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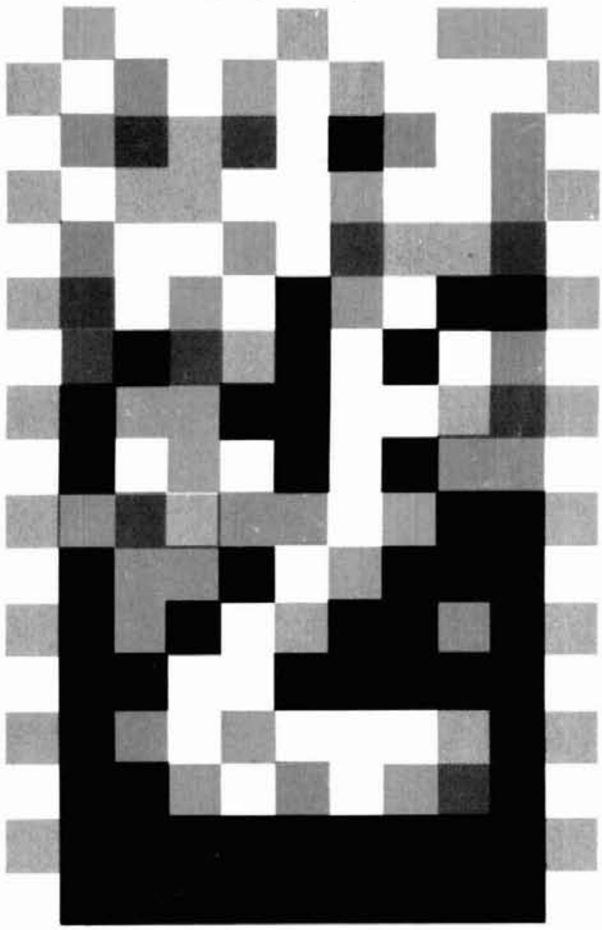
ham radio magazine

JULY 1979

DISPLAY SSTV PICTURES ON A FAST-SCAN TV



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New MFJ 3 & 1.5 KW Versa Tuners

Run up to 3 KW or 1.5 KW PEP and match everything from 1.8 thru 30 MHz: coax, balanced line, random wire. Built-in balun.

3 KW VERSA TUNER IV's — 1.5 KW VERSA TUNER III's

NEW MFJ KW VERSA TUNERS HAVE THESE FEATURES IN COMMON

These 6 new MFJ KW Versa Tuners let you run up to 3 KW or 1.5 KW PEP (depending on the model) and match any feedline continuously from 1.8 to 30 MHz: coax, balanced line or random wire. Gives maximum power transfer. Harmonic attenuation reduces TVI, out of band emissions.

All metal, low profile cabinet gives RFI protection, rigid construction, sleek styling. Black. Rich anodized aluminum front panel. 5x14x14 inches. Flip down stand tilts tuner for easy viewing.

Efficient, encapsulated 4:1 ferrite balun. 250 pf, 6000 volt capacitors. 18 position dual inductor, 17 amp, 3000 V ceramic rotary switch (3 KW version). 12 position inductor, ceramic rotary switch (1.5 KW version). 2% meters. SO-239 coax connectors, ceramic feedthru for random wire and balanced line. One year limited warranty. Made in U.S.A.

3 KW VERSA TUNER IV's

1 MFJ-984 3 KW VERSA TUNER IV

$299.95 *EXCLUSIVE RF AMMETER insures maximum power to antenna at minimum SWR. Built-in dummy load.*

This is MFJ's best 3 KW Versa Tuner IV. The MFJ-984 Deluxe 3 KW Versa Tuner IV gives you a combination of quality, performance, and features that others can't touch at this price.

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$169.95 *Heavy duty encapsulated 4:1 ferrite balun for balanced lines.*

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Features an efficient, encapsulated 4:1 ferrite balun for balanced lines.

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$169.95 *SWR, dual range forward and reflected power meter, 6 position antenna switch, encapsulated 4:1 ferrite balun.*

The MFJ-962 1.5 KW Versa Tuner III is an exceptional value.

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Black front panel has reverse lettering.

6 MFJ-961 1.5 KW Versa Tuner III

$149.95 *6 position antenna switch lets you select 2 coax lines thru tuner or direct, or random wire and balanced line.*

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If you already have a SWR/wattmeter, the MFJ-961 is for you.

Black front panel has reverse lettering.

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Why not visit your dealer today? Compare these 3 KW and 1.5 KW Versa Tuners to other tuners. You'll be convinced that its value, quality and features make it a truly outstanding value. If no dealer is available, order direct from MFJ and try it. If not delighted, return it within 30 days for a prompt refund (less shipping). Charge VISA, MC. Or mail check, money order plus $10 shipping/handling.

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More Details? CHECK—OFF Page 110

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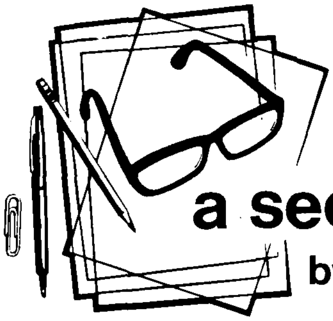
contents



a second look

by Jim Fisk

This is the time of the year when many amateurs are working on their antenna systems for the coming DX season. If you're considering installing a new tower, however, there are some potential legal problems you should consider, even before you dig the hole for the base and pour the concrete. Mervyn Hecht, Attorney-at-Law and a Trustee of the Personal Communications Foundation (PCF), discussed four of the possible problems in a recent PCF bulletin:

Error in calculating the property line. "This can come about in two ways. First, the property line may not be where you think it is, especially on hillside properties. Imagine how expensive it will be to move your misplaced tower if your neighbor discovers it is on his property and will not let you keep it there! If there are no property line survey marks you can rely on, and the tower is to be positioned anywhere near a property line, have that line surveyed before you dig the hole for the base.

Secondly, don't forget that the antenna will be wider than the tower. If the tower is right next to a property line, the antenna will protrude into your neighbor's "air space." If that happens, your neighbor has the right to make you move the tower.

Blocking the neighbor's view. This problem seems to crop up primarily on hillside properties. It may seem reasonable for the valley dweller with a hillside near his house to place his tower on the hillside, above the surrounding hills, but to a person who lives on the top of the ridge an antenna sticking up at the edge of his yard — so he has to look between the director and the reflector to see the setting sun — can be very frustrating. The legal aspects of blocking the view (or sunlight) are now in a state of change, but the trend is toward recognition by courts of these rights, and away from the absolute property rights characteristic of earlier times.

The radio operator must recognize the potential problem and try to position his tower and antenna where it will not interfere with any often-used view nor block the sunlight. If there is some problem in avoiding this result, consider an alternative such as a) a motorized or hand-cranked tower so the antenna can be lowered when not in use; b) a smaller sized antenna; c) meeting with the potentially offended neighbor to obtain the neighbor's permission to erect the tower on some less offending spot owned by the neighbor.

Interference with underground or property line easements. Many property titles are legally "burdened" by deeds to telephone companies, electric companies, cable television operators, and other utilities which give these services various rights. Usually these rights are to install (either under or over the ground) various cables and pipes, and often to enter onto the property to replace, service, and check these installations. These easements are often so broad that although you own the property — and pay the property taxes — you have given up the use of these (usually five-foot wide) strips of land. If you install anything which blocks the utility company's rights, or prevents them from exercising the rights granted, you may be required to move your tower. Even if the utility is not using the easement now, it may in the future (perhaps a few weeks after you install the tower), or the utility may just be run by difficult people who are intent on enforcing their rights.

Causing damage to the neighbor's structure. There are three general ways I have seen this happen. First, mechanical drilling, such as with a jack hammer, which can cause shock waves to nearby structures. Second, digging a hole may result in loss of lateral support which can cause unexpected land movement resulting in damage to nearby structures. By far the most common major problems I have seen resulting from property line excavation, however, are related to water drainage. Particular care should be taken not to change any drainage pattern because, during a rain storm, the slightest change can cause thousands of pounds of water to accumulate in unexpected places."

As if this is not enough to think about, Attorney Hecht further notes that although he has "not even mentioned deed restrictions, height limitations, airport clearance and lighting regulations, city permits, convenants running with the land, or neighbors running after you with a shotgun . . ." he does not wish to discourage radio amateurs from installing a tower. Just be aware that if you are going to dig a hole for a tower base, don't dig near a property line unless you take special care to avoid the special problems that can arise.

Jim Fisk, W1HR
editor-in-chief

comments

lightning protection

Dear HR:

Many thanks for publishing K9MM's excellent article, "Lightning Protection," in the December issue. It is hoped that Amateurs will heed the warning.

Author Becker suggests grounding wooden poles by placing a grounding conductor on the pole — this is quite effective, but it may act as another antenna, radiate minute ground electrical noises, and reradiating some transmitting power. It is suggested that the ground wire be cut into 10-foot (3-meter) lengths with each end bent 180° on a half-inch radius (except the top spike) and stapled to the pole with each loop separated by 2 mm (1/16 inch) from its neighbor. This spacing is adequate for Amateur use.

It is further suggested that Amateurs become acquainted with the provisions of the National Electrical Code (NFPA no. 70) published by the National Fire Protection Association; it lists specific requirements for station protection. This document is available at most public libraries and is quoted briefly in part on page 645 of the 1978 *ARRL Handbook*. Compliance with the provisions of the NFPA Code may avoid insurance adjuster hassles if lightning plays havoc with your property.

Marchal H. Caldwell, Sr., W6RTK
Sacramento, California

lightning protection

Dear HR:

I have recently become a professional associate in the Lightning Protection Institute, a group of professionals, installers, and equipment manufacturers who have joined together to promote lightning protection and the safe design and installation of lightning protection systems. For this reason, and because I am a Radio Amateur with several wire antennas, I found the article in the December issue of *ham radio* particularly informative, accurate, and up to date as it discussed lightning theory, protection against direct strikes, and protection against surge and transient high voltages.

As is usually the case, the article was well written and documented, and, in my opinion, serves as the best source of lightning protection information that I have seen to date for the Radio Amateur. Unless I miss my guess, this is a better treatise by far than that found in the ARRL *Radio Amateur's Handbook*. Quite frankly, I feel it is so good that those editors ought to consider lifting the article and using it in the *Handbook* in toto.

Gerald B. Curtis, WB2FBL
Westmont, New Jersey 08108

OSCAR 10-meter downlink

Dear HR:

Now that the 10-meter band is practically fully open for worldwide direct communications, perhaps it's time to curtail Oscar 10-meter downlinks. The reason for my position is that 100 kHz is a lot to take out of the usable hf spectrum; now that the Soviets have orbited their two vehicles this has increased the "forbidden" territory to 200 kHz (29.3 to 29.5 MHz).

The pass time over any given area may be good for only 15 to 20 minutes of acquisition, but since direct skip prevails over such a wide area, in all directions, this means that the effective interference chances are multiplied by the number of passes and orbit time.

There are several other factors which seem to make satellites with 10-meter output unacceptable, one being the large number of Civil Emergency Preparedness stations which have been on these frequencies since 1945, another being the many low-power stations which have been squeezed out of the lower part of the 10-meter band.

I have suggested to AMSAT that if they lead the way now by deleting the 10-meter downlink, the Soviets may do likewise on their next venture. AMSAT is to be congratulated for serving 10 meters during the sunspot time, but the time to discontinue is now!

Samuel H. Beverage, W1MGP
North Haven, Maine

Dear HR:

My Digital Display, which appeared in the March, 1979, issue of *ham radio*, occasionally will reset to 999.9 instead of 000.0. This problem is easily eliminated with the following simple circuit changes:

1. Lift pin 3 of U6 from ground and reconnect it to pins 2 and 8 of U6.

2. Disconnect the line between pins 6, 7 of U12, and pin 10 of U9. Reconnect pins 6 and 7 of U12 to pins 2, 3, and 8 of U6.

This ensures U12 will always begin a count cycle in the same state.

Frank C. Getz, Jr., N3FG
Media, Pennsylvania

TS-120S

ALL SOLID-STATE HF TRANSCEIVER

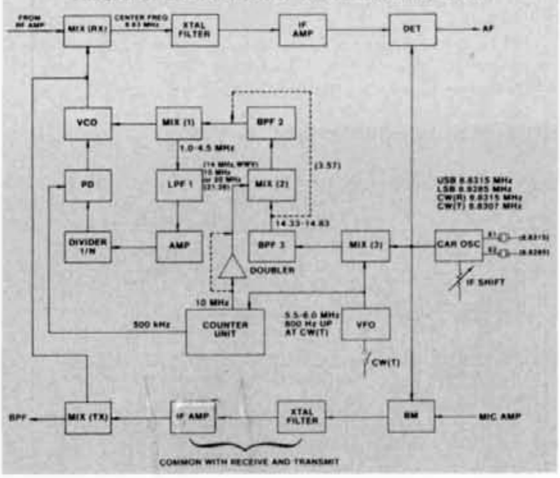
TS-120S

What's unique about the PLL circuit in the TS-120S?

A single-conversion PLL (phase-locked loop) system is employed in the TS-120S. Only one crystal is required, instead of a heterodyne crystal element for each band, resulting in simplification of circuitry, and a marked improvement in overall stability. The single-conversion PLL system also improves the spurious characteristics during transmission and reception, and makes IF shift operation and mono-dial indication available on any model.

The VCO frequency is obtained from the PLL circuit by synthesizing the VFO and CAR frequencies and reference oscillating frequencies of 10 MHz and 500 kHz supplied by the counter. Bandswitching is accomplished by changing the preset value of the programmable divider in the PLL. Therefore, when switching bands, the frequency (except, of course, the 1-MHz and 10-MHz order digits) remains the same. The frequencies for each band and PLL stage are shown in the table.

FREQUENCY COMPOSITION OF THE TS-120S PLL SYSTEM



First, MIX (3) mixes the CAR and VFO frequencies, using a double balanced mixer to reduce spurious signals. The output of MIX (3), after passing through a bandpass filter (BPF 3) is applied to the input of MIX (1) on the 3.5 and 7.0-MHz bands. On the 14-MHz and WWV bands, MIX (2) mixes the output of MIX (3) with a 10-MHz signal from the counter-unit oscillator. On the 21 and 28-MHz bands, MIX (2) mixes the output of MIX (3) with a 20-MHz signal from a doubler connected to the counter-unit oscillator.

The output of MIX (2) - or MIX (1) on the 3.5 and 7.0-MHz bands - is mixed with the VCO output at MIX (1), providing output frequencies shown in the table. The output passes through a lowpass filter (LPF 1) and is amplified, and the resulting digital signal is divided by a programmable divider, producing a 500-kHz output.

"Information" from the band switches is converted into BCD signals in the counter and the division ratio as shown in the table is preset. The loop-filter consists of transistors mounted on the outside to minimize signals. A Motorola MC4044P functions as the phase comparator. Five VCO circuits with high-output transistors cover all of the bands.

If the output of the phase comparator unlocks, VCO output is switched off to prevent emission at unwanted frequencies and, at the same time, the digital display blanks to warn the operator.

What is the concept of the TS-120S digital counter for displaying frequencies?

The TS-120S digital counter employs a VFO frequency counting system. First, the VFO frequency is mixed with a 5-MHz signal obtained from the reference oscillator chain and is converted to 0.5 to 1 MHz. This signal passes through a lowpass filter, is amplified, buffered, and shaped into a digital (square) wave, passes through a 0.1-second gate circuit, and is applied to a four-digit counter. The signal is counted from 10 Hz to 100 kHz and is fed to a preset counter to derive the carrier output.

The 100-kHz order digit presets at 5 to display the operating frequency on the 3.5, 28.5, 29.5, and WWV bands, and at 0 for display on 7.0, 14.0, 21.0, 28.0, and 29.0 MHz. The 1-MHz and 10-MHz order digits are determined by a matrix operating with bandswitch information.

The counter outputs are switched by the multiplexer and converted from BCD to seven-segment information by the decoder to light the fluorescent display tubes. The large digits have good luminous intensity and a dark filter, providing fatigue-free viewing over long operating periods. The display can be read easily, even in the car and other sunlit locations.

The reference oscillator produces a 10-MHz signal and performs time-base division, and generates gate pulses, latch pulses, and reset pulses, which are applied to the counter. The PLL circuit produces 10-MHz and 500-kHz outputs. The marker circuit produces a 100-kHz signal which synchronizes the 25-kHz multivibrator to obtain a marker signal as accurate as the reference frequency.

The 1/10 division at the first stage of the count-down chain utilizes low-power Schottky TTL, and other divisions use CMOS ICs for low power consumption and minimum spurious emission. With the IF shift circuit, the CAR frequency is independent of both transmitting and receiving frequencies.

When the VFO frequency is counted, the operating frequency is indicated as accurately as the reference oscillator frequency, provided that the 10-MHz reference is calibrated to WWV.

True operating frequencies are displayed accurate to three digits (100-Hz order), regardless of CW transmitting and receiving frequencies or the position of the band switch or mode switch. When the VFO is tuned to the extent that the 1-MHz and 10-MHz orders are switched (beyond the band edge), these digits are blanked out.

FREQUENCIES FOR EACH BAND AND PLL STAGE

BAND	RANGE (MHz)	VCO (MHz)	MIX (1) INPUT (MHz)	MIX (1) OUTPUT (MHz)	DIVIDER RATIO	DCBA
WWV	14.5-15.0	23.33-23.83	24.33-24.83	1.0	1/2	1110
3.5	3.5- 4.0	12.33-12.83	14.33-14.83	2.0	1/4	1100
7	7.0- 7.5	15.83-16.33	14.33-14.83	1.5	1/3	1101
14	14.0-14.5	22.83-23.33	24.33-24.83	1.5	1/3	1101
21	21.0-21.5	29.83-30.33	34.33-34.83	4.5	1/9	0111
28	28.0-28.5	36.83-37.33	34.33-34.83	2.5	1/5	1011
28.5	28.5-29.0	37.33-37.83	34.33-34.83	3.0	1/6	1010
29	29.0-29.5	37.83-38.33	34.33-34.83	3.5	1/7	1001
29.5	29.5-30.0	38.33-38.83	34.33-34.83	4.0	1/8	1000

presstop

PROPOSED AMATEUR HF allocations did not suffer as a result of the late maneuvering that delayed the submission of the hf band portion of the U.S. WARC proposal. Still included in the U.S. position are an exclusive worldwide allocation of 1860-1900 kHz, with 1900-2000 shared; 3500-3900 exclusive with 3900-4000 shared; 6950-7250, exclusive; 10.1-10.2 MHz (new) exclusive; 14.0-14.35, exclusive; 18.068-18.168 (new) exclusive; 20.95-21.45, exclusive; and 25.11-25.21 (new) also exclusive. Other services were not as fortunate as the Amateur Service, however, as the final document sent to Geneva does show an increase in broadcast spectrum over that proposed in the FCC "final" report and order on WARC 79 as released in December.

The 220-MHz Situation has not changed much since the FCC's rejection of the various Petitions for Reconsideration. However, it now appears that the Amateur Service is not the only potential loser in the proposed shift that would make maritime prime user of the band. The U.S. Navy, which operates sophisticated satellite tracking equipment in and around 220-225 MHz, says that it was also unaware of the FCC's last minute shift and seems almost as unhappy about it as are Amateurs.

SHIFT OF RFI RESPONSIBILITY from manufacturers of susceptible equipment back to users of transmitting equipment (specifically CB, but certainly including Amateurs) was the theme of a May 27 Washington Post article by Norm Eisenberg, contributor to the Post's Bookworld section. In his piece he underscores "the danger that the responsibility for such interference may be placed on the equipment interfered with," thus causing the "victims" to be penalized. He further follows the traditional manufacturer's line that RFI preventative measures would degrade equipment performance and raise prices, urging readers to write their Congressmen opposing the RFI measures of the proposed rewrite of the Communications Act.

AMATEUR RADIO WAS ATTACKED as "one of the main non-ionizing radiation hazards in the United States" at an April 9-10 meeting of the Subcommittee on Public Health Aspects of Energy, in New York. The group is an arm of the New York Academy of Medicine's Committee on Public Health, reports K6YB, who has an article on the effects of Amateur RF radiation on family and neighbors coming out in Ham Radio magazine later this year.

FCC'S LICENSING DIVISION will move to Gettysburg, the Commissioners decided in late May, providing Congress approves the shift. Affected would be about 160 people presently in the Washington office, leaving only Licensing Chief Dick Everett and his immediate staff behind.

Amateur And CB Licensees, whose applications are already done by the Gettysburg facility, would feel little change from the move. The greatest effect would be on the land mobile service, whose licenses are presently all processed in Washington.

A SPECTACULAR CARIBBEAN RESCUE directed by Amateur Radio saved three mariners when their sailboat went down near Saint Martin. ON7AP/MM, along with his wife and 2-year-old child, were en route from Saint Martin to the Azores in their small sailboat, l'Oiseau de Passage, when the craft began taking on water. As all their marine band equipment was in the flooded forward hold, Alfonso called into the Pacific-Caribbean DX Net on 14175 asking for help. Net control VP2VBK alerted KV4FZ via 2 meters, who in turn called Miami Coast Guard. A helicopter was dispatched, but couldn't find the stricken vessel before running low on fuel and putting into St. Martin. In the meantime FCC monitoring stations were taking bearings on ON7AP's signal, providing more accurate location information for the fixed-wing aircraft now searching.

As Alfonso Speaks Little English, VE3AUN — fluent in both French and English — took over the reins of the search and rescue effort with 9Y4HP, himself a pilot, offering valuable rescue advice on the side. The helicopter, Coast Guard 1438, was unable to reach San Juan Coast Guard directly, but joined the group on 14175 and was patched into San Juan by KV4FZ.

The l'Oiseau de Passage was finally spotted by a fixed-wing aircraft about 5:00 PM, nearly submerged with sails down and the engine dead. The helicopter arrived on the scene shortly thereafter, pulling the wife and child off the foundering vessel first and rescuing ON7AP a few moments later.

Alfonso's Greatest Regret, he said after the rescue, was not being able to save his Yaesu FT-277 — "That radio was the thing that saved our lives!"

Another Rescue In Late April found WD6FFV acting as the liaison between a sinking vessel Carmen and the Coast Guard. In this case, Mike relayed information between the vessel, which was northwest of Jamaica, and Long Beach and Miami Coast Guard. After about an hour of searching, the Coast Guard was able to locate the vessel, dropping the needed equipment to the stricken vessel.

THE AMSAT-OSCAR USERS DIRECTORY, a valuable tabulation found in each issue of the Callbook, needs a new compiler. WB2DNN, who has been doing a yeoman job on the project for the past several years, has asked for relief. Involved is reviewing logs and user reports, and adding new calls to the Directory as they appear on the air. Contact AMSAT if interested in the job.

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***ALL* FILTERS INCLUDED:** 4-position CW/SSB filter (150 Hz bandwidth with 3 selectable skirt contours) plus 8-pole Crystal filter (2.4 kHz bandwidth, 1.8 shape factor.)

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***ALL*-VERSATILE OFFSET TUNING;** dual ranges, ±5 kHz range for off-frequency DX or ±0.5 kHz range for fine tuning.

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***ALL* SIDETONE ADJUSTMENTS;** pitch and volume.

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display SSTV pictures on a fast-scan TV

Using an integrated circuit CRT controller plus software to provide the interface between a computer memory and a fast-scan TV

The missing link for all my SSTV projects[1] was the interface from computer memory to a normal fast-scan TV set. Although commercial units are available, their cost tends to be high and designs complex. In this article I will present a hardware design that is simple and can be easily constructed for less than one-hundred dollars.

Product goals. Prior to starting the project I set a few goals for the interface:

1. The hardware design should be simple, and make use of a minimum of components.
2. The hardware should be reproducible, and flexible enough to allow for future expansion.
3. The software should be modular and use as much relative addressing code as possible and run in ROM.

Obviously, to accomplish a task like this took careful planning and much thought. The item which made the whole project possible was the new family of Large Scale Integration (LSI) chips called CRT controllers.

Specifications. The hardware and software package in this article will accomplish the following:

hardware

1. Display a digitized slow-scan TV picture located in RAM on a normal TV set with 128 pixels/line and 16 gray levels, expandable to 256 pixels/line.
2. Allow for transmission of medium-scan Amateur television[2] in any format.
3. Provide the flexibility to enhance the digitized picture by simple hardware program commands which include interlaced or noninterlaced video and fast-scan picture zooming.

software

1. Receive or transmit Amateur Radio SSTV with 128 or 256 pixels per line and sixteen gray levels.
2. Zoom by the use of software to transmit on SSTV or display on fast-scan TV any one of five quadrants of a digitized picture.
3. Receive quarter-framed SSTV pictures, and display them on fast-scan TV or transmit the pictures on a composite single-framed picture.

In order to accomplish these feats, you must first have some means of digitizing the picture and interfacing the computer with the Amateur Radio receiver. **Fig. 1** is a block diagram of my entire computer configuration. The detailed design of my SSTV analog interface board is contained in my previous articles.[1]

general background

Fig. 2 is a block diagram of the computer video-interface card which is used to display the fast-scan TV. To help you understand the function of this card, I'll discuss how a microprocessor functions in this type of application.

A microprocessor is generally a complex logic element which moves data to and from memory or ports external to the system. In this process, the data could be altered in any manner. In my application, data is first moved from a port which contains an analog-to-digital converter attached to an SSTV demodulator. The data is then formatted in the microprocessor memory in such a way that if it is accessed in a serial manner, converted to an analog

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signal, and mixed with sync pulses, you could display the information as a picture on a television set. This movement of data is accomplished by a series of events called instructions. The art of creating these instructions is called computer programming.

If the microprocessor were fast enough, this process could be accomplished by software with a small amount of hardware. To date, none of the commonly available low-cost microprocessor chips are fast enough. Obviously, if you would like to display pictures from memory, some sort of hardware device must be constructed. As a result of this requirement, I designed the following video-interface card.

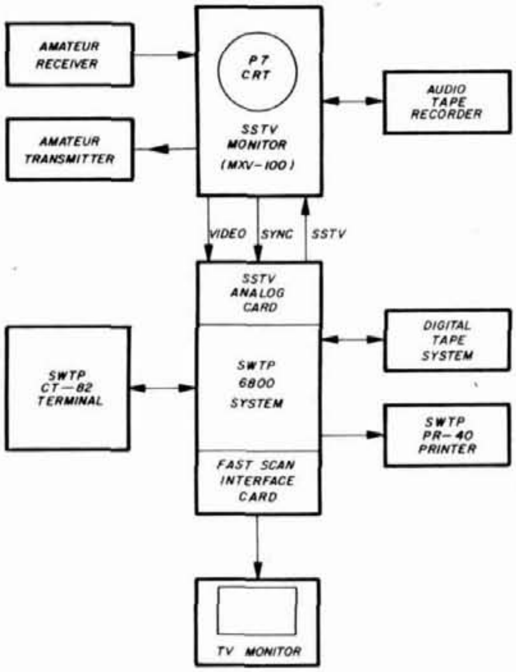


fig. 1. Block diagram of the computer and SSTV systems.

CRT controller block

At this time, four manufacturers have developed LSI CRT controller chips. They are basically complex devices which replace the function of approximately forty ICs and combine their functions into a single package. These chips are designed to interface with digital computers and are used mainly in communications terminals.

Each controller typically contains a number of functional units. **Fig. 3** is a block diagram of the MC6845 CRT controller. These devices are used to address memory as a data refresh buffer, serialize the data from RAM, and mix it at the correct time with TV sync pulses. Each manufacturer's chip design has different features. Some of these features range from built-in character generators to full-color graphics.

Since an SSTV fast-scan display application consists of addressing large blocks of RAM (up to 16k), only one CRT controller met this requirement, the Motorola MC6845.[3,4] The MC6845 is unique, because the chip has more versatility than do any of the other controllers. This IC contains eighteen programmable registers which control the vertical/horizontal timings and refresh RAM address, number of scan elements, and lines per picture.

The unique feature of the chip is that the software controls how the chip performs. For example, calculations of the various controller chip-register values were made by fine tuning with an oscilloscope and a TV monitor to achieve optimum results. This feature is similar to changing variable capacitors or potentiometers in older hardware technologies. Software is much faster and more reliable than the older techniques. With software you can achieve textbook waveforms with a little experimentation.

memory accessing

Another subject which should be briefly discussed is direct-memory accessing (DMA). DMA is a technique for reading or writing to or from memory at a much faster rate than allowed by the microprocessor software. The three DMA techniques that can be implemented in microprocessors are:

1. Halting the processor.

2. Cycle stealing.

3. Multiplexing the CPU and DMA.

Each technique has its own advantages. When planning the project, two DMA methods were investigated as possibilities in this application, halting the CPU and multiplexing. The cycle-stealing method would not be fast enough for the refreshing or accessing of a video display system.

SSTV characters as seen on fast-scan TV.

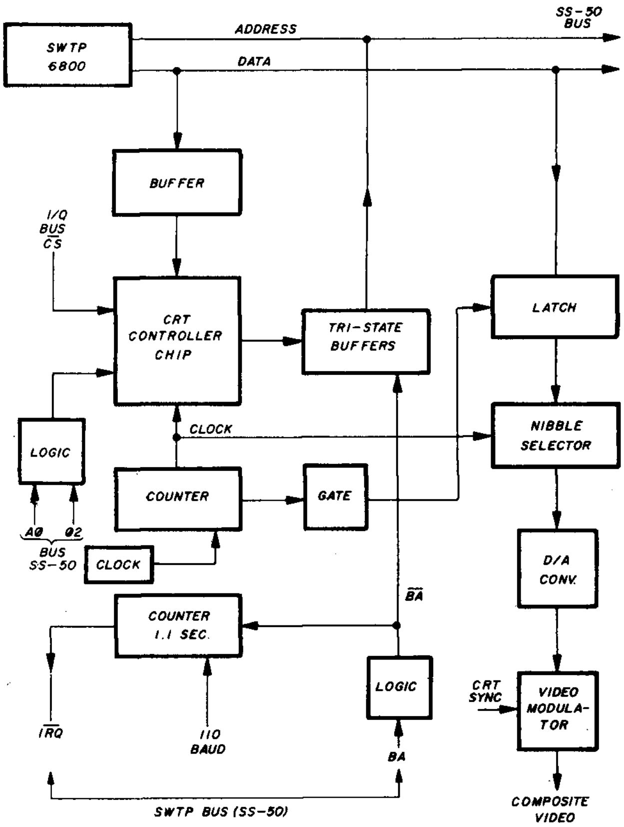


fig. 2. Block diagram of the video-interface card.

Multiplexing had a big advantage since the CPU and display could share the picture RAM area at the same time. This multiplexed-type of operation is easily implemented in the 6800 microprocessor since both phase 1 and 2 cycles have the same durations. In this configuration the CRT controller chip would drive the CPU. The CPU would operate as normal, addressing RAM at a phase 2 cycle time. The display would access memory during phase 1 cycle time. This method was considered the most desirable, however the standard SWTPC 6800 MP-A CPU card derives its baud rate from the CPU clock. Therefore, this DMA approach was not chosen. If it were, the baud rates derived from the CRT controller clock would be nonstandard.

The halting of the CPU was the method I chose for my card design. Additionally, halting of the CPU is the easy type of design to develop. All that has to be done to halt the CPU is to ground the halt line on the bus (SS-50). In my application, I decided to be a little more elegant than just grounding the halt pin to start the operation. The 6800, like many of the more popular microprocessors, has an instruction called wait (WAI). When the microprocessor executes this command, it waits or does nothing until it receives an interrupt (or signal) from another source. This is the method I chose to halt the CPU. While in wait state, my special card takes control of the bus and provides the signals to RAM to sequentially take the pixels (picture elements) and transfer them to the TV monitor. When the microprocessor receives the interrupt, the interface card is disengaged and normal microprocessor operation resumes. The SSTV hardware interface to the software is an analog-to-digital (A/D) converter and a digital-to-analog converter (D/A). The A/D is used to receive the SSTV pictures, and the D/A is used to transmit SSTV. Both units are connected to an MC6820 PIA parallel port. **Fig. 4** describes the 6820 bits assigned by the software and used by the analog card.

video-card theory

Fig. 5 contains a schematic diagram of the video-interface card. Some of the major components have been previously discussed, with the details to follow.

Initialization. Before the whole process can start, the CRT controller chip must be initialized. This initialization tells the controller chip the type of video which will be displayed and where the picture is in the microprocessor memory. To accomplish this, registers in the controller chip must first be loaded with data by software, with hardware selecting the chip at the correct time.

Chip selection in the SWTP 6800 system is conveniently located on the system mother board. I found it convenient to run a wire from the I/O selection line on the small socket to the $\overline{CS}$ line on the CRT controller chip. This left only the chip ENABLE control decoding which had to be installed on the card. Since data is valid only during phase 2 of the 6800 clock cycle, only two signals had to be ANDed, W/$\overline{R}$ and phase 2. The least significant bit of the address line (AØ) was connected to the chip RS input. Thus when AØ is true, the register number can be loaded; when off, the data is loaded into the controller chip.

One important point should be noted when debugging this circuit: It does nothing without initialization. When initialized, you can observe the various output lines changing.

Buffering. Since the card shares the same bus as the microprocessor, all lines must be buffered with either tri-state or low-power Schottky ICs (74LS). Tri-state devices have three output states, ground, high, and floating. When floating, these chips exhibit a high impedance which is almost an open circuit. When not in use, the video card floats on the bus.

When a WAI instruction is executed by the microprocessor, the bus available (BA) line rises and the CPU card floats. I found that the SWTP MP-A CPU card has a bug and requires a slight modification to properly DMA the bus. Apparently Southwest designed the card for DMA; however, they allowed one buffer to be in the high state. You can correct this problem by cutting the lead on U12 between pins 4 and 5. Leave the connection on pin 5, but connect a wire from pin 4 to pin 2 of U12. Since many manufacturers produce 6800 CPU cards, I suggest that you consult your schematics to ensure that your card will tri-state the bus when the 6800 BA line goes positive.

One line that my video card does not control during DMA is R/$\overline{W}$. Since the video card is always reading RAM during refresh, I let this line float positive. The main reason for doing this is that I ran out of buffer modules on the three tri-state buffers (U16, U17, and U18). A more desirable state would be to condition this line positive.

Memory addressing. The memory addressing of the video card is the simplest part of the whole operation. All of the difficult work is accomplished by the CRT controller chip. When initialized, the memory is addressed at one half the pixel rate (650 ns). The appropriate sync pulses are also outputted from the chip and mixed with the video.

Data flow. The most important part of the entire video card is the flow of RAM data to the TV set. Since the CRT controller chip does the difficult task of addressing memory, all that has to be done is to serialize the information. When RAM is addressed, the data is presented to two latches (U5 and U6) where each holds four bits of a byte (nibble). The data is latched at the end of an addressing cycle, with both latches feeding a multiplexer (U7). First the lower nibble then the upper nibble are fed through the multiplexer. Since each pixel is a nibble, and a byte contains two pixels, the data rate is twice the memory-accessing rate. This allows the use of 450 ns memory to refresh a picture with 128 pixels per line. If you wish to refresh a larger buffer with more pixels per line (256), you must make the following changes.

1. Change the crystal frequency to twice the rate, 12.2888 MHz for 60-video standards.
2. Re-initialize the CRT controller chip for 128 characters per line and a memory start address of 0000.
3. Load a picture in RAM from address 0000 to 3FFF (16k bytes).
4. Place 16k of static 250-ns access time RAM at locations 0000 to 3FFF.

These steps will produce a fast-scan television picture with twice the resolution of comparable commercial units.

video modulator

The video modulator was designed for its simplicity and low cost. At first I considered using a digital-to-analog converter for the modulator. This method, on the surface, appeared to be a good approach. However, the component count and cost were considerably higher than I expected. **Fig. 6** is a plot of the excellent linearity of this modulator. The four 1 per cent resistors could be replaced with 5 per cent values by a selection process. Only one resistor had to be fine-tuned in the modulator circuit, the 3.3 kilohm resistor which controls the 70-to-30 per cent

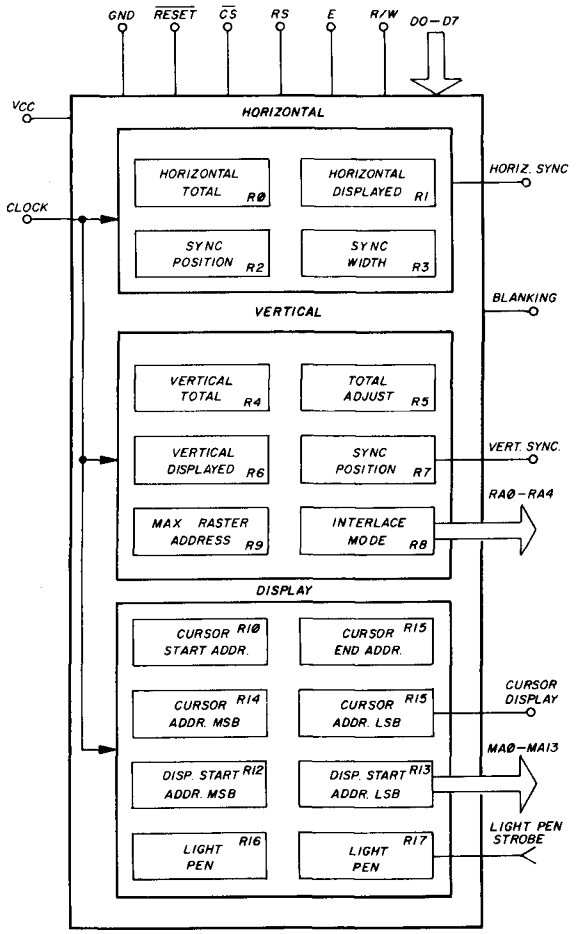


fig. 3. Diagram of the functions internal to the MC6845 CRT-controller IC.

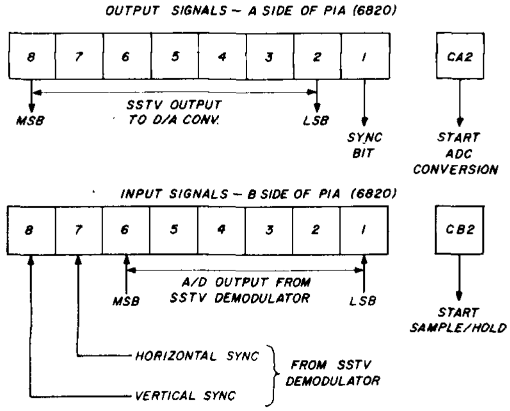


fig. 4. Format of the digital signals into and out of the 6820 PIA.

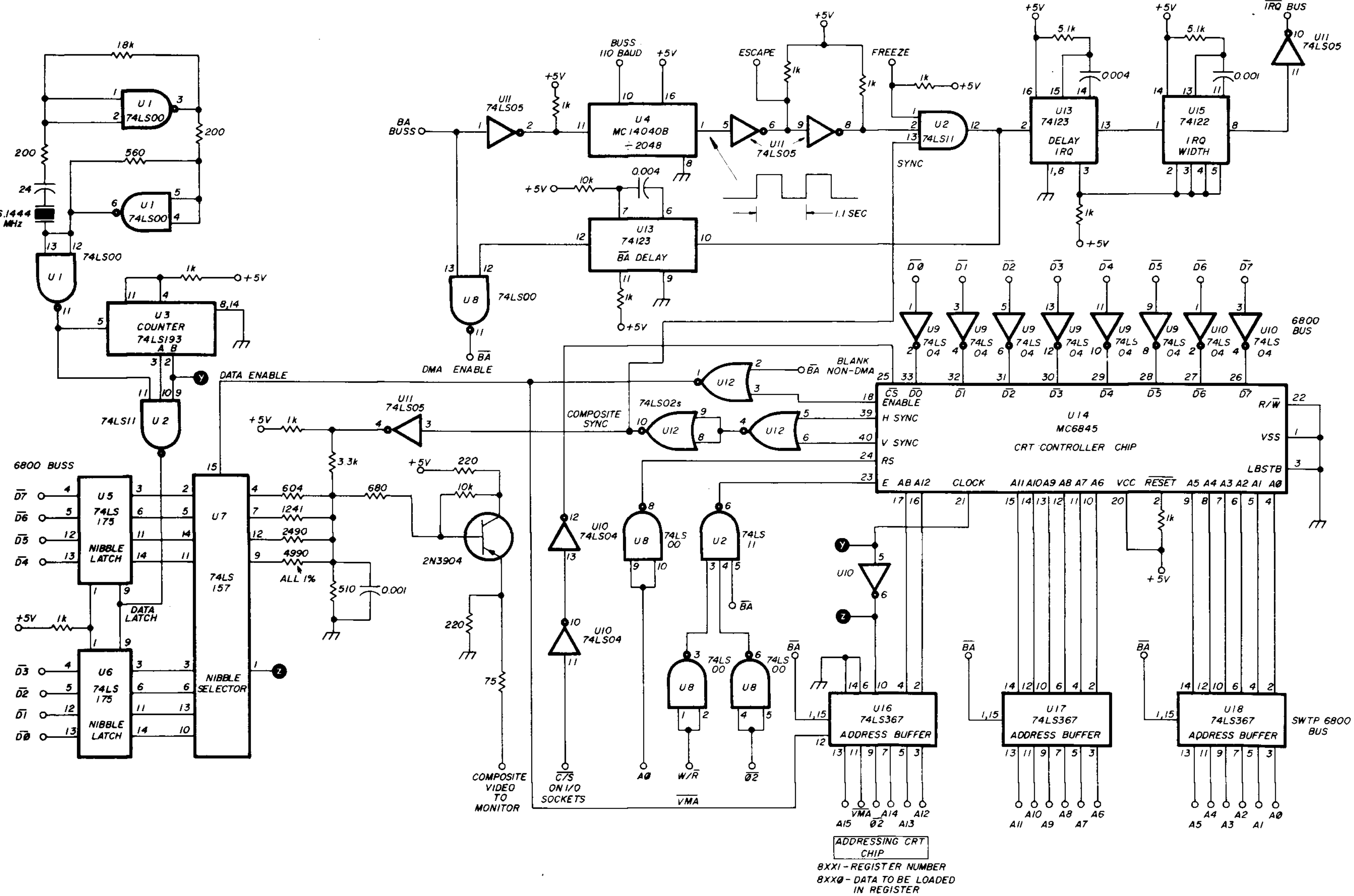


fig. 5. Schematic diagram of the video-interface card.

relationship between video and sync. If the sync is too low or high, change the 3.3-kilohm resistor in series with U11. The sync portion of the video should be.30 per cent of the total swing of the video signal.

counters and timers

The main counter on the card is very simple. The clock signal is generated by U1 and is divided down by U3. The only tricky part is the nibble latch signal derived from U2. Since the data is valid only at the end of the addressing cycle, it must be latched as close to the fall of the address as possible. Calculations show that if 250-ns memory were refreshed, 256 pixels/line could be refreshed and latched with this scheme. If the latch is marginal, inverters could be placed in series with the line for additional delay.

The timer is used to return from a wait condition of the CPU. I derived this return signal by counting down the 110-baud rate on the SS-50 bus by 2048. This method gave me an interrupt every 1.1 seconds. I serviced this interrupt by software, with the interrupt generated by grounding $\overline{IRQ}$ on the bus line for approximately 2 μs (U15). The visible effect on the fast-scan TV is one missing scan line every 1.1 seconds.

U13 is used to drop the DMA at the correct time and issue the interrupt. The BA delay side of U13 causes the video card to float 8 μs prior to and after issuing the interrupt. This time could be reduced since the capacitor used in the single shot was the only value I had in my junkbox when the card was developed. Two external control signals were placed on the I/O connector of the card. These signals are freeze and escape. Freeze is used to display a continuous picture on the TV screen by grounding the central line with a switch. Escape can be used to return to the CPU from DMA by grounding this line with a pushbutton. The push button will cause an interrupt.

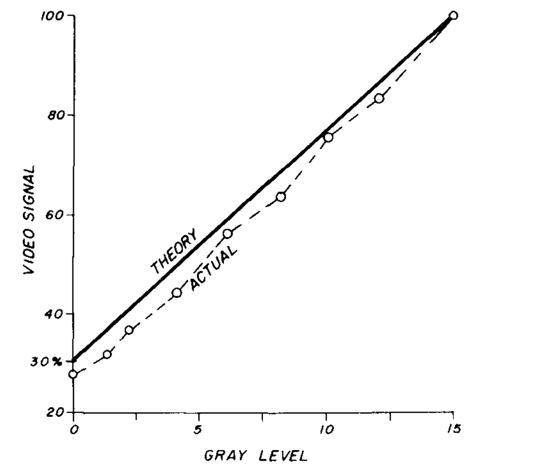


fig. 6. Diagram of the linearity of the fast-scan modulator in percentage of video signal to gray level.

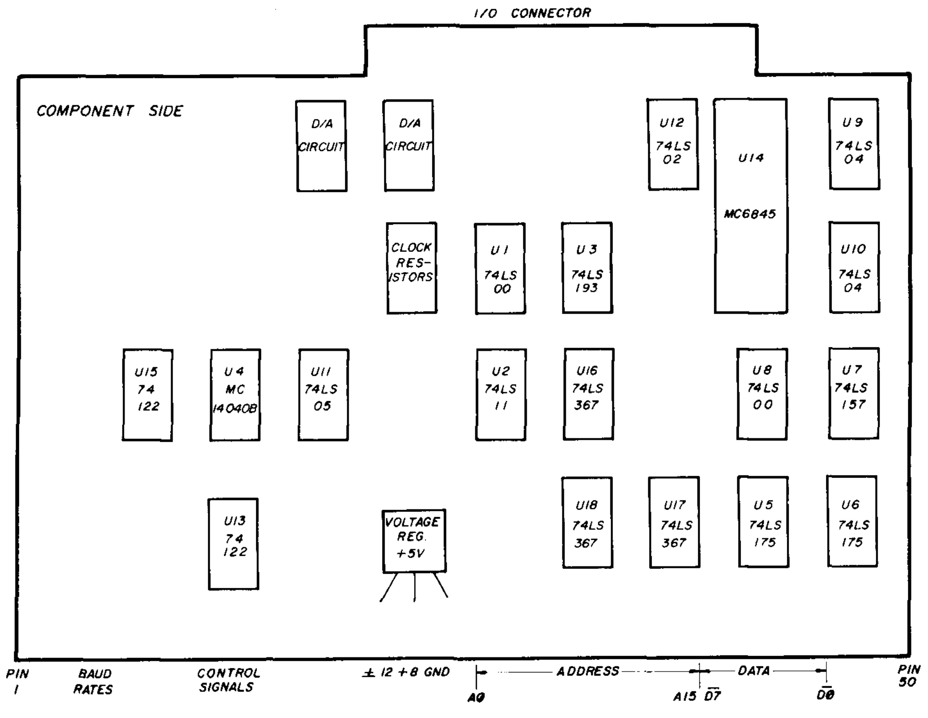
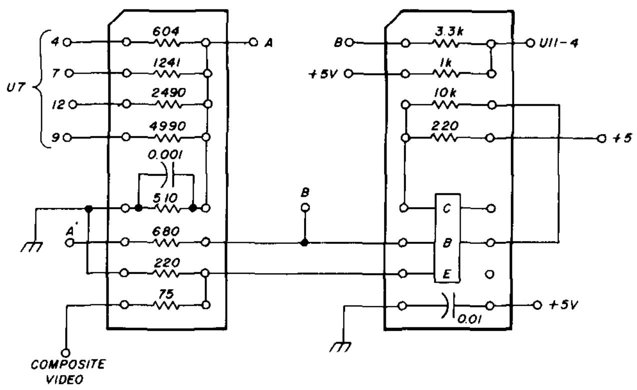
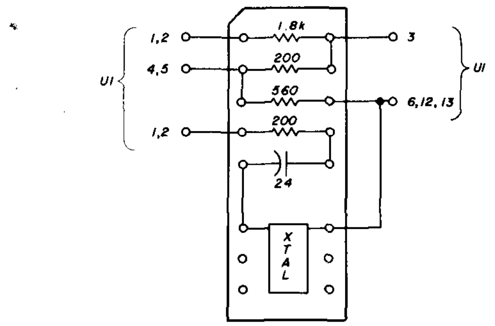


fig. 7. Layout of the video-interface circuitry on the prototype board.



D/A CONVERTER/VIDEO MODULATOR



XTAL OSCILLATOR

fig. 8. Suggested component mounting layout for use with DIP plugs.

video-card construction

My card was solder wired on an SS-50 bus prototype card. All signals to and from the card were routed through the connector at the top of the card. The power (8 volts) was obtained from the SS-50 bus, and regulated to 5 volts by a three-terminal regulator on the card.

Fig. 7 is the layout of the card. I found that the component layout was not critical due to the low frequencies involved. Three sockets were used for the components on the modulator and the clock circuit. The use of dip plugs make a convenient means of mounting discrete components. If you wish to experiment with different clock frequencies, new crystal plugs could be exchanged quickly. **Fig. 8** is a layout of the dip sockets I used.

The only component which may be difficult to obtain is the MC6845. This component is currently available by mail order from Jade Electronics for $29.95. The crystal and other chips can be obtained from the same source. The crystal frequency is a standard microprocessor frequency. A scattering of 0.01-μF capacitors should be placed between the 5-volt line and ground. These capacitors are not shown on the schematic since they are a function of the card layout. The card requires no adjustments. The software handles all initial adjustments.*

I decided to revise my software from the previous articles of this project for three reasons:

1. To allow the programming code to reside on EPROM with slight changes. No self-modifying code was used.
2. To simplify software operation by providing routines that have proven effective in the majority of Amateur Radio SSTV contacts.
3. To add new features to the software.

Fig. 9 contains a memory map of the software. The software was written in a top-down manner with all of the major routines or subroutines callable from other programs. This means that if the software were placed on EPROM, the routines could be called like macros and used as a basis of a high-level programming package. Since the software demands the use of a small amount of RAM, twenty-two bytes were reserved in the A000 region which resides physically on the CPU card. The routines were made as versatile as possible by placing all delay constants and some limited code in this RAM region.

The RAM constants are initialized during execution of the program, and can be modified at any time to produce new effects in the reception or display of SSTV signals. **Table 1** further defines the RAM constants.

CRT controller-chip software

The CRT controller chip contains eighteen registers which can be programmed to produce almost any type of video. The chip has quite a large amount of flexibility in horizontal and vertical timings. However, the crystal frequency selected must be approximately correct. I selected the CRT controller crystal by the following calculations.

The first step in crystal selection is to determine the over and under scan limits of your monitor. I determined that I could lock on video with a horizontal picture display time between 34 and 46 μs. Since the most desirable condition for my monitor (Sanyo VM4092) is to display a picture with a slight underscan, I found that 42 μs was optimum. The next step was to calculate the pixel time. I chose to display 128 pixels per line, and each pixel consisted of 64 bytes. Dividing 42 by 64, the pixel time was 656 ns. Converting this time to frequency and multiplying by four, which is the counter-divide ratio, 6.095 MHz was found to be optimum. This value was close to an off-the-shelf commercial frequency of 6.1444 MHz (651 ns).

The next task was to program the eighteen registers. The specification sheet for the MC6845 provides

*A copy of the source code is available by sending a self-addressed, stamped envelope to *ham radio*, Greenville, New Hampshire 03048.

more detail on the constant selection. I'll provide some of the logic on how I selected my constants, since I found the specifications somewhat confusing.

Horizontal-total register (RØ). The horizontal total register is the television horizontal frequency divided by the clock —

$$63.5\ \mu s/651\ ns = 96$$

Bytes to be displayed (R1). For 128 pixels per line use 64, and for 256 pixels per line use 128.

Horizontal-sync frequency (R2). This register moves the horizontal-sync position. The effect on the TV set is to move the centering of the picture right or left. A value of 77 was found to be optimum.

Horizontal-sync width (R3). The pulse width should be 4-5 μs, which is a value of 7 (4.55 μs).

Vertical-total register (R4, R5). These two registers determine the vertical frequency. These values were determined experimentally by changing R4 (coarse) and R5 (fine tune) ending at 127, 10.

Vertical-displayed rows (R6). This constant determines the number of character rows that will be displayed. Since an SSTV picture displayed on fast scan

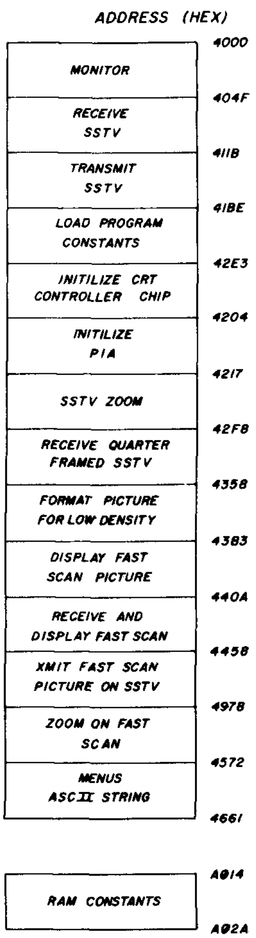


fig. 9. Program memory map for the SSTV routines.

```
                   *
                   * CRT CHIP
                   * INITILIZATION
                   * SOFTWARE
                   *
                   * 1/31/79
                   * C. W. ABRAMS
                   *
 5000                        ORG     $5000
 5000 5F           CRT       CLRB
 5001 CE 50 13               LDX     #CRT2
 5004 F7 80 3D     CRT1      STAB    $803D
 5007 A6 00                  LDAA    X
 5009 B7 80 3C               STAA    $803C
 500C 08                     INX
 500D 5C                     INCB
 500E C1 10                  CMPB    #$10
 5010 26 F2                  BNE     CRT1
 5012 39                     RTS
                   *
                   * CONSTANTS
                   * FOR INIT
                   *
                   *
 5013 60           CRT2      FCB     96,64,77,
7
 5014 40 4D
 5016 07
 5017 7F                     FCB     127,10,12
0,120
 5018 0A 78
 501A 78
 501B 01                     FCB     1,1,0,0
 501C 01 00
 501E 00
 501F 12                     FCB     $12,$40
 5020 40
                             END
      NO ERROR(S) DETECTED
```

fig. 10. CRT-controller IC initialization software.

must have the correct aspect ratio, a value of 120 was selected. This format causes eight lines not to be displayed on the fast-scan screen.

Vertical-sync position (R7). This constant was chosen by trial and error. A value of 120 produced optimum results.

Interlace (R8). This constant can select three types of interlaced video: normal, interlaced sync, or interlaced sync and video. An interlaced picture produced the best video. Therefore, a constant of 1 was selected.

Scan-line register (R9). This register is used to tell the controller the number of scan lines per character.

Fast-scan picture of a girl's face.

Since a pixel line has only one scan line, a value of 1 was programmed.

Refresh-buffer address (R12 and R13). These two registers determine the starting address for the refreshing of the fast-scan video picture. Since 120 lines are displayed, the top four and bottom four SSTV lines were truncated. Therefore, a refresh start address 0240 (hex) was chosen. This centers the SSTV pictures on the fast-scan TV display.

Fig. 10 is a source listing of a routine to load the CRT-controller registers.

A CRT controller gives you a flexibility never before attainable in a video display system. One example of this flexibility is the newly proposed medium-scan TV. When the medium-scan format is standardized, a special crystal dip socket could be constructed and new constants placed in the software. When this is done, the composite video could be connected directly to an Amateur Radio transmitter.

With a little imagination, numerous tricks can be played with the CRT-controller chip to enhance the pictures for display purposes.

software

To provide flow charts for this entire package would be an enormous task. Therefore, I've selected

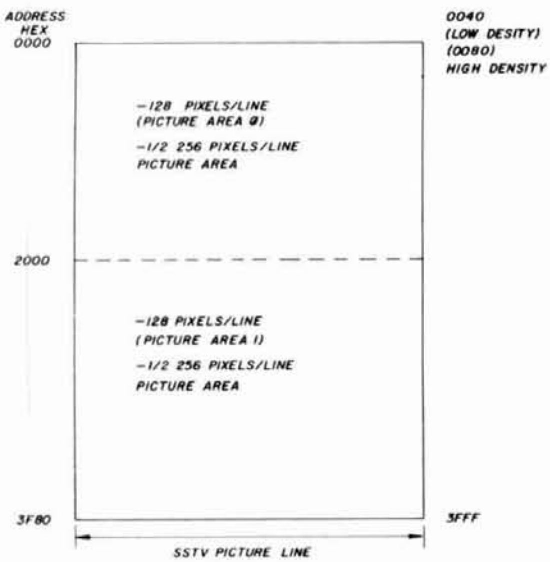


fig. 11. Diagram of the RAM space required for the SSTV pictures.

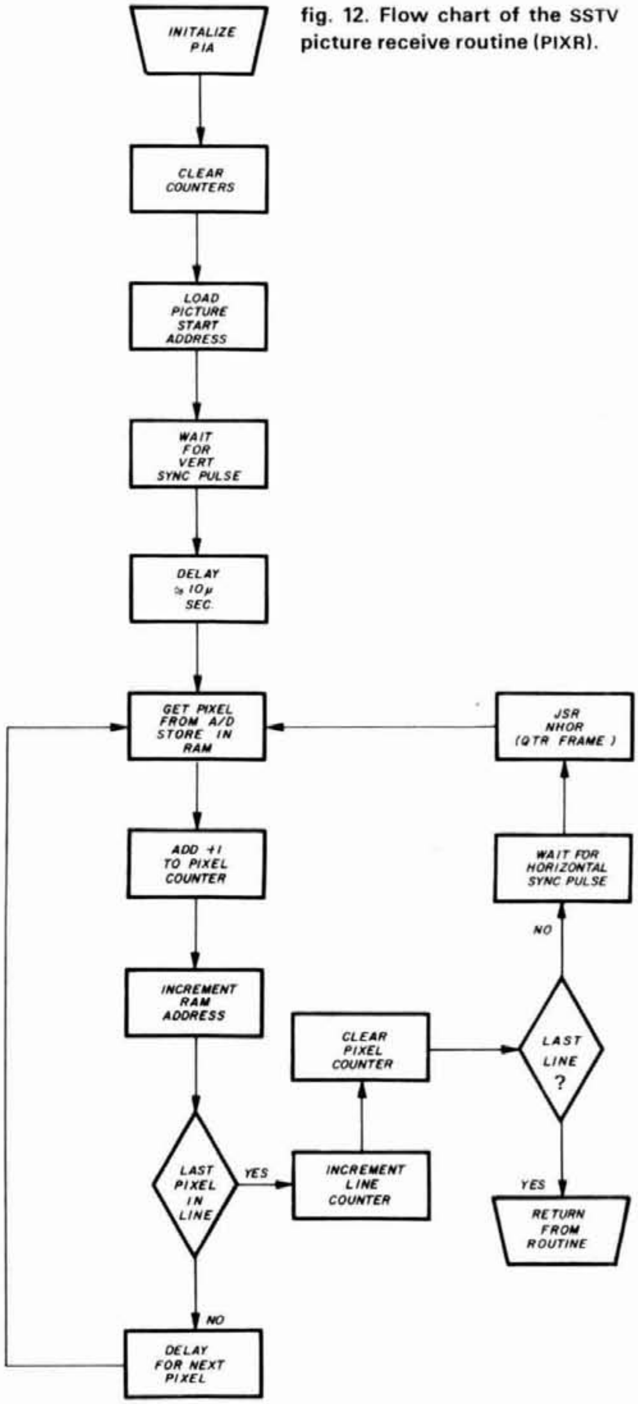


fig. 12. Flow chart of the SSTV picture receive routine (PIXR).

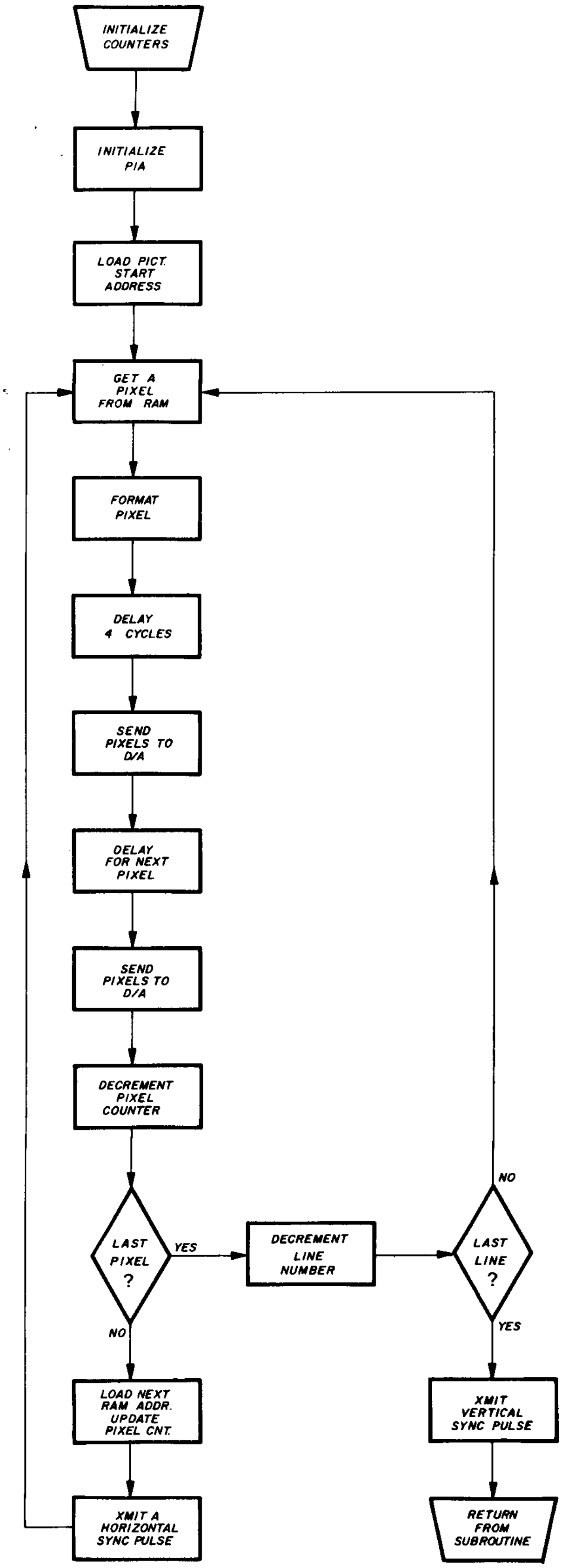


fig. 13. Flow chart for transmitting an SSTV picture (TRANS1).

portions of critical routines to flow chart which represent how the package performs.

picture area

Fig. 11 provides a pictorial view of the digitized picture in RAM. The picture consists of a 16k-block of RAM. This 16k region could be divided up into two portions for low-density TV, or a single high-density area. I decided to use both densities in the software package. The low-density television area was designated as a primary and a secondary region. The primary region was used for receiving an SSTV picture with 128 pixels per line, and for displaying on low-density fast scan. The secondary region was used for picture enhancements and a second low-density picture-storage area. If you are somewhat confused, don't worry, I'm sure you will understand as I discuss the routines in more detail.

Main-line routine (START). The program is started by executing the instruction at location 4000 (hex). The first routine executed is START, which places a menu on the screen to display the program options. A routine selection is made by hitting a single key. The ESC key is used to jump to an undefined program. The ESC jump address assembled into this program is a location immediately after the ASCII table. This was done for future program expansions. Three levels of messages were programmed. The highest level is the START routine, used for the reception or transmission of SSTV with 256 pixels/line.

The next level is FAST which is used for displaying fast-scan TV or transmitting SSTV with 128 pixels/line. The lowest level of messages are in the various routines. This menu scheme allows the calling of routines from other programs with the entry messages displayed.

table 1. RAM constants used to describe the displayed picture.

label	location	bytes	description
XSAV	A014	2	temporary index register store
XSAV1	A016	2	temporary index register store
PIXC	A018	1	pixel counter
LINE	A019	1	line counter
CNT2	A01A	1	general counter storage
CNT1	A01B	1	general counter storage
RPIXC	A01C	1	receive pixels
RLINE	A01D	1	receive lines per picture
RSTAT	A01E	2	picture start address
RECVC	A020	1	receive delay constant
TPICT	A021	1	transmit pixels per line
TLIN	A022	1	transmit lines per picture
TRX	A023	1	transmit delay constant
NHOR	A026	4	program modifications used for quarter framing, also used for temporary byte store

Receive SSTV (RECV1). This routine is a general-purpose SSTV reception program. **Table 1** lists the four constants (starting with R) which must be initialized for the routine to receive pictures from the A/D converter. This routine calls six other subroutines which store the picture in RAM (STORE), wait for vertical- and horizontal-sync pulses (VERT, HORIZ), and get pixels (GETA) from the A/D converter. The constant NHOR is used for quarter framing. This will be explained later. This constant is initialized with a RTS (39 Hex) which means the call immediately returns to the calling JSR. **Fig. 12** is a flow chart of the PIXR routine which receives a SSTV picture.

Transmit SSTV (XMIT). This routine is a general-purpose transmission routine. Like RECV1, the routine can be used as a universal transmit routine. The three constants in the RAM region, starting with T, control the type of SSTV transmitted. This routine is set up to transmit 60-Hz SSTV. For those in 50-Hz countries, you may wish to redefine the TRX transmit delay constant. The XMIT routine is the main line, and four other subroutines are called; TRANS1, SVERT, SHORIZ, and DEL5. The XMIT routine MENU allows for the transmission of up to nine pictures to be transmitted. **Fig. 13** is a flow chart of TRANS1, which is used to transmit an SSTV picture.

Initialization routine (INIT and LOAD). Two routines are used to initialize the system prior to execution of the routine, INIT and LOAD. INIT is a simple subroutine which initializes the PIA for transmission or reception of SSTV. The port assigned by the software is 8010 (Hex). The LOAD routine initializes the receive and transmit program constants, picture start address, and monitor jump address in the first part of the subroutine. In the second part of the routine, the CRT-controller registers are loaded with the constants previously described. The initialization routines set the SSTV picture formats for 256 pixels/line and the CRT controller is set to display 128 pixels per line.

SSTV zoom (ZOOM). ZOOM is used to enlarge a 256 pixel per line picture by two times and transmit it on SSTV. Five locations can be selected, the four picture corners and the picture center. The original picture is not destroyed in the process. The enlargement process is quite simple. Each pixel and line is retransmitted twice, the net result is a picture enlargement. The TRZ routine performs this operation, and is callable from another program. To use this routine, load RSTAT with the address of the upper left-hand corner position of the picture, then call the routine with a JSR instruction. **Fig. 14** is a flow chart of this routine. The ZOOM main-line routine selects the program con-

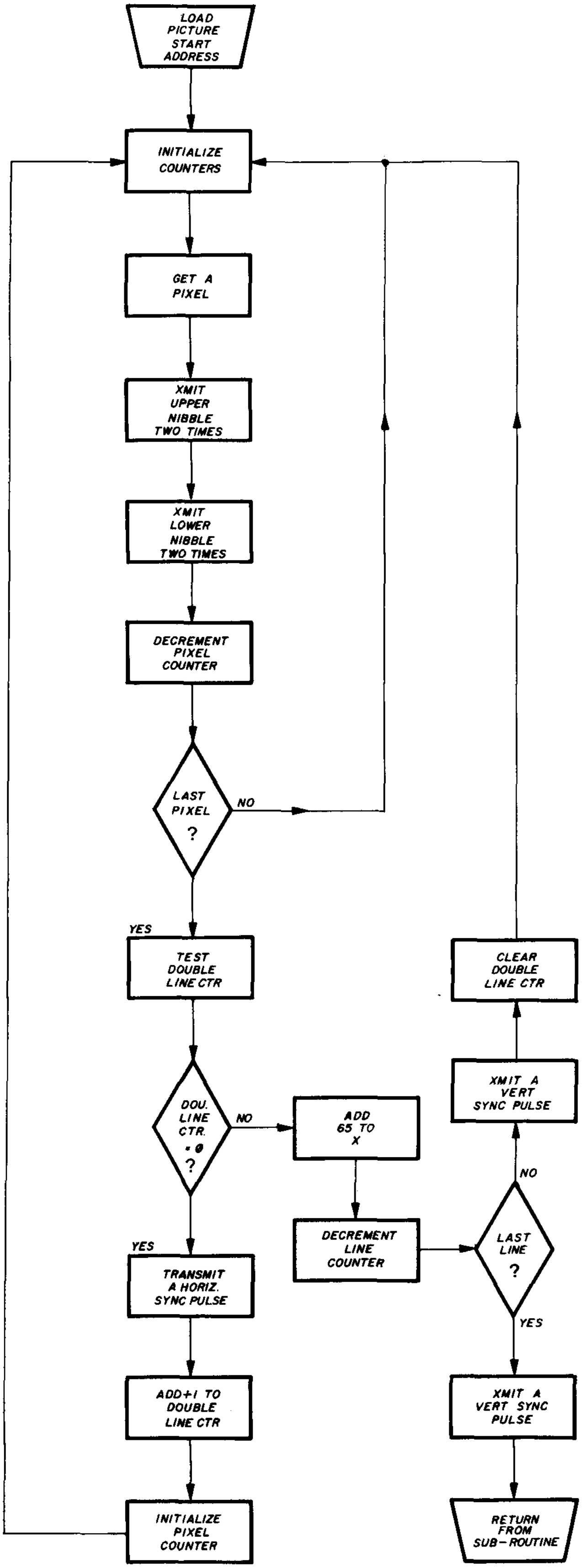


fig. 14. Flow chart of the zoom routing on the SSTV picture (TRZ).

stants and the number of loops through the program by displaying the routine's menu on the terminals screen.

Fast-scan format (FMT). This is the last of the 256 pixels/line routines. This routine takes a high-density picture and compresses it 128 pixels/line (low density). The process is accomplished by simple averaging of pixels. **Fig. 15** is a flow chart of this routine.

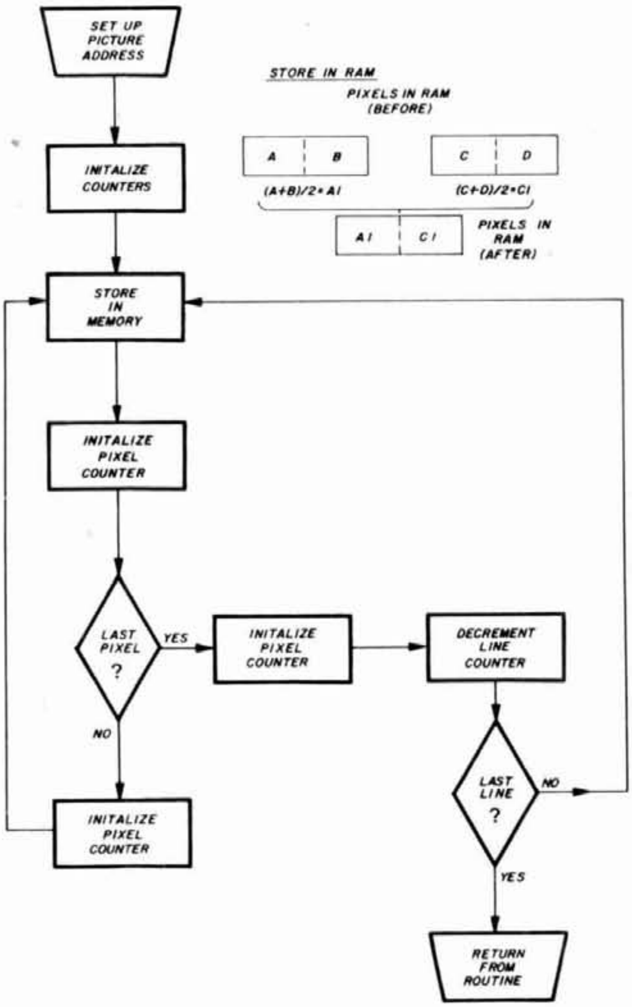


fig. 15. Flow chart of the SSTV format routine (FMT).

This process produces some interesting effects when a high-density picture is compressed and displayed on high-density SSTV. The result is the original picture duplicated two times on the upper half of the screen. The compression of high-density pictures to low density by this algorithm process produces some artifacts. These artifacts can be seen in the photographs. I concluded that this problem was due to the simple algorithm I used. Since the artifacts occur mainly with black and white edges, I decided to live with this condition.

Fast-scan picture with the zoom routine.

Quarter-framing (QTR1). This routine is used to receive four different SSTV pictures and place each picture in a different location in a composite picture. The routine, when executed, asks which quarter frame is to receive a picture. The options are 0 through 4, which equates to upper left and right and lower left and right. The addresses of the various locations are listed in TABLE, which is stored in RSTAT when selected. Since a quarter-framed picture has 128 pixels per line and 64 lines, RPICX and RLINE are changed to 64. Additionally, every other line is received, the RTS instruction at NHOR is modified to jump to GETP1. This causes the PIXR routine to add 64 to X and wait for a second horizontal sync pulse prior to placing a new SSTV picture line in RAM. This routine assumes that the picture received is the same frequency as the last picture received, *i.e.*, 50 or 60 Hz.

Fast-scan TV routines (FAST). The main-line routine for all fast-scan options is FAST. All pictures displayed or transmitted in these routines have a density of 128 pixels. In these routines two picture areas are used. These areas are identified as areas 0 and 1. Each routine uses three areas in a slightly different manner. I'll discuss their use later. In order to return from FAST to START any other key, except 1 through

Girl's face with quarter frames.

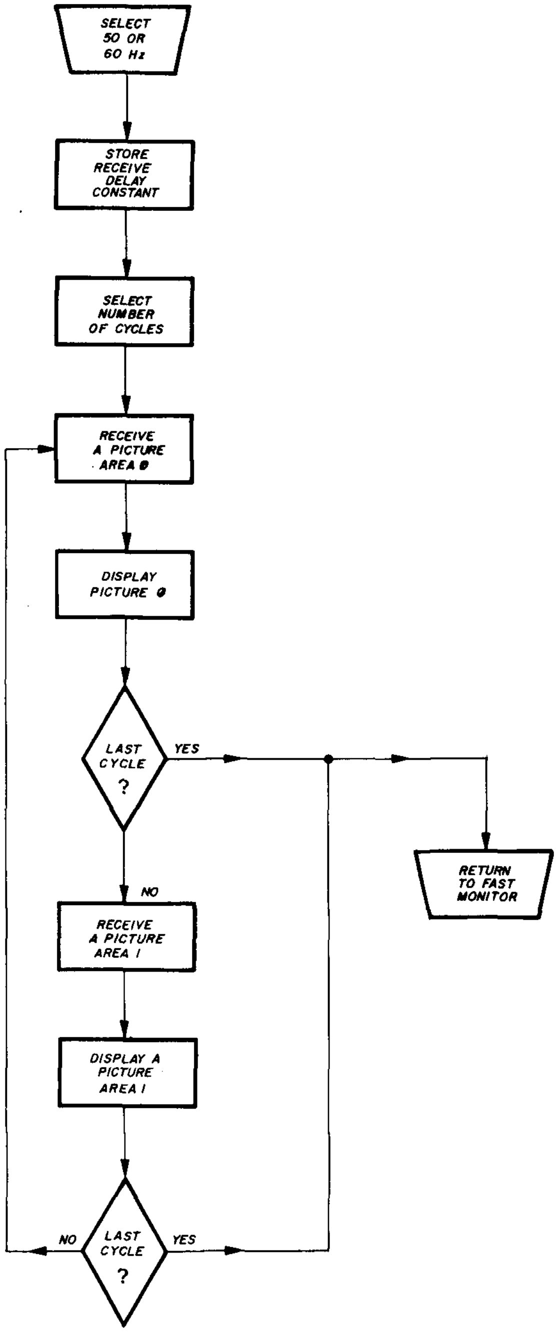


fig. 16. Flow chart of the receive then display on fast scan routine (FRECV).

5, can be pressed. All routine options selected by FAST will return to this routine after they are completed.

Display fast scan (FAST1, DISP). This subroutine controls all fast-scan displaying. When the main line program jumps to FAST1, the 256-pixel picture is formatted to 128 pixels and then displayed. If the jump is to FAST4, the 128-pixel picture is displayed. The routine places a menu on the terminal which asks for the number of cycles. A cycle is the number of times the DISP subroutine is executed. The DISP subroutine displays a picture for 7 interrupt cycles, or approximately 7.7 seconds/cycle. The response to this message should be 1 to F (15). The DISP subroutine operates in the following manner. Prior to displaying a picture three initialization steps are performed:

1. The B accumulator is loaded with the number of cycles to be displayed.
2. The interrupt service routine is loaded into the IRQ vector address in the monitor (A000).
3. Address A00E is cleared. This step is required if you use an RT-68MX monitor, as I do.

The interrupt mask is then cleared by a CLI and the display process is executed by a WAI command. The WAI causes the BA signal on the SS-50 bus to go positive, which tri-states the CPU card for DMA. After 1.1 seconds, an interrupt is generated by the hardware interface card and the RTI instruction (DISP3) is executed. This instruction restores all registers including the PC counter. The next instruction after WAI is executed and the process is repeated six more times.

Fast-scan receive/display (FRECV). This routine is used to receive and then display an SSTV picture. When FRECV is executed, a message asks if 50- or 60-Hz SSTV is to be displayed. The next message asks for the number of cycles. The response should be 1 to F (15). The number of cycles is the number of SSTV pictures you wish to receive and display on fast scan. The displayed picture will remain on the screen just long enough to allow reception of the next picture.

When two or more cycles are selected, the picture is first loaded into the secondary picture area 0. The next picture is loaded into picture area 1. This process allows you to store two low-density pictures in RAM. A flow chart of the FREC routine is shown in **fig. 16**.

Transmitting a low-density SSTV picture (FXMIT). This routine allows the displaying of low-density pictures on SSTV. The routine is an example of how to call the XMIT subroutine. Prior to calling XMIT, the number of pixels/line and display constants are changed. When XMIT is called, a low-density picture is transmitted on SSTV. The FXMIT routine displays a message which prompts the operator to display picture 0 or 1.

Fast-scan zoom (FZOOM). This routine demonstrates the flexibility of the CRT-controller chip. The routine is used to examine on fast-scan TV an SSTV picture in RAM. The picture is examined by magnifying (zooming in on) the picture by two times. The zoom is accomplished by moving the SSTV picture in area Ø to area 1. In this movement process, each pixel is doubled along with doubling the lines. The CRT-controller chip is then re-initialized for the picture 1 area by CRT3, and is then displayed on fast scan as a magnified picture. **Fig. 17** is a flow chart of this routine.

This completes the description of the operation of the software package. A few systems considerations will be discussed in this section. The programming package assumes that a MIKBUG-like monitor is used. All MIKBUG calls are contained in the equate table at the beginning of the source code. The software assumes that two memory-mapped I/O ports

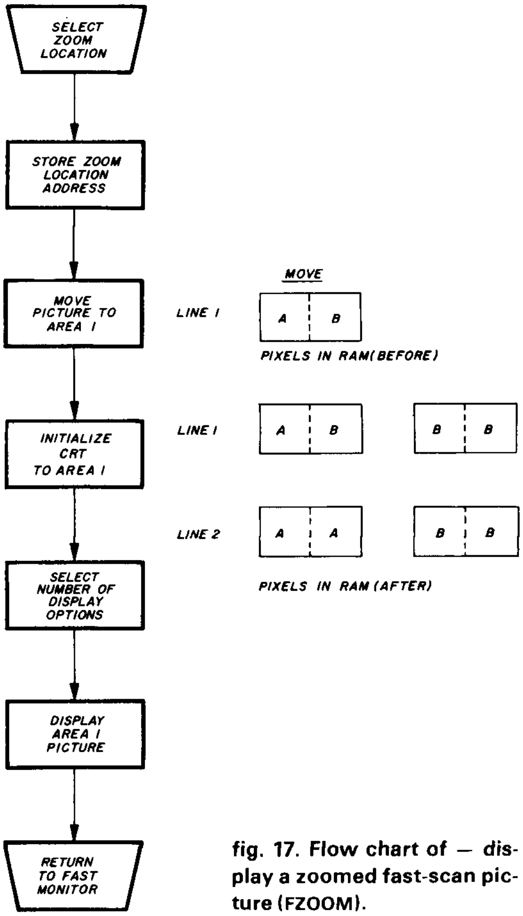


fig. 17. Flow chart of — display a zoomed fast-scan picture (FZOOM).

are used for the SSTV analog-card (8Ø1Ø) and the CRT-controller card (8Ø3C). The 8Ø3X address was used because my system has a second mother board. All of the CRT-controller program I/O calls are located in the routine with CRT 1 through 3 labels. Don't forget that the CRT-controller-chip's least-significant bit (LSB) of the address identifies either a register number or register data, *i.e.*, LSB = 0 (data), LSB = 1 (register number).

Delay loops are also used for timings. The timing loops are used to receive and transmit SSTV pictures through the hardware interface. Delay-loop constants in the software were selected and based upon the SWTP MP-A CPU clock frequency of 1.7971 MHz. If you use another CPU card, the constants will have to be altered.

EPROM program relocating

If you wish to relocate the software to reside on EPROMS, the task is quite simple. I assembled this program on a boundary which can be easily relocated. I tried to use a minimum amount of absolute code in my assembly. To relocate the program, scan the source listing for JMP or JSR instructions which address the 4XXX RAM region. All that has to be done is change the 4XXX hex to another digit, *i.e.*, CXXX. For example, I have relocated the software to run in 2708 EPROMS at location CXXX by this technique. Since the package is greater than 1k, two 2708 EPROMS are required.

summary

The displaying of gray-level pictures by use of microprocessors opens many new areas for the home hobbyist. The software techniques discussed in this article could be easily adapted for receiving/displaying weather satellite pictures by simply changing program constants. Only the hardware demodulator interface has to be modified. Potential applications are almost endless.

Some may find my SSTV character-generator picture of interest. I created this picture by software which is coresident with the fast-scan program. I do not intend to publish this program in this form.

acknowledgments

The interfacing of new devices like the CRT-controller chip was quite a challenge. Although Motorola did a fine job on their spec sheet, numerous questions arose. Without the help of Bruce Kinney (W6TED), I would have labored numerous extra hours.

If you wish to obtain a printed-circuit board for my fast-scan card, it can be obtained from Geoff Chapman, VK2AIT,* for 25 dollars, Australian, which includes shipping. If you wish to write me for more information, please include an SASE for my reply.

*G. N. Chapman, VK2AIT, 70 Cliff Road, Epping, NSW, 2121, Australia.

references

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2. Dr. Don Miller, W9NTP, "Medium-Scan Television System," *A5 Magazine*, November, 1978.
3. *MC6845 Data Sheet*, Motorola Semiconductor Products, Phoenix, Arizona, 1977.
4. Jack Fister, "Programming CRT Controllers," *Electronics Engineering Times*, June 29, 1978.

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uhf local-oscillator chain
for the purist

Design and construction of an LO system that offers excellent spectral purity, stability, and calibration tolerance with output between 380 and 540 MHz

For many experimenters a major stumbling block toward building a high-performance uhf or microwave station seems to be the local-oscillator chain. This is especially true in EME applications, where any degree of success demands spectral purity affording at least 60 dB spurious rejection, calibration tolerance to within a few hundred Hz, and frequency stability of a few tens of Hz over the temperature extremes encountered in the station. These stringent requirements, along with the extensive test-equipment required to verify them, seem to put the whole business of LO design and construction into the category of "more art than science."

background

Certainly the most artistic uhf LO developed in recent years is the circuit by Joe Reisert, W1JR, originally published in his now-defunct *W6FZJ 432 MHz EME Newsletter*. The circuit has since been presented in *ham radio*[1] and duplicated by hundreds of uhf enthusiasts with a high degree of success. I used Joe's circuit in my original 1296-MHz transceive converter[2] and was entirely pleased with the results. The design offers exceptional spectral purity (**fig. 1**), good thermal stability, and adequate calibration tolerance (all as functions of the crystal used, of course).

Joe's circuit was designed to be built in three-dimensional space above an unetched PC board, which was used merely as a ground plane. I developed printed-circuit artwork for this LO some time ago to improve its repeatability by ensuring proper component layout. During the PC-artwork development, it seemed reasonable to replace a number of discrete components with their microstripline equivalents, thus reducing component count and cost. This task completed, I trimmed from the circuit every nonessential component in further attempts at cost reduction. When I realized that my circuit bore little resemblence to Joe's original design I threw caution to the wind, abandoned his original framework altogether, and ended up with a completely new uhf LO.

spectral purity

The result is shown schematically in **fig. 2**. I call it "Mr. Clean" in recognition of the excellent spectral purity achieved (see **figs. 3** and **4**). The circuit can be

By H. Paul Shuch, N6TX, *Microcomm,* 14908 Sandy Lane, San Jose, California 95124

built for a 5-mW output at any desired frequency between 380 and 540 MHz, thus serving well as an LO for 432-MHz converters, 1296- or 2304-MHz converters (if followed by an appropriate $\times 3$ or $\times 4$ multiplier), or a weak-signal source. The circuit offers spurious rejection of more than 40 dB, a calibration tolerance of ± 10 ppm, and temperature stability on the order of ± 0.3 ppm/°C over the range of -10 to $+60$C. To date I've built more than 50 copies of this circuit, all with equal performance. The design has also been successfully duplicated with little difficulty by W6OAL, KØJHI, and WA6TLX.

The importance of spectral purity in a uhf LO cannot be overstressed, *especially when the output frequency* is multiplied into the microwave region. **Fig. 5** is an example of the LO output of a popular European 1296-MHz receiving converter. Compare this figure with the LO of my 1296-MHz system (**fig. 6**).

oscillator circuit

The primary requirements for a usable local oscillator, as mentioned previously, are stability and spectral purity. Frequency stability is generally achieved by using an oscillator circuit that draws minimum current through the crystal (thus minimizing crystal heating). This in turn dictates operating the basic oscillator at an *extremely low output power level* and making up the necessary gain in the following buffer or multiplier stages.

I learned from Joe Reisert some time ago that it's *important* to let the crystal oscillate at its natural resonant frequency. That is, when plugging a crystal into the oscillator circuit *for which it was cut*, you'll

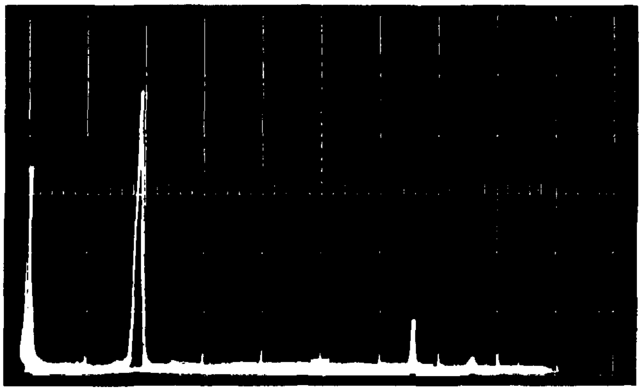
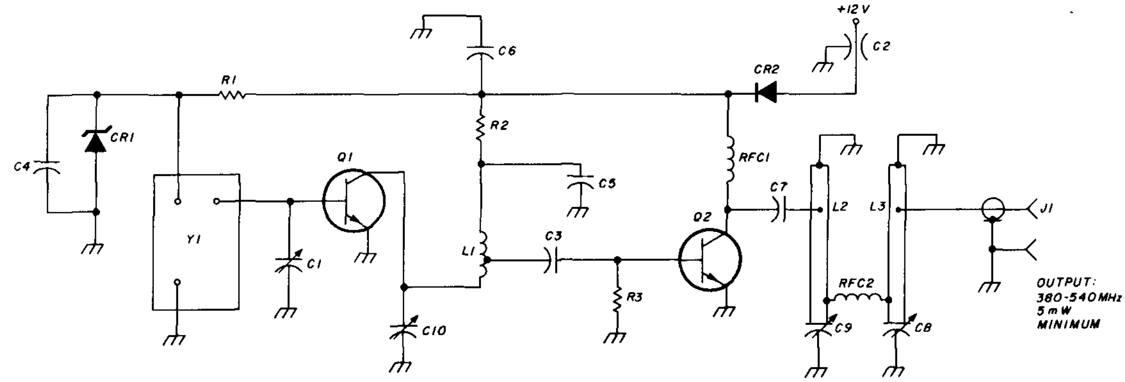


fig. 1. Dc-to-2 GHz spectral display of the Reisert local oscillator (reference 1) shows its excellent spurious-response rejection. Vertical scale is 10 dB/division; horizontal scale is 200 MHz/division; resolution is 1 MHz.

achieve the greatest stability by letting the crystal oscillate wherever it wants to. Any attempt to VXO or "rubber" the *crystal's oscillation frequency* to achieve a desired dial calibration will result in a net degradation of local-oscillator stability. This is especially true when the crystal frequency will subsequently be multiplied to the ultimate output frequency.

Since frequency pulling of the oscillator is to be avoided in the interest of stability, great precision is required in the crystal frequency calibration, with reespect to the particular oscillator circuit used, if the i-f calibration is to bear any relationship to the operating frequency. Crystal manufacturers can generally optimize custom-ground crystals for operation



C1	8-24 pF ceramic trimmer
C2	1000-pF feedthrough
C3-C6	0.01-μF miniature ceramic discap
C7	33-pF chip cap (ATC 100B or equivalent)
C8-C10	1-9 pF piston trimmer (Triko 203-09M or equivalent)
CR1	9.1-V zener (1N757A or equivalent)
CR2	1N3600 (or equivalent general-purpose silicon diode)
J1	Output receptacle (E. F. Johnson 142-0298-001 or equivalent)
L1	4t 1-mm (no. 18 AWG) tinned, 17.8 mm (0.7 inch.) diameter $\times$ 5 mm (0.2 inch) long. Tap 1t up from C5 end
L2, 3	Microstripline inductors (see PC artwork)
Q1, 2	2N5179
R1, 2	180 ohms 5% ¼w carbon composition
R3	330 ohms 5% ¼w carbon composition
Y1	International Crystal OE-5 oscillator module. Frequency between 95-135 MHz ($f_{out}/4$)
RFC1,2	0.33 μH miniature molded choke

fig. 2. Schematic of the Microcomm Model LO-70 uhf local-oscillator chain, which evolved from the design by Joe Reisert, W1JR.

in a particular circuit, provided the schematic is supplied. Unfortunately, when ordering high-precision crystals from two different reputable manufacturers for use in Reisert's oscillator circuit, I found calibration errors on the order of 10 kHz at 432 MHz — certainly beyond my expectations for a $30 crystal! And since you can be certain the crystal manufacturer certainly didn't build up Reisert's circuit and check the crystal for proper operation in it, perhaps it's better to use an oscillator circuit with which the crystal manufacturer has some experience.

I decided to use an oscillator circuit of the crystal manufacturer's choosing. In so doing I found that

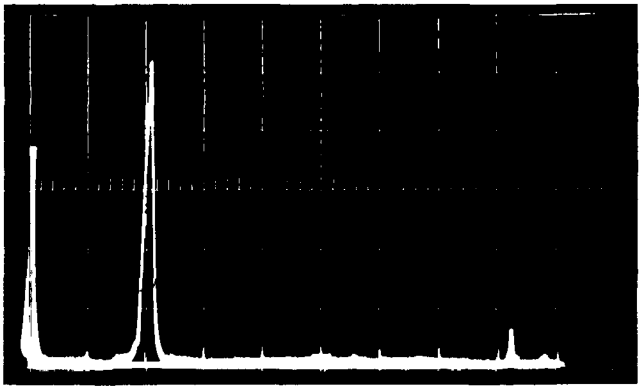


fig. 3. Spectral response of the local oscillator presented in this article compares favorably with the Reisert circuit. The analyzer settings are as in fig. 1.

crystals from widely separated production runs all fell well within the manufacturer's calibration tolerance limits of ±0.001 per cent, as well as the claimed thermal stability specifications of ±0.002 per cent from −10 to +60°C. The crystal *and* oscillator circuit (on a PC board, inside a can for shielding) are available as a preassembled module from International Crystal Manufacturing Company as their Model OE-5. Specifications and the oscillator schematic are shown in **fig. 7**. This assembly costs around $20 in single quantities, supplied at your selected operating frequency in the 100-MHz range. Since it's no more expensive than a crystal of equivalent specifications ordered separately, why bother to build your own oscillator circuit?*

Output power from the OE-5 oscillator module is low, on the order of 1/2 mW, which certainly holds down crystal heating. Spectral purity is enhanced by starting with the highest crystal frequency practical (in this case, around 100 MHz), and performing low-order integer multiplication in active stages whose bias current is optimized to the favored conduction

*Lead time for this oscillator module runs typically six to eight weeks, so order well in advance.

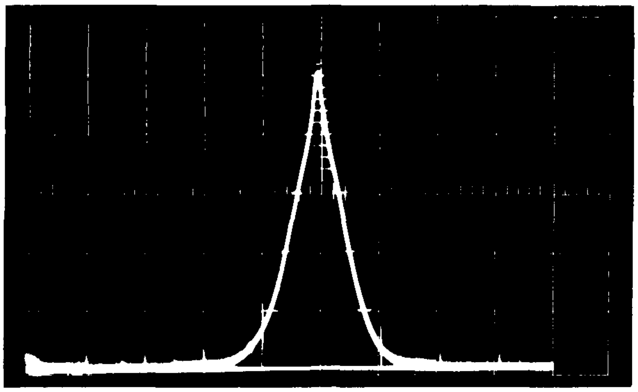


fig. 4. Spectral display of the Microcomm LO-70 LO-chain (operating frequency ±100 MHz) shows the absence of close-in spurious components. Vertical scale is 10 dB/division; horizontal scale is 20 MHz/division; resolution is 1 MHz.

angle for the multiplication desired. This oscillator, like Reisert's, uses two common-emitter bipolar doublers operating Class C. Each multiplier stage affords about 5 dB gain, so the output power from the LO chain is on the order of 5 mW (7 dBm).

Note that, from the OE-5 circuit schematic in **fig. 7**, the oscillator output is taken from a link in a parallel-resonant circuit. This coupling link provides a dc bias return for the base of first doubler transistor, Q1, as seen in the LO chain schematic, **fig. 2**. Trimmer capacitor C1 is used to resonate the OE-5 module output coupling link, which provides a double-tuned interstage and greatly improved spectral purity. However, as with all double-tuned circuits, these two tanks are somewhat interactive, so during tuneup it may be necessary to readjust the OE-5 trimmer capacitor along with C1.

circuit description of the LO chain

The 200-MHz signal from Q1 is applied through

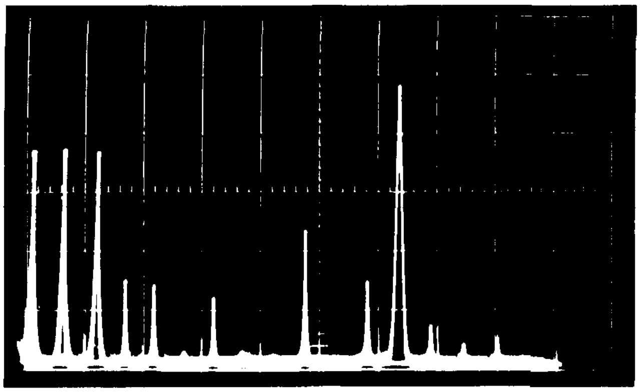


fig. 5. The importance of spectral purity in a uhf local oscillator chain is compounded when the output frequency is multiplied into the microwave region. This is the output of the local oscillator used in a popular European 1296-MHz receive converter. The effect of inadequate filtering at all stages is evident.

tuned circuit L1, C10, to the base of the second doubler, Q2. Nothing exotic here, but Q2's collector feeds a rather unusual output-filtering arrangement, which is largely responsible for the spectral purity of this LO. Basically, microstripline inductors L2 and L3, with trimmer capacitors C8 and C9, form two parallel-resonant circuits. RFC2 inductively top-couples them for a standard two-pole bandpass.

There are really more filtering elements here than meet the eye. For example, Q2's collector feed choke, RFC1, and coupling capacitor, C7, form a single L-section high-pass filter, which keeps any 200-MHz component from Q2's base from entering the output filter. Additionally, C8, C9, and RFC2 form a pi network lowpass filter which supresses harmonics from Q2. Thus the entire output circuitry consists of one lowpass filter, one high-pass filter, and two bandpass sections — all ensuring that Mr. Clean lives up to its name.

construction

All components including the OE-5 oscillator module mount on a 63.5 × 76 mm (2.5 × 3 inch) PC board. PC-board artwork is provided in **fig. 8**. Microstripline dimensions are a function of the material used, so be certain to etch this board on 1.6 mm (0.0625 inch) thick fiberglass-epoxy PC laminate, double-clad with 1-ounce copper (0.035 mm or 0.0014 inch thick). One side of the board should *remain* unetched to serve as a ground plane.

Drill the board as in **fig. 9**. Note that to avoid short circuiting the OE-5 power and output pins as well as the rf output at J1, it's necessary to remove ground plane metal from around the three holes marked countersink in **fig. 9**. A 3.25-mm, (0.125-inch) twist drill does an adequate job. Be careful not to drill too far through the board!

Note that in **fig. 2** the ends of the output filter

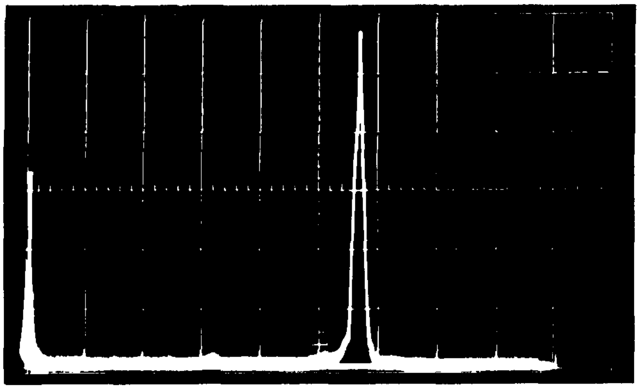


fig. 6. The output spectrum of the author's 1296-MHz system contrasts sharply with that of fig. 5. This clean display results from driving the uhf LO described in this article into a well-filtered multiplier circuit. Spurious rejection over the dc-to-2 GHz region approaches 60 dB.

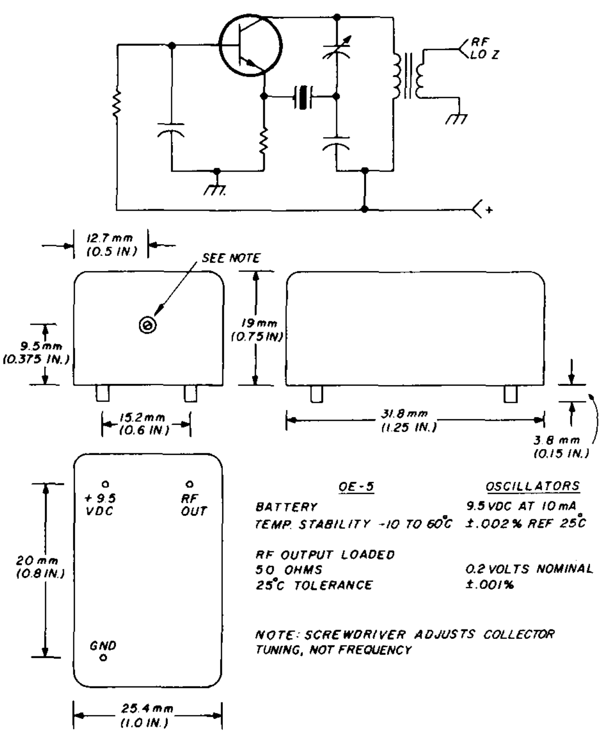


fig. 7. Schematic, dimensions, and specifications on the International Crystal OE-5 oscillator module.

microstripline inductors (L2 and L3) are grounded through the board. This can be accomplished by installing small 1-mm (0.04-inch) OD eyelets through the board at two locations indicated in **fig. 9**. These eyelets can be set then soldered to *both* sides of the board to ensure a reliable ground. For those who prefer not to prepare their own board, an etched, drilled, and plated board, with eyelets in place, is available from the author.*

Component layout on the printed circuit board is shown in **fig. 10**. I recommend mounting all components *except* the OE-5 oscillator module; save that for last. Note that R3, C8, C9, C10, and the emitter and case leads of Q1 all ground to a large ground plane area on the stripline side of the board as well as the unetched ground plane side. Be sure to solder these components at *both* sides.

When mounting the OE-5 module to the ground plane side of the main board, there's a slight chance that circuit traces on the OE-5 board might short circuit to the ground plane. Make a thin spacer from sheet acetate or Teflon the size of the OE-5 board, with holes drilled for the three pins. When installing

*An etched, drilled, and plated board for this local oscillator, complete with grounding eyelets for L2 and L3, is available for $6.50 postpaid in the U.S. and Canada ($7.00 elsewhere) from Microcomm, 14908 Sandy Lane, San Jose, California 95124. A completely assembled LO chain, adjusted to your selected operating frequency between 380-540 MHz, is also available at nominal cost. Send a stamped, self-addressed envelope to Microcomm for details. Amateurs indicate callsign on correspondence.

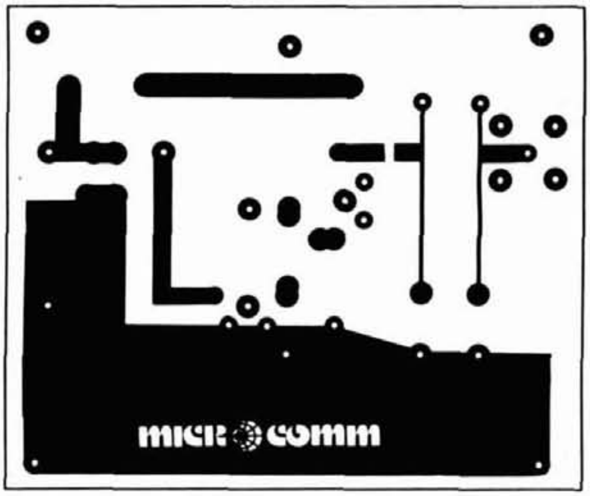


fig. 8. Full-size PC-board layout for the uhf local oscillator. Substrate material should be 1.6 mm (0.0625 inch) thick fiberglass-epoxy PC board, double-clad with 1 ounce copper (microstripline side shown).

the OE-5, grasp the three pins firmly with needle-nose pliers. Gently *ease* each pin, one at a time, into the main board. Do not use force.

tune up

There are at least three different techniques for tuning this local oscillator chain. I hope you can keep them straight, because in this section I'll tell you a) how *not* to tune an LO, b) how I tune my LOs, and c) how to tune yours.

Avoid like the plague the "maximum smoke" technique. It's *not* possible to successfully tune this circuit, Reisert's circuit, or anyone else's LO circuit, for maximum indicated output power alone. **Fig. 11** illustrates quite graphically that if you tune for maximum power it's likely to be distributed over a maximum number of frequencies. I can't overemphasize the importance of tuning up uhf LO chains using proper test equipment together with a systematic procedure for minimizing spurious spectral responses. I'm a firm believer in the use of spectral analysis and wouldn't dream of tuning up one of my own LO chains without the use of a microwave spectrum analyzer. Take another look at **fig. 3** and compare it with **fig. 11**. You can see the dramatic effect of tuning each stage of the LO chain for maximum spectral purity rather than maximum output. And the test equipment needn't put you into hock forever. Even a simple homebrew spectrum analyzer[3] will allow you to achieve spectacular purity.

But you probably don't have a spectrum analyzer and cringe at the thought of having to build one before you can tune the LO you've just finished constructing, right? There's another way; I call it the "poor man's spectrum analyzer." You'll need a vhf cavity wavemeter (a grid-dip oscillator in the wavemeter mode will do), some sort of a relative power-indicating device (the one I told you not to use in method a above), and a bandpass filter tuned to the approximate LO output frequency. (There are some constraints surrounding the selection of the proper filter, which I'll cover later.) You'll also need some *sort of resistive attenuator or pad, 3 to 10 dB, with a* 50-ohm impedance and a volt-ohmmeter.

Preliminary steps. First connect the pad to the LO output connector, the power meter to the other end of the pad, and a +12 Vdc supply to feed-through capacitor C2. **Caution**: Do *not* exceed 12 volts, as this is the V_{ceo} (maximum collector-to-*emitter potential) of the 2N5179s used as the multi*plier transistors! In fact, series diode CR2 does provide some protection, and I have not had any transistor failures operating at 13.5 volts from a fully charged car battery — but why take chances?

With power applied, tune C1 and the OE-5's trimmer cap until the OE-5 oscillates, as indicated by an abrupt increase in supply current. With the OE-5 oscillating, set up the grid dipper in the wavemeter mode, tune it to the crystal frequency, and sniff around the microstripline going to the base of Q1 for some rf. Once you've found it, disconnect V_{cc}, then reconnect it. Did the oscillator start? If not, try retuning the OE-5 trimmer and C1 slightly until the oscillator starts reliably each time.

Now tune the first multiplier. As L1 and C10 are tuned through resonance, Q2 base will be biased into

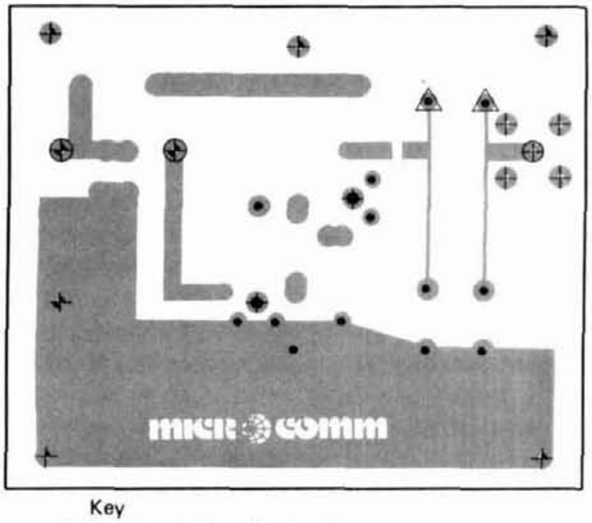


fig. 9. Drilling template for local oscillator PC board (viewed from microstripline side).

conduction and supply current will increase by 5-10 mA (Q2's collector current). Try it. The only problem is that tank L1/C10 may resonate at more frequencies than the desired $F_{xtal} \times 2$. So tune the dipmeter *(still in wavemeter mode)* to the second harmonic of the crystal frequency, couple it *loosely* to L1, and tune for an indication of rf. Once you've found it, repeak C1 and C10 for the combined occurrence of *maximum* rf and *maximum* supply current; then check to make sure the oscillator still starts up *each time power is applied*. If not, retweak the oscillator trimmer *slightly* until it does. At this point you should start to see some indication of rf at output connector J1. *Remember that your relative-power indicator can't distinguish between frequencies*, but

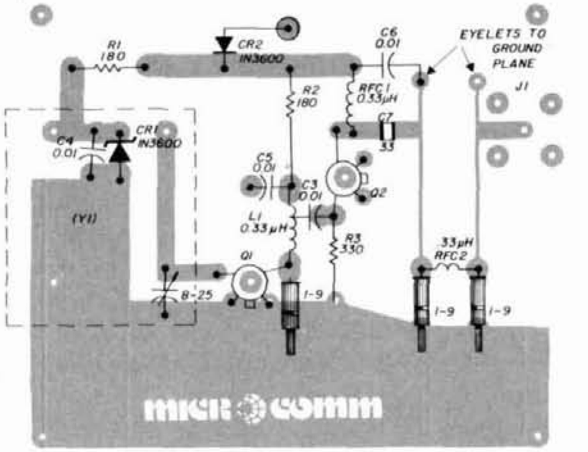


fig. 10. Parts layout, Microcomm model LO-70 uhf local oscillator (microstripline side).

just for starters, tune C8 and C9 for maximum output. At this point the output spectrum (if you could see it) would probably appear as in **fig. 11**, but don't worry about it.

Final adjustments. Now that you've completed the preliminary tune up you're ready to clean up your act. Insert the bandpass filter (tuned to the desired output frequency) between the pad and the power indicator, and *carefully* retweak all trimmers for maximum output power. The adjustments will interact, so go back and do it again. Check to make sure the oscillator still starts each time you apply power. When you're finished remove the filter and pad, and measure output power at J1. It should be on the order of 5-10 mW, and the spectrum should appear as in **fig. 3**.

But don't count on it. The first time I tried this procedure, I ended up with almost as much output at 1200 MHz as I had on 400 MHz. This didn't make much sense to me, as I was using a high-Q, quarter-

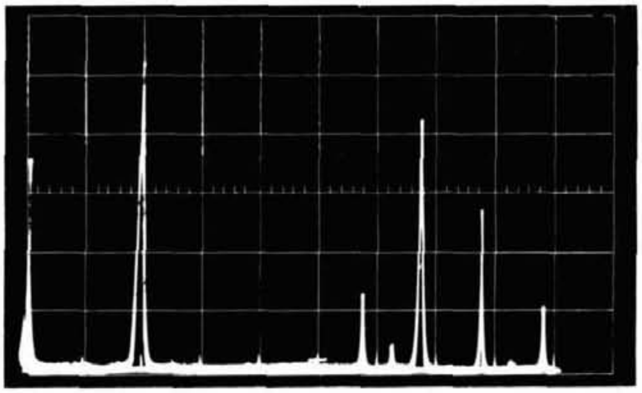


fig. 11. This spectral display, with measurement conditions as in figs. 1 and 3, illustrates the importance of tuning the local-oscillator chain using a spectrum analyzer. This is what results if the LO is tuned for maximum output as indicated on a power meter. Note that the worst spurious component is down by only 10 dB.

wavelength, trough-line filter *in aligning the LO*, and I knew it had sharp skirts! Just for good measure I swept the filter, and the problem became immediately evident (see **fig. 12**). A quarter-wave transmission line, shorted at one end, makes a dandy resonator. Unfortunately, so does a three-quarter-wavelength transmission line. The filter I chose exhibited a passband at the third harmonic of the LO frequency, and by tuning for maximum signal through the filter, I was actually optimizing the spurious output! I mention this because quite a few bandpass filters exhibit multiple resonances. The halfwave slab resonator described in the ARRL *VHF Manual and Handbook* does, so it would not yield a spurious-free output if used as a tune-up aid

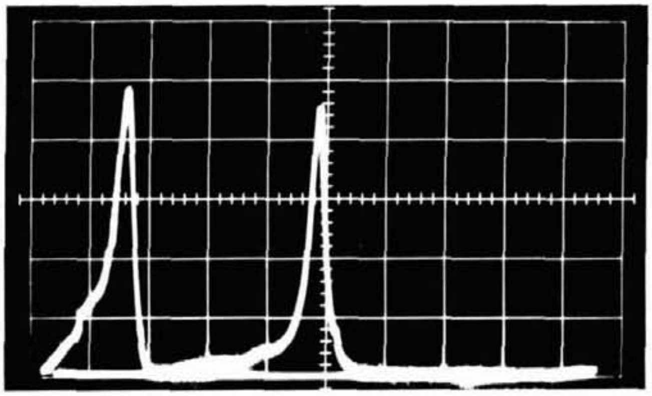


fig. 12. Swept-frequency response of the quarter-wave, trough-line resonator first used as a tune-up aid for this LO, as described in the text. Vertical scale is 5 dB/cm, with the second major division from the top of the screen representing *0 dB insertion loss. Horizontal scale is 250 MHz/cm*, yielding a dc-2.5 GHz display. Note that, while the insertion loss at 400 MHz (the desired frequency) is less than 1 dB, the insertion loss at the third harmonic (1200 MHz) is on the order of only 3 dB.

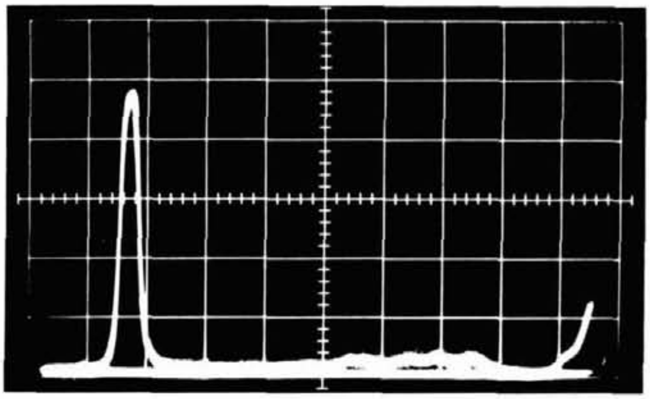


fig. 13. Swept-frequency response of the Microcomm model PB-70 filter ultimately used as a tuning aid for aligning this LO, as described in the text. Vertical and horizontal scales are as in fig. 12. Note absence of spurious responses out to 2.5 GHz, as well as the passband insertion loss of less than 1 dB.

for this LO. Best bet is to use either an interdigital filter or helical resonator, or a multipole design whose interstage coupling is designed to supress higher-order modes. The Microcomm model BP-70 is one such filter (see **fig. 13**), as is the Spectrum International model PSf432. Also useful are the surplus military filters of the F-197/U variety, which have recently surfaced at numerous ham auctions and flea markets around the country.

Given a single-response bandpass filter tuned to the approximate operating frequency of the LO, it's possible to tune this oscillator circuit to a degree of spectral purity rivaling that achieved on a laboratory microwave spectrum analyzer.

conclusion

I've presented a uhf local-oscillator chain that offers stability, calibration tolerance, and spectral purity on a par with Joe Reisert's very fine circuit, but with fewer components and easy assembly on a PC board. I am currently using this LO in my 432-MHz receive converter, driving multipliers in my 1296- and 2304-MHz converters, in my 1296-MHz hand-held transceiver, and in an S-band satellite ground station design I am producing commercially. I find the circuit easy to assemble and extremely reliable. I hope other uhf and microwave experimenters find it useful.

references

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2. H. Paul Shuch, WA6UAM, "Easy-to-Build ssb Transceiver for 1296 MHz," *ham radio*, September 1974, page 8.
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ham radio

linear amplifier design

The designer of a linear amplifier should be concerned with the proper potentials required to make the power tube operate in a linear manner. The word *linear* implies that the output signal of the amplifier is an amplified replica of the input signal. There's no such thing as a perfect linear amplifier, and the designer's problem is to make the practical amplifier (*i.e.*, the amplifier that can be built) as linear as possible.

When a linear amplifier is driven by a complex signal, such as the human voice, nonlinearity results in intermodulation distortion. This unpleasant form of distortion creates a broad, raspy signal that throws annoying "buckshot" into adjacent channels. Proper design and operation of a linear amplifier reduces this distortion to a minimum.

amplifier circuit and mode

There's a lot of confusion with regard to the so-called "grounded-grid" amplifier. Rf power amplifiers are classified according to circuitry and mode of operation. The two classifications should not be confused with one another. For Amateur service, the two most popular circuits are the grid-driven circuit and the cathode-driven circuit. As shown in **fig. 1**, the circuits are remarkably similar, the most obvious difference being the placement of the ground point in relation to the input and output circuits.

The mode of operation refers to the dynamic operating characteristics of the tube (class AB_1, class B, or class C). Characteristics of the classes are given in reference material listed at the end of this article. For linear service, the power tube amplifier is commonly run in either class AB_1 or class B service. Thus, modern equipment may have an intermix of circuitry and mode — the cathode-driven amplifier may be operated in a class AB_1 mode, for example, or the grid-driven amplifier may be operated in the class B mode.

So far, I've not discussed the popular grounded-grid amplifier. This is a sloppy term which usually refers to a cathode-driven amplifier, working in the class B mode. "Grounded grid" implies cathode drive, but in such a circuit the grid may not necessarily be at dc ground potential, especially with respect to screen voltage (see **fig. 2**). Rf ground and dc ground are not always the same in a linear amplifier, and most circuit engineers shudder at the use of the term.

amplifier plate circuit

While this series of articles concerns itself with linear, cathode-driven-amplifier design, the remarks about the plate circuit apply equally well to grid-driven amplifiers. It is desirable to operate any linear amplifier with a very minimum of intermodulation distortion, with high-plate efficiency, and with high power gain. The latter is especially important, as it affords maximum power output with a given amount of drive power. The class B mode of operation meets these requirements.

Shown in **fig. 3** is a graphical representation of a class B amplifier, showing the operating cycle of the tube. This is the portion of the electrical cycle over which the tube grid is driven positive (approaching +e) with respect to the cathode (or the cathode driven negative with respect to the grid). When the grid potential is highly negative with respect to the cathode (approaching −e), the tube is cut off and is inoperative. In the class B amplifier, the operating cycle is about one-half the electrical cycle, or approximately 180 degrees. The transfer curve plot shown indicates that the tube delivers power only over one-half of the electrical cycle and is cut-off during the other half of the cycle. Does this mean that the output signal consists of half-sine waves as shown, and is therefore highly distorted? Not at all.

The amplifier plate circuit (often called the tank circuit) saves the day, since the energy storage ability (*Q*) of the circuit balances the energy between the halves of the cycle, much as the flywheel stores energy during the operating cycles of a gasoline engine. The plate circuit must, therefore, be designed to have sufficient *Q*, or energy storage, for good operation. A *Q* value of 12 is commonly used for linear amplifier service, as it provides ample energy storage and at the same time provides reasonable reduction of harmonics generated in the amplifier.

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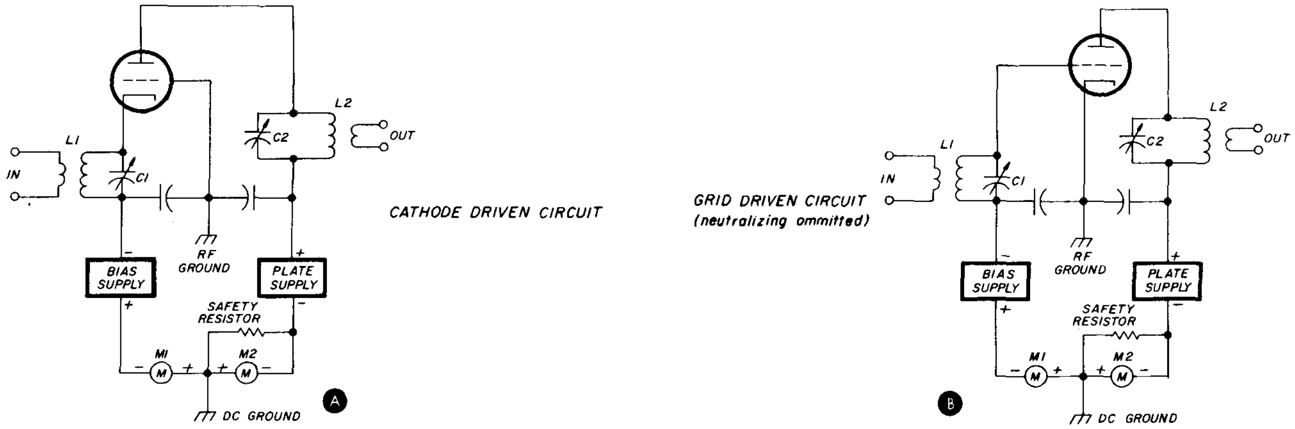

fig. 1. A comparison between grid-driven and cathode-driven amplifiers. Rf and dc circuits have been simplified for clarity. In both cases, the grid- and plate-current meters are placed in the ground return circuits to remove any dangerous voltage from the meter movement. This, however, places the plate supply above dc ground by virtue of the voltage across the plate meter. If the meter coil should open, the negative lead of the supply rises to the value of the plate voltage. As a safety factor, a wirewound resistor is usually placed across the plate meter, and often the grid meter. The circuit configuration determines the difference between cathode- and grid-driven service. The applied voltages determine the mode of operation.

A rigorous design of the plate circuit calls for manipulation of the plate voltage and current to determine the operating parameters of the tube. The results of these tedious calculations can be summed up in simple formulas that provide the designer with circuit data in everyday terms.

A network is required that matches the plate load impedance of the power tube to the characteristic impedance of the transmission line, while at the same time maintaining a Q value of 12. The popular pi network can do the job. The plate load impedance (Z_L) for a class B rf amplifier can be closely approximated by:

$$\text{load impedance (ohms)} = \frac{\text{plate voltage}}{2 \times \text{peak dc plate current (amperes)}}$$

As an example, a pi network is to be used to match a pair of 3-500Z tubes to a 50-ohm transmission line. The tubes operate with 2500 volts plate potential with a peak dc plate current of 800 mA (0.8 amp) for a PEP input of 2 kW.

$$\text{load impedance} = \frac{2500}{2 \times 0.8} = 1560 \text{ ohms}$$

Thus, the pi network plate circuit has to match a load impedance of 1560 ohms to a 50-ohm termination.

designing the plate circuit network

The approximate values of the pi network can be determined from three simple graphs. The plate inductance from **fig. 4**, the tuning capacitance (C1) from **fig. 5**, and the loading capacitance (C2) from **fig. 6**. The graphs are entered at the x axis and read up until the sloping line denoting a particular Amateur band is intersected. The value of the component is then read horizontally off the y axis. For example, the required inductance for a plate load of 1560 ohms for the 15 meter band is about one microhenry — as close as the graph can be read. Note that capacitor C1 is commonly referred to as the tuning capacitor and C2 the loading capacitor.

The graph for C2 tells us that the pi network cannot cope with impedance transformation values much greater than 100-to-1 at this value of Q. Note how the curves bunch together and "fall-off the graph" at plate impedances much higher than 5000 ohms.

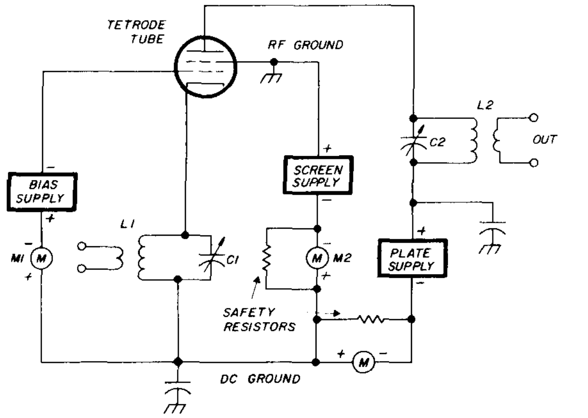

fig. 2. Diagram of the so-called "grounded-grid" amplifier. The grid and screen elements are bypassed to ground as far as rf is concerned, but each element has normal operating voltages applied and are "above ground" as far as dc is concerned. Metering is inserted in the supply return leads to dc ground. Rf ground is placed at the positive screen voltage level. This eliminates the screen bypass capacitor, a tricky component that often causes circuit instability at the higher frequencies.

A more accurate, computer-derived summary of pi network values is given in **table 1**. Note that, for a given plate impedance, when the operating frequency is doubled the capacitance and inductance values are halved. (Fifteen- and forty-meter constants are related by a factor of three as 21 MHz is the third harmonic of 7 MHz.)

coil winding

Winding plate coil L1 to a given value of inductance takes an inductance meter, or a degree of expertise and a dip-meter. A simple formula for calculating inductance when the coil dimensions are known is:

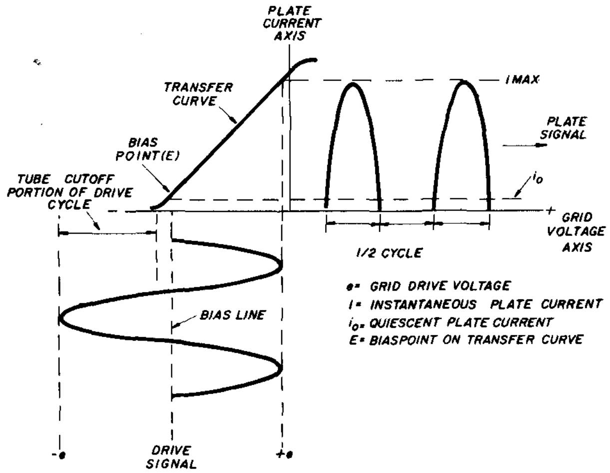

fig. 3. Transfer curve and operating cycle for a class B amplifier. The transfer curve is determined by a static test of the tube where plate current is plotted against grid bias. Once the transfer curve is established, the operating cycle may be determined. The sine wave drive signal (e) is drawn about the bias line, determining both the zero-signal plate current (i_o) and the peak plate current (i_{max}). Note that when the grid driving signal swings negative, no plate current is drawn and the tube is cut-off for one-half cycle. Pulses of plate current only appear when the drive signal is positive with respect to the bias voltage. Thus, the output waveform of a class B rf amplifier consists of a series of half-cycles, much in the manner of a half-wave rectifier. The distorted waveform is restored to a sine wave by the plate tank circuit which, by virtue of its *Q*, or flywheel effect, stores energy on the active half of the cycle and releases it on the inactive half. Circuit engineers, working from a transfer curve, can determine actual dc operating potentials for a linear amplifier.

$$Inductance\ (\mu H) = \frac{R^2N^2}{9R + 10S}$$

where R is the radius of the coil in inches
S is the length of the coil winding in inches
N is the number of turns

These calculations have been simplified in the ARRL type-A "Lightning Calculator," which is a simple slide rule providing direct read-out of the coil dimensions if the inductance is known. It takes the hard work out of designing coils.

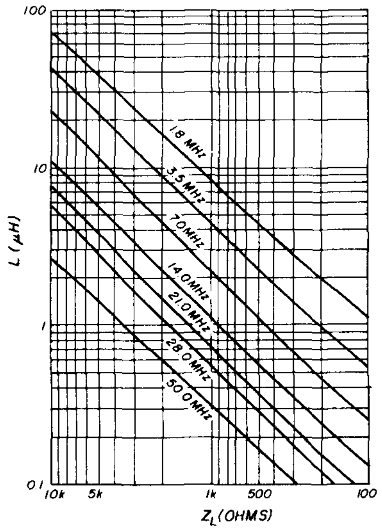

fig. 4. Plot of the plate inductance vs. plate load impedance for the high frequency Amateur bands (Q = 12).

Once the plate circuit has been designed and built, it is a good idea to "breadboard" it up and check it out with a dip-meter before the connections are finally soldered. Coil taps may have to be moved a bit to compensate for capacitance of the components to the chassis and adjacent parts.

amplifier-cathode circuit

The cathode-input circuit provides an impedance match between the 50-ohm coaxial output circuit of the driver/exciter and the input impedance of the cathode-driven amplifier (see **table 2**). The input im-

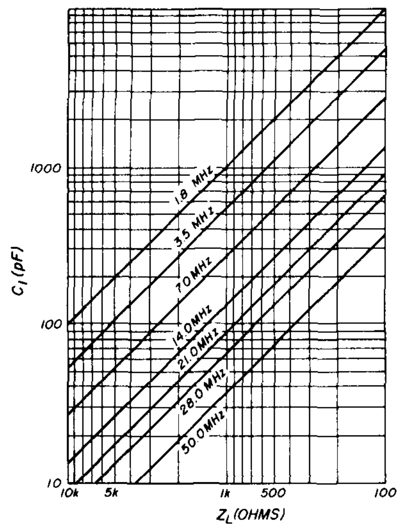

fig. 5. Plot of the tuning capacitance (C1) vs. plate load impedance (Q = 12).

pedance (Z_t) of a cathode-driven tube is related to the ratio of the peak cathode signal voltage to the peak cathode current (sum of grid and plate currents), and is commonly given in the tube data sheet. For the 3-500Z *at 2500 volts, it is about 110 ohms*. And for two tubes in parallel, it is about 55 ohms, but *only* over the operating cycle.

It is tempting to jump to the conclusion that if the *amplifier input impedance is about 55 ohms and the* coaxial line impedance driving it is 50 ohms, that no cathode impedance matching circuit is required. In fact, many commercially manufactured amplifiers leave it out for economy's sake. This omission is poor engineering practice, as the circuit Q is required in the cathode circuit as well as in the plate circuit. Omission of the cathode-tuned circuit can lead to distortion of the driving signal, increased intermodulation distortion, reduced amplifier efficiency, and driver loading problems. A circuit Q of 2 is adequate, and a simple rule of thumb is that the network circuit capacitances at resonance should be about 20 pF per meter of wavelength for one-to-one impedance transformation.

practical amplifier circuit

Armed with the information discussed so far, it is possible to draw up a schematic for a cathode driven, 2-kW PEP linear amplifier using two 3-500Z tubes in parallel (see **fig. 7**). This is a true "grounded-grid" circuit, as the grids are at both dc and rf ground potential.

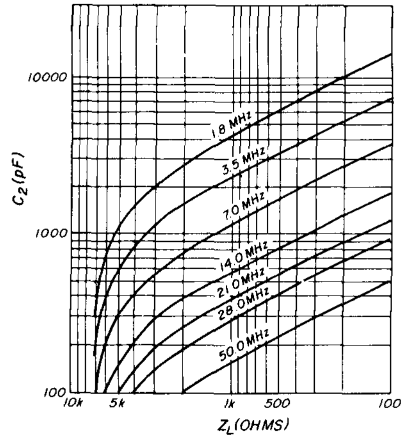

fig. 6. Plot of the loading capacitance (C2) vs. plate load impedance (Q = 12).

Note that plate and grid currents are measured in the cathode return circuit. This requires the amplifier plate power supply to "float" a little above ground potential in order to insert a meter in the negative lead to measure plate current. This removes the lethal plate voltage from the meter. The grid meter is out of the critical rf ground return path, which simplifies the metering circuit. A filament voltmeter is included. Filament voltage should be held to within

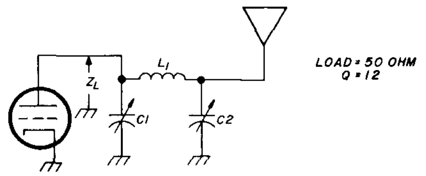

table 1. Computer-derived values for a pi network having a Q of 12 and working into a 50-ohm load. Values for C1 include the output capacitance of the tubes. These values are taken from a computer program derived by Bob Sutherland, W6PO.

component	band	Z_L plate load impedance (ohms) 1000	1500	2000	2500	3000	3500	4000	5000
C1	160	1060	690	531	430	354	309	265	212
	80	546	364	273	220	182	159	136	109
	40	273	182	136	110	91	80	68	55
	20	136	91	68	55	45	40	34	27
	15	91	61	45	37	30	26	23	18
	10	68	45	34	30	23	20	17	14
C2	160	4421	3487	2865	2440	2105	1849	1594	1186
	80	2274	1784	1473	1263	1082	951	820	610
	40	1137	892	737	632	541	475	410	305
	20	568	446	368	316	271	237	205	153
	15	379	297	246	211	180	158	137	102
	10	284	223	184	158	135	118	102	76
L1	160	8.84	13.26	16.61	20.10	24.13	27.80	31.47	38.63
	80	4.55	6.57	8.54	10.90	12.41	14.29	16.18	19.87
	40	2.27	3.28	4.27	5.50	6.20	7.15	8.09	9.93
	20	1.14	1.64	2.14	2.70	3.10	3.57	4.05	4.97
	15	0.76	1.09	1.42	1.82	2.07	2.38	2.70	3.31
	10	0.57	0.82	1.07	1.36	1.55	1.78	2.02	2.48

±5 per cent of 5 volts, and it is prudent to monitor this voltage when expensive tubes are used. A plate voltmeter may be included in the amplifier, but it is easier to place it in the power supply.

Amplifier standby plate current is reduced by means of a 10-kilohm, 25-watt cathode resistor which is shorted out by the VOX relay of the exciter, causing the tubes to operate at the proper resting plate current when the amplifier is on the air. A zener diode is placed in series with the cathode dc return path to reduce the quiescent plate current during amplifier operation.

A 50-ohm wirewound resistor from the negative side of the plate supply to ground makes certain that the negative supply terminal does not rise to the value of the plate voltage if the positive side of the supply is accidentally shorted to ground.

Two reverse-connected diodes are shunted across the safety resistor to limit any transient surges under a shorted condition which might cause wiring insulation breakdown. In addition, the diodes protect the meters from transient currents. A resistor across the zener diode provides a constant load for it and prevents cathode voltage from soaring if the zener safety fuse opens.

Note that a 10-ohm, 50-watt wirewound resistor is placed in series with the B-plus lead to the plate rf choke. This resistor serves as a vhf choke to suppress harmonic currents in the power lead and also protects the tube and associated circuitry in case of a flash-over in the tube or plate circuit. The tremendous amount of energy stored in the power supply is instantaneously "dumped" into the amplifier when a

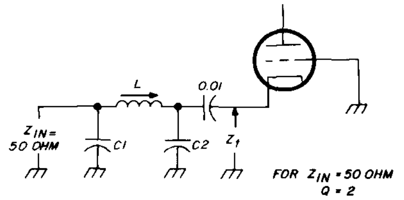

table 2. The pi-network circuit for a cathode-driven amplifier. This chart provides approximate values for the components of the cathode circuit. Capacitors should be 1-kV silver mica or equivalent. The inductor can be wound on a slug-tuned form. Value of C2 should take into account the cathode-grid capacitance of the tube which appears in parallel with C2 (information is from a computer program by W6PO).

cathode Z_t (Ω)	band	C1(pF)	C2(pF)	L(µH)	cathode Z_t(Ω)	band	C1(pF)	C2(pF)	L1(µH)
20	160	3300	4100	2.50	75	160	3300	2870	3.81
	80	1700	2120	1.34		80	1700	1540	2.05
	40	900	1120	0.68		40	900	770	1.03
	20	440	560	0.33		20	440	380	0.51
	15	300	370	0.22		15	300	250	0.34
	10	220	275	0.16		10	220	180	0.25
30	160	3300	3900	2.84	100	160	3300	2520	4.20
	80	1700	2100	1.52		80	1700	1350	2.26
	40	900	1050	0.77		40	900	680	1.14
	20	440	520	0.38		20	440	330	0.56
	15	300	350	0.25		15	300	220	0.38
	10	220	258	0.19		10	220	160	0.28
40	160	3300	3360	3.01	150	160	3300	2100	4.81
	80	1700	1800	1.62		80	1700	1130	2.59
	40	900	910	0.82		40	900	570	1.30
	20	440	450	0.40		20	440	280	0.66
	15	300	300	0.27		15	300	180	0.43
	10	220	220	0.20		10	220	138	0.32
50	160	3300	3300	3.33	200	160	3300	1800	5.32
	80	1700	1700	1.79		80	1700	980	2.86
	40	900	900	0.90		40	900	490	1.44
	20	440	440	0.45		20	440	245	0.71
	15	300	300	0.30		15	300	164	0.48
	10	220	220	0.22		10	220	120	0.35
60	160	3300	3100	3.53	250	160	3300	1640	5.78
	80	1700	1670	1.90		80	1700	880	3.11
	40	900	840	0.96		40	900	440	1.57
	20	440	417	0.47		20	440	220	0.78
	15	300	275	0.32		15	300	140	0.52
	10	220	205	0.23		10	220	100	0.38

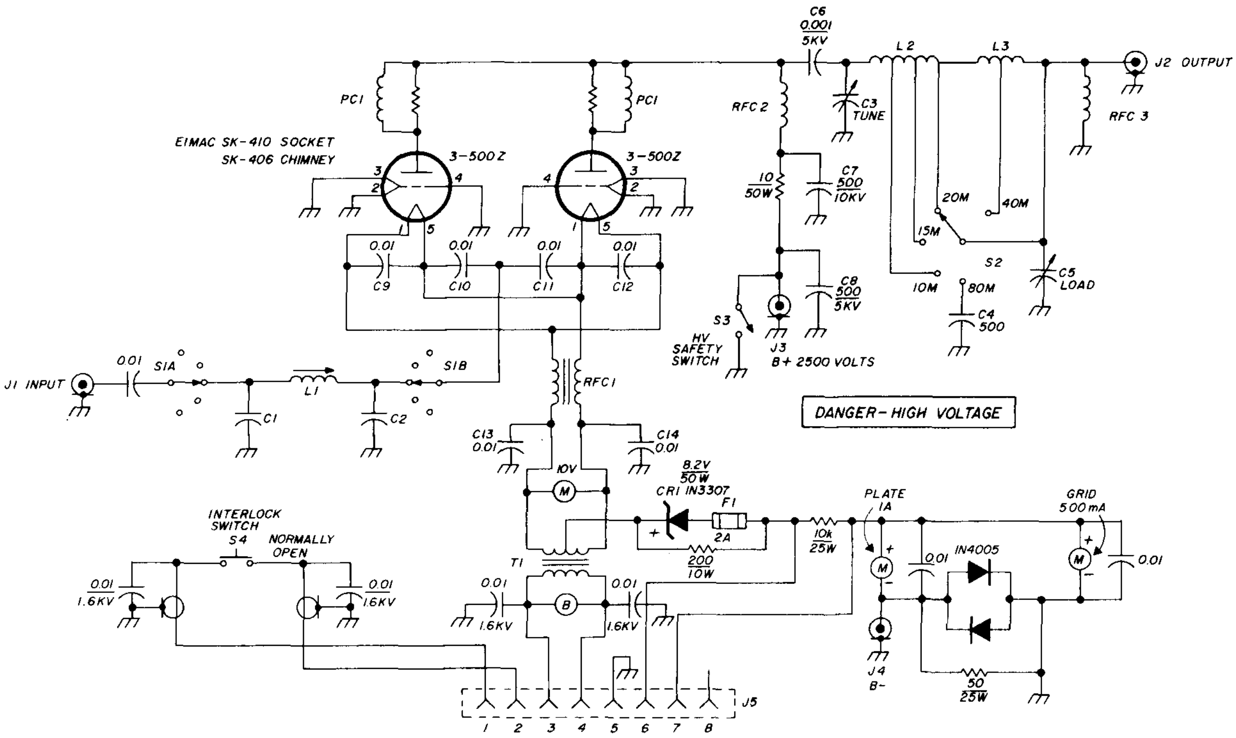

fig. 7. Schematic diagram of the 3-500Z linear amplifier.

C3	250 pF, 4.5 kV plate spacing — Johnson 154-16
C4	500 pF, 4.5 kV
C5	1000 pF, 500 volt plate spacing
C6	0.001 μF, 5 kV — Centralab 858S-1000
C7, C8	500 pF, 10 kV TV-type "door knob"
C9-C14	0.01 μF, 500 volt mica capacitor. Ceramic disc is a suitable substitute if rated 1 kV.
PC 1	Three 100-ohm, 2-watt resistors in parallel
PC 2	Three turns of no. 14 AWG (1.6 mm) wound with 12.5-mm (0.5-inch) diameter and 19-mm (0.75-inch) length connected in parallel with the resistors. The coil may be wound around one of the resistors.
RFC 1	50 μH; 14 bifilar turns of no. 10 AWG (2.6 mm) enameled wire wound on ferrite core 12.5 cm (5 inches) long and 12.5 cm (0.5 inch) in diameter (Indiana General CF-503 or equivalent).
RFC 2	100 μH, 1 ampere dc; 112 turns no. 26 AWG (0.4 mm) spacewound wire diameter on 2.5 cm (1 inch) ceramic form 15 cm (6 inches) long (Centralab X-3022H insulator). Series resonant at 24.5 MHz with terminals shorted (B&W 800).
RFC 3	2.5 mH, 100 mA
T1	5 volts at 30 amps (Chicago-Standard P-4648)
Blower	13 cu. ft./min. Use a no. 3 impeller at 3100 rpm (Ripley 8472, Dayton 1C-180, or Redmond AK-2H-01AX)

flash-over occurs, and much of this destructive energy is dissipated in the resistor.

Many modern-generation Amateurs have never worked with equipment operating at voltages higher than 12 volts. This amplifier, with the high-voltage plate supply, is positively lethal and the operator can be killed if his hands are inside the unit when the high voltage is on. It is *imperative*, therefore, that safety switches be incorporated in the amplifier design. It is poor engineering practice to leave these devices out! S4 is a normally open, pushbutton device that is closed only when the lid is placed on the amplifier enclosure. S3 is a shorting switch that shorts the high voltage to ground when the lid is removed. Construction of this special switch will be covered in a future article. *Always remember — high voltage kills*! Take necessary precautions.

Although not shown on the schematic, it is a good idea to use a filament transformer having a primary winding tapped for 105, 115, and 125 volts. This provides a plus or minus ten per cent adjustment from a normal line voltage of 115 volts. If a closer filament adjustment is desirable, the transformer can be run on the 105 volt tap with a rheostat in series with the primary winding to place the filament voltage "on the nose."

The plus and minus leads to the high voltage supply should be run through high-voltage connectors and high-voltage cable. Test prod wire having a 10-kV breakdown is satisfactory. As an alternative, RG-58/U coaxial cable can be used for high-voltage leads along with PL-259 plugs and reducers and SO-239 receptacles. The shield of the coaxial line is grounded by the connectors. **ham radio**

short Beverage for 40 meters

Discussion of a short Beverage antenna for 40 meters with particular emphasis on the matching transformer and termination

Basically, my problem is one of geography. Living in a moderately rare DX location, I have become weary of pile-ups and the quick signal report exchanges. The insipid hello, goodbye, PSE QSL routine fails to satisfy the rag chewer that I am, with the result that I now tend to avoid the higher frequency bands and seek refuge lower in the spectrum. The 40-meter band offers attractive rag chewing possibilities, but everything about my location militates against a 40-meter pipeline to the folks back home.

For a starter, the band assignment in this part of the Pacific is only from 7 to 7.1 MHz. This narrow band is cluttered with Asian BC stations, and from about 7.03 to 7.1 MHz there is one continuous roar of JA ssb signals. To copy any W/K signals above 7.03 is well nigh impossible without a highly directive antenna. The Asian signals so totally overwhelm the receiver as to completely bury the much weaker W/Ks arriving from over 9600 km (6000 miles) away. After many frustrating attempts at rag chewing while listening on my vertical, I was convinced that, without some highly directive receiving antenna, it was a losing proposition.

Extensive research and meditation on this dilemma brought me to the conclusion that some sort of Beverage antenna offered the only hope in my circumstances. For me, multi-element phased or parasitic arrays on 7 MHz were out of the question, but a patch of jungle behind the house offered possibilities for a Beverage-type long wire. At this point, I must acknowledge my debt to others for supplying me with the three basic premises upon which my project was founded.

First, a simple low-to-the-ground, properly terminated long wire can achieve astonishing rejection of signals from unwanted directions.[1] Second, such a wire will exhibit maximum front-to-back ratio if it is an odd number of quarter wavelengths long.[2] And third, although most publications show a simple 600-ohm resistor for termination, no simple resistor alone will ever give optimum termination. A little inductance will always be needed in series with the resistor.[3] (Apparently the intrinsic insulator and end capacitance of such a wire causes a slight mismatch which must be inductively cancelled out.)

After an hour of tramping about in the jungle, taking repeated compass sightings, I finally located a group of four trees that lay in a perfectly straight line, on the exact bearing needed to beam W/K. A coconut palm and a breadfruit tree about 58 meters (190

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feet) apart provided the end supports, with two trees in between providing intermediate support points along the span.

There is no simple formula by which to determine the height of the wire above ground. I wanted it low enough that I might perform all adjustments while be used in place of the slug; however, one precaution should be observed. The primary and secondary windings should be placed on opposite sides of the circle, with a tight electrostatic shield between them. The object is to prevent proximity coupling direct from the end of the hot wire over to the coax input.

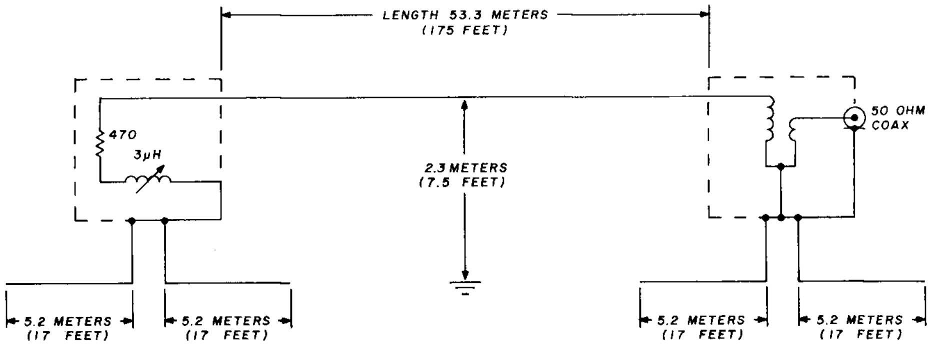

fig. 1. Diagram of the Beverage in use at the author's station. Each of the four ground wires is buried about 15 cm (6 inches) deep, on opposite sides and perpendicular to the Beverage wire. All wire used was number 10 AWG (2.6 cm), with the antenna made from Copperweld.

standing on an ordinary kitchen stool, and yet high enough to be well above the hands of any pedestrian traffic through the woods. A height of 2.3 meters (7.5 feet) satisfied both requirements. A piece of number 10 AWG (2.6-mm) copperweld was cut to a length of 53.3 meters (175 feet), which is 1.25 wavelengths at 7 MHz. With a block and tackle it was stretched taut as a fiddle string, so that with the two intermediate support points, it hangs straight as an arrow. The coupling and termination enclosures For best unwanted signal rejection, all coupling must occur through the core material.

To compute the characteristic impedance of my wire, I used the standard single wire transmission line formula $Z_o = 138 \log_{10} \frac{2h}{p}$ where h is the height of the wire above ground and p is the radius of the wire measured in the same units. For my case, the com-

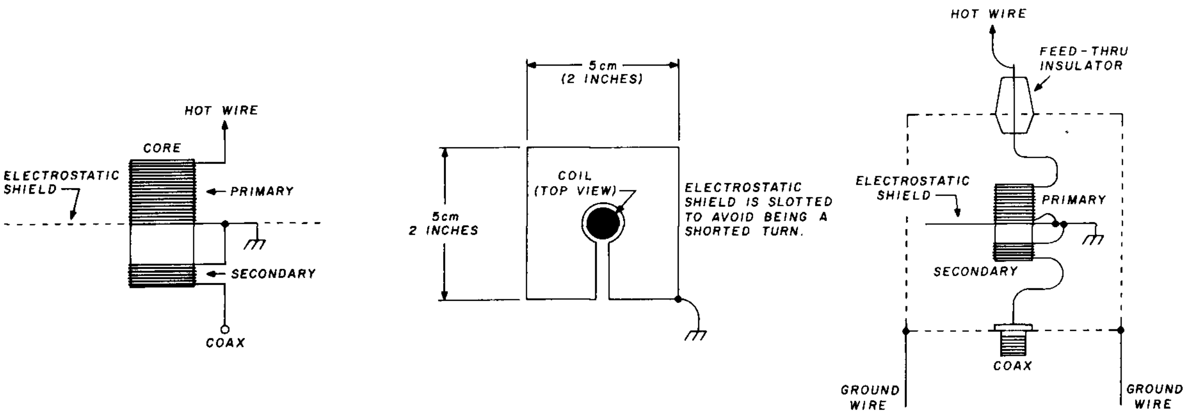

fig. 2. Diagrams of the matching transformer. The coil slug is made of powdered iron, 2.5 cm (1 inch) long and 1.3 cm (0.5 inch) in diameter. The primary is 30 close-spaced turns of number 26 AWG (0.4 mm) enameled wire, while the secondary is nine turns of number 26 AWG (0.4 mm) enameled, also close spaced. The two windings are separated by approximately 6.5 mm (¼ inch). The electrostatic shield is approximately 5 cm (2 inches) square and is made from copper foil; it is slotted to avoid being a shorted turn.

were hung at wire level, and the ground system installed as shown in **fig. 1**. Any type of minibox enclosure may be used as long as it is all metal for total shielding and weather proofing.

The coil detail is shown in **fig. 2**. A surplus powdered-iron slug of unknown pedigree was used here because I had nothing else. A toroid could well puted Z_o is 489 ohms. Reasoning that the series coil would add a few ohms of rf resistance to the lumped resistor, I chose the next smaller resistor value, 470 ohms. A commercial slug-tuned coil was used for the inductance. After all adjustments were complete, the inductance actually in use was 3 μH, or an X_L of 132 ohms at 7 MHz.

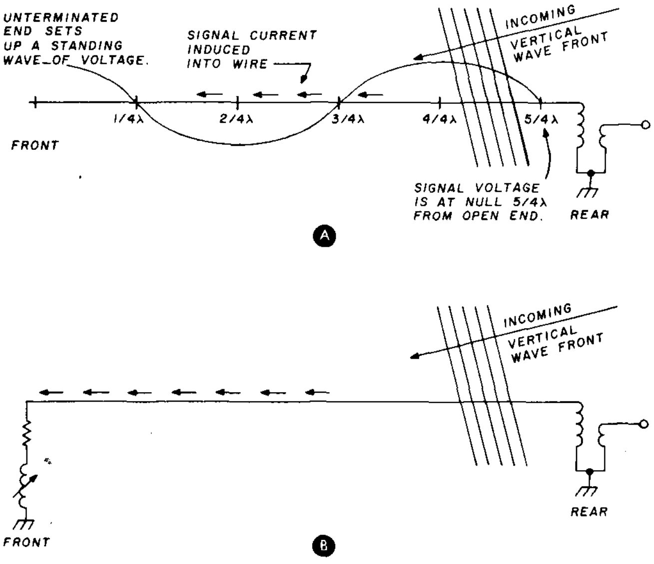

fig. 3. Diagram (A) shows the standing wave on the unterminated wire caused by an incoming signal from the rear. The signal voltage across the transformer is at a null 5/4λ from the open end. When the wire is perfectly terminated (B), the signals from the rear of the antenna are absorbed by the termination.

The Beverage antenna is located such that it is broadside to the transmitting antenna (a base-fed vertical dipole), and located 38 meters (125 feet) away. The feedline is 50 meters (165 feet) of RG-58A/U coax. Such orientation ensures minimal coupling between the two. Under key-down conditions, with 500-watts input to my trusty old 813, the measured rf voltage at the receiver input is only 0.15 volts rms.

Before step-by-step adjustments are described, a little discussion of the back rejection theory will be helpful. As shown in **fig. 3A**, incoming signals propagating along the wire from the back side will induce a signal current into the wire. If the wire is unterminated at the front end, a standing wave of voltage will be set up with a maximum at the open end. Reflections traveling backwards along the wire for an odd number of quarter wavelengths will create a voltage null where the coupling coil is located at the rear end. Because there is almost no voltage acting on the relatively high impedance of the coil, very little signal will be coupled through to the receiver.

This can be clearly demonstrated by simply removing the coil from the circuit and connecting the hot lead of the coax directly to the rear end of the wire. Under these conditions, a standing wave of current will appear in the wire with a maximum at the rear end, coupling very well into the low impedance of the coax. With the front end of the wire unterminated, take an S-meter reading on some sky wave signal arriving from the back side. This establishes the ability of the wire to receive a certain signal level, apart from any termination or phasing attenuation. Once an average level is noted, reinsert the coupling transformer. On my antenna, the rear-side signal dropped by 18 dB when the coil was reinserted, showing that some amount of front-to-back ratio is achieved through the phase relationship of the odd quarter wavelength. The drop in signal noticed is not related to coil losses when the coil is reinserted. A similar comparison was made with the signal from a Kuala Lumpur station broadcasting on 6.03 MHz. At this frequency, the wire is about one wavelength long, and it showed no front-to-back change at all when the coil was reinserted into the circuit. Coil losses with iron-core coupling are so insignificant that they do not show up in the meter readings.

After my termination was reconnected and carefully adjusted for minimum back pick-up, the front-to-back ratio was increased by another 15 dB, giving a total front-to-back ratio of 33 dB for both effects working together. Referring to **fig. 3B**, if the front end termination is a perfect match for the characteristic impedance of the wire, the induced rear side signal current is almost totally absorbed in the termination, and there is no reflection to speak of going back to the coupling end.

In my location there was no possibility of enlisting the help of a "local" 40-meter station to provide a rear side signal for tuning purposes. The closest dry land off my back is the island of Borneo, 4000 km (2500 miles) away! I selected a station in Kuching, Sarawak, (broadcasting on 7.16 MHz) to be my reference for all front-to-back adjustments. To get accurate measurements on a signal from that far away is difficult but not impossible. Taking readings on a vertically polarized local signal can be misleading. The Beverage does respond to vertical polarization, but it depends on the slight forward tilt of the incoming wave front to produce the small horizontal vector actually coupling into the wire. If a local vertical signal is used, the wavefront is so square to the ground that coupling into the Beverage is much less than a low-angle sky wave arrival would provide. Comparisons with a front-side vertically polarized signal from KG6RJ, only 3.2 km (2 miles) away, showed the Beverage about 12 dB less responsive than it would be to low-angle sky waves from the same direction.

An aged Hammarlund HQ180 receiver S-meter was used for all readings. The bandwidth was set to the narrowest position so the S-meter would respond only to the carrier of the station concerned and not to the buckshot of BC stations or QRN. The rf gain must be set to maximum for all readings. Since all readings are a comparison of the vertical reference (transmitting) antenna vs the Beverage, the first step is to establish a loss figure for the Beverage. Because it presents a very small "capture area" to incoming wave fronts, and being very long and close to lossy ground, the Beverage is very inefficient, compared with the vertical. In order to derive its intrinsic loss, the termination must be disconnected and the coupling coil temporarily removed from the circuit. The center lead of the coax is jumpered to the end of the Beverage wire for the first comparison.

The Kuching signal was then tuned in using the vertical antenna. The HQ-180 antenna trimmer was detuned to where the Kuching signal just peaked to the 20 dB over S9 mark. This is to avoid taking any readings at the compressed top end of the S-meter scale where the calibrations are very inexact. The meter is watched for about one full minute to get the feel of the QSB and to make sure the needle never swings beyond the 20 dB mark. Then the vertical coax is disconnected from the receiver and the Beverage connected.

With the Beverage antenna in use, the meter is again watched for about one full minute, noting the very highest swings of the needle. With mine, the peaks were an average of 20 dB lower, showing the basic Beverage wire alone has a receiving loss of 20 dB compared with the vertical.

Next, the coupling coil and termination were reattached. The same comparison procedure was followed; first tuning in the signal on the vertical, adjusting the antenna trimmer until the signal peaks 20 dB over S9; then attaching the Beverage antenna and noting the drop in S-meter readings. The QSB is accentuated on the Beverage because it is very selective to polarity, responding best to vertically polarized incoming wave fronts.

The procedure is repeated with different settings of the termination coil, changing it in increments of about two turns of the slug between trials. As the optimum point is approached, the S-meter responses on the Beverage will go lower and lower. When I got my termination to the optimum setting, the S-meter dropped dramatically from the 20 dB over S9 mark on the vertical to only S3.5 on the Beverage — counting downward from the 20 over 9 mark, allowing 6 dB per unit, a decrease of 53 dB.

Note that 53 dB is *not* the front-to-back ratio of the Beverage working alone! That is merely the difference between the two antennas. In the first test described, it was already established that the Beverage had an efficiency of 20 dB less than the vertical. Subtracting this constant from the difference readings between the two gives an absolute front-to-back ratio of 33 dB for the Beverage alone.

It must be remembered that S-meters are notoriously unreliable as regards absolute decibel calibration. While useful for noting changes in a given signal, they must be regarded with suspicion when seeking to establish accurate decibel levels. Listening experience with this antenna would seem to indicate the actual suppression is not quite as dramatic as these figures indicate. The Hammarlund HQ180 exhibits different sensitivity on each band, so, obviously, if the meter were accurate on one band, it would be lying on all the others. At 7 MHz, it seems to be a bit generous with its dB read-out. Nevertheless, the suppression of this antenna must be called excellent, more than worth the very small investment required for materials. It is hard to imagine more suppression per dollar than the Beverage offers.

Taking hundreds of readings by the same comparison method, I found that when the Beverage was terminated at its best front-to-back rejection, the front-to-side rejection was also best. A strong Chinese broadcast station (7.025 MHz) from somewhere in the rear quadrant was reduced 30 dB by the pattern of the Beverage alone. Japanese ssb signals arrive from a 30-degree-wide sector and do not all show the same front-to-side rejection ratio. The average values were from 36 to 40 dB front-to-side ratio for the Beverage alone (in the sector of 60 to 90 degrees relative in the pattern).

The proof of the pudding is always in the eating, and this antenna has certainly proven itself with my goals in view. The Beverage does not completely eliminate the undesired Asian signals, but it does knock them down far enough that distant signals, which would have been completely overwhelmed with the vertical, can now be heard. The only disadvantage noted is that because of its polarity selectivity, the Beverage antenna shows magnified QSB effects. That is a small price to pay for the rejection in unwanted directions. Rag chewing with W/K generals on 40-meter CW is now commonplace and pleasurable, whereas before it was a grim struggle if possible at all.

In conclusion, let me add that, due to my unique location, all of these rejection figures were derived on signals arriving from 2400 to 9500 km (1500 to 6000 miles) away, which implies low-angle arrival. I am unable to specify just how the rejection figures would work out for high-angle signals. Perhaps someone situated in the center of the United States could perform further experiments to add high-angle rejection data to what I have already established for DX-only responses. Any takers?

references

1. Barry Boothe, W9UCW, "Weak-Signal Reception on 160 — Some Antenna Notes," *QST*, June, 1977, page 35.
2. *The ARRL Antenna Book*, 13th edition, American Radio Relay League, Newington, Connecticut, 1976, page 172.
3. Edmund Laport, *Radio Antenna Engineering*, McGraw Hill, New York, 1952, page 310.

ham radio

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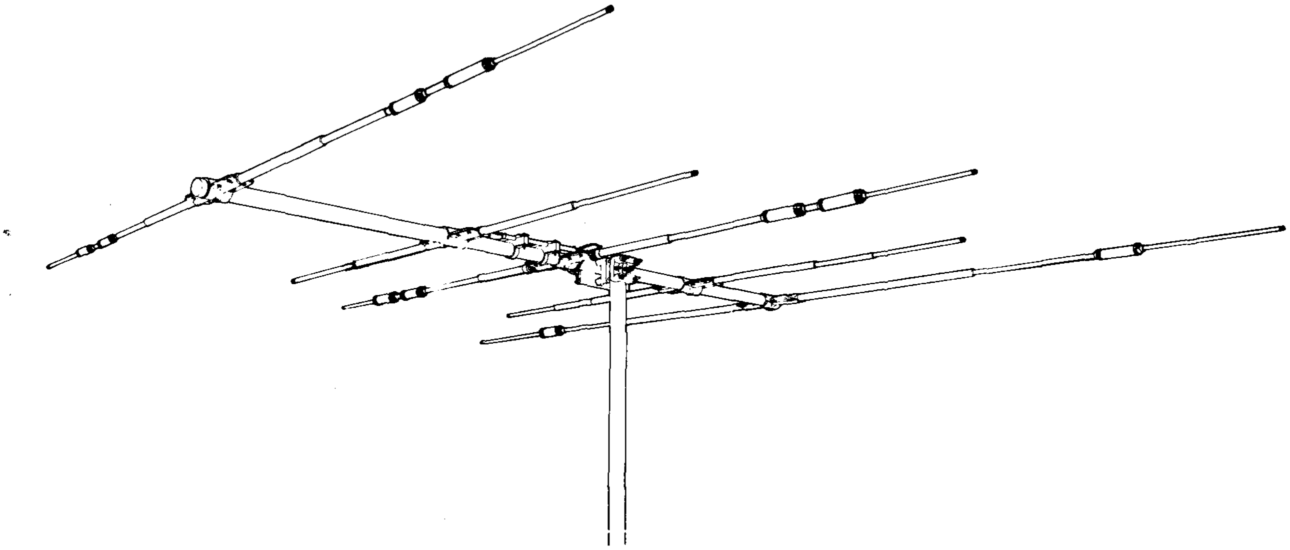
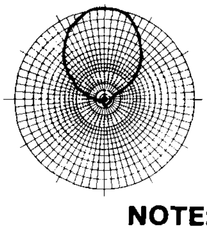


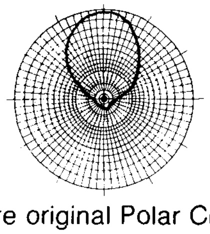
We are proud to introduce the newest member of our famous Thunderbird line of Tri-Band antennas. The TH5DX *offers outstanding performance on 20, 15, and 10 meters. It features 5 elements on an 18 foot boom,* with 3 active elements on 15 and 20 meters and 4 active elements on 10 meters. The TH5DX also features separate air-dielectric Hy-Q traps for each band. This allows the TH5DX to be set for the maximum F/B ratio and the minimum beam width possible for a Tri-Band antenna of this size. Also standard on this antenna are Hy-Gain's unique Beta-match, rugged Boom-to-mast bracket, taper-swaged elements and improved element compression clamps.

Boom length	18 feet
Longest Element	31 feet
Turning Radius	18 feet
Surface Area	6.4 sq. feet
Wind load	164 lbs.
Weight	50 lbs.
VSWR at resonance	less than 1.5:1
Power Input	Maximum Legal
Input Impedance	*50 ohms*
-3dB Beamwidth	66° average
Lightning Protection	DC ground
Forward Gain	8.5 dB
Front-to-Back Ratio	25 dB

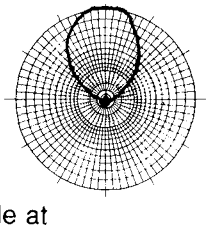
20 Meter



15 Meter



10 Meter



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More Details? CHECK—OFF Page 110

matchbox plus two

Improvements for your Johnson Matchbox antenna tuner — coax-to-coax tuning plus antenna switching

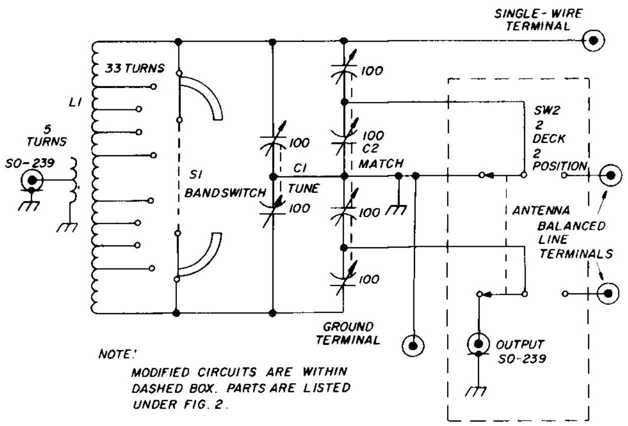
The Johnson Matchbox antenna tuner has been around for a long time. The Matchbox was manufactured in two versions, one for 275 watts and one for 1 kilowatt. The circuit used excellent quality components and was conservatively rated. This article describes modifications that can be made to the Matchbox that eliminate the need for disconnecting and connecting coax and wire feedlines and add the convenience of changing antennas with the turn of a switch.

features

The 275-watt Matchbox uses Johnson Series 154 capacitors, which are rated at 3000 Vac. The coil is wound with no. 12 (2.1-mm) wire. It is to be noted that transmatch articles in *QST* and the *ARRL Handbook* specify Series 154 capacitors for use at 2 kW.

The Johnson Matchbox will match the 52-ohm output of a transmitter into loads ranging from 25-1200 ohms for balanced transmission lines to 25-3000 ohms for unbalanced lines. The tuned circuit provides at least 15 dB harmonic attenuation.[1] Most Amateur transmitters and amplifiers for the high frequency bands use pi networks. The nominal design load impedance for this network is 52 ohms, with a maximum VSWR of 2:1[2,3,4,5] Maximum efficiency is obtained when the amplifier is loaded to its rated input and the load impedance is within design limits.

By **John D. Mitchell, K4IHV**, 436 Pinellas Road, S.E., Winter Haven, Florida 33880



	Johnson part no.	description
C1	154-505-4	capacitor, 100ED30, 3kV peak, 0.19-cm (0.075-inch) spacing, 15-plates/section, dual 100/10 pF
C2	169-25	capacitor, 100EDA30, 3kV peak, 0.19-cm (0.075-inch) spacing, 15-plates/section, dual differential, 100/10 pF
SW1	22.884	bandswitch
L1	23.1041	inductor, 33 turns no. 12 (2.1 mm), spaced 0.13 cm (0.05 inch), airwound on spreaders at 90°. Five turns in center are double spaced. Diameter 6.35 cm (2.5 inches). Winding length 12 cm (4.75 inches). Taps at 8.8, 12.7, 14.6, and 15.5 turns from each end. Coupling coil: 5 turns 2.6 mm (no. 10) double spaced, wound around center of inductor

fig. 1. Schematic of the Johnson Matchbox showing modifications (dashed box). The original parts in the Matchbox are shown for reference. These parts descriptions were omitted in early instruction manuals.

typical antenna mismatch at band edges

My triband beam, the CL-33, is assembled to favor the phone frequencies. The VSWR at the band edges is:

frequency MHz	vswr
14.00	4.0
14.35	1.8
21.00	1.5
21.45	2.0
28.00	3.0
29.70	4.7

Tuning coax with the Matchbox and experimentally selecting a line length will produce a 1:1 VSWR at the transmitter output on all frequencies within the antenna and Matchbox ranges.

test connections

The rear-panel photograph shows the simple hookup I used to experiment with coax-to-coax tuning before modifying. Remove the screw from the top center of the rear panel. Temporarily mount a SO-239, by one corner, into the screw hole. Run a lead from the center terminal of the SO-239 to the balanced-line terminal, directly below. Ground the other balanced-line terminal. Connect the end of the coax line from your beam to the temporary SO-239. Run the transmitter output through a VSWR bridge to the Matchbox input. Use the tuning procedure you used for balanced lines.

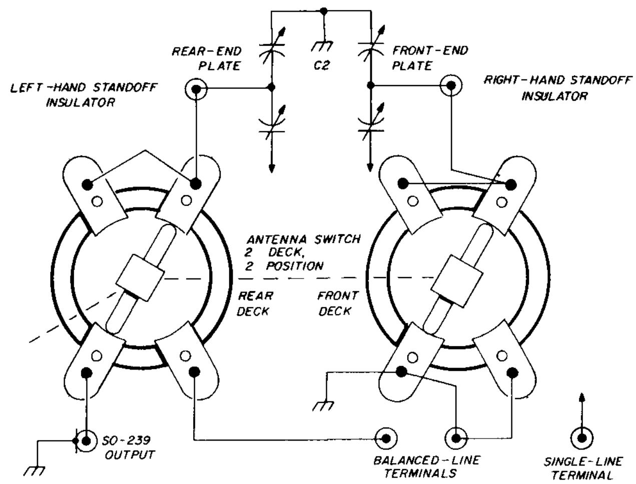
modifications

The schematic of **fig. 1** shows the Johnson Matchbox as built with the modified circuits in a dashed box. The parts list in **fig. 1** shows the values and descriptions of the parts used in the original Matchbox. (Early instruction manuals for the Matchbox did not include this information.) The parts needed to make the modification are shown in **fig. 2**. Proceed as follows:

1. Bypass or remove the relay. Run a line directly from the input SO-239 to the braid from the coupling coil.

2. Remove the tuning capacitor C1 by removing the nuts on the stators. Remove the support posts and slip C1 away from the solder lugs on the connecting leads. Do not distort the leads.

3. Remove the leads attached to the front and rear end plates of matching capacitor, C2. Remove the



quantity	description
1	antenna switch, Fair Radio cat. no. ML7464910-G1/407 or equivalent
2	standoff insulators, H.H. Smith 9502 or equivalent
1	SO-239 coaxial receptacle, Amphenol 83-1R
1	flexible shaft coupling, Fair Radio cat. no. COUN007
1	switch extension shaft, brass or aluminum, 16.5 × 0.64 cm (6.5 × 1/4 inches)
1	bar knob with brass insert
1	switch mounting plate (refer to fig. 3 and text)

fig. 2. Graphic display of all connections for the modifications, from C2 through new SW2, to the output terminals.

other ends of these same leads from the balanced-line output insulators. The leads will be used to connect C2 to the standoff insulators. Do not remove the single-wire output lead.

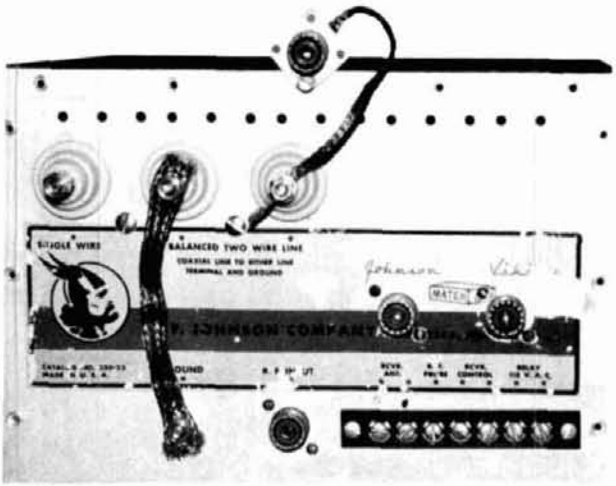
4. Install standoff insulators on each side of the center output insulator. See photograph of wiring connections.

5. Punch or drill a 1.27-cm (1/2-inch) hole for a SO-239 connector into the rear panel directly behind and below C1. Drill two mounting holes and install the connector from the inside. (You may want to add more connectors if your switch has more than two positions.)

6. Use **fig. 3** as a template. Cut a 6.35 by 10.16 cm (2.5 by 4 inch) switch mounting plate from 0.17-cm (0.065-inch) aluminum sheet. Use a sharp center-punch and mark the centers for all holes, right through the template. All screw holes are for 6-32 (M3.5) screws. (I drilled mine for 8-32 [M8] to allow for minor errors.) The ML7464910-G1/407 switch has a 1.27-cm (1/2-inch) shaft bushing. Centralab Ham Switch 2551 has a 0.95-cm (3/8-inch) bushing. The 2551 has six positions. The rear shaft bushing nut on C1 requires a 1.59-cm (5/8-inch) hole for clearance.

7. Assemble the switch plate and switch. Attach this assembly to the rear end plate of C1. Use 6-32 by 1/4-inch (M3.5 by 0.635 cm) brass screws. Longer screws will damage the C1 insulator. Install C1 in its original position. Attach connections from the band switch to the stators. Check the rear stator plate lead. It must clear the switch plate.

8. Drill a 0.635-cm (1/4-inch) hole in the cabinet front panel 6 cm (2-3/8 inches) above the C1 shaft hole.



In this view the rear panel holds an extra SO-239 which has been installed to experiment with coax-to-coax tuning.

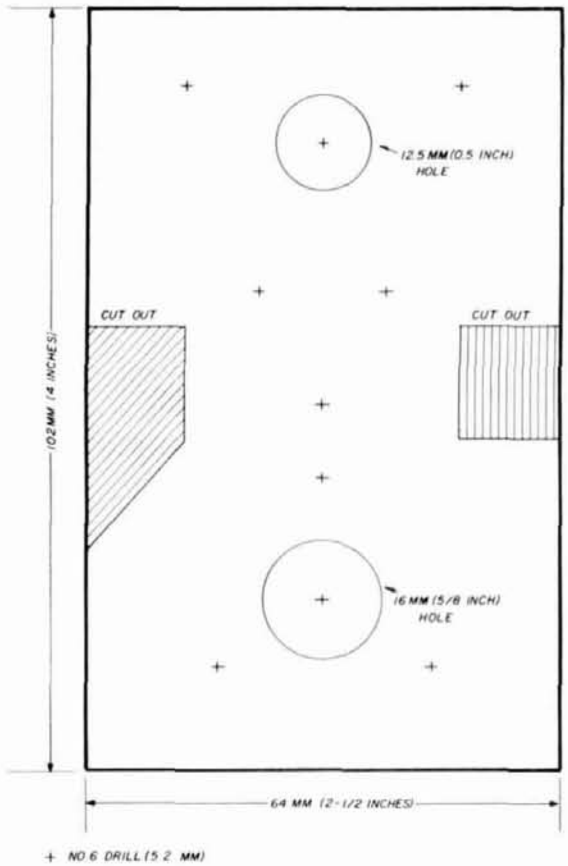


fig. 3. Switch-plate drilling template. Punch or drill through the drawing into the blank switch plate.

To complete wiring refer to the schematics, drawings, and photographs.

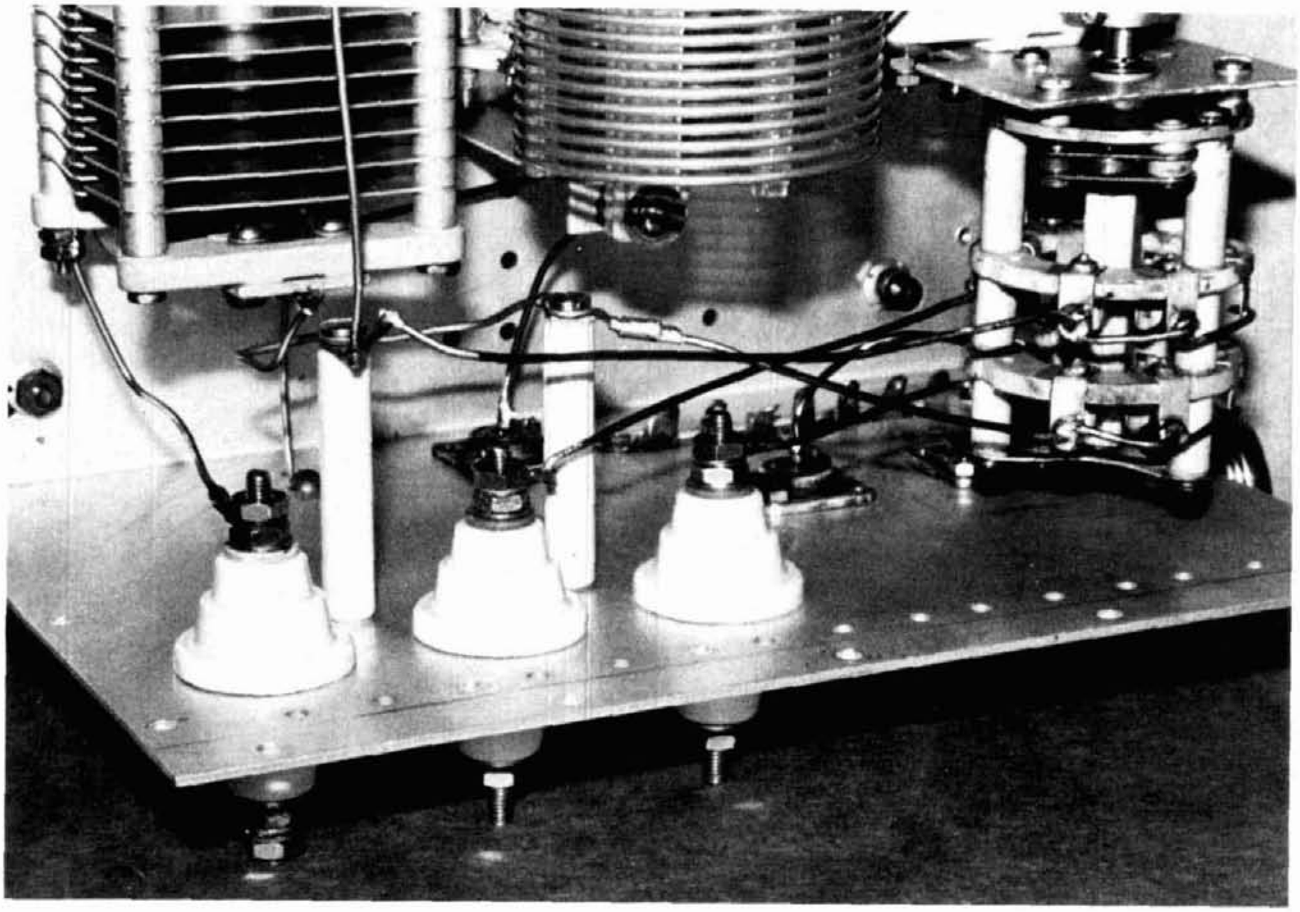
Before replacing the cover, run through these checks:

Temporarily install the dials and switch knobs. *Remember C1 and C2 are hot! Use the insulated coupling on C2. Keep your hands clear. Even at low power, you can be burned!*

Run tests on 20, 15, and 10 meters. If the impedance at your transmitter is outside the Matchbox range on any band change the feedline length.[6]

feedline tests

My feedline length was determined by inserting a 180-degree 14.0 MHz line between my wall entrance panel and the Matchbox. The impedance at the input of this 7-meter (23-foot) line was outside the Matchbox range on 20 meters but satisfactory on 15 and 10 meters. I reduced the line length by making 0.3-meter (1-foot) cuts to 0.9 meter (3 feet). I recorded readings for each length, dial readings, and measured VSWR. A review shows that at a 5.8-meter (19-foot) line length, the system was in tolerance at the edges of all bands. I made a new 5.8-meter (19-foot) line and verified the previous tests.



All wiring connections from C2 to the new selector switch are visible in this inside view of the modified Matchbox. This photo also shows the two new standoff insulators which are used for the junction points.

wrap-up

Replace the cover. Record dial readings at each 100 kHz on 20 and 15 meters and at each 500 kHz on 10 meters. Using a dummy load I can tune and load the transmitter, set the Matchbox to the recorded dial settings, select the antenna, and start transmitting without a touch-up.

During one of the many tests conducted with this Matchbox, I found that I could match the CL-33 antenna on 7155 kHz. W4TBU at Henderson, Kentucky, was worked from Winter Haven using my triband CL-33 beam. The report was S2. I haven't tried loading the two-meter beam.

some additional suggestions

A number of switches are satisfactory for this modification. The ML7464910-G1/407 from Fair Radio Sales* is excellent and inexpensive. Centralab's 2551 Ham Switch is a good commercial unit. It has two decks and six positions. Contacts are rated at 9 amperes. It has 2000-Vac insulation.[7]

*Fair Radio Sales, Post Office Box 1105, Lima, Ohio 45802.

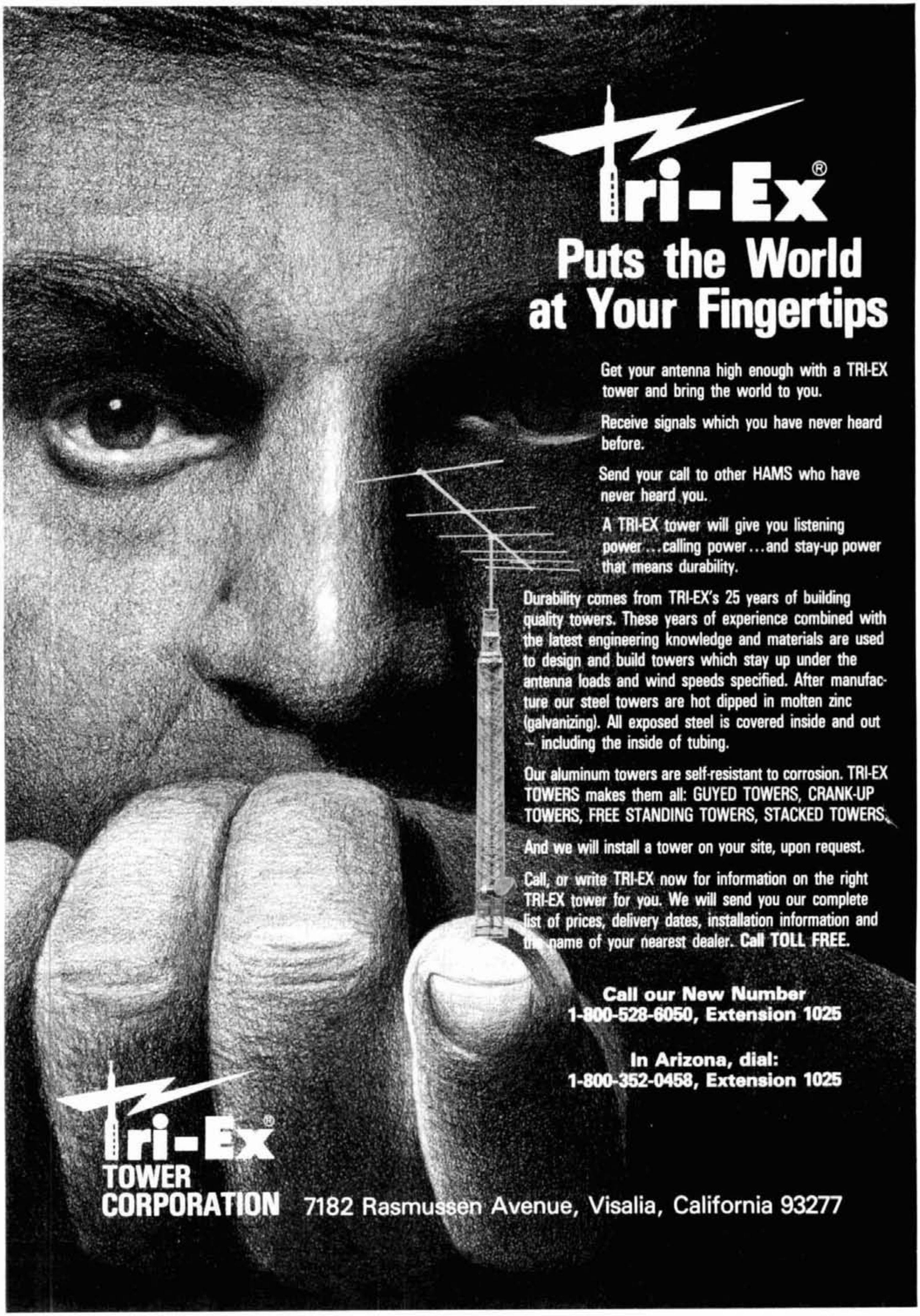
The kilowatt Matchbox can be modified for coax tuning. Switch ML7464910-G1/407 will work in the kilowatt model. Catalog no. ML7762999-G1/397 switch requires more space, 7.62 cm diameter by 12.7 cm long (3 × 5 inches). It has two decks and three positions. Contacts and insulation are more than ample for the legal Amateur power limit.

Centralab switch JV9033 will also work in the kilowatt Matchbox. This switch has two poles, eight positions, 17-ampere contacts, and 3000-Vac insulation.[7]

references

1. *Operation and Instruction Manual*, Johnson Viking Matchbox.
2. Mack Seybold, W2RYI, "Components for Pi-Coupled Amplifiers," *RCA Ham Tips*, RCA Tube Division.
3. Drake T-4X Instruction Manual.
4. Heath SB-200 Instruction Manual.
5. Earl W. Whyman, W2HB, "Importance of Standing-Wave Ratios," *ham radio*, July 1973, pages 26-33.
6. "Feeder-to-Transmitter Matching Networks," *The ARRL Antenna Book*, American Radio Relay League, Newington, Connecticut, 13th edition, page 181.
7. Centralab Industrial Distributor Catalog, Series 201.

ham radio



More Details? CHECK — OFF Page 110

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More Details? CHECK — OFF Page 110

test-equipment mainframe

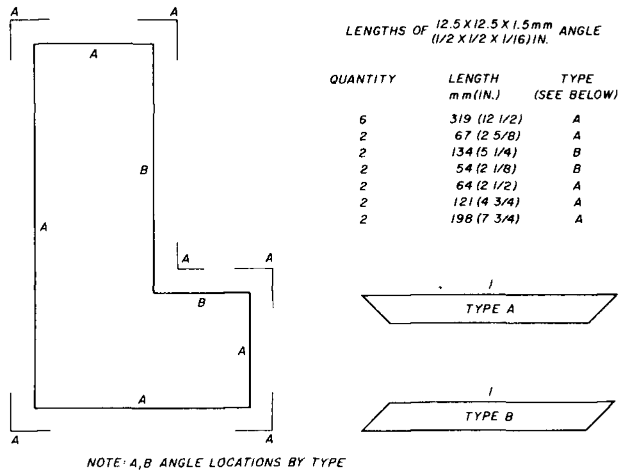
Construction ideas for those wanting convenience and a professional appearance for test equipment

Over the years I've built many pieces of test equipment, at first without paying much attention to size or appearance. Size became important because of extended operation aboard a sailboat and led to a series of units packaged in standard 51 × 77 × 128 mm (2 × 3 × 5 inch) miniboxes. As these units were developed, I realized that good appearance wasn't really difficult. (See reference for a description of many of these designs and for hints on obtaining good appearance.)

These units served me well but had some disadvantages. The main one was in assembly of a test set up, which involved chasing down the right unit or units, getting batteries together, and interconnecting the units to secure the desired signals. Storage was another problem, as well as keeping batteries on hand.

The appearance of the Tektronics 500-series plug-in units and mainframe led me to adopt some of their ideas and to the development of the mainframe and plug-in system described here — very handy and a *great time saver.*

The idea of the mainframe can be seen in the photo of the first (or prototype) version. At the bottom a chassis contains power supplies and control circuits, some interconnect circuits, and a series of switches. Receptacles at the top of the chassis are spaced to accommodate four miniboxes of the same



LENGTHS OF 12.5 X 12.5 X 1.5 mm (1/2 X 1/2 X 1/16) IN. ANGLE

QUANTITY	LENGTH mm (IN.)	TYPE (SEE BELOW)
6	319 (12 1/2)	A
2	67 (2 5/8)	A
2	134 (5 1/4)	B
2	54 (2 1/8)	B
2	64 (2 1/2)	A
2	121 (4 3/4)	A
2	198 (7 3/4)	A

fig. 1. Dimensions of angle stock needed for the first version of rack. Location of the pieces are shown.

size 51 × 77 × 128 mm (2 × 3 × 5 inch) for individual instruments. A receptacle on the front panel allows use of another instrument on an extension cable or makes the power supplies and interconnect points available externally.

The chassis used in the prototype are special boxes, having an L-shaped cross section. This can be seen more clearly in the photo of the second version,

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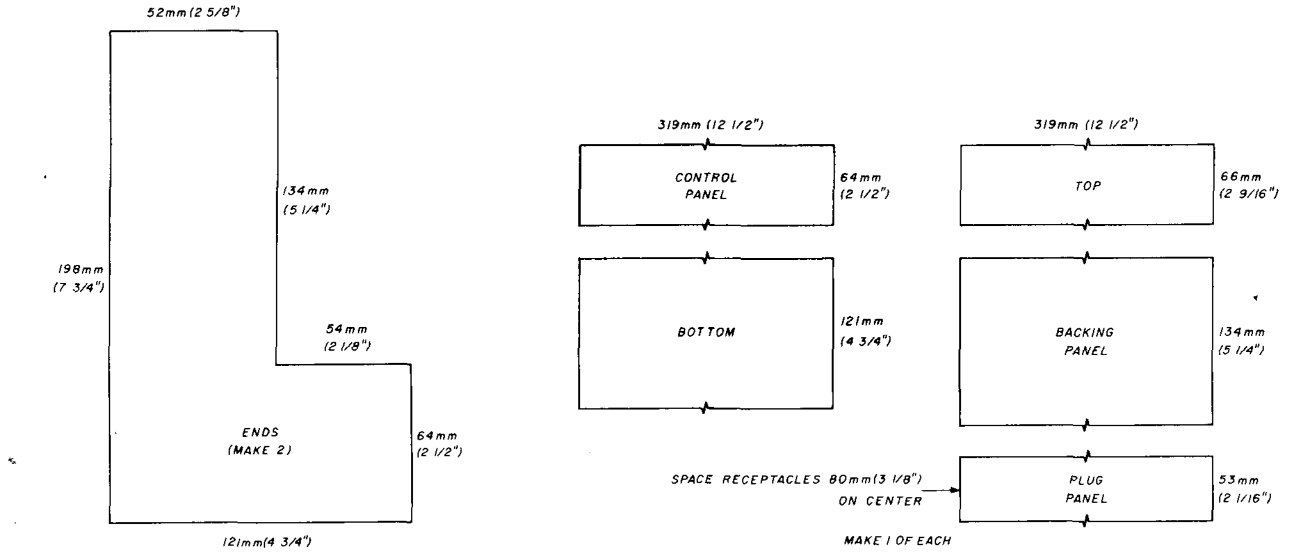


fig. 2. Dimensions of sheet metal for first version of the rack. Hardware "hobby" aluminum sheet is satisfactory.

which also shows the receptacles (Jones plugs) that accept the instrument packages. This version uses a different method of interconnect (tip jacks) instead of switches feeding a pair of buses.

mainframe construction

Two methods of construction were used. The four-unit frame is designed for hacksaw and tin-snip fabrication. The five-unit frame is designed for forming with a sheet-metal brake. With care and a little time, the bends of the second type can be made with a vise. The pieces may be fastened with rivets or self-tapping screws.

Dimensions of the four-unit rack are shown in **figs. 1** and **2** for the sheet metal and angle pieces respectively. The do-it-yourself stock available in hardware stores is easiest to work, although the rack could just as well have been made from sheet iron and iron angle.

Dimensions for the five-unit rack are shown in **fig. 3**. This unit can also be built from thin do-it-yourself aluminum stock. It will be more rugged if at least 1.3-

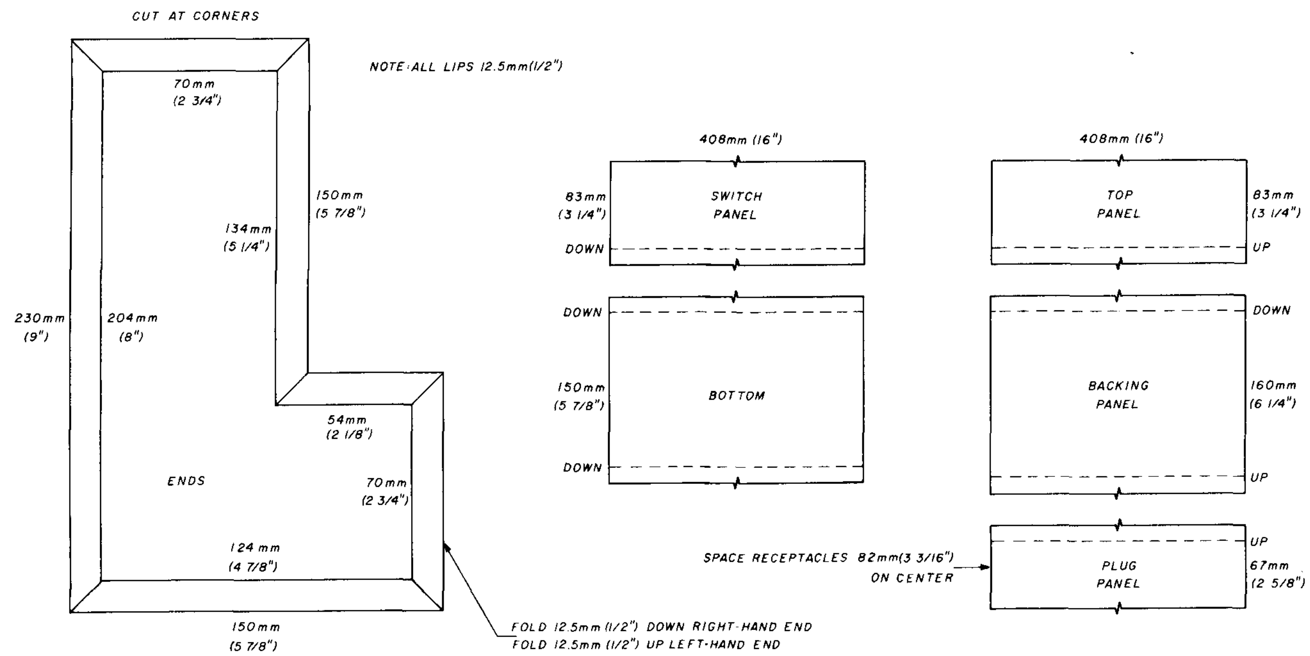
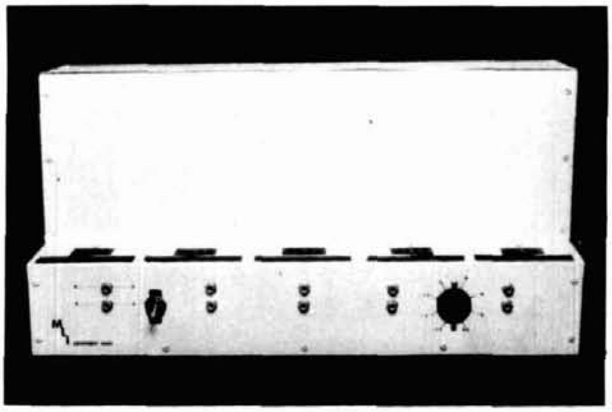


fig. 3. Sheet-metal dimensions for the second version of the rack. Bend on the dotted lines to 90 degrees. If prepainted sheet stock is used, watch the direction of bends carefully.



First version of the home-built equipment rack with home-built plug-ins. Instruments are described in reference 1. This unit can be built with tin snips and hacksaw.

mm (0.05-inch) stock is used. Aluminum sold in rolls as mobile-home skirting is satisfactory, as is sheet iron.

I've decided on a flat white finish for all small instruments, with black lettering. The mainframe was finished the same way. Steps for obtaining a good appearance are as follows:

1. Complete the instrument and get it working.

2. Remove the case and clean it with steel wool and soap. Polish any scratches; smooth all corners.

3. Spray with desired color paint, using several thin coats.

4. Add lettering, using a pressure transfer kit. Watch location with respect to dials and binding posts. If any are crooked, remove and start over.

5. With lettering complete, warm the case to about 92C (200F), which improves letter adhesion.

6. Finish the instrument with a *thin* coat of transparent spray, such as Krylon spray varnish.

7. Reassemble.

With a little practice, a professional-looking appearance can be obtained.

power supplies

Each of the units shown contains two independent power supplies. One provides ±12 volts regulated. This is used mainly for instruments based on op amps but is also for general use. A 12.6-volt ac line is also brought out of this supply. The second unit provides +5 volts, primarily for TTL logic.

Circuits for the supplies used in the prototypes are shown in **fig. 4A**. These are IC regulated circuits. The original instrument design was based on ±9 volts rather than ±12 volts. If desired, provisions for these (or other) voltages can be made. Alternative connections for this requirement are also shown (**fig. 4B**).

unit interconnections

In addition to the power leads, three bus leads are provided for unit interconnection. The interconnection schematic of the four-unit rack is shown in **fig. 5**. One bus, C, is common to all units. It is usually used for a sync signal. The other two can be switch selected as shown.

In the five-unit rack, the common bus is retained, but the unit leads A and B are brought to tip jacks, which gives more flexibility but is slightly less convenient.

The front panel also has an 8-pin receptacle (a tube socket was used in the prototype). This receptacle can be used with an extension cable to power another instrument or to power experimental equipment. It's convenient to make up several cables, a long and short one with instrument receptacles, and another pair with pigtail leads. A supply of "short preventers," made from alligator clips covered with transparent vinyl tubing, is a further convenience.

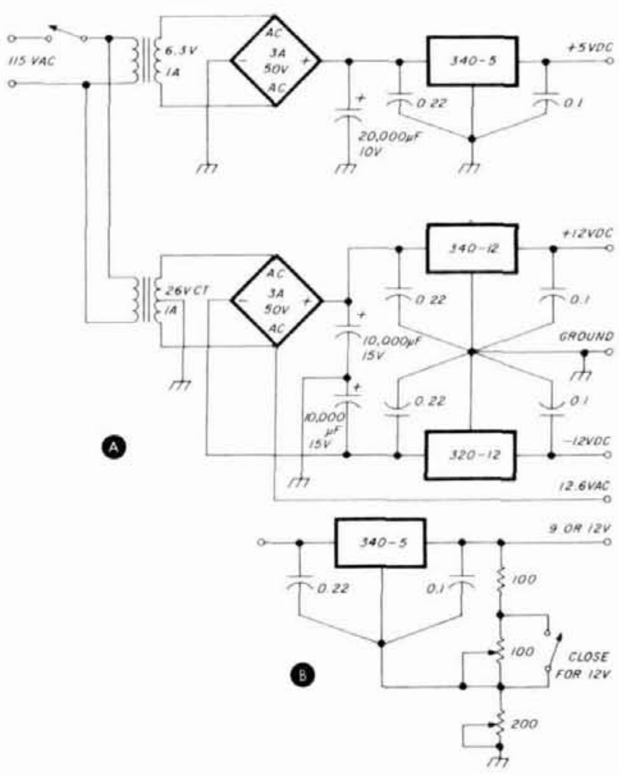


fig. 4. Circuit for power supply used in the racks, (A). The 320 regulator case must be insulated from the ground. (B) shows an alternative connection for +9, +12 volts. The negative line would be similar.

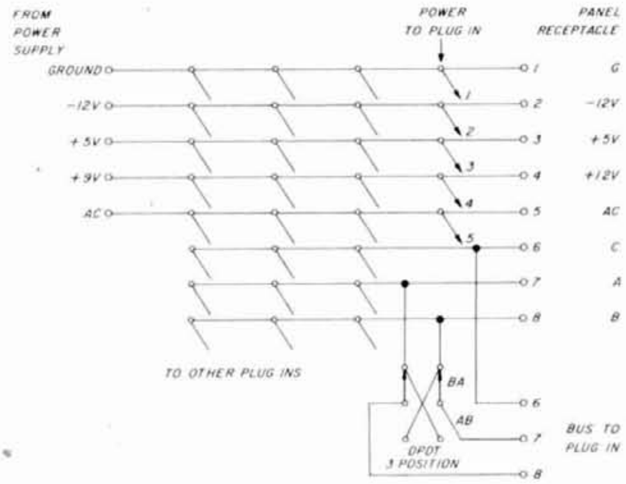


fig. 5. Schematic of interconnections for the first version of rack. For the second version, the leads from pins 7 and 8 of the receptacles end on tip jacks to give greater flexibility in interconnection.

The nominal 51 × 77 × 128 mm (2 × 3 × 5 inch) instrument cases are usually 54 × 77 × 131 mm (2-1/8 × 3 × 5-1/8 inches) and vary from one manufacturer to another. Rack spacing is laid out with this in mind.

The drilling and cutout pattern for the end of the instrument case is shown in **fig. 6**. This is for 8-pin Jones plugs. The alignment of the plug-in with the mainframe affects appearance, so the plug cutout is oversize to allow for adjustment.

A first trial at the rack used tube sockets for receptacles. These were undesirable, giving poor alignment and requiring too much insertion/removal force. The Jones plugs are much better.

battery operation

Most of the instruments used with these racks have low power drain, so battery operation for portable use is possible. A convenient way of obtaining this is to build up a case with a receptacle on each end. Eight A-cells will last quite a while as the 12-volt supply. Four D-cells with one diode in series will do reasonably well for the 5-volt supply, or a lantern battery can be used. If much portable operation is planned, use nickel-cadmiums instead of regular dry batteries.

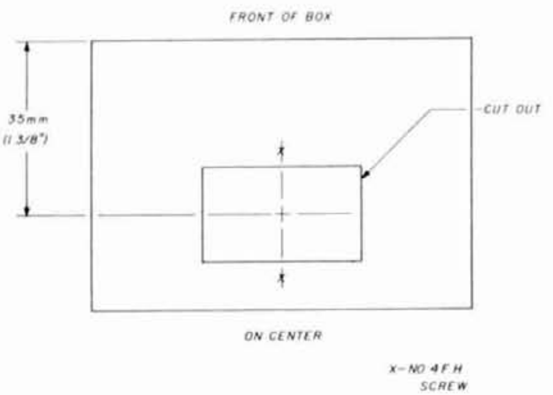
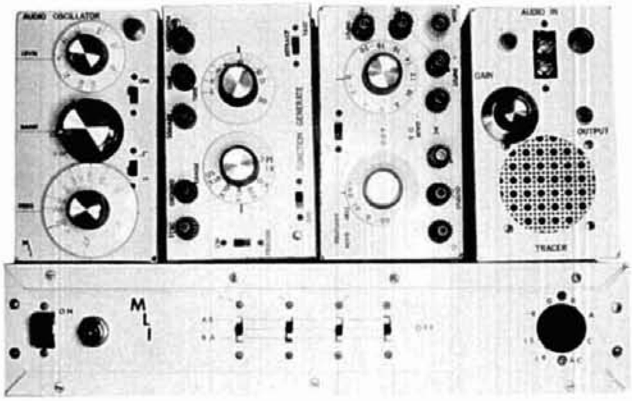


fig. 6. Location of the plug cutout on the end of the minibox. Location of the plug should be adjusted if necessary, since alignment affects appearance when the unit is plugged into the rack.

instruments

The instruments shown in the prototype setup are, from left,

Sine-wave/square-wave audio oscillator, 20 Hz-20 kHz.



Second version of the equipment rack designed for forming from sheet metal. Strips of rubber tape in front of the sockets stabilize the plugged-in instruments.

Function generator, square-wave, triangle, pulse and sine-wave, period, 20 microseconds – 20 seconds.

Summing step-gain amplifier, −40 to +40 dB gain.

Signal tracer or general-purpose amplifier.

These instruments and others are fully described in reference 1.

Two of the instruments shown in the prototype photo have been refinished and relettered to fit the plug-in format. The other two have been modified for the connector plug but have not been refinished.

Additional instruments have been designed and built. I hope to describe these in a later article.

reference

1. R. P. Haviland, "Build-It Book of Miniature Test and Measurement Instruments," TAB, (No. 792), Blue Ridge Summit, Pennsylvania, 17214, 1976.

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scaling antenna elements

Many high-performance dipole and Yagi-Uda antenna systems have been developed over the years, but scaling them for use at other frequencies can produce disappointing results when the elements' length and diameter cannot, from a practical standpoint, be scaled directly. **Fig. 1** was developed a number of years ago for element lengths near a *half* wavelength.[1] The advent of the modern hand calculator has turned nuisance calculations into a challenge.

using fig. 1

As seen in **fig. 1**, the relative wave velocity on any element is a function of that element's length-to-diameter ratio, with:

$$\frac{l_n}{d_n} = r_n \qquad (1)$$

where l_n = the length of the nth element
d_n = the diameter of the nth element
r_n = the length-to-diameter ratio

Once the relative wave velocity, v_{rn}, has been determined from **fig. 1**, the free-space wavelength and element length are related by:

$$l_o = \frac{l_n}{v_{rn}} \text{ or } l_o = \frac{d_n r_n}{v_{rn}} \qquad (2)$$

where l_n = the length of the nth element
l_o = the free-space wavelength

For changes in an element's diameter, the new and old lengths can be equated by:

$$l_o = \frac{l_n}{v_{rn}} = \frac{L_n}{V_{rn}} = \frac{D_n R_n}{V_{rn}} \qquad (3)$$

where L_n = the new length
D_n = the new diameter
V_{rn} = the new relative velocity
R_n = the new length-to-diameter ratio

practical examples

Length for a given diameter. How long should a 3/8-inch diameter rod be when it is a one-half wavelength radiator at 150 MHz? From the standard wavelength formula, a free-space, half-wavelength radiator is 39.3429 inches long.* Rearranging **eq. 2** yields:

$$\frac{l_o}{d_n} = \frac{r_n}{v_{rn}} \text{ with } \frac{r_n}{v_{rn}} = \frac{39.3429}{0.375} = 104.9$$

By moving along **fig. 1**, you will find a point on the curve where the length-to-diameter ratio divided by the relative velocity equals 104.9, $r_n = 96.3$ and $v_{rn} = 0.918$.

From **eq. 1**, the rod length then becomes

$$\begin{aligned} l_n &= d_n \cdot r_n \\ &= (0.375)(96.3) \\ &= 36.12 \text{ inches} \end{aligned}$$

Change of diameter. Assume that one-half wavelength element is 391-1/8 inches long, and that its diameter of 1.5 inches should be increased to 2.0 inches for added strength. What should the new length be? By **eq. 1**:

$$r_n = \frac{l_n}{d_n} = \frac{391.125}{1.5} = 260.75$$

From **fig. 1**, the relative velocity, v_{rn}, is about 0.9411, and substituting into a rearranged **eq. 3** produces:

$$\frac{l_n}{v_{rn} D_n} = \frac{R_n}{V_{rn}} = \frac{391.125}{0.9411(2.0)} = 207.802$$

Move along the curve on **fig. 1** and find the new length-to-diameter ratio divided by the new relative velocity factor which gives the above ratio, or:

$$\frac{R_n}{V_{rn}} = 207.802 = \frac{194.3}{0.9351}$$

The new length-to-diameter ratio is 194.3, and the new relative velocity factor is 0.9351.
From this, the new element length becomes

$$\begin{aligned} L_n &= R_n D_n = 194.3(2.0) \\ &= 388.63 \text{ inches} \end{aligned}$$

Change of frequency. Assume that a 146-MHz director has a diameter of 3/8 inch and a length of 35.0 inches, and is to be used at 14.2 MHz with a new diameter of 2.0 inches. What is the new length?

By Harold F. Tolles, W7ITB, Post Office Box 232, Sonoita, Arizona 85637

*Contrary to normal *ham radio* style, the examples in this article do not, for two reasons, include metric conversions. First, the element sizes are common in the U.S., used here as examples rather than for absolute conversion to the metric system. Second, the added complexity of metric conversions would tend to hinder understanding of this article and its formulas.

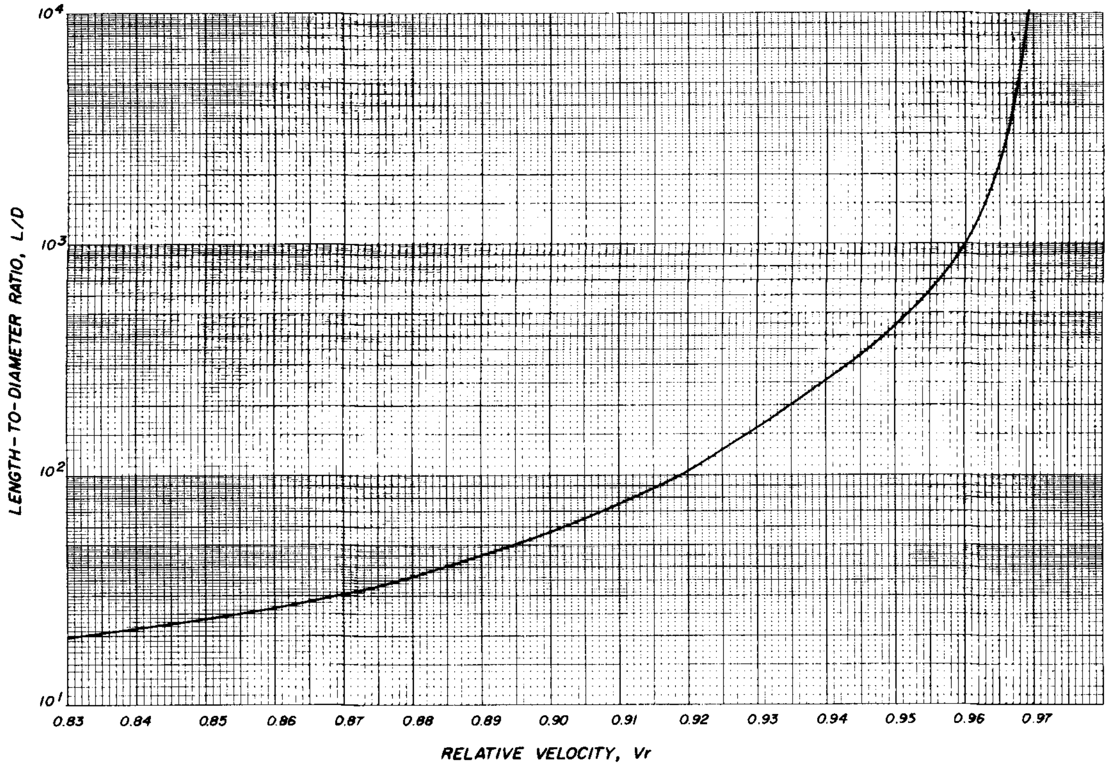

fig. 1. Graph of the cylindrical wire relative velocity vs. an element's length-to-diameter ratio.* This excludes the small spacing effects in series-fed antennas.

First:

$$\frac{l_n}{d_n} = \frac{35.0}{0.375} = 93.333$$

From **fig. 1**, the relative velocity factor is about 0.9168, and the free space wavelength is:

$$l_o = \frac{35.0}{0.9168} = 38.1763 \text{ inches}$$
$$\text{or } 0.4722\,\lambda \text{ at } 146 \text{ MHz.}$$

From this, the 0.4722 λ at 14.2 MHz is 392.5162 inches (L_o.)

Therefore:

$$\frac{L_o}{D_n} = \frac{392.5162}{2.0} = 196.2581 = \frac{R_n}{V_{rn}}$$

Move along the curve on **fig. 1**, and find that:

$$\frac{R_n}{V_{rn}} = 196.2581 = \frac{184.0}{0.9375}$$

The new element length, L_n, becomes

$$L_n = R_n D_n = 184.0\,(2.0)$$
$$= 368 \text{ inches}$$

summary

As the above examples show, **fig. 1** can be used to solve a number of element scaling problems in a short period of time when a hand calculator is available. Moving from left to right on the figure increases (quite rapidly) the R_n/V_{rn} ratio, and solving for L_n in terms of $R_n D_n$ *and* $V_{rn} L_o$ (where $L_o = L_n/V_{rn}$) is a good check (as well as refinement) of the ratio obtained from the **fig. 1** curve.

I have used this procedure many times to scale beam elements with excellent results. For example, I scaled one high-performance, free-space, 3-element Yagi-Uda array directly from the 2-meter Amateur band to the 40-meter Amateur band, and the maximum gain frequency shift on the 40-meter band was only 10 kHz!

It appears that good results can be obtained when the element lengths are within ±20 per cent of free-space, one-half wavelength, but the error is also a direct function of the number of antenna elements. I have not found this error to be significant in *array* scaling.

Fig. 1 assumes that the elements are either shunt-excited or are parasitic. When driven elements are series-fed, a small gap capacitance exists across the end of the feed line which is in parallel with the element self-series impedance. This affects the driven element impedance more than it does the driven element gain. When the driven series-fed element is essentially one-half wavelength, good scaling results occur when the gap is omitted in scaling this element.

*For greater accuracy, a full-size copy of the author's original graph is available by sending a self-addressed, stamped envelope to *ham radio*, Greenville, New Hampshire 03048.

reference

1. S. A. Schelkunoff and H. T. Friis, *Antennas: Theory and Practice*, John Wiley & Sons, Inc., Chapter 13; 1952.

ham radio

predicting close encounters:

Oscar 7 and Oscar 8

This article presents a fast, simple, and accurate method for predicting close encounters between Oscar 7 and 8

In early 1975, Amateur Radio operators added another first to their long list of communications accomplishments when two earth stations communicated via a path involving a direct satellite-satellite link.[1] Each station transmitted to AMSAT-Oscar 7 on 432 MHz; the signals were then relayed to AMSAT-Oscar 6 on 146 MHz, and back down to the ground on 29 MHz. Never before, in any radio service, had two satellites been directly interlinked to support communications between two ground stations.

Communication via the ESSE (earth-satellite-satellite-earth) path, using Amateur spacecraft, has been possible only when the satellites involved were relatively close to each other. Of course, it's also necessary that the transponder frequencies be suitable. Close-approach periods, lasting approximately three weeks, occurred about every six months for the AMSAT-Oscar 6 and AMSAT-Oscar 7. I still clearly remember the reference orbit (first orbit of the GMT day) on Wednesday, February 5, 1975, during the first close-approach period. AMSAT (and the new RS) satellites are reserved for special experiments on Wednesdays, with a very interesting test scheduled for this particular day. The distance between the two spacecraft was less than 1200 km on the reference orbit, and Amateurs with 432-MHz transmit capabilities were being encouraged to try for interlinking QSOs. Strict cooperation was needed if the tests were to succeed; anyone transmitting to Oscar 6 on 146 MHz might desensitize the transponder and con-

By Martin Davidoff, Ph.D., K2UBC, Mathematics Department, Catonsville Community College, Catonsville, Maryland 21228

fuse stations receiving on 29 MHz. The results are history — the tests were a huge success. Cooperation was excellent; rapid fading, which many feared might be a serious problem, was minimal, and dozens of QSOs were made. Rag-chewing quality signals were heard on the 29-MHz downlink from W2GN, W8DX, VE2BYG (VE3SAT), K3JTE (W3PK), and many others uplinking on 432 MHz.

AMSAT later received written reports of completed ESSE QSOs from fifty-five Amateurs in twelve countries during the January/February, 1975, close-approach period. Contacts were reported for satellite separation distances ranging up to 2000 km, and reception of the Oscar 7 mode B beacon repeated by the Oscar 6 transponder was reported for satellite separation distances ranging up to 7000 km. ESSE tests involving these two spacecraft continued during periods of close approach until mid 1977, when Oscar 6 ceased operation.

The transponder frequencies for Oscar 8 where chosen so that ESSE tests could resume. Both mode A and mode J are suitable. **Fig. 1** illustrates the links and transponder frequencies involved in ESSE communications using Oscar 7 and Oscar 8. Almost immediately following the launch of Oscar 8 (March 5, 1978), it became apparent that ESSE communications could take place when sensitivity measurements by K1HTV and W6CG of the Oscar 8 transponders (modes A and J) showed that, as long as the satellite agc wasn't being activated, good return sig-

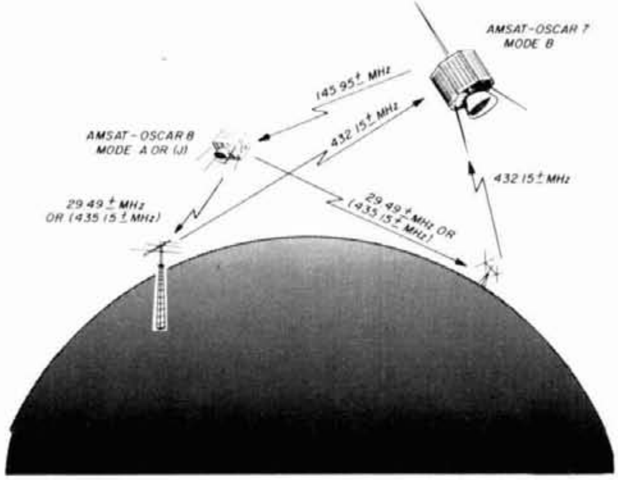

fig. 1. Diagram of the paths and frequencies involved when two earth stations communicate via a direct link between Oscar 7 and Oscar 8.

nals could be obtained over line-of-sight paths of 3000 km by ground stations using as little as 100 milliwatts to a dipole. These expectations were accidentally confirmed a few days later when a number of Amateurs using the mode B transponder on Oscar 7 were inadvertently repeated by the mode A transponder on Oscar 8. To date, I'm not aware of any successful interlinking experiments using mode J.

> Oscar 7, now more than four years old, is beginning to show signs of age. The unscheduled mode jumping and erratic behavior of the mode-B transponder and beacon observed in recent months are likely to continue. With a little luck, ground station cooperation (use minimal uplink power), and careful management by the command stations, Oscar 7 may continue to operate for many more years.
>
> Operating modes for Oscar 7 are not specified in the 1979 W6PAJ Orbit Calendar because instructions to the ground command stations are being formulated on a short lead-time basis to help prolong the satellite's life (battery voltage and internal temperatures are being carefully monitored), and because the spacecraft often jumps modes of its own accord. Users may operate through whichever transponder is on, except, of course, on UTC Wednesdays when Oscar 7 and Oscar 8 are reserved for special authorized experiments, or if AMSAT announces a spacecraft emergency. The W6PAJ Orbit Calendar can be relied upon to accurately provide Oscar 7's position, but it's up to the user to determine the operating mode. Atmospheric absorption at 10 meters (resulting from high solar activity), and almost total loss of the mode-B beacon make this a bit more involved than it first appears. Often, the only way to determine if the mode-B transponder is on is to transmit in the uplink passband. Mode B itself appears to have two distinct operating states, a normal state where it works as well as when first launched, and a degraded state where sensitivity and power output are way down. If nothing is heard on mode A or mode B, the transponder is probably in the recharge mode.

the problem

With Oscar 6 and Oscar 7 in similar orbits, close-encounter periods lasted a few weeks and were repeated on approximately a six-month schedule. The situation with Oscar 7 and Oscar 8 is quite different. Close encounters now last only part of an orbit, but they occur almost once a day. A given ground station is in range of only a small percentage of such close encounters. Since satellite separation distance is a critical factor in ESSE communications, stations seriously interested in experimenting with this mode need an accurate method of determining when close encounters will occur and what the separation distance will be. The goal of this article is to present a fast, simple method for obtaining this information. It involves the "close-encounter curves" shown in **fig. 2**. With these curves, Amateurs can select the best orbits (and sections of orbits) for linking experiments. The mathematical basis of close-encounter curves is described in the appendix.

close-encounter curves

The vertical axis of the close-encounter curve (**fig. 2**) represents the separation distance between AMSAT-Oscar 7 and AMSAT-Oscar 8. This information is presented as a function of the elapsed time (in minutes) since the last Oscar 7 ascending node. Eight curves are shown in **fig. 2**. Each one is labeled by a parameter τ, which indicates the difference (in minutes) between the Oscar 7 and Oscar 8 ascending nodes. Our convention is to use positive values for τ when Oscar 8 crosses the equator *after* Oscar 7. For example, if an Oscar 7 ascending node occurs at 0141Z, and an Oscar 8 ascending node occurs at 0144Z, the curve labeled $\tau = 3$ applies; if both ascending nodes occur at the same time, the curve labeled $\tau = 0$ is used. Fractions of a minute should be rounded off. The following series of questions and answers best illustrate how the curves are interpreted.

Q. Under what conditions will Oscar 7 and Oscar 8 pass closest to one another?

A. Fig. 2 shows that the intersatellite distance approaches a minimum value on orbits when the Oscar 8 ascending node occurs about four minutes after the Oscar 7 ascending node. The point of closest approach will occur about 27 minutes after the Oscar 7 ascending node. You can also see that the separation distance is never less than 550 km, the difference in altitudes of the two spacecraft.

Q. How can a ground station at 40 degrees north latitude pick the optimum orbits for intersatellite communications?

A. A station at 40 degrees north latitude has access to Oscar 7 only until 23 minutes after the ascending node (on an overhead pass). The station cannot access the satellite at the point of intersatellite closest approach. Looking at **fig. 2** you can see that, beginning at 15 minutes after the Oscar 7 ascending node, the intersatellite distance becomes less than 1700 km when $\tau = 2, 3,$ *or* 4 minutes (Oscar 8 ascending nodes occurring 2, 3, or 4 minutes after the Oscar 7 node). The time slot between 15 and 23 minutes after the Oscar 7 node is the best window. We've arbitrarily chosen 1700 km as our cutoff point because signals will be down 10 dB relative to 550 km (absolute closest approach) due to $1/r^2$ path losses.

Each ground station using close-encounter curves will find it convenient to shade in the area during which access to Oscar 7 is not possible. For example, a station at 40 degrees north latitude would shade in the region between 23 minutes and 35 minutes on **fig. 2**.

Q. For my ground station at 40 degrees north latitude, I see that the time period between 15 and 23 minutes after an Oscar 7 ascending node is optimal for intersatellite communications if Oscar 8 has an ascending node 2 to 4 minutes later. How is this information used to select specific orbits?

A. Just read down the Oscar 7 and Oscar 8 time columns in the W6PAJ orbit calendar until you locate an Oscar 8 node occurring 2 to 4 minutes after an Oscar 7 node. When you find one, use your usual tracking aid (Satellabe, Oscarlocator, *etc.*) to determine if *both* satellites are within range during any portion of the time slot (15 to 23 minutes after the Oscar 7 node).

Q. Should a station at 40 degrees north latitude concentrate on morning descending orbits or evening ascending orbits for intersatellite communications experiments?

A. It's hard to say. **Fig. 2** shows that, during 1979, the evening orbits provide shorter intersatellite distances. Other factors, however, such as the normally lower transponder loading early in the day, might lead to better results on morning orbits. For morning passes, a station at 40 degrees north latitude would select orbits with $\tau = 4, 5,$ *or* 6 and concentrate on times between about 35 and 40 minutes past the Oscar 7 ascending node.

Q. Over what period of time can **fig. 2** be used?

A. If the relative orientation of the Oscar 7 and Oscar 8 orbital planes remained constant, **fig. 2** could be used indefinitely. Because there is a slight drift in the relative orientation of these planes, a graph like the one shown in **fig. 2** must be drawn for a specific date. In this case, the predicted positions of the orbital planes for July 1, 1979, were used. The drift, however, is so slow that **fig. 2** will provide reasonably good results (within one minute or 200 km) for all of 1979.

Q. How often can one expect to find Oscar 7 and Oscar 8 in a position suitable for interlinking tests?

A. A close approach, while both satellites are in range of your ground station, will occur about once every seventeen days for evening (local time) orbits. For morning orbits, the figure is also about once in seventeen days. On the average then, if morning and evening passes are considered, any ground station will have a good shot at interlinking about once every eight or nine days.

These answers were derived as follows. The probability of a close encounter occurring on a given south-north satellite pass is equal to the probability of τ being 2, 3, or 4 minutes. With three suitable one minute time slots out of a 103-minute period, the probability of a close encounter occurring on a specific orbit is 3/103. On the average, there are two

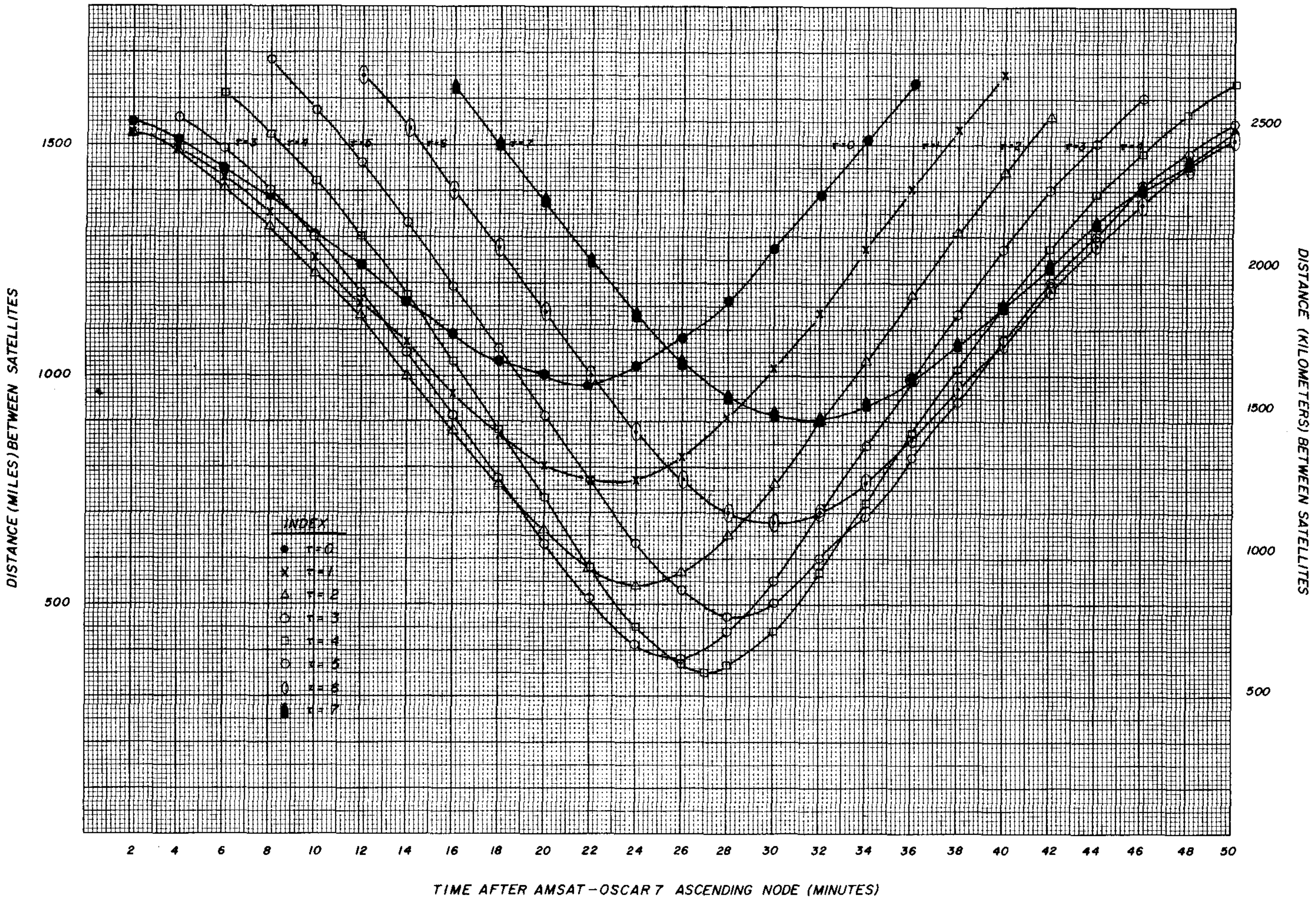

fig. 2. Close-encounter curves for Oscar 7 and Oscar 8, useful for 1979.

close in Oscar 8 south-north passes each day, so the probability of a close encounter is 2(3/103) per day, which translates into once every seventeen days. The analysis for north-south orbits is similar, except for the fact that the three desirable time slots for τ are 4, 5, and 6 minutes.

Keep in mind that Oscar 7 must be in mode B if communications are to be possible during a close encounter. Concern for Oscar 7's health and longevity has forced AMSAT to begin selecting modes on a day-by-day basis, so you just have to take a chance that it will be in mode B.

Q. Is Doppler shift a serious problem?

A. Doppler shifts are not a serious obstacle. The real problems are spurious responses (birdies) and desensitization in the receiving system. Finding your own downlink signal will always involve some searching, and you'll quickly realize the value of good filtering on the transmitter and receiver (to prevent birdies and desensitization) and thorough testing of your ground station when the satellites are not in range (to learn the location and characteristics of any remaining birdies).

The following considerations should help you reduce the amount of searching you must do for your downlink. The total Doppler shift consists of contributions from each of the three links involved. The 70-cm link(s) produce the largest effect. For a mode-B/mode-A linkup, the total Doppler should be less than ±6 kHz. A rough, but close, guess of the value can be obtained by just considering the position of Oscar 7 (mode-B transponder) and using the frequency offset regularly seen for a mode-B QSO. With a mode-B/mode-J linkup, the Doppler can be up to ±12 kHz. Once again, the value can be estimated by concentrating on the 70-cm links. If both satellites are moving either toward you or away from you, the Doppler shifts will tend to cancel. During optimal-access periods, one of these two cases usually exists, so searching for your downlink can be confined to a ±6 kHz window.

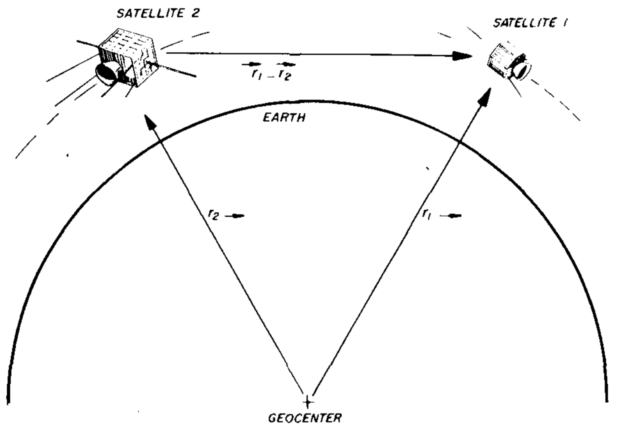

fig. 3. The position vectors for two satellites. This diagram represents Oscar 7 as satellite 1 and Oscar 8 as satellite 2.

Q. I've been using the close-encounter curves to listen to the Oscar 7 mode-B beacon through Oscar 8 mode A, and signal strength correlates reasonably well with the curves but not completely. Why?

A. Distance is only one aspect of Oscar 7/Oscar 8 radio-link performance. Another important factor is relative orientation of the spacecraft antennas. This can be accurately modeled if a computer is available. The close-encounter curves would enable us to save a great deal of computer time by restricting path-loss studies involving antenna patterns to a small portion of a limited number of orbits. Ground stations must also take into account transponder loading and the performance of the satellite-ground communications link if they hope to explain all observations of the Oscar 7 mode-B beacon through Oscar 8.

table 1. Notation for intersatellite distance problem. SSP = subsatellite point. Numerical values for Oscar 7 and Oscar 8 are shown in brackets.

parameter	satellite 1 [Oscar 7]	satellite 2 [Oscar 8]
radial distance (geocenter to satellite)	r_1[7,831.km]	r_2[7,281.km]
position vector (geocenter to satellite)	$\vec r_1$	$\vec r_2$
period (note: $P_1 \geq P_2$) (minutes)	P_1[114.945 minutes]	P_2[103.231 minutes]
orbital inclination	i_1[101.7 degrees]	i_2[99.0 degrees]
elapsed time since ascending node of satellite (minutes)	t	$t-\tau$
latitude of SSP at time indicated	$\phi_1(t)$	$\phi_2(t)$
longitude of SSP at time indicated	$\lambda_1(t)$	$\lambda_2(t)$
longitude of SSP at ascending node	λ_{10}(occurs at $t = 0$)	λ_{20}(occurs at $t = \tau$)

appendix

The mathematical derivation of the close-encounter curves is outlined in this appendix. Note that it is not necessary to read this section to use the close-encounter curves. To understand the following material, you need some background in spherical coordinates and three-dimensional vectors. Our analysis focuses on two satellites in circular orbits, as shown in **fig. 3**. The notation used is summarized in **table 1**. Note that the subscript 1 is used to refer to the satellite with the longer period (higher altitude). The intersatellite distance, $s(t)$, is given by the magnitude of the vector $(\vec r_1 - \vec r_2)$

$$s(t) = \sqrt{(\vec r_1 - \vec r_2) \cdot (\vec r_1 - \vec r_2)} = \sqrt{r_1^2 + r_2^2 - 2(\vec r_1 \cdot \vec r_2)} \qquad (1)$$

To evaluate $\vec r_1 \cdot \vec r_2$, express the Cartesian components of each position vector in terms of the spherical coordinates of the given satellite (θ = colatitude, λ = longitude). Both coordinate systems have their origins at the geocenter and rotate with the earth. The orthogonal unit vectors i, j, and k are defined as follows: i is along the line joining the geocenter to the intersection of the equator and the prime meridian, j is along the line joining the geocenter to intersection of the equator and the 90 degree east meridian, k is along the line joining the geocenter and North Pole. The position of satellite 1 is given by

$$\vec r_1 = r_1 \sin\theta_1 \cos\lambda_1 i + r_1 \sin\theta_1 \sin\lambda_1 j + r_1 \cos\theta_1 k \qquad (2A)$$

The position of satellite 2 is given by

$$\vec r_2 = r_2 \sin\theta_2 \cos\lambda_2 i + r_2 \sin\theta_2 \sin\lambda_2 j + r_2 \cos\theta_2 k \qquad (2B)$$

Transforming from colatitude, θ, to latitude, ϕ, ($\phi = 90° - \theta$)

$$\vec r_1 = r_1 \cos\phi_1 \cos\lambda_1 i + r_1 \cos\phi_1 \sin\lambda_1 j + r_1 \sin\phi_1 k \qquad (3A)$$

$$\vec r_2 = r_2 \cos\phi_2 \cos\lambda_2 i + r_2 \cos\phi_2 \sin\lambda_2 j + r_2 \sin\phi_2 k \qquad (3B)$$

The inner product, $\vec r_1 \cdot \vec r_2$, of **eq. 1** can now be evaluated

$$s(t) = \sqrt{r_1^2 + r_2^2 - 2r_1r_2[\cos\phi_1 \cos\phi_2 \cos(\lambda_2 - \lambda_1) + \sin\phi_1 \sin\phi_2]} \qquad (4)$$

The coordinates ϕ and λ, for each satellite, appearing in the brackets on the right hand side of **eq. 4**, are the same as those of the respective subsatellite points (SSPs):

$$\phi_1(t) = \arcsin\left[\sin i_1 \sin\left(360° \frac{t}{P_1}\right)\right]; \qquad (5A)$$

$$\phi_2(t) = \arcsin\left[\sin i_2 \sin\left(360° \frac{t-\tau}{P_2}\right)\right]; \qquad (5B)$$

$$\lambda_1(t) = \lambda_{10} + \frac{t}{4} + (-1)^{n_2+n_3} \arccos\left[\frac{\cos\left(360° \frac{t}{P_1}\right)}{\cos\phi_1(t)}\right]; \qquad (6A)$$

$$\lambda_2(t) = \lambda_{20} + \frac{t-\tau}{4} + (-1)^{n_2+n_3} \arccos\left[\frac{\cos\left(360° \frac{t-\tau}{P_2}\right)}{\cos\phi_2(t)}\right] \qquad (6B)$$

where

$$n_2 = \begin{Bmatrix} 0 & 90° \leq i \leq 180° \\ 1 & 0° \leq i < 90° \end{Bmatrix}$$

$$n_3 = \begin{Bmatrix} 0 & \phi(t) \geq 0° \begin{pmatrix}\text{Northern} \\ \text{Hemisphere}\end{pmatrix} \\ 1 & \phi(t) < 0° \begin{pmatrix}\text{Southern} \\ \text{Hemisphere}\end{pmatrix} \end{Bmatrix}$$

Here are the sign conventions: North latitudes are positive, south latitudes are negative, all longitudes are in degrees west, and longitude displacements toward the west are positive.

The sign convention for longitudes adopted in **eqs. 6A** and **6B** is the same as that used in the Satellabe, Oscarlocator, W6PAJ Orbit Calendar, and most other U.S. and Canadian Amateur literature. It's a very convenient convention for stations located between 0 and 180 degrees west longitude. Most non-Amateur literature, recognizing the computational advantages of a right-hand coordinate system, is based on a different sign convention — east longitudes and displacements towards the east are regarded as positive. This approach was used in the best treatment of orbits available in the Amateur literature — Peter D. Thompson, Jr., "A General Technique for Satellite Tracking," *QST*, November, 1975, page 29.

Although the situation may sound confusing at first, it's really just a minor problem once you're aware of its existence. Since both conventions have merit and are well established, the best course of action for radio Amateurs working on basic computations appears to be to use a right-hand coordinate system for computations and then, as a final step, transform to the U.S./Canadian convention.

To compute the intersatellite distance, s, as a function of time for a specific set of two orbits, **eqs. 5A**, **5B**, **6A**, and **6B** are substituted in **eq. 4**. The result is indicated symbolically by:

$$s = s[(i_1, i_2, P_1, P_2, r_1, r_2), \Delta\lambda_o, \tau, t]. \tag{7}$$

You can see that s depends on a set of constants $(i_1, i_2, P_1, P_2, r_1, r_2)$, the parameter $\Delta\lambda_o \equiv (\lambda_{20} - \lambda_{10})$, which is a measure of the difference in longitudes at the ascending node, the parameter τ, which expresses the difference in time of the two ascending nodes, and the time t measured from the ascending node of satellite 1. Once the two satellites are chosen, the six constants are known and **eq. 7** expresses the fact that the intersatellite distance is a function of three variables.

If you have a TI-59, HP-67, or similar programmable hand calculator, you can use **eq. 7** in conjunction with equatorial crossing data to first compute $\Delta\lambda_o$ and τ for a specific set of two orbits, and then calculate the distance, s, every 2 minutes over the course of the orbits. Although this method works, it is very time consuming if you're trying to evaluate a large number of orbits for their suitability for interlinking experiments. This leads to the problem of finding some simple way of expressing **eq. 7** in graphical form.

The $\Delta\lambda_o$ term in **eq. 7** can be written:

$$\Delta\lambda_o \equiv \lambda_{20} - \lambda_{10} = \frac{\tau}{4} + \Delta\lambda^* \tag{8}$$

where $\Delta\lambda^*$ is a slowly varying function describing the relative orientation of the orbital planes of the two satellites.

The 1979 W6PAJ orbit calendar, using data by Dr. Tom Clark (W3IWI), predicts that $\Delta\lambda^*$ will be 18.6 degrees on January 1, 1979, 19.0 degrees on July 1, 1979, and 19.4 degrees on December 31, 1979. If $\Delta\lambda^*$ can be treated as a constant, then **eq. 7** will depend on only two variables, and a function of two variables can often be illustrated on a single graph as a set of curves. To test this approach, three graphs (each graph consisting of a set of close-encounter curves) were drawn for $\Delta\lambda^* = 18.6$ degrees, 19.0 degrees, and 19.4 degrees. (All computations were performed on an HP-97 programmable calculator.) From these graphs, it was evident that a 0.4-degree change in $\Delta\lambda^*$ had a negligible effect on the close-encounter curves. A single graph (**fig. 2**) can therefore be used for all of 1979.

references

1. P. I. Klein and R. Soifer, "Intersatellite Communication Using the AMSAT-Oscar 6 and AMSAT-Oscar 7 Radio Amateur Satellites," *Proceedings of the IEEE* (Letters), October, 1975, page 1526.

2. "Interspacecraft Distance for Satellites in Circular Orbits and Close-Encounter Curves for A-0-7 and A-0-8," AMSAT Technical Note, dated August, 1978.

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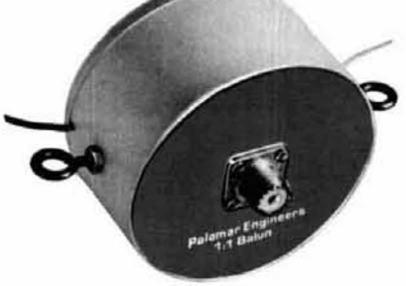

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amateur radio equipment survey

When you mention public service among a group of Amateurs, the reaction is usually something like "Oh, yeah, that message-handling stuff," or, "Well . . . I'm a member of the Sunday Morning Pizza-Parlor Net on the local repeater, and we handled twenty-one messages during the blizzard last winter."

That's public service, but it's the Amateur Radio community performing a service for the rest of the world. Let's try it the other way around; how about some service *for* Amateurs for a change, especially for the newcomers.

The idea is simply this: Evaluate your Amateur equipment and let *Ham Radio Horizons* know about it. The results will be published for all to see and heed (or disregard, as they see fit).

This type of test is based upon the old truism that the marketplace is the final test of a product. Problems can arise when you rely just on what you hear — only those who are grossly dissatisfied will make noises about it, and they may *not* represent a fair cross section of equipment in use. There may be 100 satisfied owners (the silent majority) for every ham who thinks he got a lemon (and he may have very valid reasons for thinking so).

That's why we would like to hear from everyone who has a rig of the types indicated on the Owner Report form: This month, we're looking for evaluations of the Atlas 210X/215X, the Drake Twins T4X-C/R4C, or the Kenwood TS-820. In coming months, we'll be requesting reports on other popular rigs.

To make the processing of responses a manageable job, it was necessary for us to design the Owner Report as a questionnaire. Obviously, to allow someone to ramble on for page after page about his pet or his "lemon" would present an impossible problem in evaluating the reports and sifting the data. The *Ham Radio Horizons* staff has carefully considered the type and number of questions we would like you to answer, and we believe they will provide valuable feedback. This information will serve as a guideline to new Amateurs who want to know what kind of rig they should consider, what they should expect of it, and what to avoid. It will also provide equipment manufacturers and designers with some useful guidelines for the engineering of new gear, or for correcting major problems (if any) in equipment they now have in the hands of Amateurs. The end result should be better service to all Amateurs. We'll all be winners.

guidelines

It should take you only a few minutes to fill out the Report Form on the next two pages. Most answers can be a simple yes or no, or an X or a check-mark. In some cases, comments are asked for. Don't be afraid to say what you really think about the point in question. Was the dealer uncooperative? Did it take too

long to obtain a part needed for service? Was the equipment damaged in shipment? Was the sale promotion or the advertisement misleading? Say so. Don't worry — if you indicate that you don't want your name used, we will honor that request. We're not out to "get" anyone, nor are we out to let anyone off easy. As a line in an old TV show used to go . . . "Just the facts, sir," (or Ma'am, as the case may be).

We're looking for *Owner's* reports, please; if you've listened to a buddy praise or grumble about his rig, talk him into filling out the report. A club station? Well — okay, we'll accept *your* report based on your *use* of it.

Note that we're asking about three rigs on the first Report. Just indicate which of the three you're talking about in your response, and we'll sort them out.

By Thomas McMullen, W1SL, Managing Editor, *Ham Radio Horizons*

Our published report will be on one rig at a time. Important: If you have more than one rig of the type *you're talking about, or if you own (or have owned)* one or more of the other brands and models indicated, send us an addressed, stamped envelope and *we'll rush extra forms right back to you.*

Note the optional personal data section, item 26, on the second page. You don't have to fill in every line — *you can leave them all blank if you wish.* We have no desire to get you in trouble with your friendly local dealer if you feel that might be a problem. However, if *you wish to "stand up and be counted," then* fill in the name and address portion, and sign the form. We may, or we may not, publish portions of your comments, depending upon space available.

As the saying goes, this can be a fun thing. However, it also has its serious side. If there are outstanding problems in the rigs we depend upon, *here's the* chance to call them to the attention of the people who make and sell (and service) Amateur equipment. If your rig has always lived up to your expectations, and you couldn't ask for anything better — that's a great recommendation to new Amateurs, and a pat on the back for the engineers who designed the thing in the first place.

deadline

Note the cutoff date for getting your comments back to *Ham Radio Horizons* — August 31. It will

take quite a bit of time to evaluate and arrange the responses, which means you'll see the results (on one of the three rigs) later this year. Results for each type of equipment will be published in separate issues. Note that there is a space on the form for you to tell us what rig(s) you would like to see reported on in the future. We have several in mind, but your voice counts, too. If you don't have a rig of the type named, send us a *postcard* with your choice of equipment to be reviewed.

Obviously, a very new model would not get a fair shake until enough of them are out in the field to obtain a meaningful number of comments. This will all work out well, though — by the time we have gathered and published results on the rigs that have *been around a while, the newer ones will have been* used and evaluated by more hams. Keep watching the pages of *Ham Radio Horizons* for Report Forms.

An important point must be made here: This is *not* a comparison. We're not comparing any make or

model with any other make or model. The Report Form No. 1 concerns the Kenwood TS-820, the Drake C-line, or the Atlas 210X/215X. We'll publish results of each one separately. *Future reports will* cover equipment by Yaesu, Ten-Tec, Swan, Alda, Heath, and Icom, as well as other models by Drake, Kenwood, and Atlas. *All popular equipment will have* its day in the sun.

Ham radio readers please note — the results will be published only in *Ham Radio Horizons*; an announcement will be made in *ham radio* to let you know which issue of *Horizons* to look for.

We're looking forward to some interesting results and comments. There may well be some pleasant surprises in store, as well as some that are not so pleasant. That's fine, and, to borrow a modern cliche, the bottom line tells it all: Would you buy this rig again?

Fill in the Report Form, and mail it in right away to *Ham Radio Horizons*, Owner's Report No. 1, Greenville, NH 03048.

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HAM RADIO HORIZONS

Owner Report on Amateur Radio Equipment

(Fill out this form in accordance with your experience. Please type or print clearly.)

1. Make and Model (circle *one* only) Atlas 210X/215X Drake Twins T4XC/R4C Kenwood TS-820
2. What year did you buy it? ________ New? ________ Used? ________
3. Where did you buy it? Dealer________ Mail Order________ Individual________ Flea Market________ 800 Number________ Other________
4. Would you buy from the same source again?________
5. Amount of use: Daily________ Often________ Occasional________ Seldom________
6. Is this your primary________ or backup________rig?
7. What modes have you used? CW______ SSB______ RTTY______ SSTV______ AM______ Other________________
8. What is the rig's best feature? ____________________
9. Why? ____________________
10. Worst feature? ____________________
11. Why? ____________________
12. Have you had any problems?________ Explain ____________________
13. Have you had the rig serviced?________ Where? Manufacturer________ Dealer________ Other________
14. Was the service satisfactory? Yes________ No________
15. What accessories have you purchased for this rig? ____________________
16. Have you been able to obtain all the accessories and parts you need? ____________________

17. Have you been satisfied with these accessories? Yes_________ No_________

18. If not, why? ____________________________________

19. Accessories you would like for this rig ________________________

20. Additional features you would like to see in a rig of this type __________________

21. Give the equipment a score from 1 to 10 (with 1 being poorest, 5 average, and 10 excellent).

Ease of operation ____________

Reliability ____________

Durability (in continuous use) ____________

Instruction Book ____________

Dealer Service ____________

Quality of Workmanship ____________

Performance ____________

Maintenance ____________

Parts Availability ____________

Accessories (ease of connection) ____________

Price ____________

Flexibility ____________

22. How long have you been licensed?_________ Your Age_________ License Class _________

Principal activities: Contest_________ DX_________ Rag Chewing_________

Traffic Handling_________ Experimenter_________

23. What antenna do you use most? Beam_________ Wire_________ Other_________

24. What rig would you like to see reported on in the future? ____________

25. Would you buy this same rig again? ____________

26. (Optional: fill in the following only if you wish.)

Submitted by: Name ____________________ Call_________

Address________________________

City ____________ State_________ Zip_________

____

(Signature)

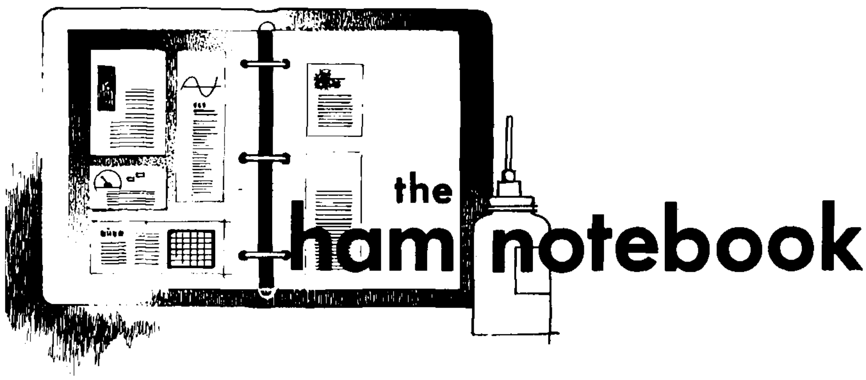
(Your signature authorizes *Ham Radio Horizons* to quote portions of your comments in our report.) May we use your name and/or call?

Yes_________ No_________

Note: If you own more than one of the rigs indicated, please write to us for additional copies of this form. Use a separate form for a report on each rig.

Completed survey forms must be returned no later than August 31, 1979, to be included in our report.

More Details? CHECK — OFF Page 110



a very simple synthesizer system

Some time ago my wife, Barbara, and I built a general-coverage receiver with a digital frequency readout. The local oscillator is a free-running MC1648, tuned by a variable capacitor with a small varactor for bandspread. Since the i-f is 10.7 MHz, the local oscillator tunes 13.7-40.7 MHz for the 3-30 MHz receiver range. The stability of this oscillator was adequate for normal operation, but when the receiver was left tuned to 30.0000 MHz for 24 hours the thermal variations in a normal room caused a slow frequency drift of about ± 1.5 kHz. This was most annoying. We dreamed of a synthesized local oscillator to alleviate this problem. Unfortunately all the synthesizers looked complicated and our small chassis was already pretty crowded, so for a long time we did without.

Recently, MacKeand[1] published a simple frequency-lock-loop circuit that reminded me of an earlier, more complex, circuit by Ryder[2]. Study of the short article by DeLaGrange[3] gave us a good insight into the theory of frequency-locked loops but no practical circuit for this application.

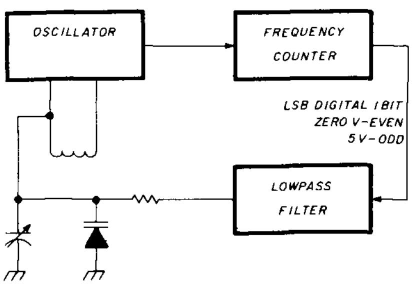


fig. 1. Basic frequency-locked-loop system.

Finally, I realized that a very simple approach could be taken, which I illustrate by the following example.

If I tune my receiver to 30.0000 MHz and it begins to drift up in frequency to 30.0001 MHz, all I have to do is sense this small change and apply it through the varactor to drive the frequency down. When it's driven down until the frequency counter reads 30.0000 MHz again, I can start forcing it back up again, hovering about the transition between 30.0000 and 30.0001 MHz. This could be accomplished simply by sensing the **1** bit of the latch on the least-significant bit of the frequency counter and applying it to the varactor through a lowpass filter. Then any odd LSB signal will drive the frequency slowly down, and an even count will drive it slowly back up.

What if the frequency were initially drifting down? When the counter reached 29.9999 MHz, the feedback scheme would drive it further down until the even count 29.9998 MHz came up. The **1** bit would change and the circuit would hover between 29.9998 and 29.9999 MHz. We could therefore lock onto any frequency in 200-Hz increments. If we invert the **1** bit before applying it to the lowpass filter, we can lock onto all the in-between 100-Hz points by taking the *even-odd transition for lock instead* of the odd-even. A block diagram of the scheme is shown in **fig. 1**. A slightly more elaborate diagram of the scheme used in our receiver is shown in **fig. 2**, and a complete schematic, except for the frequency counter, is shown in **fig. 3**.

Actually, the most important part is the use of the op amp U4B to perform the frequency lock. Although I show a free-run position, I never really use it anymore. The receiver just smoothly steadies itself on the nearest stable transition and otherwise behaves exactly as it did before we added the U4 circuit.

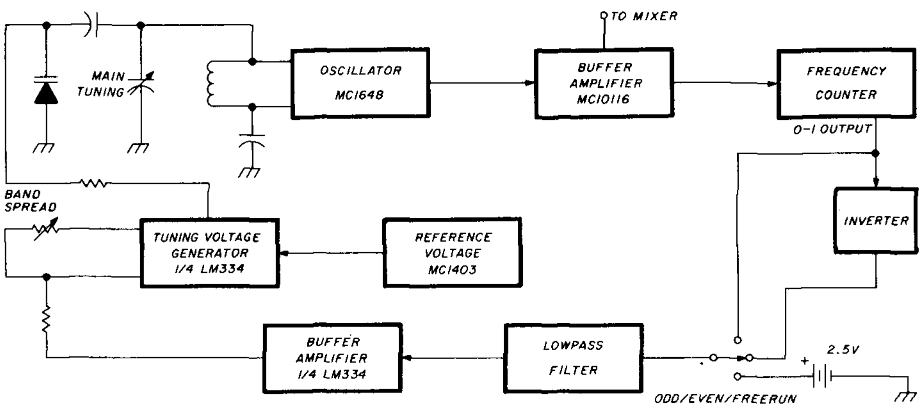


fig. 2. Frequency-locked local oscillator block diagram.

I'd like to emphasize that this scheme can be applied to any receiver with a digital frequency counter so long as it has a latched output, which I think all of them do. No special indicators of lock are needed, because proper operation is indicated by the receiver's slowly changing between 30.0001 and 30.0000 MHz — or whatever other frequency is selected. The actual frequency drift is only on the order of ± 10 Hz, and it is so slow that I can't detect it by ear. All the ICs

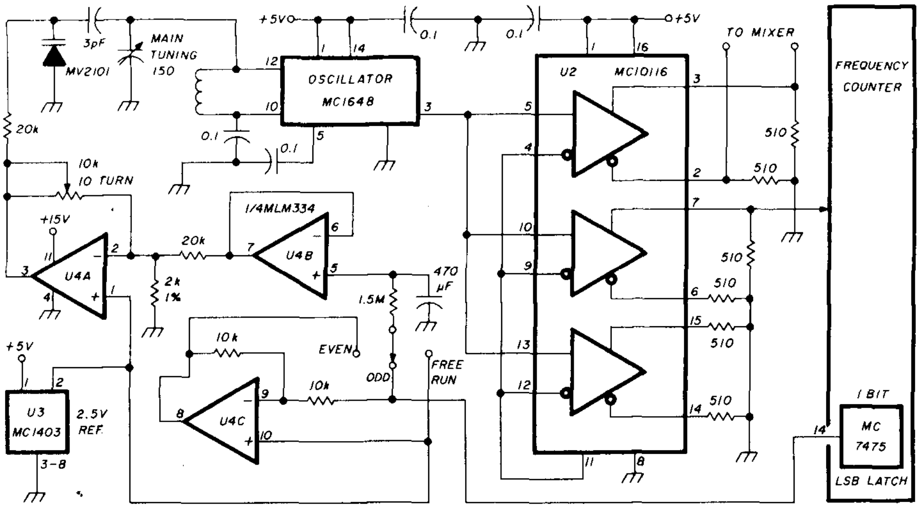


fig. 3. Frequency-locked-loop schematic.

in the loop are available from Motorola Semiconductor, Phoenix, Arizona.

references

1. C. MacKeand, WA3ZKZ, "Frequency Lock Loop," *ham radio*, August, 1978, page 17.
2. W. Ryder, W6URH, "High Performance General Coverage Communications Receiver," *ham radio*, November, 1977, page 10.
3. Dr. Arthur D. DeLaGrange, "Lock onto Frequency," *Electronic Design*, June 21, 1977.

Pat O'Neil, AA7M, and Barbara O'Neil Motorola Semiconductor, Inc.

Heath HW-101 sidetone control

I'm basically a night owl. If you're like me, you find many a late-night CW ragchew interrupted by friend wife complaining of "that loud beeping." I finally decided to correct the situation on my HW-101 by adding a sidetone volume control. Extra front-panel controls on radios tend to look somewhat tacky, so I decided that the addition must not be conspicuous.

After some pondering, I decided on a concentric af gain control as the solution. Heathkit provided the lever knob and knob insert. All that was needed was a switched dual control.

A call to the local parts distributor proved informative. They carried Clarostat controls in modular form; custom dual controls were no problem. The inside shaft would hold the original af gain-control knob; the rear pot, therefore, must be a 1-megohm replacement for the present control. (Don't forget the switch.)

I decided to control the sidetone by replacing R318 (100 kilohms) in the audio amplifier circuit with the front control in the dual assembly. Then, by connecting C311 to the wiper of the sidetone control, the amount of sidetone injected into the af circuit could be controlled. Hookup is straight-forward; I suggest, however, you use shielded cable for the interconnections.

The modification looked good, provided no surprises, and best of all — works great!

J. K. Davis, AD9M

XR-205 waveform generator as a capacitance meter

A 205 chip, a counter, and a calculator provide a means of measuring capacitance to within 1 or 2 per cent. The frequency is determined by a capacitance connected across pins 14 and 15 of the chip. *C times F* is a constant, k, with C in microfarads and F in Hz. This constant is truly constant over a very wide frequency range. The specification sheet gives this constant as 400, but I find it to be 260 with my generator, so this is apparently a nominal value.

I use a compression trimmer of about 200-1500 pF, permanently wired across pins 14 and 15, with parallel binding posts and short clip leads for connecting additional capacitance. The trimmer tunes across the i-f range.

I was fortunate in having several 1 per cent capacitors as standards, but only one is required. The first step is to determine the capacitance of the trimmer plus strays, C_{tr}, at a known frequency, after which the constant, k, may be determined from

$$k = FC_{tr} \qquad \textbf{(1)}$$

The procedure for determining C_{tr}, the trimmer capacitance, is as follows:

Set the trimmer to about mid range and note the frequency, F_1. Connect a known capacitor and note the new frequency, F_2. Divide F_2 by F_1 and call this quotient f. Now calculate C_{tr} from the following formula:

$$C_{tr} = \frac{fC_s}{(1-f)} \qquad \textbf{(2)}$$

where C_{tr} = trimmer plus stray capacitance (μF)

C_s = standard or known capacitance (μF)

$f = F_2F_1\ (Hz)$

Now calculate k from $k = F_1C_{tr}$. Save F_1 for measuring unknown capacitors.

The measurement procedure, after k and C_{tr} have been determined, is to first set the frequency to F_1 with the trimmer capacitor. Connect the unknown capacitor and measure F_2. Divide k by F_2 and subtract $C_{tr} = C_{unknown}\ (C_u)$:

$$C_u = \frac{K}{F_2} - C_{tr} \qquad \textbf{(3)}$$

As before, C is in μF, F in Hz. These calculations would be difficult without a pocket calculator but are easy with one. Assuming the trimmer, C_{tr}, is 300 pF, with 75 pF in parallel, k/F_2 would come out 0.000375 . . . on the calculator.

A half-dozen 1 per cent capacitors, from a few pF to 0.1 μF, were measured within 1 per cent of the nominal value. Indications are that the accuracy holds up to several hundred μF. EXAR-205 chips available from JAMECO.

W. S. Skeen, W6WR

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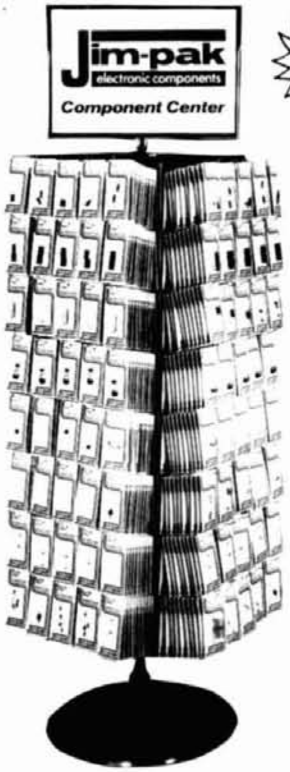

new

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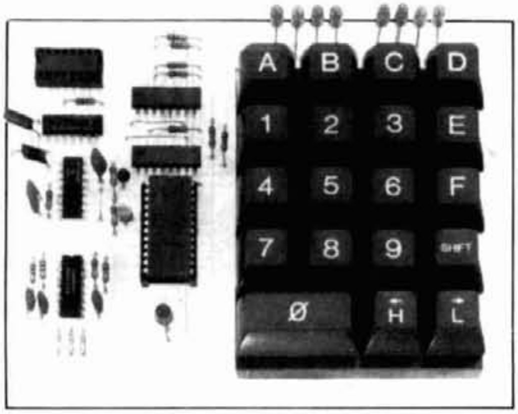
The JE600 Encoder Keyboard provides two separate hexadecimal digits produced from sequential key entries to allow direct programming for 8 bit microprocessor or 8 bit memory circuits. Three (3) additional keys are provided for user operations with one having a bistable output available. The outputs are latched and monitored with 9 LED readouts. Also included is a key entry strobe.



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NEW products

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FT-101ZD transceiver

Yaesu Electronics Corporation of Paramount, California, is pleased to announce the introduction of the FT-101ZD transceiver. The FT-101ZD is all new in design and offers many of the features of the internationally acclaimed FT-901DM.

The FT-101ZD i-f is a no-compromise high frequency SSB/CW transceiver which offers variable bandwidth of 2.4 kHz to 300 Hz, digital plus analog display, a built-in rf speech processor, built-in ac power supply, a new highly effective noise blanker, rugged 6146B final tubes, all-band coverage 160-10 meters, WWV, plus WARC band expandability, and a true frequency counter (no more re-calibrating when changing modes). Additionally, the FT-101ZD is compatible with all of the FT-901DM accessories. The FT-101ZD is now available from your local Yaesu dealer.

Hy-Gain model TH5DX antenna

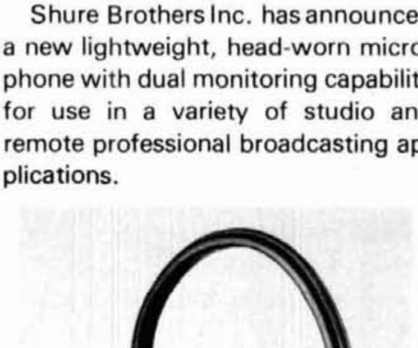
Hy-Gain Electronics, division of Telex Communications, Inc., introduces the newest member of the famous Thunderbird line of triband antennas. The TH5DX offers outstanding performance on 20, 15, and 10 meters. It features five elements on an 18-foot boom, with three active elements on 15 and 20 meters and four active elements on 10 meters. The TH5DX also uses separate air-dielectric Hy-Q traps for each band. This allows the TH5DX to be set for the maximum front-to-back ratio, and the minimum beam width possible for a triband antenna of this size.

Also standard on this antenna are Hy-Gain's unique beta-match, rugged boom-to-mast bracket, taper-swaged elements, and improved element-compression clamps.

Contact your nearby Hy-Gain dealer, or write to Hy-Gain Electronics, Division of Telex Industries, 8601 Northeast Highway 6, Lincoln, Nebraska 68505.

boom microphone

Shure Brothers Inc. has announced a new lightweight, head-worn microphone with dual monitoring capability for use in a variety of studio and remote professional broadcasting applications.



The new Shure SM14 consists of a headband, unidirectional dynamic microphone, and two integral earphone assemblies to permit the monitoring of separate sound sources. Each of the twin earphone assemblies has its own transformer and phone plug.

The SM14's dual monitoring feature provides several distinctive advantages over a single-earphone system. Besides enabling the user to monitor two separate sound sources, such as program material and studio directions, the double receiver system helps prevent background noise interference. In addition, having two monitoring systems provides a reliable back-up should one system fail.

The SM14 is a low-impedance microphone, allowing extra-long lengths of microphone cable to be used. To prevent the microphone wires from getting in the way, the SM14 is equipped with a snap-on connector that fastens to the user's belt or shirt.

The complete unit is constructed of stainless steel, aluminum, and high-impact thermoplastic. It is mounted on a lightweight, cushioned headband and features an adjustment knob to permit the boom to extend or pivot to fit any head. For additional information, write Shure Brothers Inc., 222 Hartrey Avenue, Evanston, Illinois 60204.

TRS-80 microcomputer technical reference handbook

Radio Shack has published a technical reference handbook for their TRS-80 microcomputer system. The illustrated 108-page book is intended primarily for technically oriented persons with a good working knowledge of digital logic circuits.

Written in a clear, informal manner, the *TRS-80 Microcomputer Technical Reference Handbook* includes technical information and schematics for both Level-I and Level-II TRS-80 systems.

Topics covered are theory of operation, adjustments and troubleshooting, the outside world (connections to external devices), parts list, and foldout schematics.

The *TRS-80 Microcomputer Technical Reference Handbook* is priced at \$9.95. The 22 × 28 cm (8½ × 11 inch) softbound book is available from participating Radio Shack stores and dealers worldwide.

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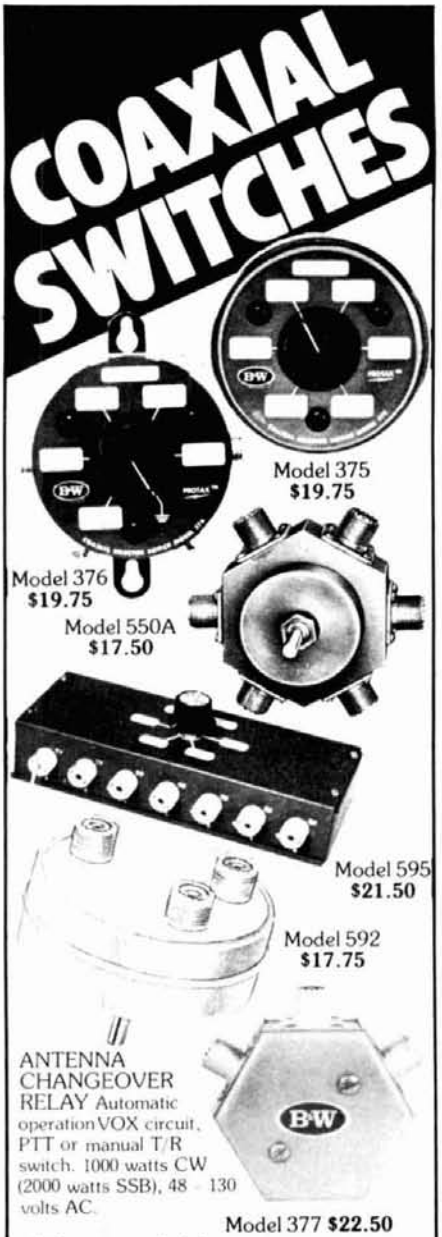

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THE MODEL SL-65* (20-2000 WATTS) AND THE QRP MODEL SL-65A* (0.2-20 WATTS) DIGITALLY INDICATE ANTENNA VSWR UNDER ANY TRANSMISSION MODE -- SSB, CW, RTTY, AM Etc. THERE IS NO CALIBRATION REQUIRED AND NO CROSSED METER NEEDLES TO INTERPRET. SIMPLY LOOK AT THE READOUT AND THAT IS THE VSWR. SPEAKING NORMALLY INTO A SSB TRANSMITTER MIC. INSTANTLY CAUSES THE VSWR TO BE DISPLAYED THROUGHOUT YOUR ENTIRE TRANSMISSION. REVERSING THE POSITION OF A FRONT PANEL TOGGLE SWITCH AND THE DISPLAY INDICATES THE NET POWER (FORWARD LESS REFLECTED) THAT IS ACCEPTED BY THE ANTENNA. THE PEAK OF THE NET PEP IS DETECTED AND DISPLAYED WITHOUT FLICKER FOR ANY MODULATION TYPE. DISPLAY UPDATE IS CONSTANT YET FLICKER FREE AS YOU MAY CHANGE THE POWER ACCORDING TO YOUR VOICE. THERE IS NOTHING LIKE THIS QUALITY INSTRUMENT AVAILABLE ANYWHERE ELSE. IT IS THE ONLY VSWR-NET POWER INDICATOR THAT LETS YOU KNOW THE STATE OF YOUR ANTENNAS AND TRANSMITTED POWER AT ALL TIMES WHILE TRANSMITTING. EITHER MODEL IS A SOPHISTICATED DEVICE CONTAINING FOUR CIRCUIT BOARDS AND THIRTEEN INTEGRATED CIRCUITS.

WARRANTY ONE YEAR

SL-65
VSWR INDICATOR

• TWO DIGIT DISPLAY SHOWS VSWR TO AN ACCURACY OF .1 FOR VALUES FROM 1.0 AND 2.2. ACCURACY IS TO .2 FOR VALUES FROM 2.3 TO 3.4 AND TO .3 FROM 3.4 TO 4.0. FROM 4.1 TO 6.2 THE INDICATION MEANS THAT VSWR IS VERY HIGH.

• FOR VSWR VALUES NEAR 1.0, THE POWER RANGE FOR A VALID READING IS 20 - 2000 WATTS OUTPUT. FOR HIGHER VALUES THE UPPER POWER LIMIT FOR A FLICKER FREE VALID READING IS SOMEWHAT LESS (35 - 1000 WATTS FOR VSWR AT 2.0).

• DIVIDE THE ABOVE POWER LEVELS BY 100 TO OBTAIN THE PERFORMANCE OF THE SL-65A QRP MODEL.

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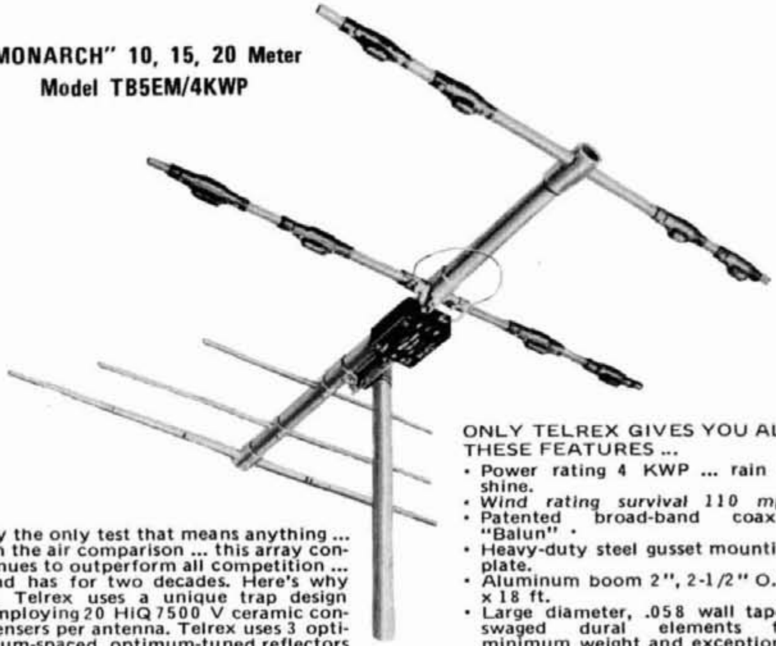

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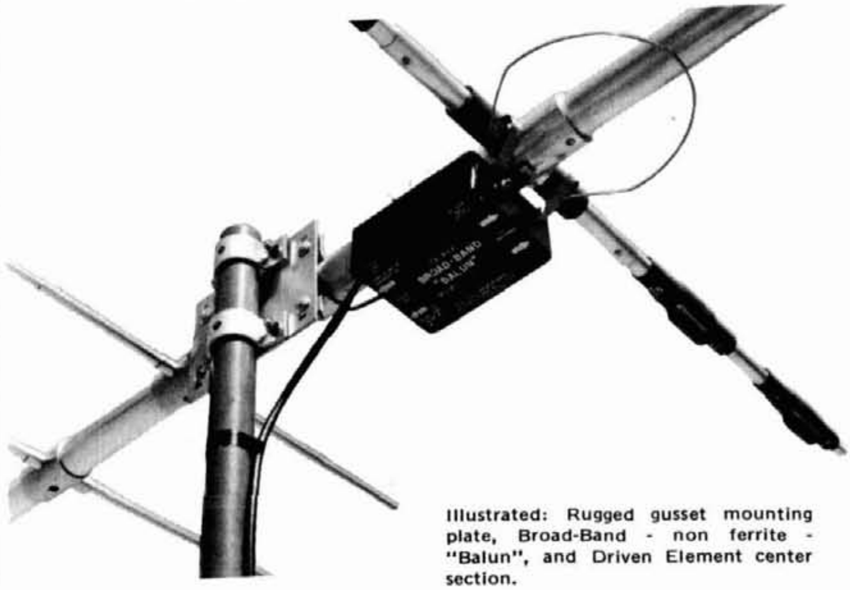

Illustrated: Rugged gusset mounting plate, Broad-Band - non ferrite - "Balun", and Driven Element center section.

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FOR SALE DRAKE "C" LINE; all filters, extra crystals for 10, 160, WWV. With matching speaker, power supply, and manuals. Excellent condition, on air daily. $1050 or closest offer. W1XU, P.O. Box 186, Peterborough, N. H. 03458; (603) 924-6759.

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TEST EQUIPMENT CATALOG listing used Tektronix, HP and GR equipment at bargain prices. PTI, Box 8699, White Bear Lake, MN 55110. Price $1.00 refundable with first order.

S LINE in perfect shape 7553A, 32SB, 312B4, 516F2, $1500.00; Swan Antenna Tuner ST-1, New $125.00; Heath Mobile Supply $50.00; Heath HP23 Supply $65.00; Johnson Matchbox 275W $65.00. Write W2CPI or call 609-881-3144 between 10 and 1. Must be picked up — no shipping.

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WANTED: Heath HO-10 monitor scope; please quote price and condition in first letter. Jim Fisk, W1HR, HAM RADIO, Greenville, NH 03048.

WANTED: Passband tuning unit from R-4A or R-4B, or complete junked receiver with tuner still intact. K1XX, *ham radio*, Greenville, NH 03048.

PC BOARDS Deluxe Memory Keyer, April HR. Glass, plated, drilled, $18.00. RTC Electronics, Box 2514, Lincoln, Nebraska 68502.

SELLING OUT — SX101-A, HT32B, test equipment, mikes, antiques, tubes & etc. (SASE) J. Davis, 802 Chain St., Norristown, PA 19401.

RECONDITIONED TEST EQUIPMENT for sale. Catalog $.50. Walter, 2697 Nickel, San Pablo, Ca. 94806.

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QUALITY NEW COMPONENTS. ¼ and ½ watt carbon film resistors; electrolytic, mylar, tantalum, disc, mica capacitors; trimpots; miscellaneous other items including chassis, enclosures. Enclose 15¢ stamp for catalogue. Midnight Engineering Group, P.O. Box 349, Galesburg, IL 61401.

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BEST OFFER TAKES! Two Motorola HT 220 walkie-talkies & battery charger. 1.8 Watt. UHF frequency. Standard squelch. Laurie Fiebiger, 13500 County Road 6; Mpls. MN 55441. (612) 559-1551.

MUSEUM for radio historians and collectors now open. Free admission. Old time amateur (W2AN) and commercial station exhibits, 1925 store and telegraph displays, 15,000 items. Write for details. Antique Wireless Assn., Holcomb, N. Y. 14469.

SATELLITE TELEVISION — For information on building or buying your own Earth Station send $3.00 to Satellite Television, R.D. 3, Box 140, Oxford, New York 13830.

COLLINS FILTERS, $30 each, F455N-20, 40, 80, 160 with matching components, Guaranteed. Ernie Franke, WA2EWT, P.O. Box 364, Colombo, Sri Lanka (Ceylon).

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MOBILE HF ANTENNA, 3.5-30 MHz inclusive, 750 watts PEP, center loaded coil, tuned from the base, eliminating coil changing or removing from mount. Less than 1.5 to 1 VSWR on all ham bands. $119.95 each — contact your local dealer or order from Anteck, Inc., Box 415, Route 1, Hansen, ID 83334. (208) 423-4100. Master Charge and VISA cards accepted. Dealer inquiries invited.

QSL CARDS 500/$10. 400 illustrations, sample. Bowman Printing, Dept. HR, 743 Harvard, St. Louis, MO 63130.

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WWVB RECEIVER. The Elemek Model LXK receiver receives the 60 kHz WWVB signal and provides the following outputs: 60 kHz and 100 kHz, phase locked to WWVB carrier, and the demodulated WWVB time code. Send for brochure describing the receiver to Elemek, Inc., Dept. H, 6500 Joy Rd., East Syracuse, N. Y. 13057.

FREQUENCY ALLOCATION CHART. See how the entire radio spectrum is used. 2 kHz to 200 GHz. Send $3.00 Collins Chart Co., Box 935, Coronado, CA 92118.

WANTED: Hilltop property near Pollock Pines, California. WA6COA, 4 Ajax Place, Berkeley, CA 94708.

CALL TOLL FREE for an EZ deal. 800-247-2476/1793. Iowa call 800-362-2371. See ad elsewhere. WØEZ, Bob Smith Electronics, RFD 3, Fort Dodge, Iowa 50501.

FERRITE BEADS: w/specification and application sheet - 12/$1.00. Assorted PC pots - 10/$1.00. Miniature mica trimmers, 3-40 pF. - 5/$1.00. Postpaid. Includes latest catalog. Stamp for catalog alone. CPO Surplus, Box 189, Braintree, MA 02184.

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WANTED: Motorola KXN 1024 and KXN 1052 channel elements. WA6COA, 4 Ajax Place, Berkeley, CA 94708.

THE MEASUREMENT SHOP has used/reconditioned test equipment at sensible prices; catalog. 2 West 22nd St., Baltimore, MD 21218.

MANUALS for most ham gear 1937/1970. Send 25¢ for "Manual Catalog." HI, Inc., Box H864, Council Bluffs, Iowa 51502.

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Coming Events

PENNSYLVANIA: The South Hills Brass Pounders & Modulators 42nd Annual Pittsburgh Hamfest, August 5, noon til dusk. New Location: Allegheny County Community College, South Campus, Route 885, 2 miles south of Allegheny County Airport. Large indoor air-conditioned area for vendors and flea market. Paved outdoor flea market. Prizes and food. Check in on 146.13/73 and 52/52. Preregistration $1.50; $2.00 at door. For info and registration: Bruce Banister, 5954 Leprechaun Dr., Bethel Park, PA 15102. Vendors must register.

FLORIDA: 1979 Jacksonville Hamfest and ARRL North Florida Section Convention, August 4th and 5th, Jacksonville Municipal Beach Auditorium. Indoor swap area, advance table reservations $5 from Robbie Roberts, 10557 Atlantic Blvd., #31, Jacksonville, FL 32211. Advance registrations $3 from R. Cutting, 303 Tenth Street, Atlantic Beach, FL 32233. Door price $3.50. Lots of fun and big programs.

OHIO: Second Annual Salem Area Hamfest, 9 AM - 3 PM Sunday, August 5, Kent State Salem campus, Salem. Advance tickets, $1.50; $2.00 at door. Inside tables, $5.00, space for yours, $2.00. Flea Market space, $1.00. Air conditioning, wheelchair ramp, free parking, refreshments, prizes. Grand prize: Atlas RX-110, TX-110, PS110. Check in 146.52 simplex. Details: Harry Milhoan, WA8FBS, 1128 West State, Salem, OH 44460.

TENNESSEE: The Oak Ridge Amateur Radio Club will hold the Oak Ridge Amateur Radio Convention and Hamfest '79 in Oak Ridge this year instead of Crossville. The date is July 14 and 15 at the Oak Ridge Civic Center. 10,000 square feet of air-conditioned area available for commercial and flea market exhibits. The FCC will be in Oak Ridge Saturday, July 14 to give exams. Exams will start promptly at 8 AM in the High School cafeteria across the street from the Civic Center. Anyone wanting to take the exam must have Form 610 completed and have your present license with you. Other activities planned for ladies and kids include movies, tour of Oak Ridge's world famous American Museum of Science and Energy. Or you might want to take advantage of the heated indoor pool or picnic and playgrounds at the Civic Center. By moving the Oak Ridge Amateur Radio Convention and Hamfest from Crossville to Oak Ridge, the Oak Ridge Club plans to expand in every way to make for a bigger and better Hamfest for all. The talk-in station will operate on 146.88. Other frequencies are 147.72 and 146.82. Local talk-in on 146.52. Camping facilities complete with everything are available just 20 minutes from the Civic Center. Motels and restaurants are conveniently located also. Commercial and flea market exhibitors are urged to make early arrangements to attend by contacting Charles Byrge, WB4OBE, P.O. Box 291, Oak Ridge, TN 37830. A welcome center operated by the Chamber of Commerce will be located at the Civic Center to provide visitors with full information on what to see while in Oak Ridge. The week of July 9-16 will be proclaimed Amateur Radio Week in Oak Ridge by the mayor. An Amateur Radio station will be on exhibit at the museum. Museum admission is free. Admission to Hamfest $1.00.

ILLINOIS: Fox River Radio League Hamfest, Kane Co. Fairgrounds Exhibition Hall, St. Charles, — Sunday, August 26th. Tickets: $1.50 advance — $2.00 at gate. Contact: Martin Schwamberger WB9TNQ, 1051 Northfield Drive, Aurora, IL 60505.

MISSOURI: Hannibal Amateur Radio Club Ham-Picnic, July 8. Talk-in 28-88. FCC exams, etc. Details: WBØRKR.

RADIO EXPO '79, September 15 and 16, Lake County Fairgrounds, Routes 120 and 45, Grays Lake, Illinois. Manufacturers' displays, flea market, seminars, ladies' programs. Advance tickets $2.00. Write EXPO, P.O. Box 305, Maywood, IL 60153. Exhibitors inquiries: EXPO Hotline (312) 345-2525.

ARIZONA: Amateur Radio Council of Arizona's Annual Ft. Tuthill Hamfest, August 3, 4, 5, Flagstaff. Prizes — TS 520 Transceivers, microwave oven, Wilson Mark II H.T. and more. Western Bar-B-Q, tech sessions, exhibits. Camping facilities available. For details: Ft. Tuthill Hamfest, 8520 E. Edward Ave., Scottsdale, AZ 85253.

31ST ANNUAL U.P. HAMFEST will be held on July 28 & 29, 1979. Add your name to our mailing list. Send QSL to Sawyer Radio Ass., P.O. Box 73, Gwinn, MI 49843.

IDAHO: Wyoming, Idaho, Montana, Utah 47th Annual Hamfest, July 27, 28, 29. Macks Inn, Idaho. 2-meter hunts, OSCAR demo, Ladies' crafts — something for everyone. Pre-registration prize: Wilson Mark II Handie Talkie with touch tone, battery pack, charger. Grand prize — choice of: Icom 211 or Kenwood TS-520. Saturday night — kids movies, adult dance. For info: Dave Hunting WB7FGV, Box 662, Kemmerer, WY 83101 or call (307) 877-9440.

MASSACHUSETTS: NoBARC Hamfest July 21, 22 at Cummington Fairgrounds. Tech talks, demonstrations and dealers. Flea market, $1.00; advance registration $3.00 single, with spouse $5.00 to Tom Hamilton, WA1VPX, 206 California Avenue, Pittsfield, Massachusetts 01201 or $4.00/$6.00 at gate. Mobile talk-in on 146.31/91. Gates open at 5:00 PM on Friday for free camping.

ILLINOIS: Hamfesters 45th Annual Picnic and Hamfest, Sunday, August 12, Sante Fe Park, 91st and Wolf Road, Willow Springs, southwest of Chicago. Famous Swappers Row. Tickets: $2.00 gate, $1.50 advance. For info or tickets (send check or money order, SASE appreciated) to Hamfesters Radio Club, Box 42792, Chicago, IL 60642.

ILLINOIS: The Radio Amateur Megacycle Society's 17th Annual QSO Party. Time: 1800Z August 4 to 2300Z August 5. Rest period 0500Z to 1200Z August 5. BANDS/MODES: All bands, CW and phone. Same station may be worked on each band and each mode. No repeater contacts. FREQS: About 60 kHz from low end on CW. About 3975, 7275, 14275, 21375 and 28675 on phone. About 25 kHz from low end of each Novice band, especially on the half hour. EXCHANGES: Illinoisians give Serial number, RS(T) and county. Others give Serial number, RS(T) and state, province or country. LOGS: Logs must be legible and must be submitted along with a summary sheet listing all claimed multipliers and claimed score. Operator(s) name, address, call sign and category of operation must be included. Send business size SASE for copy of results. FILING: Deadline for postmarks on entries is September 15, 1979. Send to: RAMS, K9CJU, 3620 N. Oleander Ave., Chicago, IL 60634.

More Details? CHECK — OFF Page 110

OHIO: Official ARRL 5th Annual Hall of Fame Hamfest. Sunday, July 15, Stark County Fairgrounds, Canton, Ohio. Mobile check-in on 19-79 and 52-52. $2.50 Advanced, $3.00 at gate. Contact WA8SHP, 10877 Hazelview Ave., Alliance, OH 44601.

CALIFORNIA: Sonoma County Radio Amateurs will be operating W6LFJ from Sonoma County Fair Exhibit, July 9 through July 20. Hours: 1000 PDT to 2200 PDT DAILY. Tentative frequencies: CW 7.050, 7.110; SSB 3.9, 7.235, 14.285, 21.360, 28.600 MHz; FM 29.5-29.6; Repeater 146.13/73; RTTY 14.075 plus, 21.075 plus, 28.075 plus. Skeds arranged via Don Bremer, KB6LO, 3200 Tobin Lane, Santa Rosa, CA 95401.

CWSP AWARD — The CWSP award is issued by the "Sao Paulo Group of CW" for all Hams that have worked 5 (five) different members of the group (mode CW only and valid QSO's after October 15, 1976). LOGS: Call, date, time band and report. Do not send QSL's — only GCR. A personal QSL is also requested. FEE: 10 IRC. SWL: Same rules. Endorsement for 25, 50, 75, 100, 125, 150 stations from Sao Paulo State (PY2). Applications must be sent to: CWSP, P.O. Box N 15.098 01000, Sao Paulo, SP, Brasil.

NEBRASKA: The Central Nebraska Amateur Radio Club's Annual Hamfest and Steakfry, July 28 and 29, Victoria Springs State Park near Anselmo. Talk-in on 146.40 147.00 through WRØAQQ. Good campground for weekenders. Registrations to: Harry Roblyer, WØDLM, Burwell, NE 68823 or C. J. Christensen, Taylor, NE 68879.

ILLINOIS: Big Thunder Amateur Radio Club's Annual Hamfest, Sunday, July 22, Boone County Fairgrounds, one mile north of Belvidere on IL 76. Talk-in on 52 Simplex. Donations $2.00 door. Advance $1.50. For info and tickets: Michael Santucci, WD9JGH, 862 Ivy Oaks Rd., Caledonia, IL 61011.

WISCONSIN: Sheboygan County Amateur Radio Club's Annual Lake Shore Swap Fest and Public Brat Fry. Sunday, July 22, 9 AM to 5 PM, Wilson Town Hall, Sheboygan. Many prizes, refreshments. Public auction at 3 PM. Kiddie Korner. Adults $1.00. Under 12 w/family free. For further info: Call (414) 457-3203.

PENNSYLVANIA: Two Rivers Amateur Radio Club's 15th Annual Hamfest, Sunday, July 22, Green Valley Fire Department Fairgrounds, US Route 30, East McKeesport. Large flea market. For further info: Two Rivers ARC, W3OC, McKeesport, PA 15132.

COLORADO: Field Demonstration Day and Swap Fest, July 22, at the home of Mr. Karl Ramstetter, WAØHJZ, Highway 93, Golden Gate Canyon Road, Golden. Door prizes, pot luck lunch (bring your favorite to contribute). Camping facilities beginning Saturday afternoon before Hamfest provided by Mr. Ramstetter. For further info: Charles Kaufman, Chairman, WAØGUN, 3734 South Poplar, Denver, CO 82037.

NEW YORK: Radio Central Amateur Radio Club's "Ham-Central", Sunday, August 5, rain date Sunday, August 12, Mt. Sinai Elementary School, Route 25A, Mt. Sinai, Long Island. 9:00 AM to 4:00 PM. (Open 7:00 AM for sellers) $3.00 tailgate selling. Admission: $1.50. Spouse and under 12 free. Monies to be used for Radio Central-St. Charles Hospital Repeater. Talk-in on K2VL/Rpt. 144.71/145.31 and 146.52 MHz; WA2UEC. Novice table, CW contest with keyer for prize. Special event — A fly-in by Suffolk County New York Police Dept. helicopter. For more info: Radio Central ARC "Ham-Central", P.O. Box 680, Miller Place, L.I., NY 11764 or call Joan Longtin, (516) 924-8438 or Robin Goodman (516) 744-6260.

NEW JERSEY: The Englewood Amateur Radio Association's 20th Annual QSO Party. TIME: From 2000 UTC Saturday, July 28 to 0700 UTC Sunday, July 29 and from 1300 UTC Sunday, July 29 to 0200 UTC Monday, July 30. Phone and CW are considered the same contest. A station may be contacted once on each band — phone and CW are considered separate bands. CW contacts may not be made in phone band segments. New Jersey stations may work other New Jersey stations. General call is "CQ New Jersey" or "CQ NJ". New Jersey stations identify by signing "DE NJ" on CW and "New Jersey calling" on phone. Suggested frequencies: 1810, 3535, 3900, 7035, 7135, 7235, 14035, 14280, 21100, 21355, 28100, 28600, 50-50.5, and 144-146. Suggest phone activity on even hours: 15 meters on odd hours (1500 to 2100 UTC); 160 meters at 0500 UTC. EXCHANGE: QSO number, RST, and QTH (ARRL section or country) New Jersey stations send county for QTH. SCORING: LOGS and comments to: Englewood ARA, P.O. Box 528, Englewood, NJ 07631. Send Size #10 SASE. Stations planning participation in New Jersey are requested to advise the EARA by July 7.

INDIANA: Delaware Amateur Radio Association's Hamfest, Saturday, August 11, County Road 300 E & 100 N, Springwater Park, Muncie. 7 AM (EST) Tickets: $1.50 advance, $2.00 gate. Reserved covered table $1.00. No extra charge for outside. Hourly drawings 9 til 3. Grand Prize: Tempo Syncom-1. For info: SASE to DARA, P.O. Box 3021, Muncie, IN 47302.

INDIANA: The Steuben County Radio Amateurs original Tri-State F.M. Picnic and Hamfest, Sunday, August 5, Angola. BBQ chicken, inside tables, overnite camping for Saturday arrivals — fee charged. Tickets at door. Communications: 146.52, 147.81-21.

MICHIGAN: Straits Area Radio Club's ARRL Hamfest, August 18 and 19, Petoskey Middle School, State and Howard Streets, Petoskey. Donation: $2.00 door. Tables $2.00. Refreshments. Swap and Shop: Saturday, 9-4; Sunday, 9-12. Prizes, ladies' program, seminars. Talk-in 146.52. Saturday night banquet — Holiday Inn, 7:00 PM. Tickets $7.50 by July 15. Mail to: Joe Werden WD8MJB, Box 444, Conway, Mich. 49722 or Bill Moss, WA8AXF, 715 Harvey St., Petoskey, Mich. 49770.

OHIO: The 15th Annual Wood County Ham-a-Rama, July 29, Bowling Green Fairgrounds, Bowling Green. Gates open 10:00 AM. Tickets $1.50 advance; $2.00 door. Dealer tables and space; trunk-sale space and food available. Prizes. K8TIH talk-in on 52. For info: Wood County ARC, c/o Eric Willman, 14118 Bishop Rd., Bowling Green, OH 43402.

KENTUCKY: The Bluegrass Amateur Radio Club's Annual Central Kentucky Hamfest, August 12, Fasig-Tipton Sales Paddock, Newtown Pike, Lexington. Grand prizes, hourly door prizes, exhibits, indoor/outdoor flea market, speakers and forums. For info: Bluegrass Amateur Radio Club, P.O. Box 4411, Lexington, KY 40504.

LOUISIANA: The Louisiana Council of Amateur Radio Clubs invites you to the '79 ARRL National Convention, July 20, 21, 22, Baton Rouge. For information and registration: LCARC, P.O. Box 891, Baton Rouge, LA 70821.

OKLAHOMA: The Central Oklahoma Radio Amateurs State ARRL Convention and "Ham Holiday", July 27, 28, and 29, Lincoln Plaza, 4445 Lincoln Blvd., Oklahoma City. ARRL Forum and technical talks on 1 GHz techniques, fast-scan TV for radio Amateurs, NBVM and more. Ladies' programs. Under cover commercial exhibits, free unlimited table space to flea market swappers. Pre-registration $4.00 prior to July 20. $5.00 after. A synthesized 800-channel VHF Transceiver awarded to encourage pre-registration. Main award — TS-120V with power supply. Full recreational facilities for all the family in the area. For information and registration: CORA, P.O. Box 14424, Oklahoma City, OK 73113.

TEXAS: The North Texas HF Association's Mini-Expeditions for Hams interested in working the portable 5 stations. The July Mini-Expedition will be to Telegraph, Texas (yes!). Operation will be CW ONLY on 40 and 15 meter bands. CW from Telegraph. The August Mini-Expedition will be to Telephone, Texas (right again). Operation will be PHONE ONLY on 40 and 15 meter bands. Phone from Telephone. Special QSL cards are printed for these two Mini-Expeditions and all QSOs will be confirmed if requested. Hours will be 8:00 AM to 6:00 PM CDST. Calls to use: WD5ICY and WD5IKY. For further info: Duncan Engler, WD5IKY, 812 Crescent St., Denton, TX 76201.

WEST VIRGINIA: The Jackson County ARC's Hamfest, August 12. Giant flea market. Bob Halprin, K1XA of ARRL Communications Department. Fun for the whole family at beautiful Cedar Lakes Park. For info: Bob Morris, WA8CTO, 628 Church Street South, Ripley, WVA 25271.

BRITISH COLUMBIA: Okanagan International Hamfest, Saturday and Sunday, July 28th and 29th, 1979, at the Gallager Lake KOA Kampsite, 8 miles north of Oliver, B.C., Canada. Prizes, entertainment, flea market, white elephant sale (bring your hobbies and crafts), bunny hunts, etc. Activities from 1 PM Saturday to 2 PM Sunday, PDT. Potluck lunch Sunday noon. Information from VE7DTX, 8802 Lakeview Drive, Vernon, B.C., Canada V1B 1W3, or VE7DKL, 584 Heather Road, Penticton, B.C., Canada V2A 1W8.

PENNSYLVANIA: The Second Annual BARC Hamfest and flea market, Sunday, July 15, Pocono Downs Race Track, Rt. 315, Plains Twp., Wilkes-Barre. 9 AM to 4 PM. Admission: $2.50. Spouse and under 12 free. Refreshments, door and raffle prizes, free FM clinic, computer displays. All indoors. Talk-in 147.66/.06 and 146.52 simplex. For info: Charles Baltimore or John Soha, (717) 823-3101, Broadcasters' Amateur Radio Club, 62 S. Franklin St., Wilkes-Barre, PA 18703.

ARKANSAS: Army MARS Meeting, Independence County Fairgrounds, Batesville, June 30 and July 1. Saturday Fish Fry, Sunday, Pancake Breakfast. Camping or motel. For info: Robert Glines, WB5KUI/ADN2MH, P.O. Box 97, Floral, ARK 72534. (501) 345-2880.

TEXAS: Encounter '79, the Texas VHF-FM Society's Summer Convention, August 3-5, Villa Inn, Irving. Hospitality room, Transmitter hunt, programs, exhibits, FCC exams, flea market. Talk-in on 146.52 and area repeaters. Registration with eligibility for pre-registration prize, $5.00 before July 1. $6.00 with no pre-reg prize after that date. For info: Encounter 79, P.O. Box 3608, Arlington, TX 76010.

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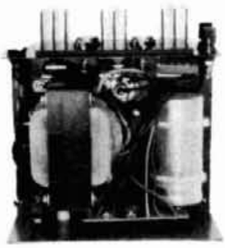

Inside View — RS-12A

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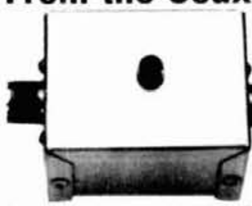

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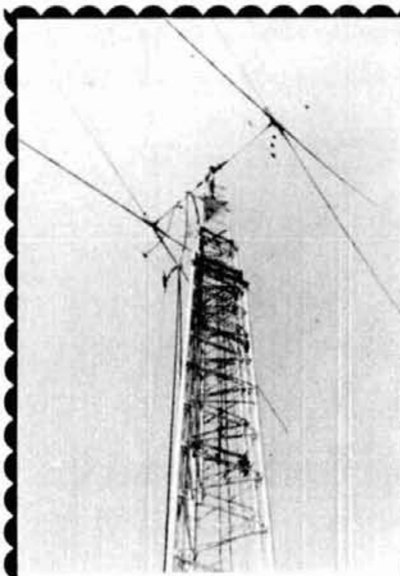

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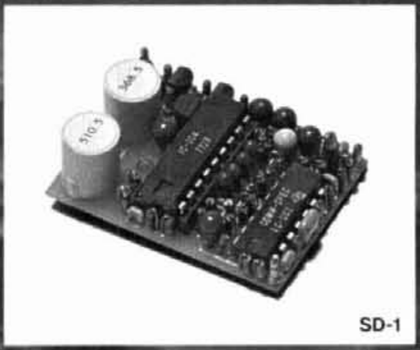

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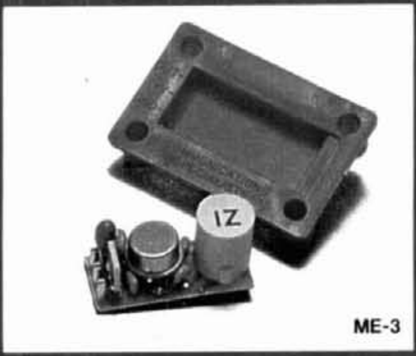
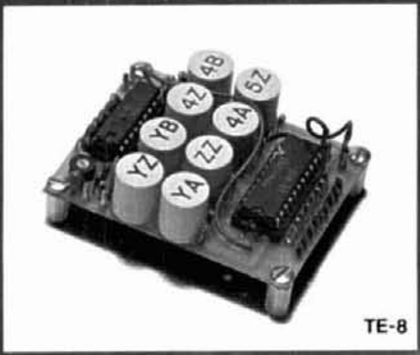
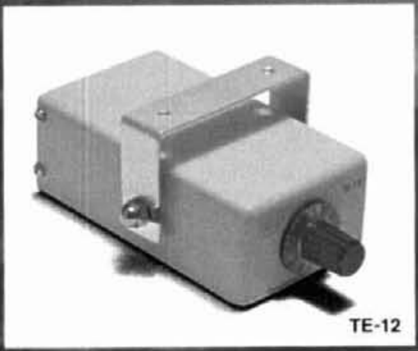


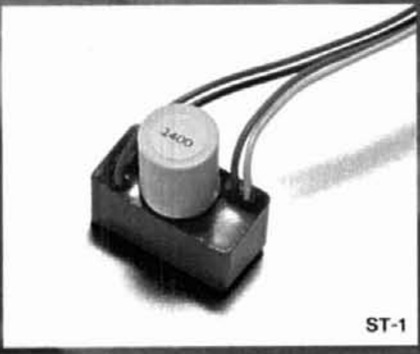
ME-3



TE-8



TE-12



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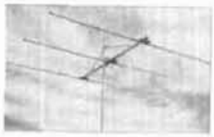

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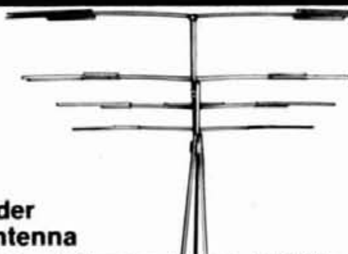

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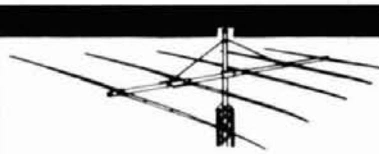

HY-GAIN 205BA monoband beam antenna

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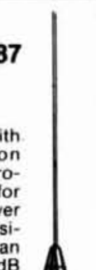

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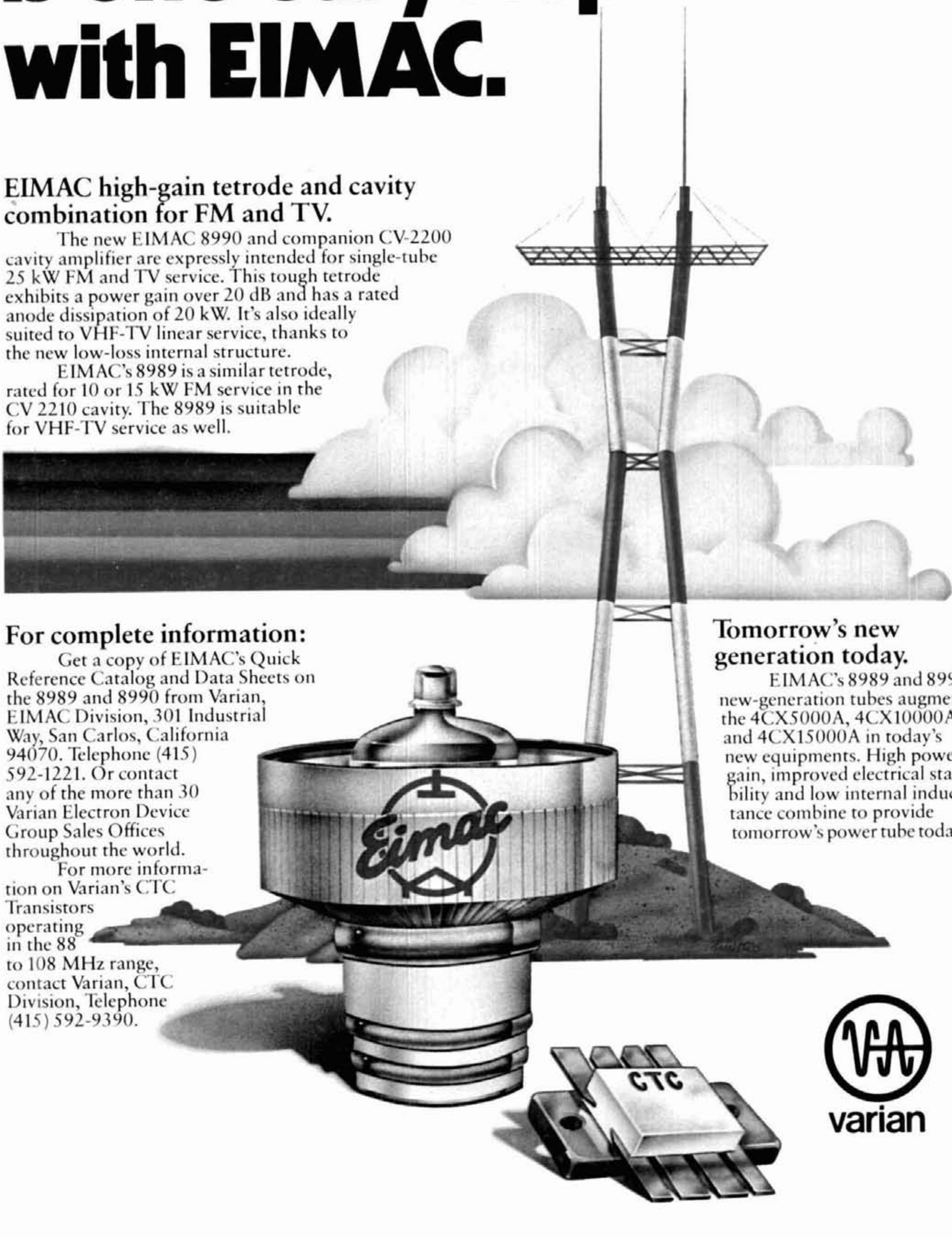

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