IFF TRANSPONDER

GENERAL

The AN/APX-64 IFF (Identification Friend or Foe) radar system consists of an airborne receiver-transmitter capable of automatically transmitting coded reply signals when challenged by a radar beacon station (Air Traffic Control Station).

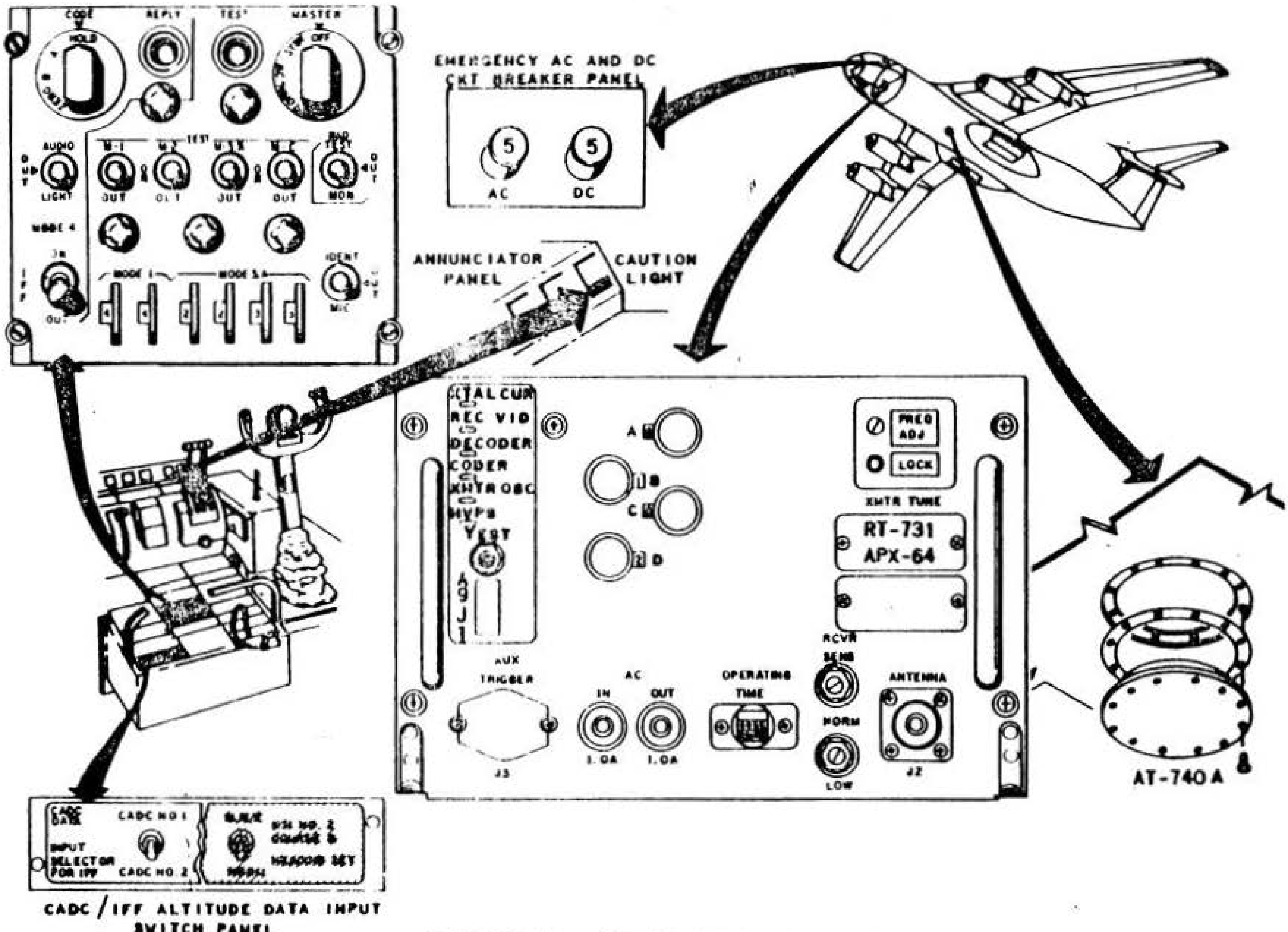
The coded reply signals are used by the beacon station to locate and identify the aircraft and to continuously track its flight path. The APX-64 is generally known as a "transponder" due to its ability to automatically transmit a reply in response to the received challenge (interrogation signal).

A radar beacon station in conjunction with the transponder equipped aircraft within its service area form a complete radar beacon system with the airborne transponders returning reply signals in much the same manner as echos are returned in a pulse-echo radar system.

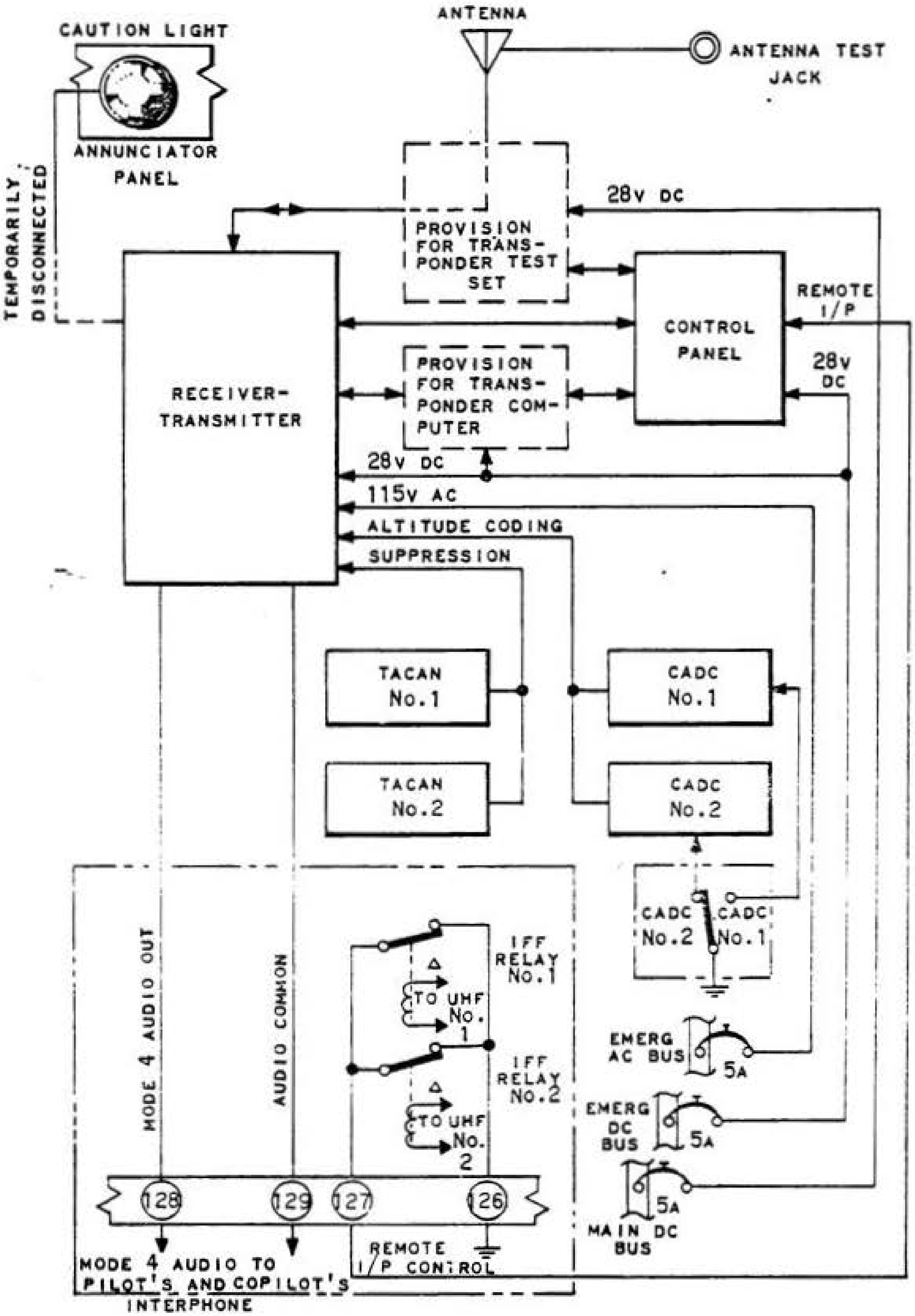
The APX-64 transponder is also capable of coding its reply signals to correspond to aircraft altitude (altitude reporting).

AIRCRAFT INSTALLATION

The AN/APX-64 radar identification system is presently installed on aircraft AF65-244 and up and on AF61-2775 through AF64-243 if modified by T. O. 1C-141A-837. Refer to aircraft installation and tie-in drawings for components and locations. The present installation provides only wiring provisions for the transponder computer and the transponder test set. The caution light on the annunciator panel will be used in conjunction with the transponder computer and is, therefore, temporarily disconnected. The AN/APX-64 system uses input signals from the selected central air data computer for altitude coding and from both TACAN systems for signal suppression. An audio output signal is wired to the pilot's and copilot's interphone system but requires the installation of the transponder computer for operation. Input signals from either UHF transmitter may be used to automatically change the reply signal coding each time either system transmits. This automatic coding, Identification of Position (IDENT) operates when selected by the APX-64 control panel.



SYSTEM INSTALLATION



SYSTEM TIE-IN

SPECIFICATIONS

CHARACTERISTIC	SPECIFICATION
Input Power Requirements	
AC	115 volts, 320 to 480 Hz single phase; 80 watts at 0.2 percent duty cycle
DC	26.5 volts, 10 watts
High Voltage Circuit Protection	1 amp. 115-volt A-C circuit breaker
Operating Temperature Ranges	$-55^{\circ}C$ to $+95^{\circ}C$ continuous, $+125^{\circ}C$ intermittent at sea level
Operating Altitude Ranges	0 (sea level) to 100,000 feet
Receiver Characteristics	
Frequency	1030 MHz
Frequency stability	±1.5 MHz
Frequency control	Crystal
Intermediate frequency	59.5 MHz
Bandwidth	7.0 to 9.0 MHz at points 6db from maximum response
Normal sensitivity	-78dbm
Low sensitivity	-66 dbm
Spurious response	Response to signals below 1010 MHz and above 1050 MHz at least 70 db below response at desired frequency of 1030 MHz

CHARACTERISTIC	SPECIFICATION
Suppression Input	
Amplitude	15 to 70 volts
Duration	1.5 to 250 usec
Polarity	Positive
Input resistance	2200 ohms
Rise time	At least 10 volts/usec
Decay time	Peak amplitude to 1.0 volt within 10 usec
Recovery time	Sensitivity returns to within 3 db of normal in no more than 15 usec after the suppression pulse falls to 1 volt.
Transmitter Characteristics	
Frequency	1090 MHz
Frequency stability	±3 MHz
Power output	29 dbw at a duty cycle of 0.2 percent (-6 dbw min under any service condition at 1 percent)
Output Pulses	
Width	0.45 ±0.1 usec
Rise time	0.05 to 0.1 usec
Decay time	0.05 to 0.2 usec
Interrogation Code	
Mode 1	2 pulses spaced 3 ± 0.1 usec
Mode 2	2 pulses spaced 5 ± 0.1 usec
Mode 3/A	2 pulses spaced 8 ± 0.1 usec

CHARACTERISTIC	SPECIFICATION
Test mode	2 pulses spaced 6.5 ± 0.1 usec
Mode C	2 pulses spaced 21.0 ± 0.1 usec
Mode 4	4 sync pulses followed by a vacant pulse position, followed by as many as 32 pulses. The spacing from the leading edge of any pulse to the leading edge of the succeeding pulse is 2 ± 0.1 usec. An Anti-Interference Interrogation (AII) pulse is inserted between any consecutive vacant pulse spaces. The spacing of the AII pulses is 1 ± 0.15 microsecond in odd multiples from the leading edge of the fourth sync pulse. Recognition-of-interference action is accomplished by sensing the lack of pulses in the mode 4 interrogation.
Interrogation Pulse	
Characteristics of modes 1, 2, 3/A, C and Test	
Pulse width	0.8 ± 0.1 usec
Rise time	Between 0.05 and 0.1 usec
Decay time	Between 0.05 and 0.2 usec
Mode 4	
Pulse width	0.05 ± 0.1 usec
Rise time	Between 0.05 and 0.1 usec
Decay time	Between 0.05 and 0.2 usec

CHARACTERISTIC	SPECIFICATION
Automatic Overload Control	
Modes 1, 2, 3/A, C, Test, I/P, emergency (Modes 1 and 3/A).	1200 replies/sec
Emergency (Mode 2)	800 replies/sec
Reply Pulses	
Mode 1	Zero to five information and two framing pulses spaced 20.3 ± 0.05 usec apart
Mode 2	Zero to 12 information and two framing pulses spaced 20.3 ± 0.05 usec apart
Mode 3/A	Zero to 12 information and two framing pulses spaced 20.3 ± 0.05 usec and the I/P pulse
Test Mode	Zero to 12 information and two framing pulses spaced 20.3 ± 0.05 usec apart
Emergency	
Modes 1 or 2	Selected code appears in the first pulse train followed by three sets of framing pulses, each framing pulse spaced 24.65 ± 0.10, 44.95 ± 0.15, 49.30 ± 0.20, 69.60 ± 0.25, 73.95 ± 0.30, and 94.25 ± 0.35 usec from the first framing pulse of the first train.

CHARACTERISTIC	SPECIFICATION
Mode 3/A	Code 7700 appears in the first pulse train followed by three sets of framing pulses as above.
I/P	
Mode 1	Selected code appears twice, the second reply train spaced 24.65 ± 0.1 usec between the leading edges of the first framing pulses
Mode 2 or Mode 3/A	Selected code appears in the first pulse train followed by a single pulse spaced 24.65 ± 0.1 usec from the first framing pulse.
Auxiliary Trigger	
Pulse width	0.3 to 1.5 usec
Amplitude	15 to 30 volts across 90 ± 10 ohms
Rise time	0.1 usec or less
Decay time	0.2 usec or less
Polarity	Positive
Suppression Output	
Polarity	Positive
Amplitude	20 volts min, 50 volts max with a 300-ohm load resistor in parallel with 1850-uuf capacitor.
Start time	Pulse reaches 20 volts minimum by the time an RF output pulse has reached 10 percent of its amplitude.

CHARACTERISTIC	SPECIFICATION
Stop time	Suppression output is less than 5 volts, 5 usec after the last RF framing pulse of the reply train has fallen to 50 percent amplitude. (The first framing pulse is always followed by a second framing pulse for the purpose of this requirement.) Suppression output is also less than 5 volts, 5 usec after each RF output pulse (resulting from the auxiliary trigger or Mode 4 input) has fallen to 50 percent amplitude.
Interrogation Side-Lobe Suppression Control	
Pulse width	0.8 ± 0.1 usec for Modes 1, 2, 3/A, C, or Test; 0.5 ± 0.1 usec for Mode 4.
Pulse position	2.0 ± 0.15 usec after the first pulse of a Mode 1, 2, 3/A, C, or Test interrogation, or 8.0 ± 0.15 usec after the first pulse of a Mode 4 interrogation.
Rise time	Between 0.05 and 0.1 usec
Decay time	Between 0.05 and 0.2 usec
Pulse frequency	1030 ± 0.2 MHz
Mode 4 Reply Input	
Pulse width	0.3 to 0.7 usec
Amplitude	3 to 6.5 volts across 90 ± 10 ohms

CHARACTERISTIC	SPECIFICATION
Rise time	0.1 usec or less
Decay time	0.25 usec or less
Polarity	Positive
Mode 4 Disparity Input	
Duration	0.3 to 1.0 usec
Amplitude	3 to 6.5 volts across 90 ± 10 ohms
Rise time	0.15 microsecond maximum
Decay time	0.5 microsecond maximum
Polarity	Positive
Mode 4 Trigger	
Duration	0.5 to 3 usec
Amplitude	1.5 to 25 volts across 90 ± 10 ohms
Rise time	0.1 usec or less
Decay time	1.0 usec or less
Polarity	Positive
Mode 4 Video	
Duration	0.4 to 0.6 usec
Amplitude	1.5 to 5 volts across 90 ± 10 ohms
Rise time	0.1 usec maximum
Decay time	0.2 usec maximum
Polarity	Positive
Mode 4 Computer Reset Trigger	
Duration	0.3 to 10 usec

CHARACTERISTIC	SPECIFICATION
Amplitude	6 to 10 volts across 1000 ohms ± 10 percent
Rise time	0.25 usec maximum
Decay time	5.0 usec maximum
Polarity	Positive

SYSTEM OPERATION

BEACON SYSTEM-GENERAL

In order to better understand the purpose and functions of the circuits within the APX-64 transponder, it is necessary to become familiar with the general operation of a complete radar beacon system, of which the APX-64 is a part.

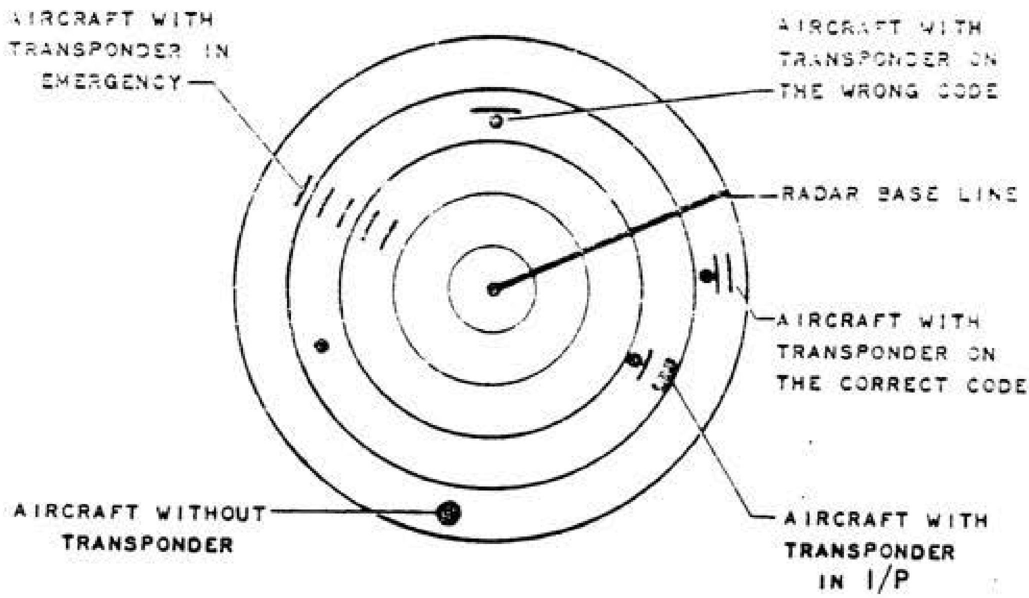
A radar beacon consits of a base station containing an interrogator and its associated display equipment. The interrogator generates a group of radio-frequency pulses called the interrogation signal and transmits these signals from a directional antenna. At the same time, the interrogator generates a trigger pulse to initiate the sweep of an electron beam across the face of a cathode ray display tube. The transmitted beam travels outward until it reaches the airborne APX-64 transponder. The transponder receives the interrogation signal and immediately transmits a group of radio frequency pulses called the reply signal. The reply signal travels back to the base station where it is received and displayed as a bright spot (or spots) on the display scope. Since radio frequency energy travels through space at a constant rate (one mile in 6.18 usec), the distance between the base station and the transponder-equipped aircraft can be determined by measuring the time between the transmitted interrogation and the received reply. The electron beam moves at a linear rate across the face of the display scope which may be calibrated in time per inch, or better still, miles per inch giving a visual indication of distance.

The interrogation signal is transmitted by a highly directional antenna, therefore the APX-64 will only respond when the antenna is pointed toward the aircraft. The position or bearing of the aircraft from the base station may be determined by noting the position of the antenna when replies are received. Aircraft position information is derived by synchronizing the display scope sweep position with the position of the antenna. The sweep will then always move from the center of the screen in the same direction as the antenna is facing. The antenna may then be rotated through an arc of 360 degrees and each transponder-equipped aircraft will appear as a bright spot on the screen as the antenna beam sweeps across its path.

The operation thus far is identical with that of a pulse-echo radar system except that the returned signals are transmitted at high power from the aircraft rather than a reflection (echo) of the base station signal. The transponder method of returning signals allows the beacon system to operate at long ranges and under noise conditions that would render an equally powered pulse-echo system inoperable.

The unique feature of the radar beacon system is in its ability to selectively identify the aircraft within its range. Identification is accomplished by the coding of both the base station interrogation signals and the transponder reply signals. The coding, or pulse spacing, of the interrogation signal indicates the "mode" of operation. The airborne transponders can be manually set to accept only signals of a selected mode and reject or refrain from replying to all others. The coding of the reply signals is also manually set on the transponder to convey information back to the base station.

Decoding circuits within the base station evaluate the coded reply and allow the operator to select specific replies to be displayed. They also allow selection of the type of display, corresponding to the coding of the signal. In this manner, the operator may identify the aircraft without replying on voice or other types of communication.



The typical base station presentation consists of one pattern for transponder-equipped aircraft with unwanted signal coding, another for correctly coded replies and another for an emergency reply. A fourth change in presentation is produced when the aircraft is instructed to Identify its Position (I/P). This causes a short duration change in the reply pattern, initiated at the transponder, and usually lasting from 20 to 30 seconds.

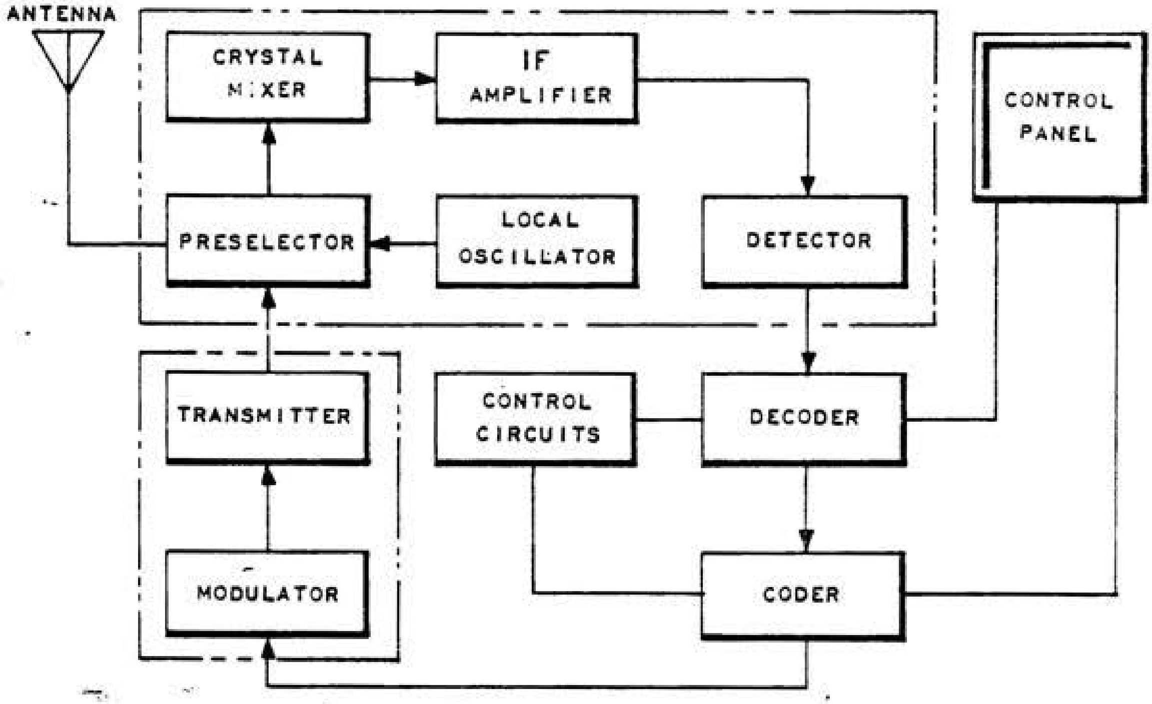
A conventional pulse echo radar is usually synchronized with the beacon system to provide a display of all aircraft in the area whether transponder-equipped or not.

AIRBORNE SYSTEM GENERAL

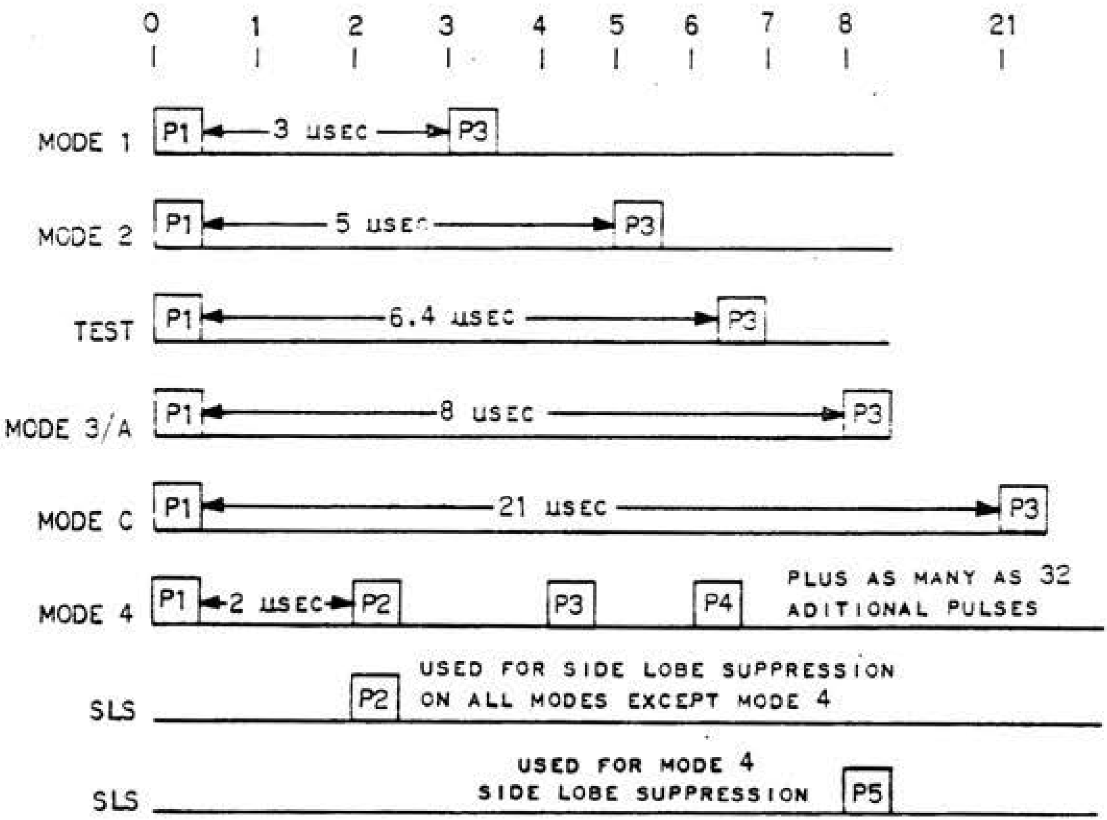
The APX-64 IFF radar system forms the airborne link in the radar beacon system. The interrogation signal from the base station is received by the antenna and coupled to the receiver-transmitter unit. The interrogation signal passes through the preselector in the receiver to a crystal mixer. A local oscillator signal also passes through the preselector and is hetrodyned with the received signal in the mixer. The resultant intermediate frequency is amplified by the IF amplifier and coupled to the detector. The detector removes the high frequency components of the signal and couples the resultant video pulses to the decoder. The decoder in conjunction with the control circuits determines that the interrogation is valid and supplies an output signal to the coder. The coder in conjunction with the control circuits generates a group of reply pulses. The reply pulses from the coder are amplified by the modulator to a level sufficient to trigger the transmitter. The transmitter produces an RF pulse for each input trigger and couples the RF reply signal through the preselector to the antenna. The antenna radiates the signal back to the base station.

Proper operation of the APX depends on the coding of both the received interrogation signal and the transmitted reply signal. The APX-64 IFF Radar System can automatically transmit a coded reply in response to a received interrogation signal if the signals has the proper characteristics of the mode selected. Any of six different modes may be selected by switches on the control panel, but only four of these modes are used with the radar beacon system in the present APX-64 installation. The four active modes (1, 2, 3A, and C) consist of a pair of 0.8 usec pulses, the spacing of which corresponds to the selected mode. The TEST mode is used for maintenance checks and Mode 4 requires the installation of a transponder computer for operation. Pulse width and spacing for each of the six modes is illustrated in the Interrogation Pulses diagram.

If an interrogation signal is received which corresponds to the mode selected, a selected coded reply signal will be generated. MODE 1 and MODE 3/A reply codes are selected on the control panel. Mode 2 reply coding is preset by knobs on the front of the receiver transmitter. Mode C coding is controlled by an altitude

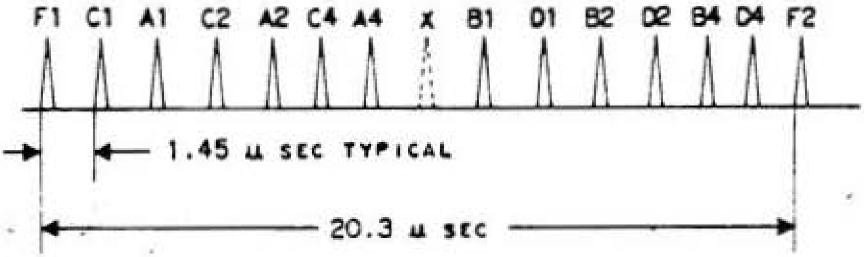


DATA FLOW DIAGRAM



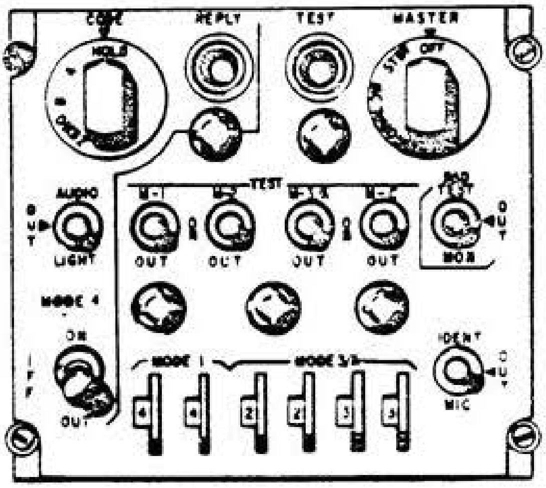
digitizer within the Central Air Data computer system and corresponds to aircraft barometric altitude. Mode 4 code will be generated within the external computer when installed.

The reply signal, or pulse train consists of accurately spaced information pulses between two reference or framing pulses. This pulse train may consist of a maximum of 14 pulses (12 information pulses and 2 framing pulses) or a minimum of two pulses (framing pulses only). The framing pulses are spaced 20.3 usec apart. The spacing between the information pulses (if all are present) is 1.45 usec. The actual spacing between information pulses and the number of pulses is determined by the coding of the reply signal.



For code-identification purposes, the 12 information pulses are divided into four lettered groups A, B, C, and D. Each lettered group has three pulses which are identified by a sub number 1, 2, or 4. The MODE 1 code (selected on the control panel) is designated by code numbers 00 through 73. Five information pulses are used in Mode 1. These are A1, A2, A4, B1, and B2. The code digit assigned to the lettered group is a number equal to the group. For example, if 62 is selected, the information pulses for the "6" digit would be A2 + A4 = 6. Information pulse B2 would be present for the second digit of the code. Mode 2 and Mode 3 both use all 12 information pulses and the code numbers available in these modes are 0000 through 7777 which correspond to pulse groups A, B, C, and D respectively. Mode 1 has 32 possible codes and modes 2 and 3/A have 4096 possible codes. Mode C uses pulses from each lettered group with the exception of the D1 and D2 pulses. If the D4 pulse is present in the mode C reply, an additional pulse will be added to the reply train 4.35 usec after the last framing pulse. A TEST mode interrogation initiates the generation of a mode 3/A coded reply.

The system provides a means of changing the reply coding for aircraft identification purposes (I/P reply). This feature is used when a group of aircraft are being interrogated in the same area and it is desired to single out one aircraft from the group. An I/P reply is initiated on request by the base station operation. The mode 1 I/P reply consists of two complete pulse trains with 4.35 usec spacing between each train. The Mode 2 and Mode 3/A I/P reply consists of a single pulse train followed by an additional pulse spaced 4.35 usec after the last framing pulse. Only these three modes provide an I/P function. The I/P reply signal is initiated by placing the IDENT-OUT-MIC switch in the "IDENT" position. The system will then automatically transmit the I/P reply when interrogated for approximately 30 seconds after the switch is released. If the switch is placed in the "MIC" position the I/P function will be initiated each time either UHF transmitter is keyed.



An emergency reply provision is also available in modes 1, 2 or 3/A. The Mode 1 or Mode 2 emergency reply consists of one pulse train followed by three sets of framing pulses with 4.35 usec spacing between each set. The mode 3/A emergency reply is a single reply train with a coding of 7700 followed by three sets of framing pulses regardless of the code set on the control box. The emergency reply is initiated by placing the function switch on the control panel in the "EMERG" (emergency) position.

DESCRIPTION AND OPERATION

FUNCTION OF CONTROLS AND INDICATORS.

IFF CONTROL PANEL

ITEM	SETTING AND FUNCTION
Master Switch	"OFF:" All power is removed from the system except for panel lighting. "STBY:" Operating power is applied and the system is ready for immediate operation when the MASTER switch is set to "LOW" or "NORM." "LOW:" Receiver-transmitter operates on low sensitivity. "NORM:" Receiver-transmitter operates on normal sensitivity. "EMERG" system transmits an emergency reply when interrogated.

FUNCTION OF CONTROLS AND INDICATORS.

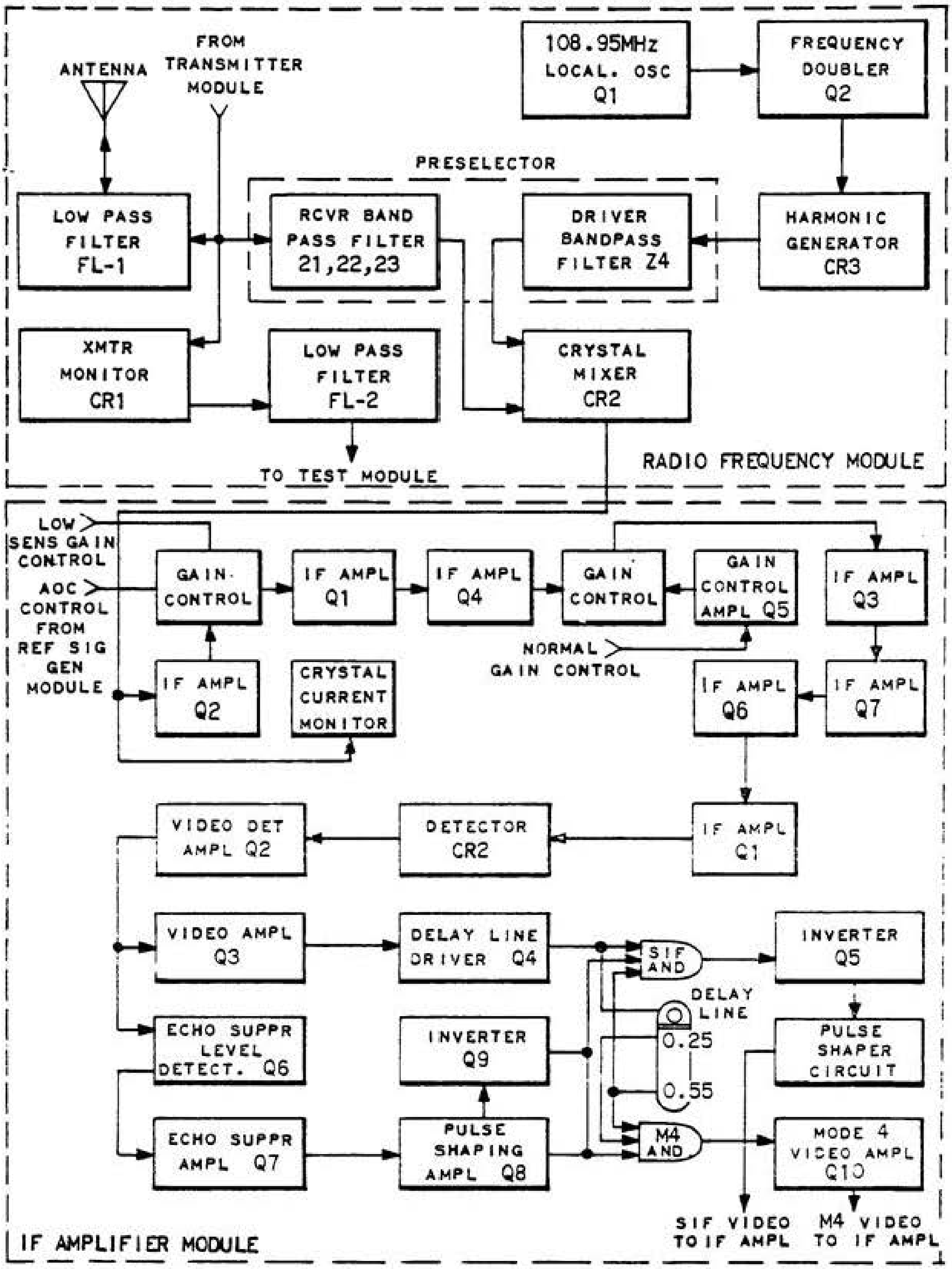
IFF CONTROL PANEL

ITEM	SETTING AND FUNCTION
IDENT-OUT-MIC Switch	"IDENT" sets a code into the MODE 1 and MODE 3 coder group selector control which enables the system to generate coded replies for modes 1 through 3. "OUT" disables the I/P function. "MIC" transfers control of the I/P junction to a remote control.
MODE 1 TEST-ON-OUT Switch	"TEST" energizes the "go, no-go" airborne transponder inflight tester which generates MODE 1 interrogations. "ON" enables the MODE 1 function. "OUT" disables the MODE 1 function.
MODE 2 TEST-ON-OUT Switch	"TEST" energizes the "go, no-go" airborne transponder inflight tester which generates mode 2 interrogations. "ON" enables the MODE 2 function. "OUT" disables the MODE 2 function.
MODE 3 TEST-ON-OUT Switch	"TEST" energizes the "go, no-go" airborne transponder inflight tester which generates MODE 3 interrogations. "ON" enables the MODE 3 function. "OUT" disables the MODE 3 function.
MODE C TEST-ON-OUT Switch	"TEST" tests the altitude reporting mode. "ON" enables the MODE C function. "OUT" disables the MODE C function.
MODE 1, 2, 3, C REPLY indicator light	Lights to indicate satisfactory operation of the transponder for self-test of MODES 1, 2, 3, and C and for monitoring proper response to any interrogation.

FUNCTION OF CONTROLS AND INDICATORS.

IFF CONTROL PANEL

ITEM	SETTING AND FUNCTION
MODE 4 ZERO-B-A-HOLD Switch	Enables operation of MODE 4.
MODE 4 Switch	Up and locked position enables the MODE 4 function. Unlocked and moved to "OUT" disables the MODE 4 function.
MODE 4 AUDIO-OUT-LIGHT	"AUDIO" enables both visual and audio reply indications. "OUT" disables the MODE 4 indication function of the system. "LIGHT" enables the visual indication of the system.
MODE 4 REPLY indicator light	Lights to indicate when MODE 4 replies are made with MODE 4 indication switch to "AUDIO" or "LIGHT" position.
RAD TEST-OUT-MONITOR Switch	"RAD TEST" energizes the test mode feature during check-out with the test set. "OUT" de-energizes the test mode feature. "MONITOR" energizes the monitor circuits of the "go, no-go" airborne transponder inflight tester and causes the self-test REPLY indicator light to go on when a reply is made to interrogations in any mode.
MODE 1 code selector control	Permits selection of coded reply for MODE 1 interrogations.
MODE 3 code selector	Permits selection of coded reply for MODE 3 interrogations.



RECEIVER CIRCUITS

RECEIVER CIRCUITS

The received interrogation signal is coupled to the Radio Frequency (RF) module in the receiver-transmitter. The 1030 MHz signal passes through a low pass filter (FL-1) to the first of three receiver bandpass filters (21, 22, 23) in the preselector assembly. These filters are tuned to 1030 MHz allowing the interrogation signal to pass and blocking undesired off-frequency signals. The received signal from the preselector is coupled to the crystal mixer (CR-2) where it is hetrodyned with an internally generated signal from the local oscillator.

The crystal controlled local oscillator (Q1) generates a 108.95 MHz signal. The signal is doubled in the frequency doubler stage (Q2) to 217.9 MHz. A harmonic generator (CR-3) clips and distorts the 217.9 MHz signal producing many harmonic components. A driver bandpass filter (Z-4) in the preselector assembly couples the 5th harmonic component 1089.5 MHz through to the crystal mixer (CR-2).

The received interrogation signal when heterodyned in the crystal mixer with the local oscillator signal, will produce a difference frequency component of 59.5 MHz which is coupled out to the intermediate frequency IF module.

Another function of the RF module is to couple the reply signal from the transmitter module to the antenna. A portion of this signal is detected by the transmitter monitor crystal CR-1 and coupled through a low pass filter (FL-2) to the test module.

The 59.5 MHz signal from the RF module is coupled to the first of three dual-transistor cascode-amplifier stages in the IF module. A gain control circuit in the first cascode stage (Q1, Q2) receives an adjustable LOW SENS signal from the control panel and the Automatic Overload Control (AOC) signal from the reference signal generator module. The LOW SENS control signal when present reduces IF gain approximately 12 db. The AOC signal automatically reduces IF gain when the interrogation rate becomes excessive thereby permitting only the strongest signals to be accepted by the APX-64.

Another gain control circuit is located in the second cascode stage (Q3, Q4) and it receives its signal from the gain control amplifier Q5. The gain control amplifier receives an adjustable normal gain control signal to control IF gain. Both normal gain and low-sens gain may be adjusted by potentiometers on the front of the equipment chassis.

The output of the second cascode stage is coupled through the third cascode stage (Q6, Q7) to the detector and video processing circuits. The 59.5 MHz signal is coupled through a final, single transistor, amplifier stage (Q1) to the detector (CR-2). The detector stage removes the 59.5 MHz signal component leaving the video pulse envelope.

The video signal is amplified by Q2 and split into two separate paths. One signal path is through video amplifier Q3 and delay line driver Q4. The output of Q4 is coupled into the delay line and into the SIF video AND gate. The signal is delayed 0.55 usec and applied as a second input to the AND gate. The SIF AND gate rejects signals that are not wider than 0.55 microseconds, thus eliminating noise spikes. The third SIF video AND gate input is developed in the echo suppression circuits.

The second output of the video amplifier Q2 is coupled to the echo suppression level detector Q6. When a pulse is received, it is coupled to the output of Q6 and also sets the threshold level of this stage. The threshold, once set, slowly returns to zero in approximately 8 microseconds. Any succeeding video pulse that does not exceed the amplitude of the variable threshold will not be coupled to the output. Echo signals are low amplitude signals that are received slightly after the interrogation pulses and are produced by the reflection of the base station from adjacent objects. Since these signals are low in amplitude and coupled into the echo suppression level detector before the threshold has returned to zero, they are not coupled to the output.

A side lobe suppression pulse (discussed in more detail later), if present in the interrogation signal, will occur 2 usec after an interrogation pulse and therefore will arrive before the threshold has returned to zero. If this pulse is at least 9 db below the level of the first interrogation pulse it will not be coupled to the output. The removal of the side lobe suppression pulse indicates that the interrogation signal is from the main lobe (valid signal) to the base station antenna.

The output pulses from Q6 are amplified by the echo suppression amplifier Q7 and shaped by pulse shaper Q8. The pulses are then amplified by the inverter Q9 and coupled to the inputs of both the SIF AND gate and the M4 AND gate.

The coincident output pulse from the SIF AND gate is amplified by inverter Q5, shaped by a pulse shaping circuit and coupled out to the decoder module.

The two inputs to the mode 4 AND gate, in addition to the echo suppression pulse, are from the 0.25 and the 0.55 usec delay line taps. The delay line inputs prevent coincidence of pulses that are not at least 0.3 usec wide (0.55-0.25 = 0.30) and thereby eliminate noise spikes from the mode 4 video signal. The output of the M4 AND gate is amplified by Q10 and coupled out to the decoder module.

DECODING CIRCUITS

The video interrogation pulses from the receiver circuits are coupled into the decoder circuits. The decoder examines the spacing between the pulses to determine the mode of the signal. If the signals are on the mode(s) selected by the control panel, gating signals will be produced. The gating signals initiate the generation of a coded reply signal in the coder circuits.

The mode recognition circuits are similar in operation and, therefore, only Mode 1 circuits will be discussed. A valid mode 1 interrogation signal from the receiver circuits will consist of two video pulses spaced 3 usec apart. Refer to the system specifications for pulse spacing and tolerances for each of the six available modes.

The mode 4 video output signal from the receiver circuits is coupled to a 1.0 usec signal switch that produces a sharply defined 1.0 usec output pulse for each received interrogation pulse. The pulses are then coupled to the input of the delay line within the delay line module. Each input pulse travels down the delay line and is picked off at various taps. The delay taps used in the mode 1 recognition circuits are 0.35, 3.0 and 3.55 microseconds. The delayed signals are then coupled back to the decoder module.

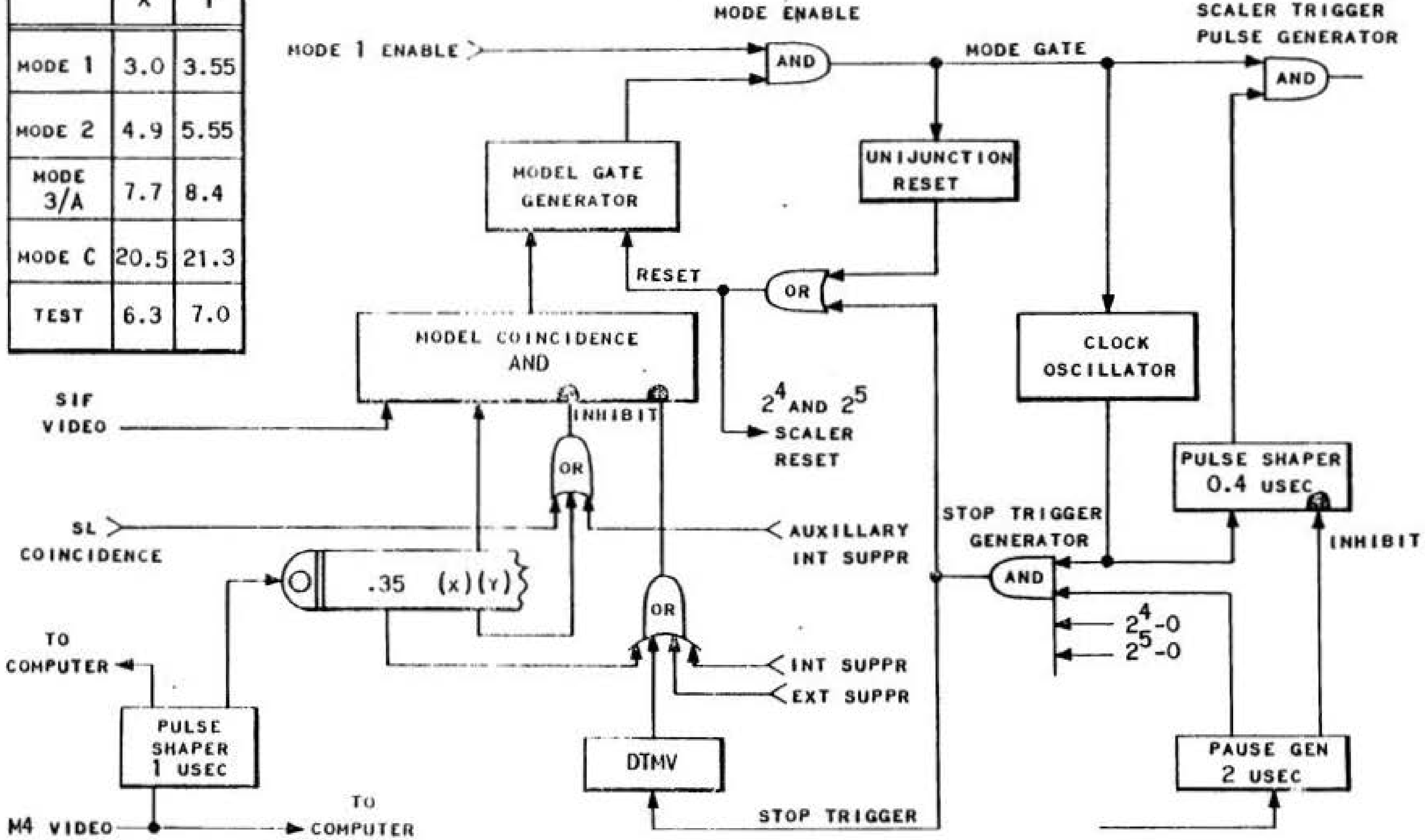
The first interrogation pulse (P1) arrives at the delay line input at the same time the SIF video pulse from the receiver circuits arrives at the mode 1 coincidence AND gate. Since two simultaneous inputs are required to produce an AND gate output no output is produced at this time.

Three microseconds later, the delayed P1 pulse from the delay line module arrives at the AND gate input in time coincidence with the undelayed last interrogation pulse P3 (SIF video). A mode 1 coincident pulse is then coupled to the mode 1 enable AND gate. Since we assume that "MODE 1" was selected on the control panel, the second AND gate (enable) input will be present. The output signal then triggers the mode 1 gate generator which is a bistable multivibrator. The gate generator switches which begins or initiates the gating signals.

To insure that the pulse spacing is within tolerance, inhibit signals are applied to the mode 1 coincidence AND gate and will prevent or inhibit the output when present. Inhibit pulses are received from the 0.35 and the 3.55 usec delay line taps. These pulses are coupled through their respective OR gates to limit the time period in which a mode 1 coincident output may be developed. If the last interrogation pulse is spaced too close or too far away (out of tolerance) from the first pulse, the inhibit pulses will prevent the generation of a mode gate trigger. Various suppression pulses are also coupled to the inhibit lines and will prevent the decoding of all interrogations when present.

One output from the mode gate generator is coupled out to the coder circuits. The other output signal is coupled to a clock enable AND gate and to a clock oscillator. The clock oscillator is gated on and generates a series of pulses spaced 1.45 usec apart. The clock pulses are coupled to a pulse shaping signal

	X	Y
MODE 1	3.0	3.55
MODE 2	4.9	5.55
MODE 3/A	7.7	8.4
MODE C	20.5	21.3
TEST	6.3	7.0



switch and to the stop trigger AND gate. The clock pulses trigger the signal switch which produces a sharply defined 0.4 usec output pulse for each input clock pulse. These pulses are then coupled through the clock enable AND gate to the coder module.

The coder module counts the pulses and returns an output pulse when the fifteenth clock pulse is generated. This pulse triggers the pause generator which inhibits the pulse shaping signal switch for approximately 2 usec and also applies a gate to the stop trigger AND gate. Assuming the other two inputs (2^4-0, 2^5-0) are present, the stop trigger AND gate will produce an output pulse when the sixteenth clock pulse is generated. The coincident pulse is coupled through an OR gate and resets the mode 1 gate generator. The stop pulse is also coupled through another OR gate to trigger the "delay time multivibrator" (DTMV) which produces an inhibit pulse preventing any further decoding for 100 usec. When the system is in "IDENT" the 2^4-0 signal from the coder will not be present and the mode gate is allowed to run for another coder period. When the system is in "EMERG," both the 2^4-0 and 2^5-0 signals from the coder are not present and the gate will be extended to cover three additional coding cycles.

The clock gate signal from the mode 1 gate generator is also applied to a unijunction reset trigger generator that will produce an output pulse approximately 250 usec after the beginning of the mode gate. This pulse will reset the mode gate generator if for some reason the normal resetting stop pulse is not generated.

The stop pulse signal is also coupled to the coder to re-enable the 2^4-0 and 2^5-0 pulse generators if these pulses have been removed due to "IDENT" or "EMERG" operation.

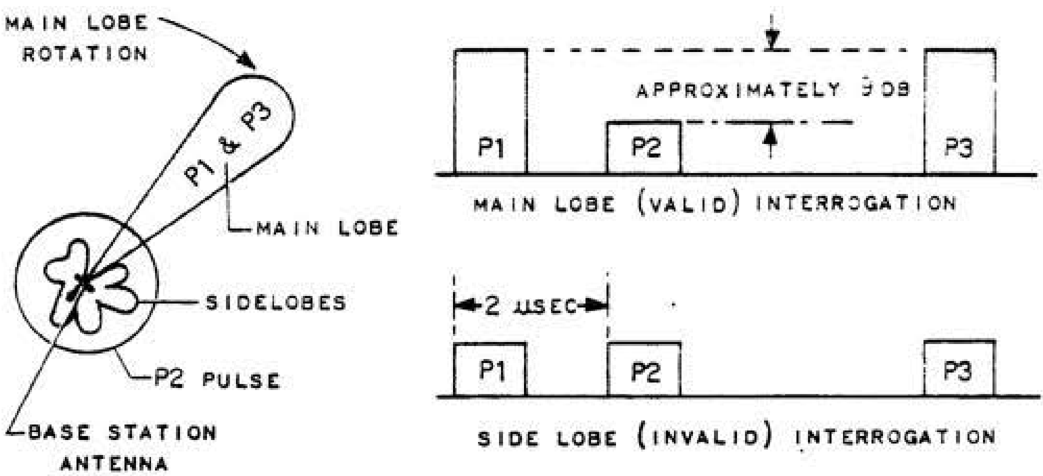
In summation, the decoding operation involves circuits in the decoder, delay line, reference signal generator and coder modules to complete its function. Mode enable signals from the control panel are also required. The decoding function provides a mode gate signal corresponding to the mode selected and a series of precisely spaced clock pulses to the coder module each time a valid interrogation is received. The length of the gate, and consequently, the number of clock pulses supplied depend on signals from the coder module that are produced by counting the clock pulses and by the I/P or emergency control signals. The clock pulses and mode gates are terminated and inhibited by a stop trigger at the end of the coding cycle.

The decoder module also contains circuits used in conjunction with the external computer in providing complete mode 4 operation. These circuits operate warning lights to indicate mode 4 operation. The mode 4 REPLY light will illuminate when the computer generated reply signal is transmitted. The mode 4 caution lights will illuminate when a mode 4 interrogation is received and no reply is transmitted. An audio signal is also provided to indicate that a mode 4 signal has been decoded.

SIDE LOBE SUPPRESSION CIRCUITS

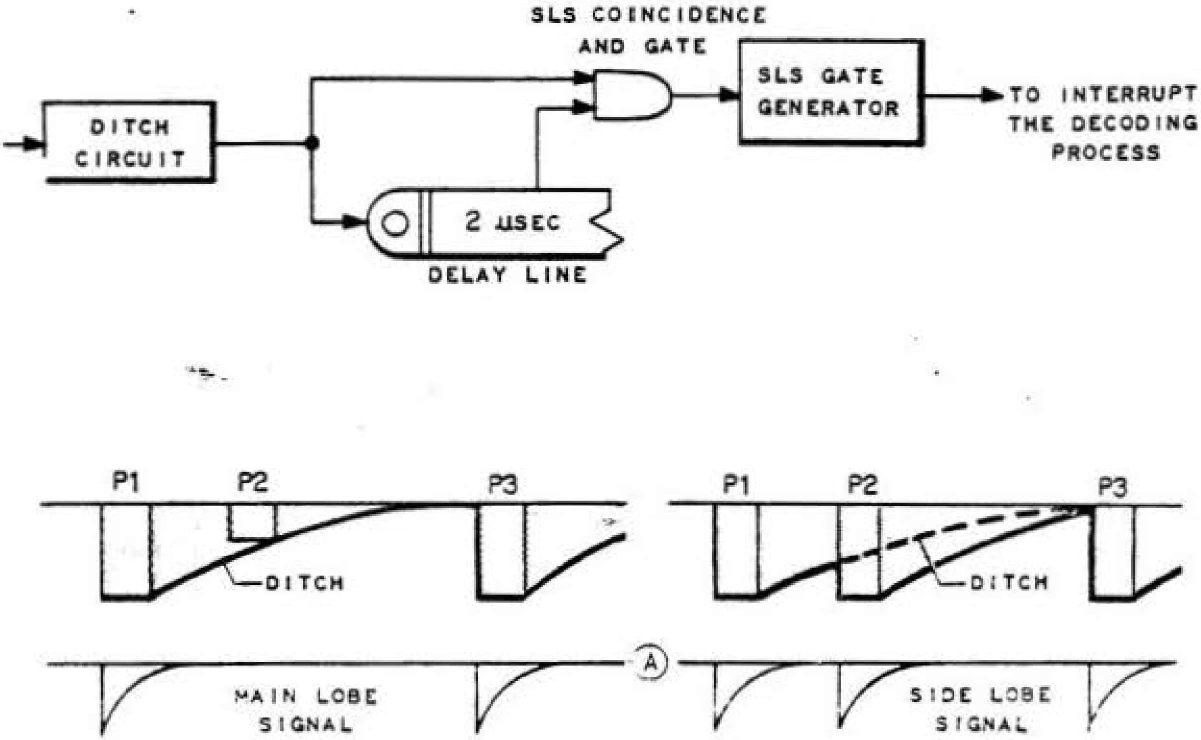
Side Lobe Suppression (SLS) is a process of interrupting the decoding process and preventing the APX-64 from replying to side lobe signals from the base station antenna. Side lobes are low amplitude "splash over" signals that are radiated in directions other than the main lobe directional beam. These undesirable signals cannot be completely eliminated and can cause the APX-64 to reply at the wrong time, thus obscuring the bearing information. To enable the APX-64 to sense side lobe interrogations the base station transmits an omni directional SLS pulse (P2) two microseconds after the first interrogation pulse. The amplitude of the SLS pulse is approximately equal to the side lobes. The APX-64 compares the amplitude relationship between the received P1 and P2 pulses. If the interrogation is valid (main lobe) the P1 pulse will be many times larger in amplitude than the P2 pulse (at least 9 db) and the interrogation is accepted. If the P1 pulse is from a side lobe it will be equal to or smaller in amplitude than the P2 pulse and the interrogation is rejected.

Side lobe detection circuits in the APX-64 generate a ditch shaped waveform for each input pulse. The depth of the ditch is determined by the amplitude of the pulse. Any succeeding pulse that does not exceed the amplitude of the ditch will not be coupled to the output. If a side lobe interrogation is received, the P2 pulse will be large with respect to the P1 pulse and will be coupled to the output.



BASE STATION INTERROGATION
SIGNAL RADIATION PATTERN

The pulses from the SLS detection circuit are applied to the decoder where an SLS gate generator will be triggered when the P2 pulse is present. The SLS gate circuit will produce a 35 usec suppression pulse to prevent a reply from being generated.



SIDE LOBE DETECTION
CIRCUITS
AND WAVEFORMS

The SLS trigger is produced in the same manner as the mode trigger (previously discussed). The delayed P1 pulse will be coincident with the P2 pulse to trigger the SLS gate generator.

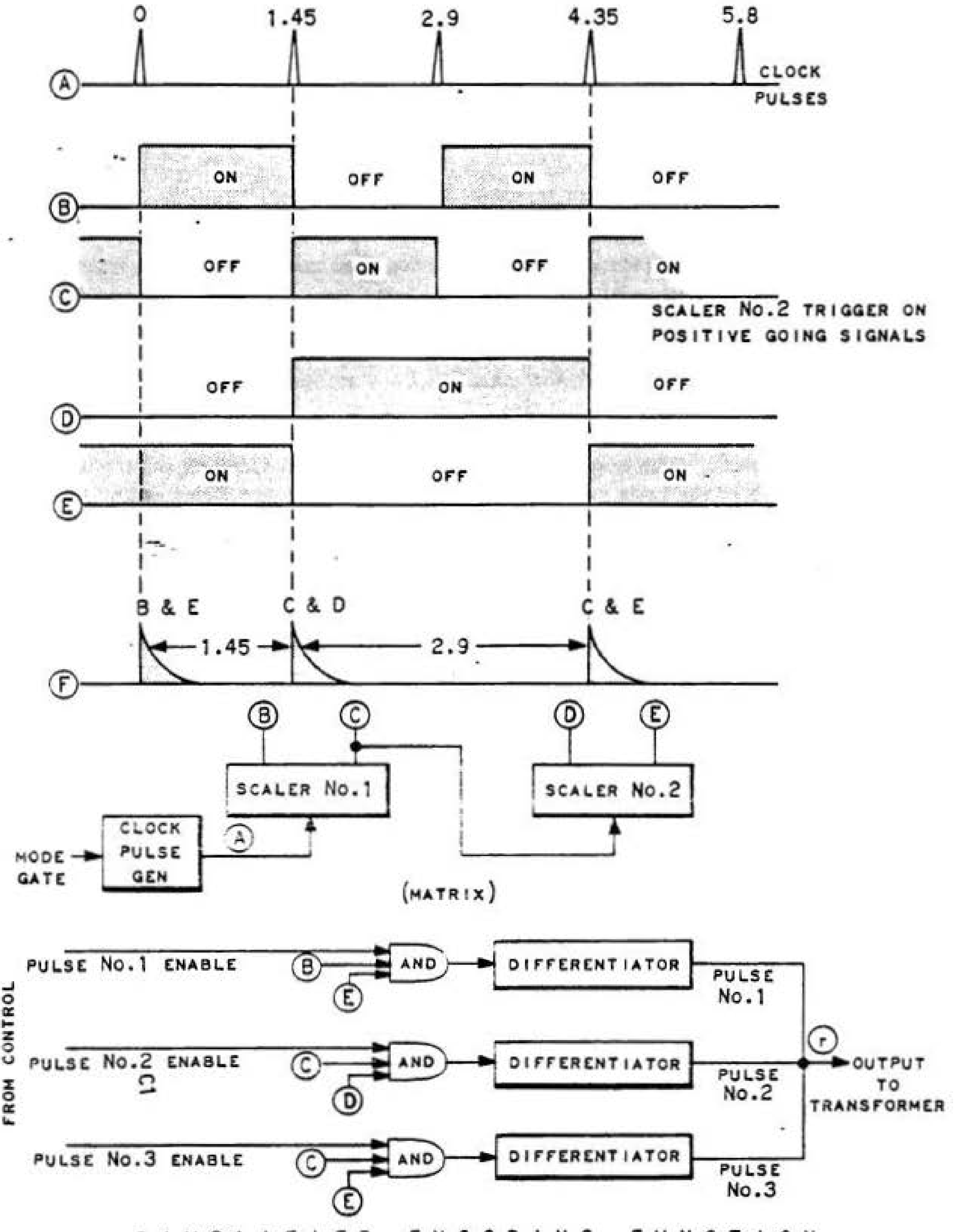
ENCODING PROCESS

Encoding the reply signal is a process of producing a train of precisely spaced pulses, the number of which is manually selected on the APX-64 controls. A reply train is produced for each valid interrogation received by the system. The mode gate generator in the decoder initiates the generation of a series of pulses spaced 1.45 usec apart from a clock pulse generator. The clock pulses are applied to a series of scalers which are in effect frequency dividers. Each scaler is an electronic switch that changes its state (switches) each time it receives a "positive going" input pulse. The outputs of the scalers are then applied to a pulse enabling matrix that will allow the selected clock pulses to appear at the output. The selection of output pulses is provided by control signals corresponding to the code selected. For example, suppose three output pulses with 1.45 usec between the first and the second and 2.9 usec between the second and the third are desired.

The first pulse will be produced when the outputs B and E of the scalers are positive and a pulse No. 1 enable signal is provided. Similarly, pulses No. 2 and No. 3 will be produced when scaler outputs C and D, plus C and E are positive and the corresponding enable signals are present. The coincident positive signals from each AND gate are differentiated, producing a spike at the time of coincidence. These spikes are the generated reply train that will be used to trigger the transmitter.

The actual encoding circuits used in the APX-64 contain three pulse-counting scalers that produce two outputs each. All the zero outputs are positive and all the one outputs are negative at the beginning of the encoding count down. The scaler output chart indicates the condition of the six output terminals at various stages of the count down. Only the positive (1) outputs are operating signals in the time matrix AND gates. From the chart and the encoder block diagram note the process of enabling the fourteen time matrix AND gates in stepped sequence as the count down progresses. Each time, matrix AND gate requires an additional pulse-enabling signal that is produced by the code select knobs on the control panels, or by the altitude coding computer. Mode gates from the decoder module must also be present to enable the pulse selecting circuits to enable the various pulses.

Automatic enabling or disabling of the time matrix and gates is controlled by signals from the I/P and emergency control circuits in the reference signal generator. When "EMERG" is selected on the control panel and a mode 3/A interrogation signal is received and decoded, a control signal is produced to

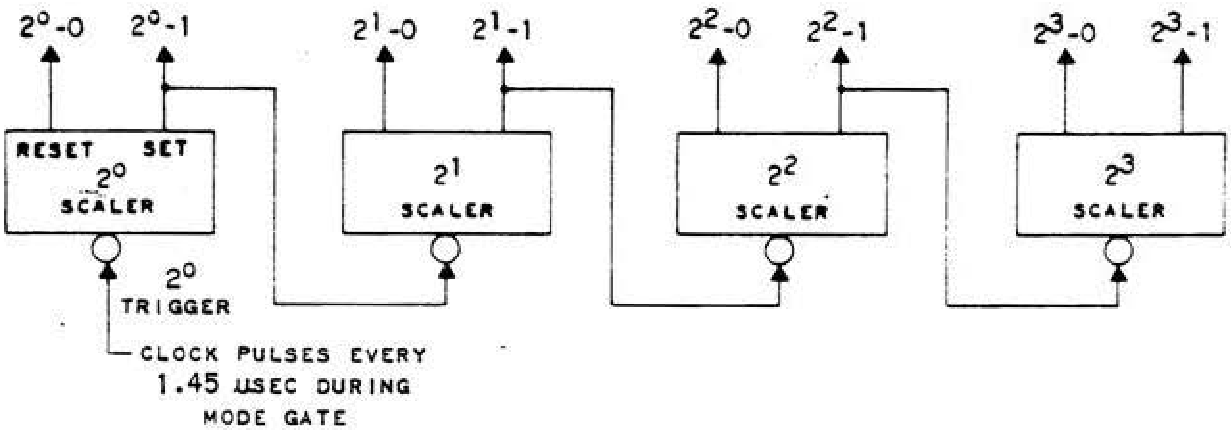


SIMPLIFIED ENCODING FUNCTION

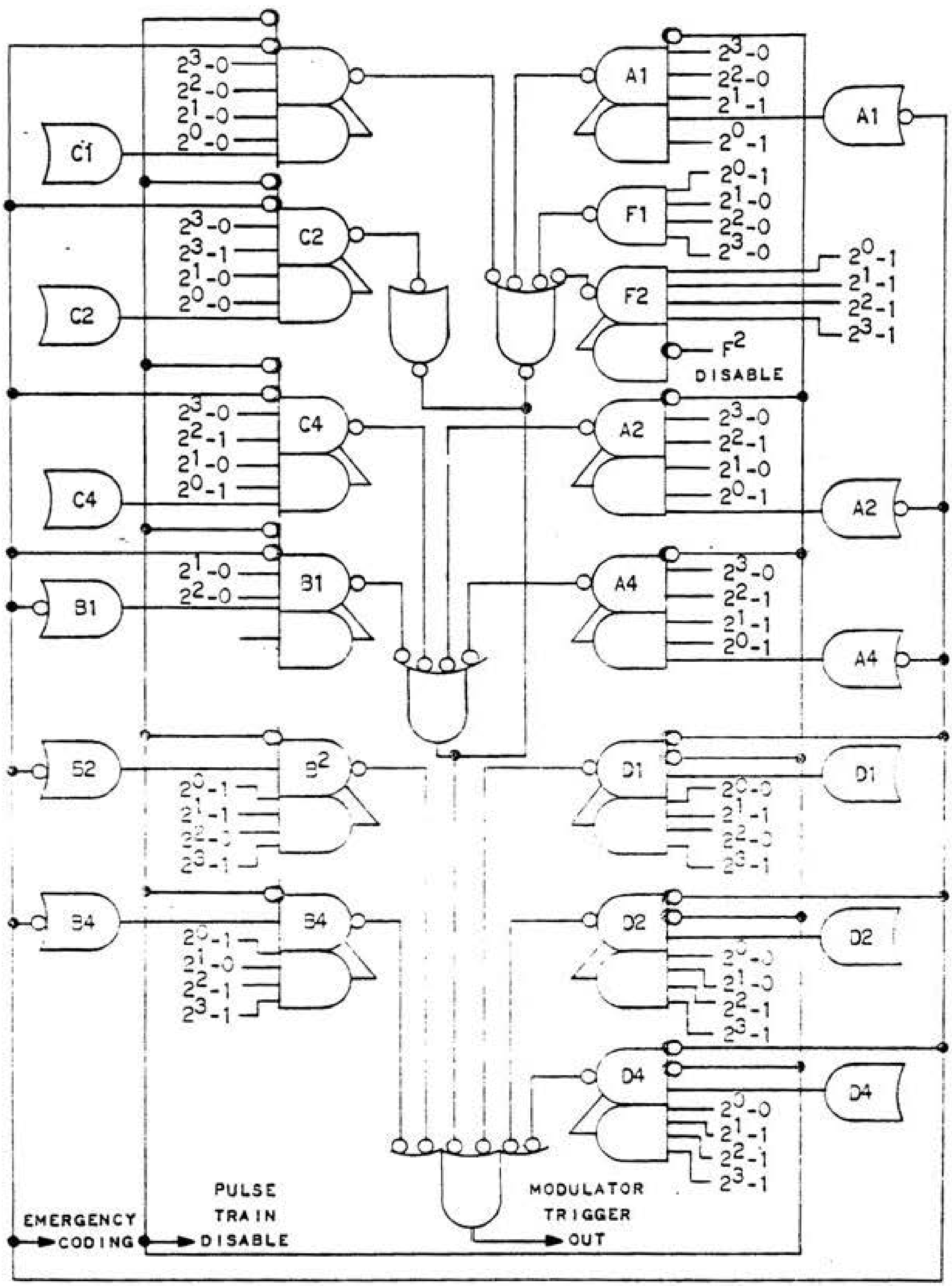
automatically enable all A and B time matrices and disable all C and D time matrices. This produces a 7700 output code regardless of the code selected by the MODE 3/A control knobs. The second control signal input will disable all information pulses when present and the F2 disable control signal will remove the second framing pulse when present.

I/P AND EMERGENCY CONTROL CIRCUITS

The I/P and emergency control circuits generate signals that change the generated reply signal. Closing either the IDENT or the EMERG switch on the control panel or by having the D4 pulse enabled by the external altitude coding computer will initiate the reply code change. The actual changes that take place depend on the mode of the received interrogation signal.



	2^0-0	2^0-1	2^1-0	2^1-1	2^2-0	2^2-1	2^3-0	2^3-1	
0	1	0	1	0	1	0	1	0	—
1	0	1	1	0	1	0	1	0	F1
2	1	0	0	1	1	0	1	0	C1
3	0	1	0	1	1	0	1	0	A1
4	1	0	1	0	0	1	1	0	C2
5	0	1	1	0	0	1	1	0	A2
6	1	0	0	1	0	1	1	0	C4
7	0	1	0	1	0	1	1	0	A4
8	1	0	1	0	1	0	0	1	X
9	0	1	1	0	1	0	0	1	B1
10	1	0	0	1	1	0	0	1	D1
11	0	1	0	1	1	0	0	1	B2
12	1	0	1	0	0	1	0	1	D2
13	0	1	1	0	0	1	0	1	B4
14	1	0	0	1	0	1	0	1	D4
15	0	1	0	1	0	1	0	1	F2
0	1	0	1	0	1	0	1	0	—



CODER - CODE SELECT MATRIX

If either the IDENT switch is closed or the mode C D4 pulse is enabled, the mode gate will stay open long enough for two complete coding cycles. The IDENT switch operates with a received model, mode 2 or mode 3A interrogation and the mode C D4 enable operates with a received mode C interrogation.

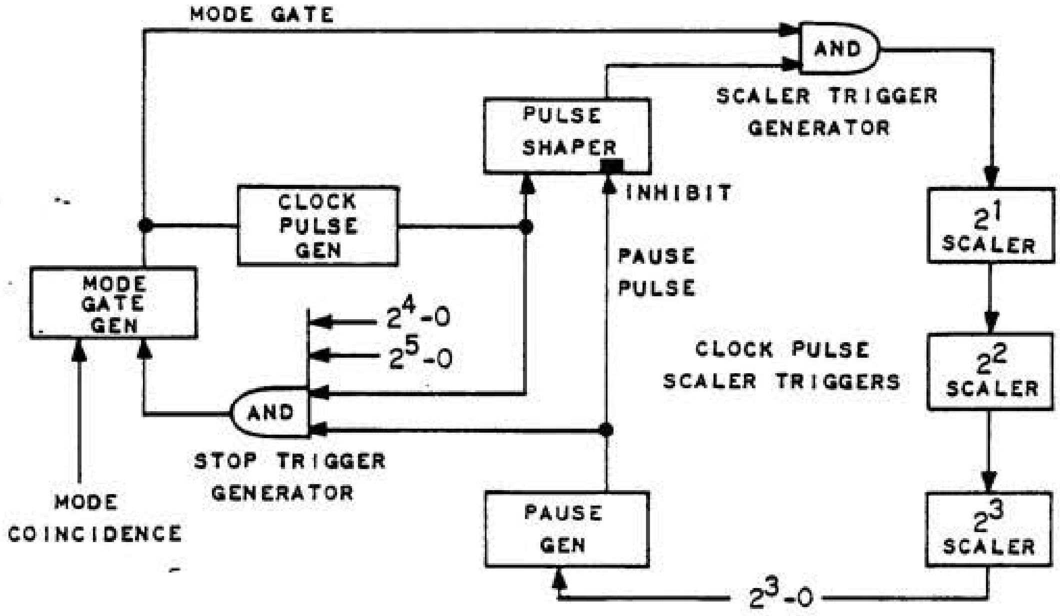
If the EMERG switch is closed the mode gate will stay open long enough for four complete coding cycles.

Mode gate extension is produced by triggering the 2^5 scaler and/or the 2^4 scaler in the coder module at the end of the first generated reply train. If the 2^4 scaler is triggered the gate will stay open two coding cycles and if both the 2^4 and the 2^5 scalers are triggered the gate will stay open for four coding cycles. When either scaler is in the set or triggered state the gate stop generator in the decoder module is disabled. Disabling the stop trigger generator prevents normal gate stoppage at the end of the first reply train. The 2^4 and 2^5 scalers will be retriggered at the proper time changing them back to the reset state thereby re-enabling the gate stop generator. Therefore, the first function of the I/P and emergency control circuits is to trigger the 2^4 and 2^5 scalers at the proper time to produce the required mode gate extension.

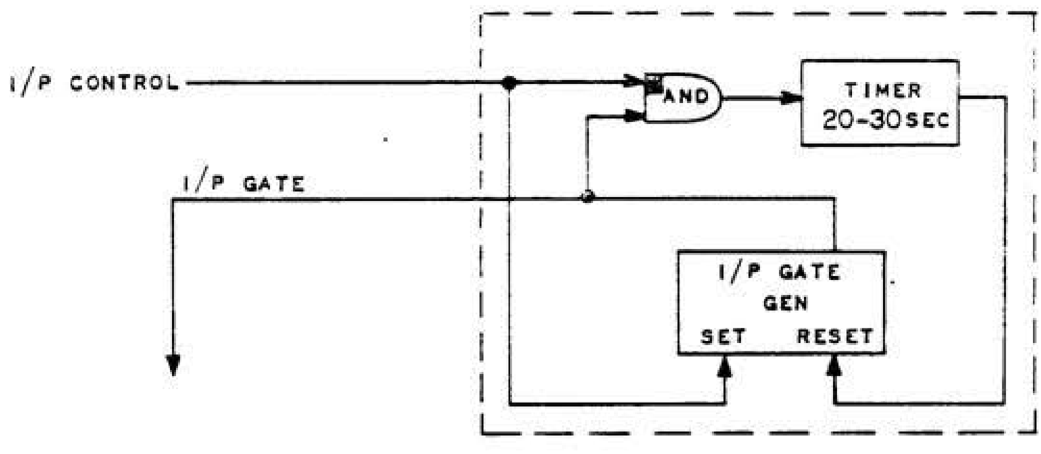
The second function of the I/P and emergency control circuits is to supply control signals to the code enable matrix in the coder module. These control circuits will automatically enable and/or disable the required information and framing pulses to correspond to the desired reply.

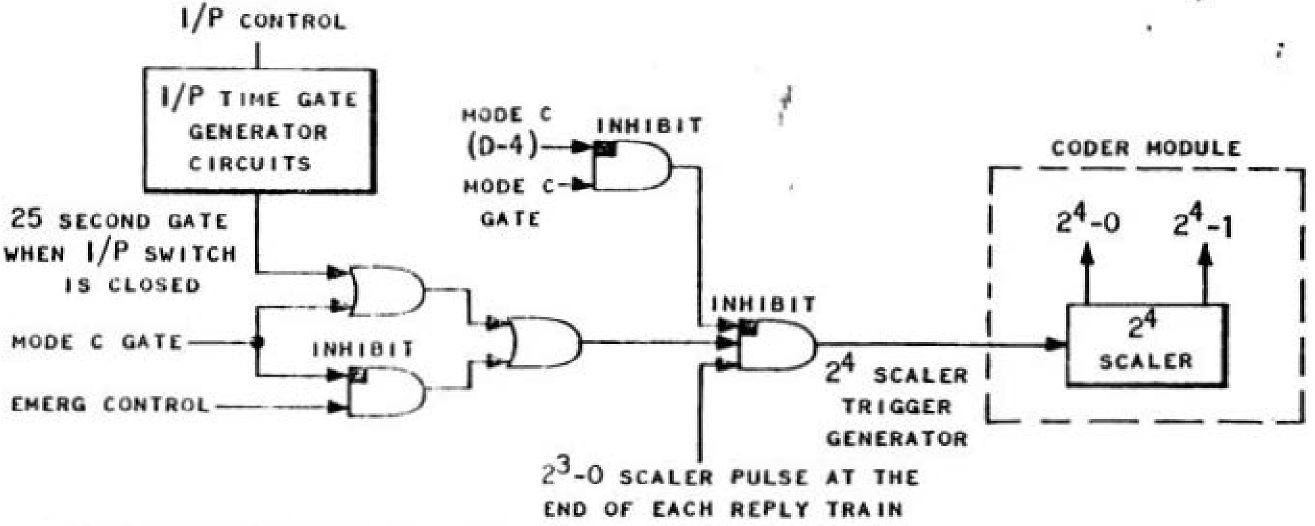
Before proceeding with the discussion of mode gate extension a brief review of normal mode gate generation will be given.

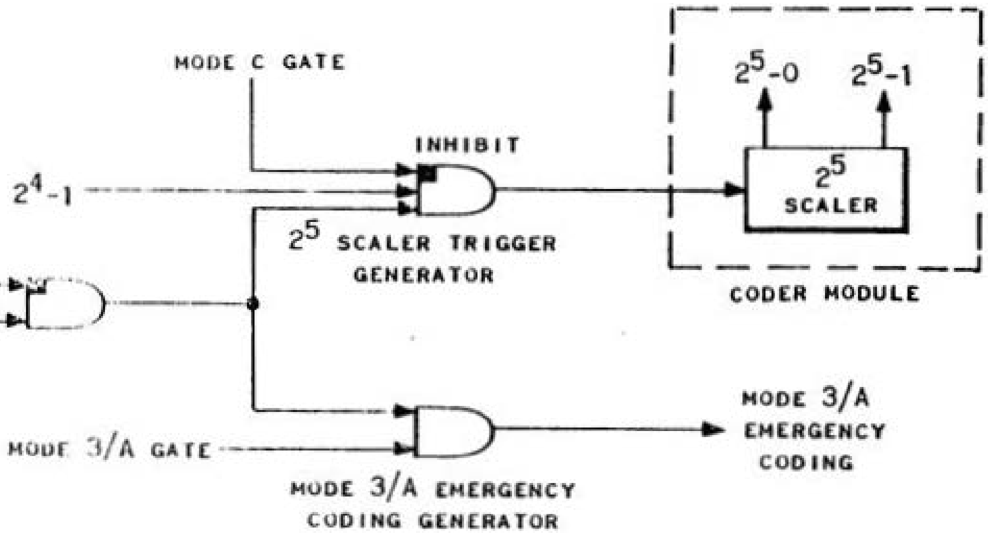
When an interrogation signal is decoded a trigger pulse is supplied to the mode gate generator multivibrator. The mode gate generator changes to the set state which begins the mode gate. The mode gate signal enables the clock pulse generator which produces a series of pulses spaced 1.45 usec apart. Each clock pulse is one count in the coding cycle count down. The mode gate also enables the scaler trigger AND gate and allows the clock pulses to trigger the pulse counting scalers (2^0, 2^1, 2^2, 2^3) in the coder module. On the sixteenth count or when the sixteenth clock pulse is produced, the 2^3-0 output of the 2^3 scaler will go positive supplying a trigger signal to the 2 usec pause gate generator. The pause gate signal inhibits the scaler triggers and enables the mode gate stop trigger generator. The next clock pulse (count No. 17) then passes thru the stop trigger generator, resetting the mode gate generator and thereby ending the mode gate. Note that the stop trigger generator is an AND gate requiring a positive 2^4-0 and 2^5-0 signal from the coder scalers to be present. If either of these inputs are removed, the stop trigger will not be generated and the mode gate will remain open.



The I/P gate generating circuits produce an I/P enabling gate signal for approximately 25 seconds each time the IDENT switch is closed. The I/P signal from the control panel supplies a trigger to the I/P gate generator and an inhibit signal to the I/P AND gate. The I/P gate generator is a bistable multivibrator that produces the I/P gate when triggered. When the IDENT switch is released, it returns to the "off" position, re-enabling the I/P AND gate. The I/P gate signal then passes through the AND gate to a timer circuit. Approximately 25 seconds later the timer supplies an output pulse that resets the I/P gate generator ending the I/P gate. The I/P gate signal is supplied to the I/P and emergency control circuits to generate the required code changing signals.




I/P CONTROL
I/P TIME GATE GENERATOR CIRCUITS
MODE C (D-4)
INHIBIT
MODE C-
GATE
CODER MODULE
2^4-0
2^4-1
25 SECOND GATE WHEN I/P SWITCH IS CLOSED
MODE C GATE
INHIBIT
EMERG CONTROL
INHIBIT
2^4 SCALER
2^4 SCALER TRIGGER GENERATOR
2^3-0 SCALER PULSE AT THE END OF EACH REPLY TRAIN


MODE C GATE
2^5-0
2^5-1
INHIBIT
2^4-1
2^5 SCALER
2^5 SCALER TRIGGER GENERATOR
MODE C GATE
EMERG CONTROL
CODER MODULE
MODE 3/A EMERGENCY CODING
MODE 3/A GATE
MODE 3/A EMERGENCY CODING GENERATOR

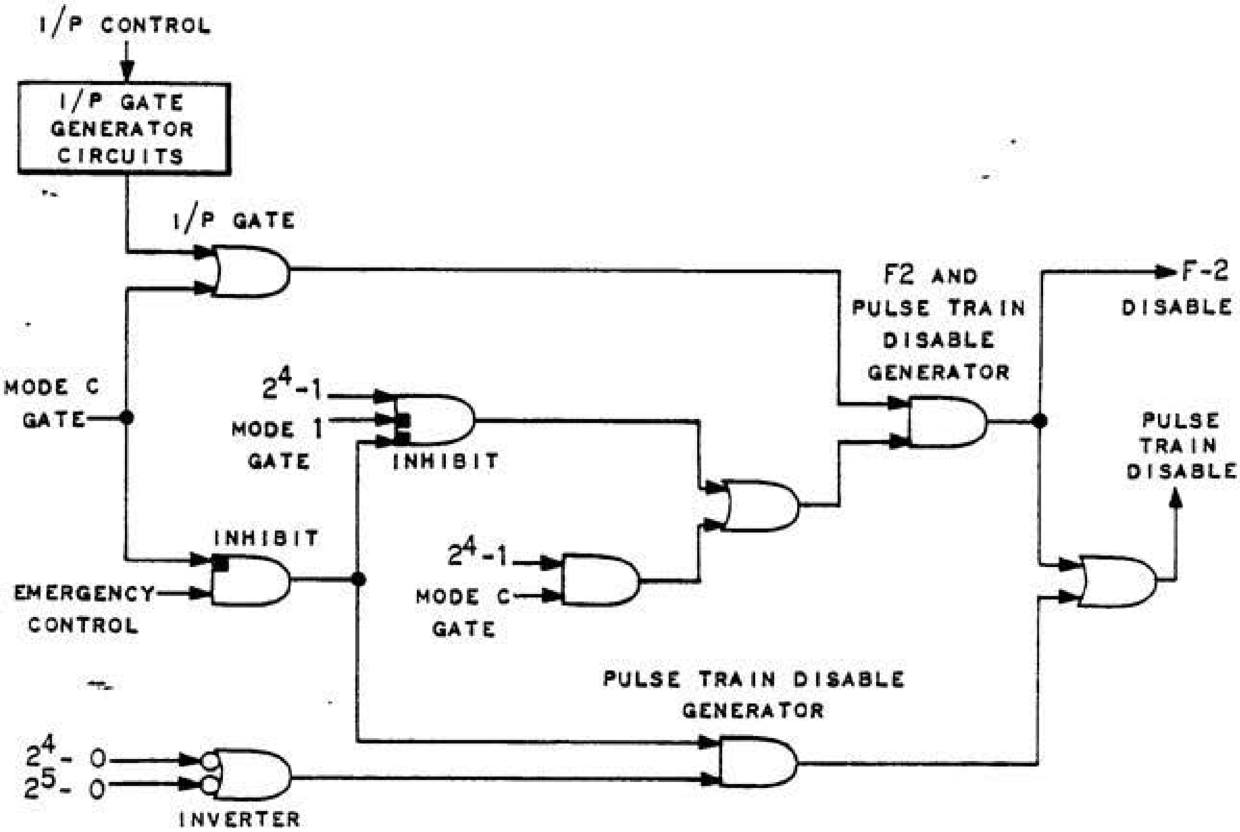
When the emergency switch is closed and no mode C signal is decoded, the emergency signal will be supplied to one input of the 2^5 scaler trigger generator. The 2^5 scaler trigger will then be generated when the 2^4 scaler is triggered due to the 2^4-1 input. At the end of the second reply train the 2^4 scaler will be triggered as explained before, removing the 2^4-1 input to the 2^5 scaler trigger generator. The 2^5 scaler is still in the set state and therefore the mode gate stop trigger generator is still inhibited. The mode gate will therefore remain open through the third coding cycle. At the end of the third coding cycle the 2^4 scaler is again triggered which supplies a trigger to the 2^5 scaler to change it back to its original state. At the end of the fourth coding cycle the 2^4 scaler is triggered again and at this time both the 2^4 and the 2^5 scalers will enable a stop pulse to be generated ending the mode gate.

If a mode 3/A interrogation signal is decoded when the EMERG switch is closed, the mode 3/A emergency coding generator will be enabled which will supply a reply code changing signal to the coder module. This signal will automatically enable all A and B reply pulses and disable all C and D reply pulses regardless of the coding set on the control panel. The reply signal produced will then be a 7700 signal.

The I/P gate passes through two OR gates to the input of the 2^4 scaler trigger generator. At the end of the first reply train a 2^2-0 pulse from the coder module is supplied to the other AND gate input. If no input is supplied to the inhibit terminal, a 2^4 scaler trigger is generated. If a mode C interrogation is decoded the mode C gate passes through the two OR gates to the AND gate. If no D4 pulse is present in the reply, the 2^4 trigger generator is inhibited. If the D4 pulse is present the inhibit pulse to the 2^4 trigger generator is inhibited by the mode C D4 AND gate. Therefore, a mode C interrogation with the D4 pulse present will allow the 2^3-0 pulse to produce a 2^4 scaler trigger at the end of the first coding cycle. The 2^4 trigger will set the 2^4 scaler removing the 2^4-0 input to the mode gate stop trigger generator (as mentioned before). At the end of the second coding cycle the 2^4 scaler is triggered back to its original condition allowing the mode gate stop trigger to end the mode gate.

When the EMERG switch on the control panel is closed and an interrogation signal is decoded other than mode C the emergency control signal passes through an OR gate to the 2^4 trigger generator allowing the 2^4 scaler to be triggered at the end of each reply train. If mode C is decoded the mode C gate inhibits the emergency control signal.

When the EMERG switch is closed and a mode 1, 2 or 3/A interrogation is received the information between the two framing pulses will be removed in the second, third, and fourth pulse trains. The pulse train disable signal is produced when the emergency signal is supplied by the control panel and not inhibited by a mode C gate. The emergency gate is supplied as one input to the pulse



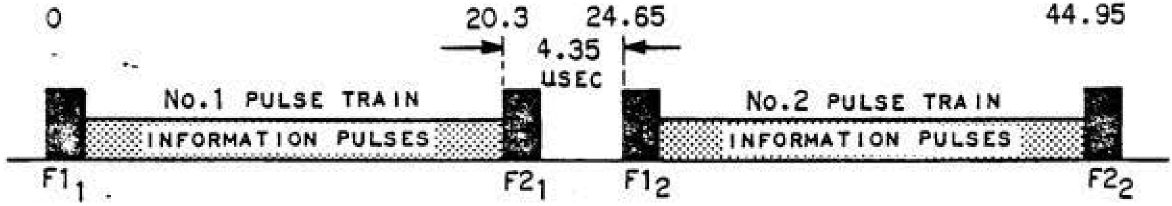
train disable generator. The second input is supplied when either the 2^4-0 scaler output or the 2^5-0 scaler output is not positive. The pulse train disable signal is then coupled through an OR gate to the code select matrix in the coder module.

When the EMERG switch is closed and a mode 2 or 3/A interrogation is decoded, both the pulse train and the second framing pulse will be disabled in the second pulse train. Since there are only two pulse trains developed in I/P the only coding change will be the addition of a second F1 framing pulse 4.35 usec after the last framing pulse in the first pulse train. If the interrogation received was a mode 1 signal the F2 and pulse train disable generator will receive only one input (I/P) and a second fully coded pulse train will follow the first pulse train.

When a mode C interrogation is received the second pulse train will only include the first framing pulse. Remember that a second pulse train is only generated if the D4 pulse is present in the first pulse train.

AOC CONTROL SIGNAL CIRCUITS

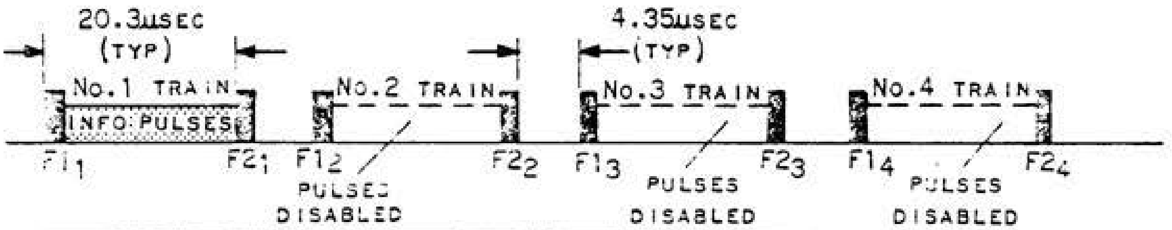
The AOC control signal is generated in the reference signal generator module.

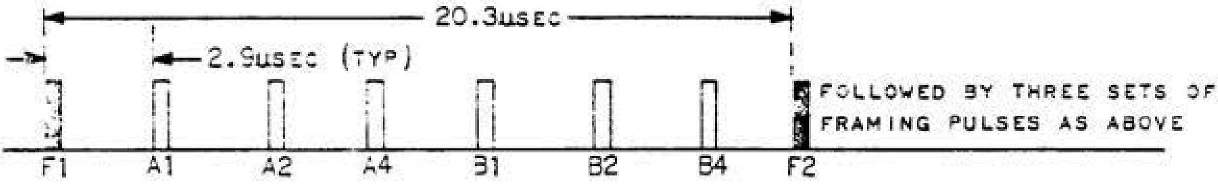


MODEL I/P REPLY

MODE 2 AND 3/A I/P REPLY
MODE C REPLY WHEN D4 PULSE IS PRESENT IN FIRST TRAIN

MODE 1 AND 2 EMERGENCY REPLY





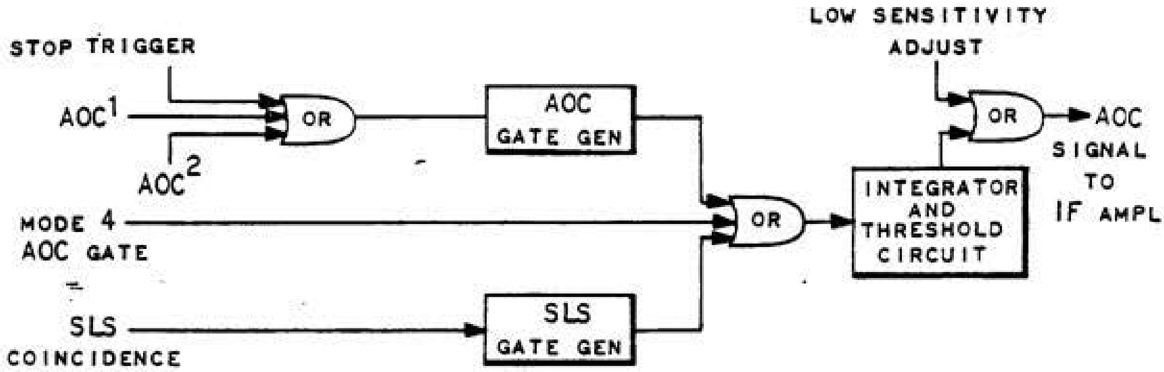
ALL C AND D PULSES DISABLED

MODE 3/A EMERGENCY REPLY

NOTE:
NO I/P OR EMERGENCY CODING IN MODE C

I/P AND EMERGENCY CODING

This signal limits the transmitted reply signal rate to any preset valve between 500 and 1500 replies per second. Reply rate reduction is accomplished by gradually reducing the sensitivity of the IF amplifier as the limiting level is approached. In this way, weaker interrogation signals are discriminated against in favor of stronger signals. Standardized pulses received from various circuits in the receiver-transmitter are applied to an integrator circuit followed by a threshold circuit. When the input pulse rate becomes excessive, the output of the integrator will exceed the threshold level. The signal from the threshold circuit is the control voltage that is coupled to the IF amplifier module. Since the level of the AOC control signal is proportional to pulse rate, the gain reducing AOC signal will increase in proportion to the pulse rate.



AOC CONTROL SIGNAL GENERATOR

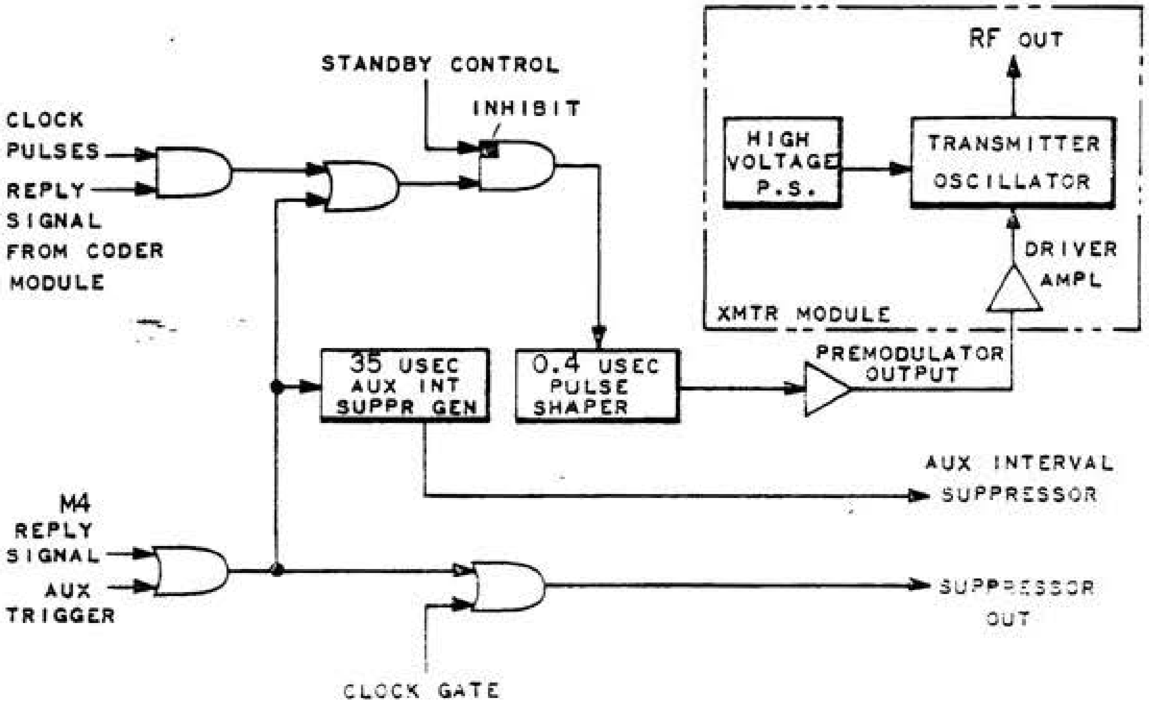
Three input signals are fed to the integrator circuit. A pulse from the AOC gate generator is produced at the beginning of the clock gate (AOC^1) and at the end of the reply signal (stop trigger). When the system decodes and transmits a mode 2 emergency signal an additional pulse will be produced by the 2^5 scaler (AOC^2). The output of the AOC gate generator will limit a mode 1, 2, or 3A reply rate to 1500 per sec. Mode 2 emergency replies are limited to 800 per sec. The second input is applied each time the system receives an invalid sidelobe interrogation signal (SLS coincidence). The third input is applied each time the mode 4 interrogation is decoded (mode 4 AOC gate).

The quiescent (no signal) output level of the AOC control circuit is adjusted by the RCVR-SENS level adjust resistor on the front panel of the receiver-transmitter.

MODULATOR-TRANSMITTER CIRCUITS

The modulator increases the reply signal gain to a level sufficient to trigger the transmitter. The transmitter consists of a lighthouse triode vacuum tube installed in a resonant cavity. Each trigger pulse from the modulator shock excites the transmitter which produces a high level 1090 MHz RF signal for the length of the trigger pulse. The RF pulses from the transmitter cavity are coupled through the preselector in the RF module to the antenna and radiated.

The modulator circuits are divided between two modules. The circuits that initially receive input signals are located in the reference signal generator module and are called the premodulator. The premodulator output signals are then coupled to the final modulator or driver circuits within the transmitter module.



MODULATOR - TRANSMITTER CIRCUITS

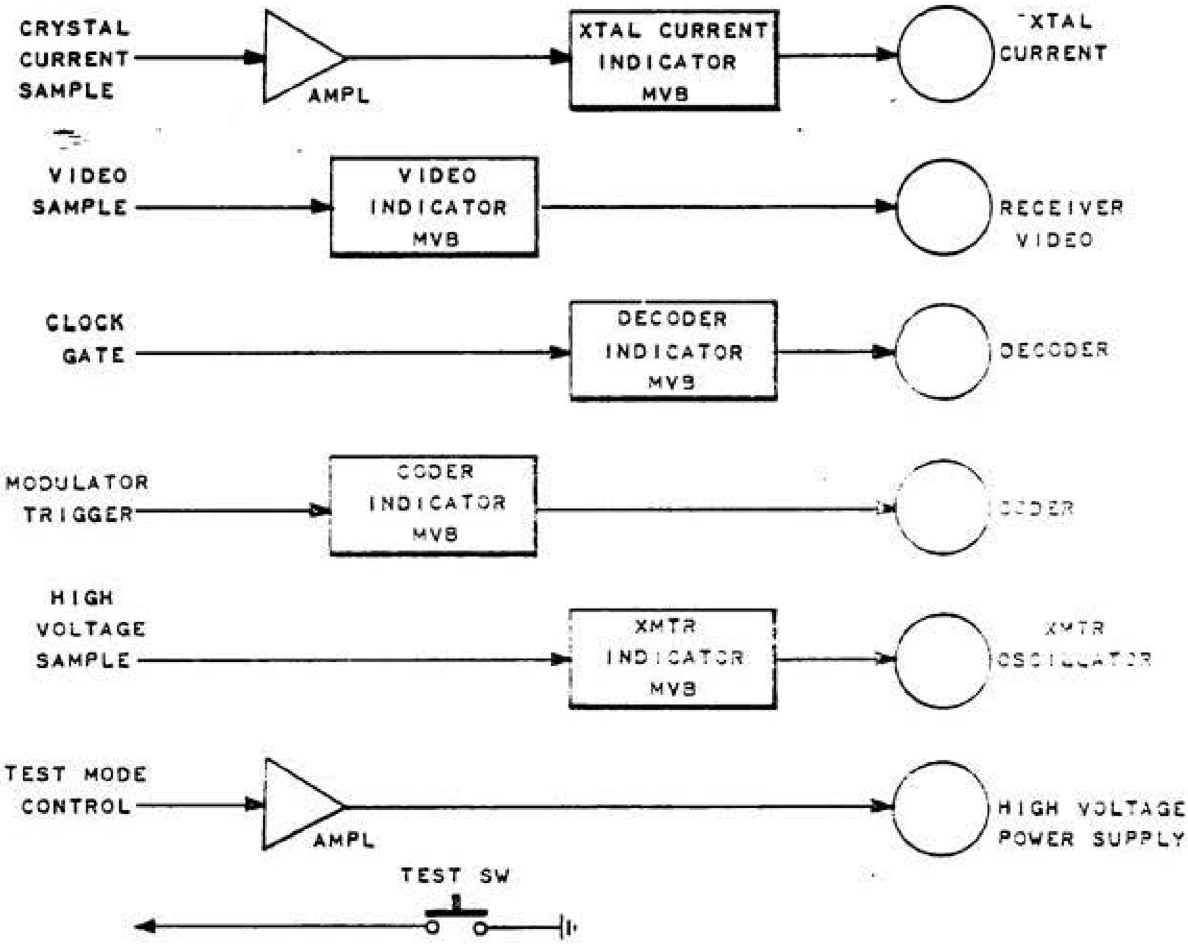
The generated reply signals from the coder module are coupled to the input of an AND gate with the output of the clock pulse generator. Each coincident pulse is coupled through an OR gate to the standby control AND circuit. When the function switch on the control panel is in "STBY" (standby), the inhibit signal prevents further processing of the modulator signal. The reply signal is coupled to a pulse shaper that developes a sharply defined 0.4 usec output pulse for each input pulse. The reply signal is then amplified further and coupled out to the transmitter module.

Mode 4 reply signals and auxiliary trigger signals are also coupled to the premodulator circuits. These signals follow the same path as the coder generated pulses after triggering the auxiliary internal suppressor multivibrator. Each pulse is also coupled to the suppressor output terminal.

The auxiliary internal suppressor produces a 35 usec gate to inhibit further signal decoding. The suppressor output signal may consist of mode 4 or auxiliary input signals or the clock gate signal from the decoder module.

TEST MODULE

The test module receives input signals from various circuits throughout the receiver-transmitter unit. Each input signal will light its corresponding monitor light indicating that the circuit monitored is operating correctly. The input signals whose time duration is too short to keep the monitor lamp illuminated



are used to trigger monostable multivibrators in the test module. Each multivibrator will produce an output pulse with approximately 5 MS duration when triggered by an input signal. The multivibrator outputs are then coupled to the indicator lights. The circuits monitored are as follows:

- Crystal Current
- Receiver Video
- Decoder
- Coder
- Transmitter Oscillator
- High Voltage Power Supply

A test switch on this module will induce noise in the IF amplifier of sufficient magnitude to trigger any selected mode gate generator when pressed. The receiver-transmitter will then generate a reply signal.

POWER SUPPLY

The power supply module furnishes regulated and unregulated voltages for the system. Input voltage is 115 volts, AC. The unregulated output voltages are +45 volts, DC, 6.3 volts, AC, and 1 volt, AC. The regulated output voltages (D-C) are +100, +20, +10, +6, +4, -2, -4, -6, and -20 volts, DC. The power supply contains transient suppressor circuit that will automatically reduce the input voltage to a safe valve if it rises above 140 volts, AC.