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ham radio magazine

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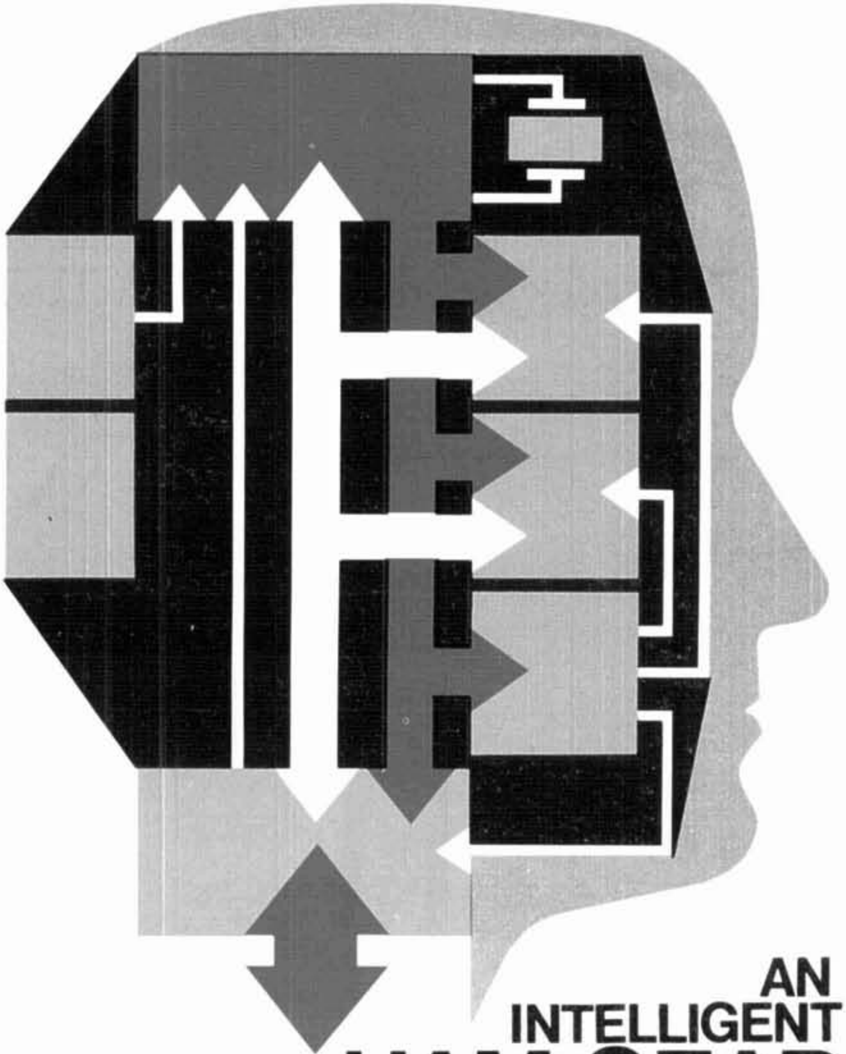

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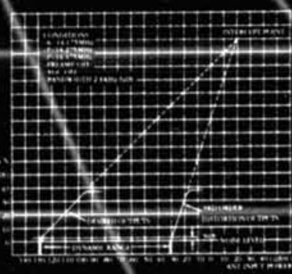

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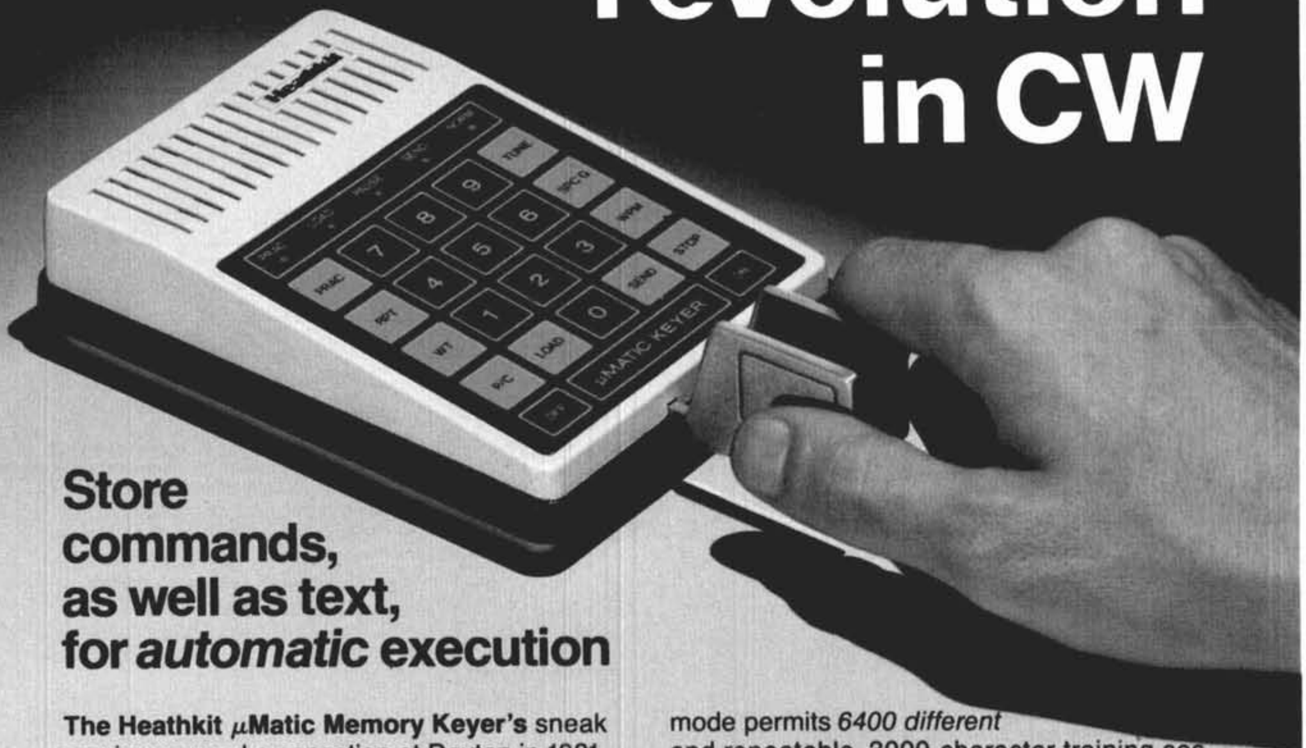

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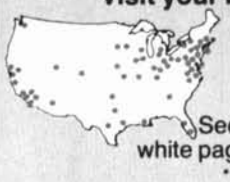

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OCTOBER 1982

volume 15, number 10

ham radio magazine
is published monthly by
Communications Technology, Inc
Greenville, New Hampshire 03048 0498
Telephone: 603-878 1441

subscription rates

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contents

Observation & Opinion

Whatever your operating preference *might* be, it doesn't take much time spent tuning the present hf U.S. phone subbands to realize most are badly overcrowded. Tuning below the lower edge of most of these bands reveals relatively sparse activity by non-U.S. phone operators. This imbalance cries out for correction. The FCC addressed the problem in Docket 82-83, with Comments due in mid-August.

The Comments came in, and now it's up to the FCC to sort them out. The ARRL's proposed reallocation of the phone bands, representing as it does the views of more than a third of the U.S. Amateur population, will certainly have a strong influence on the Commission's final decision. It should be noted, however, that about a quarter of those who responded to the League's original petition on expansion (RM-3860) were not in favor of it, so support is certainly not unanimous. Briefly, the League's response to Docket 82-83 proposed:

band	extra	advanced/extra	extra-general
80	3.75- 3.775	3.775- 3.850	3.850- 4.000
40	························	no change	························
20	14.15-14.175	14.175-14.225	14.225-14.35
15	21.2 -21.225	21.225-21.3	21.3 -21.45
10	28.3 -29.7 for all three classes		

Whatever your feelings on expansion, the ARRL proposal is well thought-out and sound. The disagreement noted thus far has been in detail rather than principle, with one important exception: the League's Canadian Division (CRRL) has very strongly opposed U.S. phone band expansion, for obvious reasons. Their natural opposition has put the League in a difficult position with its Canadian members. Strong disagreement, though of a less formal nature, was also registered by a number of IARU societies from around the world. In the final decision, however, the FCC must act to benefit the Amateurs of this country, with the interests of those overseas a minor consideration.

On the DX phone bands the trend has been toward more and more overseas Amateurs operating in the U.S. phone allocations. On the higher frequencies one rarely hears a DX station other than a DX-pedition operating in the so-called "foreign phone band" announce he's listening in the U.S. band for a response, though it's still common on 40 and 75. Of course there's still a lot of DX-DX and DX-VE phone action on frequencies we can't use, but almost without exception, that could be taking place in a narrower spectrum without reaching anything resembling the level of congestion that afflicts the U.S. 20-meter phone band on a Sunday afternoon.

Though the ARRL's suggestions will carry much weight at the Commission, theirs is not the only voice that will be heard. Comments on the expansion docket were submitted by many other groups and clubs as well as individual Amateurs, and it seems almost certain that most will differ in at least some details from those of the League. Let's take a look at some possible problem areas on a band-by-band basis.

80 Meters: This is the band most likely to cause our Canadian neighbors problems, since they are already sandwiched between U.S. phone and the heavy Novice plus RTTY and CW low-end activity. It is not unlikely that the proposed expansion of 75 phone will trigger a corresponding downward move in Canadian phone allocations, with some disruption of present non-phone 80-meter users.

40 Meters: Only the most dedicated 40-meter phone buffs seem to favor any expansion on this crowded band. Any downward shift in the U.S. phone allocation here would severely impact what is probably the most popular Novice band. Leaving 40 as-is makes great sense.

20 Meters: This is the band that most desperately needs more phone frequencies, and expansion down to 14.150 makes sense. What didn't make sense was the FCC's proposal to make the newly opened 50 kHz slot available to Generals, leaving a 75 kHz segment in the middle of the band that would still be off-limits to them. Perhaps the FCC put that in just to see if we were paying attention! Moving the current General Class 14.275 lower limit down, as in the ARRL submission, seems far more practical.

15 Meters: No problem is seen in moving U.S. phone down to 21.200. The 21.200-21.250 segment has never seemed to attract much foreign activity. The few foreign users that do want to avoid the expanded U.S. phone segment can still move a bit below 21.200 without problem, as the U.S. Novice activity on 15 meters seems to be pretty much at the bottom of the 21.100-21.200 Novice subband.

10 Meters: It's hard to see why the League felt the need to add another 200 kHz to a band that already has 1200 kHz of phone frequencies. The growing number of beacons in the underpublicized 28.200-28.300 10-meter beacon subband are going to become more important than ever in the coming years of low sunspots. Putting the lower edge of U.S. phone operations at the top of the beacon slot would certainly drive those foreign stations who do not wish to work the U.S. into the midst of the beacons. If expansion of 10 meters is needed at all, why not simply move the lower edge to 28.400 and leave a 100 kHz buffer for the beacon band? Furthermore, if incentive licensing is still considered a valid concept, why not make the new 28.400-28.500 segment an incentive subband?

In all the discussion of new phone frequencies, what about the long-suffering narrow-band mode enthusiast? What's in it for the CW or RTTY buff? Very little, at first glance. Fortunately, it seems most unlikely that the Commission would even consider encroaching on the lower band portions where these modes hold sway, seeing that the vast bulk of Comments filed on Docket 82-83 were along the order of the League's. In addition, we staunch users of those modes can look forward to an expansion of our own sometime soon, when the Senate and/or FCC finally decide it's time to catch up with much of the rest of the world and implement the new WARC 79 bands.

Despite the objections of non-U.S. Amateurs and the reservations of a minority from this country, a realistic appraisal of phone subband occupancy supports expansion. We are going to have some new phone frequencies in the near future. What they will be, who'll get to use them, and when they'll become available is now up to the FCC. We wish them good luck and Godspeed in their deliberations!

Joe Schroeder, W9JUV
associate editor

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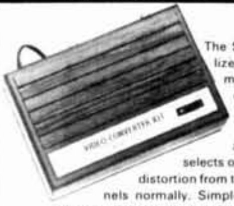

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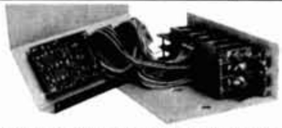

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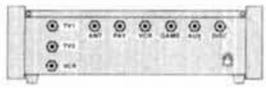

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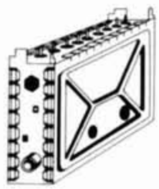

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comments

power or voltage ratio

Dear HR:

N1AL's letter in the March, 1982, issue brought a needed correction concerning the third harmonic of a triangular waveform, but the latter part of the letter is in error. The usual definition of total harmonic distortion uses voltage ratios, whereas N1AL has given the figures for power ratios. So the distortion for a square wave is about 48 percent, for a triangle about 12 percent, and for the truncated triangle about 4.6 percent.

Bill Brandt, WB5DPZ/PR7ZAY
Brazil

WB5DPZ is correct; when expressed in dB, THD is normally given as a power ratio, but "%THD" implies a voltage ratio.

Alan Bloom, N1AL
Santa Rosa, California

who pays the jammer

Dear HR:

Psychology is the science of human behavior. Behavorism is a very influential psychological school of thought which holds that organisms (rats, pigeons, human beings, jammers) repeatedly do whatever act is continually reinforced.

Put a hungry rat in a cage with a lever — eventually the rat will touch the lever. When he does, give the rat a food pellet. If you keep giving him food every time he touches the lever, very soon the rat will pump away on the lever until he is stuffed. Behavior (lever touching) get reinforced (food pellet) and becomes conditioned (habitual).

Parents do this with children: "Say please." "Please," and the child gets what he wants plus smiles and approval. He becomes conditioned to a lifetime of saying "please."

Why does someone jam for the first time? Why does the rat touch the lever the first time? Why does anyone first say "please?" Why doesn't matter, it happens and the behavior *is reinforced* so it happens again. The food pellet is easier to understand than the jammer, but the reinforcement principle applies.

The jammer gets attention, arguments, recognition, and he dominates whatever net or repeater he is on. *This is what he wants.* Why? Unimportant question: if he didn't want what he gets, he wouldn't keep jamming.

People who provide reinforcement generally take credit for the conditioning, "I taught a rat to press a lever," "I taught my child to say 'please'." Hams often argue with and counter-insult the jammer, thereby reinforcing the behavior. They are just as responsible for the results as the experimental phychologist or parent.

Any comment of any sort will let the jammer know he is successful and you are in for a long siege. Why does the jammer keep turning off his transmitter? He is listening for you to tell him he is successful. If you comment, no matter how rude or clever you may be, he will know he has been successful.

The only way to extinguish habitual behavior is to totally cut off reinforcement. Stop the food pellets and the rat will eventually stop pulling the lever. One careless food pellet will start the behavior again, more persistently. Say nothing on the air, roger for traffic you didn't copy, and carry on the conversation even if it is one-sided.

Do your detective work on the phone or a frequency you know the jammer doesn't monitor (is it the guy next to you at the club meeting? Complaining at a meeting is reinforcement).

If you have a persistent jammer it's your own fault: you get what you pay for.

Scott McCann, W3MEO
Annapolis, Maryland

DX and QRP

Dear HR:

Three hearty cheers for Alf Wilson's "Observation and Opinion" column, *ham radio*, April, 1982, regarding QRP DX. He hit it right on the TX button!

I was off the air for several years, so I've had a chance to witness the way the DX aspects of Amateur Radio have been evolving. I don't much care for some of what I see — and hear — but I am excited about what appears to be a growing interest in low-power DX.

Alf and I come from the same place: the land of big amplifiers, tall towers, and big antennas. I was a believer in the big signal. But, I returned to the air recently, after moving to W7. I got back on with 20 watts and a 5/8-wave vertical plus a terrible receiver. I never expected to work much DX, but, after six months, the total stands at 67. It can be done. As far as I'm concerned, the essence of ham radio is the experience and knowledge to be gained by building your own gear and operating it. QRP DX with homebrew combines it all, particularly when accompanied by observance of the etiquette and unwritten rules which seem to prevail in QRP DX. And, best of all, it doesn't cost an arm and a leg to get started.

The change I most regret in DX operating is the prevalence of operating habits which seem to have accom-

continued on page 79

presstop de W9JUV

RFI SANCTIONS ARE PURELY A FEDERAL MATTER under terms of the long awaited Amateur Radio bills (S.929 and H.R. 5008), passed by both houses of Congress in late August as part of the FCC authorization bill, H.R. 3239. It's on President Reagan's Western White House desk as this goes to press, awaiting only his signature to become law. To preclude Burbank (Illinois)-type confrontations, the House (Conference Committee) Report 97-765 stated:

"The Conference Substitute is further intended to clarify the reservation of exclusive jurisdiction to the FCC over matters involving RFI. Such matters shall not be regulated by local or state law..."

Amateur Exam Preparation/Administration And Use Of Amateurs as volunteer monitors were both included in the bill as it was passed. In the final version, Amateurs working the industry won't be able to administer exams, but will be able to work on their preparation. No such restrictions exist on monitoring, however. Furthermore, Amateur monitors will be empowered not only to detect and report apparent violations but may also be permitted to issue advisory notices (but take no other enforcement action).

10-Year License Terms For Amateurs and other non-broadcast services are also part of the new law, but the requirement for licensing both the CB and RC services was deleted. The bill also permits seizure and forfeiture of radio equipment used in violations.

The Many Worthwhile Benefits Of This Far-Reaching New Legislation also carry heavy responsibilities. Even before the bill was signed into law the Field Office and Enforcement Bureaus were already actively pursuing means to put its provisions into effect. Now that we have it, it's up to us to assume much of the task of making it work.

30-METER OPERATION BY U.S. AMATEURS IS CONSIDERED IMMINENT and could indeed have already come about by the time this sees print. An early August "Dear Mark" letter to FCC Chairman Fowler by Senators Goldwater and Schmitt advised him that Senate ratification of the WARC treaty could drag on into next year, and strongly urged the Chairman to provide U.S. Amateurs "immediate access" to the new 10.1 to 10.15 MHz band under Section 115 of the ITU regulations.

Chairman Fowler Promised The Senators the Commission would take up the question "in early fall" in his late August response, noting also "...I fully support early access by U.S. Amateurs to the 30-meter band." Such an action by the FCC could be accomplished quite quickly and simply with a Report and Order. Expectations are that any such "temporary" access to the new band would restrict users to narrowband modes (CW and RTTY) and less than maximum power levels.

6-METER FØ OPERATION HAS BEEN APPROVED by the FCC in a late August consent action. Acting on a Petition for Rule Making, the Commissioners agreed to add FØ to the modes permitted in the 51-54 MHz portion of the band.

The Report And Order On Digital Modes Was Set for Commission consideration at the first post-summer recess session in September, though it's considered likely that it will see a further delay. When the expected Notice of Proposed Rule Making on changes in Amateur rf power measurement will be out is still uncertain.

RICH ROSEN, K2RR, HAS JOINED HAM RADIO AS Associate Publisher and Senior Technical Editor. Rich's outstanding technical, editorial and Amateur Radio credentials will prove a very welcome addition in Greenville. Rich, formerly K2TXC, is an MS in EE whose professional background includes both hardware and propagation experience from VLF through 40 GHz. Most recently he was editor and later Associate Publisher of RF Design magazine; in addition he's an avid CW and phone contest operator who's been an active participant in the K2GL multi-multi contest team. Welcome aboard!

PROPER AMATEUR EXAM PREPARATION PAID OFF HANDSOMELY for Technician and General Class license applicants at a recent Baltimore FCC Field Office Exam session. Despite minor changes made in some of the exam questions and answers, 70% (the typical proportion) of those who'd prepared through club, school, or home study managed to make the grade.

Not So Lucky, However, Was A Group Who'd Just Finished one of the better known and highly promoted Q and A cram courses. Of this group, only 11% managed to write passing exams! The two groups could be easily distinguished, since those who'd used the cram course brought in Form 610s that had been supplied by its promoter.

MULTI-BAND OPERATION FROM THE WORLD'S HIGHEST BUILDING is scheduled for the October 16-17 weekend. The Fox River Radio League plans a two-station operation on 80-10 meter CW and SSB, as W9CEQ. Antennas will be at the 1454-foot level (110th floor) while the stations themselves will operate from the 103rd floor Observation Deck. Two-meter CW and SSB will also be used if conditions warrant; operating hours will be 1500Z Saturday through 2000Z Sunday. WD9GIG can provide further details.

THE U.S. AMATEUR POPULATION IS GROWING, and has been in recent years. In the early 50s, before the Novice and Technician licenses were introduced, it was around 50,000. By 1963 it had soared to over 250,000, but then (due perhaps to the imposition of license fees and/or incentive licensing) it became almost static for almost a decade. The mid-70s saw it start to climb again, until now (FCC July 30 figures) there are 404,534 individual Amateurs licensed in this country.

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More Details? CHECK—OFF Page 92

an intelligent ham gear controller: part 1

A computerized system that handles the operation of many equipment functions

Many good microprocessor components in the marketplace today are within the average builder's budget. Unfortunately, hams have been reluctant to build microprocessor circuits into their equipment, perhaps because of resistance to the technology or to changing from conventional to intelligent control.

This two-part article shows how simple, modular microprocessor blocks may be built and programmed for control of many ham equipment functions. There are only four basic circuit board blocks: the microprocessor; a simulator for programming; bus status indication; and application cards. These can become the heart of a memory keyer or buffered Morse keyboard, a synthesizer controller, repeater controller, transceiver controller or control for a swept-frequency signal generator. Some of these will be covered in future articles.

The boards are intended to be standard so that no hardware changes are required when changing applications. Since many application boards may be used, a common board interconnection, or HAM BUS, has been developed.

why intelligent control?

Standard, or dedicated, circuit design has its function limited by design. Function changes require hardware modification.

An intelligent controller performs a series of events under programmed control. The program can be written to make choices; it is "intelligent." A microprocessor and its peripheral chips do this digitally. More than one task can be performed and changes require only reprogramming. You don't have to rebuild from scratch.

By C.A. Eubanks, N3CA, P.O. Box 127, Valencia, Pennsylvania 16059

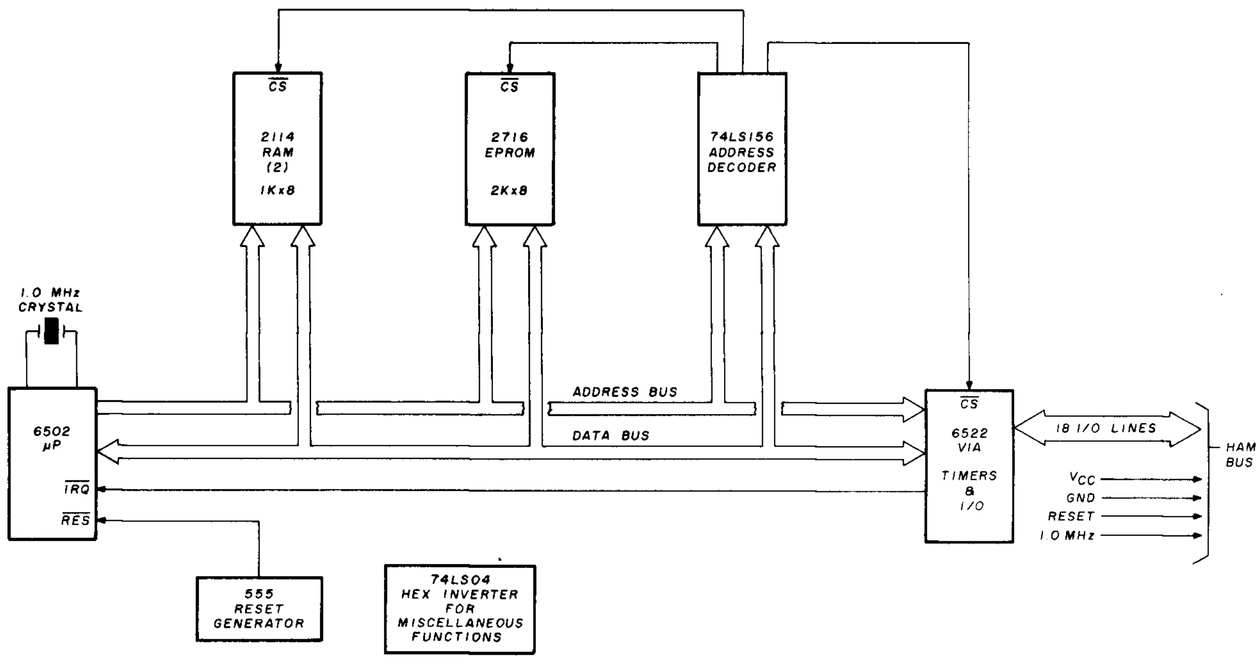

fig. 1. Microprocessor card block diagram. HAM BUS is the interconnect to application cards interfacing with external devices.

With the proper software (program), an intelligent controller could display the time of day, display a transmitter frequency, show the i-f offset, *and* control test equipment. Circuit changes aren't needed.

The greatest benefit of intelligent control is that it's easily possible to go back and change features that didn't work out quite right. It is also possible to add bells and whistles as they come to mind. If this had been tried with dedicated circuitry, the project would never have gotten off the breadboard.

beginning the system concept

The main choice is that of microprocessors and support devices. The wide selection of support devices includes many with varying degrees of internal intelligence. Another choice is the construction and interconnection method. My own choice was to write down a set of objectives (see **table 1**).

table 1. Objectives for the intelligent controller.

1. Use commonly available, low-cost components.
2. Microprocessor type should be compatible with low-cost, available-development systems to support software.
3. Reduce circuit complexity and minimize parts counts.
4. Place controller operation burden on software to minimize hardware cost and parts count.
5. Reduce the number of board interconnects for least circuit loading and RFI, minimum timing problems.
6. Segregate circuit board functions so a minimum are needed for any particular application.

Some objectives are worth detailing. Ease of program development and software/hardware troubleshooting are keys to success. Since I couldn't afford a professional microprocessor development system, an inexpensive way to assemble and test the programs was needed. Program test is crucial; it is virtually mandatory to step through programs one line at a time to ensure proper operation.

Keeping down the parts count as well as the level of complexity has several benefits. The cost in dollars for my time, for experimenting and building, is nil — but I'm willing to pay a few extra dollars if one LSI chip can replace several common devices. This reduces hardware complexity so that there is a better chance of getting the controller system debugged and running.

I wanted to reduce the number of microprocessor address and data busses. Three factors affect the design: First, the system is a controller, *not* a computer. Second, there can be timing and circuit-loading problems with extended bussing. Third, square-edged signals spread harmonics way up the spectrum. I've had microprocessor hash problems before, and I decided that RFI control is easier with fewer signal lines.

Function segregation allows debugging the system

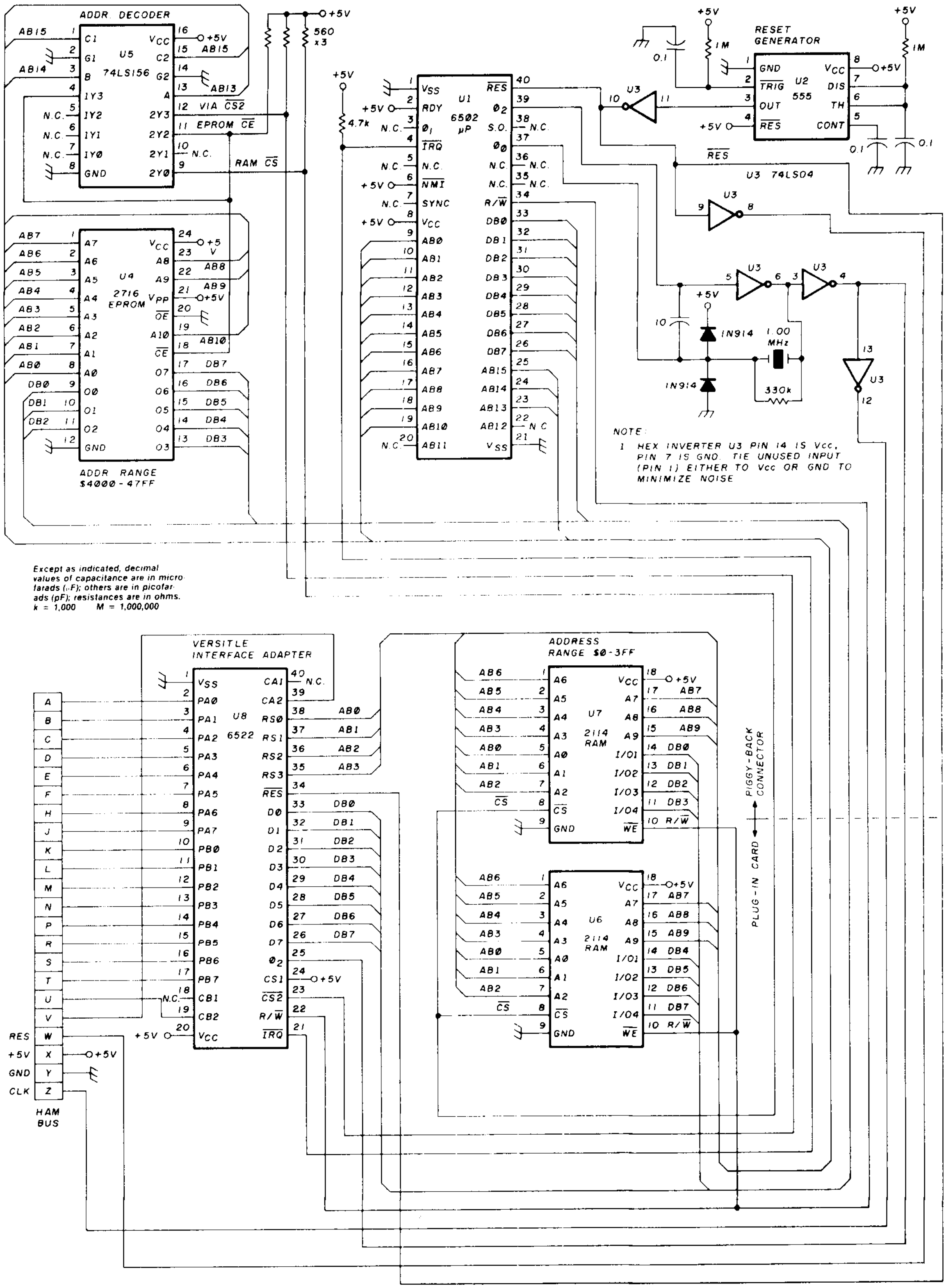

fig. 2. Schematic of microprocessor card. Two boards are used in construction, see text and *fig. 11* for details.

one board at a time. The worst trouble-shooting situation occurs when it's not clear whether the trouble lies in software or hardware; segregation reduces these software/hardware problems. Segregation also permits adding applications as required.

microprocessor selection

I did a lot of searching for the right microprocessor. My final choice was the 6502. This chip is the basis for the KIM, SYM, and AIM single-board computers, as well as for the central processor of the Apple, Commodore, and Atari personal computers. The 6502 instruction set is relatively easy to understand and is easy to interface to both memory and peripherals.

The low price of the KIM, SYM, and AIM systems is also important. These three are similar enough to be used interchangeably with the equipment described here.

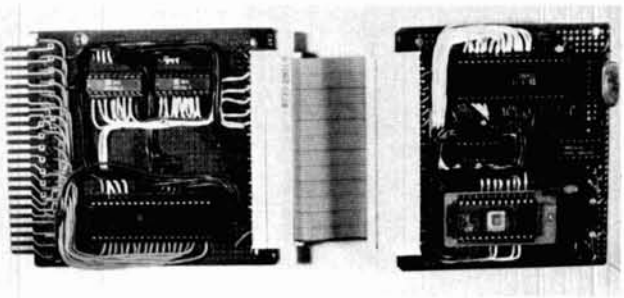

fig. 3. Microprocessor card with boards unfolded.

the microprocessor

Fig. 1 is the microprocessor card block diagram. **Fig. 2** is the schematic diagram. This module has double-board construction (see **fig. 3**). Construction is detailed later.

I decided to use a 1.0-MHz crystal oscillator for the microprocessor clock with the idea that a better, external oscillator could be used later. This later change would apply to a frequency synthesizer having a stable frequency and phase timebase.

Random Access Memory (RAM) for scratch-pad storage is provided by two 2114 static RAM chips. Each is 1K by four bits, a total of 1K by eight bytes of RAM (1024 eight-bit bytes). Programs are stored in a 2716 Erasable Programmable Read Only Memory (EPROM), giving 2K (2048) bytes of program. The 2716 is available in the five to ten dollar range.[1] A 2732 (4K by eight) may be substituted easily for more program space. Each can be erased with ultraviolet light.[2]

Address decoding uses a 74LS156 three-to-eight-line decoder to enable RAM, EPROM, or the 6522 Versatile Interface Adapter (VIA). Decoding breaks memory addressing into eight 8K blocks. This wastes addresses but I didn't expect control programs to run more than a few K.

Some AIM-65 circuit features were borrowed. The

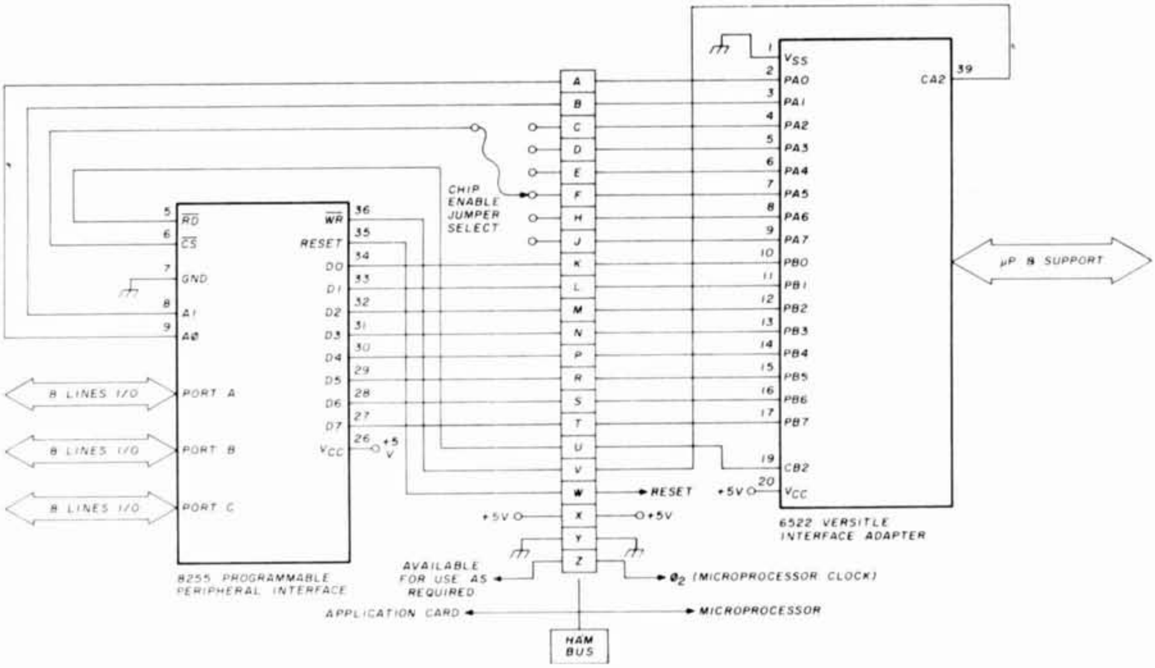

fig. 4. The basic application card. External devices input and output through ports A, B, and C.

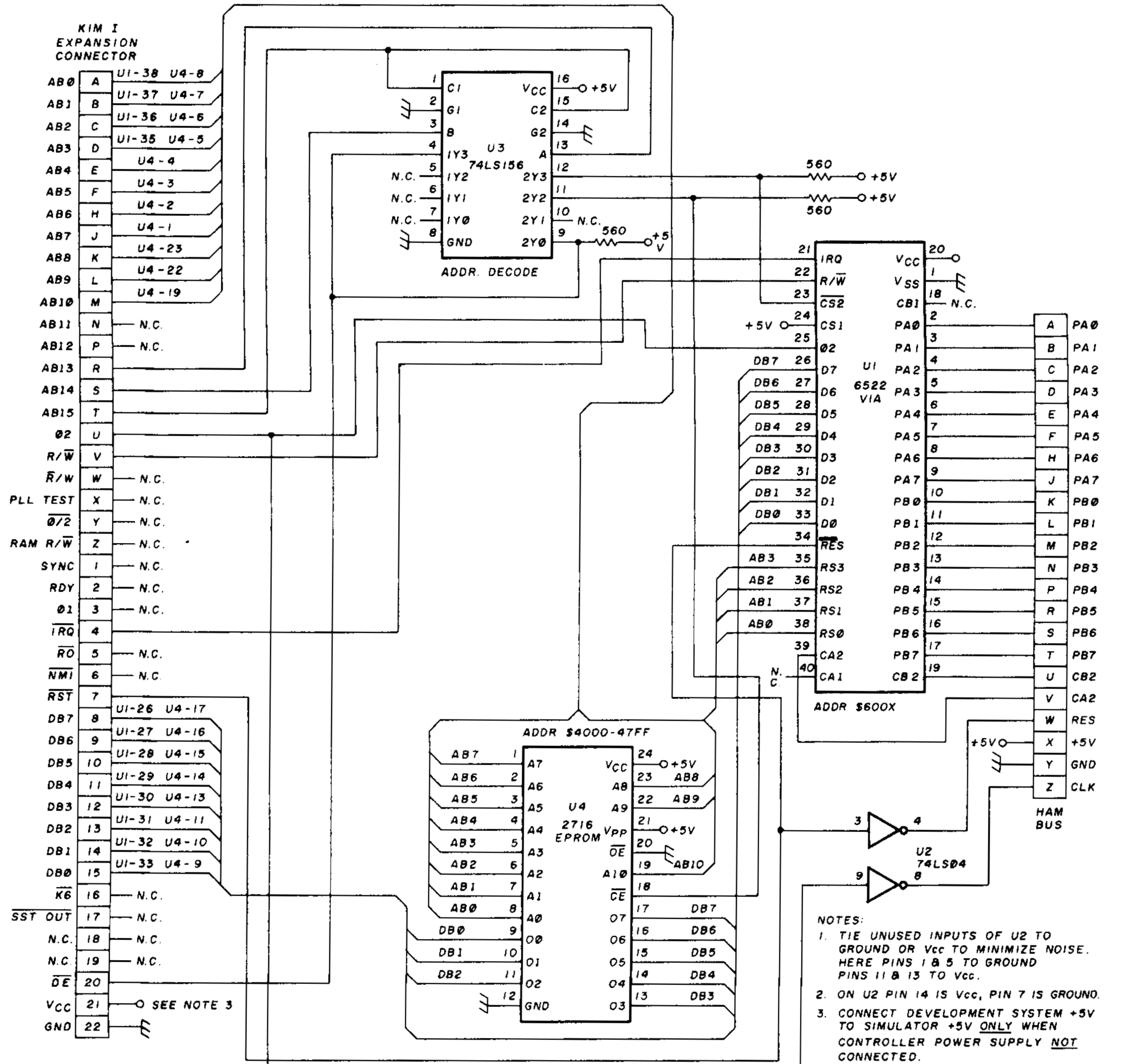

fig. 5. Simulator card schematic for program development on KIM, SYM, or AIM single-board computers.

555 timer is connected as a one-shot to reset the microprocessor on power-up. I chose the 6522 VIA to communicate with all other boards and to provide timing ("heartbeat") to service them. The VIA has twenty programmable I/O (Input/Output) lines (eighteen are used) and two sixteen-bit counters programmable to count down at the microprocessor clock rate. Either counter can provide interrupts (IRQ line) on the time-out, and one counter can interrupt on a repetitive basis. The latter is ideal as a heartbeat device.

cards and interconnection

I selected an available prototype card for board construction with twenty-two or forty-four edge connections at 0.156-inch (3.95-mm) spacing. Edge connection is compatible with expansion ports on the KIM, SYM, or AIM. I wanted to use only twenty-two pins on one side of the card, hoping to get single-side, etched circuit boards later.

Each pin of the connector is common to all boards, and I've called this the HAM BUS. This bus carries +5 Vdc, ground, the microprocessor clock, VIA control lines CA2 and CB2, and the sixteen bi-directional VIA port lines. This isn't enough for interfacing directly to external functions.

the basic application card

Each application card connects the HAM BUS to external equipment. I picked an Intel 8255 Programmable Peripheral Interface (PPI) for the basic interface shown in **fig. 4**. Originally designed for the 8080 microprocessor, it has twenty-four latched, programmable I/O lines controlled by the HAM BUS.

To avoid extra address decoding, I assigned six lines (PA2 to PA7) for jumpered chip selection ($\overline{CS}$, pin 6). This limits the number of application cards to six, but I considered this enough for the original purpose. Six application cards permit eighteen eight-bit external connections or twelve eight-bit and twelve four-bit groups; port C of the PPI can be set to either one eight-bit or two four-bit configurations by the program.

Control of the PPI is covered in Part 2 and it includes an eight-digit display card. Other application cards will be covered in future articles.

simulator card

The microprocessor board runs the program stored in its EPROM, but there is no way to tell what it is doing. The simulator card of **figs. 5** and **6** allows a KIM-1 to be substituted for the microprocessor. The KIM (or SYM or AIM) can step through each instruction in the EPROM to observe program operation.

The simulator card's cable and connector are compatible with either KIM or SYM expansion connectors or J3 on the AIM-65. Connection to pin 20 of J3 on the AIM-65 or pin 20 of the SYM expansion connector must be *open*. Labeling in **fig. 5** assumes a KIM-1 modified as follows: A jumper from the KIM application connector pin K is made to expansion connector pin 20. With no attached simulator cable, either pin K or pin 20 must be grounded so that the KIM can decode internally.

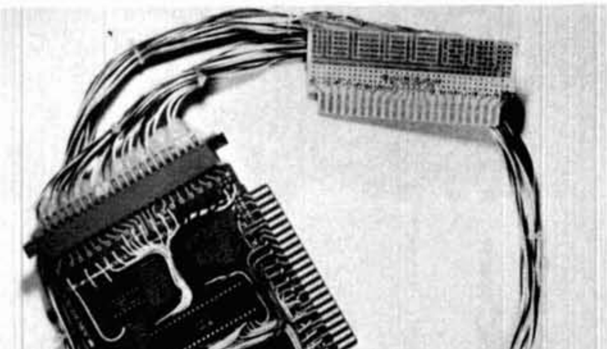

fig. 6. Simulator card with development system cable. Cable connector is edge removed from piggy-back microprocessor card.

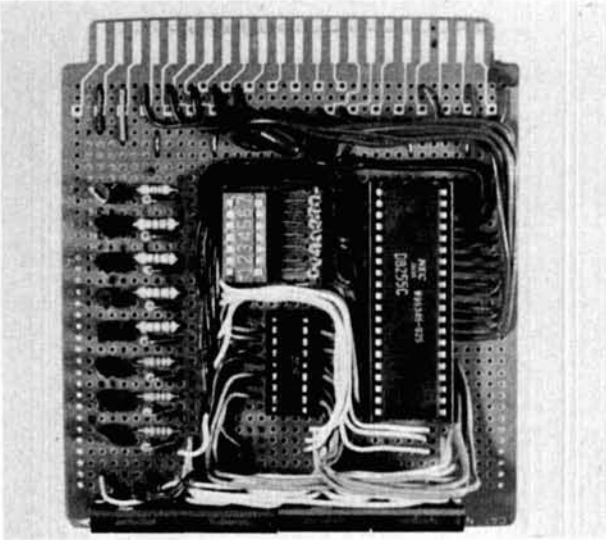

fig. 7. Mother board and KIM-1 development system. Bus status and digit display application cards are installed on mother board; simulator is plugged into KIM expansion connector.

Fig. 7 shows the controller card cage with simulator connected to a KIM-1. Bus status and eight-digit display cards are installed in the controller cage, with microprocessor card removed. The simulator card must be removed, and replaced with the microprocessor card for stand-alone controller operation.

bus status indicator

A helpful diagnostic tool is the status indicator card shown in **figs. 8** and **9**. It is simply a set of LED drivers to show all HAM BUS logic states.

The bus status indicator will work with either microprocessor or simulator cards. It is useful in checking both hardware and software, since the HAM BUS is between the external device and microprocessor.

Testing is aided by ordering the LEDs in the same location as the HAM BUS lines and including line marking labels. I used a piece of thin plastic for marking, cementing it to the LEDs and board with silicone rubber sealant.

mother board

This is the last item; see **fig. 10**. The mother board is double-sided PCB stock (mine was obtained at a hamfest) with edge connectors for all cards. Each alphabetic pin is common on all connectors, so that any card will fit any connector. The simulator card should be inserted close to the development system to minimize lead length.

I used wire-wrap sockets for edge connectors (Radio Shack P/N 276-1550) with wrap pins soldered to etched HAM BUS lines. Wire-wrap pins allow easy connection for future expansion.

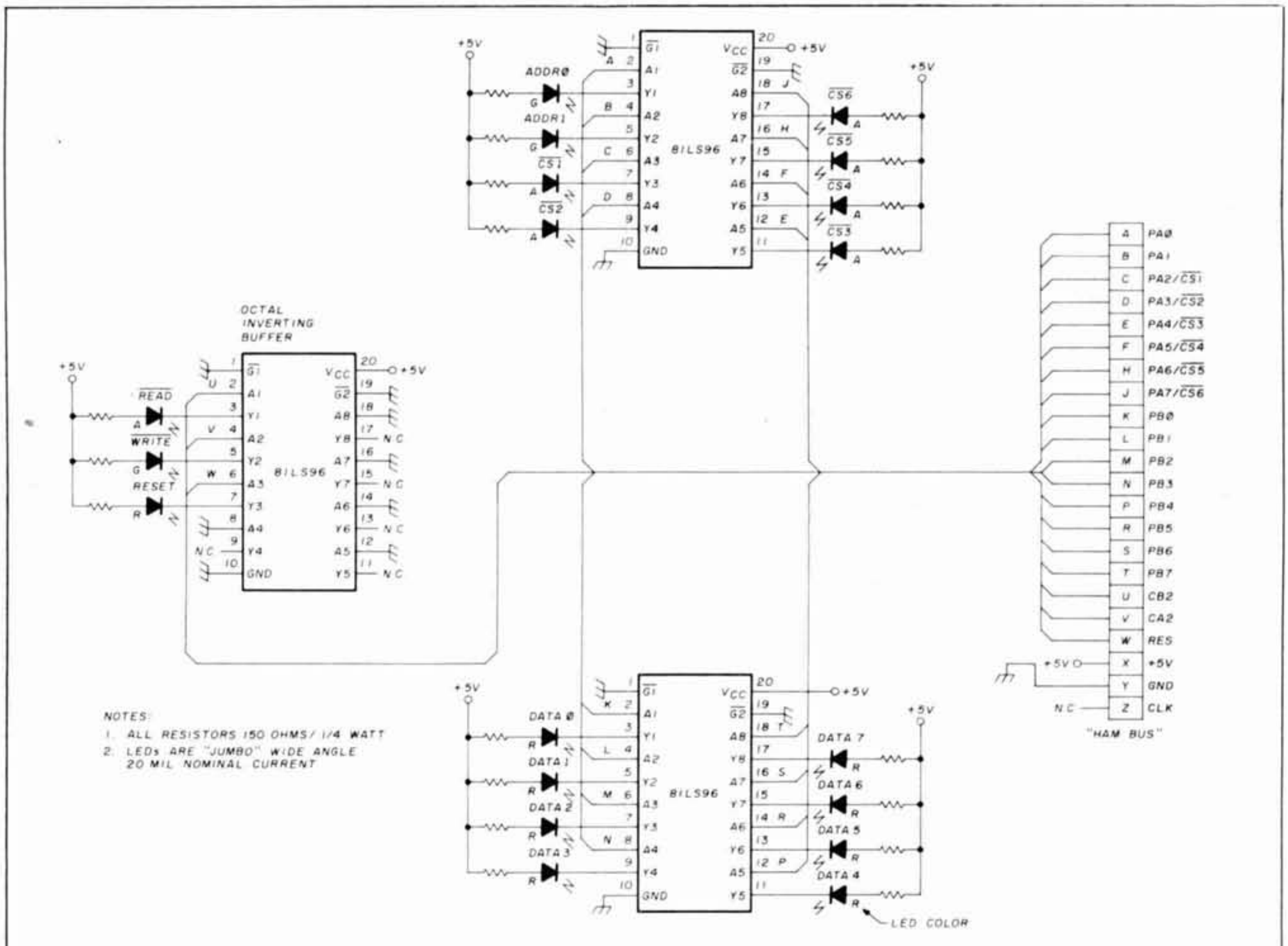

fig. 8. Bus status indicator card schematic.

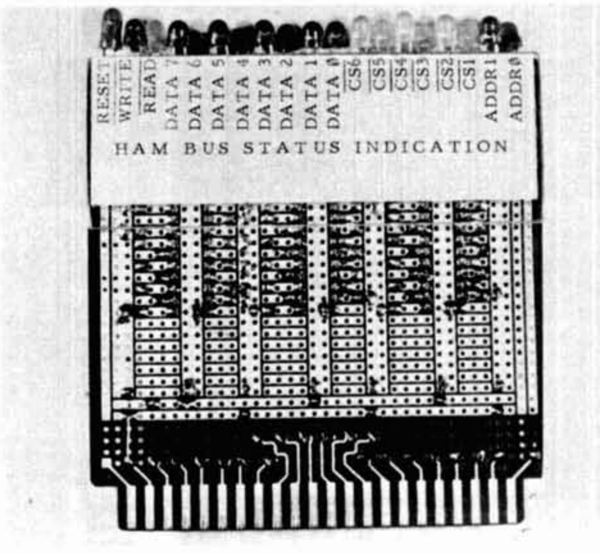

fig. 9. Bus status indicator card showing LED marking plate.

Unetched foil on both sides serves as a ground plane. Ground areas on both sides should have shorting wires every few inches. Ultimately, the mother board ground plane should be connected to a metal enclosure for minimum RFI.

construction notes

I used sockets for all ICs with short-length soldered wires. Sockets save a lot of headaches (and ICs) in the event of problems. A Zero Insertion Force (ZIF) socket was used for the EPROM to ease program changes. A ZIF is larger than normal, so some care must be taken in location and wire dress.

Exact component location on cards is not important, except that wiring should be short. **Fig. 11** indicates the piggy-back construction of the microprocessor. The removed edge connection of one board becomes the second connector for the simulator. For an "open" development system board (KIM, SYM), the simulator card is inserted in the development system with cable and leftover connector edge to the mother board. Use of an AIM-65 with cover requires reversing card and cable locations.

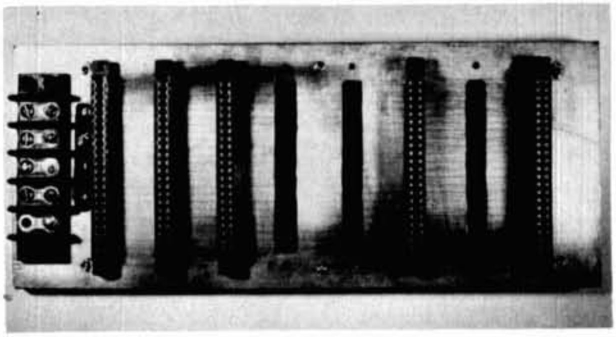

fig. 10. Top side of mother board. Terminals connect to controller power supply.

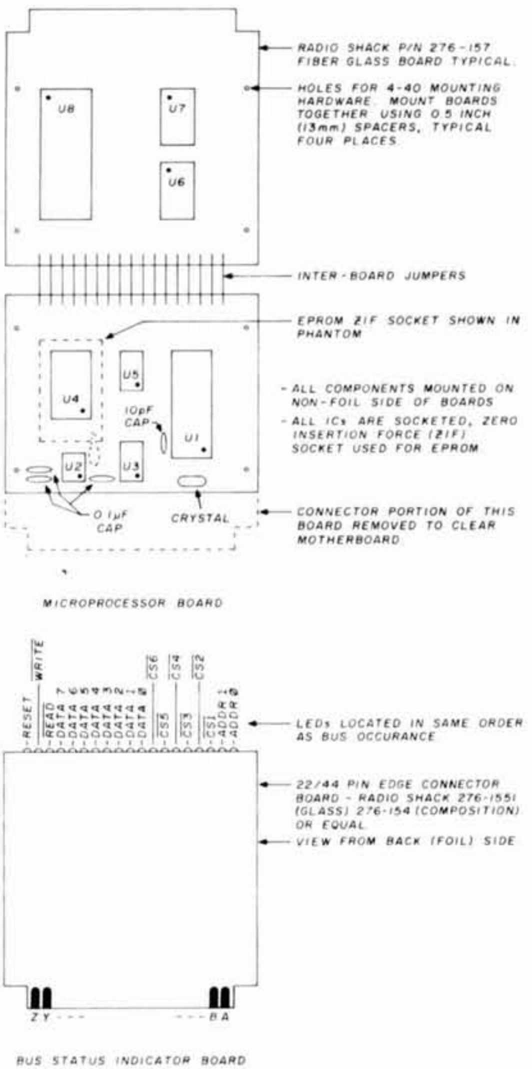

fig. 11. Circuit card construction and layout.

I suggest the following construction sequence: Simulator; mother board and bus status indicator; an application card; then the microprocessor. This gives you a break from hardware work for programming and testing.

The following extra tools and materials are suggested:

1. Fingernail clippers with a notch filed on one cutter edge, for stripping and close trimming.

2. An assortment of dental probes, reground to suit. See your dentist for thrown-away tools.

3. A *small* pencil-type iron with cleaning sponge.

4. *Solder Wick* for removing excess solder.

5. An IC extraction tool, 24-pin maximum size. I found that a little stretching would make it fit larger ICs.

6. Red fingernail polish for marking parts.

I found it handy to mark pin 1 of both ICs and sockets, including cards and their connectors. Dental probes can be used to ream holes in development boards. Solid wire with colored insulation is helpful; I used multi-conductor 22 AWG, available in 25-foot lengths, separating as needed.

Number and spacing of connectors on the mother board is optional. Edge connectors can be added as the system grows.

coming up next

The second half of this article will give details on the VIA-PPI control method and also present some general program flow diagrams. An eight-digit numeric display applications board is included. Send the author a self-addressed, stamped envelope for information on program documentation and burned EPROMs.

references

1. C.A. Eubanks, N3CA, "2716 EPROM Programmer, *ham radio*, April, 1982, pages 32-36.

2. L.B. Golter, "Build a Low-Cost EPROM Eraser," *Byte*, April, 1980, pages 234-238. A commercial version of this unit is available for $39.95 from Jade Computer products, 4901 West Rosecrans Avenue, Hawthorne, California 90250; Catalog number XME-3200.

bibliography

A large number of microprocessor tutorials and texts are available from computer stores. One softcover book covers both the 6502 and 6522, including some instruction examples: *6502 Assembly Language Programming*, Lance A. Leventhal, 1979, Osborne/McGraw-Hill.

Timing of the 6522 is covered well in the *Synertek 1981-1982 Data Catalog*, pages 3-95 to 3-144. It is available from Synertek, P.O. Box 552, MS/34, Santa Clara, California 95022. Details on the Intel 8255 can be found in their *1981 Peripheral Design Handbook*, pages 1-333 to 1-353. It is available from Intel Corporation, 3065 Bowers Avenue, Santa Clara, California 95051.

ham radio

ham radio TECHNIQUES

Bill Orr, W6SAI

The ground plane antenna was well-known as an antenna for VHF work during the early Forties, but not until about 1948 was it used for long-distance, high-frequency communications — and with much success, I might add. Even so, some hams scorn the simple ground plane antenna as being "equally weak in all directions."

The question of the relative merits of the dipole and the ground plane has floated around in limbo for some years. I have used both of them, but never at the same time. During the past year, however, I had an unparaleled opportunity to use a representative high-frequency ground plane and horizontal dipole concurrently under unusual conditions. The experience led me to make some interesting conclusions about both types of antennas. The question I asked myself and tried to answer was, "Which antenna is the best for all-round high-frequency DX operation, the dipole or the ground plane?"

testing the two antennas

The testing ground was the newly proposed 10-MHz Amateur band. In early 1980, I erected a dipole for this band, followed soon afterward by the ground plane. The physical installa-

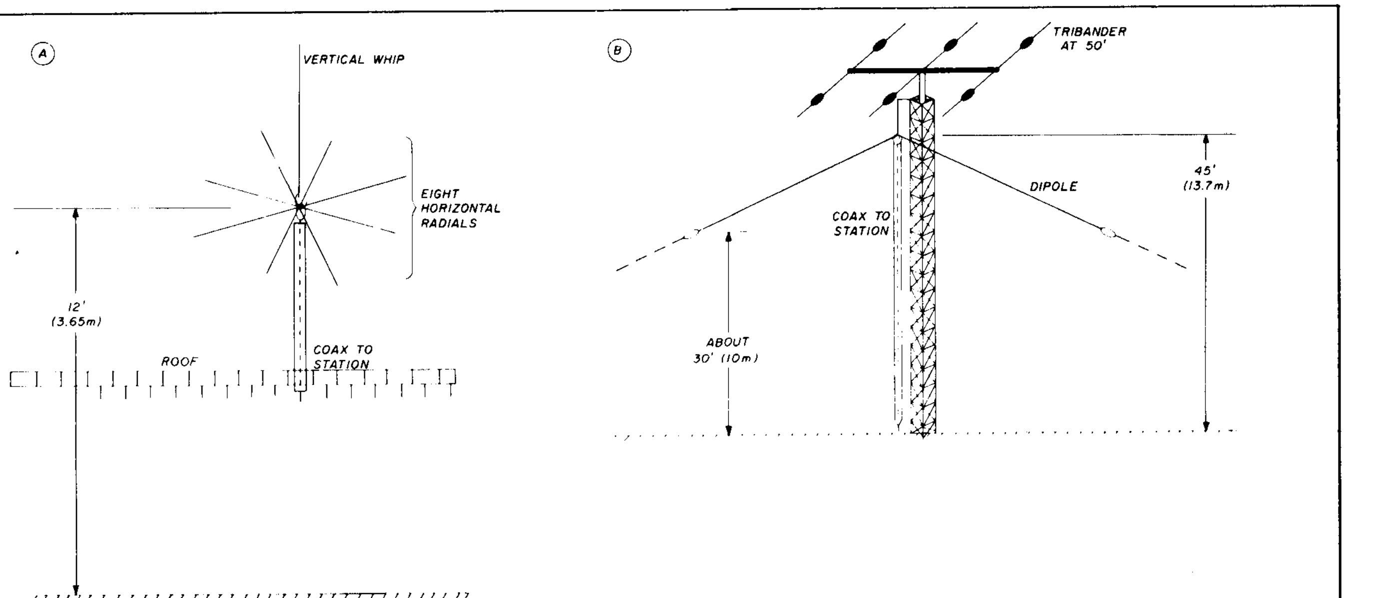

fig. 1. Comparison of a good ground plane antenna and a dipole at 10 MHz. (A) The ground plane was roof-mounted with eight radials in a near-horizontal plane. (B) The dipole was slung from a short arm on the tower 45 feet up.

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Front panel switching allows independent MODE and optional crystal filter selection.

A passive double balanced mixer is employed in the receiver front end. This stage is preceeded by a low noise high dynamic range bipolar rf amplifier to provide good, strong signal performance and weak signal sensitivity.

Accurate digital readout of operating carrier frequency is displayed to 100 Hz.

A rugged, solid-state PA provides continuous duty in SSB and CW modes. A cooling fan (FA7) is available for more demanding duty cycles, such as SSTV or RTTY. The PA also features very low harmonic and spurious output.

VOX GAIN, VOX DELAY, VOX disable, QSK, selectable AGC time constants, RIT and noise blanker selection are front panel controlled for ease of operation.

The TR5 is designed with modular construction techniques for easy accessibility and service.

GENERAL

Frequency Coverage: 1.8-2.0*, 3.5-4.0, 7.0-7.5, 10.0-10.5, 14.0-14.5, 18.0-18.5*, 21.0-21.5, 24.5-25.0*, 28.0-28.5*, 28.5-29.0, 29.0-29.7* MHz. (*With accessory range crystal).

Modes of Operation: Usb, Lsb, Cw.

Frequency Stability: Less than 1 kHz drift first hour. Less than 150 Hz per hour drift after first hour. Less than 100 Hz change for a ± 10% line voltage change.

Readout Accuracy: ± 10 ppm ± 100 Hz.

Power Requirements: 13.6 V-dc regulated, 2 A. 12 to 16 V-dc unregulated, 0.8 V rms maximum ripple, 15 A.

Dimensions:
Depth: 12.5 in (31.75 cm), excluding knobs and connectors.
Width: 13.6 in. (34.6 cm).
Height: 4.6 in. (11.7 cm) excluding feet.

Weight: 14 lb. (6.35 kg)

TRANSMITTER

Power Input (Nominal): 150 Watts, PEP or Cw.

Load Impedance: 50 ohms.

Spurious and Harmonic Output: Greater than 40 dB down.

Intermodulation Distortion: Greater than 30 dB below PEP.

Carrier Suppression: Greater than 50 dB.

Undesired Sideband Suppression: Greater than 60 dB at 1 kHz.

Duty Cycle:
Ssb, Cw: 100%.
Lock Key (w/o FA7 Fan): 30%, 5 minutes maximum transmit.
Lock Key (w/FA7 Fan): 100%.

Microphone Input: High Impedance.

Cw Keying: Instantaneous full break-in, adjustable delay.

RECEIVER

Sensitivity: Less than 0.5 uV for 10 dB S + N/N except less than 1.0 uV, 1.8-2.0 MHz.

Selectivity: 2.3 kHz minimum at − 6 dB, 4.1 kHz maximum at − 60 dB (1.8:1 shape factor).

Ultimate Selectivity: Greater than − 95 dB.

Agc: Less than 5 dB output variation for 100 dB input signal change, referenced to agc threshold.

Intermodulation: (20 kHz or greater spacing) *Intercept Point:* Greater than 0 dBm. *Two-Tone Dynamic Range:* Greater than 85 dB.

I-f Frequency: 5.645 MHz.

I-f Rejection: 50 dB, minimum.

Image Rejection: 60 dB, minimum below 14 MHz. 50 dB, minimum above 14 MHz.

Audio Output: 2 watts, minimum @ less than 10% THD (4 ohm load).

Spurious Response: Greater than 60 dB down.

ACCESSORIES AVAILABLE

Model 7021 SL300 CW Filter	Model 7026 SL4000 AM Filter	Model 1531 MS7 Speaker
Model 7022 SL500 CW Filter	Model 7024 SL6000 AM Filter	Model 1507 CW75 Keyer
Model 7027 SL1000 RTTY Filter	Model 1570 PS75 AC Power Supply	Model 1558 NB5 Noise Blanker
Model 7023 SL1800 RTTY Filter	Model 1545 RV75 Synthesized Remote VFO	Model 7077 Microphone

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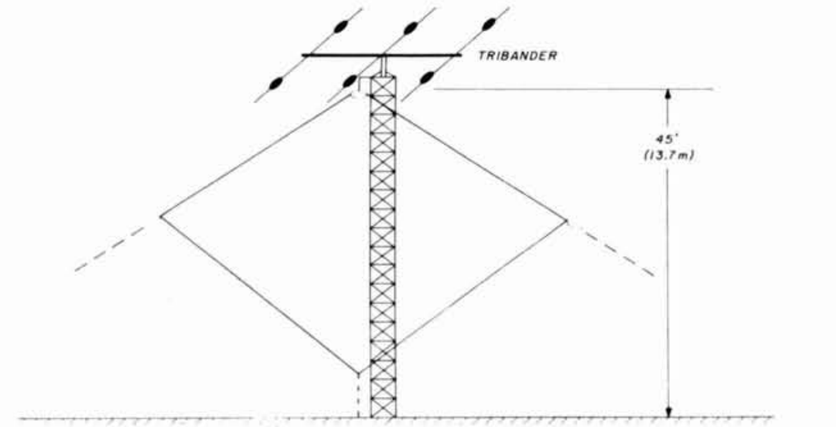

fig. 2. The dipole was converted into a quad loop, a quarter-wave on a leg. Loop was fed at the top with a coaxial line. No apparent differences in signal strength could be observed.

tion I used is detailed in **fig. 1**. Both antennas were well in the clear in all directions except to the west, where there was a slight rise in the ground level about 300 feet from the antennas. To the east there was an excellent shot down a slight grade to San Francisco Bay, about four miles away.

I was familiar with my location's idiosyncracies on both 7 MHz and 14 MHz, and I felt that leisurely observing DX signals over a period of time on the 10-MHz band (where no ham signals existed in 1980 and 1981) would be interesting. A large enough number of identifiable signals were logged among the many commercial and broadcast stations that could be heard that a good receiving check of the two antennas was possible.

January 1, 1982 — the band opens up

At the stroke of the new year, Amateur signals appeared on 10 MHz, but, alas, none from the United States (those that worked hardest to get the band will probably be the last ones on — an ironic tribute to U.S. Amateurs). A good spread of Amateur signals around the globe, coupled with a little QRM, provided an excellent test for the antennas, which could be selected at the flick of a coaxial switch. Some of the most interesting reception tests were run on VK9YC on the Cocos-Keeling Islands in the Indian Ocean, who showed up like clockwork for a short time around 0000Z, the long path over Africa. On the same skip, VK6AKG in western Australia could often be heard. European signals coming through the short path were also good checks, as were ham signals from Mexico and Central and South America.

By mid-year, 1982, I had listened to enough signals from all distances to draw some tentative conclusions as to performance of the two antennas. Here are some of the conclusions i came to:

1. The vertical ground plane antenna is vastly more sensitive to manmade noise than is the horizontal dipole. Noise rejection of the dipole over the ground plane was as high as 30 dB in some cases. If you are troubled with power line, ignition, or other manmade noises, the vertical antenna is not for you.

2. The horizontal dipole is more susceptible to atmospheric noise (background hiss, static, etc.) than the vertical. If no manmade noise is present, the vertical antenna is quieter than the horizontal.

3. On signal reception from stations as close as WWV in Colorado to

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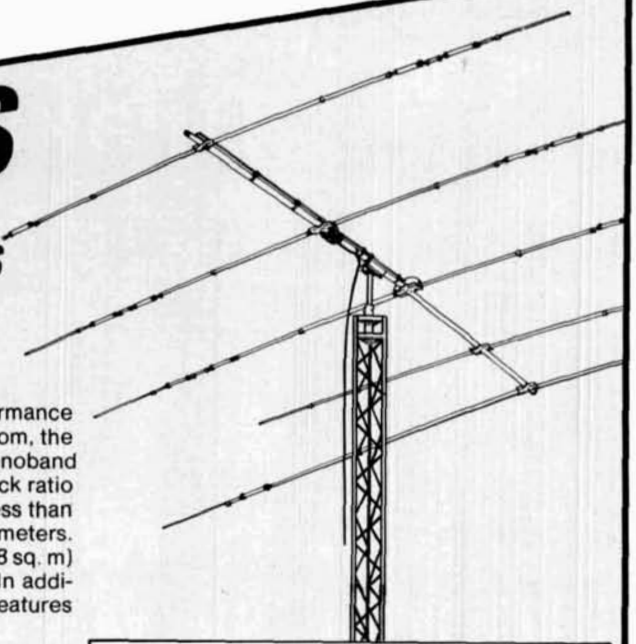

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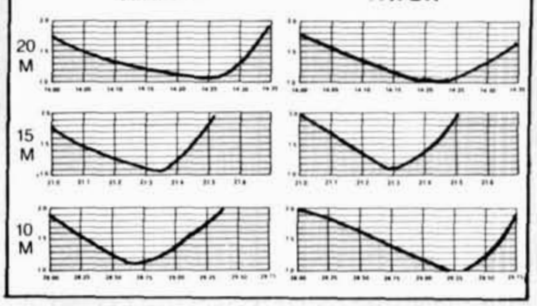
TH7DX The new standard of comparison for high performance broadband tribanders. Using a dual driven 7 element system, the TH7DX maintains a VSWR of less than 2:1 on all bands including ALL of 10 meters and WITH 8.8 dB gain. The unique combination of Hy-Q trapped and monoband parasitic elements produces an *average* front-to-back ratio of 22 dB on 20 and 15 meters, and 17 dB on 10 meters. Even with this amazing performance, the TH7DX boom is only 24 ft. (7.3 m) and the entire array is no bigger than the famous TH6DXX. Weight of the TH7DX is 75 lbs. (34 kg) with surface area of 9.4 sq. ft. (.87 sq. m) and wind-loading of 240 lbs. at 80 mph (108.9 kg-129 km/h).



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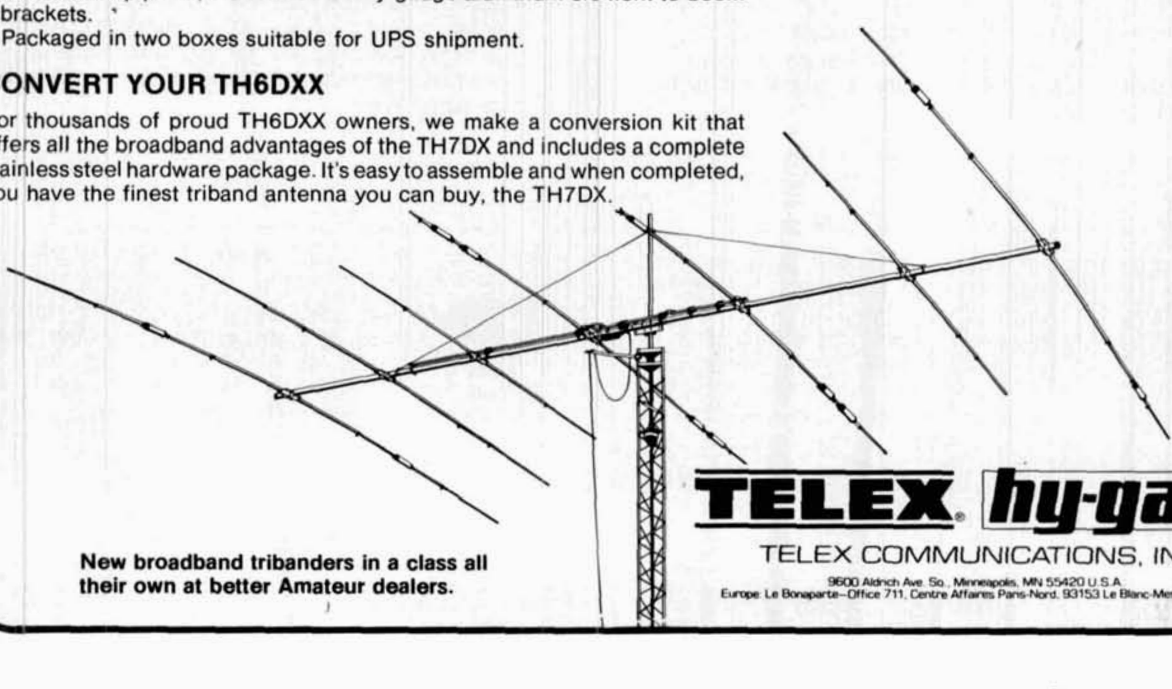

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VK9YC, *in no instance* was the ground plane vertical better than the dipole. Usually it was one-half to one S-unit weaker than the horizontal antenna. Over the long pull, even if signals appeared to be of equal strength on the two antennas, the signal on the horizontal dipole was *more readable over a period of time* than was the signal received on the vertical ground plane.

what this means

It was an interesting comparison. The vertical antenna had eight nearly-horizontal radials beneath it and it was high enough in the air so as to be clear of telephone wires and nearby objects. It was a good ground plane in a good, typical location. The dipole was suspended in the clear from my tower, with the ends drooping slightly, since they were tied to nearby handy objects. The base of the ground plane was about 12 feet (3.65 meters) above the ground and the center of the dipole was about 45 feet (13.7 meters) above the ground. Thus, the ground plane base was just about 0.13 wavelength above ground and the dipole center was about 0.5 wavelength above ground — typical dimensions for Amateur installations.

According to vertical angle radiation plots beloved by Amateur antenna specialists, the ground plane should be putting out most of its energy very close to the horizon, at perhaps ten to twelve degrees of elevation. On the other hand, the dipole should have its maximum lobe of radiation at an angle of about thirty degrees above the horizon. The dipole should be good for short distances and the ground plane good for long-distance DX.

Alas, no such clean line of demarcation can be made. In real life, the earth is a lumpy reflector of questionable conductivity, spotted with utility wires, streets, houses, and other large objects in the vicinity of the ham antenna. Scientific measurements often come unglued in suburbia.

If I had to make a choice, I'd opt for the horizontal dipole because it is less noisy and provides a better signal-to-noise ratio than the ground plane most of the time. Yes, I know many famous DXers use a ground plane with great results, but have they ever directly compared the ground plane against the vertical in a real situation? I doubt it. I'll take the extra dB or so of signal-to-noise ratio I gain with the dipole and out-hear you every time.

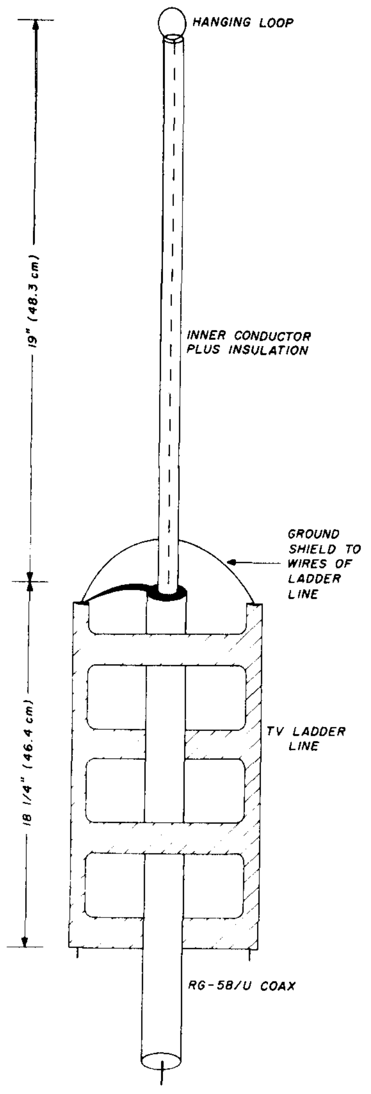


fig. 3. The KA4OFE answer to the 2-meter rubber duckie antenna. Costing just pennies, this simple dipole runs rings around an HT antenna. It can be rolled up and stuffed in your pocket (depending upon the length of the feedline). It's a great antenna for an emergency when you need the punch to break into a distant repeater!

the dipole versus the single quad loop

The final experiment was a comparison of the dipole with a single quad loop whose apex was at the same height as the center of the dipole (**fig. 2**). Unfortunately, these antennas could not be concurrently compared. One had to be taken down so the other could be erected; the only comparisons, therefore, were on a day-to-day basis. Since the 10-MHz band (like other bands) changes from day to day, the results of this investigation are open to interpretation.

After a week or so of pulling antennas up and down and listening to DX signals, I concluded that there isn't any difference worth mentioning between the two. I couldn't determine if the small gain (reputed to be about 1.2 dB) of the loop over the dipole was worth the complexity of the installation. After a few weeks, the loop was dismantled and I reached a final conclusion: it is pretty difficult to devise a better antenna than a simple dipole, mounted at least a half-wavelength in the air. If any of my readers come up with a simple antenna (the key word is *simple*) that outplays the dipole, I'd be pleased to hear about it!

a cheap and easy gain antenna for 2 meters

Do you want extended range for your 2-meter HT? Many of us have found that the rubber duckie antenna doesn't do a very good job at any distance from a repeater. Here's an inexpensive antenna that will boost your operating range many times over that of the duck.

As far as I know, this antenna was designed by Woody, KA4OFE. I received the instructions from him and immediately tried it out on some distant repeaters. Wow! It opened up a whole new world of HT communications.

This simple antenna is shown in

fig. 3. It is simply a vertical dipole with the lower half made of a section of 450-ohm TV ladder line.

The top section of the dipole is made from the center conductor of the coaxial line, with the white dielectric material left in place. A hang-up loop is formed at the top and the distance from the top of the loop to the braid is 19 inches (45 cm). Enough braid is left to form a pigtail, which is soldered to a crossover wire between the two wires of the ladder line.

The 50-ohm coax should be woven in and out through the lattices of the ladder line, keeping it centered as much as possible. The coax could then be tied in position along the ladder line by monofilament fishing line, if you desire.

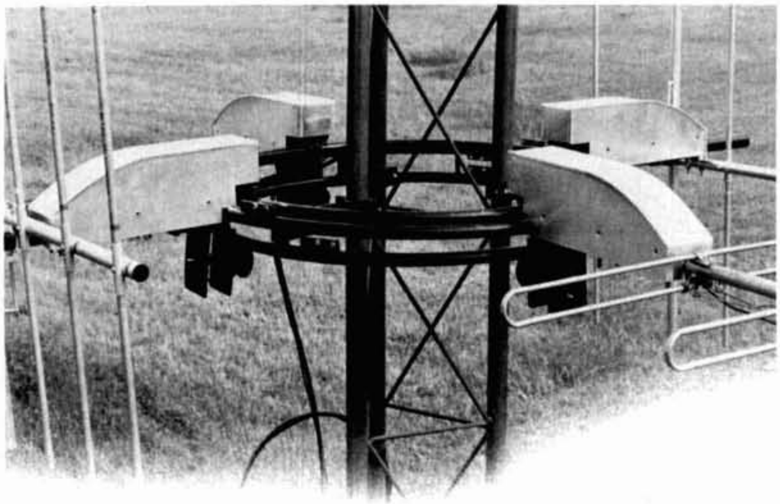
The two wires of the line are separated at the bottom end and joined at the top end, at which point the coax braid is attached. The ladder line seems to work well as a decoupling stub, and when the antenna is mounted in the clear (hung from a branch of a tree, for example) it is a great improvement over a conventional HT antenna — even a full-size one. SWR on the line is low and so far I have encountered no loading problems with any equipment.

My model of the KA4OFE antenna comes complete with a 25-foot (7.62 meter) lead-in and a matching plug to fit the HT on the free end of the line. The antenna can be coiled up into a small bundle and erected in a few minutes time. It's a lot of antenna for very little money!

last call for EME notes

Some time ago I offered readers of this column a brochure entitled *All You Want to Know About Moonbounce*, a series of reprints of interesting EME (earth-moon-earth) information. I now have more reprints and if you send me four first-class stamps or four IRCs, I'll be pleased to send the material to you. Send your request to me at EIMAC, 301 Industrial Way, San Carlos, California 94070.

ham radio



computer-aided UHF preamplifier design

A review of transistorized preamplifier considerations, plus a computer program to speed up the design procedure

By Greg Vatt, KB0O, 7170 S. Lewis Way, Littleton, Colorado 80127

How often have you wished you could find a way to use one of those bargain transistors in a preamplifier or receiver front-end project? Or, looking through the data books, how many times have you wanted a quick way to determine whether a device would work for your application before you bought it? If you have access to a computer, this program will take the data-book S-parameters of a transistor and not only tell you if it is usable, but also will design the amplifier input and output matching networks. To better understand what the computer will do for you, let's take a look at some important requirements in transistor design.

stability

Many Amateurs shy away from building preamplifiers for low-noise applications because too many times those amplifiers turn into oscillators. However, with proper construction techniques and a stable theoretical design, a preamplifier could be a simple weekend project.

The stability of a device depends not only on the device itself but also on the load and source terminations provided by the matching networks. An active device is unconditionally stable if no combination of load and source impedances will cause the circuit to oscillate. A way to mathematically determine the potential stability of a device is by evaluating the stability factor, K:

$$K = \frac{1 + |\Delta|^2 - |S_{11}|^2 - |S_{22}|^2}{2 \bullet |S_{21} \bullet S_{12}|} \qquad (1)$$

where: S_{11} = *input reflection coefficient*
S_{12} = *reverse transmission coefficient*
S_{21} = *forward transmission coefficient*
S_{22} = *output reflection coefficient*
$\Delta = S_{11} \bullet S_{22} - S_{12} \bullet S_{21}$

If $K > +1$, the device is unconditionally stable, if $K < 1$, the device is potentially unstable. Do not automatically discard a device if K is less than one, because all that has been determined is that there are passive terminations which *could* cause the stage to oscillate. There are ways around this problem. For instance, changing V_{CE}, I_C, or both in a bipolar transistor will change the S-parameters of the device, and conditions could be found that will make $K > +1$. This approach is generally not preferred because the bias point of a transistor is also determined by other requirements, such as dc power consumption and noise figure, but could be considered as an alternative solution for some conditions.

A second alternative could be selective mismatching. This approach stabilizes the device by mismatching the output of the transistor, causing the gain to be reduced. It also requires the use of constant-gain circles on a Smith chart to determine both the gain and the load termination for the device.

A third approach is to add a resistor, either in series or in parallel with the input or output. However, for small-signal amplifiers, resistive loading on the input introduces losses that will degrade the noise figure of the amplifier. (In power amplifiers, resistive loading on the output is avoided because of the associated power losses.) The computer program (**fig. 1**) has been written for selective mismatching or resistive shunt loading on the device output.

for K > +1

It is a simple task to design an amplifier when K is greater than +1. Compute the reflection coefficient of the source impedance that provides a conjugate match to the input of the transistor (**eq. 2**), and the reflection coefficient of the load impedance that provides a conjugate match to the output of the transistor (**eq. 3**). The following equations compute those reflection coefficients:

$$\Gamma MS = C_1^* \bullet \left[\frac{B_1 \pm \sqrt{B_1^2 - 4 \bullet |C_1|^2}}{2 \bullet |C_1|^2} \right] \quad \textbf{(2)}$$

where: ΓMS = *reflection coefficient of the source impedance*

$B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2$

$C_1 = S_{11} - \Delta \bullet S_{22}^*$

$$\Gamma ML = C_2^* \bullet \left[\frac{B_2 \pm \sqrt{B_2^2 - 4 \bullet |C_2|^2}}{2 \bullet |C_2|^2} \right] \quad \textbf{(3)}$$

where: ΓML = reflection coefficient of the load impedance

$B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta|^2$

$C_2 = S_{22} - \Delta \bullet S_{11}^*$

If $B_1 < 0$, then the plus sign should be used in front of the square root in **eq. 2**, or the minus sign if $B_1 \geq 0$. The same is true in **eq. 3** for B_2.

The maximum power gain, G_{MAX}, is determined from **eq. 4**:

$$G_{MAX}\ (DB) = 10 \bullet LOG \left[\frac{|S_{21}|}{|S_{12}|} \left| K \pm \sqrt{K^2 - 1} \right| \right] \quad \textbf{(4)}$$

If B_1, from **eq. 2**, is negative, the plus sign precedes the square root, or the minus sign precedes the square root if B_1 is positive.

constant-gain circles

Constant-gain circles are useful in cases where a

fig. 1. Computer program listing.

```
10 ' THIS PROGRAM DESIGNS AMPLIFIERS USING 'S-PARAMETERS'
20 ' WRITTEN BY G.VATT-16MARCH1982
30 CLS
40 PRINT:PRINT" THIS PROGRAM DESIGNS SMALL     SIGNAL AMPLIFIERS USING S-     PARAMETERS."
50 RAD=57.29577951:PI=3.1415926
60 PRINT:INPUT" S11(M,P)=";WM,WP:WP=WP/RAD
70 PRINT:INPUT" S12(M,P)=";XM,XP:XP=XP/RAD
80 PRINT:INPUT" S21(M,P)=";YM,YP:YP=YP/RAD
90 PRINT:INPUT" S22(M,P)=";ZM,ZP:ZP=ZP/RAD
100 S1=WM:S2=WP:S3=XM:S4=XP:S5=YM:S6=YP:S7=ZM:S8=ZP
110 GOSUB 890
120 GOSUB 970
130 GOSUB 1030
140 IF K<1 GOTO 490
150 GOSUB 1070
160 GOSUB 1090
170 GOSUB 1110
180 TL=(B2+(B4*SQR((B2^2)-(4*(CM^2)))))/(2*CM)
190 TCP=-CP*RAD
200 GOSUB 1180
210 TS=(B1+(B3*SQR((B1^2)-(4*(EM^2)))))/(2*EM)
220 TEP=-EP*RAD
230 CLS
240 PRINT:PRINT" MAG="(INT(MAG*100)/100)"DB   MSG="(INT(MSG*100)/100)"DB"
250 PRINT:PRINT" GAMMA MS="(INT(TS*1000)/1000)","(INT(TEP*100)/100)
260 PRINT:PRINT" GAMMA ML="(INT(TL*1000)/1000)","(INT(TCP*100)/100)
270 PRINT:PRINT" K="(INT(K*1000)/1000)" "S$
280 PRINT:INPUT" DO YOU WANT TO DESIGN FOR A     SPECIFIC GAIN, INPUT/OUTPUT     MATCHING NETWORK, OR QU
IT -     (G,M,Q)";Q$
290 IF Q$="Q" GOTO 860
300 IF Q$="G" GOTO 420
310 CLS:PRINT:INPUT" THE INPUT/OUTPUT NETWORKS WILL  BE DESIGNED USING TWO ELEMENTS, SERIES CAPACITO
RS AND SHUNT     INDUCTORS.                    WHAT IS THE TERMINATING VALUE   OF RESISTANCE FOR THE NETWORK
S  (OHMS)";Z0
320 Y0=1/Z0
330 PRINT:INPUT" WHAT IS THE CENTER FREQUENCY OF THE AMPLIFIER (MHZ)";FR:FR=FR*1E+06
340 GOSUB 1990
350 CLS:PRINT:PRINT"          INPUT NETWORK";
360 PRINT:PRINT" SERIES CAP.="(INT(U7*1E+14)/100)"PF"
370 PRINT" SHUNT IND.="(INT(U8*1E+11)/100)"NH"
380 PRINT:PRINT"          OUTPUT NETWORK";
390 PRINT:PRINT" SERIES CAP.="(INT(U3*1E+14)/100)"PF"
400 PRINT" SHUNT IND.="(INT(U4*1E+11)/100)"NH"
410 GOTO 860
420 PRINT:INPUT" AMPLIFIER GAIN(DB)";GP
430 GOSUB 1250
440 GOSUB 1360
450 CLS
460 PRINT:PRINT" CENTER OF CONSTANT GAIN CIRCLE  ON OUTPUT="(INT(GM*1000)/1000)","(INT(-CP*RAD*100)/100)
470 PRINT:PRINT" RADIUS OF CONSTANT GAIN CIRCLE  ON OUTPUT="(INT(RG*1000)/1000)
480 GOTO 720
490 GOSUB 1110
500 GOSUB 1250
510 GOSUB 1290
520 GOSUB 1180
530 GOSUB 1390
540 GOSUB 1410
550 GOSUB 2270
560 CLS
570 PRINT:PRINT" CENTER OF STABILITY CIRCLE ON   INPUT (M,P)="(INT(HM*1000)/1000)","(INT(-EQ*RAD*100)/100)
580 PRINT" RADIUS OF STABILITY CIRCLE ON   INPUT="(INT(R1*1000)/1000)"    "D$
590 PRINT:PRINT" CENTER OF STABILITY CIRCLE ON   OUTPUT (M,P)="(INT(FM*1000)/1000)","(INT(-CQ*RAD*100)/100)
600 PRINT" RADIUS OF STABILITY CIRCLE ON   OUTPUT="(INT(R2*1000)/1000)"    "E$
610 GOSUB 1070
620 PRINT:PRINT" K="(INT(K*1000)/1000)""S$"    MSG="(INT(MSG*100)/100)"DB"
630 PRINT:INPUT" DO YOU WANT GAIN CIRCLE, SHUNT  RESISTOR OR QUIT (G,R,Q)";A$
640 IF A$="Q" GOTO 860
650 IF A$="R" GOTO 790
660 IF A$="G" GOTO 680
670 GOTO 630
680 CLS:PRINT:INPUT" INPUT GAIN (DB)";GP
690 GOSUB 1250:GOSUB 1360
700 PRINT:PRINT" CONSTANT GAIN CIRCLE FOR"GP"    DB (M,P)="(INT(GM*1000)/1000)","(INT(-CP*RAD*100)/100)
710 PRINT:PRINT" RADIUS OF CONSTANT GAIN CIRCLE  ="(INT(RG*1000)/1000)
720 PRINT:INPUT" INPUT REFLECTION COEFFICIENT    OF LOAD CHOSEN FROM THE SMITH   CHART (M,P)";OM,OP:OP=O
P/RAD
730 GOSUB 1480
740 PRINT:PRINT" SOURCE REFLECTION COEFFICIENT   FOR THE LOAD IS"(INT(MM*1000)/1000)","(INT(MP*RAD*100)/1
00)
750 PRINT:INPUT" DO YOU WANT TO DESIGN MATCHING  NETWORKS OR QUIT (M,Q)";K$
760 IF K$="Q" GOTO 860
770 TL=OM:CP=OP:TS=MM:EP=MP
780 GOTO 310
790 CLS:PRINT:PRINT" THE PROGRAM WILL CALCULATE NEW  S-PARAMETERS FOR THE TRANSISTOR AND A SHUNT RE
SISTOR ON THE     OUTPUT"
800 PRINT:INPUT" ENTER VALUE FOR RESISTOR";RE:CLS
810 WM=S1:WP=S2:XM=S3:XP=S4:YM=S5:YP=S6:ZM=S7:ZP=S8
820 GOSUB 1610
830 GOSUB 1940
840 GOSUB 1610
850 CLS:GOTO 110
860 PRINT:INPUT" RUN PROGRAM OR QUIT(R,Q)";Z$
870 IF Z$="R" GOTO 30
880 CLS:END
890 T1=WM*ZM:T2=WP+ZP
900 T3=XM*YM:T4=XP+YP
910 T5=T1*COS(T2):T6=T1*SIN(T2)
920 T7=T3*COS(T4):T8=T3*SIN(T4)
930 DR=T5-T7:DI=T6-T8
940 DM=SQR((DR*DR)+(DI*DI))
950 DP=2*ATN(DI/(DM+DR))
960 RETURN
970 B1=1+(WM*WM)-(ZM*ZM)-(DM*DM)
```

*Super-Compact is a trademark of Compact Engineering, Inc.

listing continues

```
980 B2=1+(ZM*ZM)-(WM*WM)-(DM*DM)
990 IF B1>=0 THEN B3=-1 ELSE B3=1
1000 IF B2>=0 THEN B4=-1 ELSE B4=1
1010 IF B1>=0 THEN S$="+" ELSE S$="-"
1020 RETURN
1030 N=1+(DM*DM)-(WM*WM)-(ZM*ZM)
1040 D=2*YM*XM
1050 K=N/D
1060 RETURN
1070 MSG=10*LOG(YM/XM)/LOG(10)
1080 RETURN
1090 MAG=MSG+10*LOG(ABS(K+B4*SQR((K*K)-1)))/LOG(10)
1100 RETURN
1110 T1=DM*WM:T2=DP-WP
1120 T3=T1*COS(T2):T4=T1*SIN(T2)
1130 T5=ZM*COS(ZP):T6=ZM*SIN(ZP)
1140 CR=T5-T3:CI=T6-T4
1150 CM=SQR((CR*CR)+(CI*CI))
1160 CP=2*ATN(CI/(CM+CR))
1170 RETURN
1180 T1=DM*ZM:T2=DP-ZP
1190 T3=T1*COS(T2):T4=T1*SIN(T2)
1200 T5=WM*COS(WP):T6=WM*SIN(WP)
1210 ER=T5-T3:EI=T6-T4
1220 EM=SQR((ER*ER)+(EI*EI))
1230 EP=2*ATN(EI/(EM+ER))
1240 RETURN
1250 D2=(ZM^2)-(DM^2)
1260 G0=YM^2
1270 G=(10^(0.1*GP))/G0
1280 RETURN
1290 FM=CM/D2
1300 CQ=CP
1310 IF FM>=0 GOTO 1340
1320 FM=ABS(FM)
1330 IF CQ>=0 THEN CQ=CQ-PI ELSE CQ=CQ+PI
1340 R2=ABS((XM*YM)/D2)
1350 RETURN
1360 GM=(CM*G)/(1+D2*G)
1370 RG=SQR(1-(2*K*XM*YM*G)+((XM*YM)^2*G*G))/(1+D2*G)
1380 RETURN
1390 D1=(WM^2)-(DM^2)
1400 RETURN
1410 HM=EM/D1
1420 EQ=EP
1430 IF HM>=0 GOTO 1460
1440 HM=ABS(HM)
1450 IF EQ>=0 THEN EQ=EQ-PI ELSE EQ=EQ+PI
1460 R1=ABS((XM*YM)/D1)
1470 RETURN
1480 T1=OM*DM:T2=OP+DP
1490 T3=(WM*COS(WP))-(T1*COS(T2))
1500 T4=(WM*SIN(WP))-(T1*SIN(T2))
1510 T5=SQR((T3^2)+(T4^2))
1520 T6=ATN(T4/T3)
1530 IF T3>=0 GOTO 1550
1540 IF T4>=0 THEN T6=T6+PI ELSE T6=T6-PI
1550 T7=OM*ZM:T8=OP+ZP
1560 T9=1-(T7*COS(T8)):U9=-(T7*SIN(T8))
1570 U1=SQR((T9^2)+(U9^2))
1580 U2=2*ATN(U9/(U1+T9))
1590 MM=T5/U1:MP=U2-T6
1600 RETURN
1610 T1=1+WM*COS(WP):T2=WM*SIN(WP)
1620 T3=SQR(T1^2+T2^2):T4=2*ATN(T2/(T3+T1))
1630 T1=1+ZM*COS(ZP):T2=ZM*SIN(ZP)
1640 T5=SQR(T1^2+T2^2):T6=2*ATN(T2/(T5+T1))
1650 T1=T5+T3:T2=T6+T4
1660 T8=XM*YM:T9=XP+YP
1670 T3=T1*COS(T2)-T8*COS(T9)
1680 T4=T1*SIN(T2)-T8*SIN(T9)
1690 U1=SQR(T3^2+T4^2):U2=2*ATN(T4/(U1+T3))
1700 T1=1+ZM*COS(ZP):T2=ZM*SIN(ZP)
1710 T3=SQR(T1^2+T2^2):T4=2*ATN(T2/(T3+T1))
1720 T1=1-WM*COS(WP):T2=-WM*SIN(WP)
1730 T5=SQR(T1^2+T2^2):T6=2*ATN(T2/(T5+T1))
1740 T1=T5+T3:T2=T6+T4
1750 T8=XM*YM:T9=XP+YP
1760 T3=T8*COS(T9)+T1*COS(T2)
1770 T4=T8*SIN(T9)+T1*SIN(T2)
1780 U3=SQR(T3^2+T4^2):U4=2*ATN(T4/(U3+T3))
1790 U5=-2*YM:U6=-2*YM
1800 T1=1+WM*COS(WP):T2=WM*SIN(WP)
1810 T3=SQR(T1^2+T2^2):T4=2*ATN(T2/(T3+T1))
1820 T1=1-ZM*COS(ZP):T2=-ZM*SIN(ZP)
1830 T5=SQR(T1^2+T2^2):T6=2*ATN(T2/(T5+T1))
1840 T1=T5+T3:T2=T6+T4
1850 T8=XM*YM:T9=XP+YP
1860 T3=T8*COS(T9)+T1*COS(T2)
1870 T4=T8*SIN(T9)+T1*SIN(T2)
1880 U7=SQR(T3^2+T4^2):U8=2*ATN(T4/(U7+T3))
1890 WM=U3/U1:WP=U4-U2
1900 XM=U5/U1:XP=XP-U2
1910 YM=U6/U1:YP=YP-U2
1920 ZM=U7/U1:ZP=U8-U2
1930 RETURN
1940 T1=ZM*COS(ZP):T2=ZM*SIN(ZP)
1950 T3=50/RE:T4=T1+T3
1960 ZM=SQR(T4^2+T2^2)
1970 ZP=2*ATN(T2/(ZM+T4))
1980 RETURN
1990 T1=-CP:T2=-EP
2000 IF T1>=0 THEN T1=T1-PI ELSE T1=T1+PI
2010 T3=1+TL*COS(T1):T4=TL*SIN(T1)
2020 T5=SQR(T3^2+T4^2)
2030 T6=2*ATN(T4/(T5+T3))
2040 T3=1-TL*COS(T1):T4=-TL*SIN(T1)
2050 T7=SQR(T3^2+T4^2)
2060 T8=2*ATN(T4/(T7+T3))
2070 T3=T5/T7:T4=T6-T8
2080 U1=1/(Y0*T3*COS(T4)):U2=1/(Y0*T3*SIN(T4))
2090 T3=SQR((U1-Z0)*Z0):U3=1/(2*PI*FR*T3)
2100 T4=(Z0^2+T3^2)/T3
2110 T5=1/(2*PI*FR*T4)+1/(2*PI*FR*ABS(U2))
2120 U4=1/((2*PI*FR)^2*T5)
2130 IF T2>=0 THEN T2=T2-PI ELSE T2=T2+PI
2140 T3=1+TS*COS(T2):T4=TS*SIN(T2)
2150 T5=SQR(T3^2+T4^2)
2160 T6=2*ATN(T4/(T5+T3))
2170 T3=1-TS*COS(T2):T4=-TS*SIN(T2)
2180 T7=SQR(T3^2+T4^2)
2190 T8=2*ATN(T4/(T7+T3))
2200 T3=T5/T7:T4=T6-T8
2210 U5=1/(T3*Y0*COS(T4)):U6=1/(T3*Y0*SIN(T4))
2220 T3=SQR((U5-Z0)*Z0):U7=1/(2*PI*FR*T3)
2230 T4=(Z0^2+T3^2)/T3
2240 T5=1/(2*PI*FR*T4)+1/(2*PI*FR*ABS(U6))
2250 U8=1/((2*PI*FR)^2*T5)
2260 RETURN
2270 Q1=HM-R1:Q2=FM-R2
2280 IF Q1>=0 THEN D$="OUTSIDE" ELSE D$="INSIDE"
2290 IF Q2>=0 THEN E$="OUTSIDE" ELSE E$="INSIDE"
2300 RETURN
```

power gain other than G_{MAX} is desired for an unconditionally stable amplifier, or for determining source and load terminations for a potentially stable amplifier. Any reflection coefficient that falls on the circumference of a constant-gain circle can be used when designing a stage for that particular gain. That fact is particularly useful when designing wideband amplifiers, where it is necessary to design a matching network that intersects particular gain circles at many frequencies. The gain circles are determined by the following equations. **Eq. 5** determines both magnitude and phase of the center of the constant gain circle on the output:

$$C_{CG} = \left[\frac{G}{1 + D_2 \bullet G} \right] \bullet C_2^* \qquad \textbf{(5)}$$

where: $D_2 = |S_{22}|^2 - |\Delta|^2$

$G = \dfrac{10^{(0.1\,G_d)}}{|S_{21}|^2}$

G_d = *desired gain (DB)*

C_{CG} = *center of constant gain circle*

The radius of the constant-gain circle is determined by **eq. 6**:

$$R_{CG} = \frac{\sqrt{(1 - 2K\,|S_{21} \bullet S_{12}|\,G + |S_{12} \bullet S_{21}|^2 \bullet G^2)}}{1 + D_2 \bullet G} \qquad \textbf{(6)}$$

where R_{CG} = *radius of the constant-gain circle.*

Because an infinite number of load impedances fall on the constant-gain circle, it will be necessary to plot the constant gain circle on a Smith chart to select a proper load impedance. Once the load impedance is selected, the value of the source impedance that simultaneously matches the input is determined by **eq. 7**:

$$\Gamma IN = \left[\frac{S_{11} - \Delta \bullet \Gamma OUT}{1 - S_{22} \bullet \Gamma OUT} \right]^* \qquad \textbf{(7)}$$

where ΓIN = *reflection coefficient of the source impedance*

ΓOUT = *reflection coefficient of the load impedance*

mismatching

When a device is found to be only potentially stable *($K < 1$)* the mismatching technique can be used to stabilize the device. The stage gain will determine the source and load terminations, and must be less than the maximum stable gain computed in **eq. 8**:

$$G_{MSG}(DB) = 10 \bullet LOG \frac{|S_{21}|}{|S_{12}|} \qquad \textbf{(8)}$$

Once the stage gain has been selected, **eq. 5** through

7 can be used to determine the constant-gain circle and the load and source reflection coefficients that result. All that is left is to design the input and output matching networks.

One problem associated with the mismatching technique is that the output return loss, S_{22}, is usually not very good (high VSWR). This could pose a problem when the amplifier is used to drive a filter, mixer, or transmission line. In the case of a bandpass filter, for instance, passband distortion would occur due to improper filter impedance termination. Also, high reactive impedances outside the passband could cause the amplifier to oscillate. The mismatching approach to device stability is best suited for interstage matching of two or more cascaded amplifiers.

output-shunt resistor

A stabilizing technique with many advantages (even in a single amplifier stage) is using a shunt resistor on the output of the device. A proper shunt resistor will prevent the device from becoming unstable no matter what the load or source impedance. The only cost trade-off is reduced gain. The stage will also exhibit very good input and output return loss (S_{11} and S_{22}). When using this amplifier to drive (or terminate) a bandpass filter, the passband will not be distorted and no reactive impedance will cause the amplifier to become unstable (provided $K > +1$ for all frequencies).

table 1. S-parameter and Y-parameter transformations.

$$S_{11} = \frac{(1 - Y_{11})(1 + Y_{22}) + Y_{12}Y_{21}}{(1 + Y_{11})(1 + Y_{22}) - Y_{12}Y_{21}}$$

$$S_{12} = \frac{-2Y_{12}}{(1 + Y_{11})(1 + Y_{22}) - Y_{12}Y_{21}}$$

$$S_{21} = \frac{-2Y_{21}}{(1 + Y_{11})(1 + Y_{22}) - Y_{12}Y_{21}}$$

$$S_{22} = \frac{(1 + Y_{11})(1 - Y_{22}) + Y_{12}Y_{21}}{(1 + Y_{11})(1 + Y_{22}) - Y_{12}Y_{21}}$$

$$Y_{11} = \frac{(1 + S_{22})(1 - S_{11}) + S_{12}S_{21}}{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}$$

$$Y_{12} = \frac{-2S_{12}}{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}$$

$$Y_{21} = \frac{-2S_{21}}{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}$$

$$Y_{22} = \frac{(1 + S_{11})(1 - S_{22}) + S_{12}S_{21}}{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}$$

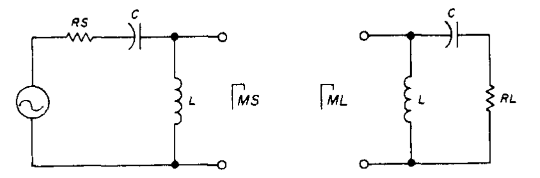


fig. 2. Computer designed input/output matching network.

The computer program determines the resistor value by calculating the new S-parameters of the device/resistor cascaded network. The stability factor, K, is then calculated. When $K > +1$, the proper resistor value has been found to make the stage unconditionally stable.

To determine the cascaded S-parameters, a transformation of the original S-parameters to Y-parameters is necessary. The device's output admittance (Y_{22}) and the equivalent admittance of the shunt resistor ($1/R_{SHUNT}$) are added together. The new Y-parameters are then converted back to S-parameters, which are now cascaded network S-parameters. Both transformations use the equations presented in **table 1**.

After the shunt-resistor value has been determined, the computer program will calculate the input and output reflection coefficients for maximum stage gain. For a specific gain less than G_{MAX}, the program can be iterated while varying the value of the shunt resistor, or, the constant-gain-circle design approach can be used.

matching network

To complete the computer-design package, a form of matching network has been included. This network is a two-pole, highpass filter (shown in **fig. 2**). This network was chosen because: it has a unique solution and is easy to calculate; it provides for easy input/output dc biasing; and it can match most transistor input/output requirements. **Fig. 3** shows the range of input and output reflection coefficients this two-pole network can match to the center of the Smith chart. The area where matches can occur is highlighted by the vertical lines.

Other configurations of the two-pole matching network could be programmed to design matching networks for the reflection coefficients falling in the other half of the Smith chart. The design equations for the network in **fig. 3** are listed in the **appendix**.

design example

The previous explanation was presented to give an idea of the capability of the computer program. However, whether you understood the theory or not, we are all on equal ground because the computer will do the work from here on.

A Motorola MRF-904 transistor was selected as a design example (because I had one available). The device has some characteristics making it a good choice for a preamplifier in the VHF and UHF bands, including low-noise figure, reasonable gain, and low cost. The design example that follows uses the MRF-904 as a single-stage preamplifier for 435 MHz with the thought that it would be used for OSCAR reception.

The design begins by determining the S-parameters for the operating conditions desired. The Motorola data book gives the S-parameters at 200 and 500 MHz. To get a reasonable estimate of the S-parameters at 435 MHz, a straight-line approximation was used to interpolate the needed S-parameters. **Table 2** lists the operating characteristics and S-parameters arrived at for 435 MHz.

When those S-parameters are entered into the computer, the initial evaluation of the device results in the following information:

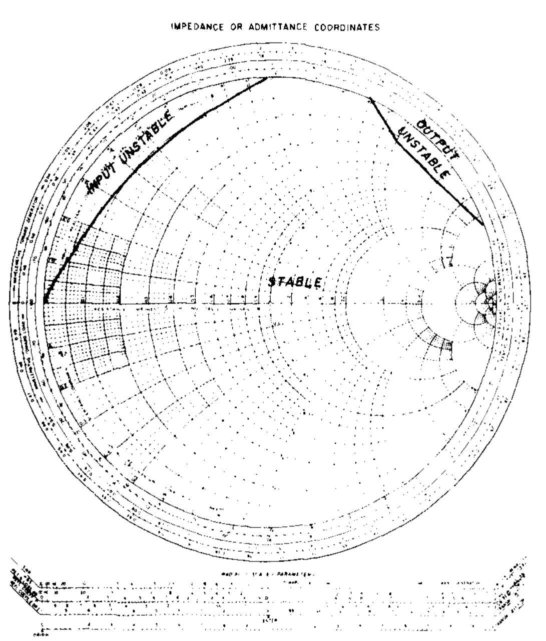


fig. 4. Stability circles for MRF-904.

table 2. *MRF-904* **device characteristics.**

V_{CE}	I_C	S_{11}
6.0 volts	5 mA	$0.35\angle -63^\circ$
S_{12}	S_{21}	S_{22}
$0.084\angle 64^\circ$	$5.2\angle 93^\circ$	$0.66\angle -27^\circ$

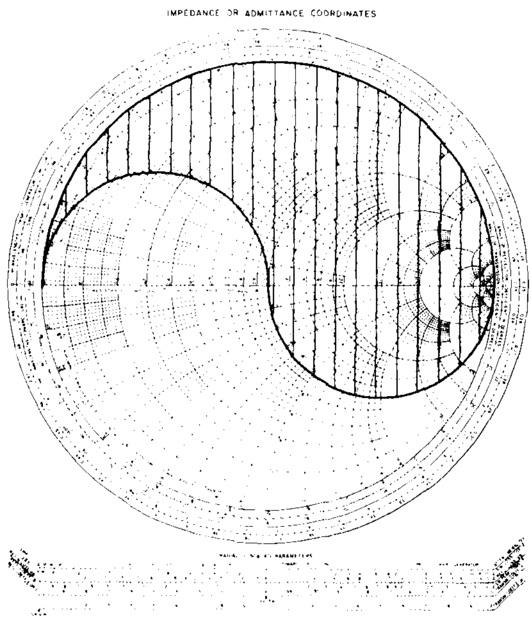


fig. 3. Transformable reflection coefficients.

$K = 0.875$ $\qquad$ $G_{MSG} = 17.91\ dB$

Center of the input-stability circle: $1.389\angle -44.75^\circ$

Radius of the input stability circle: 2.178 INSIDE

Center of the output-stability circle: $4.779\angle 42.15^\circ$

Radius of the output-stability circle: 3.879 OUTSIDE

Since $K < 1$, the device is potentially stable and the maximum stable gain is 17.91 dB. The stability circles can be plotted on a Smith chart to graphically show the areas of device stability. The words Inside and Outside that follow the radius of the stability circles determines whether the inside or outside of the circle is the stable region. **Fig. 4** shows the stability circles for the MRF-904.

shunt-resistor approach

The next step is to choose to stabilize the device by a shunt resistor on the output, or by mismatching (using gain circles). With the shunt resistor approach, an arbitrary value can be used to start the stabilization process, and the value of the resistor lowered each time until $K > +1$. A resistor value of 300 ohms was chosen, which stabilized the device with the following results:

$K = 1.216$ $\qquad$ $G_{MAX} = 15.1\ dB$ $\qquad$ $G_{MSG} = 17.91\ dB$

$\Gamma MS = .463\angle 92.21^\circ$ $\qquad$ $\Gamma ML = .554\angle 48.21^\circ$

The device, with the shunt resistor of 300 ohms, is now unconditionally stable with a gain of 15.1 dB.

The next step is to design the input and output matching networks. **Fig. 5** shows the device and matching networks. The component values in **table 3** are the result of the computer-calculated matching-network design. This completes the design of the amplifier using the shunt-resistor approach.

mismatching approach

To compare the mismatching technique to the shunt-resistor approach, the designed stage gain should be set at 15.1 dB as before. The first step is to determine the gain circle for 15.1 dB:

Center of the constant-gain circle = $0.567 \angle 42.15^\circ$
Radius of the constant-gain circle = 0.527

A reflection coefficient must be chosen that is on the circumference of the constant-gain circle. In order to do this, the constant-gain circle needs to be plotted on the Smith chart. One quick way to arrive at a load-reflection coefficient without the use of a Smith chart is to take the difference between the magnitude of the center of the gain circle and the radius. If this point falls in the transformable region shown in **fig. 3**, it can be used as the load-reflection coefficient. (If a load-reflection coefficient is chosen that does not fall in the transformable region, the computer program will stop with an error message.) The load-reflection coefficient of $0.04\angle 42.15^\circ$ was arrived at in this manner for the design example.

table 3. Input/output matching networks.

input network	output network
C_3 = 10.3 pF	C_4 = 5.23 pF
L_3 = 14.55 nH	L_4 = 20.85 nH

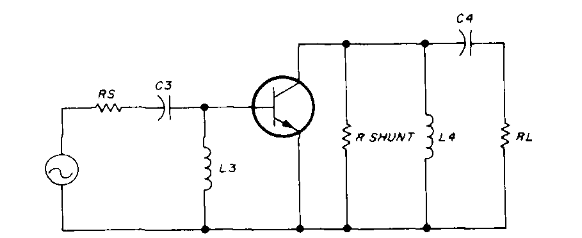


fig. 5. Computer designed matching networks, shunt-resistor type.

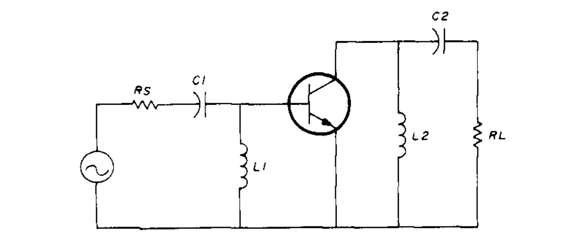


fig. 6. Computer designed matching networks.

table 4. Input/output matching networks.

input network	output network
C_1 = 9.45 pF	C_2 = 29.24 pF
L_1 = 19.53 nH	L_2 = 63.94 nH

The input-reflection coefficient was then calculated by the computer to be $0.348\angle 65.92^\circ$. The input and output matching networks can now be computed. The circuit will look like that in **fig. 6**, which is the same as **fig. 5** without the shunt resistor. The component values calculated by the computer for the mismatching case are listed in **table 4.**

performance comparison

The results of the two computer design approaches have been verified using Super-Compact™, an advanced engineering computer-aided-design program. The predicted performance data of the two amplifiers is shown in **figs. 7** through **12. Figs. 7, 9,** and **11** are for the shunt-resistor case, and **figs. 8, 10,** and **12** are for the mismatching case.

The data points out some of the characteristics of the two approaches. Two important differences that can be seen from the performance curves is that the gain (S_{21}) curves are different and the output return loss (S_{22}) is not as good for the mismatching case (**fig. 12**) as for the shunt resistor case (**fig. 11**). For the mismatching case, the gain will not necessarily be maximum at the design frequency; however, for the shunt-resistor case it always will. In either case, the gain is the same at the designed center frequency, and more importantly, it is what the computer was asked to design. The computer program is capable of calculating values for an amplifier stage using either approach, but from a performance standpoint the shunt-resistor approach appears better for a single-stage application.

conclusion

The results show that, with either design approach, the computer program can design the amplifier stage with a high degree of accuracy. In addition, the shunt-resistor approach should be of particular interest to Amateurs because a device can be made unconditionally stable, therefore any mistuning of the amplifier stage will not cause it to oscillate.

A complete listing of the computer program is in fig. 1. It was written to run on a TRS-80 Color Computer, but should run on most other home computers with little or no modification. When you are ready to try your hand at amplifier design, grab a device and put your computer to work.

bibliography

Carson, Ralph S., "High Frequency Amplifiers," John Wiley and Sons, New York, 1975.

Froehner, William H., "Quick Amplifier Design with Scattering Parameters," *Electronics*, October 16, 1967.

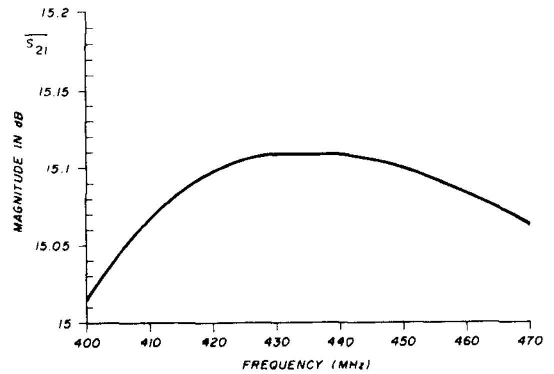


fig. 7. Gain using the shunt-resistor approach.

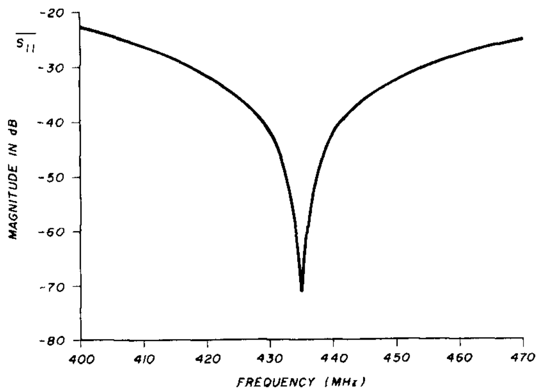


fig. 10. Input return loss for the mismatching approach.

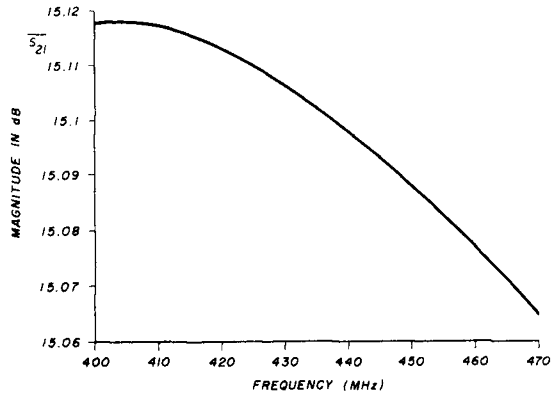


fig. 8. Gain using the mismatching approach.

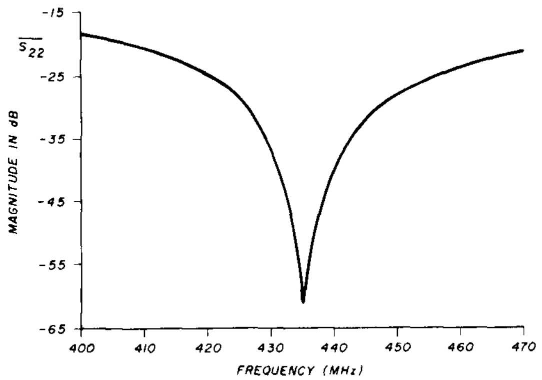


fig. 11. Output return loss for the shunt-resistor approach.

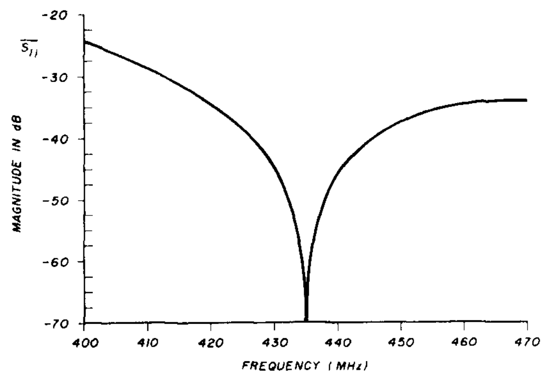


fig. 9. Input return loss for the shunt-resistor approach.

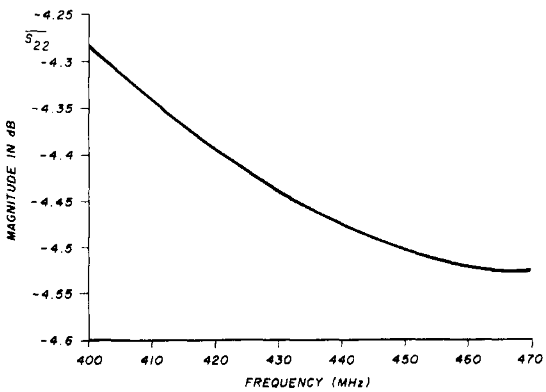


fig. 12. Output return loss for the mismatching approach.

Kraus, Herbert L., *et al*, "Solid State Radio Engineering," John Wiley and Sons, New York, 1980.

Jones, Marty, "High-Frequency Transistor Amplifier Design," *r.f. design*, September/October, 1981, November/December, 1981, January/February, 1982.

Shuch, H. Paul, WA6UAM, "Solid-State Microwave Amplifier Design," *ham radio*, October, 1976.

appendix

input/output matching network design

The first step in designing a matching network is to transform the reflection coefficient into an impedance or admittance. The first element used is a shunt inductor, therefore the reflection coefficient will be transformed into its equivalent admittance. To obtain the admittance form, it is necessary to add −180 degrees to any positive phase angle of the reflection coefficient, or add +180 degrees to any negative phase angle. The admittance is then found by using **eq. 1**:

$$Y_L = \left[\frac{1 + \Gamma ML'}{1 - \Gamma ML'}\right] \bullet Y_0 \tag{1}$$

where Y_L = *transformed admittance*
Y_0 = *20 mmhos (for a 50-ohm system)*
$\Gamma ML'$ = *parallel equivalent of* ΓML

In rectangular form, Y_L will have a real and imaginary component. The reciprocal of the real component corresponds to the resistance and the reciprocal of the imaginary component corresponds to the reactance.

The value for the series capacitor can be found from the following equations:

$$X_C = \sqrt{(R_P - R_S) \bullet R_S} \tag{2}$$

where: R_P = *reciprocal of the real part of* Y_L
R_S = *system impedance (usually 50 ohms)*

$$C_{series} = \frac{1}{2 \bullet \pi \bullet F \bullet X_C} \tag{3}$$

where: F = *amplifier design-center frequency*

The parallel equivalent of X_C is determined by **eq. 4**.

$$X_P = \frac{R_S^2 + X_C^2}{X_C} \tag{4}$$

$$C_P = \frac{1}{2 \bullet \pi \bullet F \bullet X_P} \tag{5}$$

where: C_P = *the parallel equivalent capacitance*

$$C_{IN} = \frac{1}{2 \bullet \pi \bullet F \bullet X_L} \tag{6}$$

where C_{IN} = *the capacitance due to the transistor*
X_L = *the imaginary impedance component of the reflection coefficient*

$$C = C_P + C_{IN} \tag{7}$$

The shunt inductor is then found by **eq. 8**:

$$L = \frac{1}{(2 \bullet \pi \bullet F)^2 \bullet C} \tag{8}$$

This design procedure is implemented in the computer program, and is the same for the design of input or output networks.

ham radio

)IGITAL TECHNIQUES

digital techniques: shocking truths about semiconductors

All the wonders of solid-state technology can be erased by either of two simple electrical sources: static electricity and supply-line spikes. Both problems can be eliminated with relative ease provided one is aware of the low breakdown voltages in semiconductors. Although this series of articles is on digital techniques, the same problems affect analog circuits.

Those trained in vacuum tube circuits understand the shock hazard to the worker. For most semiconductor circuits, the worker is the shock hazard! The *designer may be the hazard* by neglecting primary power source characteristics.

static electricity

A recent computer supply catalog stated, "A 7-second stroll across a carpet can generate 10,000 volts . . . ." The generated charge will vary widely with humidity and clothing, but a few hundred volts of static electricity discharged through a semiconductor can be a disaster. High-dielectric-constant fibers (polyester, nylon, acetate) can generate high-potential charges from friction.

The solution to the problem is to spread the charge across your working area to reduce both voltage and current through any device. The best practice is to *ground everything*, including yourself.

Several readers will now say, "Nonsense, I've been working with this stuff for years with no problems . . ." True enough, *most* of the time. The average experimenter will be working in comfortable clothes (older, probably cotton and including a bit of perspiration) on a less-than-clean work area (lossy dielectric) and during medium to high relative humidity. Static generation under these conditions is slight and dissipates well.

By Leonard H. Anderson, 10048 Lanark Street, Sun Valley, California 91352

Now try working in clean, polyester clothing on a clean plastic worktop while sitting on a plastic-fiber pad. In a dry atmosphere, just sliding off the pad will let you draw a quarter-inch arc to a metal object. A similar example is familiar to drivers in the north — sliding off seat covers will give an audible zap on touching a metal door handle.

setting up a better work area

My assembly work is done on a large, grounded aluminum plate taped to the bench top. An unpainted chassis cover plate is suitable. The building codes in my area require metal conduit for all ac power distribution. The conduit is grounded to both soil and water pipes. Each of my soldering irons is a *three-wire, grounded* type, and all test equipment has a ground strap to the work plate. **Fig. 1** gives a general idea of the workbench area.

Grounding test equipment may seem unnecessary until one checks ac leakage between units using a multimeter; some leakage can destroy CMOS devices. In non-conduit ac distribution installations, the ground wire connection should be checked on outlets; old, two-wire systems should have an extra ground line.*

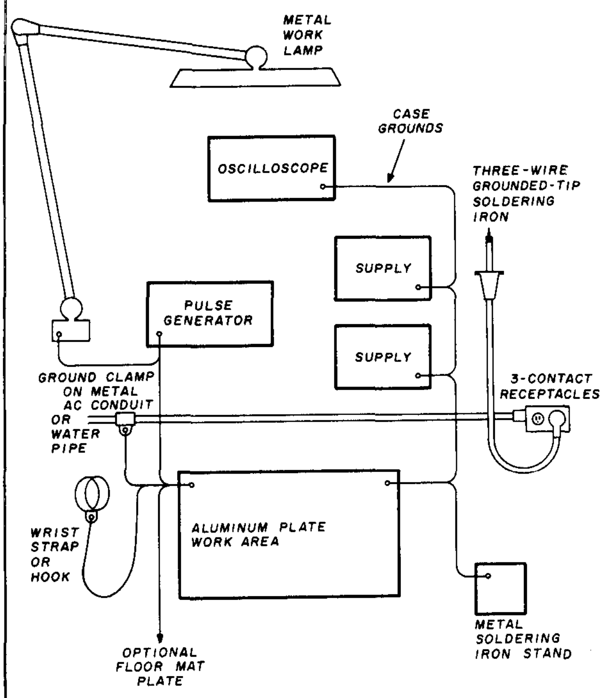


fig. 1. Layout and grounding of a static-free work area. Ground should be common to workshop's ac ground. Wrist strap and anti-static floor mat are optional.

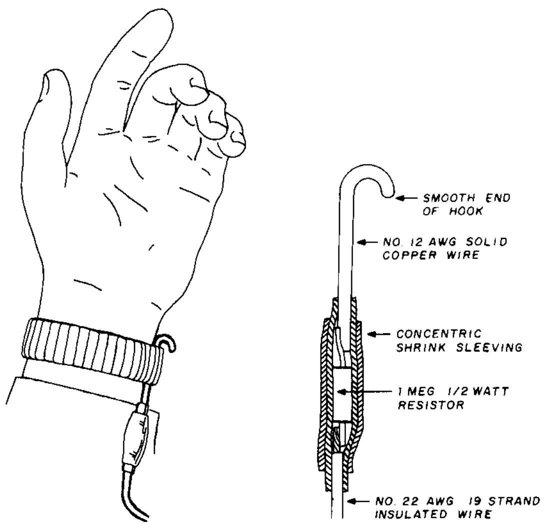


fig. 2. Wristwatch-band grounding hook used by the author. Insulated grounding wire is connected to work-area ground.

Anti-static plastic mats and storage containers are useful and can be obtained from suppliers given in the appendixes. The important point for static suppression is to provide a common charge collection point in body-movement areas.

ground yourself

Frequent touching of the common ground point is necessary to bleed off body charges. An alternative is to use a *high-impedance* wrist strap. High impedance is essential to prevent static charges from entering powered-up equipment. One megohm is a good value for 117-volt ac lines or 2.2 megohms for 220-volt ac lines.

I use a wristwatch-band hook as shown in **fig. 2.** The hook, which is made from a piece of No. 12 AWG solid copper wire, has an inside diameter about twice the watch-band thickness. Shrink sleeving encloses the nineteen-strand ground wire (multi-strand for safety) and the 1-megohm resistor. A banana plug and jack are used as a quick-disconnect to save the watch in case you forget about the hook being attached.

If neither is acceptable, try to wear natural-fiber clothes and use a metal bench stool. Experiment during low humidity for the least static charge buildup.

keeping components safe

Unmounted devices should be placed in black, *conductive* foam, whose resistance should be a few kilohms per inch. *Never* use nonconductive foam. Anti-static foam is acceptable for mailing; however, conductive foam is preferred over surface-treated nonconductive foam. Conductive foam is sometimes available at local electronics stores.* Antenna and microwave specialists can obtain scraps of Emerson and Cuming Eccosorb™ foam; most types are conductive.

Anti-static bins, envelopes, and plastic dual-inline carriers provide good protection for devices. The containers should be grounded when inserting or removing devices. Anti-static coating may be destroyed after repeated handling. Aluminum foil is unwieldy to use but is effective.

power-line spikes and transients

Power source input protection seems to be neglected by many experimenters and professionals. Transients from power lines seldom affect vacuum-tube power supplies but can damage or couple through solid-state supplies. The difference lies in breakdown voltage ratings of supplies and the source potential. Alternating current power lines can have transient peaks of 6 kilovolts; automobile battery lines can have 300-volt peaks.

General Electric's *Transient Voltage Suppression Manual*[1] contains much useful data on power-source transients. The main cause of transient generation is switch opening and closing in circuits containing transformer, motor, or solenoid inductances. **Table 1** is a listing of peak ac line spike voltages in the United States. On 220-volt ac lines these spikes can reach 10-kilovolt peaks.

Power-line radio frequency interference (RFI) filters can't handle most of the transients since their milliseconds duration puts spike power below cutoff. Automotive alternator field decay (ignition turn-off) can

table 1. Frequency of occurrence of ac power-line transient peaks in the United States. The data was interpreted from reference 1 and is a composite of industrial and residential service.

transient peak (kV)	number of transient occurrences per year
0.4	4000
0.6	800
1.0	150
2.0	30
3.0	9
4.0	3
5.0	1
6.0	0.4

*This safety measure should also be used with your rig or heavy appliances.

*I have yet to find a source that sells to individuals. Readers are invited to let *ham radio* know if such a source exists so that all can benefit.

peak to 300 volts over a 0.2-second duration.

One of the best protectors is the voltage-variable resistor, or *varistor*. A varistor is voltage-bipolar with a high impedance below breakdown voltage. Resistance is inversely proportional to applied voltage above breakdown. The General Electric GE-MOV™ metal oxide varistor and General Semiconductors' TranZorb™ devices work very well at *nanosecond* speeds.[2]

High voltage zeners and series blocking diodes are generally too slow or, if fast, too expensive.

protection with easy installation

Outlet strips or plugs are available with both electromagnetic interference (EMI) filtering and surge suppression. Their cost ranges from $10 to $20 an outlet. A list of advertisers is given in the appendixes.

Specifications should be checked carefully for your particular application. Surge ratings are generally given in joules (watt-seconds) and apply *only* to the transient; the ratings for the filter, outlet, and breaker (if any) are only for normal loads.

If in doubt of surge values at your location, set up a resistive divider on the power line and use an oscilloscope to check the line with the oscilloscope's internal sweep trigger set above normal peak. Operate as many appliances as possible and watch the trace. Include everything: furnace (igniter and blower), air conditioner, washer, garage door controller, kitchen appliances, and your shop's own equipment. The best time to check the line is when the power company is switching its own load peaks; other users can contribute spikes.

You can expect transients in the 50 to 100 microsecond range on ac lines. As a rule of thumb, a joule (watt-second) rating can be peak voltage squared, divided by normal equivalent load resistance, then multiplied by time duration of the transient. A safer margin is to multiply peak voltage by outlet current rating by duration.

Fuses will never protect against transients. They are much too slow.

unexpected transient sources

Distributing capacitance in digital circuit boards is very good for the circuits. The supply regulator can be reverse-biased and damaged if the regulator's input voltage drops sooner than the voltage on the load side. A very simple cure is the reverse diode recommended by National Semiconductor in **fig. 3.**[3]

Transients caused by a solenoid or relay driver can be suppressed by the reverse diode shown in **fig. 4.** Upon current cutoff, the inductor's magnetic field collapses and generates a black EMF or reverse voltage up to thirty times normal holding voltage. A diode or varistor can dissipate the flyback voltage and allow the use of a relay driver with a lower breakdown voltage.[4]

The regulator protector *must* be a diode and both circuits must observe diode polarity. A varistor is voltage bipolar.

Any reactive circuit drive by on-off digital circuits is a potential peak voltage danger to the circuit. It is helpful to go back to the first pages of handbooks and review the step-function voltages and currents.

conclusion

Semiconductors are low-voltage devices. Static electricity is a problem but can be reduced to safe potentials. Some old-timers might have to change workbench habits. Supply-line transients exist but can be cured by varistor surge protectors. A circuit can generate its own transients when reactances are present. These problems and solutions apply to both analog and digital circuits.

references

1. *Transient Voltage Suppression Manual*, second edition, 1978, General Electric Company, West Genesee Street, Auburn, New York 13201. Still

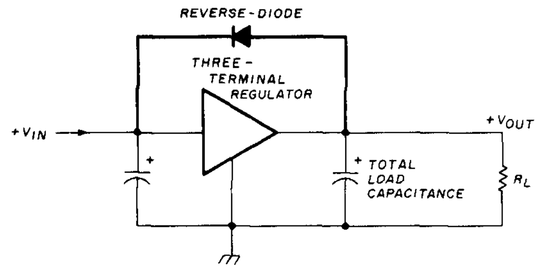


fig. 3. Reverse diode added to protect three-terminal regulators from reverse bias on turn off.

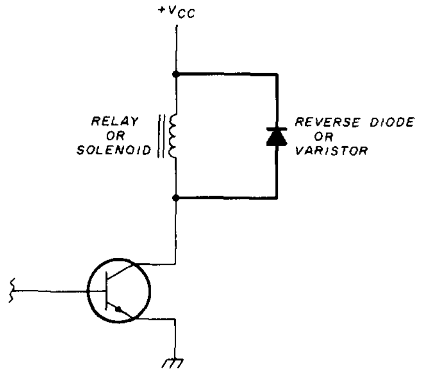


fig. 4. Reverse diode added to inductor to clip flyback voltage. Varistor can substitute for a diode but the diode's polarity must be the reverse of normal operating polarity.

available from representatives and distributors, it is well written and useful. Some data sheets on varistors are included.

2. General Semiconductor Industries, Incorporated, 2001 W. 10 Place, Tempe, Arizona 85281. Individual *TranZorb*™ data sheets are available from distributors.

3. National Semiconductor Corporation, Santa Clara, California. Either *Voltage Regulator Handbook* or *Linear Databook*, 1978.

4. William J. Prudhomme, WB5DEP, "Protecting Solid-State Devices From Voltage Transients," *ham radio*, June, 1978, pages 74-76.

appendix 1

computer supply distributors listing anti-static materials in mailed catalogs

Fidelity Products Company 5601 International Parkway P.O. Box 155 Minneapolis, Minnesota 55440	Plastic bags, mailers, work surfaces, covers, anti-static mats, aerosol spray, and surge suppressor ac outlets
INMAC 2465 Augustine Drive Santa Clara, California 95051	Anti-static mats, aerosol spray, and surge suppressor ac outlets
UARCO Computer Supplies 121 North Ninth Street DeKalb, Illinois 60115	Anti-static mats and bags
MISCO Inc. Box 399 Holmdel, New Jersey 07733	Anti-static mats, boxes, aerosol spray, and ac surge suppressors

Note: Aerosol sprays are intended for containers, furniture, and clothing. Effect on components is unknown.

appendix 2

manufacturers of surge suppressors advertising in magazines

R.L. Drake Company 540 Richard Street Miamisburg, Ohio 45342	Dymark Industries, Inc. 7133 Rutherford Road Baltimore, Maryland 21207
Electronic Specialists, Inc. 171 South Main Street Natick, Massachusetts 01760	Kalglo Electronics Co., Inc. Colony Drive Industrial Park 6584 Ruch Road Bethlehem, Pennsylvania 18017
Isobar™ GSC Electronic Corporation 25 Main Street Champlain, New York 12919	Sun Research, Inc. Box 210 New Durham, New Hampshire 03855 (dc-ac converter, used as uninterruptible power supply)
Powermaster™ SGS Waber Electric* 300 Harvard Avenue Westville, New Jersey 08093	MFJ Enterprises, Inc. Box 494 Mississippi State, MS 39762

The Newark Electronics 1981 catalog lists the following manufacturers:

GS Sola Electric	line voltage regulators
Superior Electric	Stabiline™ automatic voltage controllers
Adtech	CLIP-AC™ voltage clipper (10-50 microsecond response)

*Listed SGS Waber power outlets are convenience types only.

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A number of schemes for using 75-ohm CATV hardline in Amateur 50-ohm systems have been published. These foam dielectric solid-shield cables have loss so low they are extremely attractive to the VHF operator, where tower heights call for long cable runs and every dB counts. I obtained a 200-foot length of cable and ran into some interesting problems when integrating it into my system.

A non-synchronous transformer[1] for six meters worked very well, but when line lengths were calculated for the higher bands, the line lengths (0.08 wavelength) became very short. Since a small length error could cause a large impedance difference, any possibility of using a coaxial switch as part of the 50-ohm system was ruled out. Simple L-C networks weren't the answer because some of the capacitor sizes necessary for such low impedance transformations turned out to be unwieldy. A quick calculation of the textbook classic[2] single-stub tuner showed that not only would the line lengths be long enough to be non-critical, but a coaxial switch could be incorporated into the network as a piece of the 50-ohm line, allowing band-switching for a single line.

The principle of the single-stub tuner is that for a

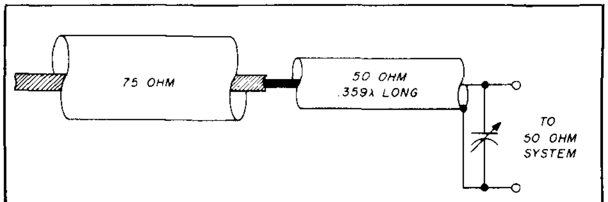

fig. 1. One-band 50- to 75-ohm match.

By Lewis T. Fitch, W4VRV, 109 Robin Street, Clemson, South Carolina 29631

mismatched load a pair of points exist at two distances from the load where the real part of the input admittance is a match to the line. The capacitive or inductive part of the load at that point can be cancelled. Admittance is used for this calculation because on coaxial systems the parallel configuration is easiest to realize. This tuner gives a good match over a ±5 percent bandwidth, so once it is set it will

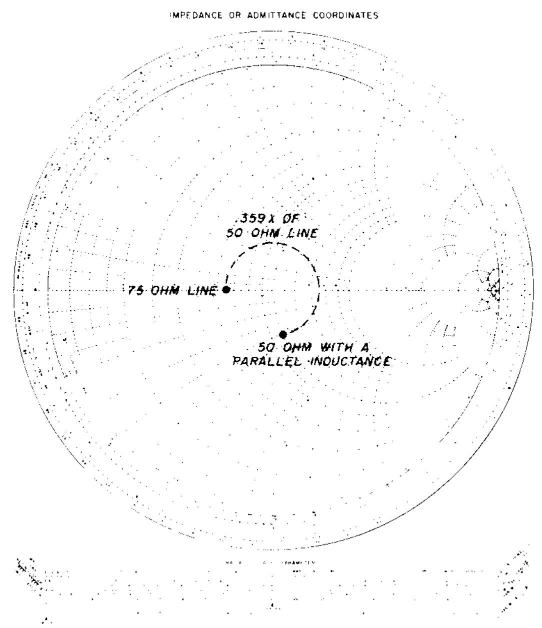

fig. 2. Impedance or admittance coordinates.

match over the used portions of the VHF and UHF bands without adjustment.

The admittance cancelling stub is usually described in textbooks as made from a piece of transmission line. A real stub made from transmission line does not allow much adjustment. The stub only serves as a capacitor or inductor, so a variable capacitance could be used and could be adjusted to compensate for minor discrepancies elsewhere in the system. This form does not show up in the textbooks because it does not illustrate a pure transmission line problem, but its electrical operation is identical. Since a capacitor is used for the shunting element, the transforming line should be chosen to present a parallel inductive term at the matched resistance point. This one-band matching system is shown in **fig. 1**.

Calculating the actual lengths to do this on the Smith Chart (**fig. 2**), the 75-ohm line is entered as a conductance of $50/75 = 0.66$ on the 50-ohm transforming section. It can then be seen that if the 50-ohm line is 0.359 wavelength long, the input admittance at that point is $(1 - j0.4) \times (20 \text{ millimhos})$. The 1 represents the resistive match and $-j0.4$ represents the part to be tuned out. A capacitor of $C = 0.008/2\pi f$ will do this, where f is in MHz and C in microfarads. The physical length of the line depends on its dielectric, so the best way to set its length is to grid dip it to a 1/4 wavelength resonance at the frequency that corresponds to the 0.359 wavelength found above (the results are shown in **table 1**).

If the capacitor installed is variable with a higher

table 1. Smith Chart calculations.

frequency	length of RG-8/U (solid polyethlene dielectric)* inches	¼ λ resonance (all cables) MHz	C in pF
28	100 (2.53 m)	19.48	45.4
50	56 (1.42 m)	34.80	25.4
146	19-1/8 (0.486 m)	101.60	8.7
222	12-5/8 (32 cm)	154.00	5.7
432	6-1/2 (16.5 cm)	302.00	2.9

*Foam dielectric cables will be longer.

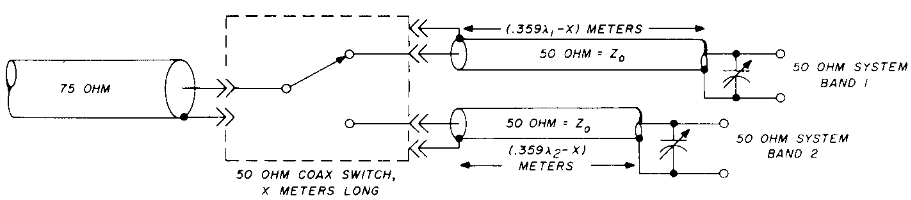

fig. 3. A multi-band system.

The six meter 75- to 50-ohm impedance converter.

capacitance than called for, some trimming may be done to compensate for small errors elsewhere in the system. In the device I finally constructed, a small mini-box was used to mount both the capacitor and the coaxial connections. The photo shows the finished 6-meter transformer.

Since the 50-ohm line connects directly to the 75-ohm line, a 50-ohm coaxial relay can be used as part of the matching system, and its length subtracted (or the tuning corrected for) from the line length listed.

Fig. 3 shows the 2-band connection with a relay. The length of line the relay replaces is shown as X.

Probably the best way to determine X would be to include the relay (switched to the desired position) in the grid-dipping operation. The frequencies in **table 1** are the same, but the line length will now include the relay length.

At the point where the capacitor is connected, the VSWR is 1:1, so the voltage across the capacitor is the voltage across a 50-ohm line. For a full rms kilowatt input to the system, the capacitor voltage at peak is 333 volts. A receiving-type capacitor could be used for most Amateur installations. The voltage at the point of connection to the 75-ohm line is 1.5 times that value, still not beyond the rating of RG-8. Two of these systems, constructed and put into use during the last year, work well. One is in an Amateur installation where the match to the antenna is a non-synchronous transformer at the top of the tower, and the other is in an fm broadcast installation where a solid-state amplifier required a very good 50-ohm match. In each case, the final value of VSWR could be adjusted to less than 1.05 to 1.

references

1. Charles J. Carroll, K1XX, *ham radio*, September, 1978, p. 31.
2. *Lines, Waves and Antennas*, Browne, Sharpe, Hughes and Post, Wiley Publishing Company.

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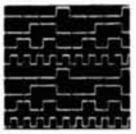

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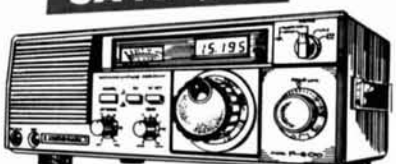

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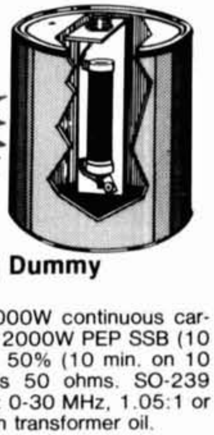

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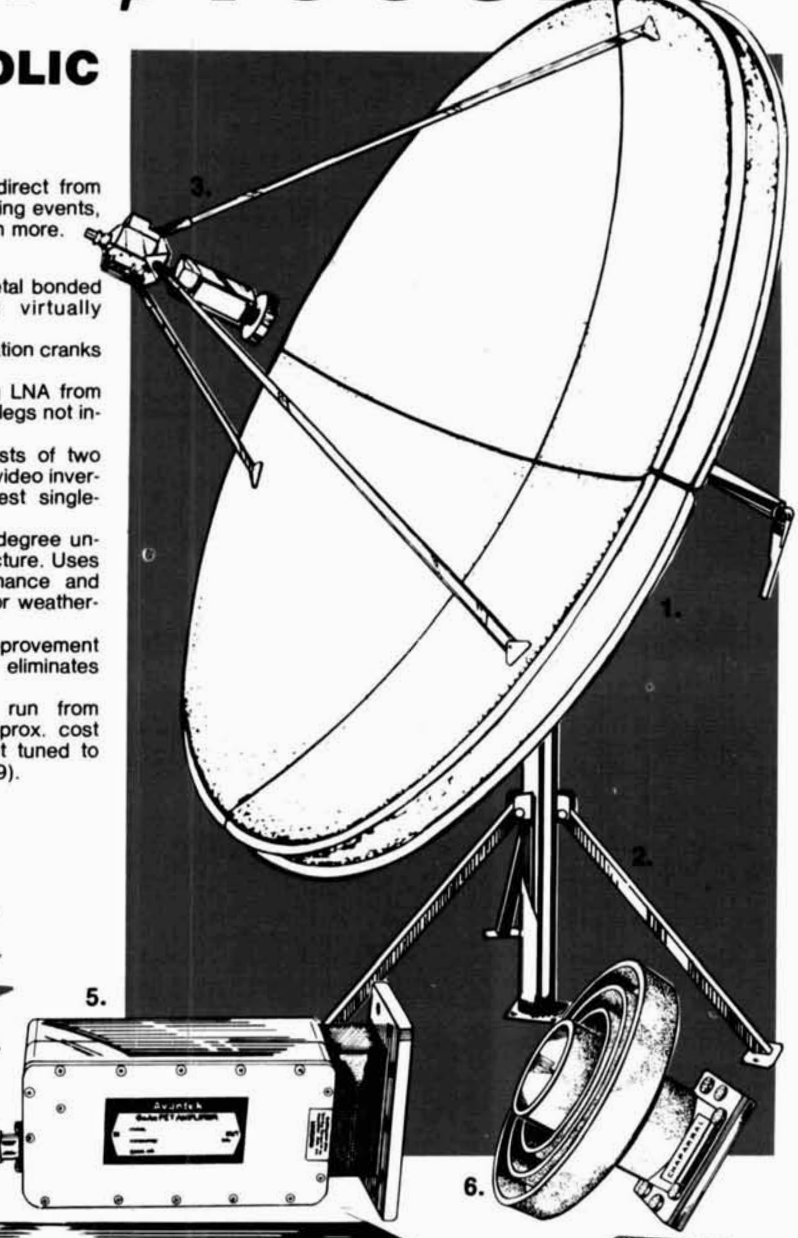

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bridged-T filters
for Amateur use

Design data for
a versatile circuit

Notch and peaking filters are useful in many Amateur applications. You may, for example, notch out 60-Hz or 120-Hz hum, peak up a particular CW note, notch out an undesired signal in a 455-kHz i-f stage, furnish additional rf preselection in multi-transmitter contest stations or where strong locals operating on other bands are bothersome, and reduce harmonics and TVI.

The bridged-T filter is a particularly nice filter choice. Unlike the T and pi, it shares a constant image impedance at all frequencies with the lattice. Also, it is unbalanced to ground and can therefore be used in coaxial-line and other grounded circuits. Finally, it has fewer components than other types. The response, maximum attenuation, and other factors (except image impedance) of the bridged-T are comparable with other filter types.

standard design relationships

Design relationships for bridged-T filters are well known, and published in many texts (see, for example, references 1, 2, and 3). These relationships, however, usually assume that you are looking for a prescribed attenuation characteristic, and they give the impression that the design is always physically possible. For example, in the circuits shown in **fig. 1**, values for resistors R1 and R2 might be impossible to achieve with inductances of finite Q.

These standard design relationships are not especially convenient when you have some inductances and capacitors available and wish to construct a filter from them. In such a case you might be willing to accept whatever attenuation you can get and use whatever image impedance is necessary.

using inductance Q

It is simpler to structure the relationships by basing them on the Q of the available inductances, as has been done in **fig. 1**. Q is the one characteristic of inductance more easily measured than any other. It is also convenient to make the inductances equal to each other, which also makes the capacitors equal to each other. While there is a slight advantage in response sharpness when the inductances are not equal, this is more than offset by the problem of finding odd-sized components.

When you proceed in this way, you need find only a *single value* of L and a *single value* of C. Also, with equal inductances, the attenuation of the filter simplifies greatly, and the maximum rejection, as well as the sharpness, is entirely dependent on the Q of the coils. Also, a lot of calculation is not necessary; finding the component values is a simple matter of proportional multiplication, which can be done on any four-function calculator.

table 1. Equal-L and equal-C values illustration.

f_r	R_o (ohms)	L	C
60 Hz	100	0.265 H	26.530 μF
120 Hz	100	0.133 H	13.270 μF
400 Hz	100	40 mH	3.979 μF
500 Hz	100	32 mH	3.183 μF
1000 Hz	100	16 mH	1.592 μF
455 kHz	100	0.035 mH	3497.9 pF
455 kHz	1000	0.350 mH	349.8 pF

To illustrate, the equal-L, equal-C case has L and C values for some representative frequencies as shown in **table 1**. As we double the frequency from 500 to 1000 Hz, the value of L is halved, as is the value of C.

By **R.W. Johnson, W6MUR,** 2820 Grant Street, Concord, California 94520

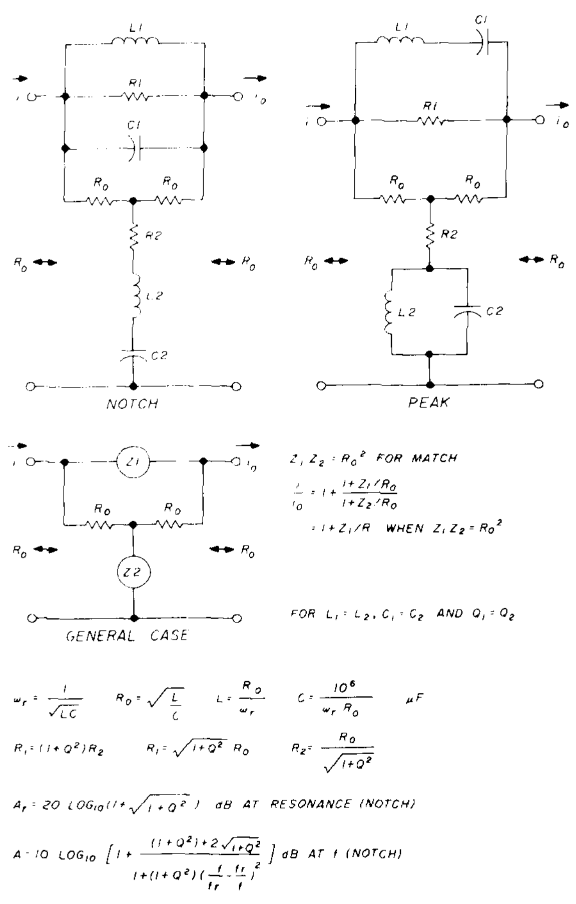


fig. 1. Basic bridged-T circuits and their relationships.

If we raise the image impedance R_0 ten times, the value of L goes up ten times, but the value of C is reduced to one-tenth. To go to 500 Hz from 400 Hz, multiply *40 × (400/500)* to get 32 mH for L, and do the same with $C(3.979 \times 400/500 = 3.183\ \mu F)$.

Say you have two fairly high-Q 88-mH toroids and want to construct a 500-Hz peak or notch filter. What R_0 must be used? For $R_0 = 100$ *ohms*, $L = 32$ *mH*: simply multiply $100 \times (88/32) = 275$ *ohms*, and this is the R_0 you would have to settle for. C becomes $3.183 \times (32/88) = 1.57\ \mu F$.

The maximum attenuation of a notch filter at resonance, or a peaking filter far from resonance, is dependent on the Q, as is the sharpness, in the equal-L, equal-C case. The relationship is simple:

$$A_r = 20 \log_{10} (1 + \sqrt{1 + Q^2})\ dB \qquad (1)$$

A plot for this is shown in **fig. 2** (lower curve). If your coils have a Q of 100, you can expect rejection notches no deeper than 40 dB. If you are stuck with a Q of 5, only 15.7 dB is possible, and you might as well not use a filter! If you need 60 dB, you will need a Q of 1000 with a single filter, which is mighty hard to find!

impedance considerations

The constant image impedance of these bridged-T filters means they can be cascaded or placed in tandem, even if they are tuned to different frequencies. When terminated in R_0, the input impedance of the filter is R_0 at all frequencies, provided that the product of Z_1 (the bridging impedance) and Z_2 (the shunt impedance) is equal to R_0^2 and is independent of frequency. This is why one impedance is the dual of the other, one being series resonant at f_r and the other anti-resonant at f_r. The square root of the product of the two impedances is a pure resistance for reasonably high Q (if Q = 5 or more).

The same component values apply for peaking filters. Only the connections change, as shown in **fig. 1**. The attenuation curves for the same Q are upside-down mirror images of each other. A_r in **fig. 2** is now the maximum attenuation that is obtained at zero and infinite frequency. Remember that peaking is actually a misnomer because the filter has no gain; it simply rejects frequencies away from resonance. There is a very slight insertion loss due to the finite Q of the coils, and some energy must be lost heating up these resistors. This loss is less than 1 dB for Q = 10, however.

notch-filter example

A notch filter for 50-ohm receive antenna lines is shown in **fig. 3**. Since Qs of 200 or so can be obtained without too much difficulty, it is clear that some 46 dB of attenuation at the notch can be obtained. If you need more, use higher Q coils or tandem more than one filter. The filter in **fig. 3** is intended for use in multi-transmitter contest stations, to reject signals from another band that might be bothersome.

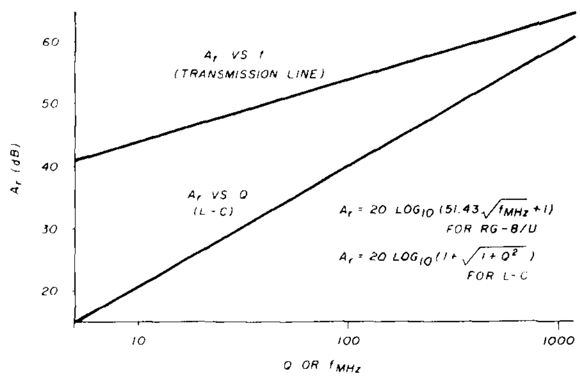
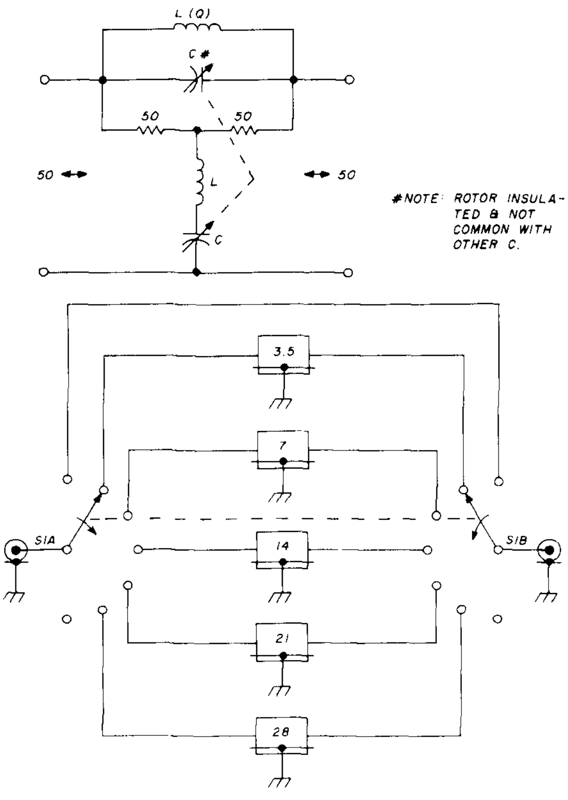


fig. 2. Maximum attenuation of notch filters.



BAND (MHz)	L (μH)	C_{max} (pF)
3.5	2.27	910
7	1.14	460
14	0.57	250
21	0.38	160
28	0.28	120

fig. 3. Receive antenna line (50-ohm) notch filter for QRM from another band.

Although the capacitors in **fig. 3** are shown ganged, a better notch might be obtained by making them independently variable, or at least using a trimmer across one or both. Practical coils will not be identical, and their proximity to shields, etc., may cause them to be different even if they seem the same. Since the rotors of the two capacitors are not common (and only one is grounded), separating them is easy.

Don't try to use this filter for notching on the same band (for example, between CW and SSB segments), except possibly on 3.5 MHz. To notch on the same band, you need crystal filters, not discussed in this article.

You can get an idea of the sharpness of these bridged-T notch filters by noting the f/f_r for attenuation of half as many *dB* as A_r (see **table 2**). If you tried to use the filter between 3.5 and 3.8 MHz, for example, $3.8/3.5 = 1.0857$ and you would still have 15.85 dB of attenuation at the desired frequency with $Q = 100$. For other bands the situation is much worse (14.0 to 14.1 MHz, for example, even with $Q = 1000$ gives 36.9 dB loss at the desired frequency).

Watch the leakage and mutual coupling between coils; keep leads short and stray capacitance down; and shield the filter. Remember that no rejection filter is going to help if there is rf due to high VSWR on antenna feedlines, poor grounding and shielding, parasitics, and so on. These filters won't help the harmonics generated by nearby transmitters in a receive line either, although they will help those generated in the higher-band receiver due to overload.

transmission-line filters

One application for bridged-T filters seems to have escaped much attention. If the impedances Z_1 and Z_2 in **fig. 1** are transmission lines, each of the same electrical length, one shorted and one open, then the required condition of duality between the two impedances is obtained as long as the lines have reasonably high Q. Suppose, for example, that we use a shorted line for the bridging impedance, Z_1, and an open line of the same length for the shunt impedance, Z_2. Then, assuming infinite Q of the lines (no losses),

$$\begin{aligned} Z_1 &= j Z_{01} \tan\theta \\ Z_2 &= -j Z_{02}/\tan\theta \end{aligned} \qquad (2)$$

so that $Z_1 Z_2 = Z_{01} Z_{02} = R_0^2$ is the condition for input impedance, being R_0 when the filter is terminated in R_0, and this condition is independent of frequency. The response of the filter is given by the simple relationship

$$A = \log_{10}\left[1 + (kT)^2\right] \qquad (3)$$

where $Z_{01} = kZ_0$, $Z_{02} = Z_0/k$, $Z_0 = R_0$, and $T = \tan\theta$; θ being the electrical length of each equal-length line, for $k = 1$, $Z_0 = R_0$ in both lines. If the lines are a quarter wave long ($\theta = 90$ *degrees*) **eq. 3** would in-

table 2. Sharpness table.

Q	f/f_r (A_r, .2)*
5	1.27107
10	1.17897
20	1.12102
50	1.07395
70	1.06199
100	1.05151
150	1.04180
200	1.03607
300	1.02933
500	1.02263
1000	1.01594

*Also the reciprocal of this.

dicate infinite attenuation in the notch filter. This is actually not the case, as will be seen.

The maximum attenuation of a notch filter using quarter-wave lines is also related to the Q of the lines, but how we define this is important. Z_0 is no longer a pure resistance with a lossy line, but is complex. Also, the hyperbolic/exponential instead of the trigonometric functions must be used, and the argument in these is also complex. This gets somewhat messy analytically, but since we are really interested in the maximum attenuation of a notch filter at resonance (and at its odd harmonics), we can draw on Dr. Terman for the answer. Reference 3, page 191, eq. 66 gives the resonant impedance (resistance) of a shorted copper coaxial line that is an odd number (n) of quarter waves long. The equation takes into account the loss resistance of the line, but assumes air insulation (no dielectric loss). Applying this to 50-ohm, RG-8/U foam line, one obtains the simple result for the bridged-T notch filter (shown in **fig. 4**).

$$A_r = 20 \log_{10} (51.43 \sqrt{f_{MHz}} + 1) \qquad \textbf{(4)}$$

A plot of A_r versus frequency (not Q, but same scale as Q) is given as the upper curve in **fig. 2**. The attenuation would be less for, say, RG-58/U, more for 75-ohm cable (requiring a 75-ohm image impedance), and more for larger diameter lines.

The transmission-line notch filter does one thing no ordinary lumped-constant filter does. It acts as a notch filter at all odd harmonics, and a pass filter at all even harmonics. Conversely, a pass filter at f will become a notch filter at 2f, 4f, 6f, etc., and a pass filter at 3f, 5f, 7f, etc. Although the Q of a given electrical line length increases with the square-root of frequency, the depth of the notch does not, because the additional resistance of the longer line (in wavelengths) enters into the picture and the resonant impedance is actually inversely proportional to n, as can be seen from Terman's eq. 66 (see above). Some typical maximum attenuation figures in dB for the harmonics up to 1000 MHz in a notch filter using RG-8/U are given in **table 3**. The list is cut off above 1000 MHz because other errors, such as dielectric loss, imperfect shorts, lossy connectors, and so on, affect the results.

These transmission-line bridged-T filters would be useful to filter harmonics out of a transmitter. A pass filter (Z_1 being an open $\lambda/4$ line and Z_2 a shorted $\lambda/4$ line at the fundamental f_r) would pass f_r but stop all even harmonics, and pass (but not amplify) all odd harmonics. Placing it in tandem with another pass filter tuned to 1.5f would notch out 3f, 6f, 9f, etc., and produce an insertion loss at f of only about 3 dB. In this particular arrangement 5f, 7f, 11f, and 13f are missed, but other filters can be devised to catch these.

table 3. Typical attenation figures for notch-filtered harmonics

n (order of harmonic)	50	75	100	150	250	500
	f (fundamental, MHz) attenuation (dB)					
1	51.2	53.0	54.2	56.0	58.2	61.2
3	46.5	48.2	49.5	51.2	53.5	
5	44.3	46.0	47.3	49.0		
7	42.8	44.6	45.8	47.6		
9	41.7	43.5	44.7			
11	40.9	42.6	43.9			
13	40.2	41.9				
15	39.5					
17	39.0					
19	38.5					

Even at 14 MHz a $\lambda/4$ coaxial line with $v_p = 0.66$ is only about 11 feet 7 inches long. Is your TVI worth 23 feet of coax?

The shield of the coax comprising Z_1 must float, creating problems at higher frequencies. One cure is to place the coax in a pipe of the same length, which has an inside diameter 2.3031 times the outside diameter of the Z_1 coax shield, as shown in **fig. 4**. This makes the shield the center conductor in a 50-ohm coax and solves the problem of the floating shield. Another solution is to make $k = 2$ and use two coax cables in series in a balanced configuration for Z_1, so that $Z_{01} = 100\ ohms$. Then, since the product $Z_{01}Z_{02}$ must be 50^2 or 2500, Z_{02} must be two coax cables in parallel for $Z_{02} = 25\ ohms$. Then the rf is confined to the inside of the shield in Z_1. This arrangement actually gives a bit higher attenuation as can be seen from **eq. 3** for electrical lengths close to 90 degrees.

Even these filters are not sharp enough for in-band rejection. Lest you be tempted to use one in a repeater with 0.6-MHz frequency separation at 146 MHz, for example, you would find you still had over 44 dB of attenuation at the receive frequency! To

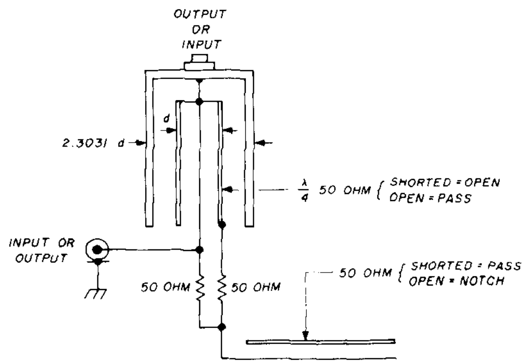


fig. 4. Coaxial line bridged-T filter.

reduce the insertion loss to 10 dB, even with lossless lines, you need about 25 percent frequency separation, for equal Z_0's.

For balanced 300-ohm circuits you would be better using the lattice equivalent of this filter. The text listed in reference 1 can provide details.

You will find that some line tweaking is required, using some sort of line stretcher or plunger tuning, to get the best null. A notch filter I assembled made of a piece of Andrew semi-flexible polyfoam line inside a piece of 1-inch copper plumbing pipe for Z_1 exhibited only about 35 dB of attenuation at 50 MHz when it should have been 51 dB or more. Displayed on a spectrum analyzer having peak hold and memory capability as a signal generator, slowly tuning across the band to 1000 MHz (keeping generator output voltage constant) showed the same multiple notches at odd harmonics that one would expect, and the same gradual lessening of the depth of the notch as frequency increased. With more precise tuning of Z_2 using a General Radio line stretcher, I was able to reach attenuation over 50 dB at the fundamental.

When you use these filters to notch out any appreciable energy, remember that at resonance Z_1 looks like essentially an open circuit and Z_2 like a short circuit. The input resistor R_0 therefore must dissipate all the energy to be rejected. If the harmonic to be rejected is only 30 dB down in a 2 kW transmitter (which is why you need the filter in the first place), you have about 2 watts of harmonic energy for 2 kW output. To play safe, even with 1 kW input and 60-dB harmonic attenuation in a good Pi-L output network, for example, use 2-watt resistors for R_0. Make sure they are carbon, non-inductive, and preferably 5 percent (51 ohms) or selected from available 56-ohm or 47-ohm 10 percent units. The shunt line Z_2 must withstand the rf voltage across a 50-ohm line at the fundamental, so it should be able to take at least 300 volts rms of rf. You could even use RG-223/U (better shielded than RG-58/U) for this impedance, although the loss will be higher than with RG-8/U or something better.

Bridged-T notch and peak filters are easy to design and highly useful around the Amateur station. Just remember to use as high a Q as you can if you want good rejection, and follow good construction practice when you build the circuits.

references

1. Landee, Davis and Albrecht, *Electronic Designers' Handbook*, McGraw-Hill, 1957, pages 17-7 through 17-14.
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3. F.E. Terman, *Radio Engineers' Handbook*, McGraw-Hill, first edition, 1943, page 191.

ham radio

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operation upgrade: part 10

The tenth part in a continuing series designed to help you upgrade your ticket

This, our tenth article in the series to help you better understand the FCC license test questions, continues the discussions on antennas begun in Part 9. This in turn followed the basics of radiotelegraph transmitters and receivers, power supplies, active devices, ac circuits and dc circuits.

After basic information on wave travel, half-wavelength ($\lambda/2$) dipoles and $\lambda/4$ verticals, open-wire and coaxial transmission lines were considered, and an SWR meter was described. This month we will discuss some other basic antennas used by Amateurs, and which may form the basis of FCC license questions.

multiple-wire folded dipoles

The bandwidth of a 7-MHz-band dipole is not too broad. If your transmitter is tuned to the center of the band, 7.15 MHz, and the feed line SWR is 1:1, you may find the SWR at the band edges, 7 and 7.3 MHz, to be between 1:2 and 1:3. This indicates less power is being radiated at these band-edge frequencies. An

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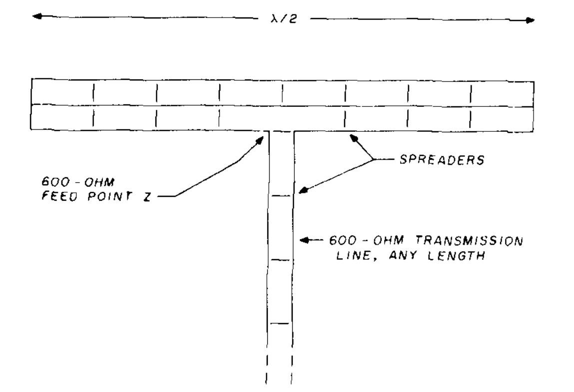


fig. 1. A three-wire folded dipole increases center feed point impedance nine times.

improved bandwidth will result from using an open-wire transmission line, $\lambda/2$ long and shorted together at the ends, as the radiating antenna element. If one of the two wires of such a folded dipole antenna is opened in the middle and its radiation resistance is measured, it will be found to be about 288 ohms. The formula for determining this impedance is $Z_0 = 72n^2$, where n is the number of similar sized wires used in the radiating element. A commonly available TV 300-ohm twin lead transmission line matches 288 ohms closely enough so that the SWR will be close to 1:1 (actually 300/288, or 1:1.04). If the SWR is checked at the band edges with this folded dipole, it will be found to be two or three times better than with a single thin wire dipole. (The thicker the radiating element the broader the bandwidth of an antenna.)

If a folded dipole of this type uses three parallel wires shorted together at the ends, and only one of the wires is cut in the center (**fig. 1**), the impedance at the feed point will be $72(3^2)$, or 648 ohms. This will match a 600-ohm open-wire line closely enough to produce a nearly 1:1 SWR also (648/600, or 1:1.08). A folded dipole like this operates as a broadly tuned antenna for any Amateur band for which it is cut. The 9-to-1 increase in center impedance over a dipole can be useful in close-spaced-element beams where the center impedance may approach 8 ohms because of the proximity of the other elements. By using a three-wire folded dipole as the driven element, it's possible to feed it with an 8-ohm times 9, or 72-ohm transmission line for a nearly perfect impedance match. The "flat-top" wires of folded dipoles must be held at a constant spacing by using insulating spreaders, or spacers between wires every 4 to 6 feet (1.5 to 2 meters). The number of inches of spacing is not too critical. The same 648-ohm center impedance can be obtained using a two-wire folded dipole if the unbroken wire has twice the surface area of the wire being fed at its center (effectively two wires in parallel).

mobile and trap antennas

Amateur mobile equipment may be HF, VHF, or UHF, using fm, SSB, or CW. In essentially all cases the antenna will be a vertical steel whip, usually an electrical $\lambda/4$ for the HF bands. In all cases the metal chassis of the vehicle operates as ground.

For HF band operation the antenna is usually mounted on the left rear bumper, or in that vicinity. (Right-side mounting tends to hit too many objects. If mounted in front it impedes vision.) Since most highway departments limit the highest point on a vehicle to 13.5 feet (4.1 meters), a 40-meter vertical (which would be approximately 33 feet long) must be inductively loaded. Either the center of the vertical whip is cut and a loading coil is added there to make up for the missing antenna length, or a loading coil can be added at the base of the antenna. In addition, wires mounted at the top of the whip and radiating outward, called a capacitive hat, have the effect of capacitively loading the antenna to a lower resonant frequency. If the antenna is mounted 2 feet (0.6 meters) above the ground, the vertical whip will be limited to 11.5 feet (3.5 meters). The loading coil will have to have about 33 − 11.5, or 21.5 feet (6.5 meters) of wire in it (actually somewhat less, determined by experimental trimming while using an SWR meter in the transmission line). Shortened antennas of this type may reduce the feed point impedance to the 10-ohm range. Using a 50-ohm coax feed line will result in an SWR of about 1:5, which is intolerable.

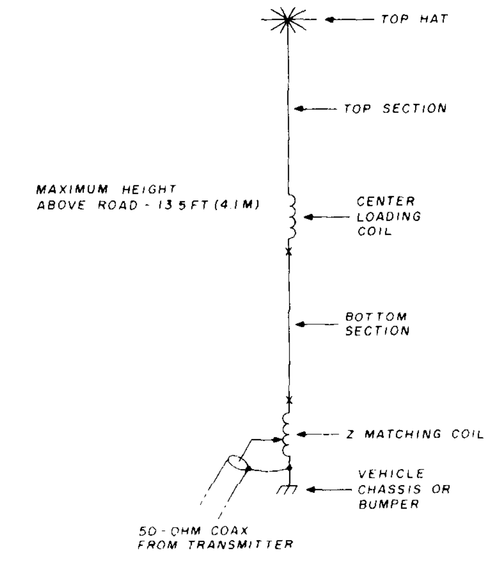


fig. 2. HF mobile whip antenna. Springs may be mounted at either point marked with an X.

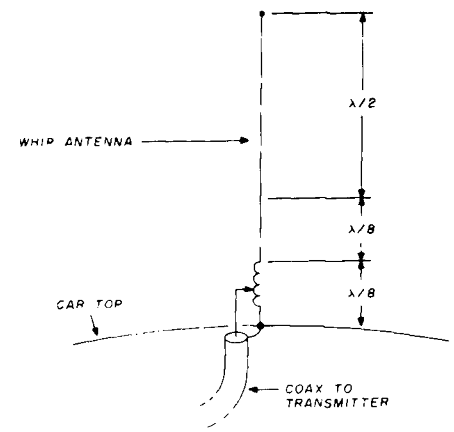


fig. 3. A 5/8-wavelength VHF/UHF mobile antenna.

Something must be done to match the feed line to the base impedance. One relatively simple and successful HF mobile antenna system is shown in **fig. 2**. The purpose of the five- to ten-turn impedance matching coil at the bottom is to allow you to find the 50-ohm point on the vertical antenna system to match the 50-ohm coaxial line. When the tap is set to the proper point the SWR will be at a minimum, assuming the loading coil also has the correct number of turns for the frequency to be used. A small capacitor inserted in the Z-match tap line may further reduce the SWR (the value is determined experimentally).

Mechanically, the loading coil must be strong enough to withstand the high wind pressures developed when the vehicle is in motion on a highway. The bottom of the lower section of the whip is fastened to a strong insulating mounting, usually on the rear bumper. The Z-match coil is connected between antenna bottom and the chassis. A stiff spring, shorted across by a copper braid, should be mounted at either of the points shown by an X in **fig. 2**. A bottom spring must be considerably stiffer than one mounted just below the center loading coil. The higher spring, being less stiff, permits the whip to strike objects with less force, and may change the tuning of the antenna less when the vehicle is in motion. When in motion, the antenna tilts backward and detunes somewhat.

In the VHF and UHF ranges the antenna may be a simple λ/4 vertical mounted in the center of the top of the vehicle, with coax fed from beneath the roof. Similar antennas may also be magnetically mounted on the top surface, with the coaxial cable running into the car through a window or door.

A popular mobile VHF/UHF antenna is the 5/8-wavelength (5λ/8) vertical. It is actually a 3λ/4 vertical, with the bottom λ/8 made up into a coil (see **fig. 3**). The proper matching impedance point for the coaxial impedance can be found by adjusting both the tap and whip length for minimum SWR. A 3λ/4 antenna of this type may also be fed directly by a 50-ohm coaxial line, with its braid or sheath connected to the car top and the inner conductor connected to the insulated bottom of the antenna.

The angle of maximum radiation of a λ/4 vertical is somewhat higher than that of the 5λ/8 antenna, resulting in a stronger signal being radiated parallel to the ground by the 5λ/8 antenna. A gain of about 2 dB over flat terrain may be expected from a 5λ/8 over a λ/4 antenna mounted on the same vehicle.

trap antennas

Trapped antennas are interesting devices. The antenna shown in **fig. 4** is a center-loaded type vertical antenna for the 7-MHz band. The loading coil is mounted at the point in the antenna which is the end of the λ/2 for the next higher Amateur band, 14 MHz. The coil acts as an rf choke at the higher frequency band, allowing the lower section to function as a vertical λ/4 at this higher frequency. A second coil can be added to make the antenna resonate on three different Amateur bands. If two of these trapped vertical antennas are mounted base to base and erected horizontally, the system will operate as two- or three-band horizontal dipoles. They may be fed by a 50-ohm coax line or a gamma match system (see next section).

beam antennas

The common horizontal λ/2 dipole radiates maximum energy at right angles to the line of the antenna wire, and zero energy off the ends of the wire. This can be indicated by the dashed circular lobes shown on the horizontal dipole in **fig. 5A**. The rays emanating from the center of the dipole indicate the relative strength of the radiated energy in the directions of the rays.

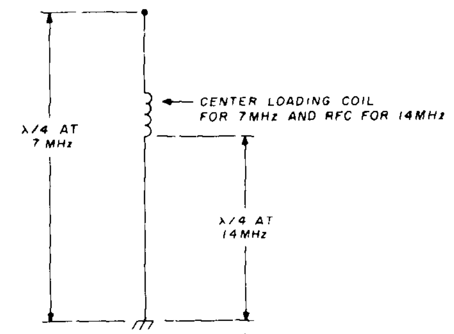


fig. 4. Basic idea of a two-band trapped vertical antenna.

The 3 dB (half power) beamwidth of this antenna is approximately 45° (from a ray length of 0.707 maximum, through maximum, to the other ray length of 0.707).

If a second $\lambda/2$ wire (element) is paralleled with the driven dipole element, as shown in **fig. 5B**, the radiation lobe narrows, but also lengthens, indicating greater energy radiation (about 4 dB more) at right angles to the driven element. The second element is not driven, but picks up energy from the driven element, changes it in phase, and reradiates energy back to the driven element. Both elements are now working to radiate energy forward (upward on the page) as well as backward, and a greatly reduced energy to the sides (out of, or into the page). This is known as a two-element parasitic beam because the second element is energized parasitically (inductively, not by any direct coupling).

If the parasitic element is made about 5 percent longer than the driven element and placed about 20 percent of a wavelength (0.2λ) from the driven element, another 1 dB of major lobe forward gain will be developed. Now energy to the back will be significantly reduced. We say the parasitic element is acting as a reflector. A third element added in front of the driven element, spaced about 0.15λ and made 5 percent shorter than the driven element, will add still another 1 or 2 dB of forward gain, reducing the backward radiation still more. The third element is called a director. Such an antenna is the popular three-element parasitic Yagi beam antenna used by many Amateurs, and also used as TV receiver antennas. If four or five elements are used, the added elements will be second or third directors in front of the first. They may be somewhat shorter and spaced at about 0.15λ from each other.

The more elements added to a beam antenna the narrower the beamwidth and the more forward gain

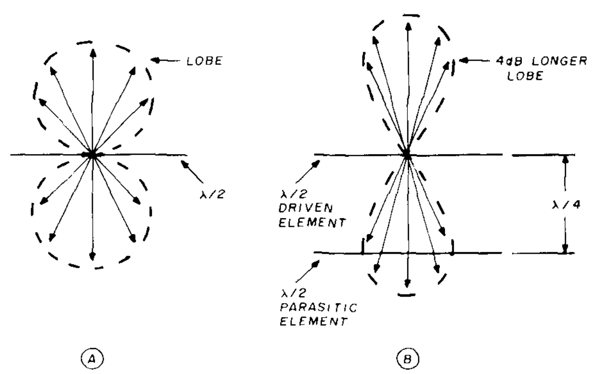


fig. 5. Radiation lobes for (A) a $\lambda/2$ dipole and (B) a $\lambda/2$ dipole with a parasitic $\lambda/2$ reflector/diameter element.

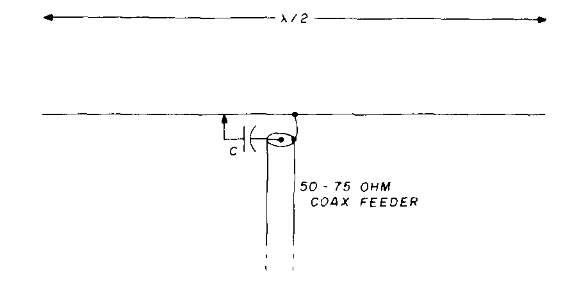


fig. 6. The gamma match method of coupling a coaxial transmission line to a $\lambda/2$ dipole.

produced. Also, the front-to-back ratio is increased as elements are added, which is an advantage. However, for every element added there will be small side lobes developed on each side of the major, or forward lobe. Yagis are relatively small antennas and are often made rotatable.

The greater the number of elements used and the closer they are to the driven element the lower the feed point impedance of the driven element. How do we match a 50-ohm coaxial line to a 5 to 15-ohm feed-point impedance? There are several possibilities. A 2, 3, or 4-wire folded dipole might be used as the driven element. A delta feed might be used on a dipole driven element, spreading out the feed lines to match proper impedance points. A half-delta-type of coupling called a gamma match (see **fig. 6**) may be used. In this system the braid of the coaxial cable is connected to the center of the driven element, which means that the unbalanced condition of a coaxial cable to an open-at-the-center dipole will not exist. The center conductor of such a 50-ohm cable is led out to the 50-ohm impedance point on the dipole, indicated by a minimum SWR shown on a reflectometer down at the transmitter output. To counteract the inductance of the center-conductor tap line, a small capacitor, C, should be added in series with the tap line to reduce the SWR still more. The more elements the beam has the further out the tap will have to be located.

An entirely different beam antenna is the driven type. Consider the two vertical $\lambda/4$ antennas being fed in phase (same length feed lines) in **fig. 7A**. Both antennas are emitting the same signal at the same time. The signal approaching you (out of the page) would be the in-phase sum of the two, or a maximum. Since the antennas are located $\lambda/2$ apart, when the signal from one reaches the other it will be 180° out of phase (180° = $\lambda/2$) with the signal being emitted by the second antenna at that instant, and there will be almost no signal transmission to the right or left along the plane of the page. The lobes transmitted, as seen from above the antennas (dots), are shown dashed.

In **fig. 7B**, the two antennas are being driven 180° out of phase (one feed line is $\lambda/2$ longer than the other). *As a result, the signals approaching you* would be 180° out of phase and would cancel. You would receive essentially no signal from them. Maximum signals would now be transmitted in the line of the two antennas, or to right and left on the page, indicated by the dashed lobes shown above the antennas. Adding a third in-line driven element will narrow the radiated beamwidth and increase the signal strength in the maximum lobe direction. By using three or more driven elements and changing the phase of the signals fed to them, the maximum signal lobe can be directed in any desired direction (not a simple project).

If you pull a two-wire folded dipole apart in the middle to make a square loop out of it, **fig. 8**, a quad antenna is the result. The center impedance is no longer 300 ohms, but approaches 70 ohms allowing it to be fed with coaxial lines (preferably through a balun). If a second square loop is added (shown dashed) and spaced a $\lambda/4$ behind the driven quad element, a two-element parasitic beam is formed. Since the pick-up or capture area is larger than that of a two-element Yagi, the quad should have added gain. If the driven element is a quad and the reflector and directors are linear parasitic $\lambda/2$ elements, the beam is known as a quagi (quad and Yagi combination).

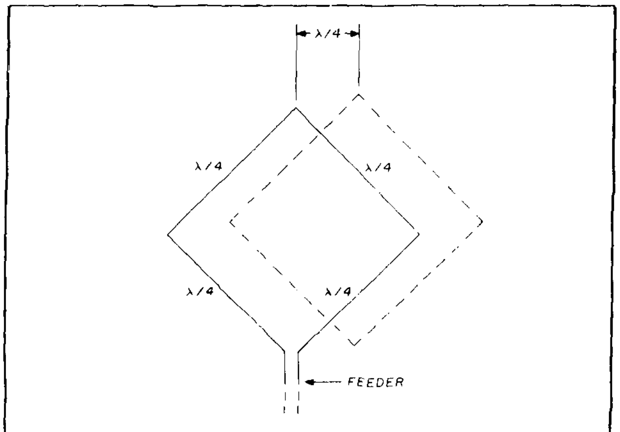


fig. 8. Quad, or four-sided radiating element. Possible reflector or director is shown dashed.

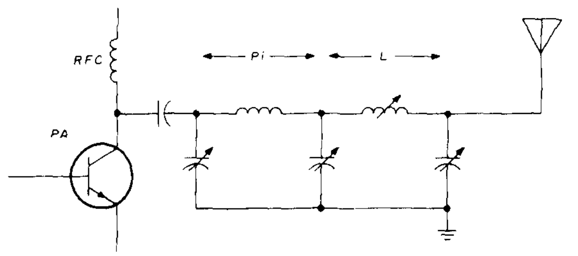


fig. 9. A Pi-L antenna tuning and Z-matching circuit.

matching networks

There are a variety of methods of coupling the final amplifier of a transmitter to the feeder of an antenna. We described a direct or capacitive coupled type, a link or inductive coupled type, and the basic pi-network which tends to attenuate harmonic output by the bypassing effect of the output capacitor if it is a large value. If a second section L and C is added to a simple pi-network, the harmonic attenuation will be better. This is known as a pi-L network, **fig. 9**. If the antenna is a random length it will exhibit either inductive or capacitive reactance to the L-network. By adjusting the C and L of these components the reactance can be tuned out to match a wide range of reactive or random length antennas to the PA stage.

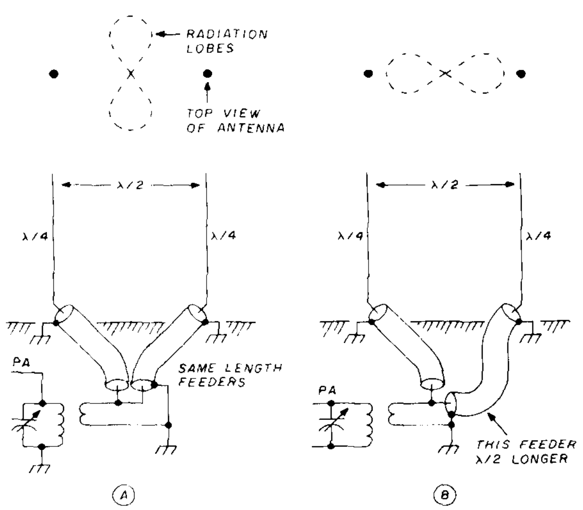


fig. 7. Two $\lambda/4$ verticals forming driven beams and means of switching lobe directions by using different lengths of feeders.

All tuning circuits between the PA active device and the antenna feeder are really some form of impedance matching circuit. They must make sure the impedance of the active device, through the tuned circuits, matches the feed line impedance to ensure maximum power into the feed line and then into the antenna. There are many different types of antenna tuners. They will usually produce an efficient coupling of the PA tuned circuit to whatever form of antenna feed is to be used: direct, high-impedance open-wire line, low-impedance open-wire line, or coaxial line. They have the advantage of adding a tuned circuit to the antenna system, which can help attenuate harmonic output. One circuit that can be used as an antenna tuner is shown in **fig. 10**. To allow tuning to resonance on different Amateur bands, some of the turns of the antenna coil are shorted out (none are shorted for the 80-meter band, a few for the 40-meter band, more for the 20-meter band, and so forth).

A 600-ohm open-wire line would be connected across the low impedance (LOW Z line) contacts. The contacts are moved up or down the coil until a minimum SWR is indicated. Tuning C_1 to a still lower SWR will indicate resonance of the LC circuit. A 300-ohm or lower impedance parallel wire line would require tapping across fewer turns of the antenna coil. A coaxial feed line would be connected to the lower link coil to accept energy from the resonant LC circuit. The high impedance (HIGH Z line) points would be connected to feeders which are cut to a resonant length ($\lambda/4$, $\lambda/2$, etc.) to produce high impedance at the tuner end. If resonant feeders are a little too long they can be electrically shortened by varying the capacitance of C_2 and C_3. These two capacitors usually have shorting switches across them. All variable capacitors in this circuit are "hot" and must have insulated shafts between them and their dials or knobs.

When tuning a transmitter, you should not connect it to an antenna until you are at the point where you want to tune the antenna matching circuit. During preliminary tuning you should use a dummy load. This is usually a non-inductive wire resistor (50-72 ohms) immersed in transformer oil and in a metal can to prevent overheating of the wire. The metal can should be grounded to prevent signal radiation. Also, an open-wire transmission line of perhaps 300-ohm impedance and perhaps a $\lambda/2$ long, using iron resistance wire instead of copper, and connected at the far end to a 300-ohm resistor, will dissipate the rf energy as heat in the air but being a transmission line will radiate almost no signal. This is known as a losser line.

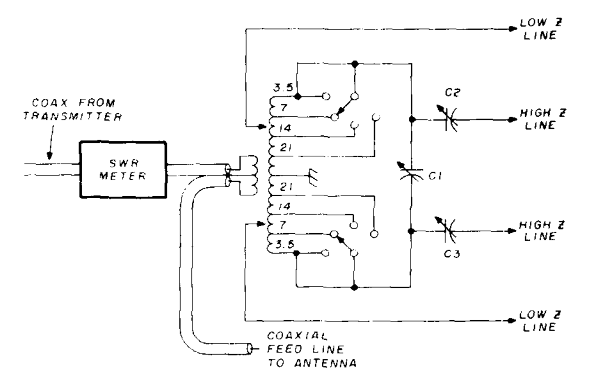


fig. 10. A possible four-band antenna tuner.

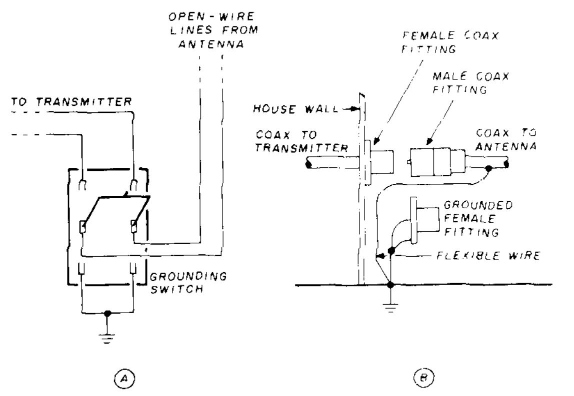


fig. 11. Protection from lightning (A) for open-wire lines, and (B) for coaxial cable transmission lines.

antenna safety tips

Antennas can have very high voltages and currents induced in them by lightning strikes that are as much as half a mile away. These can melt anything connected to the antenna. When there is lightning in the area, or if you can hear even distant thunder, ground your antenna! With open-wire feeders use a double-pole double-throw ceramic insulated high-current switch mounted on the outside of the building, **fig. 11A**. If you have a coaxial feeder, the male fitting on the feed line should be screwed into a female fitting mounted on the outside of the building that leads into the radio shack and to the transmitter. When lightning approaches, unscrew the male feeder and screw it into a dummy female fitting that is grounded, as in **fig. 11B**. Be sure you have a heavy flexible wire grounding your feeder fitting at all times. Do not get caught holding an ungrounded feed line while you are standing on the ground with lightning around!

When working on antennas be very careful about walking around with an aluminum ladder in your hands. If the ladder happens to touch an overhead power line, even if it is only 120 volts, you may put yourself between the ac hot line and ground. You will be electrocuted, and you won't be the first.

Do not climb wooden poles or metal masts without wearing an approved safety belt, and always check the condition of the belt. Make sure that feed lines are disconnected at the transmitter before you touch any antenna wires.

Be sure you use a good electrical ground on all your equipment. A good ground can usually be achieved by driving an 8-foot (2.5-meter), 1-inch-diameter iron pipe into the ground. The pipe should be pounded closed at the bottom end and sharpened. Drill small holes in the pipe every foot or so. When the pipe is in the ground you can pour water into it each day. The water will leak out and keep the surrounding ground wet to improve ground conductivity. Two such ground rods are better than one.

If you erect metal masts for your antennas be sure they are anchored and guyed adequately. Your building inspector can tell you the requirement for erecting masts and towers in your city or county. Do not climb antenna poles, towers, or masts unless you are physically qualified to do it. Be very careful when adding metal sections on top of a base tower. Work on antennas on windless days. Remember, it is a lot more windy at the top of an antenna tower than on the ground.

Guy wires should come down to ground at an angle of about 45° for optimum strength, although on restricted-size lots the angle may have to be somewhat less. With guys at lesser angles, you may require more guy wires. Anchors for guy wires must be driven solidly into the ground for at least two feet, and preferably up to six feet for heavier poles or masts. Paint the bottom 7 feet (2 meters) of any guy wires you use with white paint, or hang white rags on them to reduce the danger of people running into them.

If your antenna is not in an area shaded to aircraft, if it is over 200 feet in height, or if it is within 5000 feet of a runway, you may have to paint it with orange and white stripes and install lights on top of it. If your antenna does not exceed nearby buildings, trees, and so on by more than 20 feet (7 meters) or so, you should never have to notify the Federal Aviation Administration (FAA) of its existence. For precise legal information on antenna installations, see the FCC Rules and Regulations, Volume I, Section 17.

height above average terrain

The effective height of an antenna is the height of its center above average terrain. Average terrain can be determined from a contour map of your area. Locate your antenna position on the map or chart. Draw eight radials 45° apart starting with the first one northward. Extend each line for a distance of 10 miles. Determine the elevations above mean sea level (AMSL) of the base of your antenna and all points 2, 4, 6, 8, and 10 miles out on each radial. Add all the AMSL values and divide by the number of points used. This will be the effective elevation of the average terrain at the base of your antenna. Such information is only required for large antenna tower installations and is rarely used by most Amateurs.

FCC test topics

The following Novice class FCC test topics are discussed in this article, but should be understood by Technician/General, Advanced, and Extra class license applicants also:

- Parallel conductor feed lines
- Coaxial cable feed lines
- Ground systems
- Lightning protection for antenna systems
- Antenna installation safety

The following Technician/General class FCC test topics are discussed in this article, but should be understood by Advanced and Extra class license applicants also:

- Antenna orientation
- Balanced, unbalanced feed lines
- Characteristic impedance of antennas
- Antenna-feed line mismatch
- Significance of standing-wave ratio
- Physical dimensions of antennas
- Use of a reflectometer (VSWR meter)
- Antenna bandwidth
- Yagi antenna
- Radiation patterns, directivity, major lobes
- Quad antenna
- Use of antenna tuning or matching networks
- Use of non-radiating load or dummy antenna

The following Advanced class FCC test topics are discussed in this article, but should be understood by Extra class license applicants also:

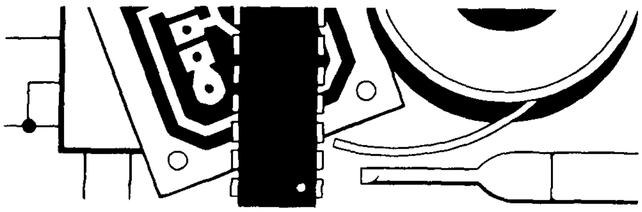
- Electrical length of feed lines
- Folded, multiple wire dipoles
- Radiation resistance
- Mobile antennas
- Loading coils, base, center, top
- Trap antennas
- Parasitic elements
- Antenna gain, beamwidth
- Driven elements
- Impedance matching networks; Pi, L, Pi-L
- Height limitations for antennas, including FAA notification criteria, and calculation of height above average terrain.

For additional information on these subjects, you can refer to *Electronic Communication*, or to *Amateur Radio Theory and Practice*, by Robert L. Shrader, W6BNB, McGraw-Hill Book Company, available through *ham radio*'s Bookstore.

ham radio

More Details? CHECK—OFF Page 92

the weekender



a single-chip keyer for QRP

The keyer described in this article was designed to be built into a Heath HW-8 transceiver. However, it should function equally well with most QRP rigs. The keyer is designed around the Curtis 8044 CMOS keyer integrated circuit. Since the HW-8 has sidetone, that function was omitted from the keyer.

Without sidetone, the keyer chip required so little power the only problem was ensuring the proper operating voltage for the IC without consuming more power in the regulator than in the rest of the keyer. The solution was the circuit consisting of D_1, D_2, R_1, and R_7. Power (9-14 Vdc) is supplied through a 5.1 volt zener (D_1) in order to limit the IC voltage from 4 to 9 Vdc. Resistor R_1 (47 K) ensures that sufficient current is drawn through D_1 to keep it functioning properly. The 9.1 volt zener (D_2) and 100-ohm resistor (R_7) protect the IC should the input exceed 14 Vdc.

R_2, C_2, R_3 and C_3 protect against false operation from key contact bounce. The combination of C_4, R_6 and the external 500K speed-control potentiometer provide proper timing for the selected speed. Diodes D_3 through D_8 protect the IC from rf or noise spikes on the input lines. Transistor Q_1 keys the CW transmitter. Your transmitter key line should not exceed a positive 50 Vdc key-up or 50 mA key-down, or the transistor (and possibly the IC) may be destroyed.

The keyer paddle will normally be connected to the ground, dot and dash inputs. If bug type operation (manual dashes and automatic dots) is desired, the paddle dash contact may be connected to the bug input instead. A manual key or tune switch may be connected between ground and the bug input.

Installation was simple. The keyer was mounted on the side panel with spacers, similar to the way Heath mounted the audio amplifier board. The speed potentiometer was fitted with a concentric shaft and SPDT switch. This assembly was mounted in place of the original narrow-wide switch. The new SPDT switch was wired to control the narrow-wide function while the potentiometer served as the keyer speed control. An extra HW-8 concentric knob set (for the rf and af controls) was ordered from Heath and used on the new controls. A 4-pin Amphenol 126 series miniature hexagonal socket was mounted in place of the key jack in order to provide the paddle connections. The Amphenol connector takes the same size mounting hole as the original key Jack.

By Robert W. Lewis, W3HVK, P. O. Box 41, Stevensville, Maryland 21666

keyer operation

If you haven't tried for many years to operate a

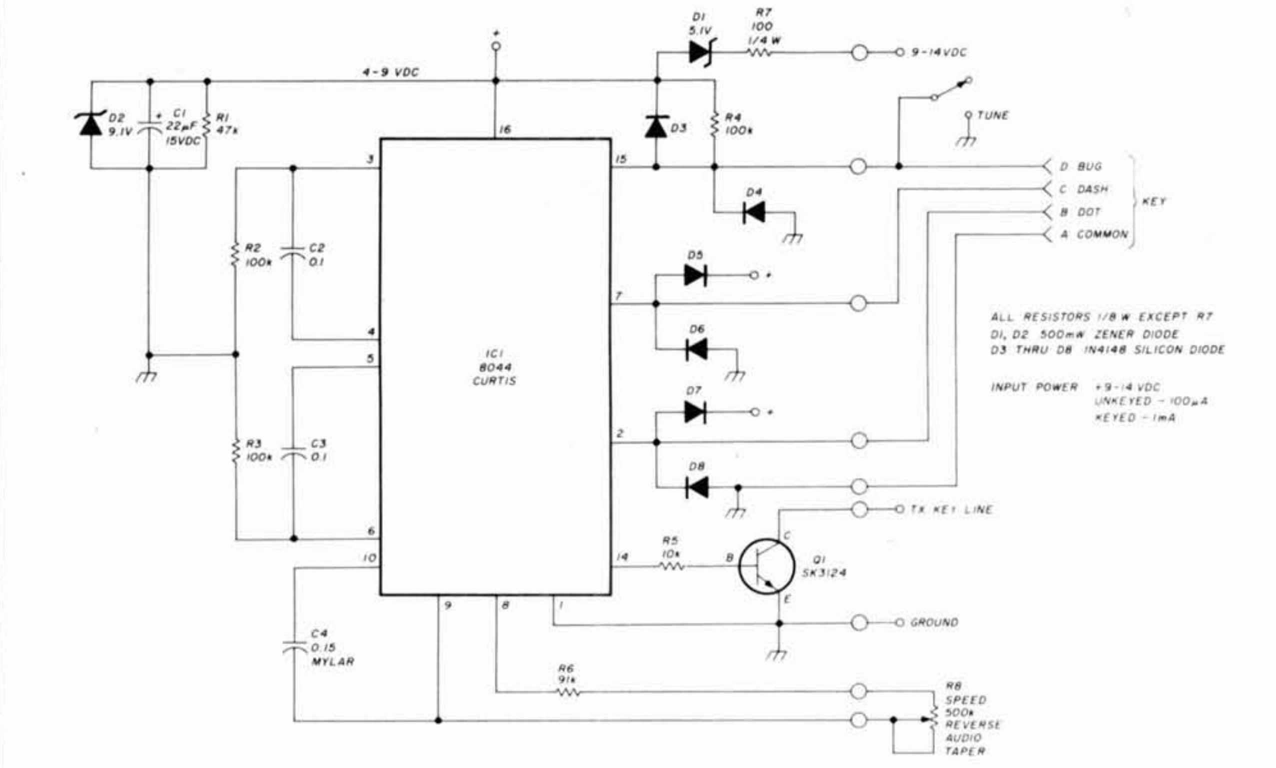


fig. 1. QRP keyer schematic.

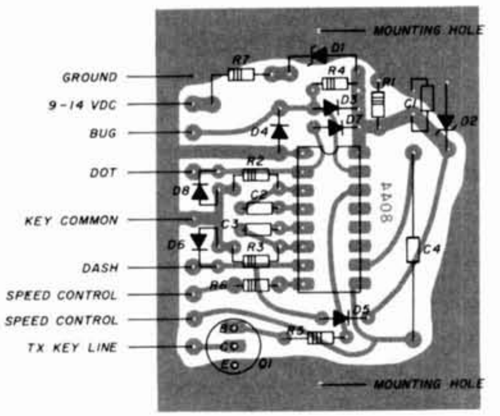


fig. 2. QRP keyer component layout (component side view).

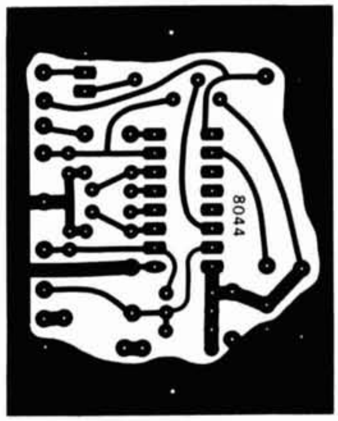


fig. 3. QRP circuit board negative (actual size, foil side view).

keyer, give one of the newer models a chance. My old tube-type keyer sat in the corner for years because I never could get accustomed to it. Adjusting to the new keyer with its self-completing function and dot/dash memories was a breeze. While the keyer will function with an older paddle or in the bug mode, I highly recommend an investment in an iambic paddle. Iambic or squeeze keying greatly simplifies sending letters C,F,K,L,Q,R,Y and the period. After an hour or so with a code practice oscillator, squeeze keying should become as natural as your old straight key.

ham radio

note

IC_1 is an 8044, and is available from Curtis Electro Devices, Inc., Box 4090, Mountain View, California 94040.

HAM CALENDAR

October

SUNDAY

W1AW Schedule

April 25 October 24 1982 MTWThFSSn Days of Week Dy Daily

W1AW code practice and bulletin transmissions are sent on the following schedule

EDT	Slow Code Practice	MWF 9 A.M. 7 P.M.	TThSSn 4 P.M. 10 P.M.
	Fast Code Practice	MWF 4 P.M. 10 P.M.	TTh 9 A.M. TThSSn 7 P.M.
	CW Bulletins	Dy 5 P.M. 8 P.M. 11 P.M.	MTWThF 10 A.M.
	RTTY Bulletins	Dy 6 P.M. 9 P.M. 12 P.M.	MTWThF 11 A.M.
	Voice Bulletins	Dy 9:30 P.M. 12:30 A.M.	
CDT	Slow Code Practice	MWF 8 A.M. 6 P.M.	TThSSn 3 P.M. 9 P.M.
	Fast Code Practice	MWF 3 P.M. 9 P.M.	TTh 8 A.M. TThSSn 6 P.M.
	CW Bulletins	Dy 4 P.M. 7 P.M. 10 P.M.	MTWThF 9 A.M.
	RTTY Bulletins	Dy 5 P.M. 8 P.M. 11 P.M.	MTWThF 10 A.M.
	Voice Bulletins	Dy 8:30 P.M. 11:30 P.M.	
PDT	Slow Code Practice	MWF 6 A.M. 4 P.M.	TThSSn 1 P.M. 7 P.M.
	Fast Code Practice	MWF 1 P.M. 7 P.M.	TTh 6 A.M. TThSSn 4 P.M.
	CW Bulletins	Dy 2 P.M. 5 P.M. 8 P.M.	MTWThF 7 A.M.
	RTTY Bulletins	Dy 3 P.M. 6 P.M. 9 P.M.	MTWThF 8 A.M.
	Voice Bulletins	Dy 6:30 P.M. 9:30 P.M.	

MON

TUES

WED

THUR

FRI

1

1982 ARRL WEST GULF DIVISION CONVENTION & HOUSTON COM VENTION Held at the Astro Village Hotel complex in Houston. For more info contact Houston Com Vention 82, P.O. Box 79252, Houston, TX 77279 (713) 481 4586 1 3

SATURDAY

2

PACK RATS SIXTH ANNUAL MID ATLANTIC VHF CONFERENCE & HAMARAMA Held in Warrington, PA. For information HAMARAMA 82, P.O. Box 311, Southampton, PA 18966 or Lee Cohen K3MXM 2 3

NEW ENGLAND DIVISION CONVENTION Held at the Sheraton Boxboro Hotel in Boxboro, MA. For more info, contact W1THT 2 3

RAGS ANNUAL HAMFEST — Held at New York State Fairgrounds in Syracuse. Flea market space available. Talk in on 90 30 and 31 91 2

VK ZL OCEANIA PHONE CONTEST 2 3

CALIFORNIA QSO PARTY 2 3

3

YONKERS ELECTRONICS FAIR & GIANT FLEA MARKET Held in the Yonkers Municipal Parking Garage. For more info Yonkers ARC, 53 Hayward St, Yonkers, NY 10704 3

RA COM '82 Sponsored by the Mt. Prospect ARC & Cook County ALERT. Held at Mt. Prospect High School, Mt. Prospect, IL. For info RA COM 82, P.O. Box 99, Mt. Prospect, IL 60056 3

1982 ROME HAMFEST Rome Civic Center, Rome, GA. For more info contact Buddy Walker ND4O, 18 London Lane SE, Rome, GA 30161 3

31ST ANNUAL ROCK HILL HAMFEST Held in Rock Hill, SC. For info YCARS, Box 4141 CRS, Rock Hill, SC 29730 3

4

WEST COAST BULLETIN 9PM PDT (8PM PST) 0400 UTC 3540 KCS A 1 22wpm 4

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AMSAT East Coast Net 3850 kHz 8PM EST (0100Z Wednesday Morning)

AMSAT Mid Continent Net 3850 kHz 8PM CST (0200Z Wednesday Morning)

AMSAT West Coast Net 3850 kHz 7PM PST (0300Z Wednesday Morning)

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8

ELECTRONICA First annual public electronics show held at the Hynes Auditorium in Boston, MA. Ham radio, computers, security systems and more 8 11

ARRL PACIFIC DIVISION CONVENTION Sponsored by the Santa Cruz County ARC to be held at the Holiday Inn in Santa Cruz, CA. For more info SCCARC Convention, P.O. Box 238, Santa Cruz, CA 95061 8 10

9

40TH ANNIVERSARY OF THE FIRST CONTROLLED NUCLEAR EXPERIMENT Sponsored by the Argonne Amateur Radio Club 9 10*

WESTERN CAROLINA ARC SEVENTH ANNUAL AUTUMNFEST Held at the Asheville Civic Center in Asheville, NC. For info WCARS, P.O. Box 1488, Asheville, NC 28802 9

ARRL VIRGINIA STATE CONVENTION & TIDEWATER COMPUTER SHOW Held at the Virginia Beach Pavilion. For more info contact N4NV 9 10

MEMPHIS HAMFEST Held at the Memphis Fairgrounds. For more info contact Clayton Elam K4FJZ 9 10

COOSA VALLEY ARC HERITAGE DAYS From 1200Z October 9 to 2200Z October 17 9 17*

VK ZL OCEANIA CW CONTEST 9 10

10

KETTLE MORAINE RAC ANNUAL HAM COMPUTER & VIDEO FEST Held at the Waukesha County Expo Center, Waukesha, WI. For more info KMRA Club, P.O. Box 411, Waukesha, WI 53187 10

HOOSIER HILLS HAM CLUB'S 21ST ANNUAL HAMFEST Held at the Lawrence County 4 H Fairgrounds, US 50, Bedford, IN. For more info contact Dick Reistter KA9JTZ 10

COLUMBIA ARA 6TH ANNUAL HAMFEST Held at the Howard County Fairgrounds in Maryland. For more info Sue Crawford, 5882 Mink Hollow Rd, Highland, MD 20777 10

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AMSAT East Coast Net 3850 kHz 8PM EST (0100Z Wednesday Morning)

AMSAT Mid Continent Net 3850 kHz 8PM CST (0200Z Wednesday Morning)

AMSAT West Coast Net 3850 kHz 7PM PST (0300Z Wednesday Morning)

COLQUITT COUNTY HAM RADIO SOCIETY Special event station from the Sunbelt Agricultural Expo 12 14*

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NEW ORLEANS HAMFEST-COMPUTERFEST Amacom 82 to be held at Delgado Community College near City Park. For more info contact Amacom chairman WA5MJM 16 17

IRWIN AREA ARA SWAP & SHOP To be held at the Circleville VFD in Irwin, PA. For more info write WB3EKB or call 412 863 8397 16

PENNSYLVANIA QSO PARTY 16 17

BOY SCOUTS JAMBOREE 16 17

ARCI QRP CW CONTEST 16 17

17

CHICAGO CITIZEN'S RADIO LEAGUE 1ST ANNUAL HAMFEST For more info Fred Mariette KA9FUD 17

19 79 REPEATER ASSOCIATION OF CHELSEA FIRST ANNUAL FLEA MARKET Held at the Beachmont VFW Post in Revere, MA 17*

RSGB 21 MHz CW CONTEST 17

18

WEST COAST BULLETIN 9 PM PDT (8PM PST) 0400 UTC 3540 KCS A 1 22wpm 18

19

AMSAT East Coast Net 3850 kHz 8PM EST (0100Z Wednesday Morning)

AMSAT Mid Continent Net 3850 kHz 8PM CST (0200Z Wednesday Morning)

AMSAT West Coast Net 3850 kHz 7PM PST (0300Z Wednesday Morning)

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MARYLAND-DISTRICT OF COLUMBIA QSO PARTY Sponsored by the Columbia ARA from 1800Z October 23 to 2100Z October 24 — 23 24*

HAMFEST CHATTANOOGA 1982 & TENNESSEE STATE ARRL CONVENTION Held at the Chattanooga State Technical Community College. Contact N4ECA or KA4BNY 23 24

24

SPECIAL EVENTS STATION Sponsored by Holmesberg ARC and University of Pennsylvania 24 25*

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26

AMSAT East Coast Net 3850 kHz 8PM EST (0100Z Wednesday Morning)

AMSAT Mid Continent Net 3850 kHz 8PM CST (0200Z Wednesday Morning)

AMSAT West Coast Net 3850 kHz 7PM PST (0300Z Wednesday Morning)

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HAM DXPEDITION AT SEA — Sponsored by the Penn Wireless Association aboard the Royal Caribbean Line's Sun Viking. For more info contact Bill Buckley W2ALG, 1156 Oxford Valley Rd, Levittown, PA 19057 31 10

MARION ARC 8TH ANNUAL HEART OF OHIO HAM FIESTA Held at the Marion County Fairgrounds Coliseum. For info W8CAX 31

FRAMINGHAM ARA 7TH ANNUAL FLEA MARKET Held at the Framingham Civic League Building. Contact Ron Ezaka, 3 Disco Rd, Framingham, MA 01701 for more info 31

*SEE COMING EVENTS

flea market

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QSLS'S: NO STOCK DESIGNS! Your art or ours; photos, originals, 50. for samples & details (refundable). Certified Communications, 4138 So. Ferris, Fremont, Michigan 49412.

FOR SALE: Dentron MLA 2500 linear. Also Yaesu FT221R 2-meter transceiver $300.00 each. (401) 789-1817.

WANTED: Micor and Mstr II Base Stations 406-420 and 450-470 MHz. Also 2 and 6 GHz solid state microwave equipment. AK7B, 4 Ajax Place, Berkeley, CA 94708.

ENTHUSIAST BEGINNER wants equipment to enhance capability of learning Morse Code to obtain Ham license for both Novice and General Class. Write Don, P.O. Box 90160, East Point, GA 30364.

CHASSIS and cabinet kits. SASE K3IWK.

ANTENNA TROUBLE ??? For $5.00, Antenna Analyst, 40 Benefit Rd., Wakefield, R.I. 02879 will cure your headache, or refund your money.

TUBES, TUBES wanted for cash or trade. 304TL, 4CX1000A, 4PR60C, WE300, 7F7, 7N7, 53, 6L6M. Any high power or special purpose tubes of Eimac/Varian. DCO, 10 Schuyler Avenue, No. Arlington, NJ 07032. (800) 526-1270.

KENWOOD TS-520, complete with DC attachment, three (3) extra final tubes and Spectronics digital frequency display DD-IK and operating manuals for transceiver and display; all in good condition. Excellent Novice starter gear. $525.00 (includes shipping by UPS). KA0EOJ (303) 963-1230.

DRAKE SATELLITE RECEIVER with modulator installed only $969. Satellite and Microwave TV catalog $1.00. TEM Microwave, 22518 97th Ave. No., Corcoran, MN 55374 (612) 498-8014.

FOR SALE: Kenwood 820-S digital, CW filter, DC converter, VFO 820, mint $775.00. Dentron Clipperton-L 160-10 meters, mint $450.00. Icom 245, Heath Micoder, mint $240.00. Icom 230, Pipo tone pad, nice $195.00. Model 28 ASR and 28 receive only 100 wpm, real nice. Make offer. KB2CR (518) 869-0809 evenings.

WANTED: Hammerlund HQ145. Call Arnie (212) 925-6048.

MOTOROLA STATION Monitor and WWV receiver 145-160 MHz $45; Cushman MCM-5 service monitor $350; SASE for test equipment list. K6KZT, 2255 Alexander, Los Osos, CA 93402.

"NEW" Kt5B Multi-band Dipole 80-10 (WARC), Mini-8 Coax $17.25/100', 450 Ohm open wire $14.75/100". Details — Kilo-Tec, P.O. Box 1001, Oak View, CA 93022.

FT 101E, B, Mk2 improved. Quieter RX, less XMod. 10 minute kit incorporates Plessey DBM. $25.00 (cheque, Visa, Master Charge) Air Post Paid. IRC's leaflet. G3LLL, Holdings Ltd., 39/41, Mincing Lane, Blackburn BB2 2AF, England.

WANTED: Surplus 1-3 kW HF transmitter type FRT-15, Collins TDH or equivalent, or higher power up to 20kW SSB not necessary. P.J. Plishner, 2 Lake Ave. Ext., Danbury, CT 06810. WA1LDU.

FOR SALE: Drake TR/DR-7 with range program board/aux-7 installed, fan, PS-7 power supply, MS-7 speaker, WH-7 wattmeter, Yaesu YD-148 mike. All used less than 4 hours. First certified check for $1325.00 takes all. W.F. English, CFWP, Box 3 FPO Seattle 98767.

RTTY-EXCLUSIVELY for the Amateur Teleprinter. One year $7.00. Beginners RTTY Handbook $8.00 includes journal index. PO Box RY, Cardiff, CA 92007.

WANTED: Socket for 4CX1000A. Also vacuum variable 500 pf/3kv. A. Brunvoll, LA3LJ, H.C. Gjeflesv. 9F, Oslo 11, Norway.

WE WANT your innovative, working antenna and ham product designs for development and marketing. Jon Titus (KA4QVK) Box 242, Blacksburg, VA 24060. (703) 951-9030.

WANTED: Usable DC/1A power supply for Tempo 1 Transceiver. Write to W6EBK.

KNOW FIRST! Ham fanatics, you need The Pink Sheets — twice-monthly award-winning Hot Insider Newsletter! Ten pages, acclaimed best! Confidential facts, ideas, insights, news, technology, predictions, alerts! Quoted coast-to-coast! We print what you don't get elsewhere! $18.00 annually w/money back guarantee! Free sample — SASE (two stamps) W5YI, Box #10101-H, Dallas, TX 75207.

SAVE MONEY on Rubber Stamps. Catalog plus discount coupon. Send 25¢. Hastings, Box 1951-HR, Pine Bluff, AR 71613.

COLLINS 204C-1 linear amplifier, as new. W6XY, 3348 Arbor Drive, Pleasanton, CA 94566. (415) 846-1459.

MANUALS for most ham gear made 1937/1970. Send $1.00 for 18 page "Manual List", postpaid. HI-MANUALS, Box R802, Council Bluffs, Iowa 51502.

SATELLITE TELEVISION — Howard/Coleman boards to build your own receiver. For more information write: Robert Coleman, Rt. 3, Box 58-AHR, Travelers Rest, SC 29690.

WANTED: Early Hallicrafter "Skyriders" and "Super Skyriders" with silver panels, also "Skyrider Commercial", early transmitters such as HT-1, HT-2, HT-8, and other Hallicrafter gear, parts, accessories, manuals. Chuck Dachis, WD5EOG, The Hallicrafter Collector, 4500 Russell Drive, Austin, Texas 78745.

BUILD YOUR OWN Satellite TV low noise amplifier and Save! *New, fully illustrated step-by-step Instruction* Manual $10.00. Satisfaction guaranteed. XANDI, Dept. 23A, Box 25647, Tempe, AZ 85282.

SATELLITE TELEVISION: Discount prices on all major *TVRO items. Communications Consultants.* (501) 452-3149.

NEVADA: "Silver State Callbook." First edition includes every Nevada amateur, repeater and more. If you need Nevada, you need this Callbook. Only $3.00 ppd. Wide Area Data Group, P.O. Box 3132, Sparks, NV (702) 358-6303.

HAM RADIO REPAIR, experienced, reasonable, commercial licensed. Robert Hall Electronics, P.O. Box 8363, San Francisco, CA 94128. W6BSH, (408) 292-6000.

HOMEBREW QUAD for under $70. See how easy quad building can be. Send for brochure to WBØVVF, 2629 N. Elsie, Davenport, Iowa 52804.

COLLECTORS: HRO-5RA1, w/speaker, w/orig. manual. Best offer. K2LM, L. Reeves, RD3, Glens Falls, NY 12801. (518) 792-5533.

DX PREDICTOR: *Computes MUF, FOT, LUF between any* two QTHs. Documented: Easy to Use: Graphical/tabular output. Adapted from algorithms currently used by US Govt. agencies. Available for Apple II + (48K: disk or cassette) and PET (16K, cassette only). Documentation $5 *(refundable). Program + Documentation* $40.00. Checks to K.J. Flynn, P.O. Box 903, Mountain View, CA 94042.

RUBBER STAMPS: 3 lines $3.25 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

$169 buys more when it's "TAIMD," The Adaptive International Morse Decoder. No adjustments! Assembled, tested, proven. Telecraft Laboratories, Box 1185, E. Dennis, MA 02641.

HAM-AD-FEST™ — Next 6 issues, $2.00. WA4OSR, Box 973, Mobile, AL 36601.

D & V RADIO PARTS — Variable capacitors, miniductors, toroids, etc. Write for flyer, stamp please. 12805 W. Sarle, Freeland, Michigan 48623.

MOBILE IGNITION SHIELDING provides more range with no noise. Available most engines. Many other suppression accessories. *Literature, Estes Engineering,* 930 Marine Dr., Port Angeles, WA 98362.

HANDIE-TALKIE OWNERS, take note! Now you can operate your HT from your car, and even charge the nicads (on certain models) with the new Mobile Energizer for only $21.95, PPD! Order now, or write for details. Contemporary Electronic Products, P.O. Box 570549, Miami, FL 33157.

SAFETY BELTS. $35.00 and up. Free information. Avatar Co., (W9JVF) 1147 - (H) N. Emerson, Indianapolis, IN 46219.

CONTESTERS: Package of programs designed for the ARRL DX, CQWW, CQWPX and IARU Radio Sport Contests produces scored, duped log, dupe sheet, QSLs and many valuable operator statistics. TRS-80 Model 1, 48k, 1 or more discs, MX-80 printer required. $69.95 plus tax non-refundable. Sample printout with SASE. P. Chamalian, W1RM, P.O. Box 1188, Burlington, CT 06013.

WANTED: New or used MS and coaxial connectors, synchros, tubes, components, military surplus equipment. Bill Williams, PO #7057, Norfolk, VA 23509.

VERY in-ter-est-ing! Next 5 issues $2. Ham Trader "Yellow Sheets", POB356, Wheaton, IL 60187.

CB TO 10 METER PROFESSIONALS: Your rig or buy ours — AM/FM/SSB/CW. Certified Communications, *4138 So. Ferris, Fremont, Michigan 49412;* (616) 924-4561.

AFC SEMI-KITS! Stop VFO drift. See June 1979 HR. $55.00 plus $3.00 UPS. Mical Devices, P.O. Box 343, Vista, CA 92083.

HAMS FOR CHRIST — Reach other Hams with a Gospel Tract sure to please. Clyde Stanfield, WA6HEG, 1570 N. Albright, Upland, CA 91786.

Coming Events

ACTIVITIES

"Places to go..."

GEORGIA: The 1982 Rome Hamfest, Sunday, October 3 at the New Location — Rome Civic Center, Turner McCall Blvd., Rome, 9 AM to 4 PM. Admission for hams will be a door prize ticket. Ladies' prizes. Enjoy the barbecue, fun and fellowship. Talk in on 147.90-30 repeater. Contact Buddy Waller, NO4U, 18 London Lane SE, Rome, GA 30161.

ILLINOIS: The Chicago Citizens Radio League's first annual Hamfest, October 17, 7 AM to 4 PM, North Shore American Legion Post, 6040 N. Clark. For table reservations: Fred Marlette, KA9FUO, 1851 W. Chase, Chicago, IL 60626.

INDIANA: The 10th annual Fort Wayne Hamfest, sponsored by the Allen County Amateur Radio Technical Society, November 14, Allen County Memorial Coliseum. *Admission: $3.00 door; $2.50 advance; children under* 11 free. Regular tables $6.00. Premium tables $20.00. $1.00 parking. Doors open 8 AM. For tickets or table information: Becky Skinner, KA9GWE, 9720 Pinto Lane, Fort Wayne, IN 46804.

INDIANA: The Hoosier Hills Ham Club's 21st annual Hamfest, Sunday, October 10, Lawrence County 4-H Fairgrounds, U.S. 50, Bedford. Registration $3.00 per person, swap shop $2.00, bring own tables. Talk in on 146.13-73 at 3910 kHz. Free fish fry, campfire, entertainment, coffee and overnite camping Saturday night, October 9. Gate open 10 AM Saturday for campers and flea market setup. Registration prizes, ladies' free bingo. Raffle prize: Hitachi Video Tape System. For information: Dick Reistter, KA9JTZ, Secretary, Hoosier Hills Ham Club, Box 891, Bedford, IN 47421.

LOUISIANA: Amacom '82, the New Orleans Hamfest-Computerfest, October 16 and 17, Delgado Community College near City Park. The new location means more space for meetings, tech forums, exhibitors, flea market and convenience to New Orleans' attractions. Admission $3.00 per person over 12 years. Forums on DXing, color SSTV and computering, ladies' activities and prizes. FCC exams Saturday morning. Radio Amateurs may use the club's repeaters, W5GAD/R, 147.285-.885 MHz, linked with 449.0-444.0 MHz for directions and Amacom information. For reservations for FCC tests and other information: W.D. Bushnell, WA5MJM, Amacom chairman, c/o Jefferson Amateur Radio Club, P.O. Box 73665, Metairie, LA 70033. (504) 887-5022.

MASSACHUSETTS: The 19-79 Repeater Association of Chelsea will hold its annual Flea Market, Sunday, October 17, 11 AM to 4 PM. (Sellers admitted at 10AM), Beachmont VFW Post, 150 Bennington St., Revere. Admission $1.00. Sellers tables $6.00 advance; $8.00 at door if available. Talk in on 19079 and 52 direct. For table reservations send check to: 19-79 Repeater Assoc., P.O. Box 171, Chelsea, MA 02150.

MASSACHUSETTS: The Framingham Amateur Radio Association's 7th annual flea market, the largest indoor ham flea market in New England, Sunday, October 31. New location: Framingham Civic League Building, 214 *Concord St., downtown Framingham (diagonally across* from previous location). Doors open 10 AM. Sellers setup starts 8:30 AM. Admission $2.00; tables $10.00. Radio equipment, computer gear, bargains galore. Talk in on 75/15 and 52 direct. For table reservations: Ron Egalka, K1YHM, *3 Driscoll Dr., Framingham,* MA 01701.

NORTH CAROLINA: The Cabarrus Amateur Radio Society's annual Hamfest, November 7, 9 AM to 5 PM, Concord Boy's Club, Spring Street, Concord. Admission $2.50 *advance;* $3.00 door. Prize drawing for advance tickets plus main prize drawing and hourly prizes. Flea market tables $4.00 or table space $2.50. Speakers, forums, ladies' bingo, refreshments, free parking. Talk in on 146.655. For advance tickets, flea market tables or space *send check* to: C.A.R.S., P.O. Box 1290, Concord, NC 28025.

OHIO: The Marion Amateur Radio Club's 8th annual Heart of Ohio Ham Fiesta, Sunday, October 31, 0800 to 1600 hours, Marion County Fairgrounds Coliseum. Tickets $3.00 advance, $4.00 door. Tables $5.00. Door prizes, XYL prizes, check-in prize. Food. Check-in on 146.52, 147.90/30, 223.34/224.94. For information, tickets or tables: Paul Kilzer, W8GAX, 393 Pole Lane Road, Marion, OH 43302.

PENNSYLVANIA: The R.F. Hill ARC's 6th annual Hamfest, November 7, Sellersville National Guard Armory, Sellersville. Doors open 7 AM for sellers; 8 AM for buyers. Prizes, refreshments. Talk in on 28/88 and 52. For information: R.F. Hill ARC, Box 29, Colmar, PA 18915.

TENNESSEE: The Memphis Hamfest, the last big one of the season, Saturday, October 9, 8 AM to 4 PM, and Sunday, October 10, 8 AM to 2 PM, Memphis Fairgrounds, Mid South Building. Children under 14 free. Radio and Computer forums, ladies' programs, hospitality party Saturday night. On site trailer hookups. Talk in on 28/88 and 25/85. For information: Clayton Elam, K4FZJ, 28 N. Cooper, Memphis, TN 38104. (901) 274-4418 days. (901) 743-6714 evenings.

TENNESSEE: Hamfest Chattanooga 1982 and the Tennessee State ARRL Convention, October 23 and 24, Chattanooga State Technical Community College, Amnicola Highway, Chattanooga. Free admission. Door prize tickets sold for hourly and main prizes. Indoor/outdoor flea markets, forums, ladies' and children's activities, refreshments available, hospitality party and Wouff Hong Ceremony. Nearby motels and camping areas. For dealer information: Hamfest Chattanooga, P.O. Box 3377, Chattanooga, TN 37404 or Maxine Barrett, N4ECA, (404) 398-3358. For indoor Flea Market spaces: Dave Roberts, KA4BNY, (615) 899-9043. Talk in on 146.19/79.

TEXAS: The 1982 ARRL West Gulf Division Convention and Houston Com-Vention, October 1-3, Astro Village Hotel complex located next to the Astrodome and Astroworld, 2350 South Loop (I-610) at Kirby Drive exit. Talk in on 147.69/.09 and 222.66/224.26. Air-conditioned exhibit area, covered flea market, prizes, transmitter hunt, homebrew competition, Saturday night banquet, Tony England, WØORE speaker, Wouff Hong ceremony and NASA-JSC tour, seminars, forums, family activities for non-amateurs. Advance registration $5.00; door $7.00. Covered flea market spaces $10.00 both days (includes table and one chair). For information and registration: Houston-Com-Vention 82, P.O. Box 79252, Houston, TX 77279. (713) 481-4586.

OPERATING EVENTS

"Things to do..."

OCTOBER 9 AND 10: The Argonne Amateur Radio Club plans to operate memorial station, W9QVE to commemorate the 40th anniversary of the first controlled nuclear chain reaction experiment which was conducted at the Alonzo Stagg field, University of Chicago campus. Two stations will operate from 1500 GMT, October 9 through 2300 GMT, October 10. Frequencies: SSB — 3985, 7285, 14285, 21285, 28585. CW — 3545, 7045, 14045, 21045, 28045, 3765, 7165, 21165 Novice bands. RTTY: 14090 and 146.70 MHz. 2M: 145.19/144.59 Rptr, 146.52 and 147.42 simplex. Send business SASE or $1.00 for an 8X11 unfolded certificate to: AARC, P.O. Box 275, Argonne, IL 60439.

OCTOBER 23 AND 24: Maryland-District of Columbia QSO Party sponsored by the Columbia Amateur Radio Association from 1800Z October 23 to 2100Z October 24. Exchange QSO number, RS(T) and state/province/country, county for MD stations. Suggested frequencies: Phone — 3950, 7250, 14,290, 21,390, 28,590. CW — 60 kHz from low end; Novice — 3720, 7120, 21,120, 28,120. Certificates for top scores in each category awarded. Mail logs, dupe sheets, summary by November 30 to CARA, Inc., c/o Robert K. Nauman, WA3VUQ, 4017 Font Hill Drive, Ellicott City, MD 21043.

OCTOBER 24 AND 25: Special events station, W3WP, the Holmesburg Amateur Radio Clubs and the University of Pennsylvania will operate W3WP for 24 hours from Penn's Landing, Philadelphia to celebrate the birthday of the City's founder, William Penn. This event is an official part of the year long celebration observing the city's 300th birthday. Exchange: RS(T), city, state, country and W3WP log number. Frequencies: Phone — 3.925, 7.257, 14.290, 21.365, 28.550 ± QRM. Also Holmesburg/U of P Repeater, 2 m, 146.685. CW: high end of each CW band. A handsome commemorative QSL card will be sent to all stations contacting W3WP. SASE to: Harry White, N3HW, QSL Manager, 7520 Verree Road, Philadelphia, PA 19111.

NOVEMBER 13 AND 14: The 50th anniversary of the Sandusky (Ohio) Radio Experimental League will be celebrated with a QSO party. Amateurs worldwide are invited to participate. Club members will operate on five Amateur bands using the club call W8LBZ. Times: 1800 UTC Saturday, November 13 until 1800 UTC Sunday, November 14. Frequencies: Novice — 28150 and 7125; CW 3740, 7040, 14040, 21040 and 28040. Phone 3910, 7265, 14280, 21360 and 28600. All ± 10 kcs. For a special QSL card/certificate send your QSL card to: QSL Manager, W8LBZ, 2909 West Perkins Avenue, Sandusky, Ohio 44870.

More Details? CHECK—OFF Page 92

EIMAC's 4CW300,000G Power Tetrode. A new generation of high-performance power tubes.

EIMAC's 4CW300,000G combines all the desired features transmitter designers look for: high peak plate current, low grid emission, low internal capacitances and low internal inductance. This is the first of a new generation of high performance power tubes for LF, HF, VHF and pulse service.

Laserfab pyrolytic graphite grids

The control grid and screen structures of the 4CW300,000G are precision-cut by a laser beam. Each element is monolithic and combines extremely low coefficient of expansion with low structural inductance. These features permit the 4CW300,000G to have a very high transconductance—10^6 micromhos—and allow efficient, high-frequency operation.

Rugged mesh filament

The EIMAC mesh filament provides exceptionally high peak plate current and permits low plate voltage operation. This leads to power supply economy, making the 4CW300,000G the economic choice for 300 KW AM broadcast service or long-pulse switch service, each of which demands a reserve of peak emission.

Improved anode structure

EIMAC's multi-phase cooling technique provides high plate dissipation to extract heat evenly and quickly from the anode, contributing to long tube life and operating economy.

EIMAC expertise

EIMAC's expertise in electron ballistics pyrolytic grid production, thermodynamics and circuit techniques combine to bring tomorrow's tubes for today's transmitter designs. More information is available from Varian EIMAC. Or the nearest Varian Electron Device Group sales office.

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Telephone: 415•592-1221, ext. 218

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the ham notebook

updating your CW station

Owners of older CW equipment, like me, find many advantages to having such gear, not the least of which is low cost and ease of repair. These rigs, however, often lack features which are almost essential for the avid CW operator. Many models lack a sidetone, and some have no internal relay for switching from transmit to receive.

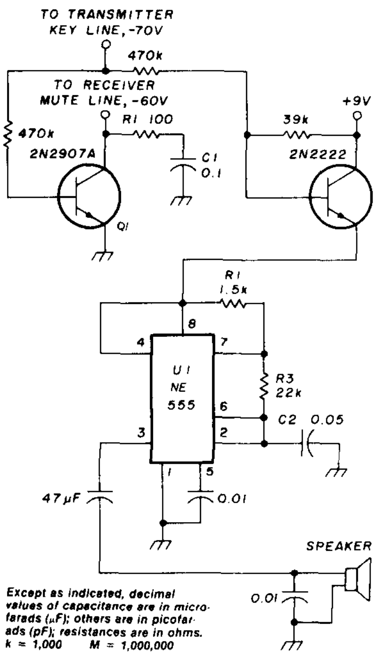


fig. 1. Schematic diagram for the mute-sidetone circuit.

My HF station consists of a Drake R-4 and a Heathkit DX-60A. The DX-60A provides a switched voltage on the accessory socket for an external relay, but I wanted full break-in. So I built a solid state T-R switch I saw in a *ham radio* article ("Solid State T-R Switch for Tube Transmitters," by Malcolm Crawford, K1MC, *ham radio*, June, 1980, pages 58-61). It worked like a charm, but I still did not have a sidetone, and, even with a sidetone, I had no way to mute the receiver. Thus was born this circuit.

This circuit does two things: It provides a pleasant sidetone and it mutes the receiver on every dot and dash.

The Drake R-4 has a mute line voltage of −60 volts and the DX-60A has a key line voltage of −70 volts. I am sure that this circuit could be used with a number of tube-type transmitter/receiver combinations.

The key-line voltage is used to turn two transistors on and off. Q1 is a PNP type, rated for at least 60 volts. A 2N2907A fits the bill perfectly. When the key is up, the negative voltage on the base of Q1 turns the transistor on, grounding the mute line and unmuting the receiver. When the key is down, the base of Q1 goes to ground and the transistor shuts off, opening the mute line and muting the receiver. R1 and C1 keep the receiver muted for a brief moment on key-up. These values may need to be changed, depending upon the keying characteristics of the transmitter.

Q2 in an NPN type. The +9 volt supply need not be regulated; a 9-volt battery would work fine. On key-up, the transistor is off. On key down, the +9 volts turns on the transistor, which turns on the sidetone provided by U1, an NE555 timer. The output of U1 is fed into a small 2-inch speaker. The pitch of the sidetone is determined by R2, R3, and C2, according to this formula:

$$frequency = 1.46/[(R2 + 2 \cdot R3)\,C2]$$

The 0.01-mF capacitor across the speaker leads will minimize rf feedback into the IC.

The entire circuit can be mounted underneath the chassis, or at any other convenient location. I mounted mine in a small box which sits loosely on top of the transmitter chassis. The box has four jacks, one for the mute line, one for the key line, one for the 9-volt power supply, and one for the speaker.

This addition to your CW station, along with an electronic T-R switch, will make your operating a real pleasure.

Dan Sanderson, KM5T

more notes on the 5CX1500A power pentode

In my earlier article, "Notes on the EIMAC 5CX1500A Power Pentode" (*ham radio*, August, 1980, page 61), I made the statement that EIMAC had changed the outer plating of the tube to nickel for reasons of cost, adding: "There is no noticeable electrical effect on the tube."

Subsequent experience has not only shown that this is *not* the case, but also that the effect is a deleterious one to both the tube and its socket if the tube and amplifier are used heavily.

The IR losses in nickel are considerably higher than those of silver or its various compounds — so much so that, in the case of the 5CX1500, the resultant heating of the various electrode rings can be enough to destroy both the rings and the surrounding socket material.

This situation was brought to EIMAC's attention late in 1980, and they subsequently returned to silver-plating all exposed metal on the

5CX1500A. Although many broadcast users of the tube were notified of this situation, it is likely, however, that some nickel-plated 5CX1500A's may still be in operation in the Amateur service, particularly some sold by broadcasters to Amateurs. The purpose of this note is to alert the Amateur community, so that users of such tubes may decide whether to continue using the nickel-plated 5CX1500A in their rigs.

Arthur Reis, K9XI

measuring coax with an RCL bridge

Not long ago I came across a bargain that was too good to be true: used coax for only 1 cent per foot. The person selling it explained that it had been used only once and admitted he didn't know exactly how long it was. After we estimated the length, I paid for what I thought was 165 feet of RG-58.

I wasn't about to unroll all that coax (besides, my tape measure was broken) to measure it the old-fashioned way. Instead, I decided to use my RCL bridge to measure the total capacitance of the coax and then calculate the length based on the capacitance per foot. At first that might seem like technological overkill, but there are times when it isn't convenient to physically measure coax length. For example, if coax is buried or installed in some inaccessible location, it might not be practical to measure its length by conventional means.

The procedure consists of four simple steps. First, check the coax for continuity; second, check the coax for shorts; third, measure the capacitance of the cable; and fourth, calculate the length of the cable. To check the continuity of the coax, put a temporary short across one end of the cable and connect the RCL bridge to the other end. With the bridge set to measure low values of resistance, you should get an indication of low resistance. High resistance is evidence of some physical damage to the coax. With this simple continuity test, we aren't measuring the impedance of the coax; we're just checking for breaks in the cable. Next, with the bridge still connected, remove the temporary short from the end of the cable. The bridge should now give an indication of infinite resistance. A low resistance would mean there was a short in the coax, and a measurable resistance would point to leakage through the dielectric between the shield and the center conductor.

When you are sure the coax has continuity but no shorts or leakage, switch the bridge to measure capacitance and measure the total capacitance. Keep the leads from the bridge to the cable as short as possible to minimize stray capacitance. The length of the coax can be calculated from this equation:

$$\textit{length in feet} = \frac{\textit{total capacitance}}{\textit{capacitance per foot}}$$

When using this method to measure the length of coax, the most important thing to know is the capacitance per foot of the coax being measured. When you consult a catalog or specification sheet to find out the capacitance of a particular type of coax, make sure it is for the exact coax you are measuring. Remember, if RG-59 from the XYZ cable corporation is rated at 17 pF per foot, there's no guarantee that RG-59 from the ABC wire company is also 17 pF per foot.

John W. Frank, WB9TQG

3-500Z tube failure

One of the most common of amplifier troubles is grid to filament short-circuits in 3-500Z. Almost every brand of 3-500Z amplifier occasionally suffers from this problem. The popular notion is that the tube shorted, which almost seems logical if the tube reads zero ohms with an ohm-meter. But such a conclusion may be putting the cart before the horse.

My own SB-220 amplifier had a persistent problem of arcing the plate-tuning capacitor — but only on the 40-meter band and never on 80 meters, the only other band I use the amplifier for. Another gremlin on 40 meters was that one plate-parasitic choke would sometimes get hot and make a burning smell. *Why only on 40 meters?*

One day a friend offered me a new set of 3-400Z tubes at a bargain price. The 3-400Z is very similar to the 3-500Zs, except for a higher amplification factor and lower plate dissipation rating. Since a higher amplification factor usually means less bias requirement, I shorted out the Zener bias-diode and fired up on 80 meters. The power gain was slightly better than the original tubes — great. I used the new tubes for several hours and went to bed thinking I had a pair of winners. The next day I loaded up on 40 meters and the amplifier made a loud noise followed by an evil smell. I shut the amplifier off and removed the line-plug from the outlet. As I removed the case, small pieces of crispy-crittered component fell on the table. I felt sick. Looking inside, I found the 1-mH grid-to-ground choke had burned open, and the individual sections of the windings had collapsed on themselves. One of the three grid- to-ground capacitors had vanished. Since this capacitor was rated at 500 working volts, there must have been at least triple the 500 volts to make it vanish so completely. The fusing current for the wire used in the burned choke must have been at least 2 amperes. A little calculating, with $\textit{watts} = 1500 \textit{ volts} \times 2 \textit{ amps}$, indicated that there must have been something terrible going on for a few microseconds.

All of these signs were commonly reported by others who had had a "tube short out." Surely an ohm-meter would verify this — but the question was whether the tube shorted out before or during the fireworks.

It did not seem to me that this much fireworks could be the result of contact between the grid and filament of a zero-bias triode. The fact of the matter is that if you connect a jumper between the grid and filament very little can happen because the two tube elements are practically at zero volts to start with. One thing that does happen is that the exciter will be looking into a short circuit which causes the output of the amplifier to decrease.

There had to be a better explanation for this problem.

The possibility of a parasitic oscillation seemed like a good place to start. Before tubes can oscillate, they need some kind of resonant circuit in the grid path.

Investigation of the remaining 1-mH choke revealed that it had a dc resistance of about 20 ohms and that it had many series resonances when checked with a dip-meter. Since grid-circuit resonances are what we would like to avoid, I substituted a 2-watt, 20 ohm carbon resistor for the choke. The resistor had none of the resonances I found with the choke. I installed one resistor in place of each choke on both tube sockets. As a further precaution against encouraging the grid resonance to reappear, I changed the three 200-pF capacitors on each tube socket to 100-pF, 1000-volt disc-ceramic capacitors.

The amplifier was tried again and it performed nicely — and the gremlins had vanished.

I would not recommend using much less, or much more, than 20 ohms resistance at 2 watts. Another amplifier was tried with 10 ohms and that amplifier had instability problems. Splitting the resistance into three parallel 62-ohm, 1-watt carbon resistors, one from each grid pin to ground, would be a better way to do it.

The tragic thing about all this is that a really hot tube, that is, one with lots of gain, is also the one that is most likely to self-destruct by oscillating in an amplifier with a marginal parasitic problem. Fortunately my tube survived, but many tubes do not.

Richard Measures, AG6K

continued from page 8

panied the appearance of the appliance operator who, judging by his language and QSO content, hasn't a clue as to what is going on behind the panel of his transceiver. Perhaps the growing interest in QRP DX, and in weak signal work in general, marks a return to the principles upon which our hobby was born and out of which have emerged most of the significant advances in communications technology.

Thomas W. Sanders, W6QJI
Port Orchard, Washington

short circuits

K2RIW Yagi

"Requirements and Recommendations for 70-cm EME," June, 1982, mistakenly notes that "the K2RIW (432 Yagi) has gone out of production."

The K2RIW Yagi, the original RIW 432-19, is still in production by RIW Products, Box 191, Babylon, New York 11702.

inductance meter

Those readers who would like additional information concerning the parts placement for the inductance meter described in the April, 1982, issue ("Easy To Build Inductance Meter"), should send an SASE to Ed Marriner, W6XM, 528 Colima Street, LaJolla, California 92037.

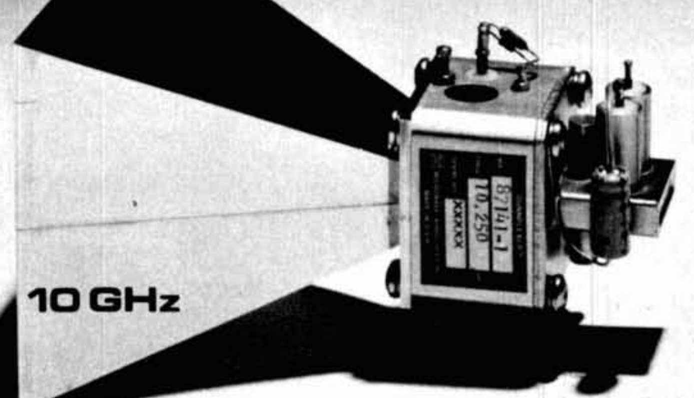
low-frequency crystal oscillator

The footnote on page 67 of the March, 1982, issue should be disregarded. Crystals are no longer available from that source.

half-square antenna

In the article "Half-Square Antenna," page 48 of the December, 1981, issue, note that in **eq. 1** the value for L should be in μH. Also, the design constant should be 25330.

& accessories



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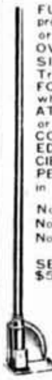

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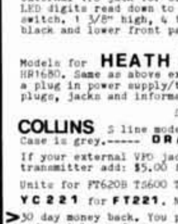

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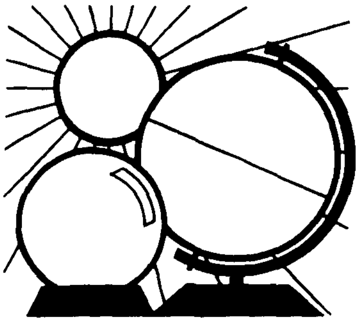

DX FORECASTER

Garth Stonehocker, KØRYW

last minute forecast

The higher frequency bands (10, 15, and 20 meters) are expected to have excellent openings the first and last weeks of the month. Openings will not be as plentiful mid-month, so you should shift DX bands as conditions may be better on the night bands (40, 80, and 160 meters). These bands should steadily improve as winter approaches. Thunderstorm noise quiets down in the northern hemisphere this time of year letting you hear the weaker DX in those night-time openings. Geomagnetic field disturbances, which give so much fading (QSB) and some VHF auroral scatter openings, could be evident around the 8th, 16th, and 25th of October.

Since October is still an equinoctial month, these periods of disturbance can be longer and more intense than at other times of the year. Don't despair; these disturbed periods can bring special openings to rare DX locations. QSB is evidence of ionospheric movement on a variable time scale. Thus, the angles of reflection are variable, too. These variable angles of reflection are the reason for the unusual azimuths (bearings) from your station to and from the DX station. Just a little more fun, especially if you're patient enough to listen intently for weak signals.

During October the Orionid meteor showers will be visible from the 15th through the 25th. The maximum rate will be 10 to 20 per hour on the 20th and 21st of the month. The moon will be full on the 3rd and will perigee on the 9th, which may interest moonbounce DXers.

Now that the sunspot number (SSN) and solar flux are showing a decided decrease, our DX operating habits need to be reviewed. By 1986, SSN minimum, our use of the 6-, 10-, and 15-meter bands will be limited, as each band slowly loses propagation. This change is caused by the ionosphere's height and ion density, varying diurnally, seasonally, and with sunspot cycles (27-day and 10.7-year periods produce the largest effects). A slight increase in height and a 50-percent decrease in ion density usually occurs at middle latitudes by the time of SSN minimum. The maximum usable frequency (MUF) and signal absorption, which sets the lowest usable frequency (LUF) limit, will both decrease. The middle latitude's MUF decreases about 20 percent in the summer, and 40 percent during other seasons. The noise, QRN, will stay constant with SSN, except for subtle changes from climatic weather. The big QRN variations are local, caused by passing weather fronts and thunderstorms.

The 27-day ionospheric variation which you may be following through the solar flux value (from WWV at 18 minutes after the hour) will still be evident. The amplitude of the solar oscillations will gradually diminish. However, the ionosphere, being a balanced energy system, will retain much of its sensitivity to the effects of solar flares or regions.

With all these variations in mind, what DX operating changes can be expected? The highest band for consistent DX will be 20 meters, with occasional openings on 15 meters on high 27-day solar flux peaks. Most 10- and 15-meter openings will be a thing of the past, except for sporadic E short skip in June, July, and August. Sporadic E is not really affected by SSN except for auroral zone effects. The 160-, 80- and 40-meter bands will have some very good openings during night-time hours throughout this minimum SSN period.

band-by-band summary

Ten and fifteen meters will be open for worldwide DX from after sunrise until after sunset during the 27-day solar flux maximum periods. Short skip of 1200 miles (maximum distance) is possible, and will follow the sun across the earth.

Twenty meters will be open to some area of the world for the entire twenty-four hour period on most days of the month. The band should peak in all directions just after local sunrise, and again toward the east and south during late evening hours. During darkness, the band will peak toward the west, in an arc from southwest through northwest, that will encompass Pacific areas.

Forty and eighty meters will be the most usable night-time DX bands. Most areas of the world will be workable from dusk until sunrise. Hops shorten on these bands to about 2000 miles for 40 and 1500 miles for 80 meters, but the number of hops can increase since signal absorption in the ionosphere's D region is low during the night. The path follows the direction of darkness across the earth, similar to the way the higher bands follow the sun. Short skip can be used during the day and even at night if low-height horizontal antennas (high take-off angle) are used. Vertical antennas over good ground systems give the lowest take-off angles for long skip on bands during darkness.

One-sixty meters will be similar to 80 meters, providing good working conditions for enthusiastic DXers who like to work into the wee hours of the night and early morning hours, especially at local dawn.

ham radio

OCTOBER

WESTERN USA

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

MID USA

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

EASTERN USA

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

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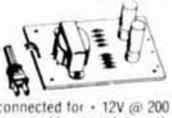

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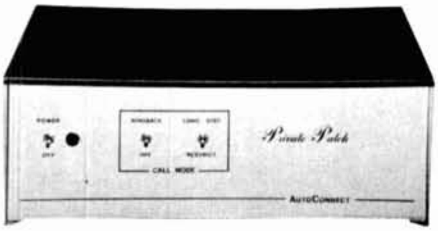

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New Yaesu FT-102 Series
Transceiver of Champions!

The long-awaited new generation of Yaesu HF technology has arrived! New research in improved receiver filtering and spectral purity is brought to bear in the competition-bred FT-102, the HF transceiver designed for active Amateurs on today's intensely active bands!

Unique Cascaded Filter System
The FT-102 utilizes an advanced 8.2 MHz and 455 kHz IF system, capable of accepting as many as three filters in cascade. Optional filters of 2.9 kHz, 1.8 kHz, 600 Hz, and 300 Hz may be combined with the two stock 2.9 kHz filters for operating flexibility you've never seen in an HF transceiver before now!

All New Receiver Front End
Utilizing husky junction field-effect transistors in a 24 volt, high-current design, the FT-102 front end features a low-distortion RF preamplifier that may be bypassed via a front panel switch when not needed.

IF Notch and Audio Peak Filter
A highly effective 455 kHz IF Notch Filter provides superb rejection of heterodynes, carriers, and other annoying interference appearing within the IF passband. On CW, the Audio Peak Filter may be switched in during extremely tight pile-up conditions for post-detection signal enhancement.

Variable IF Bandwidth with IF Shift
The FT-102's double conversion receiver features Yaesu's time-proven Variable Bandwidth System, which utilizes the cascaded IF filters to provide intermediate bandwidths such as 2.1 kHz, 1.5 kHz, or 800 Hz simply by twisting a dial. The Variable Bandwidth System is used in conjunction with the IF Shift control, which allows the operator to center the IF passband frequency response without varying the incoming signal pitch.

Wide/Narrow Filter Selection
Depending on the exact combination of optional filters you choose, a variety of wide/narrow operating modes may be selected. For example, you may set up 2.9 kHz in SSB/WIDE, 1.8 kHz in SSB/NARROW, then select 1.8 kHz for CW/WIDE, and 600 Hz or 300 Hz for CW/NARROW. Or use the Variable Bandwidth to set your SSB bandwidth, and use 600 Hz for CW/WIDE and 300 Hz for CW/NARROW! No other manufacturer gives you so much flexibility in selecting filter responses!

Variable Pulse Width Noise Blanker
Ignition noise, the "Woodpecker," and power line noise are modern-day enemies of effective Amateur operation. The FT-102 Noise Blanker offers improved blanking action on today's man-made noise sources (though no blanker can eliminate all forms of band noise) for more solid copy under adverse conditions.

Low Distortion Audio/IF Stage Design
Now that dynamic range, stability, and AGC problems have been largely eliminated thanks to improved technology, Yaesu's engineers have put particular attention on maximizing intelligence recovery in the receiver. While elementary filter cascading schemes often degrade performance, the FT-102's unique blend of crystal and ceramic IF filters plus audio tone control provides very low phase delay, reduced passband ripple, and hence increased recovery of information.

Heavy Duty Three-Tube Final Amplifier
The FT-102 final amplifier uses three 6146B tubes for more consistent power output and improved reliability. Using up to 10 dB of RF negative feedback, the FT-102 transmitter third-order distortion products are typically 40 dB down, giving you a studio quality output signal.

Dual Metering System
Adopted from the new FT-ONE transceiver, the Dual Metering System provides simultaneous display of ALC voltage on one meter along with metering of plate voltage, cathode current, relative power output, or clipping level on the other. This system greatly simplifies proper adjustment of the transmitter.

Microphone Amplifier Tone Control
Recognizing the differences in voice characteristics of Amateur operators, Yaesu's engineers have incorporated an ingenious microphone amplifier tone control circuit, which allows you to tailor the treble and bass response of the FT-102 transmitter for best fidelity on *your* speech pattern.

RF Speech Processor
The built-in RF Speech Processor uses true RF clipping, for improved talk power under difficult conditions. The clipping type speech processor provides cleaner, more effective "punch" for your signal than simpler circuits used in other transmitters.

VOX with Front Panel Controls
The FT-102 standard package includes VOX for hands-free operation. Both the VOX Gain and VOX Delay controls are located on the front panel, for maximum operator convenience.

IF Monitor Circuit
For easy adjustment of the RF Speech Processor or for recording both sides of a conversation, an IF monitor circuit is provided in the transmiter section. When the optional AM/FM unit is installed, the IF monitor may be used for proper setting of the FM deviation and AM mic gain.

WARC Bands Factory Installed
The FT-102 is factory equipped for operation on all present and proposed Amateur bands, so you won't have to worry about retrofitting capability on your transceiver. An extra AUX band position is available on the bandswitch for special applications.

Full Line Of Accessories
For maximum operating flexibility, see your Authorized Dealer for details of the complete line of FT-102 accessories. Coming soon are the FV-102DM Synthesized VFO, SP-102 Speaker/Audio Filter, a full line of optional filters and microphones, and the AM/FM Unit.

Price And Specifications Subject To Change Without Notice Or Obligation

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