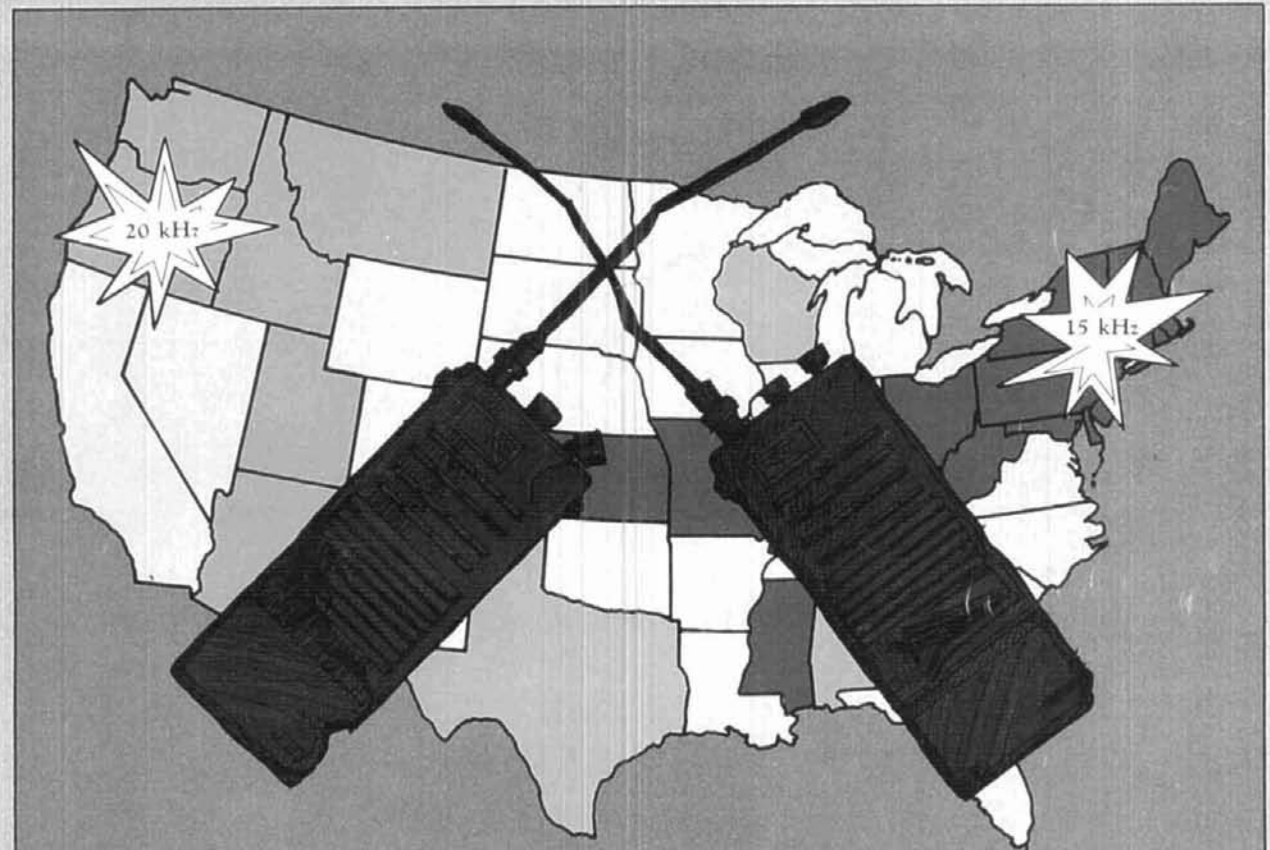
AUGUST 1985 / $2.50

ham radio magazine



15 vs 20 kHz – An Explosive Issue

hr

focus on communications technology

calculate the input impedance of tapered verticals • design toroidal tank circuits • stop blowing finals in the GLA-1000 • build a pulsed NiCad battery charger • run full power with a 3CX1200A7 amplifier • plus W1JR, W6SAI, W6MGI, and KØRYW

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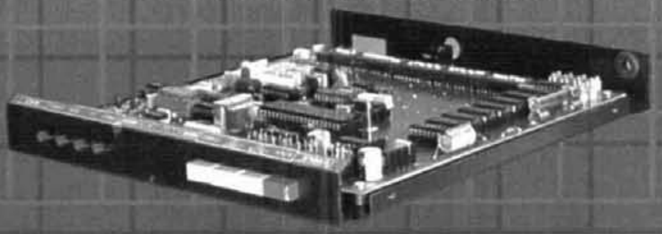

SMART PATCH is all you need to turn your base station into a personal autopatch. SMART PATCH uses the only operating system that gives the mobile complete control. Full break-in capability allows the mobile user to actually interrupt the telephone party. SMART PATCH does not interfere with the normal use of your base station. SMART PATCH works well with any FM transceiver and provides switch selectable tone or rotary dialing, toll restrict, programmable control codes, CW ID and much more.

To Take CONTROL with Smart Patch – Call 800-327-9956 Ext. 101 today.

Vhat To ook For In A hone Patch

he best way to decide hat patch is right for you to first decide what a atch should do. A patch hould:

- Give complete control to the mobile, allowing full break in operation.
- Not interfere with the normal operation of your base station. It should not require you to connect and disconnect cables (or flip switches!) every time you wish to use your radio as a normal base station.
- Not depend on volume or squelch settings of your radio. It should work the same regardless of what you do with these controls.
- You should be able to hear your base station speaker with the patch installed. Remember, you have a base station because there are mobiles. ONE OF THEM MIGHT NEED HELP.
- The patch should have standard features at no extra cost. These should include programmable toll restrict (dip switches), tone or rotary dialing, programmable patch and activity timers, and front panel indicators of channel and patch status.

ONLY SMART PATCH HAS ALL OF THE ABOVE.

Vow Mobile Operators Can Enjoy An Affordable Personal Phone Patch. . .

- Without an expensive repeater.
- Using any FM tranceiver as a base station.
- The secret is a SIMPLEX autopatch, The *SMART PATCH.*

SMART PATCH s Easy To Install

o install *SMART PATCH,* onnect the multicolored omputer style ribbon cable o mic audio, receiver iscriminator, PTT, and ower. A modular phone ord is provided for connection to your phone system. Sound simple? . . . T IS!

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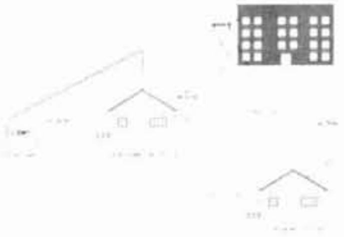
Placing a call is simple. Send your access code from your mobile (example: *73). This brings up the Patch and you will hear dial tone transmitted from your base station. Since *SMART PATCH* is checking about once per second to see if you want to dial, all you have to do is key your transmitter, then dial the phone number. You will now hear the phone ring and someone answer. Since the enhanced control system of *SMART PATCH* is constantly checking to see if you wish to talk, you need to simply key your transmitter and then talk. That's right, you simply key your transmitter to interrupt the phone line. The base station automatically stops transmitting after you key your mic. *SMART PATCH* does not require any special tone equipment to control your base station. It samples very high frequency noise present at your receivers discriminator to determine if a mobile is present. No words or syllables are ever lost.



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Use *SMART PATCH* for:

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- Mobile to Mobile via interconnected base stations for extended range. (see fig. 2.)
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ham radio magazine

AUGUST 1985

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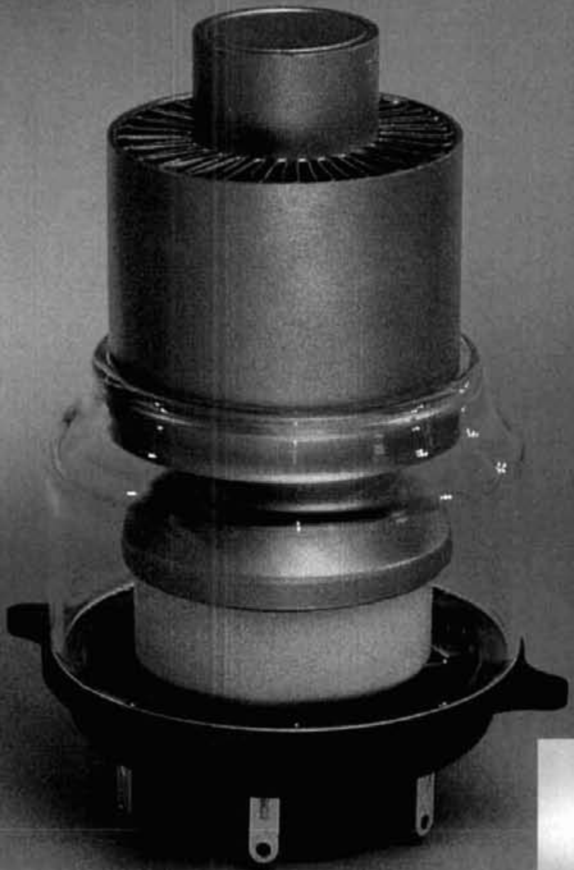

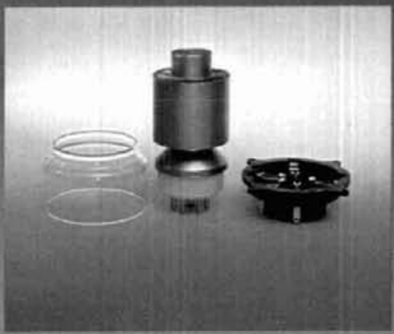

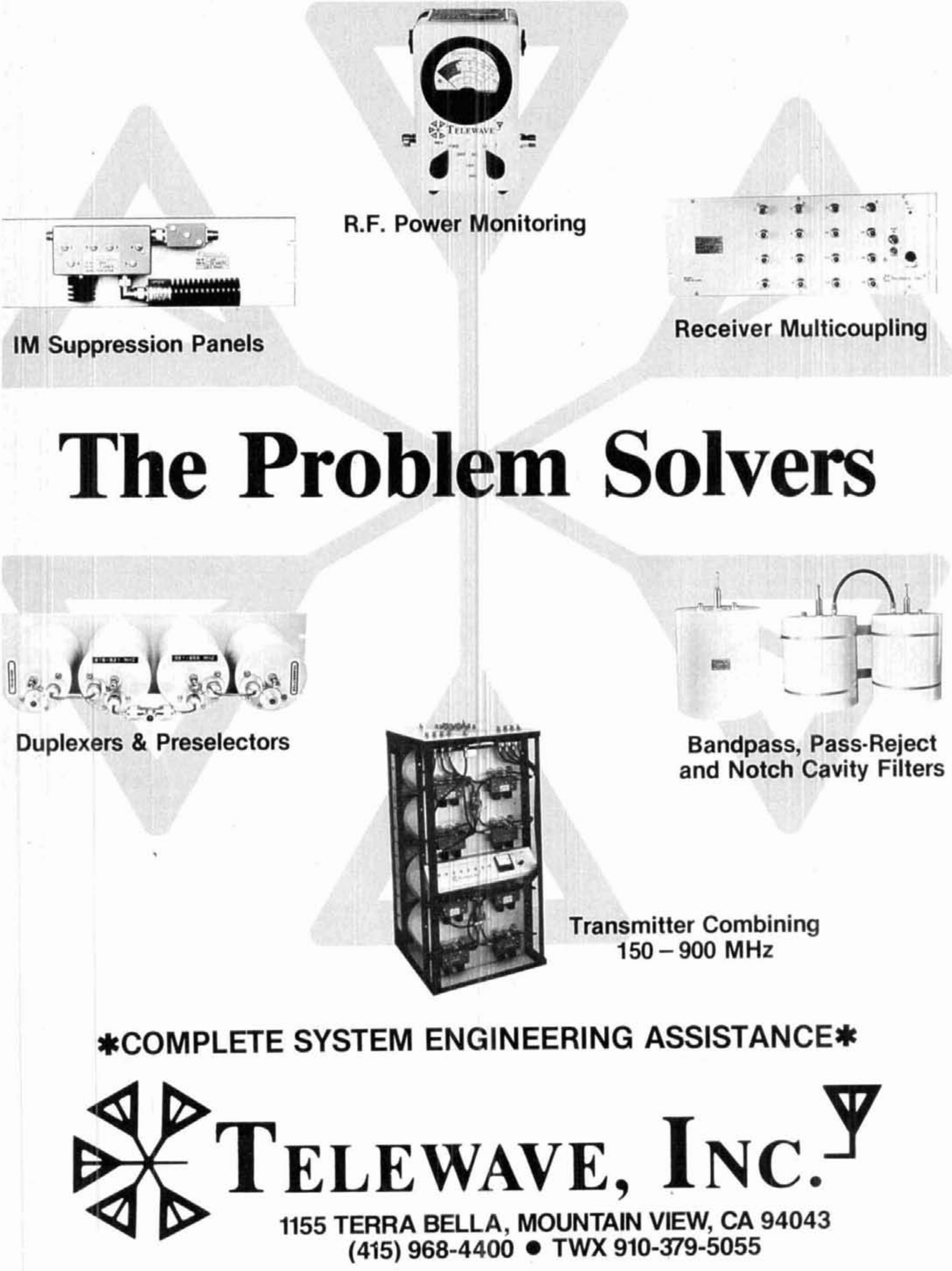

More Details? CHECK – OFF Page 126

✓ 112

presstop de W9JUV

STILL ANOTHER THREAT AGAINST 220 MHZ HAS BEEN MOUNTED by an oil exploration-related firm in Illinois. LAOAD Radio and Microwave Communications Consultants petitioned the FCC to allocate 216-220 MHz for use as 1033 ASCB data and voice channels, AND provide a 350 kHz segment of 220-222 MHz to be shared with Amateur Radio. Under terms of the proposal, LAOAD would advise the ARRL of pending operations, and the League would then alert Amateurs.

Little, If Any, Interference To Amateurs Would Result, the petitioner (W9GT, whose Norwegian call LAØAD inspired his company name) claims, as operations would be very short-lived and typically well removed from populated areas. However, 220 MHz users and others are very concerned that any such incursion could set a dangerous precedent for the future.

The Original Comment Period On RM-4983 Had Closed by presstime, but there has been considerable pressure to reopen it. Though the recent upsurge in interest in providing Novices with 220 MHz privileges (see below) certainly tends to diminish or at least postpone threats such as this one, it is still quite serious and should be challenged.

ARRL'S PETITION TO EXPAND NOVICE PRIVILEGES HAS RECEIVED its FCC Rule Making number, RM-5038, along with several other related petitions. In brief, the League proposal would give Novices limited 10-meter SSB and data privileges plus full privileges (with reduced power) on 220 and 1246-1260—see July Presstop for specific details. Somewhat similar petitions filed by KC5OQ include giving Techs and Novices ASCII (RM-5022)and phone (RM-5032) on part of 10 meters, some 30 meter privileges (RM-5024), and 220 MHz phone (RM-5025). The Comment period closed for KC5OQ's petitions July 11; a date hadn't been set for ARRL's at presstime, but its cutoff date should fall sometime in late July.

BROADCAST STATIONS MAY RETRANSMIT AMATEUR TRANSMISSIONS or use what they hear on the Amateur bands on the air, but any direct involvement between Amateurs and a broadcast station is expressly forbidden. In its June 7 Report and Order on BC Docket 79-47, the Commission agreed that the content of an Amateur transmission is not protected against reuse by others, but that to have, for example, an Amateur station at a broadcast studio to solicit traffic information during rush hours would be against the rules.

AMATEURS MAY BE ALMOST TWICE AS PRONE TO LEUKEMIA as the general population, a study reported June 23 by the New York Times News Service suggests. Underscoring ham radio Editor K2RR's July editorial, Washington state epidemiologist Dr. Samuel Milham, Jr. found the death rate from various forms of leukemia for 1691 California and Washington Amateurs who died between 1971 and 1983 was just about twice as high as would normally be expected. The increase was in myeloid and unspecified forms of leukemia; lymphatic and monocytic forms of the disease had no higher incidence among Amateurs than among others.

COMMENT DEADLINE FOR FCC'S NATIONAL REPEATER COORDINATION proposal (PR Docket 85-22) has been extended to August 15 in response to an ARRL request. The new Reply Comment date is September 30. Comments received thus far by the FCC have almost all been endorsements of the concept of national coordination, with few specific ideas on how to make it work.

VEC MAINTENANCE OF AMATEUR QUESTION POOLS WAS PROPOSED by the FCC in a Notice of Proposed Rule Making issued June 12. VEC-developed questions would have to follow the Commission's syllabus, and each pool would have to include at least 10 times the number of questions asked in that particular exam. At the same time the FCC also proposed moving up the date at which VECs may begin preparing their own exams. Comments on PR Docket 85-196 are due at the Commission by August 30, and Reply Comments by September 30.

One Regional VEC Has Already Dropped Out Of The Program, and another has said it plans to when the ARRL gets fully up to speed. Still another VEC has asked his Senator to look into the fee structure, as he feels his club isn't getting enough money for its efforts. For comparative purposes, NABER's fee for administering an exam for certification under its commercial examination program is $38!

The FCC's August VEC Meeting In Gettysburg Had Relatively Few signed up at presstime, despite a very promising program. Planned topics include improving speed of service, decreasing paperwork errors, and improving the integrity—real and perceived—of the program. Attendees will also meet the FCC people they've been dealing with and see the FCC's licensing facilities and procedures in operation.

Volunteer Examiners Are Now Averaging About 4000 Exam Elements Monthly, compared to a high of about 2750 exams a month when the FCC was still giving exams. However, the U.S. Amateur population is still well under its March, 1983, all-time high of 414,973; latest (May 30) figures show 410,846 individual FCC-licensed Amateurs.

U.S. AMATEURS MAY FINALLY USE OSCAR 10'S MODE "L" TRANSPONDER, under an FCC STA issued June 12. The Special Temporary Authorization permits uplink transmissions to OSCAR 10 from 1269.05 to 1269.85 MHz; an editorial error in the initial FCC release limited the STA to Extras only, but that was later corrected to include Technicians and above.

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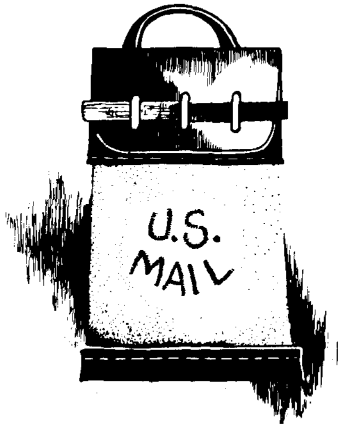


comments

can we talk?

Dear HR:

In the May, 1985, editorial it was noted that we Amateurs can't really communicate. I find this statement to be offensive, but in many respects accurate....

I find it offensive because I think it comes from a narrow perspective. It seems the persons making such statements see only one aspect of our hobby. I would agree that at times we really don't communicate much of anything interesting or important. The hard work and learning that made such contacts possible can't be judged on this evidence alone.

The major reason for this lack of ability to communicate clearly and effectively is a failure of our society and its education system, not the fault of Amateur Radio. We in Amateur Radio are only a reflection of the society which makes our hobby possible. Everywhere one looks these days, one can find someone writing about the deplorable state of our schools. We have students who can't read or write properly receiving diplomas and college degrees. To correct this sad state of affairs, we as a society will have to change our approach to education and discipline....

One last issue before I close. I don't think that many people, when they judge our ability to communicate, listen to 2 meters FM. This activity is one really bright spot in Amateur Radio when it comes to communication. Here you find truly local activity being carried out. In the case of my area, Southern New England, we have many fine activities taking place on repeaters and on simplex. We have a computer net on the W1XJ repeater that meets on Mondays at 8:30 PM, local time, where hams communicate ideas and educational information concerning this aspect of our hobby. We have several MSO-type RTTY bulletin board systems up and running, distributing Amateur information of all kinds. We now have active packet radio systems in operation with all sorts of bulletin boards, message systems, and other features that promote real communication.

Kenneth E. Stringham, Jr., AE1X
Attleboro, Massachusetts

service — not hobby

Dear HR:

Congratulations on an outstanding May issue!

It was especially interesting to read the editorial, "The Readers Speak," (page 4) regarding the problems and solutions before us. Let me call to your attention one of the problems that seems to have escaped your attention. It is one of perception, and it is reflected by you in your editorial by the use of the word "hobby" no fewer than five times. Of course, you are referring to the Amateur Radio "Service." It is, you know, a federally regulated "service" and not a "hobby."

Stamp collecting is a hobby. Model building is a hobby. Woodcraft is a hobby. Amateur Radio is a federally regulated *service* — even though it is perceived as a hobby by all too many hams and would-be hams.

Typically, hobbies don't require formal exams and licenses and involvement with federal regualtions. One has only to read Part 97 to see that the purpose and intent of Amateur Radio was not to establish a hobby, but rather a federally regulated communications service for the public interest, convenience, and necessity. Indeed, too many of us are overly involved in contesting and card-collecting — the hobby aspects of ham radio. But if it's presented to us as a hobby, why not?

Our organization, the Wireless Institute of New Orleans, was established by a group of dedicated hams to preserve the original principles of Amateur Radio and to promote the state of communications art. We continue to observe the degradation of ham radio into what appears to be an expanded version of the Citizen's Band. But what the hell? It's just another hobby, isn't it?

A.J. ("Buddy") Massa, W5VSR
New Orleans, Louisiana

matching dipoles

Dear HR:

Even though George A. Wilson, Jr., W1OLP, in "Matching Dipole Antennas," (May, 1984, page 129) made at least 24 separate references to GDO (Grid Dip Oscillators) and Grid Dipping, someone is certain to try substituting a solid-state dipper, (such as the Heathkit HD-1250 or one of several factory assembled versions) when exciting the RF Bridge discussed in the article. In fact, with the solid-state dipper far more prevalent today than the old vacuum tube grid dip oscillator (and interchangeable in most applications), no doubt a large number of hams who build the RF bridge will end up frustrated and with no discernible "dip."

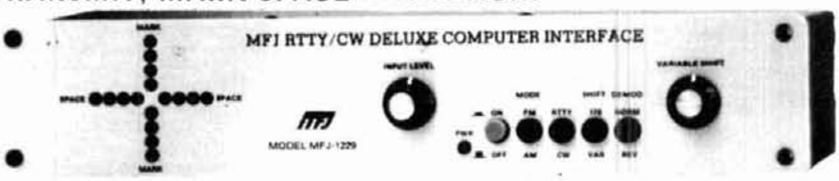
While the solid-state dippers can be used to determine resonance, per the first part of George's article, it is not likely to provide enough excitation to obtain a reading with the RF bridge unless overcoupled, with sensitivity set at maximum, and with an extremely sensitive μA meter used as the detector. Even a 50 μA meter will probably not allow a discernible "dip" to be obtained!

A rough idea of a dipper's suitability can be obtained by connecting a germanium diode and a small 2 to 3-turn link in series across the μA meter's terminals. Coupling the link to the dipper's coil should easily produce a full-scale reading. If it does not, the dipper cannot be used to excite the RF bridge.

Robert G. Wheaton, W5XW
San Antonio, Texas

NEW FROM MFJ

MFJ'S MOST ADVANCED RTTY/ASCII/AMTOR/CW COMPUTER INTERFACE HAS FM, AM MODES, LED TUNING ARRAY, RS-232 INTERFACE, VARIABLE SHIFT TUNING, 170/850 Hz TRANSMIT, MARK-SPACE DETECTION.



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Transmits on both 170 Hz and 850 Hz shift.

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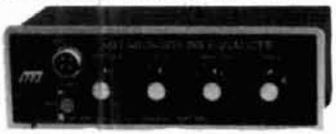

Greatly improves transmitted SSB speech for maximum talk power. Evens out speech peaks and valleys due to voice, microphone and room characteristics that make speech hard to understand. Produces cleaner, more intelligible speech on receiving end. Improves mobile operation by reducing bassy peaks due to acoustic resonances. Plugs between mic and rig. 4 pin mic jack, shielded output cable. High, mid, low controls provide ±12 db boost or cut at 490, 1170, 2800 Hz. Mic gain, on/off/bypass switch. "On" LED. 7x2x6 inches. 9 V battery, 12 VDC or 110 VAC with adapter, MFJ-1312, $9.95.

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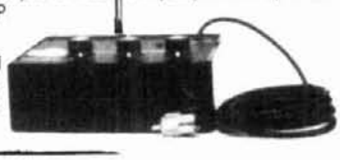

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FM repeater separation — 20 kHz *Yes*, 15 kHz *No*

Proving the point through VHF FM receiver selectivity measurements

Amateur use of the 2-meter (144-148 MHz) band is now under nationwide scrutiny in an effort to determine whether the channel spacing for FM sections of the band should be set at 15 kHz or 20 kHz. The original 30 kHz spacing was divided, as band use increased, into 15 kHz channels to allow more channels; this division led to increased adjacent channel interference in many areas, which in turn resulted in the current proposal to increase the channel spacing to 20 kHz.

Changing to the 20 kHz spacing will, of course, change the frequencies of some of the channels and change the overall number of repeater "pairs" in the band. Only the technical — not the political or emotional issues implicit in these changes — will be addressed in this article.

In trying to become better informed on the issue and thus establish a more substantial foundation for our decision in northern Colorado, we examined the nature of frequency modulation and its transmission and reception, and then made some measurements on several popular transceivers. We hope this information will be useful to other repeater groups and coordinators as they weigh this issue for themselves.

Our measurements were made to establish the actual performance levels of Amateur ("consumer") and professional ("commercial") receivers, with respect to adjacent channel rejection and variation of sensitivity with transmitter deviation setting.

frequency modulation

One factor that complicates any discussion of FM channel spacing is the varied levels of the understanding from one person to another of just how FM works. The following brief review may help to clarify the subject and shed some light on interpretation of our data.

In FM operation, the radio frequency output spectrum components vary as a function of the modulating (voice) signal amplitude. The resulting signal consists of a varying amplitude carrier and sideband pairs. (In narrow-band FM-only, the first sideband pair and carrier are significant in amplitude.) The amplitude of the carrier and sidebands is described by a mathematical term called a Bessel function of the first kind. The only thing we need to understand here is how much power is spread over how much spectrum, and what determines the signal (spectrum) width. Note that regardless of individual sideband or carrier amplitude, the *total* power of the FM signal is constant.

A simplified FM signal spectrum is illustrated in **fig. 1**. With no modulation applied, a single carrier term at a frequency f_c is visible. As the amplitude of the modulating signal is increased (from zero), a sideband pair displaced $\pm f_m$ from the carrier frequency appears. In this simplified version, we have assumed that a single-tone modulating signal (at frequency f_m) is used. Further increases in modulating signal amplitude cause additional sideband terms (pairs) to appear. At the same time, the amplitude of the carrier decreases. It is worthwhile reiterating that the total power of the FM signal is constant. This power distribution is a function of the modulation index β, which is defined as the ratio of frequency deviation (swing from carrier frequency) to modulating frequency (f_m). For small values of β, the bandwidth occupied by an FM signal is simply $2 \times f_m$. As β increases, more sidebands appear (separated f_m in frequency from each other). A natural further complication is that voice modulation can be considered to consist of many tones of varying

By **Chris Kelly, WD5IBS**, 1220 East Stuart #14, Fort Collins, Colorado 80525, and **Virgil Leenerts, WØINK**, 1007 W. 30th, Loveland, Colorado 80537

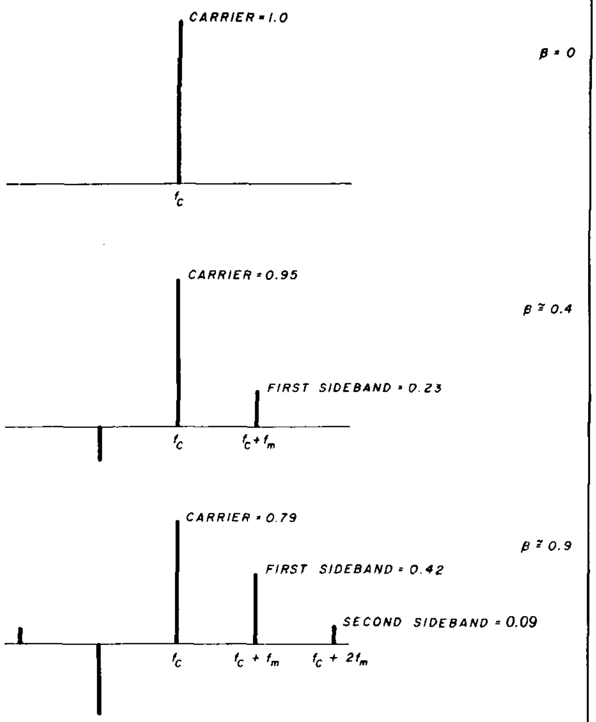

fig. 1. The spectrum distribution of an FM signal is a function of the modulation index β which in turn depends on the amplitude of the modulating (voice) signal. (*A*) the unmodulated carrier, (*B*) at a β of 0.4 a single sideband pair is evident with approximately 1/4 of the amplitude of the *un*modulated carrier, and (*C*) by increasing β to 0.9 a second sideband pair is also apparent. Notice that in both (*B*) and (*C*) the carrier power is reduced from its unmodulated value.

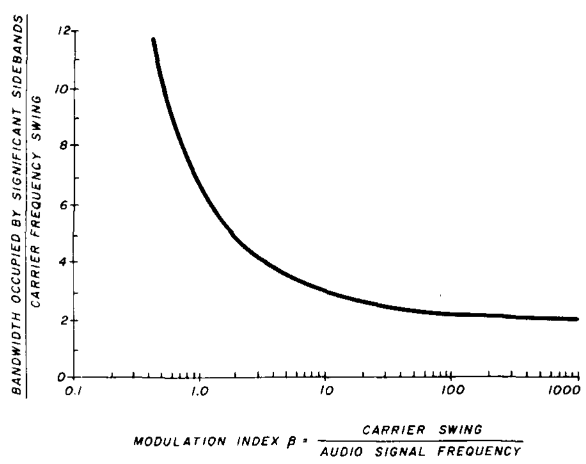

fig. 2. Bandwidth (normalized) versus modulation index β. (Adapted from C.E. Tibbs and G.G. Johnstone, *Frequency Modulation Engineering*, John Wiley & Sons, Inc., New York, as reproduced in *Reference Data for Radio Engineers*, Sixth Edition, Howard W. Sams, Inc., publisher.)

amplitudes. Consequently the total FM signal spectrum is quite complex.

For most VHF FM communications transceivers, this is 5 kHz deviation over 3 kHz maximum voice (modulation) frequency, or a β of 1.7 for high-pitched tones. Notice that lower deviation causes a lower modulation index. Using these figures, we find that 99.99 percent of the power in an FM signal will be contained in about 22 kHz of spectrum.[2] Depending on the assumed voice characteristics, this figure will change, and the older EIA specifications say that 99.99 percent of the power will occupy 19 kHz of spectrum.[3]

In the case of several FM signals, we do not have just narrow carriers that must be separated — we have finite bandwidth modulated signals occupying some spectrum.

For any given modulation frequency, we can decrease the modulation index, and thereby decrease the spectrum occupied, but not always in an exactly linear way. By increasing or decreasing the transmitter deviation control, the power ratios in the various sidebands will change, causing various effects on the radio channel and on the receiver.

effect of transmitter deviation on system performance

The Amateur 2-meter FM system is based on the commercial 5 kHz deviation FM system. System performance depends on the design and adjustment of the transmitters and the receivers used. However, design tradeoffs do exist.

Amateurs often discuss the effect of changing the deviation setting of ham transmitters, both in bandwidth and in effects on the receiver. We examined these two issues and made measurements of consumer gear and test equipment.

Figure 2 shows a curve of normalized significant bandwidth versus modulation index. Most Amateur transmitters adjusted for 5 kHz deviation will operate at a modulation index ranging between 3 and 6, depending on the operator's individual voice characteristics. The curve shows that in this range the curve begins to flatten, and that increasing deviation has less effect on bandwidth than at lower modulation indices. The "rules of thumb" used to roughly describe the bandwidth of FM signals involve a limited range where the slope of this curve can be considered constant. This is because as you decrease transmitter deviation, the modulation index for a given tone rises, changing the relative energy in each sideband.

Figure 3 illustrates the effect of the modulation index on the relative amplitude of FM sideband pairs. Consider the case of a 1 kHz tone, with the operator varying the deviation control on the transmitter. When the deviation control is at zero, all the RF power is contained in the unmodulated carrier. When the deviation rises to 1 kHz, the modulation index equals 1, and we

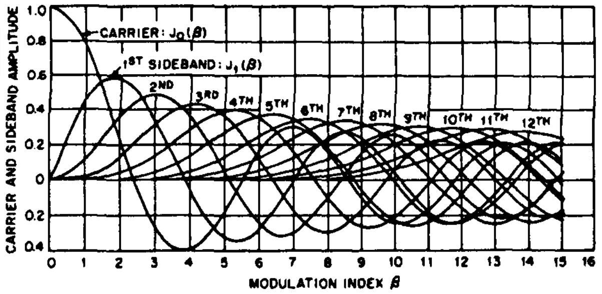

fig. 3. Plot of Bessel function of first kind as a function or argument β. (From P.F. Panter's *Modulation, Noise, and Spectral Analysis*, as reproduced in *Reference Data for Radio Engineers*, Sixth Edition, Howard W. Sams, Inc., publisher.)

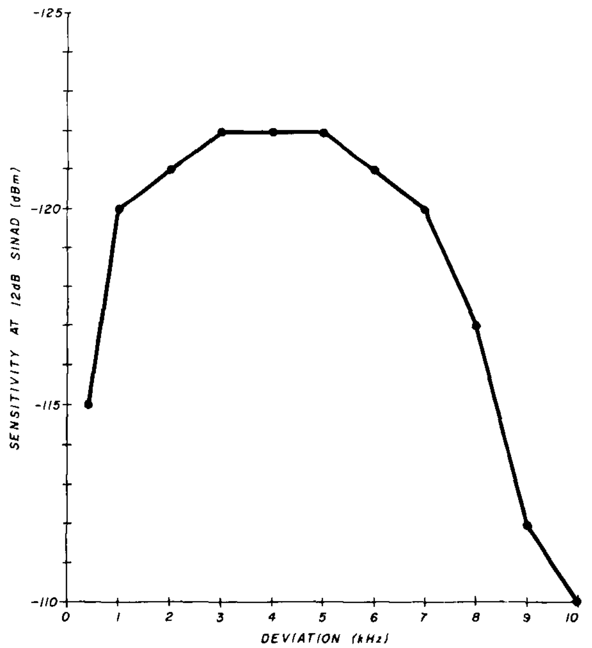

fig. 4. Effect of deviation on sensitivity for a popular Amateur 2-meter transceiver.

see a decrease in carrier power and increases in the first and second sidebands. In fact, there are increases in every sideband, but they are too small to show on this chart. At 1 kHz deviation, we see that the amplitude of the first sidebands has risen to about 0.44 times the original carrier level, and each sideband contains about 19 percent (0.44 squared) of the RF power. Now each of the second sidebands has about 1 percent (0.11 squared) of the RF power, and the carrier has only about 60 percent of the power.

As we raise the deviation to 5 kHz, the modulation index rises to 5 (5 kHz deviation/1 kHz modulation) and we can see that significant energy is now found in almost all sidebands up to the eighth. (Actually, there is energy present in other sidebands, but this chart cannot illustrate that.) The sidebands are spaced at intervals corresponding to the frequency of the modulating tone (1 kHz).

Note also how the modulation index varies with the modulating tone. Consider what would happen if we left the transmitter at 5 kHz deviation, but raised the modulating tone to 2000 Hz. The modulation index would drop to 2.5, and we would have to examine **fig. 3** at this new point to determine the relative amplitude of sidebands at the new index. Here, only the first five sidebands are noticeable — but remember, these sidebands are now 2 kHz apart. The bandwidth of the signal has increased, but it has not doubled.

It should be noted that this discussion of single-tone modulation is a very simplified version of what happens when voice is used to modulate the carrier. The voice is composed of many frequencies, and the composition changes with time. The components of the FM signal are many, and not just the sum of the voice frequencies. Consider a case of just two tones modulating the carrier. There will be carriers with amplitude of the Bessel function (J_0) at the deviation ratio of the first tone, the Bessel function (J_0) of the second tone, and sidebands having lines of all Bessel functions of f_1, f_2, $f_1 + f_2$, $f_1 - f_2$, $f_1 + 3f_2$, $3f_1 + f_2$, and so on.

If you now consider the complexity of the human voice, the problem of mathematically describing the bandwidth becomes unmanageable, at least for this author. For this reason the discussions here are limited to single-tone modulation.

The second aspect of performance affected by the deviation adjustment of the transmitter is how well the receiver is able to demodulate these signals. This is a very easily measured parameter. We checked the perormance of an Amateur receiver when receiving signals at different deviation values. In this test, we used a Hewlett-Packard 8640B signal generator and a SINADder. We measured the sensitivity of the receiver at the 12 dB SINAD point at deviations of 500 Hz, and 1 kHz through 10 kHz deviation in steps of 1 kHz. The results of the test are shown in **fig. 4**.

Notice that maximum sensitivity (−122 dBm at 12 dB SINAD) occurs at 3, 4, and 5 kHz deviation. The sensitivity is not affected by changes in deviation within this range. But above 5 kHz and below 3 kHz deviation, the sensitivity actually decreases. This result contradicts the popular notion that increasing the deviation of a transmitter increases range, and further indicates that reduction of transmitter deviation below 5 kHz does not reduce range (down to no less than 3 kHz, that is).

receiver selectivity

Although the performance of a receiver in rejecting

table 1. Level of isolation from interference experienced on channels separated from 10 to 30 kHz from an adjacent FM source.

Kenwood TW-4000A. On channel signal: −115 dBm, ±3 kHz deviation, 1000 Hz modulation.

interference modulation	30 kHz (dB)	20 kHz (dB)	15 kHz (dB)	10 kHz (dB)
400 Hz (EIA)	86	80	45	0
800 Hz	86	80	40	0
1200 Hz	86	80	33	0
2000 Hz	86	68	25	0
Kenwood TR-7800. On channel signal: −114 dBm, ±3 kHz deviation, 1000 Hz modulation				
400 Hz (EIA)	87	82	65	2
800 Hz	87	83	57	0
1200 Hz	87	83	48	0
2000 Hz	87	79	37	0
Handheld 1. On channel signal: −115 dBm, ±3 kHz deviation, 1000 Hz modulation				
400 Hz (EIA)	69	52	35	0
800 Hz	69	52	34	0
1200 Hz	69	52	30	0
2000 Hz	69	52	25	0
Motorola Syntor-X, 460.425 MHz. On channel signal: −107 dBm, ±3 kHz deviation, 1000 Hz modulation.				
400 Hz (EIA)	93	85	53	13
800 Hz	93	85	53	13
1200 Hz	93	85	50	20
2000 Hz	93	84	43	8

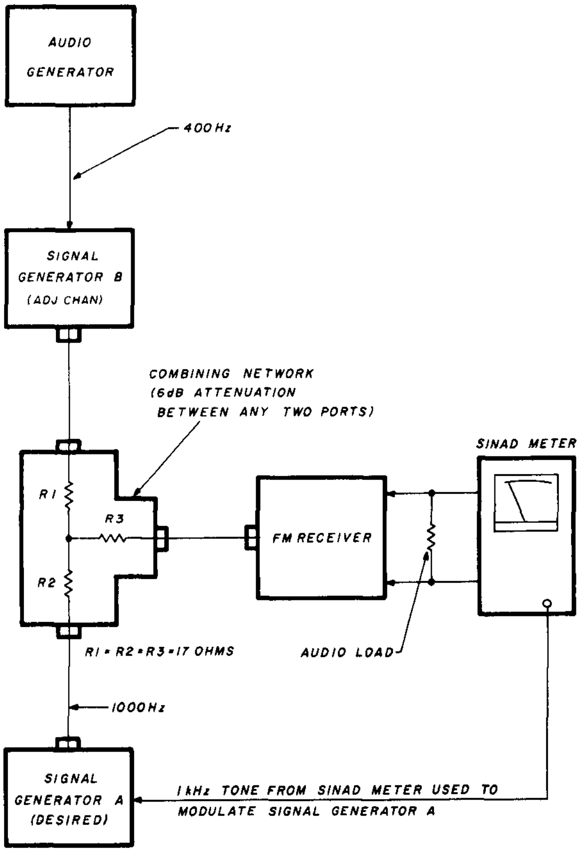

fig. 5. Setup is used to perform the adjacent channel selectivity tests. (From *Standard Radio Communications Manual* by Harold Kinley, © 1985, Prentice- Hall, Englewood Cliffs, N.J. 07632. Reprinted by permission of the publisher.)

off-channel signals is something that cannot be adjusted easily, it is a major element of any radio communications system. A receiver consists of RF, IF, discriminator, and audio sections with most of the selectivity provided by the IF filter section. Intermodulation products and images can be generated in the RF and mixer stages. However, these are not directly related to the problem of adjacent channel interference — the IF filter and discriminator are.

Most FM receivers use crystal or ceramic filters to narrow the IF bandwidth before the signals reach the discriminator, where they are demodulated (back) to audio frequencies. While it would be nice if we could build ideal filters that would pass all signals in the desired passband and completely stop all off-channel signals, this isn't possible. Filters actually have finite passbands with "skirts" that roll off signals more the further away from the channel center frequency they are. The filters are usually specified by their bandwidth at the −6 dB and the −60 dB points; this is also how most ham transceivers are specified for selectivity.

Because the actual performance of the radio depends on this and other, less easily described factors — including discriminator performance — commercial manufacturers have therefore elected to specify their receiver selectivity with a functional test that actually challenges the receiver with a signal in the adjacent channel and measures the result. This is the test we selected and performed to determine selectivity.

The Electronic Industries Association (EIA) has established an adjacent channel rejection test based on the ratio between the on-channel to off-channel signal strengths when the received signal-to-noise and distortion (SINAD) ratio becomes degraded by 3 dB by the adjacent channel signal. This test, part of the RS 204-C test, is performed by mixing the signals from two signal generators and measuring the SINAD of a 1000 Hz tone modulating the on-channel signal at 3 kHz deviation.[4]

The test setup used to perform the selectivity test is shown in **fig. 5**. The on-channel signal level is raised to obtain a 12 dB SINAD, then raised an additional 3 dB. The off-channel signal is modulated at 3 kHz deviation by a 400 Hz tone, and its signal level is raised until the SINAD is degraded back down to 12 dB. Then the ratio of the two signals' strength is calculated in dB. When this measurement is made for both the next higher and the next lower adjacent channels, the lower of the two figures is used.

When the EIA established these tests for selectivity, they also established standards they consider "mini-

the action is at the IF — not the RF — stages

When the problem of adjacent channel interference is examined, attention is focused on the filtering that takes place at the intermediate frequency (IF) stages of the receiver, not at the radio frequency (RF) stages. The reason the IF gets the attention is the very narrow bandwidth required to allow separation of channels within the receiver's radio frequency input bandwidth.

At the RF frequencies, cavity resonators are usually used by repeaters and helical resonators are found in commercial and some consumer receivers. These filters are used to control the receiver's RF bandwidth to improve performance in terms of sensitivity and reduction of out-of-band signal strength. By this filtering, desensitization ("desense") and intermodulation distortion ("intermod") are reduced. However, these filters are typically 50 kHz to several Megahertz wide, and match the input RF stages to the intended operating range of the receiver. These filters are therefore very wide compared to the spacing of the channels (15 or 20 kHz), and will not have any significant filtering effect on those adjacent channels signals.

In the IF amplifier chain, however, the very narrow filters required become practical, due to both the lower frequency used in the IF (typically from 0.455 to 10.7 Megahertz) and the fact that the intermediate frequency does not have to be varied as the radio changes operating frequencies. In the IF stages, crystal filters are most commonly used to obtain very high "Q" (resonant frequency divided by bandwidth), frequency stability and shape factor (bandwidth at −60 dB divided by −6 dB bandwidth). These filters are commonly built with very narrow passbands (12 to 20 kHz wide for FM, and as little as 250 Hertz wide for CW applications). Even these filters do not act as "brick-walls," passing all signals in the passband and completely stopping all signals outside of the passband, since their out-of-band attenuation increases as the off-channel signal moves farther away from the passband. The slope of this attenuation is another factor in the response of a receiver to the adjacent channel rejection test, and together with the filter bandwidth (3 dB bandwidth) is a major factor in determining receiver performance in the test.

The IF filter, then, plays a key part in determining the receiver's response to adjacent channel interference, while the filtering at the RF stages of the receiver has little or no effect on this problem.

mum acceptable" performance. For this test, performed on the adjacent channels, the minimum acceptable standard is 70 dB isolation from the adjacent channel.

In these tests, we used a pair of HP 8640B VHF generators, chosen for their spectrally pure output signals (SSB phase noise below −130 dBc), as the signal sources. The SINAD was measured using a Helper Instruments "SINADder 5."

After the normal RS-204-C tests, we also measured selectivity with different frequencies of modulating tone on the adjacent channel signal. We did this because we believed that the choice of a 3 kHz deviation and a 400 Hz modulation tone may not be realistic for direct comparison with the ham environment, since our DTMF tones and voices contain higher frequency components than 400 Hz, and our transmitters may be adjusted for greater deviation. While we did not change the deviation setting, we made additional measurements with tones of 800, 1200, and 2000 Hz at 3-kHz deviation.

We measured receiver performance in this way, at channel spacings of 10 kHz, 15 kHz, 20 kHz, and 30 kHz. The seven units we tested included one commercial and three consumer mobile transceivers as well as three handhelds.

results with consumer gear

The results with consumer equipment are shown in **figs. 6A, B,** and **C**. Note that at 10 kHz spacing, little or no adjacent channel rejection is evident, and signals within 10 kHz of the channel center frequency are treated as "on-channel" by the receivers. This gives some idea of the bandwidth of each receiver's IF filter.

At 15 kHz separation, the adjacent channel isolation (of an unmodulated carrier) is about 45 to 70 dB. With the introduction of modulation, the interfering signal component is up by as much as 30 dB from ideal.

At 20 kHz, the adjacent channel isolation is about 80 dB, and some adjacent channel modulation is still detected. In most cases, the 20 kHz measurement was within a few dB of the receiver's ultimate rejection (as measured at 30 kHz separation).

At 30 kHz, the adjacent channel isolation is about 85 dB, and there is no change in this figure because of modulation frequency change. This figure shows little variation among the mobile rigs, but the handheld unit shows slightly lower performance (70 dB). (See appendix for further details.)

results with commercial gear

Motorola loaned us a commercial UHF "SYNTOR-X" which tuned to 460 MHz. (A VHF unit was not available.) At UHF, commercial manufacturers and Amateurs use 25-kHz channel spacing, but shop personnel believe that both VHF and UHF radios have similar specs and IF designs. *We believe this test is*

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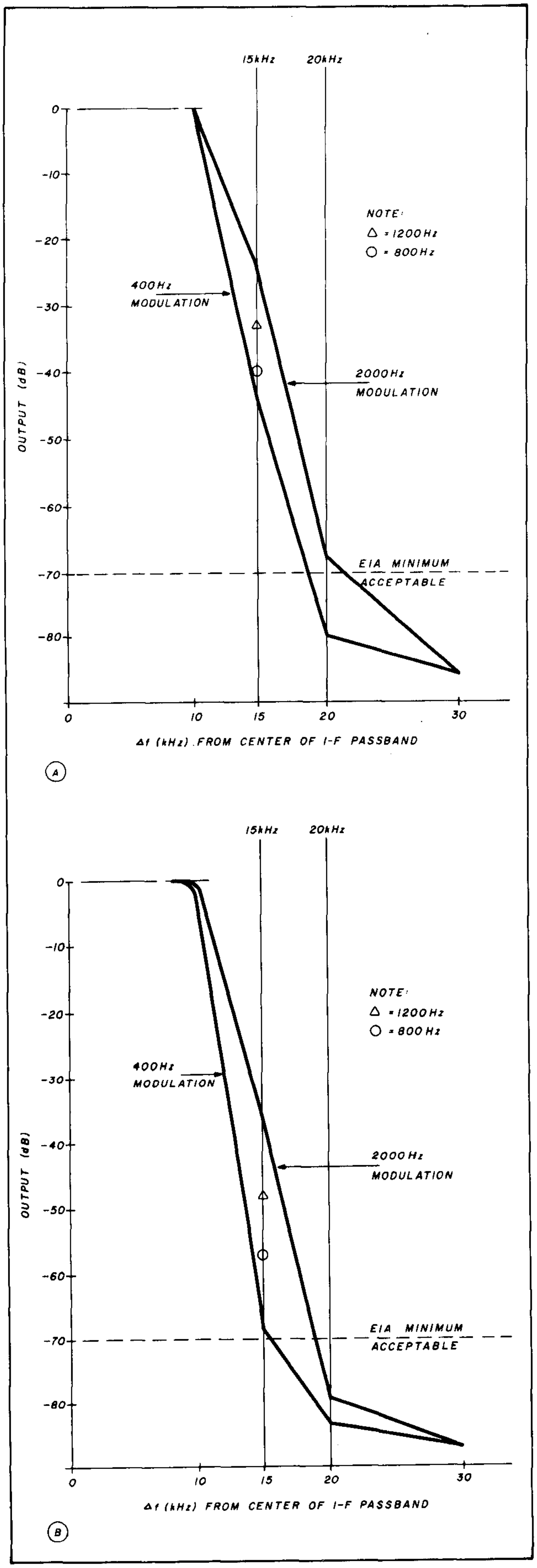

therefore representative of commercial receiver performance at VHF.

At 10 kHz, the SYNTOR showed slight rejection (see **fig. 7**), about 10 dB, of the interfering signal, indicating a slightly narrower IF filter than found in the consumer gear. Still, the low value means that receiver bandwidth is approximately 15-20 kHz total.

At 15 kHz, the SYNTOR showed 53 dB isolation, which was degraded by 10 dB when the modulating tone was increased to 2000 Hz. This again indicates, as in the case of the consumer gear, that we are on the skirts of the IF filter.

At 20 kHz, the isolation increased to 85 dB and was degraded only 1 dB by increasing the modulating tone to 2000 Hz.

At 30 kHz the SYNTOR showed 93 dB isolation, actually better than its specifications by several dB. Varying the modulating tone made no difference during the measurements.

discussion

Two major results are evident in this data. First, while commercial radio gear offers higher performance

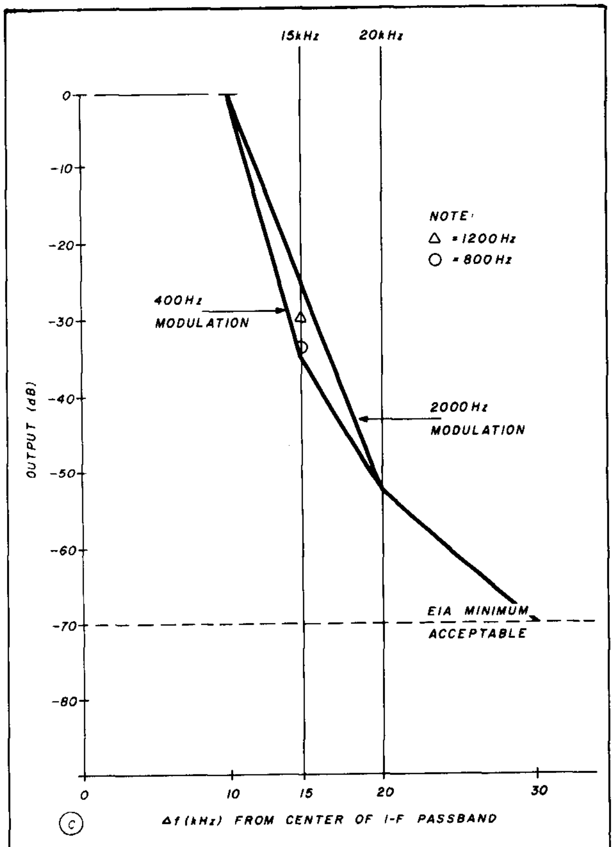

fig. 6. Effect of modulating frequency on selectivity test. Performed on three consumer (Amateur band) transceivers using 3 kHz deviation and 400 Hz (RS-204-C test), 800 Hz, 1200, and 2000 Hz modulation tones. (*A*) Kenwood TW-4000A, (*B*) Kenwood TR-7800, and (*C*) Handheld, HT1.

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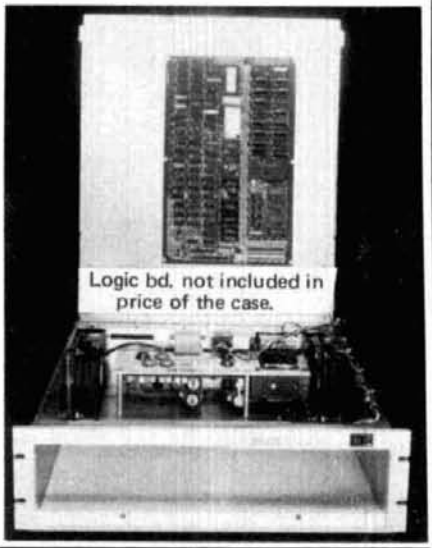

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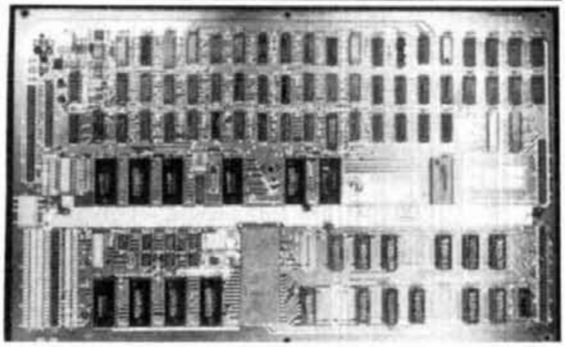

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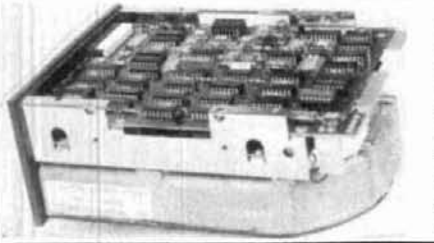

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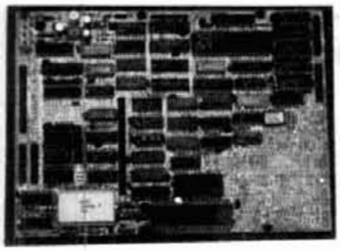

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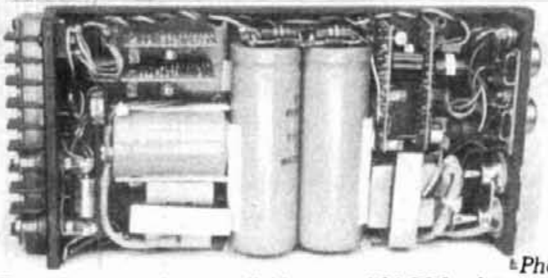

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why do we use FM?

Considering the ongoing discussions of channel spacing and FM bandwidth, one might ask why hams use FM, which occupies such a large bandwidth compared with AM or single sideband (SSB). The answer lies in the improved signal-to-noise ratio (S/N) gained by the demodulator in an FM receiver. If you compare the signal-to-noise ratio of the demodulated signal with the carrier to noise ratio (C/N) of the radio wave before demodulation, you find that above a certain threshold, the demodulated signal shows a significant enhancement in S/N. The measurement of C/N must be made in a bandwidth equivalent to the IF bandwidth of the receiver, but within these constraints, we find an enhancement factor of: $E = 6\beta^2(\beta + 1)$ where β is the modulation index of the FM signal.*

To see how significant this enhancement is, consider the case of a 1000 Hz tone modulating a carrier at 4.5 kHz deviation, and a beta of 4.5, not unusual in Amateur voice systems. In this case, the enhancement is 668 times the carrier to noise ratio, or about 28 dB.

This enhancement, seen only above a threshold C/N, is one reason FM is popular for both commercial broadcasting and communications. Below this threshold, FM actually provides lower S/N than other modes, which is why weak-signal work is seldom done using FM.

*Simon Haykin, *Communications Systems*, John Wiley & Sons, 1983.

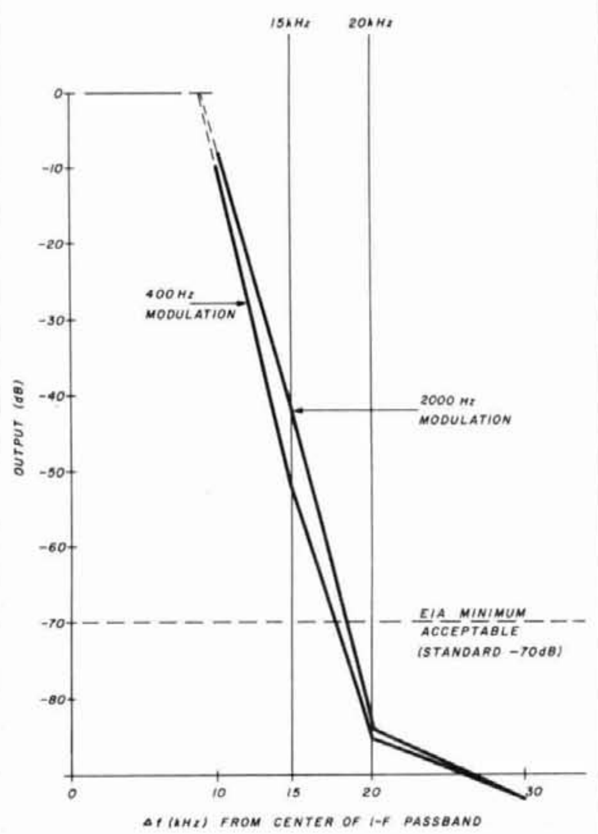

fig. 7. Selectivity test performed on a commercial UHF transceiver (Motorola "SYNTOR-X"). Both the EIA RS-204-C and 2000 Hz tones were used.

than consumer radios, the differences are not particularly large. Secondly, when operated at 15 kHz spacing, all these receivers will exhibit considerably degraded performance when compared to their use at 20 kHz.

On the first result, we wish to note that in the last several years, commercial radio suppliers have changed their radio designs from a relatively limited coverage radio to one that can cover channels separated by many Megahertz. This has been done by reducing filtering at the RF stages and enhancing the IF filters to maintain performance. While this reduction of the Q of the RF portion of the receivers does not alter the adjacent channel rejection, the enhancement of the IF stages does. The SYNTOR-X model is capable of covering the entire 450 MHz commercial band without retuning the RF stages, and represents first-class commercial radio equipment, with a price near $2800.

We expected, and found, excellent IF performance in the Motorola gear. The surprise was that the IF performance of the consumer gear *was actually quite similar*, and for most Amateurs the difference would not be significant — this was a surprise to us because we suspected that by adopting commercial standards for Amateur purposes, the interference problem could be solved. But the answer is clearly not that simple.

On the second result, we believe that when these radios are operated with 20 kHz channel spacing, they demonstrate performance which is near their ultimate design goal (as defined by their 30 kHz performance). At 15 kHz spacing, these radios *all* demonstrated very similar degradations in performance, and these degradations amounted to 30 to 40 dB. Furthermore, this degradation was significantly affected by the *bandwidth* of the interfering signal. Considering the conservative settings (3 kHz deviation, 400 Hz modulation) we believe the 15 kHz isolation numbers are generous compared to the Amateur environment, where 4.5 to 6 kHz deviation seems more common.

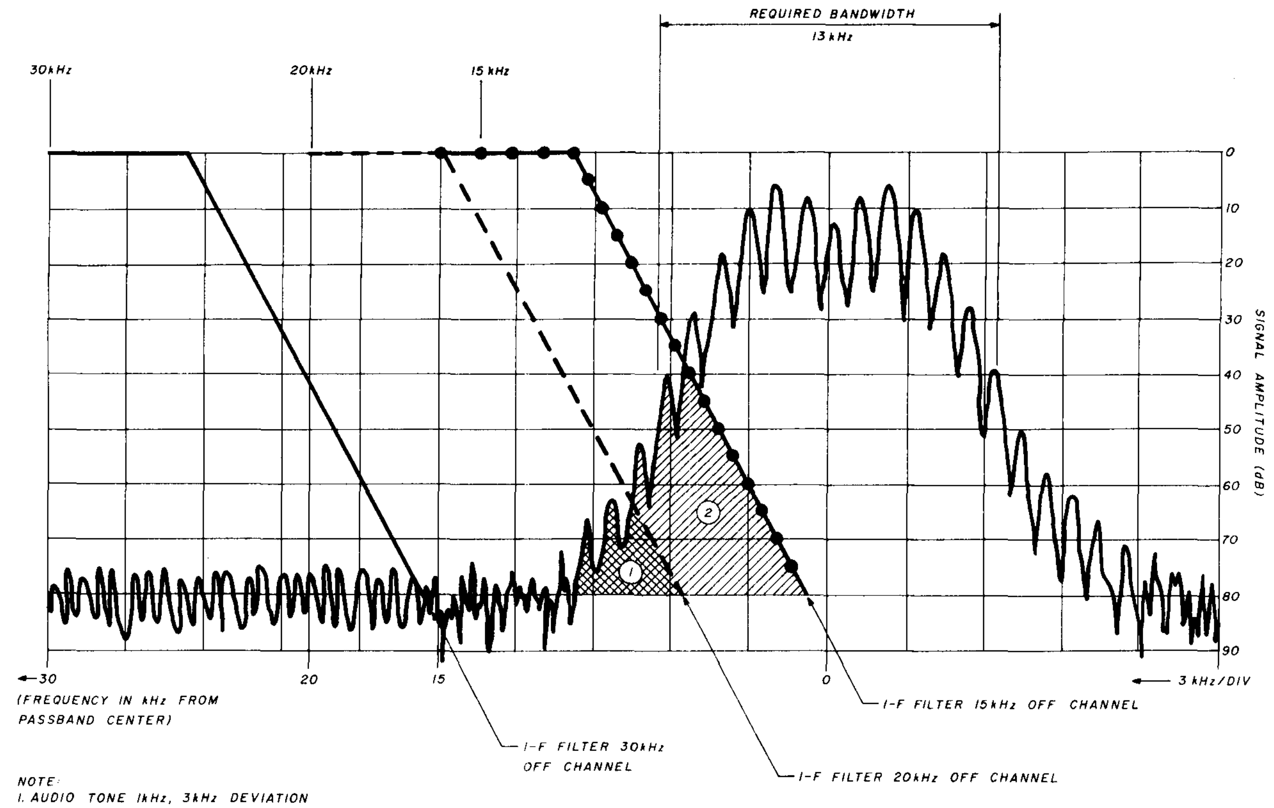

fig. 8. This graph clearly illustrates the need for at least 20 kHz separation between repeater channels.

Finally, when these results are compared with the EIA specification for minimum acceptable adjacent channel rejection, we see that all the receivers failed the test at 15 kHz spacing, and all but the handheld unit passed the test at 20 kHz spacing (see appendix).

The mechanism for this adjacent channel interference depends on both the nature of FM itself and the design of the receiver IF filters. What we believe is happening is shown in **fig. 8**. In this diagram, we have illustrated the shape of the FM signal resulting from a 1 kHz tone modulating a transmitter at 3 kHz deviation. First note the zone called "required bandwidth," which is the legendary 13 kHz wide. This zone shows the sidebands down to −40 dB from the carrier's unmodulated level. It is evident that some remaining sidebands are present, down to the −80 dB level, with the noise floor of the test instrument, an HP8568B spectrum analyzer.

On the left of the diagram, we have illustrated the filter shapes of typical consumer receivers spaced 30, 20, and 15 kHz away from the carrier frequency of the signal. Notice that at 30 kHz spacing, no power from the signal is entering the receiver's passband, down to the resolution of the instrument. At 20 kHz spacing, the edge of the receiver passband intersects a small portion of the signal, indicated by the area labeled *1*. At 15 kHz spacing, more of the signal is in the receiver passband, as noted by areas *1* and *2*. While it would be difficult to quantify the difference from this diagram, our tests have shown that this difference is in the range of 30 to 45 dB. If the more liberal EIA RS-204-C test were performed, using a 400 Hz tone, the receivers would pass at 20 kHz separation and *fail* at 15 kHz spacing.

We hope this report is informative and will be useful as you make your decisions on coordinating repeaters, both in frequency and geographical separation.

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appendix

Of the three handhelds tested (HT1, HT2, and HT3 — see **table A1**) variation existed from one unit to the other and also from the better side to the worse side of the filter. Because this test is made on the side of the filter (response) and not farther away from the passband, *the results will be very sensitive to the frequency to which the receiver is tuned.* Therefore, if the receiver drifts, it will change the better and worse isolation figures even more. There is also something else at work here: notice that HT3 shows considerable variation at 15 kHz from one side of the filter to the other, but its figures are more nearly equal at 20 and 30 kHz than HT1's. This is a dramatic demonstration of why a performance test like this is so much more revealing than merely quoting the nominal specification of the filter element.

table A1. RS-204-C test results for three handhelds (interfering signal, 400 Hz).

Channel Spacing:		15 kHz	20 kHz	30 kHz
dB isolation	(HT1)	32/50	48/70	69/77
	(HT2)	58/69	76/80	83/83
	(HT3)	23/66	70/73	76/77

This table is not meant to compare one brand name against the other (thus the anonymity) since none of the units are at their brand-new performance levels, but have been in use for varying lengths of time. Variation between individual units of a given model may also be considerable. To compare given models fairly, we would have to test several of each type to obtain a sample large enough to be considered representative of its series.

More important, though, is the difference in readings between the upper and lower adjacent channel tests and its effect on performance. Remember, the EIA (specification) procedure calls for using the lower of the two figures.

Finally, perhaps the EIA-70 dB specification is not meant for HTs; considering their intended use, it may be acceptable for HTs to have a lower isolation value since they are typically operated closer to the repeater and use a much lower gain and altitude antenna than found on most home or mobile installations.

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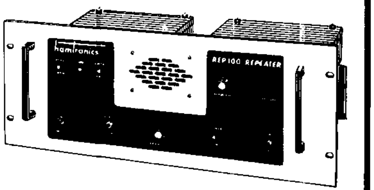

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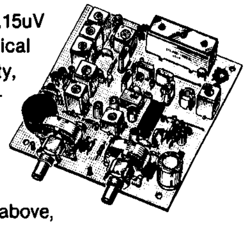

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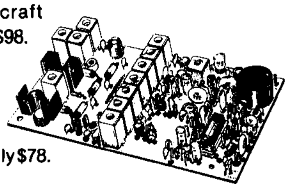

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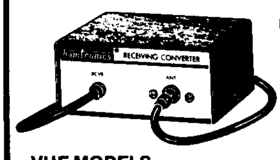

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50-54	144-148
144-146	28-30
145-147	28-30
144-144.4	27-27.4
146-148	28-30
144-148	50-54
220-222	28-30
220-224	144-148
222-226	144-148
220-224	50-54
222-224	28-30
432-434	28-30
435-437	28-30
432-436	144-148
432-436	50-54
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28-29	145-146
28-30	50-52
27-27.4	144-144.4
28-30	220-222*
50-54	220-224
144-146	50-52
50-54	144-148
144-146	28-30

For UHF, Model XV4 Kit $99 Wired $169

Exciter Input Range	Antenna Output
28-30	432-434
28-30	435-437
50-54	432-436
61.25	439.25
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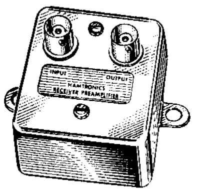

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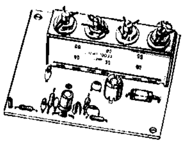

Model	Tuning Range	Price
HRA-144	143-150 MHz	$49
HRA-220	213-233 MHz	$49
HRA-432	420-450 MHz	$59
HRA-( )	150-174 MHz	$54
HRA-( )	450-470 MHz	$64

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calculating the input impedance
of a tapered vertical

Schelkunoff procedure — best method to use

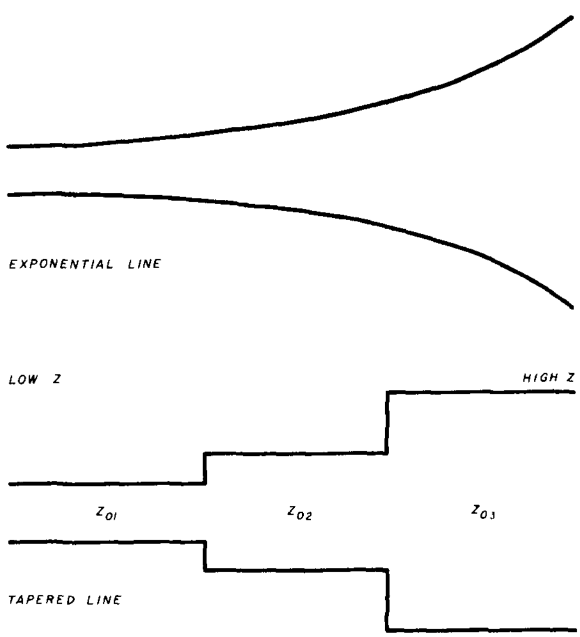

fig. 1. Comparison between tapered and exponential transmission line.

In the last decade there has been a tendency among Radio Amateurs to use vertical whip antennas on 80 and 160 meters. One clear advantage of using tapered whip elements, constructed of aluminum tubing, is their durability under severe weather conditions. But the fundamental question and the main obstacle to even more widespread Amateur use of the antenna is the problem of accurately determining the antenna feedpoint impedance for various tapers.

For cylindrical element length-to-diameter ratios, the feedpoint impedances are readily solvable by analytical methods such as Hallen's integral equation,[1] the induced EMF method,[2] and Schelkunoff's input impedance equation.[3] Using a computer and the "method of moments" approach, employing matrix algebra techniques,[4] will also provide answers.

which approach to use?

The basic question to be answered is what method should be employed to solve for the feedpoint impedance of a tapered vertical before its actual construction begins. Perhaps a clue is provided in the analytical method described by James Lawson, W2PV, in his well-known *ham radio* series on Yagi-Uda antennas.[5] Lawson stated that the inductance to capacitance (L/C) ratio of a tapered element is related to a geometrical mean diameter. Each cylindrical section has its own L/C ratio, or more specifically, its own surge impedance $Z_0 = \sqrt{L/C}$. This formula is used to describe an exponential (Collins) transmission

By Walter J. Schulz, K3OQF, 3617 Nanton Terrace, Philadelphia, Pennsylvania 19154

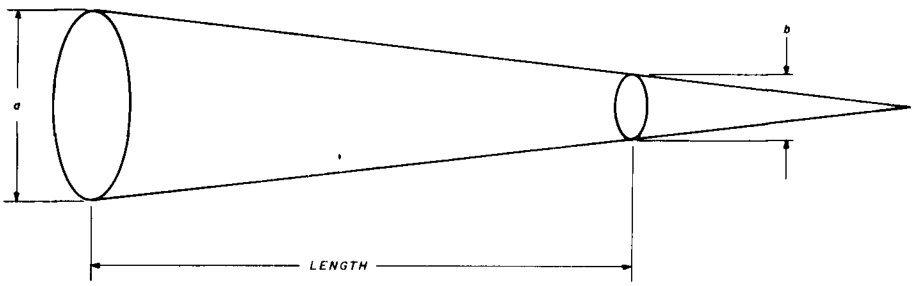

fig. 2. A tapered antenna element can be considered as a truncated cone.

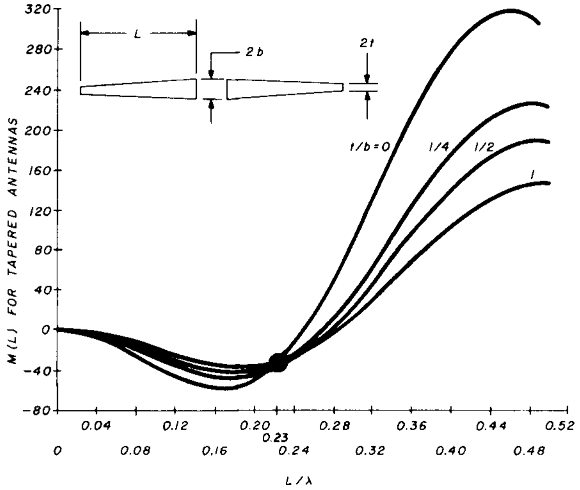

fig. 3A. "M" factor versus normalized length for tapered antenna elements. (Adapted from Sergei A. Schelkunoff's *Advanced Antenna Theory*, John Wiley and Sons, New York, 1952.)

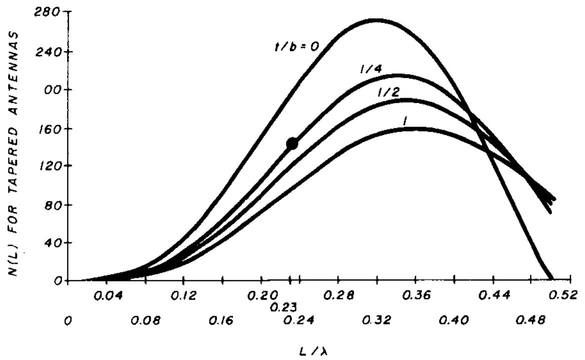

fig. 3B. "N" factor versus normalized length for tapered antenna elements. (Adapted from Sergei A. Schelkunoff's *Advanced Antenna Theory*, John Wiley and Sons, New York, 1952.)

line used for matching two different impedances (see **fig. 1**). Notice that each section of the exponential transmission line has its own surge or characteristic impedance. An impedance transformation occurs in either direction as a result of the taper. Consequently a tapered antenna element can be considered as a tapered exponential transmission line that has an average characteristic impedance described as a geometrical mean of its diameter.

W2PV took note of this physical relationship, applied that relationship to Yagi elements, and developed a method to evaluate the taper. An even earlier method, developed by Sergi A. Schelkunoff at Bell Labs is easier to work out — with either a pencil and paper or with a handheld calculator — yet still provides accurate results.

describing a tapered vertical

A tapered vertical element may be thought of as a truncated cone, as shown in **fig. 2**, with specific base and tip diameter and length, using cylindrical elements that telescope into one another, exhibiting impedance discontinuities at each section boundary. Consequently, **eq. 1** can be used to describe a tapered vertical element shape factor.[7]

$$Z_0 = 60\ \ell n(2L/b) + 60\ t/b - t\ \ell n(t/b) \qquad \textbf{(1)}$$

where L = length (inches)
b = base radius (inches)
t = tip radius (inches)

Not only was Schelkunoff able to determine the shape factor, but he was also successful in making the necessary engineering approximations to equate antennas to transmission line behavior. This resulted in the modification of the basic transmission line formula for the solution of feedpoint impedance values for arbitrarily shaped antennas.[3]

$$Z_{in} = Z_0 \frac{R_a \sin G + j(X_a - N)\sin G - j(2Z_0 - M)\cos G}{(2Z_0 + M)\sin G + (X_a + N)\cos G - jR_a \cos G} \quad (2)$$

$$R_a = 60(\gamma + \ln 2G - Ci2G) + 30(\gamma + \ln G - 2\,Ci\,2G + Ci\,4G)\cos 2G + 30(Si\,4G - 2\,Si\,2G)\sin 2G \quad (3)$$

$$X_a = 60\,Si\,2G + 30(Ci\,4G - \ln G - \gamma)\sin 2G - 30\,Si\,4G\cos 2G \quad (4)$$

where M and N values are taken from **figs. 3A** and **3B**

- G = antenna height in radians
- γ = 0.5772
- Si = sine integral
- Ci = cosine integral

example

It is desired that a vertical whip antenna is to operate on 3.8 MHz. Its height is 60 feet (18.29 meters) or 720 inches (1829 cm). The base diameter is 3 inches (7.62 cm) and its tip diameter measures 3/4 inch (2 cm). What is the vertical feedpoint impedance at this operating frequency? It is assumed that the vertical sits on a perfect ground radial system that has a minimum resistance.

Step 1. Find the shape factor (Z_0).

$$Z_0 = 60 \ln \; 2\cdot\frac{720}{1.5} \; + 60 \; \frac{0.375}{1.5} \; - 0.375\cdot\ln \; \frac{0.375}{1.5} = 384.3$$

Step 2. Find the M and N values from **figs. 3A** and **3B.**

$$\text{with } t/b = \frac{0.375}{1.5} = 0.25$$

$$M(1) = -38 \text{ and } N(1) = +125$$

Step 3. Express fractional wavelength of antenna in degrees or radians.

$$fractional\ wavelength = \frac{height}{984/Freq\ (MHz)}$$

$$= \frac{60}{(984/3.8)} = 0.2317$$

$$0.2317\cdot 360° = 83.4°$$

$$\text{or } \frac{83.4°}{57.3°} = 1.4557 \text{ radians}$$

Step 4. Calculate R_a value.

$$R_a = 60[0.5772 + \ln 2.9114 - (+0.15)]$$
$$+30[0.5772 + \ln 1.4557 - 2(+0.15) + (-0.10)]\cos 2.9114$$
$$+30(1.4356 - 2\cdot 1.8431)\sin 2.9114 = 58.2$$

Step 5. Calculate X_a value.

$$X_a = 60(1.8431) + 30(-0.10 - \ln 1.4557 - 0.5772)\sin 2.9114$$
$$-30\cdot 1.4356\cdot\cos 2.9114 = 145.31$$

Step 6. Calculate the vertical feedpoint impedance.

$$Z_{in} = 384.3 \left[\frac{58.2\sin 1.4557 + j(145.3 - 125)\sin 1.4557 - j(2\cdot 384.3 + 38)\cos 1.4557}{(2\cdot 384.3 - 38)\sin 1.4557 + (145.3 + 125)\cos 1.4557 - j58.2\cos 1.4557}\right]$$

$$Z_{in} = (384.3 + j0)\left[\frac{57.8 - j72.5}{756.8 - j6.7}\right] = (384.3 + j0)(0.0772 - j0.0951) = 29.7 - j36.5$$

$$= 29.7 \text{ ohms} - j36.5 \text{ ohms}$$

Using an HP-41C calculator eliminated the manual labor and produced answers more quickly (see **Appendix**).

This program can be used not only on tapered vertical antennas, but on tapered Yagi elements as well. To do this, calculate half the dipole length just as if it were a vertical, and then multiply the answer by two. This new product is the feedpoint impedance for a tapered dipole element.

```
01◆LBL "ZB"
02 XEQ "Ra"
03 RCL 05
04 SIN
05 *
06 STO 16
07 CLX
08 XEQ "Xa"
09 RCL 06
10 -
11 RCL 05
12 SIN
13 *
14 ENTER↑
15 XEQ "O"
16 RCL 07
17 -
18 RCL 05
19 COS
20 *
21 -
22 STO 17
23 CLX
24 XEQ "Ra"
25 RCL 05
26 COS
27 *
28 -1
29 *
30 STO 14
31 CLX
32 XEQ "O"
33 RCL 07
34 +
35 RCL 05
36 SIN
37 *
38 ENTER↑
39 XEQ "Xa"
40 RCL 08
41 +
42 RCL 05
43 COS
44 *
45 +
46 STO 15
47 CLX
48 RCL 17
49 RCL 16
50 RCL 14
51 RCL 15
52 XROM "C/"
53 RCL X
54 STO 18
55 CLX
56 RCL Z
57 STO 19
58 CLX
59 0
60 ENTER↑
61 XEQ "ZO"
62 RCL 19
63 RCL 18
64 XROM "C*"
65 "ZB IN=R"
66 AVIEW
67 RCL X
68 STOP
69 CLX
70 "J="
71 AVIEW
72 RCL Z
73 STOP
74 END
```

```
01◆LBL "ZO"
02 RCL 09
03 RCL 10
04 -
05 1/X
06 RCL 10
07 *
08 60
09 *
10 ENTER↑
11 RCL 10
12 RCL 09
13 /
14 LN
15 *
16 ENTER↑
17 RCL 11
18 2
19 *
20 RCL 09
21 /
22 LN
23 60
24 *
25 +
26 STOP
27 END
```

```
01◆LBL "O"
02 XEQ "ZO"
03 2
04 *
05 RTN
06 END
```

```
01◆LBL "Ra"
02 RCL 04
03 LN
04 .5772
05 +
06 RCL 06
07 CHS
08 +
09 60
10 *
11 ENTER↑
12 RCL 05
13 LN
14 .5772
15 +
16 RCL 06
17 2
18 *
19 CHS
20 +
21 RCL 03
22 +
23 RCL 04
24 COS
25 *
26 30
27 *
28 +
29 ENTER↑
30 RCL 01
31 2
32 *
33 CHS
34 RCL 02
35 +
36 RCL 04
37 SIN
38 *
39 30
40 *
41 +
42 STOP
43 RTN
44 END
```

```
01◆LBL "Xa"
02 RCL 03
03 RCL 05
04 LN
05 -
06 .5772
07 -
08 30
09 *
10 RCL 04
11 SIN
12 *
13 ENTER↑
14 RCL 01
15 60
16 *
17 +
18 ENTER↑
19 RCL 04
20 COS
21 RCL 02
22 *
23 30
24 *
25 CHS
26 +
27 STOP
28 RTN
29 END
```

fig. A1. HP41C calculator program for finding feedpoint impedance of tapered vertical antenna.

appendix

HP-41C calculator program for finding feedpoint impedance of tapered vertical antenna

HP-41C instructions

- Execute SIZE and key in 020.
- Key in ZB program and subroutines Z_0, O, R_a, X_a.
- Key in functions memory register 01 to 11.
- Execute program ZB.
- Each subroutine answer will be displayed, to continue program depress R/S key.

functions	memory registers
Si 2G	STO 01
Si 4G	STO 02
Ci 4G	STO 03
2G	STO 04
G	STO 05
Ci 2G	STO 06
M function	STO 07
N function	STO 08
base radius	STO 09
tip radius	STO 10
length	STO 11

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5. James L. Lawson, W2PV, *ham radio*, January, February, May, June, July, September, October, November, December, 1980. (*For limited time only a set of nine back issues containing W2PV's series of articles on yagi antenna design will be made available at the reduced price of $9.86 postpaid to U.S. addresses, $16.95 to addresses outside the U.S. Foreign payment accepted in U.S. funds drawn on U.S. bank only. Address request to Ham Radio's Bookstore, Greenville, NH 03048. Supplies are limited; order promptly.*)
6. James L. Lawson, W2PV, "Yagi Antennas: Practical Designs," *ham radio*, December, 1980, page 33.
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ham radio

August 1985

short circuit

In "Voltage Controlled Oscillator Uses Ceramic Resonators," (K2BLA, June 1985, page 23), two base bias resistors for the 2N3904 were inadvertently omitted from **fig. 8**. Add a 2.2k resistor from base to ground and a 10k resistor from the same base to +15 VDC.

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Many solid state amplifiers, by virtue of their extremely low load impedances, use this technique; this is one reason for their reasonably small size. Yet only a few experimenters have actually tried using the toroid in the high impedance circuits of the vacuum tube.

After reading this article, you'll be able to either modernize the amplifier you have on the shelf or start from scratch, building one from the many excellent schematics available in periodicals, in Bill Orr's *Radio Handbook*,* or in the various ARRL publications.

What effect does continuous high power have on the core? The high impedance of vacuum tubes causes the toroid core to become hot, causing its characteristics to change. The core would also saturate at the higher frequencies, causing instability and destruction of its composition. But the core described in this article will easily handle in excess of 2 kW maximum peak power, with no instability or saturation. (When I finished testing, the core was barely warm to the touch. Before you touch the coil, be sure the B+ is off and capacitors fully discharged to avoid shock.)

The toroid used was an Amidon T-400-2A. A nearly exact substitute for this is two Amidon T-400-2 units sandwiched together. If the amplifier you want to build is less than the 2 kW class, then a single T-400-2 core can be used. Even more space can be saved by using a pair of 3-inch (7.6 cm) T-300-2 toroids. These, however, will require five or six more turns of wire.

choosing the right tube is an important first step

You must now decide on the type tube or tubes you intend using in your amplifier. Grounded grid operation in class AB1 is a favorite for single sideband. Let's suppose you have a number of 4CX300A tubes and sockets or 4CX250Bs or Fs that were obtained surplus. The very first number you must come up with is the operating plate load impedance. This you determine

By **Robert E. Bloom, W6YUY,** 8622 Rubio Avenue, Sepulveda, California 91343

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from the level of plate voltage and current you'll be running. This information can be obtained from the sources previously mentioned or from data sheets from the tube manufacturer.

Suppose, for example, that SSB is your main interest and a pair of 4CX300A tubes is available. We've already stated that grounded grid would be the choice. But the 4CX series of tubes requires screen and grid bias voltages, so to call the operation "grounded grid" would be inaccurate. The tubes would really be running in a cathode driven circuit with the grids at RF ground potential, but above ground at DC so that the necessary voltages could be applied.

With drive applied in class AB operation, each tube draws 250 mA at a plate voltage of 2000 volts. This translates to a total input power level of 1000 watts. Output efficiency in this class of service is between 60 and 65 percent, or just over 650 watts. A circuit Q of 12 is needed to sustain the proper energy storage in the tank circuit.

determining plate load resistance

We now have all of the information necessary to calculate one of the more important values needed, and that is the load impedance, R_p, the tubes will present to the input of the Pi network. For class AB operation

$$R_p = \frac{V_p}{1.8 \cdot I} \qquad (1)$$

where V_p = plate voltage
I = total plate current

$$\frac{2000}{1.8 \times 0.5} = \frac{2000}{0.9} = 2222 \text{ ohms}$$

For class "B" operation the formula becomes

$$R_p = \frac{V_p}{2\, I_p} \qquad (2)$$

Values of components C1, C2, and L1 in a pi configuration are readily available.[1] An abbreviated version of it is provided in **table 1**. The data is divided into columns headed by the various values of plate load resistance in increments of 250 ohms. The tables are usually calculated for a Q of 10 or 12. C1 is called out as the plate tuning capacitor and C2 as the loading capacitor. The purpose of the pi networks is to step down the high level of plate load impedance to some value between 25 and 100 ohms to match the load, which is usually an antenna or possibly a dummy termination.

pi values for other load impedances

The plots provided in **figs. 1, 2,** and **3** can be used to find component values for intermediate load impedances simply by linearly interpolating. For example, if the value of capacitor C1 is needed for a load impedance half way between 1500 and 2000 ohms on the 160 meter band, take the arithmetic mean:

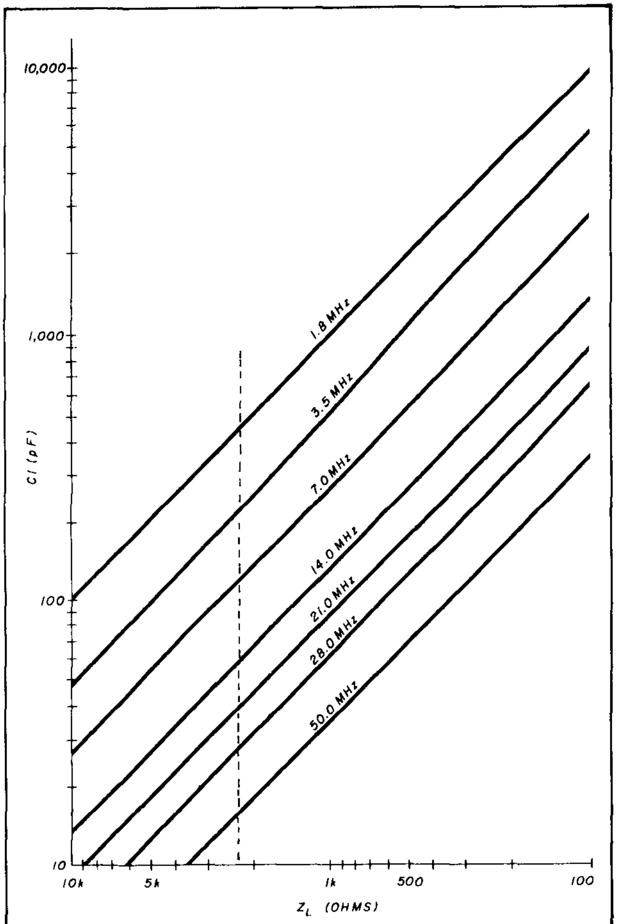

fig. 1. Plot of plate tuning capacitor, C1, plate load impedance (Q = 12).

$$C1 = \frac{531 + 430}{2} = 481 \text{ pF}$$

The same holds true for determining the values of C2 and L1. The same interpolation method can be used to find pi values for the WARC band frequencies.

effective pi-network capacitance

The two capacitors, C1 and C2, in the pi-network, are effectively in series and shunt the coil so that the resultant capacity (C_T) of the pair determines the resonant frequency (see **fig. 4**). Knowing C_T and the required resonant frequency, the coil value can be calculated. Evaluating:

$$C_T = \frac{C1 \cdot C2}{C1 + C2} = \frac{481 \times 2652}{481 + 2652} = 407 \text{ pF}$$

remember this, because we'll be using it later.

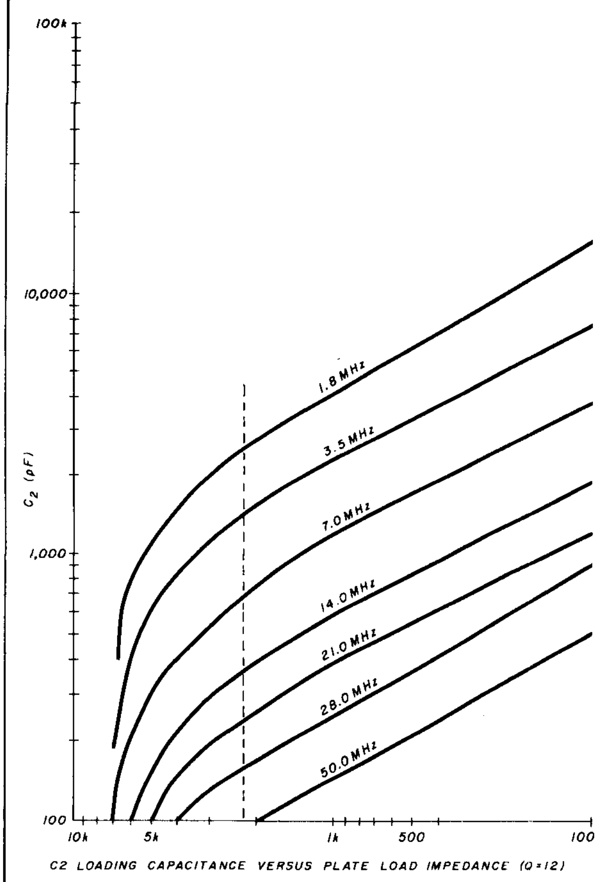

fig. 2. Loading capacitance versus plate load impedance (Q = 12).

table 1. Pi-network component values versus plate load impedance. (Capacitors C1, C2 in pF and inductance L1 in microhenries.)

	Z_L plate load impedance (ohms)			
capacitor C1				
band	**1750 ohms**	**2000**	**2250**	**2500**
160	610	531	481	430
80	318	273	246	220
40	159	136	123	110
30	120	102	93	83
20	80	68	62	55
15	53	45	41	37
10	40	34	32	30
capacitor C2				
160	3176	2865	2652	2440
80	1628	1473	1368	1263
40	815	737	684	632
30	610	492	457	422
20	407	368	342	316
15	272	246	229	211
10	204	184	171	158
inductor L1				
160	14.94	16.61	18.36	20.10
80	7.56	8.54	9.72	10.90
40	3.78	4.27	4.89	5.50
30	2.52	2.84	3.24	3.64
20	1.89	2.14	2.42	2.70
15	1.26	1.42	1.62	1.82
10	0.95	1.07	1.21	1.36

toroids in general

Information about toroidal cores and coils is available in many handbooks. Amidon's catalog, "Iron and Ferrite Cores," also includes general information about core characteristics.

Toroidal cores are basically of two types: powdered iron and ferrite. The permeability of the core (μ) helps determine the number of turns of wire required on a given physical size core; the larger the μ, the fewer the number of turns required to provide the given inductance. Powdered iron cores generally have permeabilities from 1 up to 125, while ferrite cores have permeabilities ranging from 40 to 5000. Worthwhile noting is that with toroids, there is no such thing as a partial turn. If the wire goes through the hole, you have one turn and you do not get a second turn until the wire goes through the window once more.

The core size is another factor that affects the number of turns needed for a given inductance. This is directly related to the cross sectional area and consequently the flux density of the core. It sounds complicated, but is simplified by combining everything into what is called the "A_L" value, and this alone can be plugged into a simple formula resulting in the number of turns required for a given inductance. Although the ferrite material has a much higher μ than the powdered iron core, ferrite is not as stable and saturates easily when used in power circuits.

Certain factors must be known in order to select the proper core for a specific job; first, we need the frequency range and permeability. Like resistors, all cores are marked according to a universal color code representing the compound mix number (**table 2**). The compound mix determines the core's frequency range. For the HF range, compound mix number 2 with a permeability of 10 is best. The core is powdered iron and is colored red.

Toroidal cores are prefixed either with a *T* for powdered iron or an *FT* for ferrite. The number following the *T* or *FT* identifies the diameter of the core. One of the more popular cores — because of its extensive application in antenna baluns — is the T-200-2, which is short for "toroidal powdered iron, 2 inches (5 cm) in diameter, No. 2 compound mix." **Table 2** lists core colors and mixes versus frequency.

selecting the core

The core I chose is a T-400-2A, which has an A_L

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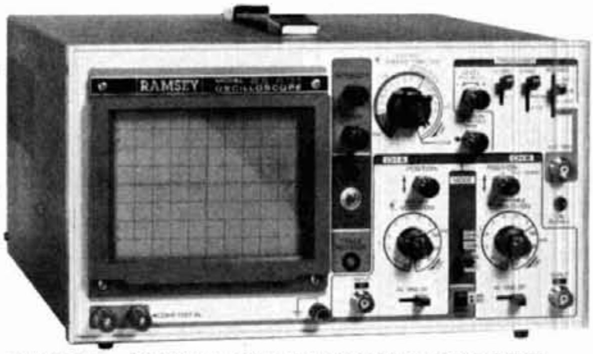

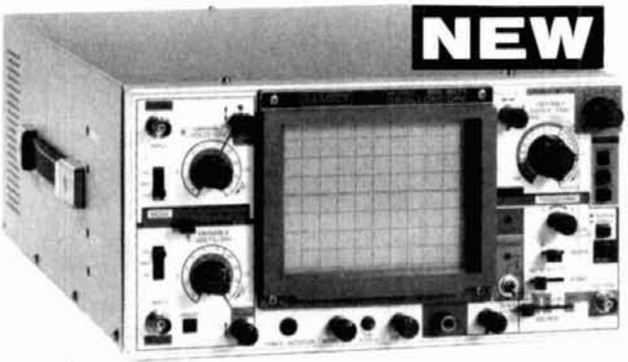

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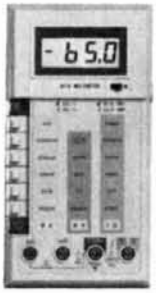

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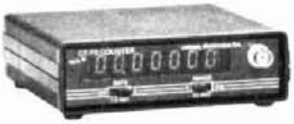

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of 360. As stated previously, two T-400-2 are a nearly exact equivalent; each 400-2 has an A_L of 185. Two stacked, therefore, would have an A_L of 370, because two of these together are a little thicker than a single 400-2A. You've probably guessed that a suffix letter relates to a core with a somewhat thicker than standard width and consequently a higher A_L. (Why the A_L number? This number represents the inductance in microhenries that 100 turns will produce on any given core.) From this important factor one can determine the number of turns required for a specific inductance.

The A_L number is used in a simple formula:

$$Turns = 100\sqrt{\frac{desired\ inductance\ (\mu H)}{A_L\ value}} \quad (3)$$

The coil number of turns is calculated for the lowest band we are to use, which is 160 meters. Referring to the capacity (inductance data) we find, under 2250 ohms, that the inductance for 160 meters will be 18.36 — let's say 18 μH. Plugging in the numbers,

$$100\sqrt{\frac{18}{360}} = 100\sqrt{0.05} = 22\ turns$$

In case of a fraction, round out the number, since there are no partial turns in winding a toroid.

As a point of interest, I noticed that Amidon now has a 3.048 inch (7.8 cm) core called a T-300; A-2 mix would have an A_L of 115. The core is 0.5 inch (12.7 mm) thick. Stacking one on top of the other would make up a 1 inch thick core with an A_L of 230. The required number of turns in this case is equal to

$$100\sqrt{\frac{18}{230}} = 27.975\ or\ 28\ turns.$$

For those of you thinking of an amplifier in the 1 kW input class, the coil should be wound with No. 12-gauge enamel covered wire. If you contemplate 2 kW, use No. 10-gauge wire.

coil preparations

Obtain a roll of glass cloth electrical tape No. 27. It costs approximately $3.50 for 66 feet, or about 20 meters (there'll be plenty left over). If you're going to stack cores, use Eastman 910 super glue or equivalent. Align the cores, applying a small quantity of the glue — possibly only a few drops — around the side of one core. Work swiftly; super glue hardens quickly. The glue prevents the cores from moving out of alignment while they're being prepared for winding.

Now wrap two layers of glass tape around the core. Apply a heavy layer of Polystyrene Q-dope (available from Radio Shack for less than $2 per 2-ounce bottle) to the glass-taped core. Set the core on a sheet of waxed paper or plastic wrap. After 20 minutes or so the Q-dope will have hardened sufficiently for another

table 2. Color code identifies core mix and frequency range.

frequency range (MHz)	color	mix
0.05- 0.5	gray	3
0.1 - 1.5	red/white	15
0.5 - 5.0	blue	15
1.0 -30.0	red	2

layer to be applied. (The core can easily be separated from the waxed paper or plastic wrap for full coverage.) When you're finished, no one — not even *you* — will know if it's one core or two.

Apply coat after coat until you've practically exhausted the contents of one 2-ounce bottle of Q-dope; you'll probably have about ten layers, which will add about 1/8 inch (.32 cm) or more to the thickness of the core. Now you'll need to add some insulation to the sides of the toroid. Some 1/16 to 1/8-inch (16 mm to 32 mm) polystyrene or fiberglass will be needed. (Don't use plexiglass.) In my search I ended up using 1/16-inch (16 mm) G-10 epoxy glass printed circuit board.

Use a propane torch to remove the copper foil. Place the board in a vise and apply the heat, stripping off the copper foil with a long-nose pliers. It takes only a few minutes to strip both sides when using a torch. Use of a fly cutter (circle cutter) to cut two identically-sized donut washers out of the epoxy board. The outside diameter should be 1/4-inch (6.4 mm) wider than the epoxied core, and the inside window or center hole 1/4-inch (6.4 mm) smaller.

Using some of the remaining coil dope, coat one side of each of the donuts you've prepared and place one on each side of the powdered iron core. Let it set. Now when you place the wire winding on the core, the wire will clear the core by 1/16 inch (1.6 mm) or 1/8 inch (3.2 mm) and there'll be plenty of insulation on the sides of the core. The Q-doped glass tape and end plates are the instruments that prevents RF from arcing to the core. If you prepare the core as directed, this will be no problem

If you're using a deep chassis the coil can be held in place by the wire leads and mounted directly to the switch, wheel fashion. My chassis was not deep enough, since it was subdivided with the input of the RF amplifier on one side and the output on the other. I prepared two more pieces of G-10 epoxy as large washers, cutting a small hole in the center of each so that the core could later be mounted from a long stud secured to the chassis. One recommended step you can take is not absolutely necessary, but does make

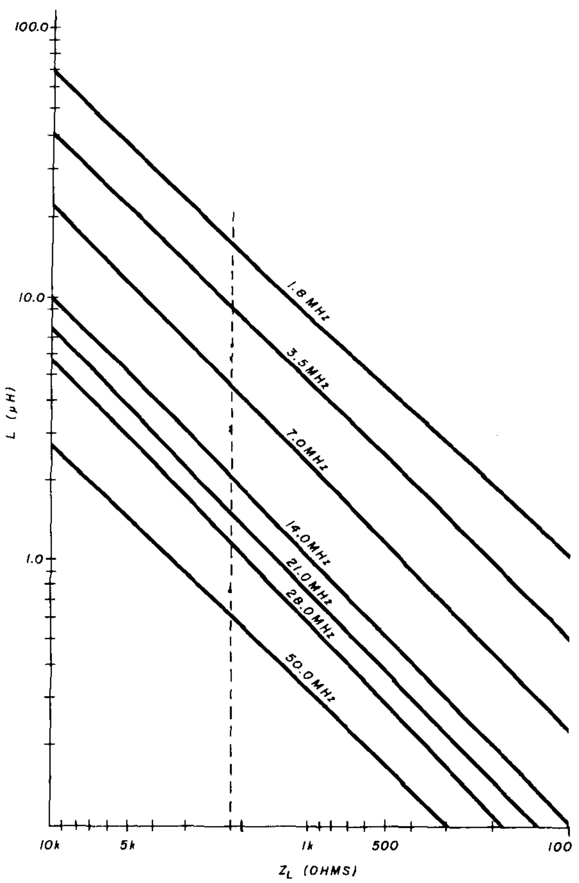

fig. 3. Plate inductance versus plate load impedance (Q = 12).

a neater package. The core does not include a 10-meter winding. As is conventional, this coil is almost always separate and is made up of about three or four turns of 1/4-inch (6.4 mm) copper tubing 2 to 2-3/4 inches (5 to 7 cm) in diameter. I mention it at this point because you may already have such a coil and the toroid core should be wound in the same direction as the turns of 10-meter coil, in order to prevent possible problems later. Take the core and determine the direction of winding, applying a sample of small wire to determine how the wire will lie in the core. With a Swiss file, file notches for the winding, making them about 3/64 inch (1.58 mm) deep. If you have 20 turns, there will be 40 notches on the inside window circumference and another 40 on the outside diameter of the G-10 epoxy donut sides.

Some pointers on winding the core: don't put the core between the jaws of a vise; it may break. Apply a test turn of wire to the core, observe the point at which a full turn is completed, remove and measure the test turn, multiply that figure by 20 and add 1 foot (30.48 cm). This is the length of wire you'll use to wind the core. Place one end of the wire in a vise, go to the far end and get a good grip on the end with large pliers, stretch the wire taut and tug sharply to remove any kinks. (I didn't have anyone to help me at this point, but I suggest you get someone to hold the core while you wind it.) Put the end of the wire through until the core is close up to the vise. (Ask your helper to hold it.) In placing the notches around the core for the wire, wind till no gap remains. Leave a space between the beginning and end of the winding equal to at least the space of 1 or 2 turns of wire. This also provides a starting point for the winding. If you start on the notches for the second turn you can get the last turn on at the beginning from the end of the wire that was held in the vise. Start threading the wire. The person holding the core can assist in holding the wire in place. When finished, tie the ends together temporarily so they will not unravel or become loose. Some coil dope can be used to secure the wire in the notches.

determining the tap positions

As the wire is spaced from the core, it's easy to scrape the enamel from the wire. Use the A_L formula to determine the tap placement. I'll take you through the first tap determination — that of 80 meters. Referring to the inductance data for L1, 80 meters = 9.72 μH.

$$100\sqrt{\frac{9.72}{3600}} = 100\sqrt{0.027} = 16.43$$ so the tap is 6.5

turns from the 160 meter end or 16.5 turns from the load end. It can be placed at 16 turns. Calculate the location of each tap for the remaining bands.

If you wish — and it might be a wise thing to do — prove you have made all the correct calculations. How? You'll need a grid dipper for this part. Most of this can be done prior to winding the coil in its finished form. You can wind a more manageable wire size of No. 14 or 16 to test for the correct value of inductance.

At the beginning of this article we determined that 407 pF was needed for C1 and C2. With 22 turns of No. 14 or 16 wire on the core, make the last turn loose so that you can couple a grid dipper to it. Using capacitors from your junkbox, make up a capacitor of approximately 350 pF (300 and 50 pF are standard values of dog bone dipped micas). Connect the capacitor across the two ends of the winding — making sure the coil is not placed on a metal bench — couple it to the last turn, and dip the meter. If the dip is broad, de-couple by backing the dipper away until you get a sharp dip. Read the dipper frequency. If the scale has poor resolution, couple it to a counter or a receiver.

Many dippers only go down to 2 MHz. Wrap the leads of a 10 or 20 pF capacitor around the pins of the dipper coil. This will extend the range of the dipper, but the readout will be null and void so listen for the dipper oscillator on your receiver reading the receiver dial or digital readout. If this is not possible, compute the resultant capacitance for 80 meters and just place the equivalent capacitance across the 14 turns, dip the meter, and read the dial. Then place a one-turn link through the coil and tie the ends of the one turn together. Couple the dipper to this one turn. It will get you close to the frequency. It won't be as accurate as coupling to a loosely wound turn of the coil itself because a shorted turn loads the coil somewhat.

tricks of the trade

Looking at the capacitor values of C1 and C2 for 160 and 80 meters makes one gasp. I used a four-gang capacitor from a surplus Hewlett Packard audio oscillator in my 800 watt output amplifier for C2. This has a total capacity of 2100 pF. I used two positions on the bandswitch for 160 and switched in 2000 pF on the lower frequency and 1000 on the higher end. The fixed capacitors used were the Hi-Q CRL-850 series 5000 volt DC.

For the plate capacitor C1, I also switch in parallel capacitors. Let's take a second look at the C1 values for 160, 80, and 40 meters 481, 246, and 123 pF respectively. We'd like to keep the physical size of the amplifier down, so let's say that a realistic practical maximum value is 250 pF. If one is to use vacuum variables, 350 becomes practical but for an air dielectric variable 250 pF seems high enough.

combining capacitors

How can we get by with using 250 pF when we need 481 pF for 160 meters and 246 for 80? How would one cover the band? We may need two positions on the bandswitch if we plan to tune the whole 160 meter band, but let's see what it takes. For an accurate frequency plot it would be nice to have a reactance slide rule, but we can come close enough by interpolating between 3.5 MHz and 1.8 MHz in **figs. 1** and **2**. We know the 160-meter inductance is 18.4 μH and the resultant capacitance (C_T) of C1 and C2 is 410 pF for the low frequency end (1.8 MHz). What capacitance is required for 2.0 MHz? We find that it will take 340 pF. This is a change in the resultant capacity (C_T) of 70 pF over the band. If C_T = 340 pF, what will be the capacity remaining in the plate tuning capacitor C1? Let's go back to the plot in **fig. 2** for C2 at 2250 ohms load impedance. Extending a line through this impedance point, we find that 2400 pF will be required at 2.0 MHz — the high end of the band. Let's now look at the chart for C1; it looks like 400 pF. Let's see when

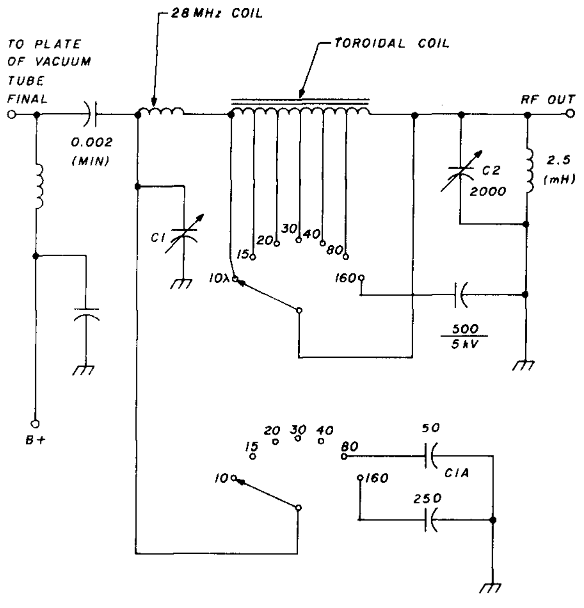

fig. 4. Final pi-network design works on all bands including WARC frequencies.

evaluating for the series capacitance how close we come to the required 340 pF. $\frac{2400 \times 400}{2400 + 400} = 342.9$ pF.

That's close enough.

This indicates that C1 must be variable from a high of 481 pF for 1.8 MHz to a low value of 411 pF for 2.0 MHz. From this, if we switch in 250 pF fixed capacity across our 250 pF C1 selected variable, there will result a 500 pF total maximum capacitance which is 19 pF more than needed. For the high frequency end, if we tune out, say, 70 pF of the 250, there will be 430 remaining in the circuit. We still have a 180 pF of variable capacity remaining. It looks as if we can do the entire 160-meter band with just one band position by switching in 250 pF of CRL-850 series capacitance.

Let's now look at 80 meters and evaluate it the same way. 246 pF is required for C1 and 1368 pF is necessary for C2. We have plenty of C2 with 2100 pF of variable, but we may need more C1 — about 50 pF more. First let's see the minimum we need to cover 4.0 MHz. The capacitance chart at 2250 ohms, although poor in resolution, looks like 230 or possibly 240 pF. Let's say we switch in 50 pF of the CRL-850 series capacitance. This will provide a variable capacitance of 300-250 + 25 (about 25 pF for minimum capacitance in the capacitor and circuit capacity). This equates to a minimum available capacitance of 75 pF and a maximum of 300. We need only 246, so we have an excess of 54 pF; we need a minimum of 230 or 240, and we have 175 — so we're well in on 80 meters by switching in 50 pF. All the other bands are OK without additional capacitance. This should be enough data to enable you to draw up a switching circuit — see **fig. 4**.

bandswitch connections

The bandswitch should be of ceramic or porcelain material, of high quality and capable of handling the RF power. The switch will need two decks to accommodate the additional C1 capacitance required to be switched in and out. The number of positions will depend on the number of bands.

Some final thoughts: keep in mind that if the load impedance of the vacuum tube or tubes selected calculates out to be 1500 ohms or less, the required L1 is somewhat less, so C1 and C2 become larger. This means there will be more capacitance to switch in. With such high values of fixed capacitance there may not be enough variable capacitance left to cover the 160-meter band. If this is the case, two positions will have to be provided on the bandswitch in order to cover both the low and high frequency segments of the band.

Note that only seven positions are shown on the switch in **fig. 2** and the bands for 18 or 24.5 MHz are omitted. Also note that to provide enough Q on the 10-meter band, a separate coil will be required the same as in any and all amplifiers on the market. This usually requires about three or four turns of 2 to 2-1/2 inch (5 to 7 cm) diameter 1/4-inch (6.4 mm) copper tubing.

The last item is the plate blocking capacitor. This 0.002 μF capacitor is an important item and must handle high current, is high Q like the CRL-850 series capacitors and also is high voltage about 10,000 volts in amplifiers of 2 kW. This value capacitor has a 45-ohm reactance on 160 meters. The 0.004 μF capacitors reactance value is 25 ohms on 160 meters. The 858 capacitors are rated at 5000 volts and require two 1000 pF units in parallel. The 2000 pF capacitors are only rated at 1.5 kV. The 5000-volt 858 is just marginal at 2500 volts and should you be running approximately 1 ampere of plate current you'll have to series-parallel eight of these just to produce 0.002 at 10 kV.

There you have it. Should you need further assistance, drop me a line (enclose an SASE).

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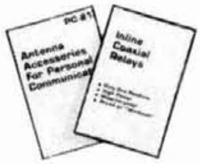

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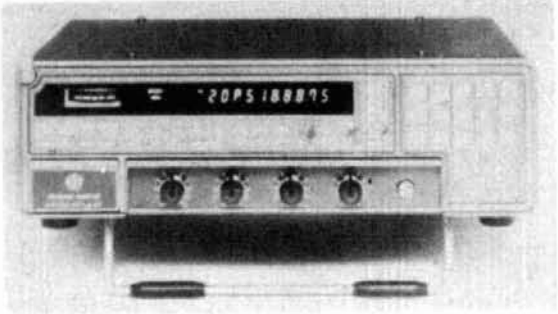

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VHF/UHF WORLD

Joe Reisert, W1JR

medium power amplifiers

In one of my earlier columns I described VHF/UHF exciters, with the emphasis on transverters.[1] These transverters are primarily designed for 2 meters and 135 and 70 cm, but only at lower power — typically 0.5 to 1 watt output. In last January's and February's columns, I discussed high-power amplifiers, with the goal of attaining the legal power limit.[2,3]

But many VHFers need intermediate power level amplifiers, typically at 10 to 100 watts, for use as either a final stage or to drive a high-power amplifier. With this in mind, I've decided to dedicate this column to that subject.

amplifier types and classes

There are two major types of medium-power amplifiers: vacuum tube and solid-state. Each has its advantages and disadvantages. Generally speaking, tube amplifiers have higher gain, are more linear, are larger in size, and require at least two or more voltages. Solid-state amplifiers, on the other hand, are generally more compact and more physically rugged than tube-type amplifiers and usually require only a single voltage power supply.

Both types can usually be run in class C, which is all that's required for CW and FM opeation. However, nowadays most Amateurs prefer a linear amplifier, since it works equally well on CW and SSB at the flip of the mode switch and is less likely to cause key clicks when operating on CW.[1,2]

Medium-power vacuum tube amplifiers. Vacuum tube amplifiers have been around for a long time. They're usually quite reliable and rugged. Mismatches and mistuning — all too familiar to users of solid-state amplifiers — seldom cause catastrophic failures.

However, this type of amplifier can be bulky. It generally requires several voltages such as filament, plate, and possibly control and screen grid as well. And while it's not usually a problem, a warmup period of 1/2 to 5 minutes is usually necessary. Therefore, they're not particularly popular — especially for portable or mobile operation!

Regardless of their shortcomings, vacuum tube amplifiers are still quite plentiful and are often available at low prices. If you already have one anyway, why throw out or sell a perfectly good amplifier that's still functioning properly?

Many single-tube 2C39 amplifiers — often from the old Motorola T44 units — are still in operation on 70 cm. They make fine output amplifiers for low-power operation and serve well as drives from typical legal-limit amplifiers. There are also many single tube 4X150/4CX250B types of amplifiers still in use. They also make excellent moderate power amplifiers. Many modern high-power amplifiers use grounded grid circuitry and often have only 10-13 dB of gain. Hence they may require 75 to 150 watts of drive to achieve the full legal Amateur power limit. This is a great application for such an amplifier.

So don't dismiss the idea of using a vacuum tube amplifier as either a moderate output power amplifier or as a driver. (See references 2 and 3 for further information on the subject.)

Medium-power solid-state amplifiers. Solid-state amplifiers can be designed for either class C or linear operation. Both bipolar transistors and MOS power FETs are commonly used. There's no doubt that the compact solid-state amplifier has done wonders to increase VHF/UHF activity as well as reduce the size of the necessary equipment.

Power bipolars are presently the most common type of device used in Amateur medium-power solid-state amplifiers. They've been available for over 15 years and are moderately priced. Most work well at 12 volts DC and are therefore convenient for mobile operation. But they're usually quite fragile, and their transistors may burn out if subjected to a high VSWR load.

More recent power amplifier designs employ high-power MOSFETs, which became available about ten years ago. Manufactured by Siliconix, the first commercially available power FETs were called VMOS (Vertical Metal Oxide Semiconductors). Soon after, other manufacturers started making and improving on their performance, power, and reliability.

The original MOS power devices, primarily designed as switches, are generally called enhancement FETs, since they have to be biased "ON" to operate — just the opposite of the way vacuum tubes work. Because they had a high input impedance, they were subject to burnout when not connected in a circuit. Therefore, the manufacturers frequently placed a zener diode across the gate, thus reducing the frequency response and limiting use to HF and down.

Siliconix introduced the VMP-1 and VMP-4 devices in RF packages without the input protection zener diode. I've been using the same VMP-4 in a 10-watt 135-cm linear amplifier since

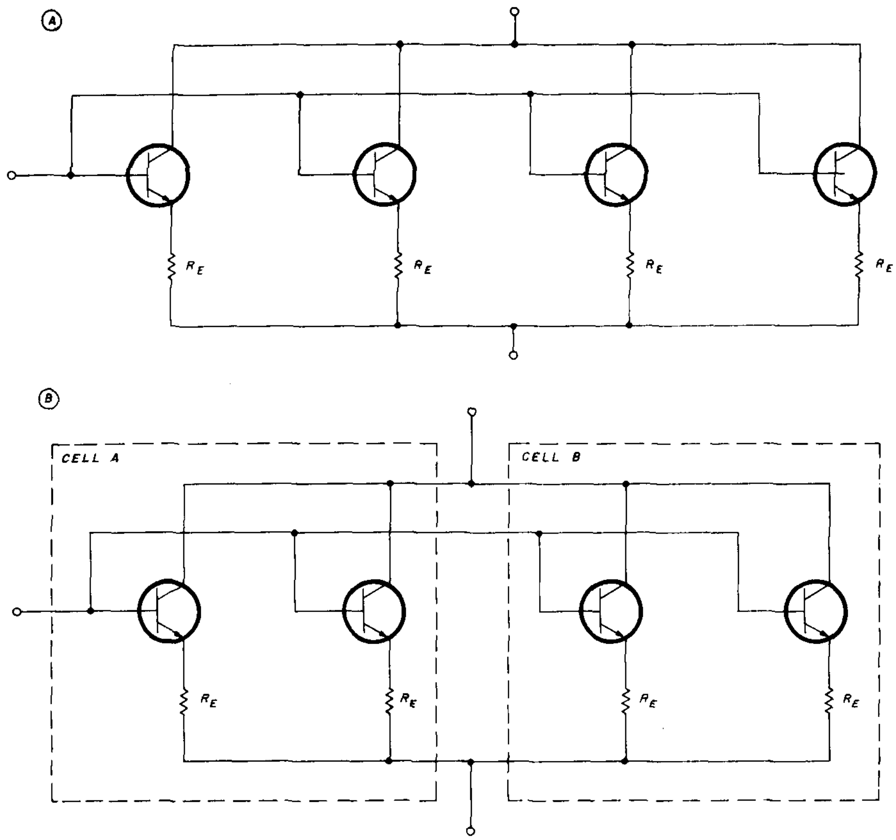

fig. 1. The typical bipolar power transistor is shown in schematic form. (*A*) single cell; (*B*) two-cell device. For values of R_E, see text.

1976! First it was my output stage and later my high-power amplifier driver.

Power MOSFETs are not as likely to be destroyed even if their output VSWR is high. When heated, many of these devices will just shut down rather than "self-destruct!" Power FETs generally have higher input/output impedances than bipolar power transistors, making them easier to impedance match (more on this later). However, the linear power MOSFET devices generally require higher operating voltage — 28 volts or more. For this reason, they're not as likely to be used in mobile or Amateur applications, where 12 volts is usually the only supply voltage available.

Power MOS devices stand an excellent chance of overtaking bipolar devices in many applications in the future. Although there may be some interest in the use of power MOS devices for Amateur applications, I'll limit this discussion to bipolar transistors because they're by far the most widely used solid-state devices in medium power amplifiers.

Before we can design and build a medium power amplifier, we must first know some of the basic properties of the bipolar transistor devices to be used. The most important parameters are the DC voltages, the power dissipation, recommended operating frequencies, RF input/output impedances and recommended circuitry for bipolar power devices.

The typical bipolar power transistor consists of many individual transistor junctions in parallel (**fig. 1A**). This configuration is chosen to increase current handling and distribute the heat within each junction. In the larger devices, there may even be multiple identical "cells" which are paralleled in the semiconductor itself to further increase the power and current handling (**fig. 1B**).

Resistance R_E (**fig. 1C**) is typically 5-30 ohms and is determined by the design requirements, manufacturing process, and material. The value chosen is very important, since the lower the resistance, the higher the gain of the transistor. This is frequently referred to as the ballasting resistor.

However, if heat increases in the junction, the typical bipolar transistor starts to draw more current and therefore heats up. If there's any potential difference between the junctions of the different transistors in parallel, the emitter current (and hence the collector current) may divide unevenly — and in an instant, there can be a chain reaction.

First one junction starts to "hog" current. It heats up until it's destroyed. Then the current is diverted to the remaining transistors, which may in turn be destroyed. The higher the resistance of R_E, the better the chances of equal current distribution (especially when heated) and the less possibility of (thermal) runaway destruction. Therefore the designer must carefully choose the optimum emitter resistance for the application and trade off gain versus power distribution and stability. Generally speaking, linear devices have higher R_E, while class C devices have lower R_E.

Power dissipation is a very serious consideration in the design of a power bipolar transistor. The junction area is quite small and the only way to cool it is with a good heat conducting package that is well heatsinked. This is in great contrast to power tubes where a large area is used and the power dissipation can usually be raised by increasing the air or water flow through the tube's plate radiator. Furthermore, the typical power bipolar transistor operates at a lower collector efficiency than its vacuum tube counterpart. While class C operation efficiency may approach 50 to 60 percent, typical linear service is usually between 33 and 50 percent.

DC voltages are most important.

However power bipolar manufacturers have made it easier for the user by optimizing the breakdown voltage and other parameters to suit the market. For example, there are power transistors for the 12 to 15, 24 to 30, and 50-volt markets. These markets are for the land mobile, aircraft/commerical and the pulse industries, respectively.

Current limits, also specified by the manufacturers, increase more or less in direct proportion to the power of the device and its application. In contrast to power tubes, the typical power bipolar transistor can be easily destroyed if the collector current rating is exceeded, even for an instant. Therefore, a current limited power supply is highly recommended. Fuses just may not operate fast enough to prevent burnout.

Most transistors are very frequency sensitive. For instance, the typical maximum gain of a bipolar power transistor usually decreases 6 dB every time the frequency is doubled. This means that if the transistor is operated at lower frequencies, it will have very high gain — typically enough to go into oscillation or "self destruct!"

Manufacturers work around this problem by designing each type of transistor to have a typical gain of 6 to 12 dB at the recommended operating frequency, much lower than that of a typical power tube! *Operation below the recommended frequency range is strongly discouraged.*

However, this is typically not a problem for Amateurs since most of us use a different power amplifier on each band. Also, power bipolar transistors are readily available for the Amateur 2-meter, 135 and 70-cm bands since they are also available for the commercial VHF, military and UHF bands, respectively.

RF input/output impedance. Unlike tubes, the input and output impedances of bipolar power transistors are extremely low and often have a significant reactive component. Input impeances of 1 to 10 ohms are quite common and the higher the power level, the lower the impedances will be. Typical input impedances are usually specified by the manufacturers either at midband or over the specified frequency band as plotted on a Smith chart. The output impedance of a power bipolar transistor is usually specified differently than the input impedance since it is a function of the internal device parameters, the operating power level, and the class of operation. Furthermore, the output or collector of a power bipolar transistor is usually not operated in a matched condition (often called "conjugate matched"). If the output were matched, this would mean that at least 50 percent of the power would have to be dissipated in the circuit, output efficiency and power would be lowered, and the device would have to dissipate more power. (This will be discussed shortly.)

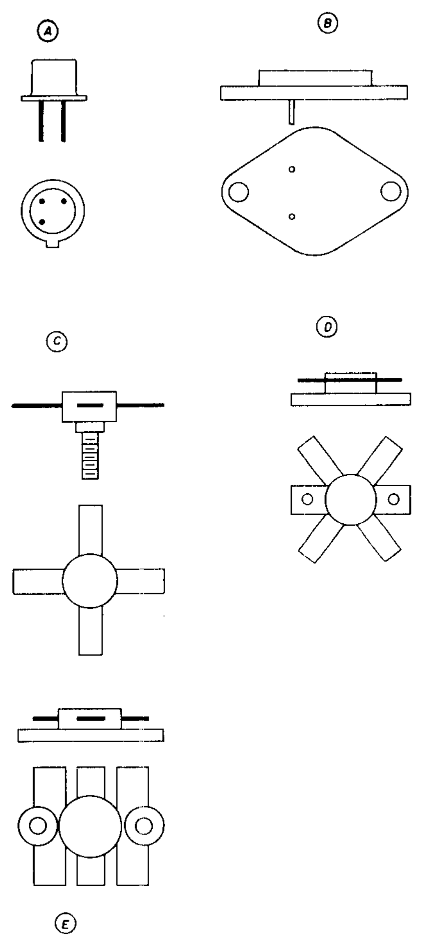

fig. 2. Typical bipolar power packages. (*A*) T05/T039; (*B*) TO-3; (*C*) stud-mounted; (*D*) high power; (*E*) high power, usually with internal matching.

Therefore, bipolar power transistors are often specified when operating into a *conjugate of the optimum load impedance* at a given frequency and power level. To simplify matters, most manufacturers usually show a typical or recommended circuit with the optimum components.

transistor configurations

Bipolar power transistors are usually operated in either a grounded emitter or grounded base configuration. Most modern devices operating below 500 MHz are specified for grounded emitter circuitry. Gain is usually slightly lower than in grounded base operation and the input impedance is higher, making it easier to match impedance. Grounded emitter configurations are also easier to bias and stabilize for linear operation.

Grounded base operation is still popular, especially above 500 MHz and where class C operation is used. Devices operating in grounded base circuits typically have higher gain (typically 1 to 3 dB), especially at the maximum frequency of operation. Another advantage is that the gain of a device increases only a moderate amount (10 to 15 dB) and flattens out as frequency decreases. Hence this circuit is less likely to oscillate at a lower frequency.

packages

Choosing the package for a high power bipolar transistor is almost as important to the device designer as designing the chip itself. At the higher power levels, heat dissipation is a complex problem. Because the area of the chip itself is usually quite small, manufacturers have selected packages with extremely low thermal resistance.

The typical three or four-lead TO-5 and TO-39 cans (**fig. 2A**) cannot dissipate heat efficiently. TO-3 packages (**fig. 2B**) are generally not suitable at VHF/UHF frequencies because of package parasitics.

Many power packages have been designed to handle power dissipation

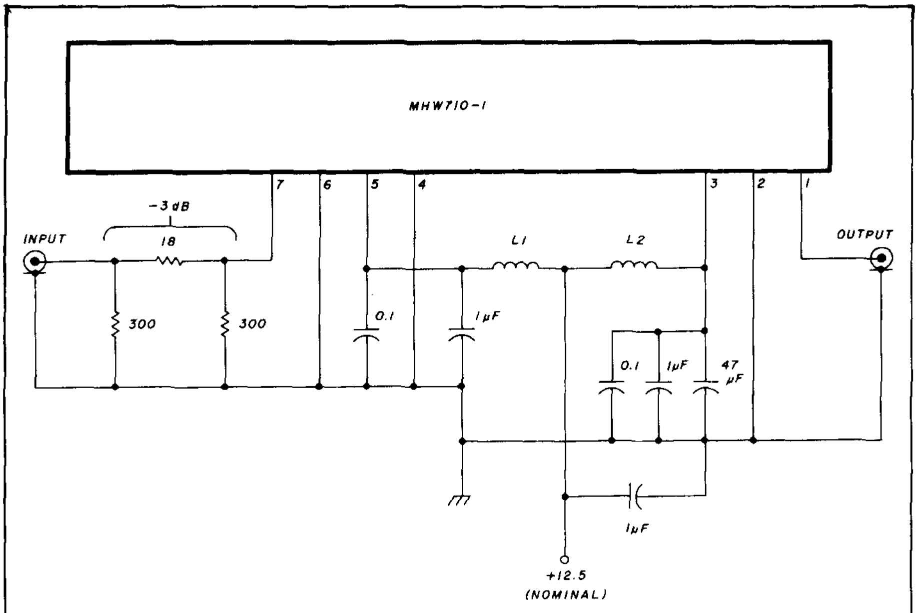

fig. 3. Hybrid power amplifier module. Unit shown is a Motorola MHW-710-1 for 400 to 450 MHz operation. Other suppliers and units may use slightly different pin layout.

while keeping the leads short. Furthermore, these packages usually have very wide leads to keep internal lead inductance at a minimum. At the lower power levels, 1 to 10 watts, stud-mounted packages are sometimes used (**fig. 2C**). However, at higher power levels, larger flat packages — generally with two mounting holes — are more common (**figs. 2D** and **2E**). In all cases, the manufacturer uses a package commensurate with the power level of the device and specifies the thermal resistance and/or the type and size of heat sink required.

To further lower the internal parasitic load inductance, the common lead (either the base or emitter) is often attached to opposing leads on the package. Thus the package can be grounded on both sides. Not only does this improve gain but it often improves circuit stability.

Caution: Many UHF power transistors use a special low thermal resistance ceramic package containing beryllium oxide. If the package is crushed, ground, or abraded, the dust resulting from such action may be hazardous if inhaled. Therefore, never try to work with packages that may contain this material. To dispose of damaged or unwanted packages, enclose in an appropriate container for burial in an approved landfill, well away from ground water supplies.

linear versus class C operation

The first bipolar transistors were almost always operated in class C. To a great extent, this is still true today on FM. Class C design is rather straightforward and, as mentioned earlier, many devices are available with good gains.

However, most of the early devices available were not suitable for linear operation since they were highly nonlinear and tended to self-destruct if even a small biasing current was applied. Therefore, manufacturers typically redesigned their devices by adding higher ballasting resistors in the emitters, as discussed above. Careful attention to frequency response, stability, and gain lead to a whole new category of devices suitable for linear operation.

Nowadays most Amateurs use linear power amplifiers since they can be placed on CW, FM, or SSB. Ample information is available on class C operation, both in the literature and from manufacturers' data sheets. In addition, most suppliers have application notes available in their data manuals.

Before we leave class C operation, there is one type of commercially available unit that's particularly well suited for certain applications. Often referred to as the "brick" or "hybrid power amplifier module," this device is typically available at the 5 to 25 watt output power level for various frequency ranges from 144 to 940 MHz. They usually have high gain (2 or 3 internal stages) and therefore require only 0.1 to 1 watt of drive. Typically they are usable over 5 to 25 MHz of bandwidth (depending on operating frequency) with 30 to 50 percent overall efficiency.

Furthermore, these modules typically require a single 12 to 14 volt power supply and a few bypass capacitors. I particularly like them for driving frequency multipliers, which are more reliable if driven from a stable power source. Quite often I see these modules listed in surplus advertisements. Amperex, Motorola, RCA, NEC, and TRW are some of the major suppliers.

A typical 70-cm hybrid amplifier is shown in **fig. 3**. A good heat sink is required because efficiencies are low (30 to 40 percent). The 3 dB pad improves input match. However, hybrid modules are not suitable for linear service, and all the attempts to linerize them that I've heard of have been unsuccessful.

linear operation

Modern bipolar power transistors are still not capable of class A operation above a few watts because their power dissipation is too high for the packages and device geometries available. Most Amateurs prefer 12-volt power transistors because they're more compatible with the power supplies available (especially in mobile operation), moderately priced, and fairly rugged. However, if good linearity is required, the 24 to 28 volt devices are usually superior, even though they are less rugged and cost more.

When good linearity is required at power levels exceeding 5 watts, class

B biasing is preferred. Since linear devices are so sensitive to heat, special biasing techniques that "track" the heat within the transistor junction and readjust the bias voltage accordingly are required. Furthermore, these biasing techniques must be able to supply high base or emitter current on demand and from a low impedance DC bias source.

The first biasing circuits developed for bipolar linears consisted of a forward biased diode connected to ground and strapped to the package or heat sink as shown in **fig. 4A**. The series resistor to the power supply was adjusted until the proper collector current, usually designated as I_{CQ}, was attained. The power transistor idling current is typically 20 to 100 mA and is dependent on the device type and power level. It's usually not critical and often specified by the device manufacturer. Increasing the idling current rarely improves IMD, except on higher order products.

The idling current drawn by this biasing circuitry can be considerable, with 250 to 500 mA a typical value. In addition, this circuit is somewhat sensitive to power supply variations. Many designers, therefore, use 3-terminal voltage regulators in the supply circuit to keep the voltage constant (**fig. 4B**). The resistor is still used, but it dissipates less power (depending on the regulator voltage). A lower value resistor can be used with one of the newer low voltage adjustable regulators.

In 1973, Communications Transistor Corporation (CTC) introduced the "byistor," a self-contained regulator that incorporated temperature tracking (**fig. 4C**).[4] This device is actually a diode similar to the base emitter junction of a power transistor in series with a silicon resistor. The final DC source impedance is less than 1.0 ohm. Mounted in a studded package similar to medium power bipolar transistors, it can be attached to the heat sink, close to the transistor being regulated, for very close temperature tracking.

The byistor, like the diode biasing scheme, typically requires 300 to 350 mA of idle current. Some applications require low power drain. Therefore, in 1976 CTC introduced an alternative device, the Z0-28.[5] This device is actually a power bipolar transistor with two internal diodes (see **fig. 4D**). The diodes track the bias regulator and the transistor being regulated. The regulator transistor acts like a source follower. Hence this device has very low output impedance and draws high current only on demand.

To set up the Z0-28, a single low-power resistor is placed externally across the device as shown in **fig. 4D**. This resistor value is adjusted to set the power amplifier idling current. Some Amateurs have reported satisfactory operation by duplicating this device and circuit using discrete diodes (1N4001 types) and a power transistor. Close attention must be paid to adequate coupling to the heat sink to assure temperature tracking.

Other bias circuits have been used. When choosing a bias regulator, remember the following guidelines: the bias regulator circuit must track the temperature of the transistor being regulated and the output impedance of the bias source should be low, typically less than 1 ohm.

impedance matching

As mentioned earlier, the input and output impedances of bipolar power transistors are very low and often reactive. The typical "L" and "Pi" networks often used with vacuum tubes do not lend themselves to these impedances and devices, since losses may be significant.

The most frequently used matching schemes for high-power bipolar transistors are called "T" networks.[6,7,8] Several are shown in **fig. 5**. They are particularly adaptable if the input and output impedances of the amplifier itself are 50 ohms, the most common case. Each network has its advantages and disadvantages. Usually only one of the elements has to be varied. However, I prefer the schemes with two variable capacitors because they seem to be the easiest to tune and optimize properly, especially in narrow band

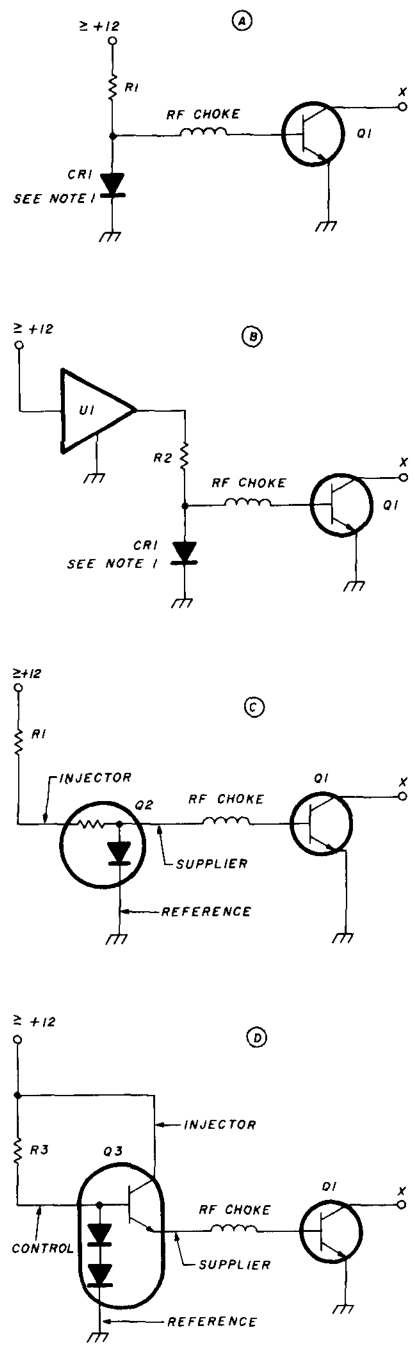

fig. 4. Typical linear biasing schemes. (*A*) single diode; (*B*) single diode with 3-terminal regulator U1 (see text); (*C*) Byistor, BY-1 (see text); (*D*) Z0-28 (see text). R1 and R2 are power resistors. Q1 is the power amplifier. Q2 is a BY-1 byistor and Q3 is a Z0-28. See text for other component value selections. Note 1: The biasing device must be thermally attached to the power device being controlled.

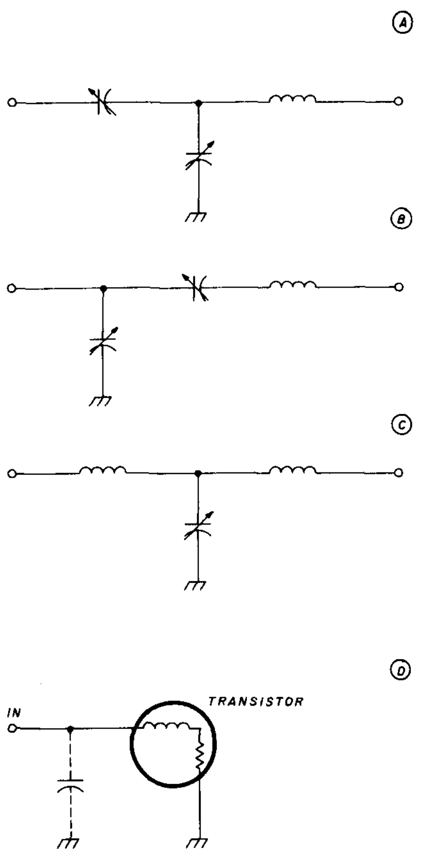

fig. 5. Typical impedance matching networks. *(A)*, *(B)*, and *(C)* are "T" networks. Value selection is discussed in text. *(D)* illustrates conversion from series to parallel equivalent circuit on transistor input as explained in text.

applications, and have a built-in DC block.

There is one rather sophisticated trick that is used extensively, especially *in the wider bandwidth amplifiers.* If the transistor series input impedance has an inductive reactance component (noted by a +j component such as the popular CM10-12A with an input impedance of 1.5 +j3.5 ohms), it can be mathematically converted from a series to an equivalent parallel network. Then an appropriate parallel capacitance can be placed at the input of the devices to tune out the inductive reactance as shown in **fig. 5D**. The transformed input impedance is higher and resistive. This makes the impedance matching network easier to design and with a smaller transformation ratio. Such techniques have been described elsewhere.[8]

This matching technique is also used extensively by the commercial suppliers of UHF transistors. First they adjust the series inductive reactance by adjusting the lengths of the bonding wires used to attach to the chip. Then they place the appropriate shunt capacitors internally in the package. The net result is more efficiency and greater bandwidth, as well as increased convenience for the circuit designer.

The output network is a function of the output power and the device. First the load impedance must be calculated using **eq. 1**:

$$R1 = \frac{V_{cc}2}{2Po} \qquad (1)$$

where $R1$ is the desired output impedance, V_{cc} is the voltage across the transistor (usually the supply voltage less the saturation voltage of the transistor) and Po is the output power in watts. For example, with a 13-volt supply, a 1-volt saturation voltage (typical for most transistors), and a desired output power of 10 watts, $R1$ is approximately 7.2 ohms. This impedance is then converted in conjunction with the internal device impedance to the desired amplifier output impedance (usually 50 ohms).

Remember that the input network chosen is primarily matching the source (usually 50 ohms) to the power transistor. The output network is designed to yield the optimum load impedance required for maximum output power (as described earlier) with the required circuit loaded Q. If the proper component values and circuit Q are chosen, losses will be quite low and harmonics kept to acceptable levels.

Describing all the network requirements and design procedures is beyond the scope of this month's column. For those interested in the subject, I particularly recommend references 6 through 8. Many other papers have also been published. Most semiconductor manufacturers can offer applicable application notes.

Sometimes two power transistors are used, particularly when high power is required. These devices can be fed in parallel using a splitter network (**fig. 6A**) or with hybrid couplers (**figs. 6B** or **6C**).

Push-pull circuitry is often used at lower frequencies because it tends to cancel the second harmonics. Many modern transistors are now offered in matched pairs in a common package, making this technique very practical. Ninety-degree hybrids are also popular, since if one side of the amplifier fails, the output power drops to only about one-half. Another advantage of the 90-degree hybrid is that the amplifier input impedance match is quite good, since any mismatch is diverted to the external loads, R1 or R2.

recommended circuitry

The scope and size of this column do not permit me to describe a cookbook of circuits. Many suitable VHF/UHF power amplifier designs have been described both in Amateur and Commercial publications and on suppliers' data sheets. However, I will provide a universal circuit that can be used on the 2 meter, 135 or 70-cm bands (see **fig. 7**).

Note, in that circuit, that the input and output networks are similar to those just described. The diode bias network described earlier is also shown because it's very inexpensive; but the Byistor or Z0-28 devices (or their equivalents) are highly recommended as a replacement because they will definitely be more stable and reliable. *The variable capacitor and inductor values are only target values and can be varied slightly to obtain the desired performance.*

Since bipolar power transistors have much more gain below the operating frequency, they are often prone to self-oscillate at a lower frequency. This can usually be completely eliminated by the use of both low value and high value bypass capacitors as well as the network shown as L4 and R3. The low value capacitors should have short leads and be self-resonant well above the operating frequency. R1 is not

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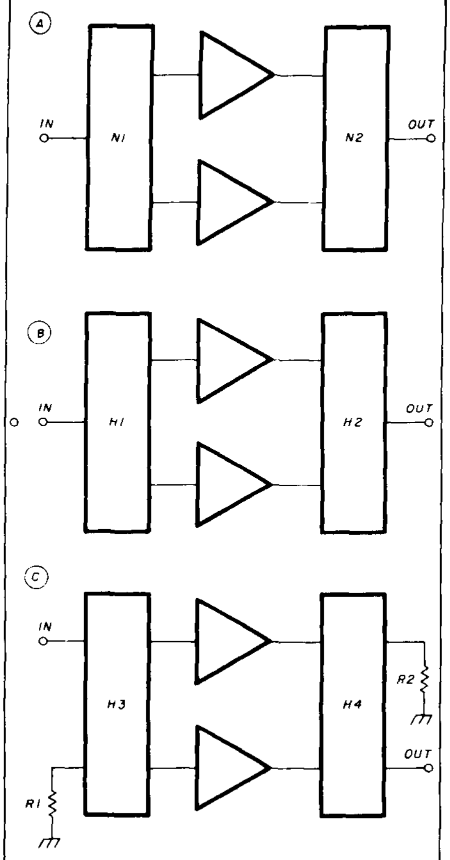

fig. 6. Various schemes for high power with combining networks. (*A*) in phase technique. N1 and N2 are reactive splitters; (*B*) H1 and H2 are 0 or 180-degree hybrid transformers. (*C*) H3 and H4 are 90-degree hybrid transformers. R1/R2 are 50-ohm loads. Resistor power rating depends on input or output power levels.

CR1	1N4001 diode strapped to heat sink/transistor
L5	4.7 μH, 28 turns No. 18 on T-80-2 toroid
Q1	See text
R1	50 ohms, 1 watts carbon (see text)
R2	20 ohms, 5 watts wire wound
R3	20 ohms, 5 watts wire wound (see text)
R4	15 ohms, 2 watts

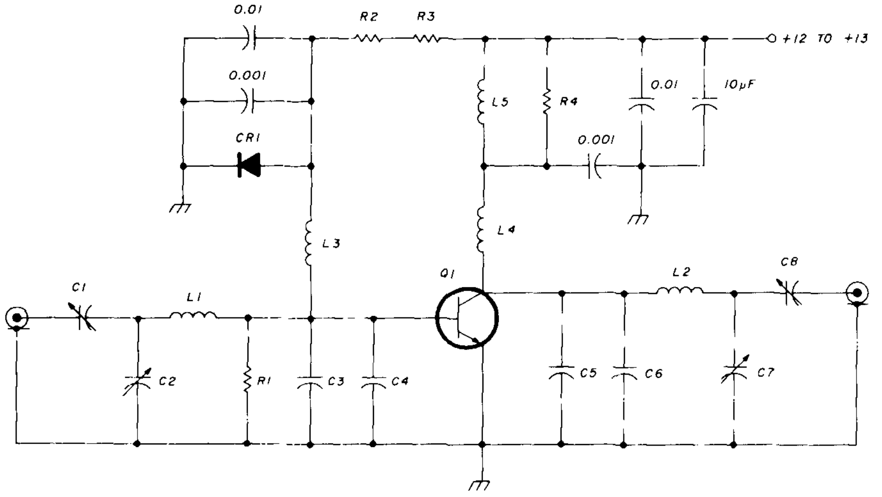

fig. 7. A typical power bipolar amplifier schematic with recommended starting values. See text for further explanation.

part of fig. 7

value	2 meters	135 cm	70 cm	units
C1	8-60	3-35	3-35	pF
C2	3-35	3-35	2-20	pF
C3	150 (Unelco)	100 (Unelco)	33 (Unelco)	pF
C4	150 (Unelco)	100 (Unelco)	22 (Unelco)	pF
C5	not used	100 (Unelco)	33 (Unelco)	pF
C6	not used	50 (Unelco)	33 (Unelco)	pF
C7	8-60	8-60	3-35	pF
C8	3-35	3-35	3-35	pF
L1	2 turns, No. 18, 0.25″ ID, 0.25″ long	2 turns, No. 18, 0.25″ ID, 0.25″ long	1.1″ × 3/16″ copper strap	
L2	2 turns, No. 14, 5/16″ ID, 0.25″ long	1 turn, No. 16, 0.25″ ID,	1.2″ × 3/16″ copper strap	
L3	0.33 RFC	0.33 RFC	0.1 RFC	microhenry
L4	4 turns, No. 18, 0.25″ ID, 0.5″ long	3 turns, No. 18, 0.25″ ID, 0.38″ long	2 turns, No. 18, 0.3″ ID, 0.3″ long	

always required, but often helps maintain stability in more stubborn cases. Since the input impedance of the power transistor is low, the value is not too critical.

component selection

The choice of components is very important. All capacitors should have short low-inductance leads and be able to handle the RF current often present when operating at these impedance and power levels. At VHF and low UHF, mica trimmers such as the Arco/Elmenco or equivalent are good for tuning elements. The Unelco type of sandwich micas are suggested for the collector RF choke bypass as well as in the fixed value input and output matching networks. These capacitors are easy to find at flea markets and are often available from surplus vendors.

At UHF and above, ATC (American Technical Ceramics) or equivalent porcelain chip capacitors are recommended. They have low loss, low inductance (if properly installed) and can handle high RF current without overheating.

Inductors should be large enough to keep the unloaded Q high.[9] The wire should also be large diameter, especially on the collector circuit, where, depending on power level, there can be high RF as well as DC amperes of current flowing.

You're probably wondering why I didn't mention microstrip or stripline inductors. These are fine if you're copying a working design, producing many copies of the same amplifier, or are proficient with the use of a Smith chart. However, for the typical one-

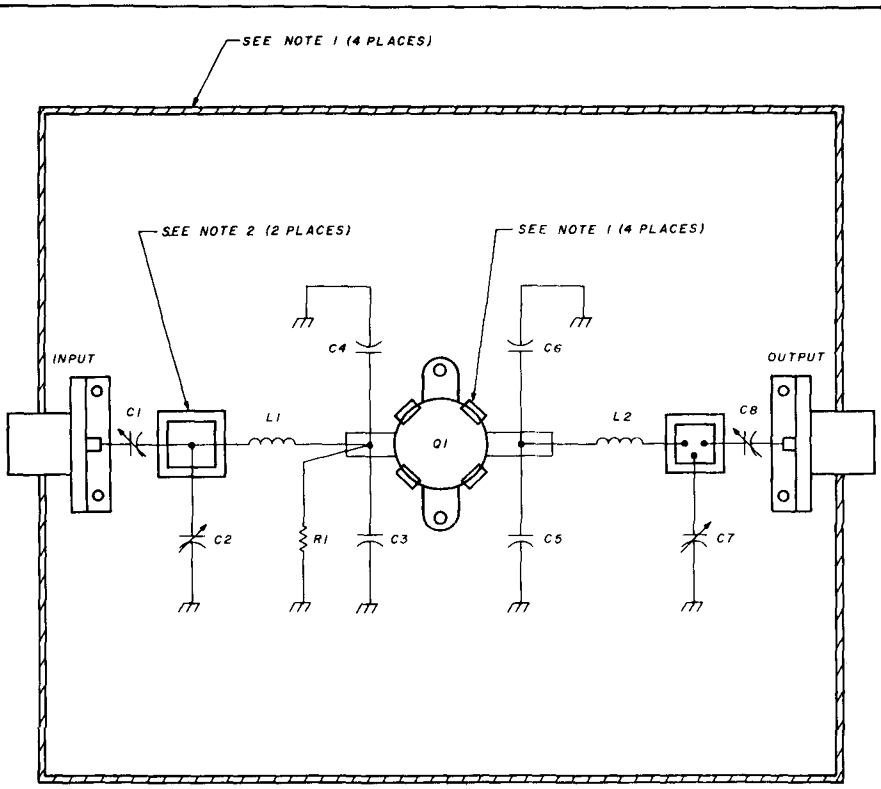

fig. 8. A typical construction technique that works well for VHF/UHF bipolar power amplifiers. Biasing and collector supply left off for clarity. Note 1: copper or brass foil soldered to top and bottom of PCB for low impedance ground. Note 2: Some PCB material has been removed to make an island to which components can be soldered.

shot design that is unproven, the discrete inductor is hard to beat. If you err in the value, just add a turn to or drop a turn from the coil and you're back in business. It isn't easy to cut up, extend, or decrease the length of a microstrip line on a printed circuit board if the tuning is incorrect!

In selecting transistors, choose those that will deliver sufficient power at the frequency of interest at the supply voltage available. As stated earlier, the 12-volt units are usually preferred for availability and price, but 28-volt units with better linearity would be a better choice, especially if you want to stay friendly with your neighborhood Amateurs. Consult manufacturers' data sheets. Don't be tempted to use a transistor at a lower frequency than recommended — it may self-destruct!

There are many power transistor manufacturers such as Acrian, Amperex, Motorola, RCA, Solid State Scientific, and TRW, to name a few. Order from the many suppliers who offer these devices in small quantities, manufacturers generally have a "minimum order" requirement that can make the per-unit price prohibitive. Many companies sell kits of parts, some even with a PC board. These are highly recommended for the Amateur who doesn't have a large junk box!

construction techniques

When building power transistor amplifiers, I prefer to build the circuits directly on or above a double-clad PC board type of material similar to the construction technique mentioned in reference 1. The choice of PCB material is not important because it's used only for ease of construction and to keep low impedance grounds.

For best performance, especially on UHF, the edges of the PCB should be wrapped with a thin copper or brass foil which can then be soldered to both the top and bottom of the board. This insures a good low-impedance ground. Next, drill a hole in the PCB sufficiently large to pass the power transistor package. Likewise, place a similar metal foil around this hole and solder it to the top and bottom of the PCB as shown in **fig. 8**. This will help keep the emitter (or base, if appropriate) at a low impedance to ground. Gain will not be reduced and the circuit will be more stable.

Then attach the PCB material to an adequately sized heat sink with an appropriate number of sheet metal or machine screws. The input/output connectors can be attached by right angle brackets at the ends of the board. Where appropriate, small squares or islands can be cut with a small sharp knife on the PCB as shown in **fig. 8**. Variable capacitors and other components can be tack soldered between these islands and grounded for mechanical circuit stability.

mismatches

Most modern power transistors are quite rugged, especially if they're emitter-ballasted. However, the voltages can soar if the amplifier looks into a high VSWR such as an open circuit. Therefore, always bring drive power up slowly and test for VSWR before running full power. If the VSWR is greater than 2:1, fix the problem before using your amplifier!

filtering

The harmonic content of a transistor power amplifier is usually quite high. This is why it's important to select the proper circuit operating *Q* and low-loss components as just discussed. Fortunately the amount of harmonic output acceptable (usually 40 dB minimum) is easy to obtain. Also your antenna system will often add some margin. If a transistor power amplifier drives a vacuum tube amplifier, the output harmonics will usually be lower due to the extra filtering usually present in tube amplifiers. However, if harmonics are unacceptable (as evidenced by TVI, etc.), an output low-pass filter may be required.[9]

heatsinking tips

Several times in this month's column I've stressed heat dissipation as an extremely important parameter when using bipolar power transistors. The thermal resistance or conductivity to the heat sink must be low if long life and reliable operation are to be achieved. All power transistors should be directly attached to a heat sink without an intermediate surface. That is why I recommend the construction techniques above.

Thermal resistance can be kept low by applying a suitable heat sink compound to the transistor base where it mates with the heat sink. Use Dow Corning 340® or an equivalent compound. Mica washers or other objects should be avoided if at all possible.

The size and type of the heat sink is also important. Heat sinks with plenty of radiating fins are highly recommended. It's almost impossible to provide too much heat sink, but remember that the heat must travel *away* from the device, so the location of the attachment point is most important. Often the sink must be milled slightly to provide room for the nuts on stud packages. Don't remove any more fin area than necessary. (For those interested in choosing the correct heat sink, I strongly recommend that you refer to recent *ham radio* articles on thermal design.[10,11])

tuneup and test

At last we get to the bottom line — the final tuneup and operation. A recommended test setup is shown in **fig. 9**.

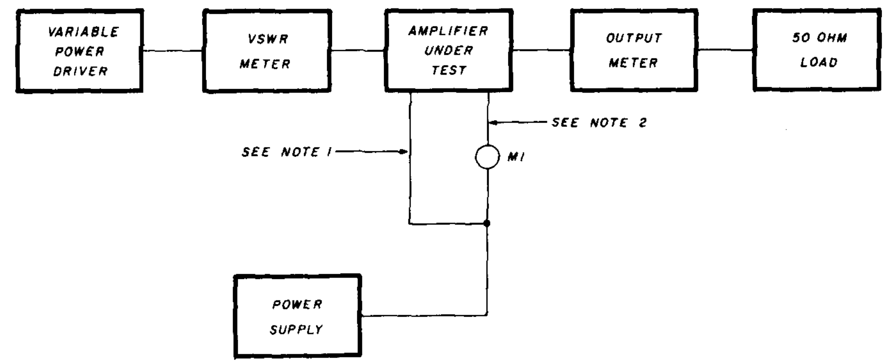

fig. 9. Test setup for tuning up a bipolar power amplifier. Note 1: to biasing circuits. Note 2: to collector circuit.

If the amplifier is operated in linear mode, first set up the I_{CQ} or collector operating current, as previously discussed. A 100 or 250 milliampere meter is usually sufficient. Temporarily break the collector line, making sure that the biasing circuitry is ahead of the meter. A variable supply is recommended for this step. Increase the supply voltage slowly while monitoring I_{CQ}. If the recommended current is obtained before the final operating voltage is reached, decrease the bias circuit current accordingly. Repeat this test and adjustments until the proper current is reached at the nominal operating voltage. If the transistor is stable and the heat sink adequate, the collector current should remain fairly stable.

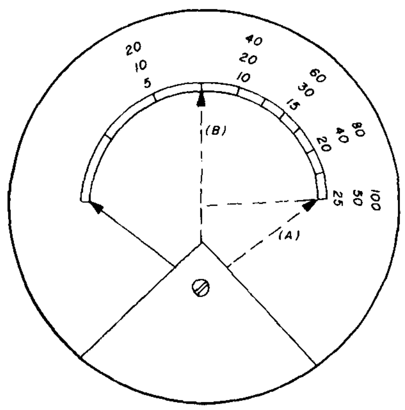

fig. 10. Typical RF power meter scale. For illustrative purposes, point A is the full power (key down) position. Point B is the maximum point at which the indicator should be when operating SSB for the same power output condition.

Next, short out the meter or put a high current type in its place. Apply a small amount of drive and quickly tune the output network for maximum output power. If none is forthcoming, tune the input network until the device starts to run power and adjust the output for maximum. Keep increasing input power while readjusting both the input and output tuning for maximum output power.

When the final desired or expected power is obtained, check the amplifier input VSWR. If it isn't 1.5:1 or better, adjust the input matching network accordingly. If you can measure collector current at maximum output power, calculate the amplifier's efficiency by dividing the indicated output power by the collector power (collector current times collector voltage). It should be at least 35 to 60 percent, depending on frequency and devices. If it is not, readjust the output tuning slightly to increase efficiency.

The final test is to see whether the amplifier output power is fairly linear. This can best be done by noting the amplifier gain (indicated power output divided by input power) at several power levels. At full power, the gain should be only slightly lower, perhaps 0.5 to 1 dB (80 to 90 percent), below that at lower power levels.

power meter syndrome

Let me broach one other subject before closing: I call it the "Power Meter Syndrome." Joe Ham tunes up to full power and sees 100 watts indicated on his wattmeter. Then he switches to SSB and proceeeds to watch the meter jump around. He's tempted to talk the power up to the same maximum tuneup level on the power meter, thinking that doing so will make him easier to copy at the other end. Doing this causes splatter galore!

Why? Well, most power meters have some meter damping. What this means is that the indicator is slow to respond. Hence, on a voice peak, the meter will typically indicate only 25 to 30 percent of the peak power. I've illustrated this in **fig. 10**. Also, the maximum output point is probably at compression and therefore the IMD is poor at best. So, if you want to stay friendly with your local competition, keep your level down so that you're running only about 25 to 35 percent of the maximum possible output power as indicated by voice peaks.

conclusion

The intent of this article was to familiarize you with the bipolar power transistor and its use, rather than to provide a cookbook design approach. For some this will be sufficient. For others it will not be enough. However, with the material presented and the references provided, you should be able to forge ahead in the direction you choose.

Note: In several previous columns I've mentioned a home computer program called "RF-CAD." It's a very useful tool for designing filters and antennas and for matching, etc. This program is now available for use on the IBM PC or compatible machines. For further details and a list of capabilities, write Gary Field, WA1GRC, 5 Pluff Avenue, North Reading, Massachusetts 01864 (enclose SASE).

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August 20:	*EME perigee*
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September 14-15:	*ARRL VHF QSO Party*
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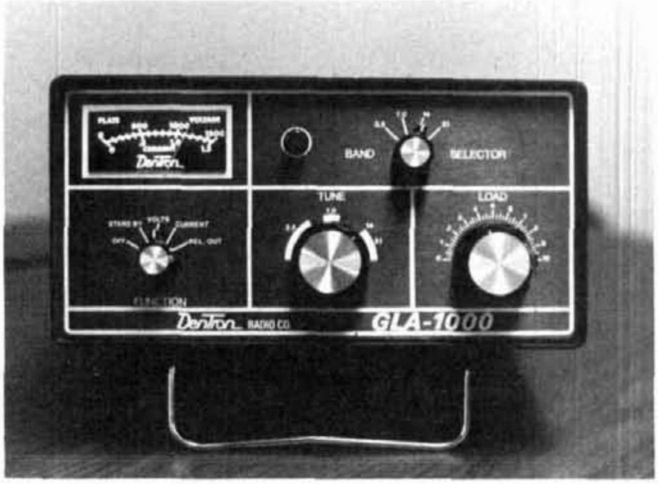

Individual cathode bias does the trick

stop blowing finals
in the GLA-1000 amplifier

The Dentron GLA-1000 linear amplifier, introduced in 1978, has since become popular with HF operators on both sides of the Atlantic. Measuring only 11 × 5-3/4 × 11 inches (27 × 13.7 × 27 cm), this compact amplifier runs up to 1200 watts PEP input when driven by any of the popular 100-watt SSB transceivers. The amplifier uses four tubes in parallel operated in grounded grid configuration with 1200 volts on the anodes.

Though the tubes are capable of supplying the rated output with ease, problems were encountered often in daily use. The techniques used for solving the problem are applicable to all amplifiers with similar bias arrangements.

tubes destroyed with high SWR

My GLA-1000 linear amplifier operated well for the first three months until operation was attempted on 15 meters into a 3:1 SWR. The AC fuse blew and examination revealed that *all* the tubes were ruined. A replacement matched set of tubes was acquired from Dentron and installed, but suffered a similar fate when an accidental mismatch occurred.

In despair, I contacted Dentron for advice. They recommended updating the GLA-1000 into the latest GLA-1000B using a tuned circuit kit, a new grid bias zener diode, and add-on resistors for the anode parasitic chokes.

The original amplifier section of the unit is shown in skeleton form in **fig. 1**, which clearly depicts the bias arrangement.

tuned input kit

The modification kit replaces the fixed filter at the input with a PC board containing five pretuned pi circuits. These reduce the input SWR and improve the power transfer from the transceiver while filtering unwanted harmonics.

The zener diode in the modification kit is a 24-volt 1N3321 that replaces the original 9.1 volt 1N3308. This increases the negative grid bias, which reduces the no-signal anode current to 150 mA and reduces both the overall dissipation and the peak currents under drive conditions.

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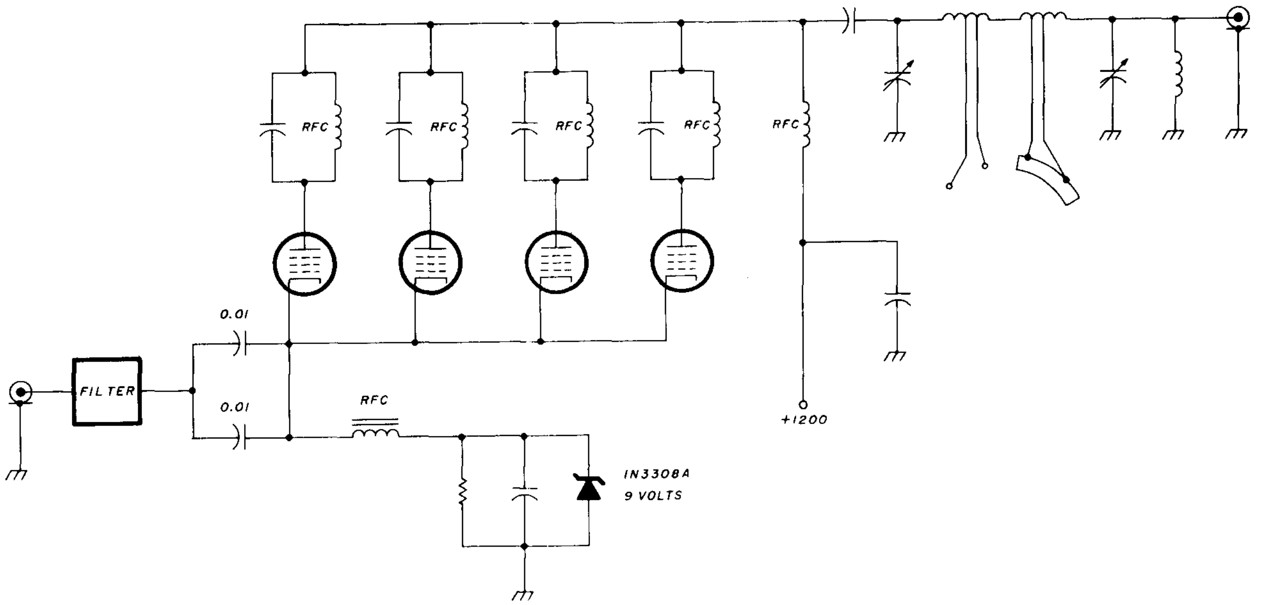

fig. 1. Simplified GLA-1000 original circuit.

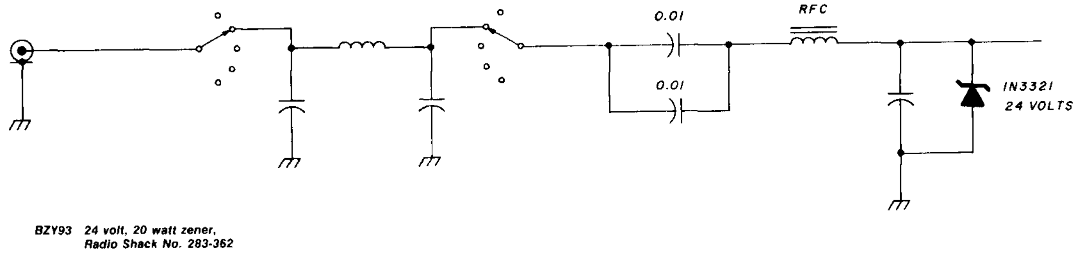

fig. 2. Dentron modification.

The four 100-ohm resistors added to the anode parasitic chokes are included to reduce their *Q*, which may prevent possible VHF instability.

A simplified diagram of the modified circuit is shown in **fig. 2**.

After modification, the third set of PA tubes lasted twelve months until an open circuit antenna feeder caused their demise together with the new zener diode. The circuit arrangement is far too critical of any mismatch, and instead of providing a fail-safe condition, it always destroys the costliest circuit components.

reason for sensitivity

Examination of the modified circuit reveals that the pi input circuit would not help power sharing between the tubes but would make the input look close to 50 ohms on all bands. While this is obviously an advantage to owners of all solid-state transceivers, it is of little help to operators of transceivers with tube power amplifier PAs that include their own pi output networks.

The zener diode replacement, obviously intended to control performance, does not accommodate unmatched sets of tubes. This is especially true if one tube is very different from the others. Under such circumstances the bad tube either shuts down by going gassy or shorts. In the shut-down case the remaining tubes would overdissipate and successively fail, just like dominos falling down. This is what appears to have happened the first two times. The third catastrophe would indicate a short circuit tube that blew the zener and left the remaining tube with no negative grid bias.

The bias is developed by drawing the cathode current of all four tubes from the single zener diode. This places the cathodes positive with respect to the grounded grids by the value of the zener voltage.

With the replacement of the Motorola zener diode likely to be expensive, drastic modifications to provide a separate bias supply were considered.

To control tube conditions both dynamically and quiescently, bias has to be supplied to each tube's cathode. This, together with the zener bias, would ensure equal power sharing. The idea was taken from the common practice used with parallel transistor stages, in which balancing resistors are used in the base or emitter circuit to overcome differences in base/emitter voltages and to ensure equal power sharing. **Figures 3** and **4** show typical transistor power-sharing circuits.

Automatic bias is provided simply by adding a resistor in the cathode so that cathode current produces grid bias. The value of resistor has to be chosen with care so that it does not drop too many volts on current peaks and cause flat topping. Nevertheless, it has to be large enough to cause about 1 volt change of bias for a 50 percent change of cathode current. With a combined current of 150 mA, each tube should be drawing 37.5 mA, about right for most class AB1 tube finals. A 50 percent change would be 18.75 mA, so for 1 volt the automatic bias resistor R_X would be

$$R_X = \frac{1V}{18.75\ mA} = 53.33\ ohms,$$

(a 56 ohm resistor was chosen).

However, since the signal is also applied to the cathodes in this configuration, the 56-ohm resistors in series would cause appreciable loss of drive and also mismatch the newly installed pi input circuit. To over-

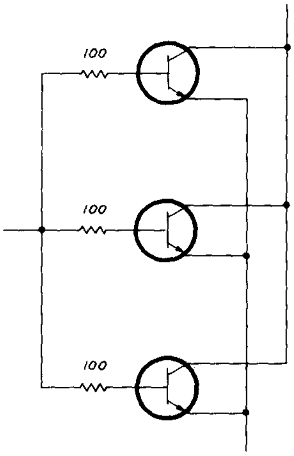

fig. 3. Bias and drive balancing.

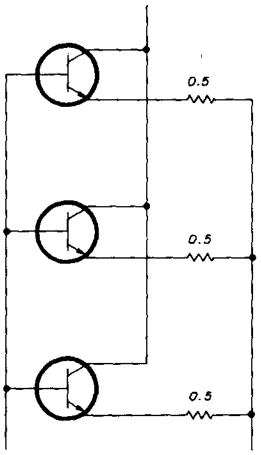

fig. 4. Bias and load sharing.

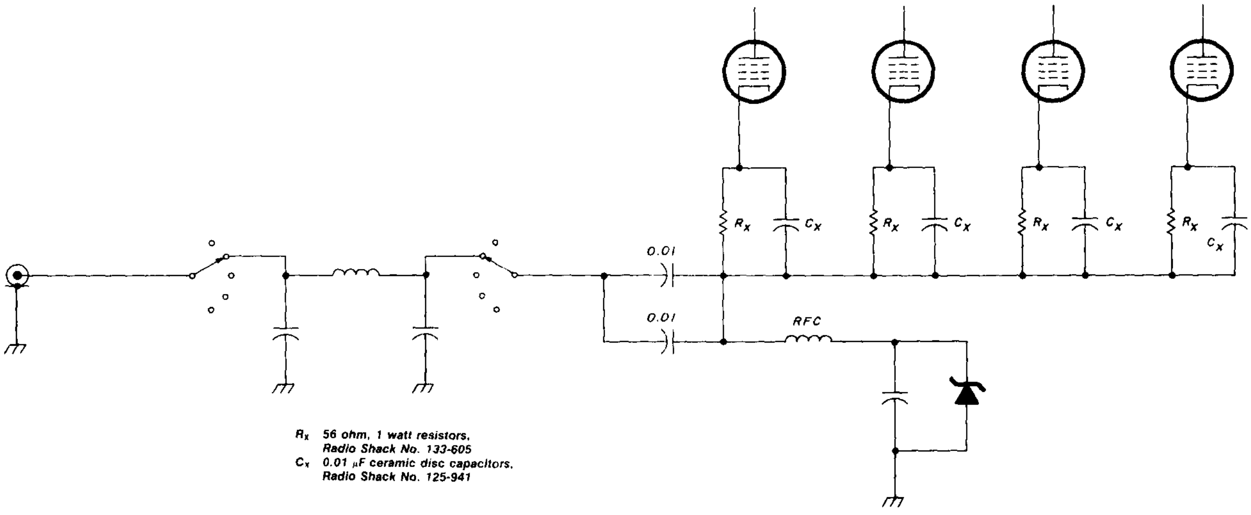

fig. 5. Bias and load sharing modification.

come this, each resistor could be bypassed to RF by a low reactance capacitor. A value was chosen by trying standard values in the formula $X_c = \frac{1}{2\pi fC}$ where it was found that 0.01 μF was 4.55 ohms at 3.5 MHz and 0.57 ohm at 28 MHz.

The new circuit configuration is shown in **fig. 5**.

construction details

The tube sockets in the GLA-1000 are mounted on a PC board. A scale drawing of this is shown in **fig. 6**. The 0.01μF bypass capacitors, C_X, are attached to the resistors as shown and wired across the breaks marked on the tracks connecting pins 3 of the tubes.

A suitable alternative to the 1N3321 zener is the BZY93 24-volt type. Available at low cost, it has a stud anode instead of cathode. It can be fitted into the hole used by the old diode but must use an insulating kit and solder tag to pick up the positive stud. Use a grounding strap on its wire end.

performance

It was well over a year since the modification was done. Since that time, the unit has undergone intense activity and repetitive abuse. The absence of TVI complaints suggests that the modification has not degraded signal purity in any way. The peak output power is easily achieved and appears stable under continued full power operation.

The current sharing technique prevents the "domino effect" breakdown under fault conditions. This was convincingly demonstrated when a severe mismatch caused the AC fuse to blow — but nothing else was damaged!

The amplifier was designed to use selected and matched tubes designated D50 by Dentron. Nevertheless the third and fourth sets were standard type 6LQ6 manufactured in the USA. Tube types 6LQ6, 6JE6, or 6MJ6 may be used, although idling currents may differ sufficiently to require adjustment of the bias zener voltage to give between 35 and 40 mA quiescent current. The 6LQ6 tube and the 6MJ6 type, which are capable of higher power at lower frequencies but unsuitable for 10-meter use, are both readily available. Although Japanese tube substitutions were found to be unstable in this design, both before and after modification, they appear to provide higher gain. The American types are the lowest cost and have shown no signs of instability. (Higher power types 6MJ6 have not been tried at any time.)

This modification has been so successful that I've shelved my half-built homebrew 813 linear. Undoubtedly the principles involved can be extended to other linears of similar design and should result in greatly extended tube life.

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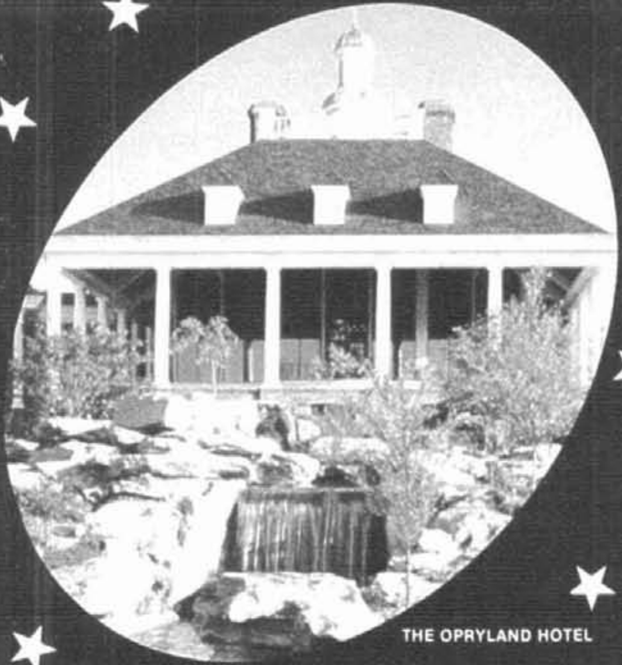

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a pulsed, constant current, NiCad battery charger

Longer life, shorter charge time — plus automatic shutoff

"Zapping" NiCad batteries with a burst of high current is an old trick often used to revive seemingly dead cells. Word has it that some RC model airplane enthusiasts extended this idea to the actual charging of batteries, with favorable results; their batteries lasted twice as long and charged more quickly than those who used conventional charging methods. The idea was to charge with a train of pulses instead of a steady current. Apparently, less energy was lost to heat during the charging process, resulting in shorter charging times and increased battery life.

This charger was designed with these goals in mind. Over the two years it's been in use, charging times have been shortened by one-third and new life has been given to a battery pack about to be thrown away.

principle of operation

The key to pulse charging is to keep the average value of the charging current the same as it would be in conventional schemes, but use a low duty cycle waveform. The plot shown in **fig. 1** is the current waveform used in this charger. For 10 percent of each cycle, current equal to I_{MAX} charges the battery. For the remaining 90 percent of the cycle, no current flows. This produces a rectangular waveform with a 10 percent duty cycle.

The DC, or average value of this waveform is 10 percent of the pulse amplitude, or

$$I_{DC} = 0.1 I_{MAX} \quad (1)$$

As long as normal charging precautions are observed and the DC charge rate is within the capability of the battery, pulse charging will in no way harm the battery. A pulse width of about 100 microseconds (μs) is appropriate for this application, which, because of the 10 percent duty cycle, yields a pulse rate of 1 kHz.

circuit description

The block diagram in **fig. 2** outlines the basic design of the charger. The schematic is shown in **fig. 3**. The charger — designed to handle from one to ten NiCad cells, with an adjustable charge rate of 50 to 450 mA — consists of the following sections:

Constant-current source. The charging current is supplied by a constant-current source that can be pulsed at peak currents of up to 5.0 amperes. A constant-current source can be made from a three-terminal voltage regulator and a resistor, as shown in **fig. 4**. In this circuit the current, I_{DC}, is simply the output voltage of the regulator, V_o, divided by R3, or

$$I_C = \frac{V_o}{R3} \quad (2)$$

Unfortunately, this method does not easily lend itself to high frequency switching.

A better approach is shown in **fig. 5A**, in which the regulator is replaced with a zener diode and pass transistor. Here, the current is equal to the zener voltage, V_Z (less the base-emitter voltage drop of Q1) divided by R3, or

$$I_C = \frac{(V_Z - 0.6)}{R3} \quad (3)$$

The current can be instantly switched off by grounding the base of Q1. This circuit worked well except at high currents.

To improve its operation at high currents, I added a second transistor as shown in **fig. 5B**.[1] This circuit worked very well. It could supply a constant current into either a short circuit or 10 cells in series and still hold the current to within 1 percent of its setting.

As shown in **fig. 3**, the current is adjusted by R3. R4 is inserted in series with R3 to limit the current if R3 is set to zero.

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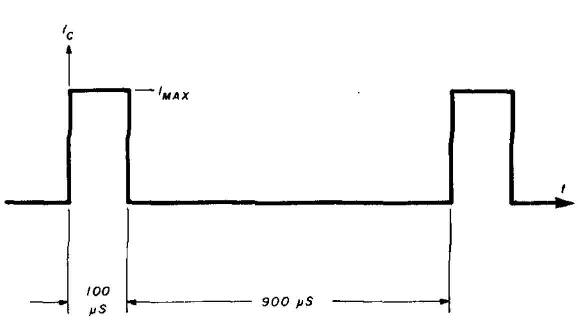

fig. 1. The charging current has a rectangular waveform with a 10 percent duty cycle. Repetition rate is approximately 1 kHz.

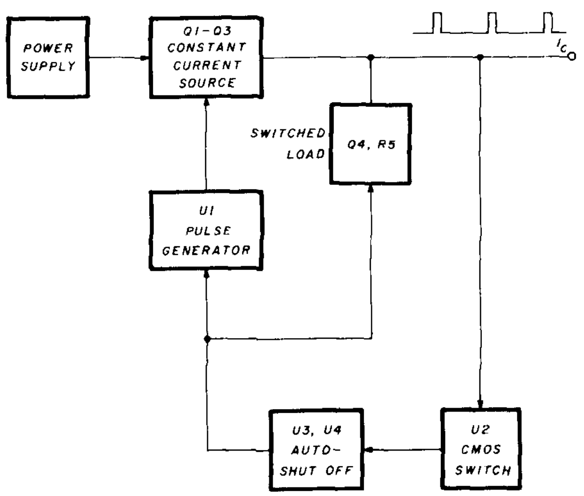

fig. 2. Block diagram of the pulse charger.

Power supply. For the constant current circuit to work properly while charging up to 10 cells in series, the power supply must provide at least 30 VDC. The unregulated power supply shown in **fig. 3** satisfies that requirement if T1's taps are wired for 22.3 VAC, as shown. A separate zener regulated section provides 15 VDC for the control circuitry of the charger.

Pulse generator. The pulse waveform is generated by U1. Actually, U1 produces a 90 percent duty cycle waveform instead of 10 percent in order to accommodate the inverting action of Q3. Q3 turns the current source off when the output of U1 is high, and on when it is low. That converts U1's 90 percent duty cycle to a 10 percent duty cycle charging current.

Automatic shutoff. Different schemes abound for controlling the charging time, each with their advantages and disadvantages. In the scheme chosen for this charger, charging stops when the battery reaches a set voltage. However, the battery voltage is not monitored in an ordinary manner.

Because of a battery's internal resistance, the voltage at its terminals during charging is less than its open circuit voltage, and will vary with the charge rate. As soon as a load is put across the battery, the voltage will drop further. In this charger, battery voltage is monitored only during that part of each cycle in which the charge current is off. Furthermore, a small load, R5, is kept across the battery to give a truer indication of the state of charge when the battery is monitored. The load is automatically switched out of the circuit during automatic shutdown.

Automatic shutoff is accomplished by monitoring the battery voltage with comparator U3. R15 and R16 divide down that voltage and U3 compares it with the voltage provided by reference diode CR8. When the voltage at the comparator rises above the reference voltage, Q5 turns on, shorts out C5, and stops U1 from oscillating. That forces the output of U1 high, which holds the constant-current source off.

R13 and R17 add hysteresis to the action of the comparator. With the values given, the battery voltage must drop about 30 percent before charging will switch on again after automatic shutoff. The amount of hysteresis can be changed by raising or lowering the value of R17.

In order for U3 to monitor the battery voltage only during the off portion of a charge cycle, CMOS switch U2 passes the voltage on to the comparator in sync with U1. In this way, when U1 stops oscillating, the comparator will still see the battery's voltage because U2 is kept closed by U1 in the automatic shutoff state.

Current metering. The torque on the pointer in a standard D'Arsonval meter movement is directly proportional to the true DC value of any current passing through it. As a result, the DC milliamp meter M1 in **fig. 3** correctly indicates the true charge rate delivered to the battery. Load resistor R5 is wired in the circuit so that the load current delivered to R5 by the battery during the off period of a cycle is taken into consideration by M1. The value of R5 was chosen to add a load of about 25 mA when charging an 11-volt battery pack.

construction

Perfboard was used for mounting most of the components. The board was connected to the rest of the circuit by an edge connector to make it removable during the design phase of the project, but any convenient construction method can be used because parts layout is not critical. A Radio Shack cabinet (former catalog No. 270-269, **fig. 6**) housed the circuit. M1 is specified as 0-500 mA, in the parts list; a 0-100 μA movement was used in the original model by adding a current shunt.

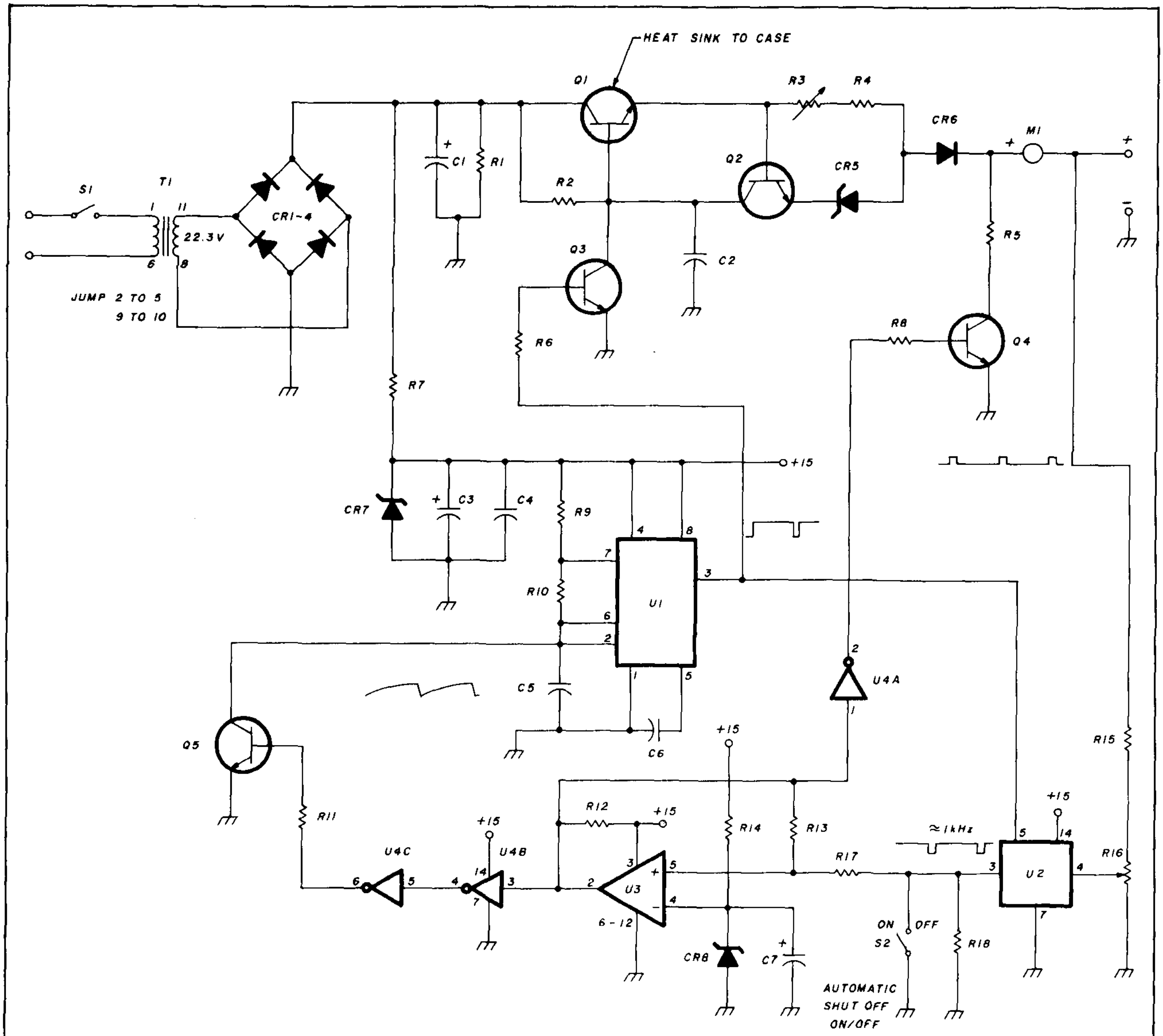

fig. 3. Schematic of pulse charger. U2-U4 can be eliminated if the automatic shutoff feature is not wanted.

Although pass transistor Q1 is heat-sinked to the case, it must be electrically insulated from it. During conduction, the current through Q1 can be as high as 5 amperes and the voltage across it about 15 volts. Instantaneous power is 5 × 15 = 75 watts, but the power which must be dissipated by Q1 is only ten percent of that because of the duty cycle. Using the case as a heat sink works well for this low power level.

The heat dissipated in R3 and R4 is proportional to the square of the RMS voltage across them, divided by their resistance. Because of the ten percent duty cycle, that RMS voltage is approximately one-third of the peak voltage across the resistors, as is the RMS current value through the resistors. With this in mind, the wattage ratings should be 10 watts for R4 and 5 watts for R3. An old loudspeaker level control was used for R3, but any 70-100 ohm, 5-watt potentiometer will do. Since the charge current is inversely proportional to R3, the higher current settings will bunch up at one end of the shaft rotation. A potentiometer with a non-linear taper can reduce that effect.

Switch S2 disables the automatic shutoff feature. If desired, the entire shutoff feature can be left out by removing U2 through U4 and their related components, as well as R5 and Q4.

operating the charger

NiCad batteries can be charged at a significantly higher rate than that provided by the average stock charger as long as the battery is not overcharged.[2] Once fully charged, the battery must dissipate any additional charging as heat. At the popular C/10

Parts list figure 3.

item	description
C1	1500 μF, 50 volt electrolytic
C2	0.001 μF
C3	100 μF, 25 volt electrolytic
C4,C6	0.01 μF
C5	0.01 μF mylar, 10 percent
C7	10 μF tantalum
CR1,CR2 CR3,CR4	6 ampere, 100 volt rectifier bridge
CR5	1N753 6.2 volt zener diode
CR6	2 ampere, 50 volt rectifier diode
CR7	1N4744, 15 volt zener diode
CR8	1.2 reference diode
M1	0-500 mA DC ammeter
Q1	TIP120 (Radio Shack No. 276-2068)
Q2	TIS97
Q3	2N3904
Q4	2N2222
Q5	2N3704
R1	2.2 kilohms, 1 watt
R2	2.2 kilohms, 2 watts
R3	70-100 ohms, 5 watt potentiometer (see text)
R4	1.5 ohms, 10 watts
R5	470 ohms, 2 watts
R6	1.5 kilohms
R7	680 ohm, 2 watts
R8,R11	10 kilohms
R9	120 kilohms
R10,R18	22 kilohms
R12	3.3 kilohms
R13	2.2 megohms
R14	15 kilohms
R15	5.6 kilohms
R16	2 kilohms, 10-turn trim potentiometer
R17	51 kilohms
S1,S2	SPST toggle switch
T1	Stancor RT-201 power transformer or equivalent
U1	NE555 timer
U2	CD4016 CMOS switch
U3	LM339 comparator
U4	National CMOS 74C04

All other capacitors are disc ceramic. Except as noted, all resistors are 1/4 watt.

charge rate, where C is the ampere-hour capacity of the battery, NiCad cells can be overcharged continuously without risk of damage from overheating. This assures safety in case the battery is left on "charge" continuously. On the other hand, if the battery is charged at a higher charge rate, say C/3, and goes into overcharge, cell temperature will rise, with possible damage and loss of battery life. However, if care is taken to avoid overcharging, there is no inherent reason why a NiCad cell cannot be charged at the higher rate. The automatic shutoff will prevent just such overcharging from occurring after it is properly set.

To set the automatic shutoff, first remove any diode in series with the HT's charging jack if the battery will remain inside the HT during charging. (If you don't do this, the automatic shutoff feature won't work.) Connect the discharged battery to the charger, turn the charger on, and turn off the automatic shutoff with S2. Set the charge rate to C/3, and add another 5 mA to compensate for changes in the load of R5 as the battery voltage rises. (For a 500 mA hour battery, that would be about 155 mA.) Monitor the battery voltage with a precision voltmeter, preferably a DVM — accuracy is not as important as precision. Check the

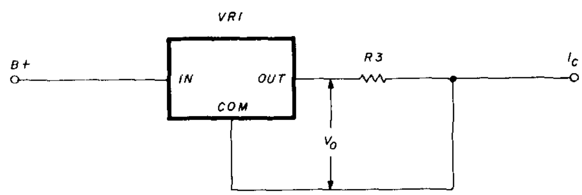

fig. 4. A 3-terminal regulator forms a constant current source by holding the voltage across and, hence, the current through R3 constant.

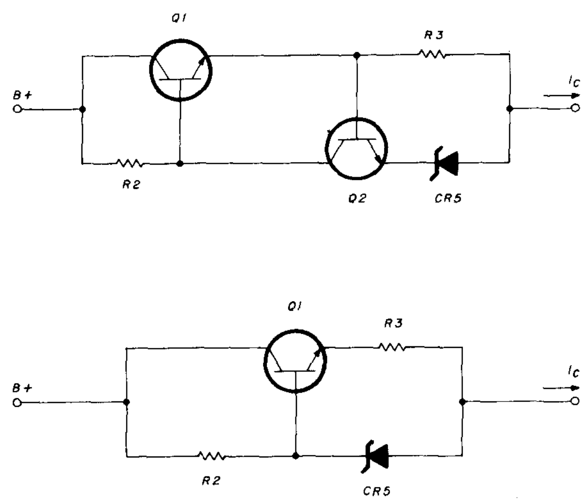

fig. 5. A constant current source can be created with a zener diode, one or two transistors, and a couple of resistors. The current can easily be switched off to form pulses by grounding the base of Q1 through another transistor.

battery frequently as it charges. The battery voltage will rise rapidly initially and gradually thereafter. When the battery nears its fully charged state the voltage will again rise, but more importantly, the battery will start to become warm to the touch. This increase in temperature indicates that the battery is now fully charged. Note the voltage when this occurs; it will probably be the equivalent of 1.45-1.50 volts per cell. Also make a note of how much charging time it took to arrive at this point, starting with a fully discharged battery.

Now turn on the automatic feature, and adjust R16 until the charge current turns off. Reduce the charge rate setting slightly and reset the automatic shutoff by cycling S2 on and off. Raise the charge current back up again and watch the voltmeter to make sure charging shuts off at the voltage just measured. If the shutoff point cannot be set exactly, err on the low side by setting it slightly below the desired voltage.

If the automatic feature is not used, charging can

fig. 6. The charger fits nicely in a standard Radio Shack cabinet. Parts layout is not critical and any convenient construction method can be used.

be controlled by time. An inexpensive mechanical timer can shut off the charger after the proper length of time, as just determined. Remove the "ON" arm of the timer to keep it from again turning on the charger 24 hours later.

conclusion

The pulse charger has been a considerable time-saver: it takes only 3-1/2 hours to fully charge a 500-mA hour battery pack at a 150 mA charge rate; a non-pulsed charger at that same rate took 4-1/2 hours. This represents a time savings of over 30 percent, and increased charging efficiency as well. As a test, the battery was discharged with a load resistor equivalent to a 100 mA load and timed to confirm that it was indeed fully charged by the pulse charger.

The charger was also used to add life to an old, seemingly dead battery pack. The battery was consecutively discharged and charged about four times. From that point on, it lasted another three months.

The pulsed charger should prove to be a worthwhile accessory for anyone who uses NiCad batteries extensively.

acknowledgement

Many thanks to Pat Spadafore, KA2MOV, for his invaluable experience and recommendations concerning pulsed charging techniques.

references

1. *The Radio Amateur's Handbook*, American Radio Relay League, Newington, Connecticut, 1983, page 4-31.
2. *Nickel-Cadmium Battery Handbook*, 2nd Edition, General Electric Company, 1975.

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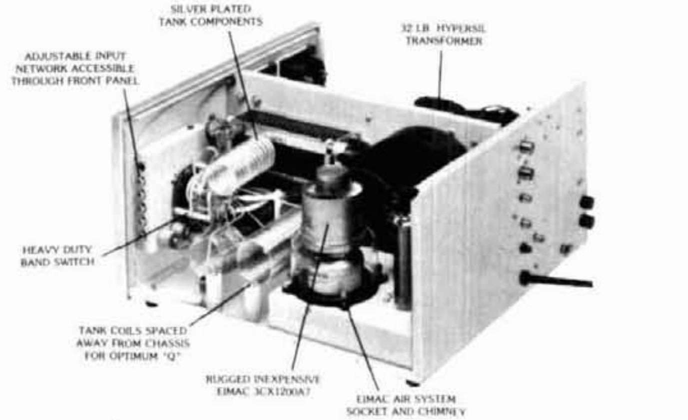

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3CX1200A7
10 to 80-meter amplifier

New EIMAC tube provides 1500 watts out

For several years, I have used the popular EIMAC 3-1000Z as the main amplifier tube in my station. I enjoy the instant-on characteristics of the tube as well as the well-matched drive requirements for a 100-watt output exciter. Recently EIMAC introduced the 3CX1200A7, the newest addition to its line of metal ceramic external anode triodes. The electrical characteristics of the tube are identical to the 3-1000Z except for the increased plate dissipation (1200 watts) allowed by the external anode.

I decided to modify my 3-1000Z RF deck to accommodate the new tube. The only change necessary was in the tube socket and chimney. (The 3CX1200A7 uses the EIMAC SK-410 or Johnson 248 socket commonly used for the 3-500Z tube. A matching glass chimney — EIMAC SK-436 — is also available). The modification took less than eight hours. This article summarizes the results of the project.

the amplifier circuit

As indicated above, this amplifier is designed around the new 3CX1200A7 (see **fig. 1**), using a tuned input network ganged to the main bandswitch. The input circuit minimizes distortion products and helps provide a 52-ohm match to the exciter. Maximum SWR presented to the exciter is 1.2:1. Approximately 100 watts is required to drive the amplifier to 1500 watts output. An effective ALC circuit is also included to prevent overdrive by higher power exciters.

Output impedance matching is accomplished with a pi-network designed for a *Q* of 12. Toroids are used for compactness for the 80-meter pi coil and the tuned input network coils.

Also included is a grid trip circuit to disengage the amplifier should the grid current exceed 300 milliamperes. This circuit protects the tube in case of excessive drive or an improper load presented to the amplifier.

The amplifier includes an effective dynamic bias circuit. Response time of the circuit is fast enough to cut the amplifier off between syllables on SSB and between dots and dashes on CW. A defeat switch is included on the rear panel of the amplifier. When engaged, the heat generated by the tube is substantially *reduced* during amplifier operation as feeling the temperature of the air exiting the amplifier cabinet will confirm.

A 100 VDC power supply is included to power the dynamic bias circuit, and a 26 VDC supply is included for panel lights and relay operation. An RF wattmeter is included for tuneup and measurement of amplifier efficiency.

amplifier control circuitry

The amplifier control circuitry is illustrated in **fig. 2**. 120 VAC enters the RF deck from the power supply. Power is applied to the amplifier by depressing the front panel switch S1. S1A applies 120 VAC to the HV power supply, the time delay relay TD1, the filament transformer, the 100 VDC bias supply and the 26 VDC supply. The blower receives power immediately through S1B. When the power is turned off with S1, the blower (*B*) keeps running for approximately three minutes to cool the 3CX1200A7. This delay is accomplished through the use of the time delay relay TD1. The control circuitry is quite simple because of the "instant on" characteristics of the 3CX1200A7 tube.

grid trip protection

A grid trip module has been included in the amplifier design to protect against high levels of grid current which could be dangerous to the 3CX1200A7 tube. High levels of grid current could be caused by excessive drive, improper tuning or lack of a 50-ohm load on the output of the amplifier. In this design, if the grid current exceeds 280 milliamperes, the circuit trips relay RL3 (see **fig. 3**), which breaks the VOX amplifier line to deactivate the amplifier and lights the front panel "grid trip reset" push button (S4). It is necessary to push the reset button to put the amplifier back into operation. Of course, one should determine why the amplifier exceeded 280 mA before proceeding with amplifier operation.

The circuit operates as follows: grid current is drawn through the 10-ohm resistor (R1) as shown in **fig. 1**. The current flowing through the 10-ohm resistor develops a voltage that turns on transistor Q3 in the grid trip circuit when the current reaches 280 mA (or any other value if desired). 280 mA through a 10-ohm

By Jerry Pittenger, K8RA, 2165 Sumac Loop South, Columbus, Ohio 43229

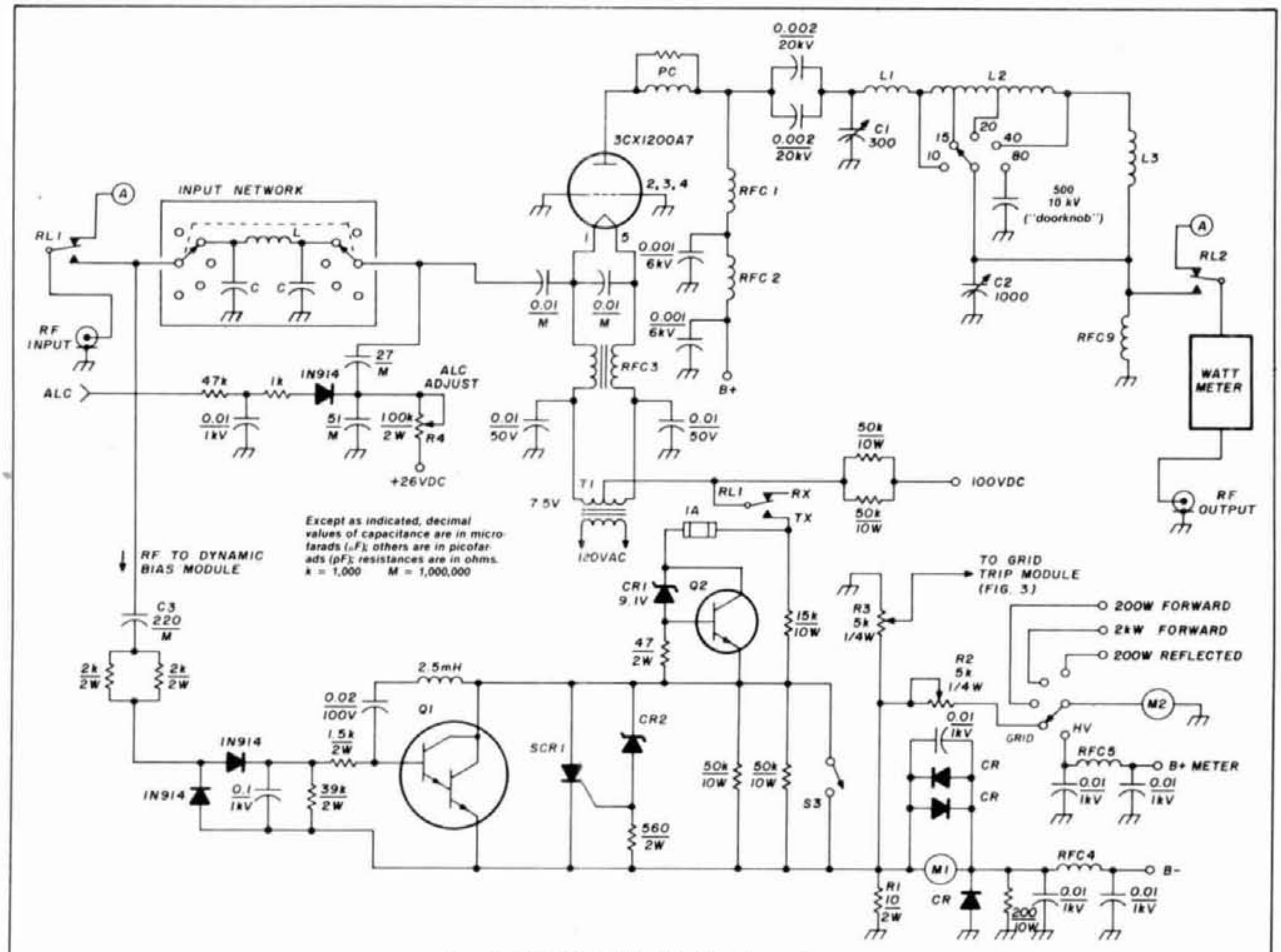


fig. 1. 3CX1200A7 RF deck schematic.

3CX1200A7 amplifier provides full legal output on 10-80 meters.

resistor results in the development of 2.8 volts. Only 0.6 volts is necessary to turn on Q3. Therefore, a 5-kilohm trim pot (R3) has been included as a voltage divider for adjustment.

When Q3 turns on, it serves as a switch providing a path to ground to actuate relay RL3. A set of the relay contacts physically grounds the relay coil of RL3, taking the current load off Q3. If this feature were not provided, the transistor would start gating the amplifier on and off. It is therefore essential to latch the grid trip relay closed. Another set of contacts on relay RL3 breaks the VOX line, deactivating the amplifier. A third set of contacts applies power to the pilot light on the front panel "grid trip reset" pushbutton (S4) located on the front panel of the amplifier to make the operator aware of what happened. Pushing S4 breaks the path to ground for relay RL3, deactivating the relay and putting the amplifier back into a ready state.

This circuit provides simple and effective protection from costly mistakes during amplifier operation.

dynamic bias circuit

The amplifier design includes a dynamic bias circuit to bias the 3CX1200A7 tube beyond cut off between speech syllables on SSB or between dots and dashes on CW. This is especially useful when operating in a full break-in mode when the amplifier is placed in ready

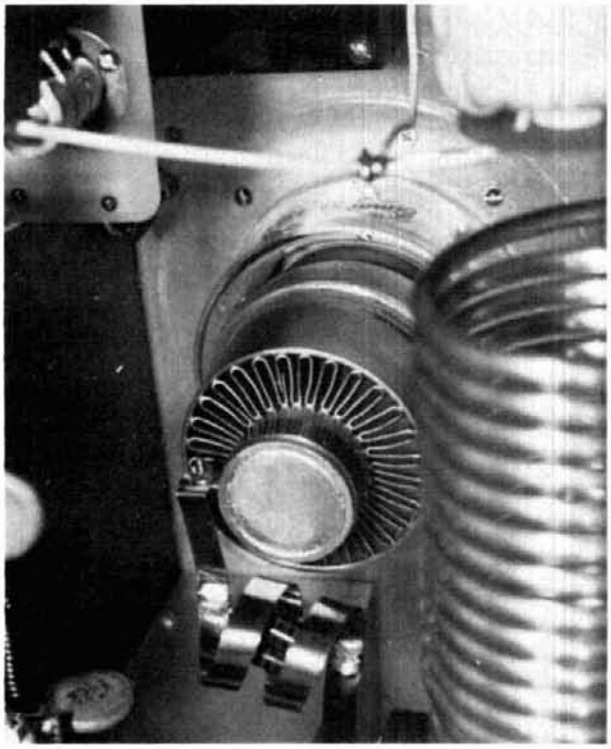
Parts list for 3CX1200A7 amplifier (figs. 1-7).

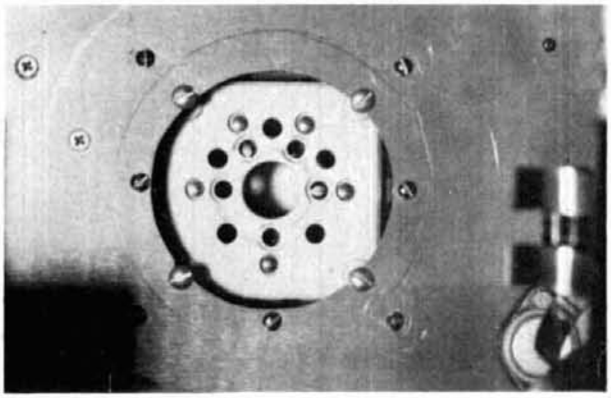
item	description
B	*blower — Dayton 1C180*
cabinet	*10 × 17 × 14 inch, CTS model MCLS-101714, SPP-1014 side panels CP-1714 chassis panel (CTS IntraFab, 660 Lenfest Road., San Jose, California 65133)*
C1	*300 pF/10 kV vacuum variable capacitor*
C2	*1000 pF/3 kV vacuum variable capacitor*
C3	*1-8 pF miniature air variable capacitor*
CR	*HEP 170 diode or equivalent*
CR1	*9.1 volt, 1 watt zener diode (1N4739)*
CR2	*75 volt, 1 watt zener diode (1N4761)*
CR3	*100 volt, 1 watt zener diode (1N4764)*
CRB1,CRB3	*400 volt/4 ampere diode block (RS 276-1173)*
CRB2	*100 volt/4 ampere diode block (RS 276-1171)*
CRB4,CRB5	*diode strings, 10 HEP 170 diodes in series, each paralleled by a 470 kilohm resistor and a 0.01/1 kV disk capacitor*
L,C	*see table 2*
L1,L2,L3	*see table 1*
L4	*RF wattmeter pickup coil, 20 turns No. 22 enameled wire on T-50-2 ferrite toroid core*
M1	*1 ampere plate meter, Triplett 320-G*
M2	*100 μA meter, Triplett 320-G*
Q1	*MJ1000 NPN Darlington or equivalent*
Q2	*2N3055 NPN power transistor*
Q3	*2N3053 NPN transistor*
PC	*2 turns, 1/2 silver strap, 1-inch diameter 3 × 150-ohm 2-watt resistors*
RFC1	*90 turns No. 20 enameled wire on 3/4-inch form*
RFC2	*11 turns No. 14 enameled wire on 1/2-inch diameter air wound*
RFC3	*30 ampere bifilar filament choke, each coil is 16 turns on 1/2-inch ferrite rod*
RFC4,RFC8	*10 turns No. 14 enameled wire on 1/4-inch diameter ferrite rods*
RFC9	*1 mH/800 mA RF choke*
RL1,RL3	*4PDT Potter & Brumfield KHU17D11, 24VDC coil*
RL2	*SPDT vacuum relay, 26VDC coil*
RL4	*2PDT mercury plunger relay, Dayton 6X598-3*
RL5	*DPDT power relay, Potter & Brumfield PR-11-DY*
S1,S2	*2PDT push-button switches: ALCO 16TL5-22 ALCO 6T-4 yellow lens (S1) ALCO 6T-2 green lens (S2)*
S4	*momentary push-button switch, 1 pole/N.C. ALCO 16SL-11 switch ALCO 6S-2 red lens*
SCR	*2N1596 100 volt/1.6 ampere SCR*
T1	*filament transformer, 7.5 volt/21 ampere*
T2	*80 VAC (approx.) transformer, low current*
T3	*24 VAC/1 ampere transformer (Stancor P8661)*
T4	*1400 VAC-2 kVA power transformer*
TD1	*time delay relay, Amperite 115-N-180 (3 minute)*
Z1,Z2	*MOV transient protectors V130LA10A (RS 276-570)*

Notes:
1. Only the major items have been indicated in this parts list. See individual schematics to determine complete component complement.
2. The letter M indicated under the component value of capacitors indicates silver mica.

state at all times. The circuit can save up to 500 watts of power dissipation in the idle state.

Operation of the dynamic bias circuit is quite simple. RF is sampled through the 220 pF mica capacitor, C3. A voltage doubler is formed by the 1N914 diodes, providing a DC voltage to turn on the Darlington transistor Q1. Therefore, Q1 acts as a switch to return the bias voltage to the level determined by the zener diode CR1. The crowbar circuit formed by the SCR and zener diode CR2 is a protection circuit to prevent the amplifier from going into class C operation or the cathode voltage to rise toward the value of the plate voltage when enough drive power is applied should the Darlington transistor Q1 fail to conduct. A full





The 3CX1200A7 tube uses the same socket and chimney as the popular 3-500Z.

theoretical treatment of this design is provided in reference 1.

Switch S3 provides a defeat of the dynamic bias circuit to set the operating bias level or defeat the circuit should the circuit fail in an open state. The circuit can be omitted if desired by replacing the bias module with a wire connecting the emitter of Q2 to the B-minus line (see **fig. 8**).

meter circuits

Metering is provided for plate current, grid current, high voltage and RF power output. Plate current is monitored at all times. This meter is in series with the B-minus lead. All other metered parameters are selected on a mulitmeter. The multimeter has a 100 mA

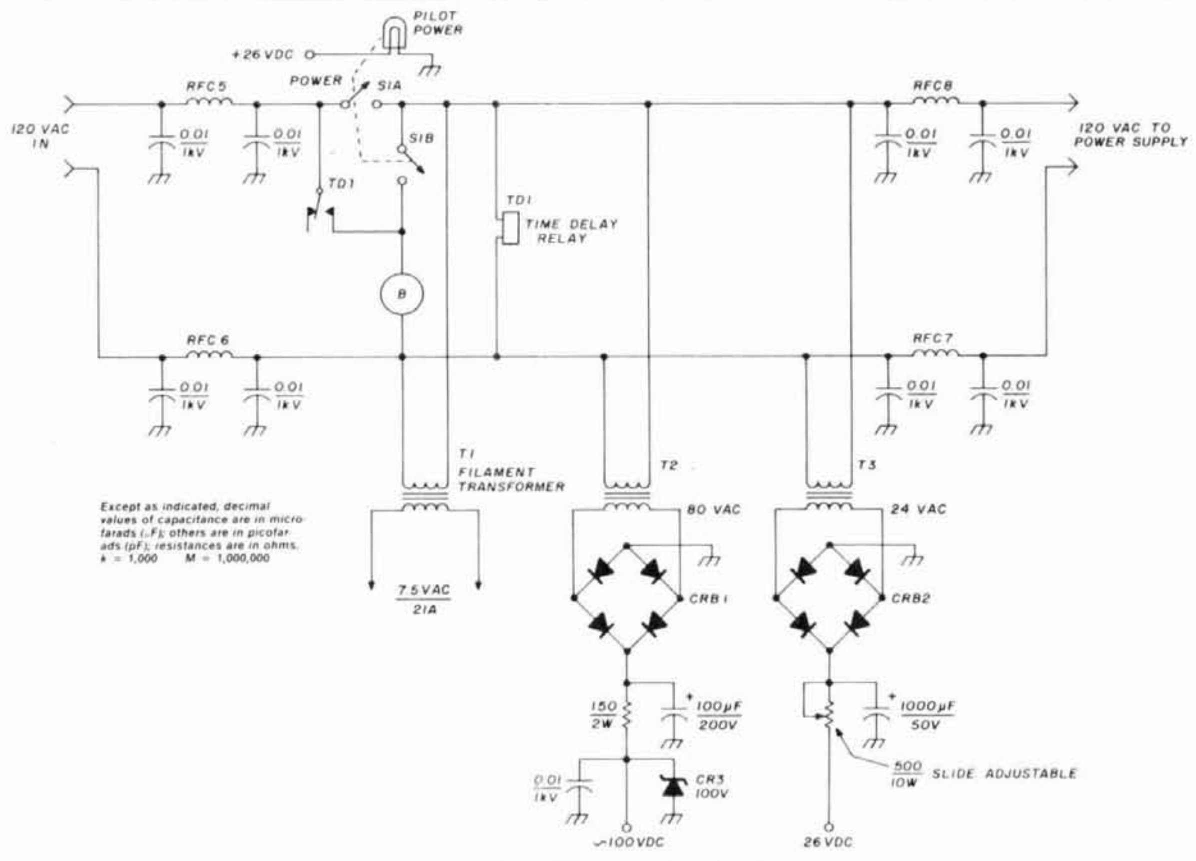
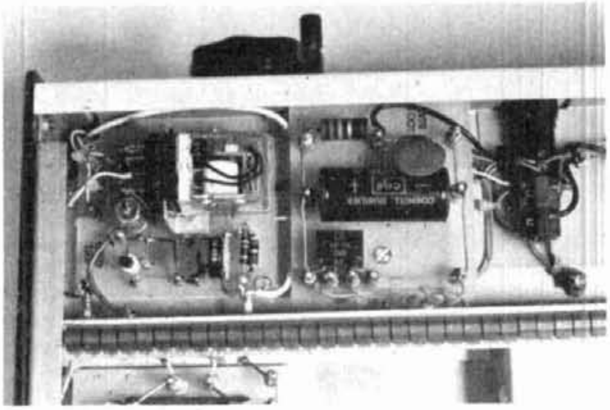


fig. 2. 3CX1200A7 control circuit.



Grid trip circuit (left side) and 100-volt bias supply (right side).

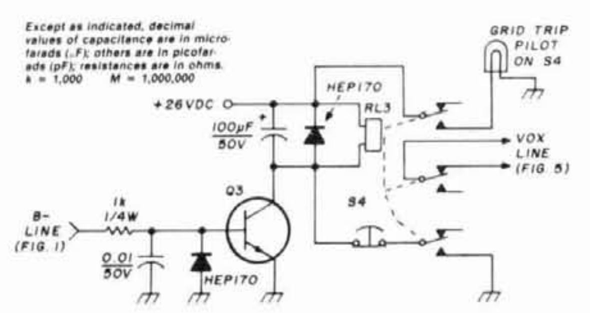


fig. 3. 3CX1200A7 grid trip circuit.

movement with proper calibration resistors for various scales. Any meter movement up to a 5 mA full scale is usable if an RF wattmeter is not desired. The wattmeter requires a very sensitive meter for proper operation.

Grid current is measured by monitoring the voltage across the 10-ohm resistor, R1, through which grid current is drawn. The 5-kilohm trim pot, R2, is used for proper calibration. R2 can be adjusted with a battery in series with a pot and current meter placed across R1 (see **fig. 4**) to vary and measure the amount of current drawn. R2 should be adjusted so that both meters read the same current.

High voltage is measured by monitoring a low voltage value developed by a voltage divider in the power supply. The sampled value is approximately 5 volts and coupled to the RF deck through the control cable.

Power is measured using a toroid-sensing RF wattmeter circuit. The wattmeter is shown in **fig. 5**. Three scales are provided: 200 watts forward, 2000 watts for-

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103	115	127	139	151	163	175	187	199	211	223	235	247	259	271	283	295	307	319	331	343
104	116	128	140	152	164	176	188	200	212	224	236	248	260	272	284	296	308	320	332	344
105	117	129	141	153	165	177	189	201	213	225	237	249	261	273	285	297	309	321	333	345
106	118	130	142	154	166	178	190	202	214	226	238	250	262	274	286	298	310	322	334	346
107	119	131	143	155	167	179	191	203	215	227	239	251	263	275	287	299	311	323	335	347
108	120	132	144	156	168	180	192	204	216	228	240	252	264	276	288	300	312	324	336	348
109	121	133	145	157	169	181	193	205	217	229	241	253	265	277	289	301	313	325	337	349
110	122	134	146	158	170	182	194	206	218	230	242	254	266	278	290	302	314	326	338	350
111	123	135	147	159	171	183	195	207	219	231	243	255	267	279	291	303	315	327	339	
112	124	136	148	160	172	184	196	208	220	232	244	256	268	280	292	304	316	328	340	

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ward, and 200 watts reflected. Voltage lines from the wattmeter into the front meter compartment use 0.001 feed-through capacitors to keep RF out. The wattmeter is in the RF line at all times even if the amplifier is not turned on.

Labeling the meters takes a lot of patience but really contributes to the appearance of the amplifier. It is necessary to choose a meter with an analog scale that has the correct number of divisions. However, the meter labeling makes no difference. In a very clean environment, remove the meter scale plate from the meter. Any markings on the meter can be removed with a pencil eraser. (Rub lightly but persistently.) The markings will come off the face plate, leaving a clean surface with an analog scale. The new number and letter markings can now be applied. I use dry transfer lettering to mark the meter scales to the desired values. The dry transfers now available from Radio Shack may be too large for small meters; varied assortments of smaller letters are available from most art supply stores.

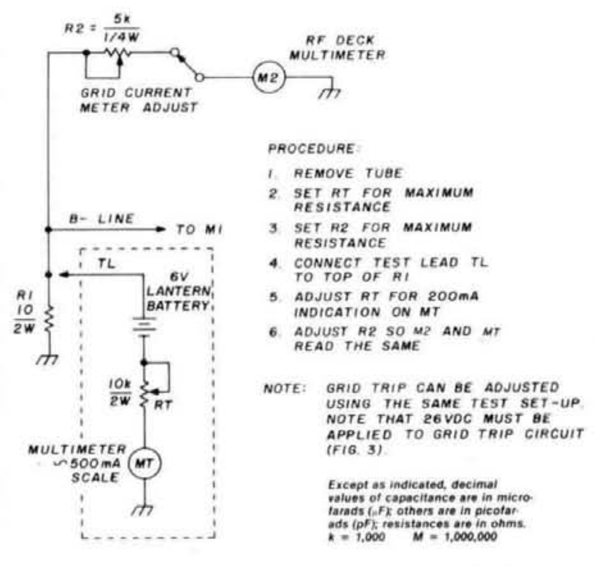


fig. 4. Set up for grid trip/grid current meter adjustments.

RF relay sequencing

It is important to properly sequence the input RF relay, RL1, and the high power vacuum relay, RL2, to insure that the antenna is always connected to the amplifier before RF drive power is applied. This is accomplished by closing the output relay, RL2, slightly before the input relay RL1.

The timing circuit is shown in **fig. 6**. The 150-ohm resistor and the 100-μF capacitor form a time constant that delays closing of the input relay, RL1. The timing can be checked by applying a small voltage across the contacts of both RL1 and RL2 and watching the voltages on the scope as the amplifier is keyed up. The output relay, RL2, should close approximately 25 milliseconds before the input relay, RL1. The timing is adjusted by increasing the value of the 100-μF capacitor for longer delay or decreasing the value for shorter delay. The timing constants are totally dependent upon the relays used for RL1 and RL2. Avoid long time delays since a 50-ohm load isn't presented to the exciter when RL1 is open.

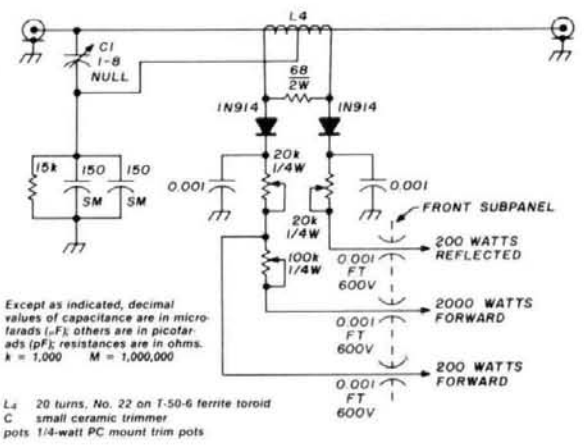
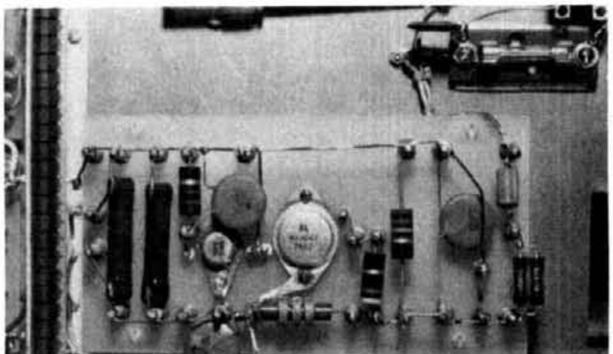


fig. 5. RF wattmeter circuit for the 3CX1200A7.

lead filtering

All control and power leads entering or leaving the RF deck are filtered with a pi-section circuit. The coils are made by winding ten turns of No. 16 enamel wire on 1/4-inch diameter ferrite rods. Bypass capacitors are placed to ground at each end of the coil to form a pi-section. Locate each filter as close to the entry or exit point on the panel as possible. The line filters may not be necessary but provide insurance against RF running on leads outside the cabinet.



Dynamic bias module.

tank circuit

The tank circuit uses a pi-network design. The

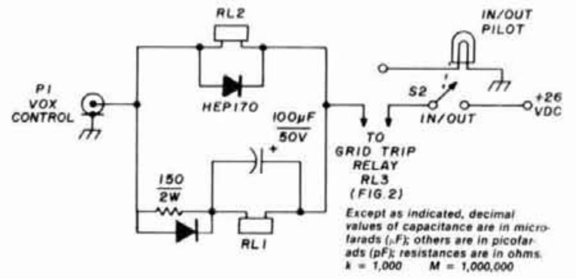
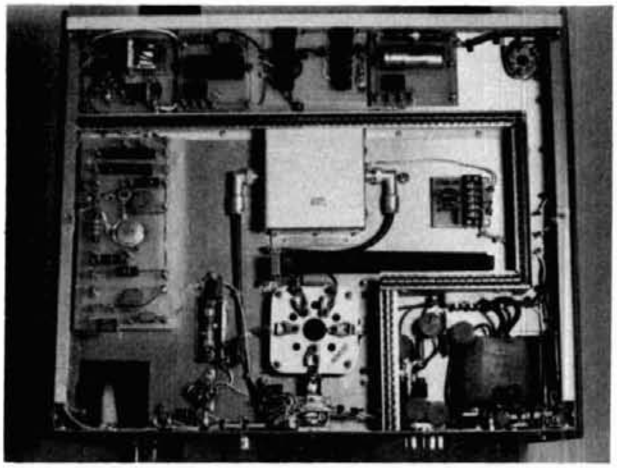


fig. 6. RF relay sequencing.



Bottom view of the amplifier illustrates the method used to isolate the RF circuitry from the control and power devices.

design was originally constructed with the 3-1000Z several years ago when the pi-network was the convention. Recent designs recommend a pi-L tank design because of a potential 15 dB improvement in attenuation of the second harmonic. However, the pi-L network needs a double pole band switch to select the inductance on both the pi-coil and the L-coil. Since a single pole switch was already in the amplifier and there was no evidence of TVI, the pi network was not retrofitted with a pi-L design. However, if this amplifier is built from "scratch," it is recommended that a pi-L design be used.

The design parameters for the pi and pi-L circuits are provided in **table 1**. The value for the plate impedance is 2500 ohms.

Vacuum variable capacitors are used for both the tune (C1) and load (C2) controls. Major advantages of vacuum capacitors include compactness, wide capacitance range with a low minimum capacitance necessary for 10 meters and tuning dial resettability. Equivalent air variables can be substituted. However, they are larger and their *Q* on 10 and 15 meters is lower.

table 1. Tank circuit design parameters.

pi network:

F(MHz)	C1	C2	L	Q = 12
3.5	206	1174	9.95	R_L = 2500 ohms
7.0	107	608	5.15	
14.0	54	307	2.60	
21.0	36	204	1.74	
28.0	27	153	1.30	

coil: 4 turns, 1/4-inch tubing, 2-inch diameter
13 turns, 1/4-inch tubing, 3-1/4 inch diameter
taps: 28.0- 3 turns on 2-inch coil
21.0- 1 turn on 3-1/4-inch coil
14.0- 4 turns on 3-1/4-inch coil
7.0-11 turns on 3-1/4-inch coil
3.5 MHz toroid tank coil
3 × T200-2 cores taped together with fiberglass tape
25 turns No. 12 enameled wire

pi-L network:

F(MHz)	C1	C2	L1	L2
3.5	244	1132	10.99	4.45
7.0	113	503	6.03	2.24
14.0	55	245	3.08	1.24
21.0	37	164	2.05	0.83
28.0	26	112	1.48	0.60

Q = 12
R_L = 2500 ohms

input network

An input network is included to minimize distortion products and help insure that a 50-ohm load is presented to the exciter. The input network is a pi design with a Q = 1. **Table 2** summarizes the component values for each pi-section. The capacitors have been selected as standard values. The coils are wound on T50-2 toroid cores. The cores are large enough for the 100 watts drive power without overheating. However, if room permits, use T68-2 or even T75-2 cores to provide an extra safety margin.

The input network is built as a separate module (see input network pictorial) and ganged to the main band-

table 2. Input network design parameters

band	C1(pF)	L(μH)	C2(pF)	No. turns (T50-2)
80	860	2.15	860	23t/No. 20
40	440	1.11	440	17t/No. 20
20	220	0.56	220	12t/No. 18
15	150	0.38	150	9t/No. 14
10	110	0.28	110	8t/No. 14

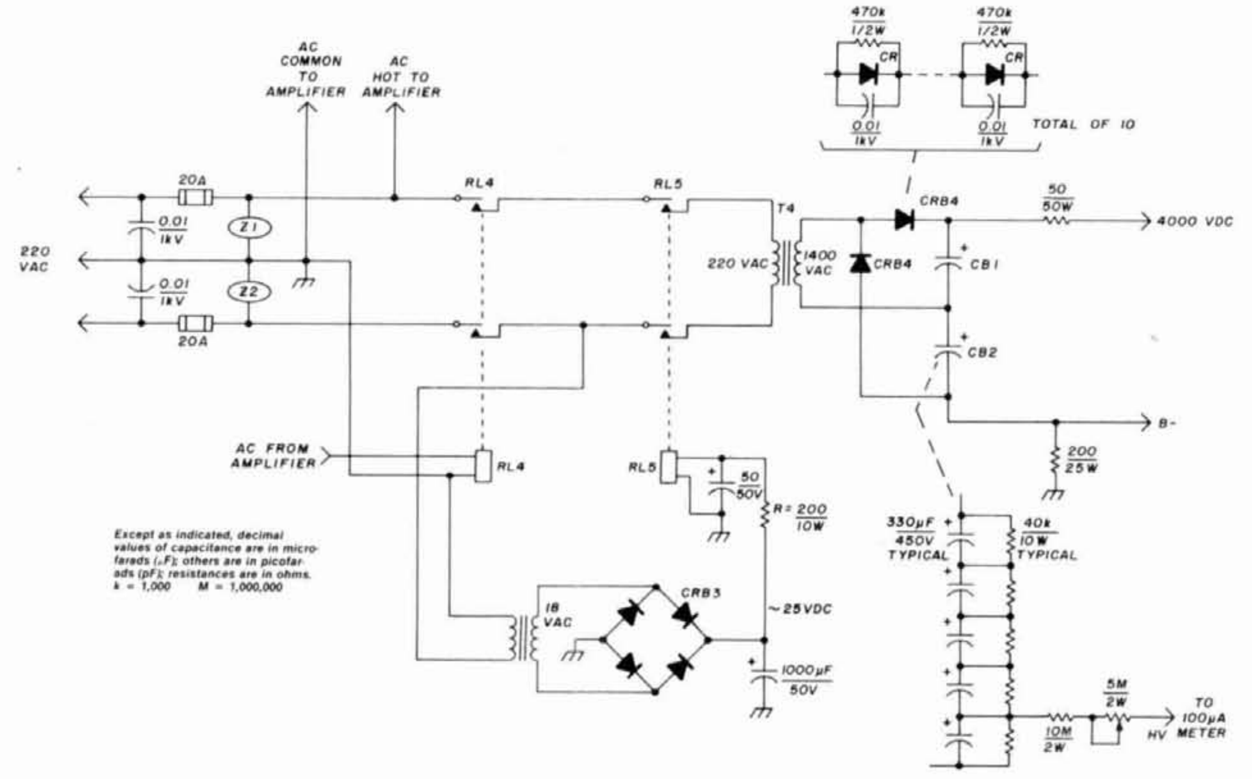
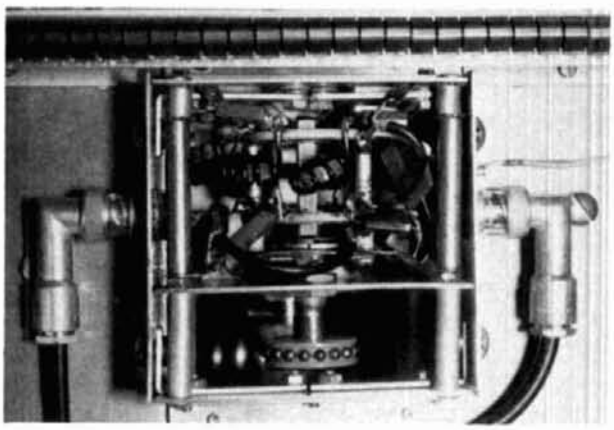


fig. 7. HV power supply.



Input network is built as a separate module.

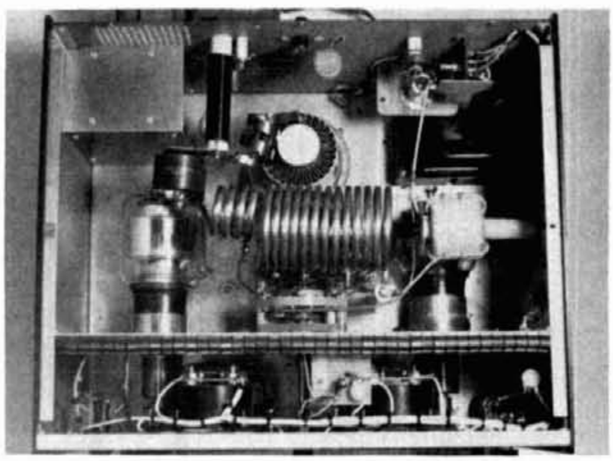
switch using a small chain sprocket available from reference 2. The unit was fully tested prior to installation into the amplifier.

cooling

Proper cooling is essential for long tube life. The 3CX1200A7 tube socket is mounted approximately 1/2 inch below the chassis. The under chassis is pressurized by a Dayton 1C180 blower mounted on the rear panel. The air flow is ducted by the tube chimney up around the base of the tube, through the external anode, and out the top of the amplifier. Refer to the 3CX1200A7 technical data sheet for more information on the cooling at different altitudes.[3]

HV power supply requirements

A good solid HV power supply is required to get the most out of any amplifier. This amplifier uses a 4000



Top view of amplifier illustrates small size of 3CX1200A7. Compare it to the vacuum variables in the lower section of the photo.

the ham notebook

a $100 printer for the Commodore 64

The interface and program for converting an ASR-33 teletype machine to an inexpensive printer for the VIC-20 ("VIC-20 Printer," ham notebook, September, 1984, page 88) can be adapted for use with the Commodore 64.

Figure 1A of the original article remains unchanged; in **fig. 1B**, only the labeling of the user's port is changed. **Figure 2** is replaced with a program listing that provides instructions to the Commodore 64.

Like its VIC-20 predecessor, the ASR-33 printer for the Commodore 64 produces typewriter-quality text appropriate for most data listing applications. Because ASR-33's can be found for as little as $50 to $75 — and because other parts and materials can be found in junk boxes or very cheaply — the total cost of this project should not exceed $100.

J.W. Dates, W2QLI

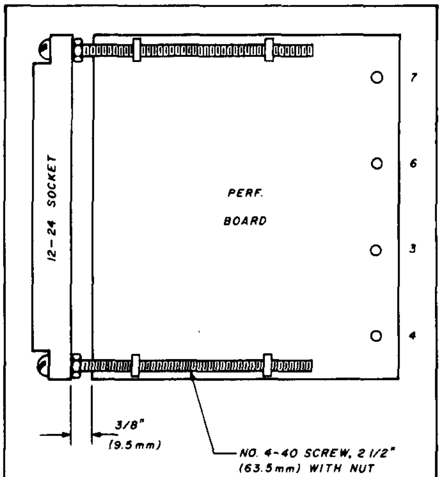
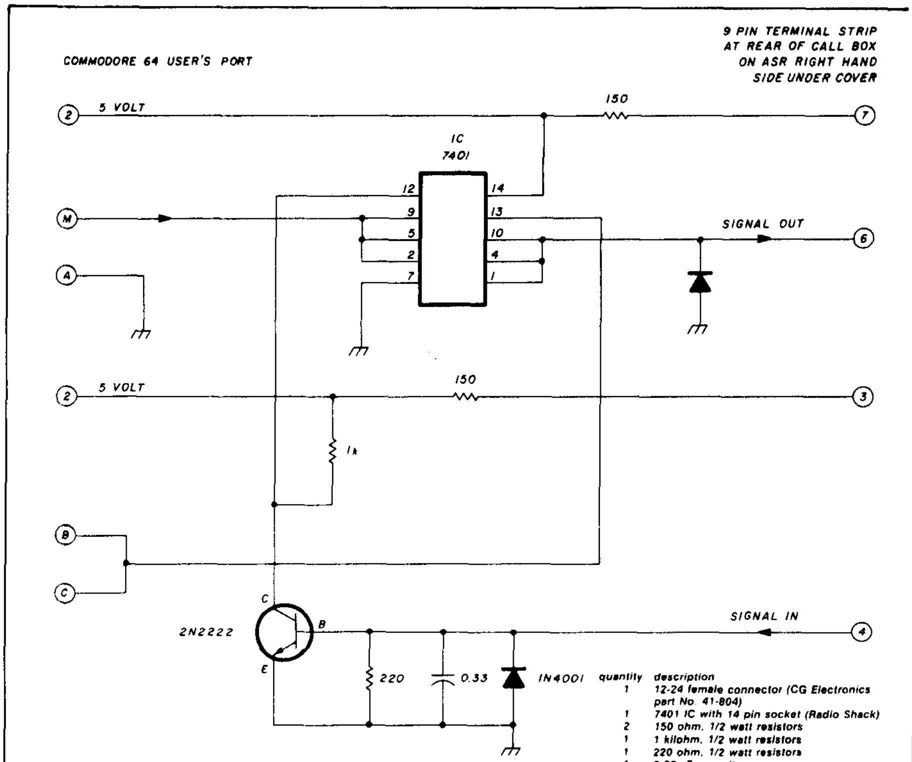


fig. 1A. Interface circuit uses multi-pin edge connector to match C-64 requirements.



quantity	description
1	12-24 female connector (CG Electronics part No. 41-804)
1	7401 IC with 14 pin socket (Radio Shack)
2	150 ohm, 1/2 watt resistors
1	1 kilohm, 1/2 watt resistors
1	220 ohm, 1/2 watt resistors
1	0.33 μF capacitor
2	1N4001 diode
1	2N2222 transistor
1	piece of perforated board 2 × 2-1/2 inches 0.100 × 0.100 hole spacing
2	4-40 × 2-1/2 inch screws with nuts

fig. 1B. Interface circuit that ties a C-64 to an ASR-33.

```
10 REM ASR 33 TTY
15 REM FILE#>128 FORCR WITH LF
20 REM 163=2STOP,7 BIT ASCII,110 BAUD
100 OPEN129,2,3,CHR$(163)+CHR$(224)
110 GET#129,A$
200 REM MAIN LOOP
210 GET B$
220 IF B$<>""THEN IF B$=CHR$(13)THEN
    PRINT#129,B$;CHR$(0);CHR$(0);:GOTO230
225 IF B$<>""THENPRINT#129,B$;
230 GET#129,C$:IFC$<>""THEN PRINT#129,C$;
240 PRINT B$;C$;
250 SR=ST: IF SR=0 OR SR=8 THEN200
300 REM ERROR REPORTING
310 PRINT "ERROR";
320 IFSR AND 1 THEN PRINT "PARITY"
330 IFSR AND 2 THEN PRINT "FRAME"
340 IF SR AND4 THEN PRINT"REC BUFF FULL
    "350 IF SR AND8   THEN PRINT "BREAK"
360 IF(PEEK(673)AND 1)=0 THEN360
370 CLOSE129:END

READY.
```

fig. 2. C-64/ASR-33 program listing.

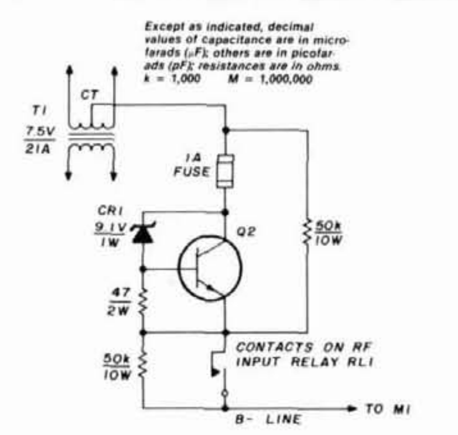
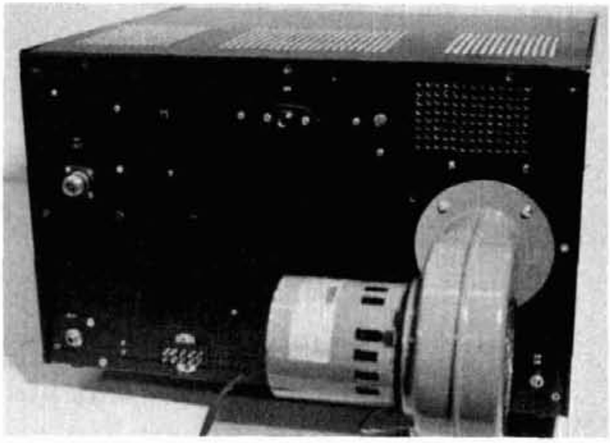


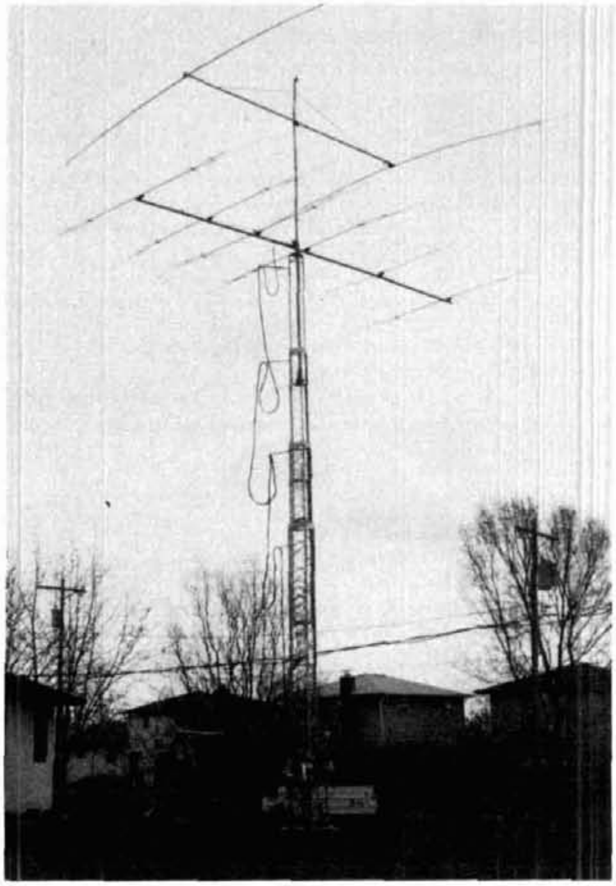
fig. 8. Alternate circuit for conventional bias control.



Amplifier rear view. Notice the dynamic bias defeat switch in the lower right corner.

volt power supply. The HV drops to 3600 volts when 800 mA is drawn.

The power supply is built as a separate unit that sits behind the operating desk. Its circuit is shown in **fig. 7**.



Set in 7½ cubic yards of concrete, author's 70-foot Tri-ex 470D tower is completely self-supporting, with fully motorized crank-up, tilt-over capability. Lower antenna is a KLM KT34XA; upper antenna, at 80 feet, is a two-element Cushcraft 40-meter beam. Both were erected by K8RA without assistance.

K8RA's station is largely home-brewed. Shelf holds receiver described in August, 1983, edition of *QST*; construction details will appear in W6SAI's forthcoming revision of *The Radio Handbook*. To the right are two homebrewed keyers and a speaker to match the amplifier. On desk top are a second speaker, a Collins KWM 380 transceiver, a Collins 30L1 linear amplifier, a rotor control and a 2-meter rig. Rack, at right, contains homebrewed equipment exclusively; from top to bottom, the 3CX1200A7 amplifier described in this article, a station monitoring oscilloscope, a station control console, and an antenna tuner with built-in memory. Blank panel marks space for new 8877 linear amplifier currently under construction. (No, Jerry didn't build the clock; it was a $25 "find" at Dayton. But he did build the 16 × 22-foot solid cedar addition to house his station. Skylights, not pictured here, afford overhead view of antennas.)

amplifier tuning

Amplifier adjustment is initally done into a 50-ohm dummy load. With filament and operating plate voltage applied, grid and plate current meters should read zero when the amplifier is not keyed up by the exciter. Shorting the VOX in/out line engages the antenna relays which switches the amplifier into the RF line. Static plate current should still be zero if the dynamic bias circuit is used. If the dynamic bias circuit is not included or bypassed with the defeat switch, S3, the static plate current should rest at approximately 150 mA. If grid current is observed with the plate or tune capacitors in any position, it is probably a sign of parasitic oscillations and should be corrected.[4]

Drive power can now be slowly increased until the plate current is approximately 250 mA. The Tune and Load controls are adjusted for maximum power output as indicated on the RF power output meter. Excitation is now increased and the plate and load tuning capacitors adjusted until approximately 800 mA plate current with 200 mA grid current is achieved, with maximum output indicated. When the above conditions have been met, the loading should be increased slightly to insure proper linearity. The RF power output should not exceed 1500 watts. Use a scope to monitor signal quality if available. Under SSB speech conditions, peak plate current with no clipping or compression will kick to about 400 mA and grid current to about 100 mA.

conclusion

The amplifier has been in operation for over six months and has operated flawlessly. As expected, another fine tube by EIMAC.

references

1. J.A. Bryant, W4UX, "Electronic Bias Switching for RF Power Amplifiers," *QST*, May, 1974, page 36.
2. *Precision Mechanical Components*, Winfred M. Berg, Inc., 499 Ocean Avenue, East Rockaway, New York 11518.
3. *3CX1200A7 Technical Data Sheet*, Varian/EIMAC, 301 Industrial Way, San Carlos, California 94070.
4. William Orr, W6SAI, *Radio Handbook*, 20th Edition, Howard W. Sams, Inc., Indianapolis, Indiana, (See "Low-frequency Parasitic Suppression," page 17.20.) (*The 22nd Edition of* Radio Handbook *is available from Ham Radio's Bookstore, Greenville, New Hampshire 03048, for $12.95 plus $3.50 shipping and handling.*)

ham radio

More Details? CHECK—OFF Page 126

ham radio TECHNIQUES

Bill Orr W6SAI

big signals from the north

Have you heard those outstanding signals from Finland? Every active DXer has heard these block-busters in DX contests. Why? Because our friends up north have no hesitation about erecting *giant* antennas.

Consider the antenna system that Marti, OH2BH, uses. A photo of his "Christmas Tree" systems and rotator are shown in **figs. 1** and **2**. The 140-foot (42 meter) rotatable steel tower was manufactured and installed by OH8QD. It is guyed by nonmetallic Parafil ropes which terminate on slip rings. A heavy duty ART-8000 rotator supports the system.

A brace of six-element KLM beams is mounted on the tower — six over six on 20 meters at the 140-foot (42.6 meter) and 170-foot (51.8 meter) levels. Single six-element beams for 21 and 28 MHz are at the 120-foot (36.5 meter) and 95-foot (29-meter) levels. Antenna switching is accomplished by a set of remotely controlled vacuum relays located at the 105-foot (32-meter) level.

The relay allows a selection of either one or both of the antennas. Three SPST (single pole, single throw) relays are used in **fig. 3**. The relays are shown in the "off" position. Coax line L1 is an electrical 1/4-wavelength of 75-ohm coax and transforms the nominal 50-ohm antenna feedpoint resistance to about 112 ohms. The two 112-ohm ports at relay 2 are put in parallel and become a 56-ohm termination that closely matches the 50-ohm system design value. The relays are in a weatherproof box mounted halfway between the antennas. Fifty-ohm lines from the box run to each antenna.

A representation of the relay wiring in the box is shown in **fig. 4**, as is the switching table located at the operating position.

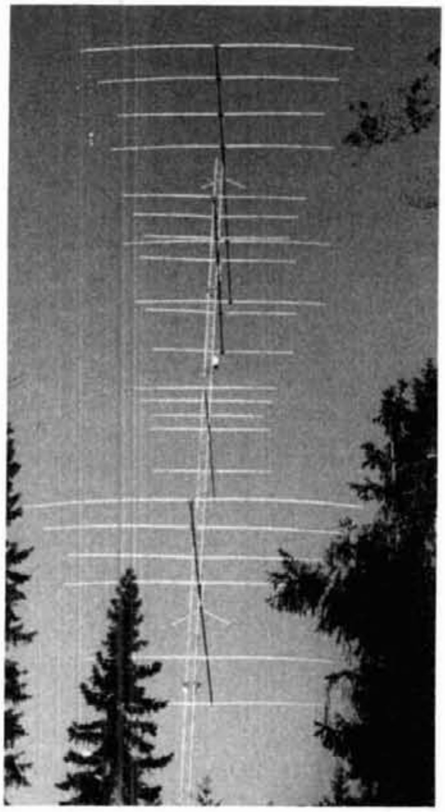


fig. 1. The "Christmas tree" antenna at the contest site of Marty, OH2BH. Six-over-six elements on 20 meters, backed up by single six-element beams on 21 and 28 MHz are mounted on the 170-foot high tower. The 20-meter beams can be switched in combinations from the operating position.

To reduce vibration in the antenna system, which could be destructive in harsh winter storms, each element has a 5-foot (1.5 meter) length of rope cemented into the inside of the outer element tips.

Another interesting antenna installation is that of Simon, OH8OS. A close-up view is shown in **fig. 5** and the slip-ring assembly is shown in **fig. 6**. The antenna is composed of eight six-element beams, stacked two-over-two! OH6JW is believed to have a similar setup. The tower sits on a rotator and the guys are attached to slip rings at appropriate levels.

No doubt other big arrays exist. I'd like to receive pictures of them to put in this column!

how about 160 meters?

Even though there aren't any stacked, rotary arrays on 160 meters that I know of, there are certainly some big signals from well-known DXers on this band. One of the prominent signals on this band (and on others) comes from Jay, AD8C. Jay has a 106-foot (32.3 meter) Rohn tower, guyed at three levels with 1/4-inch (0.6 cm) diameter stranded steel wire. Only the top set of guys is broken by insulators at 25-foot (7.6 meter) intervals. A length of heavy-wall aluminum tubing projects 15 feet (4.5 meters) above the top of the tower. The tower is turned by a WØMLY-modified prop-pitch rotator.

On 160 meters, the tower is shunt-fed with an 82-foot (25 meter) length of electrical conduit as the gamma rod, spaced 1.5 feet (0.45 meter) from the

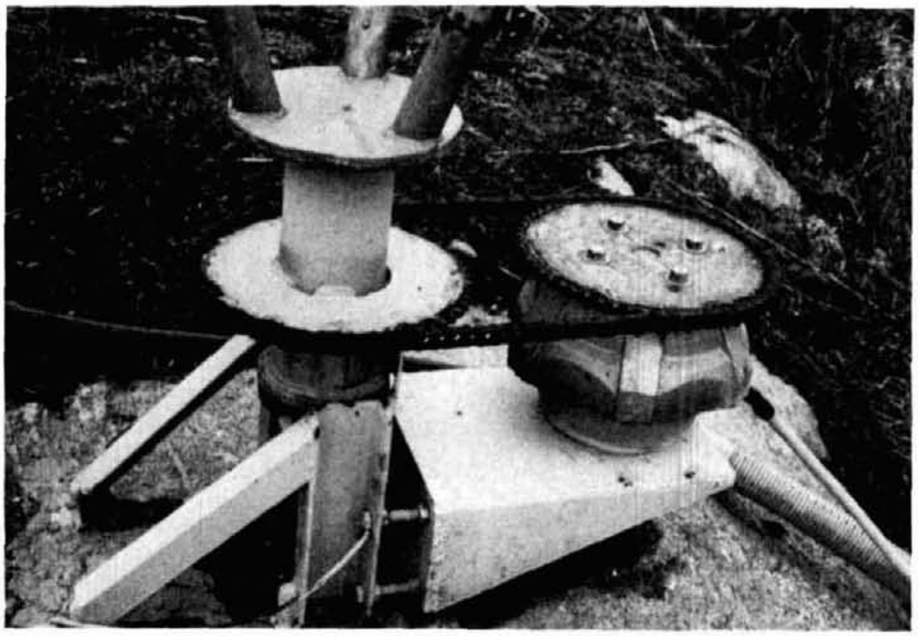
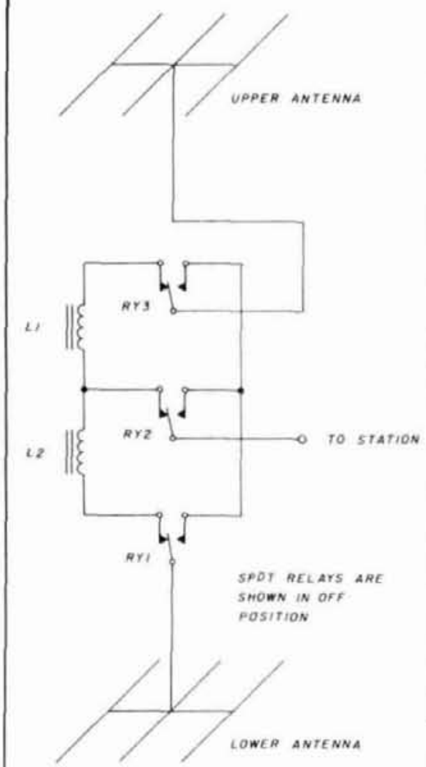


fig. 2. **The 170-foot high tower of OH2BH is rotatable. This is view of the base support and the offset rotating mechanism. The tower is guyed by nonmetallic Parafil ropes which terminate on slip rings.**



relay	both	upper	lower
1	off	off	on
2	off	on	on
3	off	on	off

fig. 3. Antenna switching system at OH2BH permits selection of lower, upper, or both antennas.

tower. Thirty radials are used, with 15 of them a full quarter-wavelength long. A 5kV, 1000 pF vacuum variable capacitor is used as the gamma capacitor. The 2-to-1 bandwidth of the antenna is about 55 kHz.

As for the other bands, Jay uses five phased slopers on 80 meters, patterned after the 40-meter system described in the ARRL *Antenna Handbook* (1974 edition). It provides about 3 dB forward gain and a front-to-back ratio of about 10 to 15 dB.

The rest of the antennas include: a three-element Yagi for 7 MHz at 107 feet (32.6 meters), a four-element Yagi for 14 MHz at 120 feet (36.5 meters), and four-element Yagis for 15 and 10 meters at 55 and 113 feet (16.7 and 34.4 meters). To complete the "antenna farm," there is an eight-element Yagi for 2 meters at 95 feet (29 meters).

Jay says he is satisfied with the installation that it has withstood severe winter storms, and does a "credible job" in DX pileups, particularly on the lower bands.

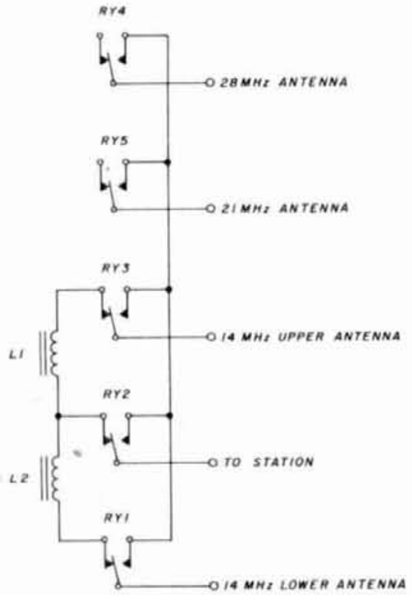
One of the outstanding 160-meter signals from Asia comes from Kuni, JA7NI, who lives in a three-story apartment house. Atop the building Kuni has a 46-foot (14 meter) high heavy wall aluminum mast (**fig. 7**). The mast is top-loaded by a 76-foot (23 meter) length of wire that slopes downward to a short pole mounted on an adjacent building. The aluminum roof trim of his building is used as a ground connection. The antenna works well; Amateurs in all US districts have been contacted, with many QSOs made along the east coast, including WA2SPL, W1FC, W2FJ, K2EK, KC2SB, W3ESU, and others.

After getting this information, I wrote Joe, WA2SPL, to see what antennas he's used for DX work to Japan. He told me that his first 160-meter antenna was an inverted-vee with the apex at 150 feet (45.7 meters) and the ends at 75 feet (22.8 meters). Joe says that although it was a "pretty good" antenna for transmitting, precipitation static during snow storms made the antenna useless for receiving. He then put up a 1000-foot (348 meter) Beverage antenna for receiving that worked very well. On the common assumption that "if big is good, bigger is better," Joe erected a 1500-foot (457 meter) Beverage wire that proved to be even better than the shorter one.

The next step was to raise the inverted-vee to 200 feet (61 meters), with the ends at 90 feet (27.4 meters). This produced an immediate improvement in his signal — to the point at which he couldn't hear some of the DX that called him! So Joe went back to modifying the Beverage receiving antenna.

It was obvious that more and better Beverages were needed, so Joe put up a 2100-foot (640 meter) wire for Europe, a 1500-foot (457 meter) wire aimed at Japan, a 1000-foot (348 meter) wire for South America, a 1,000-foot wire on the Caribbean and a 3100-foot (944 meter) wire aimed at Australia/New Zealand. (Where do these guys get the space to put up these antennas?)

RELAYS SHOWN IN OFF POSITION



relay	14 both	14 upper	14 lower	21	28
1	off	off	on	off	off
2	off	on	on	on	on
3	off	on	off	off	off
4	off	off	off	off	on
5	off	off	off	on	off

fig. 4. Complete schematic of OH2BH antenna selection relays. L1 and L2 are 1/4-wavelength sections of 75-ohm coxial cable.

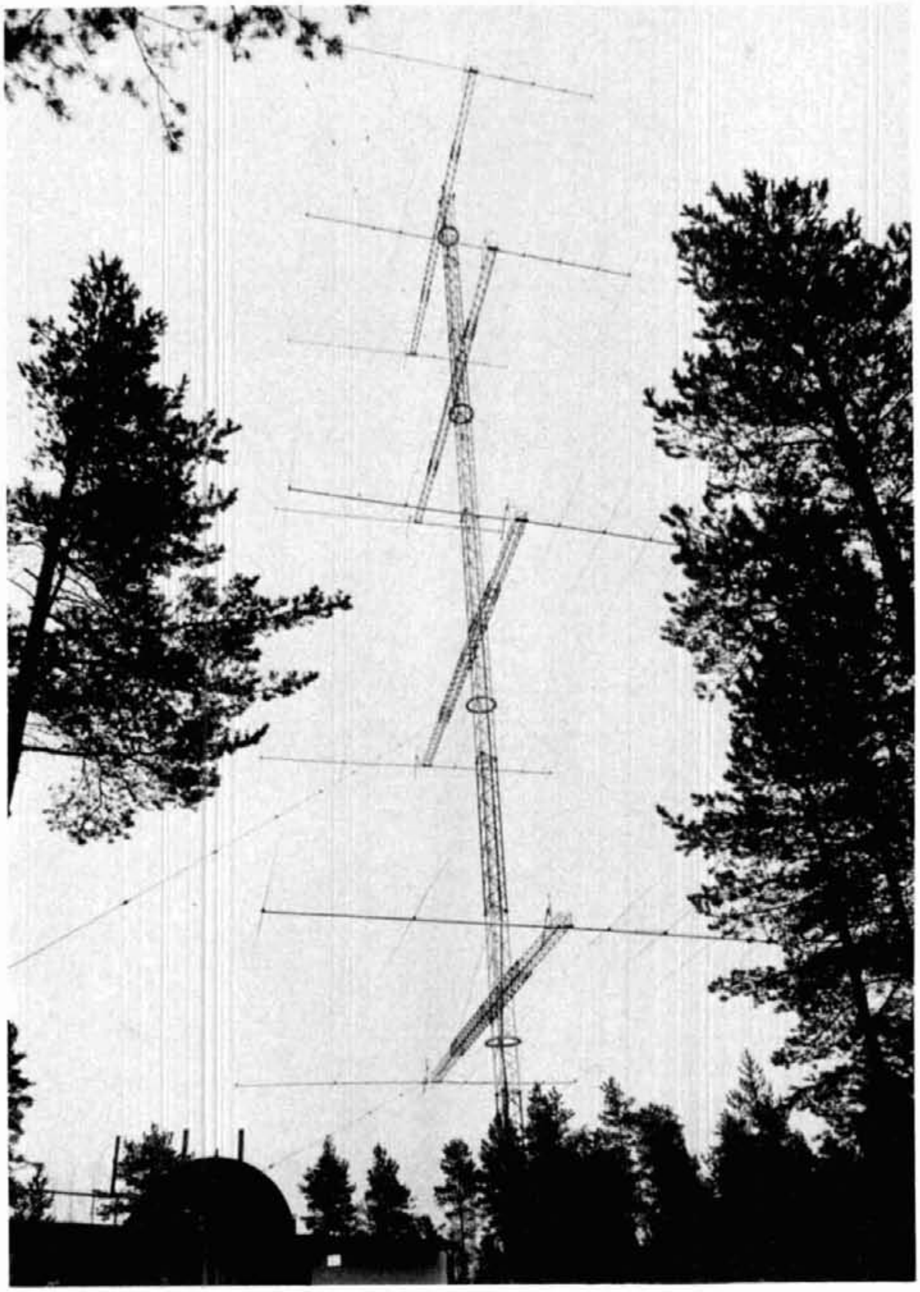


fig. 5. The monster 20-meter array of Simon, OH8OS. The antenna consists of eight six-element beams, stacked two-over-two. Simon puts through an S-9+ signal on the West Coast of the USA when other Europeans are inaudible. The complete tower is rotatable.

After a few months Joe found out that a Beverage antenna could be too long. He pruned the 3100-foot wire back to 1500 feet (457 meters) and it worked much better.

With each antenna, a 20 dB preamplifier was used to bring signals up to good copy. By this time, Joe had 150 countries to his credit on 160 meters!

Even with his success with the Vee and the Beverages, Joe was curious about the luck his DX friends had with vertical antennas on 160 meters. For various reasons, he couldn't shunt-feed his 200-foot tower, so he dropped a rope down on a 45-degree angle to the ground and lowered a wire to ground level from the 130 foot (40 meter) elevation on the rope. He placed 24 quarter-wave radials beneath the vertical antenna.

He soon discovered, by direct comparison, that under no conditions did the vertical perform better than the high Vee antenna. He was sure that the vertical was relatively worthless until he later met Dana, W1CF, and went to Dana's station to work it during a *CQ* Worldwide DX contest. The station was equipped with two 1200-foot (365 meter) Beverage receiving antennas, plus two Col•Atch•Co 61-foot (18.6 meter) verticals with 80 radials under each one. The contest results were amazing — the W1CF station ended up with 830 QSOs and a score of 323,000 points!

Now Joe is wondering why his full-size vertical seemed to perform so poorly. Too few radials? Low conductivity ground in the vicinity of the antenna? He may soon have the answer. He's moving to a new location, and by the time you read this, he may have put up his new 160-meter antenna system — four full-size, phased

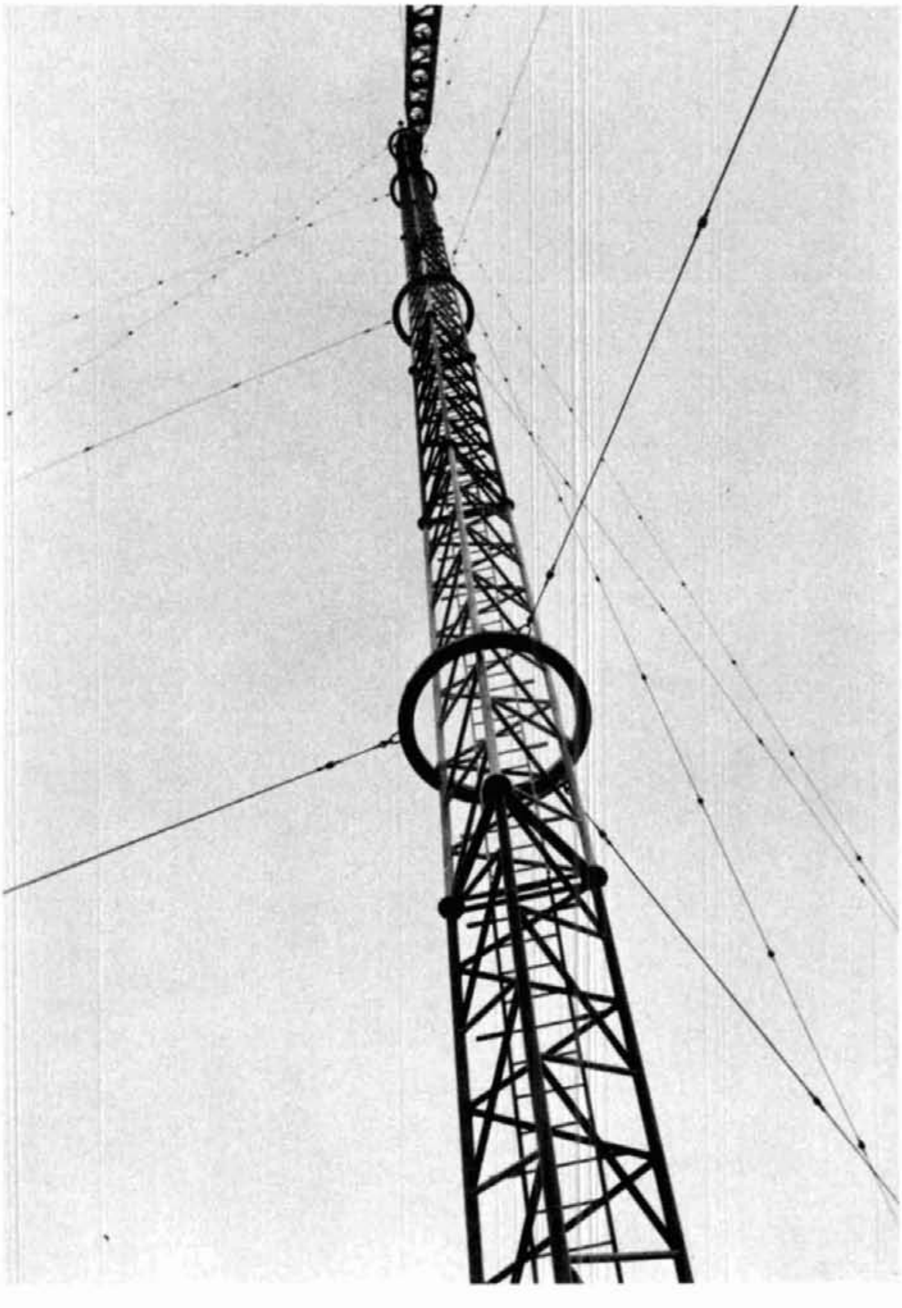


fig. 6. Slip-ring installation on tower of OH8OS. Would you care to climb the ladder to the top array? (Visible at top of picture is the arm of the crane ready to lift the antennas to their final positions on the tower.)

verticals on a mountain in northern Vermont. JA7NI, keep your ears open for this one!

You *can* be a topnotch 160-meter DXer with only a simple antenna. Bob, VE1YX, says, "No super-antenna here! I have a simple, coax-fed dipole, 60 feet high on a hilltop about 450 feet above sea level. So far, 135 countries — the best DX being VK6HD long path at 2100Z."

long-wave hams in Australia

Sixteen years ago, before WARC 79, the United States considered an Amateur band in the 160-190 kHz region. The idea had merit, but opposition arose because this was the range used by carrier current data transmissions on power lines and also by long-wave European broadcasting stations. Sadly, the idea was dropped before WARC 79 started.

Even so, John (VK3ACA) and Pet (VK3QI) pursued the idea with th Department of Communications i Australia and, after a pause, they wer issued experimental licenses for lov frequency operation on 196 kHz (153 meters). John received the call sig AX3T35 and Peter became AX3T36. third Amateur, Dennis (VK3WV), joi ed them and got the call sign VL3 (**fig. 8**). The stations all ran about 10 watts input.

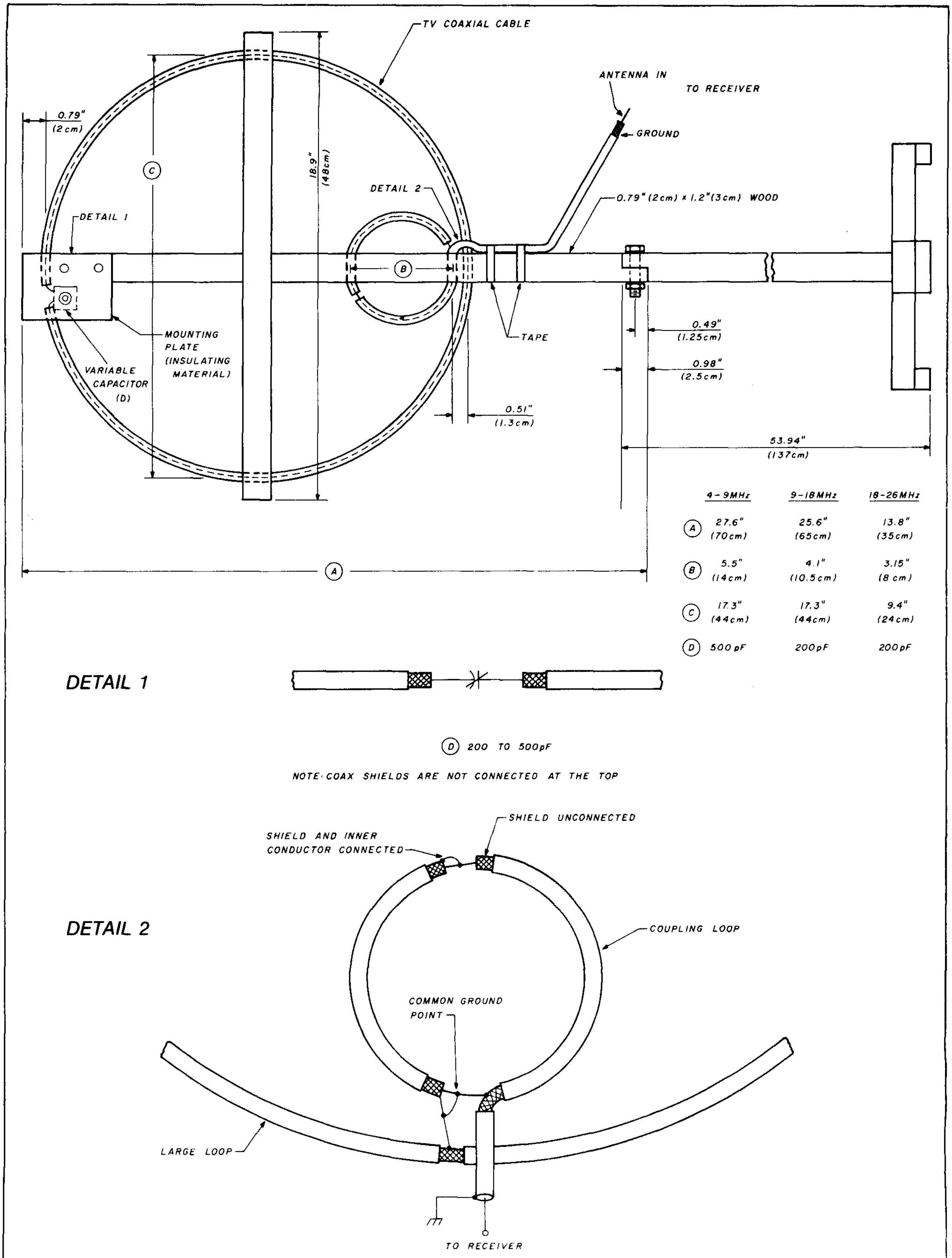
Antennas were a problem. AX3T3 used a 30-foot vertical with a hug base loading coil and an extensiv grounding system. He estimated h antenna efficiency was about 0.37 pe cent. Station VL3Y used a 135-foo wire, which wasn't much better. Eve with the poor antennas, the first cor tact was made in April, 1981. Cor tinued contacts between the three se tions showed that the propagatio range via ground wave was about 30 miles during daylight, and possib more during the hours of darkness.

AX3T35 is writing an article, sched uled to appear shortly in the journal o the Wireless Institute of Australia *Amateur Radio*, about the experience of the only three licensed low-fre quency ham staions in the worl (Good work, lads — I'll put a shrim on the barbie for you!)

an anti-jamming HF loop antenna

People other than Radio Amateu are interested in efficient and effectiv HF antennas. Radio Free Europe, i particular, tries in every way to com bat the Soviet jamming that plague their broadcasts. In this regard, the have published information on buildin a simple and inexpensive direction receiving antenna that can be helpf in reducing jamming interference Details of this antenna are shown i (**fig. 9**.)

The antenna consists of a shielde loop made of coax cable (RG-58/U, o RG-59/U, for example). A smaller loo couples the tuned loop to the receive To hold the cables in the loop form a wooden support in the shape of cross is used. The coax is passe



	4-9MHz	9-18MHz	18-26MHz
A	27.6" (70cm)	25.6" (65cm)	13.8" (35cm)
B	5.5" (14cm)	4.1" (10.5cm)	3.15" (8 cm)
C	17.3" (44cm)	17.3" (44cm)	9.4" (24cm)
D	500 pF	200pF	200pF

fig. 9. Receiving loop recommended by "Radio Free Europe." (Dimensions provided in centimeters.)

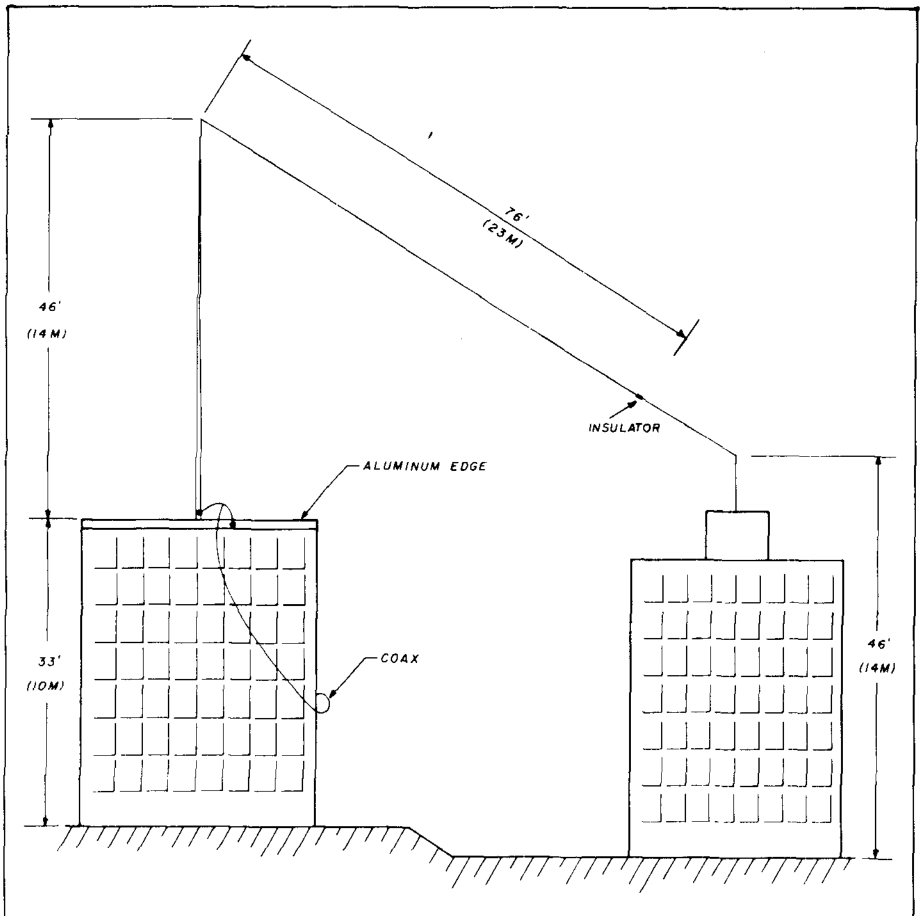


fig. 7. Apartment antenna of 160-meter DX operator Kuni, JA7NI, consists of top-loaded 46-foot (14 meter) mast atop a three-story apartment building. Shield of coax is grounded to aluminum roof trim.

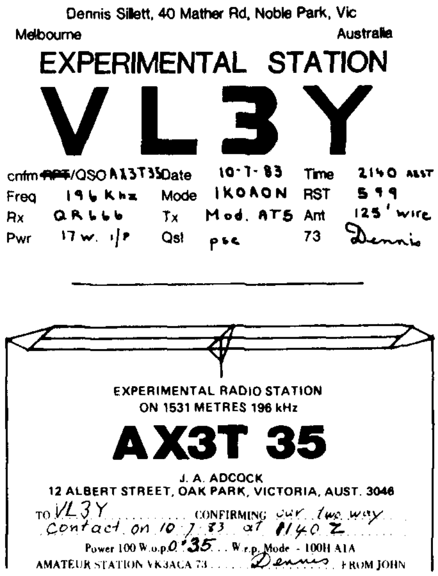


fig. 8. QSL cards of low-frequency experimental Amateur stations in Australia.

through appropriate holes in the structure. A variable capacitor at the open end of the loop tunes it to the required frequency. The coupling link matches the symmetrical, balanced loop to the unbalanced coax line to the receiver.

The vertical portion of the support structure is hinged to allow tilting the antenna for improvement of the rejection null. The antenna can be rotated horizontally to provide both azimuth and elevation alignment.

To cover the shortwave spectrum from 4 to 26 MHz, three loop sizes are required, as shown in **fig. 9**.

To use the loop antenna, receiver and antenna are tuned for maximum signal at the desired frequency. The antenna is then rotated and tilted to minimize the interfering signal. A reduction of 30-to-1 in jamming strength is predicted for short wave listeners, depending upon the location of the jamming station with respect to the desired station.

While Radio Amateurs may not use the loop for reduction of intentional jamming, this design may prove to be of benefit for operation in DX contests where it's helpful to null out loud local competition.

Because of the reduced pickup of the loop compared to a full-size antenna, it may be necessary to add a preamplifier between loop and receiver to bring signals up to full strength.

the new *Beam Antenna Handbook*

For the past two years I've been absent from the bands, devoting every moment of my spare time to completing, with Stu, W2LX, the extensive revision of the *Beam Antenna Handbook*. It was a lengthy job; the old text was ripped apart and new text prepared. New illustrations were added. New, up-to-date antenna dimensions, based upon recent computer studies conducted on Yagi arrays were cataloged. The result, after much hard work, is a completely new edition of *Beam*.*

The book includes new data on HF Yagi antennas (two to five elements), element spacing, and the effect of element taper. There's new information on erecting beams and general installation data as well. VHF long Yagis are covered, together with complete design tables for the home constructor. Complete English and metric dimensions are given for all antennas.

There's helpful information on feed systems and SWR measurements. A systematic test procedure is provided to help you determine whether your beam is operating properly. The information on checking the accuracy of your SWR meter is worth the price of admission!

Now that the book is ready, perhaps I'll have time to get on the air! Or will another project come along?

*Available from Ham Radio's Bookstore, Greenville, New Hampshire 03048, $9.95 plus $2.50 shipping and handling.

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LS14	.40	LS195	.60
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LS20	.20	LS197	.85
LS21	.25	LS221	.65
LS27	.28	LS240	1.00
LS30	.20	LS241	.80
LS32	.25	LS242	1.00
LS33	.40	LS243	1.00
LS37	.33	LS244	1.00
LS38	.30	LS245	1.00
LS42	.40	LS251	.50
LS51	.24	LS253	.50
LS54	.25	LS257	.50
LS55	.24	LS258	.55
LS73	.35	LS259	2.00
LS74	.30	LS260	.50
LS85	.60	LS266	.40
LS86	.25	LS273	1.00
LS90	.50	LS279	.40
LS93	.55	LS280	1.00
LS107	.37	LS283	.50
LS109	.25	LS290	.85
LS112	.30	LS293	.85
LS122	.45	LS298	.75
LS123	.55	LS299	1.60
LS124	2.00	LS323	2.60
LS125	.40	LS348	.75
LS126	.49	LS364	1.10
LS132	.50	LS366	.45
LS133	.35	LS367	.50
LS138	.45	LS368	.40
LS139	.40	LS373	1.00
LS151	.45	LS374	1.00
LS153	.40	LS375	.50
LS154	.99	LS377	1.00
LS155	.50	LS378	.85
LS156	.50	LS390	1.00
LS157	.40	LS393	1.00
LS158	.50	LS399	1.25
LS160	.65	LS670	1.50
LS161	.50	25LS2569	3.00
LS162	.65		

TTL

7400	.22	7473	.34	74162	.60
7402	.22	7474	.40	74163	.60
7405	.22	7483	.45	74164	.80
7406	.33	7485	.55	74165	.80
7407	.33	7486	.30	74166	1.00
7408	.24	7490	.35	74173	.75
7410	.19	7493	.33	74174	.85
7413	.33	7496	.40	74175	.80
7420	.22	74107	.28	74181	1.50
7425	.25	74109	.45	74185	1.70
7427	.25	74121	.27	74192	.70
7428	.25	74123	.40	74193	.80
7430	.20	74125	.49	74195	.80
7432	.27	74132	.40	74199	1.00
7433	.25	74148	1.00	74221	1.00
7440	.19	74151	.50	74273	1.75
7442	.40	74153	.50	74365	.60
7451	.20	74154	1.19	74366	.60
7453	.22	74157	.50	74367	.60
7454	.22	74160	.80	74390	1.40
7472	.25	74161	.60		

EPROM

2708 1KX8 450 n.s.	2.20
2758 1KX8 +5V 450 n.s	2.00
2716 2KX8 450 n.s.	2.75
2716-1 2KX8 350 n.s.	4.50
2732 4KX8 450 n.s.	3.65
2732A	4.00
2732A-35	3.75
2532 4KX8 450 n.s.	3.00
2764-25	3.50
2764-45	3.00
27128-25	5.00
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27128-45	3.50

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21L02-1 350 n.s.	.65
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INS8250B	7.95

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75451	.35
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2118-4 16KX1-5Volt	1.50
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4116-16KX1-250 n.s.	.60
4116-16KX1-200 n.s.	.75
4116 16KX1-150 n.s.	1.00
4164- +5v 64K 200 n.s.	1.05
4164 150 n.s.	1.30
TMS4416-16KX4-150 n.s.	3.95
MK4516-15 16KX1-5Volt	1.50
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8251	4.20	8287	5.75
8253-5	5.95	8288	7.50

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Z80 2.5 MHZ CPU	1.25
Z80CTC	.75
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1793 Special	12.50
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6821	1.50	68B45	10.00

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3.120	1.20
3.2	1.49
3.4560	1.49
3.579545	.75
3.6864	1.10
4.000	1.75
4.194304	1.50
4.433618	.75
4444.000	1.25
4.9152	2.49
4.916 Bd. Rate	1.25
5.000000	1.50
5.0688	2.50
5.616	1.59
6.000	2.49
6.176	1.49
7.164112	1.00
7.3728	1.49
8.000	1.49
9.000	1.49
9.90000	1.25
10.69425	2.50
10.8864	1.49
10.920	1.49
11.088	1.59
12.000	2.75
13.440	1.00
14.31818	1.00
15.2	1.10
16.00000	1.50
16.5888	1.49
17.430	2.49
18.000	1.49
18.2259	1.00
18.4320	1.49
20.000	1.50
21.87108	1.00
22.092	1.00
32.000	2.49
40.000	2.00
87.3333	1.00
91.000	1.00
104.8	1.00

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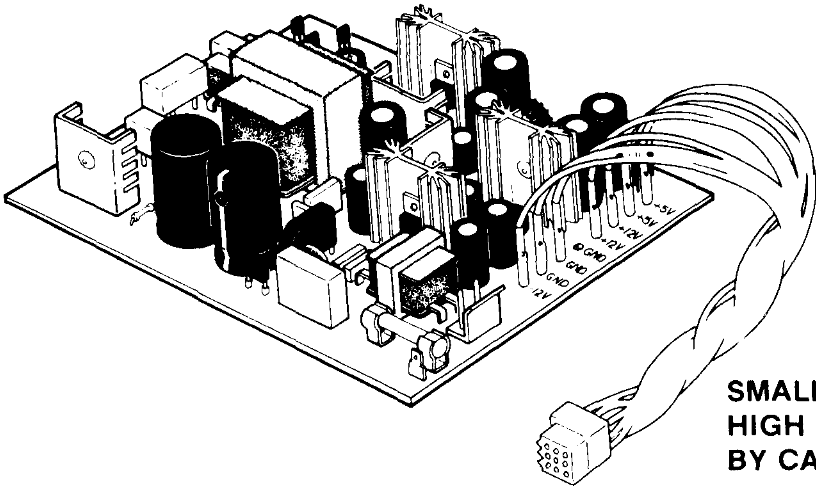

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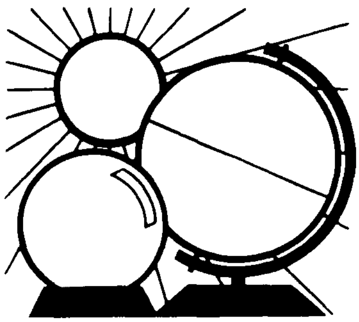
✓ 162



DX FORECASTER

Garth Stonehocker, KØRYW

signal levels during the summer months

Absorption results in loss of energy from the signal as it collides with ions on its path through the D region, 60-80 miles (100-120 km) above the earth. How much energy is absorbed per transit of the D region depends on the location of the sun, and is a function of cosine X, the zenith angle to the sun. Maximum absorption occurs at the subsolar point, directly under the sun; absorption decreases as the signal path moves away from the subsolar point in any direction.

On any propagation path, absorption increases with the number of crossings of the D region and also varies inversely with frequency. Therefore, in working DX it pays to use the higher frequency bands and obtain consequently greater distances per hop.

In a study of several midlatitude communication links of varied lengths over the years of this 10.7 solar cycle, some general trends were noticed. The ionosphere, a balanced energy system tends to return to a "normal" level of ion density after each new solar perturbation. It is a fact that between sunspot numbers 20 and 120, signal absorption changes only by approximately 8 dB for a one-hop path 2500 km in length. The one-hop path is the easiest in which to see changes. When the signal travels three or more hops, the changes get blurred between the hops. There is more absorption with the larger number of hops, but the effect of absorption per hop is not linearly additive. Each additional hop subtracts less energy from the signal.

Absorption is inversely proportional to frequency when the angle the signal wave makes with the ionospheric layer is constant, as in vertical ionospheric sounding. However, this frequency dependency is hard to assess because as the frequency changes so does the extent of layer penetration, thereby changing the incidence angle somewhat. As a rough estimate, 10 MHz signals tend to incur twice as much signal absorption as 20 MHz signals. However the largest absorption effect occurs between night and day; it is so great it tends to mask out the measurement of the secondary causes. The midlatitude communication link paths showed 10-30 dB of signal loss between night and day in most seasons, with paths near the equator surpassing even these. These different absorption effects add up to give an overall signal loss of 120 dB on the average.

What can DXers do to enhance their effectiveness during summertime operations? Review the chart on the next page for the highest band available to the DX area you wish to contact. Operate on towards evening, taking advantage of its lower absorption, but before the maximum usable frequency drops off very much. Then use the graph provided in the February, 1985, column that shows take-off angle (TOA) vs. ionosphere height. Use the height chart provided, too. The lowest TOA means fewer hops and less absorption of your signal. Make sure your antenna radiates substantial energy at that low TOA in order to give you the best chance of contacting the desired DX station.

Know the current conditions (in terms of signal absorption and variability, QSB) by listening to radio station WWV on 5, 10, 15 MHz at 18 minutes after the hour. If the solar flux has just increased, absorption will be high. In addition, potential fading conditions (QSB) are associated with an A figure of greater than 15 or a K figure greater than 4. These indicate pronounced signal absorption on the higher latitude paths. These clues can help you be your own forecaster — therefore a better DX operator.

last-minute forecast

During August noise will be up and signal strength down, however sporadic-E propagation will occur. This just means that we can expect good DX conditions on the higher frequency bands in the third and last weeks of the month while the lower bands are expected to be best the first week of the month. It's always helpful to check WWV broadcasts to confirm these conditions. For the VHF/UHF enthusiast the moon's perigee will occur on the 19th, with a full moon on the 30th. The Perseids meteor shower will occur from the 10th to 14th, with a maximum rate expected on the 11th and 12th, with better than fifty meteors per hour. This is an excellent shower. Meteor shower activity has already been reported as heavier than usual this year.

band-by-band summary

Six-meter paths will open for a half hour to a couple of hours on some days around local noon. Sporadic-E propagation will make this short-skip path possible out to nearly 1200 miles (2000 km) per hop.

Ten and fifteen meters will have a few short-skip E_s openings and some long-skip openings to southern areas of the world during daylight, though only during periods of high solar flux. Some transequatorial (TE) openings associated with mildly disturbed geomagnetic-ionospheric conditions may occur in the evening hours toward the end of the month.

Twenty, thirty, and forty meters will have DX from most areas of the world

AUGUST

WESTERN USA

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

MID USA

MDT	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	
ASIA FAR EAST	20	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	20	20	20	15	15	20	N
EUROPE	20	20	20	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	20	20	20	20	20	20	NE
S. AFRICA	20	20	20	20	20	15	15	15	15	15	15	15	20	20	20	30	20	30	30	20	20	20	20	20	E
S. AMERICA	15	15*	15	15	15	20	20	15	15	20	20	20	20	30	20	20	20	20	20	20	20	15	15	15	SE
ANTARCTICA	20	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	20	20	20	20	20	S
NEW ZEALAND	15*	15	15	15	15	15	15	20	30	20	20	30	20	20	20	20	20	20	15	15	15	15	15	15*	SW
OCEANIA AUSTRALIA	15	15	20	20	20	30	30	20	20	20	20	20	20	20	20	20	20	15	15	15	15*	15	15	15	W
JAPAN	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	20	20	20	20	20	20	20	20	NW
CDT	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	

EASTERN USA

EDT	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	
ASIA FAR EAST	20	20	20	20	20	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	20	N
EUROPE	20	20	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	20	20	20	20	20	20	NE
S. AFRICA	20	20	20	15	15	15	15	15	15	15	15	15	15	15	20	20	20	20	30	30	20	20	20	20	E
CARIBBEAN S. AMERICA	15	15	15	15	15	15	15	15	15	15	20	20	20	30	30	20	20	20	20	20	20	20	15	15	SE
ANTARCTICA	20	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	20	20	20	20	20	S
NEW ZEALAND	15*	15	15	15	15	15	15	15	20	20	20	20	30	20	20	20	20	20	20	20	15	15	15	15*	SW
OCEANIA AUSTRALIA	15	15	15	15	20	20	20	30	30	20	20	20	20	20	20	20	20	15	15	15	15	15	15	15	W
JAPAN	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	20	20	20	20	20	20	NW

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

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

during the daytime and into the evening hours almost every day. Forty meters will join this daytime group toward the end of the month because of lower signal absorption (lower lowest usable frequency) during these sunspot minimum years. During unusually high 27-day solar flux days, 40 meters may not be usable; both 40 and 30 meters may not be usable at the predawn hours after the high flux day. The DX on these bands may be either long-skip to 2500 miles (4000 km) or short skip E_s to 1250 miles (2000 km) per hop. The length of daylight will be decreasing noticeably at the end of the month.

Thirty, forty, eighty, and one-sixty are all good for nighttime DX, even though the background thunderstorm noise may be severe, especially on 80 and 160 meters. Propagation of signals via sporadic-E layer may occur and assist around sunset. This will be the final month of the E_s season.

ham radio

HF Equipment	Regular	SALE
IC-735 Xcvr/SW rcvr/mic	849.00	749^{95}
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AT-120 Automatic antenna tuner	TBA	
FL-32 500 Hz CW filter	59.50	
EX-243 Electronic keyer unit	50.00	
IC-730 8-band 200w PEP xcvr w/mic	829.00	569^{95}
FL-30 SSB filter (passband tuning)	59.50	
FL-44A SSB filter (2nd IF)	159.00	144^{95}
FL-45 500 Hz CW filter	59.50	
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HM-10 Scanning mobile microphone	39.50	
MB-5 Mobile mount	19.50	
IC-720A 9-band xcvr/.1-30 MHz rcvr	1349.00	799^{95}
FL-32 500 Hz CW filter	59.50	
FL-34 5.2 kHz AM filter	49.50	
SM-5 8-pin electret desk microphone	39.00	
MB-5 Mobile mount	19.50	
IC-745 9-band xcvr w/.1-30 Mhz rcvr	999.00	779^{95}
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EX-241 Marker unit	20.00	
EX-242 FM unit	39.00	
EX-243 Electronic keyer unit	50.00	
FL-45 500 Hz CW filter (1st IF)	59.50	
FL-54 270 Hz CW filter (1st IF)	47.50	
FL-52A 500 Hz CW filter (2nd IF)	96.50	89^{95}
FL-53A 250 Hz CW filter (2nd IF)	96.50	89^{95}
FL-44A SSB filter (2nd IF)	159.00	144^{95}
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SM-6 Desk microphone	39.00	
HM-12 Extra hand microphone	39.50	
MB-12 Mobile mount	19.50	

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FL-32 500 Hz CW filter (1st IF)	59.50	
FL-63 250 Hz CW filter (1st IF)	48.50	
FL-52A 500 Hz CW filter (2nd IF)	96.50	89^{95}
FL-53A 250 Hz CW filter (2nd IF)	96.50	89^{95}
FL-33 AM filter	31.50	
FL-70 2.8 Khz wide SSB filter	46.50	
HM-12 Extra hand microphone	39.50	
SM-6 Desk microphone	39.00	
CR-64 High stability reference xtal	56.00	
RC-10 External frequency controller	35.00	
MB-18 Mobile mount	19.50	

Options: 720/730/745/751	Regular	SALE
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EX-144 Adaptor for CF-1/PS-15	6.50	

ICOM

Options - continued	Regular	SALE
CF-1 Cooling fan for PS-15	45.00	
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SP-3 External base station speaker	49.50	
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PS-30 Systems p/s w/cord, 6-pin plug	259.95	234^{95}
OPC Optional cord, specify 2 or 4-pin	5.50	
GC-4 World clock .... (Closeout!)	99.95	79^{95}

HF linear amplifier	Regular	SALE
IC-2KL w/ps 160-15m solid state amp	1795.00	1299

VHF/UHF base multi-modes	Regular	SALE
IC-551D 80 Watt 6m transceiver	699.00	599^{95}
EX-106 FM option	125.00	112^{95}
BC-10A Memory back-up	8.50	
SM-2 Electret desk microphone	39.00	
IC-271A 25w 2m FM/SSB/CW xcvr	699.00	569^{95}
AG-20 Internal preamplifier*	56.95	
IC-271H 100w 2m FM/SSB/CW xcvr	899.00	759^{95}
AG-25 Mast mounted preamplifier*	84.95	
IC-471A 25w 430-450 SSB/CW/FM xcvr	799.00	699^{95}
AG-1 Mast mounted preamplifier*	89.00	
IC-471H 75w 430-450 SSB/CW/FM xcvr	1099.00	969^{95}
AG-35 Mast mounted preamplifier*	84.95	

For a Limited time!
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Common accessories for 271A/H and 471A/H		
PS-25 Internal power supply for (A)	99.00	89^{95}
PS-35 Internal power supply for (H)	160.00	144^{95}
PS-15 External power supply	149.00	134^{95}
CF-1 Cooling fan for PS-15	45.00	
EX-144 Adaptor for PS-15/CF-1	6.50	
SM-6 Desk microphone	39.00	
EX-310 Voice sythesizer	39.95	
TS-32 CommSpec encode/decoder	59.95	
UT-15 Encoder/decoder interface	12.50	
UT-15S UT-15S w/TS-32 installed	79.95	

VHF/UHF mobile multi-modes		
IC-290H 25w 2m SSB/FM xcvr, TTP mic	549.00	479^{95}
IC-490A 10w 430-440 SSB/FM/CW xcvr	649.00	579^{95}

VHF/UHF/1.2 GHz FM	Regular	SALE
IC-27A Compact 25w 2m FM w/TTP mic	369.00	319^{95}
IC-27H Compact 45w 2m FM w/TTP mic	409.00	359^{95}
IC-37A Compact 25w 220 FM, TTP mic	449.00	299^{95}
IC-47A Compact 25w 440 FM, TTP mic	469.00	419^{95}
UT-16/EX-388 Voice synthesizer	29.95	
IC-3200A 25w 2m/440 FM w/TTP	549.00	489^{95}
UT-23 Voice synthesizer	29.95	
IC-120 1w 1.2 GHz FM transceiver	499.00	449^{95}
ML-12 10w amplifier	339.00	299^{95}

6m portable	Regular	SALE
IC-505 3/10w 6m port. SSB/CW xcvr	449.00	399^{95}
BP-10 Internal Nicad battery pack	79.50	
BP-15 AC charger	12.50	
EX-248 FM unit	49.50	
LC-10 Leather case	34.95	
SP-4 Remote speaker	24.95	

Hand-held Transceivers

Deluxe models	Regular	SALE
IC-02AT for 2m	349.00	289^{95}
IC-04AT for 440 MHz	379.00	289^{95}

Standard models	Regular	SALE
IC-2A for 2m	239.50	189^{95}
IC-2AT with TTP	269.50	199^{95}
IC-3AT 220 MHz, TTP	299.95	239^{95}
IC-4AT 440 MHz, TTP	299.95	239^{95}

Accessories for Deluxe models	Regular
BP-7 425mah/13.2V Nicad Pak - use BC-35	67.50
BP-8 800mah/8.4V Nicad Pak - use BC-35	62.50
BC-35 Drop in desk charger for all batteries	69.00
BC-60 6-position gang charger, all batts	SALE 359.95
BC-16U Wall charger for BP7/BP8	10.00
LC-11 Vinyl case	17.95
LC-14 Vinyl case for Dlx using BP-7/8	17.95
LC-02AT Leather case for Dlx models w/BP-7/8	39.95

Accessories for both models	Regular
BP-2 425mah/7.2V Nicad Pak - use BC35	39.50
BP-3 Extra Std. 250 mah/8.4V Nicad Pak	29.50
BP-4 Alkaline battery case	12.50
BP-5 425mah/10.8V Nicad Pak - use BC35	49.50
CA-2 Telescoping 2m antenna	10.00
CA-5 5/8-wave telescoping 2m antenna	18.95
FA-2 Extra 2m flexible antenna	10.00
CP-1 Cig. lighter plug/cord for BP3 or Dlx	9.50
DC-1 DC operation pak for standard models	17.50
LC-2AT Leather case for standard models	34.95
RB-1 Vinyl waterproof radio bag	30.00
HH-SS Handheld shoulder strap	14.95
HM-9 Speaker microphone	34.50
HS10 Boom microphone/headset	19.50
HS-10SA Vox unit for HS-10 & Deluxe only	19.50
HS-10SB PTT unit for HS-10	19.50
ML-1 2m 2.3w in/10w out amplifier ..... SALE	79.95
SS-32M Commspec 32-tone encoder	29.95

Shortwave receiver	Regular	SALE
R-71A 100 kHz-30 Mhz digital receiver	$799.00	659^{95}
RC-11 Wireless remote controller	59.95	49^{95}
FL-32 500 Hz CW filter	59.50	
FL-63 250 Hz CW filter (1st IF)	48.50	
FL-44A SSB filter (2nd IF)	159.00	144^{95}
EX-257 FM unit	38.00	
EX-310 Voice synthesizer	39.95	
CR-64 High stability oscillator xtal	56.00	
SP-3 External speaker	49.50	
CK-70 (EX-299) 12V DC option	9.95	
MB-12 Mobile mount	19.50	

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TUBES

TYPE	PRICE	TYPE	PRICE	TYPE	PRICE
2C39/7289	$ 34.00	1182/4600A	$500.00	ML7815AL	$ 60.00
2E26	7.95	4600A	500.00	7843	107.00
2K28	200.00	4624	310.00	7854	130.00
3-500Z	102.00	4657	84.00	ML7855KAL	125.00
3-1000Z/8164	400.00	4662	100.00	7984	14.95
3B28/866A	9.50	4665	500.00	8072	84.00
3CX400U7/8961	255.00	4687	P.O.R.	8106	5.00
3CX1000A7/8283	526.00	5675	42.00	8117A	225.00
3CX3000F1/8239	567.00	5721	250.00	8121	110.00
3CW30000H7	1700.00	5768	125.00	8122	110.00
3X2500A3	473.00	5819	119.00	8134	470.00
3X3000F1	567.00	5836	232.50	8156	12.00
4-65A/8165	69.00	5837	232.50	8233	60.00
4-125A/4D21	79.00	5861	140.00	8236	35.00
4-250A/5D22	98.00	5867A	185.00	8295/PL172	500.00
4-400A/8438	98.00	5868/AX9902	270.00	8458	35.00
4-400B/7527	110.00	5876/A	42.00	8462	130.00
4-400C/6775	110.00	5881/6L6	8.00	8505A	95.00
4-1000A/8166	444.00	5893	60.00	8533W	136.00
4CX250B/7203	54.00	5894/A	54.00	8560/A	75.00
4CX250FG/8621	75.00	5894B/8737	54.00	8560AS	100.00
4CX250K/8245	125.00	5946	395.00	8608	38.00
4CX250R/7580W	90.00	6083/AZ9909	95.00	8624	100.00
4CX300A/8167	170.00	6146/6146A	8.50	8637	70.00
4CX350A/8321	110.00	6146B/8298	10.50	8643	83.00
4CX350F/8322	115.00	6146W/7212	17.95	8647	168.00
4CX350FJ/8904	140.00	6156	110.00	8683	95.00
4CX600J/8809	835.00	6159	13.85	8877	465.00
4CX1000A/8168	242.50*	6159B	23.50	8908	13.00
4CX1000A/8168	485.00	6161	325.00	8950	13.00
4CX1500B/8660	555.00	6280	42.50	8930	137.00
4CX5000A/8170	1100.00	6291	180.00	6L6 Metal	25.00
4CX10000D/8171	1255.00	6293	24.00	6L6GC	5.03
4CX15000A/8281	1500.00	6326	P.O.R.	6CA7/EL34	5.38
4CW800F	710.00	6360/A	5.75	6CL6	3.50
4D32	240.00	6399	540.00	6DJ8	2.50
4E27A/5-125B	240.00	6550A	10.00	6DQ5	6.58
4PR60A	200.00	6883B/8032A/8552	10.00	6GF5	5.85
4PR60B	345.00	6897	160.00	6GJ5A	6.20
4PR65A/8187	175.00	6907	79.00	6GK6	6.00
4PR1000A/8189	590.00	6922/6DJ8	5.00	6HB5	6.00
4X150A/7034	60.00	6939	22.00	6HF5	8.73
4X150D/7609	95.00	7094	250.00	6JG6A	6.28
4X250B	45.00	7117	38.50	6JM6	6.00
4X250F	45.00	7203	P.O.R.	6JN6	6.00
4X500A	412.00	7211	100.00	6JS6C	7.25
5CX1500A	660.00	7213	300.00*	6KN6	5.05
KT88	27.50	7214	300.00*	6KD6	8.25
416B	45.00	7271	135.00	6LF6	7.00
416C	62.50	7289/2C39	34.00	6LQ6 G.E.	7.00
572B/T160L	49.95	7325	P.O.R.	6LQ6/6MJ6 Sylvania	9.00
592/3-200A3	211.00	7360	13.50	6ME6	8.90
807	8.50	7377	85.00	12AT7	3.50
811A	15.00	7408	2.50	12AX7	3.00
812A	29.00	7609	95.00	12BY7	5.00
813	50.00	7735	36.00	12JB6A	6.50

NOTE * = USED TUBE NOTE P.O.R. = PRICE ON REQUEST

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RF TRANSISTORS

TYPE	PRICE	TYPE	PRICE	TYPE	PRICE	TYPE	PRICE
2N1561	$25.00	2N5920	$ 70.00	40608 RCA	$ 2.48	BFY90	$ 1.50
2N1562	25.00	2N5921	80.00	40673 RCA	2.50	BLW60C5	15.00
2N1692	25.00	2N5922	10.00	40894 RCA	1.00	BLX67	12.25
2N2857	1.55	2N5923	25.00	60247 RCA	25.00	BLX67C3	12.25
2N2857JAN	4.10	2N5941	23.00	61206 RCA	100.00	BLX93C3	22.21
2N2857JANTX	4.50	2N5942	40.00	62800A RCA	60.00	BLY87A	7.50
2N2876	13.50	2N5944	10.35	62803 RCA	100.00	BLY88C3	13.08
2N2947	18.35	2N5945	10.00	430414/3990RCA	50.00	BLY89C	13.00
2N2948	13.00	2N5946	12.00	3457159 RCA	20.00	BLY90	45.00
2N2949	15.50	2N5947	9.20	3729685-2 RCA	75.00	BLY92	13.30
2N3118	5.00	2N6080	6.00	3729701-2 RCA	50.00	BLY94C	45.00
2N3119	4.00	2N6081	7.00	3753883 RCA	50.00	BLY351	10.00
2N3134	1.15	2N6082	9.00	615467-902	25.00	BLY568C/CF	30.00
2N3287	4.90	2N6083	9.50	615467-903	40.00	C2M70-28R	92.70
2N3288	4.40	2N6084	12.00	2SC568	2.50	C25-28	57.00
2N3309	4.85	2N6094	11.00	2SC703	36.00	C4005	2.50
2N3375	17.10	2N6095	12.00	2SC756A	7.50	CD1659	20.00
2N3478	2.13	2N6096	16.10	2SC781	2.80	CD1899	20.00
2N3553	1.55	2N6097	20.70	2SC1018	1.00	CD1920	10.00
2N3553JAN	2.90	2N6105	21.00	2SC1042	24.00	CD2188	18.00
2N3632	15.50	2N6136	21.85	2SC1070	2.50	CD2545	24.00
2N3733	11.00	2N6166	40.24	2SC1216	2.50	CD2664A	16.00
2N3818	5.00	2N6267	142.00	2SC1239	2.50	CD3167	92.70
2N3866	1.30	2N6304	1.50	2SC1251	24.00	CD3353	95.00
2N3866JAN	2.20	2N6368	30.00	2SC1306	2.90	CD3435	26.30
2N3866JANTX	3.80	2N6439	55.31	2SC1307	5.50	CD3900	152.95
2N3866JANTXV	4.70	2N6459	18.00	2SC1424	2.80	CM25-12	20.00
2N3866AJANTXV	5.30	2N6567	10.06	2SC1600	5.00	CM40-12	27.90
2N3924	3.35	2N6603	13.50	2SC1678	2.00	CM40-28	56.90
2N3926	16.10	2N6604	13.50	2SC1729	32.40	CME50-12	30.00
2N3927	17.25	2N6679	44.00	2SC1760	1.50	CTC2001	42.00
2N3948	1.75	2N6680	80.00	2SC1909	4.00	CTC2005	55.00
2N3950	25.00	021-1	15.00	2SC1945	10.00	CTC3005	70.00
2N3959	3.85	01-80703T4	65.00	2SC1946	40.00	CTC3460	20.00
2N4012	11.00	35C05	15.00	2SC1947	10.00	DV2820S	25.00
2N4037	2.00	102-1	28.00	2SC1970	2.50	DXL1003P70	22.00
2N4041	14.00	103-1	28.00	2SC1974	4.00	DXL2001P70	19.00
2N4072	1.80	103-2	28.00	2SC2166	5.50	DXL2002P70	14.00
2N4080	4.53	104P1	18.00	2SC2237	32.00	DXL3501AP100F	47.00
2N4127	21.00	163P1	10.00	2SC2695	47.00	EFJ4015	12.00
2N4416	2.25	181-3	15.00	A2X1698	POR	EFJ4017	24.00
2N4427	1.25	210-2	10.00	A3-12	14.45	EFJ4021	24.00
2N4428	1.85	269-1	18.00	A50-12	24.00	EFJ4026	35.00
2N4430	11.80	281-1	15.00	A209	10.00	EN15745	20.00
2N4927	3.90	282-1	30.00	A283	6.00	FJ9540	16.00
2N4957	3.45	482	7.50	A283B	6.00	FSX52WF	58.00
2N4959	2.30	564-1	25.00	A1610	19.00	G65739	25.00
2N5016	18.40	698-3	15.00	AF102	2.50	G65386	25.00
2N5026	15.00	703-1	15.00	AFY12	2.50	GM0290A	2.50
2N5070	18.40	704	4.00	AR7115	20.00	HEP76	4.95
2N5090	13.80	709-2	11.00	AT41435-5	6.35	HEPS3002	11.40
2N5108	3.45	711	4.00	B2-8Z	10.70	HEPS3003	30.00
2N5109	1.70	733-2	15.00	B3-12	10.85	HEPS3005	10.00
2N5160	3.45	798-2	25.00	B12-12	15.70	HEPS3006	19.90
2N5177	21.62	3421	28.00	BAL0204125	152.95	HEPS3007	25.00
2N5179	1.04	3683P1	15.00	BF25-35	56.25	HEPS3010	11.34
2N5216	56.00	3992	25.00	B40-12	19.25	HF8003	10.00
2N5470	75.00	4164P1	15.00	B70-12	55.00	HFET2204	112.00
2N5583	3.45	4243P1	28.00	BF272A	2.50	HP35821	38.00
2N5589	9.77	4340P3	18.00	BFQ85	2.50	HP35826B	32.00
2N5590	10.92	4387P1	27.50	BFR21	2.50	HP35826E	32.00
2N5591	13.80	7104-1	28.00	BFR90	1.00	HP35831E	30.00
2N5596	99.00	7249-2	10.50	BFR91	1.65	HP35832E	50.00
2N5636	12.00	7283-1	37.50	BFR99	2.50	HP35833E	50.00
2N5637	15.50	7536-1	30.00	BFT12	2.50	HP35859E	75.00
2N5641	12.42	7794-1	10.50	BFW16A	2.50	HP35866E	44.00
2N5642	14.03	7795	15.00	BFW17	2.50	HXTR2101	44.00
2N5643	25.50	7795-1	15.00	BFW92	1.50	HXTR3101	7.00
2N5645	13.80	7796-1	24.00	BFX44	2.50	HXTR5101	31.00
2N5646	20.70	7797-1	36.00	BFX48	2.50	HXTR6104	68.00
2N5651	11.05	40081 RCA	5.00	BFX65	2.50	HXTR6105	31.00
2N5691	18.00	40279 RCA	10.00	BFX84	2.50	HXTR6106	33.00
2N5764	27.00	40280 RCA	4.62	BFX85	2.50	J310	1.00
2N5836	3.45	40281 RCA	10.00	BFX86	2.50	J02000	10.00
2N5842	8.45	40282 RCA	20.00	BFX89	1.00	J02001	25.00
2N5847	19.90	40290 RCA	2.80	BFY11	2.50	J04045	24.00
2N5849	20.00	40292 RCA	13.05	BFY18	2.50	KD5522	25.00
2N5913	3.25	40294 RCA	2.50	BFY19	2.50	KJ5522	25.00
2N5916	36.00	40341 RCA	21.00	BFY39	2.50	M1106	13.75

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M1131	5.15	MRF464	25.30	NE021350	5.30	SD1009-2	15.00
M1132	7.25	MRF466	18.97	NE13783	61.00	SD1012	10.00
M1134	13.40	MRF472	1.50	NE21889	43.00	SD1012-3	10.00
M9116	29.10	MRF475	3.10	NE57835	5.70	SD1012-5	10.00
M9579	6.00	MRF476	3.16	NE64360ER-A	100.00	SD1013	10.00
M9580	7.95	MRF477	20.00	NF64480 (B)	94.00	SD1013-3	10.00
M9587	7.00	MRF479	8.05	NE73436	2.50	SD1013-7	10.00
M9588	5.20	MRF492	23.00	NE77362ER	100.00	SD1016	15.00
M9622	5.95	MRF502	1.04	NE98260ER	100.00	SD1016-5	15.00
M9623	7.95	MRF503	6.00	PRT8637	25.00	SD1018-4	13.00
M9624	9.95	MRF504	7.00	PT3127A	5.00	SD1018-6	13.00
M9625	15.95	MRF509	5.00	PT3127B	5.00	SD1018-7	13.00
M9630	14.00	MRF511	10.69	PT3127C	20.00	SD1018-15	13.00
M9740	27.90	MRF515	2.00	PT3127D	20.00	SD1020-5	10.00
M9741	27.90	MRF517	2.00	PT3127E	20.00	SD1028	15.00
M9755	16.00	MRF525	3.45	PT3190	20.00	SD1030	12.00
M9780	5.50	MRF559	1.76	PT3194	20.00	SD1030-2	12.00
M9827	11.00	MRF587	11.00	PT3195	20.00	SD1040	5.00
M9848	35.00	MRF605	20.00	PT3537	7.80	SD1040-2	20.00
M9850	13.50	MRF618	25.00	PT4166E	20.00	SD1040-4	10.00
M9851	20.00	MRF626	12.00	PT4176D	25.00	SD1040-6	5.00
M9860	8.25	MRF628	8.65	PT4186B	5.00	SD1043	12.00
M9887	2.80	MRF629	3.45	PT4209	25.00	SD1043-1	10.00
M9908	6.95	MRF641	25.30	PT4209C/5645	25.00	SD1045	3.75
M9965	12.00	MRF644	27.60	PT4556	24.60	SD1049-1	2.00
MM1500	25.00	MRF646	29.90	PT4570	7.50	SD1053	4.00
MM1550	10.00	MRF648	33.35	PT4577	20.00	SD1057	10.00
MM1552	50.00	MRF816	15.00	PT4590	5.00	SD1065	4.75
MM1553	50.00	MRF823	20.00	PT4612	20.00	SD1068	15.00
MM1607	8.45	MRF846	44.85	PT4628	20.00	SD1074-2	18.00
MM1614	10.00	MRF892	35.50	PT4640	20.00	SD1074-4	28.00
MM1810	15.00	MRF894	46.00	PT4642	20.00	SD1074-5	28.00
MM1810	15.00	MRF901 3 Lead	1.00	PT5632	4.70	SD1076	18.50
MM1943	1.80	MRF901 4 Lead	2.00	PT5749	25.00	SD1077	4.00
MM2608	5.00	MRF902/2N6603JAN	15.00	PT6612	25.00	SD1077-4	4.00
MM3375A	17.10	MRF902B	18.40	PT6619	20.00	SD1077-6	4.00
MM4429	10.00	MRF904	2.30	PT6708	25.00	SD1078-6	24.00
MM8000	1.15	MRF905	2.55	PT6709	25.00	SD1080-7	7.50
MM8006	2.30	MRF911	2.50	PT6720	25.00	SD1080-8	6.00
MM8011	25.00	MRF965	2.55	PT8510	15.00	SD1080-9	3.00
MPSU31	1.01	MRF966	3.55	PT8524	25.00	SD1084	8.00
MRA2023-1.5	42.50	MRF1000MA	32.77	PT8609	25.00	SD1087	15.00
MRF134	10.50	MRF1004M	31.05	PT8633	25.00	SD1088	22.00
MRF136	16.00	MRF2001	41.74	PT8639	25.00	SD1088-8	22.00
MRF171	35.00	MRF2005	54.97	PT8659	25.00	SD1089-5	15.00
MRF208	11.50	MRF5176	24.00	PT8679	25.00	SD1090	15.00
MRF212	16.10	MRF8004	2.10	PT8708	20.00	SD1094	15.00
MRF221	10.00	MSC1720-12	225.00	PT8709	20.00	SD1095	15.00
MRF223	13.00	MSC1821-3	125.00	PT8727	29.00	SD1098-1	30.00
MRF224	13.50	MSC1821-10	225.00	PT8731	25.00	SD1100	5.00
MRF227	3.45	MSC2001	30.00	PT8742	19.10	SD1109	18.00
MRF230	2.00	MSC2010	93.00	PT8787	25.00	SD1115-2	7.50
MRF231	10.00	MSC2223-10	245.00	PT8828	25.00	SD1115-3	7.50
MRF232	12.07	MSC2302	POR	PT9700	25.00	SD1115-7	2.10
MRF237	3.15	MSC3000	35.00	PT9702	25.00	SD1116	5.00
MRF238	13.80	MSC3001	38.00	PT9783	16.50	SD1118	22.00
MRF239	17.25	MSC72002	POR	PT9784	32.70	SD1119	5.00
MRF245	35.65	MSC73001	POR	PT9790	56.00	SD1124	50.00
MRF247	31.00	MSC80064	35.00	PT31083	20.00	SD1132-1	15.00
MRF304	36.00	MSC80091	10.00	PT31962	20.00	SD1132-4	12.00
MRF306	50.00	MSC80099	3.00	PTX6680	20.00	SD1133	9.50
MRF313	11.15	MSC80593	POR	RE3754	25.00	SD1133-1	10.00
MRF314	29.21	MSC80758	POR	RE3789	25.00	SD1134-1	2.50
MRF315	28.86	MSC82001	33.00	RF35	16.00	SD1134-4	12.00
MRF316	55.43	MSC82014	33.00	RF85	17.50	SD1134-17	12.00
MRF317	63.94	MSC82020M	130.00	RF110	21.00	SD1135	10.25
MRF412	18.00	MSC82030	33.00	S50-12	23.80	SD1135-3	12.00
MRF420	20.12	MSC83001	40.00	S3006	15.00	SD1136	12.50
MRF421	25.00	MSC83003	82.00	S3007	10.00	SD1136-2	12.50
MRF422	38.00	MSC83005	70.00	S3031	22.00	SD1143-1	10.00
MRF427	17.25	MSC83026	POR	SCA3522	5.00	SD1143-3	17.00
MRF428	63.00	MSC83303	POR	SCA3523	5.00	SD1144	4.00
MRF433	12.07	MSC84900	60.00	SD345	5.00	SD1145-5	15.00
MRF449/A	12.65	MT4150	14.40	SD445	5.00	SD1146	15.00
MRF450/A	14.37	MT5126	25.00	SD1004	15.00	SD1147	15.00
MRF452/A	17.00	MT5596(2N)	99.00	SD1007	15.00	SD1188	10.00
MRF453/A	18.40	MT5768(2N)	95.00	SD1007-2	15.00	SD1189	24.00
MRF454/A	20.12	MT8762	25.00	SD1007-4	15.00	SD1200	1.50
MRF455/A	16.00	NE02136	2.00	SD1007-5	15.00	SD1201-2	15.00

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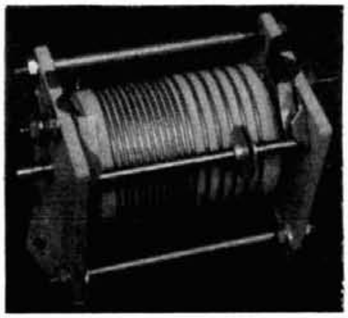
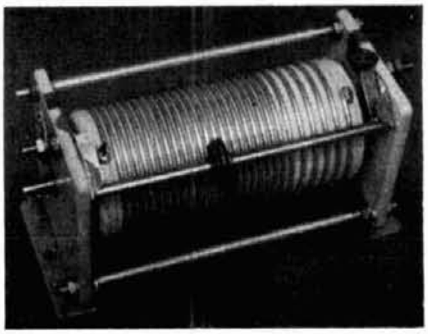
More Details? CHECK—OFF Page 126

E.F. JOHNSON ROLLER INDUCTORS



MODEL 229-0201-01
10UH at 3AMPS MAX. $36.99

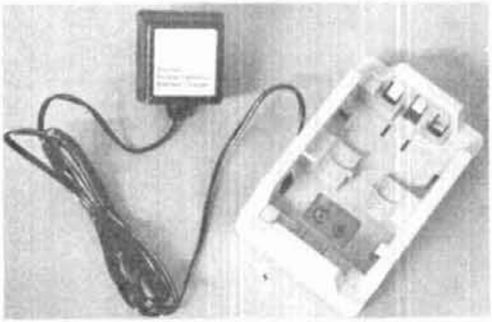


MODEL 229-0202-01
18UH at 5AMPS MAX. $44.99

NI-CAD BATTERY CHARGERS

UNIVERSAL CHARGER $19.99

MALLORY CHARGER $23.99



EVEREADY CHARGER $9.99

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UNELCO,SEMCO,ARCO METAL CLAD MICA CAPACITORS

Standard Size					Micro Size	
3.9	14	33	62	175	5	25
4.7	15	34	68	180	6	27
5	18	36	75	200	7	33
5.1	20	38	80	220	8	36
6.8	22	39	82	240	9	51
7	24	40	100	250	12	62
8.2	25	43	110	300	15	
9.1	27	44	120	360	16	
10	27.5	47	123	470	18	
11	28	50	125	500	20	
12	30	51	140	820	22	
13	32	56	150	1000	24	

********NOTE ALL VALUES LISTED IN PICO FARAD********

PRICE INFORMATION
1 to 10 $ .90ea. 11 to 51 $.80ea. 52 to 102 $.70ea.
103 and up call

****

GOULD NI-CAD BATTERIES

AA size 1.25v at 500mahr	new	a	$ 1.99
D size 1.25v at 4 AMPHR	new	h	7.49

GENERAL ELECTRIC NI-CAD BATTERIES

AA size 1.25v at 500mahr	new	a	2.99
195194 3.75v at 100mahr	new		1.99
AA size 3.75v at 100mahr	new	a	2.99
AA size pack of 10 12.5v at 450mahr	used	a	5.99
Sub C Pack of 10 12.5v at 2.5Amphr	new	c	9.99

UNION CARBIDE NI-CAD BATTERIES

193817 3.75v at 225mahr	new	a	2.99

GLOBE GEL-CELL BATTERIES

2v at 8AMPHR GC280	new	g	5.99
12v at 20AMPHR GC12200	new	g	49.99
12v at 23AMPHR GC12300	new	g	54.99

EAGLE PICHER GEL-CELL BATTERIES

12v at 1.5AMPHR CF12V1.5	new	d	11.99

GATES SEALED RECHARGEABLE LEAD ACID BATTERIES AND PACKS

2v at 2.5AMPHR D Cell	new	b	5.99
8v at 5AMPHR 4 X Cell	used	f	14.99
12v at 2.5AMPHR 6 D Cells	new	f	24.99
18v at 2.5AMPHR 9 D Cells	new	f	29.99

GENERAL ELECTRIC SEALED REACHARABLE LEAD ACID BATTERIES AND PACKS

6v at 2.5AMPHR 3 D Cells	used	e	10.00
12v at 2.5AMPHR 6 D Cells	used	e	19.99
12v at 5AMPHR 6 X Cells	used	e	24.99

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RF Transistors (continued)

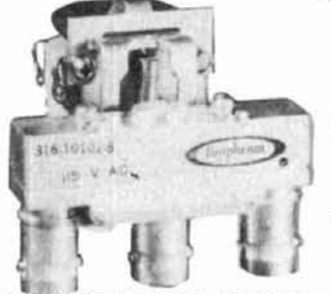
SD1202	$10.00	SD1304-8	$ 2.50	SD1451-2	$15.00	SRF1427	$50.00	SD1244H12	25.00	SD1410-8	21.00	SD1536-1	41.00	SRF2917	15.00
SD1212-8	4.95	SD1305	3.00	SD1452	20.00	SRF1431	40.00	SD1262	15.00	SD1413-1	18.00	SD1539H	100.00	SRF2918	15.00
SD1212-11	4.95	SD1307	3.00	SD1452-4	24.00	SRF1834	40.00	SD1263	15.00	SD1416	28.00	SD1542H1	170.00	SRF2919	15.00
SD1212-16	4.95	SD1308	3.00	SD1453H1	20.00	SRF2053-3	60.00	SD1263-1	15.00	SD1422-2	24.00	SD1544	26.00	SRF3071FF	50.00
SD1214-7	5.00	SD1311	1.00	SD1454-1	48.00	SRF2092	50.00	SD1272	10.95	SD1428	24.00	SD1545	33.00	SS4006	25.00
SD1214-11	5.00	SD1317	8.00	SD1477	35.00	SRF2147	22.00	SD1272-1	10.95	SD1428- 6084	12.00	SD1546H1	55.00	SS4152	15.00
SD1216	12.00	SD1319	2.50	SD1478	21.00	SRF2225	15.00	SD1272-2	10.95	SD1429-2	15.00	SD1561	79.00	TA7686	15.00
SD1219-4	15.00	SD1345-6	5.00	SD1480	53.00	SRF2264	25.00	SD1272-4	10.95	SD1429-3	14.90	SD1574-1	6.95	TA8559	15.00
SD1219-5	15.00	SD1347-1	1.00	SD1484	1.50	SRF2265	100.00	SD1278	13.75	SD1429-5	15.00	SD1575	6.95	TA8561	15.00
SD1219-8	15.00	SD1365-1	2.50	SD1484-5	1.50	SRF2281	5.00	SD1278-1	13.75	SD1430	12.00	SF4557	25.00	TA8562	15.00
SD1220	8.00	SD1365-5	2.50	SD1484-6	1.50	SRF2371	15.00	SD1278-5	13.75	SD1430-2	18.00	SK3048	5.00	TA8563	15.00
SD1220-1	9.50	SD1375	7.50	SD1484-7	1.50	SRF2347	50.00	SD1279-1	18.00	SD1434	28.00	SL501-59	15.00	TA8564	15.00
SD1220-9	8.00	SD1375-6	7.50	SD1488	22.85	SRF2356	38.00	SD1279-3	18.00	SD1434-5	28.00	SL501-173	15.00	TA8894	15.00
SD1222-8	16.00	SD1379	15.00	SD1488-1	28.00	SRF2378	16.00	SD1281-2	8.00	SD1434-9	28.00	SM7714	5.00	TIS189	3.55
SD1222-11	7.50	SD1380-1	1.00	SD1488-7	27.00	SRF2572	25.00	SD1283	10.00	SD1438	26.00	SRF112	15.00	TP312	2.50
SD1224-10	18.00	SD1380-3	1.00	SD1488-8	28.00	SRF2584	40.00	SD1283-2	10.60	SD1441	56.00	SRF395	50.00	TP1014	5.00
SD1225	18.00	SD1380-7	1.00	SD1499-1	36.00	SRF2597	25.00	SD1283-3	10.00	SD1442	15.00	SRF750	36.00	TP1028	15.00
SD1225-1	15.00	SD1405	21.00	SD1511H3	75.00	SRF2741	40.00	SD1283-4	10.00	SD1444	3.25	SRF769H	20.00	TRW3	5.00
SD1229-7	10.95	SD1408	25.00	SD1520-2	18.00	SRF2747	40.00	SD1289-1	15.00	SD1444-8	3.25	SRF887K3	2.50	TXVF2201/HP	450.00
SD1229-16	10.95	SD1409	18.00	SD1522-4	33.00	SRF2767H	40.00	SD1290-4	15.00	SD1444-9	3.25	SRF989K	15.00	V222-2	25.00
SD1232	4.00	SD1410	18.00	SD1528-1	24.00	SRF2821	25.00	SD1290-7	15.00	SD1446	4.03	SRF1005	50.00	V410IE	20.00
SD1240-8	15.00	SD1410-3	21.00	SD1528-3	34.00	SRF2822/2N6603	13.50	SD1300	1.25	SD1450-1	28.00	SRF1018	5.00	V415	5.00
SD1244-1	14.00	SD1410-6	21.00	SD1530-2	38.00	SRF2857	20.00	SD1301-7	3.00	SD1451	15.00	SRF1074	50.00		

Relays

BNC To Banana Plug Coax Cable RG-58 36 inc. or BNC to N Coax Cable RG-58 36 inch.

$7.99 or 2 For $13.99 or 10 For $50.00

$8.99 or 2 For $15.99 or 10 For $60.00



Amphenol
Part # 316-10102-8
115Vac Type BNC DC to 3 GHz.

$29.99

COAXIAL RELAY SWITCHES SPDT

FXR
Part # 300-11182
120Vac Type BNC DC to 4 GHz.
FSN 5985-543-1225

$39.99

FXR
Part # 300-11173
120Vac Type BNC Same
FSN 5985-543-1850

$39.99

TERMS: DOMESTIC: Prepaid, C.O.D. or Credit Card
FOREIGN: Prepaid only, U.S. Funds, Money Order, or Cashier's Check Only.

C.O.D.: Acceptable by telephone or mail. Payment from customer will be by CASH ONLY. We are sorry but we cannot accept personal checks for C.O.D.'s. C.O.D.'s are shipped by air only and thru United Parcel Service.

CONFIRMING ORDERS: We would prefer that confirming orders not be sent after a telephone order has been placed. If company policy requires a confirming order, please mark "CONFIRMING ORDER" boldly on the order. If problems or duplicate shipments occur due to an order which is not properly marked, the customer will be held responsible for any charges incurred, plus a 15% restocking fee on the returned parts.

CREDIT CARDS: We are now accepting MASTERCARD, VISA, AND AMERICAN EXPRESS

DATA SHEETS: When we have data sheets in stock on devices we will supply them with the order.

DEFECTIVE MATERIALS: All claims for defective materials must be made within 30 days after receipt of the parcel. All claims must include the defective material (for testing purposes), a copy of our invoice, and a return authorization number. The return authorization number can be obtained by calling (602) 265-0731 or sending us a postcard. This must be obtained before shipping the merchandise back to us otherwise the package could be refused and notification will not be considered completed until this number has been assigned. Due to manufacturers warranties we are unable to replace or issue credit on items which have been soldered to or have been altered in any way. All return items must be packed properly, and insured if this is not done so it will void all warranties. We do not assume any responsibility for shipping charges incurred.

DELIVERY: Orders are usually shipped the same day they are placed or the next business day, unless we are out of stock on an item. The customer will be notified by post card if we are going to backorder the item. Our normal shipping method is UPS or U.S. Mail depending on size or the weight of the package. Test Equipment is shipped only by air and is freight collect, unless prior arrangements have been made and approved.

FOREIGN ORDERS: All foreign orders must be prepaid with Cashier's check, Money Order, or bank wire made out in U.S. Funds only. We are sorry but C.O.D. is not available to foreign countries and letters of credit are unacceptable forms of payment.

HOURS: Monday thru Friday 8:30 a.m. to 5:00 p.m. Saturdays 8:30 a.m. to 4:00 p.m.

INSURANCE: Please include 25¢ for each additional $100.00 over $100.00 UPS only. All insured packages are shipped thru UPS and U.S. Mail, U.S. Mail insurance is calculated at the time of shipment. In the United States insured packages are shipped only by UPS.

ORDER FORMS: New order forms are included with each order for your convenience. Additional order forms are available on request.

PARTS: We reserve the right to substitute or replace any item with a part of egual or comparable specification.

POSTAGE: Minimum shipping and handling in the U.S., Canada, and Mexico is $3.00 for ground shipments. Foreign countries is $5.40 or 25% of order whichever is greater. Air rates are available at the time of your order. C.O.D.'s are shipped AIR ONLY.

PREPAID ORDERS: Orders must be accompanied by check, bankcard number, or money order.

PRICES: Prices are subject to change without notice.

PURCHASE ORDERS: We accept purchase orders accompanied by a check. All others must have prior approval by management.

RESTOCK CHARGES: If parts are returned to MHz Electronics, Inc. due to customer error, the customer will be held responsible for all fees incurred and will be charged a 15% restocking fee with the reminder in CREDIT ONLY. Return authorization must be obtained within 5 working days of receipt of the parcel, otherwise the order will be considered complete. The following must accompany any return: A copy of our invoice, return authorization number which must be obtained prior to shipping merchandise back and must appear on the outside of the package. Return authorizations can be obtained by calling (602) 265-0731. Return authorizations will not be given out on the 800 number. All items must be properly packed and insured. We will not give any credit on items which are damaged due to improper packing.

SALES TAX: ARIZONA residents must add 6% sales tax, unless a signed ARIZONA resale tax card is currently on file with us. All orders placed by persons outside of ARIZONA, but delivered to persons in ARIZONA are subject to the 6% sales tax.

SHORTAGES OR DAMAGED MERCHANDISE: All claims for shortages or damages must be made within 5 DAYS of receipt of parcel. Claims must include a copy of our invoice, along with a return authorization number which must appear on the outside of the package. The return authorization number can be obtained by calling (602) 265-0731 or sending us a postcard. Authorizations cannot be given on our 800 number. All items must be properly packed and insured. We are not responsible for any damages which may occur in shipment back to us. We do not assume any responsibility for shipping charges incurred. If you have received a damaged package please make sure to contact the carrier so that they can come out and inspect the package before it is shipped back to us. All damaged packages must be returned to us with its original shipping material and contents. Customers which do not notify us within this time period will be held responsible for the entire order as we will consider the order complete.

OUR 800 NUMBER IS STRICTLY FOR ORDERS ONLY (800) 528-0180. INFORMATION CALLS ARE TAKEN ON (602) 265-0731

MHz electronics

3802 North 27th Ave., Phoenix, AZ 85017

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(For orders only)

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NEW products

900-MHz scanner converter

Hamtronics, Inc. has announced a new converter for scanner radios to cover the 900-MHz land mobile band. An adaptation of the very popular CVR-806, which covers the 806-896 MHz band, the new 900-MHz converter allows coverage of new services now being assigned or proposed for the 880-960 MHz range, including additional land mobile services, such as police and fire departments, government and non-government fixed stations, industrial, scientific, and medical services, and the proposed 902-928 MHz Amateur band. Also included are proposed new cellular telephone and paging services and existing and new broadcast studio-transmitter links. The price of the CVR-900 is $88 plus $3 for shipping and handling. Other converters are available for the 72-76, 135-144, 240-270, 400-420, and 806-896 MHz bands at the same price.

For a complete catalog of Hamtronics® products, send $1 to Hamtronics, Inc., 65-F Moul Road, Hilton, New York, 14468-9535. (For overseas mailing, please send $2 or 4 IRCs.)

UHF cavity amplifiers

Varian/EIMAC has introduced six new UHF cavity power amplifiers designed for FM, CW, pulse, or single-sideband linear service in the 280 to 530 MHz frequency range.

Using the EIMAC 3CX800A7 high-μ power triode, the cavity amplifiers eliminate equipment design complications and extra power supplies associated with UHF tetrode cavities, yet provide comparable stage gain. Power gain in FM or CW service for all cavities is on the order of 11 dB with efficiency ratings in excess of 55 percent.

In addition to being more efficient, the new cavity amplifiers offer reliability in the targeted bands because of the comparatively simple design.

The cavities provide approximately 450 watts power output in CW and FM service over the following ranges: CV-2401, 390 to 450 MHz; CV-2402, 375 to 420 MHz; CV-2403, 280 to 300 MHz; CV-2404, 470 to 530 MHz; CV-2405, 330 to 370 MHz; and CV-2406, 450 to 470 MHz.

Standard 50-ohm Type N input and output RF connectors are used for all cavities. Silver-plated components are used to ensure the best performance and efficiency.

The cavities are forced-air cooled and designed for mounting to a customer's 19-inch panel. Each has a net weight of about 13 pounds. All are 14 inches wide, 10 inches deep, and range in height from 6.2 to 9.3 inches.

For additional information or literature, contact Varian/EIMAC, 301 Industrial Way, San Carlos, California 94070.

Circle #308 on Reader Service Card.

packet communicator

Kantronics has announced a new product for Amateurs using computers in the shack: the Kantronics Packet Communicator.

Interest in packet radio has grown in recent years with volunteer Amateur groups doing research and testing of the new mode. With the ARRL adoption of the AX.25 protocol as the Amateur standard, packet radio became a viable form of data exchange. Thousands of Amateurs have proven the new mode reliable using a hardware and software program devised by the Tuscon Area Packet Radio group (TAPR).

To better utilize the new packet technology Kantronics has designed a new hardware format for processing the packet protocol. By using an internal microprocessor to handle the protocol, and integrated circuits for signal processing, the Kantronics Packet Communicator becomes the most compact and inexpensive finished packet unit available today.

Data is transmitted between the Kantronics Packet Communicator and the computer using a Series RS232 or TTL port. Baud rates of 300, 1200, and 9600 can be used. Any terminal or communications software program can be used to set up the computer to communicate with the Packet Communicator. Special Packet Terminal (PAC-Term™) programs for many popular personal computers will be available soon from Kantronics.

System compatability, the ability to exchange data with existing Packet Terminal Node Controllers, has been achieved with the Kantronics Packet Communicator by using the popular TAPR software.

Almost all of the commands and operation procedures used by the TAPR group are used with the Kantronics Packet Communicator. Both the ARRL standard AX.25 and Vancouver protocols are incorporated in the unit. The Kantronics Packet Communicator supports baud rates of 300, 400, 600, and 1200, but the unit does not support full duplex operation.

An added feature of the Kantronics Packet Communicator is the ability to select either Bell 103 or 202 tones for 300 baud operation. This will allow the operator to switch to the lower tone set, improving performance at slower speeds on the HF bands. This feature makes the Kantronics Packet Communicator an excellent choice for gateway use on the HF bands. The suggested retail price is $389.95.

For further information, contact your local Kantronics dealer, or Kantronics, 1202 East 23rd Street, Lawrence, Kansas 66046.

Circle #307 on Reader Service Card.

headset/boom microphone for TR-720

Communications Specialists has announced the availability of a high quality headset/boom microphone that plugs directly into the TR-720 handheld airband transceiver. The CS-65 HEADSET/MIC was developed to permit improved transmission and reception with the TR-720 in noisy environments. This new accessory is light (12 ounces) and features cushioned, noise-attenuating ear pads that can be adjusted for a comfortable fit. A flexible boom supports and electret noise-cancelling microphone. Supplied with a 5-foot cable to connect to the radio, the unit comes with a push-to-talk switch attached. The CS-65 HEADSET/MIC lists for $69.95.

For further information, contact Communications Specialists, Inc., 426 West Taft Avenue, Orange, California 92665.

Circle #306 on Reader Service Card.

Invitation to Authors

ham radio welcomes manuscripts from readers. If you have an idea for an article you'd like to have considered for publication, send for a free copy of the *ham radio* Author's Guide. Address your request to *ham radio*, Greenville, New Hampshire 03048 (SASE appreciated).

NEW products

touchtone decoder kit

Engineering Consulting has announced the model TSD 4-digit sequential touchtone (DTMF) decoder for mobile and base station use. Each board can have a unique 4-digit user-programmable access code. The board will install in most VHF/UHF and HF gear, allowing alarm or mute functions to be implemented. Typical applications include muting the audio circuit until a valid 4-digit code is received. An alarm can be sounded upon receipt of the access code to alert the operator that someone is calling on the channel, without having to listen for your call sign.

The model TSD decoder is easy to install in any 12-volt radio. Speaker audio or low-level audio may be used to listen to the tones. An open collector transistor provides the output control to switch a small relay or alarm device. Either momentary or latching control is provided with jumper selection. Upon receipt of the access code a latch or momentary pulse is provided. Send the code again and the latch will reset. The TSD is available wired and tested from Engineering Consulting for $59.95.

For further information, contact Engineering Consulting, 583 Candlewood Street, Brea, California 92621.

Circle #305 on Reader Service Card.

super CW

Super-CW, a CW audio processor from Hildreth Engineering, includes an 8th order Butterworth cascade of staggered pairs to provide excellent skirt rejection without excessive response to impulse noise. The 3-dB passband is from 700 to 800 Hz with a 3 to 30 dB shape factor of less than 3.

More than just a filter, the unit features an S/N BOOST function, which is driven by the pre-filter, to provide a signal-to-noise ratio enhancement of over 10 dB as compared with the linear filter position. It does this for signals that are well below the noise in a typical 3 kHz audio bandwidth. This boost circuitry uses compound-complex filter/limiter/filter elements with added active circuits (patent applied for) that creates S/N enhancement for CW — or any pulse-code-modulation (PCM) signal — analogous with that enjoyed by FM communications systems. A second and very important benefit is ear protection. When in the S/N BOOST position, the sudden onset of strong signals or noise pulses just can't happen. You get a clean, distortion-free signal at a sound pressure level uniquely determined by the AF GAIN control.

A 2-watt power amplifier with a controlled voltage gain of 25 is included to allow a reduction in receiver RF gain, which reduces the tendency toward non-linear disturbances in your receiver's IF and/or product detector when listening to a weak signal under the condition of strong signal QRM outside of the 700 to 800 Hz passband. The unit receives its input from your receiver's speaker output. Power supply requirements are 12 to 15 VDC at a nominal 350 mA peak. The unit will drive a 4 to 8 ohm speaker.

For more information, contact Hildreth Engineering Corporation, P.O. Box 60003, Sunnyvale, California 94088.

Circle #303 on Reader Service Card.

filters for TS-940S

Matched sets of filters for the Kenwood TS-940S are available from International Radio, Inc. The SSB-2.1 kHz set consists of one 8.83 MHz, 2.1 kHz drop-in, 8-pole crystal filter and one 2.1 kHz 455 kHz 8-pole crystal filter (wired in). This matched set will provide an overall system selectivity of 2.0 kHz at 6 dB and 2.5 kHz at 60 dB. The shape factor is 1.25.

The CW-400 Hz matched set consists of one drop-in 8.8 MHz 400 Hz 8-pole crystal filter and one drop-in 455 kHz filter, for system selectivity of 400 Hz at 6 dB and 700 Hz or less at 60 dB. The shape factor is 1.75 or less.

Sets are priced at $139.00 each, or $260 for both. All crystal filters are guaranteed for two years. Quantity discounts are available.

For further information, contact International Radio Inc., 364 Kilpatrick Avenue, Port St. Lucie, Florida 33452.

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solar breakthrough

The ENCON Corporation has introduced the first commercially available amorphous (thin film) photovoltaic to the Amateur Radio marketplace. Genesis,™ a state-of-the-art 5-watt PV module, represents a breakthrough in solar cell technology. Typical applications for the new modules, which may be wired together for increased power, include battery maintenance on ham equipment, recreational vehicles, and boats. The modules can produce enough power for telecommunication from QRP stations, security equipment, and some home lighting.

Manufactured by ARCO Solar, the Genesis is designed for easy use. Convenient front mount-

NEW products

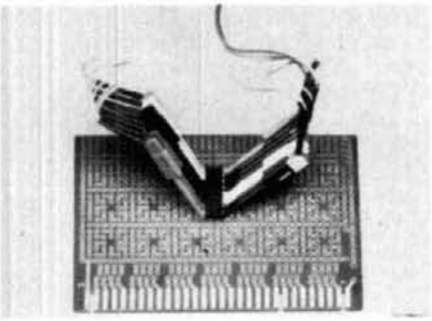
ing holes and a long lead wire make the Genesis module easy to install and use. Modules bolt directly to almost any secure surface and produce power even in low or diffused light. Power specifications for the Genesis include: voltage at maximum power, 14.5 VDC; current at maximum power, 0.35 amperes; open-circuit voltage, 20.8 VDC; and short-circuit current, 0.435 amperes. Carrying a one-year warranty and retailing for under $100, its advanced technology provides an affordable solar alternative accessible to everyone.

For more information, contact ENCON Corporation, 27600 Schoolcraft, Livonia, Michigan 48150.

Circle #302 on Reader Service Card.

pico hook adapter with wire/cable plug-on capability

Designed specifically for narrow test contact access, the E-Z HOOK P-25 "pico Hook" adapter features an ultra-thin blade and housing to allow connector stacking and ease of use, while allowing the flexibility of independent wire and cable assembly.



Incorporated into the design is a one-piece, gold-plated beryllium copper conductor and hook for assured signal accuracy, qualified to MIL-G-45204. The P-25 permits connection to 0.025-inch square or 0.030-inch round push-on jumpers and is designed for connection directly to a single leg of a DIP or other components which have a maximum diameter of 0.025 inch.

Lightweight and Finger-eze Hypo Action permit hook-up to delicate wires where weight and leverage may otherwise damage components. The barrier on the tip prevents shorting between DIP legs. A durable plastic body and plunger, and stainless steel compression spring provide approximately eight ounces of contact pressure.

For details, contact E-Z hook, Inc., P. O. Box 450, Arcadia, California 91006-0450.

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MEMO

from the desk of **Skip Tenney, W1NLB**

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The modern home computer, with some priced at less than $150, is certainly one of the most exciting and challenging new items to be offered to the Radio Amateur in many years. These machines are such a logical extension of our Amateur activities, that it's a wonder that it has taken some of us as long as it has to get involved.

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Skip Tenney, W1NLB

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COMPUTER PROGRAMS FOR THE RADIO AMATEUR

by Wayne Overbeck, N6NB, and Jim Steffen, KC6A

Here's the first source book of computer programs for the Radio Amateur. Besides covering computer basics, this book gives you programs that will help you log, determine sunrise/sunset times, track the Moon's path across the sky, use Greyline propagation and set up record systems for WAS, DXCC and VUCC, or any other award. You can either buy the book alone or you can buy the book with the programs already on disk. Take full advantage of your computer with this well written source book. ©1984, 1st edition, 327 pages.

Program Listing

Data Base Mgmt.
Logs, Awards Data Base, Gridlocator

Latitude/Longitude Programs
Data File, Beamheadings, DX Display, Sunrise Ch
Greyline, DX Checker

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HAM DATA By Chip Lohman NN4U
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This self-prompting program covers dipoles, Yagis, long wires, rhombics, quads, loops, verticals and other antennas. You simply enter the frequency you are designing an antenna for, the antenna you want to make, and the computer will give you all the initial design specifications you need. The results can be stored on disk for permanent retention.

☐**HD-AD** (For C-64) **$9.95**

CONTEST LOG

This disk contains four different contest programs; ARRL Sweepstakes, Field Day, Universal WW Contest log, plus a dupe checking routine. Each program is designed for real time use. It automatically enters date, time, band and serial number for each contact. A 24-hour clock is displayed at the top of the VDT screen. When the contest is over, the program will print your results listing all duped and scored contacts in serial sequence with all the necessary information as well as completed score at the bottom of the page.

☐**HD-CL** (For C-64) **$24.95**

SUPER LOG

Super log gives you all the advantages of a computerized data base without significantly changing the traditional log format. For contesters, Super Log can be configured to either manually or automatically enter serial number as well as time of contact. Make an error and you can easily go back and edit the entry. Super Log also allows you to print out either selected contents or the whole log. Will print QSLs. Easy to modify.

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Invaluable addition to any Hamshack. The Propagation Chart allows you to determine the maximum usable frequency (MUF) and the optimum frequency (FOT) between your QTH and any spot on the globe. You can get either a screen display, a printed tabular list over several days, or a printed graph of MUF and FOT. You also get automatic beam headings and distance to the DX station. Covers 160-10 meters and the new WARC bands.

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STAR 1.0 DESIGN PROGRAM

by Randall Rhea

STAR, S-parameter Two part Analysis Routine, is a professional engineering program designed to help analyze electronic circuits. It is particularly helpful in frequency domain analysis of RF and microwave circuits. To use STAR, you input circuit information by component; inductors, resistors, capacitors, transformers, transmission lines, two port data and several two port manipulations. STAR will then give you S-parameter data for each requested frequency in tabular or plot form. You can also use STAR to optimize component values for maximum circuit performance. This program is definitely not for electronic beginners. Engineers and serious hams, however, will find STAR to be an invaluable design tool.

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☐**XN-C64** (For Commodore C-64) **$34.95**

EOTRON RF NOTES

by John Simmons, W6MDI

Here's an easy way to get answers for often asked electronics questions. RF NOTES contains programs written by broadcast engineers that answer: *dB conversion*, to convert voltage, current or power levels to dB; *dBm conversions*, converts voltages or power levels to dBm and dBm to voltage or power; *VSWR calculations*, calculates VSWR and return loss when both reflected and incident powers are known; *Filter design*, 14 different filter configurations including schematics (6 low pass, 4 high pass, 2 band pass and 2 band elimination circuits); *Basic Microstrip and basic strip line design*; and *resonant circuits*, design parallel and series resonant circuits, PI, capacitive impedance divider and inductive impedence divider. This disk is an invaluable reference for all Radio Amateurs.

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This Commodore C-64 program will meet just about every logging need you can imagine. It can be used as a contest log, general log or dupe checker and can be used for all band WAS, WAZ or DXCC. The storage disk holds up to 2,000 exchanges and can be edited and updated simply and easily. Each entry contains callsign, signal reports, automatic or manually entered time and date, band and mode as well as name and QTH. Contender will also pri QSL's, mail labels and contest dupe sheets. The Conten USA-CA (three disks) is a Worked All County data base that saves time and hassle and a tremendous amount o paperwork.

CT-C **$34.**
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RTTY MAILBOX MSO for Vic 20 and C-64 Computers

Here's a super user friendly software package that turns Commodore home computer into a powerful, easy-to-use message handling system. Messages can be stored, rea or deleted by either incoming RTTY signals or by using computer's keyboard. Each message is listed in a direct by file name, along with date and time of message initia tion. The Basic/Assembly language software combines hi speed with user friendly features and fully controls your transmitter and receiver with automatic identification, an optional special message and automatic transmission of date and time during MSO use. You can also use this pr gram to operate direct RTTY and 60, 67, 75 or 100 wpn Baudot or 110 baud ASCII. Vic 20 needs 24k of memory use this program.

VC-CP Use with AEA CP1 interface & equiv. **$79.**
VC-MF Use with MFJ interface & equiv. **$79.**
VC-KT Use with Kantronics interface & equiv. **$89.**

AMPRO SOFTWARE FOR THE IBM PC

Edited by E.B. Rough, KB3GX

Programming by Ron Nord, N3AKP

These four programs have been written with the Active Amateur in mind and are designed to greatly simplify record keeping chores. You simple enter basic QSO data; call, prefix, country, state, or zone, date, RST and mode The program then adds the contact to the disk data base You can review your current status of stations worked, confirmed or verified at a glance. You can also print up "wish list" to give to your friends who are helping you find those missing stations. The DXCC and 5 band DXCC lists are current through January 1, 1985 and can be eas updated should any new countries be added. These programs are a great value at a good price and represent a major time saver.

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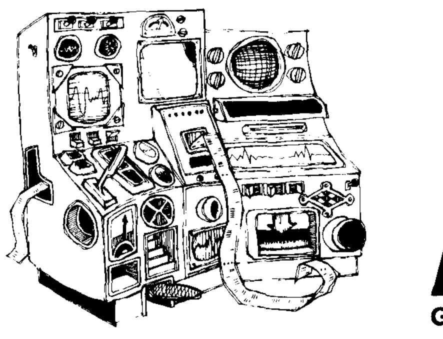

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Herts EN6 3JW
England

Holland Radio
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Greenside, Johannesburg
Republic of South Africa

Coming Events

ACTIVITIES

"Places to go..."

KENTUCKY: The Central Kentucky ARRL Hamfest, sponsored by the Bluegrass ARS, Sunday, August 11, 8 AM to 5 PM, Scott County HS, Longlick Road and US 25, Georgetown. Tech forums, license exams, awards and exhibits. Air conditioned facilities. Free outdoor flea market space. Tickets $3.50 advance and $4.00 at gate. Talk in on 76/16. For information or tickets SASE to Scott Hackney, KI4LE, 629 Craig Lane, Georgetown, KY 40324.

PENNSYLVANIA: The Tioga County Amateur Radio Club's 9th annual Hamfest, Sunday, August 18, Island Park, Blossburg. 9 AM to 5 PM. VE's will give walk-in exams. For information write TCARC, PO Box 56, Mansfield, PA 16933. Flea market, dealers, park and pool, snack bar. Admission $3.00. Spouse and kids free. Talk in on 146-19/79, 146-52/52 and CB. For information: Durwood Learn, WB3DKZ, 11 Bryden Street, Wellsboro, PA 16901. (717) 724-5613.

TEXAS: The Austin ARC and the Austin Repeater Association in conjunction with the Texas VHF-FM Society announces the third annual Austin Summerfest, August 2, 3 and 4, Austin Marriott Hotel, I-35 and US 290, Austin. Seminars, QCWA hospitality suite, dealer displays. FCC exams for all classes Saturday. Ladie's programs. Austin's "Aquafest" is this same weekend and will provide additional entertainment. Registration $5 advance, $7 at the door. Persons under 18 admitted free. Swapfest tables available starting 6 AM Saturday at $1 per table, limit two. Talk in on WA5YAN/R 146.34/94. For more information: Austin Summerfest, PO Box 13473, Austin, TX 78711.

PENNSYLANIA: The 48th annual South Hills Brasspounders and Modulators Hamfest, August 4, 9 AM to 4 PM, South Campus, Community College of Allegheny County, Pittsburgh. Tickets $3 each. 2/$5. Oscar, RTTY and packet radio forums. Flea market. Talk in on 146.13/73 and 146.52 simplex. For more information: Bill Gardiner, 4756 Child Drive, Pittsburgh, PA 15236.

INDIANA: The annual Bloomington Hamfest, Sunday, September 1, 147.18/.78 repeater site, Vernal Pike off SR 37 bypass. 8 AM to 2 PM. Admission $2.00. Food concession. No charge for setups, bring your own tables. For more information: Bob Myers, K9KTH, 306 S. Fairview Street, Bloomington, IN 47401. SASE or dall (812) 332-1105.

INDIANA: The 6th annual Grant County Amateur Radio Club Hamfest, Sunday, August 11, 4H Fairgrounds, Marion. Doors open 8 AM. Refreshments, free parking, license exams. Table reservations $2/8' table. Donation $2.00 advance. $3.00 gate. For more information SASE to WB9EAP, Brooks Clark, 2202 South Boots Street, Marion, IN 46953.

WASHINGTON: Tacoma Hamfair, sponsored by the Radio Club of Tacoma. August 17 and 18, Pacific Lutheran University, Tacoma. Tech seminars, forums, travelogs and more. Large flea market. License exams, send 610 to W7BUN. Registration $5.00. Dinner $8.00. Flea market table $15/day; $20/2 days includes one registration. Register with Grace Tietzel, AD7S, PO Box 45079, Tacoma, WA 98445 or call Eva Anderson, WB7QNS, (206) 564-8347.

OHIO: 43rd annual Findlay Hamfest sponsored by the Findlay Radio Club at the Hancock County Fairgounds. Sunday, September 8, 6:30 AM to 5 PM. Advance tickets $3.00 by September 1. At the door $4.00. Tables $6.00 each. Outdoor flea market spaces $3.00 each. Talk in on 147.75/15. For more information write Findlay Radio Club, PO Box 587, Findlay, Ohio 45839.

MISSOURI: The St. Charles Amateur Radio Club's Hamfest '85, August 25, St. Charles City Hall complex, 200 North 2nd Street, St. Charles. Giant flea market, commercial vendors, XYL programs, FCC exams, food available. All under cover. Parking $1.00, tickets $1.00 advance; $1.50 door. Talk in on 146.07/67 and 146.52. Tickets from WDØCZE, 121 Barkwood Trail, St. Charles, MO 63303.

CALIFORNIA: Valley of the Moon Amateur Radio Club's fifth annual "Ham" breakfast and swapmeet, Sunday, August 11, Sonoma Community Center, 276 East Napa Street, Sonoma. 9 AM to 4 PM. Breakfast 9 to 11:30 AM. Sausage, eggs, pancakes, 'taters, o.j. and coffee, all you can eat for $5.00! Swap tables setup starts 8 AM, spaces $5.00 each. Better bring your own tables. Open auction at 1 PM. Surrounding points of interest for the whole family. Admission $1.00. For reservations or more information: Darrel Jones, WD6BOR, 358 Patten St., Sonoma, CA 95476. (707) 996-4494.

VERMONT: The annual BARC International Hamfest, August 10 and 11, Old Lantern Campgrounds, Charlotte. $4.00 both days. Children under 12 free. Outdoor flea market space $2.00. Indoors $5.00. RC model airplane show. CAN-AM tug-o-war. Talk in on 34/94, 01/61 and 52. Queries to Roger, WA1OZE; flea market info Bob, W1DQO. Both at Box 312, Burlington, VT 05402.

ILLINOIS: The Shawnee Amateur Radio Association is sponsoring SARA Hamfest '85 Sunday, September 8, John A. Logan College Gym, Highway 13 near Carterville. New equipment and computers, ladies' activities, displays, flea market, crafts. All inside. FCC exams Sunday AM. Lunch available. Admission $3.00. Talk in on 146.25/.85, 146.52 simplex, 3.925 MHz. For information: Shawnee ARA, 502 West Kenicott, Carbondale, IL 62901. (618) 457-7586.

1985 BLOSSOMLAND BLAST, Sunday, October 6, 1985. Write "BLAST", PO Box 175, St. Joseph, MI 49085.

MAINE: The 1985 Windsor Hamfest, Saturday, September 7, Windsor Fairgrounds. Flea market, programs, speakers, distributors, and the traditional Saturday bean and casserole supper. Gate donation $1.00. Camping $3.00 per night; $5.00/2 nights. Talk in on 146.22/82 repeater. For information: Ron Dishman, N1CMZ, 37 Marlboro Avenue, Augusta, ME 04330. (207) 623-8351.

NEW JERSEY: The Ramapo Mountain ARC, WA2SNA, presents its 9th annual flea market, August 17, Oakland American Legion Hall, 65 Oak Street, Oakland, 20 miles from GW bridge. Admission $1.00. Non-ham family members free. Indoor tables $6.50. Tailgating $3.00. Talk in on 147.49/146.49 and 52. For information: Tom Risseeuw, N2AAZ, 63 Page Drive, Oakland, NJ 07436. Tel. 337-8389 after 6 PM.

WISCONSIN: Green Bay Mike & Key Club's Summer Swapfest, Saturday, August 17, Ashwaubenon Community Center, Anderson Drive across from Baypark Square Mall. Free admission and parking. Doors open 8 AM. Sellers 7 AM. Buy, sell, trade. Reserved 8' tables $5.00. Limit 4. SASE with check to Green Bay Mike & Key Club, Bill Johnson, N9CNO, 2177 Orrie Lane, Green Bay, WI 54304. (414) 494-8948.

MISSOURI: The Ozarks Amateur Radio Society's 4th annual Congress & Swapfest, Sunday, September 8, City Park, Jct. of US 60 and Highway 37, Monett. Swapfest 11:00 AM. Buffet dinner 1:00 PM. No tickets necessary. All Amateurs and families welcome. Talk in on 146.37/.97, 146.52 and 7.250 MHz. For information: Ozarks Amateur Radio Society, Box 327, Aurora, MO 65605. (417) 678-5330.

GEORGIA: Augusta Hamfest, September 15. Dealers and tailgaters welcome. Food and drinks available. ARRL/VEC exams 8 AM. Tickets $1.00. 6/$5, 13/$10. Talk in on 34/94. SASE to Bill Hardin, 4430 Forrest Drive, Martinez, GA 30907. (404) 863-4360.

INDIANA: The Tippecanoe Amateur Radio Association's 14th annual Hamfest, Sunday, August 18, Tippecanoe County Fairgrounds, Teal Road and 18th Street, Lafayette. Grounds open 7 AM. Tickets $3.00. Large flea market, dealers, refreshments and fun. Talk in on 13/73 or 52. For tickets or information: Lafayette Hamfest, Route 1, Box 63, West Point, IN 47992.

ILLINOIS: Bolingbrook Amateur Radio Society's B.A.R.S. Hamfest '85, Sunday, September 8, Santa Fe Park, 91st and Wolf Road, Willow Springs. Advanced registration $2.00. $3.00 at the gate. Talk in on 147.33/93 and 146.52. For information: Ed Weinstein, WD9AYR, 7511 Walnut Ave., Woodridge, IL 60517. (312) 985-0527.

MICHIGAN: The Grand Rapids Amateur Radio Association's annual Swap and Shop, Saturday, September 21, Hudsonville Fairgrounds. Dealers, indoor sales area, outdoor trunk swap, concession. Gates open 8 AM. Talk in on 146.16/76. For information: Grand Rapids ARA, PO Box 1248, Grand Rapids, MI 49501.

PENNSYLVANIA: The Skyview Radio Society's annual Hamfest, Sunday, September 16, Clu Grounds, Turkey Ridge Rd., New Kensington. Noon to 4 PM. Registration $2.00. Vendors $4.00. Talk in on 146.04-.64 and 52.

PENNSYLVANIA: The Central Pennsylvania Repeater Association's 12th annual Hamfest/Computerfest, August 25, adjacent to Hersheypark, Chocolate Town, USA. Registration $3.00. Children 12 and under free. Special reduced admission to Hersheypark for registrants and families. Large indoor dealer and flea market. Large outdoor tailgate area. Food and refreshments. Talk in on 145.47 repeater or 146.52 simplex WA3KXG. For information: Paul W. McDonnell, N3BKI, (717) 697-1880, noon to 8 PM.

PENNSYLVANIA: The Uniontown Amateur Radio Club (W3PIE) will hold its 36th annual Gabfest, Saturday, September 7, Club grounds, Old Pittsburgh Road, Uniontown. Registration $3.00 or 2/$5.00. Free Parking — Free Coffee — Free Swap & Shop with registration. Talk in on 147.645-.045 & 144.57-.17. For information: John Cermak, WB3DOD, U.A.R.C. Gabfest Committee, PO Box 433, Republic, PA 15475. (412) 246-2870.

VIRGINIA/WEST VIRGINIA: The Bluefield Hamfest, sponsored by the East River Amateur Radio Club, will be held Sunday, August 25, Brushfork Armory Civic Center, 1 mile north of Bluefield, WV. 9 AM to 3 PM. Admission $4.00. Children under 12 free. Large indoor flea market, satellite TV and various specialty dealers. Paved parking, food on site, other activities. Walk in license exams 9 AM. Bring copy of license and completed 610 Form. $4.00 fee. Talk in on 144.89/145.49 and 146.52. For information: Jim Perdue, KC8NG, Rt. 5, Box 457, Bluefield, WV 24701.

NEW YORK: The Putnam Emergency Amateur League (PEARL) will have its annual Electronics Extravaganza, August 17, 9 AM to 4 PM, J.F. Kennedy Elementary School, Brewster. Admission $2.00. Tables $5.00. Walk in VEC exams. For table reservations and information: R. Dillion, N2EFA, RFD 7, Noel Court, Brewster, NY 10509. Talk in on 144.535/145.135.

ALABAMA: The Huntsville Hamfest, Saturday and Sunday, August 17 and 18, Von Braun Civic Center in Huntsville. Free admission. Exhibits, forums, air-conditioned indoor flea market and non ham activities. Walk in FCC exams 9 AM Saturday, August 17. Family tours of the Alabama Space & Rocket Center available. Some camp sites with hookups available, first come, first served. Reserved flea market tables $5/day. For more information: Huntsville Hamfest, 2804 S. Memorial Parkway, Huntsville, AL 35801.

PENNSYLVANIA: The Mid Atantic Amateur Radio Club's annual Hamfest, Sunday, August 11, 9 AM to 4 PM, rain or shine, Bucks County Drive-In Theater, Rt. 611, Warrington. Admission $3.00 + $2.00 for tailgating. Setup starts 8 AM. Bring your own table. Plenty of parking, refreshments. Talk in on WB3JOE/R, 147.66/.06 or 146.52. For information: MARC, PO Box 352, Villanova, PA 19085 or call Bob, WA3PZO (215) 449-9727.

ARKANSAS: The 16th annual Queen Wilhelmina Hamfest, Queen Wilhelmina State Park, September 7 and 8. This beautiful state park facility on top of Rich Mountain near Mena, offers family fun and relaxation. Free admission, dealer display, Saturday night banquet, $7.00, camping, tailgating, flea market, miniature golf, wild life zoo, new playground, miniature train ride, ladies' tour. Talk in on 146.19/.79. For information: John Harris, KC5XK, 5018 S. 9th, Ft. Smith AR 72903.

ILLINOIS: Vermilion County Hamfest, August 25, W9MJL Clubhouse, Harrison Park West, Danville. Donation $1.50 at gate; $1.00 advance. Saturday evening steak cookout, $5.00/reservations. Talk in on 146.22-82. For information and reservations: Joe Mayer, KB9GS, 613 E. Kelly, Box 356, Westville, IL (217) 267-2946.

OPERATING EVENTS

"Things to do..."

Riding Radio Operators — Amateur Radio Motorcycle Club Net meets every Thursday night at 0300 UTC at 3888 kHz standard time and 7237.5 kHz daylight saving time. An eastern USA group meets one hour earlier at 3888 kHz year-round. Send business SASE to AGØN, Gary McDuffie, Rt. 1, Box 464, Bayard, NE 69334 and ask for net information.

September 4: Howdy Days. Eligibility — all licensed women operators throughout the world. Operations — all bands and modes. No cross band. Station counted only once. Exchange — YLRL member or non YLRL member. Score 2 points for each YLRL member worked and 1 for non YLRL member. All logs must show YLRL membership or not, score and must be received by October 4, 1985. Send to Marty Silver, NY4H, 3118 Eton Road, Raleigh, NC 27608.

August 18: The DuPage Amateur Radio Club will operate special event station W9DUP from the War Museum submarine, U.S.S. Silversides, Navy Pier in Chicago. 1300Z August 18 to 0200Z August 19. For a special submarine QSL card, SASE to W9DUP, PO Box 71, Clarendon Hills, IL 60514.

August 17: 26th annual New Jersey QSO Party: 2000 UTC Saturday, August 17 to 0700 UTC Sunday, August 18 and from 1300 UTC Sunday, August 18 to 0200 UTC Monday, August 19. Phone and CW are considered same contest but separate bands. Station may be contacted once on each band. Suggest phone activity on even hours; 15 meters on odd hours. Exchange QSO number, RST, and QTH. NJ stations send county for QTH. Send logs and comments to: Englewood Amateur Radio Association, PO Box 528, Englewood, NJ 07631-0528. Include #10 SASE for results.

THE GUERRI REPORT

Ernie Guerri W6MGI

surface-mounted components improve circuit designs

The traditional approach to printed circuit board design has been to lay out the board so that component leads go through holes in the board and are soldered to pads on one or both sides of the board. A technique first developed in the mid-1970's, using Surface Mounted Components (SMCs), has finally caught on, and achieves dramatic improvement over standard PCB designs. In the new approach, the PCB is designed for the same functional application, but the components are all mounted directly on the surface of the circuit paths themselves — *no holes*! All of the components are designed with short, flat leads that are flush with the PC path. This technique is particularly useful for RF circuits because lead lengths are dramatically shortened, thereby reducing parasitic inductance and capacitance, and improving EMI/RFI problems. Proper design of the components can maintain the impedance integrity of stripline designs right into the active region of the component. Circuits using this approach at 1200 to 1500 MHz give performance nearly as good as their low frequency counterparts. Let's hope that this attracts some real attention to the development of more equipment for the 1200 MHz Amateur band! Additionally, manufacturing costs are significantly reduced and reliability is improved. Circuit densities can be increased by 30 to 50 percent, resulting in considerable reduction in size, for use in complex equipment. The technique is particularly well suited to full automated production, and high volume producers such as the audio and TV industry are now regularly delivering products incorporating this approach. We should see the first uses of this improved technique in Amateur equipment in the immediate future.

computer-aided everything

The flood of information that seems to fill everyone's mailbox these days includes an increasing amount of data promoting the ways in which a computer can make each of our personal endeavors a snap. Productivity is the magic word, but much of what's offered seems to actually add complexity to such nominally simple tasks as home budget management.

This is not the case with computer-aided engineering, design, and manufacturing — CAE, CAD, CAM as they're called. Each of these tasks normally involves thousands of steps, each of which must be executed exactly, in complete compliance with design rules, and in concert with other phases of the process. All must be organized so that the final product is technically and physically correct, and on time. Modern product development cycles are frequently so short that there would be no way to do all the necessary steps by hand.

Take the example of designing a new computer chip. Such a chip may have a complex architecture, and 30 to 40 thousand active elements. By using computer-aided techniques, the design rules for circuit interconnects, layout, propagation delays, etc., can all be simultaneously considered every time a single change is made. A CAE tool called a "silicon compiler" actually contains the design rules for making the IC masks stored in computer memories. As the system architect and design engineer work on the chip's functional characteristics, the silicon compiler automatically includes the necessary semiconductors, routings, chip real-estate and thermal characteristics in the final design. Using these techniques, three employees of a major computer manufacturer were able to design a 32-bit minicomputer chip set (including nearly 40,000 transistors) in less than a year.

It's been estimated that there are fewer than 5000 integrated circuit designers in the entire world. With the design tools offered by CAE and CAD systems, at least half of all electronic engineers could participate directly in the design of semi-custom ICs.

The prospects for even more dramatic advances in electronics are thus enhanced by the broad participation of another half-million or so engineers whose creativity is now frustrated.

microwaves cook rocks

The success of commercial mining operations depends on assessing the extent to which rocks bearing sufficient quantities of desired material can be processed. Therefore, the quantity of desired ore per ton of rock is an important measure of the ultimate financial value of the process. Because one of the major problems in ore processing is keeping impurities out of the desired product, complex — and therefore expensive — steps must be taken to resolve these problems.

A new technique developed by a Colorado company may represent a major breakthrough in this field. Recognizing that each element has an atomic structure that can be excited by external energy sources, the company has devised a technique for illuminating rocks containing various elements with microwave energy matched to the resonant frequency of the element. The result is an ability to selectively melt desired material and leave surrounding material and impurities "cool" and undisturbed. Although the energy expenditure/recovery ratio is not obvious, the technique merits watching as yet one more example of RF in the "workhorse" environment.

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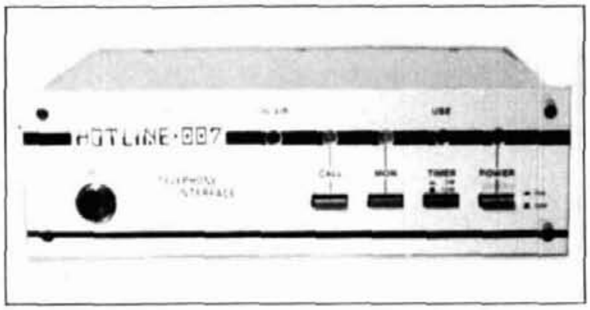

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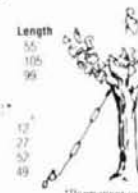

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