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

Optional Accessories:
- RC-10 Multi-function handset/remote controller
- PS-430 Power supply
- TSU-6 CTCSS decode unit
- SW-100B Compact SWR/power/watt 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.

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

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July 1988
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
"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!

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  - Covers 80-10 meters.
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- PS-50 heavy duty power supply
  - PS-430 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 (BP) 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
  - 5M-220 station monitor
  - VS-1 voice synthesizer
  - SW-100A/200A/2000A SWR power meters
  - TU-8 CTCSS tone unit
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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.

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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.

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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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**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.

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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 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 QST, 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 winners and losers.

A weight control lets you penetrate QRM with a distinctive signal or lets your transmitter send perfect sounding CW.
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 cliche). 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 KA8RUM, 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 feedthrough 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

July 1988
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. The characteristics of $E_s$ in the equatorial region, and $E_s$ connected with $E_s$: an overview

By Geoffrey H. Grayer, G3NAQ, “Bagatelle”, 3 Southend, Brightwalton, Newbury, Berks RG16 0BE, England
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)$^2$ and uneven in density.$^3,4$ 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, $f_c E_s$. (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 $f_{\text{max}}$ is normally related to $f_o$ by $f_{\text{max}} = f_o / \cos i = f_o \sec i$, 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.$^5$ 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,$^4$ 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
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

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

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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<thead>
<tr>
<th>EIMAC Cavity</th>
<th>Matching EIMAC Tube</th>
<th>Tuning Range (MHz)</th>
<th>Power Output</th>
</tr>
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<tr>
<td>CV-2200</td>
<td>4CX20,000A</td>
<td>86-108</td>
<td>30 kW</td>
</tr>
<tr>
<td>CV-2220</td>
<td>3CX1500A7</td>
<td>86-108</td>
<td>1.5 kW</td>
</tr>
<tr>
<td>CV-2225</td>
<td>4CX3500A</td>
<td>86-108</td>
<td>5 kW</td>
</tr>
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<td>CV-2240</td>
<td>3CX10,000U7</td>
<td>54-88</td>
<td>10 kW†</td>
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<td>CV-2250</td>
<td>3CX10,000U7</td>
<td>170-227</td>
<td>10 kW†</td>
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<tr>
<td>CV-2400</td>
<td>8874</td>
<td>420-450</td>
<td>300/1250 W*</td>
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<td>CV-2800</td>
<td>3CX400U7</td>
<td>850-970</td>
<td>225 W</td>
</tr>
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<td>CV-2810</td>
<td>3CX400U7</td>
<td>910-970</td>
<td>190 W</td>
</tr>
</tbody>
</table>

*pulsed power
†peak sync, or 2.5 kW combined in translator service
where a is the "half thickness" of the ionized layer ionosondes. It can be shown that with some penetration effects occur with vertical incidence other quantities having been defined above. Similar assumptions a sumilar model of fig. 1A, this is given by

$$D_{\text{max}} = 2 R_0 \cos^{-1} \left( \frac{R_0}{R_0 + h} \right)$$  (2)

This expression is a simpler form of that given by Kimbell, 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

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

where a is the "half thickness" of the ionized layer assuming a parabolic distribution of electrons, the other quantities having been defined above. Similar penetration effects occur with vertical incidence ionosondes. It can be shown that with some assumptions this extra distance is included in the rectilinear 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.
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), Argentia (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 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 ionospheric reflections (fig. 1D). As many authors 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.

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 A.S.L with their horizon at sea level, their range (ignoring refraction effects) would be increased by 100 km. There is an effect countering 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 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. Summary of principal 50-MHz openings during 1987 used in fig. 3. Callsigns and prefixes are in bold. †ARU World Locator System**

<table>
<thead>
<tr>
<th>Date</th>
<th>Start</th>
<th>End</th>
<th>Locators† worked/heard</th>
</tr>
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<tr>
<td>May 25</td>
<td>1605</td>
<td>1830</td>
<td>IN80, JN36</td>
</tr>
<tr>
<td>May 26</td>
<td>2220</td>
<td>0037</td>
<td>EN90, EM74, EM90, FM09, FM18, FM25, FN31, FN32, FN42, FN43, FN44, FN53, GN37</td>
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<tr>
<td>Jun 7</td>
<td>1253</td>
<td>1552</td>
<td>FK97(V2A1), IN53, IN60, IN61, JN02, KM64, KP01, JN36, JN87</td>
</tr>
<tr>
<td>Jun 15</td>
<td>1643</td>
<td>2041</td>
<td>EM70, EM79, FM09, FM18, FM29, FN20, FN31, FN32, FN42, FN43, FN44, FN53, GN37</td>
</tr>
<tr>
<td>Jun 17</td>
<td>2136</td>
<td>0042</td>
<td>EM70, EM79, FM09, FM18, FM29, FN20, FN31, FN32, FN42, FN43, FN44, FN53, GN37</td>
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<tr>
<td>Jun 18</td>
<td>1155</td>
<td>1552</td>
<td>EL96, EL97</td>
</tr>
<tr>
<td>Jun 21</td>
<td>1714</td>
<td>2200</td>
<td>FN44, FN74, GP60(OX3VHF)</td>
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<tr>
<td>Jul 10</td>
<td>1908</td>
<td>2116</td>
<td>GP60(OX3VHF), JP61, KP01</td>
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<tr>
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<td>1815</td>
<td>2200</td>
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<tr>
<td>Jul 19</td>
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<td>2010</td>
<td>IM12(CT3), IM59, JN69, JO28, JO29, JO53, JO59, JO65, JP61</td>
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<td>1829</td>
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<td>FM15, FM26, FN20, FN31, FN32, FN41, FN42, FN43, FN44, FN53, FN74, FN84, GN37</td>
</tr>
</tbody>
</table>
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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 $f/f_0 < 7$ — 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 $f_{\text{max}}$ 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 $f_0E_s$ 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 $f_0$ to $f_{\text{max}}$, assuming the secant law with and without the correction factor $e = 1.25$. Note that $f_{\text{max}} = 50$ MHz is exceeded on 52(26) days, compared with 128(76) days when $f_{\text{max}} > 30$ 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. 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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(2) Power Value

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(2) RS-232 Mini Tester. Diagnose interface problems! Dual-color LEDs indicate status of D, RTS, DSR, CD, CTS and DTR lines. #226-1401 ... 14.95

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July 1988
“NEW” SUPER LINEAR ANTENNA SYSTEM

<table>
<thead>
<tr>
<th>MODEL</th>
<th>FREQUENCY</th>
<th>GAIN</th>
<th>POWER</th>
<th>LENGTH</th>
<th>USE</th>
<th>PRICE</th>
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<td>1260/1300</td>
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<td>100 W</td>
<td>8'4&quot;</td>
<td>Base</td>
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NEW! SWR Power Minimeters

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24 July 1988
fig. 6. Map showing the percentage of time $f_e E_e$ exceeds 7 MHz in the temperate zones between May and August (Northern Hemisphere) and between November and February (Southern Hemisphere)* (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 \( f_{\text{max}} \) 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. This gives for Region A (Europe and North Africa) \( f_0E_s \) exceeding 7.5 MHz, corresponding to \( f_{\text{max}} > 50 \text{ MHz} \) 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 \( f_{\text{max}} > 50 \text{ MHz} \) 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 \( f_0E_s = 12 \text{ MHz} \), 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 \( f_0 \). 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 \( \times 13 \text{ percent} = 8.6 \text{ percent} \), 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 \( f_0 = 10.2 \text{ MHz} \), amply exceeding the minimum \( f_0 \) for 50-MHz propagation. An hour earlier it had reached the highest value of \( f_0E_s \) recorded at this station during the year, 12.1 MHz (table 2).

**Table 2. Ionosonde data for July 10, 1987. The \( f_0E_s \) in brackets are the monthly median values for that time of day.**

<table>
<thead>
<tr>
<th>UTC</th>
<th>( f_0E_s ) MHz</th>
<th>( h' \text{ km} )</th>
<th>( f_0E_s ) MHz</th>
<th>( h' \text{ km} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1600</td>
<td>3.4(4.7)</td>
<td>110</td>
<td>3.2</td>
<td>105</td>
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<tr>
<td>1700</td>
<td>3.5(4.4)</td>
<td>110</td>
<td>3.2</td>
<td>105</td>
</tr>
<tr>
<td>1800</td>
<td>3.0(4.4)</td>
<td>110</td>
<td>3.8</td>
<td>125</td>
</tr>
<tr>
<td>1900</td>
<td>3.0(4.3)</td>
<td>115</td>
<td>12.1</td>
<td>120</td>
</tr>
<tr>
<td>2000</td>
<td>3.1(4.4)</td>
<td>110</td>
<td>10.2</td>
<td>110</td>
</tr>
<tr>
<td>2100</td>
<td>3.7(3.7)</td>
<td>105</td>
<td>8.4</td>
<td>110</td>
</tr>
<tr>
<td>2200</td>
<td>3.8(3.8)</td>
<td>110</td>
<td>2.5</td>
<td>120</td>
</tr>
<tr>
<td>2300</td>
<td>2.9(3.4)</td>
<td>115</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This intense \( E_s \) to the north also gave short-hop \( E_s \) contacts into Norway and Finland (1140 to 1600 km). Considering the high values of \( f_0 \) 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
fig. 7. The ionogram recorded at Slough on June 19, 1987 at 1800 UTC. It shows at least four reflections from a blanket layer at a virtual height of 130 km.
time (Table 3), though only one value (that for Slough at 1600 UTC) exceeds the $f_0$ 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 $f_0$ 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 3. Ionosonde data for July 19, 1987.**

<table>
<thead>
<tr>
<th>Time (UTC)</th>
<th>Slough</th>
<th>South Uist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500</td>
<td>5.5(5.0)</td>
<td>120</td>
</tr>
<tr>
<td>1600</td>
<td>8.5(4.7)</td>
<td>115</td>
</tr>
<tr>
<td>1700</td>
<td>5.5(4.4)</td>
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<td>1800</td>
<td>4.0(4.3)</td>
<td>120</td>
</tr>
<tr>
<td>1900</td>
<td>2.8(4.3)</td>
<td>125</td>
</tr>
<tr>
<td>2000</td>
<td>5.7(4.4)</td>
<td>115</td>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Time (UTC)</th>
<th>Slough</th>
<th>South Uist</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500</td>
<td>5.9(4.0)</td>
<td>120</td>
</tr>
<tr>
<td>1600</td>
<td>3.6(4.1)</td>
<td>150</td>
</tr>
<tr>
<td>1700</td>
<td>6.7(5.0)</td>
<td>125</td>
</tr>
<tr>
<td>1800</td>
<td>9.9(4.0)</td>
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<tr>
<td>1900</td>
<td>10.1(5.0)</td>
<td>115</td>
</tr>
<tr>
<td>2000</td>
<td>8.7(3.3)</td>
<td>115</td>
</tr>
<tr>
<td>2100</td>
<td>1.6(3.2)</td>
<td>–</td>
</tr>
</tbody>
</table>

---

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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The Kansas City Tuner is a companion product that is used in satellite work to provide automatic doppler-shift compensation. It interfaces to your radio through its serial computer control port (RS232) or "mike click" interface to update the receive and/or transmit frequencies once a second. It can be used in digital or analog modes. The Tuner is compatible with most rigs including the Yaesu 726 & 736, the ICOM 271/471, 275/475, and R-7000. Call regarding your specific rig.

The Kansas City Tracker and "Tuner" have several advantages over other products available today. They do not use your computer's COMM ports or hardware interrupts. The software runs in your computer's "spare time," letting you run other programs at the same time. Several Kansas City products can be installed in one PC, letting you control up to 16 separate antenna arrays at the same time.

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The rotor driver and status programs are TSR programs that attach themselves to DOS and "disappear." You can run other DOS programs while your antenna tracks its target under computer control at the same time. This unique feature is especially useful for satellite and land digital work, as communications programs like PROCOMM can be run while the PC aims the rotors at the same time. The status "pop-up" allows the user to view and change the current antenna position and upcoming pass information. The Kansas City Tracker is compatible with DOS 2.00 or higher, and will run under DESQ-VIEW.

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- Crowbar Over Voltage Protection on all Models except RS-3A, RS-4A, RS-5A,
- Maintain Regulation & Low Ripple at line input Voltage
- Heavy Duty Heat Sink • Chassis Mount Fuse
- Three Conductor Power Cord
- One Year Warranty • Made in U.S.A.

### Performance Specifications
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- Output Voltage: 13.8 VDC ± 0.05 volts (Internally Adjustable: 11-15 VDC)
- Ripple Less than 5% peak to peak (full load & low line)
- Also available with 220 VAC input voltage

### RS Series

<table>
<thead>
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<th>Model</th>
<th>Continuous Duty (Amps)</th>
<th>ICS* (Amps)</th>
<th>Size (IN)</th>
<th>Shipping Wt. (lbs.)</th>
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<tr>
<td>RM-12A</td>
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<td>RM-35A</td>
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<td>5½ x 12 x 12</td>
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<td>37</td>
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<td>5½ x 12 x 12</td>
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- Separate Volt and Amp Meters
- RS-12M: 9 12 5½ x 9 x 13/16 16
- RS-35M: 25 35 5½ x 12 x 12 38
- RS-50M: 37 50 5½ x 12 x 12 50

### RS-A Series

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- Separate Volt and Amp Meters
- RS-12M: 9 12 4½ x 8 x 9 13
- RS-35M: 25 35 5½ x 11 x 11 27
- RS-50M: 37 50 6 x 13½ x 11 46

### RS-M and VRM-M Series

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<td>VS-50M</td>
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- Variable rack mount power supplies
- VRM-35M: 25 35 5½ x 19 x 12½ 38
- VRM-50M: 37 50 5½ x 19 x 12½ 50

### VS-M and VRM-M Series

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- Built in speaker

### VS-M and VRM-M Series

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<td>VS-35M</td>
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<td>35</td>
<td>5½ x 11 x 11</td>
<td>29</td>
</tr>
<tr>
<td>VS-50M</td>
<td>37</td>
<td>50</td>
<td>6 x 13½ x 11</td>
<td>46</td>
</tr>
</tbody>
</table>

- Variable rack mount power supplies
- VRM-35M: 25 35 5½ x 19 x 12½ 38
- VRM-50M: 37 50 5½ x 19 x 12½ 50

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<tr>
<th>Model</th>
<th>Continuous Duty (Amps)</th>
<th>ICS* (Amps)</th>
<th>Size (IN)</th>
<th>Shipping Wt. (lbs.)</th>
</tr>
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<tr>
<td>RS-7S</td>
<td>5</td>
<td>7</td>
<td>4 x 7½ x 10½</td>
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<tr>
<td>RS-10S</td>
<td>7.5</td>
<td>10</td>
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</tr>
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<td>16</td>
<td>20</td>
<td>5½ x 9½ x 10½</td>
<td>18</td>
</tr>
</tbody>
</table>

- Built in speaker

---

*Please note that the above specifications are subject to change without notice.*
not reaching particularly high values of $f_0$ 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 Argentia. This is unlikely to be material for two reasons: the $f_0F2$ 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

\[ \text{fig. 10. (A) Reception of DL0IGI on 28.205 MHz; (B) reception of 5B4CY on 28.220 MHz, for June, July, and August 1976 and 1977.} \]

<table>
<thead>
<tr>
<th>UT</th>
<th>Slough $f_0E_s$ MHz</th>
<th>Argentia $f_0E_s$ MHz</th>
<th>Wallops Is. $f_0E_s$ MHz</th>
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<td>none</td>
<td>none</td>
<td>none</td>
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<tr>
<td>1600</td>
<td>5.8</td>
<td>5.1</td>
<td>5.4</td>
</tr>
<tr>
<td>1700</td>
<td>4.4</td>
<td>130</td>
<td>4.2</td>
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<tr>
<td>2100</td>
<td>2.8</td>
<td>120</td>
<td>4.8</td>
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<tr>
<td>2200</td>
<td>none</td>
<td>none</td>
<td>6.1</td>
</tr>
<tr>
<td>2300</td>
<td>none</td>
<td>none</td>
<td>110</td>
</tr>
</tbody>
</table>

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. 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 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 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 DL0IGI at 3450 km must be double-hop propagation with the reflection taking place at around 13$^\circ$ and 24$^\circ$ 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$^\circ$ longitude is equivalent to 1 hour). Note also that
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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 audi-
able is $0.36^\circ \times 100\% = 13\%$. Obviously the occurrence
of $E_s$ at the two points of reflection was highly cor-
related, 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 longi-
tude 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 requir-
ing 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 pat-
tern 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 pos-
sible) 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 which occurred
during 1982-1985 (see fig. 11E). It appears that dur-
ing that period, following the solar maximum, trans-
atlantic 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 cor-
related. The fact that the treatment works supports
this assumption. This could give a clue to the originat-
ing mechanism of $E_s$.

A similar exercise was performed with the data of
the reception of the 50-MHz beacon in French Gui-
a, 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 require-
ment 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 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 employ-
ing 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 King-
dom 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 Bahrain reaches grazing incidence over the Black
Sea, and a similar time analysis shows a good over-
lap 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 for May to July 1979-1985.](image)

![fig. 13. The predicted hourly distribution for liaison with Bahrain.](image)

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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propagation. If a few interested Amateurs calibrate their equipment to give approximate signal field strengths and accurate beam headings, the results could lead to a greater understanding of $E_2$ phenomena.

acknowledgments

I wish to thank Dr. Mike Happgood 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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10. K.G. Budden, ibid, 12.8, pages 345-347.
11. VHF/UHF Newsletter, Radio Society of Great Britain, October 1987. Log extracts were provided by G3SEK, GW4LXO, G4VXE, and G4DAZ.
13. Radio Communication 60 no. 4, April 1984, pages 315-316.
16. The plots were constructed from observations recorded and made available to the author by Prof. M. Harrison, G3USF, at 53°0'N. 2°17'W.
17. DL6IGI is located on Predigtstuhl Mountain, South Germany at 47°42'N. 12°53'E.
18. 5B4CY is located at Zyli, Cyprus at 34°45'N. 33°19'E.

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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propagation update-
part 3

In June we reviewed the latest VHF/UHF/Microwave DX records. 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 F4L. 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 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. 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.

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). The MSB crossing tends to occur when the “K”

*In July 1988

References:


4. 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.
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 crossed 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 during 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 1956-57.\(^3\) The terminal point of meteors likewise was higher during these same minimum sunspot years.

Throughout the summer of 1987
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 $F_0E_s$, 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 $F_0E_s$, summer months worldwide map assembled by Ernest K. Smith, N6HQK, and shown in fig. 2. These data are taken from ionosondes when the $F_0E_s$ was about 7 MHz, a typical value to yield 6-meter and higher sporadic E propagation.

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.¹ 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 EABXS (ILL28GA) 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).¹ ²

Both contacts were probably double 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 (EM90GC) on June 14, 1987 over a 932-mile (1499 km) path.¹ ² 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. 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*.

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 does the number of occurrences of auroral propagation. This mode of propagation 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 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.

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. 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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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. A recent claim in Europe would extend the worldwide 2-meter aurora record out to 1439 miles. That’s real DX!

auroral Es

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 nighttime 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.

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 VHFs.

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.*

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. 13,14

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. 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

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

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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 propagation beacon. They are most prevalent about 500 miles. Aim antenna into storm cell especially if it is elevated. Lots of signal distortion.

### 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.

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

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 QRMs. 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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- Designed for 50 ohm feedline
- Weather proof balun and balancing network

U.S. Patent No. 4,423,423

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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 UVAC 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 are beacons between 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.

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 meters</td>
<td>50.110 MHz DX *</td>
</tr>
<tr>
<td>6 meters</td>
<td>50.200 MHz Domestic *</td>
</tr>
<tr>
<td>2 meters</td>
<td>144.2 MHz</td>
</tr>
<tr>
<td>135 cm</td>
<td>220.1 MHz</td>
</tr>
<tr>
<td>70 cm</td>
<td>432.1 MHz</td>
</tr>
<tr>
<td>33 cm</td>
<td>903.1 MHz</td>
</tr>
<tr>
<td>23 cm</td>
<td>1296.1 MHz</td>
</tr>
<tr>
<td>13 cm</td>
<td>2304.1 MHz</td>
</tr>
<tr>
<td>9 cm</td>
<td>3456.1 MHz</td>
</tr>
<tr>
<td>6 cm</td>
<td>5760.1 MHz</td>
</tr>
<tr>
<td>3 cm</td>
<td>10.368 GHz</td>
</tr>
</tbody>
</table>

*See text for explanation.

There are also clubs and publications. KA3B now publishes a North American 50-MHz SSB Directory and beacon list and a 6-meter repeater.
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 WWV 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 50.1 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 (AMSAT newsletter), bulletin no. 171, March 21, 1988: Dr. Patrick MacIntosh, the Director of Solar Physics

*Harry Schools, K3AB, 1606 S. Newkirk Street, Philadelphia, Pennsylvania 19145, 88 for each directory.
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 GRM 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 (EM605M) worked Al Ward, WB5LUA, McKinney, Texas (EM13QG) 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 F0E5 maps article.6 Thanks also to those who took the time to write with comments and suggestions for future columns.

important VHF/UHF events

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
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</thead>
<tbody>
<tr>
<td>July 1</td>
<td>1 month. Look for USA to Europe</td>
</tr>
<tr>
<td>July 2</td>
<td>EME perigee</td>
</tr>
<tr>
<td>July 13</td>
<td>New moon</td>
</tr>
<tr>
<td>July 16-17</td>
<td>CO VHF WPX Contest ±3 weeks. Look for 2-meter sporadic E</td>
</tr>
<tr>
<td>July 20</td>
<td>Central States VHF Conference, Lincoln, Nebraska (contact WD0DGF)</td>
</tr>
<tr>
<td>July 21-24</td>
<td>Predicted peak of the Delta Aquarids meteor shower at 2100 UTC EME perigee</td>
</tr>
</tbody>
</table>

references

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 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, Richardson, Texas 75080
It's a lesson you learn very early in life. Many can be good, some may be better, but only one can be the best. The PK-232 is the best multi-mode data controller you can buy.

1 Versatility

The PK-232 should be listed in the amateur radio dictionary under the word Versatile. One data controller that can transmit and receive in six digital modes, and can be used with almost every computer or data terminal. You can even monitor Navtex, the new marine weather and navigational system. Don't forget two radio ports for both VHF and HF, and a no compromise VHF/HF/CW internal modem with an eight pole bandpass filter followed by a limiter discriminator with automatic threshold control.

The internal decoding program (SIAM™) feature can even identify different types of signals for you, including some simple types of RTTY encryption. The only software your computer needs is a terminal program.

2 Software Support

While you can use most modem or communications programs with the PK-232, AEA has two very special packages available exclusively for the PK-232...PC Pakratt with Fax for IBM PC and compatible computers, and Com Pakratt with Fax for the Commodore 64 and 128.

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.

3 Proven Winner

No matter what computer or terminal you plan to use, the PK-232 is the best choice for a multi-mode data controller. Over 20,000 amateurs around the world have on-air tested the PK-232 for you. They, along with most major U.S. amateur magazines, have reviewed the PK-232 and found it to be a good value and excellent addition to the ham station.

No other multi-mode controller offers the features and performance of the PK-232. Don't be fooled by imitations. Ask your friends, or call the local amateur radio store. We're confident the PK-232 reputation will convince you that it's time to order your very own PK-232.

Call an authorized AEA dealer today. You deserve the best you can buy, you deserve the PK-232.
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.

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.
No other repeaters or controllers match Mark 4 in capability and features. That's why Mark 4 is the performance leader at amateur and commercial repeater sites around the world. Only Mark 4 gives you message output in real speech; voice readout of received signal strength, deviation, and frequency error • 4-channel receiver voting • clock time announcements and function control • 7-helical filter receiver • extensive phone patch functions. Unlike others, Mark 4 even includes a microphone and a handsome cabinet.

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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, ±5 percent of a nominal value. The popular 3-500Z high-µ 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 ±2 percent of the full scale reading. This doesn’t leave much margin for error when you’re trying to ascertain voltage limits of ±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 ±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 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.
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!

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, W0SV, 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 dipole seems to generate...
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.

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 wire 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 OSL 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?)
Are you looking for a simple club project? How about a spare 2-meter receiver? A receiver to take backpacking? A scanning receiver for those times on the road? A digital data link? Radio control receiver? Direction finding receiver? Here's one that's hard to beat for simplicity and performance. One or two evenings and a little searching in the old junk box is all it takes.

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 IF 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 IF 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

By Rodney A. Kreuter, WA3ENK, 319 McBath Street, State College, Pennsylvania 16801
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ELECTRICAL SPECIFICATIONS:
Measured gain 15.8 dB
E-Plane beamwidth 2° x 11.5°
H-Plane beamwidth 2° x 12°
Gain tolerance ± 1.5 dB
Cross-polarization -15.5 dB
Polarization Error ± 2°
SWR 1.4:1

MECHANICAL SPECIFICATIONS:
Length 14 ft
Diameter 6" x 2" x 2½"
Wind Surface Area 78 sq ft
Cross-section 24% of area
2 Mast up 1½" diameter
Element insulation U.V. resistant
Black Delrin
Covers 100 MHz to 199.999 MHz in 1 kHz steps with thumbwheel dial
Accuracy +/- 1 part per 10 million at all frequencies
Internal FM adjustable from 0 to 100 kHz at a 1 kHz rate
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Table 1. MC3362 specifications

<table>
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<th>Feature</th>
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<tr>
<td>Second i-f</td>
<td>455 kHz</td>
</tr>
<tr>
<td>Power Supply</td>
<td>2 to 7 volts</td>
</tr>
<tr>
<td>Current Consumption</td>
<td>4 mA</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.7 microvolts</td>
</tr>
<tr>
<td>Maximum Frequency</td>
<td>180 MHz</td>
</tr>
<tr>
<td>First Mixer Input</td>
<td>690 ohms in parallel</td>
</tr>
<tr>
<td>Cost</td>
<td>$1.86 in 100-piece quantity</td>
</tr>
</tbody>
</table>

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.

**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.
from the signal. The limiter response is good to about 1 MHz. Output is dependent on the carrier “swing.”

A limiter is used to remove any a-m component 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-4551.

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). Perfbased 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 L1!

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 VCC plane. Actually, at 150 MHz and with proper power supply bypassing, the VCC 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 VCC 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

<table>
<thead>
<tr>
<th>parts list</th>
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<tbody>
<tr>
<td>C1</td>
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<tr>
<td>C3</td>
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<tr>
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<tr>
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<td>U1*</td>
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<td>U2*</td>
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<tr>
<td>U3*</td>
</tr>
<tr>
<td>Crystal*</td>
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Printed Circuit Board

All capacitors should be as small as possible.

All resistors 1/4 watt.

fig. 3. Plan view of 2-meter receiver showing parts placement.
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 MHz). 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.
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<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote #1</td>
<td>8080/20MHz, 4080/40MHz, 2080/80MHz</td>
</tr>
<tr>
<td>Remote #2</td>
<td>4080/40MHz, 2080/80MHz, 1080/10MHz</td>
</tr>
<tr>
<td>Remote #3</td>
<td>1080/10MHz, 5480/50MHz, 2480/25MHz</td>
</tr>
<tr>
<td>Remote #4</td>
<td>2480/25MHz, 12480/125MHz, 62480/625MHz</td>
</tr>
</tbody>
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Additional Features:
- Change of variables remotely:
  - Switching voice sel phone
  - Program default box or select ID list
  - Auto voice selections
  - Individual user voice
  - Variable frequency voice
  - Single mode only
  - J.L.E. Remote
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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 6 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 * in 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.)

Ham radio
all-new TM-721A FM dual bander

Kenwood's new FM Dual Bander includes a dual channel watch function, selectable full duplex operation, 30 multifunction memory channels, extended frequency coverage, large multicolor digital LCD displays, programmable scanning, with 45 watts of output on VHF and 35 watts on UHF.

Other features include:
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- 35 wans on UHF.
- plex operation, 30 multifunction memory chan-
- Dual channel watch function, selectable full du-
- other antennas between main and sub-band when a signal is
- CTCSS, and reverse. Channels “A and
- multicolor digital LCD displays, programmable
- Set upper and lower limits for programmable
- Bands “A” and “B” set upper and lower limits for programmable.
- Band scanner. Channels “C” and “D” store transfer and receive frequencies independently for “odd splits”.
- Dual frequency display for “main” and “sub-band.”
- Automatic Band Change (A.B.C) changes between main and sub-band when a signal is present.
- Dual watch function allows VHF and UHF receive simultaneously.
- Handset/remote control option (RC-10).
- Dual antenna ports.
- Programmable memory and band scanning, with memory channel lock-out and priority watch function.
- Supplied accessories: 16-key DTMF hand microphone, microphone hook, mounting bracket, and dc cable.

The suggested retail price is $649.95. For details see your Kenwood dealer or write Kenwood USA Corporation, Communications and Test Equipment Group, 2201 E. Dominguez Street, Long Beach, California 90810.

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 radiotelephone 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 801 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 alternating 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 802 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.

SAY YOU SAW IT IN HAM RADIO
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-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:

$$I_{off} = I_1 - I_2$$  

(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 ($R_1$) and feedback resistor ($R_2$), and produces an input offset voltage equal to the product of the current and the parallel combination of $R_1$ and $R_2$. By Ohm's law, this voltage is equal to:

$$V = \frac{I_{off} \cdot R_1 \cdot R_2}{R_1 + R_2}$$  

(2)
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 in 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:

\[ V_{out} = \frac{(V) (R1 + R2)}{R1} \]  

(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 offset 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. Therefore, the value of \( R3 \) is the parallel combination of \( R1 \) and \( R2 \), or:

\[ R3 = \frac{R1 \cdot R2}{R1 + R2} \]  

(4)

**Figure 4** shows the use of built-in offset null terminals on some op-amps.

![fig. 4. Use of offset null terminals on some op-amps.](image-url)
The potentiometer 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.

Figures 6 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 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, giving 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:

\[
V_2 = \frac{V1 \cdot R5}{R4 + R5} \tag{6}
\]

or, given the value of R5:

\[
V_2 = \frac{100 \cdot V1}{R4 + 100} \tag{7}
\]

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

\[
V_o = V2 \frac{R2}{R1} + 1 \tag{8}
\]

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 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. 10. Gain-Bandwidth plot for a typical op-amp.](image)
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C\text{req} = C \times B \quad (12)

Where:

C\text{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:

\[ B = \frac{R_1}{R_1 + R_2} \quad (13) \]

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:

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

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

\[ C_{\text{req}} = C \times B \quad (15) \]
\[ C_{\text{req}} = (30 \text{ pF})(0.091) \quad (16) \]
\[ C_{\text{req}} = 2.7 \text{ pF} \quad (17) \]

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.
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, \( F_1 \), the gain of the amplifier is given by the equation:

\[
A_v = -\frac{R_2}{R_1}
\]

At frequency \( F_1 \), the gain begins to drop off at a rate of \(-6\) dB per octave. The breakpoint frequency \( F_1 \) at which this happens is:

\[
F_1 = \frac{1,000,000}{2\pi R_2 C_1}
\]

Where:
- \( F_1 \) is the frequency in Hz
- \( R_2 \) is in ohms
- \( C_1 \) 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 \( 1/2\pi R_1 C_1 \), 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 \( C_1 \) (fig. 12) that has a capacitive reactance of approximately one-tenth the resistance of \( R_2 \).

**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**


Joe Carr, K4IPV, can be contacted at POB 1099, Falls Church, Virginia 22041. He welcomes your questions, comments, and criticisms.
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 (±0.05 percent) is used in this model, more accurate 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 ±0.05 percent (about ±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;

*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.

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

<table>
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</table>

f igs. 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 ±1 dB from 0 to 100 MHz (careful adjustment of C5 can reduce the flatness to less than ±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 ± 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-
ments 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. 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.

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.

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.

ham radio
summer thunderstorm noise

At any given moment an estimated 3600 thunderstorms are in progress around the world. They can be classified as air mass, frontal, or orographic, depending on how they’re formed. The main source of summertime QRN is the air mass thunderstorm, which builds up from the sun heating the ground and the air above it.

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 (typically 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 $E_s$ 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
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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Thirty, 40, 80, and 160 meters are all good for nighttime DX, even though the background noise is severe in the evenings. The direction of the openings will rotate from the east to the south and then westward in the morning. If you want to avoid thunderstorm QRN, sporadic E propagation may be helpful in the early evening toward the east and south. Try the early morning hours for communication paths to the west and monitor WWV or WWVH on 2.5 and 5 MHz as beacons.

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Ham Radio Magazine
Greenville, NH 03048
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 with each other. Two sine waves exactly in phase will reinforce each other. Two that are exactly out of phase (180 degrees out) will cancel each other.

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-

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.

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**

The dimensions of the reflector and director...
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.

<table>
<thead>
<tr>
<th>Reflector Length (Feet)</th>
<th>Spacing (Feet)</th>
<th>Driven Element Length (Feet)</th>
<th>Spacing (Feet)</th>
<th>Director Length (Feet)</th>
<th>Approximate Gain (dBd)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.6</td>
<td>5.21</td>
<td>16.8</td>
<td>3.47</td>
<td>16.1</td>
<td>4.5</td>
</tr>
<tr>
<td>17.6</td>
<td>6.95</td>
<td>16.4</td>
<td>5.21</td>
<td>16.1</td>
<td>7.8</td>
</tr>
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</table>

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

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 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 insulating 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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**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.)

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MISSOURI: July 17. The Zero Beaters ARC is sponsoring their 26th annual Zero Beaters Hamfest, on the 17th, at Millersville Park, Washington, 7 AM to 3 PM. Free admission. Parking fee. For information, contact Al Lanovmer, W0BQS, (314) 229-2072.

ILLINOIS: July 17. The Fox River Radio League’s annual Hamfest, Piccadilly Run Lodge, North Avenue, St. Charles. Doors open 8 AM. Advance tickets $4 plus SASE to Phil Fox, W9PQX, 104 May Street, West Chicago, IL 60185. Indoor/outdoor flea market, VEC exams. Free parking. Fly in to DuPage County Airport. Talk in on 145.700.000 or 1440.216-000. Commercial and inside tables contact Kermit Carlson, W9KKA, 36W93X McKee Rd, Batavia, IL 60510.


INDIANA: July 20-24. The County Hunters 28th 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 Amateurs should SASE for information and registration forms to Herb Morgan, W0SMGH, 736 East 50th Street, Marion, IN 46953.


ILLINOIS: July 31. The 54th annual Hamfest sponsored by the Hamfesters Radio Club, NEW LOCATION—Will County Fairgrounds, Plainfield, 5 AM to 3 PM DST. Admission $3 advance or $4 door. FCC exams, overnight parking. Nearby camping, Displays, swaps, door prizes. Talk in on 146.76 and 146.32. Club call W9RAA. For tickets send Check or MO in No. 10 SASE to Hamfesters Radio Club, 13068 Finch Ct, Lockport, IL 60441. For information John Schipke, W9YMR, 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 9 PM Saturday and continue through the night until noon Sunday at the Big Bend picnic shelter in conjunction with the annual ARAU “Radioport” DX Contest. To highlight this special event, the Lake Canton Field Day Committee will provide a commemorative certificate for contacts with event stations W0DSP, W4SLTM and other Amateur stations. Listen in the General phone portions 40-10M. Also 6M and 2M SSB.

INTERNATIONAL HAMFEST: July 7-9. VHF/HF 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. DO NOT use 9 AM CST to 9 PM CST. To receive the “Peace Garden Award” send a G5L and 3 IRC’s along with SASE to K9XVM, Dave Snider, 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, 15002 to 22002 and KY2Q, 5002 to 10002 on 40 and 15 meters. For information contact Herb, W2FXZ, or Jack, W2JRT, 833 State St., Oswego, NY 13126.

MARYLAND: July 23-24. The Laurel ARC will operate special event station W3GFZ from 18002 7/23 to 18002 7/24 from a small uninhabited island in Chesapeake Bay the world’s largest estuary, Feet: Lower 25 kHz of General 80-10m and 147.54. Attractive 8x11 certificate for SASE: G3L to LARC, PO Box 1496, Laurel, MD 20707.

July 23-29: The Long Island Mobile ARC will operate special event station W2WVL, CW and phone on all HF bands. G3L with sank via WA2LXK, 120 West Hudson Street, Long Beach, NY 11761.

HAM RADIO TODAY has joined the programming lineup from the Voice of the Andes, HCBR Radio, an international broadcasting station that has been operating from Quito, Ecuador, since 1931. Programming includes news from all over the world, construction kits, propagation news, equipment reviews and much more. For more information contact John E. Beck, Producer, HAM RADIO TODAY, c/o HCBR Radio, Box 68, Quito, Ecuador.

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, 2 forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 774-4023.

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100% Duty Cycle  
100 Memories  
Direct Keyboard Entry  
Optional Built-in AT  
On Sale Now, Call for Price! |
| YAESU | FT-767GX | VHF/UHF Base Station  
Add Optional 6m, 2m & 70cm Modules  
Full VFO's  
Lots More Features |
| ICOM | IC-761 | NEWEST HF SUPER RIG  
160-10M General Coverage Receiver  
Built-in Power Supply and Automatic Antenna Tuner  
SSB, CW, FM, AM, RTTY  
QSK to 60 WPM |
| ALINCO | ALD-24T | DUAL BAND MOBILE  
140-149.95 MHz / 440-450 MHz  
25 Watts on Both Bands  
Crossband Full Duplex  
21 Memory Channels  
CTCSS Encoder/Decoder, Standard |
| KENWOOD | TS-140S | NEW!  
HF Transceiver With General Coverage Receiver  
All HF Amateur Bands  
100W Output  
Compact, Lots of Features |
| YAESU | FT-736R | VHF/UHF Base Station  
SSB, CW, FM on 2 Meters and 70 cm  
Optional 50 MHz, 220 MHz or 1.2 GHz  
25 Watts Output on 2 Meters, 220 and 70 cm  
10 Watts Output on 6 Meters and 1.2 GHz  
100 Memories |
| ICOM | IC-735 | COMPACT HF TRANSCEIVER  
All HF Band/General Coverage Receiver  
12 Memories/Frequency and Mode  
USB, LSB, AM, FM, CW  
100 Watts Output  
Includes HM-12 Scanning Mic |
| KENWOOD | TM-221A | 2m FM Mobile Transceiver  
45W Output w/HiLo Switch  
14 Multi-Function Memories  
TM-421A Available For 440 MHz |
| YAESU | FT-212RH | THE "ANSWERING MACHINE" MOBILE  
Rx: 138-174 MHz  
Tx: 144-146 MHz  
45W Output  
Digital Voice Recorder  
FT-712 RH for 70cm |
| ICOM | IC-900 | SIX BANDS IN ONE MOBILE  
Remote Controller, Interface A Unit, Interface B Unit, Speaker, Mic and Cables  
Six Band Units to Choose  
10 Memories Per Band  
Programmable Band Scan  
Fiber Optic Technology |
| ASTRON | Power Supply | | |
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POCKET SIZE
SIZE: 4" H x 3.5" W x 1" D
MADE IN USA

OPTOELECTRONICS INC.

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TO 2.4 GHZ

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ALUMINUM CABINET
INTERNAL NI-CAD BATTERIES INCLUDED
AC ADAPTER/CHARGER INCLUDED

EXCELLENT SENSITIVITY & ACCURACY

AC-DC • PORTABLE OPERATION

Small enough to fit into a shirt pocket, our new 1.3 GHz and 2.4 GHz, 8 digit frequency counters are not toys! They can actually out perform units many times their size and price! Included are rechargeable Ni-Cad batteries installed inside the unit for hours of portable, cordless operation. The batteries are easily recharged using the AC adapter/charger supplied with the unit.

The excellent sensitivity of the 1300H/A makes it ideal for use with the telescoping RF pick-up antenna; accurately and easily measure transmit frequencies from handheld, fixed, or mobile radios such as: Police, firefighters, Ham, taxi, car telephone, aircraft, marine, etc. May be used for counter surveillance, locating hidden “bug” transmitters. Use with grid dip oscillator when designing and tuning antennas. May be used with a probe for measuring clock frequencies in computers, various digital circuitry or oscillators. Can be built into transmitters, signal generators and other devices to accurately monitor frequency.

The size, price and performance of these new instruments make them indispensable for technicians, engineers, schools, Hams, CBers, electronic hobbyists, short wave listeners, law enforcement personnel and many others.

STOCK NO:
#1300H/A    Model 1300H/A 1-1300 MHz counter with preamp, sensitivity: <1mV, 27MHz to 450MHz includes Ni-Cad batteries and AC adapter .................................. $169.95
#2400H   Model 2400H 10-2400 MHz microwave counter includes Ni-Cad batteries and AC adapter ...................................................... $299.95
#CCA   Model CCA counter/counter, for debugging, ultra sensitive, <50 micro volts at 150MHz-1-600 MHz with adjustable threshold, RF indicator LED. Includes Ni-Cad batteries and AC adapter .................................. $299.95

ACCESSORIES:
#TA-100S   Telescoping RF pick-up antenna with BNC connector ......................... $12.00
#P-100   Probe, direct connection 50 ohm, BNC connector .................................. $20.00
#CC-12   Carrying case, gray vinyl with zipper opening. Will hold a counter and #TA-100S antenna .......................................................... $10.00

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OPTOELECTRONICS INC.
5821 N.E. 14th Avenue
Ft. Lauderdale, Florida 33334

Orders to US and Canada add 5% of total ($2 min, $10 max)
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Foreign orders add 15%
Yaesu’s FT-736R
Because you never know who’s listening.

Why just dream of talking beyond earth?


You see, the FT-736R is the most complete, feature-packed rig ever designed for the serious VHF/UHF operator. But you’d expect this of the successor to our legendary FT-726R.

For starters, the FT-736R comes factory-equipped for SSB, CW and FM operation on 2 meters and 70 cm (430-450 MHz!), with two additional slots for optional 50-MHz, 220-MHz, or 1.2-GHz modules.

Crossband full duplex capability is built into every FT-736R for satellite work. And the satellite tracking function (normal and reverse modes) keeps you on target through a transponder.

The FT-736R delivers 25 watts RF output on 2 meters, 220 MHz, and 70 cm. And 10 watts on 6 meters and 1.2 GHz. Store frequency, mode, PL frequency, and repeater shift in each of the 100 memories.

For serious VHF/UHF work, use the RF speech processor. IF shift. IF notch filter. CW and FM wide/narrow IF filters. VOX. Noise blanker. Three-position AGC selection. Preamp switch for activating your tower-mount preamplifier. Even an offset display for measuring observed Doppler shift on DX links.

And to custom design your FT-736R station, choose from these popular optional accessories: Iambic keyer module. FTS-8 CTCSS encode/decode unit. FVS-1 voice synthesizer. FMP-1 AQS digital message display unit. 1.2-GHz ATV module. MD-1B8 desk microphone. E-736 DC cable. And CAT (Computer Aided Transceiver) system software.

Discover the FT-736R at your Yaesu dealer today. But first make plenty of room for exotic QSL cards. Because you never know who’s listening.
TS-940S
Competition class HF transceiver
TS-940S—the standard of performance by which all other transceivers are judged. Pushing the state-of-the-art in HF transceiver design and construction, no one has been able to match the TS-940S in performance, value and reliability. The product review with superlatives, and the field-proven performance shows that the TS-940S is "The Number One Rated HF Transceiver!"

- 100% duty cycle transceiver. Kenwood specifies transmit duty cycle time. The TS-940S is guaranteed to operate at full power output for periods exceeding one hour (14.250 MHz, CW, 110 watts.) Perfect for RTTY, SSTV, and other long-duration modes.
- First with a full one-year limited warranty.
- Extremely stable phase locked loop (PLL) VFO. Reference frequency accuracy is measured in parts per million!

Optional accessories:
- AT-940 full range (160-10m) automatic antenna tuner
- SP-940 external speaker with audio filtering
- YG-455C-1 (500 Hz), YG-455C-1 (250 Hz), YK-88C-1 (500 Hz) CW filters
- YK-86A-1 (6 kHz) AM filter
- VS-1 voice synthesizer
- SO-1 temperature compensated crystal oscillator
- MC-43S UP/DOWN hund mic.
- MC-60A, MC-80, MC-85 deluxe base station mics.
- PC-1A phone patch
- TL-922A linear amplifier
- SM-220 station monitor
- BS-8 pan display
- SW 200A and SW 2000 SWR and power meters
- IF-232C/IF-10B computer interface

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

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