ideal amplifiers of any type have an infinite bandwidth, so they will amplify all signals accurately and cleanly. Real amplifiers have frequency response limitations; for op-amps these limitations can be quite severe. There are two problems to consider with regard to frequency response: the bandwidth and stability of the system. The frequency response problem requires us to understand the gain bandwidth product of the amplifier.

The gain bandwidth product (GBP) is the product of the voltage gain and the maximum bandwidth of the device. GBP is specified as the frequency in MHz or kHz at which the

tion amplifiers are examples where gain and wide bandwidth frequency response go hand in hand. These examples also illustrate the problems of GBP most distinctly. Suppose you need a voltage gain of 40 dB (a gain of 100) and a frequency response of 10 kHz (10,000 Hz). The gain bandwidth product required of the op-amp is:

$$\text{GBP} = A_v \times F \quad (9)$$

$$\text{GBP} = (100) (10,000 \text{ Hz}) \quad (10)$$

$$\text{GBP} = 1,000,000 \text{ Hz} = 1 \text{ MHz} \quad (11)$$

Stability is always an issue whenever op-amps are used. Almost invariably, when breadboarding a new circuit with wideband op-amps, the first attempt will result in an unwanted oscillation. One solution is to use a frequency compensated op-amp like the 741 (if the application permits). These devices are unconditionally stable — a condition that occurs at the expense of gain bandwidth product. Such an op-amp will work as an ac amplifier only to frequencies of a few kHz.

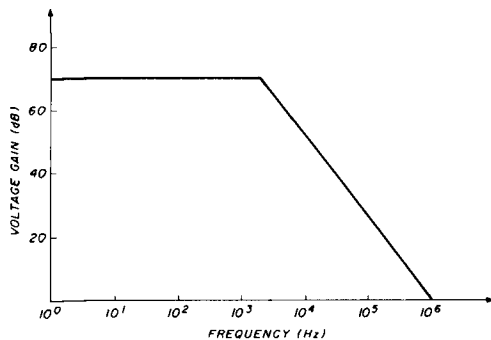


fig. 10. Gain-Bandwidth plot for a typical op-amp.

gain of the op-amp drops to unity (i.e., 1). **Figure 10** plots the voltage gain against the frequency response of an amplifier. The gain remains relatively constant over a certain frequency range, but begins to fall above a certain point. At some frequency (1,000,000 Hz in this case), the gain drops to unity.

You'll run into GBP when you try to obtain high gain and wide frequency response in the same amplifier. A cassette tape preamplifier, a microphone preamplifier, and certain instrumenta-

These difficulties can be created from any of several problems. Layout, for example, can create oscillation. If the stray capacitances and inductances create a resonant situation at a frequency lower than the unity gain frequency, then the circuit will oscillate. Similarly, if the dc power supply is not properly decoupled, problems can occur. This latter problem occurs especially in multistage circuits where one stage can affect the other. Be careful of disc ceramic capacitors — some of those components have very

significant stray inductances and can form resonant circuits that do not bypass very well at one frequency. If that resonant frequency is below the GBP frequency, oscillation may occur.

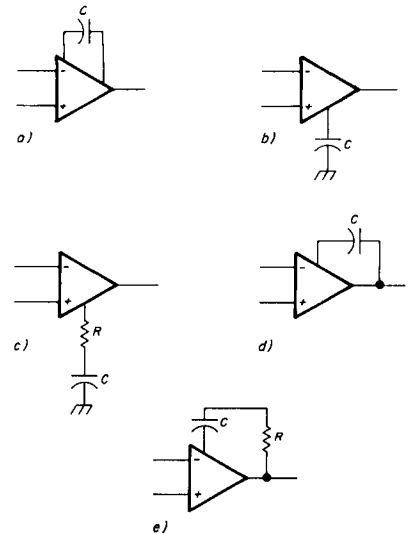


fig. 11. Frequency compensation capacitor circuits.

Grounding problems in the circuit can also create obstacles. One cause of oscillations here is an impedance in the ground circuit common to both input and output circuits. Because output signal flowing in that impedance is also in series with the input circuit, feedback automatically exists.

If any combination of feedback and phase shift occurs between output and input, at a frequency that is less than the unity gain GBP frequency, oscillation can occur. Several ploys are used to reduce the gain at frequencies less than GBP to prevent oscillation. Some of these methods are shown in **fig. 11**. Note the use of a capacitor (**fig. 11A**) across the frequency compensation terminals found on some op-amps. The manufacturer typically specifies a capacitance in the data sheet for the device. Values in the 30-to-100 pF range are common. Standard practice is to make this capacitance the value for the noninverting unity gain follower configuration. For all other configurations with gain, the value of the capacitance required is the noninverting unity gain value multiplied by the feedback factor, B:

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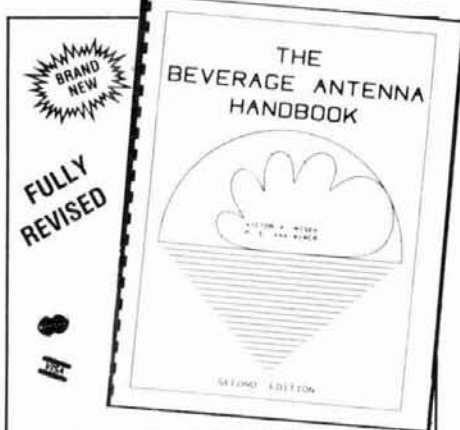
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$$C_{req} = C \times B \quad (12)$$

Where:

$C_{req}$  is the required capacitance

C is the specified capacitance for noninverting unity gain

B is the feedback factor

Factor B is merely the transfer function of the feedback network. In the usual circuit with a resistor feedback network, the value of B is:

$$B = \frac{R1}{R1 + R2} \quad (13)$$

Where:

B is the feedback factor

R1 is the input resistor

R2 is the feedback resistor

For example, let's suppose that an inverting amplifier with a gain of 10 has a rated compensation capacitance of 30 pF for the unity gain configuration. Assume the feedback resistor (R2) is 100k, and the input resistor (R1) is 10k. The value of B is:

$$B = \frac{10k}{10k + 100k} \quad (14)$$

$$B = 10/110 = 0.091$$

The value of the capacitance required to stabilize this amplifier is:

$$C_{req} = C \times B \quad (15)$$

$$C_{req} = (30 \text{ pF}) (0.091) \quad (16)$$

$$C_{req} = 2.7 \text{ pF} \quad (17)$$

Figures 11B through 11E show variations. The values of the components are taken from charts or graphs in the specifications sheet for the particular op-amp being used.

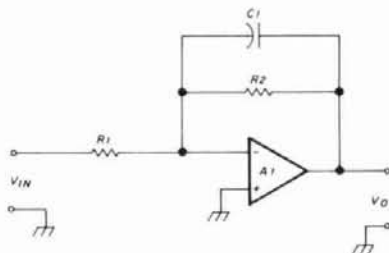


fig. 12. Feedback capacitor controls frequency response.

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**Input Capacitance Compensation.** Figure 12 shows the method for compensating for stray input capacitance. The circuit shown here is an inverting follower with a capacitance shunting the feedback resistor. From dc to a given frequency, F1, the gain of the amplifier is given by the equation:

$$A_v = -R_2/R_1 \quad (18)$$

At frequency F1, the gain begins to drop off at a rate of -6 dB per octave. The breakpoint frequency (F1) at which this happens is:

$$F1 = \frac{1,000,000}{2 \pi R_2 \cdot C1} \quad (19)$$

Where:

F1 is the frequency in Hz

R2 is in ohms

C1 is in microfarads

The input resistance and the input capacitance (which consists mostly of stray capacitances) form a phase shift at certain frequencies defined by  $1/2\pi R1C$ , where C is the stray input capacitance. If that frequency is below the unity gain frequency, then it is possible for the phase shift that occurs at this frequency to add to the op-amp's ordinary phase shift (180 degrees  $\pm$  error for inverting followers) to form a 360-degree phase shift, which is the criterion for oscillation. To compensate for this stray capacitance, select a value of C1 (fig. 12) that has a capacitive reactance of approximately one-tenth the resistance of R2.

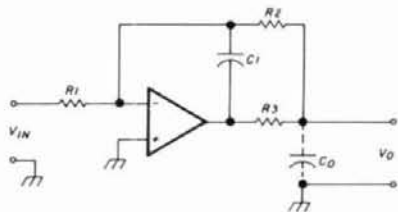


fig. 13. Alternate feedback capacitor circuit.

Figure 13 shows the method for compensating for high output load capacitances. This situation occurs, for example, when the op-amp drives a coaxial cable or twisted pair transmission line. Capacitor C1 is selected to have a capacitive reactance of one-tenth R2, while R3 is selected to have a value of several hundred ohms.

### conclusion

The linear IC, especially the operational amplifier, is a powerful tool for communications circuit designers. Although the practical IC device doesn't measure up to the textbook version, it is useful because its problems are easily solved.

### for further reading

Joseph J. Carr, *IC User's Casebook*, Howard W. Sams & Company, Inc., No. 22488, \$12.95.

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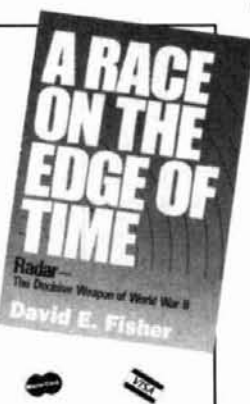
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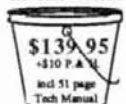


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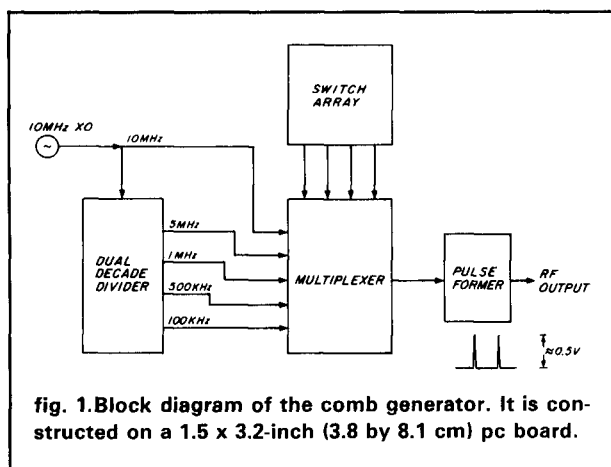
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# a simple low-cost comb generator frequency calibrator

Produces pulses  
for test equipment  
calibration



Here's the construction and theory behind a simple digital comb generator\* that produces accurate (crystal-controlled) pulses and can be used to calibrate a wide variety of test equipment. One possible application is the calibration of a spectrum analyzer (like the "Low-cost Spectrum Analyzer with Kilobuck Features," *ham radio*, September 1986, pages 82-90). It can also be used to align receivers, and to provide a stable comparison for calibrating various kinds of signal sources. A bandpass filter can be used to select any *tooth* of the comb to provide a single, pure signal.

A block diagram is shown in fig. 1. The heart of the generator is a crystal-controlled 10-MHz clock oscillator. Although a clock with moderate accuracy ( $\pm 0.05$  percent) is used in this model, more accurate

\*It is called a comb generator because when its output is viewed in the frequency domain, as with a spectrum analyzer, the pattern resembles a comb.

oscillators are available in the same package style if you want higher stabilities. The oscillator's output is then divided down in frequency by a digital divider to a minimum frequency of 100 kHz. A multiplexer is used to select one of the signals from the divider chain or the 10-MHz signal. The multiplexer output drives the clock input of a high-speed CMOS D-type flip-flop, connected so that when a clock pulse is applied it tries to reset itself. This causes a narrow pulse about 6 nanoseconds wide to appear at its output. The repetition rate of this pulse train is the same as the applied input signal to the flip-flop, and when viewed in the frequency domain appears as a series of teeth separated in frequency by the repetition rate of the pulses. The schematic for the comb generator is shown in fig. 2; a parts list is provided.

The crystal oscillator, U3, can be purchased as a component in a DIP style package with a wide variety of specifications in terms of output levels and frequency accuracy. You'll need a part with either a CMOS or TTL compatible output for this application. The accuracy of the oscillator used in this comb generator is specified as  $\pm 0.05$  percent (about  $\pm 72$  kHz at 2 meters). Oscillator output is applied to both a frequency divider, U1, and one input of an eight-input multiplexer, U2. The frequency divider is a 74LS390 dual decade counter. It is hooked up so that its outputs furnish pulse repetition rates of 5, 1, 0.5, and 0.1 MHz simultaneously. All these outputs are then connected to the multiplexer inputs.

A quad DIP switch is used to select one of the five signals which appear at the output of the multiplexer, U2 (a 74LS151). DIP switch coding for the various output frequencies is shown in table 1. The multiplexer output is connected to the clock input of a high-speed CMOS D-type 74AC74 flip-flop, U4. The D input of the flip-flop is always wired high, so the flip-flop will set when the rising edge of a clock pulse occurs. The Q complement is wired to the flip-flop's reset pin; as

By Larry Martin, PO Box 997, Sebastopol, California 95472

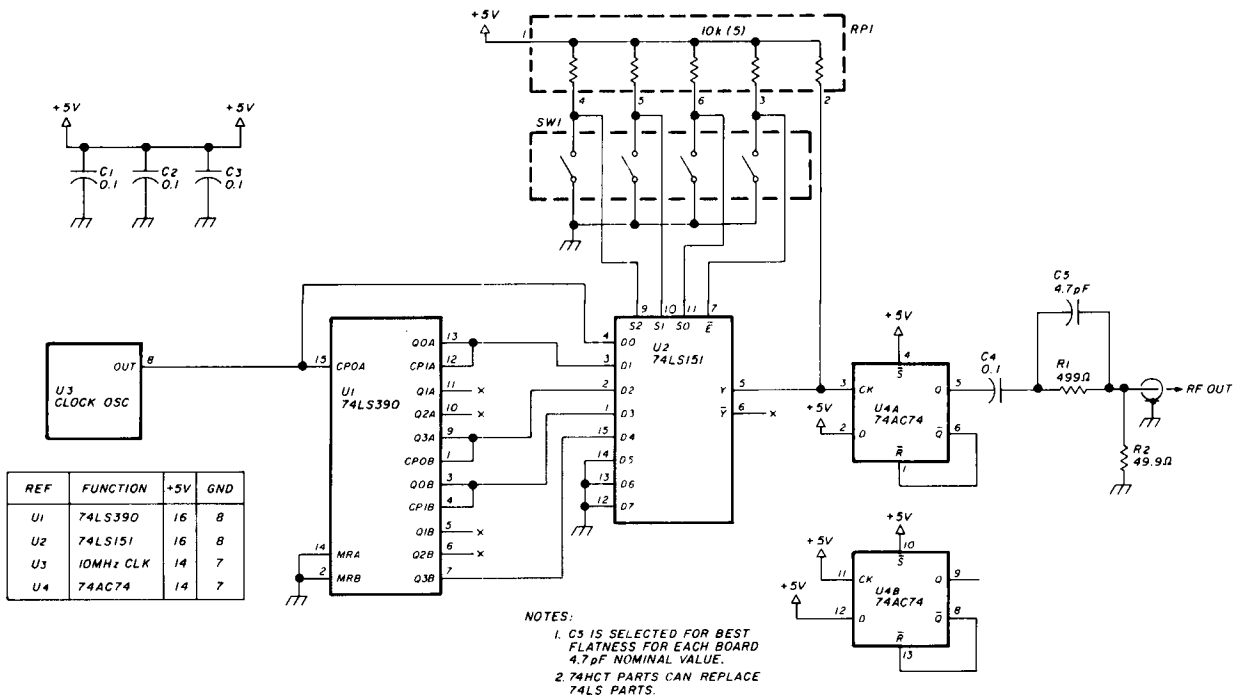


fig. 2. Detailed schematic of the comb generator. It uses four integrated circuits and a few other passive components.

Table 1. Output Frequency Coding

DIP Switch Code	Output Pulse Repetition Rate
0000	Output is disabled
0001	Output is disabled
0010	Output is disabled
0011	Output is disabled
0100	Output is disabled
0101	Output is disabled
0110	Output is disabled
0111	Output is disabled
1000	Output is disabled
1001	Output is disabled
1010	Output is disabled
1011	100-kHz rate
1100	500-kHz rate
1101	1-MHz rate
1110	5-MHz rate
1111	10-MHz rate

soon as the flip-flop is set (its output rises to 1), the complement output goes low, and the flip-flop is forced to reset. Its output is a narrow pulse whose width is limited only by the time delays through the internal logic of the flip-flop and the wiring delays associated with the pc board. This pulse, shown in fig. 3, is typically 6 nanoseconds wide.

This pulse train, when viewed in the frequency domain, looks like a comb (see footnote) as shown in

Ref. Desig.	Part Description	Manf'r	Qty.
C1	0.1 uF 50 V CK05 Capacitor	AVX	4
C2	0.1 uF 50 V CK05 Capacitor	—	—
C3	0.1 uF 50 V CK05 Capacitor	—	—
C4	0.1 uF 50 V CK05 Capacitor	—	—
C5	4.7 pF nominal value, CK05 Capacitor (Set at test)	AVX	1
J1	BNC PC Mount Jack	AMP	1
R1	499 ohm 1% 0.1 W resistor	Corning	1
R2	49.9 ohm 1% 0.1 W resistor	Corning	1
RP1	6 pin 5 resistor 10K ohm SIP	Bourns	1
SW1	4 position DIP switch	Grayhill	1
U1	74LS390N Dual Decade Counter	TI	1
U2	74LS151N Multiplexer	TI	1
U3	10 MHz Clock Oscillator	Dale	1
U4	74AC74PC Dual D Flip-flop	Fairchild	1
X1	Printed Circuit Board	LMCA	1

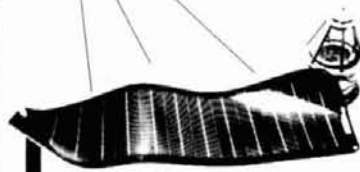
figs. 4 and 5 for a 10-MHz pulse repetition rate. Figure 4 shows the output of the comb generator with a 10-MHz repetition rate from 0 to 100 MHz, while fig. 5 shows the output spectrum of the same waveform from 0 to 1000 MHz. These figures show that the typical output is flat to within  $\pm 1$  dB from 0 to 100 MHz (careful adjustment of C5 can reduce the flatness to less than  $\pm 0.6$  dB) and that the comb generator is useful to above 1000 MHz.

The comb generator can be used as a very stable, pure tone generated by filtering one of the output teeth. The spectral purity of the 100-MHz tooth of the comb generator is seen in fig. 6, which shows the noise within a 1-kHz frequency span (with a 10-Hz resolution bandwidth). Note that the line-related sidebands are over 70 dB down.

Figures 7, 8, 9, and 10 show the output spectrum



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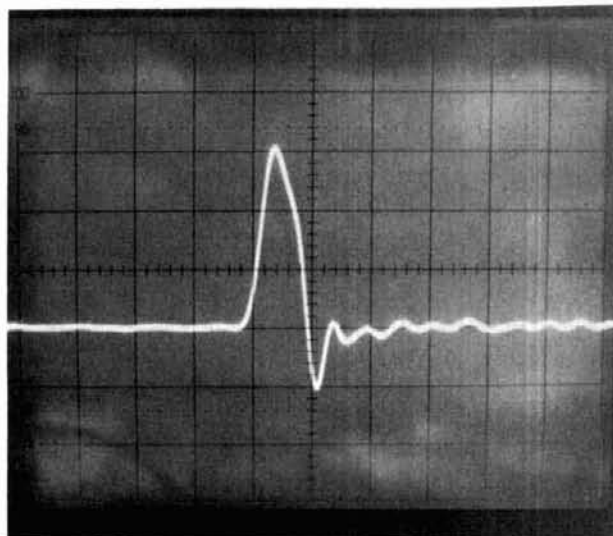


fig. 3. Output pulse of the comb generator. The horizontal scale is 10 nSec/div and the vertical scale is 0.2 V/div. The repetition rate of the pulses depends on the switch settings.

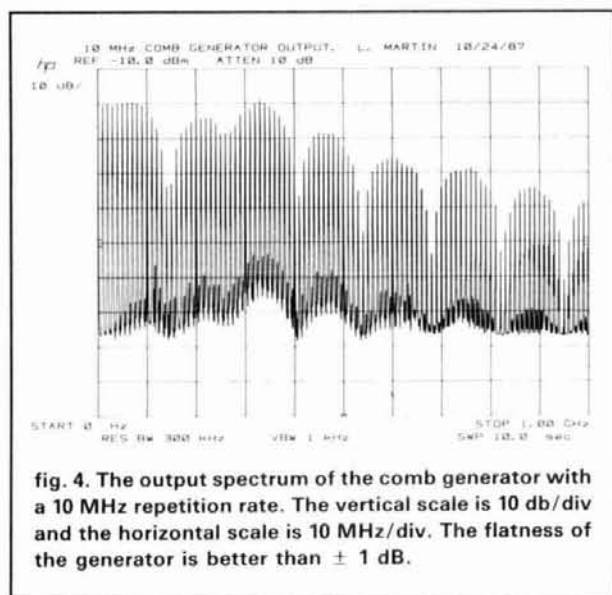


fig. 4. The output spectrum of the comb generator with a 10 MHz repetition rate. The vertical scale is 10 dB/div and the horizontal scale is 10 MHz/div. The flatness of the generator is better than  $\pm 1$  dB.

for a 5-MHz repetition rate, a 1-MHz repetition rate, a 500-kHz repetition rate, and a 100-kHz repetition rate, respectively. Note that the amplitude of each tooth is reduced by the ratio of the repetition rates. This is because the energy in each pulse is spread into many more comb teeth, reducing the amplitude of each tooth when the repetition rate is reduced. **Figure 11** shows the output of the 100-kHz repetition rate signal over the 20 to 30-MHz frequency range and gives an indication of the flatness of the comb generator in the hf frequency bands.

The comb generator is constructed on a double-sided pc board with plated through holes. All compo-

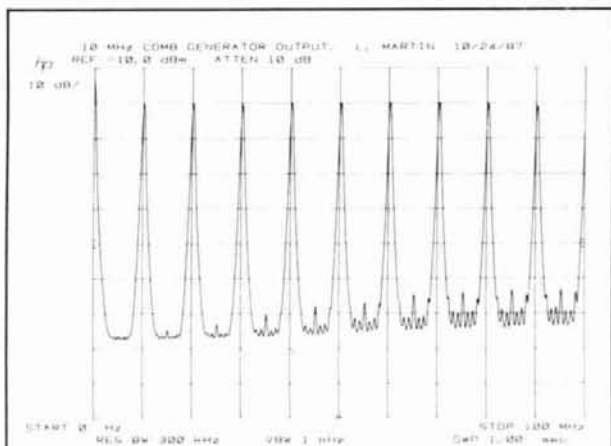


fig. 5. A broadband view of the comb generator output. The vertical scale is 10 dB/div and the horizontal scale is 100 MHz/div. This shows that the comb generator has useful outputs up into the low microwave range.

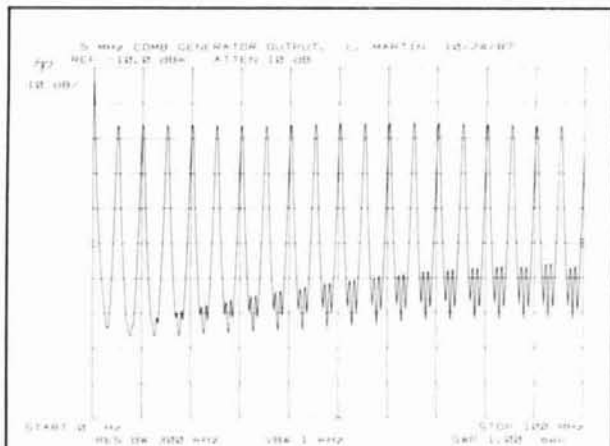


fig. 7. The output of the comb generator with a 5-MHz repetition rate. The horizontal scale is 10 MHz/div and the vertical scale is 10 dB/div.

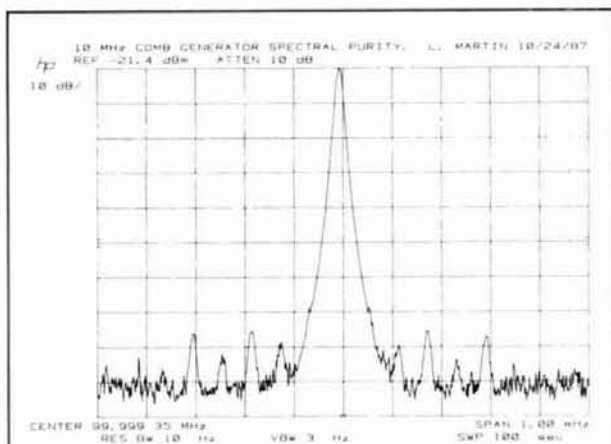


fig. 6. The close in spectral purity of the 100-MHz tooth of the comb generator when set to a 10 MHz-repetition rate. The horizontal scale is 100 Hz/div and the vertical is 10 dB/div. The spurious sidebands are multiples of 60 Hz.

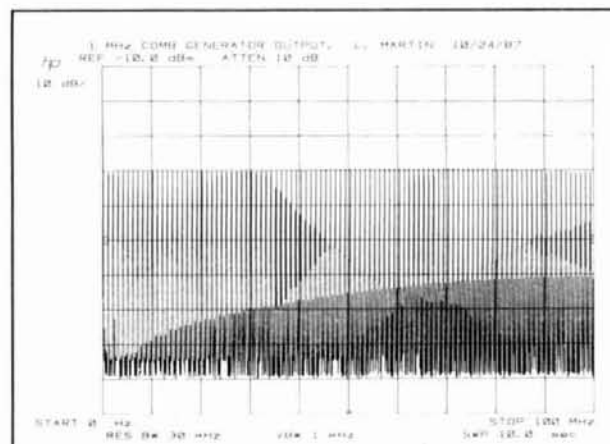


fig. 8. The output of the comb generator with a 1-MHz repetition rate. The horizontal scale is 10 MHz/div and the vertical is 10 dB/div. Note that the amplitudes of each of the teeth has decreased as their quantity has increased.

nents are soldered to the board without sockets to minimize component lead lengths and reduce any switching spikes which could upset the output pulse waveshape. The generator uses 65 mA from a +5 volt supply.

A major use of the comb generator is calibration of test equipment — for example, a typical spectrum analyzer. The tunable oscillator in most rf spectrum analyzers is a varactor-tuned oscillator. This oscillator has an inherently nonlinear tuning curve, so when an unknown signal is measured, the analyzer must be calibrated to determine its frequency. The comb generator allows this calibration to be done efficiently.

First connect the unknown signal to the spectrum

analyzer, set the analyzer to a wide frequency span (0 to 100 MHz), and note the position of the signal on the screen. Disconnect the signal and connect the comb generator to the spectrum analyzer. Set the comb repetition rate of the generator to 10 MHz, and count the number of comb teeth to the unknown signal to the nearest 10 MHz. Next, set the comb generator to 5 MHz and repeat the process; this sets the frequency of the unknown signal to 5 MHz. Then retune the analyzer so the unknown signal is on the screen and bracketed by two visible comb teeth (whose exact frequencies are known). Reconnect the unknown signal to the spectrum analyzer and note its new position. Repeat the above procedure, with

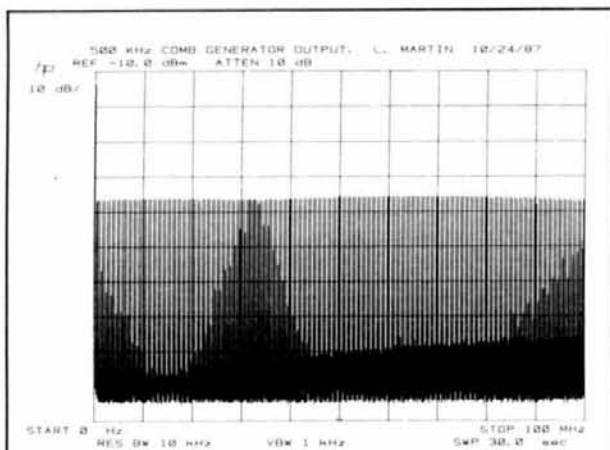


fig. 9. The output of the comb generator when set to a 500-kHz repetition rate. The vertical scale is 10 dB/div and the horizontal is 10 MHz/div.

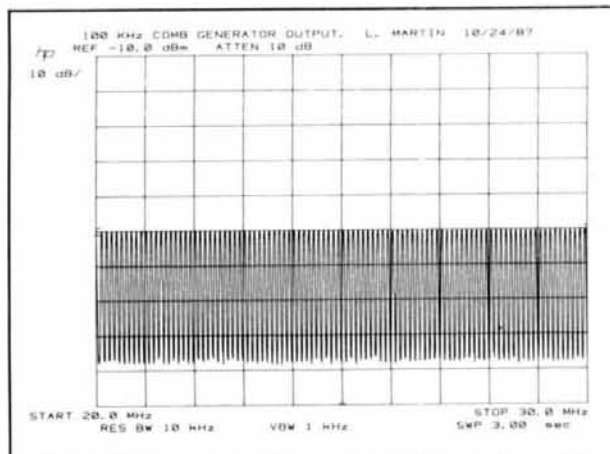


fig. 11. A closer look at the output of the comb generator with a 100-kHz repetition rate. The vertical scale is 10 dB/div and the horizontal scale is 1 MHz/div centered at 25 MHz.

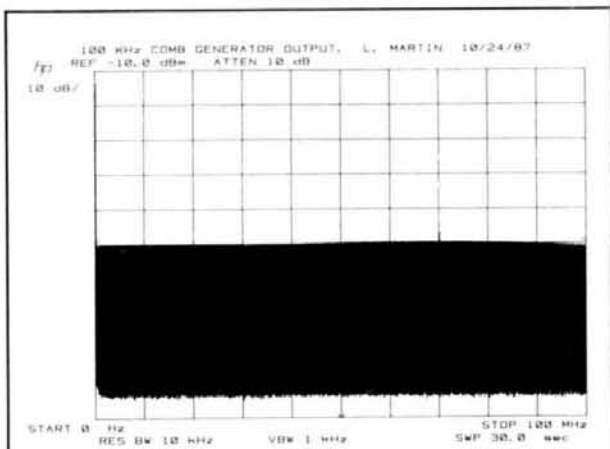


fig. 10. The output of the comb generator with a 100-kHz repetition rate. The vertical scale is 10 dB/div and the horizontal is 10 MHz/div.

smaller and smaller steps between the comb teeth, until the frequency of the unknown signal is estimated by interpolation between the nearest two 100-kHz comb teeth. You will be able to determine the frequency of the unknown signal to about 1 or 2 kHz resolution because most oscillators are relatively linear over very small tuning ranges. The absolute accuracy of the crystal oscillator sets the absolute accuracy to which the unknown frequency can be measured. The above accuracy specification means that a 100-MHz comb tooth will have an accuracy of 50 kHz — much poorer than the measurement capability of the newly calibrated spectrum analyzer.

Many low-cost receivers are not frequency synthesized. The comb generator can also be used to calibrate receiver dials in steps as fine as 100 kHz with an iterative procedure similar to that used for spectrum analyzer calibration.

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## summer thunderstorm noise

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The process works as follows. The sun heats the ground; as the heat from the ground rises, it warms the air above and causes it to rise. As this heated air meets the colder air above, its moisture condenses, forming clouds. The clouds — some of which may be seized by the winds and carried into the jet stream to form the characteristic anvil-shaped top of a thunderhead at 30 to 40,000 feet — continue to rise until their condensed moisture forms drops heavy enough to fall as rain. Some drops are taken further upward and freeze into hail. This fast up-and-down motion generates static electricity strong enough to cause the air to break down between a cloud and the earth or between one cloud and another. As the lightning stroke releases this energy it produces sound and electromagnetic pulses.

Our receivers pick up the hf radio frequency pulse we call "noise." Most air mass storms form on afternoons when the humidity is above 50 percent, and last into the night before cooling off enough to dissipate. Air mass thunderstorms linger for several days until rain releases their moisture or they slowly move on.

During the evening DXing hours, air mass thunderstorm QRN may limit the usefulness of low-band signals to local ragchewing, and for the most part, rule out weak-signal DX. The QRN, propagated from the equatorial land regions, or closer, increases the overall average noise level on the 80- and 160-meter bands. This is because the tropical areas get closer to those of us in the Northern Hemisphere in the summer as the sun comes up to 23°N. A hop or two is cut off from the propagation distance adding a few dB to the noise. Several areas which develop many air mass thunderstorms are even closer — Florida and the eastern side of the Rocky Mountains in Colorado and Nebraska, followed by the southeastern part of the United States are the top producers.

How can you communicate with DX stations on these bands? Directional antennas may help if the thunderstorm activity is in the opposite direction from the DX stations. If you can avoid pointing your beam at these areas, you can help minimize noise pickup. In fact, if you can get the back of the antenna pointed in that direction, you can use the front-to-back ratio (typi-

cally 15 dB) to further decrease noise pickup. This may mean working a DX country over the long path or over the Pole. If the ionosphere will support propagation in that direction and no geomagnetic field disturbance is occurring, you may find this the solution to some of the summer noise problems.

## last-minute forecast

Expect DX conditions for the higher frequency bands to be best during the middle of the month because of increased solar flux with its higher MUFs. Transequatorial one-long-hop skip is nil this month but sporadic E short skip and regular long skip should fill in well. The lower frequency signal strengths decrease during daylight hours when the flux is high, and because of noise this month, conditions really suffer. Nighttime signals will be best the first and last weeks of the month. Look for sunrise and sunset enhancement from sporadic E short skip to help signals get through the noise. Try those early morning operating hours.

## band-by-band summary

Six-meter sporadic E short-skip conditions on some days will last anywhere from 30 minutes to a couple of hours around local noon. Expect about 1000 miles per hop.

Ten, 12, and 15 meters will have quite a few short-skip E<sub>s</sub> openings and some long-skip openings during the 27-day solar flux peaks to southern areas of the world during daylight hours. Fifteen meters will be best for only an hour or two as the maximum usable frequency decreases during the late afternoon.

Twenty, 30, and 40 meters will be

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GMIT	PDT	Directional Indicators							
		N	NE	E	SE	S	SW	W	NW
0000	5:00	20	20	20	12	15	10	10	15
01:00	6:00	15	30	20	12	15	10	10	15
02:00	7:00	15	30	20	15	20	10	10	12
03:00	8:00	15	30	20	15	20	10	10	12
04:00	9:00	15	30	20	20	20	10	10	15
05:00	10:00	20	20	20	20	30	12	12	15
06:00	11:00	20	20	15	20	30	12	12	15
07:00	12:00	20	20	15	20	30	12	15	20
08:00	1:00	20	30	15	20	30	15	20	20
09:00	2:00	20	30	20	20	30	15	20	20
10:00	3:00	30	20	20	20	30	20	20	20
11:00	4:00	30	20	20	30	30	20	20	20
12:00	5:00	20	20	15	20	30	20	20	30
13:00	6:00	20	20	12	20	30	20	20	30
14:00	7:00	20	20	12	15	30	20	20	20
15:00	8:00	20	15	10	12	30	20	20	20
16:00	9:00	20	15	10	12	30	20	20	30
17:00	10:00	20	15	10	12	30	20	20	30
18:00	11:00	20	12	12*	10	20	15	30	20
19:00	12:00	30	15	12	10	20	12	20	20
20:00	1:00	30	15	15	10	15	12	12	20
21:00	2:00	20	20	15	10	15	12	12	20
22:00	3:00	20	20	20	10	15	10	10	20
23:00	4:00	20	20	20	10	15	10	10	15

### MID USA

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

### EASTERN USA

EDT	PDT	Directional Indicators							
		N	NE	E	SE	S	SW	W	NW
8:00	8:00	20	20	20	12	20	10	10	15
9:00	9:00	20	20	20	12	20	10	10	15
10:00	10:00	20	30	20	15	20	10	10	15
11:00	11:00	20	30	20	15	30	10	10	20
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5:00	5:00	20	20	20	30	30	20	20	20
6:00	6:00	20	20	15	20	30	20	30	20
7:00	7:00	20	20	15	20	30	20	20	20
8:00	8:00	20	20	12	15	30	20	20	20
9:00	9:00	20*	20	12	12	30	20	20	20
10:00	10:00	15	15	10	12	30	20	20	20
11:00	11:00	20*	15	10	12	30	20	30	20
12:00	12:00	20	15	10	12	30	20	30	30
1:00	1:00	20	15	10	10	20	15	30	20
2:00	2:00	20	15	12	10	20	15	30	20
3:00	3:00	20	20	12	10	20	12	15	20
4:00	4:00	30	20	15	10	20	12	12	20
5:00	5:00	30	20	15	10	20	12	10	20
6:00	6:00	20	20	20	10	20	10	10	15
7:00	7:00	20	20	20	10	20	10	10	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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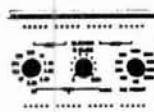
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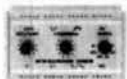
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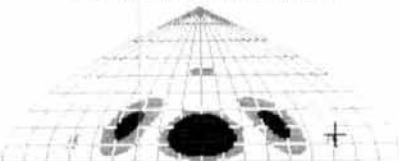
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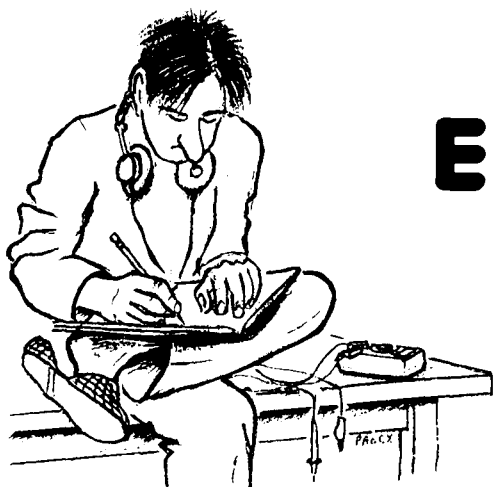
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# ELMER'S NOTEBOOK

Tom McMullen, W1SL

## ten-meter skyware

The next upswing in the sunspot cycle is beginning, and the DX I've been hearing on the band lately indicates some interesting years ahead. It's time to get some equipment together, practice some operating techniques, learn to predict conditions, and use the band to garner a wall full of cards and awards.

Ten is a fun band. When it's open, big power and huge antennas don't count as much as operating technique and "being at the right place at the right time!" A few watts can pin an S-meter on the other side of the world, and there can be so many signals that you don't know which one to go after. At times you'll need a high frustration threshold; you'll hear plenty of loud signals that you can't work, but someone who is only an S7 or S8 will give you a "rock solid" QSO.

When the band decides to quit, the biggest beam and the highest power won't lengthen the QSO more than a few moments. That's what makes it so interesting for Novice operators. A 200-watt station and a modest antenna will often have a big signal; a few minutes spent analyzing the locations you're hearing and the paths that signals are using will tip you off as to what's going on.

## antenna choices

As in many other parts of the spectrum, you have several antenna choices for 10 meters: verticals, dipoles, wire arrays, and beams. A vertical antenna, like a 1/4-wave groundplane, is a great all-around antenna for 10, and when conditions are good, makes a good showing. It's also useful for local ragchews when the band is not open; its nondirectional pattern lets you hear everyone within range without adjustment. When the band is open, a 1/4 or 1/2-wave antenna's lack of gain won't be any great hindrance, but your range will be limited for local work.

A dipole performs in much the same way; it does well on an open band, but shows a pronounced directional pattern. If you can rotate the dipole, you can use the directional characteristic to decrease the strength of unwanted signals and still pick up the wanted DX. For local work, rotate a dipole to favor stations you want. Again, lack of gain will limit the range on local contacts.

Wire arrays are not common on higher bands like 10 meters. Because this is a cross-over region, it is just as easy to make a rotary beam antenna like a Yagi as to rig supports for multi-element wire arrays. A relatively small

lot can support a respectable amount of gain from arrays of phased dipoles, loops, etc., but you'll be gambling that the band will open in the direction that the array favors with its radiation pattern.

Ten-meter enthusiasts often choose Yagi antennas; it is surprisingly easy to put together a few pieces of tubing on an inexpensive rotator and push-up mast. Even a modest tripod on a roof will support a small beam. Let's look at a few basics of Yagi antennas and a couple of easy-to-construct examples.

The Yagi antenna was named for its developers — a couple of Japanese scholars named Yagi and Uda. It used to be called a "Yagi-Uda" array, but most people simply call it a "Yagi."

The Yagi array works on the principle that a piece of metal in the strong field of a nearby radiator will re-radiate a considerable amount of the energy it intercepts, and that this energy will differ in phase from that given off by the main radiating element. **Figure 1** shows this action in a two-element array. The main radiating element is the one that is fed energy from the transmitter and feedline. It is referred to as the driven element (DE). The second element intercepts the field radiated by the driven element. If the second ele-

ment is somewhat longer than the driven element, it is called a "reflector" (more on this later); if it is slightly shorter, it is called a "director." A simple two-element beam can be made with a driven element and *either* a reflector or a director; the difference in performance between the two types is minor. For slightly better performance, you can build a three-element Yagi using *both* a reflector and director.

In designing directional antennas of any type, the key to performance is the proper phasing of waves that interact

ing a weak-signal area ("null") off the back of the beam.

Some of the field is radiated up (where it's of no use) and some goes back toward the driven element. After this field passes the driven element it begins to do some good. If the reflector is spaced just right and is just the right length, the field it radiates forward will be "in phase" with the one from the driven element reinforcing it and providing gain in that direction. The name "reflector" comes from the element's apparent mirror reflection of the energy.

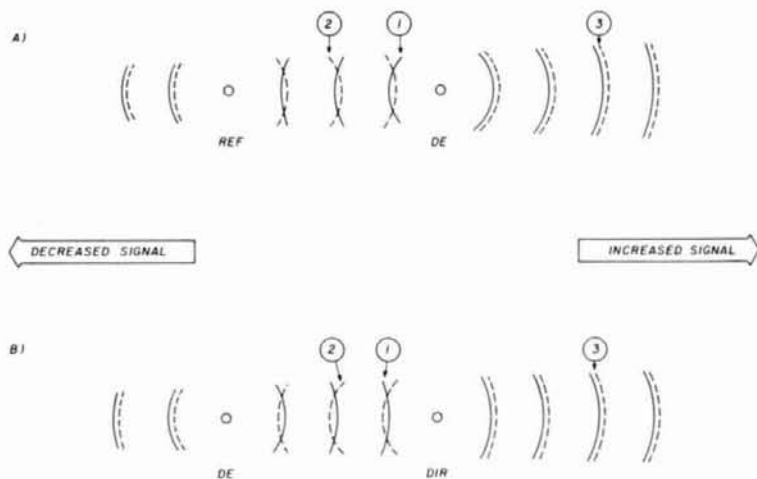


fig. 1. Yagi antennas work by radiated fields canceling or reinforcing each other. In A, the field (1) from the driven element (DE) is canceled to the rear by the field (2) from the reflector. The fields combine to provide a stronger signal (3) toward the front. The same action takes place in (B) where a director is used. The field from the director (2) cancels the driven-element's field (1) to the rear, and combines for a stronger field to the front (3).

with each other. Two sine waves exactly in phase will reinforce each other for a net gain; two that are exactly out of phase (180 degrees out) will cancel each other. The secret of directional antenna construction is to vary the spacing between elements and their length to get the correct phase for the desired result.

In fig. 1A, the second element (a reflector) has had energy induced in it by the field from the driven element and re-radiates that energy as a field of its own (the dotted pattern). Some of this field continues to the back of the array, where it partially cancels the field from the driven element, produc-

A director re-radiates the energy in a way that reinforces the field from the driven element after that field has passed the director (see fig. 1B). This achieves the desired result of providing gain at the "front" of the beam, but doesn't produce as deep a null at the back. The director element is slightly shorter than the driven element. This length, along with the spacing from the driven element, provides the correct phasing so that the waveforms reinforce rather than cancel each other.

### what's critical

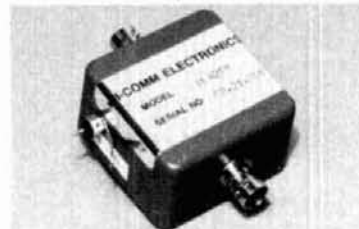
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director, and their spacing from the driven element are crucial to a Yagi's performance. The lengths are most critical. If they are too short or too long, they won't work, or will produce a beam pattern that has more holes than gain. The spacing between elements is not as critical as is their length — a reflector can be moved several inches (or a considerable fraction of a wavelength) before performance begins to fall off. However, the spacing between elements does have a great effect on the impedance of the driven element. It's possible to vary the spacing and element length to obtain a very deep null at the back of the antenna, but these are not the same dimensions that produce the maximum gain at the front. Most designs are a compromise that favors maximum gain, acceptable front-to-back ratio, and a driven element impedance that you can live with.

**Table 1** shows dimensions you can use to put together two- or three-element beams and the approximate gain you can expect. The spacing between elements is not too critical; it can vary a couple of inches either way to take advantage of boom length. The element lengths shown should work very well, but are probably not optimum because the diameter-to-length ratio of the tubing used has some effect on the resonant frequency. If the antenna has a persistent high VSWR at your operating frequency, try changing the driven element length an inch or so. A wide range of impedance matching can be handled by the gamma match described later.

### getting it all together

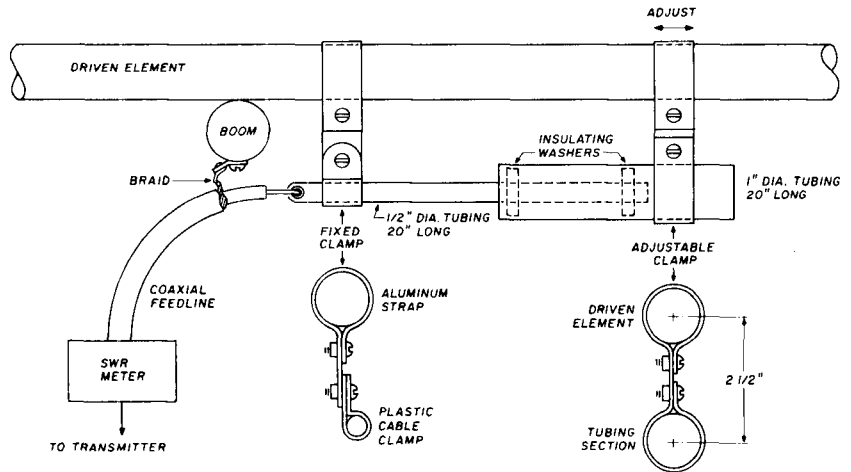
There are numerous advertisements in *ham radio* for antennas that come ready to assemble and put up, and you can hardly go wrong by this route. Some are single-band antennas, and many are versatile multiband systems that allow you to switch to a lower band when the highest frequency one folds up for the day.

If you're an incurable experimenter, it's easy to grab a few pieces of aluminum, some screws and bolts, and

**Table 1. Element dimensions and spacing for two- and three-element beams. Two two-element types are shown along with two sizes of three-element beams.**

Reflector Length (Feet)	Spacing (Feet)	Driven Element Length (Feet)	Spacing (Feet)	Director Length (Feet)	Approximate Gain (dBd)*
17.6	5.21	16.8	—	—	4.5
—	—	16.8	3.47	16.1	4.5
17.6	3.47	16.8	5.21	16.1	7.8
17.6	6.95	16.4	6.95	15.7	8.5

\*dBd = gain referenced to 1/2-wave dipole.



**fig. 2. Gamma match will match coaxial-cable impedance (50 or 75-ohms) to the driven element of a Yagi antenna. The fixed clamp is not moved. The adjustable clamp is moved along the driven element, and the tubing section is moved within the clamp to provide lowest VSWR. Plastic or Teflon® washers inside the larger tubing keep the smaller tubing centered. The coaxial cable braid can be fastened to the boom with a sheet-metal screw, or a coaxial fitting and bracket can be placed there to make a more "professional" installation.**

put together a simple signal snagger that satisfies the urge to try something new. Many hardware stores and do-it-yourself centers have aluminum angle stock and tubing that can be pieced together to make a respectable two- or three-element beam for 10 meters. Pieces of angle stock placed back-to-back form a "T" section boom that make it a cinch to fasten elements. Pieces of tubing that telescope into each other make excellent elements. Use a hacksaw to make slits in the ends of the larger pieces, slide the smaller ones inside a short distance, and use a stainless hose clamp to squeeze the larger one to grip the smaller. Sliding the outer sections in and out (especially on the driven element) allows some adjustment for proper VSWR. Don't worry about in-

ulating the elements from the boom — it's not necessary.

You can often pick up damaged antennas of various types for next to nothing and salvage the parts to build your beam. Although damaged TV antenna elements are not large enough for 10-meter or lower bands, element-mounting hardware, boom material, and brackets to fasten the boom to the rotator mast are worth harboring for future need.

Another source of good parts is cast-off or surplus antennas for the 27-MHz Citizen's Band. Simply shorten the elements to the correct length and they'll work fine on 28 MHz. A word of advice — don't go for the fancy types with strange shapes or gadgets hanging from the elements; they add nothing but wind resistance. Fol-

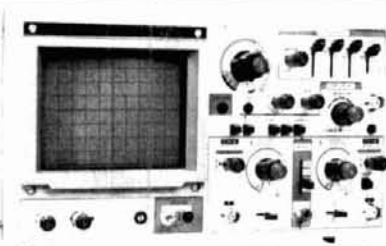


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There are larger CB antennas made on the "quad" principle, and some of these could perform quite well. Quad antenna design is almost a science unto itself and there's not enough space to cover it here. If you get the urge to try one of these, remember these points: frequency of operation is determined by the total length of the wire around the outside of the supports, not the tip-to-tip length of the crossed supports; and, the feedpoint determines whether the polarization is vertical or horizontal. If the feedline is attached at the bottom, the quad will radiate as if it were a horizontal antenna; if fed at the side, it will act like a vertical antenna.

**matching**

The feed impedance of the driven element in a Yagi antenna can vary from a few ohms up to 100 or so, depending upon element lengths and spacing. A versatile matching device for use with coaxial cable is shown in fig. 2. Called a gamma match, it works by providing a variable tap point to the driven element, a variable inductance (the adjustable length of tubing), and a variable capacitance (the smaller tubing that slides inside the larger). To adjust the match for your antenna move the tap point along the driven element an inch or so at a time, then slide the outer section of tubing toward or away from the boom an inch or two and check the VSWR to note whether or not it improved. After making all your adjustments, weatherproof the assembly with clear Krylon.

I talked about power and SWR meters and their use in the January and February 1988 issues of *ham radio*; here's a chance to try them. Get out your hacksaw, drill, screwdriver, and some pieces of aluminum. You'll have some fun building something and using it afterward. (I think I'll follow my own advice and then submit the results as a "Weekender" project! Watch to see how I make out.)

ham radio



## THE MOST AFFORDABLE REPEATER

ALSO HAS THE MOST IMPRESSIVE PERFORMANCE FEATURES  
(AND GIVES THEM TO YOU AS STANDARD EQUIPMENT!)

**KIT, ONLY \$675**  
**WIRED \$975**  
**VHF OR UHF**



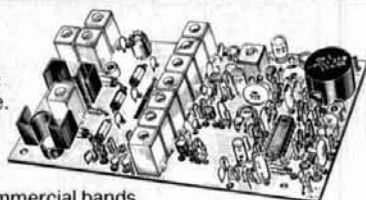
### FEATURES:

- **SENSITIVITY SECOND TO NONE!** GaAsFET front end on vhf models gives 12dB SINAD of 0.12uV (vhf), 0.15uV (220). UHF model 0.25uV std, 0.1uV with optional helical resonator preamp.
- **SELECTIVITY THAT CAN'T BE BEAT!** Both 8-pole xtal filter & ceramic filter for > 100dB at only ±12kHz. Helical resonator front end to combat desense & intermod.
- **CLEAN, STABLE TRANSMITTER**, up to 18W output standard; 50W with accessory power amplifier.
- **FCC TYPE ACCEPTED** for commercial high band and uhf.
- **Courtesy beep**, field-programmable CWID, flutter-proof squelch, automatic frequency control to compensate for off-frequency transmitters (all standard features).
- **Full range of options** available, such as autopatch, phone line or radio remote control, sub-audible tones, duplexers.

## HIGH PERFORMANCE TRANSMITTERS & RECEIVERS FOR REPEATERS AUDIO & DIGITAL LINKS, TELEMTRY, ETC.

### FM EXCITERS:

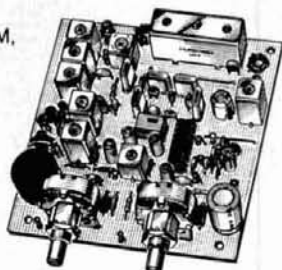
- Kits \$99, w/t \$179. 2W continuous duty. TCXO & xtal oven options available.
- **TA51 for 10M, 6M, 2M, 150-174, 220 MHz.**
- **TA451 for uhf.**



FCC type accepted for commercial bands.

- Call for latest information on 900 MHz transmitters.
- **VHF & UHF AMPLIFIERS.** For FM, SSB, ATV. Output from 10 to 50 Watts. Several models, kits starting at \$79.

- **R144/R220 FM RECEIVERS** for 2M, 150-174, or 220 MHz. GaAs FET front end, 0.12uV sensitivity! Both crystal & ceramic filters plus helical resonator front end for exceptional selectivity: > 100dB at ±12kHz (best available anywhere)! Flutter-proof squelch. AFC tracks drifting transmitters. Kit \$149, w/t \$229.



- **R451 UHF FM RCVR.** Similar to above. Tuned line front end, 0.25uV sens. (0.1uV with optional hel. res. preamp). Kit \$149, w/t \$229.
- **R901 FM RCVR FOR 900 MHZ.** Triple-conversion, GaAs FET front end, 0.2uV sens. Kit \$169, w/t \$259.
- **R76 ECONOMY VHF FM RCVR** for 10M, 6M, 2M, 220. Without hel res or afc. Kits only \$129.
- **Weather satellite & AM Aircraft receivers also avail.**

FCC TYPE-ACCEPTED TRANSMITTERS & RECEIVERS AVAILABLE FOR HIGH-BAND AND UHF. CALL FOR DETAILS.

- **Send \$1 for 36 page catalog by return mail.** (Send \$2.00 or 4 IRC's for overseas mailing)
- **Order by phone or mail • Min \$3 S & H per order**
- **Use Visa, Mastercard, Check, or UPS COD.**

## GaAs FET PREAMPS at a fraction of the cost of comparable units!

### LNG -(\*)

#### GaAs FET PREAMP

**ONLY \$59!**  
Wired/tested



### FEATURES:

- **Very Low Noise:** 0.7dB VHF, 0.8dB UHF
- **High Gain:** 13-20dB, depending on frequency
- **Wide Dynamic Range:** to resist overload
- **Stable:** new-type dual-gate GaAs FET

\* Specify tuning range desired: 26-30, 46-56, 137-150, 150-172, 210-230, 400-470, or 800-960 MHz.

### LNW -(\*)

#### MINIATURE GaAs FET PREAMP



**ONLY \$24/kit,**  
**\$39 Wired/tested**

GaAs FET Preamp similar to LNG, except designed for **low cost & small size.** Only 5/8"W x 1-5/8"L x 3/4"H. Easily mounts in many radios.

\* Specify tuning range desired: 25-35, 35-55, 55-90, 90-120, 120-150, 150-200, 200-270, or 400-500 MHz.

### LNS-(\*)

#### IN-LINE PREAMP

**ONLY \$79/kit,**  
**\$99 Wired/tested**



GaAs FET Preamp with features similar to LNG series, except **automatically switches out of line during transmit.** Use with base or mobile transceivers up to 25W.

\* Specify tuning range desired: 120-175, 200-240, or 400-500 MHz.

## HELICAL RESONATOR PREAMPS

Low-noise preamps with helical resonators **reduce intermod & cross-band** interference in critical applications.

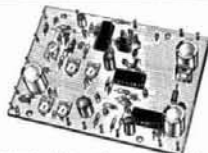
**MODEL HRA-(\*)**, \$49 vhf, \$84 uhf.

\* Specify tuning range desired: 143-150, 150-158, 158-162, 162-174, 213-233, 420-450, 450-465, or 465-475 MHz.

## NEW HIGH-SPEED DIGITAL RF LINKS

You've waited a long time for a simple, reliable, **low-cost 9600 baud PACKET NETWORKING** system. Now you've got it! Our new MO-96 MODEM and direct FSK Transmitters and Receivers for 220 or 440 MHz interface directly with most TNC's. Fast diode switched PA's output 15 or 50W. **Call for complete info on the right system for your application.**

## ACCESSORIES



- **COR-3 Kit.** Control ckts and audio mixers needed to make a repeater. Tail & time-out timers, local spkr ampl, courtesy beep ..... \$49
- **CWID Kit.** Field programmable, timers, the works ..... \$59
- **TD-2 DTMF DECODER/CONTROLLER Kit.** Full 16 digits, switches 5 functions, toll call restrictor, programmable, much more. Great for selective calling too! ..... \$79
- **AP-3 AUTOPATCH Kit.** Use with above for repeater autopatch. Reverse patch and phone line remote control std. .... \$79
- **AP-2 SIMPLEX AUTOPATCH TIMING BOARD Kit.** Use with above for simplex autopatch ..... \$39
- **MO-202 FSK DATA MODULATOR Kit.** Run up to 1200 baud digital signals through any fm transmitter with full handshakes. Radio link computers, telemetry gear, etc. .... \$39
- **DE-202 FSK DATA DEMODULATOR Kit** for rcvr end of link ..... \$39

## RECEIVING CONVERTERS



	Antenna Input Range	Receiver Output
	28-32	144-148
	50-52	28-30
	50-54	144-148
VHF MODELS	136-138	28-30
	144-146	28-30
Kit with Case	\$59	146-148
Kit less Case	\$39	220-222
Wired w/case	\$89	222-224
UHF MODELS	432-434	28-30
Kit with Case	\$69	432-436
Kit less Case	\$49	432-436
Wired w/case	\$99	902-928
		902-922
		430-450

See catalog for full line of 2w transmitting converters for vhf & uhf. Kits only \$79. Linear Amplifiers avail. up to 50 w.

Our 25th Anniversary

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65-H MOUL ROAD • HILTON NY 14468-9535  
Phone: 716-392-9430 Hamtronics® is a registered trademark

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**DEADLINE** 15th of second preceding month.

**SEND MATERIAL TO:** Flea Market, Ham Radio, Greenville, N. H. 03048.

**TEST EQUIPMENT WANTED.** Don't wait — we'll pay cash for LATE MODEL HP, Tek, etc. Call Glenn, N7EPK, at SKAGITRONICS CO. (800) 356-TRON.

**MOTOROLA T45 RTA** 860 MHz Trunking \$450. Several H23, H33, HT 220's VHF low split \$100 each. Scott (801) 224-3783.

**MACINTOSH SATELLITE** Tracking and Propagation Software. MacTrak™ displays graphic maps (rectangular, polar, great circle), views from space, schedules, windows. Also tracks Sun and Moon. Compatible with KLM/MIRAGE rotor interface. Shows gray line, sunrise/sunset, bearing/distance, mUF vs time, areas of world "open". SASE for info or \$49.95 from R. Stegemeyer, PO Box 1550, Port Orchard, WA 98366.

**TEKTRONIX 547** Oscilloscope, 50 MHz BP \$135, Tek-1A1 \$60, Tek-1A4 \$120, Tek-1L30 Spectrum Analyzer, 0.9-10.5 GHz \$350, Hewlett-Packard 606A Signal Generator, 0.05-65 MHz, \$100K, HP-8708A Synchronizer \$150, HP-3300A Function Generator \$95, HP-686C Sweep Generator, 8-12 GHz \$95, HP-9865A Cassette Memory \$95, Lambda LB-701-FMV Variable Regulated Power Supply, 300 amps, new \$295, A. Emerald, 8956 Swallow, Fountain Valley, CA 92708. (714) 962-5940.

**HALL ELECTRONICS** buys radio broadcast equipment for cash! Jon Hall, WB4MMV, PO Box 7732, Charlottesville, VA 22906. (804) 973-8697.

**WANTED** Old and Unique bugs especially looking for Dow Key and Vibroplex Zephyr models. Smiley White, WB4EDB, POB 5150, Fredericksburg, VA 22403. (703) 373-0996.

**MININEC** antenna analysis for IBM-PC. New enhanced version \$10. With plotting \$35. With antenna and plot libraries \$50. See May QST p. 70. K6STI, 507-1/2 Taylor, Vista, CA 92084.

**CUSTOM EMBROIDERED EMBLEMS,** & Enameled Pins, your design, excellent quality, low prices, free booklet. A.T. PATCH CO, Box 682 Dept 19, Littleton, NH 03561. (603) 444-3423.

**BM-PC RTTY/CW.** New CompRtty II is the complete RTTY/CW program for IBM-PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging. 24 programma-

ble 1000 character messages. Ideal for MARS and traffic handling. Requires 256K PC or AT compatible, serial port, RS-232C T.U. \$65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 25 Village View Bluff, Ballston Lake, NY 12019.

**SELL:** AEA PK64A/HFM packet \$175. ICOM IC-271A 25W, 2m Xcvr \$525. Hallicrafters SX115 Receiver \$250. Spectrum Communications 450/2m repeater circuit boards TX/RX \$50 each and RF power amplifiers \$35 each. VHF Engineering ID #25 and COR \$10. Radio Shack Color 3 Computer with RS-232C interface \$150. ICOM 251A 2m, 10W multimode Xcvr \$300. Floyd Chowning, K5LA, 5637 Prince Edward Avenue, El Paso, Texas 79924. (915) 751-6204.

**HAMLOG COMPUTER PROGRAMS.** 17 modules auto-logs, sorts 7-band WAS/DXCC. Full features. Apple \$19.95, IBM or CP/M \$24.95. KA1AWH, POB 2015, Feabody, MA 01960.

**DIGITAL AUTOMATIC DISPLAYS.** All Radios. GRAND SYSTEMS, POB 2171, Blaine, Washington 98230.

**CHASSIS & CABINETS KITS.** SASE. K31WK, 5120 Harmony Grove Rd, Dover, PA 17315.

**GIANT POWERSTAT** Variable Transformer. 240V input, 28 Amps. 0-280V output, 7.8KVA \$145. plus ship. Joseph Cohen, 200 Woodside, Winthrop, MA 02152 (617) 846-6312.

**COMMODORE/AMIGA CUSTOM CHIPS FOR C64/128** Computer/peripherals at low prices. 24 hour delivery. #6510 - \$9.95, #6526 - \$9.95, #6567 - \$14.75, #6581 - \$12.85, PLA - \$12.50, 901 ROMS at \$10.95 each and many others, including Amiga... "The COMMODORE DIAGNOSTICIAN". A complete diagnostic reference chart for fixing Commodore computers, etc. An absolute must for those who want to fix their own computers and save money and downtime. \$6.95 plus \$1.00 postage... COMMODORE REPAIR. We are the largest/oldest Authorized Service Center in the country. (eg. C64 - \$39.95). (We ship worldwide). Heavy duty Power Supply for C64 - \$27.95 plus UPS. Send for complete chips/parts catalog... VISA/MC... Kasara, Inc, 36 Murray Hill Drive, Spring Valley, NY 10977. 1-800-642-7634, 800-248-2983 (outside NY) or 914-356-3131.

**WANT COLLINS KWM 2/A** and accessories. Also looking for other Collins gear. Call after 4 PM EDST (201) 728-7938.

**ANTENNA TUNER WANTED.** Heath Model SA-2500 only, non-working acceptable. W2BL, RD 2, Box 72, Boonton, NJ 07005.

**WANTED RECEIVERS.** (ICOM: IC-745, IC-R7000, Bearcat DX-1000). Scopes and Monitors: Heath: EVV-3 Imp scope, SB-620 spect. analyzer, SB-610 monitor. Tektronix: 502A, 544, 546, 547, 548, 556; a relatively new 5 MHz to 10 MHz scope, single channel, do not need time delay; a 500 MHz to 1 GHz scope without the use of sampling. Scope Plug In's: Tektronix. I can use most of the 1 ser. and letter series plug in's, including the spectrum analyzer plug in's, (IL5, IL10, IL20, IL30, IL40) for the 530-, 540-, 550- series main frame. I have a special need for the Type "T" time base plug in. POWER SUPPLIES: Tektronix, type 127, 132, 133. SIGNAL GENERATOR: Hewlett Packard: 606B or 606A, 608F, 608C, 608E, 612A or 610B, 614A, 616B or 616A. FUNCTION & SWEEP GEN: Heath: UE-81A, IG-1271, IG-1273, IG-52, IG-1275. NOISE GEN: For the 5 Hz to 2 GHz range. STEREO AMPS: Heath: AA-2004, AA-15, AA-1506, AA-1640, AA-2005A, AA-29, AA-1515, AA-1219. POWER SUPPLIES: Heath: IP-17 or IPW-17 or IP17A, IP-2700, IP-2701, IP-28, IP-2718, IP-15, IP-18, IP-2715, IP-12. FILTERS: Receiver audio output filters—tunable; woodpecker noise blanker. PREAMPS: Receiver RF preamps—tunable. WATT METER: B&W 334A dummy load watt meter. VIDEO: Video cameras as used in closed circuit TV. CAR RADIO MOUNT: IIX Equipment Ltd. Mobile radio mount MM1007 or MM10013. ANTENNAS: Wide band scanning antennas for 10 kHz to 2 GHz. Write to: J.L. Courtney, PO Box 391, Canal Winchester, OH 43110.

**CALL SIGN BADGES:** Custom license plate holders. Personal, distinctive. Club discounts. SASE. WB3GND, Box 750, Clinton, MD 20735. (301) 248-7302.

**FOR SALE:** Kenwood TS-820S, digital display. Excellent condition, very clean. \$475. Matt, WA1HRE, (203) 693-0468.

**PROFESSIONAL QUALITY** DTMF Decoder and Select Call System, by Vince Yakamavich, AA4MY, see Feb QST Magazine for details. Blank board #152-PCB only \$17.95. Kit of Parts including board, #152-KIT only \$69.95. Assembled and tested board #152-ASY only \$99.95. Add \$2.50 per order S/H. A & A ENGINEERING, 2521 W. LaPalma, Unit K, Anaheim, CA 92801. (714) 952-2114.

**ANALOG AND RF CONSULTING** for the San Francisco Bay area. Commercial and military circuits and systems. James Long, Ph.D., N6VY (408) 733-8329.

**WANTED:** Klystron tubes especially 2911; Magnatrons; also 304TL, 6012, 810 and 5CX1500A. All types of sockets for transmitting tubes. Harold Branstedt, 6104 Egg Lk Rd, Hugo, MN 55038. (612) 429-9397.

**UHF PARTS.** GaAs fets, mimics, chip caps, trimmer caps, and other builder parts. MGF 1402 @\$14.00 MFG 1320 @\$10.00. 8-117F Trimmer caps @\$3.75. Porcelain chip caps @.80-1.75. Orders add \$1.00 p+h. SASE for complete list. MICRO-WAVE COMPONENTS, 11216 Cape Cod, Taylor, MI 48180.

**JENNINGS UCS-300-7.5 KV** variable vacuum capacitor \$135, RJ1A/HC-1 vacuum relay \$75, RJ2C \$140. Cardwell 2100PF-3 KV variable capacitor \$45. Eimac 3CX1200A7 \$375, 4CX3, 000A \$675, 4CX5, 000A \$950, SK-2210/SK-2216 \$85. Centralab 858-1000PF \$5 ea. (All new). A. Emerald, 8956 Swallow, Ptn. Vty, CA 92708 (714) 962-5940.

**PACKET: Macintosh** packet program, \$39.95. For details write to S. FINE SOFTWARE, POB 6037, State College, PA 16801.

**PHOTOVOLTAIC PANELS.** Lowest prices on Sovonics, Arco panels. From 1 watt to 50. Send \$1 for price specs and data sheets. Michael Bryce, 2225 Mayflower, Massillon, Ohio 44646.

**RTTY JOURNAL**—Now in our 36th year. Read about RTTY, AMTOR, PACKET, MSO'S, RTTY CONTESTING, RTTY DX and much more. Year's subscription to RTTY JOURNAL \$10.00, foreign slightly higher. Order from: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

**IMRA** International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

**MARCO:** Medical Amateur Radio Council, Ltd. operates daily and Sunday nets. Medically oriented Amateurs (physicians, dentists, veterinarians, nurses, physiotherapists, lab technicians, etc) invited to join. Presently over 560 members. For information write MARCO, Box 73's, Acme, PA 15610.

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

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

**CUSTOM MADE EMBROIDERED PATCHES.** Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

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

## COMING EVENTS

Activities — "Places to go . . ."

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

**BRITISH COLUMBIA:** July 8-10. The Okanagan Ham Society is sponsoring the annual Okanagan Ham Fair, Illahie Beach RV Park, Hwy 97 N., Summerland, BC. 4 PM Friday to 4 PM Sunday. Admission \$5.00. Flea market, auction, new equipment, surplus and more. Talk in on 146.34/94 or 146.52. Contact VE7GSB, Glenn Borgens at (604) 492-5684 or write Okanagan Ham Fair, Box 477, Penticton, BC, Canada V2A6K6 or VE7BEE at (604) 493-1122.

**WISCONSIN:** July 9. Swapfest '88 sponsored by the South Milwaukee ARC. American Legion Post 434, Oak Creek. Starts 7 AM. Tickets \$3. Amateur Radio exams. Talk in on 146.58, WA9TXE/9.

**OHIO:** July 10. The Wood County ARC is sponsoring their 24th annual Ham-A-Rama at the Wood County Fairgrounds, Bowling Green. 8 AM to 4 PM. Free admission. Tables \$7.00. Trunk sales \$3.00. Food and drink available. Talk in on 147.18/78 and 146.52. For more info contact Jim Davis, N8DWR, 10990 Newton Rd, Bowling Green, OH 43402. (419) 352-3321.

**ILLINOIS:** July 10. The DuPage Amateur Radio Club is sponsoring a Hamfest/Computer show, American Legion Post 80, 4000 Saratoga, Downers Grove. Admission \$3/gate or \$2/advance. Gates open 8 AM. Outdoor flea market and swappers row, indoor tables, VEC exams for all classes. Talk in on 146.52, 145.250-600, 224.55 and 442.55. For tickets or reserved tables SASE to Hamfest Chairman, W9DUP, PO Box 71, Clarendon Hills, IL 60514 or call (312) 985-0527 evenings or weekends.

**NEW YORK:** July 10. The 8th annual Batavia Hamfest sponsored by the Genesee Radio Amateurs, Alexander Firemen's Grounds, Rt 98, Alexander. 6 AM to 4 PM. Indoor exhibits open 9 AM. OM/YL programs, spacious flea market, chicken BBQ, free camping, VEC exams. Advance tickets \$3 before July 1. \$4/gate. Talk in on 144.71/145.31 and 146.52. For information G.R.A.M., POB 572, Batavia, NY 14021. For tickets Knute Carlson, N2DRX, 26 Burke Drive, Batavia, NY 14020.

**MAINE:** July 16. The First annual Mid-Coast/Yankee Hamfest, Union Fairgrounds, Union, midway between Augusta and Rockland. Tailgating, swap table space (bring your own tables), demonstrations, crafts, food and entertainment. Lobster dinner at 1 PM Saturday. Camping available Friday and Saturday. Talk in on 146.385/985. For more info Carl Ingerson, N1DXM, PO Box 929, Union, Maine 04862. (207) 785-4948 or on packet via KA1FKS-1 on 145.03.

**NEW JERSEY:** July 17. The Sussex County ARC will sponsor "SCARC '88", Sussex County Fairgrounds, Plains Road, off Rt 206, Augusta. Doors open 8 AM. Registration \$3.00. Indoor tables \$7.00 each. Tailgate space \$5.00. Food and refreshments. Plenty of free parking. For more info write Don Stickle, K2OX, Weldon Road, RD 4, Lake Hopatcong, NJ 07849. Tel: (201)-663-0677.

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—AND RENEW—

## TOLL-FREE

**MISSOURI:** July 17. The Zero Beaters ARC is sponsoring their 26th annual Zero Beaters Hamfest, Bernie H., Hillermann Park, Washington, 7 AM to 3 PM. Free admission. Parking \$2. for Flea Market. FCC exams. Talk in on 84/24 and 52. For information Al Lanwermeier, WB0QBS, (314) 239-2072.

**ILLINOIS:** July 17. The Fox River Radio League's annual Hamfest, Pheasant Run Lodge, North Avenue, St. Charles. Doors open 8 AM. Advance tickets \$4 plus SASE to Phil Fors, N9FXQ, 104 May Street, West Chicago, IL 60185. Indoor/outdoor flea market. VEC exams. Free parking. Fly in to DuPage County Airport. Talk in on 145.470-600 and 1465.210-600. Commercial and inside tables contact Kermit Carlson, W9XA, 36W345 McKee Rd, Batavia, IL 60510.

**ILLINOIS:** July 23-24. The Amateur Cross Link Repeater Club is having its 2 day Hamfest and Banquet, DeVry Institute of Technology, 3300 N. Campbell, Chicago. Advance tickets \$3; \$4/door. Setup 7 AM. Doors open 8 AM. Outdoor flea market sellers bring own tables. Indoor dealers tables provided. Banquet \$15. Guest speaker Gordon West, WB6NOA. For tickets SASE to Peter Hughes, WB9EYR, 3315 N. Oakley, Chicago, IL 60618. For more information call (312) 712-5100. Talk in on 147.225, 224.480 and 443.700.

**INDIANA:** July 20-24. The County Hunters 20th annual convention, Ramada Inn-South, Indianapolis. All Amateurs are welcome to attend and participate in the various activities. Tours of Conner Prairie Settlement and the Indy 500 Motor Speedway highlight the week. Interested Amateur should SASE for information and registration forms to Herb Morgan, WD9GBH, 735 East 50th Street, Marion, IN 46953.

**NEW JERSEY:** July 31. The W2WEB East Coast VHF Society's annual Antenna Gain Measuring Contest and Flea Market, Trenton State College, Ewing Township, Trenton. 8 AM. Flea Market Handicap and Wheelchair accessible. Free registration and parking. Talk in on 146.67- (W2ZQ/R). For information SASE to Russ Pillsbury, K2TXB, RR 7, Oakshade Rd, Tabernacle, NJ 08088 (609) 268-9586.

**ILLINOIS:** July 31. The 54th annual Hamfest sponsored by the Hamfesters Radio Club. NEW LOCATION - Will County Fairgrounds, Peotone. 5 AM to 3 PM DST. Admission \$3/advance or \$4/door. FCC exams, overnight parking. Nearby camping. Displays, swappers row. Talk in on 146.78/16 and 146.52. Club call W9AA. For tickets send check or MO in No. 10 SASE to Hamfesters Radio Club, 13068 Finch Ct, Lockport, IL 60441. For information John Schiptsch, W9ENR, 13068 Finch Ct, Lockport, IL 60441. (312) 403-1043.

## OPERATING EVENTS

"Things to do . . ."

**OKLAHOMA:** July 9-10. "Field Day" exercises conducted by Oklahoma Amateur Radio Operators at Lake Canton. Activities begin 3 PM Saturday and continue through the night until noon Sunday at the "Big Bend" picnic shelter in conjunction with the annual IARU "Radiosport" DX Contest. To highlight this special events, the Lake Canton Field Day Committee will provide a commemorative certificate for contacts with event stations WD5HPU, WA5LTM and other Amateur stations. Listen in the General phone portions 40-10m. Also 6 and 2m SSB.

**INTERNATIONAL HAMFEST.** July 7-9. VE4HF will be in operation to help celebrate the 25th anniversary of the International Hamfest held in the Peace Gardens on the Manitoba, Canada, and North Dakota, USA border. 9 AM CST to 9 PM CST. To receive the "Peace Garden Award" send a QSL and 3 IRC's along with SASE to VE4XN, Dave Snydal, 25 Queens Crescent, Brandon, Manitoba, Canada R7B 1G1.

**NEW YORK:** July 23 and 24. The Oswego County Amateur Radio Emergency Service (ARES) and the Fulton ARC will operate KY2F, 1500Z to 2300Z each day from the Oswego County Air Show. Lower third of General 40, 20, 15, 10 and 2m bands and Novice portion of 10m. For certificate send large SASE to Fred Swiatlowski, KY2F, PO Box 5227, Oswego, NY 13126.

**MARYLAND:** July 23-24. The Laurel ARC will operate special event station W3GFS from 1800Z 7/23 to 1800Z 7/24 from a small uninhabited island in Chesapeake Bay the world's largest estuary. Freqs: Lower 25 kHz of General 80-10m and 147.54. Attractive 8x11 certificate for SASE. QSL to LARC, PO Box 1436, Laurel, MD 20707.

**July 23-29:** The Long Island Mobile ARC will operate special event station W200VL. CW and phone on all HF bands. QSL with SASE via WA2KXE, 162 West Hudson Street, Long Beach, NY 11561.

**HAM RADIO TODAY** has joined the programming lineup from the Voice of the Andes, HCJB Radio, an international broadcasting station that has been operating from Quito, Ecuador since 1931. Programming includes news from all over the world, construction hints, propagation news, equipment reviews and much more. For more information contact John E. Beck, Producer, HAM RADIO TODAY, c/o HCJB Radio, Box 691, Quito, Ecuador, SA.

**HAM EXAMS:** The MIT UHF Repeater Association and the MIT Radio Society offer monthly Ham Exams. All classes Novice to Extra. Wednesday JUNE 22, 7 PM, MIT Room 1-150, 77 Mass Ave, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 646-1641. 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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# ADVERTISER'S INDEX AND READER SERVICE NUMBERS

Listed below are the page and reader service number for each advertiser in this issue. For more information on their products, select the appropriate reader service number make a check mark in the space provided. Mail this form to ham radio Reader Service, I.C.A., P.O. Box 2558, Woburn, MA 01801.

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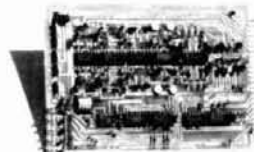
Please use before August 31, 1988.

READER SERVICE #	PAGE #	READER SERVICE #	PAGE #
144 - Ace Communications, Inc	53	108 - Kantronics	6, 7
120 - Advanced Receiver Research	24	117 - Kennedy Associates	20
149 - AEA	57	* - Kenwood U.S.A. Corp	2, 5, CIV
147 - All Electronics Corp	54	129 - Larsen Antennas	36
187 - Aluma Tower Co.	94	180 - Madison Electronics Supply	87
122 - AMC Sales, Inc	24	121 - Magnaphase Industries, Inc	24
130 - Amidon Associates	36	109 - MFJ Enterprises	8
*156 - AMSAT	62	150 - Micro Control Specialties	59
118 - Antennas West	20, 77, 89	176 - Microflex	87
141 - ARRL	49	116 - Midland Technologies	20
175 - ARRL	87	184 - Mission Communications	94
124 - Astron Corp	30	188 - Missouri Radio Center	99
168 - ATFAB Computers and Electronics	77	126 - Mobile Mark, Inc	32
* - Barker & Williamson	52	153 - Morlan Software	59
* - Barry Electronics	63	133 - Motron Electronics	36
191 - Bilal Company	98	119 - NCG	24
131 - Buckmaster Publishing	36	* - Nema Electronics	20
171 - Buckmaster Publishing	82	174 - Nuts & Volts	86
* - Butternut Electronics	20	193 - OPToelectronics	100
172 - C&S Sales	85	134 - P.C. Electronics	37
* - Caddell Coil Corp	82	125 - Pac-Comm Packet Radio Systems, Inc	32
145 - CIE	53	115 - Radio Shack	23
112 - Command Technologies	17	157 - Radiokit	62
140 - Communications Specialists	44	127 - Radiosporting	32
107 - Connect Systems Inc	1	177 - The Radio Works	87
196 - CTM	80	183 - Ramsey Electronics, Inc	93
186 - Cygnus-Quasar Books	94	152 - The RF Connection	59
195 - Datacom, International	53	167 - Riebstone Software Co	76
114 - DMQ	17	161 - Rutland Arrays	65
155 - Doppler Systems	63	185 - S-Com Industries	94
151 - Down East Microwave	59	* - Sherwood Engineering, Inc	77
158 - DRSI	65	* - Spec-Com	94
139 - EGE, Inc	47	132 - Stridsburg Engineering Co	36
* - Engineering Consulting	70	143 - STV/OnSat	52
178 - Epsilon Co	87	164 - Synthetic Textiles, Inc	76
182 - Fair Radio Sales	91	162 - TIC General	70
* - Fox Tango Corp	91	163 - Transverters Unlimited	73
154 - Giffler Shortwave	61	* - University Microfilm Int	86
135 - GLB Electronics	37	159 - Vanguard Labs	65
146 - Gordon West Radio School	55	113 - Varian EIMAC	16
123 - L.L. Grace	29	148 - VHF Communications	54
165 - GTI	76	166 - W9INN Antennas	76
190 - GTI	98	170 - Western Electronics	82
138 - HAL Communications Corp	43	181 - Wi-Comm Electronics Inc	91
189 - Doug Hall Electronics	98	137 - Yaesu USA	41
169 - Hal-Tronix	80	192 - Yaesu USA	CIII
111 - Ham Radio Outlet	14, 15	179 - E.H. Yost Co	87
* - Ham Radio's Bookstore	32, 52, 76, 77		
* - Hamtronics, NY	95		
128 - Henry Radio	35		
106 - ICOM America, Inc	CII		
142 - ICOM America, Inc	50, 51		
173 - Jan Crystals	86		
110 - JDR	13		
160 - Jensen Tools, Inc	65		
136 - Jun's Electronics	39		

### PRODUCT REVIEW/NEW PRODUCTS

* - Engineering Consulting	71
* - Ham Radio's Bookstore	71
302 - Kantronics	71
* - Kenwood U.S.A. Corp	71
301 - Universal Radio	71

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2-211	2 in/110 out	
3-312	30 in/120 out	
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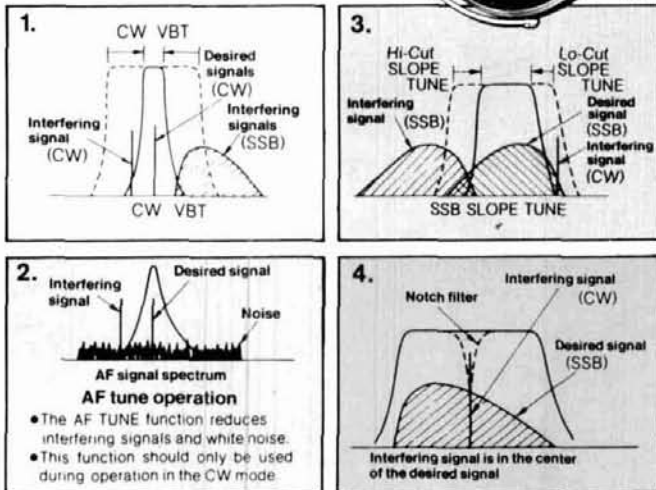
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