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400-CHANNEL SYNTHESIZER

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SYNTHESIS

to control frequency

by GILBERT BOELKE*

A complete and comprehensive article covering theory and techniques of indirect frequency synthesis, plus schematics and a description of a practical 400-channel synthesizer used in a two-meter FM transceiver with only one frequency-determining crystal.

The Process

Frequency synthesis is the term used to describe the process of synthesizing (or "putting together") many frequencies from a small number of starting frequencies. In theory, any number of channels may be so generated from only one master oscillator, using the electronic techniques of adding, subtracting, multiplying, and dividing frequencies. In practice, the larger the number of channels the more worthwhile it is to go the synthesizer route.

A *direct* synthesizer uses such conventional techniques directly, filtering the undesired output products at each step in the process. This technique has the disadvantage that many high quality filters are required to reduce the undesired (spurious) output frequencies to the desired extent.

An *indirect* synthesizer uses a voltage-controlled oscillator to generate the output signal, electronically "steers" it to the correct frequency and "locks" it there. Its main advantage is that the output needs no filtering; it comes from an on-frequency oscillator. All spurious products are kept within the confines of the synthesizer loop (with any luck) and do not appear in the output.

Figures 1 and 2 illustrate two ways a synthesizer can be used. In Fig. 1, the synthesizer covers the full range of transmitter and receiver frequencies for a General Electric TPL unit. An extra X8 multiplier must be added to the receiver so that both re-

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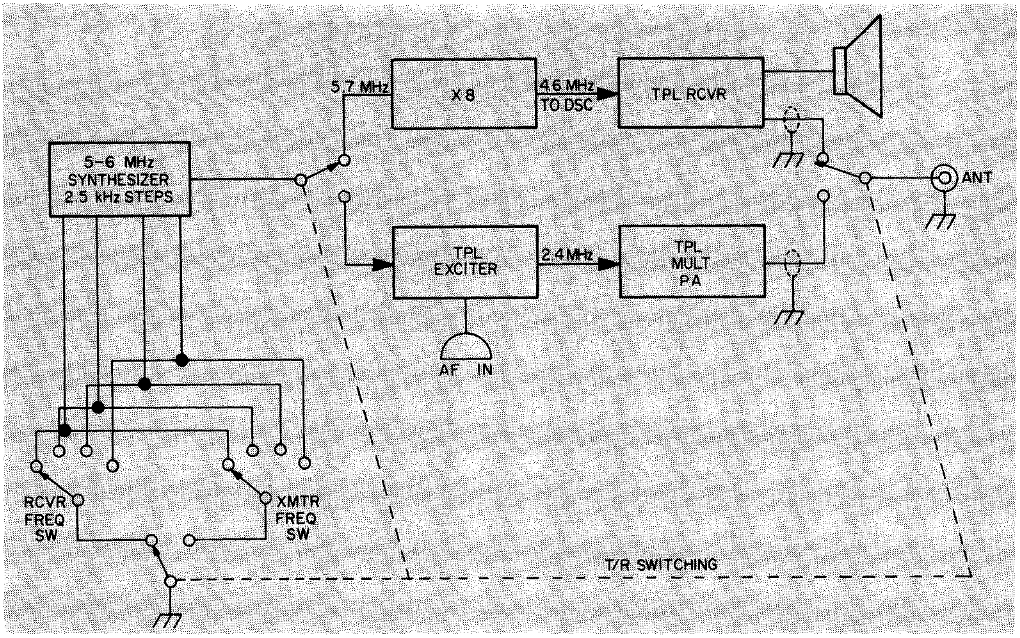


FIG. 1 How to use synthesizer for 60 kHz incremental switching in existing units

ceiver and transmitter multiply the synthesizer output by 24, to make channel spacing the same for both receiver and transmitter.

Although a synthesizer could be built as a crystal oscillator substitute for existing types of equipment, it can be more effectively exploited in a "start from scratch" design, as shown in Fig. 2. True FM can be produced by direct modulation of the synthesizer, eliminating the need for a phase modulator or frequency multiplication to build up the deviation level. Or, as a receiver local oscillator, a synthesizer can just as well be designed to deliver the oscillator injection frequency directly, eliminating the need for frequency multipliers.

Figures 3 and 4 show block diagrams representing the synthesizers used in Figs. 1 and 2. The synthesizer block diagram of Fig. 3 generates 2.5 kHz steps in the 6 MHz range. Used to drive existing transceivers, this arrangement produces 60 kHz steps in the two-meter band. If the range is extended to 5.7 MHz and the output multiplied by 24, the same synthesizer can be used for the receiver.

Addition of a mixer and a multiplier as in Fig. 4 makes it possible to generate 60 kHz steps directly in the two-meter band. A separate crystal oscillator is used to heterodyne the output signal down to a frequency suitable for division. By switching crystals — in this case to 141 MHz — the synthesizer output can be moved down 9 MHz to provide oscillator injection for a receiver having a 9 MHz i-f. These mixer injection frequencies could also be obtained by suitable means from the basic reference oscillator, rather than adding two more crystals.

How it Works

Consider the simplified synthesizer of Fig. 5. This example is for a 5 – 6 MHz output range in 10 kHz steps. A tunable VCO (voltage-controlled oscillator) is used to generate the output signal; in doing so, of course, it must tune electronically from 5 to 6 MHz by varying the dc input voltage. The stability of such an oscillator doesn't even begin to match that of a crystal oscillator, but it *does* have the flexibility of operating on any channel in the desired range. So the remainder of the circuitry is devoted to detecting the VCO frequency,

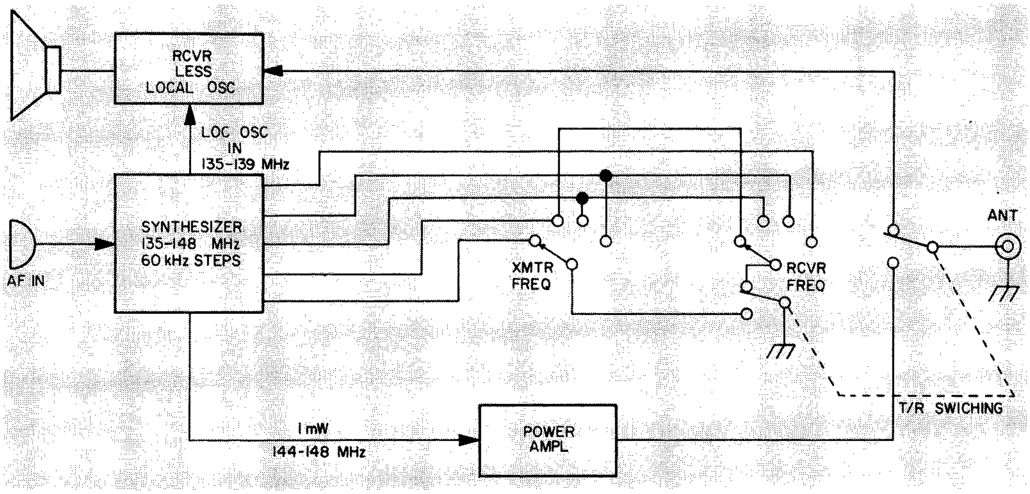


FIG. 2 Synthesis of local oscillator and transmitting frequencies eliminates frequency multipliers and greatly simplifies receiver design

relating it to the *desired* frequency, and adjusting the oscillator *electronically* to it.

Spacing of the output steps is determined by the reference frequency. In this case, a 10 kHz reference means that the circuit can lock to any harmonic of 10 kHz such as 5.000, 5.010, 5.020, 5.030 . . . etc. to 6.000 MHz. Direct multiplication could be used to get the same result, but it would be nearly impossible to eliminate undesired harmonics of the 1 kHz signal, even with the best of filters. So, instead of multiplying 10 kHz to, say, 5 MHz, start with the VCO at (or near) 5 MHz and divide it by 500 instead. This function is accomplished in the programed divider ($\div n$, or "divide-by-n"). Consisting of a chain of flip-flops, this circuit can be programed to divide by any ratio between 500 and 600. When it divides the 5 MHz output of the VCO by 500, the result is 10 kHz.

The phase detector circuit compares the $\div n$ output to the reference signal, delivering a dc output proportional to the phase difference between them. This dc level controls the VCO. When the VCO output drifts from exactly 5 MHz, the output of the $\div n$ will drift in exact proportion to it since it always is 1/500th of the output signal. The phase detector sees this as a phase change and shifts its dc output to the phase detector immediately to steer it back to 5.000 MHz exactly. Since it compares phase instead of frequency, the frequency at the $\div n$ output is never permitted to shift so much as one hertz either way, and the output of the VCO is held precisely to 5.00 MHz. *Frequency accuracy depends only upon the stability of the reference frequency oscillator.*

To change frequency to 5.760 MHz it is only necessary to change the *divide* ratio of the $\div n$ circuit by switching the programing inputs of the $\div n$. Since this is a larger divide ratio than 500, the $\div n$ output will at first be below 10 kHz. The phase detector senses this shift as a phase change in the very first cycle following the shift and immediately starts action to correct it. When the correction is complete, the $\div n$ output is again on 10 kHz, but the VCO is on 576 X 10 kHz, or 5.760 MHz.

The synthesizer of Fig. 3 is only a little more complicated than the basic unit of Fig. 5. Since 2.5 kHz steps are desired, the reference frequency must be 2.5 kHz. Stable crystals of this frequency are not notably practical, so a 1 MHz master oscillator is used, divided down to 2.5 kHz by a series of flip-flops. A harmonic of the 1 MHz signal is conveniently adjusted to zero-beat with WWV, thus precisely aligning all channels to frequency. A higher divide ratio is necessary in the $\div n$ circuit due to the lower reference frequency, as shown.

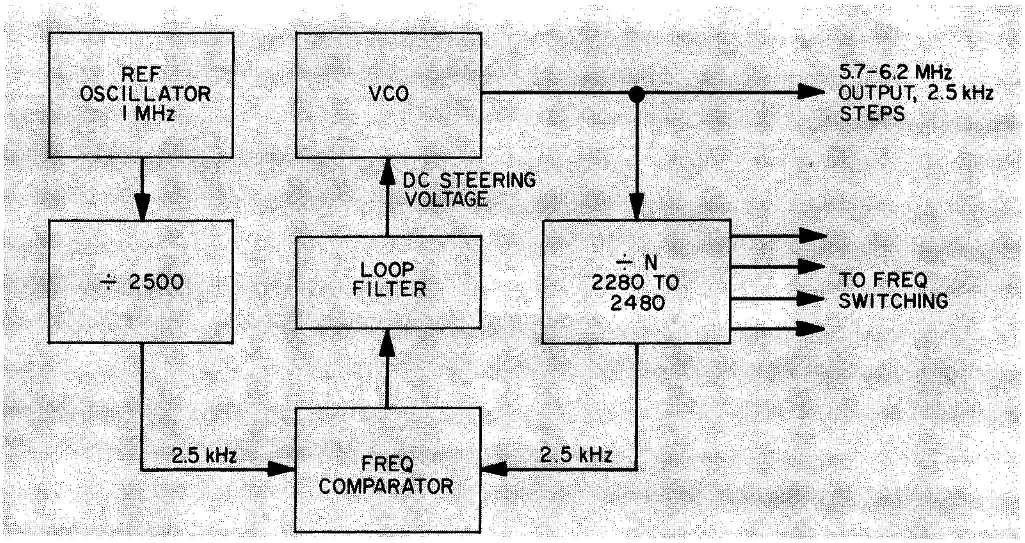


FIG. 3 Block diagram of synthesizer for use in existing transceivers (see also Fig. 1)

The loop filter, necessary in all cases must remove all traces of the reference frequency at the output of the phase detector (in this case 2.5 kHz). A simple *RC* low-pass filter configuration is usually employed.

The next step in synthesizer development, shown in Fig. 4, has a VCO operating in the 135 — 148 MHz range, heterodyned to the 2 — 6 MHz range. This mixing process is necessary because present-day low-cost flip-flops can only divide to about 8 — 10

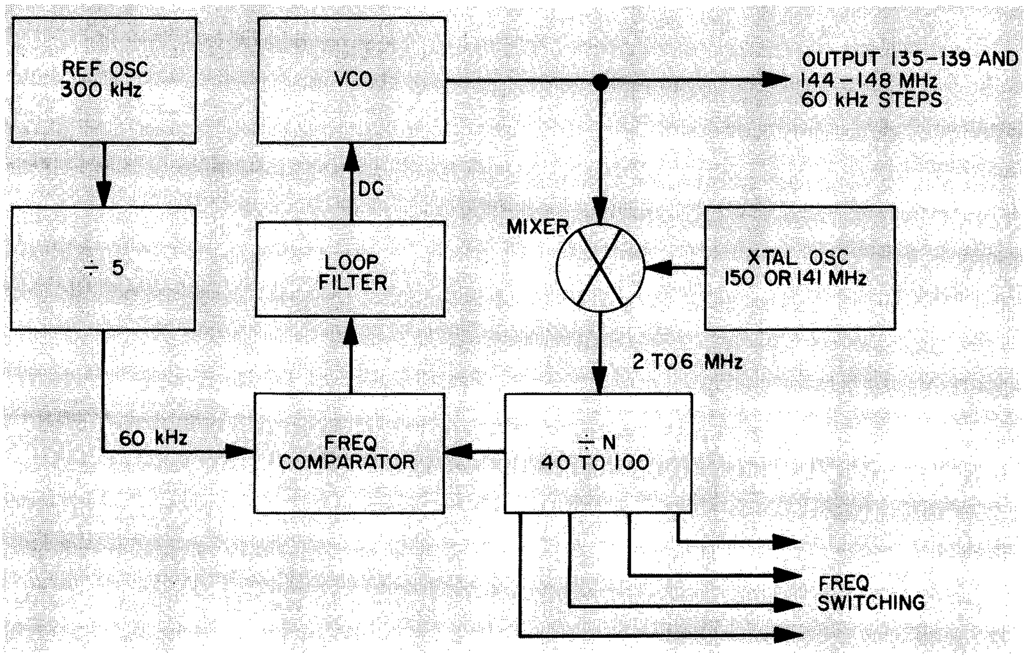


FIG. 4 Block diagram of synthesizer incorporating a mixer and multiplier for generating 60 kHz steps directly in two-meter band

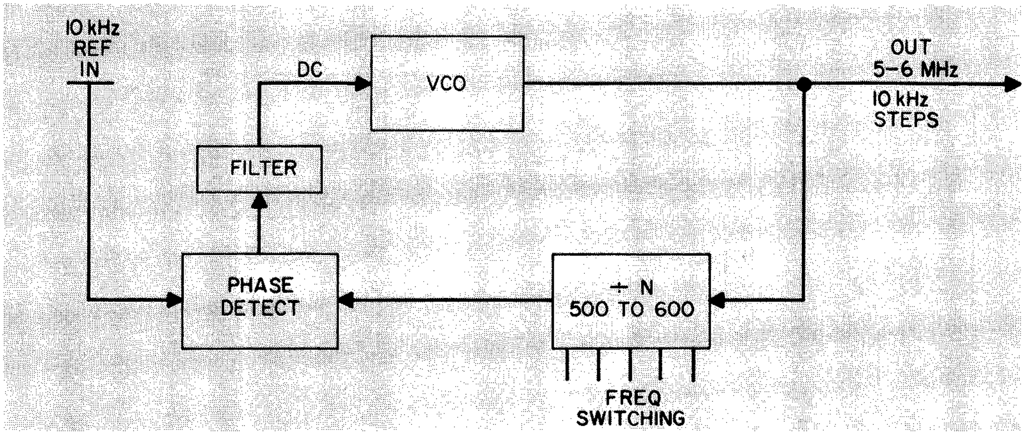


FIG. 5 Simplified synthesizer diagram

MHz in a programed divider circuit. A 60 kHz reference can be used to generate 60 kHz steps because the signal is not multiplied in the receiver and transmitter as in Fig. 3, thus simplifying both dividers greatly. Frequency stability in Fig. 4 depends mainly upon the accuracy of the 150 and 141 MHz oscillators. Frequency adjustment is necessary in all three oscillators with this scheme. Judicious selection of the frequency spacing, reference oscillator frequency, receiver i-f, and the mixer injection frequencies can result in a design that uses a single crystal.

The Phase-Locked Loop

Indirect frequency synthesizers are basically feedback systems, where phase error is detected and fed back as a correction signal. Such a closed loop is called a phase-locked loop. As a consequence, certain rules must be followed to keep the system stable, as in any feedback system.

The phase-locked loop must have a loop filter at the output of the phase detector to prevent rf from leaking into the VCO control signal (which should be as clean a dc signal as possible). If any rf or ripple appears at this point, it will frequency-modulate the VCO. If the ripple is deliberately applied *as audio*, a desired FM signal can be produced. Undesired high frequency components such as the reference frequency will produce spurious sidebands. Thus, it is the function of the loop filter to remove these undesired products. A second function, however, is to determine the phase — gain characteristics of the loop, which determine its response time, stability, and "capture range."

Capture range is the term applied to the maximum frequency difference the loop will tolerate between the VCO output and the desired output frequency and still *lock up*. Capture range is directly proportional to loop bandwidth. The higher this bandwidth, the higher the adjacent spurious levels — the lower it is, the closer the VCO must be before it will lock up to the desired frequency. A low loop bandwidth also takes longer to lock up. So a compromise is necessary. Despite all of these design criteria, the loop filter is usually a very simple circuit when used in conjunction with a good phase detector.

PHASE DETECTORS

Since the reference frequency of an indirect synthesizer is typically equal to the frequency spacing between channels, the phase detector also operates at this relatively low frequency. The best phase detector circuits are those which deliver the highest ratio of dc to inherent ac ripple. A flip-flop can be used as a digital phase detector, but its output is quite high in ripple content, and it requires a more sophisticated loop filter than other circuits. The

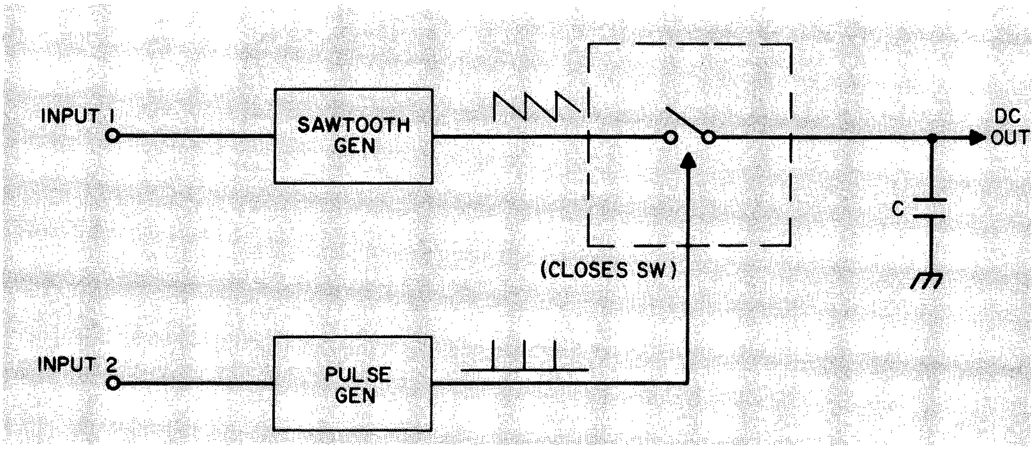


FIG. 6 Sample-and-hold phase detection

best phase detectors in current use work on a *sample and hold* principle. One of the two input signals is converted to a sawtooth, the other to a narrow pulse. The former is called the *ramp*, the latter a *sampling pulse*. As shown in Fig. 6, the sampling pulse operates a series switch for brief intervals so that the value of the ramp voltage at that instant is transferred to a "holding" capacitor. If at the next sampling time there was no change in relative phase between the two signals, the output will not change from the first sample. If there *is* a difference, the output capacitor voltage shifts abruptly up or down to the new value. It can be seen that as long as the two signals are in *phase lock* the output ripple is (ideally) zero. With practical implementation it isn't zero, but it can be made extremely low with careful design.

False Locks

When the phase-locked loop is initially turned on or the frequency is changed, the VCO may be out of the capture range of the loop. Under this condition the synthesizer output is that of the free-running VCO: unstable and at an unknown frequency. The VCO must therefore be tuned to the near vicinity of the desired frequency before the loop will lock up. With most phase detectors a number of *false lock* conditions can occur. A false lock is present when the $\div n$ and the reference frequencies are not equal, but the phase detector "thinks" they are and locks the VCO to the wrong place. A circuit which assures proper acquisitionof the desired frequency is called a "search." It acts as an AFC-type control of the VCO by detecting frequency differences between the $\div n$ output and the reference frequency, rather than phase differences. The search is normally turned off when the phase detector locks the loop. There are a number of ways in which a search can be implemented. Digital methods are compatible with the pulse-type signals available, and they offer simplicity of construction and freedom from adjustment. Best of all, they are nearly foolproof.

$\div n$ CIRCUITS

Except for the advent of low-cost integrated circuits, this part of an indirect synthesizer would probably be impractical to build. It consists of a chain of flip-flops whose function is to divide the VCO signal down to the reference frequency. The number of flip-flops depends upon the maximum divide ratio. Since each flip-flop can divide by a maximum of 2, two can divide by 4, three by 8, etc.; and *n* flip-flops can divide by 2^n. If the maximum divide ratio is 100, as in Fig. 4, it takes 7 flip-flops, which can divide up to $2^7 = 128$. Six would not be enough because they can divide by only $2^6 = 64$. In Fig. 3, a divide ratio of 2240 is needėd; $2^{11} = 2048$, too low; $2^{12} = 4096$. Therefore, 12 flip-flops are needed.

The next problem is to find some way to change the ratio of the $\div n$ by switching so that channels may be selected. Two common methods are used. To understand them, some of the properties of binary dividers must be known. First, the divider can be considered a counter since at each input pulse, or step, the flip-flops take on a unique combination of states. A useful analogy can be drawn to an automobile odometer (mileage indicator), which works in a similar way but counts in decades (powers of ten) instead of binary (powers of two). Including the *tenths* decade, a typical car odometer can count up to 999,999 tenths of miles, and the millionth step brings it back to all zeros. If a switch was provided to close only when all zeros are present, the switch would close once for every 1,000,000 input steps, thus dividing by one million.

One method of changing this ratio would be to reset the odometer to zero whenever it reached the desired count. For example, if a divide-by-567,000 count is desired, it could be accomplished by providing a resetting device which detects the 566,999 state, then resets all decades to zero on receipt of the 567,000th input. By programing the desired state when this occurs, the divide ratio can be any desired number.

Another way is to preset a number into the divider each time it recycles to zero. Achieving a $\div 567{,}000$ with this method requires that a 433,000 be inserted when the counter reaches a natural state of all zeros. The counter then counts from 433,000 to 1,000,000, where it is again preset. This count is 1,000,000 minus 433,000, or 567,000.

Presetting is the preferred method because it is usually easier to implement. Design of high-speed $\div n$ circuits is full of subtleties which make it deceptively easy to design on paper, but another matter to make workable.

FREQUENCY DISPLAY

Up to about 12 channels, switching and display of the channel in use is a simple matter. For 30 or more channels it can become a problem, because even if a 30-position switch could be obtained, it would be considerably less convenient to

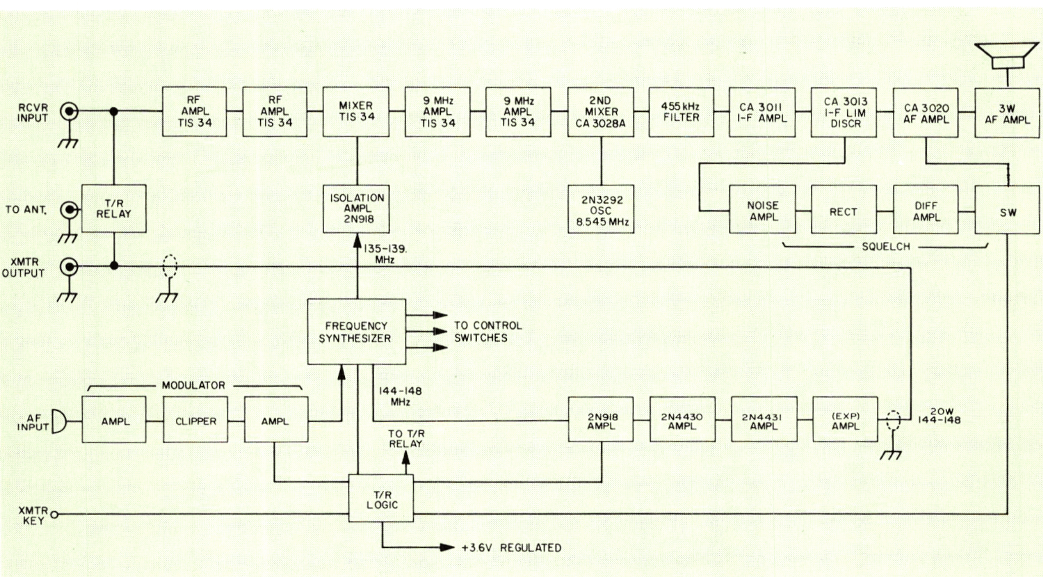


FIG. 7 Block diagram of an FM two-meter transceiver showing how frequency synthesis is incorporated

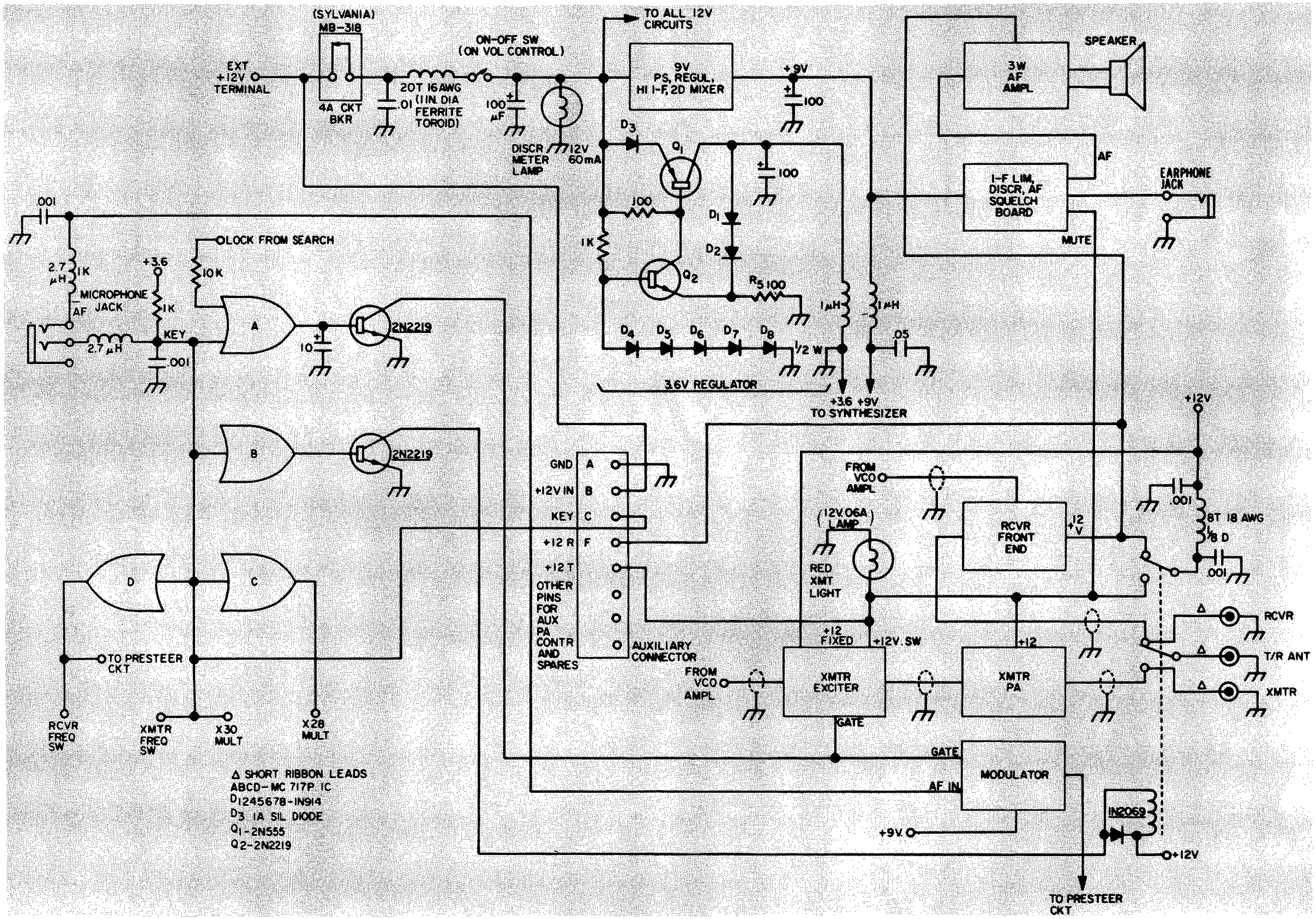


FIG. 8 Transmit and receive wiring for a typical FM transceiver

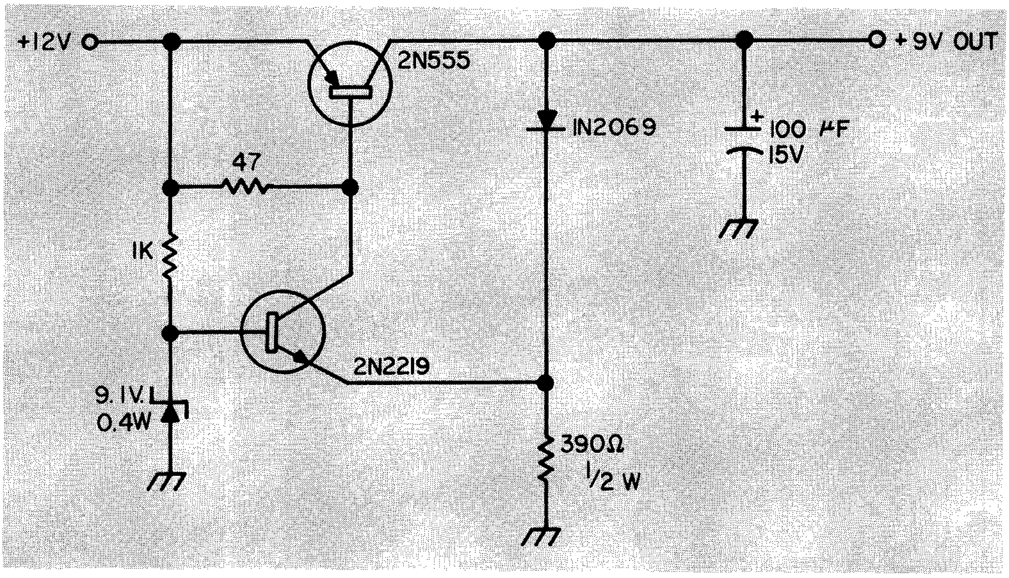


FIG. 9 +9V regulator

find the channel you want than with only 12 channels.

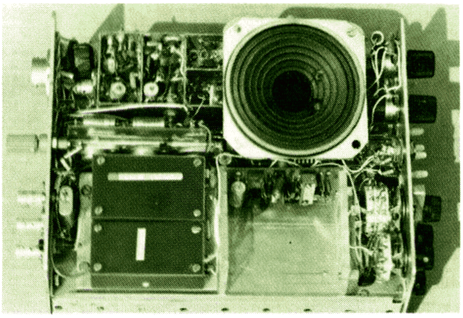
For this reason, switches are usually arranged in a power sequence, such as a *MHz, hundreds of kHz, and tens of kHz* arrangement, extended to as many places as desired. If the $\div n$ were left in its natural state, the switches would have to be set in a binary fashion, which could be awkward. However, the decade type of display is easily accomplished by designing the $\div n$ circuit to work in decades instead of straight binary. It takes 4 flip-flops to produce a $\div 10$ section; cascading three such decades results in a capability of up to 1000 channels. If the channel kilohertz spacing is 1, 10, 100, etc., the frequency display is in familiar decimal numbers. Other schemes can be worked out for different channel spacings, but the decimal method is the most convenient, since most of us think in terms of decimal numbers.

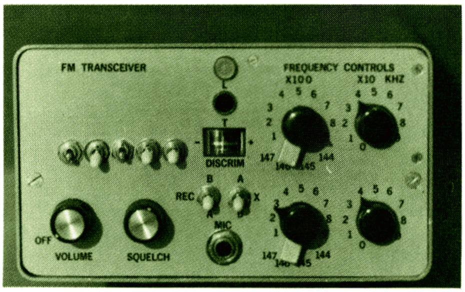
It should be kept in mind that the VCO output is the output of the synthesizer, and even though the loop keeps it exactly on frequency, it can't correct for audiofrequency variations (below the loop filter response). Even if it could, it would be necessary to slow it down for modulation purposes; otherwise the loop would attenuate the audio. Therefore, the VCO of a synthesizer is as sensitive to microphonics as a VFO is, and good VFO construction techniques should be used. VCO tuning range should just overlap each end of the desired output range, and its temperature drift should be kept low to maintain band coverage.

The following text describes the synthesizer used in a 10-kHz-step, 400-channel, 144 — 148 MHz transceiver utilizing a single 5 MHz crystal.

A PRACTICAL 10-kHz-STEP SYNTHESIZER FOR TWO METERS

Figure 7 shows the full transceiver block diagram. Output from the synthesizer is 1 mW in the frequency range of 144 — 148 MHz (transmitter), and 1 mW, 135 — 139 MHz, to the receiver first mixer. Modulation is applied directly to the synthesizer for the transmit function. The block labeled *T/R logic* is the circuit board that changes the synthesizer output range when the transmitter is keyed; it also serves to switch the receiver and transmitter and drive the antenna relay.





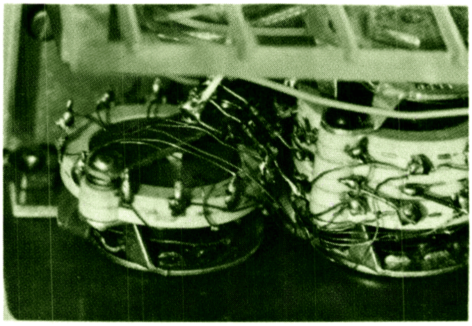
W2EUP'S homebrew two-meter FM transmitter/receiver looks unbelievably professional. The synthesizer controls are the four at the right of the panel. The top pair sets the receiver frequency, the bottom pair sets the transmitter. The basic frequencies of operation are selected by the integral four-position switches (under the X100 knobs). The frequencies of operation on the pictured unit are 146.34 MHz for the transmitter (national repeater input frequency), and 146.94 MHz for the receiver (national repeater output frequency).

Figure 8 shows the transceiver transmit – receive circuits and the system wiring. Two power supply regulators are used; one generates +9V at 250 mA and the other +3.6V at 1A. Nine volts is the B+ level used in the receiver circuits, the transmitter modulator, and the synthesizer. The schematic for the +9V regulator is shown in Fig. 9.

The +3.6V supply is used to provide power for the digital integrated circuits, which are rated for a temperature range of +15 – +55°C (guaranteed performance). Instead of a zener diode, a series string of silicon diodes is used as a voltage reference for this regulator. This technique produces a temperature-programed supply that delivers over 4V when cold and less than 3.5V when hot. The logic works reliably over a very wide range of temperatures when operated in this manner.

Figure 10 shows the synthesizer block diagram. The single 5 MHz crystal oscillator drives, through an amplifier, a ÷500 fixed divider to obtain the 10 kHz reference frequency, and a dual-frequency multiplier section. When in the receive mode, a multiplication factor of X28 is used, producing a 140 MHz signal. When transmitting, a X30 multiplier supplies a 150 MHz signal to the mixer. The multipliers are selected by the transmit – receive (T/R) logic. When receiving, the VCO output range is 135 – 139 MHz (9 MHz below the corresponding transmit frequency). When mixed with the 140 MHz signal, the mixer output ranges from 5 to 1 MHz (140 − 135 = 5; 140 − 139 = 1) and the $\div n$ divide ratio is preset to divide by any number between 500 and 100, to deliver the 10 kHz output. Since 10 kHz is the reference frequency, the channel spacing is 10 kHz. In the transmit mode the mixer produces from 6 to 2 MHz (150 − 144 = 6; 150 − 148 = 2), and the $\div n$ is preset to any ratio between 600 and 200.

The VCO and VCO amplifier are shown schematically in Fig. 11. The B+ to the VCO should be kept small to maintain maximum tuning range. As it turned out in the unit pictured, tuning range was no problem and had to be reduced by trimming the high end of the range with C6. The VCO is housed in a section of the oven assembly, which also contains the 5 MHz oscillator and an electronic temperature regulator. The VCO itself could have been mounted in a nonheated environment without stability problems because frequency drift with temperature turned out



Detail of frequency selection switches show how "MHz" section connections are skewed 1 MHz offset on receive mode. At right an extra detent (switch clicking and locking mechanism) is reversed and mounted behind. A 1/8-inch shaft is attached and brought to panel through drilled-out shaft of front detent. Rear deck is X100 (hundreds of kilohertz, front two are MHz selection decks. Solderable magnet wire was used for connections to keep the wiring manageable.

to be very low. However, in the author's transceiver, the oven insulation also acts as sound and vibration shielding (polyurethane foam), minimizing VCO microphonics.

Radiofrequency shielding is absolutely essential in the VCO. In the prototype unit, the VCO amplifier was mounted in a separate shielded box, but it was later combined with the VCO itself.

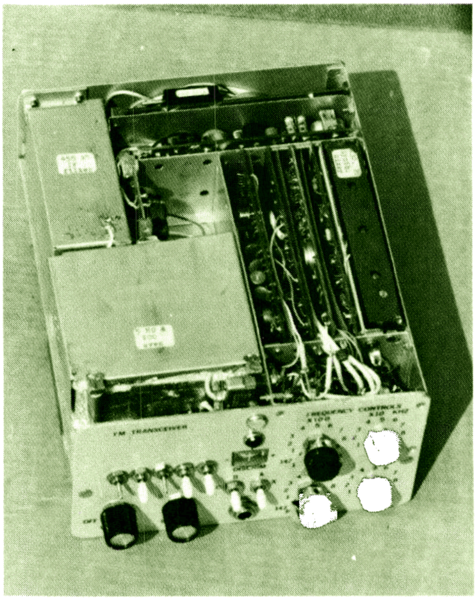
The *steer* input of the VCO comes from the frequency comparator (consisting of the phase detector and search) for electronic lock. An extra varactor (D4) is used to accomplish this by means of a voltage supplied from a presteer circuit (described later) and switched by the T/R circuits.

Three outputs are provided by the VCO amplifier: In addition to the receiver and transmitter outputs, there is a 0.1 mW signal fed to the synthesizer mixer for loop feedback, The resistor network provides some degree of isolation between the outputs. Again, shielding of the VCO amplifier is a must.

Figure 12 shows the frequency multiplier section, the synthesizer mixer and the amplifier used to square up the waveform to feed the $\div n$ circuit. The multipliers are conventional and their outputs are connected in series to feed the mixer. Only one multiplier operates at a time, selected by the T/R circuits. Grounding the X28 or X30 lines selects the desired one.

Mixer output is amplified by several resistance-coupled stages. Transistor Q8 squares the waveform and Q9 acts as an inverter to provide the two out-of-phase signals needed to drive the $\div n$ circuit.

The $\div n$ schematic is shown in Fig. 13. Note that the divider is sectioned into decades I and II and a $\div 8$ section. The terminals shown along the bottom are the



Top view of unit shows circuit board construction and "plug-in" accessibility concept of two-meter FM transmitter/receiver. The two rearmost cards are for receiver. Card next to i-f filter is i-f amplifier. The synthesizer section is shown at right. Left to right, the cards are: phase detect and divide-by-500; search; diode matrices; divide-by-n; mixer-multiplier. The heavy white leads from switches to matrix board are insulating sleeves; each sleeve contains 8 — 12 leads of 32 AWG magnet wire. Slots and holes in shields are similarly guarded with insulation to prevent the possibility of shorts by chafing.

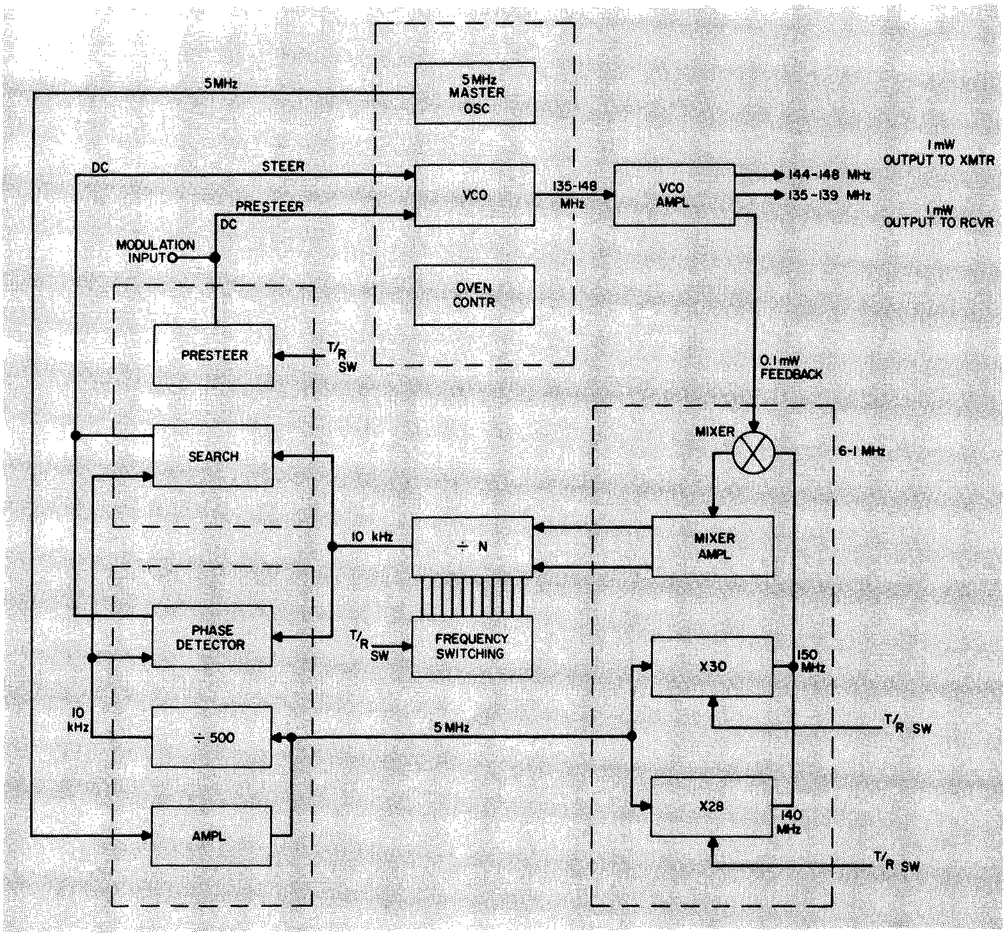


FIG. 10 Detail block diagram of frequency synthesizer

preset inputs. For maximum divide ratio (÷800) all of these terminals are biased to a positive 1 — 4 volts and thus no presets are inserted. Other divide ratios are chosen by selectively grounding (or opening) these terminals. For example, if A1 is grounded, it will divide by 799; if B1 is grounded, it divides by 798; C1 grounded yields ÷796, etc.

A table of presets is given in table I, showing how the presets affect the divide ratio and the resulting frequencies of operation in this synthesizer. A zero indicates no preset; a "1" indicates a preset on terminals A1 through C3. Under the $\div n$ ratio heading is shown what happens to the normal ÷800 ratio as different combinations of presets are inserted. For example, a preset at A1 only (second line) shows a − 1; this means that the ratio is reduced by a 1 and a 10, or 11; therefore, n = 789. Preset lines A1 to D1 thus switch *tens of kilohertz*, lines A2 to D2 go to the *hundreds of kilohertz* switch, and lines A3, B3, and C3 go to the *megahertz* switch.

A 10 MHz shift is accomplished in this design by changing the injection frequency into the synthesizer mixer. Since the receiver oscillator injection requirement is in the 135 — 139 MHz range (to produce a 9 MHz i-f), a 10 MHz shift is necessary to get the output into this range. As previously described, this function is accomplished by the T/R logic selecting the appropriate fre-

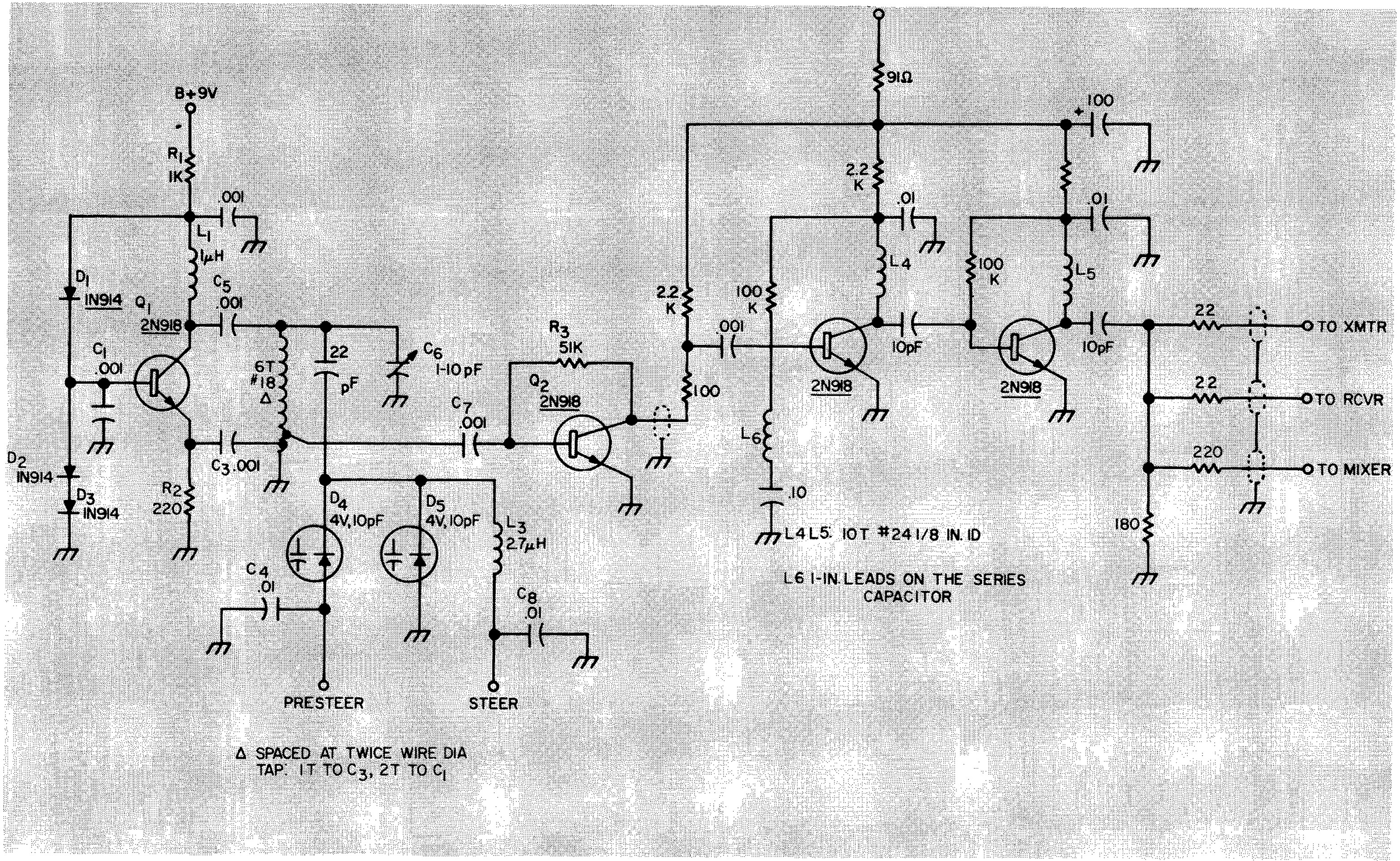


FIG. 11 Voltage-controlled oscillator and associated amplifier

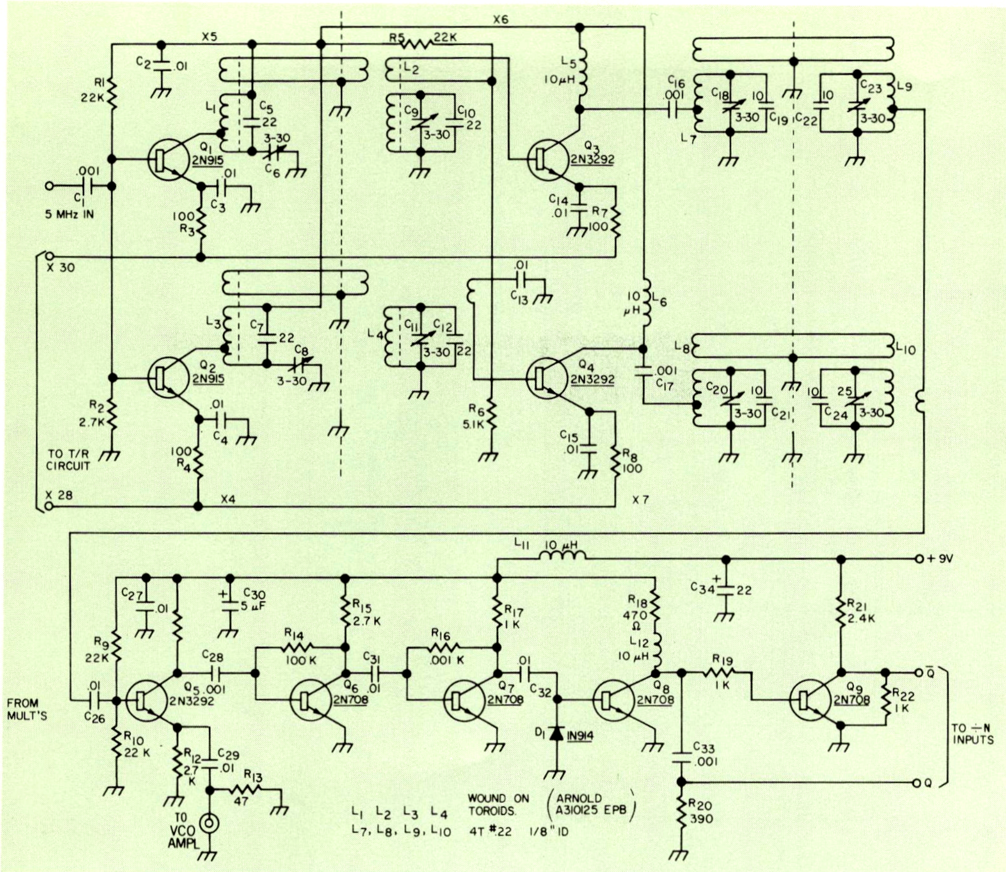


FIG. 12 Multiplier, mixer, squaring amplifier schematic diagram

quency multiplier. However, the MHz preset must also be shifted by 1 MHz to receive the same frequency as the transmitter is on, since only a 9 MHz offset is desired. Thus, as seen in the table, the *receive* presets are offset one place in the MHz column.

The ÷*n* circuit shown is capable of operation to 10 MHz for all presets and represents the results of a hard brainstorming session. It should be reproducible and will work as it is shown, as long as the wiring is correct. Unless you understand its theory of operation *completely* it is recommended that you simply copy it *carefully!* Have someone else check *every connection* since troubleshooting is difficult. Space doesn't allow a complete explanation of its operation.

Frequency switching circuitry is shown in Fig. 14. Two complete sets of switches allow independent selection of receive and transmit frequencies. The diode matrices shown permit the use of standard 10-position rotary switches. Input voltage for the preset lines is provided through the 10K resistors. When one of the lines is grounded, a combination of presets is grounded through the diodes.

The arm of S1 is grounded in the transmit mode, and the arm of S2 is grounded in the receive mode. If S1 is in the *A* position, the transmit frequency is controlled by switch set *A*; if it is in the *B* position it transmits on the frequency on set *B*. The same is true for S2 on receive.

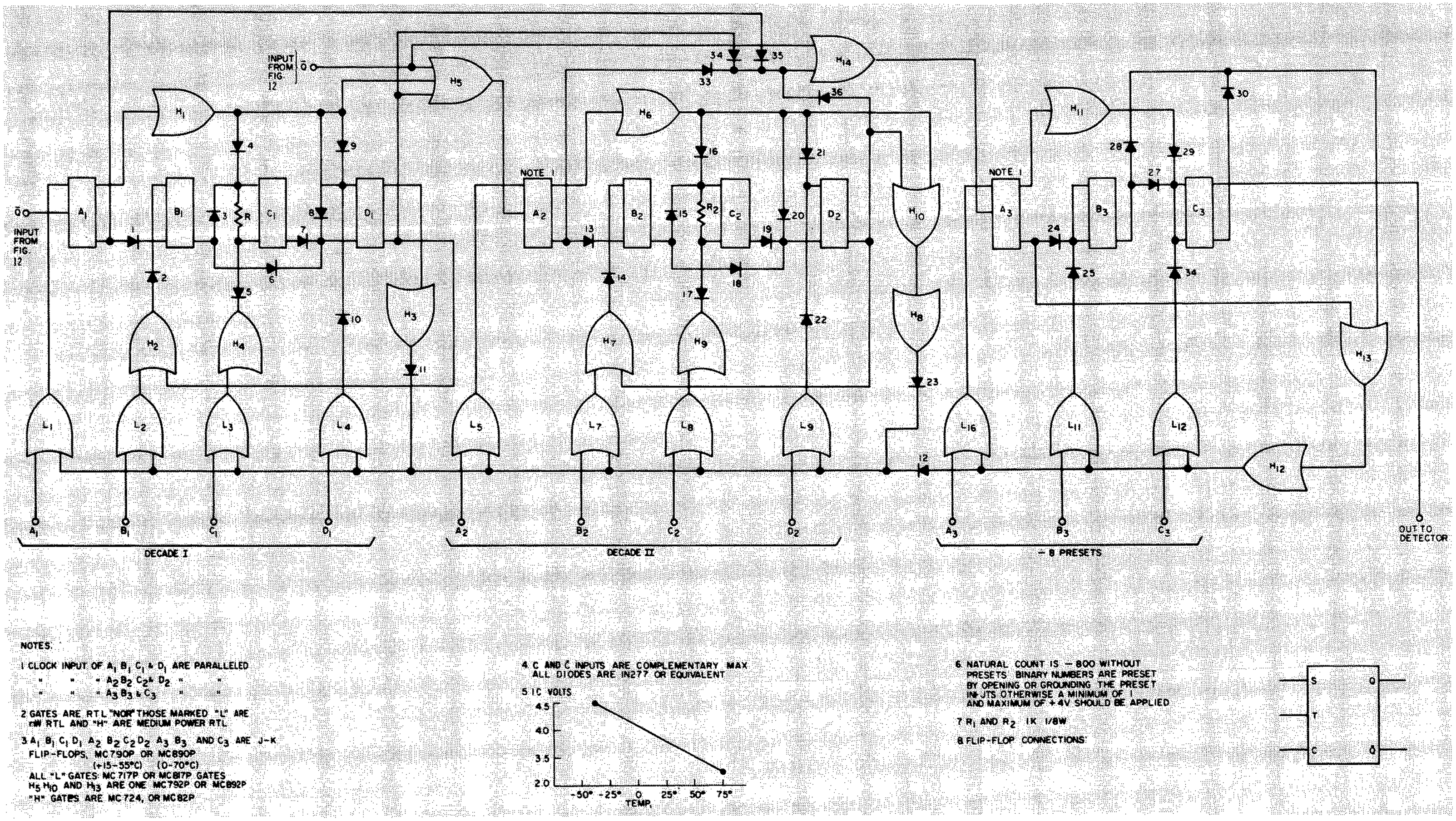
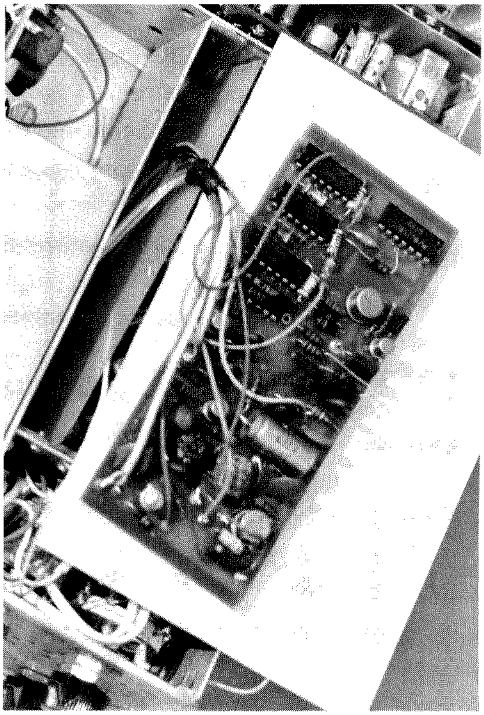


FIG. 13

÷*n* CIRCUIT



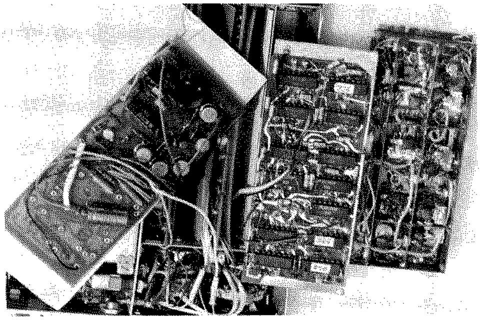
Closeup photo shows that it is practicable to get all the components of the phase detect and divide-by-500 circuit onto a single small card.

These switches provide great flexibility. With both switches in the *A* position, you transceive on frequency *A*. Similarly, with both in the *B* position you transceive on frequency *B*. Receive A and transmit *B*, receive *B* and transmit *A* are other combinations. It may sound complicated, but this system is very easy to use and a beginner can master it in seconds.

Once understanding of the method of controlling the synthesizer is complete, you can dream up all kinds of ways to control it. For example, it is simple to instantly select a preset channel, such as 146.94 (the national FM repeater output frequency) by throwing a toggle switch. This addition can be completely independent of other switch positions. And remote switching is easy because all control lines to the ÷*n* circuit handle only dc and simply are grounded in different combinations.

Figure 15 shows the master oscillator. It uses a field-effect transistor and has an automatic gain control arrangement for high stability. It is completely shielded and oven-controlled (Fig. 16). Asterisked components are thermally mounted to the oven box; the thermistor senses the oven temperature, and the other asterisked components deliver heat to it. In the original unit, the temperature control pot is mounted outside of the oven.

Referring to Fig. 17, the 5 MHz low-level signal from the master oscillator is amplified in Q1 and Q2. Output from Q2 goes to the multiplier section and to squaring amplifier Q3, which drives the ÷500 circuit. Two outputs are used from the last flip-flop (I) 180 degrees out of phase. One goes to the search circuit, the other to the phase detector, below. The 10 kHz square wave is converted to a *spike* by C6 – R9, as seen in waveforms *a* and *b* in Fig. 18. Each positive spike turns Q5 on momentarily, charging C7 to +9V. Between spikes (waveform *c*), C7 discharges through R15, producing a sawtooth. (A linear sawtooth could be used instead of the nonlinear one used here, but the nonlinear waveform is actually beneficial in this system and is easier to generate.



Closeup photo shows the search board at left, the divide-by-n card and, at right, the mixer – multiplier assembly. The wall shield between those boards still in place are made from a conducting material deposited onto the fibrous board material; the close spacing increases the possibility of card-to-wall shorting, so a Mylar insulation sheet was attached over the surface of each of the shield walls.

Table I

Frequency		÷*n* Ratio Reduction	A_1	B_1	C_1	D_1	A_2	B_2	C_2	D_2	A_3	B_3	C_3
0		0	0	0	0	0							
10		-1	1	0	0	0							
20		-2	0	1	0	0							
20		-2	1	1	0	0							
30		-3	0	0	1	0							
40		-4	1	0	1	0							
50		-5	0	1	1	0							
60		-6	1	1	1	0							
70	Steps,	-7	0	0	0	1							
80	kHz	-9	1	0	0	1							
0		0					0	0	0	0			
100		-10					1	0	0	0			
200		-20					0	1	0	0			
300		-30					1	1	0	0			
400		-40					0	0	1	0			
500		-50					1	0	1	0			
600		-60					0	1	1	0			
700		-70					1	1	1	0			
800		-80					0	0	0	1			
900		-90					1	0	0	1			
142		0									0	0	0
143		-100									1	0	0
144	XMT,	-200									0	1	0
145	MHz	-300									1	1	0
146		-400									0	0	1
147		-500									1	0	1
142		-100									1	0	0
143		-200									0	1	0
144	RCV,	-300									1	1	0
145	MHz	-400									0	0	1
146		-500									1	0	1
147		-600									0	1	1

Sampling pulses are produced from the ÷*n* output in a blocking oscillator (Q3) and fed to the gate of Q6 (waveform *d*). This pulse turns Q6 on briefly, charging or discharging C9 to the value of voltage on C7 at that instant. Capacitor C9 can only charge or discharge through Q6, so it holds that value of voltage until the next sampling pulse. Different ÷*n* outputs and the resulting voltages across C9 are shown in Fig. 18, *d* through *i*. Transistor Q7 is a source follower which drives the following circuitry at a low-impedance level, while maintaining a near-infinite load on C 9. The loop filter consists of R13, C10, R14, R16, diodes D5 and D6, and the rf bypasses at the VCO. The diodes effectively short out R16 for sudden large shifts in phase-detector output to speed the lockup process. For small changes, as seen when the loop is in lock, they have no effect.

A bias voltage is developed from the high-amplitude blocking oscillator output with D3 and D4. This bias is used to hold Q6 off between sampling pulses and to bias the varactor presteer input on the VCO.

Figure 19 shows the search circuit. It operates from the same two frequency inputs that the phase detector uses, except that its purpose is to detect *frequency* in-

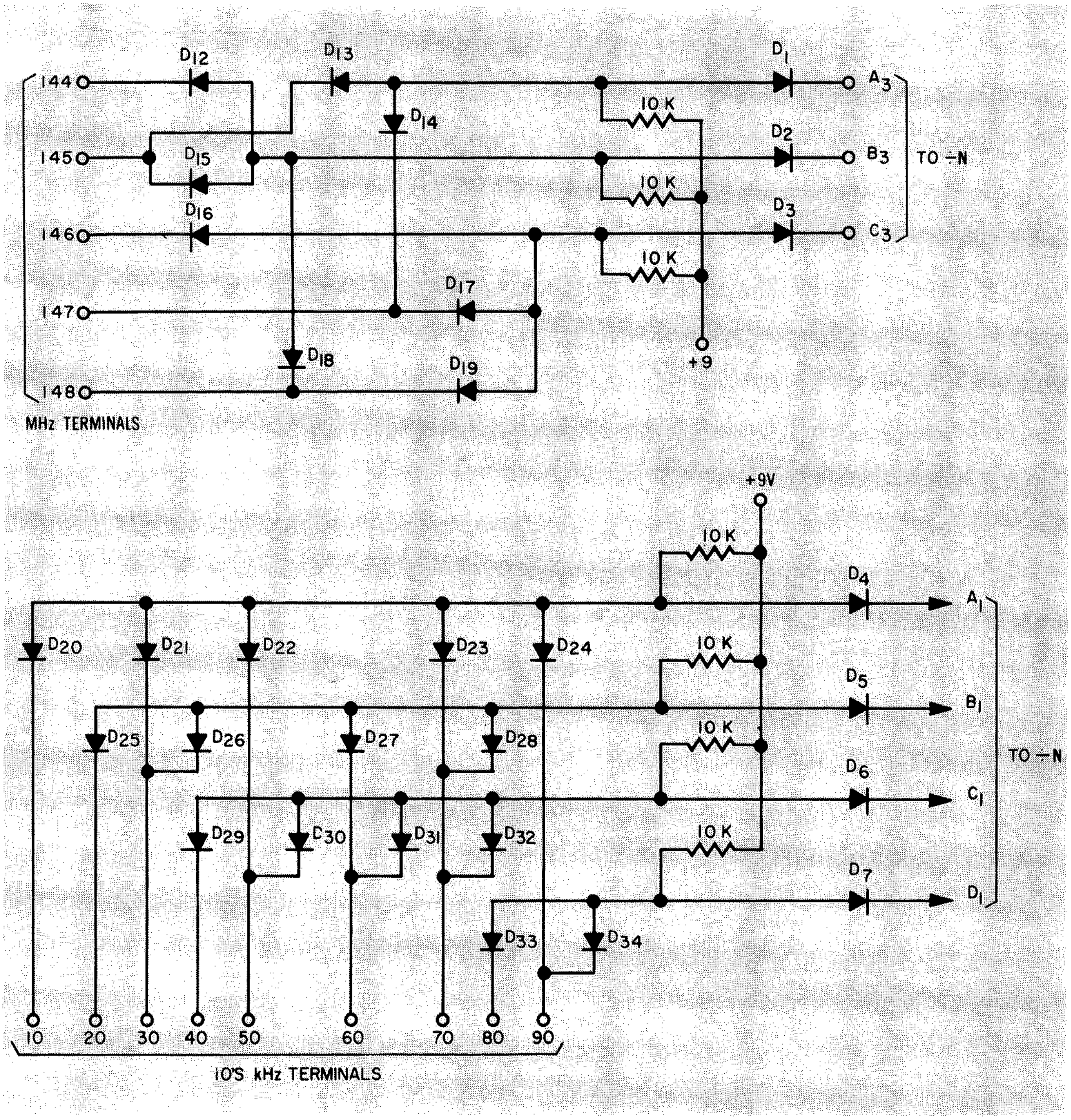
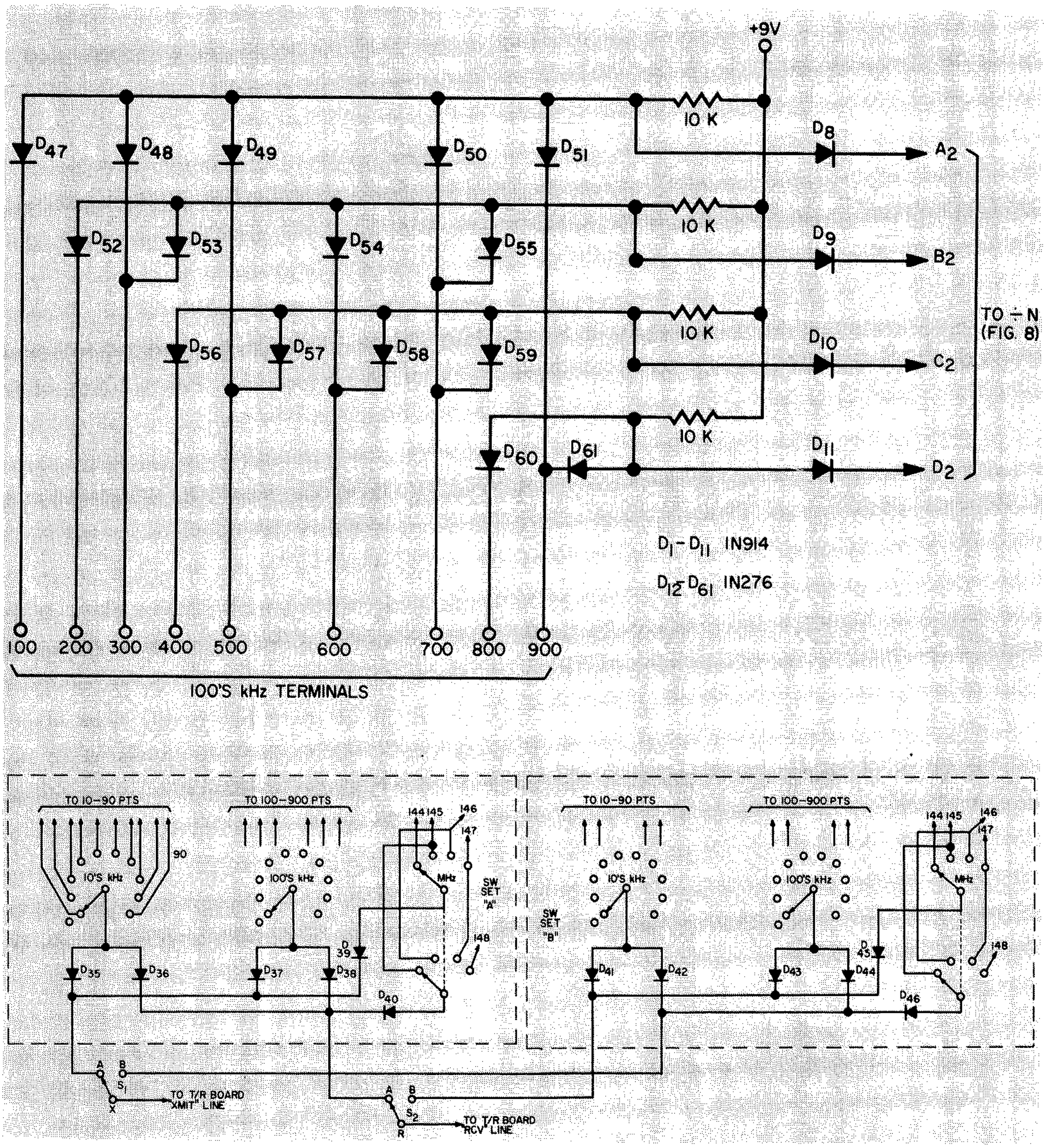


FIG. 14 Frequency-switching with

stead of *phase differences,* and to coarse-tune the VCO to the desired frequency, where the phase detector takes over. It accomplishes this by checking for pulse interlace; that is, to see that for every pulse received on one input there is *only one* pulse received at the other input. Obviously, if two pulses occur from one input during which time no pulse from the other input is received, the two pulse trains can't be of the same frequency.

Figure 20 shows waveforms for the locked condition (*a, b, c*) where the comparator, consisting of gates BCGEHF, etc., does not produce any output pulses; and where the ÷*n* output is too high in fre-



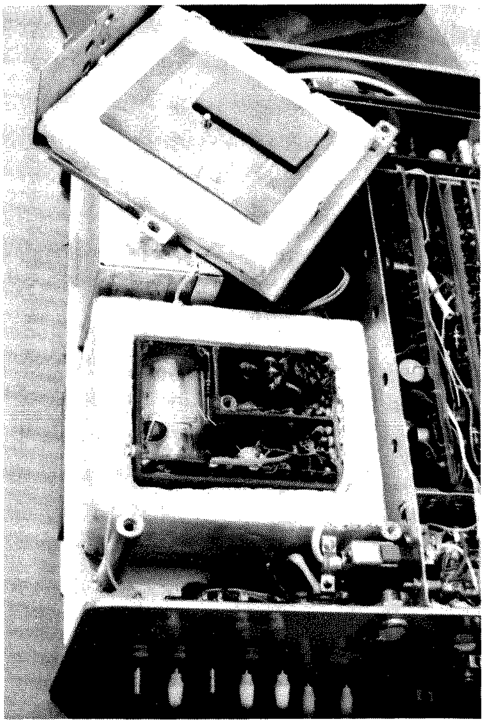
diode matrices for rotary-switch utilization

quency (*d*, *e*, *f*). When this case exists, gate H delivers pulses. When the $\div n$ output is too low in frequency, gate F puts out a series of pulses. When pulses come from H, Q6 and Q3 are pulsed on, producing a stepwise increase in voltage across C9. This voltage is summed with the voltage from the phase detector. As it rises, the VCO is tuned higher in frequency, which decreases the output frequency from the synthesizer mixer, decreasing the $\div n$ output frequency as desired. A correction in the opposite direction is accomplished by pulsing Q4 from gate F, decreasing the C9 charge in steps.

Gates I, J, and D do two things: they gate the transmitter off while the loop is searching (so you don't search while on the air) and they drive the out-of-lock indicator light (which tells you when something is wrong). The indicator normally flashes briefly between receive and transmit If anything goes wrong in the synthesizer the light is almost sure to indicate it.

Transistor Q8 is used as a presteering gate. Controlled by the T/R circuit, it is biased on in the receive mode, placing a positive voltage on the presteer input of the VCO. This voltage, adjusted by R16, reduces the voltage across varactor D4, increasing its capacitance and shifting the VCO tuning range down. When Q8 is off (in the transmit mode) the bias is allowed to swing to −10 volts, which reduces the capacitance of D4 to a minimum. Diode D9 regulates this bias level. Modulation is ac-coupled to the presteer input instead of the steer input so that it does not interfere with the operation of the loop. The 220 pF capacitor is an rf bypass. Modulation input impedance is 330K, and very little voltage swing is needed for 15 kHz deviation. Linearity for this level of deviation is excellent and hi-fi audio is possible.

The oven assembly should be thermally isolated to the greatest extent possible. In the unit pictured, the crystal oven circuit is isolated from the remainder of the circuitry by means of a thick styrofoam surround. Shown in the oven are: the crystal (at left), voltage-controlled oscillator (in corner compartment), and 5 MHz oscillator with oven control circuit.

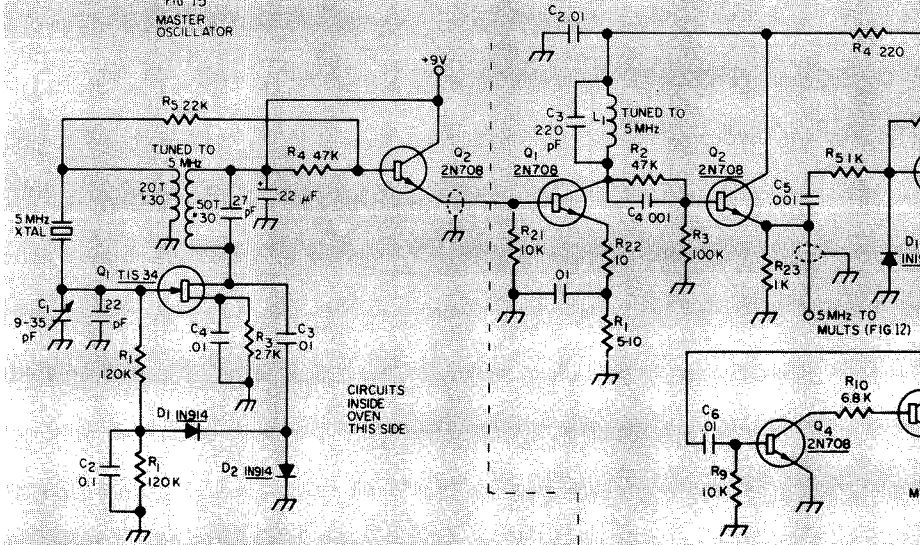


Transistor Q2 is used to prevent a possible hangup condition of the loop, where the VCO gets tuned so low that the frequency supplied to the $\div n$ is beyond its counting capability. The $\div n$ would then start counting erratically, delivering too few pulses instead of too many, due to skipping pulses. The search circuit interprets this to mean that the $\div n$ output is too low instead of too high, so it steers the VCO in the wrong direction, perpetuating the situation. Luckily, the bias supply in the phase detector happens to depend upon a continuous supply of $\div n$ pulses, so that when this hangup condition occurs, it can be detected by a large drop in bias voltage. Transistor Q2 is normally biased off by this supply, but when the loop hangs up, bias collapses, so Q2 turns on and turns search transistor Q3 on in good *Rube Goldberg* fashion. Transistor Q3 charges C9 to maximum voltage, sweeping the VCO to the high end of its range, where normal lockup can take place. The entire process takes place in a few milliseconds. C3 causes a delay to make sure that Q3 turns on completely.

Shielding

Most of the circuits are susceptible to the high-level rf fields typically generated by an adjacent transmitter. The $\div n$ circuit is an efficient hash generator to nearby receivers at nearly any frequency. It is therefore important that most of the synthesizer circuits be shielded from the outside world as well as from each other. All leads should be filtered and bypassed with *RC* or *LC* circuits. Extra B+ bypasses in

FIG 15
MASTER OSCILLATOR



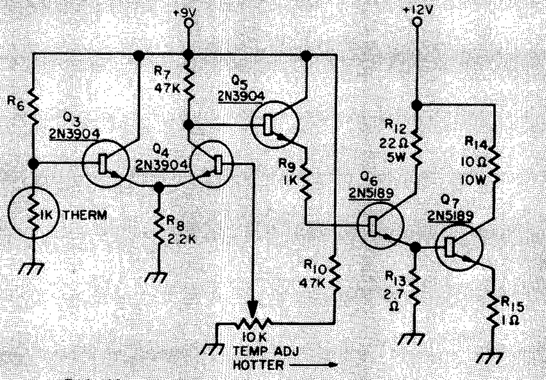


FIG. 16
PROPORTIONAL OVEN CONTROL

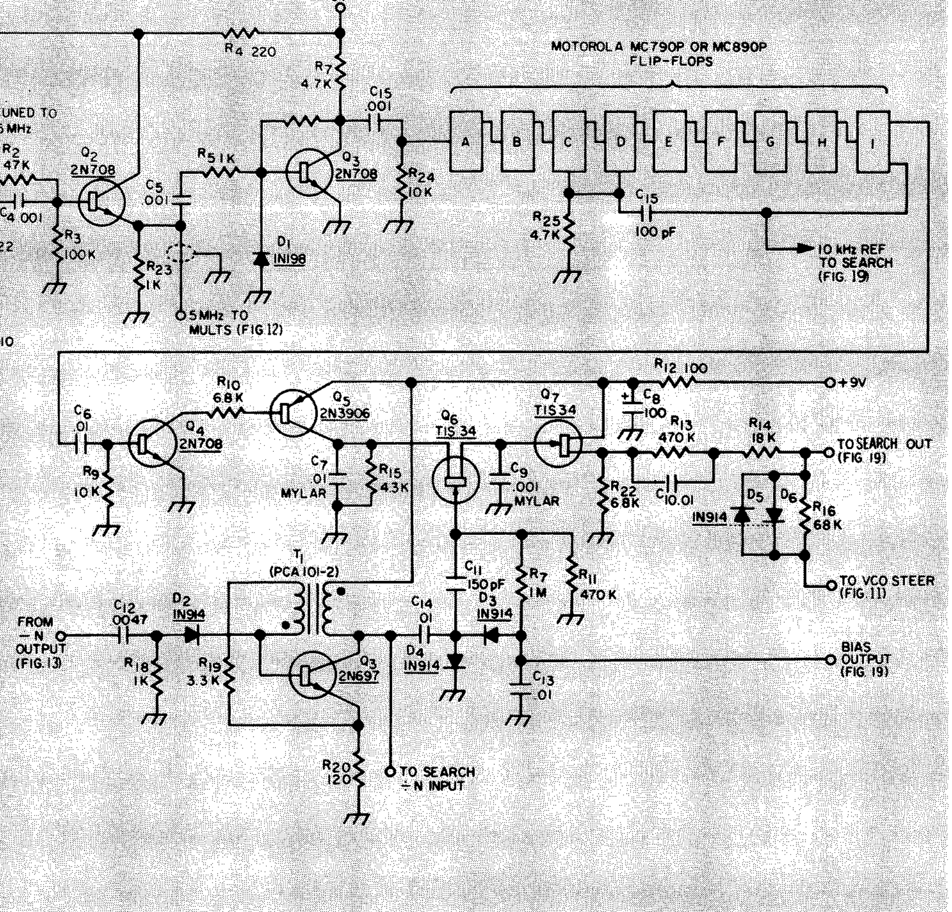


FIG 17
5 MHz AMPLIFIER ÷ 500, PHASE DETECTOR

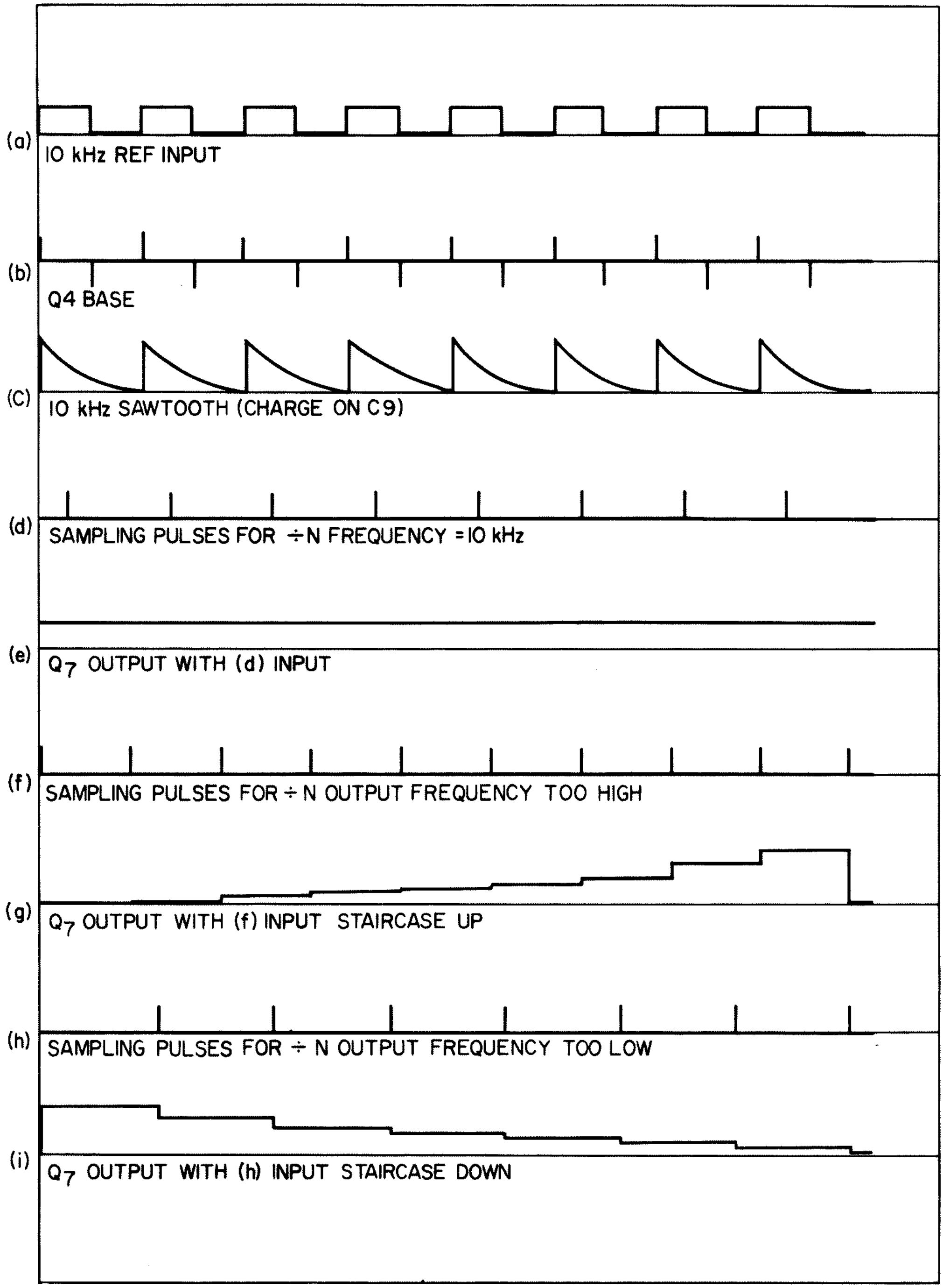


FIG. 17 Phase detector waveforms

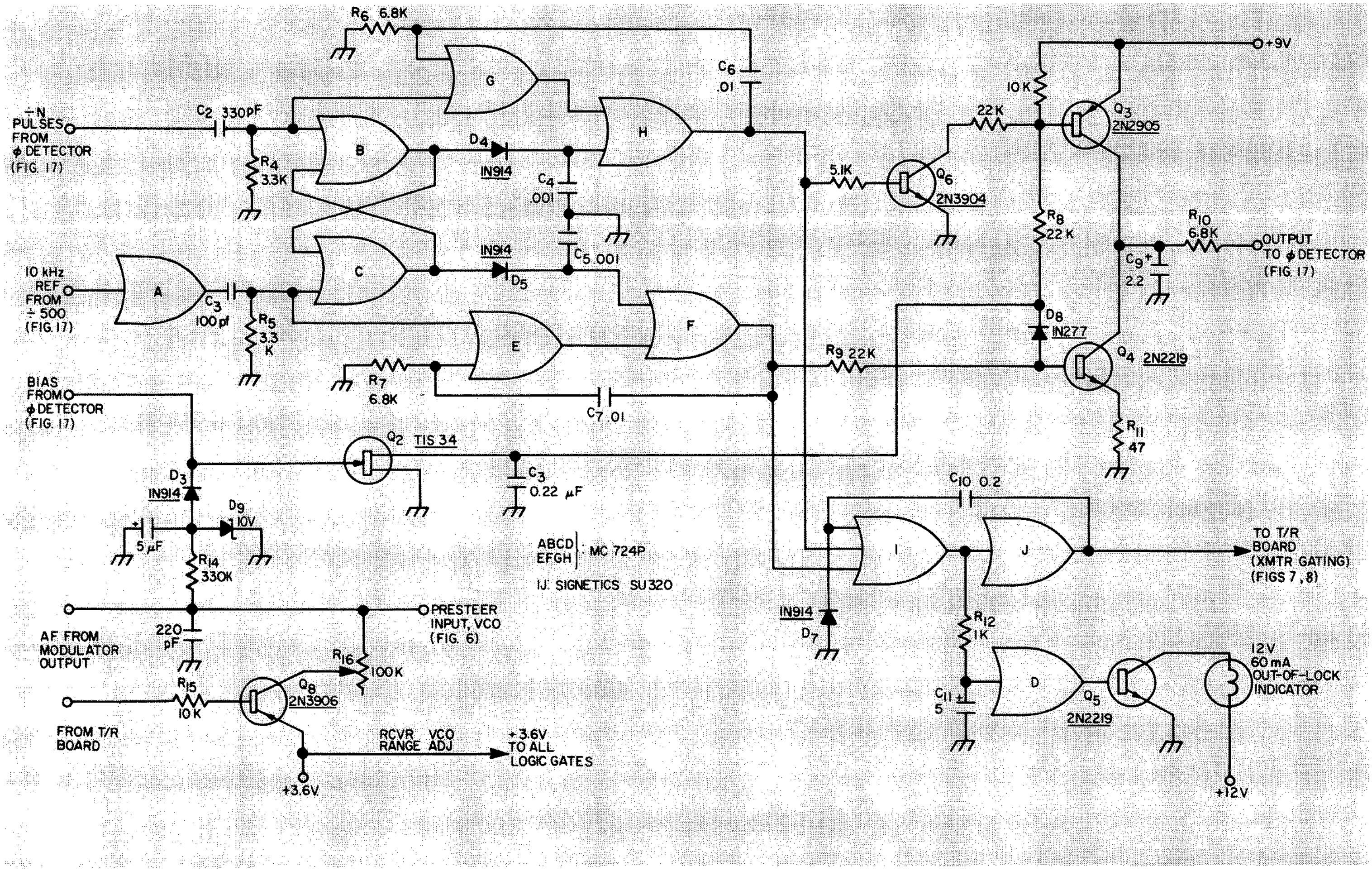


FIG. 19 Search, out-of-lock indicator, and presteer

the system will be found helpful in various spots. The most insidious form of system trouble is when complex circuits interact in ways not anticipated; so make sure the circuits function as they should separately, and then combine them in sections. Test everything for proper function before making any attempt to close the loop. When the loop is out of lock, everything jumps at once, and it is truly enough to make a grown man cry. Usually, the only hope is to open the loop and check individual circuits. With experience you can read the signs and troubleshooting becomes just as easy as robbing Fort Knox.

Performance

With a good master oscillator you can get counterlike frequency accuracy on all channels. The author's unit is accurate to better than plus or minus 20 Hz at two meters with a 20 minute warmup. Even without a warmup period, it is considerably better than most crystal-controlled rigs after stabilization.

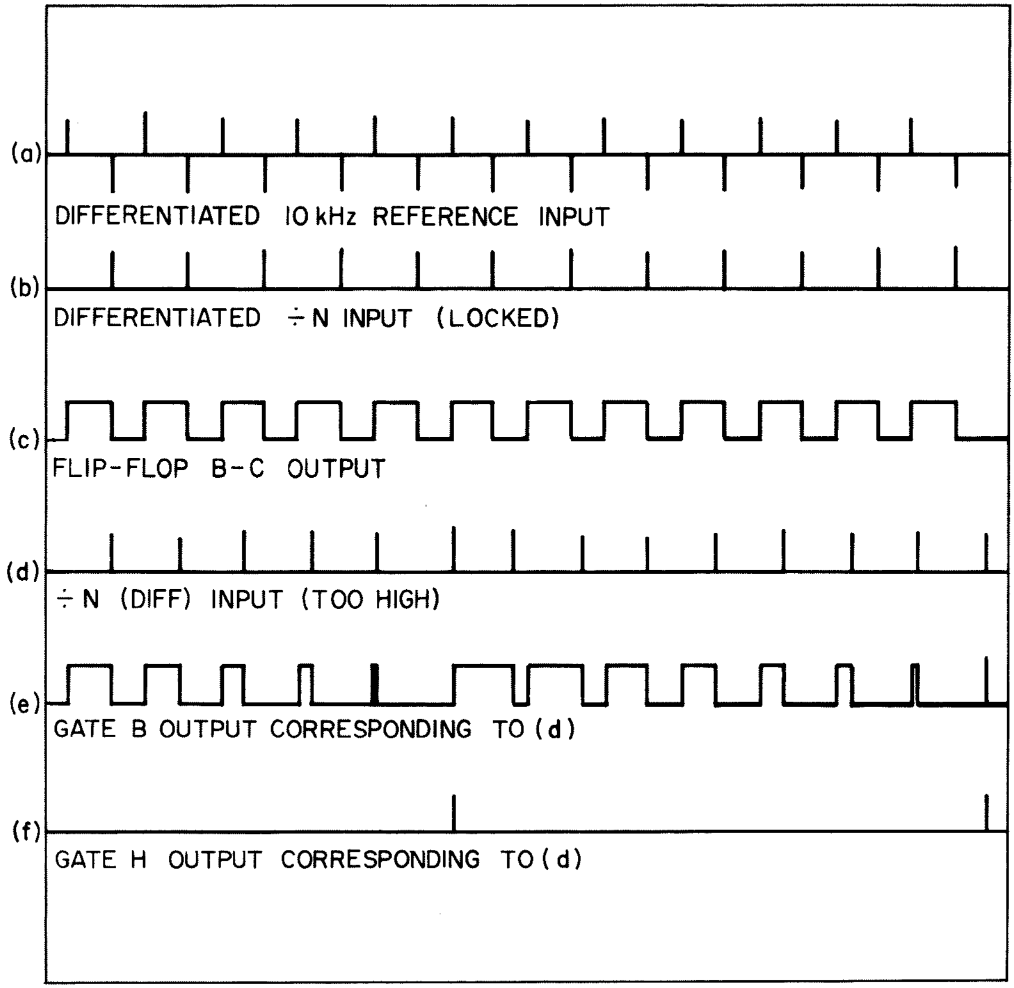


FIG. 20 Search waveforms

Unlimited channel flexibility is a recurring pleasure that intensifies with time. Anyone who tells you that you are off frequency has just *got* to be from out of town! Even if you have a doubt, it takes only one quick zero-beating check against WWV to *guarantee* superaccuracy on all channels!

The big worry most people have about synthesizing frequencies is the potential spurious outputs. The author's unit was cheked on an H-P spectrum analyzer from 10 MHz to 2,000 GHz and found to be clean to –70 dB from carrier, excepting harmonics. And even at that level there was only a 5 MHz sideband pair, originating from the master oscillator. Adjacent 10 kHz sidebands couldn't be measured directly, but calculations based on the ripple level measured in the VCO feedback loop indicate them to be over 65 dB down. This figure is consistent with on-the-air observations.

It *is* worth the trouble. You must use a synthesized rig to appreciate it!

GILBERT BOELKE

BOOK REVIEW

ARTHUR W. BROTHERS

One year late, the $32.50 *Standard Handbook for Electrical Engineers* has finally made its publication date from McGraw Hill, 300 W. 42nd St., N.Y. 10036. This is one of the bibles of the industry, and for the dough, you get 2506 pages with some 29 sections dealing with the practical aspects of most things interesting to the electrical engineer. The book is published every ten years, and part of the data is revised and upgraded. New sections deal with semiconductors; various ways of generating power such as thermal, magnetohydrodynamic, fuel cell, etc., and a host of other topics. It's tough trying to put the sum total electrical knowledge of man in a digestible form, but for the most part the editors have done a fair job.

As far as state-of-the-art applications are concerned, however, the book appears to be about five years behind in some areas. The telephone, telegraph and data systems chapter, for instance, has quite a bit of information missing from its tables, and is just not up to date. But, for the electrical engineer, as opposed to someone within that industry, this might be sufficient. Also, there is a bland assumption by some of the editors that the reader knows abbreviations blithely tossed around in the text, such as MKSA and USAS in the Measurements section. To sum up — it's not as good as it should be, but you won't find this much information contained elsewhere for less money.

TRANSISTORIZING THE HYBRID MOTOROLA HANDIE-TALKIES

by P. J. FERRELL*

The old H23 Handie-Talkie was a hybrid job: The receiver was a mismash of vacuum tubes and transistors. This article tells how to eliminate the tubes in these early versions and end up with an all-transistor receiver capable of easily outperforming the later stock units.

Motorola introduced the first commercially available transistorized portable FM transceivers some time around 1956. These beautiful little units are now widely available to amateurs, but they come in a bewildering assortment of type numbers. For example, a P33-4 is a single-frequency transceiver for the 144 — 174 MHz region with 7 watts output, microphone, speaker, and rechargeable nickel — cadmium battery; an H23AAC-310AH is a high-band split-channel one-watt unit with handset and extra-duty dry battery.

The year 1956 was such a short time ago that it is sometimes startling to remember that available transistors at that time would not oscillate above about 1 MHz — and anything above that was vacuum tube country. So it was that the local oscillator and the two first i-f's of the Motorola HT receivers used vacuum tubes. Later units were completely transistorized, and a conversion kit is still available from Motorola (NED6004A, $74.00) which updates the early receivers to the fully transistorized configuration. If your unit has the late-model receiver, go immediately to some other article, because the remainder of this one will just make you wish you hadn't splurged on the nonhybridized vintage.

Using inexpensive N-channel field-effect transistors, the early receivers can be readily converted to fully solid-state operation, and these modified receivers will perform rings around the newer units (which use bipolar transistors rather than the hotter FET's). The necessary modifications will cost about $7, and the work can be finished in little more than an hour.

The FET cascode shown in Fig. 1 is generally useful as a pentode vacuum tube replacement. The transistors specified are readily available either locally or from the larger mail-order supply outlets. Other N-channel FET's, such as 2N3823 and those of the Motorola MPF series, will work equally well. In this application, the supply potential of 50 volts is just right as the two

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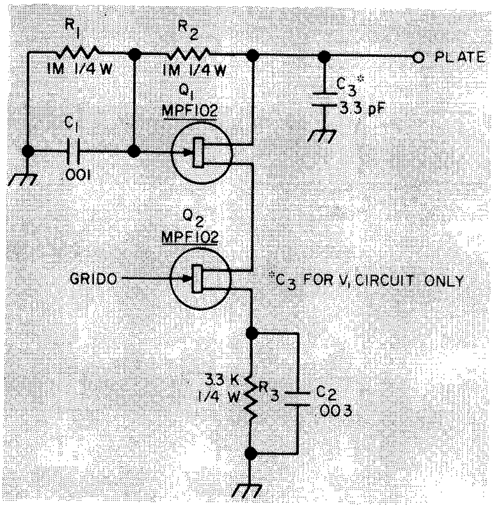


Fig. 1 FET cascode arrangement replaces each pentode i-f amplifier in the H23 hybrid receiver.

Note that C_3 is required for the first i-f amplifier, though it is not used in the second.

FET's are in series for dc and each gets about 27 volts from drain to source. Resistor R_3 determines the current drawn by the series transistor pair. The current in milliamperes is approximately $2000/R_3$. More than adequate gain is obtained at a current of 600 microamperes, and with the higher gains obtained at higher currents, stability problems can arise.

The output capacitance of this circuit is negligible, so that C_3 is required to correctly tune the output of the V_1 tube replacement. There is sufficient capacity in the output circuit of the second stage (V_2) so that a C_3 equivalent is not required.

Vacuum tube V_3 is triode-connected, so a single FET is used. Capacitors C_4 and C_5 return the crystal operating frequency to that of the original tube circuit. Resistor R_5 drops the 60-volt B+ to a level that is safe for the FET.

As a last touch, replace the first crystal-mixer diode CR_1 (it will be a 1N72 or a 1N147A) with an HP 5082-2800 *hot carrier* diode. This will only cost a buck, and the expense is worthwhile. My own wide-band H23AAM measures better than 0.4 microvolt sensitivity at 20 dB of quieting, and adjacent-channel problems due to cross modulation have disappeared.

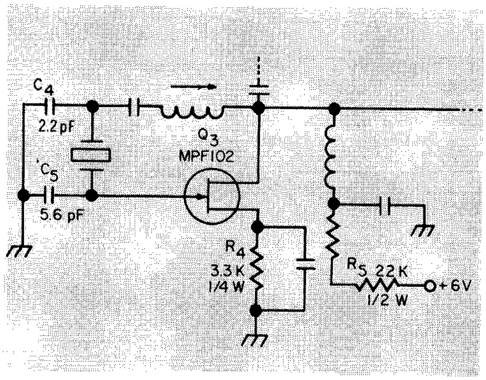


Fig. 2 FET replaces vacuum tube in the H23 oscillator to complete the transistorization operation. Components not labeled in the sketch are those components that are already part of the existing oscillator circuit.

Transistor Preamp

HI·FI AUDIO from CARBON MIKE CIRCUITS

by Dick Thomas

Audio quality is becoming increasing important for FM operation, and for some very good reasons. The advent of repeaters that is now upon us almost guarantees that the average operator will be communicating with the aid of a repeater at least part of the time. But the repeater, with all its range-extending capabilities, poses special problems in terms of signal intelligibility, because the repeater can't help but introduce some distortion to a signal, and it compounds problems of less-than-perfect audio.

A carbon microphone, though considered the workhorse of communications, does not lend itself well to high-fidelity audio transmission. It reproduces a narrow range of voice frequencies well enough, but it attenuates the highs and lows and adds such a high degree of *coloration* to the modulating voice signal that unintelligibility often results when the signal is regenerated through a repeater. And when the repeater's audio system is less than the ultimate, or when multiple repeaters are used, the carbon microphone can no longer be considered as a candidate.

One excellent way to get around the problems of low-fidelity audio transmission is to use a dynamic microphone. Typically, its reproduction range extends far below and above that of the carbon mike, and the coloration is nowhere near as severe. One nice thing about converting to a dynamic microphone is that no modifications are required to the transmitter audio circuits. The dc drive voltage once used for the carbon-mike excitation voltage, can be applied without change to a tiny transistor amplifier circuit which can be readily incorporated into practically any standard microphone case.

The amplifier circuit shown in Fig. 1, for example, will fit beautifully inside the case of an Electro-Voice Model 602 differential dynamic microphone housing. The amplifier has a gain of about 35 dB, which serves to bring the microphone signal up to the normal output of the carbon microphone.

Once the amplifier is built and a dynamic microphone is added, the unit will plug directly into the mike connector of any standard FM transmitter. I have used the

*Revised from Dick Thomas article of similar title which appeared in Toronto FM Communications Association Bulletin, Toronto, Canada.

circuit successfully with Motorola, GE, RCA, and Narco. The quality is always high and audio is always in abundance.

Most any audio transistors (one NPN and one PNP) will work. The NPN should have a dissipation rating of at least 125 mW.

There is nothing critical in the selection of the microphone, either; most any dynamic, ribbon, controlled reluctance, or magnetic unit will prove ideal. The circuit will work equally well whether the mike element is high- or low-impedance, though the high-impedance types will tend to give a few decibels more gain.

To get optimum performance from your unit, vary R_1 for best audio quality and volume. The total current measured on the dc line should not exceed 9 mA. For compactness, R_1 may be replaced a fixed resistor rated at one-eighth watt.

Fig. 1 Transistor preamplifier can be used with dynamic microphone to replace carbon microphone for improving fidelity of transmitted audio. Circuit can be nestled into most conventional microphone housings.

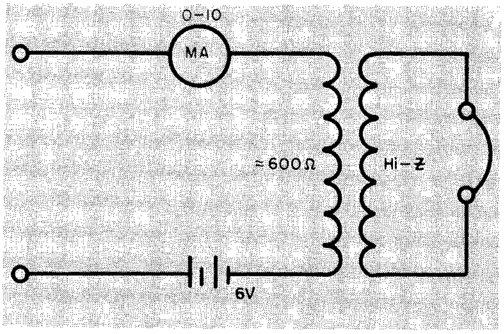
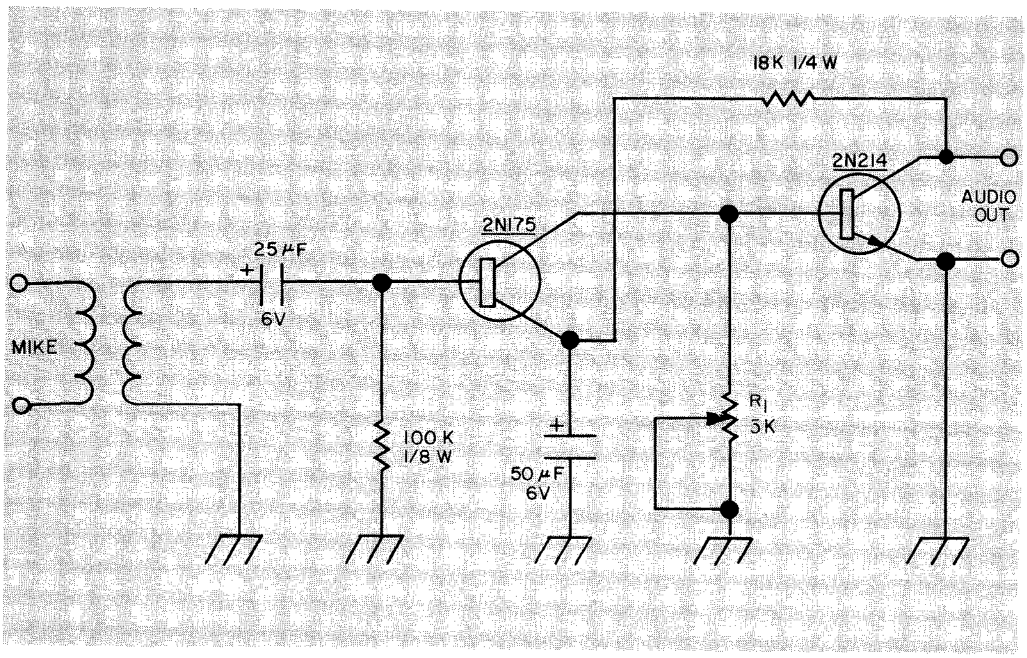


Fig. 2 Test circuit can be built up to optimize the quality of the preamplifier by experimenting with component values and monitoring with high-impedance headphones.

A test circuit may be set up using a 6-volt battery and a 500-ohm transformer (to simulate the input transformer in the transmitter itself), as shown in Fig. 2. Connect a pair of high-impedance headphones to the transformer secondary so you can monitor the amplified audio. The point of best quality will probably be when R_1 is between 3 and 4K, and when the total battery current is between 3 and 6 mA.

W8VJC



MULTIPLEX MULTIPLEX

by GORDON PUGH*

Most repeater systems are developed around a remotely controlled base station located some distance from the control point or points. The control link is either wireline or radio, depending upon the cost of the wire facility versus that of the radio circuit. It frequently becomes desirable to transmit several individual voice signals over the same wire or radio circuit simultaneously without conflict with each other. This is known as *multiplexing*.

Multiplexing can be done on radio channels and over some wire facilities, depending upon the type of leased circuit. Most wirelines used in amateur remote control are short and within the area of a single central office. If the wireline is a physical copper circuit (that is, one that consists basically of a pair of wires between the two points) without amplifiers, it is usually possible to transmit several voice signals over the same wireline. It is necessary to use different channel frequencies on the multiplex to provide two-way transmission when using a single pair of wires. It may be of interest to note that the telephone companies are now using an FM multiplex system to provide additional voice circuits in places where additional cable pairs are not available. The multiplex channel operates at about 24 kHz in one direction and 60 kHz in the other. This is coupled to an existing telephone line with special filters.

There are two types of multiplexing. *Frequency division* is the type used in stereophonic FM broadcasting and will be considered in this article. The other type, *time division*, can be used only with signals that have been converted into pulses. Pulse modulation requires bandwidth beyond the capability of equipment now in general use and also is not authorized on the VHF and lower UHF amateur bands. One item of surplus military equipment that may be modified to operate on amateur microwave frequencies is the AN/TRC-6, using pulse-position multiplex to derive eight voice-grade channels. The bandwidth required for these eight channels is several megahertz compared with less than 35 kilohertz required for eight voice channels multiplexed using frequency division SSB channels.

FREQUENCY DIVISION MULTIPLEXING

An FM or AM dsb or ssb signal may be transmitted in a certain carrier frequency band or channel in the same way that radio signals are produced. For example, a 3 kHz voice channel can be modulated on a 60 kHz radio carrier. Another signal can be similarly modulated on a neighboring

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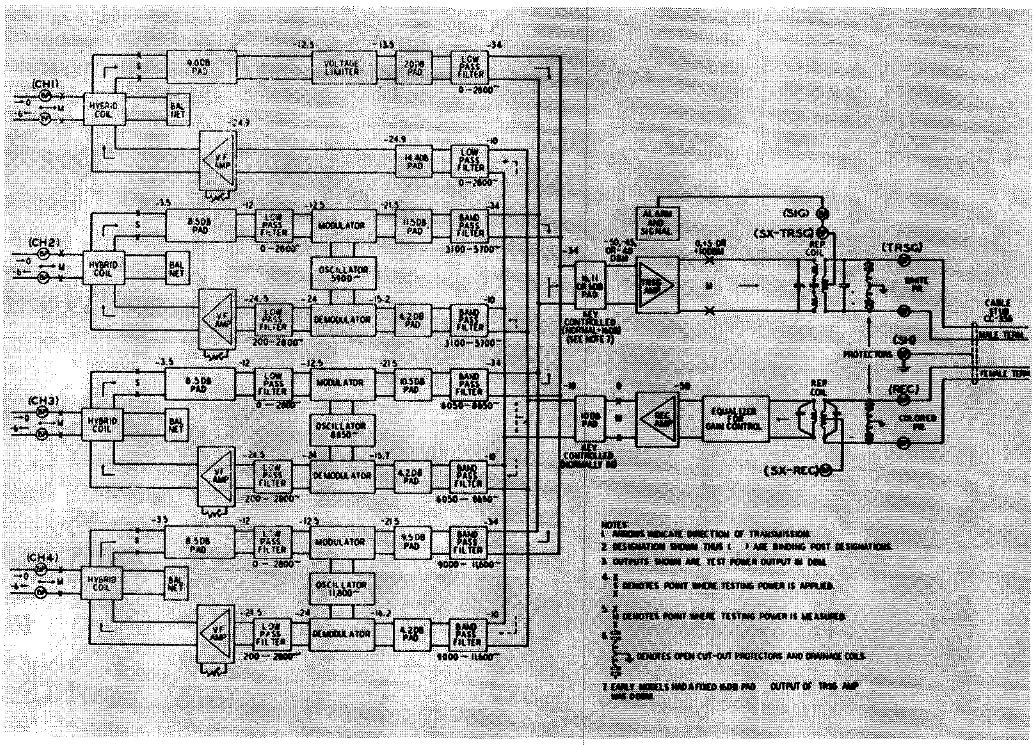


Fig. 1 Multiplex terminal unit.

radio carrier, say at 50 kHz. If these signals are transmitted over a wire or radio channel to a receiving point, they may be separated by filters and detected individually. This is known as frequency division multiplexing.

Telephone lines are generally leased as a particular grade line. Most amateur installations use the *radio* tieline or even a telegraph loop. (It may be interesting to note that telegraph loops in a single central office are frequently nothing more than a pair of wires that come much cheaper than the radio tieline if the distance between terminals is over 2½ miles.) The number of channels that can be transmitted over a pair of wires depends upon the type of modulation and loss of the circuit. SSB multiplex allows the maximum number of channels in the least amount of spectrum. The channels must be transmitted so that the total energy of all channels operating simultaneously does not exceed a level established by the common carrier. Loss and noise at the receive terminal will limit reception of the higher frequencies and set up limits as to the number of channels that may be used.

The same holds true to a lesser extent for radio channels. A number of voice channels may be multiplexed on a standard wideband FM carrier. Holding the deviation constant and increasing the number of channels increases the maximum modulation frequency. The deviation ratio (the ratio of maximum frequency deviation to the highest frequency in a multifrequency signal) decreases with increase in system loading (number of channels). The deviation ratio is a measure of the capability of the system to override noise.

Two methods may be used to overcome the loading: the deviation may be increased and the receiver bandwidth increased appropriately, or the transmitter power may be increased, or both methods may be used. It should be noted that the deviation ratio need not be large (telephone microwave systems with many hundreds of channels operate at or near a deviation ratio of one) but the received signal must be capable of quieting the receiver at the highest modulating frequency in the system.

MULTIPLEX VERSUS SEVERAL TRANSMITTERS

The following example will point out the advantages of multiplexing. Assume that four voice channels are to be fed from four receivers at the repeater site back to the control point. Four transmitters could be used — with four antennas, cavities, duplexers, and so on — with four receivers at the other end of the circuit each feeding a monitor speaker. Alternately, a single transmitter with four channels of CF carrier could be used — with a single antenna, no filters or duplexers, and only one receiver. Each transmitter in the four-transmitter system requires 50 kHz minimum using existing 450 MHz equipment. Not counting the third and higher order products caused by the four transmitters all radiating simultaneously side-by-side, that's 200 kHz of spectrum used up!

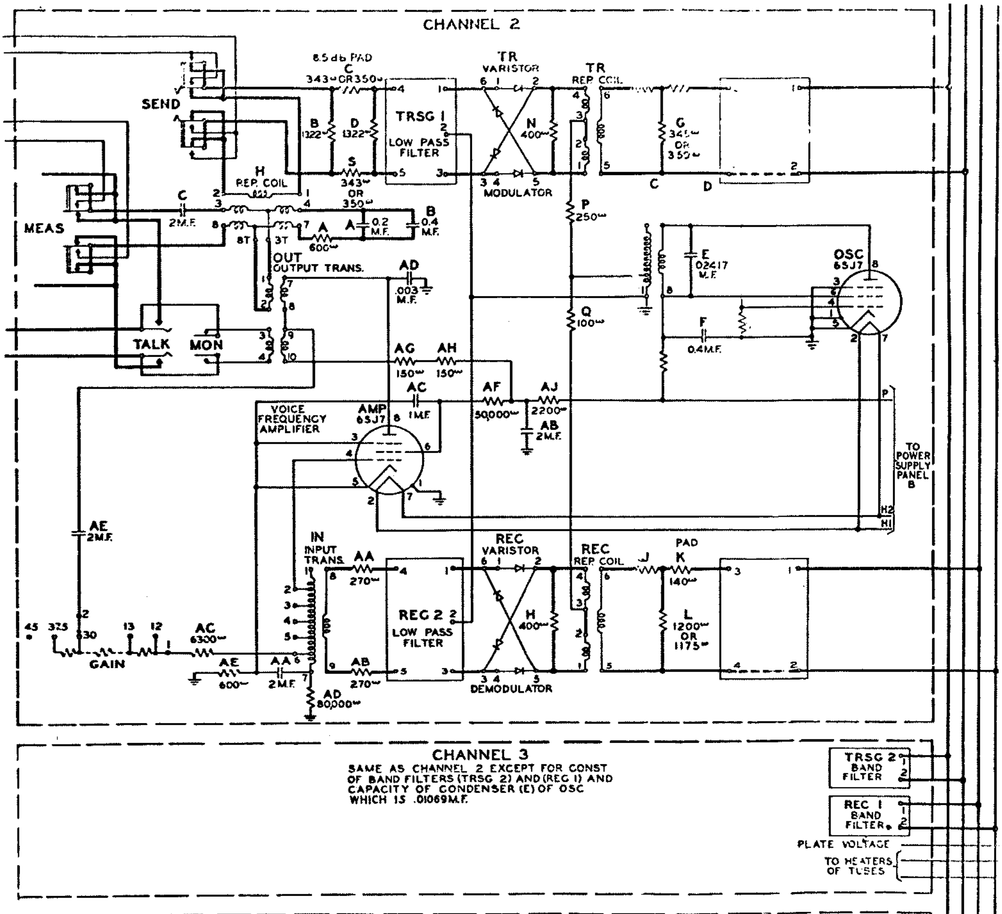


Fig. 2 Modulator – demodulator (modem) unit.

Frequency division multiplex can squeeze four channels of audio into about 12 kHz using single sideband for the upper three channels and retaining the 0 — 3 kHz slot for an *unmultiplexed* voice channel. To maintain a good immunity to noise, a deviation ratio of 2½ may be used; this requires doubling the transmitter deviation (or a deviation ratio of 5 may be obtained by increasing the deviation four times). The receiver must also be modified to accept the wider deviation, and audio stages require alteration to permit modulation and demodulation amplification of the multiplex signal. The bandwidth required for the multiplex system is only 80 kHz for a 30 kHz deviation. Excluding the intermodulation products of the four-transmitter method the spectrum need is reduced 60% by multiplexing. Power requirements for the multiplex system are similarly reduced. The power required to operate three transmitters is eliminated and the losses in rf filtering will increase the antenna power to partly compensate for the increased deviation. A

tube type requires about 50 watts — or about the same as the standby power of one low-power transmitter. One terminal is needed at both ends of the system, but they each work as sending and receiving units. The power consumed by three receivers is also eliminated.

Other modulation methods may be used to generate the multiplex signal. N carrier systems, for example, use double-sideband AM. Others use FM subcarriers. All these methods require more spectrum per voice channel, reducing the advantages described above. The single-sideband method also lends itself to easy demodulation for monitoring if necessary. An audio oscillator may be connected to the receiver audio stage to reinsert the carrier of the multiplex channel to be checked. A low-pass filter inserted at the output circuit will eliminate unwanted audio products. Adjusting the oscillator to the carrier frequency of the desired channel will produce the original audio information contained in the multiplex channel, provided there is some intermodulation (distortion) in the audio system being used.

The distortion may be generated in most cases by increasing the output of the audio oscillator above the linear amplification range of the audio amplifier.

Setting up a multiplex system is relatively easy if suitable equipment is available. The military carrier telephone equipment (designed for spiral-four cable) that is now considered surplus is adaptable to radio circuits. The units, called CF-1 terminals, are large and heavy but not expensive. Each terminal is installed in a six-foot rack intended for operation in the field. They operate from 115 volts ac with emergency 12V dc changeover built into the power supplies.

The CF-1 equipment passes the first channel as received except for amplification and filtering. (See Fig. 1, block diagram of terminal portion.) The other three channels are converted to A3j (lower sideband) with carrier frequencies at 5.9, 8.85 and 11.8 kHz using balanced modulators and bandpass filters for each channel. The local

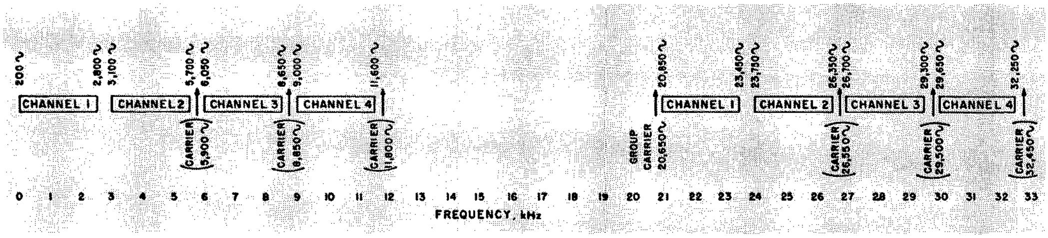


Fig. 3 Multiplex frequency allocation.

oscillator for each channel is used for generating and demodulating the multiplex signal. (A typical *modem* or channel unit is shown in Fig. 2.)

CF-1 equipment does not generate any pilots or reference signals to lock the local oscillators together or maintain constant audio level under varying conditions. Feedback control of the levels is relatively unimportant in a properly aligned FM transmission system since very little change takes place in the recovered audio under varying signal conditions. Lack of synchronous local oscillator operation may present problems with tone control or signaling equipment unless it will tolerate frequency errors of 50 — 100 Hz. Errors this great are unusual but could develop in unattended equipment over a long period of time. (In operating a CF-1 system over a two-hop radio circuit we found that the drift between terminals on the worst channel was on the order of about 12 Hz per year.)

If it is necessary to transmit accurate tones on CF-1 equipment, channel 1 may be used since there is no conversion on this channel. Narrow-shift tone channels may also be inserted between 2800 Hz, the upper edge of channel 1, and 3100 Hz, the upper edge of channel 2. Control tones could also be added above 11.8 kHz. Figure 3 shows the channel allocations used with CF-1 carrier systems. Carrier systems cannot transmit on the same channel frequency in both directions over the same pair of wires. The transmission path in the reverse direction must be on a different pair of wires or on different channel frequencies.

The CF-1 was designed to use spiral-four cable transmitting in one direction on one pair and the other direction on the other. The CF-4 converter allows transmission in both directions over open wireline. The high group allocation between 20 and 33 kHz is used when a CF-4 converter is added to the system. Radio systems are usually one-way devices in that they can normally operate in only one direction at a time. Transmission in the reverse direction would be on a different radio channel (pair of wires), making a "four-wire" system. When both directions will work at the same time between two terminals the system is known as *four-wire, full duplex*.

Another carrier system that has turned up on the surplus military equipment market is the TCC-3 (also the TCC-7, which is similar but will handle 12 channels). The TCC-3 system has one straight-

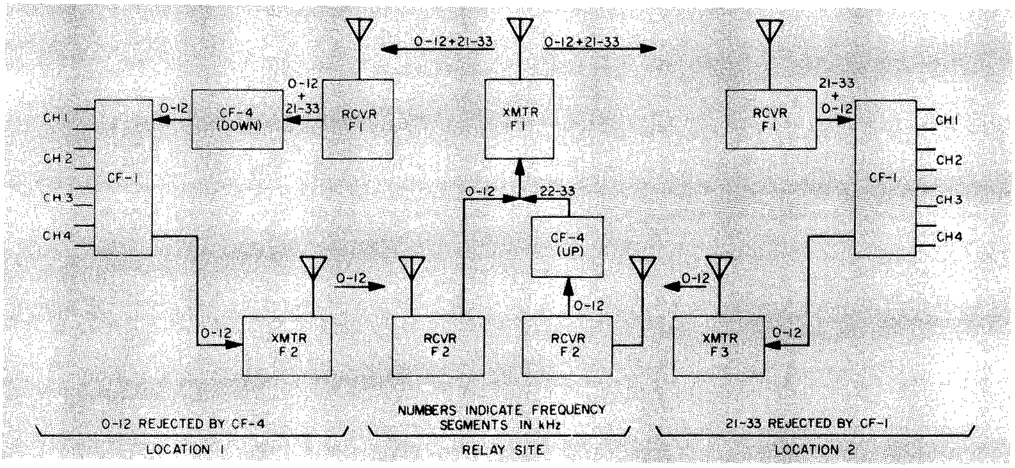


Fig. 4 Deployed multiplex system.

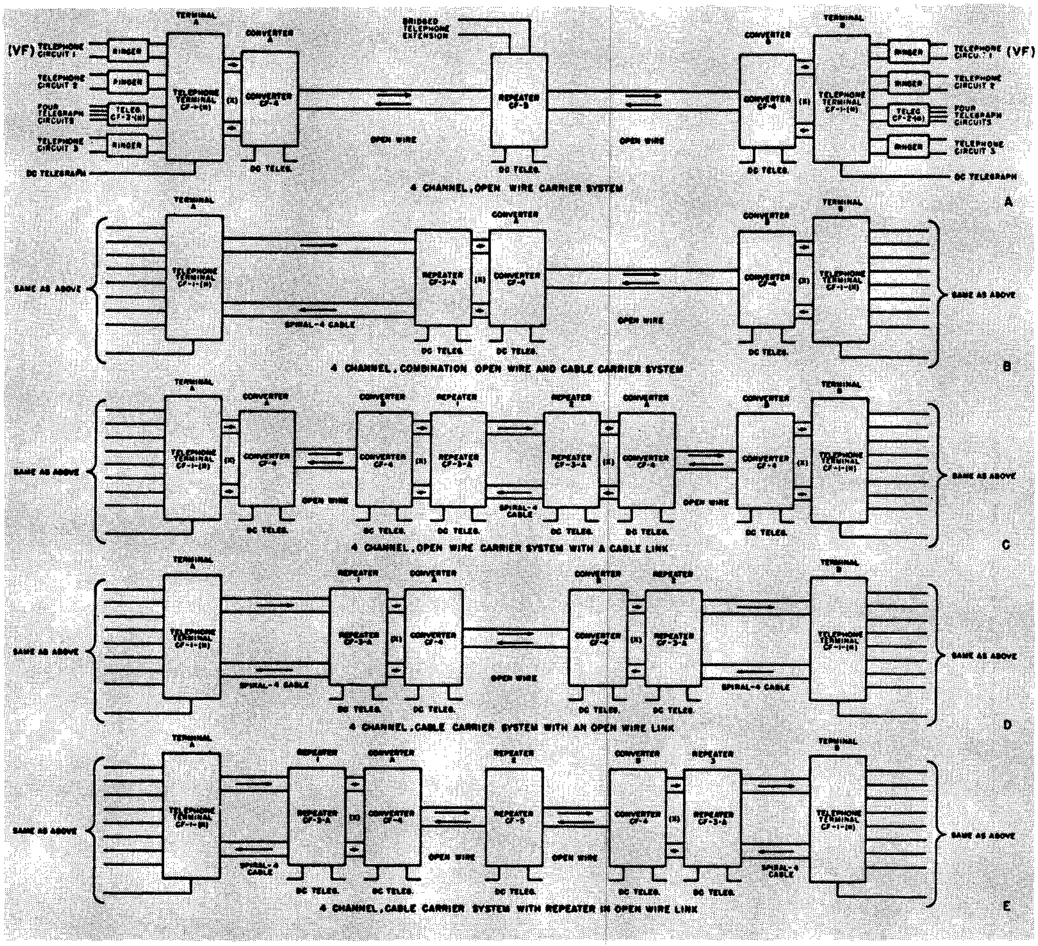


Fig. 5 Open-wire multiplex system using CF-4 unit.

through channel and four carrier channels spaced 4 kHz apart. This equipment is about one-fourth the size and weight of the CF-1 and requires more ac power for operation. The TCC-3 is much newer than the CF equipment and is also more expensive (when it can be located).

On the current commercial market are several types of multiplex equipment that serve what is called light traffic routes. Most of the telephone suppliers such as Lenkurt, Lynch, and GE have light-route systems. One of the newest systems is the Cardion 29B multiplex and 22B, transmit – receive device, a combination 960 MHz radio system and light-route carrier terminal. This equipment is designed to meet the new requirements of commercial point-to-point systems that are being forced to move up from the 450 MHz band.

MAKING ONE TRANSMITTER WORK LIKE TWO

Assume for a moment that a relay site is needed between two locations in a radio system but only one transmitter can be operated at the relay site. It is desired to operate a two-way relay through the site in both directions at the same time. One method might work — using a fast switch in the audio and rf circuits to transmit a short time in one direction — then, with the other audio input, a short time in the other direction, etc. The switching rate would have to be about 8 kHz for ordinary voice bandwidth.

A better method would be to use multiplex. The transmission from location A through the relay station to location B would be on the regular voice frequencies (or what would be channel 1 on a CF-1 system) and the transmission from the relay station to location A in the other direction would be on a carrier channel *through the same transmitter!* The transmitter and antenna system would have to be capable of reaching *both* locations at the same time.

Going one step further, suppose that a CF-1 system was operating between these two locations under the same conditions. Both receivers at the relay site receive channels 1 through 4 from their respective terminal locations. The channels from location A are fed to the relay transmitter as received without any conversion. The channels from location B are fed to a CF-4 converter operating to convert the four channels up to the high-group allocation. These channels are then added to the other four channels and transmitted on the same radio channel. At the second location, a CF-1 terminal is used to modulate (and demodulate) the system. At location A, the CF-1 modulates four channels and couples them to the transmitter feeding the relay site. The receiver at location A feeds another CF-4 operating as a *down* converter translating the high-group channels into signals that can be fed to the CF-1 for demodulation. This system is shown in Fig. 4. Figure 5 shows a block diagram of a complete CF-4 open-wire system.

No provision is included in the amateur rules (Part 97) for multiplex operation. Multiplex is allowed in other services on frequencies that are authorized for F3 emission. However, new rules for commercial services are pushing the use of multiplex up into the 900 MHz region and above. The FCC has not been averse to use of multiplex on the UHF amateur bands and has indicated that authorization would be considered if a need for it can be shown. There are several amateur radio remote control systems using multiplex now licensed in the United States.

. . . Gordon Pugh W2GHR

Letters

Feedback

Editor:

Re *Telephone Command of Repeater Operations* (FM, January 1969): The phone rings during the first second and the stepper steps to contact 1 at the same time and the timer is activated through the *off normal* contacts to 28V. Two seconds of silence follows. During the fourth second the stepper goes to position 2, the timer two seconds later provides an *off* pulse and, since there is no ring and the reset contacts are closed, the stepper is automatically reset. However, if there is a third ring at seven seconds the stepper again goes to position 1 and, during the tenth second, the stepper goes to position 2, at which time the timer pulses, but the stepper will not reset since the contacts for reset on the stepper relay are open due to the ring at this time. Therefore, at the end of four rings we have an *off* pulse and we also had one at the end of two rings.

The point is this: as soon as two rings come in, the *off* pulse goes out, regardless whether there is a third ring or not, since the timer activates two seconds after the second ring and the stepper is on position 2.

It would seem, if my analysis is correct, that rather than two seconds after the second ring, 32 seconds after the second ring is desirable. This would be a total time delay from the close of the *off normal* contacts until the timer activates of 36 seconds. This amount of time would allow the maximum number of rings one might expect on any phone, 12 rings, before the operation would start over again. The advantage of this would of course be that the relay would step at 1 second, 4 seconds, 7 seconds, 10 seconds, 13 seconds, 16 seconds, 19 seconds, 22 seconds, 25 seconds, 28 seconds, 31 seconds, 34 seconds, but there would be no chance of the relay hitting the position 2. At 36 seconds there is no ring present, and the circuit resets.

Desired operation would be, of course, to let the phone ring twice and hang up. Exactly 32 seconds later, the *off* pulse would be produced, turning off the transmitter.

Richard Jacobs WA0AIY
4941 Tracy Avenue
Kansas City, Mo. 64110

Your analysis is essentially correct, but a 36-second period is too much to ask of a relay and capacitor. A better approach might be to use a slow-recovery (noninstantly resettable) thermal delay relay. The period should be set for position 2 plus 3 seconds (rather than 2 seconds). After the thermal element heats and causes reset, a new applied voltage will cause the delay device to operate as a relay (causing repeated stepper reset at position 1) until the heating element of the thermal delay has the chance to cool (several minutes after a ring series). Bear in mind that the telephone-stepper arrangement is designed for "emergency off" applications. An inadvertent "off" command could presumably be easily countered by a legitimate radio-transmitted "on" command. If the operator can't turn the function on, he demonstrates an inability to maintain control of his system, in which case the "off" function should have been energized anyway.

Dear FM:

This letter is in response to your editorial, *The Code: A Step Backward?*, in the November 1968, issue of *FM*.

I agree with you fully. Code is a mode of communication out of the stone age of radio and wire communications. In this modern, technically advanced world we live in, there is no *necessity* to communicate via this means, when such advanced types such as SSB, RTTY, ATV, FM, etc. exist. While I do not advise outlawing cw on the amateur bands, I do recommend abolishing it as a *requirement* for use of the amateur frequencies.

No amateur should be required to be able to send and receive with code just as no amateur should be required to be able to send and receive with ATV. We should be encouraged to use new, state-of-the-art communications, instead of yesteryear's traditional ways. If by the international law, as old as radio itself, we must comply with code requirements, then we should only have a five-word-per-minute test, at most.

To upgrade the abilities of radio amateurs, the FCC should make the theoretical part of the test more and more difficult with increasing license classes. Also the possibility exists that the FCC could require the amateur, getting his first license or upgrading a present one, to build a piece of equipment of equal difficulty as the written test. This is done in some countries now, but this might be financially out of the question in the U.S. with the number of amateurs here.

As far as the code used as a means of restricting nonserious hams, this is absurd. The electronic minds in schools and business who wish to communicate via amateur radio with other people, cannot possibly be considered nonserious just because they couldn't care less about the code. The League also says the code gives us a taste of our heritage. Well then, why not require all prospective hams to build a sparkgap transmitter. The idea that anyone can learn code is somewhat wrong. It takes much time to become skilled in code, and some never grasp it. Code skill is a gift, just as a watchmaker's skill is a gift — it by no means shows a technical prowess.

In conclusion, code cannot advance the amateur's technical skill. Code can only serve to hinder the prospective amateur and those who wish to upgrade their present licenses.

Sincerely yours,
H. Alan Rhodes, WB2ZGA
Box 1071, Castle Pt. Stn.
Hoboken, N.J. 07030

Gentlemen:

I have been all too long finding this opportunity to write you in reference of your anti-cw article in the November, 1968 issue of FM.

Some prejudice may well be inherent in my remarks, having been a ham with cw preference since 1927. I recently retired from a position in which my colleagues often did and still do the impossible thanks to telegraph operation. Mobile roll calls were executed quickly and efficiently by telegraph and bogged down hopelessly when only voice was used. Remote stations hit a key with one or two letters without picking up a phone to advise quickly of a power failure or breaker operation or control problem, the telegraph sounder standing out in a room full of voices and voice transmissions. Most of our best people were the cw hams. The telegraphers generally developed an understanding and appreciation of communication through their pride in a skill beyond the reach of the average person. They acquired a small degree of self discipline ordinarily achieved only by extended scholastic activity.

There have been many instances of trapped miners and men in sunken submarines who were able to tap out messages by code to aid rescue. Our military will for some time continue to benefit from the telegraphic abilities of enlisted hams.

The failure of sophisticated telephone equipment leaves cw as a simple alternative in a case of distress. People who can read this stuff still have an important place in our mercy or rescue situations and they are scarce enough now without suggesting their further reduction.

I will not enter into the argument of time versus bandwidth. However, when my ham son finds 21 or 28 MHz wide open, no phone method can compete with his speed of QSO's by cw!

Yours very truly,
William F. E. Droese
W2BDQ
129 James Street
Rochelle Park, N.J. 07662

I got my November FM today. I read your editorial. By your request I'm writing.

I think you are being hasty and short sighted!! I stand as opposed to doing away with code requirements, yes, even for Technician licensees.

Cw is not, *I repeat*, IS NOT yet as outmoded and oldfashioned as you may think.

To cite two prime examples:

1.) Literally thousands of ships plying the oceans communicate by means of cw telegraphy. Why??

First, cw gear is far less complex than any "voice" equipment. It is far easier to maintain with simpler test gear. It is ultimately more reliable. Perhaps the most important reason for its use is that by means of "Q" signals and international code books, cw is an international language, understood by all. Please explain how you can talk to, say, a Mexican in Baja, California who speaks no English, at the same time assuming you know no Spanish?? A mike here would be a useless item indeed!!

2. Current long-range all year round communication with remote polar areas, etc. are maintained in the VLF - LF spectrum using cw, where RTTY creates problems save ANY kind of voice communciations.

The examples are legion but these are only two.

No, I won't be petty and quit my FM subscription like some soretails quit QST. You published your opinion, I will be grateful and appreciate it if you publish mine.

Yours and 73,
E. "Sandy" Blaize, Jr.
W5TVW
600 Deckbar Ave.
New Orleans, La. 70121

We're still wondering how you manage to hold conversations with Mexicans using cw when you don't speak their language and they don't speak yours!

Dear Mr. Sessions:

Upon reading your editorial in FM entitled "Code: A Step Backward" I found it hard to resist the urge to write you a line.

I feel that the article is extremely biased and although not impossible it leans startlingly toward trying to turn our amateur frequencies into another 11 meter band. It would seem to me that if people did not care for or did not want to bother with the code then they should see about acquiring a Citizen Band license.

I hope that you realize that attempting to drop the code regulations alone would be a very poor way of attempting to go about this so-called amateur radio reform.

G. Baldwin
Silverdale, Penna.

Dear Editor:

If you are planning to petition the FCC to drop the code requirement from Technician license exams, please do not assume or imply that your subscribers support you in your views. I think your editorial in the November issue is a disgrace to amateur radio. Do you seriously think the 5 wpm code requirement is a deterrent to really interested and technically competent would-be amateurs? Many small children have mastered this seemingly insurmountable obstacle and have become amateurs at the age of 10*. If you are worried about the physically handicapped, let me remind you that thousands of these have become hams, some of whom can tap out 20 wpm with their feet. I know of one ham who can communicate only by cw, since he is totally deaf. What good is FM to him?

I wonder if you have listened on 27 MHz, lately? There's a good example of a code-free license. Maybe you would like to get all these clowns in ham bands. Are you proposing a CB type license for 2 meters?

And another point — I wonder if you have ever tried cw. It can be a very enjoyable change from the monkey chatter of SSB and the heterodynes of AM. And you are kidding yourself if you don't think cw has a greater range than either one. Just listen to the QRP boys with their 20 milliwatts working the world on cw. Do you think they are less technically competent just because they are on cw?

And while on the subject of technical competence, your October issue was a technical *zero*. And lets face it, the boom in 2 meter FM of recent years is not due to any preponderance of technical achievement, but to the availability of large quantities of obsolete equipment which is no longer up to FCC standards for commercial use. Do you call that keeping up with the state of the art? In my book, that puts the FM'er one or two steps behind the commercials in technical competence. As far as repeaters and duplex are concerned, the commercials have been doing this for 15 years.

Perhaps you should have saved your editorial for the April issue, for 2 reasons. It would be a good April fool joke, and my subscription runs out in March.

Sincerely,
Kenneth Seil, WA2JYX
66 Sharon Drive
Rochester, N.Y. 14626

**Many small children have become chess masters and piano virtuosos also. Does that mean anyone can do it?*

Gentlemen:

You asked for comments from your subscribers in last paragraph on page 6 of your November number. I am a subscriber. My feeling is that the person who wrote the editorial has been brainwashed by a CB'er. I hold an Advanced class license, have had ticket since 1946 so I think I see all phases of amateur radio. I hold a 25 wpm certificate and stand ready to defend it any any time. I have not gone to seed on cw but think it a basis of amateur radio. Yes, I have two rigs on FM, base station and mobile on 146.34/146.94, so take part in FM activities.

I think you are clear out of line to attempt a petition to FCC to dispense with cw. Before the day of Novice license (I don't know if you can remember that far back), we amateurs had a pretty high grade of operation. Now since a person can get on with a *general* grade ticket, he hasn't learned to value his license. With the Conditionals that we have scattered over the country, we get all kinds of intentional interference.*

I want to call your attention to the fact that the Army MARS gives its members credit for two hours participation for each one hour they check into a cw net. If the Military didn't believe in cw as a backup service, they certainly wouldn't do that.

I am principally a traffic man, both cw and phone nets, and there have been times, when we had high QRN, that phone couldn't be understood and we got through with the message on cw. Of course, that doesn't happen very often.

When the day comes that we cannot serve the public in everyday operation and in emergency work, then there will be no excuse for us to occupy the frequencies. And whether we like it or not, the big commercial needs will crowd in and we can all join the CB ranks, where they break more FCC regulations in one day than amateurs do in a lifetime. WHY? Because the amateur had to work for his license, but the CB'er doesn't have to do any studying at all. I even know people here in Enid, who didn't bother to apply for license. Just use a friend's call, and call it good. Build a kw linear, get on the air and tear up every TV within five blocks and laugh about it.

So let's upgrade our thinking and make the examinations tougher, if anything. You will then loose (sic) the freeloaders, the lazy, and indolent ones. If you don't like cw on a personal basis, which I surmise, just you promote FM and VHF frequencies and you will have your hands full. You wasted two and a half pages in FM which could have been devoted to some phase of FM. Keep your nose clean and stay away from the subject of cw if you don't like it.

Sincerely yours,
C. P. Andrews, W5MFX
ORS/OPS/PAM/Asst-Dir.
901 West Cherokee
Enid, Oklahoma

FM staff fails to see the correlation between interference and Conditional class.

Dears Sirs:

In reference to your article, "The Code, A Step Backward" in the November 1968 issue.

I agree with your views and thoughts 100% but why limit it to VHF (6 and 2 meters) The code requirements should be eliminated for *all bands* and in its place a stiffer technical section . . . I fail to see where the code requirements add anything to present-day amateur operations.

Wilbur T. Golson, W5CD
5465 Washington Avenue
Baton Rouge, La.

EDITORS NOTE:

The code petition would never get off the ground without full support. The feelings appear to be about 50-50 divided, and we are thus compelled to forsake the idea. We do intend to file a repeater rule petition, however. Suggestions for inclusions and deletions are invited. Write to Editorial Office.

SOLVING THE SEPARATION PROBLEM

The majority opinion says the two meter FM repeater activity should be in the 145-147 MHz band since these are the Technical limitations. Much talk goes around and back and forth as to what frequencies should be used for repeaters. However, none of the suggestions I have read in print or heard on the air take into consideration the technical design of a repeater system.

The more widely separated the transmitter output frequency is from the receiver input the more easily repeater problems are cured. Since the spread in frequencies that a mobile unit will cover without degradation in performance is limited to perhaps 60 kHz, most repeaters seem to stay with this spacing or less. However, by going in one direction with the transmitter and in the other direction with the receiver from a given frequency (generally the simplex or direct operation frequency), we could get 600 kHz plus 600 kHz, or 1.2 MHz, separation in the repeater — which would make one-site repeaters practical with a minimum of problems.

Also of interest to me is why, when picking spot frequencies, we pick odd numbers and do not use even 100 kHz multiples which would make frequency setting by the average amateur accurate with nothing more than a 100 kHz frequency standard.

In view of the above I would propose two solutions — (A) petition the FCC to extend the Technician's section of the band to 147.75 and move existing .34 - .94 repeater outputs to 147.54, keeping 146.94 as a direct frequency; (B) set up a new frequency arrangement using 145.70 as repeater input, 146.30 as a direct frequency, and 146.90 as a repeater output frequency.

Rick Thayer
Thayer Two-Way Radio
Box 271, Greenview, Ill.

Dear Sir:

I have just finished reading your November editorial — and rereading it, since I find it difficult to believe your proposal. It is incomprehensible to me, in light of the 11 meter mess, that anyone could advocate abolishment of the meager 5 wpm code requirement for the Technician class license.

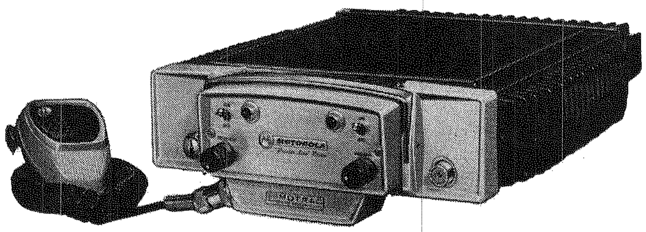
I feel that your suggestion that the written exam be stiffened to compensate for dropping of the cw requirement is as unfair to those hams not interested in the finer technical aspects of VHF (or even FM), as you claim cw is to those who are.

And, while I have always supported your anti-ARRL stand in the past — your equating cw with the League is reminiscent of calling fluoridation a Communist "plot."

In my estimation, a much more useful end could be served by petitioning for the opening of the upper and lower megahertz of 2 meters to the Technician licensees. Otherwise, "Let's leave the petitions to the CB'ers and our televiewing neighbors and make an attempt to approach our own problems without outside intervention." (From FM Magazine, Vol. 2, No. 5, p. 27.)

Terry W. Beverly
2415 Blackwood Road
Little Rock, Arkansas 72207

MOTOROLA



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THE DISEASE CALLED OVERLAP

by Gordon Pugh

The repeater at Mt. Beacon, N.Y. was first operated as a six-to-two-meter repeater (52.64 in — 146.94 out). Later the 146.34 input was added, and eventually the 52.64 input was dropped due to simplex activity on that channel. A controversy developed over the use of 146.94 as an output and the omnidirectional output was relocated to 146.76.

While the repeater operated .34-to-.76 (plus 52.96 in) it was discovered that 146.94 could be repeated to 146.76 with less trouble than 146.34 to 146.76! When the Poughkeepsie club joined the operation at Mt. Beacon, the basic .34-to-.94 was reestablished but directional antennas were added to limit coverage to the central Hudson Valley area. This seems to have solved the problem, since the repeater came well before the activity on 94.

From Poughkeepsie north through upstate New York and New England the repeaters are well standardized on 146.94 MHz output. Unfortunately, there is considerable overlap of the receiver coverage, especially when 30 — 60 watt base stations talk through the repeaters. Common ouput on .94 is not as troublesome as the same input frequency running open-line.

Getting back to Mt. Beacon, the repeater operated for several years as .34-to-.94 directional — .94-to-.76 omnidirectional (or semiomnidirectional) with good results. Since most multifrequency-equipped stations were capable of receivihg on both .76 and .94, a simplex .94 station could work through the repeater to .76 while the replying station would use the normal .34-to-.94 setup. While the station is being redesigned to include several other operations, only the .34-to-.94 (plus down link on 449.4) is in service.

Two repeater output channels (.94 and .76) have been well established in the United States. Use of 146.94 depends upon the area of coverage. This is well demonstrated in the southeastern New York area. The omnidirectional use of .94 as a repeater output at Mt. Beacon creates an intolerable situation; however, when it is directed north away from the congested New York metropolitan area, satisfactory operation results.

As for the use of 146.16, this maintains the 600 kHz spacing at the repeater but spreads the mobile transmitters over more spectrum than most of them can tolerate. An input frequency such as 146.28, while slightly less than half a megahertz away from the output, seems to be a better choice.

I would like to report a system of channel spacing which has been in use in the Indiana area on six FM and which might be put to good use on a national basis. From channel two on they are all on 40 kc spacings, rather than the 60 or 30 spacings of two meters.

Channel	Freq.	Use
One	52.525	National calling and working frequency.
Two	52.600	Rtty, (including autostart).
Three	52.640	Alternate (and some repeater use).
Four	52.680	Repeater input (for 52.525 output)
Five	52.720	
Six	52.760	
Seven	52.800	
Eight	52.840	

I would like to see some coordination of repeater input and output frequencies as has been attempted on two. At least the inputs could be standard, unless skip makes that impractical; but even then coordination on a regional basis could allow mobiles to work through repeaters near them when they are traveling in nearby areas. If six-meter users would write in expressing their choice of frequencies, perhaps we could come up with some sort of agreement.

Phil Snider K3UWZ/9

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Southern Electronics Corp.
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Opelika

ARIZONA
Valley Ham shock
4109 N. 39th St.
Phoenix

CALIFORNIA
Amrad Supply, Inc.
3425 Balboa St.
San Francisco

Amrad Supply, Inc.
1025 Harrison Street Oakland,
Oakland,

Arrowhead Radio & TV Supply
1212-16 "D" Street
San Bernardino

C & A Electronic Enterprises
2529 E. Carson Street
Long Beach

Dow Radio - Milo
1759 E. Colorado
Pasadena

Dymond Electronics
501-515 Blackstone
Fresno

Electronic's Best Buys
1219 Monterey Street
Vallejo

Henry Radio
931 E. Euclid
Anaheim

Henry Radio
11240 W. Olympic
Los Angeles

Lafayett Radio Associated Store
4244 East Belmont
Fresno

Mann Communications
18669 Ventura Blvd.
Tarzana

Quement Electronics
P.O. Box 6000
San Jose

Radio Products Sales, Inc.
1501 S. Hill St.
Los Angeles

COLORADO
CW Electronic Sales Co.
1237 – 16th St.
Denver

CONNECTICUT
Hatry Electronics
500 Ledyard St.
Hartford

Kaufman Electronics
73 Frank Street
Bridgeport

FLORIDA
B & C Electronics, Inc.
616 Race Track Road
Fort Walton

Kinkade Radio Supply
1719 West Kennedy Blvd.
Tampa

Tedco of Melbourne, Inc.
2678 N. Babcock st.
Melbourne

ILLINOIS
Crawford Electronics
301-W. Main St.
Genoa

Heights Electronics, Inc.
835 Halsted St.
Chicago Heights

Klaus Radio & Electric Co.
8400 N. Pioneer Parkway
Peoria

Spectronics, Inc.
1009 Garfield Street
Oak Park

INDIANA
Graham Electronics
122 S. Senate Ave.
Indianapolis

Radio Distributing Co., Inc.
1212 High St.
South Bend

Riegel's Pipe & Tabacco Shop
634 South Calhoun
Fort Wayne

IOWA
Bob Evans Amateur Radio Supply
2200 Ingersoll Ave.
Des Moines

Hawkeye Amateur Radio Center
627 - E. 27th Street
Cedar Falls

World Radio Laboratories, Inc.
3415 West Broadway
Council Bluffs

KENTUCKY
Mobile Communication, Inc.
4331 Poplar Level Road
Louisville

MAINE
Down-East Ham Shack, Inc.
57 Main Street
Lewiston

MARYLAND
Electronic Distributers Inc.
11324 Fern Street
Wheaton

Electronic Trading Post
514 S. Broadway
Baltimore

MASSACHUSETTS
Graham Radio Inc.
505 Main St.
Reading

MICHIGAN
Electronic Distributors, Inc.
1960 Peck Street
Muskegon

Heathkit Electronic Center
18645 W. 8 Mile Road
Detroit

Purchase Radio Supply
327 E. Hoover Ave.
Ann Arbor

Main Electronics Co.
5558 S. Penn. Ave.
Lansing

Radio Supply & Engineering
90 Seldon Ave.
Detroit

Reno Radio
1314 Broadway
Detroit

MISSISSIPPI
May Electronics Supply Co.
605-9 Ingalls Ave
Pascagoula

MISSOURI
Gateway Electronics Corp.
6150 Delmar Blvd.
St. Louis

Ham Radio Center
8342 Olive Blvd.
St. Louis

MONTANA
Electronic Supply Company
250 - 11th St. West.
Billings

NEBRASKA
Ladd Electronics Co.
111 North 41 Street
Omaha

NEW JERSEY
Gregory Electronics Corp.
249 Route 46
Saddle Brook

NEW MEXICO
Electronic Parts Co., Inc.
222 Truman Street NE
Albuquerque

NEW YORK
Adirondack Electronics, Inc
2469 Albany Street
Schenectady

Genesee Radio & Rarts Co., Inc
2550 Delaware Ave.
Buffalo

Harrison Radio Corp.
20 Smith St.
Farmingdale, Long Island

Harrison Radio Corp.
8 Barclay St.
New York

Harvey Radio Co.
2 W. 45th St.
New York

Stellar Industries
10 Graham Rd. W.
Ithaca

OHIO
Coston Electronic Dist.
2345 Ferguson Rd.
Cincinnati

Haungs Enterprise
10615 Thornview Dr.
Evendale

Hillebrand Electronic Supply
4665 W. Bandcroft
Toledo

Jeff-Tronics
4252 Pearl Rd.
Cleveland

L & S Electronics
17813 Euclid Ave.
Cleveland

Lafayette Radio Electronics
5429 N. Detroit St - US 25
Toledo

Mendelson Electronics Co., Inc.
516 Linden Ave.
Dayton

Selectronic Supplies
3185 Bellevue Rd.
Toledo

Universal Service
114 N. 3rd St.
Columbus

OKLAHOMA
Radio, Inc.
1000 S. Main
Tulsa

The Bookstore
Postal Station 18
Oklahoma City

OREGON
Portland Radio Supply
1234 S.W. Stark St.
Portland

PENNSYLVANIA
Hamtronics
4033 Brownsville Rd.
Trevose

Kass Electronics Dist.
2502 Township Line Road
Drexel Hill

Valley Electronic Supply Co.
101 N. 7th St.
Allentwon

West Side News
314 W. Crawford Ave.
Connellsville

TEXAS
Alltec Electronics Corp.
3854 Lexington Blvd.
Corpus Christi

Douglas Electronics Distributors
1118 South Staples
Corpus Christi

Ed Juge Electronics, Inc.
1514 Pennsylvania Ave.
Ft. Worth

Electronics Center, Inc.
2929 North Haskell
Dallas

Electronic Supply Co.
1524 Texas Ave.
Texas City

Hargis - Austin
410 Baylor
Austin

UTAH
Manwill Supply Co.
2511 So. State St.
Salt Lake City

WASHINGTON
Radio Supply Co.
6213 13th Ave. South
Seattle, Wa 98108

WISCONSIN
Amateur Electronic Supply
4828 W. Fond du lac Ave.
Milwaukee

Satterfield Electronics, Inc.
1900 S. Park St. - Box 1438
Madison

CANADA
Ham Shack
1566 A. Avenue Road
Toronto, Ont.

Payette Radio Limited
730 Rve St - Jacques
Montreal, Rue

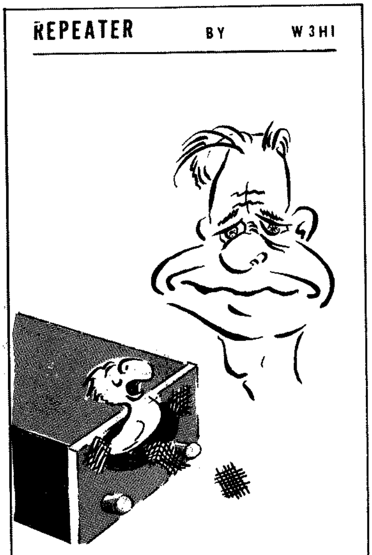
Rendell - Paret Electronics Ltd.
2048 West 4th Ave.
Vancouver, BC

Smalleys Radio, Ltd.
Box 6220 Station D
Calgary, Alberta

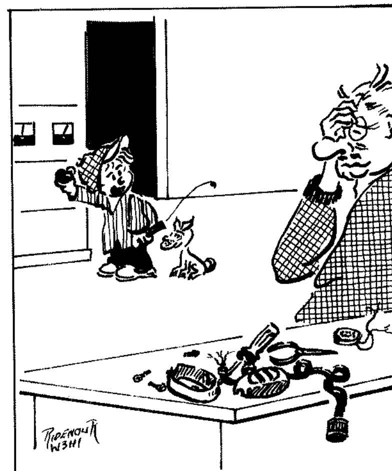
For counter sales information write to:

FM, Counter Sales
2005 Hollywood
Grosse Pointe, Mich. 48236

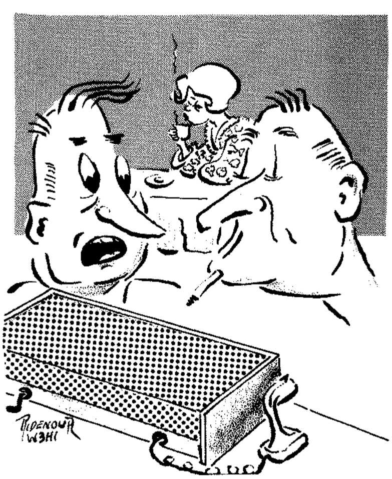
FUNNY MODULATION



"The distortion was in the speaker."



"I turned your transmitter off when I went out with my walkie-talkie."



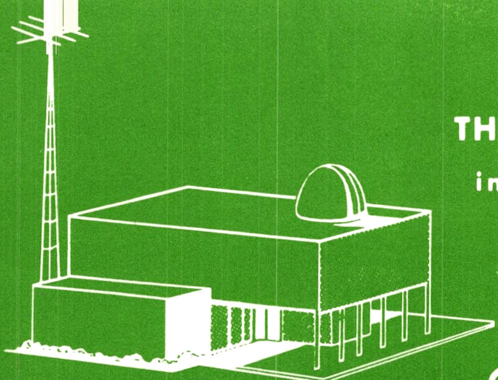
"No it wasn't burning but it smells like coffee."

"I'm not really chicken, but,-- he wants ME to take new coax to the top of the tower."

THE DAYTON AMATEUR RADIO ASSN.

invites you to attend the

DAYTON HAMVENTION



DARA STATION W8BI

Saturday, April 26, 1969

Exhibits . . .

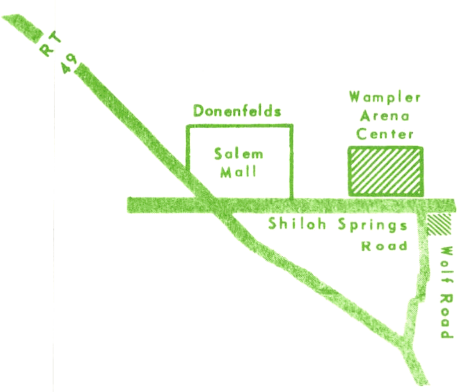
The following are among the many radio equipment manufacturers and parts distributors who will have their latest products on display during the Hamvention:

Amateur Electronic Supply, Milwaukee, Wis.
Antenna Mart, Rippey, Iowa
Collins Radio Company, Cedar Rapids, Iowa
Coston Electronics, Cincinnati, Ohio
Cowan Publishing Company, Port Washington, L.I., N.Y.
CQ Magazine, Port Washington, L.I., N.Y.
Cush Craft, Manchester, New Hampshire
Design Industries, Dallas, Texas
Ed Moory Wholesale Radio, DeWitt, Arkansas
E.F. Johnson Company, Waseca, Minnesota
E. T. Clegg Associates, Inc., East Hanover, N.J.
Evansville Amateur Radio Supply, Evansville, Ind.
E-Z Way Products, Inc., Tampa, Florida
Fallert's Engraving, Hamilton, Ohio
FM Magazine, Grosse Pointe, Michigan
Galaxy Electronics, Council Bluffs, Iowa
Hammerlund Manufacturing Company, Mars Hill, N.C.
Ham Radio, Greenville, New Hampshire
Heath Company, Benton Harbor, Michigan
HyGain Electronics Corporation, Lincoln, Nebraska
Kirk Electronics, Dayton, Ohio
L.A. Amateur Radio Supply, Redondo Beach, Calif.
Mosley Electronics, Inc., Bridgeport, Missouri
Organs and Electronics, Lockport, Illinois
Pioneer-Standard Electronics, Inc., Cleveland, Ohio
Raytrack Company, Columbus, Ohio
R. L. Drake Company, Miamisburg, Ohio
73 Magazine, Peterborough, New Hampshire
Signal/One, St. Petersburg, Florida
Spaulding Products Company, Frankfort, Indiana
Squires Sanders, Morris Plains, New Jersey
Srepco Electronics, Dayton, Ohio
Stellar Industries, Ithaca, New York
Swan Electronics Corporation, Oceanside, Calif.
Sylvania Electric Company, New York, N. Y.
Tektronix, Inc., Beaverton, Oregon
The Hallicrafters Company, Rolling Meadows, Ill.
Tri-Ex Tower Corporation, Visalla, Calif.
Universal Service, Columbus, Ohio
VHF Communications, Topsfield, Mass.
Waters Manufacturing Company, Weyland, Mass.

Wampler
ARENA CENTER

1001 SHILOH SPRINGS ROAD
DAYTON 15, OHIO

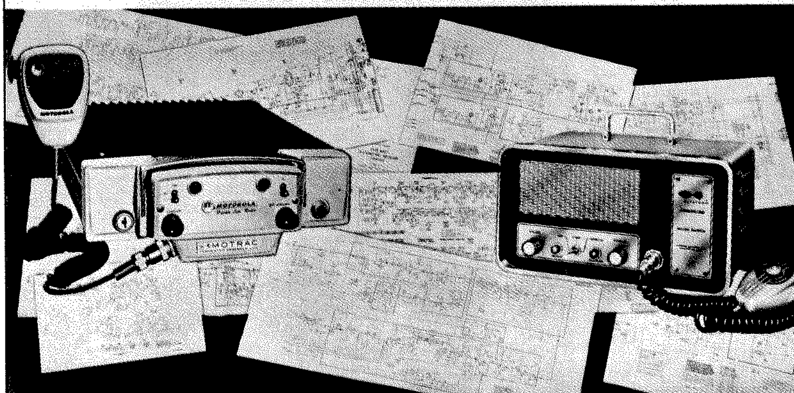
Minutes From Downtown



DAYTON HAMVENTION / BOX 44 / DAYTON, OHIO 45401

A Howard W. Sams PHOTOFACT PUBLICATION

communications equipment schematic manual



Complete schematic diagrams and basic theory for modern equipment, including:

- FM TRANSMITTERS
- DOUBLE SUPERHETERODYNE RECEIVERS
- POWER SUPPLIES
- ALIGNMENT PROCEDURES

This book presents principles and practices of tuning, aligning, and troubleshooting modern FM two-way radios. Actual circuits are shown and analyzed in such a manner that even individuals with little knowledge of transmitters and dual-conversion receivers can understand.

Dealing solely with radios operating in the 145- to 170-mc regions, *Communications Equipment Schematic Manual* gives detailed explanations, in block-diagram analyses, of the fundamental concepts of typical two-way transmitters and receivers. The content assumes no prior knowledge of radio transmission and reception technology as applied to the business services. Even if you do have a working knowledge of the principles and practices of modern two-way FM radio, you will find this book an excellent refresher, in addition to serving as a working service and reference manual.

Although tube-type radios are still in use, this book deals primarily with transistorized versions. Manufacturers are constantly changing over to semiconductors as the answer to more compact equipment and increased reliability. Therefore, if you aren't too familiar with transistor techniques as used in wide and narrow bandpass amplifiers, limiters, and speech amplifiers, here is a good opportunity to study them.

The book is broken down into five sections: basic theory on two-way radios; the FM transmitter; the FM double-superheterodyne receiver; power supplies; and alignment procedures—all clearly explained and profusely illustrated to provide easily understandable text for the equipment user, and valuable reference for the experienced technician.

only $3.95 postpaid

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ICE
2 METER FM TRANSCEIVER

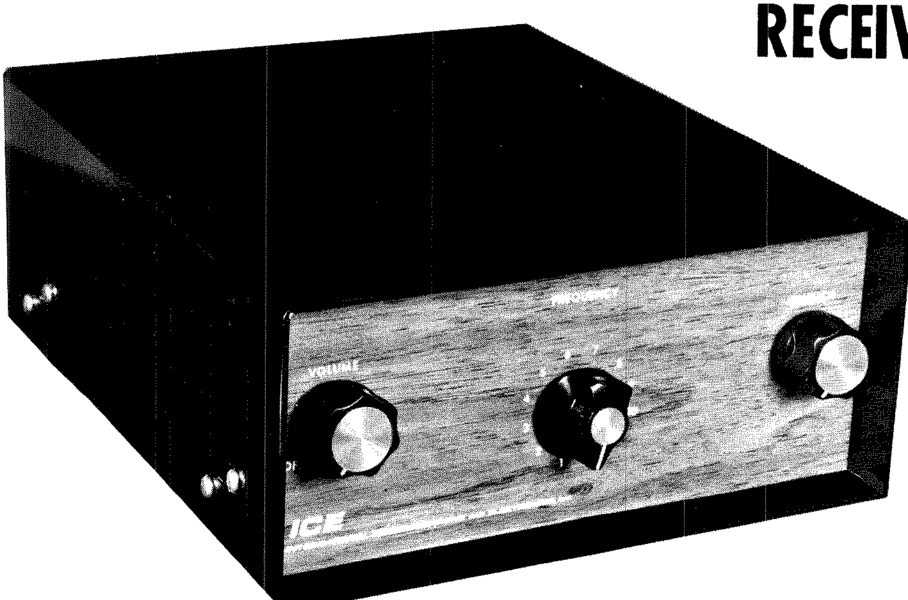
Circle Number **14** on Reader Service Card

- Small size: 8"w X 3½"h X 9½"d
- Light weight — Less than 4½ lbs.
- Simply plug in proper power cable to charge from 117 VAC to 12 VDC operation
- Transmitter and receiver channels individually switchable
- 3 channels transmit — 3 channels receive

INTERNATIONAL COMMUNICATIONS AND ELECTRONICS, INC.
1917 NW MILITARY HIGHWAY/SAN ANTONIO, TEXAS 78213/512 341-1311

- 12 channel operation
- Field effect transistor front end
- Operation on either 115 VAC or 12 VDC

ICE
2 METER FM RECEIVER



CIRCLE NO. 83 ON READER SERVICE CARD

FULLY SOLID STATE - NO TUBES

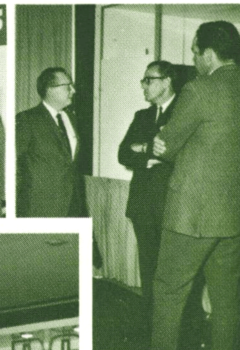
FM and the IEEE

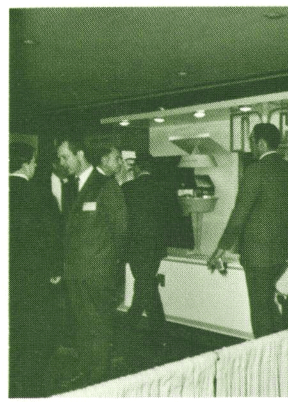
The Vehicular Technology Group of the IEEE held its annual conference at the Hilton Hotel in San Francisco in December, and FM was there. And so were all the big names in two-way radio . . .

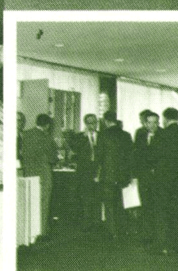
The hands-down success of the conference was foretold when the technical sessions began smashing all previous records for attendance. By the end of the second day, registrations proved the conference outdrew all previous such affairs.

Much of the credit for the radiofest's unprecedented success goes to Mr. R. B. Pearce, an executive of Standard Oil Company of California, who, by enlisting the services of his many associates, poured an unending torrent of advance publicity into key segments of the communications industry.

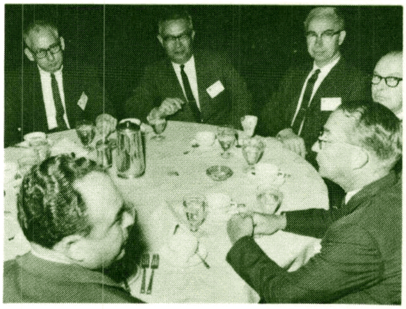
Many of the seminars were keyed to new developments in the communications field, and some of these were exhibited in the form of revolutionary products. One such advance in the state of the art was Amperex' new in-line high-power rf amplifier, described in the February 1969 issue. The photos here show the activity in the exhibit area and many of the conference's unnamed guests.







Fred Link, the man who made vehicular communications into an industry, tells Ken Sessions and Don Milbury some of the history of commercial communications. Herb Watson, a former key executive in Link's original empire and current business associate, laughingly remembers those "pioneer" days. Motorola Vice President Bill Weisz (extreme right) remembers too; when Fred Link's LINKs were the only two-way FM units on the market, Bill was a bright young engineer working for the company that was only later to become the giant of the industry. The discussion developed as a result of a mention of Bill Harris' satire in the January issue of FM, "It Started in Chocaga!"



FM

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FM is not responsible for the reliability of the statements made here in.

FOR SALE

GE PROGRESS LINE, Parts & Accessories:

Control Unit 4EX17A	$10.00
Control & Power Cables	12.00
Speaker 4EZ4A	4.00
Crystal Ovens	3.00
Microphone Reluctance	5.00
Microphone Carbon	5.00
Handset w/carbon Mike	3.00
Mobile P.S. 12v EP2K	8.00
14" Case w/basket	10.00
Rec. Strip ER25	35.00
Trans Strip ET21A2	30.00
Rec Strip ER24A12, 2 freq.	55.00
Trans Strip ET22A13, 2 frq.	45.00
Mobile P.S. EP2M1 Vib	20.00
Remote Control Panel KC7B	25.00
P.L. Portable n/cad Bat.	90.00
Mobile Audio Amp EA12A	29.00

GE Pre Progress 150-170 MHz, 12 volt, 25 watt 4ES16, complete with accessories. Sold as is: $40.00 M.H. Klapp, W2EQV, 25 Gladwish Road, Delmar, NY 12054

WIDE-BAND FILTERS, Permakay type K8436A with installation inst. - $5 ea. Great Lakes Repeater Assn., 20245 Oakfields, Detroit, Mich. 48235

SECODE ENCODER with 40 function control. Ideal for repeater control. $60 W. Wallace Murray WA8OXK, 5696 Williamson, Dearborn, Mich.

GE PROGRESS LINE mobile MA/E-13, 30 watt, 6/12 volts, operating on 52.525 and 52.640 MHz.. With antenna, control head, Mike and all cables. Will Trade for Two Meter FM base operating on 146.340 and 146.760 MHz. Gary L. Blacksmith Jr., 21 Granada Bldg., Briarcrest Gardens, Hershey, PA 17033 Phone: (717) 533-9237

LAVOIE 70B frequency meter $500.00. Range 10 Khz to 3.0 GHz with 0.0005% accuracy. Lamkin 205A modulation meter, $50.00. This equipment meets FCC requirements. For further information call or write C.C. Stratton, 4882 E. Nevada, Fresno, CA 93727 Phone: (409) 227-2234

GE PROGRESS LINE receiver, lo-band, completely narrow-band $40.00. Progressline accessories-Includes: cables, control head and mike $5.00 per set. R.S.M.C. lo-band receiver-transmitter strip 30 watt transmitter. Wide band receiver $20.00 for both units. Telephone equipment from magneto to touchtone · equipment. Ken Anderson, K7LDZ, 1229 9th Ave., SW., Great Falls, Montana 59401

CONVERTERS, three transistor, low noise, 50-54 MHz in, 14-18 MHz out. Adjustable frequency, $5. Crystal controlled, $6. Syntelex, 39 Lucille, Dumont, NJ 07628

MOTOROLA FMTRU-80D, dual frequency, less control head and cables, good condition, $50.00; also Motorola FMTRU-41V complete, like new. Hood May, Jr., 2883 Redwing road, Memphis, TN 38118 Phone (901) 363-0672

LAMPKIN 205-A FM Modulation Meter, new quad scale model, perfect cond. $200., BC-221 Freq Meter w/cal book $35., Heath PS-3 Bench 0-500V Var Reg P/S $18., PTE 12/w FM transceiver, like new on 146.940 MHz w/ control, spk, cables $50., GE Pre-Prog 30w T-Powered on 146.94, w/ control $65., GE 50/w on 150 MHz w/ control $50. W. Davis, 4434 Josie Ave., Lakewood, CA 90713

HAYDO time delay relays, 3 min. ideal for your repeater. Repeater Station, W8LGL /W8AIC, 15 N. Franklin St., Delaware, OH 43015

MOTOROLA T61GJD-41, low band,—110 watt with "P.L." receiver; dynamotor needs brushes; unit complete with 15" housing and key lock and TAB 1032B low band swivel-base antenna complete with whip: no Cable Kit or accessories; however accessory items can be negotiated. $85 Contact: Bill Michals, 1726 N. 78th CT., Elmwood Park, IL 60635

FM EQUIPMENT, The following units are for 12V and are complete with cables, control head and speaker, Where frequencies are indicated units have been tuned and are ready to go, complete with crystals. GENERAL ELECTRIC: 75 watt Progress Line, 2 channel, 52.525 and 52.640 mhz - $140; Voice Commander II all transistorized with 2 channel 1 watt transmitter, receiver, nicad batteries and charger, 146.940 mhz - $125; 30 watt TPL Highband, rear mount, with 10 watt power speaker- $150. MOTOROLA: 30 watt 80D, 2 channel, 52.525 and 52.640 mhz - $100; 60 watt modified 80D with sensicon receiver and nuvistor pre-amp, 2 channel TX-146.94 and 146.34, RX-146.94 mhz - $110. WANTED: FM signal generator either MILITARY or MEASUREMENTS MODEL 80. State price and condition in letter. All units sold FOB Plainfield N. J. W3AUK/2 131 King Srreet, Fanwood, N. J. 07023 201-889-4788.

FIVE TRANSISTORIZED SECODE, Model TGS735-M1 Encoders; One Secode transistorized Model SD30 Decoder, Tone Frequency 1500; Encoder Cables Plug into control head mike socket. Presently wired for GE Progress Line. When New this equipment. William Thorpe. P.O. Box 306, Southborough, Mass. 01772.

MOTOROLA CRYSTALS, mfg by International,
52.525 MHz: 2-R04, 2-R02, 1-R10, 1-R22
50.290 MHz: 2-R04, 2-R02, 1-C01, 1-C02
432-050 MY z: 2R24, 2-A15
Make offer for one or all. Wanted: 250TH, Norman Coltri, Box 199, Landisville, NJ 08326

RCA CMU-15A, Professionally overhauled, 450 MHz, complete with all accessories, crystaled and tuned to frequency, $100. Hammarlund HQ130C with speaker, $225. Tapetone XC144, 2 meter converter, $30. SASE for more details. John Gubernard K2LSX, 220 MT. Vernon Pl, Apt. 6A, Newark, N.J., 07106

MOTOROLA T44A-1, 450 MHz 12 volt, mobile with accessories, $35. As above, but less transmitter strip, $20. Also, need hi-band mobile or portable gear in good condition. J. M. Hagedon, K8YQH, 1265 Cloverfield Ave., Dayton, Ohio 45429

GE PROGRESS LINE, T-power, 100 watt mobile unit, 12 volt. Now on 52.525 MHz Like new inside and out including all accessories, manual, and Antenna Specialists mobile antenna. $200 plus shipping. Mallory Pickens, 4045 Xenwood Ave. 50., Minneapolis, MN 55416

LINK 60 WATT, 3-foot upright base station or hi-band, 829B final, audio termination panel, handset and hanger box, pre-amp, solid state HV supply, clean, $100. George Evans, K2SLI, E. George St., Freehold, N.J., 07728

MOTOROLA D33BAT, hi-band FM Transistor Dispatcher and Portable H23BAM: $100 each or offer. Complete, on frequency, guaranteed. STATER, WA7IKJ/4, 3535 Marbin St., Annandale, VA 22003

MOTOROLA DISPATCHER, 8 watt, hi-band, T-power transceiver state price and condx. All replies answered. Jack Molnar, WA3-ETD, III S. Allen St. #45, State College, PA 16801

MOTOROLA 80D, 12 volt, with 52.525 xtals on freq., two freq unit with head, $80. Also Dumont model 301, 12 volt with 146.940 & 146.340 MHz crystals, with head and cables, $40. Ed Pores, WA2ZBV. 16 Dorchester Drive, Manhasset, NY 11030

MOTOROLA 5V, 12 volt, operating on 146.940 MHz complete with head and cables, also with Pre-Amp $55.00. William Baxter, 402 E. Jacinto, Tucson, AZ 85705

WANTED

MOTOROLA MOTRAC, or GE MASTR or TPL lowband unit (to cover the 36-42 MHz split). Will consider unit with or without accesories, operating or not, but do want a unit with PL or reed-type tone squelch. GE TPL 30, 60, or 100 - watt transmitter and power supply capable of covering 36-42 MHz split. Want Motorola PT-200 style handie-talkie (450 MHz) with PL. Want Motorola TU-217 "Vibrasender", code YZ (82.5 Hz) or code ZA (94.8 Hz) and TU333 Vibrasponder, code YZ or ZA. Alfred A. De Figio, Box 524. Republic, Pennsylvania 15475. Phone (412) 785-6320

RCA MODEL CX-9A, KHz I-F Alignment oscillator, Gerry Baldauf, 175 Werneville Blvd., Wernerville, PA. 19565

MOTOROLA TU112, AC POWER SUPPLY. L44AAB Motorola desk top base station. Also best deal for info. on how to use Touch - Tone loop around & blue box multi-frequency. Robert Young, 319 Wyatt Rd., Harrisburg, PA., 17104

DUPLEXER, for 440 & 446 MHz. Robert Young, 319 Wyatt Rd., Harrisburg, PA 17104

MOTOROLA P8501A, Portable test set manual, also Ocs. decks P8465 for Motorola FMTRU 80D transmitters. George B. Meserole. WAZUCP, 647 - 88 Street, Brooklyn. New York. 11228

GE PROGRESS LINE, 12 volt power supply, lo-band, also motorola PK Filter #K9035A. contact; Edward Matthers, WA8MWS, Box 164, Bridgeport, Mich. 48722

HANDIE - TALKIE, or Packset operating on 146.940, hi or low power. Looking for trade-let me know what you need. Prefer local deal. Al Klein, 214 E. Mineola Ave., Valley Stream, N.Y. Phone (516) 825-0384

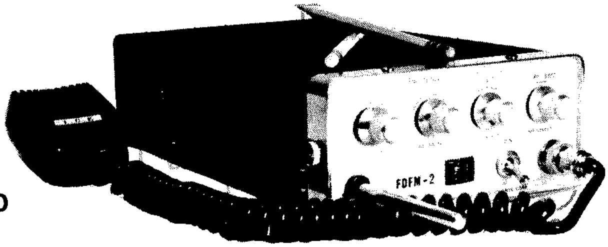
INDUSTRIAL PS-150, two way Radio packset information. Need Crystal, battery and IF info. Also crystal information on LINK transmitter 1872 and rcvr 1873. Warren, 9017 - 8th Ave. S.W., Seattle WN. 98106

455 KHz PERMAKAY FILTER, used in the W8BCI Two - Meter FM Handie - Talkie. See Dec. '67 'FM' or June '62 QST. page 37. Need two units. Paul Frankle, 215 Stewart Hall, Angola, IN 46703

MICH. ARRL CONV., May 9-10 at the Grand Rapids Civic Auditorium and Pantlind Hotel in Grand Rapids, Michigan. FM meeting 11 a.m. Saturday, May 10. See ad in this issue. Check in on 52.525 or 146.940

DAYTON HAMVENTION, April 26, 1969: Sponsored by the Dayton Amateur Radio Association for the 18th year. Technical

VARITRONICS REVISITED



The Varitronics people (4109 N. 39th St., Phoenix) proved two things to FM: They have a deep respect for the FM'ers' fetish about being on frequency; and they are as conscious of quality as any of the communications giants. The off-channel condition of the Varitronics FDFM supplied for review in the January issue was caused by erroneous frequency correlation on the part of an unnamed American crystal maker. Varitronics wised up quick and learned not to experiment on such an important area as frequency — they cut the crystal supplier off cold! As a result, the FDFM's appear now to be rock stable and dead on the frequencies of operation.

Plaudits and orchids and other niceties to Varitronics for nipping in the bud a situation that could have created many headaches for FM'ers had it not been checked in time.

SEE IT AT THE DAYTON HAMVENTION - APRIL 26

MICHIGAN STATE 1969 ARRL CONVENTION

MAY 9-10

PRESENTED BY THE
GRAND RAPIDS AMATEUR RADIO ASSOCIATION
AT THE
GRAND RAPIDS CIVIC AUDITORIUM AND PANTLIND HOTEL IN
GRAND RAPIDS, MICHIGAN

FM MEETINGS, etc-etc &etc....

CONTACT WA8ABT FOR FM INFORMATION
5646 SKYWAY DR.
Comstock Park, Mi. 49321

SUMMER 1969

Mann COMMUNICATIONS

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Used Two-Way FM Units · Microwave
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Repeaters · Walkies · Mobile Phone

Unless otherwise specified, equipment is used, and is sold as-is. All items shipped FOB Tarzana, California. Crystals, ovens, antennas not included unless specifically stated in catalog. All equipment is sold on a first-come, first-served basis.

TRANSMITTER STRIPS

Motorola 80 D * 30 watts * low band...... $14.98

ITT MT 600 * high band $24.98

...for that "extra channel" capability

ITT MT 600 Receiver strips $35

Pwr supply strips (mobile) 30 watts $20

Used CRYSTAL OVENS

For RCA or GE $3

For Motorola $1.50

Lots of 12 $1

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NARROWBAND $85

50 MHz BASE STATION

REMOTE CONTROL $25

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CONTINUOUS TONE SQUELCH

Compatible with major manufacturers' tone equipment, such as

PRIVATE LINE * CHANNEL GUARD

QUIET CHANNEL

Be sure to specify type of equipment in which SILENT SENTRY is to be mounted. List frequency desired. Allow approximately thirty days for delivery.

SPECIAL DEALERS' PRICE . . . $69 Mounting bracket $5.95

BASE STATIONS

Motorola 2 meters

FSTRU 140 BY	60 watts	...	$200
FSTRU 140 BR	60 watts	...	224.95
FSTRU 520 BR	250 watts	...	495

6 meters

FSTR 140 BY	60 watts	...	174.94
FSTR 140 BR	60 watts	...	200
FSTR 520 BR	250 watts	...	475

GE HIGH BAND 2M Fifty watts F1-36N $250

LOW BAND 6M Fifty watts F1-16N $250

GE 450 MHz F1-42N 15 Watts $249.98

MOTOROLA * * * * * * * * * * * *

DESKTOP L44AAB 450 MHz 15-18W $123.95

In OUTDOOR HOUSING Model J44AAB 450 MHz $160

HIGH BAND FSTRU 80 BY 30 watts $149.95

GE Base station 15 – 18 watts out PRE-PROG 460MHz $125

MANN COMMUNICATIONS

GE WTA/E33 mobile telephone unit
6/12 volts - 25 watts
$134.95
without accessories

MOTOROLA TA104
6/12V vibrator pwr
STRIPS
25 watts **$19.95**

MORE TWO METERS

THE BUYS ARE BETTER AT **Mann**

MOTOROLA **$19.95**
Transmitter strips
TA139 6/12V 2 meters
Twenty-five watts of rf

GE 450 MHz
T-POWER MODEL MT42
Includes ALL accessories **$195**

DuMont 450 MHz mobile
M-430-RTN 50W NARROWBAND
NEW! on channel, w/xtal:
****
No warranty **$399**
UNTUNED, LESS XTALS: **$350**

RCA
16-18 watts CMU 15B
Includes control head,
mike, speaker, cables.
6/12V
$75 Without accessories: **$55**

RCA
16-18 watts CMU 15A-1
Includes control head,
mike, speaker, cables.
6/12V **$40**

450 MHz

GE ME 42
16 watts PROG LINE
Includes control head,
mike, speaker, cables
6/12V **$175**

GE
6/12V 16 watts
PRE-PROG 4ES 14A1 **$75**
Includes control head, mike, speaker, cables.
Without accessories: **$50**

MOTOROLA T44 AAV
6/12V
up to 20 watts output
Includes control head,
mike, speaker, cables. **$65**
Without accessories: **$45**

See also BASE STATIONS listing for other 450!

MOTOROLA T44 A6A
6/12V
up to 20 watts output
Includes control head,
mike, speaker, cables **$55**
Without accessories: **$40**

Many other items available that are too numerous to list herein.
Late model equipment available in limited quantity; call for quote.
For the convenience of out-of-town buyers, we maintain one number
that is answered only by **JIM MANN** or **BOB KRANHOLD:** (213) 342-0375

MANN COMMUNICATIONS