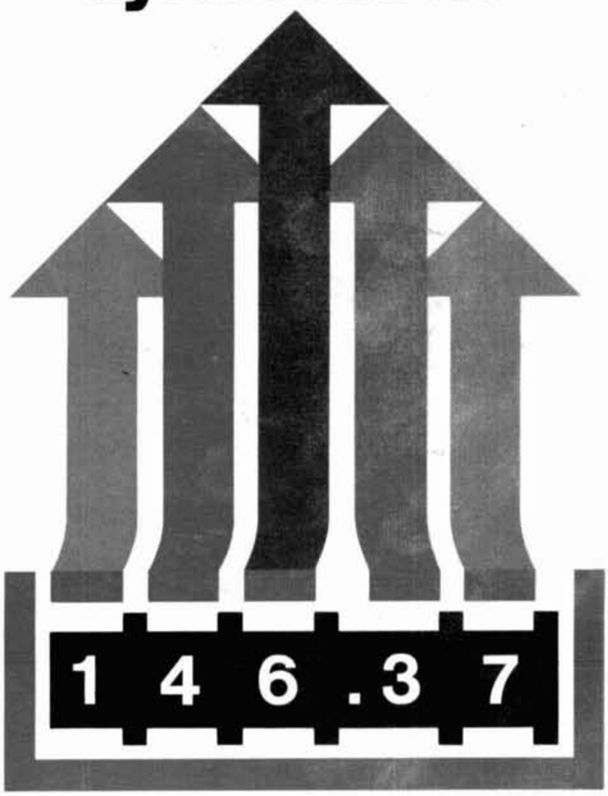
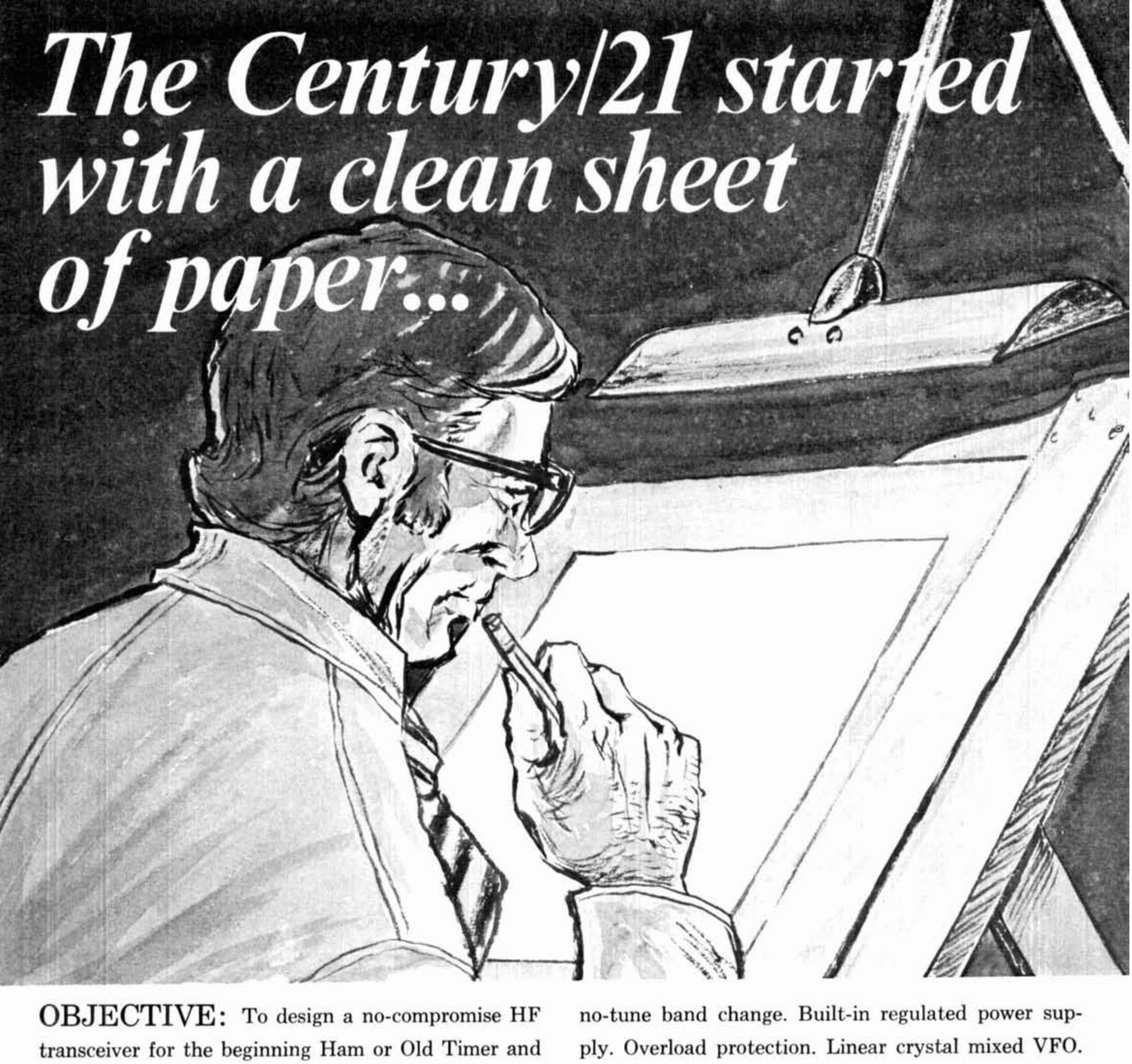
$1.50

ham radio magazine

AUGUST 1977

direct output two·meter synthesizer





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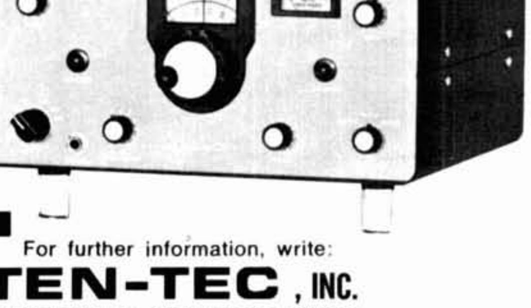

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contents

a second look

by Jim Fisk

As more and more amateurs switch to factory-made gear, and as industry uses more ICs and disposable plug-in modules, the life of the dyed-in-the-wool ham homebrewer gets tougher and tougher. If you've recently tried any of the construction articles in the amateur magazines, you are already well acquainted with the hassle involved in obtaining a few needed components.

At one time you could drop in at your local corner radio store with a list of parts and the man behind the counter would fill your order. But that was when the vacuum tubes, resistors, and capacitors in your ham gear were the same as those in the family radio. It's not the same anymore — now the transistors and ICs in the radios and television sets are designed specifically for that purpose and have operating characteristics that are of little use elsewhere. There are exceptions, but they are few and far between.

Another problem that faces the serious home builder is the tremendous variety of transistors and ICs available from different manufacturers. Although some types of devices are made by more than one company, in most cases the semiconductor manufacturers crank out devices that are completely different from those of their competitors. And to add insult to injury, the same device may carry a dozen different part numbers: a 2N number, a replacement number, plus special numbers for units sold in large quantities to equipment manufacturers.

There is only one way to combat this lunacy: arm yourself with a good semiconductor cross-reference guide and a wide selection of electronic parts catalogs. Tops on the list of replacement guides is Howard Sams' *Transistor Substitution Handbook* available from *Ham Radio's* Communications Bookstore. This handy little paper back, which is updated every year, covers practically every transistor ever made, from 2N34 to 2N6500, with recommended substitutes. It also covers devices from Japan and Europe, as well as replacement types manufactured by Delco, General Electric, International Rectifier, Motorola, RCA, Semitronics, Sylvania, and Workman. Most of these manufacturers also publish replacement guides, available for the asking from their authorized distributors.

If you live in a large metropolitan area, chances are that there is an industrial electronics supply house that can fill your parts needs. Many of these firms don't advertise because they are not particularly interested in small quantity sales, but if you show up at their office, they will sell you the parts. If you want to find them, pick up your telephone directory and check the *Yellow Pages*: look under "Electronic Equipment and Supplies."

If you live out in the sticks, the problem is more difficult, unless you can get into the city. If you can't, you must purchase your components through the mail. Allied Electronics is the best bet in this case and you can get a catalog from any Radio Shack store. Be sure to get their industrial catalog though — the more common entertainment catalog is devoted primarily to CB and hi-fi and lists few electronic parts for amateur communications equipment.

Jim Fisk, W1HR
editor-in-chief

That's all, Folks!

All you need for All Mode Mobile, that is.

All Mode Mobile is now yours in a superior ICOM radio that is a generation ahead of all others. The new, fully synthesized **IC-245/SSB** puts you into FM, SSB and CW operation with a very compact dash-mounted transceiver like none you've ever seen.

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* a registered trademark of AT&T.

- **FM stability on SSB and CW:** The **IC-245/SSB** synthesis of 100 Hz steps make mobile SSB as stable as FM. This extended range of operation is attracting many FM'ers who have been operating on the direct channels and have discovered SSB.

The **IC-245/SSB** is the very best and most versatile mobile radio made: that's all. For more information and your own hands-on demonstration see your ICOM dealer. When you mount your **IC-245/SSB** you'll have all you need for All Mode Mobile.

SPECIFICATIONS

FREQUENCY COVERAGE	*144.00 to 148.00MHz
MODES	FM (F3) *SSB (A3J), CW (A1)
SUPPLY VOLTAGE	DC 13.8V ± 15%
SIZE (mm)	90H x 155W x 235D
WEIGHT	2.7
TRANSMITTER TX OUTPUT	F3 10W *A3J 10W (PEP), A1 10W
CARRIER SUPPRESSION	40 dB OR BETTER
SPURIOUS RADIATION	-60 dB BELOW CARRIER
MAXIMUM FREQUENCY DEVIATION	±5KHz
MICROPHONE IMPEDANCE	600 OHMS
RECEIVER SENSITIVITY	*A3J, A1 0.5 MICROVOLT INPUT GIVES 10 dB S+N/N F3 0.6 MICROVOLT OR LESS FOR 20 dB QUIETING S+N+D/N AT 1 MICROVOLT INPUT 30 dB
SQUELCH THRESHOLD	-8 dB OR LESS (F3)
SPURIOUS RESPONSE	-60 dB OR BETTER
SYNTHESIZER FREQUENCY RANGE	144 MHz to 148 MHz
STEP SIZE	5 KHz for FM *100 Hz or 5 KHz for SSB
STABILITY	PER C IN THE RANGE OF -10 TO +60C, ±0.0000145%

*VALID WITH SSB UNIT ONLY

More Details? CHECK — OFF Page 126

presstop

IMMINENT COMMUNICATOR LICENSE action is being rumored by several industry sources. Departing Chairman Dick Wiley's support of the Communicator concept and his reported desire to see it realized before he steps down is one very strong agrument; its probable impact on the Personal Radio Division's budget, which will be reviewed shortly along with next year's proposed budget, is another.

It Appears Very Likely that the Communicator license will see some sort of official review within the next few weeks or so. What will come out of that review is another question.

EXISTING AMATEUR TRANSMITTERS WERE "GRANDFATHERED" June 2nd by an FCC modification to the first Report and Order on Docket 20777 that had become effective April 15. Under the modification all Amateur transmitters and transceivers (but not amplifiers) manufactured before April 15 are permanently exempted from the Report and Order's harmonic and spurious specifications. All Amateur equipment made after April 15 must meet the new specs, of course, but existing new equipment made before that date can be marketed until January 1, 1978. Individual Amateurs, however, are still responsible for meeting the 40-dB harmonic and spurious specifications of the FCC's first Report and Order on Docket 20777 in the operation of their own stations, even though the equipment itself has been grandfathered. The FCC's June 2nd relaxation applied only to the sale of non-complying equipment, and users are still expected to use it in such a way (with appropriate filters or an antenna tuner) that their stations meet the tighter requirement. Officially, the relaxation became effective July 18th.

UNRETURNED NOVICE EXAMS are still a big problem with the FCC in Gettysburg despite the dropping of multiple-exam mailings. Volunteer examiners have a major responsibility to see that a Novice exam, whether or not the applicant actually takes it, is returned to Gettysburg on time. Failure to do so can jeopardize the volunteer examiner's own license, and continuation of the present "unacceptable" number of unreturned exams could trigger drastic changes in Novice licensing!

GETTYSBURG RECEIVED A REPRIEVE when a radical personnel cut scheduled for June 10th didn't come off. Best news of all is that the previous "temporary" positions the people leaving had held are to be made permanent, and those people who have been filling the slots so well, will be staying in their jobs and working into permanent status.

The Reprieve Doesn't solve all of Gettysburg's problems, however. The Amateur workload continues to increase, and an estimated 10-20 additional people are going to be needed if the facility is to keep working smoothly.

"GUILTY ON TWO COUNTS" was the verdict the jury handed down June 6th in the trial of FCC Special Licensing Chief Richard Ziegler (July Presstop). One of the original four counts of bribery for the issuance of special Amateur callsigns was dropped and the jury failed to reach a decision on the second during the two-day trial.

18-YEAR-OLD GENERAL CLASS, or higher, Amateur license holders were permitted to administer Novice exams, effective June 13th. The amendment to Section 97.28(b) of the rules came about as a result of a Petition for Rule Making filed by WB4EKC.

A NEWLY-UPDATED EDITION of the FCC's Amateur Radio Rules, including all Part 97 changes through March 7, is now available from the Superintendent of Documents, U.S. Government Printing Office, Washington D.C. 20402. It's stock number 004-000-00338-1 and postpaid price is $1.30.

EXTENSIVE ELECTRONIC CONTROLS used in 1977 autos are causing RFI problems — a recent Illinois Bell notice warned that the "cruise control" in 1977 Cadillacs (and presumedly other GM cars) is sensitive to strong RF fields, which could cause sudden speed up or slow down. Some electronic skid control braking systems have locked up from RFI, and complete engine failure in fuel-injected engines has been reported by two-meter users.

A BOOKLET PROMOTING CANADIAN Amateur Radio has been published by the Radio Society of Ontario, Inc. The very attractive publication is available free to Canadian clubs or groups wishing to use it — an SASE to RSO, Box 334, Station U, Toronto, Ontario M8Z 5P7 will bring a sample and ordering information.

COMPUTER VOICE GENERATOR shown at the Dayton Hamvention is being used on 6 meters by WB4IVG in Dalton, Georgia. K1ZZ was "its" first contact.

DenTron amateur radio products have always been strikingly individual. This is the result, not of a compulsion to be different, but of a dedication to excellence in American craftsmanship. This dedication now extends to one of the worlds finest high performance Military amateur amplifiers.

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San Diego, CA 92112
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Ham Radio Outlet
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Los Angeles, CA 90064
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Baltimore, MD 21204

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Clawson, MI 48017

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Minneapolis, MN 55401

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Henry Radio Company
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St. Louis, MS 63144

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Durham, NC 27702

OHIO
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Cleveland, OH 44112
Srepco Electronics
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Dayton, OH 45404

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Tulsa, OK 74119

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...pacesetter in amateur radio

direct output two-meter synthesizer

New techniques permit the construction of a synthesized vhf transmitter which does not require frequency multiplication

This article will describe a unique, to amateur radio, method of building a two-meter synthesizer. Rather than function as a replacement for a crystal, *direct synthesis* generates the desired frequency without multiplication. Using ECL, TTL, and CMOS integrated circuits, the completed transmitter will produce 800 individual frequencies spaced every 5 kHz between 144 and 147.995 MHz. In addition, a local oscillator output, 10.7 MHz above the transmitter, can be used for receiver injection. With a phase-locked loop (PLL) ultimately controlling the vco (voltage-controlled-oscillator), the frequency accuracy is determined by a single crystal.

Contrary to some synthesizer designs, the receive and transmit frequencies in this unit are totally independent. This eliminates problems when odd frequency splits are encountered. Also, the two frequencies are available as BCD data for further processing or for a convenient readout rather than the thumbwheel switches. Again, another step into the realm of microprocessor-controlled equipment! The total cost for this 15-milliwatt exciter and local oscillator is approximately 100 dollars.

frequency generation

The two-meter fm frequencies are all multiples of 5 kilohertz; therefore, with an accurately generated 5-kHz reference frequency, each channel can be produced through multiplication by using the proper integer (**fig. 1**). However, there are inherent problems in this scheme, primarily because no easily programmed frequency *multipliers* are available. On the other hand, programmable *dividers* do exist. By inserting the correct number of dividers (counters) into a feedback loop as shown in **fig. 2**, we have effectively created a frequency multiplier; this is the beginning of our PLL. Unfortunately, this method has several problems. For the output to be exactly on frequency, the difference detector must be driven to zero. Therefore, the detector must not have any offset; in addition, the error amplifier should have infinite gain. To overcome these problems, a PLL uses the phase of the vco as the controlling factor rather than its frequency. The phase detector will be discussed in more detail later.

There are two special problems in PLL frequency synthesis. Extreme care must be taken in the design to prevent the radiation of excessive sidebands and spurious outputs. The reference sidebands are caused by the vco being modulated at the sampling rate of the phase detector. The more difficult (to control) spurious outputs are caused by close physical proximity to the digital logic. Also, the spurs can cause birdies in a companion receiver. Proper mechanical design, however, has reduced the levels to −55 dB and −90 dB, respectively.

programmable divider and prescaler

Unfortunately, since we are working with a closed loop system, any problems in one area are reflected in other portions of the circuit. Consider the final output signal; there should be a minimum of buzz or hum associated with the signal. Also, the transient response (time to settle after a channel change) should be small. These problems can be reduced by

By Jerry Pulice, WB2CPA, 143 Gibson Avenue, Staten Island, New York 10308

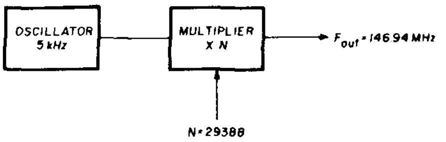


fig. 1. Block diagram of a basic frequency synthesizer that uses integer multipliers to generate the output frequency.

using a high performance loop to control the vco. As an example consider the PLL shown in **fig. 3**. With the vco prescaled by a factor of 20, the output frequency is determined by

$$F_{OUT} = 20(N)(0.005\ MHz) \quad (1)$$

Therefore, the minimum channel spacing will be 100 kHz instead of 5 kHz. To regain the original channel spacing, it would be necessary to divide the reference by a factor of 20. With a low reference frequency (250 Hz), the vco must have exceptional stability

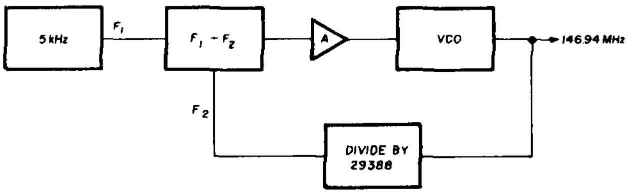


fig. 2. This system eliminates the multipliers and uses more commonly available dividers to generate the required integer.

since it can only be corrected 250 times per second. From these facts it can be seen that for best loop performance the digital logic should operate at the highest possible frequency.

TTL logic cannot operate directly at 144 MHz, and prescaling by at least 10 is required for any two-meter synthesizer. Conventional designs call for a programmable divider that can be preset to some number other than zero to modify the count length. Regardless of the counters toggle speed, this method will limit the upper frequency to approximately 15 MHz because not enough time elapses during one clock cycle to guarantee presetting the counters. It would appear that these problems would require the reference frequency to be lowered regardless of the loop considerations. However, return to **eq. 1**, which is one step beyond the basic form

$$F_{OUT} = (N)(M)(0.005\ MHz) \quad (2)$$

where N = integer number
M = prescale factor

Rearranging **eq. 2** yields

$$N = \frac{F_{OUT}}{(M)(0.005\ MHz)} \quad (3)$$

Where N is now the number of divisions required by the prescaler and reference frequency. With a prescaler that divides by 20, N would be 1440 divisions at 144 MHz.

Now, consider a prescaler that can divide by not only M, but $M + 1$. To maintain the same output frequency, **eq. 2** must be rewritten to account for M and $M + 1$:

$$F_{OUT} = [M(N - A) + (M + 1)(A)]\,(0.005\ MHz) \quad (4)$$

where N = total number of divisions (integer number)
M = prescale factor
A = number of divisions at $M + 1$

or $$144\ MHz = [20(1440 - 0) + 21(0)]\,(0.005\ MHz)$$

Reducing **eq. 4** to real components shows that a relatively slow counter (divider) can be used to control a fast two-mode (modulus) prescaler. In other words, the slow counter tells the prescaler to divide by twenty 1440 times and by 21 zero times. This technique is called pulse swallowing.

If one division though is by 21 instead of 20, **eq. 4** produces

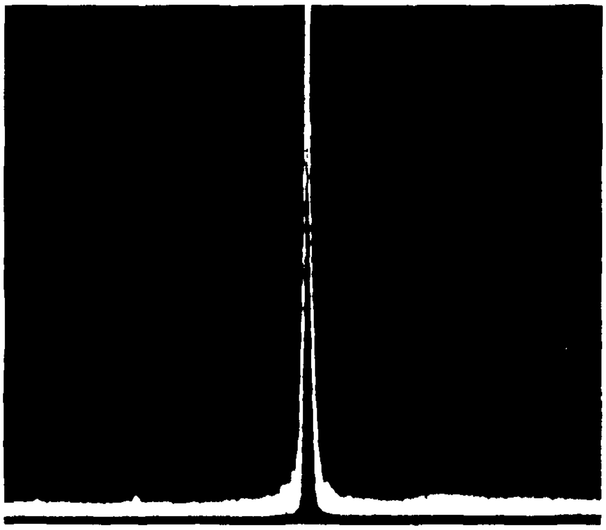
$$[20(1440 - 1) + 21(1)]\,(0.005\ MHz) = 144.005\ MHz$$

Therefore, for each division by 21, the vco frequency is raised 5 kHz. This relationship will continue each time the integer number is changed, producing channels that are separated by 5 kHz. The use of pulse-swallowing techniques overcomes the problems of vco and reference frequency, permitting the design of a vhf synthesizer with a channel spacing equal to the reference frequency.

divider details

As shown in **fig. 4**, the programmable divider is

As shown on this spectrum analyzer photograph, the output is very clean from 0 to 200 MHz. The signal frequency is 146 MHz. The low-frequency noise is being generated by the rf amplifier on the rf board.



Spectrum analyzer presentation of the final output. The signal is centered at 146 MHz. The left and right edges represent 143.5 and 148.5 MHz, respectively. The base line is approximately 80 dB down from the full output.

split into a two modulus prescaler and a low-speed main counter. In conjunction with the 7474 flip-flop, the prescaler will divide by either 20 or 21, depending upon the level on the 95H90s SWALLOW ENABLE line. If this line is held high, one output will occur for each 21 input pulses. If the line is low, the output will be 1 pulse for each 20 input pulses. This output from the prescaler section then drives three synchronous-binary 4-bit counters arranged as a 12-bit binary divider. In transmit the counters are reset by U15 at 1479_2 and in receive at 1586_2 by U14. The initial input frequency is converted by the 7483s into data that presets the binary counters between 0 and 39. Assuming a transmit condition, the 1479_2 count is shortened by the amount of preset, 0 to 39. The output of the counter will then occur at 1479_2 to 1440_2 representing 147.9XX to 144.0XX (**eq. 2**). It's now possible to generate any multiple of 100 kHz between the two frequency extremes.

Bit 1024_2 (pin 12 U13) goes high once per count cycle and is used as the 5-kHz output to feed the phase detector. This pulse is much wider than the 5-kHz pulse at pin 9 of the binary counters and will provide a more reliable trigger for the CD4046 phase detector.

Unfortunately, the 100-kHz multiples have not fulfilled the requirement of 5-kHz channel spacing. Between 100-kHz increments there are nineteen desired channels spaced every 5 kHz. As determined by **eq. 4**, each time the prescaler divides by $M+1$ the vco frequency will increase by 5 kHz. Using 144.035 MHz as an example, the prescaler would have to divide by $M+1$ seven times and by M, 1433 times. To generate the required number of $M+1$ divisions, 10 and 5 kHz data, a rate multiplier is used. This device, comprised of a series of gates and counters, will produce a specific number of pulses on command. Controlled by frequency data (144.035 MHz) from thumbwheel switches, the rate multiplier will, each time it's enabled, generate seven pulses. The 1024_2 bit from the binary counters is used to enable the multiplier. After 64 clock pulses EN OUT goes low, stopping the multiplier at 1088_2. The rate pulses from U4 are temporarily held in a D-type flip-flop, U2. When released, these pulses are synced with the next clock pulse and also stretched into a full clock period for the SWALLOW ENABLE line. U2 is only enabled between counts 1024_2 and 1088_2, the same as the rate multiplier. The RS flip-flop (U3) controls U2. A timing diagram is shown in **fig. 5**. The use of hard-wired BCD data from the thumbwheel switches prevents the rate multiplier from generating more than 19 pulses for the prescaler.

voltage controlled oscillator

One of the main criteria for vco design is that it be stable by itself. This synthesizer uses the Motorola MC1648 ECL logic oscillator (**fig. 6**). Of its many features, most important is its use of an external LC network as the frequency determining element. This type oscillator has less phase jitter than the RC switching oscillators (NE566 or MC4024).

The tank circuit consists of a Motorola MV109/209 varactor diode and a tuned line made from 3 inches (7.6mm) of miniature Teflon coax (RG-17U). This combination is extremely effective in combating the microphonics that plague other configurations. You

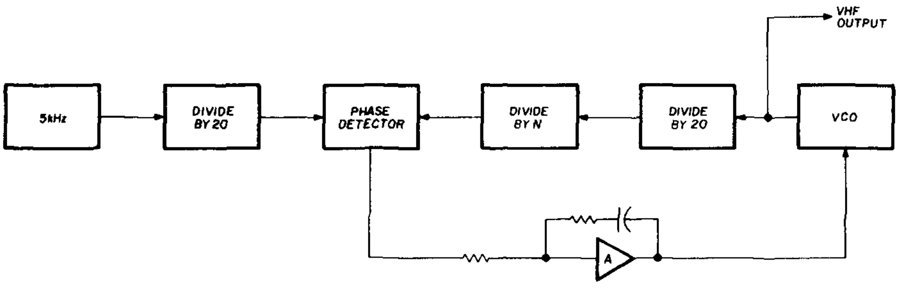


fig. 3. Block diagram of the basic phase locked loop system. With a vco that runs greater than about 50 MHz, a prescaler is required for the loop.

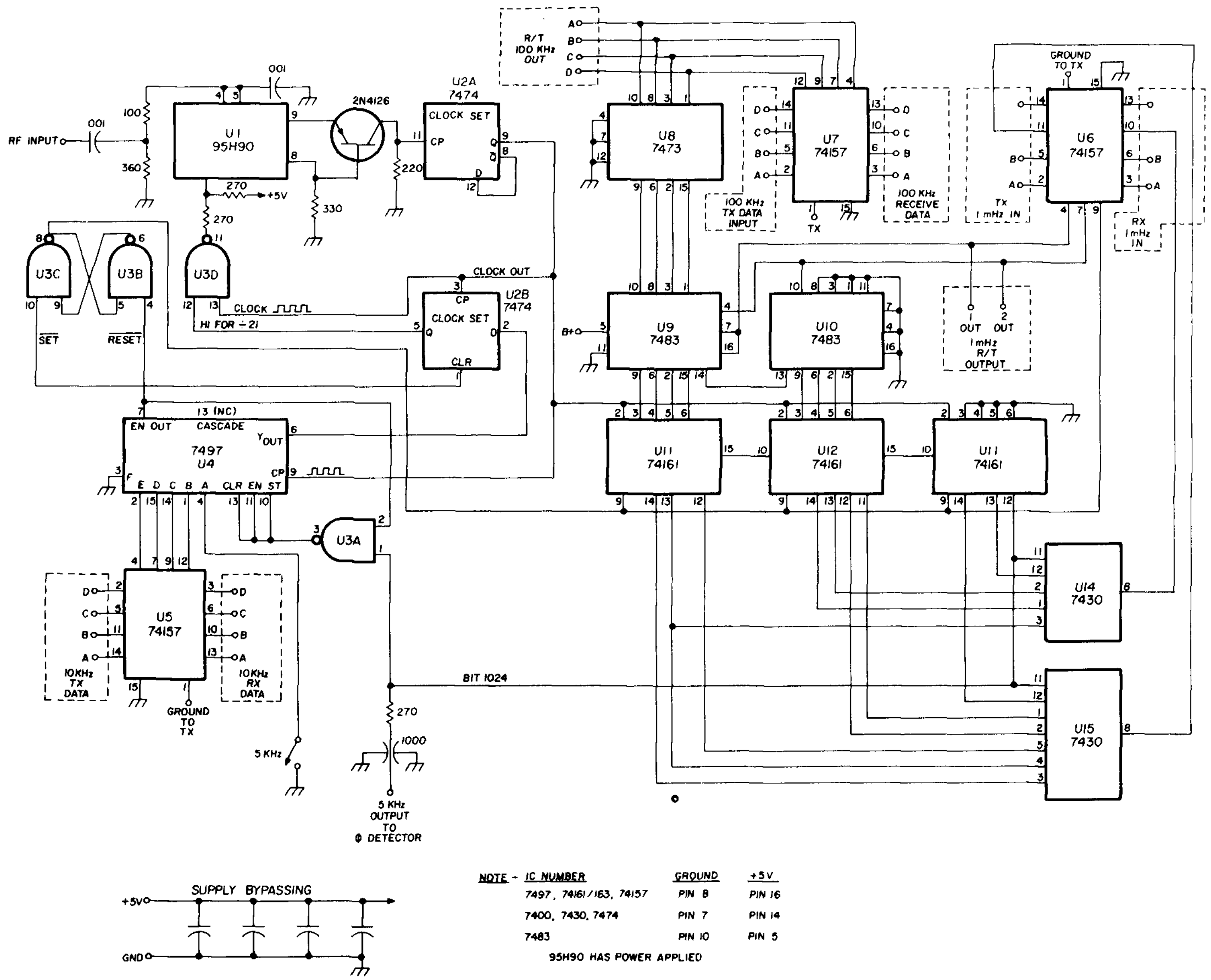


fig. 4. Schematic diagram of the digital board. The prescaler section contains the 95H90 and the dual-D flip-flop. Pin 2, SWALLOW ENABLE, controls whether the prescaler is in the divide by 20 or 21 mode. The 0.001 μF capacitor connected to pin 5 of U1 should be mounted close to the IC. The V_{CC} line requires bypassing with several values of capacitors to eliminate any switching transients from appearing on the line. Low-power Schottky ICs have been tested, and are recommended for replacement of the 74161/163, 7483, 74157, 7430, and 7474. When transmitting, the line marked TX should be grounded.

can substitute any combination which will tune from 144 to 159 MHz with a tuning voltage of not less than 2.5 volts nor more than 10.5 volts.

The MC1648 drives three rf amplifiers in parallel. Each stage is untuned and delivers at least 20 milliwatts into a 50-ohm load. Even though hand-wound transmission line transformers are used, the lack of tuning makes the boards less prone to parasitics. One output drives the digital logic, another is used for the receiver local oscillator, and the last drives the transmitter. In this case, the "transmitter" is nothing more than additional power amplifiers.

A CMOS CD4046 is used as a frequency/phase detector. During a channel change, it departs from true phase lock and forces the vco to slew back to the correct frequency. When this point has been reached, the CD4046's output becomes a series of pulses with a duty cycle that is proportional to the phase difference. As soon as the phase difference also reaches zero, the output from the CD4046 enters a third state that effectively disconnects it from the loop amplifier. When correction is needed, the detector switches into the appropriate state.

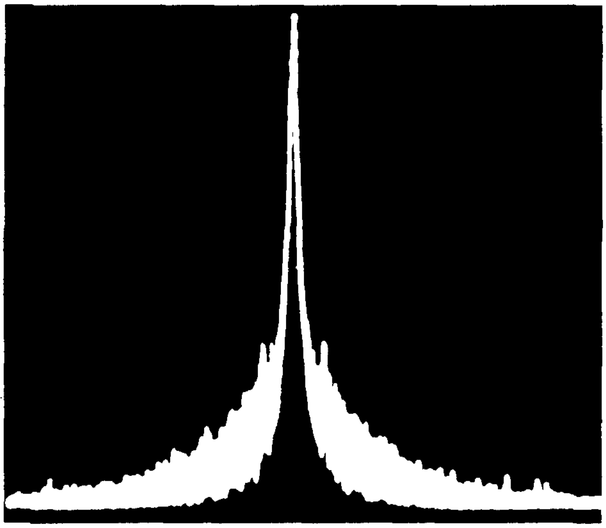
The advantages of the CD4046 over a simple phase detector are many. Among these are the faster response to large channel changes and also lower reference frequency sidebands in the rf output. A simple digital phase detector has a square-wave output with a 50 per cent duty cycle when locked. This represents no dc output so no further frequency change is required. However, there is a large ac output at the reference frequency which can be difficult to remove. In the design presented here, a locked condition is signalled by an open circuit from the detector which considerably simplifies the loop amplifier design. In practice the phase detector cannot operate at a zero phase difference and it has been set to produce an output pulse of approximately 5 per cent duty cycle.

The CD4046 drives a loop amplifier consisting of a MC1458V dual-operational amplifier. Despite what some articles on PLL would lead you to believe, more than just a lowpass filter is needed for optimum results. The first op amp could be classed as an integrator, but it also provides three time constants which insure stability of the loop. The second op amp is a simple 12 dB/octave lowpass filter which reduces the 5-kHz ripple on the tuning voltage. The simpler approach of using a lowpass filter versus a notch filter is justified since the performance improvement is very small.

The 5-kHz reference frequency is generated by the CMOS CD4060. This IC contains a 14-stage binary divider and three inverters for use as a crystal oscillator. The only other parts required are a parallel-resonant crystal and a few resistors and capacitors. The trimmer adjusts the crystal exactly to frequency and sets the final output accuracy.

audio

To produce direct fm, the audio is summed with



This spectrum analyzer photograph shows the output within 50 kHz of the center frequency. The 5-kHz sidebands can be seen to be 54 dB down from full output.

the tuning voltage after the op amps. The following requirements should be adhered to:

1. Audio compression and/or limiting should be used to hold constant deviation level.

2. Employ rapid rolloff past 3500 Hz to keep the radiated bandwidth narrow.

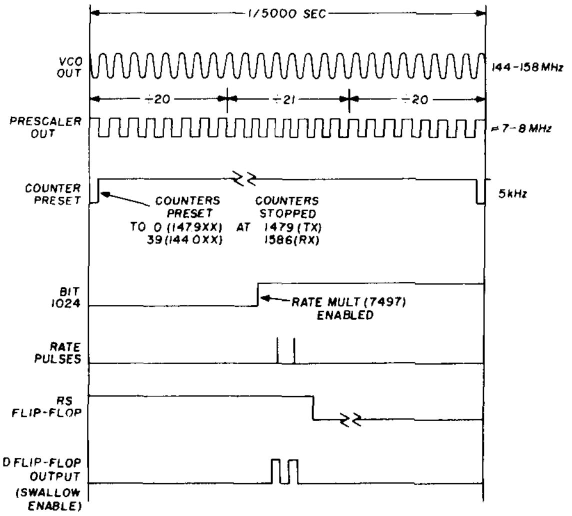


fig. 5. Programmable divider timing diagram. This diagram represents a frequency of 14X.X10 MHz.

3. Use standard 75 μsec pre-emphasis (**fig. 7**). This is direct fm and the audio will sound muffled if pre-emphasis is not included. The pre-emphasis should be applied after the clipping and filtering. There should be 1 volt p-p available after preconditioning the audio. As a warning, the vco has a sensitivity of 5 MHz/volt. Therefore, it only takes 1 mV of noise in the system to make this synthesizer useless in a narrowband fm system. Ground noise, loops, and proximity to other systems can also cause problems. The vco assembly *must* be housed in a completely sealed metal box. Diecast aluminum boxes are the best. Attempts at ultimate miniaturization will only produce 5 kHz whine, and possibly 60 Hz hum on the signal.

circuit board checkout

Digital card. The initial testing of the digital board can be done at a frequency that will allow the pulses to be seen without relying on a high performance oscilloscope. An approximately 0.8 V p-p, 10-MHz signal should be injected into pin 1 of the 95H90. With power applied, the prescaler will run warm and total current drain will be about 600 mA for standard TTL. The complementary output pins, eight and nine, of the 95H90 should show an ECL level square-wave (3.3V to 4.1 V). The waveform will alternate between *one tenth* and *one eleventh* of the input frequency, which will cause blurring of the oscilloscope display. With the rest of the prescaler section working properly, the binary counters (U11-U13) will have a clock input on pin 2 that alternates between 1/20 and 1/21 of the input signal. If multiples of 100 kHz are selected, the input to the binary counters will be 1/20 of the input frequency; otherwise blurring will occur.

When it has been confirmed that the prescaler is functioning properly, the divide by $M+1$ function can be disabled by applying 5 volts to pin 3 of the 95H90. If gates U14 and U15 are operating correctly, a narrow negative-going pulse will appear on pin 9 of the binary counters. This pulse is used to load the binary counters after each cycle has been completed, 1479_2 for transmit and 1586_2 for receive. The ratio of the pulses at pins 2 and 9 of U11-U13 will correspond to the channel selected, 1440 to 1479. If the transmit line is high, 107 will be added to the ratios. This process can be extended to the entire programmable counter. With the 95H90 input as B and the pulses at pin 9 of the counters A, the ratios will be:

144.00 MHz Transmit	B/A - 28800
144.005 MHz Transmit	B/A - 28801
146.940 MHz Transmit	B/A - 29388
146.940 MHz Receive	B/A - 31528
147.995 MHz Receive	B/A - 31739

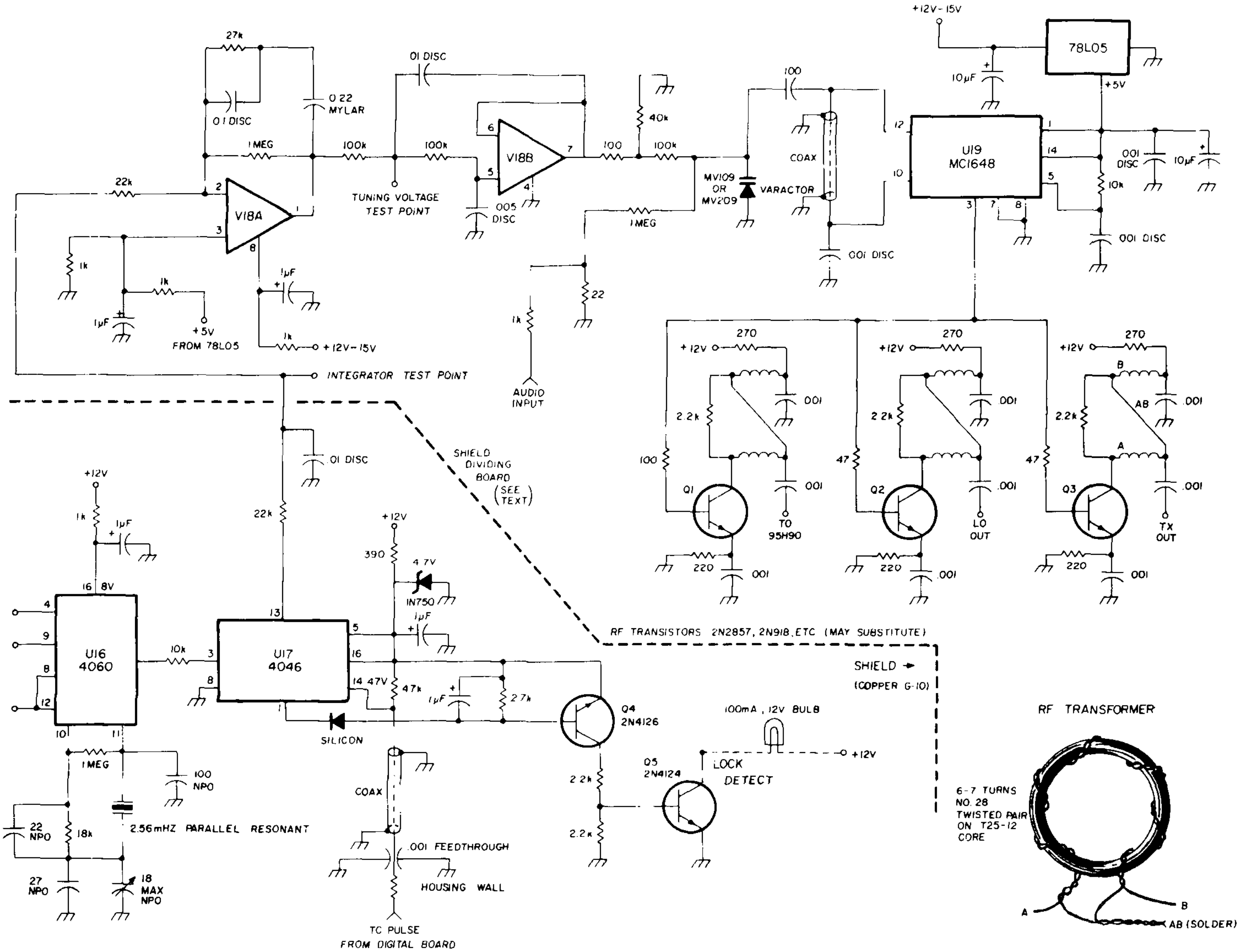


fig. 6. Schematic diagram of the rf circuitry for the synthesizer. All resistors are ¼ watt; the electrolytics are dipped radial lead tantalums. The coax line can be replaced with 3 turns of number 22 AWG (0.6mm) wire. It should initially be wound to be ¼-inch (0.6mm) in diameter. The final configuration will be dictated by the required tuning voltage vs tuning range. The rf transformers are 6 to 7 turns of number 28 AWG (0.3mm) twisted pair wound on a T25-12 core. The 2.2k resistors across the transformers are soldered on the back of the printed circuit board.

Rf Board. With power applied to the board from a 12-15 volt supply, the current drawn should be 60-75 mA. Check for the desired voltages on U16-U19 as shown on **fig. 6**. Testing of the vco and associated amplifiers will start at the vco and work back to the crystal oscillator. I recommend the Motorola MV109/209 varactor diode because of its wide ΔC range. This allows the vco to tune from 144 to 159 MHz with an input voltage of 2.5 to 10.5 volts. For test purposes only, the voltage can be supplied by a small adjustable supply connected to the test point just prior to the second op amp. Since the op amp has unity gain, correct operation of the vco can be determined from this point.

The integrator, first half of the MC1458, can be tested by grounding its inverting input. The vco should swing to at least 159 MHz when the junction of the two 22k resistors (integrator test point) is grounded. Conversely, it should move to below 144 MHz when 5 volts is applied to the same point.

At pin 4 of U16 there should be a 40-kHz square wave that can be used to set the crystal on frequency. By using the 125th harmonic of the 40-kHz signal, the crystal can be zero beated against the 5-MHz WWV frequency standard. The phase detector requires a 5-kHz input that is TTL compatible.

To test the phase detector, connect an NE555, or similar, oscillator to the 5-kHz pulse input on the rf board. With a pulse frequency less than 5 kHz, the vco should be driven to its lower frequency limit. If the pulse frequency is decreased below 5 kHz, the vco should swing to its upper limit. At this point the boards can be connected together forming an almost complete synthesizer.

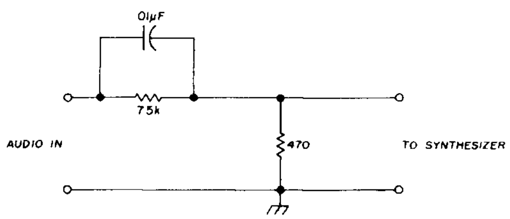


fig. 7. Schematic diagram of a standard 75 µsec pre-emphasis network.

Switches. Due to the method of generating the correct presets for the binary counters and inputs to the rate multiplier, two forms of input data were used, BCD and $\overline{\text{BCD}}$. The information for the 10-kHz frequencies is in the normal BCD form, while that for the 100 kHz and MHz is $\overline{\text{BCD}}$. Using the basic premise that an open on a line is equivalent to a digital 1 (high) the appropriate switches can be selected. It should be remembered that a $\overline{\text{BCD}}$ switch, not a BCD switch, produces four open circuits for a BCD zero. Regardless of the switch type you select, to use the switch in its true form connect the common terminal to ground and pull the four outputs to 5 volts through 4 to 10-kilohm resistors. To complement the switch, connect the common lead to 5 volts and pull each output to ground through 270-ohm resistors. **Table 1** shows the correct BCD input information. To add 5 kHz to the output frequency, the 5-kHz line should be taken high (1).

The complete synthesizer can now be tested. The appropriate inputs and outputs on the two boards can be connected with lengths of either miniature coax or twisted-pair cable. A small 12-volt lamp can be attached to the LOCK DETECT terminals. Since this is only a test, the output will not be very clean and the signal should not be put on the air. Connect one rf output to a frequency counter and terminate the third in 50 ohms. When power is applied to both boards the lamp should flash once and the synthesizer *should* be on the correct frequency. If the synthesizer does not lock at all, the lamp will remain lit.

table 1. Synthesizer truth table

1 MHz	B A	100 kHz	D C B A	10 kHz	D C B A
144	0 0	0.0	1 1 1 1	0.0	0 0 0 0
145	0 1	0.1	1 1 1 0	0.1	0 0 0 1
146	1 0	0.2	1 1 0 1	0.2	0 0 1 0
147	1 1	0.3	1 1 0 0	0.3	0 0 1 1
		0.4	1 0 1 1	0.4	0 1 0 0
		0.5	1 0 1 0	0.5	0 1 0 1
		0.6	1 0 0 1	0.6	0 1 1 0
		0.7	1 0 0 0	0.7	0 1 1 1
		0.8	0 1 1 1	0.8	1 0 0 0
		0.9	0 1 1 0	0.9	1 0 0 1

troubleshooting

If there are problems, a return to the circuit board checkout phase might be appropriate. Remember that this is a feedback system and trouble in one section can cause apparent difficulty in another. A good way to troubleshoot the unit is to clamp the tuning voltage at some fixed value from an external power supply. If the vco will not tune within the desired range, lock cannot be achieved.

A more subtle problem is a locked synthesizer but with the output on the wrong frequency. The cause of this problem will be found on the digital board, assuming the initial 5-kHz signal is correct. Make sure that the components are soldered on each side of the printed-circuit board. Unless plated-through holes are used, it may be difficult to solder sockets on both sides of the board. One solution is to use Molex pins, another is to mount the sockets over spacers. If the synthesizer is still off frequency, observe the pattern of the errors.

1. No channel spacing less than 100 kHz. This means that the divide by 21 function of the prescaler is not being enabled. Start at pin 2 of the 95H90 and work back to pin 6 of the rate multiplier (U4).

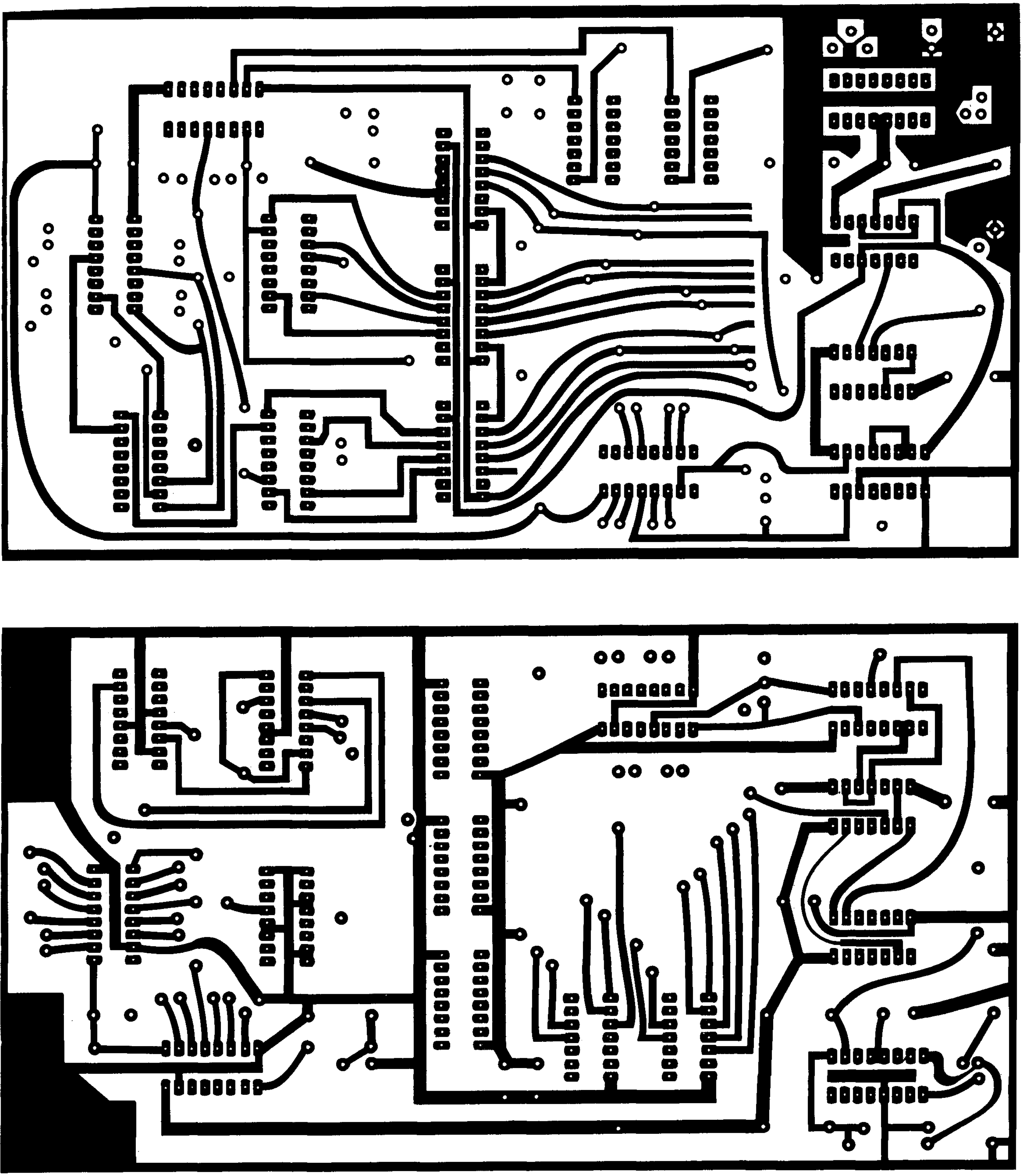


fig. 8. Circuit-board layout for the digital board. The top diagram shows the foil pattern for the top of the board, while the other side of the board is shown at the bottom.

2. Constantly high frequencies. The divide by 21 feature is being enabled too long.

3. Constant error in hundreds of kHz could mean that a 7483 full adder is faulty. They convert the $\overline{BCD}$ data into a binary code.

4. An output that is correct only on alternating binary increments means that a bit has been dropped between the 7483s and the preset inputs of the counters. For example, 144.000 to 144.200 is correct, 144.200 to 144.400 is wrong, and 144.400 to 144.600 is correct, etc.

5. If one of the 7430s (U14 or U15) is bad, either *all* the transmit or *all* the receive channels will be off.

Substitution is the best method of checking the ICs. You can save enormous amounts of time by mounting them in sockets, except the MC1648 and 95H90. If you don't have adequate test equipment, use a signal generator at a lower frequency to test the digital board.

synthesizer related problems

With the techniques used to generate this type of synthesized equipment, there can be many problems that are system oriented. Some areas may require a look at the overall performance before the basic problem can be solved.

1. Sidebands at the TTL clock rate are caused by insufficient isolation between the circuit boards. If these sidebands are radiated by your transmitter, they are illegal; they will appear at the output frequency divided by 20, 144.00 ± 7.2 MHz, ± 14.4 MHz ± 21.6 MHz, etc. The general cure for this type of problem is to put the rf board into a sealed metal box (leads that enter the box should go through 0.001 μF feedthrough capacitors).

2. This synthesizer delivers 10 kHz p-p deviation with less than 0.2 volt input so it will be prone to overmodulation. The deviation can be set quite easily if you make use of the synthesized local-oscillator output. With this output connected to a receiver, modulate the synthesizer until the audio level is the same as a local repeater. It doesn't matter to the discriminator whether its's the actual incoming signal that is being modulated or the local oscillator. For normal operation though, use a relay contact to short out the audio line during receive periods. Otherwise, audio feedback will occur.

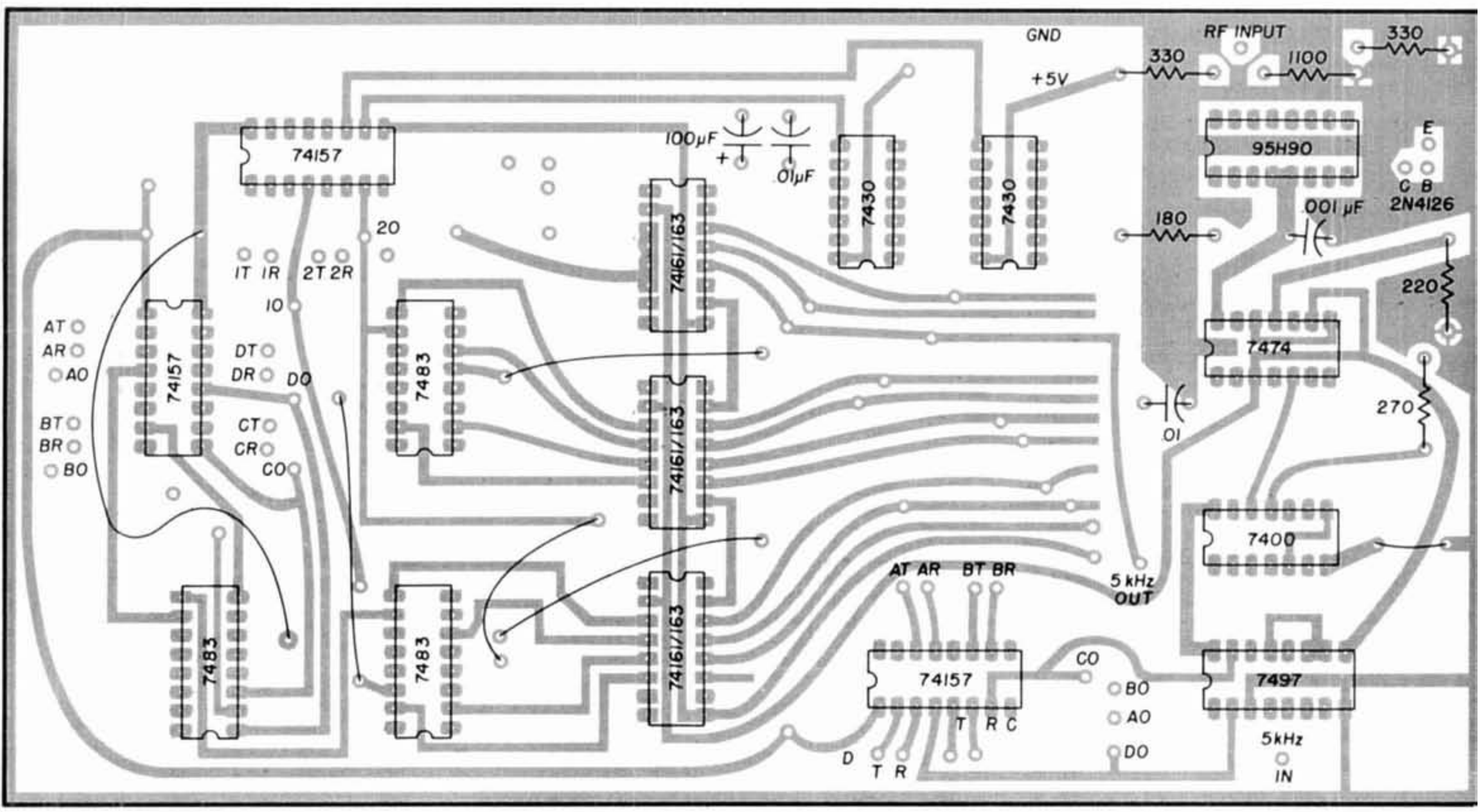


fig. 9. Component placement for the digital board.

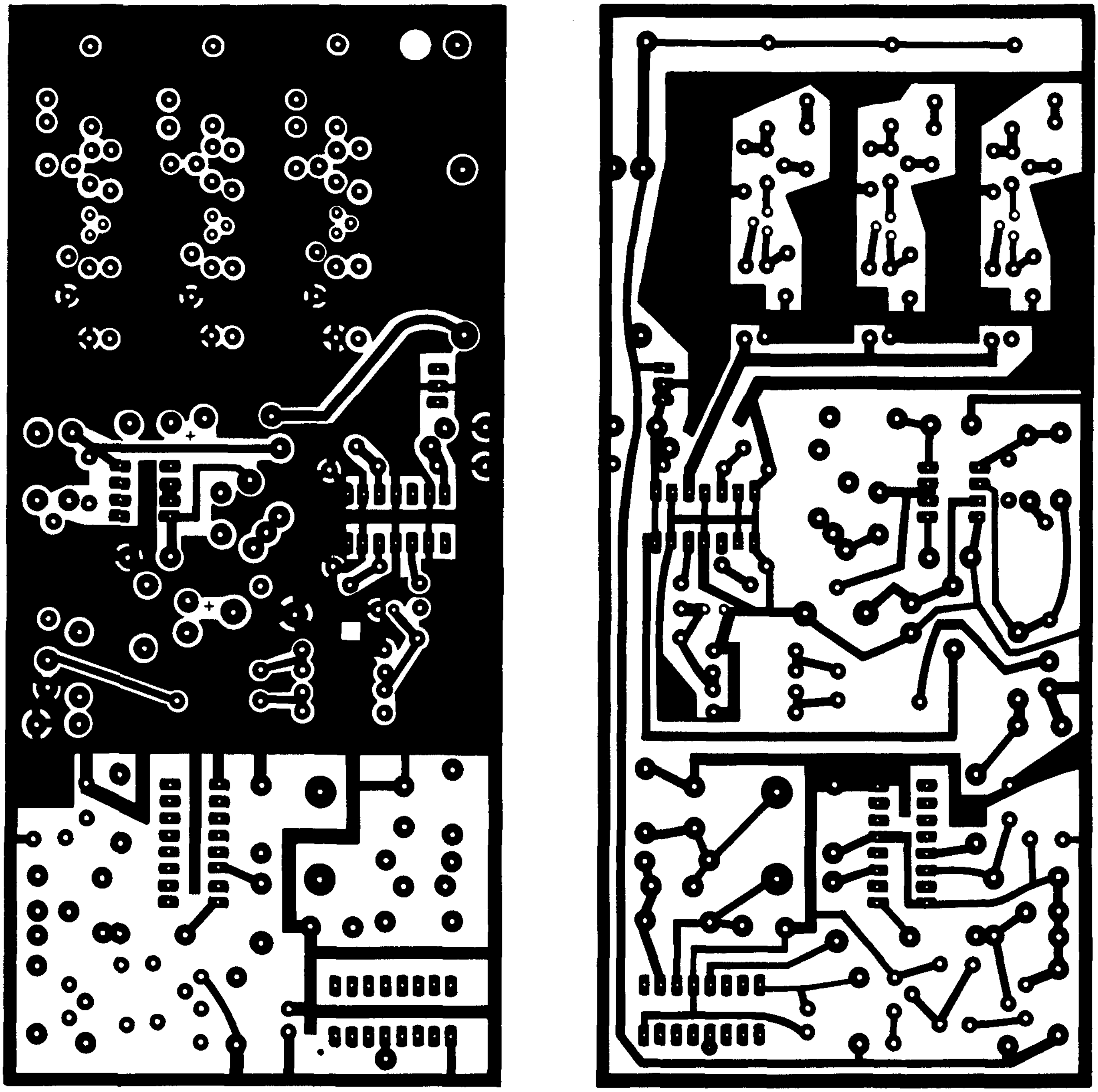


fig. 10. Circuit-board layout for the rf board. The top of the board is shown at the left and the bottom at the right.

3. *Sidebands at 5 kHz cause annoying whine in your receiver and will be transmitted as well.* Any sidebands experienced are caused by the physical placement of the rf board. Also, the shield between the portions of the board must be in place. This can be made from a piece of double-sided printed-circuit board. The output of the digital board must enter the enclosure through the resistor and capacitor combinatigns shown on the schematic diagram (**fig. 4**).

4. Receiver birdies are possible if the programmable divider is not shielded. Microphonics are not a problem and the enclosure does not have to be some type of sealed box. To avoid the problem of many feedthrough capacitors for the digital switches, I suggest that you mount the switches inside this box.

If you follow the previous suggestions, a clean transmitter should be no problem. I use four amplifier stages to directly increase the output to 40 watts. The LOCK DETECT output should be used to prevent keying the transmitter if the synthesizer is running wild.

receiver interfacing

To be entirely free of birdies, on-channel spurious radiations must be on the order of 100 dB below the local-oscillator level. Achieving this requires constant attention to smalll details such as shielding, removal of ground loops, and maintaining isolation. Certain receiver designs can give you perhaps 20 dB margin against such birdies (this assumes the birdies are

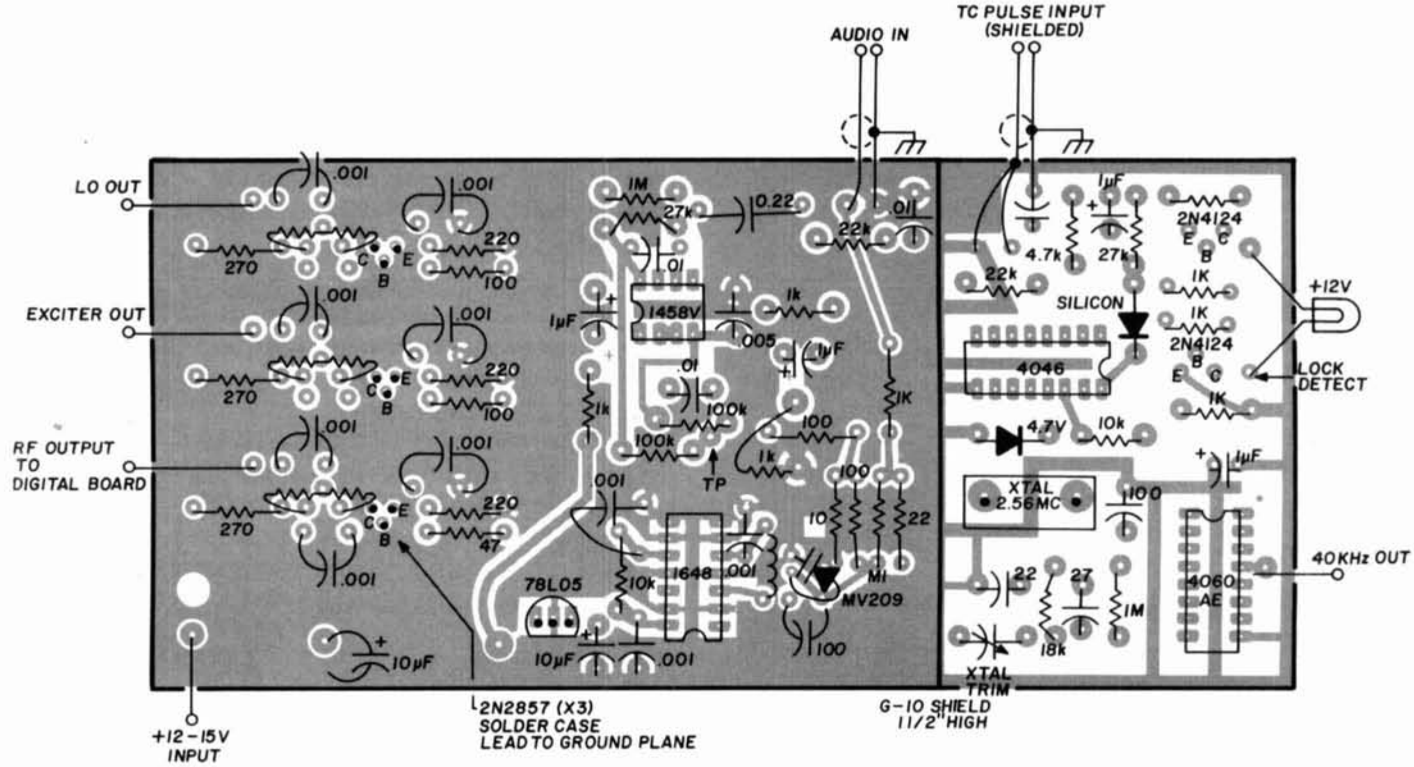


fig. 11. Parts placement diagram for the rf board. The resistor across the toroids is mounted on the rear of the board.

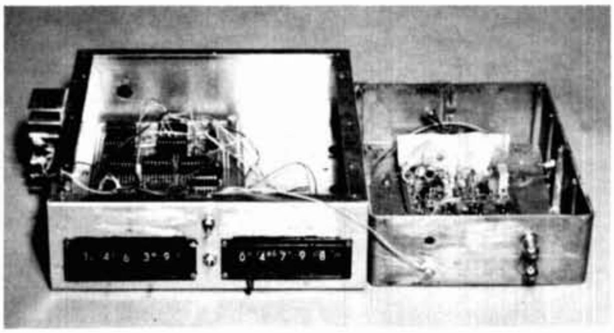
produced by the local oscillator and not radiated into the frontend).

A product or balanced mixer has the ability to reject certain forms of noise near the local-oscillator frequency. If you are contemplating the design of a companion receiver, think twice before going with the now standard dual-gate MOSFET mixer. A better choice might be a JFET mixer using a device such as the high I_{dss} U310. A single-balanced mixer with this transistor will have a wider dynamic range as well as significant local-oscillator noise rejection. These items are important when operating in urban areas, or when trying to achieve 0.2 μV sensitivity on all channels.

No matter what first mixer configurations you select, two old design rules still apply.

1. Set your mixer so that conversion gain does not increase if you raise the local-oscillator power. If it does, the local-oscillator port is not saturated and the receiver will be overly sensitive to birdies and noise from the synthesizer.

2. The input ports of the first mixer should see only the minimum necessary bandwidth. If you don't filter the i-f output, you'll have no selectivity, obviously. Image and intermod problems will occur if the rf input isn't filtered. This includes both sides of the rf amplifier. If the local oscillator isn't filtered, you will have a severely degraded mixer noise figure. This applies more to single-ended mixers. Such a mixer acts as a high-gain amplifier to i-f frequency signals injected into either input. The solution is a highpass filter or, preferrably, a tuned circuit with a moderate loaded Q in the injection line. The tuned circuit



Photograph of the completed synthesizer. The rf circuitry is housed in the cast aluminum box on the right. The digital portion of the synthesizer is on the left.

serves the dual purpose of voltage transformation as well which can be useful in gate-driven fet mixers.

The previous comments should enable you to build a transceiver equal in all respects, except one, to a crystal-controlled unit. The final problem area is ultimate receiver selectivity. The noise sidebands of the MC1648 do not fall off quite as fast as those of a well designed discrete vco. The difference is slight and transmitter performance is uneffected. Residual audio fm measures less than 100 cps in this design. However, adjacent channel rejection in the receiver will be degraded. In normal operation, crystal-controlled equipment would be able to maintain DX communications within 10 kHz of a repeater channel. This design will require a spacing of about 15 kHz from the active channel. The difference is not noticeable unless your receiver has a good quality i-f filter and the shielding necessary to make full use of it. Also, you'd have to check closely to notice the difference. It is worth mentioning that Heathkit chose the same vco for their down-converting multiple-crystal synthesizer; they were able to attain a 30-kHz selectivity of 60 dB minimum.

convenience options

Because the synthesizer has the BCD frequency data available at all times, some other type of display can be connected. It would be much easier to see a seven-segment display in the dark than the thumbwheel switches. In fact, you do not need switches at all. The channel information could be generated by a circuit that would scan a frequency range until a signal is detected. The combinations are almost endless. Remember though, both BCD and $\overline{BCD}$ data is required.

conclusions

I hope that this article has removed some of the air of black magic that seems to have been associated with frequency synthesizers in the past. Unlike other articles, this one was concerned with how to get the radio to work, what you can expect to go wrong with it, and what you can do about it. Most of the literature on synthesizers has been an endless tirade about Laplace transforms and loop stability. These are important, but a critically damped response and the associated theoretical model by themselves only make a good BSEE senior term paper. This unit has been on the air for a year at WB2CPA, and successful duplication should not pose a problem to a reasonably competent amateur.

ham radio

how to design Yagi antennas

Discussion of a new Yagi design method, developed at the National Bureau of Standards, which allows you to design Yagis for your own operating requirements with optimized, reproducible gain characteristics

Have you ever wondered how to design a really good Yagi for your own requirements rather than just guessing, or using an existing design? If so, this article should be just what you are looking for. By using the information presented here you can design your own optimum Yagi for any frequency, from hf through uhf, with booms up to 4.2 wavelengths long.

Up until now, there has been little design information for Yagi antennas in the amateur literature. Kmosko and Johnson[1] designed a 13-element Yagi at 144 MHz but gave information only on that specific model. Greenblum[2] provided ranges of design values but was not specific as to exact sizes. The tables from Greenblum's article have appeared in recent *ARRL VHF Handbooks* and *Antenna Handbooks,* and several amateurs have reported good correlation using the mean values specified. Recent articles in the professional journals (such as the *IEEE Professional Group on Antennas and Propagation,* and others) have published computer-aided designs, but specific *cook-book* information is not available.

Now, for the first time, a straightforward approach to Yagi designs of various sizes and gains is available.[3] It is the result of an exhaustive study by the National Bureau of Standards in the early 1950s to explore all the major antenna types (Yagis, corner reflectors, rhombics, etc.) suitable for use on vhf

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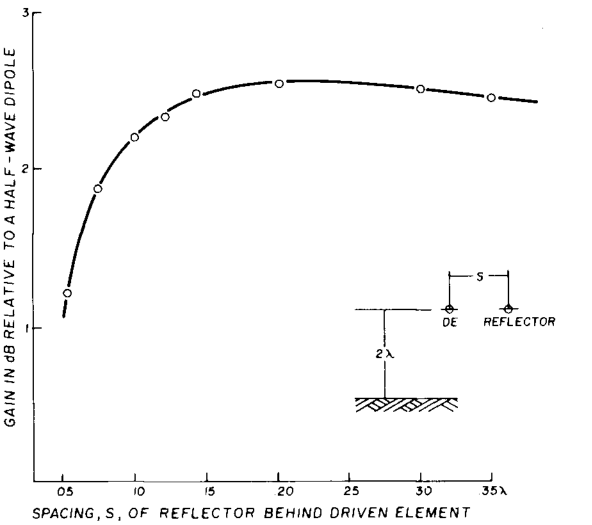

fig. 1. Gain in dB of a driven element and reflector for different spacings between elements.

ionospheric scatter. The NBS report tabulates all the design information necessary to construct six different boomlength Yagis (this portion of the project took nine man years to complete). The only known amateur use of these data are the WØEYE 432-MHz Yagi[4] and several unpublished Yagi designs by WØPW (ex WØEYE) and W1JR.

This NBS report shows the interrelationship between director and reflector diameters, lengths, and spacings, as well as the effects of a metal supporting boom. Optimum designs and gains for various boomlengths from 0.4 to 4.2 wavelengths are shown along with nomographs for designing a Yagi for your own operating requirements. Those readers who are interested in all the specifics will find the NBS publication invaluable. This article will highlight the results and present all the information necessary to design such Yagis; several working design examples will also be discussed.

reflectors

During the NBS investigation into optimum Yagi design, various reflector lengths and spacings were tried on a two-element Yagi. As can be seen from **fig. 1**, maximum gain is 2.6 dBd, peaking broadly at 0.2λ behind the driven element. Hence, all the Yagi designs presented here are optimized using this reflector spacing.

The NBS engineers tried various other reflector configurations in order to realize any possible increase in gain. The trigonal configuration shown in **fig. 2** yielded the maximum increase, 0.75 dB over a single reflector, when tested on a Yagi 4.2λ long. It should be applicable to the other designs and may be desirable if high front-to-back ratios are desired.

The heart of any Yagi design is the director. Extensive tests have shown that the diameter, length, and spacings are all interrelated. Also, it should be pointed out that these parameters become increasingly critical as the number of directors (and hence the boomlength) increase.

NBS tested various director lengths using spacings of 0.01 to 0.40λ on booms to 10λ long. Plots of these combinations show that there are optimum spacings for maximum gain. As the boomlength is increased, the optimum director spacing also increases. In addition, the gain of the antenna can be further increased if the length of each director is carefully chosen. It is noted that the diameter of the element affects its length, thicker directors being shorter than thinner ones. A comparison of maximum gain versus boomlength for uniform and optimized length directors is shown in **fig. 3**. Those readers desiring further information are referred to *NBS Technical Note 688*.[3]

A set of optimum director and reflector lengths normalized to 0.0085λ diameter elements is

table 1. Optimized lengths of parasitic elements for Yagi antennas of six different lengths (reflector spaced 0.2λ behind driven element, element diameter 0.0085λ).

	Length of Yagi in Wavelengths					
	0.4	0.8	1.20	2.2	3.2	4.2
Length of Reflector, λ	0.482	0.482	0.482	0.482	0.482	0.475
1st	0.442	0.428	0.428	0.432	0.428	0.424
2nd		0.424	0.420	0.415	0.420	0.424
3rd		0.428	0.420	0.407	0.407	0.420
4th			0.428	0.398	0.398	0.407
5th				0.390	0.394	0.403
6th				0.390	0.390	0.398
7th				0.390	0.386	0.394
8th				0.390	0.386	0.390
9th				0.398	0.386	0.390
10th				0.407	0.386	0.390
11th					0.386	0.390
12th					0.386	0.390
13th					0.386	0.390
14th					0.386	
15th					0.386	
Spacing between directors, in λ	0.20	0.20	0.25	0.20	0.20	0.308
Gain relative to half-wave dipole, dB	7.1	9.2	10.2	12.25	13.4	14.2
Design curve (see fig. 4)	(A)	(C)	(C)	(B)	(C)	(D)

presented in **table 1**. These data, with respective gains noted, yield optimum performance for the six boomlengths which are shown. If a different element diameter is desired (isn't that always the case?), the elements can be scaled by using the nomograph in **fig. 4**. Element diameters from 0.001 to 0.04λ can be easily scaled as will be discussed later.

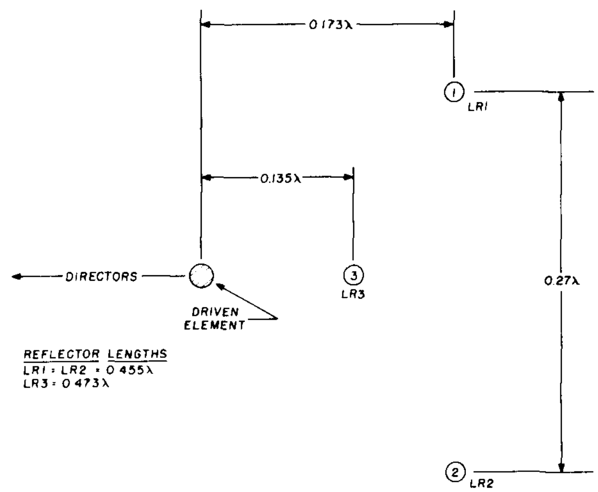

fig. 2. Trigonal reflector arrangement (three reflector elements), when used with 4.2λ Yagi, provides 0.75 dB increase in gain (lengths *not corrected for boom thickness*).

The element data presented in the NBS report is based on an *air* boom which, in the original tests, was simulated by a triangular plexiglass structure. After optimization was completed, various booms and materials were tested to check the effects of the test boom. All measurements verified that the designs tested on plexiglass were optimum in an air dielectric. However, attempts to repeat these results using wooden booms were dismal. According to Peter Viezbickie, the author of the NBS report, changes in moisture and directivity due to the wooden booms made repeatability almost impossible despite various coatings applied to the wood.

Metal-boom Yagis were entirely repeatable if the elements were lengthened to compensate for the boom structure. At first glance, it may seem that a constant factor could apply. However, tests conducted by NBS showed that small diameter booms (with respect to wavelength) had less effect on element lengths than larger booms. These data are plotted on **fig. 5** for boom diameters up to 0.04λ. Tests also showed that, for correction purposes, the effect of square and round booms were identical.

feed systems

Detailed feed systems are not discussed in the report. On most tests, a folded dipole using a 4:1 half-wavelength coaxial balun was followed by a stub tuner. However, any of the usual feed systems can be used.[5] Reference 6 describes how to test these matching systems.

patterns

Finally, the NBS report shows radiation patterns for the E and H planes. For the sake of brevity, only the patterns for the 1.2λ and 4.2λ Yagis are presented in this article (see **figs. 6** and **7**). You will note the symmetrical pattern, the low side lobes, and the high front-to-back ratio, all characteristics of a well-designed Yagi antenna.

Tests made by W6FZJ and WØEYE on a 15-element, 4.2λ Yagi for 432 MHz, designed with the method described in this article, showed that the antenna had about 1% vswr and 1-dB gain bandwidth, slewed to the low-frequency side of the center design frequency; performance above the center frequency fell off quite rapidly. It is estimated that the gain and vswr bandwidth for the 1.2λ Yagi is about 2%. It should be pointed out that the bandwidth of a Yagi is quite often limited by the matching and feed system, not by the basic Yagi design. In this respect most amateur beams use narrowband feed systems compared with Yagis designed for use in commercial service.

designing a yagi antenna

We will now proceed to design a 1.2λ Yagi for 50.1 MHz, a 2.2λ Yagi for 205 MHz, and a 4.2λ Yagi for

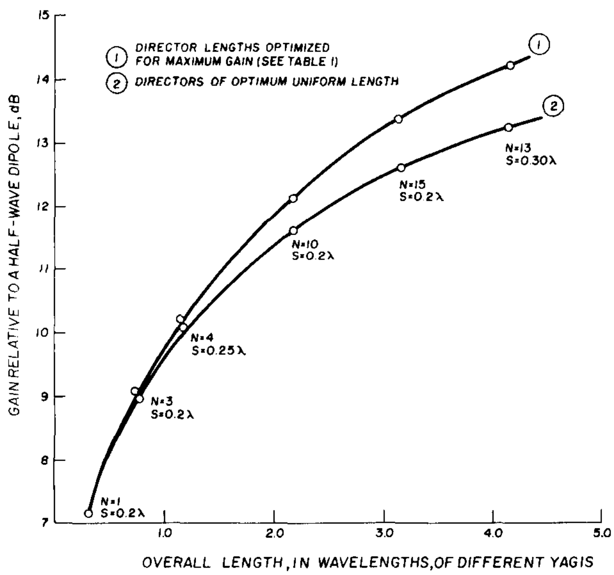

fig. 3. Gain comparison of different length Yagis, showing the relationship between directors optimized in length to yield maximum gain, and directors of optimum uniform length. N is the number of directors; S is the spacing between directors (reflector spaced 0.2λ on all antennas).

432 MHz to demonstrate how the NBS design material can be used. I actually built and tested each of these designs to verify the validity of the design data. In all cases the performance of the finished antennas matched the results reported by NBS.

The first step in any design is to choose the desired gain, compare it with the designs in **table 1**, and see if the stated boomlength is within the desired range. Next, the element diameter should be chosen to fall within the specified ranges (0.001 to 0.04λ) on the design nomograph, **fig. 4**. Finally, the boom or supporting structure should be chosen.

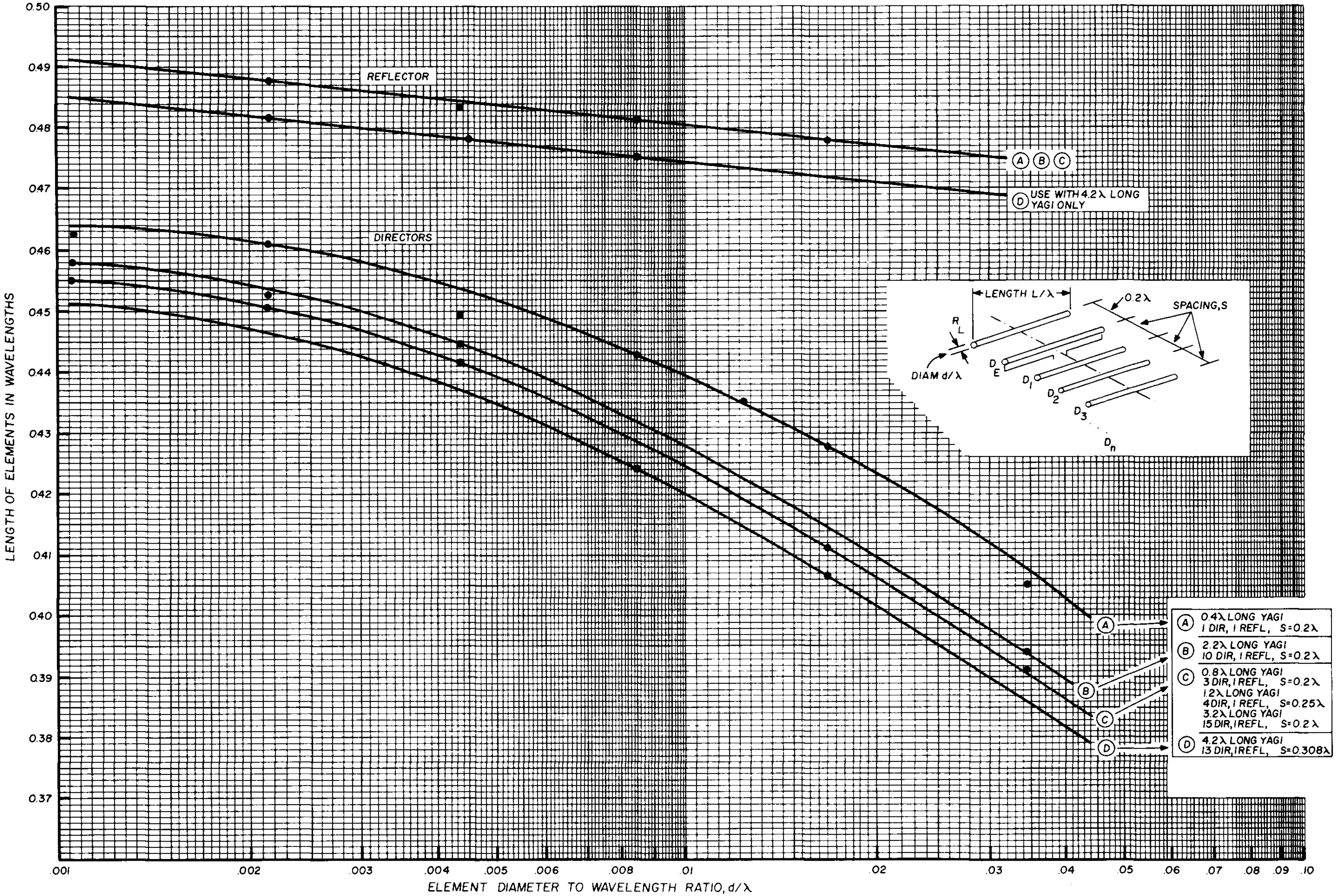

fig. 4. Yagi antenna design nomograph showing the relationship between element diameter to wavelength ratio (d/λ), and element length for different antennas. Detailed procedure for using this chart is presented in the text.

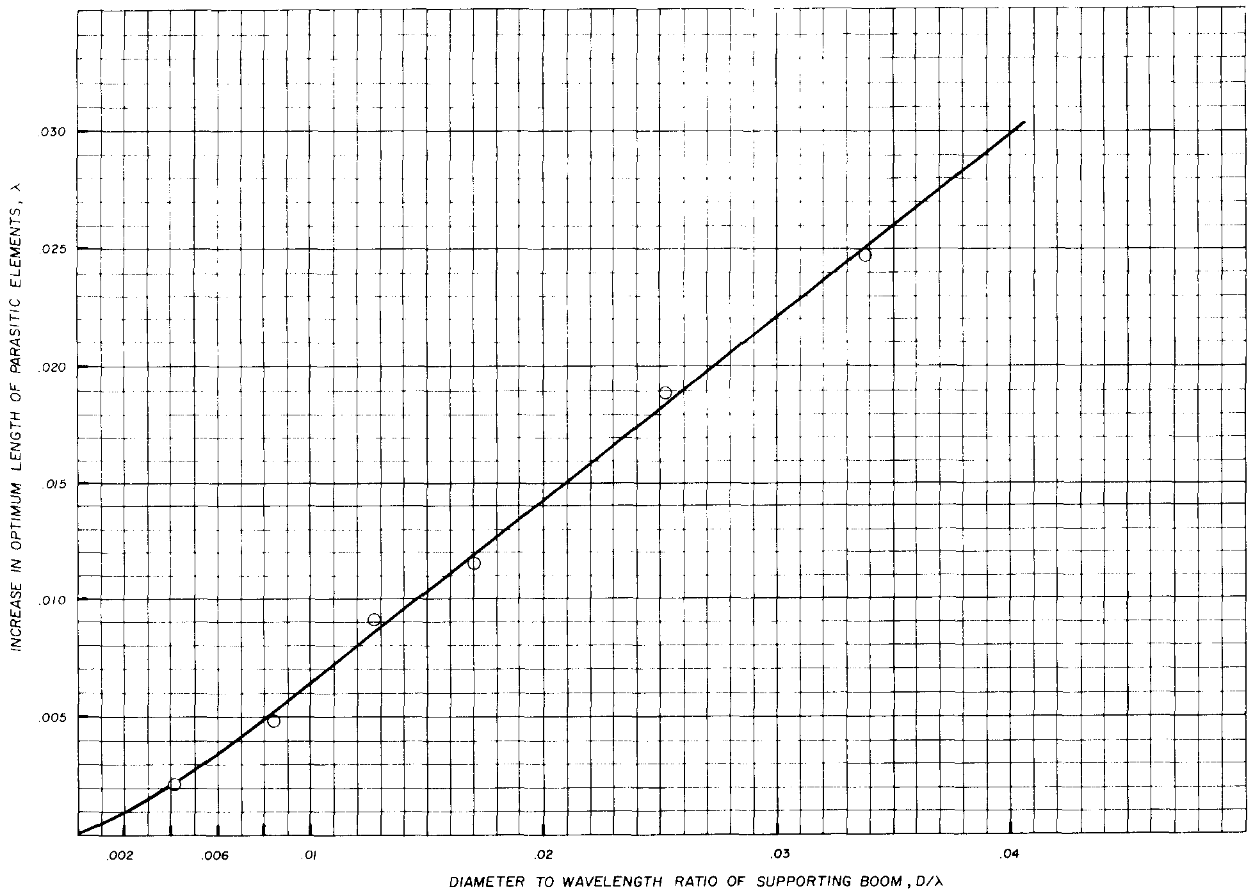

fig. 5. Graph showing the effect of a supporting metal boom on the length of the parasitic elements.

Example 1. It is desired to build a 6-meter Yagi with 10.2 dBd gain, using 0.5 inch (13mm) diameter elements mounted on insulating blocks above a 1.5 inch (38mm) diameter boom. This is the 1.2λ design in **table 1**.

The formula for wavelength is

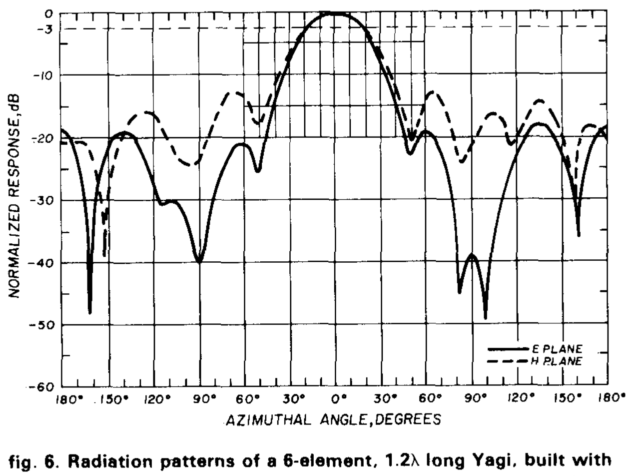

fig. 6. Radiation patterns of a 6-element, 1.2λ long Yagi, built with the dimensions shown in table 1. Beamwidth of the *E* plane is 40 degrees; *H* plane beamwidth is 42 degrees.

$$L = \frac{11803}{F} \ (inches) \qquad (1)$$

$$L = \frac{29980}{F} \ (cm) \qquad (2)$$

where L = length
F = frequency in MHz

Frequency	50.1 MHz
Wavelength	235.6 inches (5.98 meters)
Element diameter (d/λ)	0.0021λ
Reflector spacing	47 inches or 120 cm (0.2λ)
Director spacings	59 inches or 150 cm (0.25λ)
Boom diameter	not important, discussed later
Overall length	283 inches (approximately 24 feet) or 7.2 meters (1.2λ)

1. *Plot the lengths of the parasitic elements for the* 1.2λ design from **table 1** on the design nomograph

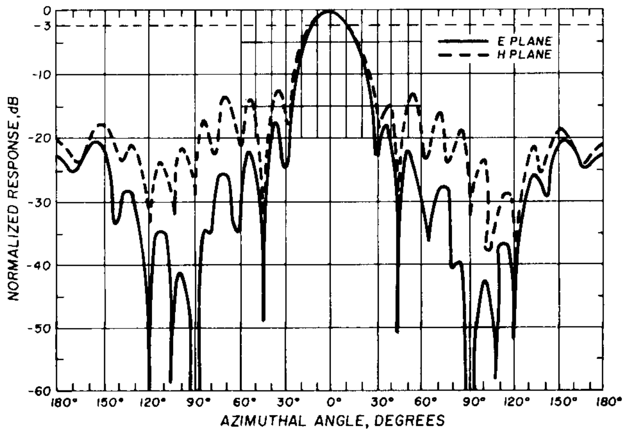

fig. 7. Radiation patterns of a 15-element, 4.2λ long Yagi. Beamwidth of the E **plane is 26 degrees;** H **plane beamwidth is 29 degrees.**

(see **fig. 8**) for parasitic elements with a diameter, $d/\lambda = 0.0085\lambda$.

$$L_R = 0.482\lambda$$
$$L_{D1} = L_{D4} = 0.428\lambda$$
$$L_{D2} = L_{D3} = 0.420\lambda$$

2. However, our element diameters are 0.0021λ so the element lengths must be adjusted. Draw a vertical line from 0.0021λ on the horizontal axis on the nomograph. This intersects the compensated lengths for the reflector and directors 1 and 4:

$$L_{R'} = 0.488\lambda$$
$$L_{D1'} = L_{D4'} = 0.451\lambda$$

3. Using a pair of dividers (or a compass), measure the distance between director 1 (D1) and director 2 (D2) determined in **step 1**. Transpose this distance from the point established in **step 2** to the left along the 1.2λ Yagi curve to 0.0021λ to determine the compensated length for directors 2 and 3:

$$L_{D2'} = L_{D3'} = 0.446\lambda$$

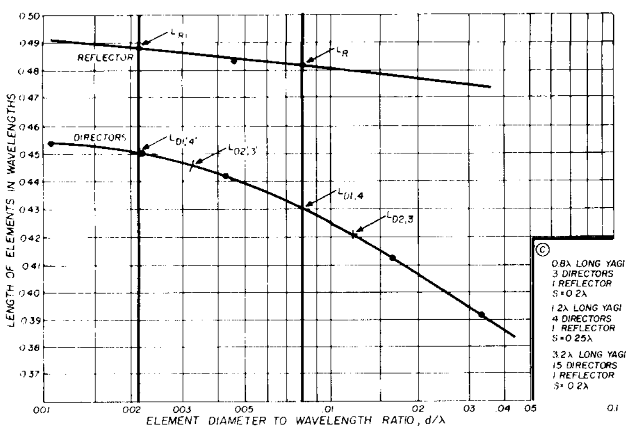

fig. 8. Use of the Yagi design curves (fig. 4) to determine the element lengths for a 6-element, 50.1-MHz Yagi on a boom 1.2λ long (see example 1 in text).

When I built this antenna I decided to use large element insulating blocks which I purchased from Swan Antennas (now KLM). Therefore, it wasn't necessary to put the elements through the boom. Since the wavelength is long with respect to the chosen boom diameter, I didn't feel that any boom correction was necessary. This was verified by subsequent tests. When the boom diameter represents a substantial portion of the operating wavelength, however, a correction for the boom diameter is required; this will be discussed in *example 3*.

The reflector and director lengths for the 50.1-MHz Yagi are as follows:

Reflector	0.488λ = 115 inches (2.92m)
Director 1	0.451λ = 106.25 inches (2.70m)
Director 2	0.446λ = 105.06 inches (2.67m)
Director 3	0.446λ = 105.06 inches (2.67m)
Director 4	0.451λ = 106.25 inches (2.70m)

The approximate length of the driven element can be calculated from

$$L = \frac{5500}{F} \ (inches) \quad \textbf{(3)}$$

$$L = \frac{13970}{F} \ (cm) \quad \textbf{(4)}$$

where L = length
F = frequency in MHz

Therefore, at 50.1 MHz, the length of the driven element is 109.75 inches or 2.79 meters. For simplicity I decided to use a gamma match and to attach the driven element to the boom with a U bolt. During the matching adjustments the driven element was short-

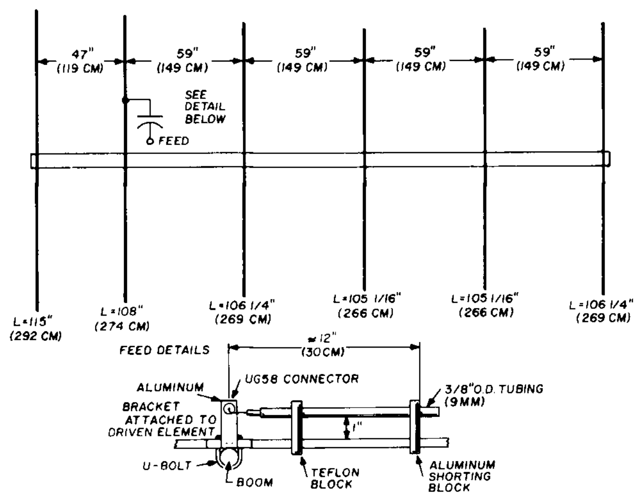

fig. 9. Layout of a 6-element Yagi for 50.1 MHz on a 1.2λ boom. All elements are ½ inch (13mm) OD aluminum tubing, mounted on insulating blocks attached to a 1½ inch (38mm) OD aluminum boom. The gamma capacitor is approximately 12 inches (30cm) of RG-8/U coaxial cable with the outer jacket and shield removed, then inserted in a 3/8-inch (10mm) diameter tube.

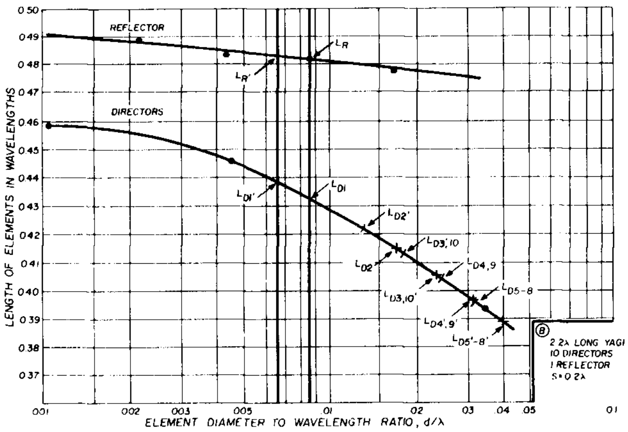

fig. 10. Use of the Yagi design curves (fig. 4) to determine the parasitic element lengths for a 12-element 205.25-MHz Yagi on a boom 2.2λ long (example 2).

ened to 108 inches (2.74m) for optimum vswr (the length of the driven element is not critical for maximum gain, as will be discussed later).

The completed 6-meter Yagi is shown in **fig. 9**. On-the-air receiving tests at W1JR have shown the 3 dB beamwidth to be between 40-45 degrees, while all sidelobes were at least 15 dB down; the front-to-back ratio was 18 dB. This agrees closely with the published NBS data.

Example 2. During the summer of 1973, when I was W6FZJ, transpacific tests to Hawaii were conducted on 220 and 432 MHz. Television video carriers seemed like a good propagation indicator so I designed a converter for Channel 12 on Mt. Haleakela on Maui. Since I had no good designs for a moderate gain Yagi with low sidelobes (to discriminate against Channel 12 TV stations in California), I chose the NBS 2.2λ Yagi design using 3/8 inch (1cm) diameter elements.

Frequency	205.25 MHz
Wavelength	57.5 inches (1.46 meters)
Element diameter (d/λ)	0.0065λ
Reflector spacings	11.5 inches or 29.2 cm (0.2λ)
Director spacings	11.5 inches or 29.2cm (0.2λ)
Boom diameter	not important, discussed later
Overall length	126.5 inches or 3.21 meters (2.2λ)

1. Plot the director element lengths for the 2.2λ Yagi design from **table 1** on the design nomograph (see **fig. 10**) for $d/\lambda = 0.0085$.

$L_R = 0.482\lambda$
$L_{D1} = 0.432\lambda$
$L_{D2} = 0.415\lambda$
$L_{D3} = L_{D10} = 0.407\lambda$
$L_{D4} = L_{D9} = 0.398\lambda$
L_{D5} through $L_{D8} = 0.390\lambda$

2. Since the chosen element diameters are 0.0065λ, draw a vertical line from 0.0065λ on the horizontal on the nomograph. This intersects the compensated length for the reflector and the first detector:

$L_{R'} = 0.483\lambda$
$L_{D'} = 0.4375\lambda$

3. Using a pair of dividers, measure the distance be-

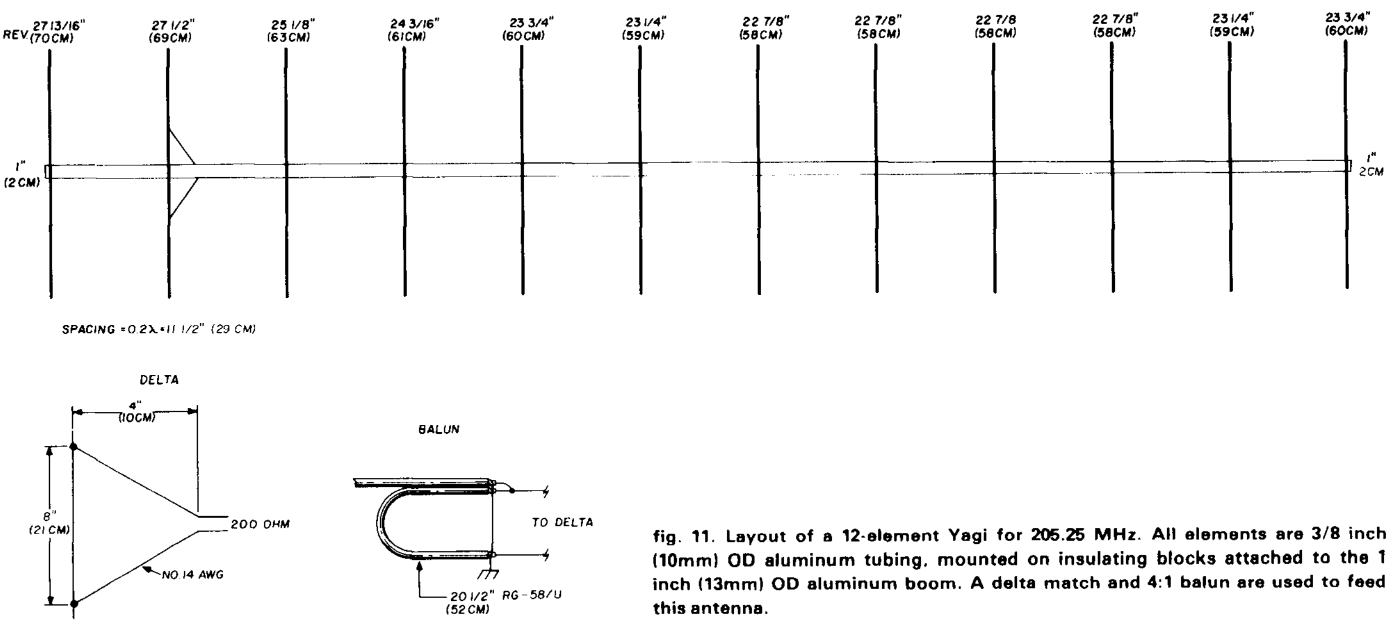

fig. 11. Layout of a 12-element Yagi for 205.25 MHz. All elements are 3/8 inch (10mm) OD aluminum tubing, mounted on insulating blocks attached to the 1 inch (13mm) OD aluminum boom. A delta match and 4:1 balun are used to feed this antenna.

tween director 1 (D1) and director 2 (D2) determined in **step 2**. Transpose this distance from the point established in **step 2** to the left along the 2.2λ curve to determine the compensated length of director 2 ($L_D{}' = 0.421\lambda$). Now span the distance between directors 1 and 3 (D1 and D3) with the dividers, and move this dimension along the curve, making sure to reference D1′ (at the 0.0065 line). Follow this same procedure until all directors have been scaled. The remaining director lengths are as follows:

$$L_{D3}{}' = L_{D10}{}' = 0.414\lambda$$
$$L_{D4}{}' = L_{D9}{}' = 0.405\lambda$$
$$L_{D5}{}' \text{ through } L_{D8}{}' = 0.398\lambda$$

As in the case of the 6-meter Yagi, I decided to use element insulators which I purchased from KLM Electronics. Since the elements are mounted well above the boom, an element correction factor was not applied. The reflector and director lengths for the 205.25 MHz Yagi are as follows:

Reflector	0.483 = 27-13/16 inches (70.6cm)
Director 1	0.4375λ = 25-1/8 inches (63.9cm)
Director 2	0.421λ = 24-3/16 inches (61.5 cm)
Directors 3 and 10	0.414λ = 23-3/4 inches (60.5cm)
Directors 4 and 9	0.405λ = 23-1/4 inches (59.2cm)
Directors 5 - 8	0.398λ = 22-7/8 inches (58.1cm)

You will note that these lengths have been slightly rounded off. The NBS report states that tolerances of 0.003λ should be maintained (0.173 inch or 4.4mm at 205.25 MHz). Furthermore, tests made by W0EYE

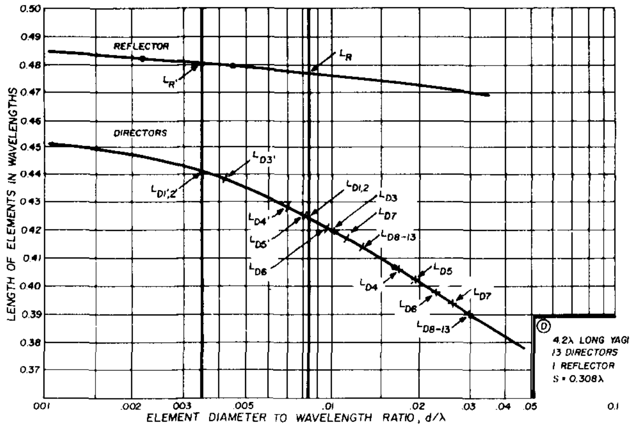

fig. 12. Use of the Yagi design curves (fig. 4) to determine the parasitic element lengths for a 15-element Yagi for 432 MHz; boom is 4.2λ long (example 3).

and W6FZJ in 1973 clearly showed that the gain and radiation pattern of a Yagi antenna degrades quite rapidly on the high side of the design frequency, but much more slowly on the low side. Therefore, if you must round off to a standard dimension, it is better to

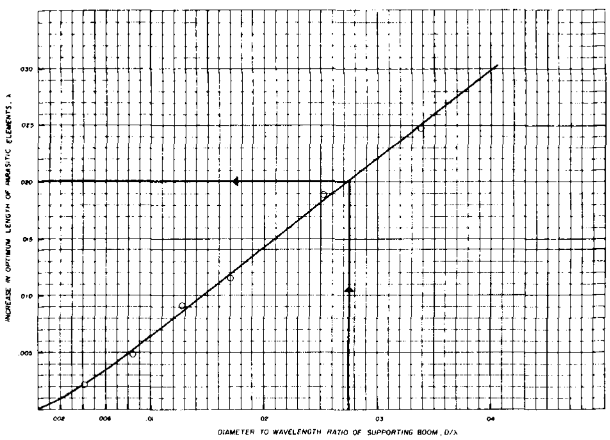

fig. 13. Supporting boom correction factor for the 15-element 432-MHz Yagi. Boom diameter is 0.0275λ (3/4 inch or 1.9cm at 432 MHz); length of each parasitic element must be increased to 0.2λ.

cut the director elements slightly shorter — not longer. Reflector length, on the other hand, should be rounded off on the long side. The element lengths for the Channel 12 Yagi were shortened to the nearest 1/16 inch, or only about 0.001λ.

For simplicity I decided to use a delta matching system and a 4:1 balun on this antenna. The driven element length was calculated using **eq. 3**. During final tests using the procedures outlined in reference 6 the driven element was extended slightly to obtain a 1:1 vswr. The length of the driven element is not a critical factor as long as the driven element is always shorter than the reflector.

The final design for the 205.25-MHz Yagi is shown in **fig. 11**. The desired discrimination to other Channel 12 television stations was achieved. This antenna is now in use at W1JR for indicating tropo, meteor shower, and aurora openings.

Example 3. The transpacific tropo tests mentioned in the previous example required an easily transportable antenna for the 432-MHz system to be installed at KH6BZF's station in Hawaii. I decided to use four 4.2λ *Yagis similar to the W0EYE type*[4] *and stack* them accordingly. The humidity and salt air are high in Hawaii so the elements were mounted through the boom using knurled 3/32-inch (2.4mm) diameter brass rods; this is similar to the method used on the W6FZJ extended, expanded collinear array described in *QST*.[7]

For the sake of brevity, **steps 1, 2,** and **3** will not be repeated here. However, the marked up nomograph for the 4.2λ 432-MHz Yagi is shown in **fig. 13**;

Since I decided to mount the elements through a *metal boom, the elements must be lengthened to*

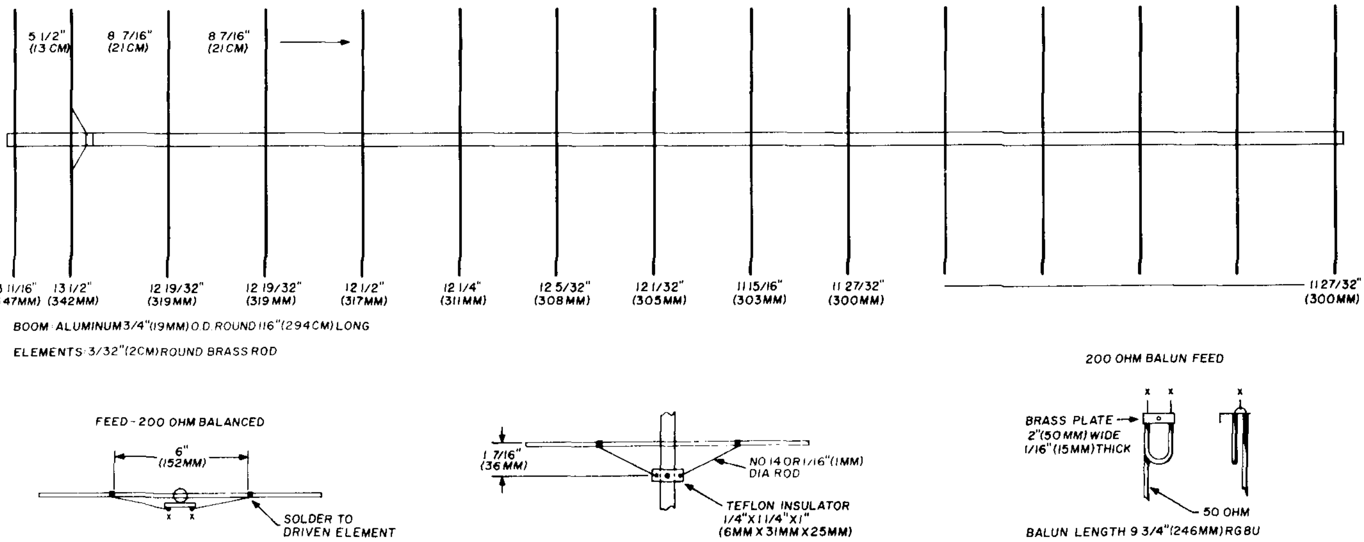

fig. 14. Layout of the 15-element 432-MHz Yagi on a 4.2λ boom. All elements are 3/32 inch (2.4mm) OD brass rod; elements are knurled and tapped into under-size holes in the 3/4 inch (1.9mm) aluminum boom. Element spacing of all directors is 8-7/16 inches (21.4cm); reflector is 5½ inches (14cm) behind the driven element. Details of the delta matching system and 4:1 balun are also shown.

compensate for the shortening effect of the boom.

Frequency	432 MHz
Wavelength	27.32 inches (69.40 cm)
Element diameter (d/λ)	0.00343λ
Reflector spacing	5-1/2 inches or 13.9cm (0.2λ)
Director spacing	8-7/16 inches or 21.4 cm (0.308λ)
Boom diameter	3/4 inch or 1.9cm (0.0275λ)
Overall length	115 inches or 2.915 meters (4.2λ)

$L_{R'} = 0.480\lambda$
$L_{D1'} = L_{D2'} = 0.441\lambda$
$L_{D3'} = 0.438\lambda$
$L_{D4'} = 0.428\lambda$
$L_{D5'} = 0.425\lambda$
$L_{D6'} = 0.421\lambda$
$L_{D7'} = 0.417\lambda$
$L_{D8'}$ through $L_{D13'} = 0.414\lambda$

To determine the corrected element length, first convert the boom diameter (3/4 inch or 1.9cm in this case) to wavelength (d/λ) or approximately 0.0275λ. Draw a vertical line from 0.0275λ on the boom correction nomograph (see **fig. 13**) to the DATA line. Move to left-hand axis and read the correction factor; 0.02λ for this antenna. Add this length correction factor to all elements as shown below.

Note that all the director lengths have been rounded off to the *short* side, as in **example 2**. The driven element length was calculated with **eq. 3**, but a better match was obtained when it was extended to 13½ inches (34.3cm); a delta match with a 4:1 balun was used. The final design for the 432-MHz Yagi is shown in **fig. 14**.

This antenna stacks well at 1.6λ in the H plane, and 1.8λ in E plane. As tested at NBS, this quad Yagi array yielded 19.6 dBd. A one-way 432-MHz contact was attained between KH6BZF and W6FZJ in July, 1973 (don't ask me why it wasn't two-way because I'll cry loudly). During October, 1973, using only 200

Reflector	0.480 + 0.02 = 0.500	13-11/16 inches	(34.7cm)
Directors 1 and 2	0.441 + 0.02 = 0.461	12-19/32 inches	(32.0cm)
Director 3	0.438 + 0.02 = 0.458	12-1/2 inches	
			(31.8cm)
Director 4	0.428 + 0.02 = 0.448	12-1/4 inches	(31.1cm)
Director 5	0.425 + 0.v2 = 0.445	12-5/32 inches	
			(30.9cm)
Director 6	0.421 + 0.02 = 0.441	12-1/32 inches	(30.6cm)
Director 7	0.417 + 0.02 = 0.437	11-15/16 inches	
			(30.3cm)
Directors 8 - 13	0.414 + 0.02 = 0.434	11-27/32 inches	(30.1cm)

watts and this array, EME signals from KH6BZF were copied and identified at W6FZJ. KH6BZF now uses this setup on Oscar 7, Mode B.

This article has presented a new and relatively precise way to consistently design and build Yagi antennas with optimum, reproducible gain characteristics — selecting a boomlength to suit your own requirements. Three design examples have shown Yagi antennas with demonstrated performance. If construction tolerances are held to 0.003λ maximum (0.001λ preferred), you should be able to design your own Yagis with the same excellent results. As pointed out earlier, director elements should be slightly shortened, while reflectors should be lengthened when rounding off the calculated dimensions.

Before actually starting to build a given design, double check your mathematics and scaling; it will pay off a 100-fold in time saved (and frustration). In those cases where the numbers in **table 1** do not agree exactly for the first director, reference at 0.0085 (d/λ) on the chart. The feed methods are not critical, and attention to the details outlined in references 5 and 6 should fill any voids in this article.

In closing, I would especially like to thank Don Hilliard, WØPW (ex WØEYE), who first introduced me to this information, and to Peter Viezbickie who, after much prodding by Don and myself, finally published this wealth of information. Now you, too, can be an expert in designing your own Yagi antennas.

references

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ham radio

the future of the
amateur satellite service

During Phase III of the amateur satellite program AMSAT will place advanced communications satellites in high-altitude orbits which will allow long-range communications for up to 15 hours per day. This article discusses the capabilities of those satellites, and the financial support required from the amateur community

Amateur radio stands on the threshold of the most exciting and comprehensive change in its history, a change more revolutionary than that from spark to CW, or a-m to ssb, or the advent of vhf-fm repeaters. The Phase III Amateur Satellite Program, about which you'll be reading a great deal in the coming months, sounds more like science fiction than fact. However, in the past few years the *facts* have become increasingly clear: amateurs are already in command of the technology needed to produce a cost-effective satellite system — a *system*, not just a single satellite, capable of greatly enhancing the reliability of long-distance communications while simultaneously reducing the cost of the average amateur radio station.

One day, probably in late 1979, the first amateur Phase III satellite will be launched, and a new era in amateur communications will begin. It's possible that within ten years from today the majority of long-distance communications (over 50 miles or 80 km) by amateurs interested in DX, contests, traffic handling, and casual rag chewing will be by satellite. As a result, crowding of the high-frequency bands may be significantly reduced, even with a rapidly increasing amateur population.

Using satellite relays for global radio communications was first proposed by Arthur C. Clarke in the British journal *Wireless World* in 1945. Approximately 20 years later (March 9, 1965) the first active communications satellite, OSCAR 3, was launched. It may be hard to believe, but radio amateurs were communicating through OSCAR 3 months before the first commercial communications satellite, *Early Bird* (Intelsat I), was placed into orbit. Yet today, 12 years later, while satellites are carrying approximately two-thirds of all commercial transoceanic communications,[1] amateurs are still relying almost entirely on erratic high-frequency circuits for distant contacts.

Long-distance propagation on the high-frequency bands depends on signals being reflected by the ionosphere. A much more reliable communications system results when a satellite is substituted for the somewhat erratic ionosphere, and vhf or uhf bands are used for the radio links. You don't need to know much about the workings of the ionosphere to use the high-frequency bands; surprisingly, you don't need to know much about satellites to enjoy the advantages of this new mode of communications.

The satellite subsystem of primary interest to radio amateurs is the transponder, the electronic package which receives signals from stations on the ground and then retransmits them, on a different frequency with great amplification, back to earth. Although transponders are somewhat similar to 2-meter fm repeaters, there are significant differences: the linear transponders used on AMSAT satellites work equally well with ssb and CW signals, and they can simultaneously handle a large number of users.

To appreciate the communications capabilities which high-altitude spacecraft will provide we can

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compare communications links involving Phase III (high-altitude) satellites, Phase II (low-altitude) satellites such as OSCAR 6 and OSCAR 7 which are currently in orbit, and the 20-meter band. The comparison will consider a number of characteristics of specific interest to radio amateurs using these systems.

1. **Daily access time**. How many hours each day does the user have access to the satellite?
2. **Maximum communications range**. What is the maximum terrestial distance over which two stations can communicate?
3. **Communications performance**. How strong and intelligible are received signals? Can openings over specific paths be predicted reliably?
4. **Communications capacity**. How many stations can use the satellite at the same time?
5. **Frequencies**. What frequency bands will Phase III satellites use?
6. **Tracking techniques and operating schedules**. Will the paper work involved in tracking and checking operating schedules be complicated and laborious?
7. **Ground-station equipment**. How much transmitter power and how large an antenna will be needed? Will commercial or surplus equipment be available for a moderate cost ground station?
8. **Antenna aiming**. Will the direction in which the antenna is pointed have to be continually adjusted while operating?
9. **Miscellaneous**. How will factors such as satellite lifetime, signal time delay, lack of skip zone, Doppler shift, and crowding affect users?
10. **Financing the Phase III program**. Can amateurs afford the Phase III program?

daily access time

The average amount of time that a satellite will be within range of a specific ground station each day (daily access time) is determined solely by the ground station's latitude. The first Phase III satellite will be injected into an orbit that initially places it within range of ground stations at mid-northern latitudes (this includes most of the United States) for about 15 hours each day, and within range of ground stations at mid-southern latitudes for about 5 hours each day. The first Phase III satellite will therefore provide northern hemisphere amateurs with as much access time as ten optimally spaced OSCAR 7 satellites! Can you recall the last time that 20 meters was open 15 hours per day on a regular basis?

As the years pass, ground stations will find that their average daily access time will change. By 1985 the first Phase III satellite will only be within range of northern hemisphere stations about 5 hours each day while southern hemisphere stations will have about 15 hours of access time each day. But don't despair, AMSAT is capable of producing two additional Phase III spacecraft before 1985. If these spacecraft are inserted into orbits similar to that of the first Phase III spacecraft, ground stations anywhere on earth will have access to at least one Phase III satellite for about 20 hours each day.

This article focuses on the potential impact of the amateur satellite program on amateur radio over the next ten years. The author, Dr. Martin Davidoff, K2UBC, is an assistant professor of mathematics at a community college in Maryland where he directs a National Science Foundation project involving satellites and college level science instruction. In conjunction with the NSF project, he recently authored a textbook featuring the AMSAT-OSCAR series of satellites, *Using Satellites in the Classroom: A Guide for Science Educators*. K2UBC obtained his doctorate in Physics from Syracuse University in 1974 and has held an amateur license since 1956. **Editor.**

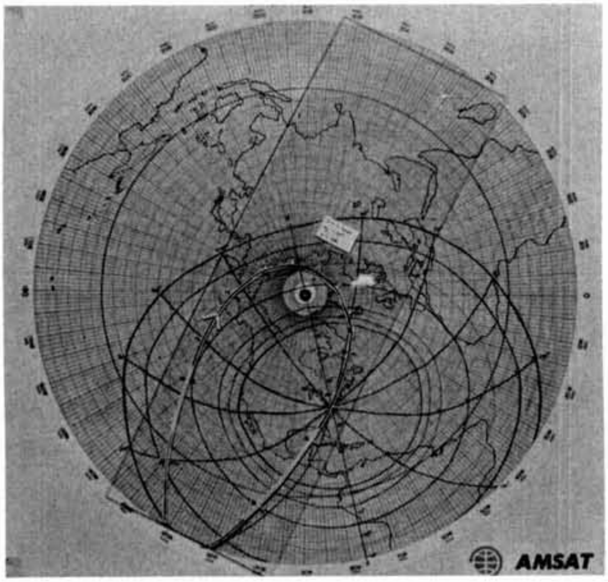


fig. 1. Photograph of *Satellable* style tracking nomograph for elliptical orbit of the type used by the Phase III-A spacecraft.

maximum communications range

Phase II satellites provide a maximum communications range of about 5000 miles (8000km). While this is adequate for Worked All States and DXCC, it's not very satisfactory by high-frequency standards. Phase III satellites will enable amateurs to communicate over a much greater distance — up to about 11200 miles or 18000 km — leaving only a very small region at the opposite side of the earth out of range. The 20-meter band will continue to reward its followers with somewhat unpredictable openings to all parts of the globe.

If you've had the opportunity of listening to ssb stations using the 432/146-MHz transponder on OSCAR 7, you know that satellites are capable of providing *telephone quality* links. The 20-meter band can provide similar performance, albeit in a somewhat erratic manner. As an example, assume it's August, 1977, and you're interested in the Denver-Frankfurt path during January, 1978. The best prediction high frequency propagation experts can offer is that 20 meters will probably be open over the path of interest sometime between 1600 and 1800 UTC on about 15 days during January. If the first Phase III satellite was in orbit at this time, you could predict with better than 99% certainty, that the Denver-Frankfurt circuit would be open for several hours every day in January during time slots specified almost to the minute.

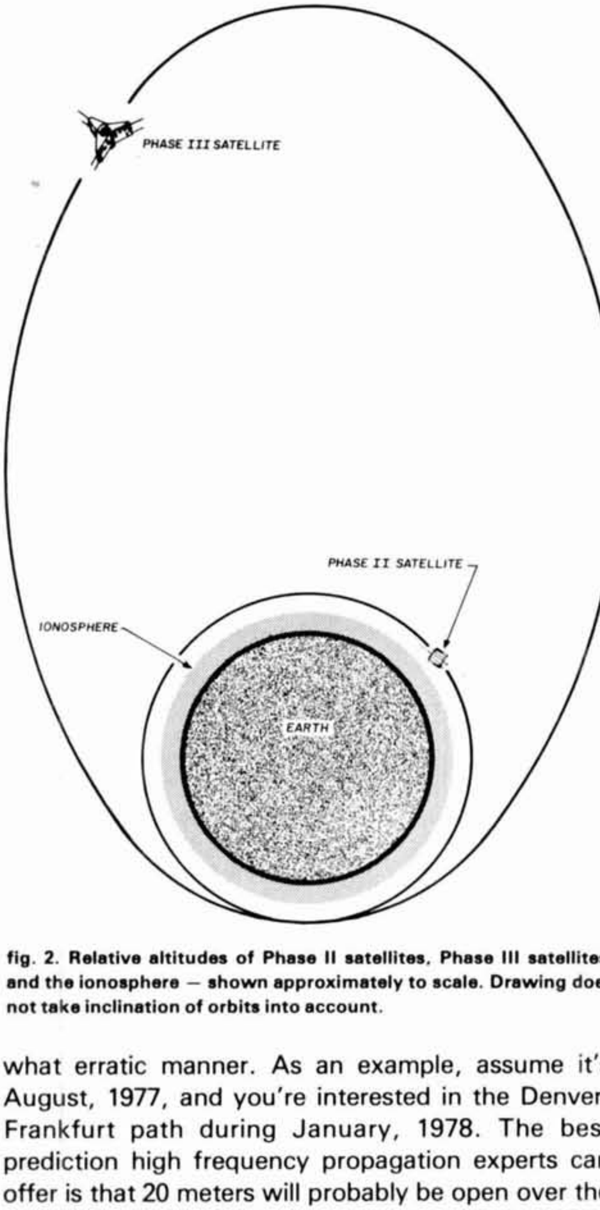


fig. 2. Relative altitudes of Phase II satellites, Phase III satellites, and the ionosphere — shown approximately to scale. Drawing does not take inclination of orbits into account.

The advantages of a Phase III satellite for prearranged point-to-point schedules are even more impressive when you consider a three-way contact between, for example, New York, London and Tokyo. Satellites will make such contacts possible daily with clocklike regularity. What are the odds of being able to accomplish this on 20-meters?

The received signal strengths observed by stations communicating through a high-altitude satellite will be largely independent of the distance between the stations. This results from the fact that the earth-satellite-earth distance and path loss are, for all practical purposes, constant regardless of how far apart the two ground stations might be. Since distance doesn't count, a station across town and one nearly halfway around the globe will produce similar signals if they are using similar equipment. In fact, listening to your own signal being returned from the transponder will indicate quite accurately how you sound to any station within range of the satellite.

communications capacity

The first Phase III satellite will provide a band of frequencies, nominally 150 kHz wide, capable of handling hundreds of simultaneous conversations. All users will be sharing the 50-watt satellite transmitter. Therefore, ssb and CW will be the preferred modes because they efficiently use the available satellite power. The satellite transponders will also be able to handle slow-scan TV, RTTY, and fm. But these modes should only be used in emergencies, or for special experiments coordinated with AMSAT, because they use a disproportionate amount of satellite transmitter power and, in the case of fm, excessive bandwidth.

A recent cost-effectiveness study suggests that crowding will not become a serious problem with the first Phase III spacecraft until 30,000 users are equipped to transmit on the uplink frequency.[2] To prevent crowding problems AMSAT plans an ongoing Phase III construction program which is designed to keep pace with a rapidly increasing user population. Placing an additional satellite in orbit every 24 months appears to be a realistic goal.

frequencies

The first Phase III satellite will include two transponders. Therefore, even if one transponder fails, the satellite will still be available for communication on a full-time basis. If possible, the two transponders on the first Phase III spacecraft will use reciprocal frequency combinations: one transponder will receive on 435 MHz and transmit on 146 MHz, the other will receive on 146 MHz and transmit on 435 MHz. Users will be able to compare the performance of both transponders and express their preferences for scheduling and for future satellites.

The amateur satellite program will continue to rely heavily on the 146-MHz and 435-MHz bands throughout the 1980s. In the mid or late 1980s Phase III satellites are likely to include links at even higher frequencies such as the 920 MHz (32cm) and 2.3 GHz (13cm) bands; specific plans must await the outcome of the 1979 World Administrative Radio Conference.

Low-altitude (Phase II) satellites may continue to use 10 meter downlinks, a band which is not suitable for Phase III. Readers interested in the factors involved in selecting frequencies for amateur satellite systems are referred to the excellent paper by Ray Soifer, W2RS.[3]

tracking techniques and operating schedules

You may be pleasantly surprised to learn that you won't need to know anything about tracking to use a Phase III satellite. After the first Phase III spacecraft is in orbit, you'll be able to turn on your receiver (with an omni-directional antenna connected) and check to see whether or not the band is open (satellite within range) by simply tuning for signals. About 65% of the time stations in mid-northern latitudes (most of the United States) will find that they're in luck — signals will be present. If a second Phase III spacecraft is launched into a similar orbit, the probability of finding the band open will be about 90%. When the band is open, you'll switch to a beam antenna and home in on the satellite by peaking your S-meter on a beacon signal. The same antenna setting will work for all stations received via the satellite. Peaking the antenna every 15 minutes should be more than sufficient.

While the casual user can get away without any knowledge of tracking, some tracking skill (like a little insight into 20-meter propagation) will pay big dividends by enabling you to predict specific openings, to rare countries.

Many radio amateurs think that satellite tracking is very difficult and requires a strong mathematical aptitude. This just isn't true. Tracking is a simple, mechanical skill that takes only a few minutes to learn, and the only math needed is basic arithmetic. The ability to predict 20-meter propagation stands in sharp contrast; it's an impressive skill which requires a great deal of knowledge and experience.

Most tracking methods use some sort of nomograph which usually consists of a map and transparent overlay. Until recently everyone had to build their own tracking nomograph from scratch — a straightforward but tedious job which is no longer necessary since excellent commercial tracking aids are now available.[4] With minor modifications the basic tracking techniques and nomographs used with OSCAR 6 and 7 will also work for the radically different orbits which early Phase III spacecraft will introduce. In fact, these same nomographs were actually used to evaluate the communications capabilities provided by the various orbits considered for Phase III. Construction details for Phase III tracking nomographs will be published in the near future.

In the past, OSCAR 6 and 7 users have sometimes complained about the bookkeeping involved in determining which OSCAR 6 orbits are available for general use and which OSCAR 7 transponder is scheduled to operate. The latest W6PAJ orbit calendar[5] eliminates most of the bookkeeping drudgery by clearly listing the times and operating status for every OSCAR 6 and OSCAR 7 orbit during 1977. AMSAT will have a great deal of flexibility in scheduling future Phase III satellites because they will be controlled by onboard microcomputers that can be programmed by suitably equipped ground stations. User convenience will be the primary consideration when satellite schedules are chosen so bookkeeping requirements should be minimal. Tracking nomographs and orbit calendars will be made available for Phase III satellites soon after they're in orbit.

ground station equipment

Receiving. Ground stations working with Phase III satellites will need a good ssb/CW receiver capable of tuning a few hundred kHz around 146 MHz and/or 435 MHz.

Transmitting. A CW or ssb transmitter with about 50 watts output at 146 or 435 MHz will be required for the uplink.

Antennas. Ground station communication via the Phase III satellite will usually require moderate gain (10-15 dBi) beam antennas for receiving and transmitting. A typical antenna array may consist of two or more Yagis mounted on a common mast using a single set of azimuth and elevation rotators. The entire structure can be smaller and lighter than the average three-element beam used on 20 meters.

The selected antenna site should place the antenna clear of surrounding objects and relatively close to the operating position since feedline losses are an important consideration at 146 and 435 MHz. As a result, a chimney mount will often be as effective as a large tower. Neighbors (and zoning committees) will probably be unable to distinguish between a roof-mounted Yagi array for satellite work and a large television antenna!

Although beam antennas will usually be required for reliable communications, simple omnidirectional antennas will also be useful at times. For example, an omnidirectional receiving antenna can be used during the entire orbit to determine whether the satellite is within range. In addition, omnidirectional transmitting and receiving antennas will sometimes be convenient for communication when the satellite altitude is relatively low (less than 15% of each orbit).

General. The satellite ground station that you put together will no doubt depend on the size of your pocketbook, the equipment you already own, the amount of time you have to devote to the project, and the transponder frequency.

Here are some options that you may want to consider. If you presently own a good high-frequency receiver, a top-line vhf or uhf converter will provide you with a state-of-the-art receiving setup. For transmitting, the 10-watt multimode or ssb/CW transceivers currently available for 2 meters and 70 cm look like a good choice. A linear amplifier with 6-10 dB of gain will keep the transmitting antenna requirements within modest limits.

Numerous pieces of commercial equipment suitable for satellite work (converters, transmitters, antennas) are currently available off the shelf; I'm not speculating as to what the future may offer. If you have some time and a little technical knowhow, you'll be able to put together a relatively inexpensive station using a surplus fm strip as a CW transmitter and homebrew helix antennas. In any event, if you're currently thinking of investing in a vhf or uhf fm transceiver or amplifier, consider paying a little extra to obtain a rig with ssb/CW capabilities and purchasing an amplifier that can be run in the linear mode for ssb.

Let's look at the equipment procurement problem from a different perspective by putting ourselves in the shoes of a newcomer to amateur radio five years from now (1982). If the newcomer intends to stick with the hobby for quite a few years and wants to set up a first-class station for local and DX work with new, off-the-shelf equipment what are the options?

Option A

Synthesized 2-meter fm transceiver
Separate transmitter and receiver for high-frequency bands
Kilowatt high-frequency amplifier
50-foot (80m) tower and triband Yagi

Option B

10-watt multimode 2-meter transceiver
10-watt multimode 70-cm transceiver
50-watt, 2-meter and 70-cm linear amplifiers
Modest roof-mounted antenna array

While each of these options will provide roughly equivalent capabilities, **Option B**, which depends on satellites for long-distance work, costs approximately half as much as **Option A**. Since prices for vhf and uhf ssb/CW gear are likely to decrease when a big new market opens up, the financial advantage of **Option B** is likely to increase.

The first Phase III satellite will be a moving target. The question that concerns radio amateurs is: How difficult will it be to track this satellite with a moderate gain beam? In other words, how frequently will the ground station operator be required to adjust the azimuth and elevation controls? The answer depends on a number of factors including: satellite orbit characteristics, location of the ground station with respect to the satellite, and the beamwidth of the antenna.

An analysis of the problem, taking these factors into account, shows that a ground station using a moderate gain beam will, on the average, need to adjust azimuth and elevation controls about once every 15 minutes during most of the orbit. However, there will be times while the satellite is near the low point on its orbit (perigee) when almost continual adjustment of beam elevation and azimuth will be required. Since signals will be very strong near perigee, ground stations will find it convenient to switch from beams to simple fixed omnidirectional antennas during this relatively short period of time.

Let's compare the dynamic antenna aiming requirements for Phase III, as just outlined, to requirements for Phase II satellites and the 20-meter band. Radio amateurs who have been using low or moderate gain beams to access OSCAR 6 and OSCAR 7 will find that they'll be able to pay far less attention to azimuth and elevation controls when they communicate via a Phase III satellite. Operators familiar with 20 meters will probably also be pleased to observe how a single antenna setting will work for all stations using the satellite; there's no need to repeatedly adjust the antenna for each weak DX signal.

AMSAT hopes that some future Phase III satellites may be placed in geostationary (or nearly geostationary) orbits.[6] A satellite in a geostationary orbit will appear to remain fixed directly above a spot on the earth's equator; a satellite in a nearly geostationary orbit will appear to drift slowly in longitude while remaining directly above the equator. Ground stations using these satellites will only need to adjust azimuth and elevation controls when switching from one satellite to another or when turning on the ground station after it's been off for a day or longer.

miscellaneous

Lifetime. Satellite lifetime concerns radio amateurs for several reasons. First, lifetime affects the yearly cost of the satellite. This subject will be covered in detail in the next section. Second, lifetime affects the long-term reliability of a satellite communications system. If a system depends on a single satellite, satellite failure shuts down the system. Potential users of a system based on a single satellite are naturally hesitant about investing time, energy, and money in a ground station that might suddenly have no function. Although the long lifetimes of OSCAR 6 and OSCAR 7 have alleviated this concern to some extent, the real solution is to produce a multiple satellite system so that the failure of a single satellite causes users only minor inconvenience. The term Phase III connotes just such a system. For this reason amateurs building ground stations for Phase III need not worry about their station suddenly becoming useless.

Let's look briefly at some of the plans for implementing the Phase III system. Experience with Phase II has shown that it's reasonable to expect operational lifetimes of five years for Phase III satellites. During the five year period following the launch of the first Phase III satellite, additional spacecraft will be placed into orbit; a new satellite every two years is a realistic goal for the 1977-1985 time frame. By 1984 the system should average three or more Phase III spacecraft in orbit and operating at any given time.

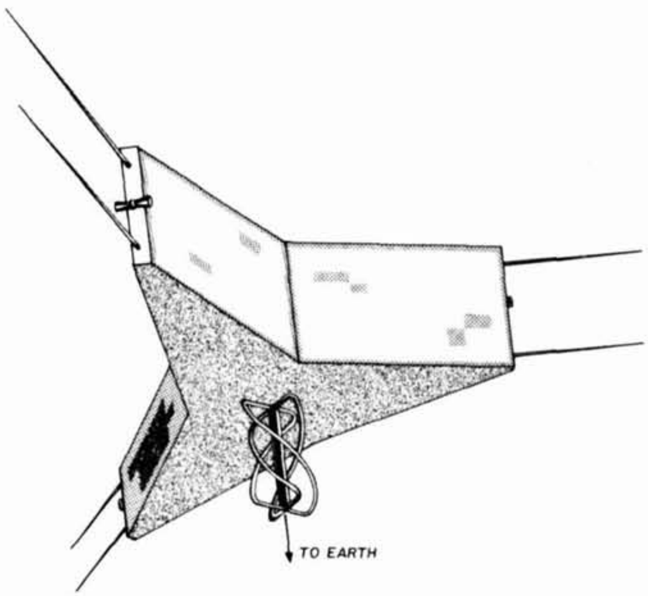
In the past amateurs thought that a satellite's useful life ended when it ceased to function. In the future AMSAT might decide to retire an old operating spacecraft from service in order to replace it with a new, more powerful model before total failure occurs

Time delay. Time delays from 10 to 300 milliseconds on the earth-satellite-earth path will make continuous monitoring of your own downlink distracting — to say the least. This is just one illustration of the many subtle differences between terrestial and satellite communications systems which amateurs will encounter in the future.

Each time amateurs have introduced new communications systems (ssb in the 1950s, for example, or fm repeaters in the 1960s), they've had to develop new operating procedures. Satellite systems will also require such innovations. One way to compensate for the time delays encountered while using high-altitude satellites might be to set the hang time on the vox or CW break-in system to 300 milliseconds and pause periodically for a second or two to enable the other party to break in.

No skip zone. Satellite communication systems do not exhibit skip zones. Consequently, it's easy to tell if a frequency is being used and a lot of unintentional interference can be avoided. In addition, round-table and net operation will be greatly facilitated since all users will hear each other. No problems to cure here — just a big bonus for satellite operators.

Doppler shift. Anyone who has listened to signals from a low-altitude satellite such as OSCAR 6 or 7 has probably noticed the pronounced downward shift in frequency that signals exhibit during nearby passes. A similar downward shift in frequency can be observed when a train passes with its whistle blowing. In both cases the frequency shift (called Doppler shift) is observed even though the source frequency is constant. The magnitude of the Doppler shift which amateurs encounter during satellite com-



Sketch of AMSAT-Phase III-A spacecraft.

munications depends on the relative velocity between satellite and ground station and the frequency being used — higher relative velocities and higher frequencies produce greater shifts.

Single-sideband communication is especially sensitive to Doppler shift since frequency changes of a few hundred cycles can make an ssb signal unintelligible. The largest Doppler shift that amateur radio operators have so far encountered during two-way communications occurs when OSCAR 7 passes directly overhead with the 432/146 MHz transponder in use. Under these conditions the Doppler shift is annoying, but ssb stations are able to compensate by frequent receiver tuning.

The first Phase III satellite will be moving slowly (relative to the surface of the earth) most of the time. During this portion of the orbit, Doppler shift will be smaller than observed with Phase II spacecraft which use the same transponder frequency combinations. However, there will be a small segment of each orbit, amounting to less than 10% of the period, when Doppler shift may be annoying, although ssb communications should still be possible.

Later Phase III satellites may be placed in geostationary orbits. Since these satellites will appear to remain fixed in space (no relative motion between satellite and ground station), no Doppler shift will be observed. In sum, Doppler shift will be of minor concern only with early Phase III satellites and of no concern with geostationary Phase III satellites.

Crowding. It has been estimated that the first Phase III satellite can accommodate 30,000 users equipped to transmit on the uplink bands. The estimate is based on ssb stations using 100 kHz and CW stations using 50 kHz of the transponder. If crowding becomes a problem before the follow-on Phase III spacecraft is launched, users have several options. Many may shift from ssb to CW to accommodate more stations in a given bandwidth. However, the opposite strategy, switching from CW to ssb, may actually be more effective in reducing crowding problems because a station can pass a given amount of information in a much shorter time period with ssb than with CW, while using less total spacecraft energy. This strategy would work only if amateurs limit themselves to essential information — a questionable objective.

Crowding effects can also be minimized by increasing the amount of roundtable and net operation. Phase III satellites are especially suitable for such use since there will not be any skip zone, and Doppler shift will be minimal. In any event, it should be evident that a number of viable options exist in response to any crowding problems that may temporarily occur. I have no doubt that amateurs who were raised on the 40- and 80-meter Novice bands will be able to devise satisfactory solutions.

financing

Phase III will become a reality only if the international amateur community is willing and able to financially support the program. While large donations from individuals, corporations, and foundations are needed to produce the first Phase III spacecraft, a long-term Phase III program depends on small donations from a very wide base of support in the amateur community.

An educated guess places the procurement cost for a commercially built Phase III satellite in excess of five million dollars. An early AMSAT estimate pegs the cost of the first Phase III satellite at two-hundred thousand dollars, a considerably smaller but still imposing figure. A much more meaningful number is the cost per year of service. Experience has shown that it's reasonable to expect an operational lifetime of five years for a Phase III spacecraft, so the cost per year of service for the first Phase III satellite is expected to be less than $45,000.

Let's look at this figure more closely. When the number of amateur radio operators equipped for the uplink reaches 15,000 (half the estimated spacecraft capacity), the yearly cost per user will be less than three dollars! This means that when AMSAT membership reaches 50% of user capacity, the current $10 AMSAT membership fee* should be able to support an expanding program of satellite construction and provide for membership services, educational programs, and the *AMSAT Newsletter*. However, AMSAT satellites will always be free access and available to anyone licensed to operate on the uplink frequencies. Readers interested in cost breakdowns for the first Phase III satellite should read the current series in *QST* by Jan King, spacecraft project manager.

general comments

Phase III satellites have been compared to Phase II satellites and 20 meters throughout this article. The points of comparison were chosen to illustrate Phase III satellite capabilities in familiar terms. As a result many of the unique and desirable characteristics of Phase II satellites and 20 meters have been ignored. I will now briefly discuss some of these features.

The 20-meter band will certainly remain a favorite of amateurs for a number of reasons. It's probabilistic nature is actually a very appealing characteristic — a skilled, knowledgeable, patient operator with a simple low-power 20-meter station will eventually be rewarded with exciting openings to the entire world. In addition, RTTY and sstv buffs can use 20 meters for hour after hour without ever worrying about using an unfair amount of satellite power.

Low-altitude satellites can be used by very simple ground stations. Contacts through Phase II satellites have been made with as little as 100 milliwatts, and numerous amateurs have had contacts using less than 1 watt of transmitter power; it is therefore possible to communicate through low-altitude satellites using small hand-held portable units. Low-altitude satellites can also be used in a broadcast mode, for example, to carry a single bulletin to the entire United States via 2-meter fm. Because of these features AMSAT will launch another Phase II satellite in late 1977 and continue the Phase II program through the 1980s. If you haven't already done so, try your hand at using the low-altitude satellites currently in orbit; they can provide a great deal of fun and excitement.

I think it's clear that Phase III will add a new dimension to amateur radio by augmenting the existing long-distance communication modes, not by replacing them.

*Regular AMSAT membership is $10 per year; life membership is $100. *Write to AMSAT, Post Office Box 27, Washington, DC, 20044.*

With the uncertain outcome of amateur frequency allocations at the World Administrative Radio Conference in 1979, and the rapidly increasing amateur population in the United States and abroad, the question is no longer "Can we afford to go ahead with the Phase III project?" The question is, "Can we afford not to go ahead with the Phase III project?"

The European Space Agency has selected the first AMSAT Phase III satellite for a late 1979 launch. The selection was a significant honor for the AMSAT team, but satellite construction can proceed on schedule only if AMSAT can obtain adequate funds. The money needed can be raised if amateurs are willing to demonstrate their commitment to the Phase III satellite program by joining AMSAT now, before the first Phase III satellite is launched.

Individuals who would like to make a more substantial contribution are encouraged to do so by donating money — contributions are tax deductible under section 170 of the IRS codes and/or donating time — volunteers are needed for a myriad of Phase III related activities (and you don't have to live in the greater Washington, D.C. area to participate).

Ten years from today amateurs will probably look back at the years 1977-1981, bracketing the launch of the first Phase III satellite, as one of the most exciting periods in the histoory of amateur radio. Take part in making history and enjoy it as it happens; *invest yourself in the future of amateur radio.*

acknowledgements

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More Details? CHECK — OFF Page 126

homebrew
Touch-Tone encoder

Details for building a simple encoder designed around the 555 timer IC

For those who like to make their own *Touch-Tone*† encoders, a cursory review of the amateur radio literature shows several reliable circuits. Several are built around the Western Electric Model 35 pad.[1-4] Another encoder used a pair of 565 IC voltage-controlled oscillators,[4] while others have used the recently developed MC14410 cmos encoder.[5,6] However, to my knowledge, no encoder has been built or described using the type 555 IC timer.

This article is the result of the challenge to design and build a simple *Touch-Tone* encoder with automatic PTT control using the 555 timer.

design

For a 12-button pad, *Touch-Tone* information is encoded in pairs using two of seven possible frequency tones. As shown in **table 1**, these seven tones are divided into a "low" group (rows) of 697, 770, 852, and 941 Hz; and the "high" group (columns) of 1209, 1336, and 1477 Hz.

To generate the required *Touch-Tone* codes, two 555 timers are required, each connected as an astable multivibrator with an output frequency given by

$$f(Hz) = \frac{1}{0.693(R_A + 2R_B)C}$$

R_A is the resistance between the timer discharge output and $+V_{CC}$, and R_B is the resistance between the threshold input and discharge output. As shown in **fig. 1**, R_A is replaced by a resistive divider string for both the low- and high-tone oscillators.

table 1. Frequencies used in the Touch-Tone signaling system.

	high-tone group		
low-tone group	1209 Hz	1336 Hz	1477 Hz
697 Hz	1	2	3
770 Hz	4	5	6
852 Hz	7	8	9
941 Hz	*	0	#

For the low tone oscillator, U1, letting R_A = R1 = 4.3k ohms, C = 0.047 μF, and f = 941 Hz, solving for R_B yields 14,164 ohms. To generate the next lower tone (852 Hz), R_A is now equal to R1 + R2, so that R2 = 3.3k ohms. For the 770-Hz tone, R_A now equals R1 + R2 + R3, giving R3 = 3.9k ohms. In a like manner, R4 = 4.3k ohms.

The high-tone oscillator U2, is designed in a similar manner. Starting with the 1477-Hz tone, letting R5 = R_A = 3.9k ohms and C = 0.047 μF, R6 = 2.2k ohms and R7 = 2.4k ohms.

For both oscillators the outputs are taken from the

†*Touch-Tone* is the registered trademark of the American Telephone and Telegraph Company.

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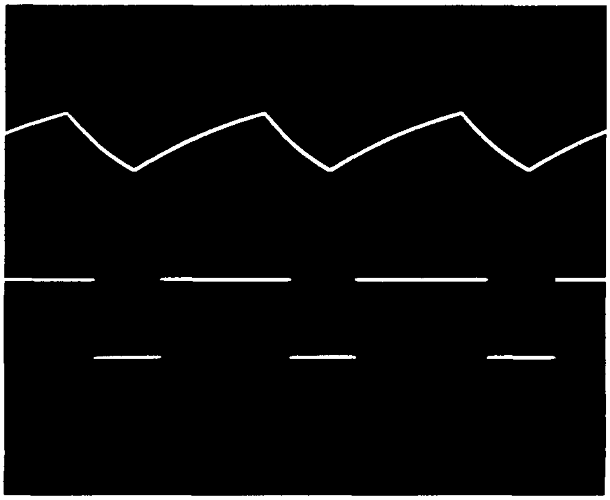

fig. 2. Type 555 timer output waveforms. When connected as an astable multivibrator upper trace is obtained from pins 2 and 6; lower trace from pin 3.

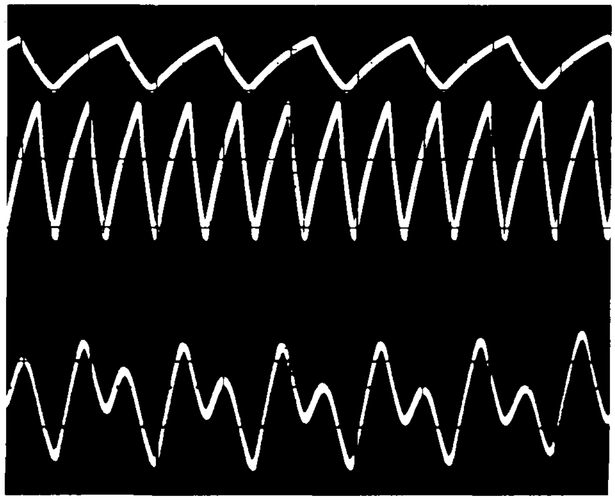

fig. 3. Addition to the low-tone oscillator (top trace) and the high-tone oscillator (center trace) to give a two-tone output signal when the digit 2 is pressed.

timer discharge junction and trigger pins (pins 2 and 6), which produce a pseudo-triangular waveform between 1/3 and 2/3 V_{CC} (**fig. 2**). A 741C op-amp, U3, adds the output of both oscillators, shown in **fig. 3**, and is coupled to a 10-k ohm pot, which is an output-level control.

The automatic PTT control consists of another 555 timer, U4, connected as a 1-second one-shot and relay K1.

components

For good thermal stability the 0.047-μF capacitors should be either tantalum or mylar, and resistors R1-R9 should be 1%. Several manufacturers currently advertise a 4X3 pad similar to the Chomerics type ER-21623. R10 and R11 are 10-turn pots. If desired, a type 556 dual timer can replace U1 and U2. **Fig. 4** compares the pin connections to of the 555 and 556 timers.

adjustment

Start by pressing the * key and adjust R10 so that the low-group oscillator reads 941 Hz at pin 3 of U1. Consequently, frequencies of 852, 770, and 697 Hz should be obtained to within 2% when the numbers 7, 4, and 1 are respectively pressed. For the high tone

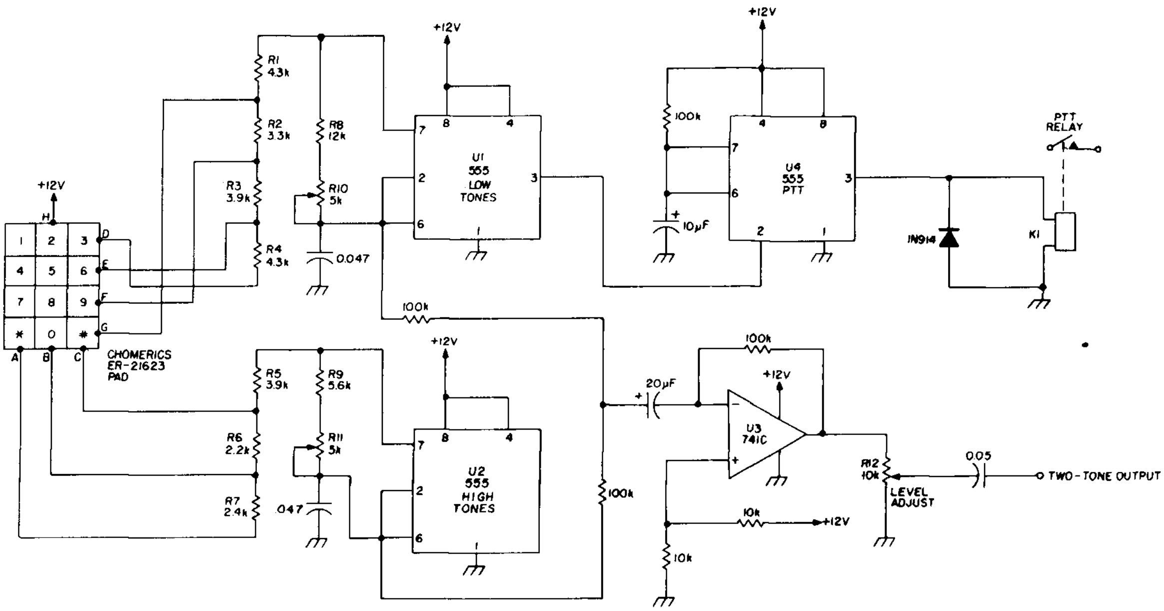

fig. 1. Touch-Tone encoder schematic using the type 555 IC timer with high and low tones. Automatic PTT control is also included.

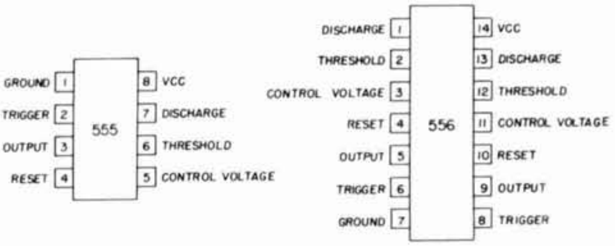

fig. 4. Pin-connection comparison for the type 555 and 556 timers.

group, press the # key and adjust R11 so that the oscillator reads 1477 Hz at pin 3 of U2. Consequently, frequencies of 1336 and 1209 Hz should be obtained to within 2% when the **0** and * keys are pressed.

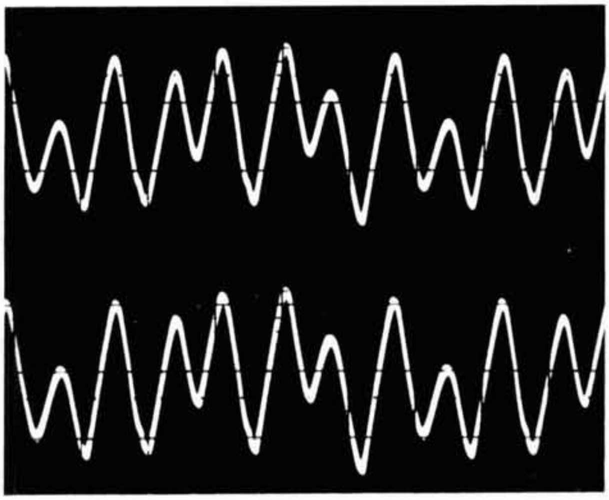

fig. 5. Comparison of two-tone output obtained from the 555 timer encoder (upper trace) with Western Electric Model 35 pad (lower trace) for the digit 1.

A comparison of the digit **1** generated by a Model 35 pad and the 555 encoder is shown in **fig. 5**.

For proper operation output-level control R12 should be set against a deviation meter; otherwise on-the-air testing will be required to set the output level.

references

1. William P. Lambing, WØLPQ, "Mobile Operation with the Touch-Tone Pad," *ham radio*, August, 1972, page 58.
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ham radio

frequency-marker standard

using CMOS logic

Low power consumption and fast switching speeds through the hf bands are featured in this circuit

A few frequency-marker standards have appeared in the amateur literature, but most use linear ICs or TTL logic. The frequency standard described here uses CMOS CD4000-series logic elements, which result in reduced power consumption but switch fast enough to allow sufficient switching speed and harmonic energy throughout the hf bands for good response.

circuit description

The divider arrangement is shown in **fig. 1**, in which a 400-kHz crystal-reference frequency is used. A 1-MHz reference would be better; however, the 400-kHz frequency was chosen because of available parts.

The oscillator is somewhat different than others using logic elements,[1] such as that using TTL ICs.[2] Resistor R1 keeps the input of the first NOR gate, U1A, stable; otherwise the oscillator refuses to oscillate at the crystal frequency. Resistor R2 is not critical and can be any value between 1 and 20 megohms. It should be close to 10 megohms if temperature extremes are experienced.[1] Resistor R3 provides load isolation between Y1 and the NOR-gate output. RC network C2, R3, R2, C1 forms a feedback arrangement similar to that recommended by reference 1, wherein C2 can be adjusted to vary crystal frequency to zero-beat with WWV or CHU. Capacitor C1 is used for crystal loading and centering of the crystal-frequency range.

Buffer NOR gate U1B isolates the crystal oscillator from the following divider chain, U2-U6. U2A-U3B are a divide-by-4 circuit in which the logic elements are JK flip-flops connected as D flip-flops (D flip-flops could be used here).

Calibration markers were desired at 200, 100, 50, 25, 10 and 5 kHz. This means that some additional dividing was necessary along with the following flip-flops to allow the desired symmetrical waveshape, since any feed back-type counter-divider produces an unsymmetrical waveform output. Therefore, U4 was chosen as a divide-by-N counter IC, and the latch arrangement of U5 was used to reset the selected divide-by-5 logic.

The 100-kHz output was first divided by 5, which was then divided by 2 to provide the symmetrical 10-kHz output; this output was then divided by 2 to provide 5-kHz. A switch, S1, and a final buffer, U1C, were used between selected output and the output coupling point. (A small 100-pF capacitor can be used for output coupling.)

construction

The photo shows component layout. I used perf board with straight pin-to-pin wiring. If you wish to use a PC board, one could be easily designed. Nothing is critical about parts layout; however, short leads should be used in the oscillator circuit to preclude problems with stray capacitance.

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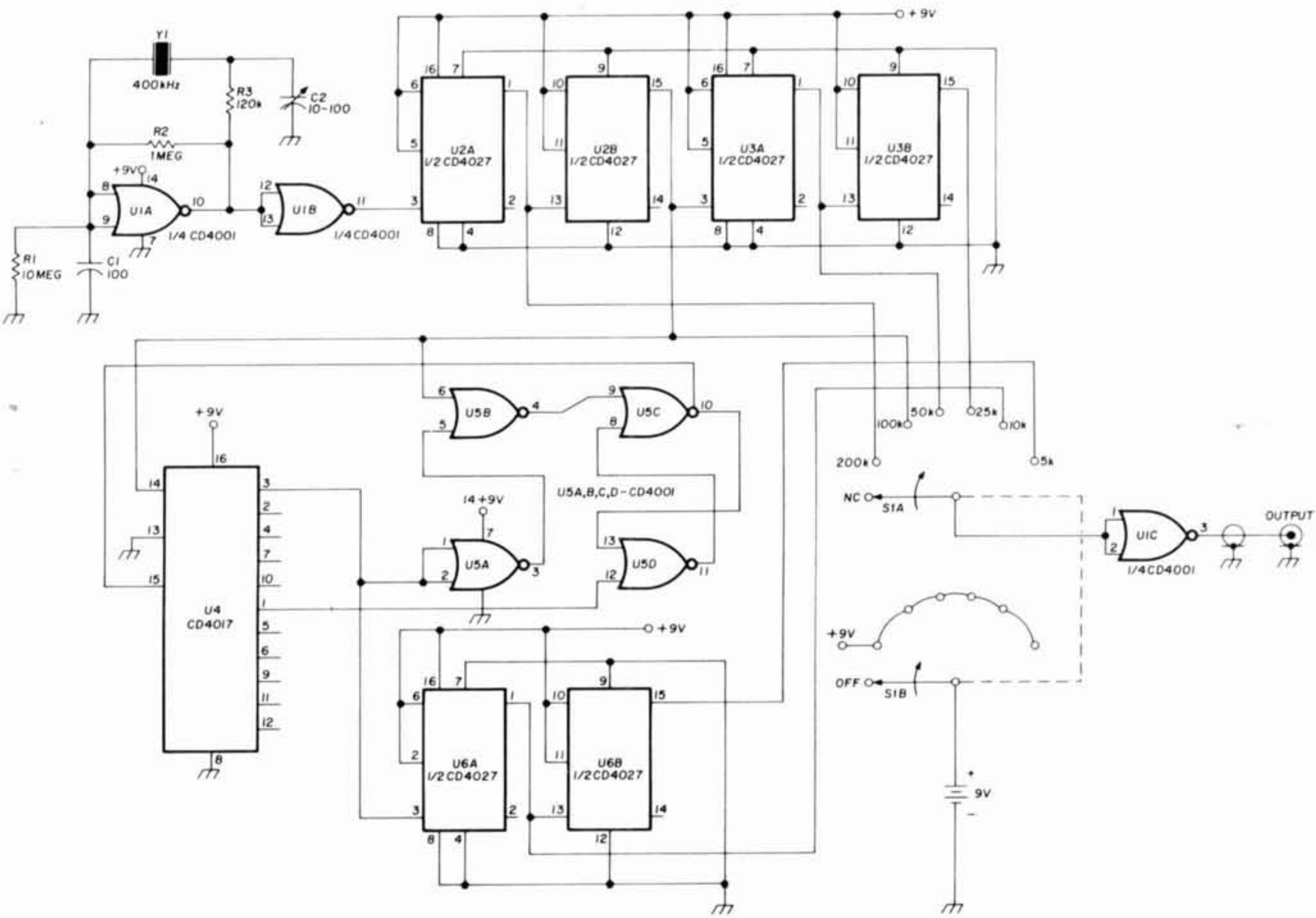
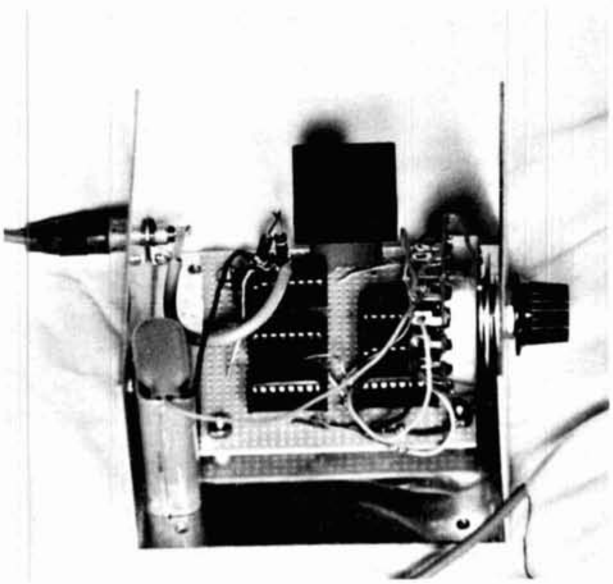


fig. 1. The CMOS IC frequency-standard schematic. Type JK flip-flops connected in a D configuration are used in the divide-by-4 circuit (U2A-U3B). Type D flip-flops could be used here.



Component arrangement of the CMOS frequency standard. Layout is not critical; straight pin-to-pin wiring is used. Oscillator requires short leads for minimum frequency variation due to stray capacitance.

This CMOS crystal -frequency marker standard is a big improvement over the standard once used and consumes only 2.8 milliamperes at 9 volts, or 25.2 milliwatts. A 9-volt transistor radio battery power source was used and will probably last close to its shelf life. The frequency standard works fine through 10 meters. However, no equipment was available to check it through uhf, so I don't know whether sufficient energy will be present at these frequencies. The switching speed appears to be adequate, however.

Incidentally, a DT-cut crystal should be used for minimum temperature effects and frequency drift problems, since this type cut has much less frequency variation due to nearby heat sources.

references

1. *The Solid-State Databook*, Series SSD203B, RCA Communications, Inc., pages 352-353.

2. Gerald Hall, K1PLP, "A TTL Crystal Oscillator," *QST*, February, 1974, page 34.

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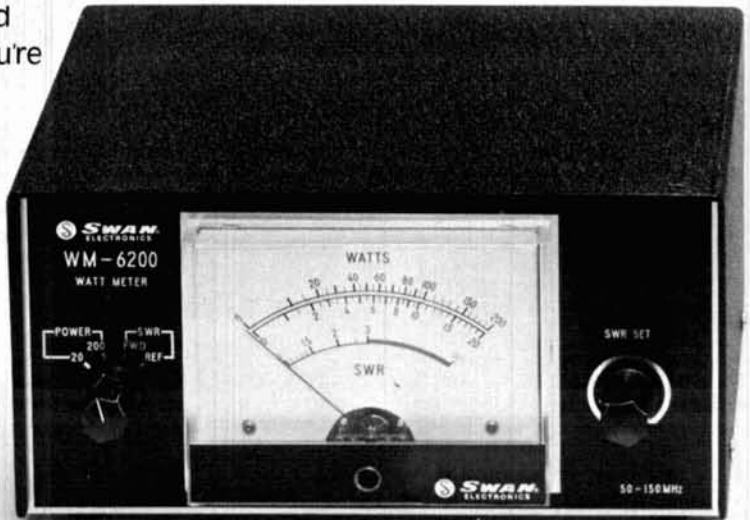

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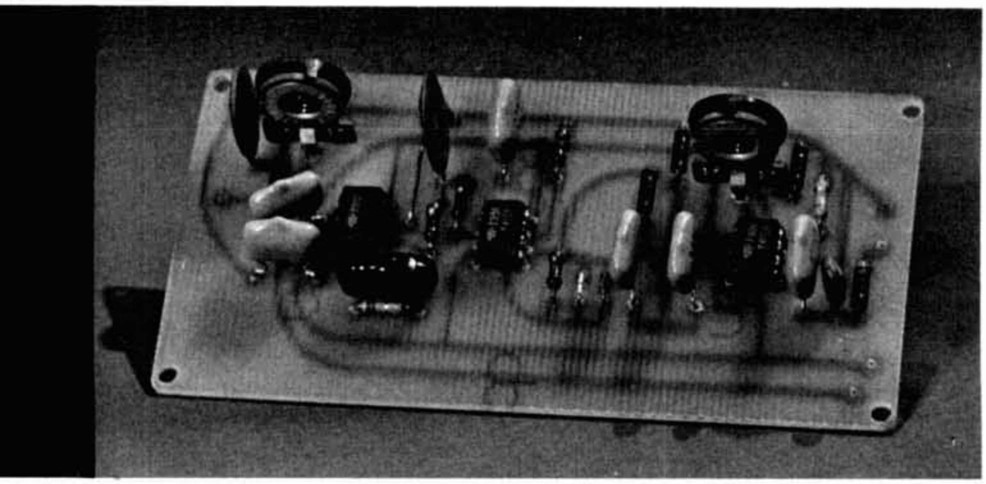

audio-frequency speech processor

Design and construction of a logarithmic limiting type speech processor featuring μA741 ICs

An easy way to improve ssb-transmitter performance is to use a well-designed speech processor between microphone and transmitter. Such a processor, if properly adjusted, will make a noticeable improvement in your transmitter speech readability. Contrary to current rumors, poor audio quality and increased bandwidth are not inherent in a good design.

Audio-signal conditioning requires no transmitter modifications with the exception of a cooling fan to protect components because of the increase in average power input to the final amplifier. Such a fan may be mounted externally if needed.

The speech processor described here is of the logarithmic type[1] and is easy to adjust and use. When used with my SB-401, this speech processor resulted in a signal-strength increase at the receiving end of at least two S-units. I've yet to get a report of poor audio quality or splatter, even from operators using monitor scopes. As a result, I use the processor at all times.

response

Much has appeared in the amateur literature regarding the ideal response of speech processors. For example, reference 2 states that, "The only way to accurately evaluate the actual improvement of-

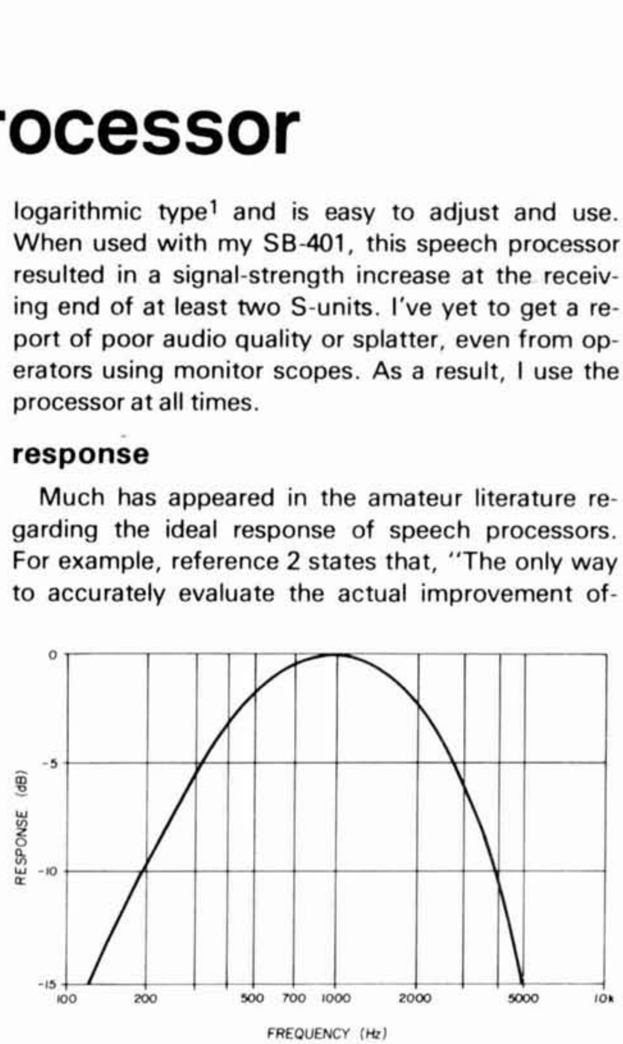

fig. 1. Speech-processor response below clipping level. V_{in} = 0.054 volt p-p; V_{out} = 0.230 volt p-p at 0 dB; Generator Z_{out} = 50 ohms; Z_{load} = 1 megohm.

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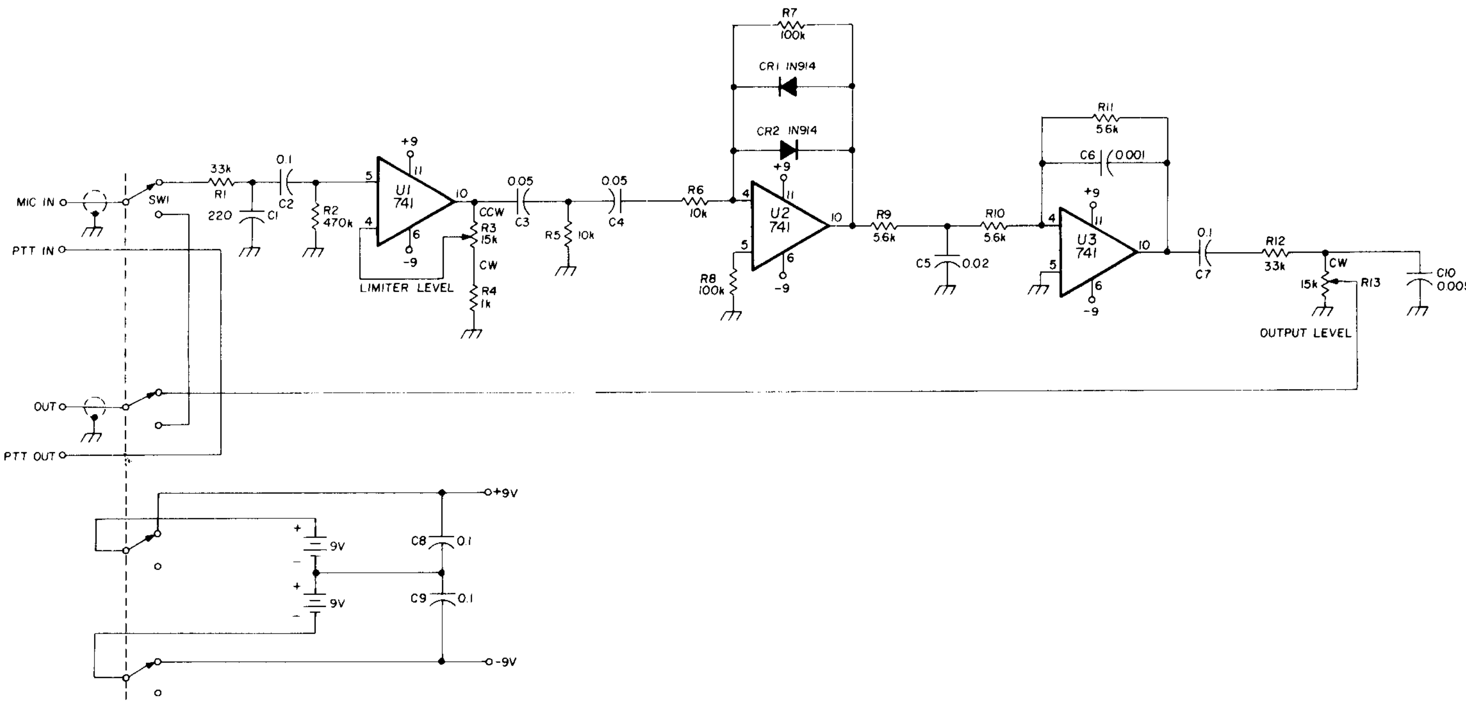


fig. 3. Speech-processor schematic. Numbering for 14-pin DIPs is shown.

U1,U2,U3	μA741 operational amplifier (use mini-dip for PC board)
SW1	4 pdt rotary switch
C1	220 pF, 50 WVdc disc ceramic
C2,C7,C8,C9	0.1 μf, 50 WVdc mylar
C3,C4	0.05 μf, 50 WVdc , 5% mylar
C5	0.02 μf, 50 WVdc, 5% mylar
C6	0.001 μf, 50 WVdc, 5% mylar
C10	0.005 μf, 50 WVdc mylar
CR1,CR2	1N914 diodes
R3,R4	15k or 10k linear pot, composition type
All other resistors	1/4 watt, 5%
SW1	4 pole, 2 position

fered by a speech processor is to measure the Intelligibility Threshold Improvement (ITI)." After much experimentation, I found the frequency response of **fig. 1** to be a good compromise between maximum readibility and good audio quality. The audio band width is sufficiently limited without impairing voice quality.

circuit description

Fig. 2 shows the block diagram for the processor. The schematic is shown in **fig. 3**. R1C1 forms an rf filter to prevent rf on the microphone cable from getting into the processor. C2R2 gives some highpass filtering action. R2 provides bias to the noninverting input of U1, and combined with the input impedance of U1, will provide sufficient load to a crystal or ce ramic microphone to attenuate low-frequency components and reduce harmonic distortion produced by very-low-frequency energy entering the microphone.

U1 is an adjustable gain-preamplifier, which overcomes losses in the highpass filter (C3, C4, and R5) and sets the input level to U2, the limiting amplifier. U2 limits because the nonlinear resistance characteristics of CR1 and CR2 supply increasingly heavier negative feedback as U2 output amplitude increases, which provides a logarithmic response. Limiting is soft and is similar to that of a compressor followed by a hard limiter. R8 eliminates any dc offset in U2 output due to input bias current. R9, R10, R11, and C5, C6, and U3 form a lowpass active filter, which attenuates frequencies above 2.8 kHz that may be generated in the clipping process. R13 provides output level adjustment, so that the transmitter drive-

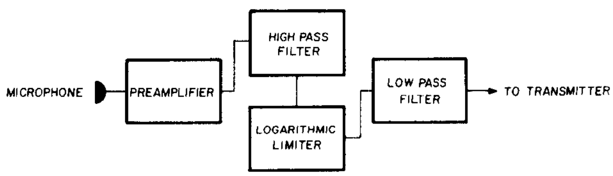


fig. 2. Block diagram of the logarithmic speech processor.

level control doesn't have to be changed when the processor is switched in or out.

construction

Wiring and component values with the possible exception of the resistors and capacitors that comprise the high- and lowpass filters are not particularly critical. The usual precautions applicable to audio circuitry should be observed.

The original version was wired on a small PC board intended for breadboarding DIP integrated circuits. It was then mounted along with two standard alkaline transistor radio batteries, in a 3 x 4 x 5-inch (77x102x 128mm) aluminum box with plenty of room to spare.

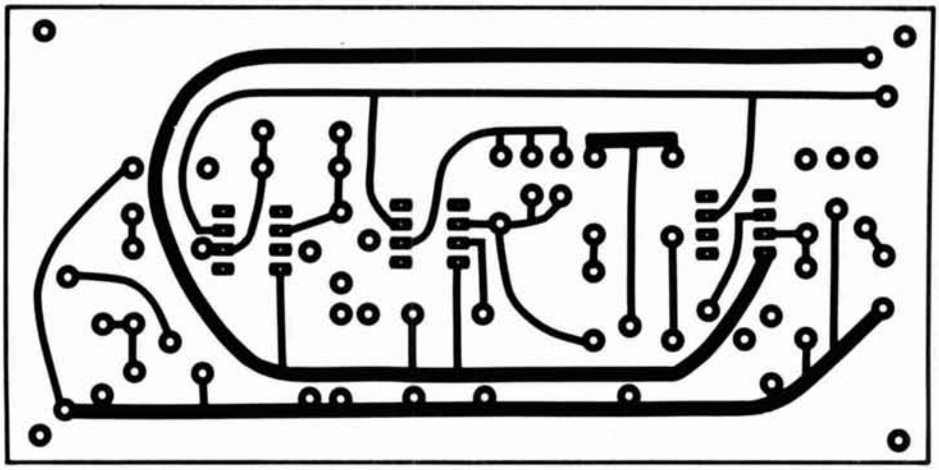


fig. 4. PC board layout, foil side.

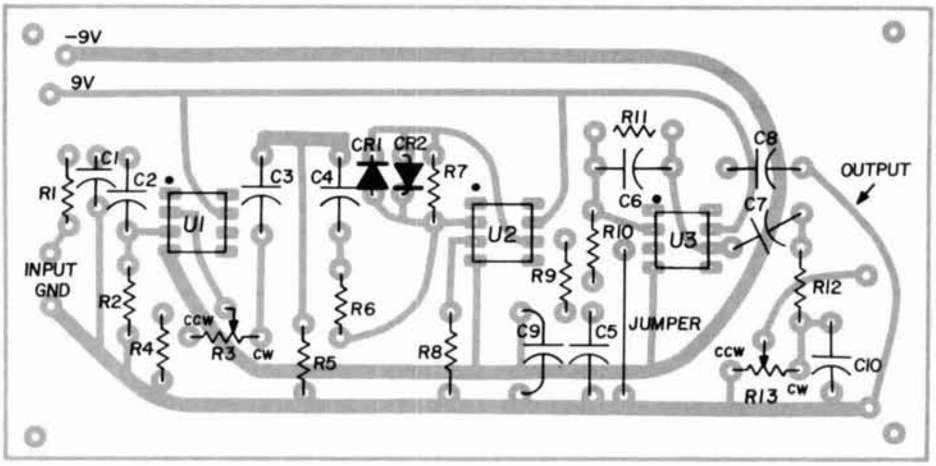


fig. 5. Component side of the PC board showing parts placement.

A PC board layout is shown in **figs. 4** and **5**.* I used IC sockets in my original unit, but these are not absolutely necessary.

The alkaline batteries should be good for about a year of normal operation, but an ac power supply could be substituted if precautions are taken to minimize ac hum, which would be particularly troublesome if introduced at this level.

I mounted two double-pin audio connectors of the same type used for the transmitter microphone connector on the rear of my processor. These are the input and output connectors and permit easy insertion and removal of the processor. The cable between processor and transmitter is of the same type as used on the microphone and is terminated at each end with a connector identical to that used on the microphone. (Don't forget to carry any PTT lines directly through the unit.)

*A printed-circuit board is available from the author for $4.95 and a self-addressed stamped envelope.

Although holders are available for 9-volt batteries, I found that the heavy flat plastic wire ties used by electricians to bundle conductors make a very secure mounting. Make sure to use the type with a mounting hole molded in one end. Standard battery clips were used for the electrical connections.

operation

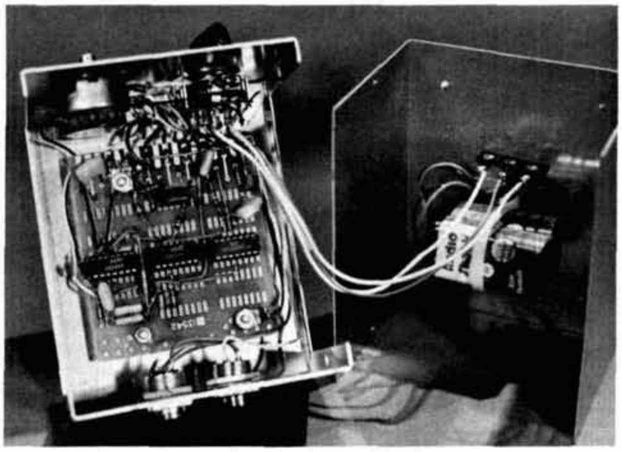
Operation is simple. Once the settings of R3 and R13 have been established, the on-off switch is the only control used. I used screwdriver-adjust pots in my unit.

The transmitter should be tuned in the normal fashion with the processor switched out. The transmitter microphone gain control should be set at the proper level, using a monitor scope or the transmitter's ALC indicator according to the instruction manual. Turn limiting control R3 about one-half turn clockwise, switch in the processor, and adjust output control R13 for the same ALC indication or peak-monitor-scope deflection that was obtained without the processor. On-the-air reports can then be used to determine the optimum setting of R3.

After adjusting R3, always recheck the setting of R13. Use discretion in adjusting R3. Extreme limiting should be avoided if the best combination of signal strength and audio quality is to be attained.

A too-high setting of R3 will also cause normal background noise to become objectionable as the audio gain for low-level signals is increased. Consequently, the processor can be used most effectively in a quiet, echo-free environment.

The use of this speech processor will increase the average power input to the final amplifier and cause some increase in final-amplifier -tube dissipation. To extend tube life, I added a small cooling fan. The fan I used is of the axial type. It is rectangular, about 5 inches (128mm) on a side and about 1½ inches (38.25mm) thick, with mounting holes in each corner. I fastened four small rubber feet at the mounting holes and placed the fan on top of the perforated lid of the transmitter, directly above the final tubes, so that the fan draws air from inside the cabinet. I decreased the air flow and noise level of the fan, both of which were excessive, by installing a resistor of about 375 ohms in series with the fan motor, which resulted in a quiet cooling system.



Breakaway section showing wiring and underchassis layout.

Performance over a 12-month period has been excellent. The increased range and number of solid ssb contacts have more than justified the modest investment in time and material for the speech processor.

references

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2. Gene Nurkka, VK9GN, "Integrated-Circuit Single-Sideband Speech Processor," *ham radio*, December, 1971, page 31.

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low-cost microwave spectrum analyzer

How to put together a microwave spectrum analyzer from surplus odds and ends — the completed unit covers dc to 2 GHz

My ongoing efforts to develop low-cost modules for the 1296-MHz band have often required the use of a spectrum analyzer for monitoring (and minimizing) harmonic and spurious frequency components. Numerous excursions through the local surplus test equipment emporiums revealed that an acceptable instrument could cost several thousand dollars — well beyond the budget of the most dedicated experimenter. While searching for the unbeatable surplus buy which never materialized, I noticed the ready availability and comparatively low cost of a wide variety of S-band (2-4 GHz) test instruments and components. It occurred to me that a microwave spectrum analyzer could be put together from these available parts at a considerable savings. This article documents the design, construction, operation, and performance limitations of the resulting microwave spectrum analyzer. While I doubt that any reader will want to duplicate my design in its entirety, I hope this article will provide guidance and encouragement to anyone attempting a similar project.

performance requirements

The operation of any spectrum analyzer can be characterized in terms of its frequency coverage, dispersion, dynamic range, sensitivity, and resolution. To display frequency components well into the microwave region, I designed my spectrum analyzer to cover dc to at least 2 GHz. The same design strategy could be easily applied to other frequency bands. In fact, the upper frequency limit of this analyzer was later extended to 2.5 GHz, as discussed later.

Dispersion describes the ability of a spectrum analyzer to display a broad slice of the frequency spectrum in a single sweep. Many of the low-cost analyzers on the surplus market display only a few MHz at a time. Such narrow-dispersion spectrum analyzers are useful as panadaptors, which display all signals within several hundred kHz of a specified operating frequency, but when tuning a microwave local-oscillator chain, monitoring mixer image response, or measuring transmitter harmonic content, it is often desirable to display a band several hundred (or even thousand) MHz wide. The spectrum analyzer shown here can display the spectrum from dc to 2 GHz in a single sweep. Since it's often desirable to narrow this sweep for a closer look at a particular signal, variable dispersion capabilities are included in the design.

Sensitivity and dynamic range define the minimum and maximum signal amplitudes which an analyzer can display without distortion. In accordance with good engineering practice, I try to suppress all transmitted spurious products by 50 dB or more. To accurately measure this performance, the spectrum analyzer requires at least 50 dB of dynamic range. As

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for maximum input level, I often want to display a + 10 dBm (10 mW) signal (this is the local-oscillator injection level required of many balanced mixers). Thus, 50 dB dynamic range with a + 10 dBm maximum input level yields an ultimate sensitivity requirement of − 40 dBm, or 0.1 μW. Greater sensitivity (a lower minimum discernible signal) could have been obtained, but only at the expense of dynamic range.

The objective of any spectrum analyzer is to display the various components of a complex waveform in the frequency domain. The closer the frequencies of any two components, the more difficult it is to separate them on the spectral display. Resolution relates to the minimum frequency separation between two signals of equal amplitude which will still permit the operator to discern two separate frequency components on the display.

Resolution can be approximated as twice the i-f bandwidth of the analyzer system. Generally, the objectives of wide dispersion and narrow resolution are mutually exclusive. When measuring transmitter audio intermodulation products with a two-tone test, for example, a resolution of a few hundred Hz is required, and dispersion is likely to be several tens of kHz. When viewing harmonics of a 100-MHz oscillator, on the other hand, 2-GHz dispersion may be required, but a resolution of several tens of MHz is acceptable.

Resolution is primarily a function of i-f bandwidth, which for my analyzer is fixed at 1 MHz. Therefore, with this design, I can resolve frequency components to within about 2 MHz.

As most amateurs know, a general-coverage communications receiver can be used as a rudimentary high-frequency spectrum analyzer. With an input signal applied to the antenna terminals, the receiver is manually tuned through its frequency range (dispersion). Frequency components are detected and displayed (perhaps with the receiver's S-meter). Resolution is a function of the i-f bandwidth, which is probably a few kHz. Sensitivity is a function of the receiver's noise floor, and dynamic range is limited by the receiver's agc and overload characteristics. Obviously, wide dispersion measurements require considerable operator intervention, in the form of tuning. Gain variations of the receiver from band to band will limit the accuracy of its amplitude indication. Additionally, any nonlinearity in the receiver's agc circuit may prevent accurate amplitude measurement across the receiver's entire dynamic range. Also, the receiver's image and spurious rejection may be insufficient to eliminate false indications.

Ideally, a workable spectrum analyzer should be a superheterodyne receiver in which these shortcomings are minimized. Frequency tuning should be both automatic and rapid. Instead of an S-meter, amplitude is displayed on an oscilloscope. If the scope's horizontal deflection is slaved to the receiver's tuning mechanism, the result is a display in the frequency domain. Dynamic range must be max-

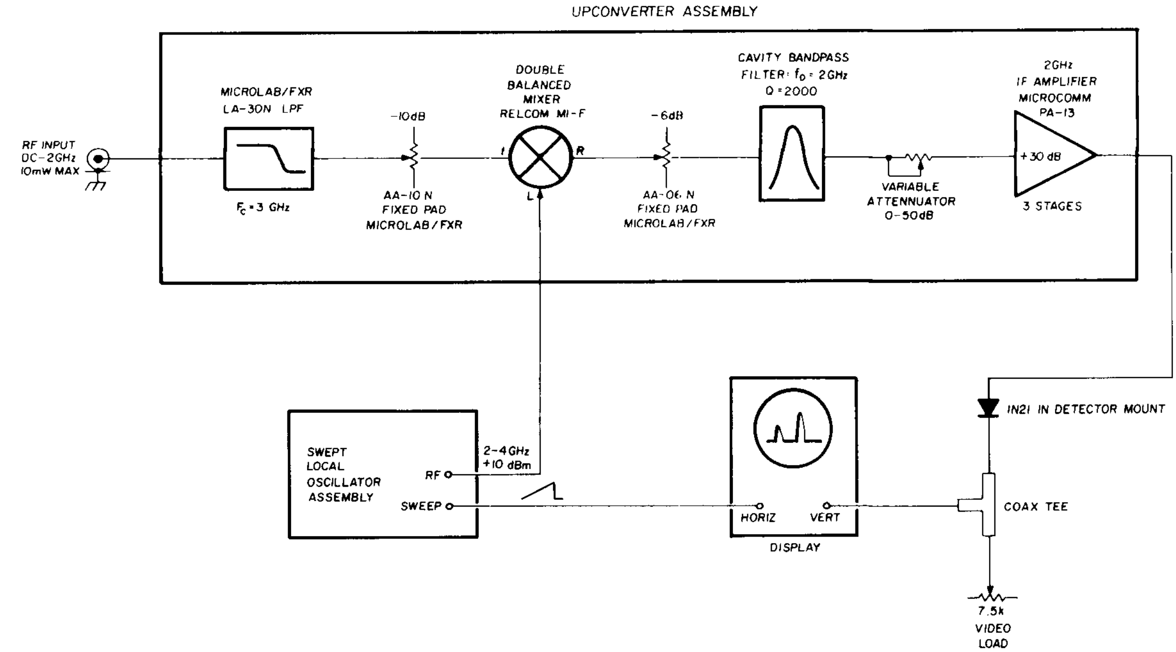
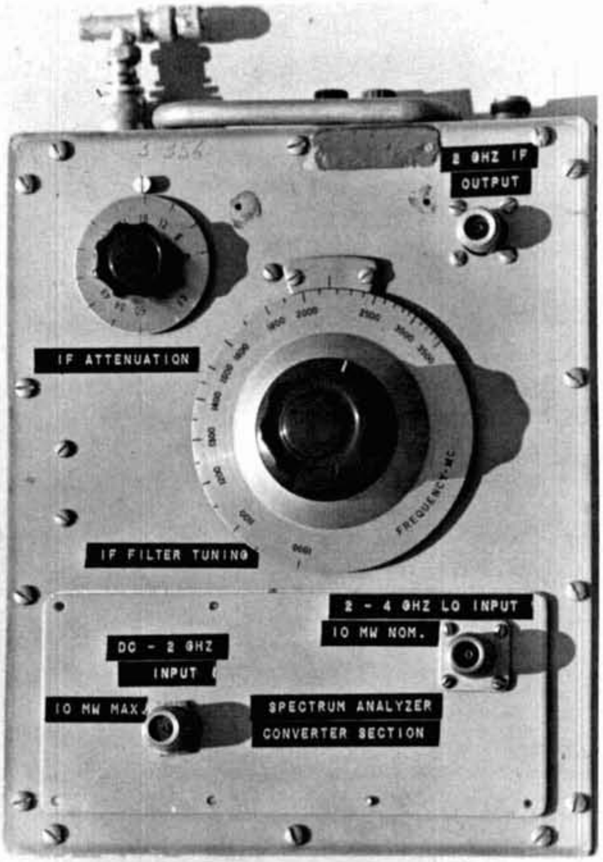


fig. 1. Block diagram of the microwave spectrum analyzer. Most components were purchased on the surplus market. The swept local oscillator, the key to the analyzer, is a surplus 2-4 GHz backward-wave oscillator. The display is an ordinary oscilloscope with dc coupling and provisions for external sweep.



Front panel of the microwave spectrum analyzer showing the operating controls. The variable i-f attenuator (upper left), although calibrated in 6 dB steps, permits amplitude comparison of signals displayed on the oscilloscope. The i-f bandpass filter (center) sets the frequency coverage of the analyzer, as discussed in the text.

imized, and spurious/image responses eliminated, to the greatest possible extent.

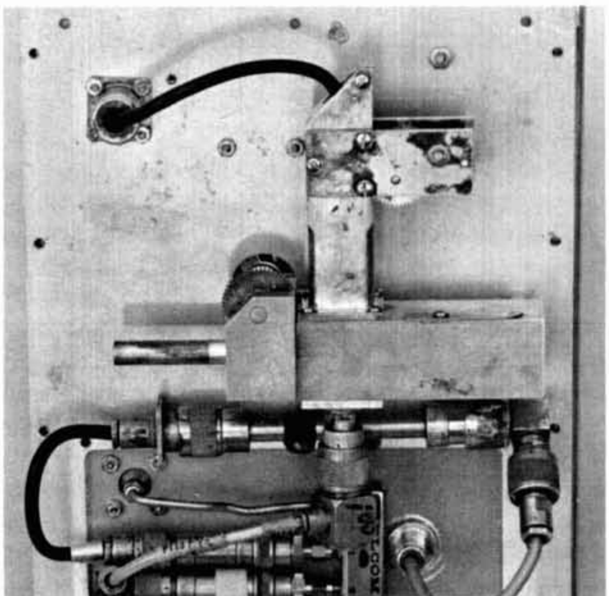
Many of the objectives discussed previously are met in the design shown in **fig. 1**, a wide dynamic range microwave receiver with an electronically tuned local oscillator and ample image rejection. It includes a 2-GHz i-f amplifier with variable gain and fixed bandwidth, and a sensitive detector for driving an oscilloscope. Unlike conventional receivers, this design up-converts the incoming signal to an i-f in the microwave region. Although this approach complicates i-f design, it permits wide dispersion tuning. It also improves separation of the rf and image signals so a simple lowpass filter can be used to eliminate image responses.

The microwave spectrum analyzer is divided into three separate sub-systems: the local oscillator, unity-gain upconverter, and display sections.

local oscillator

Central to the design of this spectrum analyzer was the availability, on the surplus market, of a leveled, swept signal source covering 2 to 4 GHz. I used an Alfred 622BK sweep oscillator, but any similar generator should work satisfactorily. These sweep generators consist of a voltage-controlled oscillator, typically a backward wave oscillator or BWO (a microwave oscillator built around a device similar to a traveling wave tube), power supplies, a sawtooth generator for developing a constantly varying vco control voltage, and leveling circuitry to maintain constant output across the band. *Start* and *stop* frequency adjustments permit the oscillator to sweep all, or any portion of, the 2 to 4 GHz band. Leveled output power is typically 10 to 30 milliwatts.

Many companies are currently retiring their BWO sweep generators in favor of wideband, solid-state units, so quite a few BWO generators have recently appeared on the surplus market at prices ranging from $200 to $400 or so. Since this is the most costly component of the microwave spectrum analyzer, make sure the unit you buy is in good operating condition. Reputable electronics surplus dealers will often let you power up an instrument and make a few measurements prior to purchase. A practical test requires the use of a microwave power meter (bolometer bridge or equivalent) to observe output power in the leveled CW mode as the generator is manually tuned across the band. Although a few dB variation is acceptable, dead spots or severe power drop-off at the high end of the band indicates a failing BWO. A good, used BWO should provide years of reliable life in intermittent amateur service.



Interior of the spectrum analyzer converter section showing the double-balanced mixer and attenuation pads, input filter, i-f filter, and variable i-f attenuator.

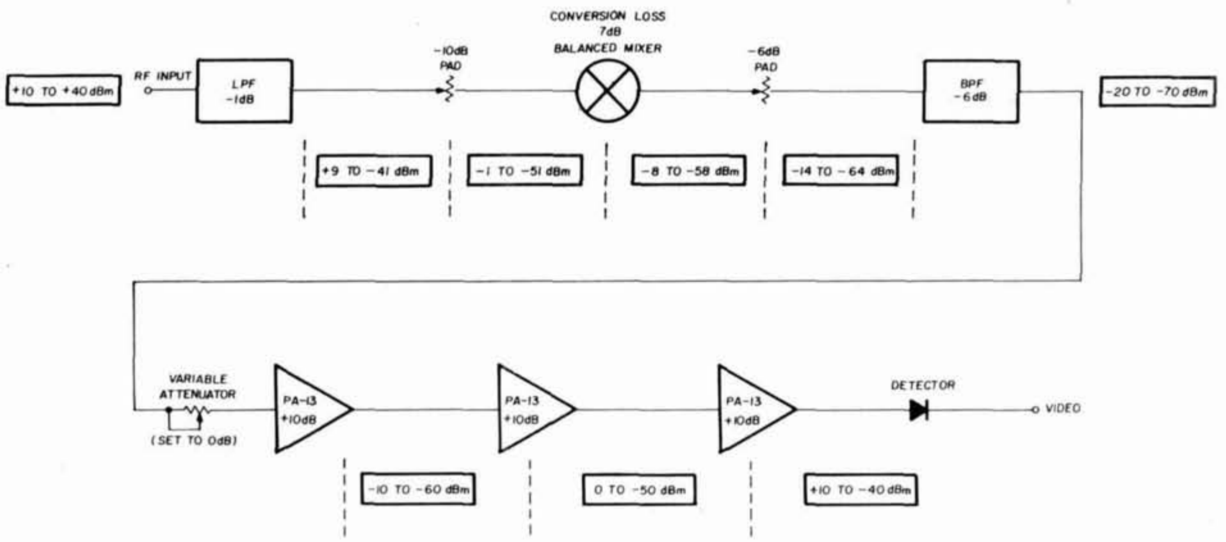


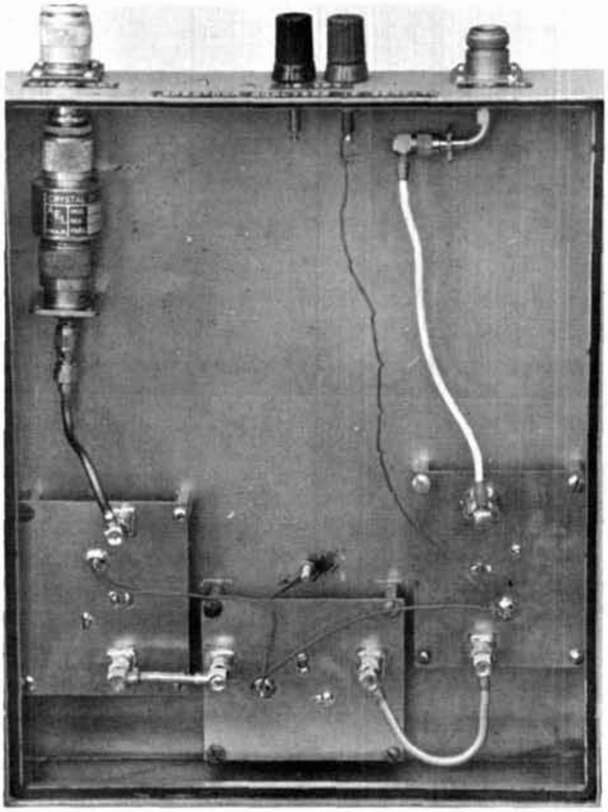
fig. 2. Power levels in the upconverter used with the microwave spectrum analyzer (with the variable attenuator set at 0 dB, which results in unity conversion gain).

As can be seen in the block diagram, **fig. 1**, the spectrum analyzer converter assembly consists of an input lowpass filter, an S-band double-balanced mixer, some attenuator pads, a high-Q i-f filter, a variable i-f attenuator, and sufficient i-f amplification to bring maximum conversion gain to unity. The i-f detector and its video load, though installed in the converter assembly, are discussed later with the display.

The characteristics of the balanced mixer, more than any other component, establish the linearity and dynamic range of the analyzer. I used a Relcom M1F mixer which I found on the surplus market for $35 (the mixer retails for about $200). The rated frequency response of this mixer is dc-2 GHz at the i-f port, and 2-4 GHz at the rf and LO ports. Note that the incoming signal is applied to the *i-f port*; the *rf port* drives the i-f system. Thus, all ports are operated withinn their specified frequency ranges.

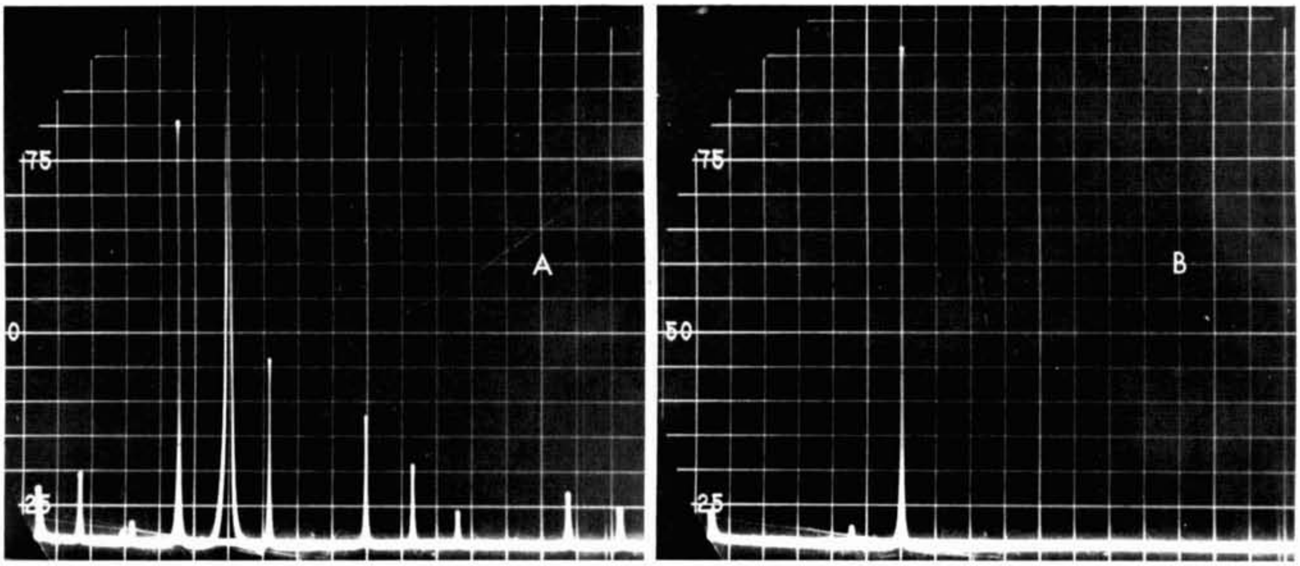
With the 10 mW of local-oscillator injection applied to the mixer from the sweep generator, the mixer's conversion efficiency is compressed by 1 dB at an input signal level of 1 mW. Since I wanted to analyze a 10 mW signal on the spectrum analyzer without exceeding 1 dB compression, it was necessary to place a 10 dB attenuation pad ahead of the mixer's input (i-f port). This pad also assures proper impedance termination for the mixer, as does the 6 dB attenuator at the output (rf port). Fixed attenuators for dc to 2 GHz are available to the surplus bargain hunter for as little as $5.00, or may be purchased new for $15 to $20.

With 2 GHz i-f, and a swept LO covering 2 to 4 GHz, the mixer will respond to signals in the dc-2 GHz region, as well as in the 4-6 GHz image band. Any components in the image band will cause considerable confusion on the display. Thus an input lowpass filter was installed in the system to block all signals above 3 GHz from entering the mixer. I used a Microlab/FXR LA-30N filter which I salvaged from another piece of equipment. Although the filter originally cost $40, similar devices are available through surplus outlets for $5 to $10.



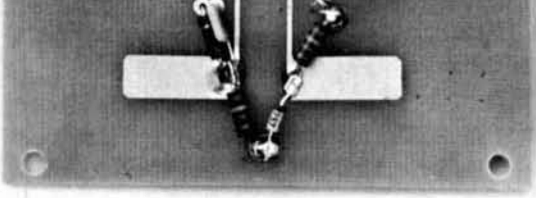
Spectrum analyzer i-f section. The three 2-GHz amplifiers are at the bottom. Diode detector is at upper left.

The i-f bandwidth of this analyzer is established by a high-Q tunable coaxial or cavity filter which is tuned to 2 GHz. I used the filter from a surplus TS-406 noise generator, but any cavity with a Q of 1000 or greater should be acceptable. It's also possible to use a *transmission-mode* cavity wavemeter as an i-f filter. These widely available devices have a loaded Q of several thousand, and exhibit only a few dB of insertion loss at resonance. Note that an absorption-type wavemeter is *not acceptable* because the filter must pass maximum signal to the i-f amplifiers at resonance.



Example of spectral impurity, as displayed on the microwave spectrum analyzer. Presence of harmonic, subharmonic, and spurious signals shown in *A* is the result of an overdriven uhf amplifier. The same amplifier, with drive reduced to the rated level, is shown at *B*; the one spurious component is down by more than 20 dB. Display is from dc to 2 GHz.

A 50 dB variable attenuator was installed after the filter to vary i-f gain . The attenuator I used was also salvaged from the TS-406 noise generator, but any continuously variable or step attenuator rated to 2 GHz is acceptable — 10 dB steps will allow coarse system gain control; if 1 dB resolution is included, the attenuator can also be used for accurate signal level comparison. This is accomplished by viewing one signal component, setting a convenient reference level on the display, varying the attenuator for a like indication on the other signal component, and noting the change in attenuator settings.



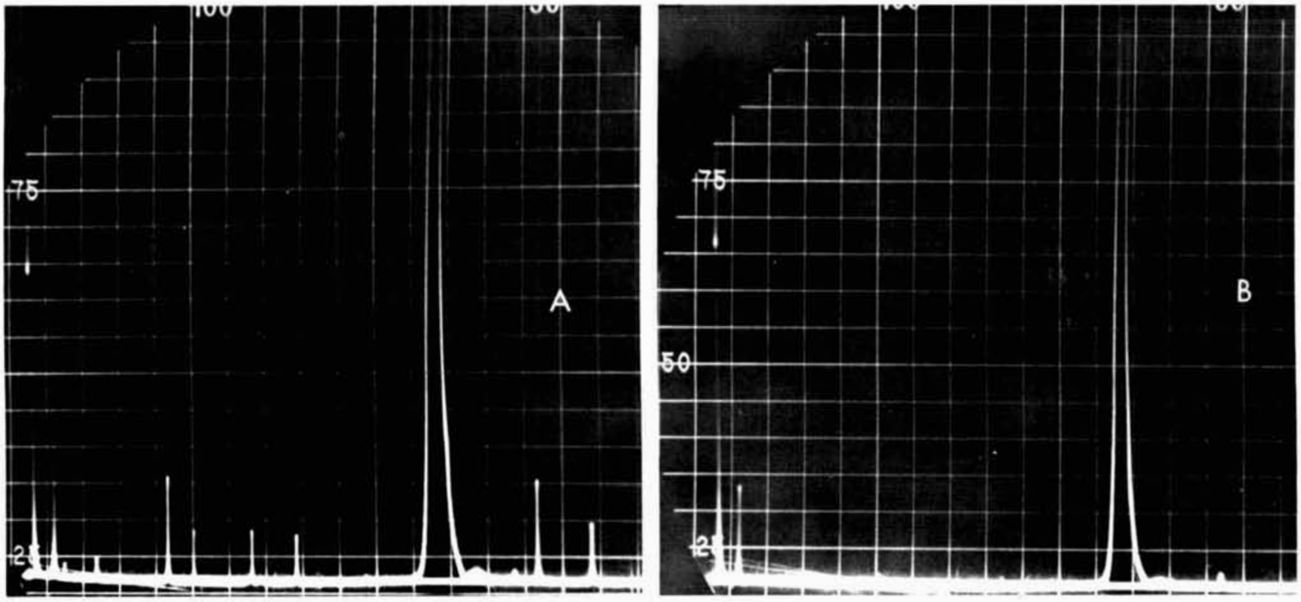
Microstripline side of the 2-GHz amplifier (Microcomm PA-13). Three of these units provide 30 dB gain at 2 GHz.

Considerable i-f gain is required to achieve the desired sensitivity. I cascaded three stages of the Microcomm PA-13 buffer amplifier.* These microstripline amplifier modules offer 10 dB of gain per stage across the 2.0-2.3 GHz band, and are biased for 30 mW output at 1 dB gain compression. Since i-f noise figure is not a limiting factor so far as system sensitivity is concerned, any available wide dynamic range amplifier for 2 GHz may be used.

display

The local-oscillator signal for the spectrum analyzer is swept by a sawtooth waveform; therefore, displaying a signal in the frequency domain is simply a matter of detecting the output signal from the i-f amplifiers, applying the recovered video to the vertical deflection amplifier of an oscilloscope, and applying the sawtooth output voltage from the sweep generator to the oscilloscope's horizontal axis. Since a relatively slow sweep rate is used, the

*Available for $64.95 per stage (plus postage and handling) from Microcomm, 14908 Sandy Lane, San Jose, California 95124.



Output of a local-oscillator chain for a 1296-MHz converter. At *A* the i-f gain of the spectrum analyzer has been increased to show the spurious signals, which are 30 dB below the desired signal. The display at *B* shows the output of the same local oscillator after it has passed through a 3-pole bandpass filter. Although the filter has attenuated the desired signal by 1 dB, all spurious signals are down more than 50 dB.

frequency response of the oscilloscope is unimportant. Virtually any scope with dc coupling and provisions for external sweep may be used.

The dynamic range of the detector which follows the i-f amplifiers is of major concern. **Fig . 2** shows the nominal gain or loss of each element of the analyzer upconverter, as well as maximum and minimum signal levels present at each stage with zero i-f attenuation (maximum sensitivity). Since the upconverter is operated at unity gain, the power available to the detector will vary from +10 to −40 dBm. Thus the diode's tangential sensitivity must be considerably below −40 dBm, and the diode's saturation point above +10 dBm, for a usable display. Although I know of no diode whose transfer characteristics are uniform over so wide a range, the 1N21 family of point-contact diodes are acceptable within certain limitations (discussed later).

Diode dynamic range is enhanced by the optimum terminating impedance, which may vary between 1000 ohms and 10 kilohms or so. The input impedance of an oscilloscope's vertical deflection amplifier is typically 1 megohm; thus, to assure proper termination for the diode, a loading resistor is required, as shown in **fig. 1**. Since terminating the diode's video port degrades the amplitude of the recovered video, increased oscilloscope vertical sensitivity is required. On my analyzer, a 7.5k ohm video load, in conjunction with a vertical sensitivity of 10 mV/cm, provides an acceptable display.

Note that the vertical display of the spectrum analyzer is approximately linear, not logarithmic. Therefore, it is possible to view only about 25 dB of amplitude range at once, and only with extremely limited amplitude resolution. However, by using the i-f attenuator to establish reference levels as described previously, the entire 50 dB of usable

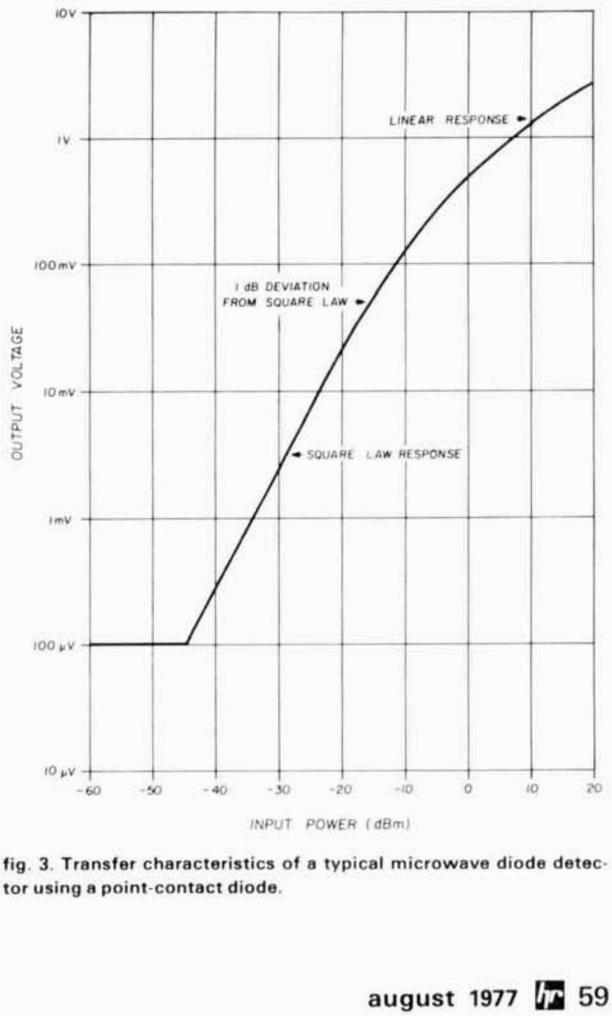


fig. 3. Transfer characteristics of a typical microwave diode detector using a point-contact diode.

dynamic range can be put to use. Future plans include capability for a logarithmic display, as outlined toward the end of this article.

I built the entire upconverter module in the case of a surplus noise generator (the filter and attenuator of which formed key i-f elements in my system). As can be seen in the photographs, the i-f amplifiers are mounted on standoffs inside the main chassis, and connected with UT-141 semi-rigid coaxial cable. If flexible coax is used, I recommend RG-142B/U. This ¼-inch (6.5mm) cable is double-shielded, silver plated, has a Teflon dielectric, and accepts clamp-type SMA plugs of the low-cost E. F. Johnson JCM series.

If desired, the i-f amplifiers may be mounted in Pomona 3601 die-cast aluminum boxes. These boxes present a neat appearance and afford somewhat better shielding than the standoff approach I used.

The various components of the upconverter assembly sport a variety of connectors; between-series adapters are required to interface types N, SMA, and TNC receptacles.

operation and applications

A recent article discussed a variety of spectrum analyzer applications of interest to amateurs.[1] For additional information, Hewlett-Packard has published two application notes which discuss both the procedures and the theory of spectrum analysis.[2,3]

The accompanying photographs show the displays obtained with this analyzer when measuring LO harmonic content, balanced mixer carrier rejection, converter image response, and transmitter intermodulation products.

improving sensitivity

One of my primary design objectives was the ability of the analyzer to handle relatively large (+10 dBm) input signals without overloading. The input pad shown in **fig. 1**, although it prevents mixer overload at these signal levels, obviously limits the ultimate sensitivity of the system. Additional i-f amplification would enhance the ability of the analyzer to display very small signals — but then the detector diode would saturate at high input signals.

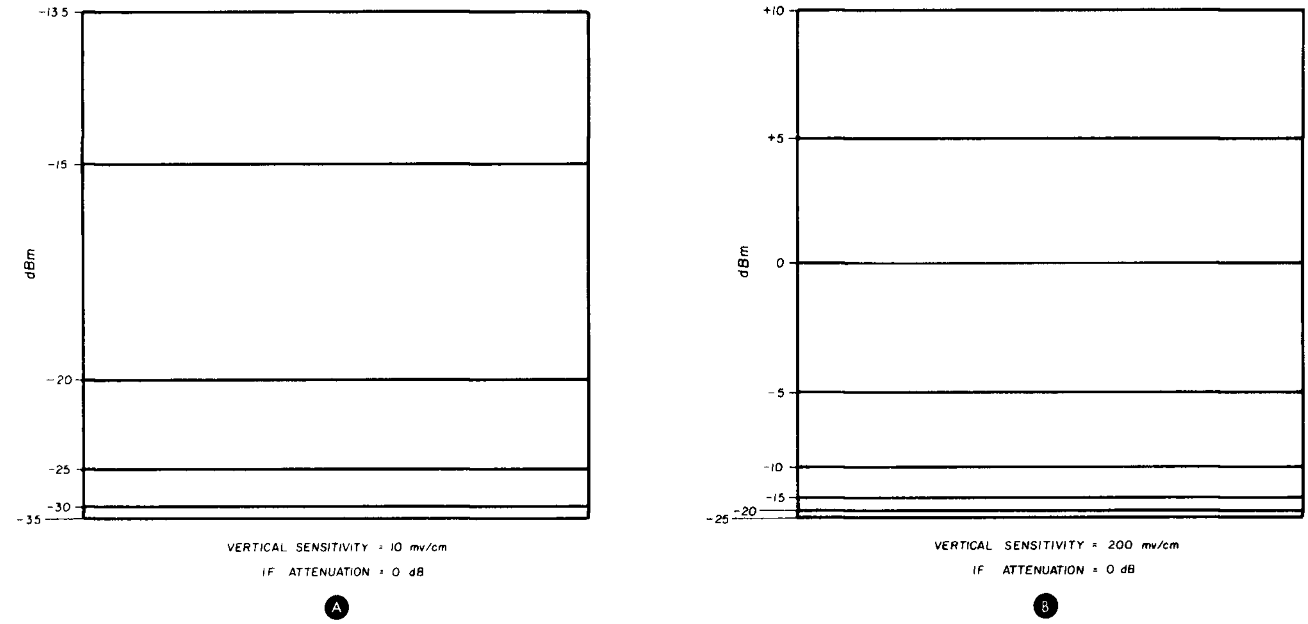
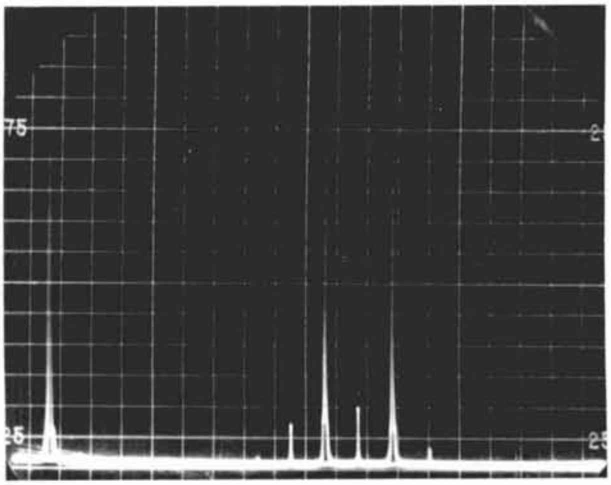


fig. 4. Approximate vertical scale calibration of the analyzer display (no video processing). Note the excellent linearity at high power levels, and the compressed display when the detector diode is operated in the square-law region.

Where both increased sensitivity and large-signal handling capability are required, it's necessary to replace the 10 dB input pad with an appropriate step attenuator (and possibly adding additional i-f stages). One candidate for the input attenuator is the Kay 520 which offers 10 dB steps to 70 dB and is flat to 2 GHz. This unit is priced under $100, but like everything else in my spectrum analyzer, units are often available through surplus sources at considerable savings.

Note that no variation in input attenuation or i-f gain can increase the dynamic range of this analyzer beyond 50 dB or so. Therefore, it is essential that the operator select input attenuation which is appropriate for the anticipated signal level. In short, input attenuation should be such that the signal applied to the mixer does not exceed 1 mW, and that to the detector remains below 30 mW. A simple operating check involves increasing the input at-



As a transmitting mixer's i-f port is overdriven, intermodulation products at $LO \pm 2i\text{-}f$ become more pronounced, and the amplitude of signals at $LO \pm 3i\text{-}f$ begins to increase. This display also shows the second harmonic of the i-f injection signal (at the left).

tenuation by 10 dB while decreasing i-f attenuation by the same amount. An increase in the apparent amplitude of the displayed signal indicates that the mixer was being over-driven.

expanding frequency coverage

Recently I became involved in designing amplifier, mixer and LO modules for 2304 MHz, and wanted to extend the upper frequency limit of this spectrum analyzer. This could be accomplished by varying either the swept LO frequency or the i-f frequency, or both. Since the LO frequency range is limited by the coverage of the available sweep generator, I chose to change the i-f frequency.

With a 2 to 4 GHz swept LO, frequency coverage from 500 MHz to 2.5 GHz could be obtained by modifying the analyzer's i-f to 1.5 GHz. However, this exceeds the rated frequency range of the mixer's rf and i-f ports. Fortunately, the frequency response of the i-f port of the mixer I used exceeded the specified 2 GHz. At 2.5 GHz input, vswr is degraded somewhat, but the use of the 10 dB input pad effectively masks this mismatch. As for the frequency response of the mixer's rf port (used to develop i-f output), reducing the i-f frequency to 1.5 GHz degrades conversion efficiency by several dB. The i-f is fixed, however, so this degradation applies equally to all input signals, and no system linearity is sacrificed.

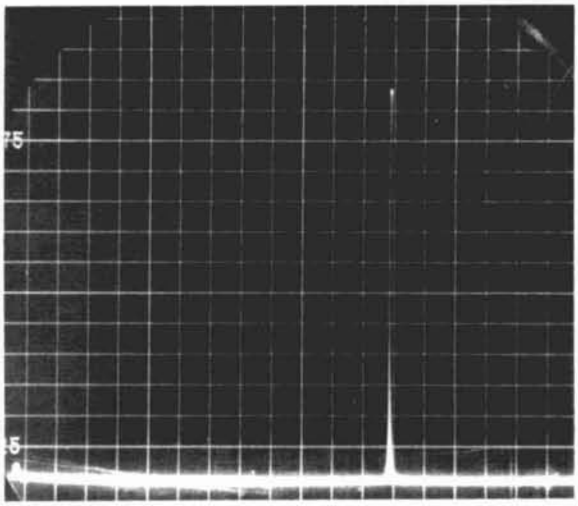
I originally planned to switch in a separate i-f system for high band (0.5-2.5 GHz) coverage, but I discovered that the PA-13 i-f amplifiers were sufficiently broadband that they have usable gain at 1.5 GHz. Since the cavity filter used to establish i-f bandwidth is tunable, setting the spectrum analyzer up for high-band coverage is simply a matter of retuning the i-f filter to 1.5 GHz. In this mode, overall analyzer sensitivity is degraded by about 10 dB, but it is still adequate for many applications.

With a 1.5 GHz i-f, the input signal range extends from 500 MHz to 2.5 GHz, and the image band from 3.5 to 5.5 GHz; therefore, the existing 3-GHz lowpass filter provides ample image rejection without degrading input frequency coverage.

detector limitations

In normal operation (**fig. 2**) the diode detector sees a power level from −40 to +10 dBm. **Fig. 3** shows the transfer characteristics of a typical microwave detector diode over this range. It can be seen that the diode is being driven from its square-law region into its linear region. Thus, at high signal levels, 10 dB of signal change results in approximately a 10 dB change in recovered video amplitude; at lower power levels a 10 dB input signal variation may change video amplitude by up to 20 dB. Obviously, the linearity of the display is marginal, at best, and usable dynamic range is restricted to about 25 dB unless the operator varies i-f gain, or vertical sensitivity or both.

Hewlett-Packard introduced a series of oscilloscope overlays for interpreting non-linear



Properly driven 1296-MHz transmit mixer, at the output of a 3-pole bandpass filter. The image, i-f, and LO signals are all 40 dB down; intermodulation products are more than 50 dB down. The small pip at the left side of the trace is the bandedge marker and represents zero frequency; it is produced when the LO sweeps through the i-f filter.

(more properly, non-logarithmic) swept displays.[4] A similar set of overlays, which I have derived for my spectrum analyzer, is shown in **fig. 4**. Although this calibration data is valid only for my analyzer, a similar vertical axis can be derived for any spectrum display. All you have to do is apply an input signal of known amplitude through an accurate step attenuator. By varying the attenuation and noting the displayed amplitude, calibration lines can be grease-penciled directly on to the face of the CRT.

The utility of this spectrum analyzer would be greatly enhanced if it were possible to display simultaneously all signals between −40 and +10 dBm. If you want to view the entire 50 dB dynamic range without adjusting reference levels with the i-f attenuator or varying vertical sensitivity, it will be necessary to apply the output of the detector into a compression video amplifier.

There are several integrated circuits available which provide logarithmic video amplification; with a logarithmic amplifier a display such as that shown in **fig. 5** can be obtained. Note that below about −10 dBm, the display approaches a uniform 5 dB per centimeter deflection. However, the transition from square-law to linear detection results in severe scale compression at higher power levels.

An ideal spectrum analyzer display should have vertical response similar to that shown in **fig. 6**. Although I have not yet been able to achieve this performance, it should be possible by developing a logarithmic video amplifier which makes its transition to linear response above a selected input level.

An approach used successfully by Pacific Measurements in their logarithmic power meters involves an operational amplifier in which the feedback resistance is a nonlinear element (a semiconductor junction). As the junction potential of this feedback path is exceeded, the gain curve of the op amp changes. The result is an amplifier which makes its transition from logarithmic to linear response at selected power level. Perhaps some reader will be able to contribute a similar circuit for appropriately shaping the video output of the spectrum analyzer's diode detector. What is needed is a display whose amplitude is graduated at 5 dB per centimeter, over the entire dynamic range of the system. This modification would significantly enhance both measurement accuracy and ease of operation.

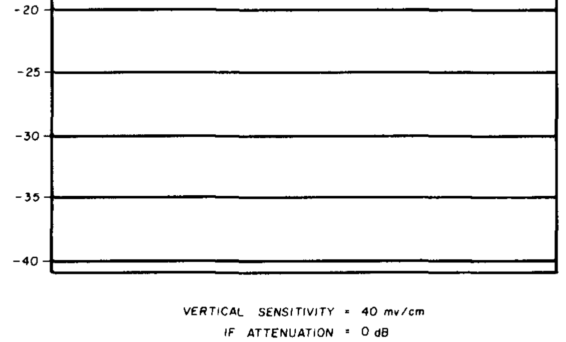


fig. 5. Typical vertical scale calibration of a spectrum analyzer with a logarithmic video amplifier. In this case display linearity is good at lower input signal levels, but compresses rapidly as the detector diode enters the linear region.

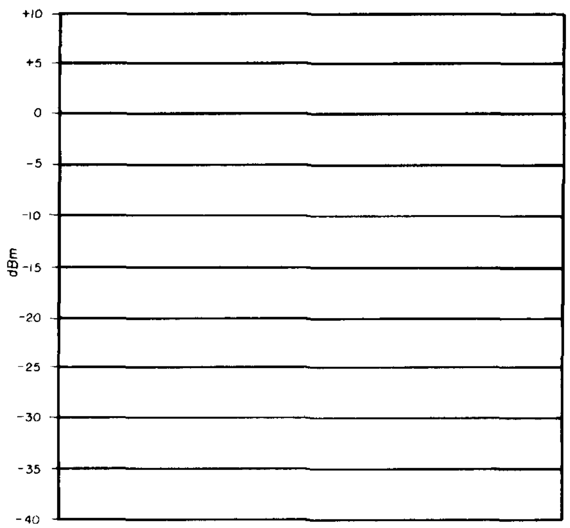


fig. 6. Ideal vertical response for a spectrum analyzer. This response requires a video amplifier with a logarithmic compression curve below an input of 200 mV, and linear response above 400 mV.

acknowledgements

Thanks are in order to Nick Marshall, W6OLO, for first encouraging me to try to build my own spectrum analyzer, and to Richard Chatelain, WB6JPY, who took the photographs. I must also acknowledge the eager support of my wife, WA6PLF. She reasoned that, if I built my own analyzer rather than spending funds I didn't have to buy one I couldn't afford, we would make good use of the money we saved. Although I'm not sure I understand the economics, I'm enjoying both the homebrew spectrum analyzer and our new car.

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1. Courtney Hall, WA5SNZ, "Understanding Spectrum Analyzers," *ham radio*, June, 1974, page 50.
2. *Spectrum Analysis*, Application Note 63, Hewlett-Packard, 1501 Page Mill Road, Palo Alto, California, May, 1965.
3. *More On Spectrum Analysis*, Application Note 63A, Hewlett-Packard, Palo Alto, California, November, 1965.
4. *Swept Frequency Techniques*, Application Note 65, Hewlett-Packard, Palo Alto, California, August, 1965.

ham radio

TR-7500

There are a number of good 2 meter FM transceivers on the market. You may already own one. But, even if you do, we suggest that you put your radio to this test. And, if you're thinking of buying one, this test should be a helpful guide.

	NO	YES
Is it PLL synthesized?	☐	☐
Does it have 100 channels (88 pre-programmed)?	☐	☐
Does it have 12 extra diode programmable channels?	☐	☐
Does it have single knob channel selection?	☐	☐
Does it have a LED digital frequency display?	☐	☐
Dos it have a powered tone pad connection?	☐	☐
Does the receiver have helical resonators?	☐	☐

If your answer is NO to any of these, the TR-7500 is the radio that you should own. And, in addition to these important features, you get proven Kenwood quality, value and service.

TR-7500 Specifications

Semiconductors: Transistors 41
FETs 8
ICs 7
Diodes 35

Frequency Range: 146.01 to 147.99 MHz
Mode: FM
No. of Channels: 100
Operating Temperature: −20 to +50 degrees C
Power Voltage: 11.5 to 16.0V DC (13.8V *DC nominal*)

Grounding Polarity: Negative ground
Antenna Impedance: 50 Ohms
Current drain: Less than 0.5A *in receive* with no input signal Less than 3A in transmit (HI) Less than 1.5A in transmit (LOW) (at 13.8V DC)
Dimensions: 172 mm (6—3/4") wide *250 mm (9—7/8") deep* 75 mm (2—15/16") high
Weight: Approximately 2.2 kg (4.8 lbs.)

TRANSMIT SECTION

RF Output Power: High: 10 Watts Low: 1 Watt (approximately)
Modulation: Variable reactance frequency shift
Frequency Deviation: ±5 KHz
Spurious Radiation: Better than −60dB

Tone Pad Input Impedance: 600 Ohms
Microphone: Dynamic microphone with PTT switch, 500 Ohms

RECEIVE SECTION

Receive System: Double conversion superheterodyne
Intermediate Frequency: 1st IF: 10.7 MHz 2nd IF: 455 kHz
Sensitivity: Better than 0.4 uV for 20dB quieting Better than 1 uV for 30dB S/N
Squelch Sensitivity: Better than 0.25 uV
Selectivity: 12kHz at −6dB down 40 kHz at −70dB down
Image Rejection: Better than −70dB
Spurious Interference: Better than −60dB
Audio Output: More than 1.5 watts across 8 Ohms load 10% distortion
Intermodulation: Better than 66dB

TRIO-KENWOOD COMMUNICATIONS INC. 1111 WEST WALNUT/COMPTON, CA 90220

KENWOOD

KENWOOD'S NEW TS-520S

AND DG-5 DIGITAL FREQUENCY DISPLAY

A NEW STANDARD IN ECONOMY TRANSCEIVERS

The NEW TS-520S combines all of the fine, field-proven characteristics of the original TS-520 together with many of the ideas, comments, and suggestions for improvement from amateurs worldwide. Kenwood's ultimate objectives . . . to make quality equipment available at reasonable prices.

FULL COVERAGE TRANSCEIVER

The new TS-520S provides full coverage on all amateur bands from 1.8 to 29.7 MHz. Kenwood gives you 160 meter capability, WWV on 15.000 MHz., and an auxiliary band position for maximum flexibility. And with the addition of the TV-502 and TV-506 transverters, your TS-520S can cover 160 meters to 2 meters on SSB and CW.

DIGITAL DISPLAY DG-5 (option)

The new Kenwood DG-5 provides easy, accurate readout of your operating frequency while transmitting *and* receiving.

OUTSTANDING RECEIVER SENSITIVITY AND MINIMUM CROSS MODULATION

The new TS-520S incorporates a 3SK-35 dual gate MOSFET for outstanding cross modulation and spurious response characteristics. The 3SK35 has a low noise figure (3.5 dB typ.) and high gain (18 dB typ.) for excellent sensitivity.

NEW IMPROVED SPEECH PROCESSOR

A new audio compression amplifier gives you extra punch in the pile ups and when the going gets rough.

VERNIER TUNING FOR FINAL PLATE CONTROL

A new vernier tuning mechanism allows easy and accurate adjustment of the plate control during tune-up.

FINAL AMPLIFIER

The new TS-520S is completely solid state except for the driver (12BY7A) and the final tubes. Rather than substitute TV sweep tubes as final amplifier tubes in a state of the art amateur transceiver, Kenwood has employed two husky S-2001A (equivalent to 6146B) tubes. These rugged, time-proven tubes are known for their long life and superb linearity.

HIGHLY EFFECTIVE NOISE BLANKER

An effective noise blanking circuit developed by Kenwood that virtually eliminâtes ignition noise is built-in to the TS-520S.

RF ATTENUATOR

The new TS-520S has a built-in 20 dB attentuator that can be activated by a push button switch conveniently located on the front panel.

VFO-520 — NEW REMOTE VFO

The VFO-520 remote VFO has been designed to match the styling of the TS-520S and provide maximum operating flexibility on the band selected on your TS-520S.

AC POWER SUPPLY

The TS-520S is completely self-contained with a rugged AC power supply built-in. The addition of the DS-1A DC-DC converter (option) allows for mobile operation of the TS-520S.

EASY CONNECTION PHONE PATCH

The TS-520S has 2 convenient RCA phono jacks on the rear panel for PHONE PATCH IN and PHONE PATCH OUT.

CW-520 — CW FILTER (OPTION)

The CW-520 500 Hz filter can be easily installed and will provide improved operation on CW.

AMPLIFIED TYPE AGC CIRCUIT

The AGC circuit has 3 positions (OFF, FAST, SLOW) to enable the TS-520S to be operated in the optimum condition at all times whether operating CW or SSB.

The TS-520S retains all of the features of the original TS-520 that made it tops in its class: RIT control • 8-pole crystal filter • Built-in 25 KHz calibrator • Front panel carrier level control • Semi-break-in CW with sidetone • VOX/PTT/MOX • TUNE position for low power tune up • Built-in speaker • Built-in Cooling Fan • Provisions for 4 fixed frequency channels • Heater switch.

Specifications

Amateur Bands: 160-10 meters plus WWV (receive only)
Modes: USB, LSB, CW
Antenna Impedance: 50-75 Ohms
Frequency Stability: Within ±1 kHz during one hour after one minute of warm-up, and within 100 Hz during any 30 minute period thereafter
Tubes & Semiconductors:
- Tubes .... 3 (S2001A x 2, 12BY7A)
- Transistors 52
- FETs 19
- Diodes 101

Power Requirements: 120/220 V AC, 50/60 Hz, 13.8 V DC (with optional DS-1A)
Power Consumption: Transmit: 280 Watts Receive: 26 Watts (with heater off)
Dimension: 333(13⅛) W x 153 (6-0) H x 335(13-(13-3/16) D mm(inch)
Weight: 16.0 kg(35.2 lbs)

TRANSMITTER
RF Input Power: SSB: 200 Watts PEP CW: 160 Watts DC
Carrier Suppression: Better than -40 dB
Sideband Suppression: Better than -50 dB
Spurious Radiation: Better than -40 dB
Microphone Impedance: 50k Ohms
AF Response: 400 to 2,600 Hz

RECEIVER
Sensitivity: 0.25 uV for 10 dB (S+N)/N
Selectivity: SSB:2.4 kHz/-6 dB, 4.4 kHz/-60 dB
Selectivity: CW: 0.5 kHz/-6 dB, 1.5 kHz/-60 dB (with optional CW-520 filter)
Image Ratio: Better than 50 dB
IF Rejection: Better than 50 dB
AF Output Power: 1.0 Watt (8 Ohm load, with less than 10% distortion)
AF Output Impedance: 4 to 16 Ohms

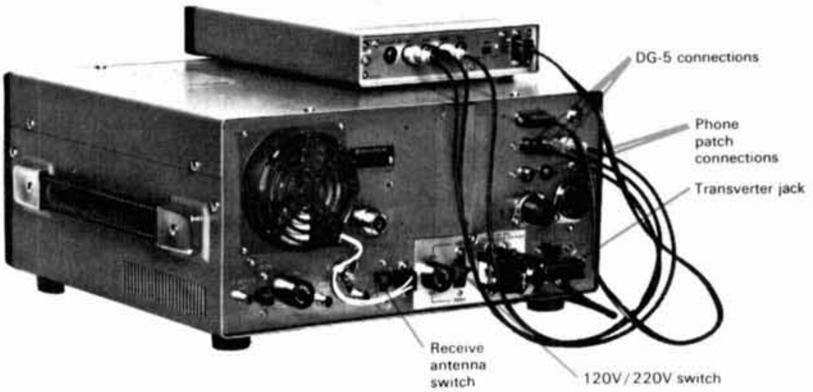
DG-5

SPECIFICATIONS
Measuring Range: 100 Hz to 40 MHz
Input Impedance: 5 k Ohms
Gate Time: 0.1 Sec.
Input Sensitivity: 100 Hz to 40 MHz . . . 200 mV rms or over, 10 kHz to 10 MHz . . 50 mV or over
Measuring Accuracy: Internal time base accuracy ±0.1 count
Time Base: 10 MHz
Operating Temperature: -10° to 50° C/14° 122° F
Power Requirement: Supplied from TS-520S or 12 to 16 VDC (nominal 13.8 VDC)
Dimensions: 167(6-9/16) W x 43(1-11/16) H x 268(10-9/16) D mm(inch)
Weight: 1.3 kg(2.9 lbs)

DG-5
(optional)

The luxury of digital readout is available on the TS-520S by connecting the new DG-5 readout (option). More than just the average readout circuit, this counter mixes the carrier, VFO, and heterodyne frequencies to give you your exact frequency. This handsomely-styled accessory can be set almost anyplace in your shack for easy to read operation . . . or set it on the dashboard during mobile operation for safety and convenience. Six bold digits display your operating frequency while you transmit and receive. Complete with DH (display hold) switch for frequency memory and 2 position intensity selector. The DG-5 can also be used as a normal frequency counter up to 40 MHz at the touch of a switch. (Input cable provided.)

NOTE: TS-520 owners can use the DG-5 with a DK-520 adapter kit.



TS-820S

We told you that the TS-820 would be the best. In little more than a year our promise has become a fact. Now, in response to hundreds of requests from amateurs, Kenwood offers the TS-820S* . . . the same superb transceiver, but with the digital readout factory installed. The worldwide demand for the TS-820 far exceeded our initial production plans. However, production capacity has been substantially increased and our objective is to make the TS-820S more readily available to you. As an owner of this beautiful rig, you will have at your fingertips the combination of controls and features that even under the toughest operating conditions make the *TS-820S the Pacesetter that it is.*

Features

Following are a few of the TS-820S' many exciting features.

SPEECH PROCESSOR • An RF circuit provides quick time constant compression using a true RF compressor as opposed to an AF clipper. Amount of compression is adjustable to the desired level by a convenient front panel control.

IF SHIFT • The IF SHIFT control varies the IF passband without changing the receive frequency. Enables the operator to eliminate unwanted signals by moving them out of the passband of the receiver. This feature alone makes the TS-820S a pacesetter.

TV-506 TV-502 VFO-820 TS-820S SP-520

PLL • The TS-820S employs the latest phase lock loop circuitry. The single conversion receiver section performance offers superb protection against unwanted cross-modulation. And now, PLL allows the frequency to remain the same when switching sidebands (USB, LSB, CW) and eliminates having to recalibrate each time.

DIGITAL READOUT • The digital counter display is employed as an integral part of the VFO readout system. Counter mixes the carrier, VFO, and first heterodyne frequencies to give *exact* frequency. Figures the frequency down to 10 Hz and digital display reads out to 100 Hz. Both receive and transmit frequencies are displayed in easy to read, Kenwood Blue digits.

Specifications

FREQUENCY RANGE: 1.8-29.7 MHz (160 - 10 meters)
MODES: USB, LSB, CW, FSK
INPUT POWER: 200W PEP on SSB
160 W DC on CW
100 W DC on FSK
ANTENNA IMPEDANCE: 50-75 ohms, unbalanced
CARRIER SUPPRESSION: Better than -40 dB
SIDEBAND SUPPRESSION: Better than -50 dB
SPURIOUS RADIATION: Greater than -60 dB (Harmonics more than -40 dB)
RECEIVER SENSITIVITY: Better than 0.25uV
RECEIVER SELECTIVITY:
SSB 2.4 kHz (-6 dB)
4.4 kHz (-60 dB)
CW* 0.5 kHz (-6 dB)
1.8 kHz (-60 dB)
*(with optional CW filter installed)
IMAGE RATIO: 160-15 meters: Better than 60 dB 10 meters: Better than 50 dB
IF REJECTION: Better than 80 dB
POWER REQUIREMENTS: 120/220 VAC, 50/60 Hz, 13.8 VDC (with optional DS-1A DC-DC converter)
POWER CONSUMPTION: Transmit: 280 Watts Receive: 26 Watts (heaters off)
DIMENSIONS: 13-1/8" W x 6" H x 13-3/16" D
WEIGHT: 35.2 lbs (16 kg)

VFO-820

Function switch provides any combination of transmit/receive/transceive with the TS-820S. Both are equipped with VFO indicators showing which VFO is in use.

SP-520

Although the TS-820S has a built-in speaker, the addition of the SP-520 provides improved tonal quality. A perfect match in both design and performance.

TV-502

The TV-502 transverter puts you on 2-meters the easy way. Operates in the 144.0-145.7 MHz frequency range with a 145.0-146.0 MHz option. Completely compatible with the TS-820S, the TS-520S and most any HF transceiver.

TV-506

Similar to the TV-502 except that it opens up the 6-meter band (50.0-54.0 MHz) to your HF rig.

*The TS-820 and DG-1 are still available separately.

serial converter

for 8-level teleprinters

This converter translates Baudot to ASCII and ASCII to Baudot using readily available ICs — recommended for the experienced amateur only

At the outset I'd like to stress that this is a project for the experienced amateur with the technical know-how to connect the converter described to appropriate points in his demodulator or fsk circuit.

The heart of the converter is the universal asynchronous receiver/transmitter (UAR/T), a 40-pin IC that contains both an independent, 8-bit asynchronous, digital-data receiver, and an 8-bit asynchronous, digital-data transmitter. The UAR/T has been described earlier in *ham radio*.[1,2]

Parts layout and wiring of the converter is quite a task in itself. Sockets are mandatory for the ICs as some are MOS devices, which are sensitive to ungrounded soldering irons. Fairly heavy bus wire is necessary for ground (common) and +5-volt leads. Also, liberal use of 0.01-μF ceramic disc capacitors (not shown in the schematic) is required to bypass +5, and −12 volt circuits.

All NAND gates used as inverters can be replaced by hex inverters to reduce component count. Type 74121s can be replaced by 74123s except where both A inputs are used.

Those readers interested only in receiving RTTY with an 8-level machine can save much time and money by deleting the connections (except for grounds and clock inputs) to the much more complex ASCII-to-Baudot section, which is shown below the dashed lines of both UAR/Ts in **fig. 1**.

The cost for the complete converter should be well below $100; possibly around $50. The 8223 proms can be replaced with 82S23s, which are currently on the market for about $3 each. The UAR/T ICs can be replaced with the GI AY-5-1013A, which is less expensive, about $6.50. The 3351 fifo devices can be obtained for about $14 through W6KS, as mentioned in the *RTTY Journal*. The other chips are standard devices and are available for about 50 cents or so.

Baudot-to-ASCII/ASCII-to-Baudot converters have been described in other publications but were not directly compatible with RTTY, which is a serial system, and didn't take advantage of the UAR/Ts.

circuit description

The converter schematic is shown in **fig. 1**. The serial 5-bit Baudot signal at TTL level enters U1 at pin 20 and appears in parallel form at pins 8 through 12. ICs U2, U3 sense whether letters or figures have been sent and set R/S flip-flop U4 to enable either U5 or U6, which translate the 5-bit Baudot code to 7-bit ASCII code; this translation appears at U6 pins 1 through 7. (The no. 8 bit is a parity bit, which is used with computers, and is unnecessary for amateur RTTY. I have modified my model 35ASR so that the no. 8 bit is always a zero.)

Output from U6 is applied to UAR/T U7 and appears in serial form at pin 25, which is connected through driver Q1 to a 4N33 opto-isolator, U8. Another 4N33, U9, is connected in series with U8, whose output with that of U8 is inserted into the loop of a model 33 or 35 ASR. This circuit keeps modifications of the ASCII machine to a minimum.

The signal originating from either the keyboard or tape reader of the ASCI machine is connected to the input of the second 4N33, U9, and its output serially feeds into U7-20. This data appears in parallel form at U7 pins 12 through 19.

Because there are no *LTRS* or *FIGS* in the ASCII code, these characters must be generated. For this reason the 6th and 7th ASCII bit, which appear at pins 7 and 6 respectively to U7, are sensed by 7474 flip-flop U10. In combination with 7474 flip-flop U11, U10 will disable the 8223 proms U12, U13 temporarily.

By Eric Kirchner, VE3CTP, Ontario Science Center, Don Mills, Ontario, Canada

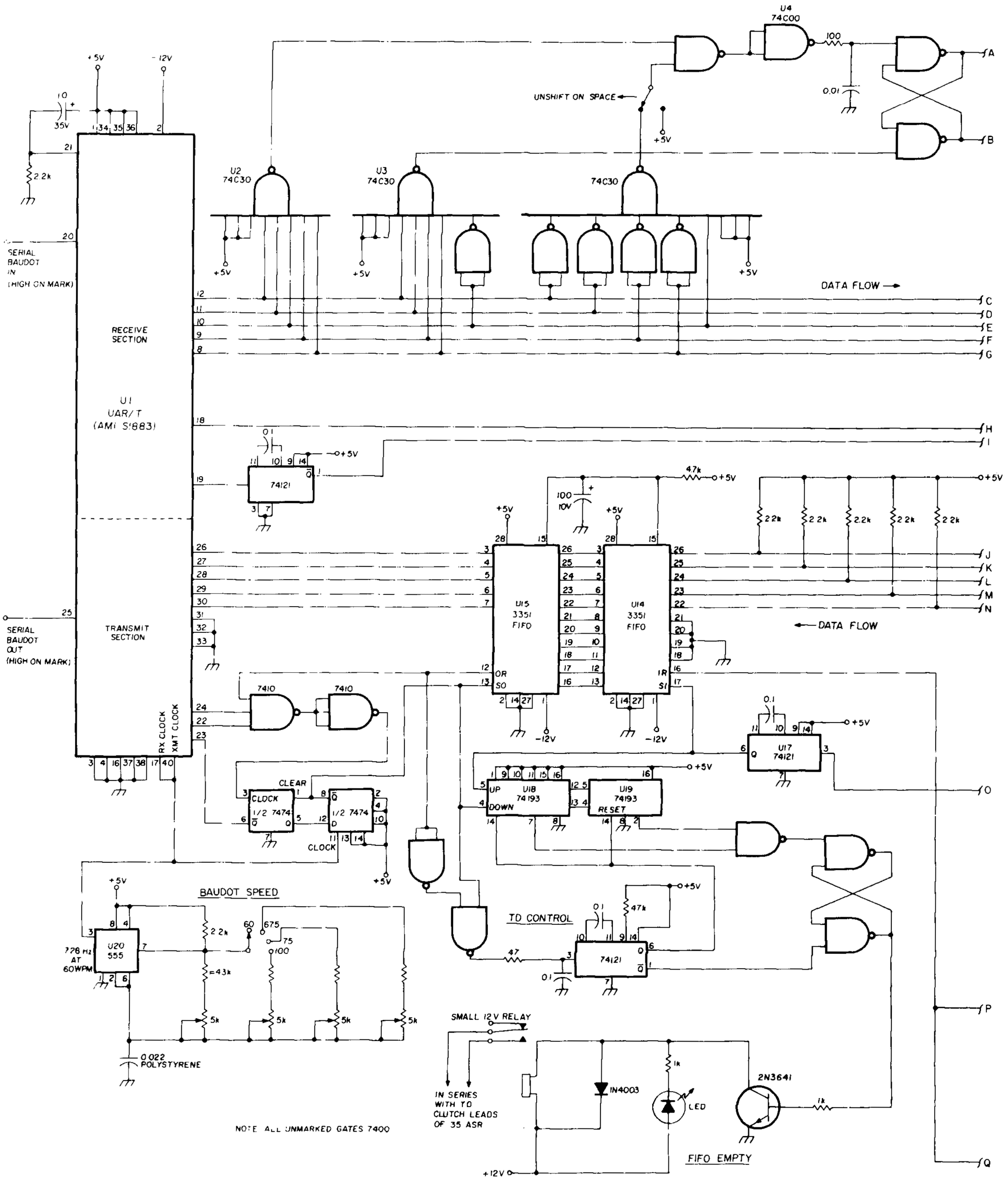


fig. 1. Schematic of the serial Baudot-to-ASCII-to-Baudot converter for model 33 and 35 ASR machines.

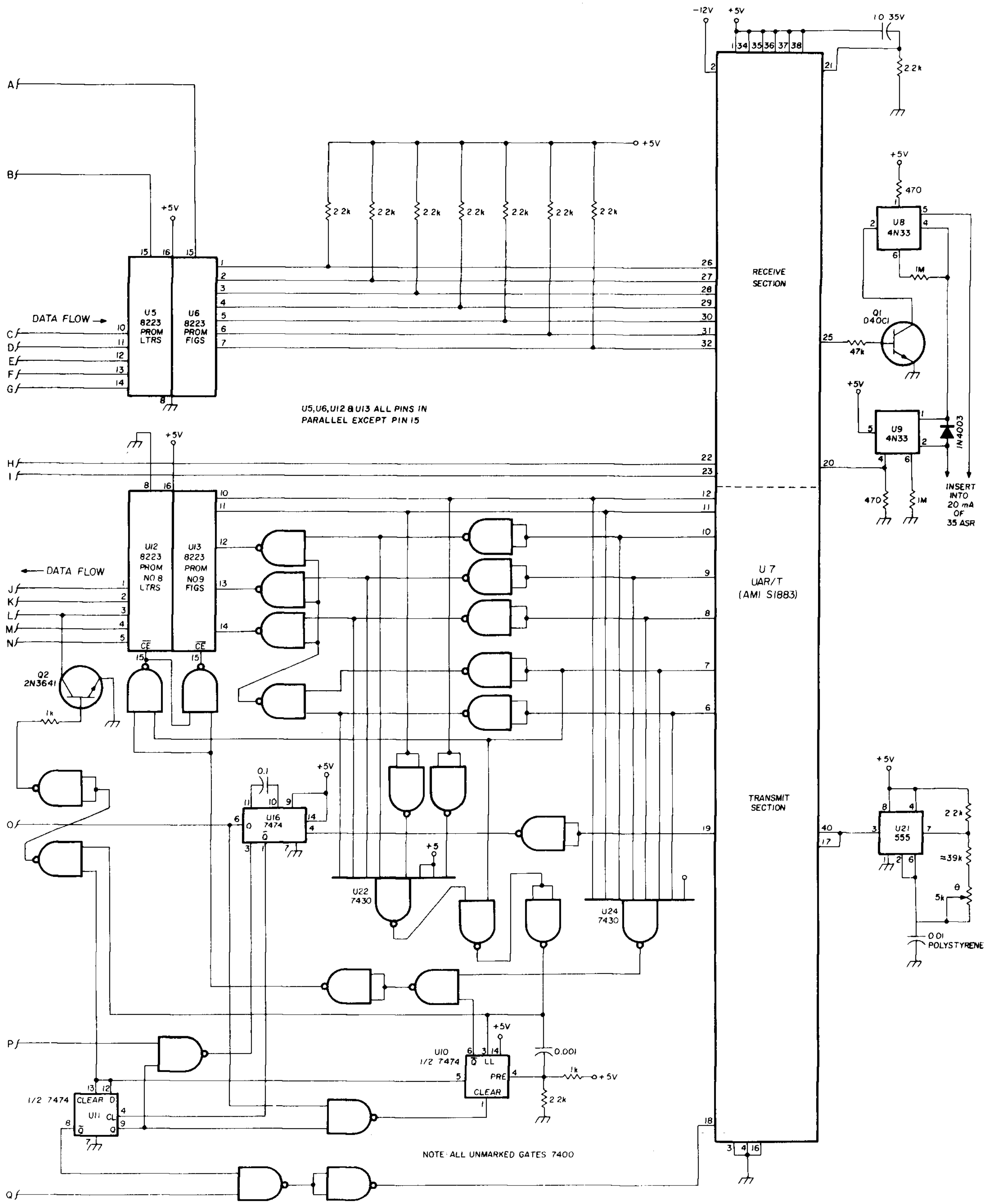

DATA FLOW
U5 8223 PROM LTRS
U6 8223 PROM FIGS
U5,U6,U12 & U13 ALL PINS IN PARALLEL EXCEPT PIN 15
DATA FLOW
U12 8223 PROM NO 8 LTRS
U13 8223 PROM NO 9 FIGS
Q2 2N3641
U16 7474
U22 7430
U24 7430
U10 1/2 7474
1/2 7474 U11
NOTE: ALL UNMARKED GATES 7400
RECEIVE SECTION
U 7 UAR/T (AMI S1883)
TRANSMIT SECTION
U8 4N33
Q1 D40C1
U9 4N33
IN4003
INSERT INTO 20 mA OF 35 ASR
U21 555
0.01 POLYSTYRENE

table 1. Program for 8223 prom, Baudot-to-ASCII letters (U5).

Word	A 4 3 2 1 0	Symbol	B 0 1 2 3 4 5 6 7
0	0 0 0 0 0	Blank	0 0 0 0 0 0 0 0
1	1 0 0 0 0	T	0 0 1 0 1 0 1 0
2	0 1 0 0 0	CR	1 0 1 1 0 0 0 0
3	1 1 0 0 0	O	1 1 1 1 0 0 1 0
4	0 0 1 0 0	Space	0 0 0 0 0 1 0 0
5	1 0 1 0 0	H	0 0 0 1 0 0 1 0
6	0 1 1 0 0	N	0 1 1 1 0 0 1 0
7	1 1 1 0 0	M	1 0 1 1 0 0 1 0
8	0 0 0 1 0	LF	0 1 0 1 0 0 0 0
9	1 0 0 1 0	L	0 0 1 1 0 0 1 0
10	0 1 0 1 0	R	0 1 0 0 1 0 1 0
11	1 1 0 1 0	G	1 1 1 0 0 0 1 0
12	0 0 1 1 0	I	1 0 0 1 0 0 1 0
13	1 0 1 1 0	P	0 0 0 0 1 0 1 0
14	0 1 1 1 0	C	1 1 0 0 0 0 1 0
15	1 1 1 1 0	V	0 1 1 0 1 0 1 0
16	0 0 0 0 1	E	1 0 1 0 0 0 1 0
17	1 0 0 0 1	Z	0 1 0 1 1 0 1 0
18	0 1 0 0 1	D	0 0 1 0 0 0 1 0
19	1 1 0 0 1	B	0 1 0 0 0 0 1 0
20	0 0 1 0 1	S	1 1 0 0 1 0 1 0
21	1 0 1 0 1	Y	1 0 0 1 1 0 1 0
22	0 1 1 0 1	F	0 1 1 0 0 0 1 0
23	1 1 1 0 1	X	0 0 0 1 1 0 1 0
24	0 0 0 1 1	A	1 0 0 0 0 0 1 0
25	1 0 0 1 1	W	1 1 1 0 1 0 1 0
26	0 1 0 1 1	J	0 1 0 1 0 0 1 0
27	1 1 0 1 1	FIGS	0 0 0 1 1 0 0 0
28	0 0 1 1 1	U	1 0 1 0 1 0 1 0
29	1 0 1 1 1	Q	1 0 0 0 1 0 1 0
30	0 1 1 1 1	K	1 1 0 1 0 0 1 0
31	1 1 1 1 1	LTRS(delete)	1 1 1 1 1 1 1 0

table 2. Program for 8223 prom, Baudot-to-ASCII figures (U6).

Word	A 4 3 2 1 0	Symbol	B 0 1 2 3 4 5 6 7
0	0 0 0 0 0	Blank	0 0 0 0 0 0 0 0
1	1 0 0 0 0	5	1 0 1 0 1 1 0 0
2	0 1 0 0 0	CR	1 0 1 1 0 0 0 0
3	1 1 0 0 0	9	1 0 0 1 1 1 0 0
4	0 0 1 0 0	Space	0 0 0 0 0 1 0 0
5	1 0 1 0 0	#	1 1 0 0 0 1 0 0
6	0 1 1 0 0	,	0 0 1 1 0 1 0 0
7	1 1 1 0 0	.	0 1 1 1 0 1 0 0
8	0 0 0 1 0	LF	0 1 0 1 0 0 0 0
9	1 0 0 1 0	)	1 0 0 1 0 1 0 0
10	0 1 0 1 0	4	0 0 1 0 1 1 0 0
11	1 1 0 1 0	&	0 1 1 0 0 1 0 0
12	0 0 1 1 0	8	0 0 0 1 1 1 0 0
13	1 0 1 1 0	Ø	0 0 0 0 1 1 0 0
14	0 1 1 1 0	:	0 1 0 1 1 1 0 0
15	1 1 1 1 0	;	1 1 0 1 1 1 0 0
16	0 0 0 0 1	3	1 1 0 0 1 1 0 0
17	1 0 0 0 1	"	0 1 0 0 0 1 0 0
18	0 1 0 0 1	$	0 0 1 0 0 1 0 0
19	1 1 0 0 1	?	1 1 1 1 1 1 0 0
20	0 0 1 0 1	Bell	1 1 1 0 0 0 0 0
21	1 0 1 0 1	6	0 1 1 0 1 1 0 0
22	0 1 1 0 1	!	1 0 0 0 0 1 0 0
23	1 1 1 0 1	/	1 1 1 1 0 1 0 0
24	0 0 0 1 1	-	1 0 1 1 0 1 0 0
25	1 0 0 1 1	2	0 1 0 0 1 1 0 0
26	0 1 0 1 1	1	1 1 1 0 0 1 0 0
27	1 1 0 1 1	FIGS	0 0 0 1 1 0 0 0
28	0 0 1 1 1	7	1 1 1 0 1 1 0 0
29	1 0 1 1 1	'	1 0 0 0 1 1 0 0
30	0 1 1 1 1	(	0 0 0 1 0 1 0 0
31	1 1 1 1 1	LTRS	1 1 1 1 1 1 1 0

If a *LTRS* character must be inserted into the text, transistor Q2, a 2N3641, will be nonconducting so that all bits on the left-hand side of proms U12, U13 will be high, signifying the *LTRS* code. If a *FIGS* character must be inserted into text, Q2 will conduct, making the center bit a zero, which signifies the *FIGS* code.

The ASCII bits are applied to the address lines of 8223 proms U12, U13. Here the ASCII code is translated into the corresponding Baudot code; this data is fed into the two 3351 fifos, U14 and U15. A "data available" pulse at U7-19, delayed by the two 74121 one-shots (U16, U17), appears at the "shift-in" pin of U14 (pin 17). The Baudot characters are thus loaded into the fifo memory.

The fifo memories are necessary because the information from the ASCII machine is fed in at 100 wpm, while the Baudot output from UAR/T U1 is at 60 wpm. When typing, the ASCII speed will exceed 60 wpm only occasionally. However, when the ASCII tape reader runs, the memory will eventually become fully loaded. Because the two fifos can store only 80 characters, the tape reader control circuit, consisting of up-down counter U18, U19, will interrupt current to the tape-reader clutch, holding it until the fifo memory is again empty.

The parallel data at fifo U15 output is applied to UAR/T U1 and appears in serial form at TTL level at U1-25. This signal can be used to key an afsk generator, as described below.

The 555 clocks, U20, U21, will be stable if high-grade components are used. Crystal stability is nice but unncecessary. Precise resistance values have not been given as they may differ from case-to-case, but they can be easily determined with a frequency counter.

Because the equivalent Baudot character for the ASCII space signal is contained in the ASCII-to-Baudot *FIGS* prom, a space signal between words is always preceded and followed by a *LTRS* and *FIGS* signal. This is undesirable because two extra characters will be sent, which are unnecessary. This problem can be resolved by TTL IC U22 which steers U10 (**fig. 1**).

Note that when using the converter with an fsk demoodulator it may be necessary to insert a level changer, inverter, or both between the demodulator and U1-20. The data must enter this point at TTL level. The *Baudot speed* switch (**fig. 1**) allows you to copy signals at speeds other than the amateur speed of 60 wpm.

Pin numbers for the gates in **fig. 1** (type 7400s) have not been given as a new layout will be made for the final version. Except for the proms, the ICs in the Baudot to ASCII section are CMOS devices. These happened to be available, so they were used. The cir-

table 3. Program for 8223 prom, ASCII-to-Baudot letters (U13).

Word	A 4 3 2 1 0	Symbol	B 0 1 2 3 4 5 6 7
0	0 0 0 0 0	Null	0 0 0 0 0 0 0 0
1	0 0 0 0 1	A	1 1 0 0 0 0 0 0
2	0 0 0 1 0	B	1 0 0 1 1 0 0 0
3	0 0 0 1 1	C	0 1 1 1 0 0 0 0
4	0 0 1 0 0	D	1 0 0 1 0 0 0 0
5	0 0 1 0 1	E	1 0 0 0 0 0 0 0
6	0 0 1 1 0	F	1 0 1 1 0 0 0 0
7	0 0 1 1 1	G	0 1 0 1 1 0 0 0
8	0 1 0 0 0	H	0 0 1 0 1 0 0 0
9	0 1 0 0 1	I	0 1 1 0 0 0 0 0
10	0 1 0 1 0	J	1 1 0 1 0 0 0 0
11	0 1 0 1 1	K	1 1 1 1 0 0 0 0
12	0 1 1 0 0	L	0 1 0 0 1 0 0 0
13	0 1 1 0 0	M	0 0 1 1 1 0 0 0
14	0 1 1 1 0	N	0 0 1 1 0 0 0 0
15	0 1 1 1 1	O	0 0 0 1 1 0 0 0
16	1 0 0 0 0	P	0 1 1 0 1 0 0 0
17	1 0 0 0 1	Q	1 1 1 0 1 0 0 0
18	1 0 0 1 0	R	0 1 0 1 0 0 0 0
19	1 0 0 1 1	S	1 0 1 0 0 0 0 0
20	1 0 1 0 0	T	0 0 0 0 1 0 0 0
21	1 0 1 0 1	U	1 1 1 0 0 0 0 0
22	1 0 1 1 0	V	0 1 1 1 1 0 0 0
23	1 0 1 1 1	W	1 1 0 0 1 0 0 0
24	1 1 0 0 0	X	1 0 1 1 1 0 0 0
25	1 1 0 0 1	Y	1 0 1 0 1 0 0 0
26	1 1 0 1 0	Z	1 0 0 0 1 0 0 0
27	1 1 0 1 1	Null	0 0 0 0 0 0 0 0
28	1 1 1 0 0	Null	0 0 0 0 0 0 0 0
29	1 1 1 0 1	CR	0 0 0 1 0 0 0 0
30	1 1 1 1 0	LF	0 1 0 0 0 0 0 0
31	1 1 1 1 1	Null	0 0 0 0 0 0 0 0

table 4. Program for 8223 prom, ASCII-to-Baudot letters (U12).

Word	A 4 3 2 1 0	Symbol	B 0 1 2 3 4 5 6 7
0	0 0 0 0 0	Space	0 0 1 0 0 0 0 0
1	0 0 0 0 1	!	1 0 1 1 0 0 0 0
2	0 0 0 1 0	"	1 0 0 0 1 0 0 0
3	0 0 0 1 1	#	0 0 1 0 1 0 0 0
4	0 0 1 0 0	$	1 0 0 1 0 0 0 0
5	0 0 1 0 1	Null	0 0 0 0 0 0 0 0
6	0 0 1 1 0	&	0 1 0 1 1 0 0 0
7	0 0 1 1 1	'	1 1 0 1 0 0 0 0
8	0 1 0 0 0	(	1 1 1 1 0 0 0 0
9	0 1 0 0 1	)	0 1 0 0 1 0 0 0
10	0 1 0 1 0	Null	0 0 0 0 0 0 0 0
11	0 1 0 1 1	Null	0 0 0 0 0 0 0 0
12	0 1 1 0 0	,	0 0 1 1 0 0 0 0
13	0 1 1 0 1	-	1 1 0 0 0 0 0 0
14	0 1 1 1 0	.	0 0 1 1 1 0 0 0
15	0 1 1 1 1	/	1 0 1 1 1 0 0 0
16	1 0 0 0 0	Ø	0 1 1 0 1 0 0 0
17	1 0 0 0 1	1	1 1 1 0 1 0 0 0
18	1 0 0 1 0	2	1 1 0 0 1 0 0 0
19	1 0 0 1 1	3	1 0 0 0 0 0 0 0
20	1 0 1 0 0	4	0 1 0 1 0 0 0 0
21	1 0 1 0 1	5	0 0 0 0 1 0 0 0
22	1 0 1 1 0	6	1 0 1 0 1 0 0 0
23	1 0 1 1 1	7	1 1 1 0 0 1 0 0
24	1 1 0 0 0	8	0 1 1 0 0 0 0 0
25	1 1 0 0 1	9	0 0 0 1 1 0 0 0
26	1 1 0 1 0	:	0 1 1 1 0 0 0 0
27	1 1 0 1 1	;	0 1 1 1 1 0 0 0
28	1 1 1 0 0	Null	0 0 0 0 0 0 0 0
29	1 1 1 0 1	Null	0 0 0 0 0 0 0 %
30	1 1 1 1 0	Null	0 0 0 0 0 0 0 0
31	1 1 1 1 1	LTRS	1 0 0 1 1 0 0 0

cuit should work just as well with TTL devices. **Fig. 2** shows socket connections for the devices.

The circuit in **fig. 3** makes programming a cinch as the burn-out time is automatically determined by the 74121 one-shot, U1. The time is fixed at 150 milliseconds. Programming must be done carefully, while you're wide awake, or mistakes are bound to occur! The +15 and +5-volt leads must be connected to a regulated power supply that provides at least 1 ampere. Proceed as follows:

1. With the power supply shut off, insert the 8223 to be programmed into its socket.

2. Set S2B to *BURN*.

3. Set address switches S3-S7 and output switch S8 according to the program pattern for the first bit.

4. Switch on the power supply and depress S1.

5. Set S3-S7 and S8 to the next bit and depress S1. Continue this procedure, bit-by-bit, until the entire pattern is programmed into the chip. You can test the programming by setting S2 to *TEST*. Go through the entire pattern again, using switches S3-S7 and S8. The LED will illuminate for a 1 and remain dark for a zero. If the test yields the desired pattern your 8223 is ready for use.

Four 8223s are necessary for the Baudot-to-ASCII conversion and vice versa. For more information on the makeup of the programming pattern, see reference 3. An article describing a memory for automatic CW identificaton using an 8223 prom can be found in reference 4.

In **tables 1-4** you'll find one program for each of the four proms used in the code converter. The *A* column determines the prom address line switch positions, while the *B* column determines the switch positions of the prom outputs.

example

To program the letter *Y* into the prom that translates Baudot to ASCII letters (**table 1**), proceed as follows:

1. Set switches S2A-B to *TEST* and set the prom output line-selector switch, S8, to *B0*.

2. Look up the letter *Y* on the program (**table 1**).

3. Set the address line switches, S3-S7 (**fig. 3**) according to the information in the table: *A4* = high; *A3* = low; *A2* = high; *A1* = low; and *A0* = high — i.e., 10101. (Low is ground and high is +5 volts.)

4. Set switches 2A-B to *BURN*.

5. Set the prom output line switch to *B0* (a 1 in this case), then depress switches S1A-B.

6. Advance the output line selector switch to *B3*, picking up another 1.

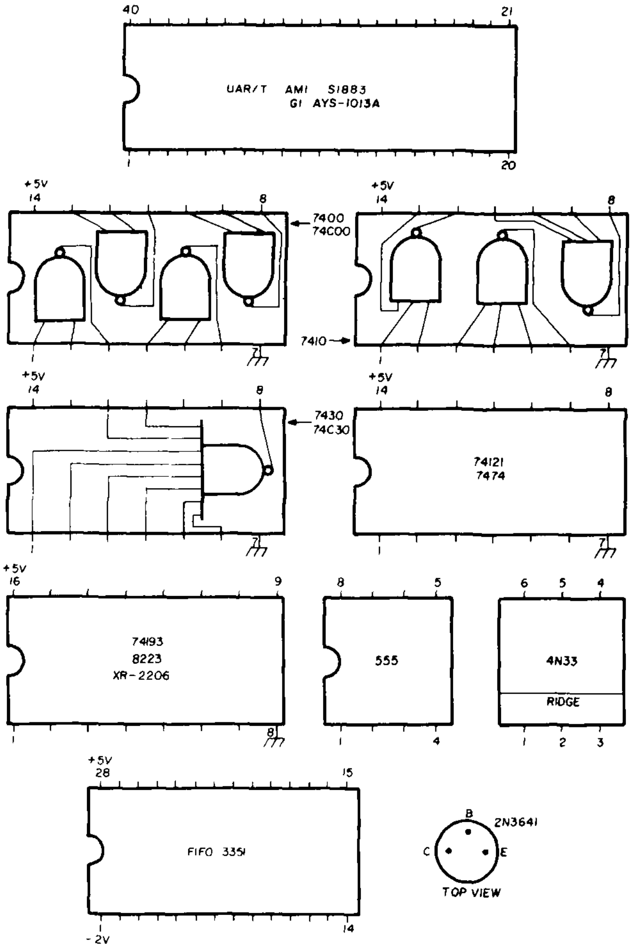


fig. 2. Socket connections (top view) for the devices used in the converter.

7. Press switches S1A-B again.

8. Repeat the procedure at *B4* and *B6*, picking up a 1 in each case.

9. Set switches S2A-B to *TEST*. With S8 in *B0, B3, B4,* and *B6* positions, the LED should light, indicating a 1; in positions *B1, B2, B5,* and *B7* it should remain dark, indicating a low, or zero. Should one of the prom fuses refuse to open at the first attempt at testing, try burning it repeatedly.

Start the programming from the top of the table and work down,. When you have one prom fully programmed, go through the check procedure with switches S2A-B in the *TEST* position to verify that the fuses have opened according to the program in use. If the prom checks out okay, mark it for identification.

Type 82S23 proms are presently offered on the surplus market at a reasonable price. These can also be used, but to program these devices the 390-ohm ½-watt resistor at the top contact of S2A (**fig. 3**) must be changed to 4.7 ohms ½-watt, and the +15-volt supply must be increased to 16 volts.

In reference 5, I pointed out the importance of phase-continuous frequency shift to prevent transients, which can cause interference on adjacent channels. I described a rather commplex circuit of an afsk generator that featured phase continuity of the sine-wave output when keyed.

In the meantime integrated circuits have appeared on the market especially designed for waveform generation. One of these, the EXAR XR-2206 CP, is particularly interesting for RTTY. Pin 9 of this IC can be directly connected to pin 25 of U1, **fig. 1**, of the Baudot-to-ASCII/ASCII-to-Baudot converter. The output at pin 2 of the XR-2206 can then be used to modulate an ssb transmitter or transceiver with a phase-continuous afsk signal.

The afsk circuit (**fig. 4**) is extremely simple. The sine-wave frequency is determined by the value of C1 and the total resistance connected to either pin 7 or 8 of the XR-2206. When pin 9 is high pin 7 is active; when pin 9 is low pin 8 is active.

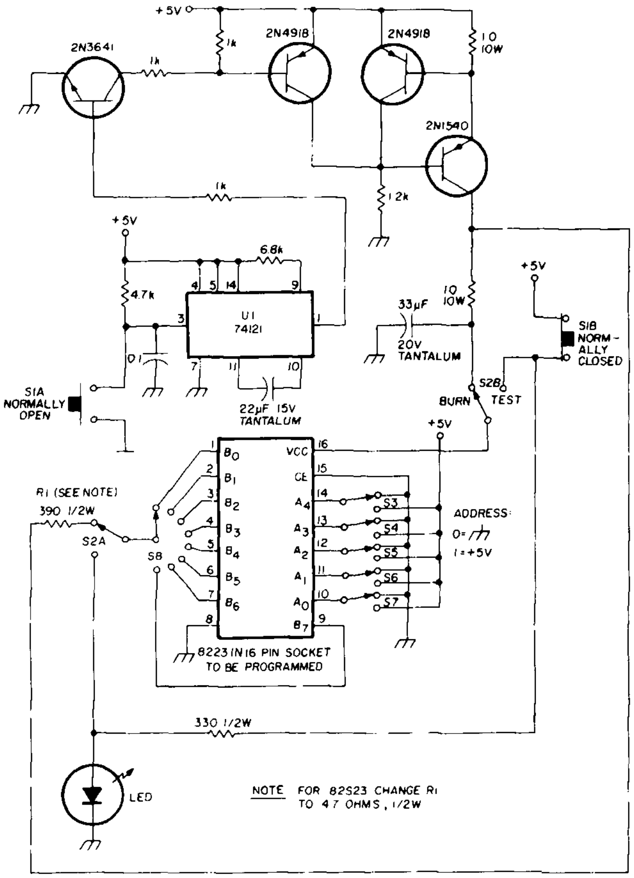


fig. 3. Circuit for programming the 8223 proms.

For excellent frequency stability, C1 should be a polystyrene (Phillips 295 AA/C 8K2) or a Mylar capacitor. The frequency-determining resistors should be carbon film; or better yet, metal film types.

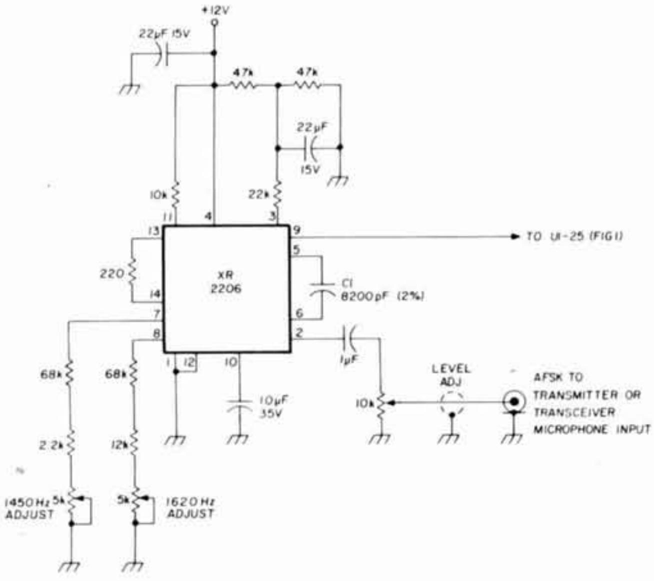


fig. 4. AFSK generator. Phase-continuous frequency shift is featured to prevent out-of-band transients. Sine-wave frequency is determined by C1 and the total resistance connected to either pin 7 or 8 of the XR2206.

The afsk-generator audio frequencies of 1620 and 1450 Hz were chosen to put the second harmonic outside the passband of modern ssb equipment and to eliminate the need for special carrier-frequency crystals in such equipment.

The overall converter system can be tested by feeding data from a Baudot keyboard or tape reader to U1-20 (**fig. 1**). As the output and input of U7 are a closed loop through the two 4N33 optoisolators, U8 and U9, the data is fed back to U1, and its output at pin 25 can be used to operate the printer magnets of the Baudot machine through a suitable driver. In this case, the Baudot data is converted to ASCII, then back to Baudot. The only character not translated from ASCII to Baudot is the bell signal. With additional gates this could be accomplished, but I felt that the additional complexity was unjustified.

acknowledgement

I'd like to thank my friend, Paul Hudson, VE3CWA, for suggestions in preparing this article.

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ham radio

More Details? CHECK — OFF Page 126


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admittance, impedance and circuit analysis

A circuit with impedances seems very complicated to those lacking experience in circuit analysis. Throw in names like *admittance, conductance,* or *susceptance,* and circuit analysis seems to take on a certain mystique beyond the average amateur. Many texts present such a bewildering array of symbols and mathematical operators that analysis seems hopeless unless you have a computer. Wrong — all you need is paper, pencil, and a pocket calculator.

Impedance, admittance, and complex numbers are really simple expressions with a few extra rules. Once you know them and how to set up an analysis "model," the rest is just careful number manipulation. Presented here are the basics, how to handle them, and simple circuit modeling for the majority of transmitter and receiver circuits.

If the names and expressions are unfamiliar, just read and study slowly. They will become familiar with a little practice.

the rectangular form

The two forms of expressing impedance or admittance are *rectangular* and *polar*. **Fig. 1** shows the rectangular form with the expressions and circuit symbols in columns for impedance, Z, and admittance, Y.

Any L C R (inductance, capacitance, and resistance) combination can be shown as either an impedance or an admittance because each is the inverse of the other. Common use has a series combination given as impedance, a parallel combination as admittance. Opposite expressions are shown later.

If you are unfamiliar with complex number notation, pay attention to the j symbol. The j, also called the *j-operator*, denotes everything to the right of it as *imaginary*. This is in the mathematical sense since $j = \sqrt{-1}$, an imaginary number. A complex number has a *real* part (the resistance, R, or conductance, G) and an *imaginary* part (the reactance, X, or susceptance, B). Ordinary math rules apply only to the real part or the imaginary part. Rules for handling both at the same time are given later.

Values of impedance, resistance, and reactance are given in familiar ohms values. Values of admittance, conductance, and susceptance are given in *mhos*. Some time ago the inverse spelling was applied because admittance is the inverse of impedance. If $R = 10$ *ohms*, then $G = -0.1$ *mho*.

reactance and susceptance

Both are frequency sensitive; that is, their ohm and mho values vary with frequency. This is shown by

$$X_L = \omega L \qquad B_L = -1/\omega L$$
$$X_C = -1/\omega C \qquad B_C = \omega C$$

with L in henries, C in farads, and

$$\omega = 2\pi f$$

where f is in hertz (radian frequency). The subscript refers to inductance or capacitance. Total reactance or susceptance is expressed without a subscript as

$$X = \omega L - (1/\omega C)$$
$$B = \omega C - (1/\omega L)$$

Note especially that signs are shown; this *must* be followed in reactance and susceptance calculation. Remember the resonance condition where inductive and capacitive reactance (or susceptance) cancels.

Imaginary parts can be stated in opposite terms:

$$X = -1/(B_C + B_L) = -1/B$$
$$B = -1/(X_C + X_L) = -1/X$$

Note the signs. Reactance and susceptance are related by *negative* inversions while resistance and conductance are related by *positive* inversions. Real and imaginary parts are handled separately andd the part relationships are different but admittance is still the inverse of impedance and vice-versa. Y and Z are complex numbers of different rules while R, X, G and B are simple numbers with ordinary rules.*

Most modern hand-held calculators have a pi-constant key and at least one memory register. Storing the radian frequency ($2\pi f$) in memory allows rapid calculation of X or B values. For rf circuits, entering scaled values of megahertz, microhenries,

*A good algebra text will show the proof and following rules for those readers desiring more information.

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

or microfarads saves using the exponent key or inputing lots of zeros.

With complex numbers $(a+jb)$ and $(c+jd)$, the rules are:

$$(a+jb)+(c+jd)=(a+c)+j(b+d)$$
$$(a+jb)-(c+jd)=(a-c)+j(b-d)$$

Notice the expression statements on each side. On the left there are two complex numbers indicated by the parenthesis. The right side shows that each part of the complex answer has at least two terms. The j-operator designates the entire b, d term group as imaginary.

The addition rule is useful for expressing a combination LCR circuit as one impedance if all components are in series. Suppose the inductor has winding resistance. The total resistance is the sum of R and winding resistance. The inductive reactance adds to capacitive reactance and each could be in the two impedances or combined in one of them. Any number of combinations, including parallels, can be added to give one real part and one imaginary part. Remember to keep the parts separate, observe signs, use admittance for parallel combinations, and impedance for series combinations.

table 1. Keyboard steps, HP-35 calculator impedance/admittance conversion.

	Keyboard	Stack Registers x	y	z	t	Display, (remarks)
	Input R	R				
1	STO	R				(hold R in memory)
	Input X	X				
2	ENTER	X	X			
3	ENTER	X	X	X		(fill stack with X)
4	X	X^2	X			
5	RCL	R	X^2	X		
6	RCL	R	R	X^2	X	
7	X	R^2	X^2	X		
8	+	Mag^2	X			
9	$\sqrt{x}$	Mag	X			Z Magnitude
10	1/x	1/M	X			Y Magnitude
11	x⇄y	X	1/M			
12	RCL	R	X	1/M		
13	÷	X/R	1/M			
14	arc					
15	tan	pha	1/M			Z phase angle
16	CHS	− pha	1/M			Y phase angle
17	STO					(hold angle in memory)
18	R↓	1/M				
19	ENTER	1/M	1/M			
20	ENTER	1/M	1/M	1/M		(fill stack with Y magnitude)
21	RCL	− pha	1/M	1/M	1/M	
22	cos	Cos	1/M	1/M	1/M	
23	X	G	1/M	1/M		conductance
24	x⇄y	1/M	G	1/M		
25	RCL	− pha	1/M	G	1/M	
26	sin	Sin	1/M	G	1/M	
27	X	B	G	1/M		susceptance
28	1/x	1/B	G			
29	CHS	Xp	G			parallel reactance
30	x⇄y	G	Xp			
31	1/x	Rp	Xp			parallel resistance

The sign in front of the j-operator can take the sign of the imaginary part. This is strictly a sign and *does not* mean the *parts of one* complex number add or subtract. The subtraction rule will be useful in impedance matching to be discussed later.

why admittance?

There are as many parallel combinations of com-

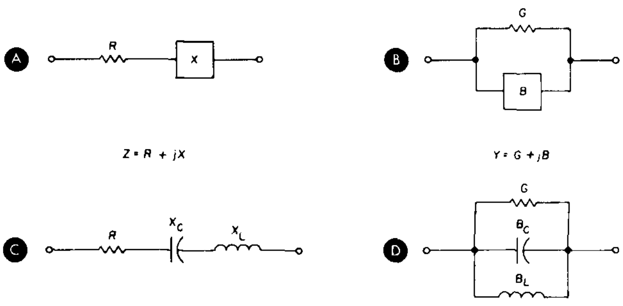

fig. 1. Rectangular form of impedance and admittance.

ponents as there are those in series. Any circuit to be analyzed should be separated into *branches* of component combinations in series or parallel. Each branch is then expressed as an admittance or impedance having only two connections or *nodes*. The easiest form of expressing a parallel combination is admittance since all real parts and all imaginary parts add.

In fact, you have probably been using admittance without realizing it. The familiar parallel resistance formula

$$R_{total}=\frac{R_1 R_2}{R_1+R_2}$$

was derived from the basic expression

$$R_{total}=\frac{1}{(1/R_1)+(1/R_2)+\cdots(1/R_n)}$$

Invert the basic expression and you will find the sum of conductances $(1/R)$ equals total conductance.

multiplying and dividing complex numbers

These will be used in solving the circuit or converting admittance to impedance and vice-versa. The rules are:

$$(a+jb)\times(c+jd)=(ac-bd)+j(ad+bc)$$

$$\frac{(a+jb)}{(c+jd)}=\left[\frac{(ac+bd)}{(c^2+d^2)}\right]+j\left[\frac{(bc-ad)}{(c^2+d^2)}\right]$$

$$(inversion)\,1/(a+jb)=[a/(a^2+b^2)]-j[b/(a^2+b^2)]$$

These rules are hard to work with, even with a calculator. There is an easier way by using the *polar form equivalents* shown in **fig. 2**. The angle symbol is as important as the j-operator: All terms to the right of the angle symbol are, appropriately, *angles;* terms to the left are *magnitudes*.

$$(A \angle \phi) \times (B \angle \theta) = (A \times B) \angle (\phi + \theta)$$

$$\frac{(A \angle \phi)}{(B \angle \theta)} = \frac{A}{B} \angle (\phi - \theta)$$

$$(inversion) \quad \frac{1}{A \angle \phi} = \frac{1}{A} \angle - \phi$$

Magnitudes operate algebraically just like the polar expression, but angles add or subtract. Again, the

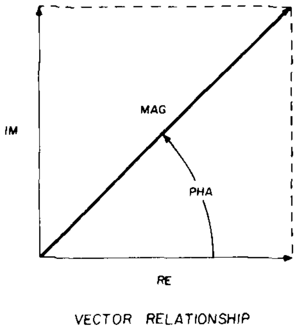

fig. 2. Comparison of the rectangular and polar form.

parts are different from the whole. A calculator with trig functions is preferred; one with built-in polar/rectangular conversion is even better.

polar form

Y and Z can be expressed equally well this way. This has the advantage of showing magnitude and phase angle as shown by the little vector diagram of **fig. 2**. Voltage and current in a complex circuit will also be complex quantities. The ac or rf voltage you measure in a circuit is the magnitude. Phase angle is also measurable although the instruments cost more. Some rf bridges read directly in polar form.

Both forms are needed in circuit analysis. Rectangular form can be used in calculating circuit branch values while the polar form is used for voltage response and as an intermediate step in conversion. Input impedance or admittance can be expressed in either form. The angle is a signed number but the magnitude is always a *positive* number.

form conversion by calculator

All of the expressions and forms necessary for circuit analysis have now been presented. Before going into the analysis setup it is useful to observe conversion of impedance to admittance with the aid of rectangular/polar form changes. The program steps in **table 1** apply to the older HP-35 model or any other *RPN/Stack* machine that does not have polar/rectangular conversion functions.

This form conversion is basic to the ladder network solution to be presented later. Calculators with built-in functions can use part of this step sequence, either manually or automatically with a programmable version.

Steps 4 through **15** change rectangular impedance to polar impedance. **Step 10** finds the polar admittance magnitude; its location in the sequence is arbitrary and could be placed after **step 18. Step 16** *finds the polar admittance angle.*

Steps 17 to **20** set up the registers for polar to rectangular conversion — the remaining steps perform it. The magnitude inversion and angle sign change has already done conversion of impedance to admittance. Polar/rectangular identities are the same for impedance and admittance.

Steps 28 to **31** are used only to show how parallel resistance and reactance are derived from the main program. There are simpler ways to derive the parallel equivalents from series components. You are invited to try out the simpler way from the formulas given. If you succeed, you have already begun programming.

Steps 1 to **27** will convert admittance to impedance without changing any steps. To prove this to yourself, just change the terms and expressions *in the register and remarks columns.*

As an example, $Z = 4 + j3$ *ohms* converts to $Y = 0.16 - j0.12$ *mhos*. The parallel reactance equivalent is 8.33 ohms, resistance equivalent is 6.25 ohms.

the analysis model

The term *model* simply means the branches connected at nodes. A reduction to this structure is done to simplify overall calculations calculation time and effort. The basic pi structure in **fig. 3** can be used with almost every circuit and is expandable to a ladder structure.

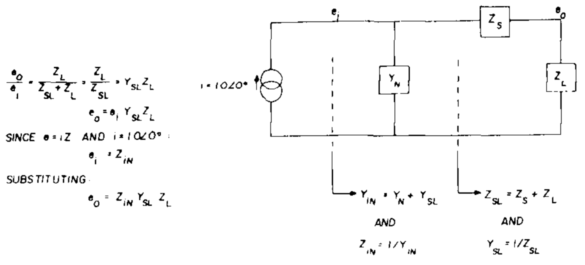

fig. 3. Basic model structure of the familiar pi network.

The model is allowed only one signal source, a current of 1.0 ampere with no phase angle. Any source admittance must be included as part of Y_n. A unity current source allows each output voltage, e_o, to be relative and the solution to be dependent solely on impedances and admittances in the model. This is the simplest method and applies well to calculator solution.

It may seem that a relative e_o solution is unrealistic but this is only partly true. Networks such as filters are almost always described in relative terms. As an example, an i-f amplifier can be modeled as several individual blocks with individual block model response summed for overall response. The actual e_o can be found by multiplying relative e_o by the actual input current.

Most of us think of an amplifier stage as output vs input. For the model the transistor or tube must be split into the input impedance and the output admittance with a current source that is dependent on input signal. Most data sheets on transistors and tubes are oriented to this form.

Most of us also think of an amplifier output in terms of voltage. Since voltage is easiest to measure, it is easy to neglect current. All transistor collectors and pentode tube plates are really current sources with an output admittance (h_{oe} for common emitter, $1/r_p$ for pentodes). Measured output voltage is the product of the current source and the *total* load impedance, including output admittance of the device. The scarcity of ac current measuring instruments has misled a lot of us in understanding actual circuit operation.

The basic pi model can be thought of as the coupling circuit between two amplifiers. The output admittance of the first becomes part of Y_n, and the input impedance of the second becomes part of Z_L. The current flowing into the second state input can be found relative to unity (the model input current) because the output voltage is known.

You can use Ohm's law with complex quantities. The difference from dc is that current and voltage have *both* magnitude and phase angle. The rectangular form also applies, but the polar form is more convenient since an ac voltmeter measures magnitude. An oscilloscope will display voltage phase angle but that is dependent on the scope sweep triggering point; a dual-trace scope shows *relative* voltage phase.

Note the progression of Z and Y looking towards the load in **fig. 3**. This is important to the model extension following.

extending the model for ladder networks

A *ladder* configuration is a shunt-series-shunt sequence — a five-branch model is shown in **fig. 4**. Again, the current source is unity and e_o is relative and solved directly from impedances and admittances. This model is well suited to filter analysis.

Output voltage solution is self-explanatory but note the progression of Y_{12} to Z_{45}.* Y_{12} is the inverted sum of Z_d and Z_L; Z_{23} is the inverted sum of Y_c and Y_{12}, and so on. Each Y or Z is the total, looking towards the load, of the model Y and Z at each node. Z_{45} is the *total* input impedance; the network input admittance is found by subtracting source admittance from $Y_{45}(1/Z_{45})$.

So far, circuit analysis seems complicated and a lot of work. Here is where the calculator comes in handy and it is useful to recall the form-conversion calculator steps in **table 1**. Let's assume that all shunt branches have been precalculated for admittance and all series branches in impedance.

Enter Y_L and begin the conversion. Pause when you reach the magnitude and angle of Z_L and write down the polar values. By **step 27** the rectangular

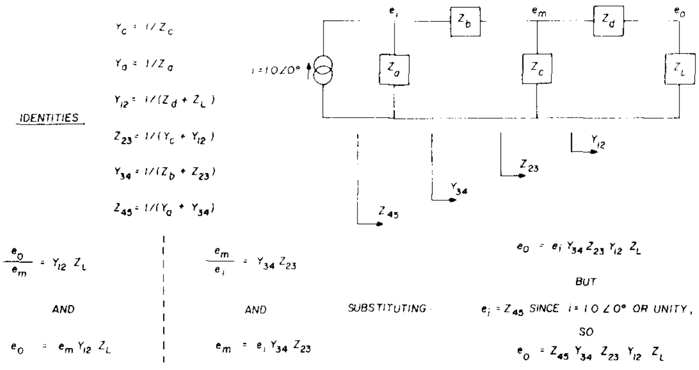

fig. 4. Five-branch ladder network, showing derivation of circuit quantities. A hand-held calculator is very useful in solving problems of this type.

form of Z_L is reached and the real and imaginary parts of Z_d are added. Go back to the beginning and start the conversion for Y_{12}; the calculator's stack already has the entry so it is just a matter of storing the real part in memory and the imaginary part in the stack. Pause at the polar form of Y_{12} and write down the values. At the end of the second run add the precalculated Y_c parts to parts of Y_{12} and return to the beginning. Continue the repetition, writing down each numbered-subscript polar value, until the input branch has been reached.

Solution of e_o is made by multiplying all tabulated magnitudes and adding all tabulated angles. This is the same as the last e_o expression in **fig. 4** and polar multiplication rules are used. Network input impedance can be found by subtracting source admittance using rectangular form rules and converting.

Six-digit accuracy of precalculation and tabulation is more than sufficient for most purposes; angle tabulation can be rounded to three fractions using degrees, four with radians. If a mistake is made in stepping through the sequence, just begin in mid-

*Amateurs who are not familiar with networks are often confused by the numeric subscripts which are used. The designator Y_{12}, for example, refers to the admittance looking into sections 1 and 2 of the network; likewise, Z_{45} refers to the impedance looking into sections 4 and 5 of the network (see **fig. 4**). In filters, capacitors and inductors are often designated in the same manner — in terms of their relative positions within the filter network.

sequence by clearing registers and entering the last tabulated polar value; just make certain that magnitude and angle are positioned correctly.

The repetitive sequence or iteration is well suited to a programmable calculator. If it has a larger memory, the partial products of e_o can be accumulated automatically.

modifying a model with branches that jump adjacent nodes

Fig. 5 shows this condition and defeats the ladder configuration. **Fig . 5** also shows how a model subsection can be transformed by the *delta-to-tee* method, yielding a result that fits the ladder. Transformation must be done with precalculated values.

A delta sub-section that is pure resistance requires transformation only once. Any other condition requires a transform at every solution frequency. The resulting tee values become the new precalculated values for solution iteration.

Similar transformations can be made for tee-to-delta and lattice networks. Most engineering handbooks contain the transform equations, usually given as impedances, but the equations work just as well with admittances. It is worthwhile to study the circuit to be modified and arrange the branches for the least amount of transformation.

Pi networks are good examples and published design data can be used as a starting point. Unfortunately, most designs assume only a resistive load while an actual load such as an antenna will vary considerably. The object of impedance matching is to make the real part of the matched load equal to the source, and reduce the imaginary part to zero.

Let's take the case of matching an antenna over a few frequencies with a pi network. The basic design data is available and the components can be modeled as in **fig. 3**. The approximate antenna impedance data is known either by measurement or from handbook data. Will the network components do the job?

A way to find out is to solve only for Z_{in}, *omitting* source admittance and susceptance of the first-branch network componentt (usually a variable capacitor). The rectangular form of Z_{in} is a bit better for solution.

Tabulate the results at each frequency and antenna impedance expected and examine the imaginary part sign. If the sign does *not* change, the input component can be reactive and the value can be calculated by the *opposite-sign* reactance. The imaginary part must go to zero when the component is included in the model. Value range variation can also be seen; make certain that this can be realized in practice.

An imaginary-part sign change means that another component value must change. The most common

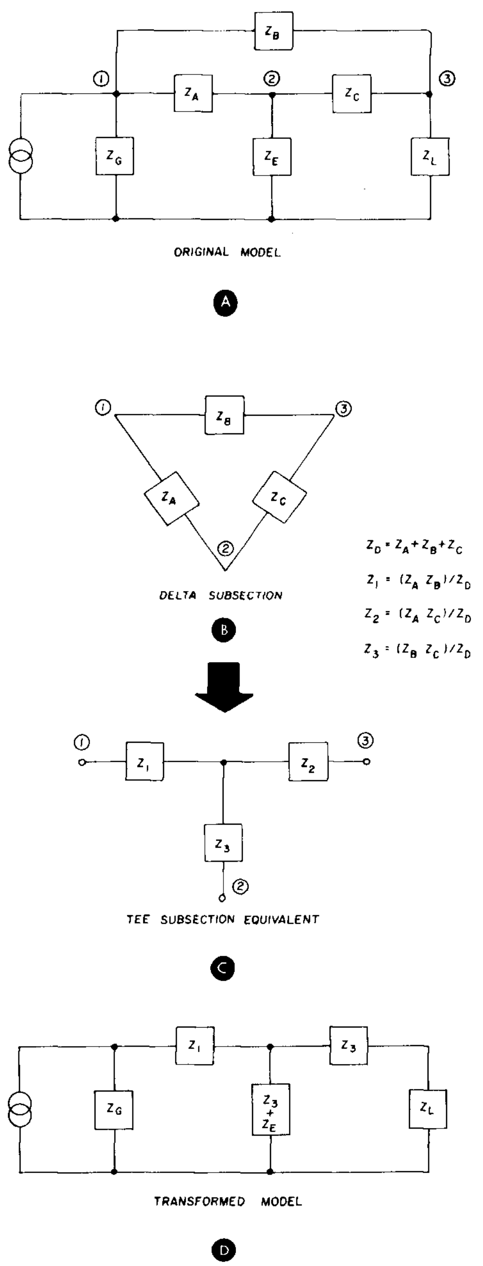

fig. 5. Model transformation. Here the delta subsection (consisting of Z_A, Z_B, and Z_C) is transformed into an equivalent tee section. The tee section is then added to Z_G, Z_L, and Z_O to yield the transformed model.

pi network uses a variable capacitor at each end with a fixed series inductor. If this is the circuit, try varying the other capacitor, solving again and inspecting the signs.

The real part of Z_{in} should be reasonably close to the required resistive value for best power transfer. The difference depends on the type of source. A 20 to 30 per cent variation is probably good enough in most cases. If this part is not close, another component value must be changed. After a few changes you will be able to tell which way to change and you can zero in on the correct set of values. The best efficiency occurs with source impedance equal to matched load impedance.

Other networks can be designed from the efficiency rule and reducing reactance to zero. Some careful study and algebra will result in a matching formula. Impedance or admittance — as a quantity — obeys algebraic rules. The only difference is that real and imaginary parts must be handled by the rules given.

circuits with more than one load

Suppose you have a circuit model like **fig. 4** and there are two Z_d and two Z_L branches in separate paths. Solve Y_{12} for the second path and record it. Solve the first path as before except the second path's Y_{12} is also added to Y_c plus Y_{12} of the first path. Z_{23} is the total impedance of both paths.

The second path e_o is found from Z_{45}, Y_{34}, Z_{23} recorded in solving the first path and Y_{12} and Z_L of the second path. This can be extended to longer paths with different lengths provided that the common-node impedance value is the total impedance of all paths.

bilaterality

All illustrations have shown the source at left, load at right. This conforms to conventional left-to-right flow but doesn't mean the schematic must be interpreted this way. Many schematics are drawn differently, so take care in forming the model — properly locate the source and load.

Q equivalents

Every coil and capacitor is lossy. To properly analyze a filter this loss must be modeled as resistance or conductance in the proper branches. General values are X/Q for impedance and a series resistance, B/Q for admittance and a parallel conductance. Add losses in LC branches.

Some simplification is possible. Q is fairly constant over an octave of frequency. A fixed R or G value can be used for resonant circuits and filters. The fixed value would be obtained at the center frequency or cutoff frequency for highpass and lowpass filters.

other analysis methods

Most circuit theory texts have them. The inexperienced should be cautious since the math is high level, usually involved with matrices or transfer functions. A matrix is best solved on a computer. The other methods are more versatile, but not more accurate. The ladder form given here will fit a manual or programmable pocket calculator better. It will not solve all circuits, but most of them. Programs for the HP-25 will be given in a future article.

ham radio

NOTICE: 73 MAGAZINE printed an untrue report in the June, 1977, issue regarding the KDK FM144. They are now printing a retraction regarding this untrue report. The FM144 does not need tuning to cover the full 5 MHz range.

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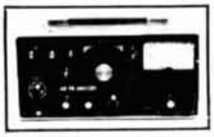
SIGMA RF-2000 SWR & POWER METER
Introductory Price $29 Cal PWR Scales 200W-2000W Freq Range 3.5 - 150 MHz Please do not confuse the RF2000 with similar appearing lower priced units - RF2000 is an individually calibrated professional quality instrument - Unequaled at many times the price. Size 7" (w) x 2½" (h) x 2 1/3" (d).

NEW AM/FM ANALYZER
SIGMA AF-250L

INTRODUCTORY PRICE **$199**
Deviation/Modulation Meter - FM: 0-20 KHz, AM: 0-100%. Size: 5½ (h) x 10¼" (w) x 7¼" (d) Weight 7 lbs. Frequency: 1.8MHz-520MHz



ALSO MODEL AF-251LW WITH BUILT IN 125 WATT CALIBRATED WATT METER & DUMMY LOAD PRICE **$289.** PLEASE WRITE FOR COMPLETE INFORMATION.

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STANDARD NEW 2 METER FM TRANSCEIVERS
Model SRC 146A
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AT 19 Rubber Ant and Whip	$6
NI-Cads	$30
Reg.	$400
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NEW!!! Touch Tone pad completely wired and ready to plug in-$69.00

NEW! FMSC-2 SCANNER
FOR KDK FM-144

14 CHANNEL PROGRAMMABLE
INTRODUCTORY PRICE $109

NEW! 7400 SCANNER
FOR KENWOOD TR-7400A

14 CHANNEL PROGRAMMABLE
INTRODUCTORY PRICE $109

FMSC-1 - $169

7400 Scanner II-$189

TWO NEW SCANNERS!

FMSC-1 Scanner for KDK FM 144 and 7400 Scanner II for Trio-Kenwood TR-7400A.
• Full scan 146 and 147 MHz consecutively or 1 MHz, or any MHz range • Scan rate: 1 MHz/2 seconds adjustable) • Controls: Scan/Hold, Latch/Delay, 600 KHz offset (off, up, down), program 1 MHz • Simple installation.

KDK

ACCESSORIES FOR KDK FM 144

FMPS 4R	Regulated AC/PS	$49
FMTP 1	Touch Tone Pad	$59
FMTP 2	Touch Tone Pad with 10 Number Programable Memory	$99
FMMC 1	Microphone with Built in Touch Tone Pad	$59
FMTD 1	Private Call Decoder for use with and Programed by Any Touch Tone Pad	$129
SC 12A	Audible Tone Encoder Decoder	$119
FMSC 1	Scanner – Random. Any Range	$169
FMSC 2	Scanner – Programable. 14 Channels	$109
MARS CAP	Option Kit – Any Frequency. Any Split	$12
FMOF-1	Offset Option Kit – 2 Extra Positions. Crystals Required	$19
FMOF 2	±1 MHz Offset Option Kit (No Crystals To Buy)	$19
FMTE 1	Sub Audible Tone (100 Hz – Adjustable 67 203 Hz)	$29
FMAT 1	½ Wave Portable Antenna for Hotel, Motel or Apartment	$7.95
Extra DC Cord & Plug		$3.50
ACC Socket 5 Pin Din Plug		$1.50
Owners Manual (Extra)		$5.00
Service Manual		$2.00
Mounting Bracket (Extra)		$6.00

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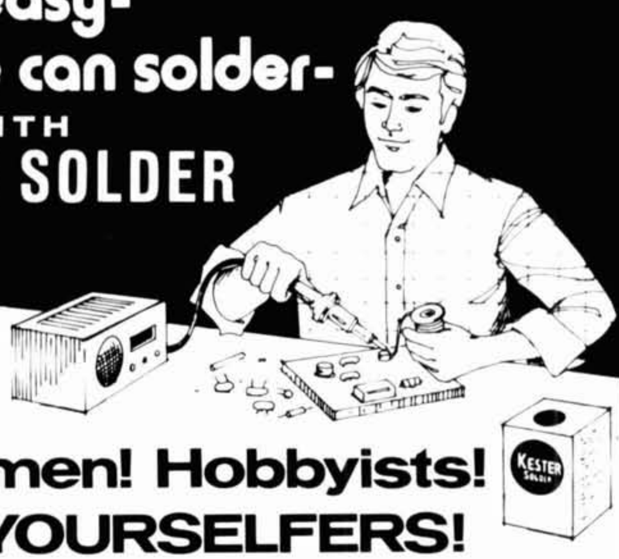

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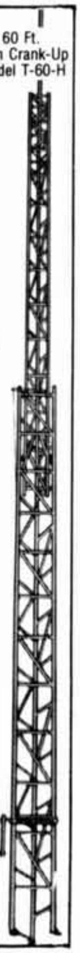

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More Details? CHECK—OFF Page 126

NEW FROM HY-GAIN 2-METER BEAMS THAT LAST LONGER. WORK HARDER. AND COST LESS.

Introducing a whole new generation of Hy-Gain 2-Meter beams.

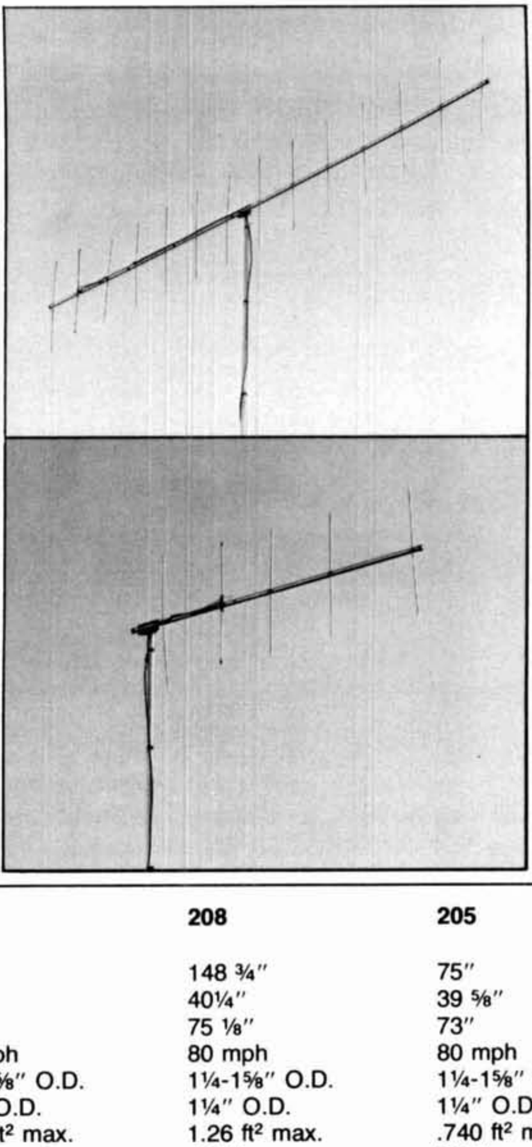
Completely redesigned for greater strength and corrosion resistance. So they last longer.

Newly engineered for greater performance and maximum efficiency. So they work harder, your transceiver works better.

And built better. So you pay less for the performance you want.

Our new 2-Meter beams give you the kind of performance you expect from the world's largest manufacturer of quality antennas. Yet, thanks to Hy-Gain technology, they weigh less, have lower wind loading and are UPS shippable.

They use an exclusive new element to boom mounting system that's mechanically stronger and electrically more efficient. All can be vertically or horizontally polarized. And all are constructed of the finest aluminum and ZMI hardware.



Hy-Gain 214 14-element close spaced beam with extremely high forward gain and narrow beam width. **$26.95**

Also available with 8-element optimum spacing, **Hy-Gain 208. $19.95**

Hy-Gain 205 5-element optimum spaced end mount beam with high forward gain and broad frequency response. **$16.95**

Also available with 3 elements, **Hy-Gain 203. $12.95**

See the new generation of Hy-Gain 2-Meter beams at your amateur radio dealer. Or write Hy-Gain; 8601 Northeast Highway Six; Lincoln, NE 68505.

hy-gain®

WE KEEP PEOPLE TALKING.

Hy-Gain reserves the right to change prices, designs and/or specifications at any time without notice.

SPECIFICATIONS	214	208	205	203
Mechanical				
Boom length	186″	148 ¾″	75″	43½″
Longest element	39½″	40¼″	39 ⅝″	40¼″
Turning radius	95″	75 ⅛″	73″	43½″
Wind survival	80 mph	80 mph	80 mph	80 mph
Mast diameter	1¼-1⅝″ O.D.	1¼-1⅝″ O.D.	1¼-1⅝″ O.D.	1¼-1⅝″ O.D.
Boom diameter	1¼″ O.D.	1¼″ O.D.	1¼″ O.D.	1¼″ O.D.
Wind load area	1.65 ft^2 max.	1.26 ft^2 max.	.740 ft^2 max.	.496 ft^2 max.
Net weight	5.5 lbs	4.1 lbs	2.9 lbs	2.2 lbs
Electrical				
Forward gain	13.0 dBd*	11.8 dBd*	9.1 dBd*	6.1 dBd*
Front-to-back ratio	20 dB	20 dB	20 dB	20 dB
Maximum SWR	2:1	2:1	2:1	2:1
Band width	2 MHz	2 MHz	4 MHz	4 MHz
Maximum power	250/500 PEP	250/500 PEP	250/500 PEP	250/500 PEP
Impedance w/balun	52 ohms	52 ohms	52 ohms	52 ohms
½ power beam width	35° vertical	43° vertical	60° vertical	95° vertical
	35° horizontal	36° horizontal	45° horizontal	60° horizontal
Stacking distance	82″ min.	82″ min.	82″ min.	82″ min.

*Hy-Gain antennas are gain rated against a standard dipole antenna (dBd) instead of a theoretical isotropic source (dBi). This is a more honest and realistic means of comparing forward gain.

More Details? CHECK — OFF Page 126

ME-3 microminiature tone encoder

Compatible with all sub-audible tone systems such as: Private Line, Channel Guard, Quiet Channel, etc.

- Powered by 6-16vdc, unregulated
- Microminiature in size to fit inside all mobile units and most portable units
- Field replaceable, plug-in, frequency determining elements
- Excellent frequency accuracy and temperature stability
- Output level adjustment potentiometer
- Low distortion sinewave output
- Available in all EIA tone frequencies, 67.0 Hz-203.5 Hz
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$29.95 each

Wired and tested, complete with K-1 element

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K-1 FIELD REPLACEABLE, PLUG-IN, FREQUENCY DETERMINING ELEMENTS

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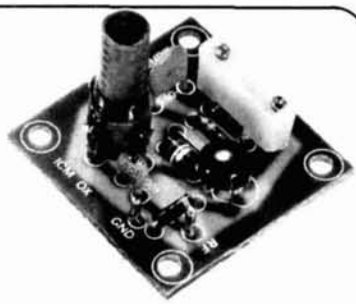
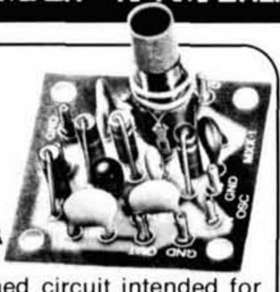
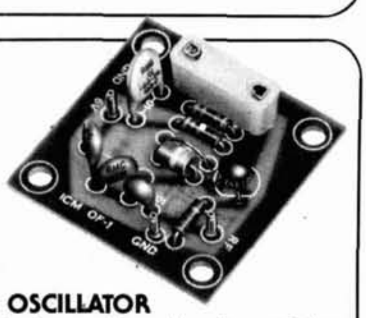


OX OSCILLATOR
Crystal controlled transistor type. 3 to 20 MHz, OX-Lo, Cat. No. 035100. 20 to 60 MHz, OX-Hi, Cat. No. 035101
Specify when ordering.
$3.95 ea.

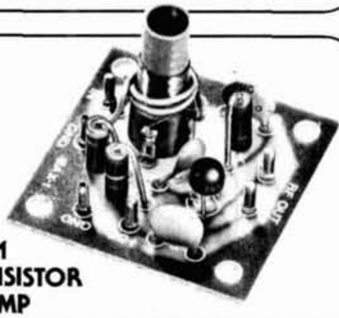


MXX-1 TRANSISTOR RF MIXER
A single tuned circuit intended for signal conversion in the 30 to 170 MHz range. Harmonics of the OX or OF-1 oscillator are used for injection in the 60 to 179 MHz range. 3 to 20 MHz, Lo Kit, Cat. No. 035105. 20 to 170 MHz, Hi Kit, Cat. No. 035106
Specify when ordering.
$4.50 ea.

PAX-1 TRANSISTOR RF POWER AMP
A single tuned output amplifier designed to follow the OX or OF-1 oscillator. Outputs up to 200 mw, depending on frequency and voltage. Amplifier can be amplitude modulated. 3 to 30 MHz, Cat. No. 035104
Specify when ordering.
$4.75 ea.



OF-1 OSCILLATOR
Resistor/capacitor circuit provides osc over a range of freq with the desired crystal. 2 to 22 MHz, OF-1 LO, Cat. No. 035108. 18 to 60 MHz, OF-1 HI, Cat. No. 035109
Specify when ordering.
$3.25 ea.



SAX-1 TRANSISTOR RF AMP
A small signal amplifier to drive the MXX-1 Mixer. Single tuned input and link output. 3 to 20 MHz, Lo Kit, Cat. No. 035102. 20 to 170 MHz, Hi Kit, Cat. No. 035103.
Specify when ordering.
$4.50 ea.

BAX-1 BROADBAND AMP
General purpose amplifier which may be used as a tuned or untuned unit in RF and audic applications. 20 Hz to 150 MHz with 6 to 30 db gain. Cat No. 035107
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Cat. No.	Specifications	
031080	3 to 20 MHz — for use in OX OSC Lo *Specify when ordering*	$4.95 ea.
031081	20 to 60 MHz — For use in OX OSC Hi *Specify when ordering*	$4.95 ea.
031300	3 to 20 MHz — For use in OF-1L OSC *Specify when ordering*	$4.25 ea.
031310	20 to 60 MHz — For use in OF-1H OSC *Specify when ordering.*	$4.25 ea.

Shipping and postage (inside U.S., Canada and Mexico only) will be prepaid by International. Prices quoted for U.S., Canada and Mexico orders only. *Orders for shipment to other countries will be quoted on request.* Address orders to:
M/S Dept., P.O. Box 32497,
Oklahoma City, Oklahoma 73132.

ICM

International Crystal Mfg. Co., Inc.
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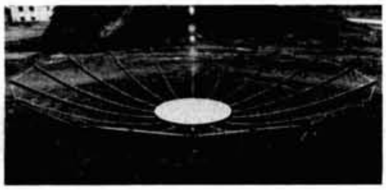
More Details? CHECK — OFF Page 126

NEW products

parabolic dish reflector kit



Moonbouncers, radio astronomers, TV DXers, and others who have needed a parabolic dish antenna at a reasonable price will like the *Paraframe* — a rigid, accurate, parabolic antenna framework kit which one person can easily assemble with ordinary hand tools. The *Paraframe* design permits the reflector to be fine-focused for peak performance, yet the weight is low, while strength is high.

Prestressed *Paraframes* are made of wood, and the ribs are furnished with two coats of premium-quality latex exterior sealer-primer, followed by two coats of premium quality latex exterior paint in a neutral gray. Other colors are available upon request.

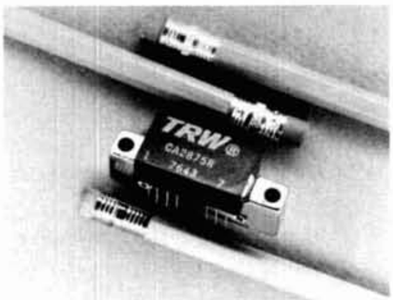
The *Paraframe's* price is such that you can build a parabolic reflector for less than one-third the cost of a similar antenna of equivalent aperture. For example, the SD12 is a 12-foot (3.66-meter) design with a focal length/diameter (f/d) ratio of 0.5. Sixteen prestressed ribs provide sufficient rigidity for useful work at 2300 MHz in a 40-mph (65-kmh) wind. The ribs will accept 7/16 inch (11mm) staples for attaching the aluminum window-screen reflector material. Model SD16 has a sixteen foot (4.88 meter) diameter and 20 ribs; model SD20 has a twenty-foot (6.1 meter) diameter and 24 ribs.

A complete selection of expanded and perforated aluminum covering material, together with low-loss coaxial cable suitable for uhf purposes, is available from the *Paraframe* kit supplier.

The model SD12 is priced at $690 (shipping weight is 140 pounds or 64 kg); model SD16 is $1120 (shipping weight is 230 pounds or 104 kg); and model SD20 is priced at $1680 (shipping weight 400 pounds or 181 kg). Shipping cost will be approximately $25 per cwt (45kg), maximum, anywhere in the continental United States. Terms are 50% of the purchase price with the order, the balance COD. Illinois residents are asked to include 5% sales tax.

For a complete description and illustrated brochure, write to James K. Vines, 611 Farmview Road, Park Forest South, Illinois 60466, or call (312) 534-0889 after 7 PM CDT.

rf hybrid amplifiers



TRW RF Semiconductors has introduced an rf-hybrid gain block which will meet or exceed the most demanding requirements of i-f amplification in advanced microwave radio relay system applications.

The amplifier, designated CA2875/2875R, has a noise figure of typically 4 dB and a third-order intercept of +42 dBm. Requiring a 15 to 24 volt power supply, the CA2875 is suitable for positive power supply polarity while the CA2875R will accommodate a negative supply polarity.

Other parameters of the hybrid amplifier include a return loss of greater than 30 dB at both the input and output ports, phase linearity from 30 to 110 MHz and wide dynamic range. These i-f gain/blocks have a center frequency of 70 MHz as well as a nominal gain of 17.5 dB and an operating temperature range of −40°C to +100°C.

In quantities of 100 pieces, the CA2875/2875R is priced at $31.50. For more information contact Warren Gould at (213) 679-4561 or TRW RF Semiconductors, 14520 Aviation Boulevard, Lawndale, California.

equipment directory

Have you ever searched through a pile of magazines, a loose-leaf collection of product releases, or a collection of dog-eared catalogs looking for a particular antenna, the specs on a new transceiver, or the nearest distributor-dealer for a certain brand of amateur equipment, only to give up in frustration?

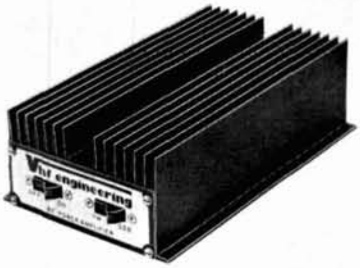
Well, you don't have to repeat that futile exercise this year. The new *1977 Amateur Radio Equipment Directory*, published by Kengore Corporation, got it all together just for you. Here is a comprehensive catalog of amateur equipment, complete with the names and addresses of manufacturers and distributors, together with product photographs, specifications, and prices, conveniently and

More Details? CHECK—OFF Page 126

attractively bound between soft covers for your reference library.

Not every last item made by every manufacturer is listed, nor do the prices reflect recent price increases, but the catalog lists telephone numbers where you can get the latest, correct information. In spite of these minor (and expected) shortcomings, you'll have to look a long time before finding anything nearly as useful or informative. For your copy, send $2.95 to Kengore Corporation, 9 James Avenue, Kendall Park, New Jersey 08824.

70-watt two-meter amplifier



A new 70-watt, four-mode, two-meter amplifier has been introduced by VHF Engineering. This new amplifier, the Blue Line BLC 10/70, is designed to be used with the popular 10-watt fm transceivers and multimode transceivers in the 5-15 watt class; it will deliver 70 watts output in both the class C or linear mode. An additional model, the Blue Line BLC 2/70, offers the same features as the BLC 10/70 but will operate with transceivers or transmitters in the 1 or 2 watt class.

The VHF Engineering Blue Line series of amplifiers have been designed for reliability and long life and feature unique broadband, stripline designs which require no tuning or adjustment during their lifetime. Automatic sensing and relay switching are provided to automatically switch the amplifier into the circuit when drive is applied in the class C (fm) or linear (ssb) modes. The amplifiers offer high efficiency and introduce a receive insertion loss of less than 1 dB. They are designed for

12-14 Vdc operation in base station or mobile service.

The BLC 10/70 sells for $139.95 and the BLC 2/70 sells for $159.95. These new four-mode amplifiers are available from dealers nationwide or from VHF Engineering, 320 Water Street, Binghamton, New York 13902, as wired and tested units.

new antennas from cubic corporation

A series of new amateur radio antennas, including four beam, two mobile, and one trap vertical model, are available now from Swan Electronics, a subsidiary of Cubic Corporation. The fixed antennas include the TB-4HA, a triband beam for $259.95, featuring four working elements on 10, 15, and 20 meters; the 24-foot boom permits optimum spacing for maximum forward gain and front-to-back ratio.

Also available are the TB-3HA, a triband beam for $199.95 which features three working elements on 10, 15, and 20 meters with a 16-foot boom; and the TB-2A, a triband beam for $129.95 which features two working elements on 10, 15, and 20 meters. The MB-40H, a new heavy-duty two-element, 40-meter beam is priced at $199.95, and features two working elements on a 15.75-foot steel boom. All Swan beam antennas are rated for 2000 watts PEP and are designed for a vswr of 1.5:1 or better at resonance.

The deluxe mobile models include a five-band mobile 45 antenna which features all band manual switching

More Details? CHECK—OFF Page 126

for 10, 15, 20, 40 and 75 meters, a *High-Q* tapped coil, eight positive stop manual positions with gold-plated contacts, featuring a base section, mobile coil and 6-foot whip top section. It is power rated at 2000 watts PEP; cost is $119.95.

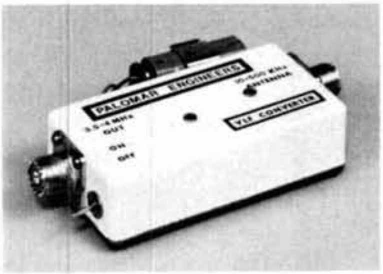
The new Swan 742 tri-band antenna, priced at $109.95, which, once adjusted to desired operating frequency for 20, 40, and 75 meters, requires no further adjustment. It is power rated at 500 watts PEP.

The Golden Swan Trap Vertical antenna, Model 1040V, an omni-directional, low radiation angle unit designed for 52 ohm coaxial feedline is priced at $122.95. Power rated at 2000 watts PEP, it measures 21 feet high and covers 20, 15, 20, and 40 meters. A 75-meter add-on kit is available for $39.95.

Accessories include a *Kwik-on* connector for easy installation and removal of the mobile antenna for $7.95; an MMBX mobile impedance in-line, low loss match box, $23.95; and WM 3000 in-line peak reading wattmeter for $79.95.

For further information about products and prices, contact Swan Electronics, 305 Airport Road, Oceanside, California 92054.

10-500 kHz vlf converter



Palomar Engineers has introduced a new vlf converter which converts signals in the 10-500 kHz vlf band to the amateur 80-meter band so they can be heard on an ordinary short-wave receiver. The converter provides reception of the 1750-meter band at 160-190 kHz where transmitters of one-watt power can be operated without FCC license. It also covers the navigation radio-beacon band, standard frequency broadcasts, ship-to-shore communications, long-range navy transmitters, and the European low-frequency broadcast band.

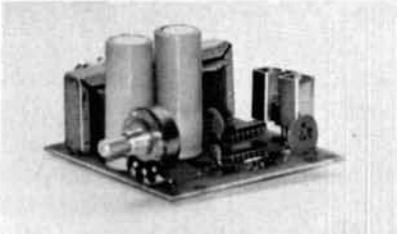
The Palomar converter is simple to use and has no tuning adjustments. Tuning of vlf signals is done by the associated receiver which picks up 10-kHz signals at 3510 kHz, 100-kHz signals at 3600 kHz, and 500-kHz signals at 4000 kHz. The converter features crystal control for accurate frequency conversion, a low noise rf amplifier for high sensitivity, and a multi-pole filter to reject broadcast and shortwave interference. Price is $55.00 postpaid in the United States and Canada. For more information write to Palomar Engineers, Post Office Box 455, Escondido, California 92025.

co-resident 8080 editor/assembler

Tychon has announced its co-resident editor/assembler (TEA) for 8080 systems. Requiring only 5k of memory (R/W or PROM) it is completely I/O independent and relies upon its own I/O software or the I/O routines already available in a user's system. The Tychon Editor/Assembler accepts both octal and hexadecimal values throughout the program and the program listings may be in either octal or hexadecimal form. The switch between octal and hex is made at any time using keyboard commands. The TEA package is the only editor/assembler available which allows the user to easily change the numbering system used. The editor/assembler is relocatable using a special relocator within the program which will place TEA anywhere in the 8080's memory space. The program is available in 1702A or 2708 PROMs and on paper tape. Listings are also available. Prices start at $35 for a paper tape version plus the User's Manual. For further information contact Tychon, Inc., Blacksburg, Virginia 24060.

More Details? CHECK—OFF Page 126

ADVA



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MAKES ALMOST ANY FM OR AM RADIO PORTABLE

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The Universal Porta-Pak is designed to fit anything from a 5-watt CB to a 25 watt commercial 2-way radio. The Universal Porta-Pak comes in two versions, one is a 4.5 AMP HR unit that will recharge in 13 to 16 hours, and the other is a 9 AMP HR unit that recharges in 28 to 30 hours.

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Porta-Pak started out as a very versatile accessory for the amateur, but, now the word is out and as a result 85% of our sales are now to the business radio services. Among enthusiastic users of the Porta-Pak are the C.A.P., ambulance services, fire departments, Red Cross disaster teams, towing services and private surveilance organizations. The Porta-Pak and VHF Marine radio have provided small craft with reliable communications where it was impractical a short time ago.

Be sure to state the make and model of your transceiver when ordering, and a custom model will be provided if one is made for it. The regular mobile mount holes are used to attach the custom models. No modification of your radio is necessary.

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More Details? CHECK—OFF Page 126

Proposed bands for tomorrow?

13950-14400 kHz

160-190 kHz

20700-21200 kHz

6950-7300 kHz

1750-1900 kH

Drake FS-4 Solid State Synthesizer shown with Drake R-4C, MS-4 and T-4XC

Drake is ready for 1979 TODAY!

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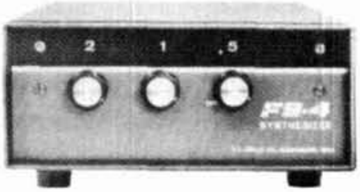
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146.13	146.61	146.94	147.27	147.81
146.16	146.64	146.97	147.30	147.84
146.19	146.67	147.00	147.33	147.87
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★ 21L02(250ns)	2.25
2102(450ns)	1.69
2102(650ns)	1.59
2102(1 sec)	1.40
2111	3.95
21L11	4.25
2112	2.95
2101	2.95
21L01	3.95
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74S189	2.95
7489	1.88
★ 4116 16K	44.95
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21078-4	4.25
MM5261	3.95
MM5262	1.95
MM5280	4.95
8599	1.88
P3101	2.95
5101C-E	9.95
3107	3.95
1101	1.95
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6331	2.95
6300	3.50
6301	3.50
6340	18.95
6341	18.95
6305-1	9.95
6306-1	9.95
6352	18.95
6353	18.95
★ 2708	27.00
1702A	7.95
1702A-6	4.49
5204	16.95
6834	21.95
6834-1	16.95
82816	4.50
8223	2.95
5203	6.95

7400TTL

7400N	.15
7401N	.19
7402N	.18
7403N	.19
7404N	.19
7405N	.22
7406N	.29
7407N	.29
7408N	.25
7409N	.25
7410N	.18
7411N	.28
7412N	.39
7413N	.45
7414N	.69
7416N	.35
7417N	.35
7420N	.20
7421N	.33
7422N	.47
7423N	.37
7425N	.39
7426N	.35
7427N	.35
7428N	.49
7430N	.22
7432N	.31
7437N	.27
7438N	.27
7440N	.22
7441N	.85
7442N	.59
7443N	.75
7444N	.75
7445N	.75
7446N	.79
7447N	.65
7448N	.75
7450N	.22
7451N	.26
7453N	.26
7454N	.22
7459N	.29
7460N	.29
7470N	.44
7472N	.36
7473N	.36
7474N	.31
7475N	.48
7476N	.36
7479N	4.70
7480N	.59
7482N	.99
7483N	.70
7485N	.97
7486N	.39
7488N	3.95
7489N	2.25
7490N	.45
7491N	.65
7492N	.45
7493N	.45
7494N	.75
7495N	.79
7496N	.99
7497N	4.25
74100	.99
74104	.69
74105	.69
74107	.39
74109	.49
74121	.35
74122	.49
74123	.65
74125	.58
74126	.58
74132	1.05
74136	1.10
74141	1.10
74142	3.75
74143	3.95
74144	4.95
74145	1.05
74147	2.25
74148	1.79
74150	.95
74151	.75
74153	.90
74154	1.29
74155	.99
74156	.95
74157	.95
74158	1.79
74160	1.20
74161	.95
74162	.95
74163	.95
74164	1.05
74165	1.05
74166	1.00
74170	2.49
74172	8.49
74173	1.69
74174	1.25
74175	.90
74176	.90
74177	.90
74180	.89
74181	2.39
74182	.95
74184	2.10
74185	2.25
74186	14.50
74190	1.15
74191	1.15
74192	.99
74193	.99
74194	1.39
74195	.75
74196	1.19
74197	1.19
74198	1.69
74199	1.69
74200	5.95
74251	1.69
74279	1.10
74298	1.99
74365	.79
74366	.79
74367	.79
74368	.79

74LS00 TTL

74LS00	.22
LS02	.24
LS04	.24
LS05	.28
LS08	.28
LS10	.28
LS13	.79
LS14	1.69
LS20	.26
LS27	.38
LS30	.26
LS32	.34
LS40	.26
LS42	1.10
LS51	.26
LS73	.56
LS74	.56
LS75	.79
LS76	.59
LS83	1.69
LS85	1.99
LS86	.55
LS90	1.10
LS92	1.10
LS93	1.10
LS95	1.69
LS107	.56
LS109	.56
LS112	.56
LS113	.56
LS123	.99
LS132	1.10
LS136	.99
LS138	1.39
LS139	1.49
LS151	1.49
LS153	1.29
LS155	1.49
LS157	1.29
ES158	1.29
LS161	1.39
LS162	1.39
LS163	1.39
LS164	1.39
LS174	1.39
LS175	1.39
LS190	2.49
LS191	2.49
LS192	2.49
LS193	2.49
LS194	2.49
LS195	.52
LS251	1.39
LS253	1.49
LS257	1.29
LS258	1.29
LS279	1.10
LS283	1.10
LS367	.99
LS368	.99
LS377	1.29
LS378	1.29
81LS95	1.10
81LS96	1.10
81LS97	1.10
81LS98	1.10

74S & 74L

74S00	.40
74S04	.42
74S08	.49
74S10	.40
74S11	.40
74S20	.40
74S30	.40
74S32	.78
74S37	.85
74S38	.95
74S40	.40
74S74	.79
74S138	1.69
74S139	1.69
74S151	1.49
74S158	1.49
74S174	1.59
74S175	1.59
74S189	2.95
74S201	3.95
74S251	1.69
74S257	1.69
74L00	.39
74L04	.39
74L10	.39
74L20	.39
74L30	.39
74L42	1.29
74L73	.89
74L74	.89
74L85	1.49
74L86	1.49
74L90	1.29
74L95	1.29
74L154	1.59
74L164	1.69
74L165	1.89
74L192	1.99
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CD4000	.25
CD4001	.25
CD4002	.25
CD4006	1.69
CD4007	.25
CD4008	1.69
CD4009	.55
CD4010	.55
CD4011	.25
CD4012	.25
CD4013	.55
CD4014	1.95
CD4015	1.95
CD4016	.56
CD4017	.99
CD4018	2.39
CD4019	.55
CD4020	1.39
CD4021	1.85
CD4022	1.20
CD4023	.29
CD4024	1.25
CD4025	.29
CD4026	1.95
CD4027	.59
CD4028	1.50
CD4029	1.70
CD4030	.42
CD4033	2.49
CD4034	4.95
CD4035	1.79
CD4040	1.05
CD4041	1.95
CD4042	1.45
CD4043	1.45
CD4044	1.45
CD4047	1.95
CD4049	.61
CD4050	.61
CD4051	1.25
CD4052	1.25
CD4059	1.95
CD4063	2.49
CD4068	.35
CD4069	.35
CD4070	.35
CD4071	.35
CD4072	.35
CD4073	.35
CD4075	.35
CD4078	.35
CD4081	.40
CD4082	.40
CD4094	2.49
CD40160	
40160	2.10
40161	2.10
40174	2.10
4508	3.95
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4522	2.56
4526	2.56
4527	2.69
4528	1.50
4531	1.99
4532	2.69
4543	2.25
4555	1.79
4556	1.79
4581	4.90
4582	1.99
4585	2.49
4901	.49
4911	.49
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74C04	.35
74C10	.35
74C20	.35
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LM741CN	.39
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LM7520	2.25
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QSL CARDS, $10/500, postage paid. Includes all pertinent data. Bowman Printing Service, 743 Harvard, St. Louis, Mo. 63130.

QRP TRANSMATCH with Preamp for HW7 Ten-Tec. Send stamp for details to Peter Meacham Associates, 19 Lorreta Road, Waltham Mass. 02154.

VARIABLE AND TRIMMER CAPACITORS — RF chokes — Miniductors; stocked for immediate shipment. First class stamp for flyer. D & V Radio Parts, Rt#2, 12805 W. Sarle, Freeland, Michigan 48623.

CANADIANS 1,000,000 surplus parts. Bargains galore. Free catalog. Etco-HR. Box 741, Montreal, H3c 2v2.

PRESCALER BOARD for 650 MHz 11C90. Includes instructions and parts source, 3.00. Also CSJ counter boards 15.00 (see 76 ads). RTC Electronics, P.O. Box 2514, Lincoln, Nebr. 68502.

DISCOUNTS — KLM, Larsen, Brimstone, Stereo Systems, Police Monitors, etc. Catalog available. BankAmericard & Mastercharge. 201-962-4695 Narwid Electronics, 61 Bellot Road, Ringwood, N.J. 07456.

TRANSMITTING TUBES, HV and filament xfmrs, rotary inductors, transmitting capacitors. Send stamp for flyer. T.S. Marinich Electronics, 102 Bell St., Weirton, W. Va. 26062.

ALL TYPES ELECTRONICS supplies and kits, just released, 8 digit, 500 MHz counter kit, all parts, case 169.95, specials include TO-3 heatsinks 1.50 555V, 723N 3/1.25 FND-359 75¢, all new parts, you'll appreciate our serivce, write for flyer, Chemlab-MMC, Box 41472H, Chicago, Il. 60641.

PORTAPAK the accessory that makes your mobile really portable. $67.50 and $88.00. Dealer inquires invited. P.O. Box 67, Somers, Wisc. 53171.

SELL GREENLEE CHASSIS PUNCH'S, a few used one to five times rest are new. 1/2, 9/16, 5/8, 11/16, 3/4, 13/16, 7/8, 15/16, 1, 1-1/16, 1-1/8, 1-3/16, 1-1/2, 1-5/8, 2-1/2, 2-3/4, 2-25/32. Sold.as one lot at $45.00. Local buy $40.00 T.G. North, 2016 N. Adams St., Arlington, Virginia 22201.

RADIO MUSEUM now open. Free Admission. 15,000 pieces of equipment from 1850 telegraph instruments to amateur and commercial transmitters of the 1920's. Amateur station W2AN. Write for information. Antique Wireless Assn., Main St., Holcomb, N. Y. 14469.

47 MFD 4500 VDC OIL CAPACITOR. Ideal for linears or laser discharge cap. NEW. $30 — 2/$55.00. 30 lbs. Transmitter Air Variable Capacitor. 55 to 500 MMF. Spacing .219. NEW. $8.95. 14 lbs. Please include shipping charge. R. W. Electronics, Inc., 3203 N. Western Avenue, Chicago. IL. 60618. 312-248-2480.

QSL — BROWNIE W3CJI — 3035B Lehigh, Allentown, Pa. 18103. Samples with cut catalog 50¢.

MOVING: Six meter, teletype, test gear. Miscellaneous meters, tubes. Too much to list. SASE. W1JTL, P.O. Box 297, Leominster, Mass. 01453.

NEW 4-Varactor, 3-transistor UHF TV tuner. Tunes thru 440 MHz for ATV or repeater applications. $7.95 ppd. Workshop, Box 393H, Bethpage, NY 11714.

TRAVEL PAK QSL KIT — Send call and 25¢; receive your call sample kit in return. Samco, Box 203, Wynantskill, N.Y. 12198.

STOP LOOKING For a good deal on amateur radio equipment — you've found it here — at your amateur radio headquarters in the heart of the Midwest. We are factory-authorized dealers for Kenwood, Drake, Collins, ICOM, Ten-Tec, Atlas, Regency, Tempo, Swan, Midland, Alpha, Standard, Dentron, Hy-Gain, Mosley, Cushcraft, and CDE, plus accessories. Thousands of thrifty hams from coast to coast already know us and we invite you to join them by writing or calling us today for our low quote and trying our personal and friendly Hoosier service. HOOSIER ELECTRONICS, P. O. Box 2001, Terre Haute, Indiana 47802. (812)-238-1456.

BUY — SELL — TRADE — write for free mailer. Give name address and call letters. Complete stock of major brands new and reconditioned equipment. Call for best deals. We buy Collins-Drake-Swan Etc. SSB & FM. Associated Radio, 8012 Conser, Overland Park, Ks. 66204. 913-381-5901.

MOTOROLA HT220, HT200, and Pageboy service and modifications performed at reasonable rates. WA4FRV (804) 320-4439, evenings.

RF GENERATOR B&K 2050, one month old, warranty card. $80 General Radio precision variable, 1000 pf, cast housing, 50:1 gear drive, superb dial, $45. Stephen Johnson, 2011 Ferry Ave., Apt. I-#2, Camden, NJ 08104.

WANTED: Collins 455 Kc mechanical filters. Stephen Johnson, 2011 Ferry Ave., Apt. I-#2, Camden, NJ 08104.

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

THE BEST HANDBOOK in Amateur Radio. The Radio Communication Handbook from the RSGB in 2 volumes $31.90 from *ham radio's* Communications Bookstore, Greenville, NH 03048.

HT100 Motorola wanted. Also pre 1935 QST's. Al Blank W1BL, 272 Pine St., Bristol, Ct. 06010.

TRANSMITTER TECHNICIANS — Voice of America has opportunities for qualified technicians at VOA stations in California, North Carolina, and Ohio. Duties include operations/maintenance of high power shortwave transmitters and related facilities on shift basis. Minimum qualifications: 3-years broadcast chief engineer 5 to 50 KW, or 3-years supervisor of operations/maintenance high power military transmitting plant, or equivalent. U.S. citizenship required. Salary $15-19,000. Submit standard government application form, SF-171 to: VOA Personnel Office, Code 05-77, 330 Independence Avenue, S.W., Washington, D.C. 20547. AN EQUAL OPPORTUNITY EMPLOYER.

RIDER'S RADIO volumes 4 to 22; fair to new condition. Sams Photofacts, 200 duplicate sets. Will swap for RADEX magazines, WRTHs, Broadcasting Yearbooks, EKKO stamp material and other radio literature. Also have thousands duplicate magazines to swap for my needs. Donald Erickson, 6059-H Essex Street, Riverside, California 92504 714-687-5910.

POWER SUPPLIES — Brand New 2.5 amp. Less regulator circuit. You add. With circuit plans. $13 PP. Telstar Ent., E. 16109 Longfellow, Spokane, WA 99216.

More Details? CHECK—OFF Page 126

flea market

MOBILE IGNITION SHIELDING provides more range with no noise. Available most engines. Many other suppression accessories. Literature, Estes Engineering, 930 Marine Dr., Port Angeles, WA 93862.

TRANSISTORS, IC's, Communications — CB "Buy Dependability" at Low Costs. Send for your dealer confidential price list. B&D Enterprizes, Box 32, Dept. 2 Mt. Jewett, PA 16740.

TELETYPE EQUIPMENT for beginners and experienced operators. RTTY machines, parts, supplies. Beginner's special: Model 15 Printer and demodulator $139.00. Dozen black ribbons $6.50; case 40 rolls 11/16 perf. tape $17.50 FOB. Atlantic Surplus Sales, 3730 Nautilus Ave., Brooklyn, N. Y. 11224. Tel: (212) 372-0349.

SWTP AC30 cassette interface, excellent in performance and appearance, with manual, $60 postpaid. Model 19/14 TELETYPE with printer, keyboard, tape distributor, typing reperforater, power supply, table, manuals — all working, many pieces nearly new. $100, will deliver within 150 miles. Robert Boyd, Woodlawn Avenue, Kennebunkport, Maine 04046.

MOBILE BONDING STRAPS under 50¢ each. Literature, Estes Engineering, 930 Marine Drive, Port Angeles, Wash. 98362.

CASH for any Collins unit, 618T, 490T, modules, parts, accessories. Air Ground Electronics, P. O. Box 416, Kearny, N. J. 07032.

ELECTRONIC COMPONENTS, Kits, Transistors, IC's. Send stamp for catalog. Electronics Hobbies, 3421 S.E. Hawthorne Rd., Gainesville, Fla. 32601.

FERRITE BEADS: w/specification and application sheet - 10/$1.00. Assorted PC pots - 5/$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.

THE "CADILLAC" of QSL's! New! Samples: $1.00 (Refundable) — MAC'S SHACK; Box #1171-D; Garland, Texas 75040.

FREE Catalog. Solar Cells, Nicads, Kits, Calculators, Digital Watch Modules, Ultrasonics, Strobes, LEDS, Transistors, IC's, Unique Components. Chaney's, Box 27038, Denver Colo. 80227.

MODERN CODE PRACTICE. 0-22wpm on four 60 min. cassettes, $10. Royal, P. O. Box 2174, Sandusky, Ohio 44870.

TECH MANUALS for Govt. surplus gear — $6.50 each: SP-600JX, URM-25D, OS-8A/U, TS-173/UR. Thousands more available. Send 50¢ (coin) for 22-page list. W3IHD, 7218 Roanne Drive, Washington, DC 20021.

EXCLUSIVELY HAM TELETYPE 23rd year, RTTY Journal, articles, news, DX, VHF, classified ads. Sample 35¢. $3.50 per year. 1155 Arden Drive, Encinitas, Calif. 92024.

FIGHT TVI with the RSO Low Pass Filter. For brochure write: Taylor Communications Manufacturing Company, Box 126, Agincourt, Ontario, Canada. MIS 3B4.

RUBBER STAMP, name/call/QTH $2.50 ppd. (CA residents add tax). LWM Press, Box 22161, San Diego, CA 92122.

TELETYPEWRITER PARTS, gears, manuals, supplies, tape, toroids. SASE list. Typetronics, Box 8873, Ft. Lauderdale, FL. 33310. Buy parts, late machines.

WHAT'S GNU WITH LaRue? Factory-authorized dealer for: ICOM, Regency, Standard, Cushcraft and CES Tough-Tone pads. Also stock Antenna Specialists 2-meter 5/8 wave mobile antennas and Bomar 2-meter crystals for the above radios. Mastercharge and BankAmericard accepted. For the greatest deal call or write LaRue Electronics, 1112 Grandview St., Scranton, Pennsylvania 18509. (717) 343-2124.

VERY in-ter-est-ing! Next 4 issues $1 "Ham Trader Yellow Sheets," Sycamore, IL 60178.

Coming Events

FLINT, MICHIGAN. Greater Genesee Valley A.R.C. swap & shop Sunday September 11, 1977, 8 to 4 pm at Southwestern High School in Flint, Michigan. Tickets are $1.00 in advance, $1.50 at the door. Large tables at reasonable price for sellers. No Trunk Sales. Talk-in on 31/91 and 52 Simplex. For advances tickets, table reservation, and additional information, contact Jack Walters WA8UXN, 1315 Butcher Road, Fenton, Michigan 48430.

More Details? CHECK—OFF Page 126

K9TRG

A Message from Art . . .

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flea market

MEMPHIS IS BEAUTIFUL IN OCTOBER! The Memphis ARRL-sponsored Hamfest, bigger and better than the 4,500 who attended last year, will be held at State Technical Institute, Interstate 40 at Macon Road, on Saturday and Sunday October 1 and 2. Demonstrations, displays, MARS meetings, flea market, ladies flea market, too! Hospitality room, informal dinners, XYL entertainment, many outstanding prizes. Dealers and Distributors welcome. Contact Harry Simpson W4SCF, PO Box 27015, Memphis, TN 38127 for further information.

BETTER THAN EVER — 1977 EDITION Golden Spread Hamfest and Flea Market- Holiday Inn West Amarillo, Texas Aug. 12, 13 & 14. Six big tech sessions. Commercial exhibits. Family recreation. Two Hospitality Hours. Big pre-registration prize and super Grand Prize, others. $3.00 advance, $4.00 at door. For info. pre-registration packet, P.O. Box 10221, Amarillo, Texas 79106.

THE LaPORTE COUNTY Summer Electronic Swapfest will be on Sunday, August 28th at the County Fairgrounds in LaPorte, Indiana, 50 miles Southeast of Chicago. Paved Midway and Indoor booths available at no charge. Good food and cold drink available. Talk-in on 37-97, 01-61, or 52 simplex. Tickets $2.00 at the gate. Information from P.O. Box 30, LaPorte, IN 46350.

MELBOURNE, FLORIDA, SEPTEMBER 10-11. The 12th Annual Melbourne Hamfest will be held Saturday and Sunday, from 9 a.m. to 5 p.m. each day in the airconditioned Melbourne Civic Auditorium located on Hibiscus Boulevard. Donation is $2.50 per person. Full program includes forums, meetings, auction, swap tables, commercial exhibits, awards, prizes, etc. Contact K4HPT, 2749 Herford Road, Melbourne, FL 32935 for swap table reservations. FCC exams on Saturday, donation not needed for exams. Form 610 must be filed with FCC, Room 919, 51 S.W. First Avenue, Miami, FL 33130, not later than August 31, 1977. Hamfest talk-in on 25/85 and 52/52. Sponsored by Platinum Coast Amateur Radio Society. For more info write P.O. Box 1004, Melbourne, FL 32901.

MONTREAL HAMFEST '77. August 6 & 7, 9 AM to 6 PM. St. Lambert Arena.

BARC International Field Day, Burlington, VT. August 13-14 at the Old Lantern (same location as last year). Starts at 7AM Saturday and closes 5PM Sunday. This year's hamfest is dedicated to the memory of K1URQ. Camping at site, flea market both days, early bird registration $3.00 ($3.50 at door). Talk-in on 01-61. Write Burlington Amateur Radio Club, P.O. Box 312, Burlington, VT 05401 for information and advance tickets.

FLORIDA: The BOLD CITY HAMFEST sponsored by the Jacksonville Range Association will be held at the Jacksonville Beach Auditorium AUGUST 6-7 . . . Vacation at our Hamfest — 'FLORIDA'S FRIENDLIEST' . . . Visit our special 'SOLAR' and 'QRPp' forums. Send request for information and tables to HAMFEST COORDINATOR, Jacksonville Range Association, P.O. BOX 10623, Jacksonville, FL 32207 . . . For Motel reservations call RAMADA INN toll free 1-800-228-2828.

MICROCOMPUTER INTERFACING Workshop, September 15, 16, 17, 1977. A three-day workshop based on the popular 8080 microprocessor. Over 20 operating 8080 computers are available for participant use. This session will be held at the VPI & SU Extension Center in Reston, VA (Dulles Airport). For more information contact Dr. Norris Bell, V.P.I. and S.U., Blacksburg, Virginia 24061, (703) 951-6328.

DIGITAL ELECTRONICS for Automation Workshop, September 13, 14, 1977. A two-day workshop based on the small scale and medium scale TTL integraded circuits. Many hours of laboratory time with indepth lectures. This session will be held at the VPI & SU Extension Center in Reston, Va. (Dulles Airport). For more information contact Dr. Norris Bell, V.P.I. and S.U., Blacksburg, Virginia 24061, (703) 951-6328.

HAMFESTERS 43rd Annual Picnic and Hamfest. Sunday August 14, 1977, Santa Fe Park, 91st and Wolf Road, Willow Springs, Illinois, Southwest of Chicago. Exhibits for OM's and XYL's, Famous Swappers Row. Tickets at gate $2.00, advance $1.50. For advance tickets send check or money order to Bob Hayes W9KXW, 18931 Cedar Ave., Country Club Hills, Ill. 60477.

SARA HAMFEST Desoto, Illinois, August 22, 1977. Prizes, food, auction, no charge for flea merchants write: Nick Koeningstein, 2009 Gray Dr., Carbondale, Ill. 62901.

SOUTH DAKOTA, Signal Hill A.R.C. of the Northern Black Hills area Ham Flea Market 10:00 AM to 6:00 PM August 20, 1977 at the South Sturgis Church of Christ, Sturgis, South Dakota. Talk-in on 52/52. For further information contact: Dennis Painter WBØFYG , Box 759, Sturgis, South Dakota 57785. Phone 605-347-3087.

More Details? CHECK—OFF Page 126

7400N TTL

SN7400N	.16	SN7459A	.25		
SN7401N	.16	SN7460N	.22	SN74154N	1.00
SN7402N	.21	SN7470N	.45	SN74155N	.99
SN7403N	.16	SN7472N	.39	SN74156N	.99
SN7404N	.18	SN7473N	.37	SN74157N	.99
SN7405N	.24	SN7474N	.32	SN74160N	1.25
SN7406N	.20	SN7475N	.50	SN74161N	.99
SN7407N	.29	SN7476N	.32	SN74163N	.99
SN7408N	.25	SN7479N	5.00	SN74164N	1.10
SN7409N	.25	SN7480N	.50	SN74165N	1.10
SN7410N	.18	SN7482N	.98	SN74166N	1.25
SN7411N	.30	SN7483N	.70	SN74167N	5.50
SN7412N	.33	SN7485N	.89	SN74170N	2.10
SN7413N	.45	SN7486N	.39	SN74172N	8.95
SN7414N	.70	SN7488N	3.50	SN74173N	1.50
SN7416N	.35	SN7489N	2.49	SN74174N	1.25
SN7417N	.35	SN7490N	.45	SN74175N	.99
SN7420N	.21	SN7491N	.75	SN74176N	.90
SN7421N	.33	SN7492N	.49	SN74177N	.90
SN7422N	.49	SN7493N	.49	SN74180N	.99
SN7423N	.37	SN7494N	.79	SN74181N	2.49
SN7425N	.29	SN7495N	.79	SN74182N	.95
SN7426N	.29	SN7496N	.89	SN74184N	1.95
SN7427N	.37	SN7497N	4.00	SN74185N	2.20
SN7429N	.42	SN74100N	1.00	SN74186N	15.00
SN7430N	.26	SN74107N	.39	SN74187N	6.00
SN7432N	.31	SN74121N	.39	SN74188N	3.95
SN7437N	.27	SN74122N	.39	SN74190N	1.19
SN7438N	.27	SN74123N	.50	SN74191N	1.25
SN7439N	.25	SN74125N	.60	SN74192N	.89
SN7440N	.15	SN74126N	.60	SN74193N	.89
SN7441N	.89	SN74132N	1.09	SN74194N	1.25
SN7442N	.59	SN74136N	.95	SN74195N	.75
SN7443N	.75	SN74141N	1.15	SN74196N	1.25
SN7444N	.75	SN74142N	4.00	SN74197N	.75
SN7445N	.75	SN74143N	4.50	SN74198N	1.75
SN7446N	.81	SN74144N	4.50	SN74199N	1.75
SN7447N	.69	SN74145N	1.15	SN74200N	5.59
SN7448N	.79	SN74147N	2.35	SN74279N	.90
SN7450N	.26	SN74148N	2.00	SN74251N	1.79
SN7451N	.27	SN74150N	1.00	SN74284N	6.00
SN7453N	.27	SN74151N	.79	SN74285N	6.00
SN7454N	.20	SN74153N	.89	SN74367N	.75

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CD4002	.25	CD4040	2.45	74C20N	.65
CD4006	2.50	CD4042	1.90	74C30N	.65
CD4007	.25	CD4044	1.50	74C42N	2.15
CD4009	.59	CD4046	2.51	74C73N	1.50
CD4010	.59	CD4047	2.75	74C74	1.15
CD4011	.25	CD4049	.79	74C90N	3.00
CD4012	.25	CD4050	.79	74C95N	2.00
CD4013	.47	CD4051	2.95	74C107N	1.25
CD4016	.56	CD4053	2.95	74C151	2.90
CD4017	1.35	CD4060	3.25	74C154	4.00
CD4019	.55	CD4066	1.75	74C157	2.15
CD4020	1.49	CD4069	.45	74C160	3.25
CD4022	1.25	CD4071	.45	74C161	3.25
CD4023	.25	CD4081	.45	74C163	3.00
CD4024	1.50	CD4511	2.50	74C164	3.25
CD4025	.25	CD4518	2.50	74C173	2.60
CD4026	$3.95	MC14566	3.00	74C193	2.75
CD4027	.69	74C00N	.39	74C195	2.75
CD4028	1.65	74C02N	.55	MC4044	4.50
CD4029	2.90			MC14016	.56

LINEAR

LM300H	.80	78MG	1.75	LM1351N	1.65
LM301H	.35	LM370N	1.15	LM1414N	1.75
LM301CN	.35	LM373N	3.25	LM1458C	.65
LM302H	.75	LM377N	4.00	LM1496N	.95
LM304H	1.00	LM380N	1.39	LM1556V	1.85
LM305H	.95	LM380CN	1.05	LM2111N	1.95
LM307CN	.35	LM381N	1.79	LM2901N	2.95
LM308H	1.00	LM382N	1.79	LM3065N	.69
LM308CN	1.00	NE501K	8.00	LM3900N	.55
LM309H	1.10	NE510A	6.00	LM3905N	.60
LM309K	.99	NE531H	3.00	LM3909	1.25
LM310CN	1.15	NE536T	6.00	LM5556N	1.85
LM311H	.90	NE540L	6.00	MC5558V	1.00
LM311N	.90	NE550N	.79	LM7525N	.90
LM318CN	1.50	NE555V	.39	LM7535N	1.25
LM319N	1.30	NE560B	5.00	8038B	4.95
LM320K-5	1.35	NE561B	5.00	LM75450	.49
LM320K-5.2	1.35	NE562B	5.00	75451CN	.39
LM320K-12	1.35	NE565H	1.25	75452CN	.39
LM320K-15	1.35	NE565N	1.75	75453CN	.39
LM320T-5	1.75	NE566CN	1.25	75454CN	.39
LM320T-5.2	1.75	NE567H	1.95	75491CN	.79
LM320T-8	1.75	NE567V	1.50	75492CN	.89
LM320T-12	1.75	LM703CN	.45	75494CN	.89
LM320T-15	1.75	LM709H	.29	**RCA LINEAR**	
LM320T-18	1.75	LM709N	.29	CA3013	2.15
LM320T-24	1.75	LM710N	.79	CA3023	2.56
LM323K-5	9.95	LM711N	.39	CA3035	2.48
LM324N	1.80	LM723H	.55	CA3039	1.35
LM339N	1.70	LM723N	.55	CA3046	1.30
LM340K-5	1.95	LM733N	1.00	CA3059	3.25
LM340K-6	1.95	LM739N	1.00	CA3060	3.25
LM340K-8	1.95	LM741CH	.35	CA3080	.85
LM340K-12	1.95	LM741CN	.35	CA3081	2.00
LM340K-15	1.95	LM741-14N	.39	CA3082	2.00
LM340K-18	1.95	LM747H	.79	CA3083	1.60
LM340K-24	1.95	LM747N	.79	CA3086	.85
LM340T-5	1.75	LM748H	.39	CA3089	3.75
LM340T-6	1.75	LM748N	.39	CA3091	10.20
LM340T-8	1.75	LM1303N	.60	CA3102	2.95
LM340T-12	1.75	LM1304N	1.19	CA3123	2.15
LM340T-15	1.75	LM1305N	1.40	CA3130	1.39
LM340T-18	1.75	LM1307N	.85	CA3140	1.25
LM340T-24	1.75	LM1310N	2.95	CA3600	1.75
LM350N	1.00			RC4194	5.95
LM351CN	.65			RC4195	3.25

74LS00 TTL

74LS00	.29	74LS74	.49	74LS139	1.95
74LS02	.29	74LS75	.69	74LS151	1.55
74LS03	.29	74LS76	.49	74LS153	1.89
74LS04	.35	74LS83	1.75	74LS157	1.55
74LS05	.35	74LS85	2.49	74LS162	2.25
74LS08	.29	74LS86	.49	74LS163	2.25
74LS10	.29	74LS90	1.25	74LS164	1.95
74LS13	.69	74LS92	1.25	74LS175	1.95
74LS14	1.75	74LS93	1.25	74LS181	3.69
74LS20	.29	74LS95	1.95	74LS190	2.85
74LS26	.39	74LS96	1.89	74LS191	2.85
74LS27	.39	74LS107	.59	74LS192	2.85
74LS28	.39	74LS109	.59	74LS193	2.85
74LS30	.29	74LS112	.59	74LS194	1.89
74LS32	.39	74LS132	1.25	74LS195	1.89
74LS40	.39	74LS136	.59	74LS257	1.75
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74LS55	.29			74LS279	.79
74LS73	.49			74LS670	3.95

CLOCK CHIPS

MM5309	6 Digit, BCD Outputs, Reset PIN	$9.95
MM5311	6 Digit, BCD Outputs, 12 or 24 Hour	4.95
MM5312	4 Digit, BCD Outputs, 1 PPS Output	4.95
MM5314	6 Digit, 12 or 24 Hour, 50 or 60 Hz	4.95
MM5316	4 Digit, Alarm, 1 PPS Output	6.95
MM5318	Video Clock Chip, For Use With (MM5841 - $9.95)	9.95
CT7001	6 Digit, Calendar, Alarm, 12 or 24 Hour	5.95

DATA HANDBOOKS

7400	Pin-out & Description of 5400/7400 ICS	$2.95
CMOS	Pin-out & Description of 4000 Series ICS	$2.95
Linear	Pin-out & Functional Description	$2.95

ALL THREE HANDBOOKS $6.95

Timeband® by FAIRCHILD — Watches —

T201 Black Bracelet LED $19.95

T237 White w/bracelet $29.95
T236 Yellow w/bracelet $34.95
LED

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- Solid State
- Displays hour, minute, second, month & day
- Snap-out battery replacement
- Free set of replacement batteries
- Choose LED or LCD styles
- One year factory warranty

TC441 White w/strap $29.95
TC440 Yellow w/strap $34.95
LCD

LADIES LED

T311 White w/strap $34.95
T310 Yellow w/strap $39.95

CHANNEL F™ FAIRCHILD VIDEO ENTERTAINMENT SYSTEM

$159.95

- Freeze Action • Speed Option
- Automatic time and scorekeeping
- Battery-free AC operation
- Dual controls with 8-way action
- Built-in Pro Hockey and Tennis games
- Easy hook-up on any B/W or Color TV
- Factory warranty

Channel F — additional cartridges — $19.95 ea.

#8112 - Desert Fox/Shooting Gallery
#8113 - Blackjack (1 or 2 players)
#8114 - Spitfire (1 or 2 players)
#8115 - Space War
#8111 - Tic-Tac-Toe/Shooting Gallery/Doodle/Quadra-Doodle

DISCRETE LEDS

.125" dia.			.190" dia.		
XC209	Red	10/$1	XC111	Red	10/$1
XC209	Green	4/$1	XC111	Green	4/$1
XC209	Orange	4/$1	XC111	Yellow	4/$1
XC209	Yellow	4/$1	XC111	Orange	4/$1

.200" dia.			.185" dia.			.200" dia.		
XC22	Red	10/$1	XC526	Red	5/$1	XC556	Red	10/$1
XC22	Green	4/$1	XC526	Green	4/$1	XC556	Green	4/$1
XC22	Yellow	4/$1	XC526	Yellow	4/$1	XC556	Yellow	4/$1
XC22	Orange	4/$1	XC526	Orange	4/$1	XC556	Orange	4/$1
SSL-22	RT	4/$1	XC526	Clear	4/$1	XC556	Clear	7/$1

.085" dia. MV50 - Red - 6/$1

INFRA-RED LED ¼" x ¼" x 1/16" Flat 5/$1.00

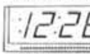
DISPLAY LEDS

DL707 DL338

TYPE	POLARITY	HT		TYPE	POLARITY	HT	
MAN 1	Common Anode	270	2.95	MAN 3640	Common Cathode-orange	300	1.75
MAN 2	5 x 7 Dot Matrix	300	4.95	MAN 4710	Common Anode-Red	400	1.95
MAN 3	Common Cathode	125	3/1.00	DL701	Common Anode-red ±	300	.99
MAN 4	Common Cathode	187	1.95	DL704	Common Cathode	300	.99
MAN 7	Common Anode	300	1.25	DL707	Common Anode	300	.99
MAN 7G	Common Anode-green	300	1.95	MAN 4740	Common Anode-Red	400	.99
MAN 7Y	Common Anode-yellow	300	1.95	DL741	Common Anode	600	1.50
MAN 52	Common Anode-green	300	.99	DL747	Common Anode	600	2.25
MAN 64	Common Anode-red	400	.99	DL750	Common Cathode	600	2.49
MAN 74	Common Cathode	300	1.50	DL338	Common Cathode	110	.50
MAN 82	Common Anode-yellow	300	.99	FND70	Common Cathode	250	.75
MAN 84	Common Cathode-yellow	300	.99	FND503	Common Cathode	500	1.00
MAN 3620	Common Anode-orange	300	1.75	FND507	Common Anode	500	1.00

FCS 8000A — 3½ Digit — .8" Display

NEW! 25 Pin Version with colon & am/pm indicator



FRONT VIEW - FSC8000

SPECIAL $4.95 EA.

- MAXIMUM FORWARD CURRENT — 25 mA
- Connects almost one for one with 3817, 3817A or D. (3817 available at $5.00 each)
- Typical segment current 8mA except colon, 10 hrs. b & c and 10 min. a & d which are 16 mA
- Forward voltage drop 1.5 volts

HP 5082-7300 Multi-Digit Series

- ⅛" Ht. • Common Cathode • Dip Package
- 3 to 5 volts @ 5 mils per segment
- 7 segment Monolithic • Red Display

2 Digit	$ .79
3 Digit	.89
4 Digit	.99
5 Digit	1.19

IC SOLDERTAIL — LOW PROFILE (TIN) SOCKETS

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin	$.17	.16	.15	24 pin	$.38	.37	.36
14 pin	.20	.19	.18	28 pin	.45	.44	.43
16 pin	.22	.21	.20	36 pin	.60	.59	.58
18 pin	.29	.28	.27	40 pin	.63	.62	.61
22 pin	.37	.36	.35				

SOLDERTAIL STANDARD (TIN)

14 pin	$.27	.25	.24	28 pin	$.99	.90	.81
16 pin	.30	.27	.25	36 pin	1.39	1.26	1.15
18 pin	.35	.32	.30	40 pin	1.59	1.45	1.30
24 pin	.49	.45	.42				

SOLDERTAIL STANDARD (GOLD)

8 pin	$.30	.27	.24	24 pin	$.70	.63	.57
14 pin	.35	.32	.29	28 pin	1.10	1.00	.90
16 pin	.38	.35	.32	36 pin	1.75	1.40	1.26
18 pin	.52	.47	.43	40 pin	1.75	1.59	1.45

WIRE WRAP SOCKETS (GOLD) LEVEL #3

10 pin	$.45	.41	.37	24 pin	$1.05	.95	.85
14 pin	.39	.38	.37	28 pin	1.40	1.25	1.10
16 pin	.43	.42	.41	36 pin	1.59	1.45	1.30
18 pin	.75	.68	.62	40 pin	1.75	1.55	1.40

50 PCS. RESISTOR ASSORTMENTS $1.25 PER ASST.

SPECIAL

ASST. 1	5 ea.	10 OHM 27 OHM	12 OHM 33 OHM	15 OHM 39 OHM	18 OHM 47 OHM	22 OHM 56 OHM	1/4 WATT 5% - 50 PCS
ASST. 2	5 ea.	68 OHM 180 OHM	82 OHM 220 OHM	100 OHM 270 OHM	120 OHM 330 OHM	150 OHM 390 OHM	1/4 WATT 5% - 50 PCS
ASST. 3	5 ea.	470 OHM 1.2K	560 OHM 1.5K	680 OHM 1.8K	820 OHM 2.2K	1K 2.7K	1/4 WATT 5% - 50 PCS
ASST. 4	5 ea.	3.3K 8.2K	3.9K 10K	4.7K 12K	5.6K 15K	6.8K 18K	1/4 WATT 5% - 50 PCS
ASST. 5	5 ea.	22K 56K	27K 68K	33K 82K	39K 100K	47K 120K	1/4 WATT 5% - 50 PCS
ASST. 6	5 ea.	150K 390K	180K 470K	220K 560K	270K 680K	330K 820K	1/4 WATT 5% - 50 PCS
ASST. 7	5 ea.	1M 2.7M	1.2M 3.3M	1.5M 3.9M	1.8M 4.7M	2.2M 5.6M	1/4 WATT 5% - 50 PCS

ASST. 8R Includes Resistor Assortments 1-7 (350 PCS.) **$7.49 ea.**

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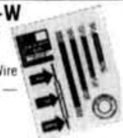
HOBBY-WRAP TOOL-BW-630

- Battery Operated (Size C)
- Weighs ONLY 11 Ounces
- Wraps 30 AWG Wire onto Standard DIP Sockets (.025 inch)
- Complete with built-in bit and sleeve

$34.95
(batteries not included)

WIRE-WRAP KIT — WK-2-W

WRAP • STRIP • UNWRAP



- Tool for 30 AWG Wire
- Roll of 50 Ft. White or Blue 30 AWG Wire
- 50 pcs. each 1", 2", 3" & 4" lengths — pre-stripped wire.

$11.95

WIRE WRAP TOOL WSU-30

WRAP • STRIP • UNWRAP - $5.95

WIRE WRAP WIRE — 30 AWG

25 ft. min. $1.25 50 ft. $1.95 100 ft. $2.95 1000 ft. $15.00
SPECIFY COLOR — White - Yellow - Red - Green - Blue - Black

Plastic Push Button Switch

- 18 AWG Solid Wire - 5" Long
- .50 (wide) X .60 (high) ⅜-27 Thread
- 8 AMP @ 14 Volt - 1 AMP @ .10 Volt

		1-9	10-Up
J-188-1	Push On-Push Off	.59	.49
J-188-2	Normally Open	.59	.49
J-188-3	Normally Closed	.59	.49

DIP SWITCHES

SPST Slide Action

#206-4	(8 pin dip)	4 switch unit	$1.75 ea.
#206-7	(14 pin dip)	7 switch unit	$1.95 ea.
#206-8	(16 pin dip)	8 switch unit	$2.25 ea.

TV GAME CHIP SET — $14.95

Includes AY-3-8500-1 chip and 2.010 mhz crystal — if purchased separately would cost $18.95.

ZENERS — DIODES — RECTIFIERS

TYPE	VOLTS	W	PRICE	TYPE	VOLTS	W	PRICE
1N746	3.3	400mm	4/1.00	1N4005	600 PIV	1 AMP	10/1.00
1N751A	5.1	400m	4/1.00	1N4006	800 PIV	1 AMP	10/1.00
1N752	5.6	400m	4/1.00	1N4007	1000 PIV	1 AMP	10/1.00
1N753	6.2	400m	4/1.00	1N3600	50	200m	6/1.00
1N754	6.8	400m	4/1.00	1N4148	75	10m	15/1.00
1N959	8.2	400m	6/1.00	1N4154	35	10m	12/1.00
1N965B	15	400m	4/1.00	1N4305	75	25m	20/1.00
1N5232	5.6	500m	.28	1N4734	5.6	1w	.28
1N5234	6.2	500m	.28	1N4735	6.2	1w	.28
1N5235	6.8	500m	.28	1N4736	6.8	1w	.28
1N5236	7.5	500m	.28	1N4738	8.2	1w	.28
1N456	25	40m	6/1.00	1N4742	12	1w	.28
1N458	150	7m	6/1.00	1N4744	15	1w	.28
1N485A	180	10m	6/1.00	1N1183	50 PIV	35 AMP	1.60
1N4001	50 PIV	1 AMP	12/1.00	1N1184	100 PIV	35 AMP	1.70
1N4002	100 PIV	1 AMP	12/1.00	1N1185	150 PIV	35 AMP	1.50
1N4003	200 PIV	1 AMP	12/1.00	1N1186	200 PIV	35 AMP	1.80
1N4004	400 PIV	1 AMP	12/1.00	1N1188	400 PIV	35 AMP	3.00

SCR AND FW BRIDGE RECTIFIERS

C36D	15A @ 400V	SCR	$1.95
C38M	35A @ 200V	SCR	1.95
2N2328	1.6A @ 200V	SCR	.50
MDA 980-1	12A @ 50V	FW BRIDGE REC	1.95
MDA 980-3	12A @ 200V	FW BRIDGE REC	1.95

TRANSISTORS

MPS A05	5/$1.00			PN4249	4/$1.00
MPS A06	5/$1.00	PN3567	3/$1.00	PN4250	4/$1.00
2N2219A	3/$1.00	PN3568	4/$1.00	2N4400	4/$1.00
2N2221	4/$1.00	PN3569	4/$1.00	2N4401	4/$1.00
2N2222A	5/$1.00	2N3704	5/$1.00	2N4402	4/$1.00
2N2369	5/$1.00	2N3705	5/$1.00	2N4403	4/$1.00
2N2369A	4/$1.00	2N3706	5/$1.00	2N4409	5/$1.00
2N2484	4/$1.00	2N3707	5/$1.00	2N5086	4/$1.00
2N2906A	4/$1.00	2N3711	5/$1.00	2N5087	4/$1.00
2N2907A	5/$1.00	2N3724	$.65	2N5088	4/$1.00
2N2925	5/$1.00	2N3725	$1.00	2N5089	4/$1.00
2N3053	2/$1.00	2N3903	5/$1.00	2N5129	5/$1.00
2N3055	$.89	2N3904	4/$1.00	2N5138	5/$1.00
MJE3055	$1.00	2N3905	4/$1.00	2N5139	5/$1.00
MJE2955	$1.25	2N3906	4/$1.00	2N5209	5/$1.00
2N3390	5/$1.00	2N4013	3/$1.00	2N5951	5/$1.00
2N3398	5/$1.00	2N4014	3/$1.00	C106B1SCR	2/$1.00
		2N4123	10/$1.00	2N5437	$2.00

CAPACITOR CORNER

50 VOLT CERAMIC DISC CAPACITORS

	1-9	10-49	50-100		1-9	10-49	50-100
10 pf	.05	.04	.03	.001µF	.05	.04	.035
22 pf	.05	.04	.03	.0047µF	.05	.04	.035
47 pf	.05	.04	.03	.01µF	.05	.04	.035
100 pf	.05	.04	.03	.022µF	.06	.05	.04
220 pf	.05	.04	.03	.047µF	.06	.05	.04
470 pf	.05	.04	.035	1µF	.12	.09	.075

100 VOLT MYLAR FILM CAPACITORS

.001mf	.12	.10	.07	.022mf	.13	.11	.08
.0022	.12	.10	.07	.047mf	.21	.17	.13
.0047mf	.12	.10	.07	.1mf	.27	.23	.17
.01mf	.12	.10	.07	.22mf	.33	.27	.22

+20% DIPPED TANTALUMS (SOLID) CAPACITORS

.1/35V	.28	.23	.17	1.5/35V	.30	.26	.21
.15/35V	.28	.23	.17	2.2/25V	.31	.27	.22
.22/35V	.28	.23	.17	3.3/25V	.31	.27	.22
.33/35V	.28	.23	.17	4.7/25V	.32	.28	.23
.47/35V	.28	.23	.17	6.8/25V	.36	.31	.25
.68/35V	.28	.23	.17	10/25V	.40	.35	.29
1.0/35V	.28	.23	.17	15/25V	.63	.50	.40

MINIATURE ALUMINUM ELECTROLYTIC CAPACITORS

Axial Lead				Radial Lead			
.47/50V	.15	.13	.10	.47/25V	.15	.13	.10
1.0/50V	.16	.14	.11	.47/50V	.16	.14	.11
3.3/50V	.15	.13	.10	1.0/16V	.15	.13	.10
4.7/25V	.16	.14	.12	1.0/25V	.16	.14	.11
10/25V	.15	.13	.10	1.0/50V	.16	.14	.11
10/50V	.16	.14	.12	4.7/16V	.15	.13	.10
22/25V	.17	.15	.12	4.7/25V	.15	.13	.10
22/50V	.24	.20	.18	4.7/50V	.16	.14	.11
47/25V	.19	.17	.15	10/16V	.14	.12	.09
47/50V	.25	.21	.19	10/25V	.15	.13	.10
100/25V	.24	.20	.18	10/50V	.16	.14	.12
100/50V	.35	.30	.28	47/50V	.24	.21	.19
220/25V	.32	.28	.25	100/16V	.19	.15	.14
220/50V	.45	.41	.38	100/25V	.24	.20	.18
470/25V	.33	.29	.27	100/50V	.35	.30	.28
1000/16V	.55	.50	.45	220/16V	.23	.17	.16
2200/16V	.70	.62	.55	470/25V	.31	.28	.26

More Details? CHECK — OFF Page 126

flea market

NEW ORLEANS HAMFEST/COMPUTERFEST at the Hilton Inn in Kenner, LA. September 24 & 25. Information on tickets, room reservations and etc. will be furnished upon request by contacting the New Orleans Hamfest/Computerfest; PO Box 10111, Jefferson, LA 70181.

ALL SAINTS AMATEUR RADIO GROUP invites you to Hamfest '77 in Saint Andrews-By-The-Sea at the Algonquin Hotel, September 2, 3, & 4. St. Andrews, New Brunswick is a very popular resort area on the border between Maine and New Brunswick with many attractions for the whole family. We have been fortunate to obtain the famous Algonquin Hotel for our Hamfest headquarters. Full info from Barb Sheppard, secretary, RR 325-8, Rothesay NB Canada EOG 2WO.

WARREN, OHIO, HAMFEST — August 21, 1977. Moved again! Trumbull K.S.U. Branch Campus on Route 45 at Warren Outerbelt. Best site in our 20 years. Bigger flea market; all close-in parking; parks & lakes nearby. Displays; talk-in; $2 door prize registration. Arrowsigns lead from I-80; I-90; Ohio 5; 11; 45. Details? QSL: Hamfest, Box 809, Warren, Ohio 44483.

LAFAYETTE, INDIANA HAMFEST. Sunday, August 21, 1977 at Tippecanoe County Fairgrounds located at 18th St. & Teal Rd., (Indiana Highway) in Lafayette. 55 miles northwest of Indianapolis off I65. Send check or money order with SASE to WA9BZDI, Bill Bayley, 1021 Beck La., Lafayette, IN 47905 for tickets by mail.

"GREATER LOUISVILLE HAMFEST is Sunday Sept. 25, 1977 at Kentucky State Fairgrounds with exits off either I-65 or I-264. Indoor exhibitors area and Flea Market air conditioned. Also an outdoor flea market. Ladies Bingo, Meetings and Forums, refreshments available. Admission is $2.00 adults, 12 and under free. Flea market venders pay admission price plus $2.00 per space indoor or $1.00 per space outdoor. For more info or motel/camping contact Denny Schnurr, K4GOU 2415 Concord Dr., Louisville, Ky. 40217 (502-634-0619)."

35TH ANNUAL FINDLAY HAMFEST, Riverside Park, Findlay, Ohio September 11. Advance tickets are $1.50 and $1.00 at the gate. For tickets and additional information send S.A.S.E. to Clark Foltz, W8UN, 122 W. Hobart, Findlay, Ohio 45840.

THE OLD PUEBLO RADIO CLUB (W7GV) of Tucson, Arizona will conduct a world-wide contest over Labor Day weekend 1977. Permission has been granted for the club to operate from the South Rim of the Grand Canyon on September 2, 3, and 4, 1977. The 80, 40, 20, and 15-meter bands — SSB and CW — will be used. For additional information, contact Ian W. Thomson, W7BQN, P.O. Box 6497, Tucson, AZ 85733.

HAMFEST Zero-Beaters ARC Sunday, August 7, 1977, Washington, MO City Park — 10 AM. Write Box 24, Dutzow, MO 63342. Flea Market, Army Mars Meeting, Prizes, Bingo, Cake Walk, Candy Scramble, fun for whole family.

L'ANSE CREUSE ARC Swap and Shop, Sunday September 18, 1977, 9 am to 3 pm, at the L'Anse Creuse High School, Mt. Clemens, Michigan. Tickets $1.00 in advance, $1.50 at the door. Talk-in 146.52, 146.94. Tickets and information from Harold Price, WB8QFR, 32111 Harper St., Clair Shores, Mich. 48082.

SANGAMON VALLEY Radio Club Second Annual Hamfest on Sunday, September 25th, at the Sangamon County Fairgrounds, New Berlin, Illinois, 16 miles west of Springfield. Indoor display area and covered pavilion. Exhibits, food and ladies activities. Overnite camping! Tickets: $1 advance, $1.50 at gate. First Prize — Wilson HT. Talk-in: 146.28/.88 and .52 MHz. Information: WB9-QWR, Carole Churchill, 622 Magnolia, Rochester, IL. 62626.

CINCINNATI HAMFEST: 41st Annual — Sunday September 18, 1977 at the improved Stricker's Grove on State Route 128, one mile west of Ross (Venice) Ohio. Flea Market, Contests, Model Aircraft Flying, Food and Beverages all day. Advance Ticket Sales $7.50 — Tickets at the Gate $8.00 — covers everything. For further information: Lillian Abbott K8CKI, 1424 Main Street, Cincinnati Ohio 45210.

THE GRAND RAPIDS Amateur Radio Club will hold its annual Swap-N-Shop Saturday, September 17 from 8 a.m. to 4 p.m. at the Hudsonville Fairgrounds in Hudsonville, Michigan, 12 miles southwest of Grand Rapids on M-21. Talk-in on 146.52 and 16/.76. $2 donation at the gate with plenty of refreshments and free tables available.

MT. BEACON Amateur Radio Club 4th Annual Hamfest Saturday, August 6th, 9 AM to 5 PM at Stewart Field, Newburgh, N. Y., inside Hanger. Flea Market & Auction. Talk-in on 37/97 and 16/76. Rain or shine. Plenty of free parking. Admission, $1; Tailgating, $1; under 12 free.

More Details? CHECK—OFF Page 126

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More Economical RTTY

The ST-5000 from HAL

The HAL ST-5000 sets the pace for an economical demodulator/keyer for radio-teletype (RTTY). All the features you need for reception and transmission of HF and VHF RTTY are here.

The demodulator features a hard-limiting front end, active filter discriminator, and active detector circuitry for wide dynamic range. Autostart and motor control circuitry make for easy VHF and HF autostart operation.

Convenient front panel switches are provided for 850 and 170 Hz shift, normal or reverse sense, autostart on/off, print - line or local, and power on/off. 425 Hz press transmissions may also be copied with the ST-5000. High voltage 60 ma. loop output as well as low level RS-232 compatible output are provided by the demodulator.

The audio keyer section of the ST-5000 generates stable, phase-coherent audio tones. Transmission is a simple matter of applying these tones to your HF SSB or VHF FM transmitter.

The ST-5000 is housed in an attractive blue and beige cabinet and is backed by the HAL Communications one year warranty.

For complete specs on the HAL ST-5000, write or call HAL today.

$275.00

HAL Communications Corp., Box 365, 807 E. Green St.
Urbana, Illinois 61801 • Telephone (217) 367-7373

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#2. **HANDSET ONLY** **$79.00**
Requires wiring accessory socket on IC-245 & IC-22S.

#3. **TOUCH TONE HANDSET** with
IC-22S $299.00
Handset 30.00
You pay only **$329.00**
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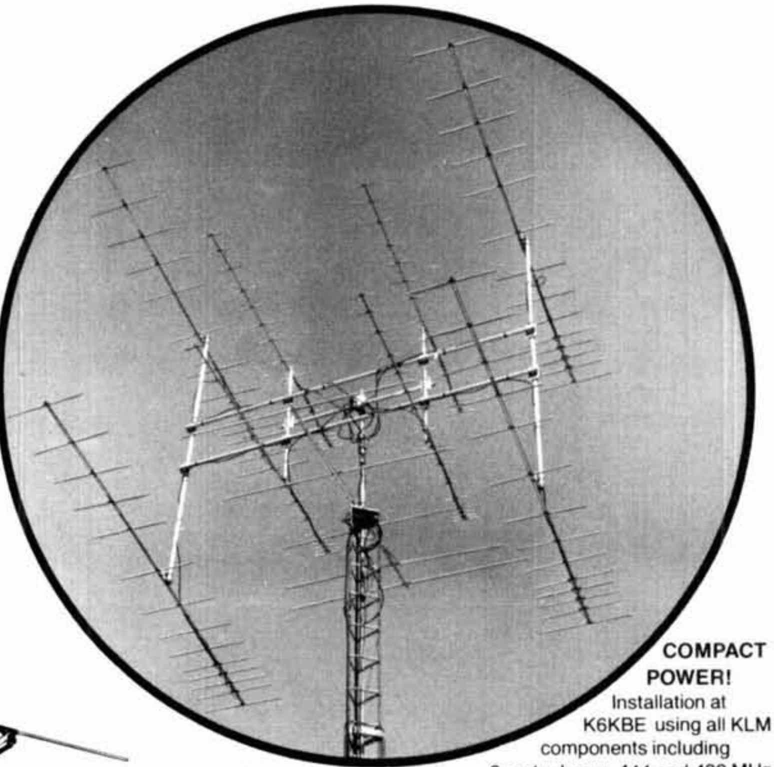
COMPACT POWER!

KLM ANTENNAS

HF VHF UHF

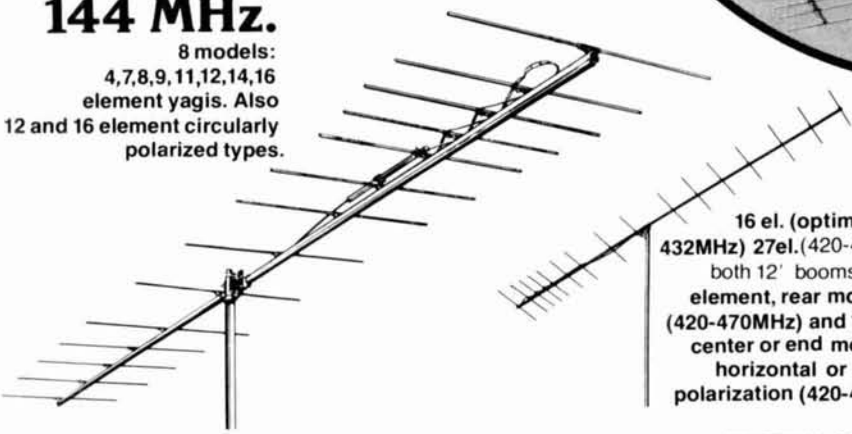
Excellent mechanical designs feature multiple driven elements and optimized spacing for wide band operation with low VSWR, clean patterns, maximum power gains.



COMPACT POWER!
Installation at K6KBE using all KLM components including 6 meter beam, 144 and 432 MHz arrays, KR-400 and KR-500 rotators.

144 MHz.

8 models: 4,7,8,9,11,12,14,16 element yagis. Also 12 and 16 element circularly polarized types.



A broad-band antenna to meet every need; each with contest winning gain and flat VSWR across the entire amateur band. For serious moon bounce (EME) and tropho work, "stack" 'em, using available KLM baluns and couplers. Built tough . . . with weather resistant 6063-T832 aluminum . . . stainless steel hardware.

70 CM 4 models:

16 el. (optimized for 432MHz) 27el.(420-450MHz) both 12' booms. **Also 6 element, rear mountable (420-470MHz) and 14 el. for center or end mounting, horizontal or vertical polarization (420-470MHz)**

One of the most versatile series available. Included are rear mount types that can be arranged for either horizontal or vertical polarization. A 16 element long boom type (optimized for 432MHz, ±2 MHz), really pours out the power! Four or eight are often stacked for EME or DX using efficient KLM couplers.

ANTENNA COUPLERS/POWER DIVIDERS

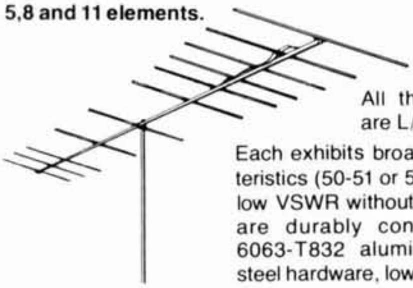
Several broad band models are available for stacking VHF or UHF beams. These replace two, quarter wave matching cables, barrels and "T" needed to interconnect two or four antennas. Phasing and match to 50 ohm line is automatic. Will handle 2KW p.e.p. with ease.

STACKING FRAMES.

"H" frames suitable for antenna stacking are available on special order. See top photograph for a typical installation.

50 MHz. 3 models:

5,8 and 11 elements.



All three antennas are L/P types.

Each exhibits broad band characteristics (50-51 or 50-52 MHz) and low VSWR without tuning. Beams are durably constructed with 6063-T832 aluminum stainless steel hardware, low loss insulation.

ELEVATION ROTATOR KR-500

Provides 180° boom rotation. Heavy duty (used on array illustrated). Rotation, 180°/1 min. Motor disc brake holds to 1750 inch/pounds. Holds booms 1.25 to 1.625"D, masts to 1.5-2.5"D. Weather resistant. Attractive direction indicator. 115VAC.

AZIMUTH ROTATOR KR-400

Medium duty, supports 400 lbs. Ideal for long boomers, HF tri-banders, used in array shown. Motor disc brake holds to 1750 inch-pounds. Has limit switches. Rotation, 360°/1 min. Accommodates 1.5-2.5"D masts. Direction indicator. 115VAC. 50/60 Hz.

HEAVY-DUTY ROTATOR HD-1500

Use for high torque, heavy systems.

Also 3.5, 7, 14, 21, 28 MHz ham antennas and a full line of commercial log-periodic types.

At your dealer. Write for catalog.

KLM electronics, inc.
17025 Laurel Road, Morgan Hill, CA 95037 (408) 779-7363

More Details? CHECK — OFF Page 126

LUNAR

proudly announces a NEW 2-Meter AMPLIFIER/PREAMPLIFIER
the *2M10-80P*

The Marriage Between Power Amplifiers and Receiving Preamplifiers is Finally Consummated! Lunar Offers an SCS **2M10-80L** Power Amp and an "Anglelinear" **144W** Preamp in a Single, Functionally-Designed Package that Combines Two Superior Products Into One!

Features:

★ Ten watts input — eighty watts output
★ Harmonic reduction exceeds −60 dB to meet FCC R&O 20777 Specifications
★ Variable T-R Delay for CW/SSB
★ Functionally-Designed Extrusion Includes Mounting Lip
★ Preamplifier Selectable Independently of Power Amplifier
★ Automatic T-R Switching of Amp & Preamp
★ Preamp gain: Nominally 11 dB
Noise Figure: Nominally 2.5 dB
(Including Relay Losses)
★ Remote Control Head Available Separately

Introductory Price: . . . . Lunar Model 2M10-80P $189.95

Please add $3.00 shipping and handling

Also From Lunar:

Available Now: Complete Line of Separate Preamplifiers 50-450 MHz
Coming Soon: Complete Line of 50-450 MHz Amp/Preamp Combinations
Preamps Through 2.5 GHz
Transverter Systems 50 MHz-2.5 GHz
Converters and Filters 28 MHz-2.5 GHz

California residents add 6%. Order today at your dealer or direct from:

LUNAR electronics
P. O. BOX 82183
SAN DIEGO, CA 92138
714-222-9518
Louis N. Anciaux WB6NMT

STEP UP TO TELREX

WITH A
TELREX "BALUN" FED—"INVERTED-VEE" KIT
THE IDEAL HI-PERFORMANCE
INEXPENSIVE AND PRACTICAL TO INSTALL LOW-FREQUENCY
MONO OR MULTIPLE BAND, 52 OHM ANTENNA SYSTEM

Telrex "Monarch" (Trapped) I.V. Kit
Duo-Band / 4 KWP I.V. Kit $63.50
Post Paid Continental U.S.

Optimum, full-size doublet performance, independent of ground conditions! "Balanced-Pattern", low radiation angle, high signal to noise, and signal to performance ratio! Minimal support costs, (existing tower, house, tree). A technician can resonate a Telrex "Inverted-Vee" to frequency within the hour! Minimal S/W/R is possible if installed and resonated to frequency as directed! Pattern primarily low-angle, Omni-directional, approx. 6 DB null at ends! Costly, lossy, antenna tuners not required! Complete simplified installation and resonating to frequency instructions supplied with each kit.

For technical data and prices on complete Telrex line, write for Catalog PL 7 (HRH)

COMMUNICATION SYSTEMS SINCE 1921 telrex Laboratories
ASBURY PARK NEW JERSEY 07712 U.S.A.

IF WE WERE YOU

MODEL 6154 TERMALINE®

I'D BUY FROM US

YOUR INQUIRY OR ORDER WILL GET OUR PROMPT ATTENTION

AUTHORIZED

BIRD DISTRIBUTOR

WEBSTER COMMUNICATIONS
115 BELLARMINE
ROCHESTER, MI 48063
313-375-0420

More Details? CHECK—OFF Page 126

NEW

DIGITAL CLOCK with 10 MINUTE TIMER

6 digits — 12/24 hour

Here's the kit everyone has been asking for! Never fail to identify your station again. And it's easy to use, just tap timer button to start, 9 minutes later the display will flash on and off to alert you. Reset it by simply touching the timer button or it will reset itself automatically after two minutes! Other features are: jumbo .4" LED readouts, durable extended aluminum case available in 5 colors, plug transformer, Polaroid lens filter, time set buttons, finest quality PC boards and super instructions. You get all parts — no extras are needed, unlike some of the kludges our competitors offer! Colors available: gold, black, silver, bronze, blue (specify). Size: 4.25" x 1.5" x 1.5".

Clock Kit with 10 min. timer, DC-10 .... $25.95
Regular 12/24 hr clock kit 22.95
Alarm clock, 12 hr only, DC-8 .... 24.95
Kits are also available fully assembled and tested, just add $10 to kit price.

CAR CLOCK 12/24 HR 6 DIGIT $25.95

- High accuracy (1 minute/month)
- Big .4" LED display
- Special circuit suppress all voltage spikes and transients
- Same case as illustrated above
- Display blanks with ignition off
- Reverse polarity protected

Complete Kit, DC-7 ...... $25.95
Assembled and calibrated ... 35.95

CALENDAR ALARM CLOCK 6 Digit LED 12/24 Hour

Has every feature one could ever ask for. Kit includes everything except case, build it into wall, station or even car! **FEATURES:**

- 6 Digits, .5" High LED
- 12/24 Hour Format
- Calendar shows mo./day
- Snooze button
- True 24 Hour Alarm
- 7001 chip does all!!
- Battery back up with built in on chip time base

Complete Kit, less case, DC-9 .... $34.95

600 MHz PRESCALER $59.95

Assembled and tested. Extend the range of your counter to 600 MHz. Works with all counters. Available in kit form for $44.95. Specify ÷10 or ÷100 with order.

30 WATT 2 Meter Power Amp

The famous RE class C power amp now available mail order! Four Watts in for 30 Watts out, 2 in for 15 out, 1 in for 8 out. Incredible value, complete with all parts, instructions and details on T-R relay. Fully stable, output short proof, infinite VSWR protected! Case not included.

Complete Kit $22.95

COMING SOON: VIDEO TERMINAL KIT

SEND FOR DETAILS $149.95

TTL		LINEAR		REGULATOR		TRANSISTORS	
74S00	.35	555	.50	309K	.99	NPN 2N3904 type	10/$1.00
74S112	.75	556	.75	309H	.99	PNP 2N3906 type	10/$1.00
7447	.79	567	1.75	340K-12	1.25	NPN Power Tab 40W	3/$1.00
7473	.35	1458	.50	7805	.99	PNP Power Tab 40W	3/$1.00
7475	.50	LED DRIVER		7812	.99	FET MPF-102 type	3/$2.00
7490A	.55	75491	.50	7815	.99	UJT 2N2646 type	3/$2.00
74143	3.50	75492	.50	7818	.99	2N3055 NPN Power	.75

SPECIAL

DIODES: 1KV,2.5A .... 5/$1.00 100V,1A .... 10/$1.00 1N914A type .... 50/$2.00

LED DISPLAYS

FND 359 ...... .4" C.C. ...... .75
FND 510 ...... .5" C.A. 1.25
DL 707 .... .33" C.A. 1.25
HP 7730 ...... .27" C.A. 1.25
Red Polaroid Filter ... 4.25" X 1.125" ... .59

741 OP-AMP SPECIAL

Factory prime mini dip with both Xerox and 741 part numbers
10 for $2.00

SOCKETS

14 PIN 5/$1.00
16 PIN 5/$1.00
24 PIN 2/$1.00
40 PIN 3/$2.00

FERRITE BEADS

with info and specs 15/$1.00
6 hole Balun Beads 5/$1.00

SOCKET KIT

Assortment of 12 most used IC sockets. Good to have around the shop. $1.95

8080A $18.95

Factory Prime — includes FREE socket!

21L02-1 $1.95

Fast 450 ns Low Power

60 Hz XTAL TIME BASE

- Runs on 5-15 VDC
- Low current (2.5 ma)
- Operate clocks in car, boat, plane
- 1 minute/month accuracy

Kit, TB-7 ... $5.50
Assembled & Calibrated ... $9.95

CHEAP CLOCK KIT $9.95

DC-4 Features:
- 6 digit .4" LED
- 12 or 24 format

Does not include board or transformer

PC Board $2.95
Transformer $1.49

Dealers Write for our wholesale price list. Hi M•D

ramsey electronics

P.O. Box 4072 Rochester NY 14610
(716) 271-6487

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Satisfaction guaranteed or money refunded. COD, add $1.00. Orders under $10.00 add $.75. NY residents add 7% tax.

MINI-KITS

FM Wireless Mike Kit $2.95

Transmit up to 300' to any FM broadcast radio. Sensitive mike input requires crystal ceramic or dynamic mike. Runs on 3 to 9 V.

TONE DECODER KIT

A complete tone decoder on a single PC Board. Features: 400-5000 Hz adjustable frequency range, voltage regulation, 567 IC. Useful for touch-tone decoding, tone burst detection, FSK demod, signaling, and many other uses. Use 7 for 12 button touchtone decoding. Runs on 5 to 12 volts.

Complete Kit, TD-1 .... $4.95

LED BLINKY KIT

A great attention getter which alternately flashes 2 Jumbo LEDs. Use for name badges, buttons, or warning type panel lights. Runs on 3 to 9 volts.

Complete Kit $2.95

SUPER-SNOOP AMPLIFIER

A super-sensitive amplifier which will pick up a pin drop at 15 feet! Great for monitoring baby's room or as a general purpose test amplifier. Full 2 watts of output, runs on 6 to 12 volts, uses any type of mike. Requires 8-45 ohm speaker.

Complete Kit, BN-9 .... $4.95

MUSIC LIGHTS KIT

See music come alive! 3 different lights flicker with music or voice. One light for lows, one for the mid-range and one for the highs. Each channel individually adjustable, and drives up to 300 watts. Great for parties, band music, nite clubs and more.

Complete Kit, ML-1 .... $7.95

SIREN KIT

Produces upward and downward wail characteristic of police siren. 5 Watts audio output, runs on 3-9 volts, uses 8-45 ohm speaker.

Complete Kit, SM-3 .... $2.95

CODE OSCILLATOR KIT

Powerful 1 watt audio oscillator of approx. 1 kHz, good for many uses. Great for warning alarm, battery checker, voltage indicator and code oscillator.

Complete Kit, CPO-1 .... $2.50

POWER SUPPLY KIT

Complete triple regulated power supply provides variable ±15 volts at 200 mA and +5 volts at 1 Amp. 50 mV load regulation good filtering and small size. Kit less transformers. Requires 6-8 V at 1 Amp and 18 to 30 VCT.

Complete Kit, PS-3LT $6.95

DECADE COUNTER PARTS KIT

INCLUDES
- 7490A decade counter
- 7475 latch
- 7447 LED driver
- LED readout
- Current limit resistors

$3.50

Complete with instruction and details on how to build an easy, low cost freq. counter. R8

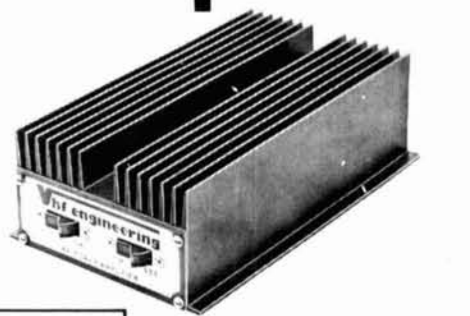
More Details? CHECK — OFF Page 126

More Details? CHECK—OFF Page 126

Vhf engineering

BLUE LINE RF Amplifiers

Don't sacrifice maximum power output and high efficiency for linearazation. The BLUE LINE offers you the best of both designs. The BLUE LINE amplifiers are engineered using the latest state of the art stripline technology. This design technology means efficient broad band output with a very high degree of mechanical stability.



Vhf engineering is the only name you have to remember when it comes to VHF or UHF amplifiers, just look at the variety available.

MODEL	BAND	EMISSION	POWER INPUT	POWER OUTPUT	WIRED AND TESTED PRICE
BLC 10/70	144 MHz	CW-FM-SSB/AM	10W	70W	139.95
BLC 2/70	144 MHz	CW-FM-SSB/AM	2W	70W	159.95
BLC 10/150	144 MHz	CW-FM-SSB/AM	10W	150W	259.95
BLC 30/150	144 MHz	CW-FM-SSB/AM	30W	150W	239.95
BLD 2/60	220 MHz	CW-FM-SSB/AM	2W	60W	159.95
BLD 10/60	220 MHz	CW-FM-SSB/AM	10W	60W	139.95
BLD 10/120	220 MHz	CW-FM-SSB/AM	10W	120W	259.95
BLE 10/40	420 MHz	CW-FM-SSB/AM	10W	40W	139.95
BLE 2/40	420 MHz	CW-FM-SSB/AM	2W	40W	159.95
BLE 30/80	420 MHz	CW-FM-SSB/AM	30W	80W	259.95
BLE 10/80	420 MHz	CW-FM-SSB/AM	10W	80W	289.95

Don't forget our popular PA-2501 and PA-4010 at $74.95 (wired and tested) $59.95 (Kit)

FEATURES

- High efficiency means low current drain.
- Broad band design (no tuning).
- Direct 12 volt DC operation.
- Indicator lamps for On/Off and FM/SSB.
- Relay switching (allows you to put amplifier in or out of circuit at the flip of a switch).
- Insertion loss of less than 1 dB.
- One year limited warranty on parts and labor.

WANT TO BRING YOUR AMPLIFIER INDOORS?

LOOK AT THESE POWER SUPPLIES!

- Over-voltage protection crowbar.
- Electrostatic shield for added transient surge protection.
- A foldback output limiter operates for loads outside of the operating range.
- Isolation from ground. The circuit is isolated from the case and ground.
- 115/220 volt input — 50/60 cycle.
- Units are factory wired for 115 volt AC, 50/60 cycle power. A simple jumper will reconfigure the input for 220 volt AC, 50/60 cycles.
- Temperature range — operating: 0° to +55° C.
- Black anodized aluminum finish.

PS-25M WITH CURRENT METERS

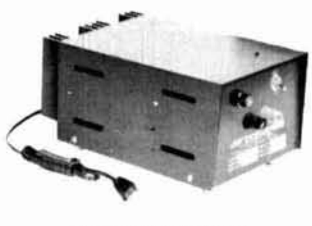
Recommended for:

BLC 10/70 BLD 2/60 BLE 30/80
BLC 2/70 BLD 10/60 BLE 10/80

Voltage Output: adjustable between 10-15V
Load Regulation: 2% from no load to 20 a
Current Output:
25 amps intermittent (50% duty cycle)
Ripple: 50 mV at 20 amps
Weight: 22-1/2 pounds
Size: 12-1/4" x 6-3/4" x 7-1/2"

PS-25M Kit $149.95
PS-25M Wired & tested . $169.95

PS-15C LOW COST



Recommended for:

BLE 10/40 BLE 2/40

Voltage Output: adjustable between 12-14V
Load Regulation: 2% from no load to 10 amps
Current Output:
15 amps intermittent (50% duty cycle)
Ripple: 50 mV at 10 amps
Weight: 13 pounds
Size: 11-1/4" x 5-1/2" x 4-3/4"

PS-15C Kit $79.95
PS-15C Wired & tested . $94.95

PS-3012 COMMERCIAL

Recommended for:

BLC 3/150
BLC 30/150
BLD 10/120

Output Voltage: Adjustable, 11-15 VDC
Output Current: 30 amps (50% duty cycle)
Regulation: Better than 2 percent
Output Ripple: 50MV pk-pk maximum
Temperature Range: 0°-60° C operating
Overvoltage Protection: Built in OVP crowbar
Overcurrent Protection: Foldback current limiting at 30 amps
Short Circuit Current: 2 amps maximum
Input Voltage: 105-120 or 208-230 at 50-60Hz
Size: 13-1/4" L x 7-1/8" W x 6-5/8" H
Weight: 25 lbs.
Finish: Black anodized aluminum

PS-3012 Wired & tested . . . $239.95

Export prices are slightly higher. Prices subject to change.

Vhf engineering
DIVISION OF BROWNIAN ELECTRONICS CORP.

BOX H / 320 WATER ST. / BINGHAMTON, N.Y. 13901
Phone 607-723-9574

WE HONOR master charge THE INTERBANK CARD BANKAMERICARD

More Details? CHECK — OFF Page 126

SPECIALS FROM MHz electronics

Fairchild VHF Prescaler Chips

11C01FC	High Speed Dual 5-4 Input no/nor	15.40
11C05DC	1 GHz Counter Divide by 4	74.35
11C05DM	1 GHz Counter Divide by 4	110.50
11C06DC	UHF Prescaler 750 MHz D Type flip/flop	12.30
11C24DC	Dual TTL VCM same as MC4024P	2.60
11C44DC	Phase Freq. Detector same as MC4044P	2.60
11C58DC	ECL VCM	4.53
11C70DC	600 MHz flip/flop with reset	12.30
11C83DC	1 GHz 248/256 Prescaler	29.20
11C90DC	650 MHz Prescaler Divide by 10/11	16.00
11C90DM	same as above except Mil. version	24.00
11C91DC	605 MHz Prescaler Divide by 5/6	16.00
11C91DM	same as above except Mil. version	24.00
95H90DC	350 MHz Prescaler Divide by 10/11	9.50
95H90DM	same as above except Mil. version	16.50
95H91DC	350 MHz Prescaler Divide by 5/6	9.50
95H91DM	same as above except Mil. version	16.50

Batteries

Gel-Cell 12 volts at 1.5 Amp Hr. #GC-1215 $19.95

Crystals

1.000000 MHz	4.95
5.000000 MHz	4.95
3579.545 KC	2.95
10 MHz	$4.95

JUST ARRIVED! These radios have just been pulled out of service. Set up for approx. 150 MHz. Clean. All tubes included. No accessories. Prices FOB Phoenix.

Motorola U43 GGT	$49.95
GE TPL	$99.95
GE MT-33	$39.95
GRC10 Radio Set	$169.95

Motorola MC14410CP CMOS tone Generator uses 1 MHz Crystal to produce standard dual frequency telephone dialing signal. Directly compatible with our 12 key Chomeric pads. Kit includes the following.

1 MC14410CP
1 1 MHz Crystal
1 Printed Circuit Board (From Ham Radio Sept. 1975)
And all other parts for assembly. NOTE: Touch Tone Pad not included! $15.70

Fairchild 95H90DC Prescaler divide by 10 to 350 MHz. Will take any 35 MHz Counter to 350 MHz. Kit includes the following.

1 95H90DC
1 2N5179
2 UG-88/u BNC's
1 Printed Circuit Board
And all other parts for assembly.
$29.95

Fairchild 11C90DC Prescaler divide by 10 to 650 MHz. Will take any 65 MHz Counter to 650 MHz or with a 82S90 it will divide by 10/100 to 650 MHz. This will take a 6.5 MHz counter to 650 MHz. Kit includes the following.

1 11C90DC
1 2N5179
2 UG-88/U
1 MC7805CP
1 Bridge
1 Printed Circuit Board and all other parts for assembly.
82S90 add $5.70 to total.
$59.95

Fairchild 3817 Clock Kit from Ham Radio, Feb. 1976, Pg. 26 — All parts included except transformer and case. 12 hour $24.95 24 hour $29.95

I.C.'s

8223B	$3.00
2102	$1.99

MuRata 10.7 MHz Ceramic Filters #SFW-10.7MA $3.95
10.7 Narrow Band Crystal Filters Type 2194F $7.95 each

Johanson and Johnson Trimmer Capacitors

1 to 14 pf.	$1.95
1 to 20 pf.	$1.95

Ferrite Beads
12 for .99 or 120 for 9.99

FET's

2N3070	1.50	2N5460	.90	MFE3002	3.35
2N3436	2.25	2N5465	1.35	MPF102	.45
2N3458	1.30	2N5565	5.45	MPF121	1.50
2N3821	1.60	3N126	3.00	MPF4391	.80
2N3822	1.50	MFE2000	.90	U1282	2.50
2N4351	2.85	MFE2001	1.00	MMF5	5.00
2N4416	1.05	MFE2008	4.20	40673	1.39
2N4875	1.75	MFE2009	4.80	40674	1.49

TUBES

2E26	5.00	572B/T160L	25.00	7377	40.00
3B28	4.00	811A	9.95	8156	3.95
4X150A	15.00	931A	11.95	8908	9.95
4X150G	18.00	5849	32.00	8950	5.50
4CX250B	24.00	6LQ6	4.50	4-400A	29.95
4CX350A/8321	35.00	6146A	5.25	4-250A	24.95
4CX15000A	150.00	6146B/8298A	6.25	4-125A	20.95
DX415	25.00	6360	7.95	4-65A	15.95
		6907	35.00		

TRANSFORMERS

F-18X	6.3vct at 6 amps	3.56
F-93X	6.5v to 40v at 750 ma.	3.53
F-92A	6.5v to 40v at 1 amp	4.59
N-51X	Isolation 115vac at 35va.	2.80
Model D-2	6.5v at 3.3 amps 6.5v at 3.3 amps	4.95
BE-12433-001	30v at 15 ma.	.49
BGH-9	6.3vct at 10 amps.	6.95
F-107Z	12V @ 4A or 24 V @ 2A	7.80
P6377	12v @ 4a or 24v @ 2a	6.31
P6378	12v @ 8a or 24v @ 4a	10.31
P8196	80vct @ 1.2a	6.28

New Motorola Carbon Microphone Model P-7255A.
This unit is a "noise cancelling" palm type microphone. These mikes come with or without cables. Price without $19.95 — with $29.95.

FANS

Pamotor Fans, Model 4500C 117 VAC, 60 Hz, 19 w. $7.95

DIODES

1N270 Germanium Diodes	$7.95/c
HEP170, 2.5A, 1000 PIV	$4.95/20
Semtech SFMS 20K, 20KV, 10 ma, fast recovery	$1.26 ea.

H.P. 612A UHF Signal Generator, 450 MHz to 1230 MHz $900.00
H.P. 624B Microwave test set, 6565 MHz to 7175 MHz $900.00
Beckman "Eput" meter and Heterodyne Plug-in/Freq. meter D.C. to 1 GHz. $900.00

RF TRANSISTORS

2N1561	15.00	2N3927	11.50	2N5641	4.90
2N1562	15.00	2N3948	2.00	2N5643	20.70
2N1692	15.00	2N3950	26.25	2N5764	27.00
2N1693	15.00	2N3961	6.60	2N5841	11.00
2N2631	4.20	2N4072	1.70	2N5842/MM1607	19.50
2N2857	1.80	2N4073	2.00	2N5849/MM1622	19.50
2N2876	12.35	2N4135	2.00	2N5862	50.00
2N2880	25.00	2N4427	1.24	2N5942	49.50
2N2927	7.00	2N4430	20.00	2N5922	10.00
2N2947	17.25	2N4440	8.60	2N6080	5.45
2N2948	15.50	2N4957	6.30	2N6081	8.60
2N2949	3.90	2N5070	13.80	2N6082	11.25
2N2950	5.00	2N5090	6.90	2N6083	12.95
2N3287	4.30	2N5108	3.90	2N6084	14.95
2N3300	1.05	2N5109	1.55	2N6166	36.80
2N3302	1.05	2N5177/MRF5177	20.00	MRF8004	1.90
2N3307	10.50	2N5179	.68	HEPS3014/76	4.95
2N3309	3.90	2N5184		HEPS3002	11.03
2N3375/MM3375	7.00	2N5216	47.50	HEPS3003	29.88
2N3553	1.80	2N5583	5.60	HEPS3005	9.55
2N3571	4.10	2N5589	4.60	HEPS3006	19.90
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7411	.25
7412	.30
7413	.45
7414	1.10
7416	.25
7417	.40
7420	.15
7426	.30
7427	.45
7430	.15
7432	.30
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7438	.35
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7441	1.15
7442	.55
7443	.85
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7446	.95
7447	.95
7448	.95
7450	.25
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74L55	.65
74L72	.45
74L73	.40
74L74	.45
74L75	.55
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74L123	.55
74S00	.55
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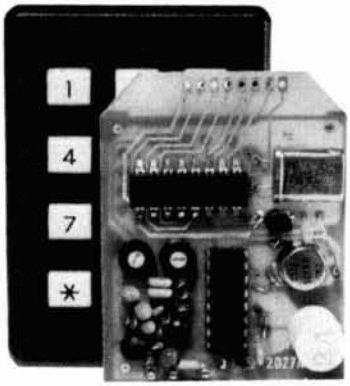
More Details? CHECK—OFF Page 126

More Details? CHECK—OFF Page 126

NEW — 2027 DUAL ENCODER



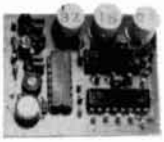
The 2027 dual encoder has both Touch-Tone and Sub-Audible tone on one small board. Simple installation in most radios requires only three connections: ground, plus VDC and tone output. The encoder itself slips over the pins of either a 12-key or 16-key DIGITRAN® keyboard.

The 2027 also offers:

- **individual tone level controls**
- **power by 9-16 VDC, unregulated**
- **replaceable plug-in tone elements**
- **EIA tone frequencies from 67.0 Hz to 203.5 Hz. Other EIA frequencies available on special order.**
- **reverse polarity protected**

Priced at:
$71.96 for 2027A, 12-key keyboard
$78.95 for 2027B, 16-key keyboard

TG-1A



TG-3A

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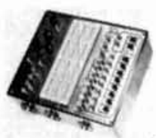

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Drive Power	20 W PEP max
Output Power	100 W PEP max
Rx Pre-Amp Gain	20 dB typ
N.F.	2.5 dB typ
Power Supply	115 V A.C.
Size:	10″ x 6″ x 7″

The EDL144 amplifier contains a high power transmit linear amplifier (5894 PA) and power supply (115v) together with a low noise receive pre-amplifier (2.5 dB NF). T/R switching is automatic by an internal VOX circuit; no changes are needed to your existing transceiver.

EDL432P $299.95

Drive Power	10 W PEP max
Output Power	50 W PEP max
Power Supply	115 V A.C.
Size:	10″ x 6″ x 11″

The EDL432P amplifier contains a high power triode amplifier (2C39A) with matching power supply (115v). The cabinet also contains the cooling air blower, antenna relays and full metering. The RF section is also available as a complete sub-assembly for use with an existing power supply etc.,
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EDT50-28	50-52 MHz
EDT144-28	144-146 MHz
Drive Power, 10M	0.5 W max
Output Power	100 W PEP max
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N.F.	2.5 dB typ
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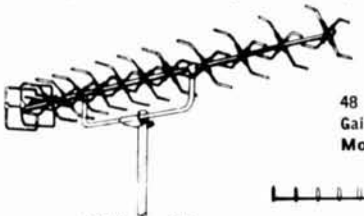

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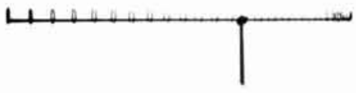

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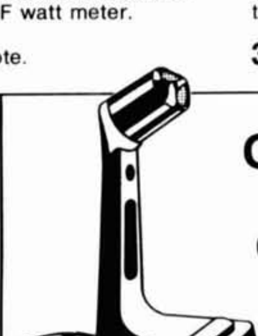

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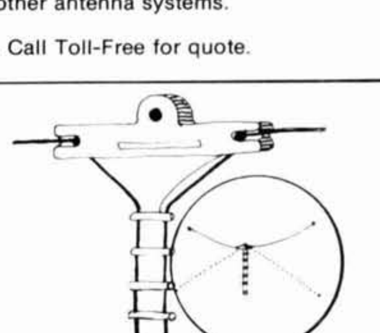

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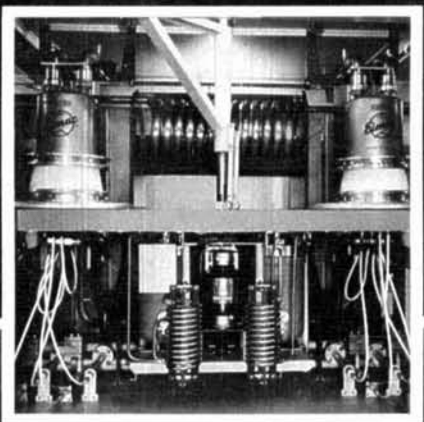

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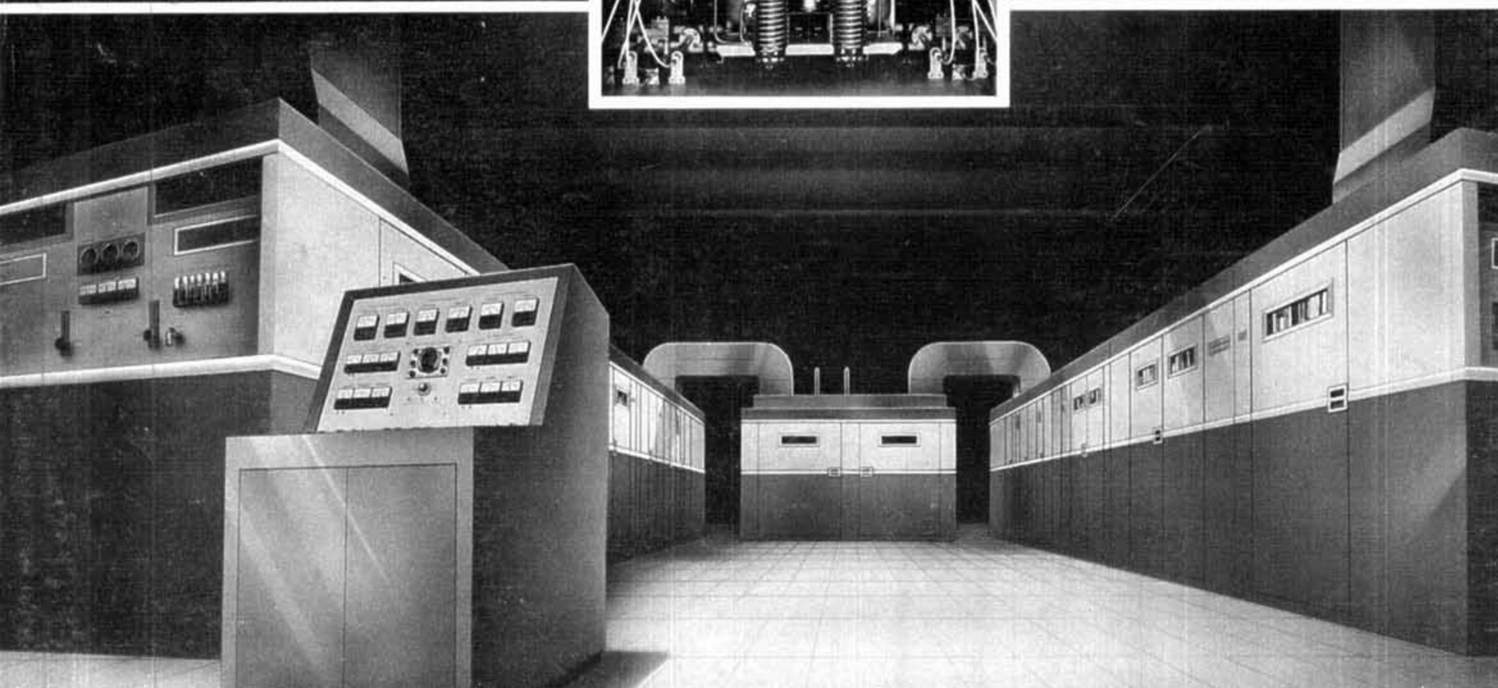

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