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 [73] Assignee **the United States of America as represented by the Secretary of the Navy**

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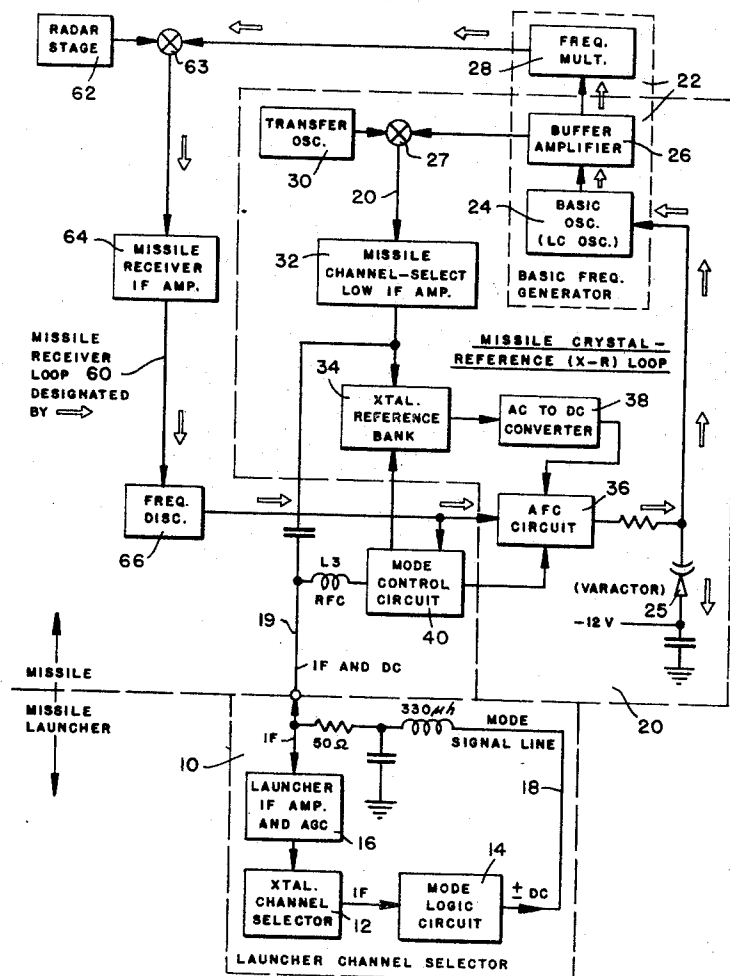
[54] **MULTICHANNEL FREQUENCY-SELECT SYSTEM**
 4 Claims, 12 Drawing Figs.

[52] U.S. Cl. **343/5, 343/7**
 [51] Int. Cl. **G01s 9/02**
 [50] Field of Search. **343/5, 5 (AFC), 7 (RS), 17.5, 17.7**

[56] **References Cited**
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ABSTRACT: A multichannel frequency-select system which allows for operation of a remotely-controlled device, for example a missile, at various frequencies, e.g. radar frequencies. In the missile, there is located a crystal bank capable of generating a set of reference frequencies one at a time, each crystal of which holds a basic oscillator in a standby position. An automatic frequency control (AFC) circuit in the missile provides a two-speed sweep-ramp voltage for changing the frequency of the basic oscillator by controlling a voltage-sensitive capacitance or varactor, in the tank circuit of the basic oscillator. A channel selector unit based in a missile launcher provides means to select the desired channel of operation in the remotely-controlled device by furnishing the proper mode voltages, which are related to the sweep voltages, in the device at a precise time.



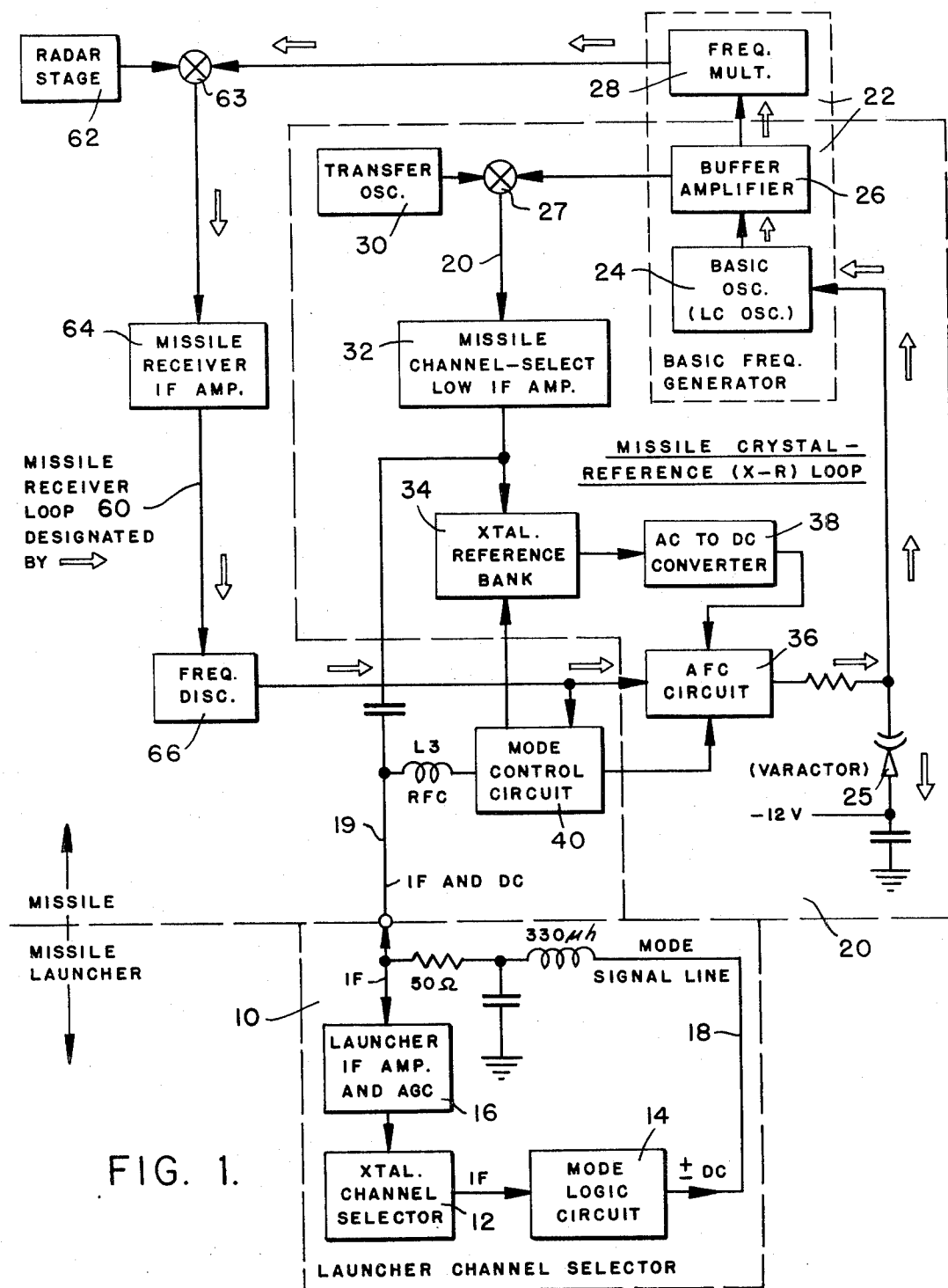
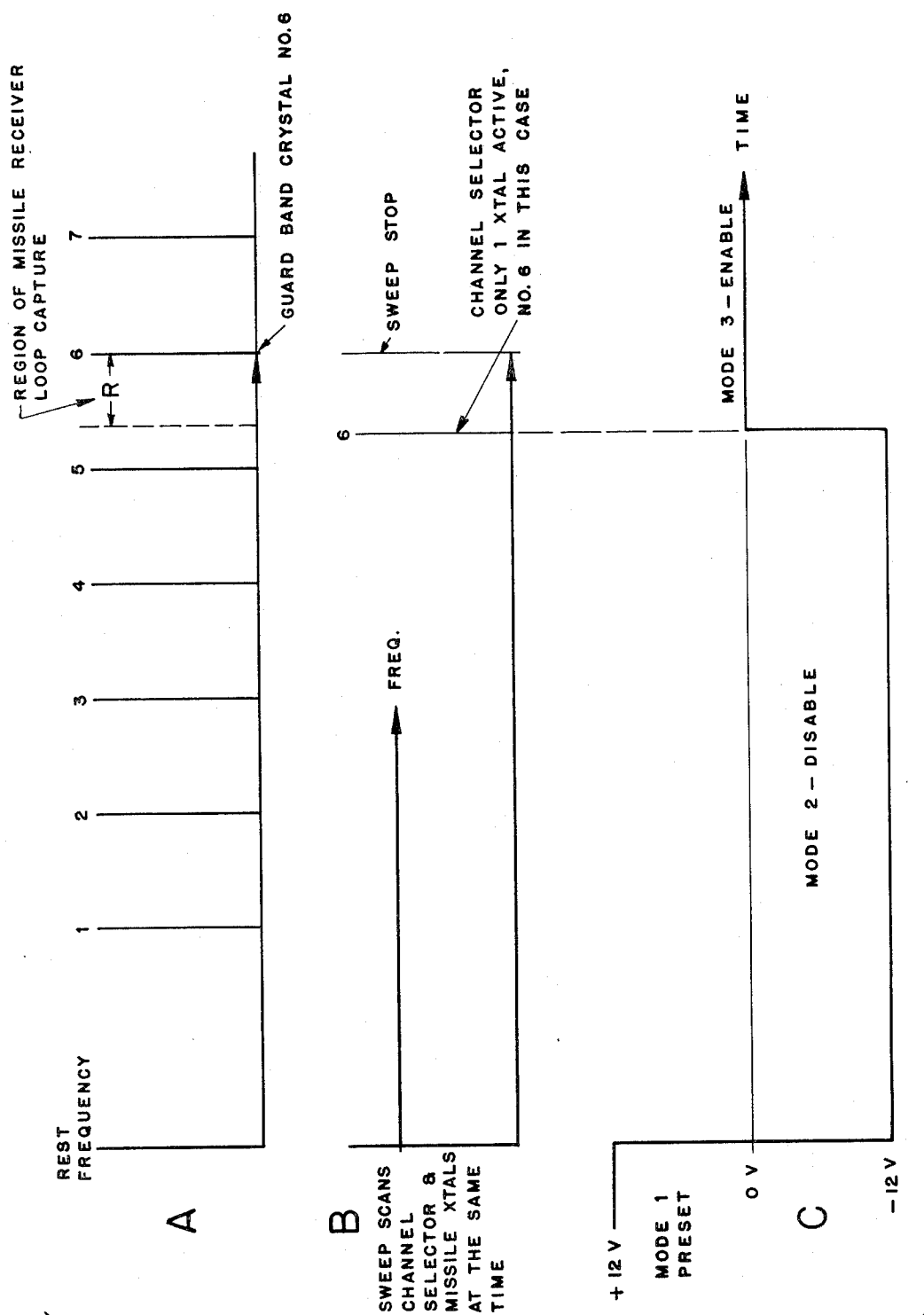


FIG. 1.

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REGION OF MISSILE RECEIVER
LOOP CAPTURE

REST
FREQUENCY

1

2

12

५

15

CO

2.

2

GUARD BAND CRYSTAL NO. 6

SWEEP SCANS
CHANNEL
SELECTOR &
MISSILE XTALS
AT THE SAME
TIME

FREQ.

WEEP STOP

CHANNEL SELECTOR
ONLY 1 XTAL ACTIVE,
NO. 6 IN THIS CASE

MODE 1
PRESET

MODE 2 - DISABLE

MODE 3 - ENABLE

TIME

 $+12V$

VO

-12 V

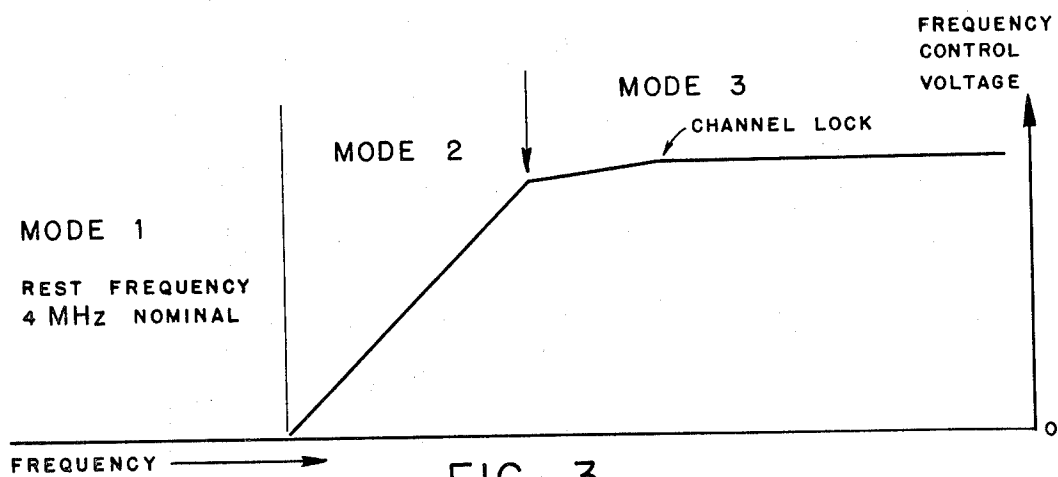
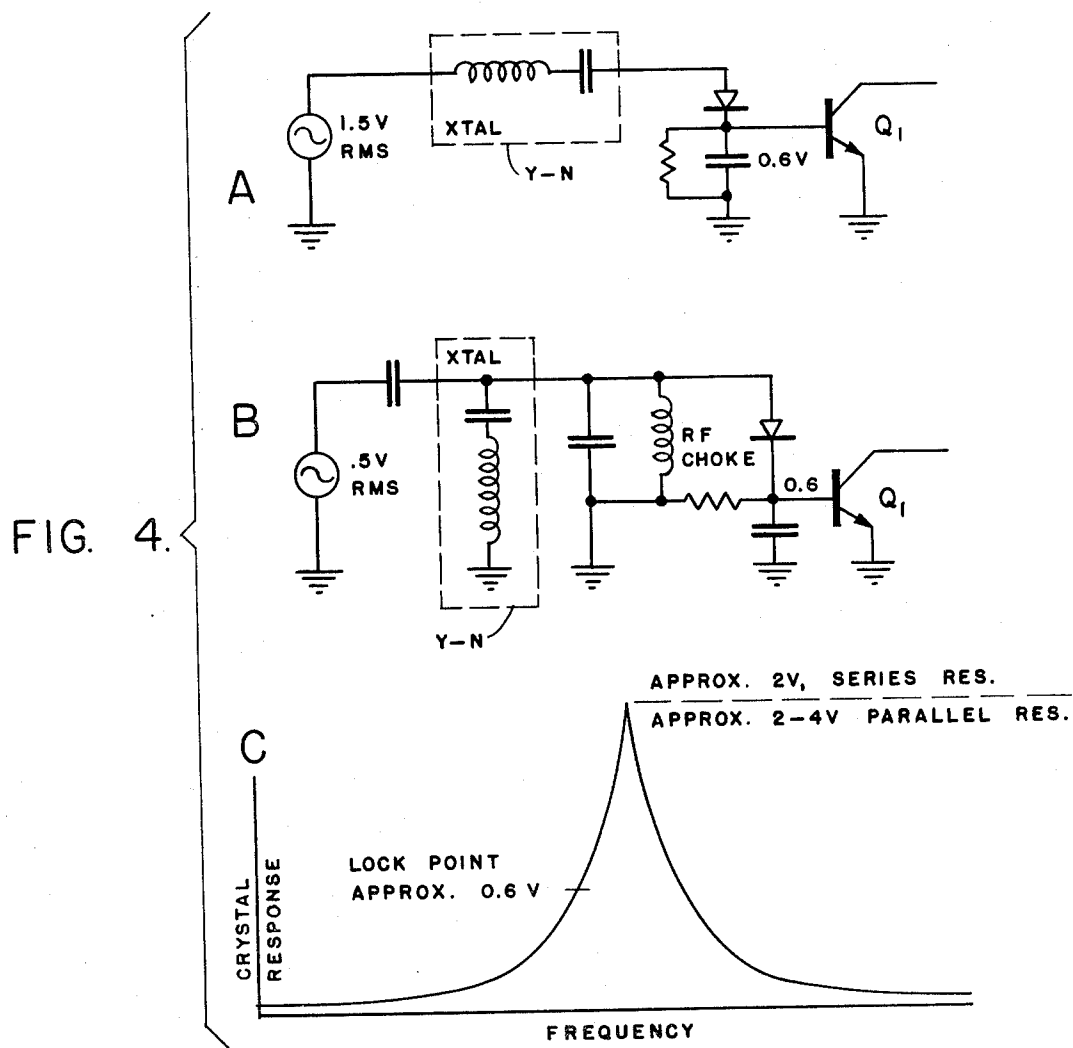
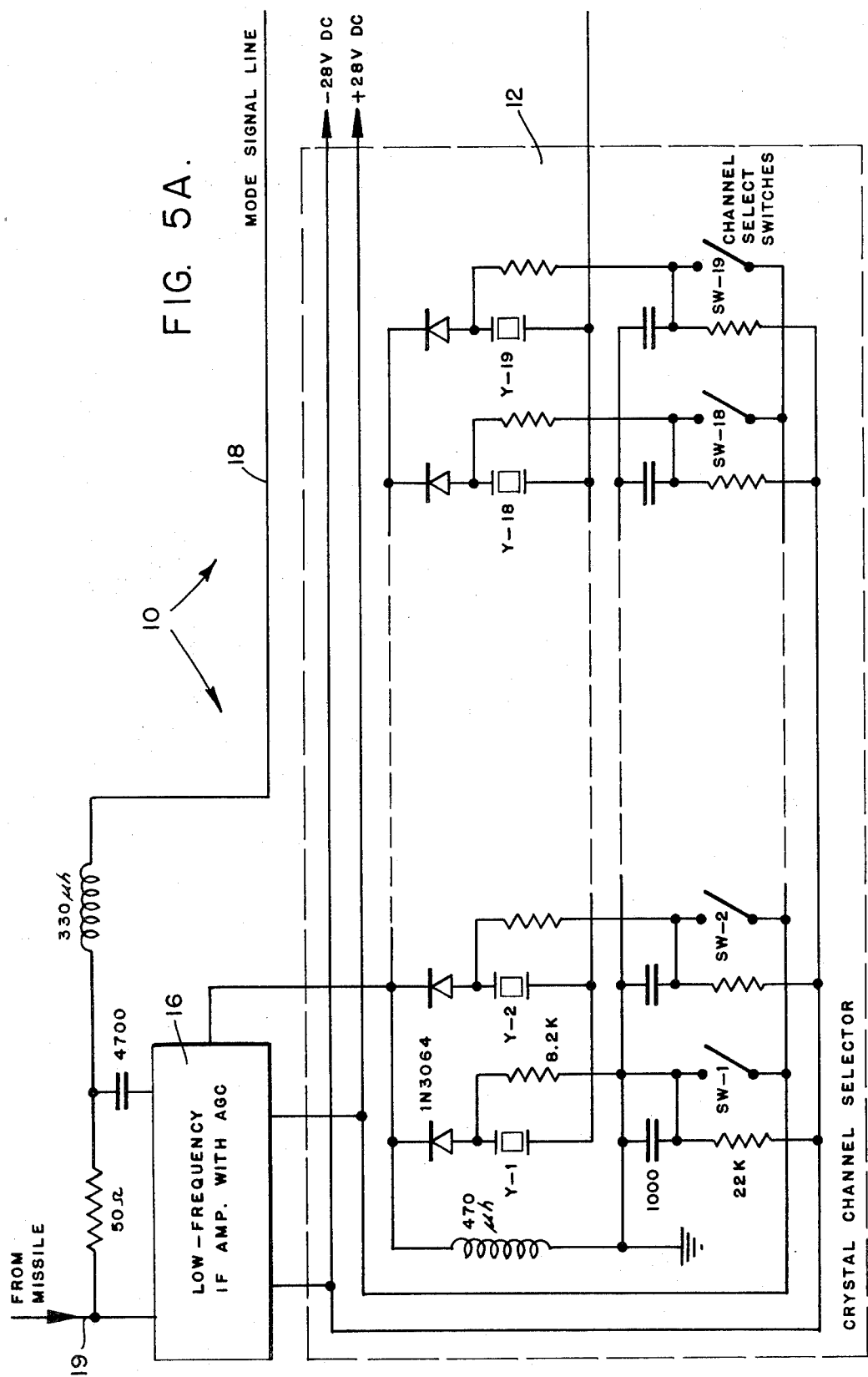


FIG. 3.





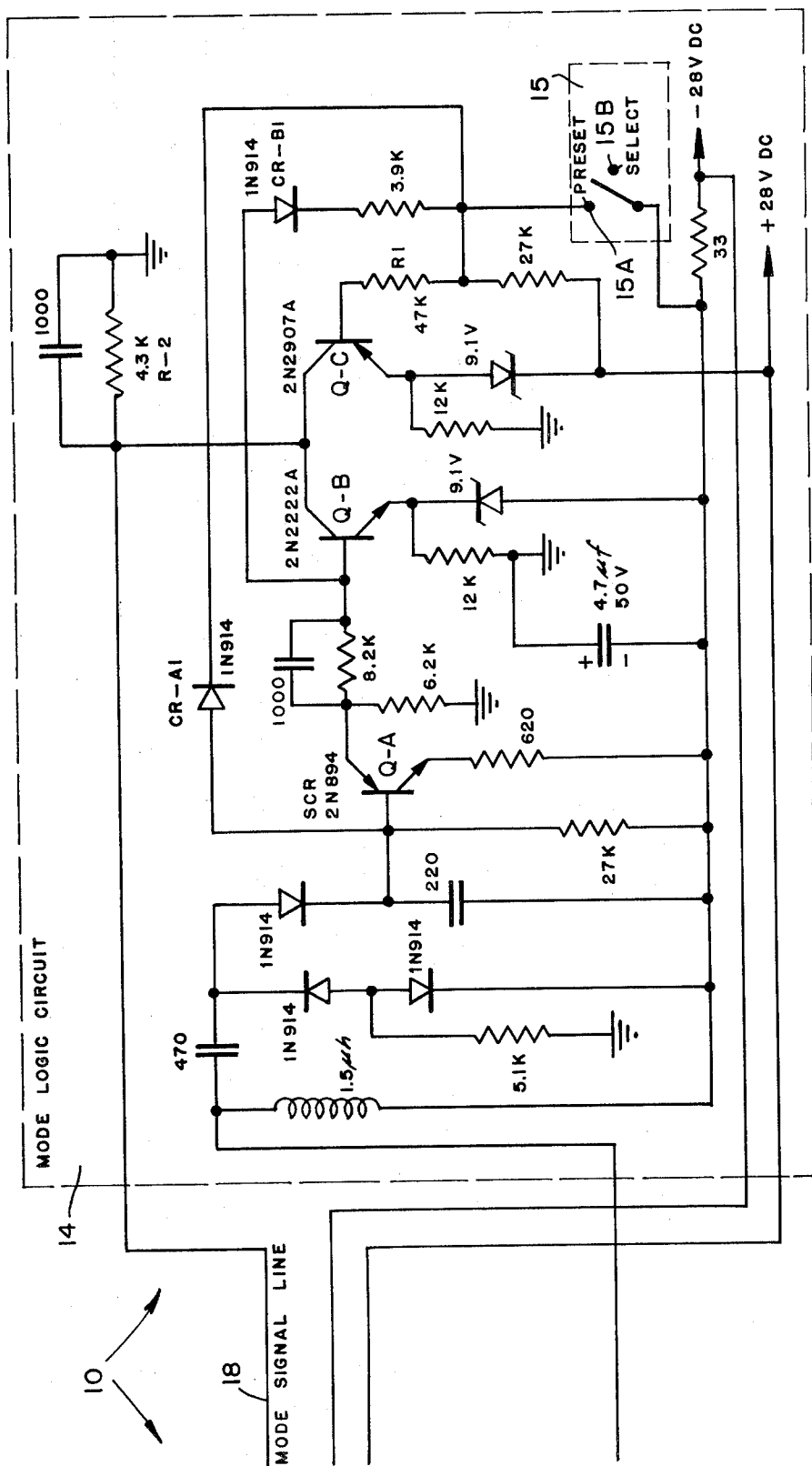


FIG. 5B.

NOTE
EXCEPT AS NOTED
ALL CAPACITANCES ARE IN μf

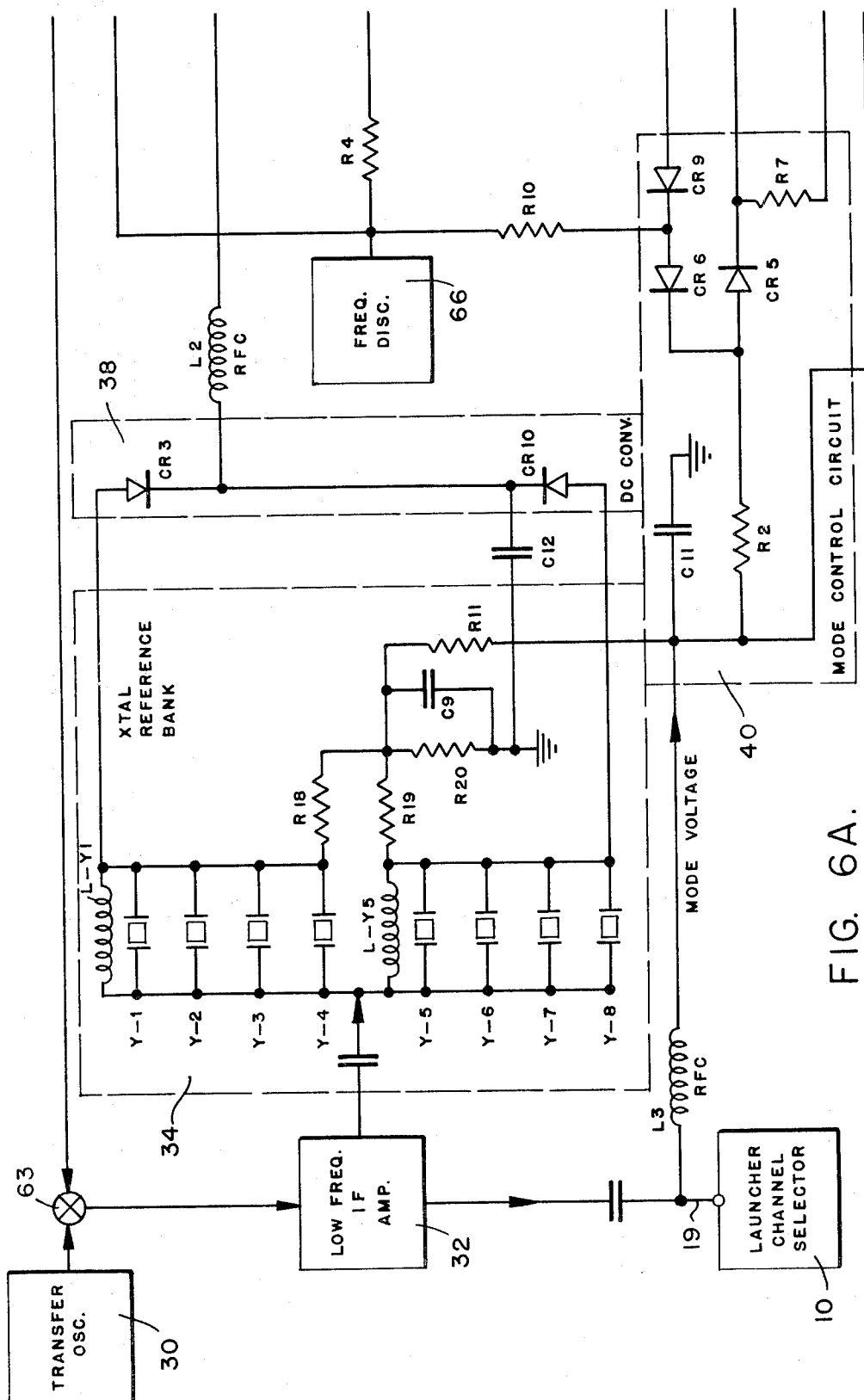
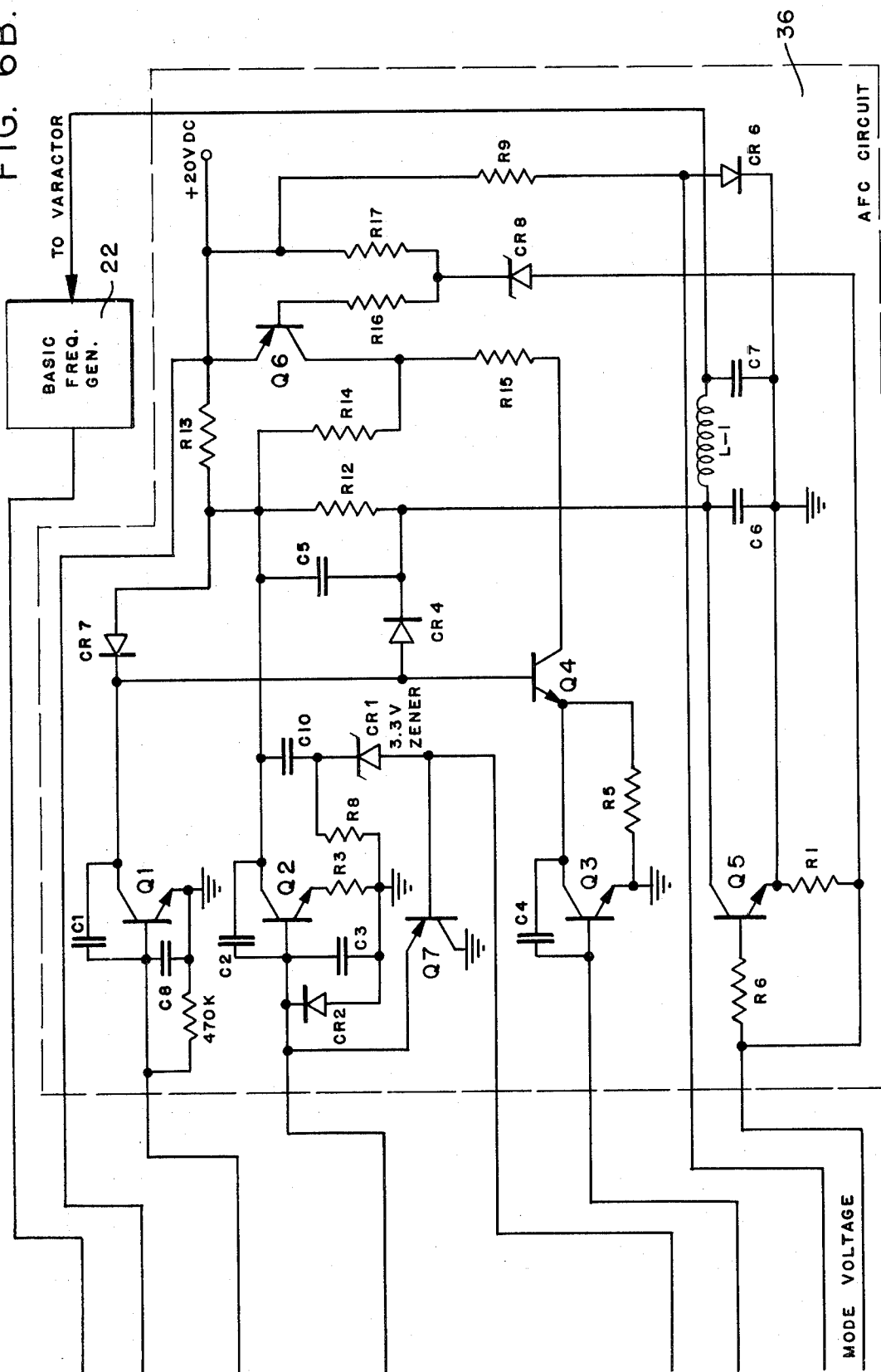
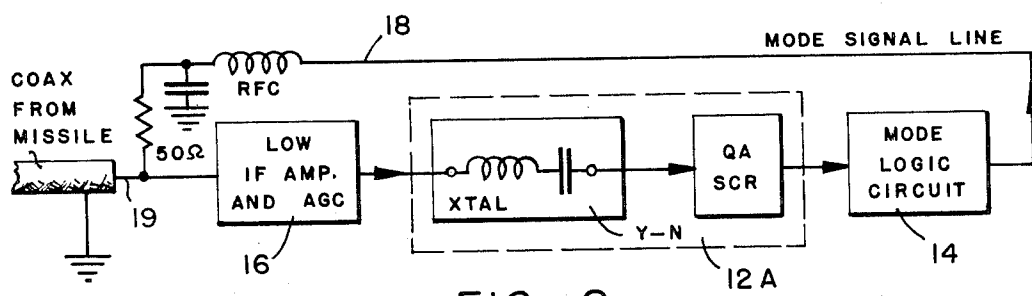
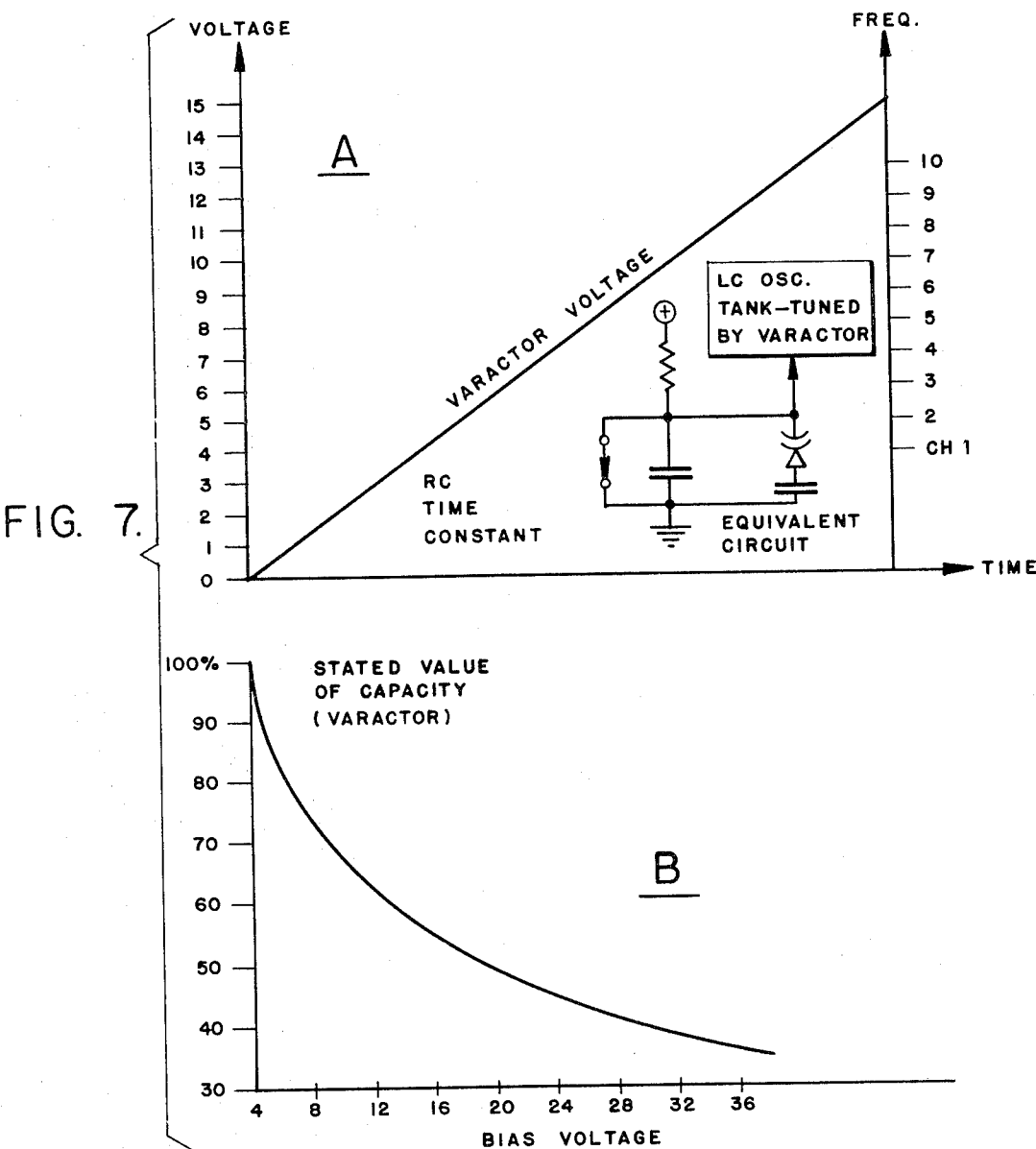


FIG. 6B.





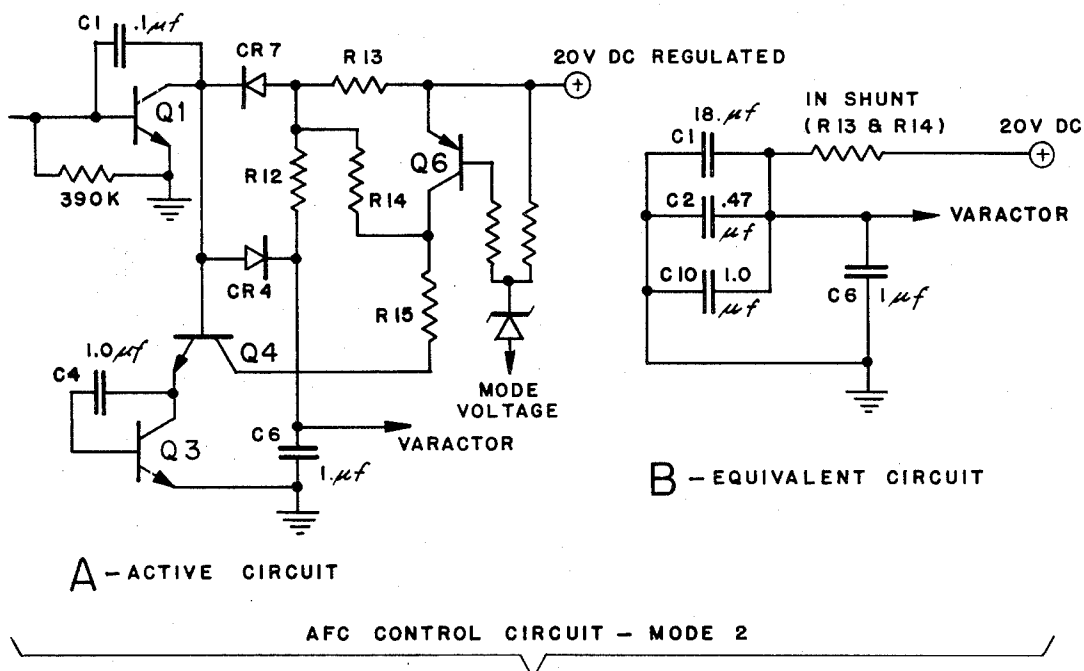


FIG. 9.

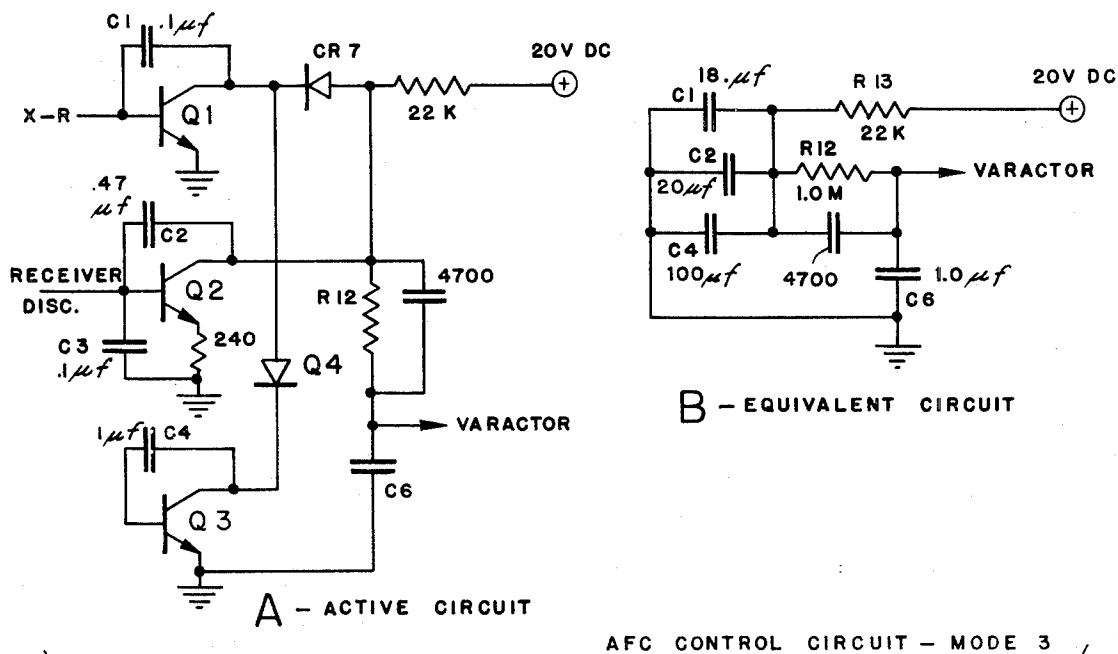


FIG. 10.

MULTICHANNEL FREQUENCY-SELECT SYSTEM

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

In the prior art, are multichannel frequency-select systems and there are systems incorporate a sweep voltage which aids in obtaining the desired frequency of operation. However, they all have disadvantages which will be pointed out in the brief description which follows.

The first system of the prior art to be discussed includes a system wherein there is a dual output from a discriminator network, each output being similar in shape to a typical FM discriminator output, one discriminator output being the mirror image of the other. A key feature of this prior art system is that the local oscillator locks a frequency determined by one of the discriminator outputs and not the other. Strictly speaking, this system hardly qualifies as a frequency-select system, inasmuch as the system merely discriminates between two sideband frequencies. The second multichannel frequency-select system to be discussed solves the difficulties involved with a phase-lock oscillator operating at more than one frequency, in that in order to properly lock onto the desired frequency, a sine wave, derived from the output of the oscillator, is sampled preferably at the zero crossing for that frequency. However, it is difficult to have sampling at precisely zero crossing for more than mitigated. frequency. temperature-compensation can temperature-compensated temperature-sensitive detrimentally

In another system in the prior art, there is a crystal-controlled oscillator whose frequency may be varied to a limited extent, thereby permitting several output frequencies when passed through various narrow-band filters. As may be seen, this system has the disadvantage that the several selectable frequencies must be close to each other. Another prior art system includes a method of precision tracking of electrically tuned circuits, wherein a control voltage for a reactance element is obtained from a discriminator of an automatic frequency control circuit of an oscillator. If the frequency of the oscillator drifts, the output voltage from the discriminator drifts in a direction which would tend to bring the oscillator frequency back to its desired value. The same incremental DC voltage change is applied to a reactance element in a tuned circuit to be controlled, so that the frequencies of the two tuned circuits are effectively locked together. In addition, there is featured a means varying a basic oscillator frequency, for example by inserting one of several alternate resistors in series with capacitive reactance elements of the tank circuits. The system herein described is rather complex and has the further disadvantage that it includes many sets of tapped switches, which tapping is always subject to corrosion and poor contacts, thereby causing very noisy circuits. It should be pointed out that, in all of the prior art just discussed not of it had the feature of controlling an oscillator frequency at a remote location. The invention herein disclosed describes a multichannel frequency-select system wherein it is desired to select a frequency at one location, for example on a missile launcher channel selector with the same channel at a remote location, for example, an oscillator located on a missile.

Following is a brief description of the invention.

Inasmuch as the system operates in three different, successive, modes for the circuitry in both the missile launcher and the missile, with a specific mode of

in the launcher preceding that of the same mode in the missile, the multichannel frequency-select system will be described with particular emphasis on the modes of operation.

Mode 1 is a preset mode, in which the frequency of oscillation in the missile is a rest frequency.

Mode 2 is a "channel" select mode in which the frequency spectrum covered by the crystal bank in both the missile launcher channel selector and the missile is swept or scanned at a rapid rate.

Mode 3 is an acquire mode, wherein the scanning rate slows down and stops when lock is acquired.

Modes 1 and 2 may be manual or timer-controlled or work on AGC, missile battery power, or when the heterodyned signal from a low-frequency IF amplifier is present and detected in a switching device. Mode 3 is initiated electronically by the sweep scan frequency corresponding to a plotted crystal or band-pass frequency in the launcher channel selector unit. attenuation network radio be transmitted

The manner in which the various channels are changed and tracked is a key feature of this invention. In the missile, the whole F1 19 different crystal-controlled frequencies and the single F2 the shown. selector in the embodiment disclosed, is scanned, at a rapid rate in Mode 2. ohms. The channel selector in the launcher completes its function when the scanning frequency corresponds to the channel crystal selected, this in turn initiates Mode 3. The channel selector becomes inactive after Mode 3 is initiated.

In the missile itself there is a circuit in which the time changes (with a longer time constant in Mode 3), the change in the time constant being in step with the variation in the frequency scanned in the missile crystal bank. When the intermediate frequency (IF) in the missile, which scans upward in frequency, corresponds the desired frequency of the crystal in the crystal band of the missile, it represents the desired channel, the sweep is stopped and the AFC of the crystal reference loop or the receiver loop takes over. There may also be a return radar signal reflected off the missile and returned back to the missile launcher, which may assist an automatic frequency control (AFC) circuit equalizer the missile launcher in locking onto the specific desired frequency. db

As stated above, there are two μ banks, H; the missile launcher and one in missile. The resonant frequency of a particular in the crystal bank on the missile launcher is lower than the frequency of the corresponding in the crystal bank the missile, thus allowing for sweep time in the launcher to lock onto the proper crystal μ H; μ H;

The sweep of the frequencies 12 the missile launcher channel selector is in step with the sweep of the frequencies in the missile crystal bank. The sweep of the frequencies originates in the missile and this compensating is the same in the missile launcher channel selector. A signal goes back from the missile to the missile launcher channel selector. The same sweep and IF appears in both, the missile and the missile launcher. When the sweep frequency in the missile launcher channel selector attains the desired frequency in the channel selected an SCR transistor fires and initiates Mode 3. The sweep continues at a much slower rate. Once the desired frequency is acquired, with a specific crystal frequency chosen from the crystal frequency bank the missile, the sweeping operation ceases. An AFC circuit in the missile launcher locks the chosen frequency the operating frequency of the missile itself. Circuitry in the missile launcher selector includes an element which fires and initiates Mode 3. This, in turn, sends series-connected Mode 3 (zero voltage) signal back to the missile, which removes a voltage in the an and initiates the slow sweep (time constant change). there were no disabling circuit, lock would be achieved on the first crystal. When the F1 taken off F2 the that is, inactivated, the next higher frequency in the crystal bank in the missile is the one which is locked onto, instantly stopping the sweep. This next higher frequency is several hundred kiloHertz kHz. above the corresponding frequency in the missile launcher channel selector crystal.

After the scanning of the frequency spectrum in the missile launcher has stopped, at the end of Mode 3, it does not resume scanning for that missile operation. In effect, the frequency acquisition is a "one-shot" operation. An AFC circuit, having a frequency tolerance, keeps it locked at the proper frequency at which the particular missile operates. There is a multiplicity of channels in order to avoid interference, in operational use, between various ships in the same general area attempting to control their respective missiles at the same time. A system could have been developed with only one fixed frequency for the missile and a reference crystal band only in the missile launcher, however such a system would not be as versatile or adaptable or as interference-proof as one with a crystal bank in both the missile launcher and the missile.

Accordingly, an object of the present invention is the of a multichannel frequency-select system which permits selection of any one of 19 channel frequencies. The channel selected has its frequency automatically controlled by the missile receiver loop or the channel guard band crystal.

Another object is to provide a multichannel frequency-select system wherein any crystal (guard band crystal) in a reference crystal bank, located on the missile, can employed without individual crystal H;

A further object the invention is the provision of a multichannel frequency-select system in which either series or parallel crystal resonance can be used.

Still another object is to provide a multichannel frequency-select system wherein any channel in the crystal reference bank can be reached within a very short time, less attenuation 100 msec.

Yet another object of the present invention is the provision of a multichannel frequency-select system using a 2-speed single-ramp wave, a fast sweep for channel selection and a much slower sweep in the channel region prior to locking onto the desired frequency. Other objects and many of the attendant advantages of this invention will be readily as the same becomes better understood by reference to the following detailed description, when considered in connection with the accompanying drawings, in which like reference numerals designate like parts throughout the FIGS. thereof and wherein:

FIG. 1 is a F1 diagram of the complete multichannel frequency-select system, for circuitry on both the missile and the missile launcher. F2 detrimentally

FIG. 2 is a set of graphs showing:

A. the crystal responses in the missile; B. the manner of frequency scanning; and and

C. the three mode control voltages generated in the launcher temperature-sensitive conducted to the missile. close-loop open-loop open-loop voltage-controllable

FIG. 3 is a graph showing the variations in ramp voltages and frequency for the three modes of operation.

FIG. 4 is a different diagram showing: voltage-controllable PIN so of

A. series; and DC DC B. parallel connection for the crystals in the crystal banks in the multichannel frequency-select system; and oscillator

C. the AFC discriminator response point for both. FIGS. 5A and 5B are primarily schematic diagrams of the missile channel selector.

FIGS. 6A and 6B are partly block and partly schematic diagrams of the missile crystal-reference X-R (from Xtal Reference) loop.

FIG. 7 is a pair of graphs showing: frequency-selective DC is DC DC F3

A. DC voltage on the DC used to control the frequency of the basic frequency generator as a function of time; and B. the capacitance of varactor as a function of the bias voltage on the varactor.

FIG. 8 is a diagram, primarily in block form but partially schematic, of the mode DC loop circuit.), DC .02 μ F. DC emitter-base

FIG. 9 a schematic diagram of

A. active; and across-the-band B. equivalent circuits of the automatic frequency control (AFC) circuit of the missile in Mode 2. F3 closed-loop

FIG. 10 is similar type forth schematic diagram for operation in Mode 3. claims. Referring now in more detail to the FIGS. and beginning with FIG. 1, there is shown herein the three basic circuit blocks of the multichannel frequency-select system, namely, a missile-launcher channel-selector 10, a missile crystal-reference loop (X-R loop) 20, and a missile receiver loop 60. A few of the circuit blocks are common to both loops. The components that make up the X-R loop 20 include the blocks labeled 34, 38, 36, 25, 24, 26, 27, 32 and back to block 34, the totality of the blocks forming a closed circuit loop (AFC loop), or servo loop. In the embodiment shown, transfer oscillator 30 must be

considered part of the X-R loop, along with low IF amplifier 32. In a simplified embodiment, discussed hereinbelow, neither of these circuits would be necessary.

The components that make up the missile receiver loop 60 include the blocks labeled 66, 36, 25, 24, 26, 28, 63, 64 and back to block 66, these blocks also forming a closed circuit loop (AFC loop) or servo loop. temperature-sensitive The launcher channel selector unit 10 provides a means to select the desired channel of operation in the missile by furnishing the proper mode voltages, by means of mode control circuit 40, into the missile at a precise time. A single crystal or band-pass device in the launcher channel selector 10, when scanned by the variable basic oscillator 24, and by means of the low IF amplifier 32 triggers the mode logic circuit 14 into Mode 3 (only function), thus activating the missile receiver loop 60 and the X-R loop 20 and allowing a channel lock onto either loop. If the missile receiver loop 60 has a radar signal, it will lock onto it with the X-R loop 20, providing a barricade or stand-by position in the event of loss of signal in the receiver loop. The launcher channel selector 10 is remote from the missile in one embodiment actually built, but could be used as part of the missile and its functions controlled by a radio link from the ground.

The circuitry on the missile launcher channel selector 10 is connected to circuitry on the missile by a single-wire coaxial cable 19 which carries all the information necessary for channel selection, namely: 1. the RF sweep signal; 2. the +12 V DC Mode 1 voltage; 3. the -12 V DC or disable voltage, for Mode 2; and the Mode 3 zero V DC or enable voltage.

Discussing now the major circuits in the missile crystal reference loop 20, one element of the basic frequency generator 22 includes a basic oscillator 24, which is an LC oscillator that is frequency-controlled by a voltage-sensitive capacitor in its tank circuit, that is, by a varactor 25. The output of the basic oscillator 24 feeds a buffer amplifier 26, which in turn powers a frequency-multiplying system, or frequency multiplier 28. One output of the buffer amplifier 26 is mixed in mixer 27 with a transfer oscillator 30 to lower the frequency to a more practical value for transmission to the remote location of the launcher channel selector unit 10. The transfer oscillator 30 is a fixed-frequency crystal-controlled oscillator operating at a frequency which is approximately 60 MHz., above that of any of the crystals in the crystal reference bank 34. Mixing of basic oscillator frequency with the frequency of the transfer oscillator 30 results in an intermediate frequency (IF) which is equal to the difference between the two frequencies. This IF is nevertheless an RF frequency.

The crystal reference bank equalizing is a grouping of piezoelectric quartz filter crystals each of which provides the reference frequency of the guard band in the X-R loop 20. The guard band of the desired channel holds the basic oscillator 24 in a standby position for the missile receiver loop 60 to take over control of the basic oscillator when the missile receiver loop is active. By the very nature of an AFC loop, the loop corrects the oscillator frequency, thereby eliminating the error signal. The radiofrequency (RF) output of the reference band 34 is converted to a DC voltage, by means of DC converter 38, supplying the lock and error signals for the X-R loop 20.

An AFC circuit 36 provides a two-speed sweep-ramp, that is, a triangular sweep voltage having two slopes, connected to the varactor 25, which in turn changes the frequency of the basic oscillator 24, to cause a lower intermediate frequency (IF), which is amplified in low IF amplifier 32, preselected

Connected between the crystal reference band 34 and the AFC DC amplifier 36 is an AC to DC converter 38 that stops and locks the sweep, and provides the DC DC AFC amplifier 36 is controlled by the missile receiver loop 60, which preempts control of the basic oscillator 24 when the missile receiver loop is active. voltage-controlled the receiver signal is present, an error signal is introduced, thus again the frequency is corrected. cable, It should be pointed out that, the missile receiver loop 60 is not needed to lock the selected channel

crystal. In fact, voltage-controlled no signal appears in the missile receiver IF amplifier 64, loop 60 is "open," and system will lock onto the guard band crystal (stand-by).

Discussing now the missile IF and RF receiver AFC loop 60, the multiplied signal from the frequency multiplier 28 is mixed with a received radar signal from radar stage 62 in the mixing circuit 63, forming an IF signal amplified by the missile receiver IF amplifier 64. When the IF signal is mixed with the radar reference signal, the resulting signal is a band-centered IF signal which is maintained by the missile receiver's AFC closed loop 60. The missile receiver IF amplifier 64 is terminated in a frequency discriminator 66 that furnishes lock and error signals to the AFC circuit 36 to provide control of the basic oscillator 24 and its frequency-multiplying system, the AFC action thus eliminating the error signal.

Both the X-R loop 20 and the missile receiver loop 60 are automatic frequency control (AFC) loops. The X-R loop 20 holds the basic oscillator X-R (LC oscillator) 24 within the error limits of the channel selected. When a target signal, a radar signal, is present in the missile receiver loop 60, it preempts control of basic oscillator 24, by introducing an error signal which pulls the basic oscillator lower in frequency away from the influence of the guard band crystal. One loop or the other is active: with no target signal, the X-R loop AFC is active; with a target signal, the missile receiver loop 20 is active. The missile receiver loop 60 is active under the following circumstances. When a homing signal, that is, a target signal, is present in the missile receiver 60, the AFC of the receiver controls the basic oscillator 24 thus reducing or eliminating the radar error. If the signal (target) is interrupted or lost, the crystal-reference loop 20 resumes control and holds the basic oscillator 24 within error limits until the receiver signal is restored.

Both the crystal-reference loop 20 and the missile receiver loop 60 are frequency discriminators. When the basic oscillator 24 is in a standby condition, the crystal acting as a discriminator presents the necessary error signals to control the basic oscillator. A signal in the receiver discriminator 66 is a plus (+) error signal which drives the basic oscillator 24 lower in frequency away from the guard band into the receiver discriminator crossover curve at band center. An error signal below this crossover presents a minus (-) error voltage which drives the basic oscillator 24 higher in frequency. Thus at crossover, corrective voltage-controlled signals are eliminated. Before discussing the manner of operation in detail, it will be useful to make a few general remarks about the multichannel frequency-select system.

Any crystal in the reference bank 34 can be employed without individual crystal switching. Series or parallel crystal resonance, as is shown in FIGS. 4(A) and 4(B), respectively, can be used and the response slope, as is shown in FIG. 4(C), can be used as an AFC discriminator for frequency error control. A system of disable and enable voltages (see FIG. 2) generated by the mode logic circuit 14 are switched by the crystal channel selector 12 at precise times. This is made possible by scanning the crystal bank 34 of the missile and the crystal channel selector 12 of the launcher channel selector 10 simultaneously. A crystal or other band-pass device in the crystal channel selector 12 will switch the disable voltage off the crystal reference bank 34 just before it approaches the desired crystal, thus allowing it to lock onto this crystal. This is accomplished because the crystal, or some other type of band-pass device allows the IF scanning signal to go through to the SCR, which fires (like a switch) thus cutting off the disable voltage. This locking is termed guard band lock. If the missile RF receiver loop 60 is active, it will lock onto it before reaching the guard band. On loss of missile receiver signal, the signal will move higher in frequency, and it will lock onto the guard band crystal, this being a standby position whereby the missile receiver can always preempt control. The sweep control system receives its commands from the disable and enable voltages (mode voltages) produced by the crystal channel selector unit 12.

Any channel in the crystal reference bank 34 in the missile can be reached in 50 msec. 100 msec. is required for any channel in the crystal channel selector 12. Either the X-R loop 20 or the missile receiver loop 60 can exercise control in the AFC circuit 36 of which the sweep circuit is a part. The sweep circuit furnishes a fast sweep for channel selection, then a very slow sweep in the channel region prior to

The number of crystals in the crystal reference bank 34 corresponds to the number of channels desired. In the embodiment disclosed, 19 were used, consisting of 4 groups having 4 in each group and 1 group of 3. region which

Two groups of four crystals are shown in FIG. 6A. As may be seen from this FIG., in each group, of four or three crystals, the series capacity of the crystals is reduced to a small value by shunt chokes L-y1 and L-y5 which are tuned to near resonance, and uses separate diode rectifiers CR3 and CR10 with 1.5K resistors R18 and R19 as a DC return. The crystal reference bank 34 is driven by a single signal source, the low IF amplifier 32, and the output impedance is reduced by $1,500/5 = 300$; this reduces crystal bank feed-through by a factor of 5. Also, the case of each individual crystal is grounded to reduce feedthrough.

With respect to alternative embodiments, can be readily understood by one skilled in the art that a multichannel frequency-select system could be devised not requiring a transfer oscillator 30 nor a IF amplifier 32, but instead feeding the output of the basic frequency generator 22 directly into the crystal reference bank 34 and into an amplifier analogous in function to launcher low IF amplifier 16, but which could no longer be termed an IF amplifier. The system herein described has distinct advantages over such a simplified system. The manner in which the voltage on the varactor 25 is related to frequency is shown in FIG. 2. When a guard band crystal is selected, it presents a "stone wall" to any further rise in frequency. In other words, this sets a frequency limit. It can go lower in frequency if the missile receiver loop 60 is active, to a point of discriminator crossover, or no-error signal.

Inasmuch voltage-controlled the three mode voltages shown in FIG. 2 are very important in the of the manner in which the multichannel frequency-select system operates, the description of the operation will be keyed to the three modes. Reference is directed to FIG. 3, which shows the voltage at the varactor (25 in FIG. 1) and the frequency of oscillator as a function of the modes.

Mode 1: Missile Launcher

In this voltage-controlled the basic oscillator 24 in the missile is oscillating at a rest frequency, in one embodiment was 4 MHz. The voltage on cable 19 and therefore on the mode signal line 18 is +12 V DC.

On the missile DC channel selector 10, one of the 19 voltage-controlled channels is selected by a single-pole 19-position rotary or pushbutton switch, shown as SW-1 to SW-19 in FIG. 5A. The preset-select switch 15 in FIG. 5B is closed, that is, set to the preset position 15A. This sets up Mode 1 by permitting current flow through diode CR-A1 (1N914) and sets up transistor Q-A (2N894) for channel selection signals. Transistor Q-A is a silicon-controlled rectifier (SCR) switching transistor, and under Mode 1 conditions is "open," or nonconducting. Transistor Q-B is also cut off by bias voltage through diode CR-B1 and the closed preset-select switch 15. The "closed" preset-select switch 15, in position 15A, puts a -28 V DC potential through a resistor R1 (47 K) on the base of transistor Q-C (2N 2907A), which saturates this transistor, resulting in maximum conduction. The resulting mode signal voltage at the mode signal line 18 is $+28 - 9.1 \approx +19.0$

Mode 1: Missile

The crystal channel selector 12 is now ready for missile launch and therefore the missile is ready for launch.

In the preset Mode 1, with the preset-select switch 15 of FIG. 5B in the select or open position 15B, the following trans-

pires, beginning with the application of the +12 V DC Mode 1 voltage (as may be seen in FIG. 1). Current flows from the mode logic circuit 14, of the launcher channel selector 10, through the mode signal line 18, through the coaxial cable 19, and into the mode control circuit 40, whence it is distributed to various circuits.

Referring now to FIG. 6A, the +12-volt Mode 1 voltage is distributed as follows:

- a. Through the two resistors R11 and R20 forming a voltage divider to ground, through resistor R18, and through diode CR3 and inductance L2. Referring now to FIG. 6B, the +12 V enters the AFC circuit 36 through the base of transistor Q1, saturating its collector, whereupon the potential across condenser C1 drops to a value near zero. Transistor Q1 normally conducts with a bias voltage greater than +0.6 V, otherwise it is cut off.
- b. Through resistor R2, diode CR5, and into the base of transistor Q3, reducing the potential across condenser C4 to a value near zero.
- c. Through resistor R6 into the base of transistor Q5, reducing the potential across capacitors C6 and C7 to a value near zero, placing the sweep circuit into its ground state.

This corresponds to the rest frequency of the basic oscillator 24, and is shown as Mode 1 in FIG. 3.

Summarizing the +12 V DC Mode 1 voltage saturates transistors Q1, Q3 and Q5 (see FIG. 6B), which in turn effectively shorts out the capacitors which make up the capacitance C of the RC sweep circuit. The condition shown in the circuit of FIG. 7A now exists.

In FIG. 6B, capacitors C1, C2, C4 are used as Miller capacities, and are magnified by the gain $(1 + A)$ of the transistor Q1, Q2 and Q4, respectively, to whose collector they are connected, A being the gain of the transistor. Condenser C1 and transistor Q1, for example, in combination result in the well known "Miller effect," which is a voltage multiplication of capacitance.

Still referring to FIG. 6B, the capacitance of condenser C10 is magnified by the beta of transistor Q7. The multiplication of the capacitance of condenser C10 by transistor Q7 is believed to be a novel result. Capacitance-multiplying by current methods is to be contrasted with the voltage multiplication of capacitance just discussed. The function of the circuit which includes condenser C10 is to offer resistance to scanned jamming signals and to prevent loss of channel in the event of jamming. It offers a long time constant so that signals of short duration will not take over.

Mode 2: Missile Launcher

In Mode 2, the missile power is up, that is, the battery is activated and the missile is made ready for launch. Some of the ways in which power in the missile can be used to automatically initiate Mode 2 in the channel selector 10 is by detection devices, such as those which sense when the actuated missile battery voltage is up to normal or the basic oscillator 24 heterodyned signal is present in the crystal channel selector 12. These are two ways which may be used to start the sweep in the in starts in Mode 2. In the methods herein disclosed, as the multichannel frequency-select system was used in the laboratory and for operational use, it was only necessary to flip the preset-select switch 15 into the select or open position 15B, as shown in FIG. 5B.

In the select Mode, after the preset-select switch 15 is flipped to the select position 15B, in the launcher channel selector unit 10, within 1 msec. or less, the mode voltage switches from +12 to -12 volts (refer to FIG. 2C), the ± 12 V resulting from a 7-volt drop across a Zener in the missile. The sweep ramp voltage starts to rise instantly, changing the frequency of the basic oscillator 24 upward with it, as may be seen in FIG. 3.

The following now takes place in the launcher channel selector 10. Refer to FIG. 5B. The preset switch 15 is still open. Transistor Q-C (2N2907A) cuts off, the +19.0 V DC

voltage at resistor R2 drops out. Transistor Q-B (2N2222A) conducts, the -19.0 V DC cuts in. Transistor Q-A (2N894), which is a switching transistor, remains cut off. Mode signal voltage on mode signal line 18 is now -19.0 V DC as a result of transistor Q-B conducting.

Meanwhile the basic oscillator 24 in the missile starts up from its rest frequency of approximately 4.0 MHz. (see FIG. 3) and sweeps upward in frequency. When the RF frequency reaches the band-pass or crystal frequency, it fires the transistor Q-A (2N894), a silicon-controlled rectifier, which immediately decreases the magnitude of the mode voltage from -12 V DC to zero, at the end of Mode 2, in 0.5 msec. or less. See FIG. 2C.

As may be seen in FIG. 8, the crystal Y-N provides the path between the low IF amplifier 16 and the Q-A SCR. The SCR fires on RF signal, its action being not unlike that of a thyatron.

In the laboratory embodiment, and referring back to FIG. 5B, if the operator wishes to select a different channel before missile launch, the preset-select switch 15 is returned from the select position 15B to the preset position 15A, the desired channel is switched in, then the switch 15 is returned from the preset position 15A to the select position 15B. There is no limit on the number of times this can be done except for considerations of battery life of the missile. While the battery life is approximately 12 min. in the embodiment actually built, only 0.5 min. of this represents the drain on the missile launcher.

Mode 2: Missile

The following is what transpires in the missile in Mode 2. As stated above, within 1 msec. after the preset-select switch 15 is flipped to the select position 15B (see FIG. 5B), the mode voltage changes from +12.0 to -120 V (see FIG. 2C).

Within this same time of 1 msec., the -12 V mode voltage is distributed as follows, referring first to FIG. 6A.

- a. through the two resistors R11 and R20 forming a voltage divider. This negative voltage of 12 V puts a reverse bias on diode CR3, thus disabling the crystal reference bank 34. Diode CR10 is also cut off.

Refer now to FIG. 6B. Transistors Q5 and Q2 are cut off, also, thus allowing the sweep to start.

When the selected channel is approached in frequency, the crystal in the channel selector 12 being resonant at a frequency approximately 35 HKz. lower in frequency than the corresponding crystal in the crystal reference bank 34 (the basic oscillator 24 heterodyned scanning signal scans from lower to higher frequencies), the channel selector 10 removes the disable voltage and makes the next crystal in the missile crystal reference bank 34 the desired one. This represents a change from Mode 2 to Mode 3.

- b. Continuing again with Mode 2, and now referring back to FIG. 6A, the -12 V mode voltage is distributed through resistor R2, diodes CR 6 and CR 9, and, referring now to FIG. 6B, into the base of the p-n-p transistor Q7, which saturates its collector and disables the missile receiver IF and RF loop frequency discriminator 66. CR 1 is a 3.3 V Zener diode which holds the low potential end of condenser C10 to a value of +2.7 volts, thus allowing it to charge up with the sweep. Conduction of transistor Q7 shorts out the missile receiver discriminator 66 and prevents a false lock on spurious signals, as may be seen from FIGS. 6A and 6B where they join.

The active and equivalent circuit for Mode 2 operation is shown in FIG. 9.

Referring back to FIG. 6B, transistor Q6 is switched on and transistor Q4 is switched on. When transistor Q6 is switched on, resistor R14, approximately 820 Ω , and resistor R13 are effectively connected in parallel (see FIG. 9B). This parallel combination of resistors changes the sweep rate to approximately 60 msec. for a complete channel sweep. This sweep is unidirectional, upward in voltage and frequency. See FIG. 3.

When the sweep has arrived at the proper frequency in the launcher channel selector 10, the mode voltage goes from -12 V DC to zero at the end of Mode 2, as may be seen from FIG. 2C. Capacitor C10 in FIG. 6B provides a long time constant downward in ramp voltage, which is the varactor 25 voltage. The long time constant is made possible by current transformation in a transistor, base to emitter. Increasing DC betas result in longer time constants.

c. Finally, and still referring to FIG. 6B, the -12-volt mode voltage is distributed through diode CR 8, which is a 24 V Zener diode, through resistor R16 and into the base of transistor Q6 which is a p-n-p switching transistor. It is this switch Q6 that changes the sweep from a 100-millisecond rate to one of several seconds. These are the rates and times involved in the sweep rising from 0 volts to 15 volts. The fast sweep is related to Mode 2, and the slow sweep to Mode 3 as may be seen from FIG. 3.

Now with increasing time, within 1 msec. after the preset-select switch 15 has been set to the select position 15B (see FIG. 5B), as the frequency of the basic oscillator 24 rises and its related lower IF frequency is scanning upward in the launcher channel selector 10, it arrives at a crystal or other band-pass element with the desired channel frequency. The signal is passed through (a window) which in turn triggers the -12-volt mode voltage off to zero voltage in 0.5 millisecond or less.

Mode 2 requires 18 to 100 milliseconds to complete depending on the specific channel; 18 milliseconds for channel 1 and 100 milliseconds for channel 19 in the embodiment actually built.

Mode 3: Missile Launcher and Missile

The switch from Mode 2 to Mode 3 is initiated electronically by the launcher channel selector 10 by a sweep scan frequency corresponding to a single crystal or band-pass frequency in the crystal selector unit 12. The preset-select switch 15 remains in its select or open position 15B. The Mode 3, zero mode, voltage is consummated 0.5 sec. after Mode 2 is completed.

Disable voltages are removed from the crystal reference bank 34 and the missile receiver frequency discriminator 66, causing the crystal reference bank 34 and the missile discriminator 66 to become active (see FIG. 1). Transistor Q6 (FIG. 6B) is inactive, or cut off, and the slow sweep rate prevails (see Mode 3, in FIG. 3), and drifts upward into the capture region R (see FIG. 2A) of the missile receiver's discriminator 66. If a reference signal, that is, a radar signal, is available in the receiver loop 60, it will lock onto this loop.

Transistors Q6 and Q4 are cut off and as may be seen in FIG. 3, the long time constant sweep results. See A, B, C, of FIG. 2 for the position where this takes place. As presented in FIG. 2, the sweep continues on toward crystal 6 in the missile. If a signal is present in the region of R in the receiver frequency discriminator 66, capture will be made and the sweep stopped. R is the channel width allowing ± 2 MHz. radar error limits at the X band. The ± 2 MHz. is divided in R region; the R bandwidth is 4 MHz.

If no signal is present in the discriminator 66, the frequency sweep will continue upward up to the resonant frequency of crystal No. 6, and the sweep will stop there, indicating that the crystal reference (X-R) loop 20 is now in control. Effectively, the sweep frequency locks onto the X-R loop. The X-R loop 20 forms a barricade or guard band in the desired channel (see FIG. 2C). When the missile receiver is active, it will preempt control of the basic oscillator 24 as the guard band provides a standby position for capture by the missile receiver loop 60. When a receiver signal develops within the region of R, it will pull the basic oscillator 24 lower in frequency to band center of the receiver frequency discriminator 66. The position at 6 is the stand by frequency which sets up the guard band limits. Position 6 is just an example, it can be any one of 19 crystals in the embodiment shown.

The missile can now be launched.

The following are the component values used in the embodiment built.

TABLE OF COMPONENT VALUES FOR FIGS. 6A AND 6B

Q1, Q2, Q3, Q4, Q5	2N2222	R1—3.3K
Q6, Q7	2N2907A	R2, R6—8.2K
C1, C3	0.1 F	R3—240
C2,	0.47 F	R4—510
C4, C6, C10	1.0 F	R5—510K
C5, C11	4700 F	R7—160K
C7, C9	0.01 F	R8, R10—2.2M
C8, C12	1000 F	R11, R18, R19—1.5K
CR1	3.3 V Zener 1N746A	R12—1.0M
CR2, 3, 4, 5, 6, 7, 8, 10	1N914	R13—22K
CR8	24 V Zener 1N970BM	R15—180
	R17—18.K	

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

I claim:

1. A multichannel frequency-select system wherein the frequency of a crystal in a crystal bank on a missile controls a voltage on a voltage-sensitive capacitor, such as a varactor, and is to be selected to correspond with the frequency of a crystal in a crystal bank on a channel selector on a missile launcher, the frequency-select system being capable of operating at any of a plurality of crystal-controlled frequencies in the missile, and in any one of three different modes:

- a preset Mode 1, in which the intermediate frequency (IF) in both the missile launcher channel selector and the missile is a rest frequency, with a corresponding constant voltage on the varactor;
- a select Mode 2, in which the frequency spectrum covered by the crystal bank in the missile and the single crystal in the launcher channel selector is swept or scanned at a rapid rate, with a corresponding voltage on the varactor rising at a greater rate; and
- an acquire Mode 3, wherein the scanning rate slows down and stops when frequency lock is acquired, with a corresponding voltage on the varactor rising at a lesser rate, the three kinds of varactor voltages, the constant and the 2-speed ramp voltage, appearing first in circuitry on the missile;

the multichannel frequency-select system comprising:

- a launcher channel selector on the missile launcher including:
 - a crystal channel selector, which includes:
 - a plurality of crystals, or crystal bank, arranged in order of increasing resonant frequency; and
 - a multiposition switch, for choosing that one of the plurality of crystals at which the missile is to operate;
 - a mode logic circuit operatively connected to the crystal channel selector and including a preset-select switch which determines the mode of operation and furnishes proper mode direct-current voltages to the missile at a precise time;
 - a mode control circuit, located on the missile, having as an input the three DC mode voltages from the mode logic circuit in the missile launcher channel selector, which mode voltages trigger the one constant and two sweep voltages in the mode control circuit, which subsequently appear on the varactor;
- a crystal-reference (X-R) loop on the missile including:
 - a basic frequency generator, whose frequency is controlled by the voltage-sensitive capacitor in its tank circuit;
 - a crystal reference bank, having the same plurality of crystals as the crystal channel selector in the missile launcher, one of whose inputs is an output from the mode control circuit, and the other of whose inputs is

an output from the basic frequency generator, which sweeps the frequency spectrum of the crystals in the crystal reference bank until the frequency of the selected crystal is reached, at which time the frequency sweeping in the crystal reference bank stops at the predetermined crystal, whereupon the frequency sweeping in the launcher stops;

an AC to DC converter, operatively connected to the crystal reference bank, for converting the radiofrequency from the crystal bank into a direct current which supplies the lock and error signals for the X-R loop;

an automatic frequency control (AFC) circuit having an input from the mode control circuit and from the AC to DC converter, which provides the DC voltage in Mode 1 and the 2-speed ramp voltage for Mode 2 and Mode 3 to the voltage-sensitive capacitor in the tank circuit of the basic frequency generator, for increasing the frequency of the basic frequency generator until operation at the selected frequency is achieved.

2. A multichannel frequency-select system according to claim 1, wherein:

the basic frequency generator comprises:

- a basic LC oscillator whose frequency is controlled by the voltage-sensitive capacitor; and
- a buffer amplifier for amplifying the output of the basic oscillator.

3. A multichannel frequency-selected system according to claim 2, wherein:

the X-R loop on the missile further comprises:

- a transfer oscillator, operating at a fixed frequency;
- a transfer oscillator, operating at a fixed frequency;
- an X-R mixing circuit having as its two inputs outputs from the buffer amplifier and the transfer oscillator, to produce a missile low intermediate frequency which varies directly as the voltage on the varactor;
- a missile channel-select low intermediate frequency amplifier, for amplifying the IF;

the launcher channel selector on the missile launcher further comprises:

- a launcher low IF amplifier and automatic gain control, operatively connected to the missile channel-select low IF amplifier and having an output to the crystal channel selector, for amplifying the IF frequency.

4. A multichannel frequency-select system according to claim 3, further including:

a missile receiver loop which preempts control of the multichannel frequency-select system when there is a signal at its input, the missile receiver loop including the following components from the missile crystal-reference (X-R) loop:

- the varactor;
- the AFC circuit;
- the basic oscillator;
- the buffer amplifier; and wherein the basic frequency generator includes:

a frequency multiplier, whose input is the output of the buffer amplifier, for multiplying the frequency of the basic oscillator;

a radar state at the input to the missile receiver loop for intercepting and detecting a signal reflected off a target;

the missile receiver loop further comprising:

- a missile receiver mixing state for mixing the output of the frequency multiplier with the output of the radar stage;
- a missile receiver IF amplifier for amplifying the output of the missile receiver mixing state;
- a frequency discriminator, for providing lock and error signals to the AFC circuit in the missile receiver loop;

the relationship of the frequency discriminator output to the other inputs to the AFC circuit being such that when a target signal is present in the missile receiver, which corresponds to an active missile receiver loop, the frequency discriminator preempts control of the basic oscillator, while if the radar signal is interrupted or lost, the circuits associated with the X-R AFC circuit, the X-R loop, resume control until the missile receiver loop is active again.