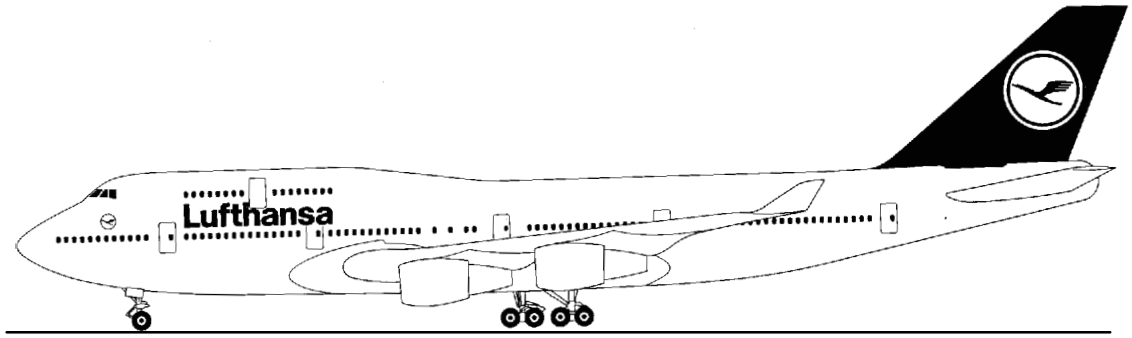
Lufthansa Technical Training

Training Manual B 747-400



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ATA 34-53 AIR TRAFFIC CONTROL

AIR TRAFFIC CONTROL - INTRODUCTION

ATC General

The airborne transponder is an important part of the air traffic control system being used today. The air traffic control (ATC) system responds to interrogations from both ATC ground stations, and WAS equipped airplanes.

ATC Operation

ATC ground facilities or TCAS equipped airplanes interrogate the airborne transponder and the transponder automatically sends back replies. The ATC ground facility interrogation is transmitted out on a secondary surveillance radar (SSR) that is mounted on the ATC primary surveillance radar (PSR). The SSR is scan synchronized with the PSR. This allows the ATC controller to see both the PSR return and the ATC transponder reply together on a radar display. A special side-lobe suppression (SLS) antenna prevents close-in targets from replying to any interrogation transmission side-lobes. WAS interrogations are covered in the WAS lesson.

The ATC system transmits interrogation signals on 1030 Mhz, and the airborne transponders reply on 1090 Mhz. There is a variety of different interrogation signal formats. The air traffic control radar beacon system (ATCRBS) format uses two modes. Mode A tells the air traffic controller the selectable 4096 airplane identification code. Mode C shows the airplanes altitude.

There is now a new mode S (Select) that allows the ATC controller or a WAS equipped airplane to interrogate in a digital data link format. This allows the interrogator to receive much more data than the old ATCRBS format. Each mode S transponder replies with either a 56-bit or a 112-bit digital data transmission. This is a report of airplane altitude, ATCRBS 4096 code, flight status, special position identification, and a 24-bit discrete airplane address. These interrogation formats are covered in more depth later in this lesson.

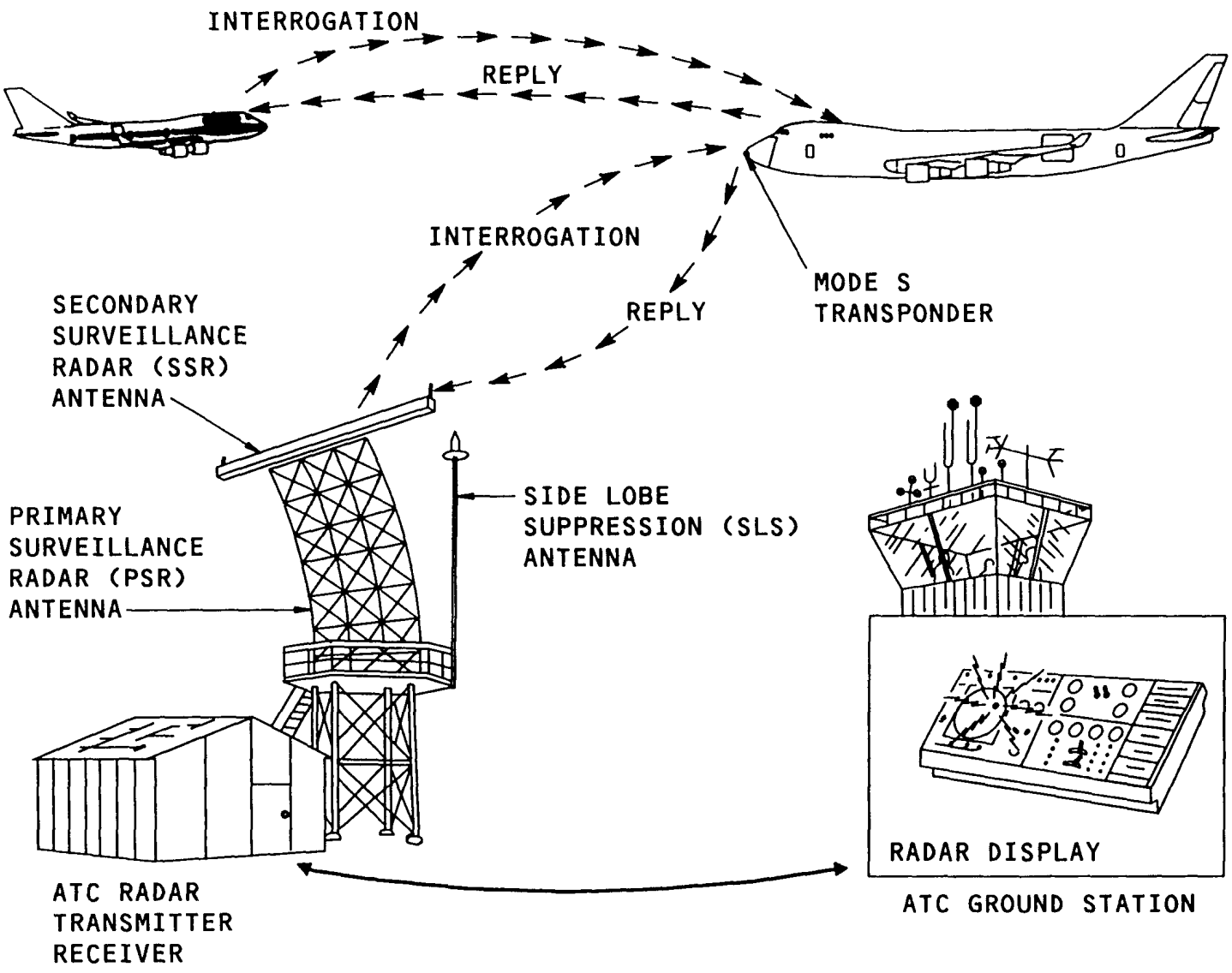


Figure 1 AIR TRAFFIC CONTROL - INTRODUCTION

AIR TRAFFIC CONTROL SYSTEM

General

The dual Mode S ATC/TCAS system has ground and airborne components. When interrogated, the airborne system automatically transmits a pulse-coded reply signal. The reply signal identifies, locates and shows altitude of airplanes equipped with ATC equipment. The TCAS portion of the transponder is not discussed in this lesson.

General Description

The components of an ATC system are:

- Left ATC Transponder
- Right ATC Transponder
- ATC/TCAS Control Panel
- Top ATC Antenna
- Bottom ATC Antenna

The interfacing components of the system are:

- Left Air Data Computer (ADC)
- Right ADC
- Center ADC
- Left central maintenance computer
- Right central maintenance computer
- TCAS Computer
- Left DME
- Right DME

The two antennas supply inputs/outputs to the ATC transponder through switching relays.

The left, center or right ADC supplies altitude data through the ADC source select relays.

The ATC receives interrogations on 1030 MHz and transmits replies on 1090 MHz.

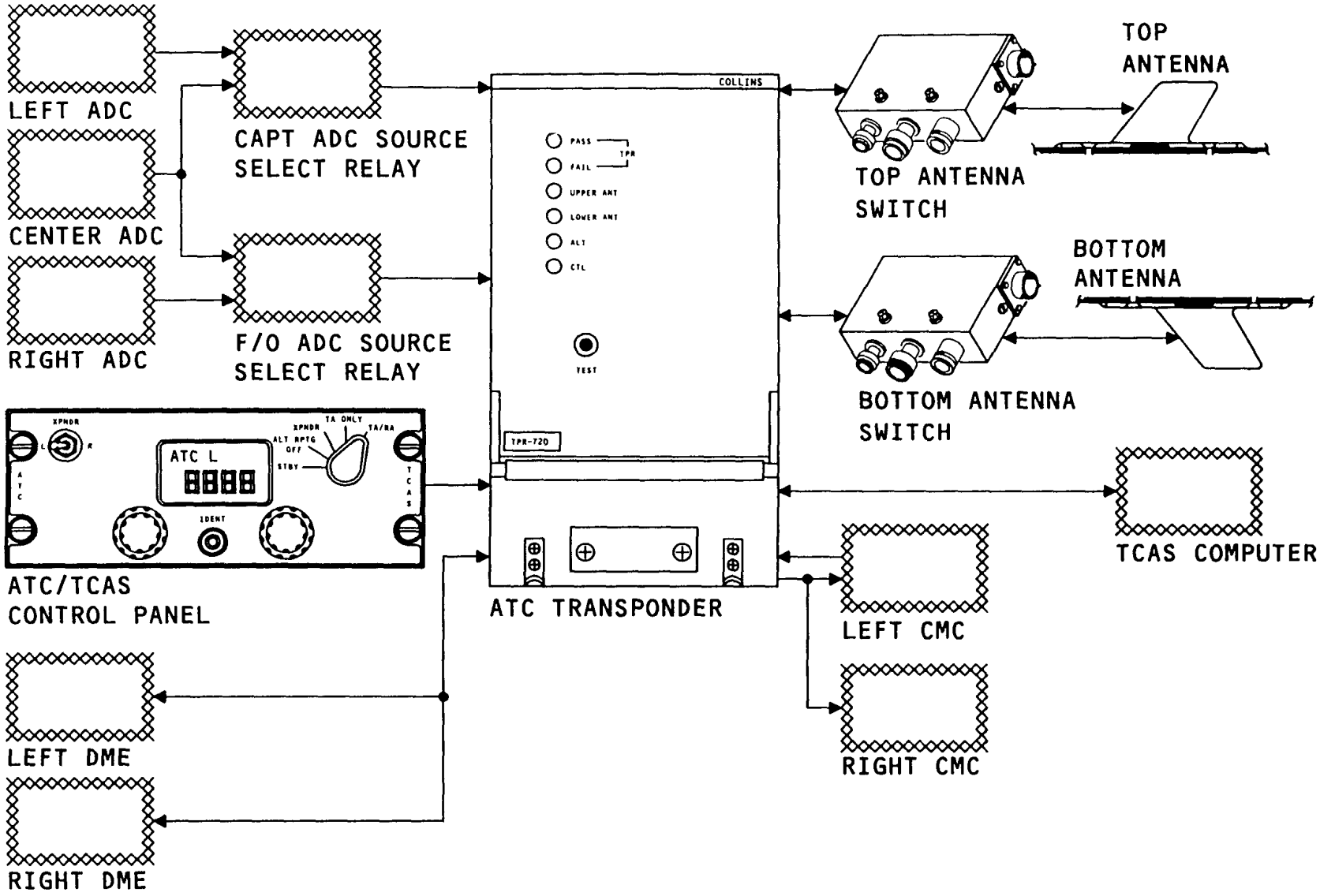


Figure 2 AIR TRAFFIC CONTROL SYSTEM

COMPONENT LOCATION - FD

The ATC system components in the flight-deck are:

- Left ATC circuit breaker
- Right ATC circuit breaker
- ATC antenna switch circuit breaker
- ATC control panel

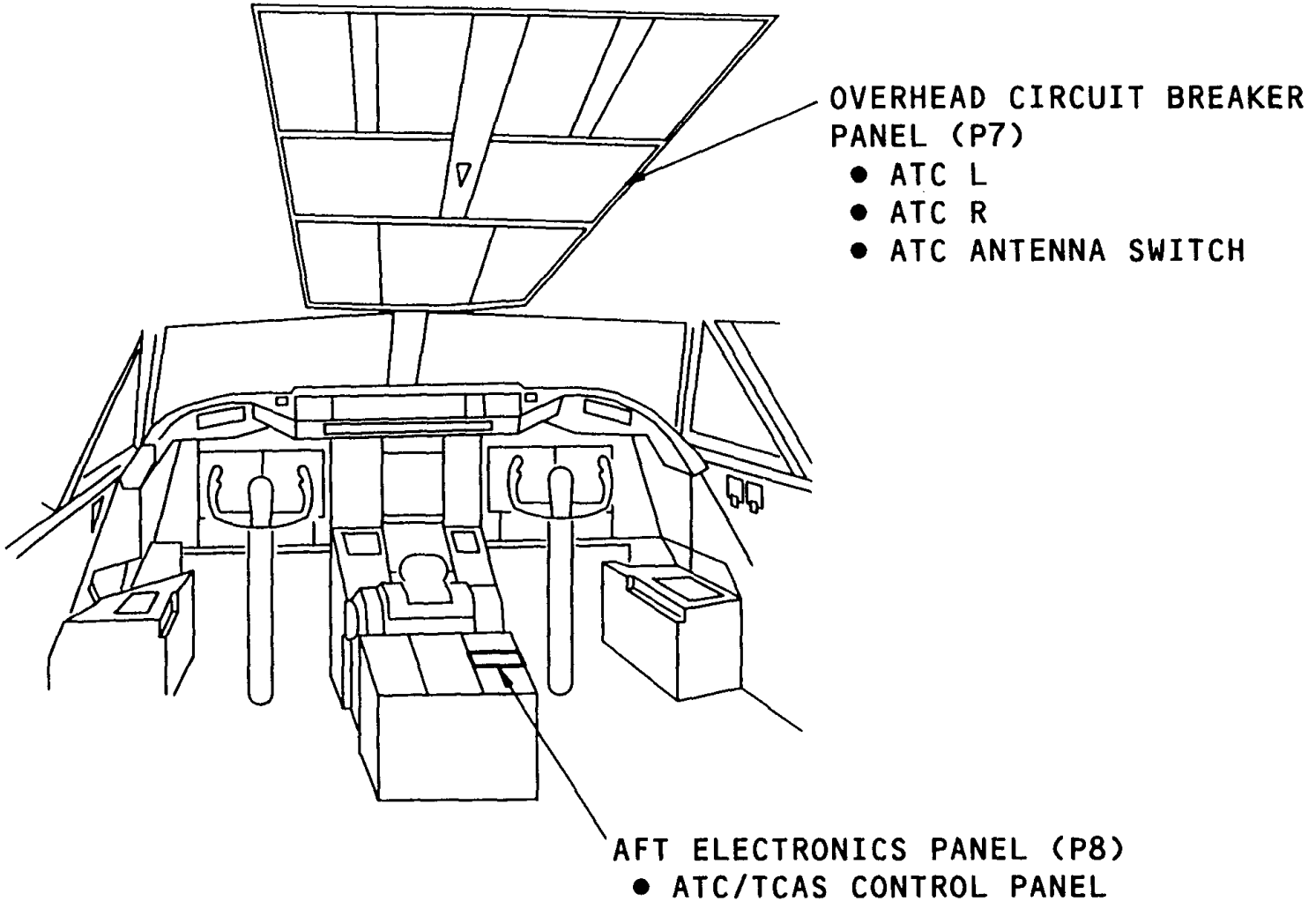


Figure 3 COMPONENT LOCATION - FD

COMPONENT LOCATION - 2

These ATC system components are shown:

- Left ATC transponder
- Right ATC transponder
- Top ATC antenna
- Bottom ATC antenna
- Top ATC antenna switch
- Bottom ATC antenna switch

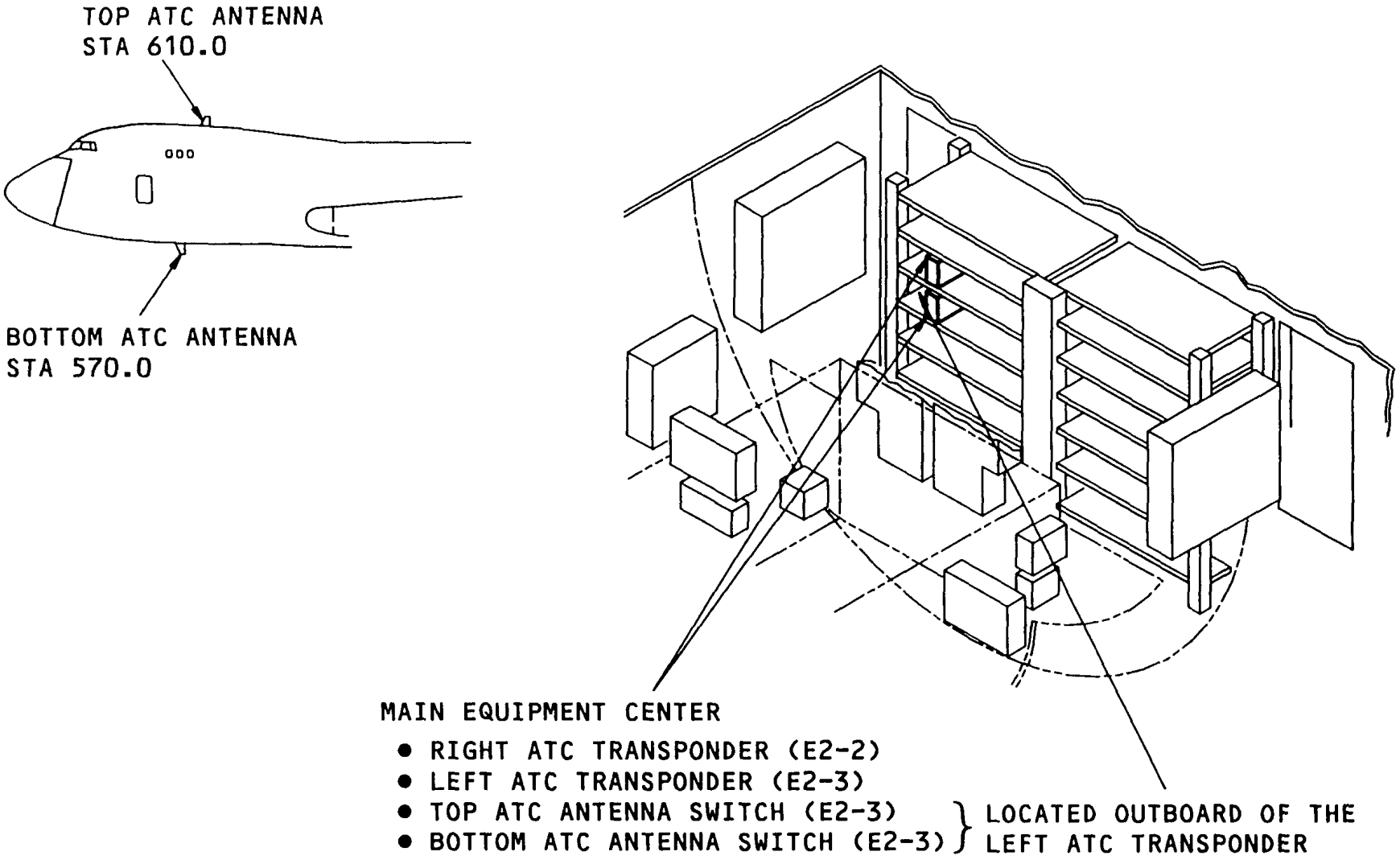


Figure 4 COMPONENT LOCATION - 2

INPUTS

Power

The left ATC transponder receives 115 volts ac from the standby bus. The right ATC transponder receives 115 volts ac from bus 2. The dual control panel receives 115 volts ac from both standby bus and bus 2.

Standby/On Discrete

When the left or right transponder is set on the ATC control panel, a ground standby discrete goes to the transponder that is not set.

The transponder in standby is not on but BITE (Built-In Test Equipment) stays in operation.

Identity and Control

The identity code is set by the flight crew and shows on the ATC control panel. The code is sent to each transponder. The ATC control panel also digitizes two switch discretes. One switch is ALT RPTG (altitude reporting) ON/OFF and the other switch in IDENT for Special Position

Identification (SPI). These are sent on data buses to each transponder.

Test

A test command is sent from a CDU through the left CMC, when a ground test is started.

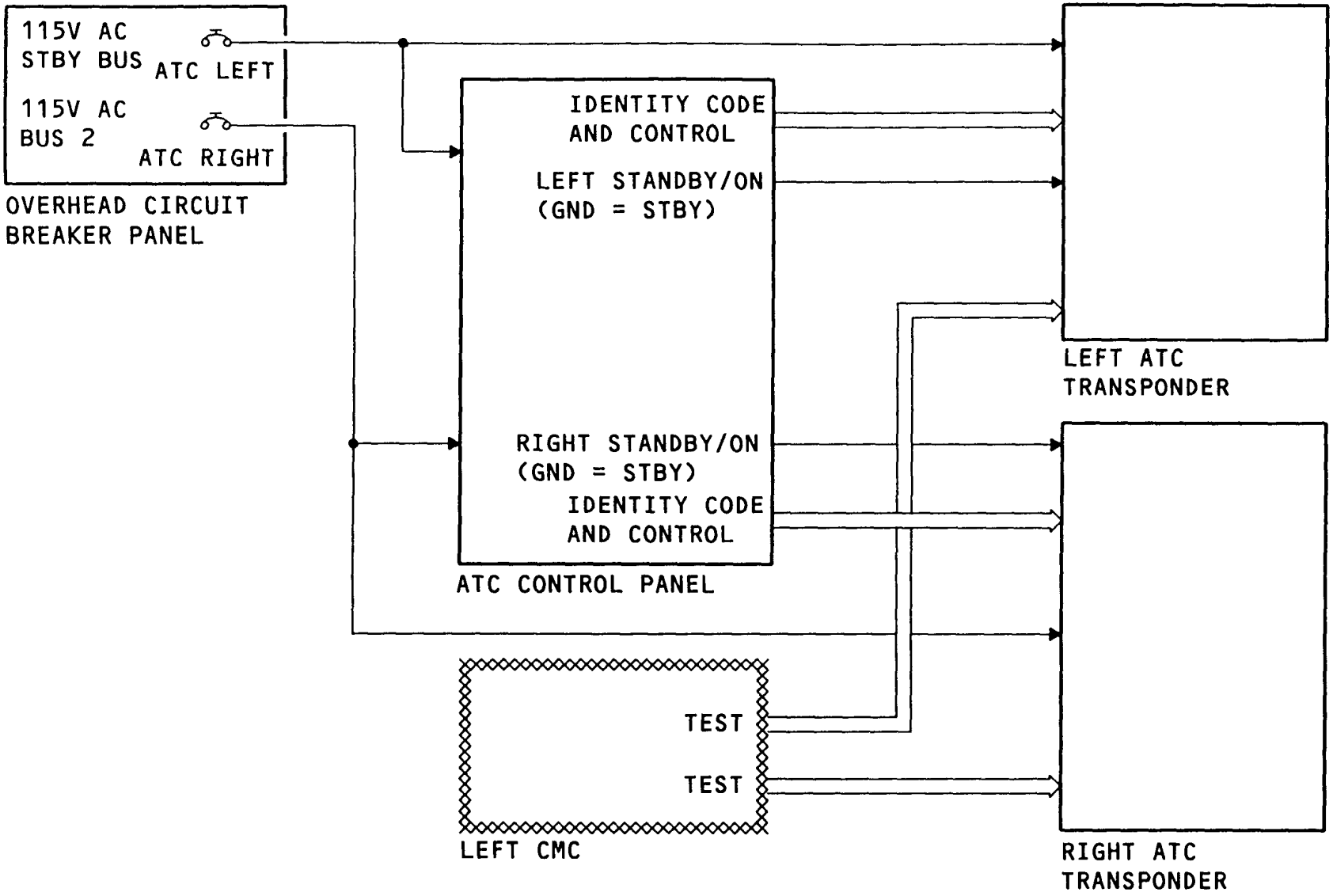


Figure 5 INPUTS

INPUTS - 2

Each ATC transponder receives standard (29.92 IN Hg/1013 Hp) altitude.

Each ATC transponder is connected to two buses. One bus provides altitude from the left or center Air Data Computer (ADC). The other bus supplies altitude from the right or center ADC. The position set on the ADC source-select switches causes the applicable ADC to supply altitude data. The ADC source-select switches supply control of the ADC source-select relays.

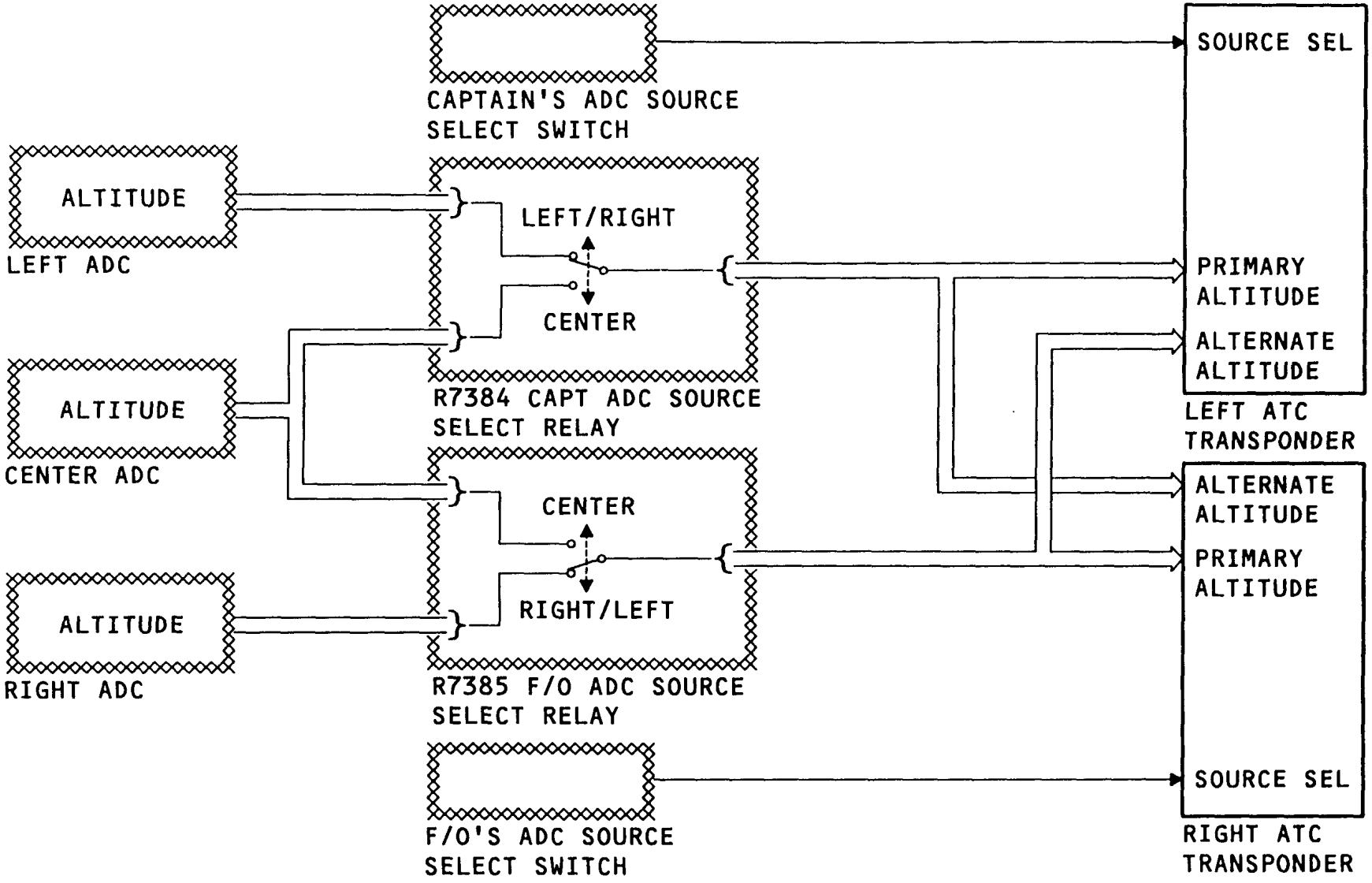


Figure 6 INPUTS - 2

TCAS INTERFACE

ATC interfaces with the traffic alert and collision avoidance system (TCAS) with an ARINC 429 data link. The active ATC sends maximum airspeed, pressure altitude, airplane 24-bit address, and WAS coordination message data. ATC also sends any failure data to the TCAS. The TCAS sends operation mode status, and coordination update data to the active ATC transponder.

This interface is covered in more detail in the TCAS lesson that follows ATC.

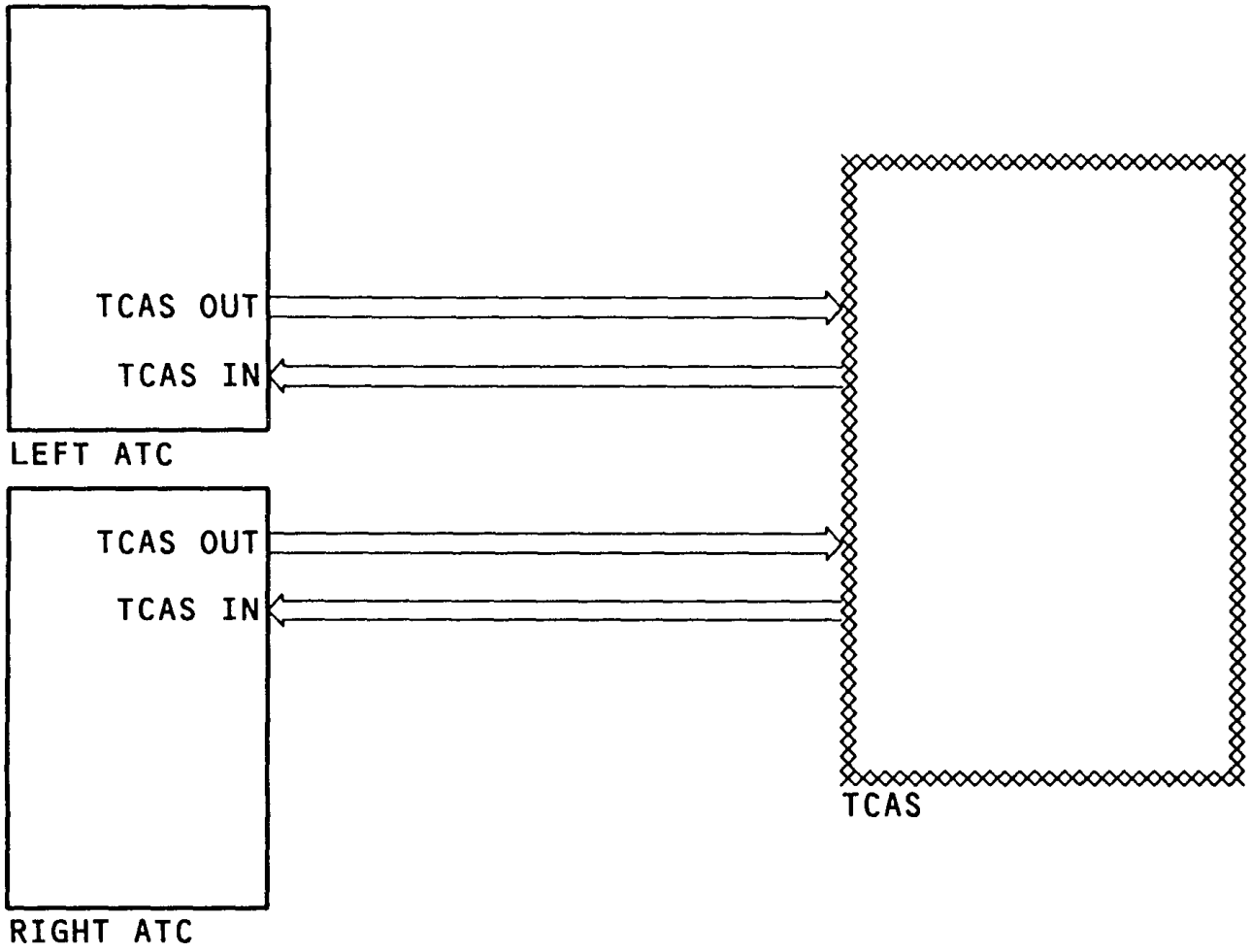


Figure 7 TCAS INTERFACE

ANTENNA INTERFACE

The ATC control panel sends a discrete (ground) to the top and bottom ATC antenna switches when the right transponder is selected. This gives power to both switches and connects the right transponder to the top and bottom ATC antennas.

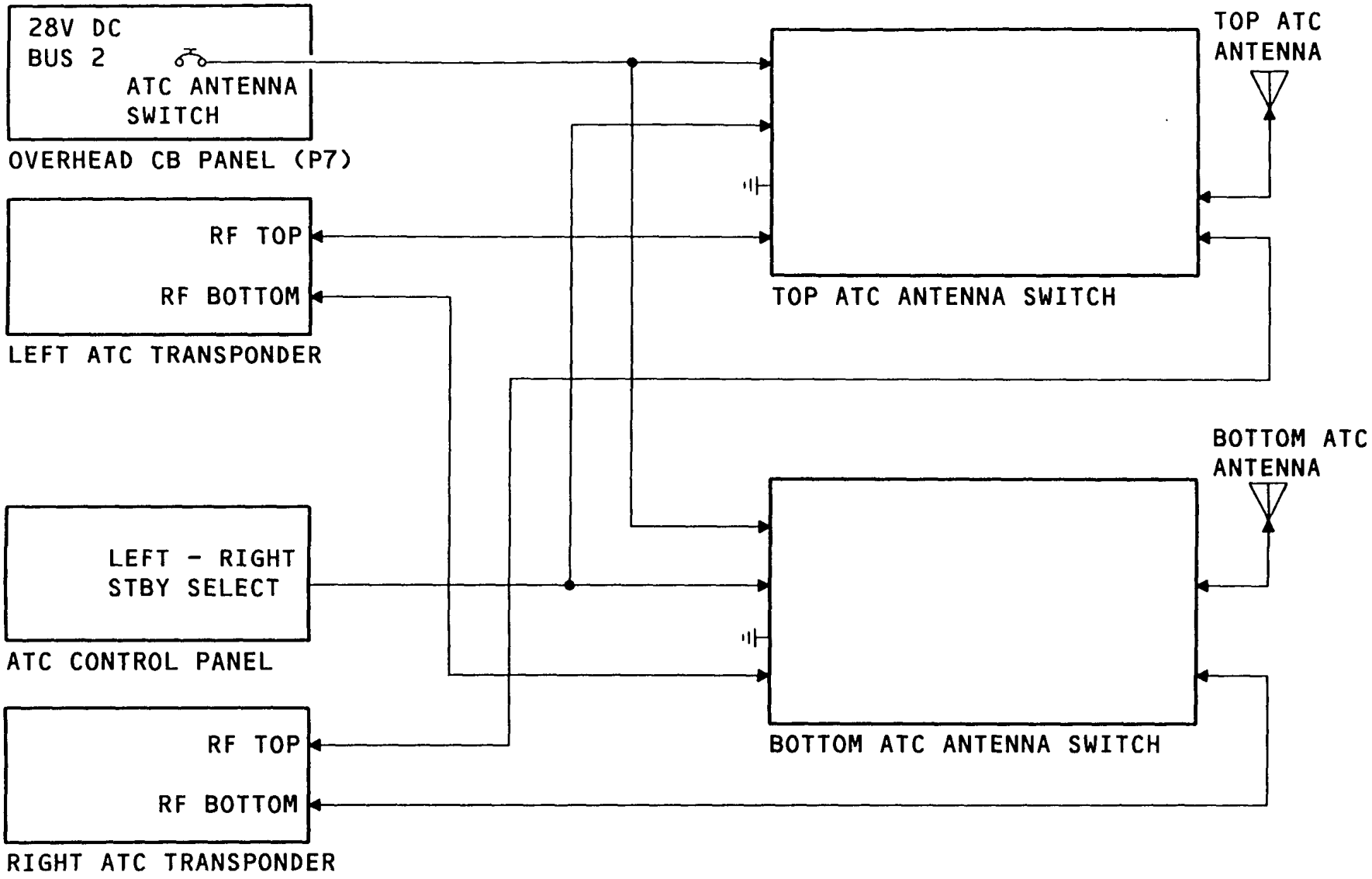


Figure 8 ANTENNA INTERFACE

MAINTENANCE DATA AND SUPPRESSION

Maintenance Data Output

Each ATC transponder supplies maintenance data to both left and right central maintenance computers. Two words are transmitted to the CMCs. The two words contain:

- Ground test messages
- Maintenance discretes

Access to this maintenance information is from the Control Display Units (CDUs).

Air/Ground Input

Each ATC transponder receives an air/ground discrete through the ATC control panel from the air/ground system. The air/ground discrete counts flight segments in the fault-history nonvolatile memory. This discrete also prevents ATC transponder replies when grounded.

Suppression

In order to prevent interference between the ATC transponders, TCAS, and the DME interrogators, these systems are connected together by a suppression line. The first unit to transmit sends out a suppression pulse which prevents operation in the other units.

ATC Fail Discrete

The ATC transponders output two fail discretes. Discrete #1 goes to the ATC control panel and will show FAIL on the LED display when set. Discrete #2 goes to the left, center, and right EIU's, and causes an EICAS advisory message to show.

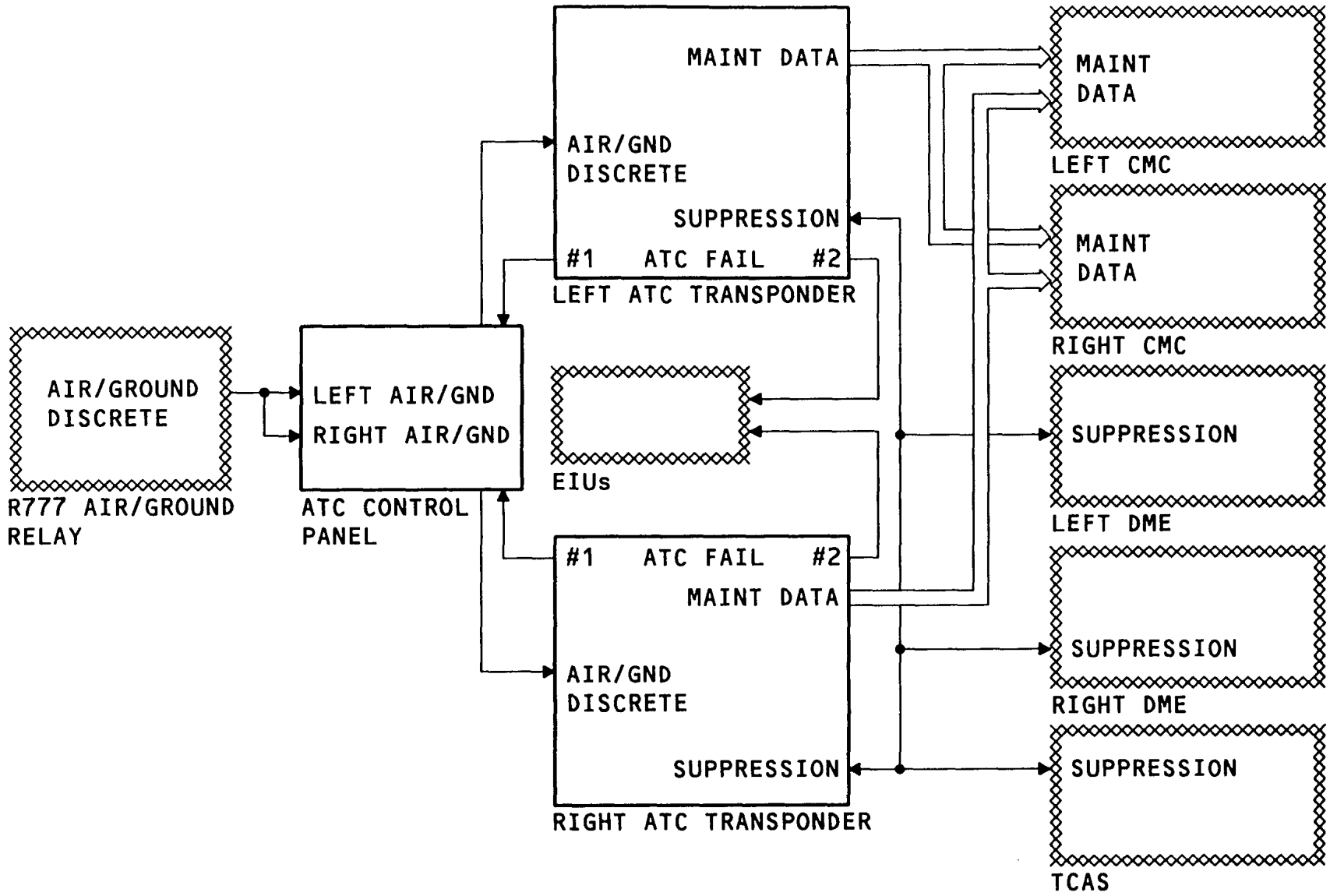


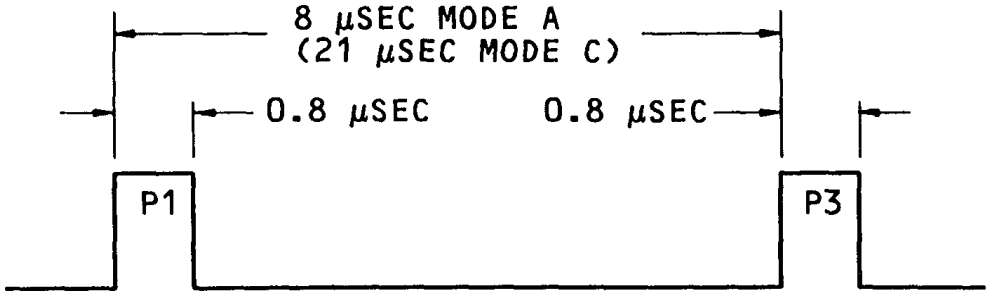
Figure 9 MAINTENANCE DATA AND SUPPRESSION

ATCRBS INTERROGATION SIGNALS

The ground ATC secondary surveillance radar (SSR) radiates an air traffic control radar beacon system (ATCRBS) P1 and P3 pulse spaced at different intervals on 1030 Mhz. Mode A is spaced 8 microseconds apart and mode C is spaced 21 microseconds apart. Mode A is a request for the airplanes identification and mode C is a request for the airplanes altitude. These interrogations are radiated sequentially with reply times built-in to allow the transponders time to reply to each mode.

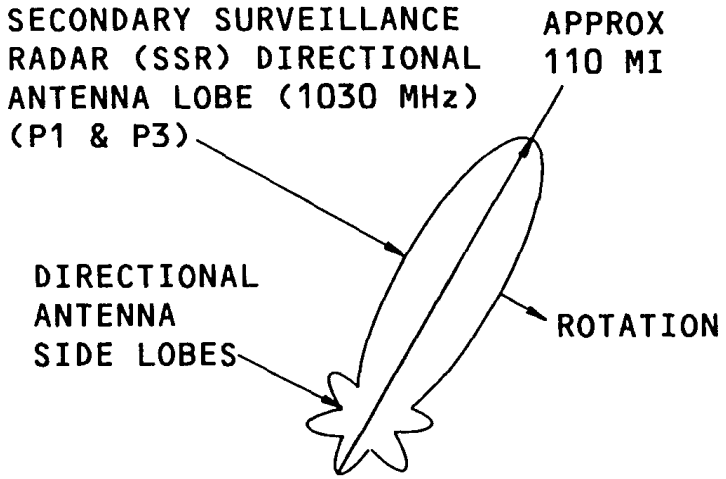
The transponder analyzes these interrogation signals to determine validity and mode. To be valid, the signal must be from the main lobe.

A P2 pulse is transmitted on the side lobe suppression (SLS) antenna 2 microseconds after the P1 pulse. The amplitude of the P2 pulse is equal or greater than the maximum side lobe pulse of either the mode A or mode C interrogation pulses. If a P2 pulse is detected, the transponder will not reply to the interrogation.

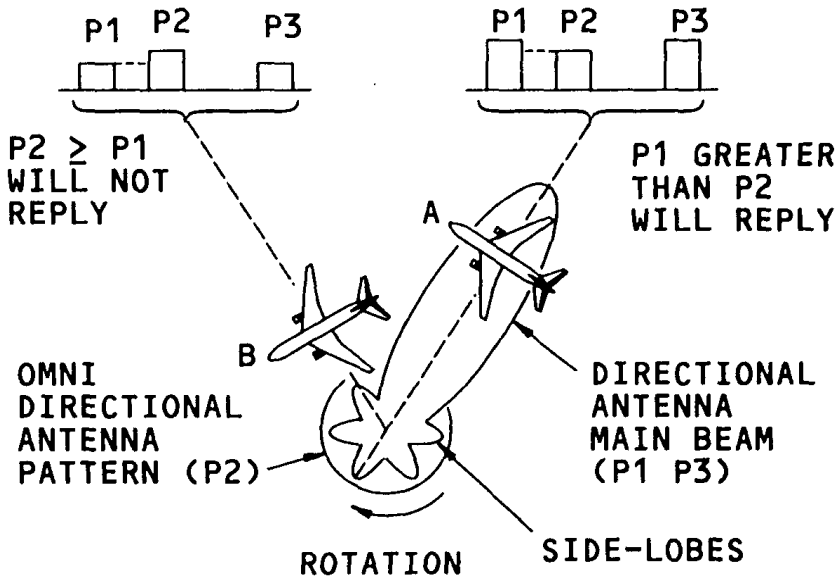


PULSE PATTERNS FOR ATCRBS INTERROGATIONS

MODE A AIRPLANE IDENTIFICATION
MODE C ALTITUDE REPORTING



GROUND RADAR ANTENNA RADIATION PATTERNS



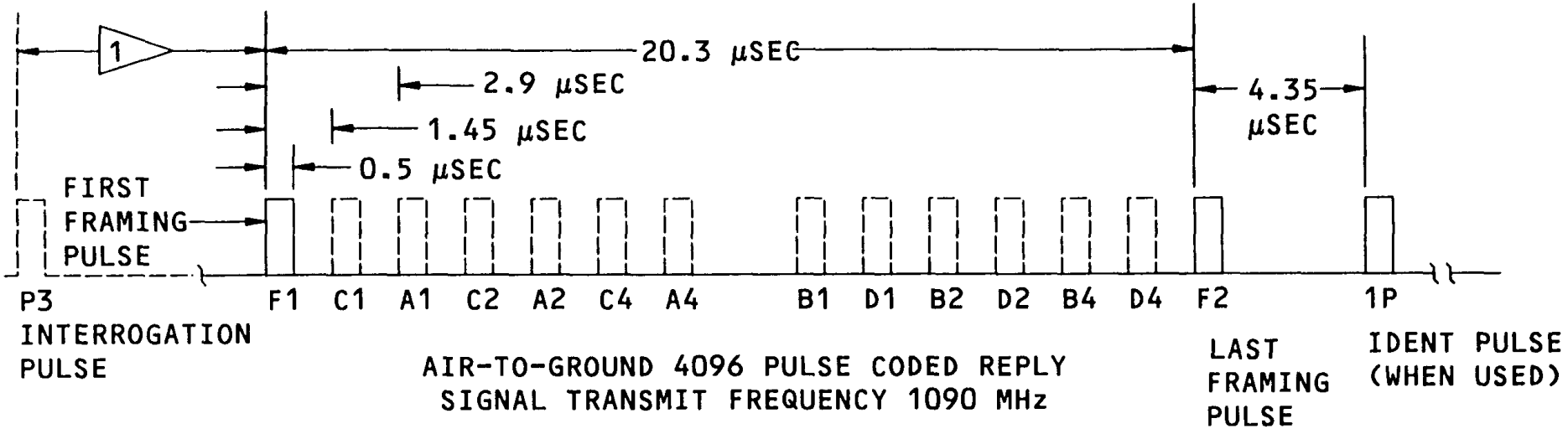
SIDE-LOBE SUPPRESSION

Figure 10 ATCRBS INTERROGATION SIGNALS

TRANSPONDER REPLY SIGNALS

The transponder ATCRBS reply signal is composed of a series of coded pulses. The transponder transmit frequency is 1090 Mhz. The number of pulses generated is determined by the 4096 code selected at the ATC control panel for mode A and by the altitude information for mode C. Two framing pulses (F1 and F2) spaced 20.3 microseconds apart are always present. The coded information pulses are spaced between the framing pulses. The identification pulse is present only when the IDENT switch on the control panel is pressed.

Pulses from group A make up the first digit. Pulse groups B, C and D make up the second, third, and fourth digits, respectively. Suffixes 1, 2 and 4 indicate the binary weighting for the pulses in each group. The absence of all pulses in a group indicates 0. An example of a code 3342 reply is given.



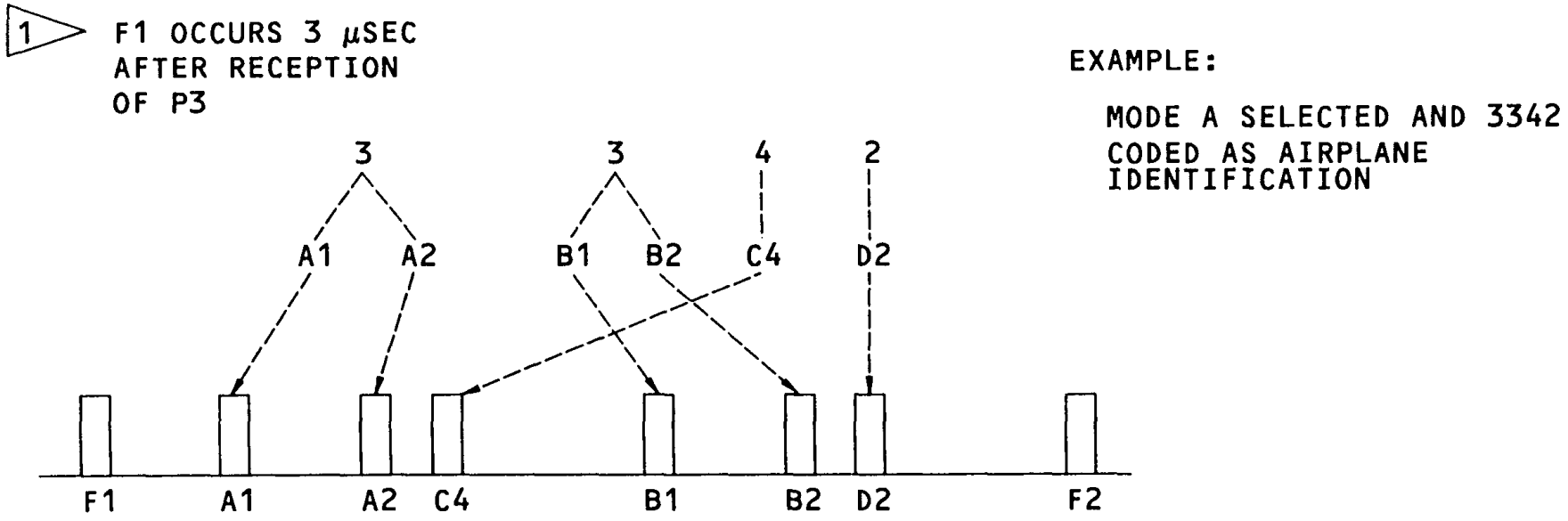


Figure 11 TRANSPONDER REPLY SIGNALS

MODE S OPERATION

General

The primary function of mode S is surveillance. ATC mode S operates similar to ATCRBS modes A and C. When a mode S transponder is interrogated with a mode S interrogation, it reponds automatically with digital data words that provide the interrogator system with a variety of airplane information. A mode S transponder uses a 56-bit transmission to report its altitude, ATCRBS 4096 code, flight status (airborne, on-ground, alert, or special position identification (SPI). A unique discrete 24-bit mode S address is transmitted to identify the airplane and allow the interrogator to add it to a roll-call list of other mode S transponders.

Mode S Discrete Addressing

The address and location of the mode S airplane is entered into a roll-call file. From then on, the airplane is discretely addressed for interrogation. This is done by a mode S only interrogation, which only interrogates airplanes with mode S transponders.

Ground station ATC interrogators send a data command field that causes the airplane mode S transponder to not respond to further mode S all-call interrogations. This is called mode S lock-out, and is used to prevent large numbers of airplanes from cluttering the ATC radar scope.

ATC/Mode S Airplane Coordination

As a mode S airplane flies into the airspace served by another ATC ground station, the first ATC station may send all airplane mode S data, along with the discrete address, to the second ATC station by way of ground communication. Thus, the need to remove the lock-out may be eliminated, and the second ATC station may schedule discrete roll-call interrogations for the mode S airplane. Due to the discrete address of mode S, the ATC ground stations can work at a lower rate or handle more airplanes.

In areas where ATC ground stations are not connected by ground communication, the protocol for mode S transponders is to be in the lock-out state for only those interrogations that have the airplane on it's roll-call. If the airplane enters airspace served by a different ATC mode S interrogator, this one acquires the airplane via a reply to a mode S all-call interrogation. If the airplane does not receive an interrogation of any kind for 16 seconds, the mode S transponder automatically cancels the mode S lockout mode.

Mode S transponders transmit a squitter signal once every second. The squitter signal is the same as a mode S all-call reply and contains the airplanes identification address. The squitter signal is received by TCAS equipped aircraft and used to add this airplane to its roll-call for tracking and air-to air interchange of data.

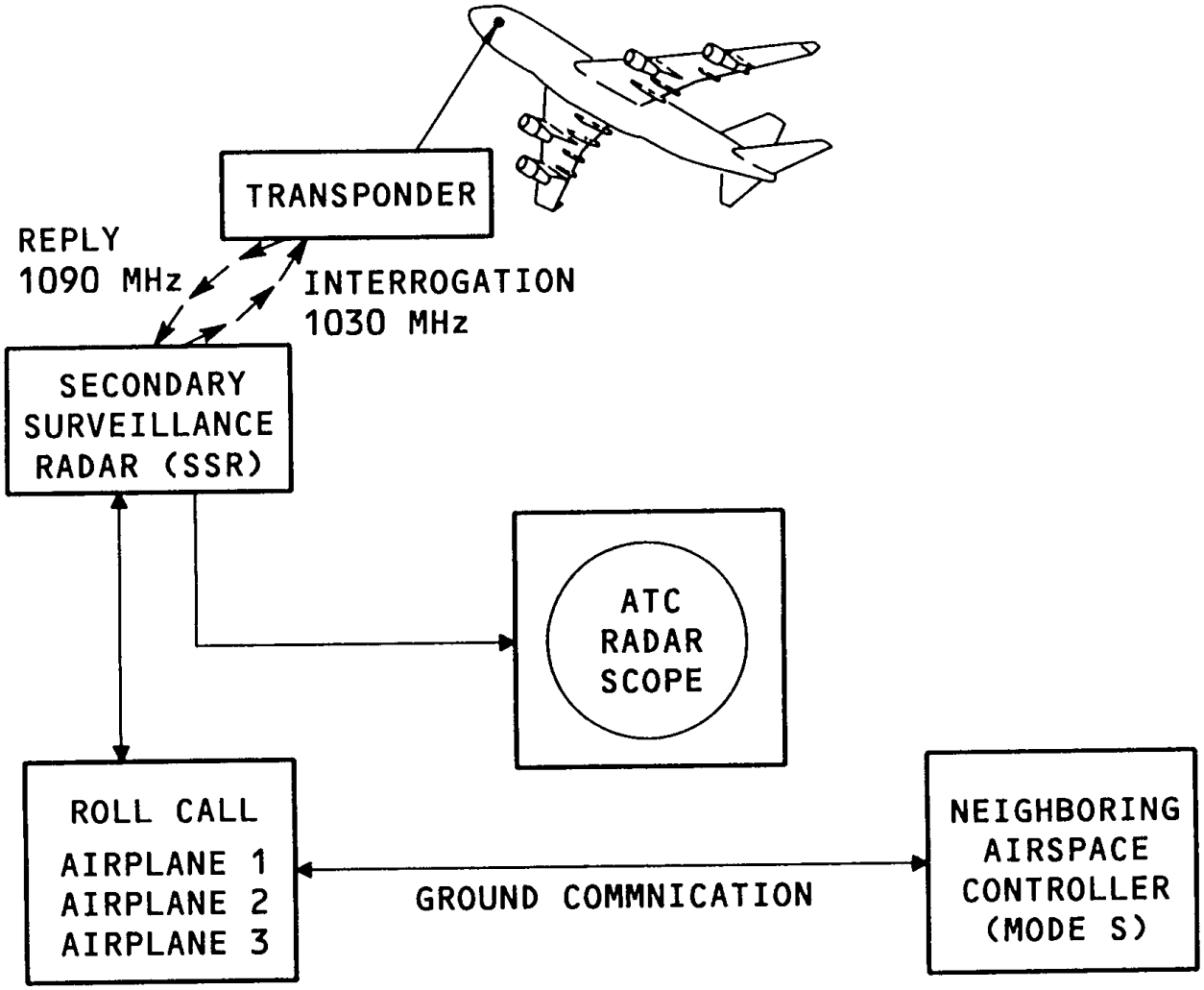


Figure 12 MODE S OPERATION

MODE S INTERROGATION SIGNALS

Mode S Interrogation Format

The Mode S interrogation signal is made up of a P1-P2 pulse pair followed by a long P6 pulse. The P1 and P2 pulses are transmitted with equal amplitude on the directional antenna. This pulse combination suppresses all replies from ATCRBS transponders, and allows responses from any mode S transponders. The P6 pulse contains data request fields that request different types of information from transponders.

The P6 pulse data is in the form of binary differential phase shift keying (DPSK) modulation. DPSK is accomplished using a process called sync phase reversal (SPR) to synchronize the decoding of the interrogation signal by the transponder. SPR occurs when the unmodulated RF carrier is shifted 180 degrees in phase, 1.25 microseconds after the leading edge of the P6 pulse.

The P6 pulse is made up of a series of bit times refered to as chips that contain the interrogation data. These chips are unmodulated intervals of RF 0.25 microseconds duration, that start 0.5 microseconds after the SPR. The

phase of the carrier in a chip is compared to the phase of the carrier in the previous chip. If preceded by a phase reversal of the rf carrier wave, a chip represents a logic level one, if not, it is a logic level zero.

Mode S Only All-Call

The mode S only all-call is used to interrogate mode S transponders without interrogating any ATCRBS airplanes. This is done by sending out all logic level ones in the destination address. All mode S transponders will reply to this interrogation with their discrete address unless they are locked out.

ATCRBS/Mode S All-Call

Both ATCRBS and mode S transponder can be interrogated with this type of pulse amplitude modualtion (PAM) interrogation. A mode S reply is generated 128 microseconds after the leading edge of the P4 pulse, when the width of the P4 pulse is 1.6 microseconds. No reply is transmitted when the P4 pulse is only 0.8 microseconds.

Mode S Sidelobe Suppression (SLS)

Sidelobe suppression for mode S is done by overlaying a P5 pulse on the P6 pulse, spaced 0.4 microseconds on either side of the sync phase reversal position. The signal strength of the P5 pulse is equal to or greater than the signal strength of a P6 sidelobe transmission, this will prevent any transponder from replying to a P6 sidelobe interrogation.

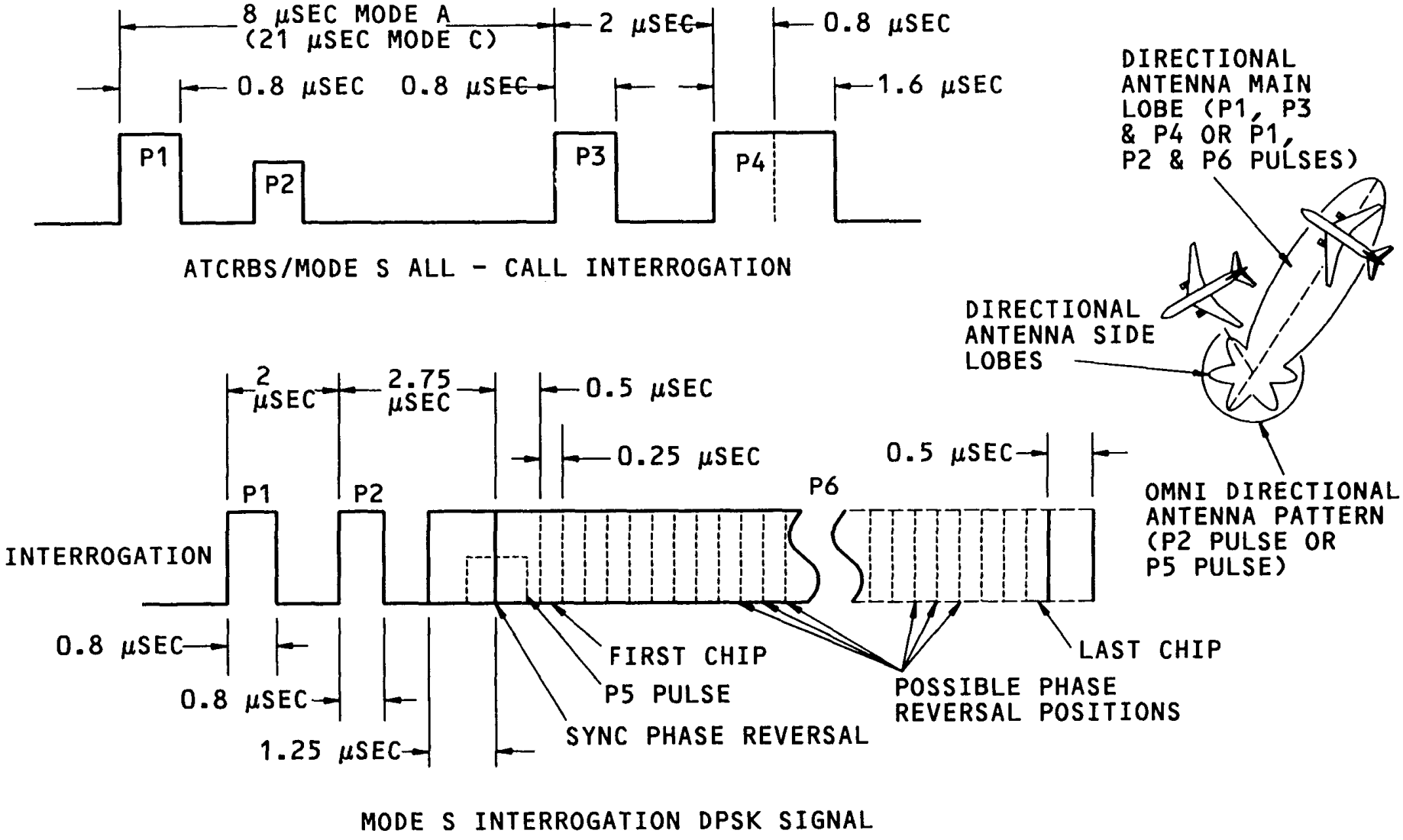


Figure 13 MODE S INTERROGATION SIGNALS

MODE S REPLY SIGNALS

Mode S Replies

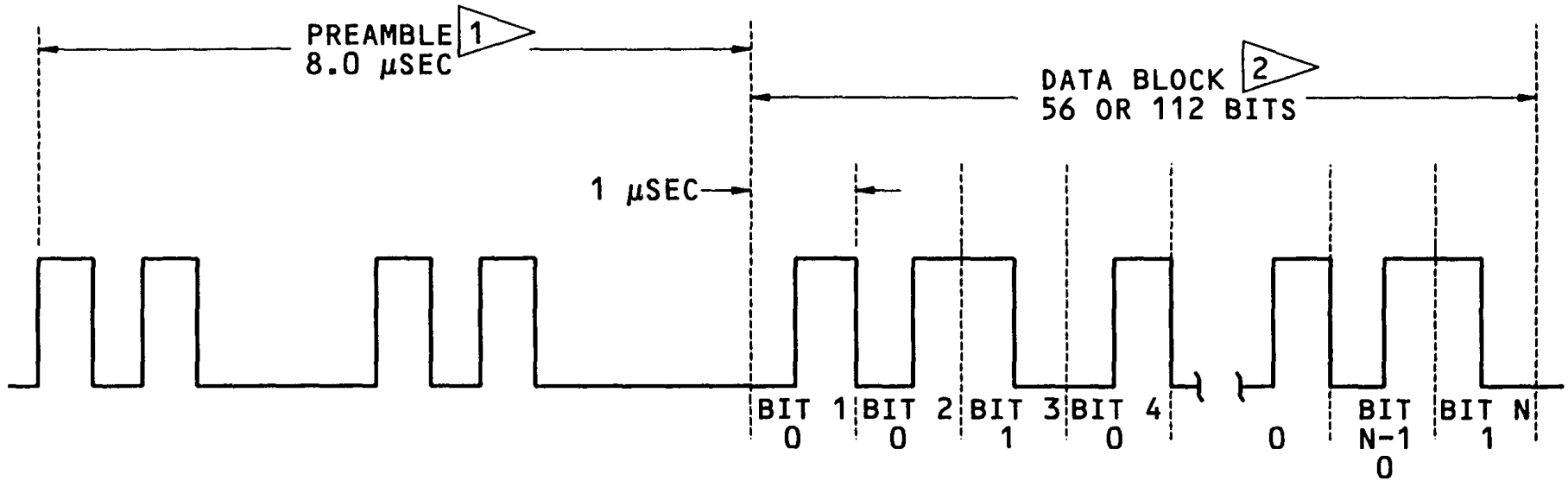
Mode S replies are different than ATCRBS replies. Mode S replies contain up to 25 different downlink digital data formats of information. At present there is only eight mode S downlink formats defined. These downlink formats contain designated fields that have a variety of data.

Mode S Transponder Reply Format

Mode S replies consist of an 8 microsecond 4 pulse preamble and a 56 or 112 bit data block. The preamble allows the ATC interrogator to prepare to receive the transponder data block. The preamble starts 128 microseconds after the sync phase reversal of the mode S interrogator P6 pulse or the ATCRBS/Mode S all-call interrogation P4 pulse. The data block is formed by pulse position modulation (PPM) encoding. A pulse transmitted in the first half of the data block interval equals a logic level one. A pulse in the second half equals a logic level zero.

Mode S transponders can transmit either ATCRBS or mode S replies, in response to ATCRBS or mode S interrogations. The different types of mode S interrogations are:

- Mode S interrogations
- ATCRBS/Mode S all-call
- Mode S only all-call



MODE S REPLY WAVEFORM

1 PREAMBLE ALLOWS INTERROGATOR TO PREPARE TO RECEIVE DATA BLOCK

2 EXAMPLE REPLY DATA BLOCK CORRESPONDING TO BIT SEQUENCE; 0010...001.

Figure 14 MODE S REPLY SIGNALS

ATCRBS/MODE S INTERROGATION SIGNALS

There are five different types of possible ATC interrogation signals. The replies from an ATCRBS only transponder are different than replies from an ATCRBS/ Mode S transponder.

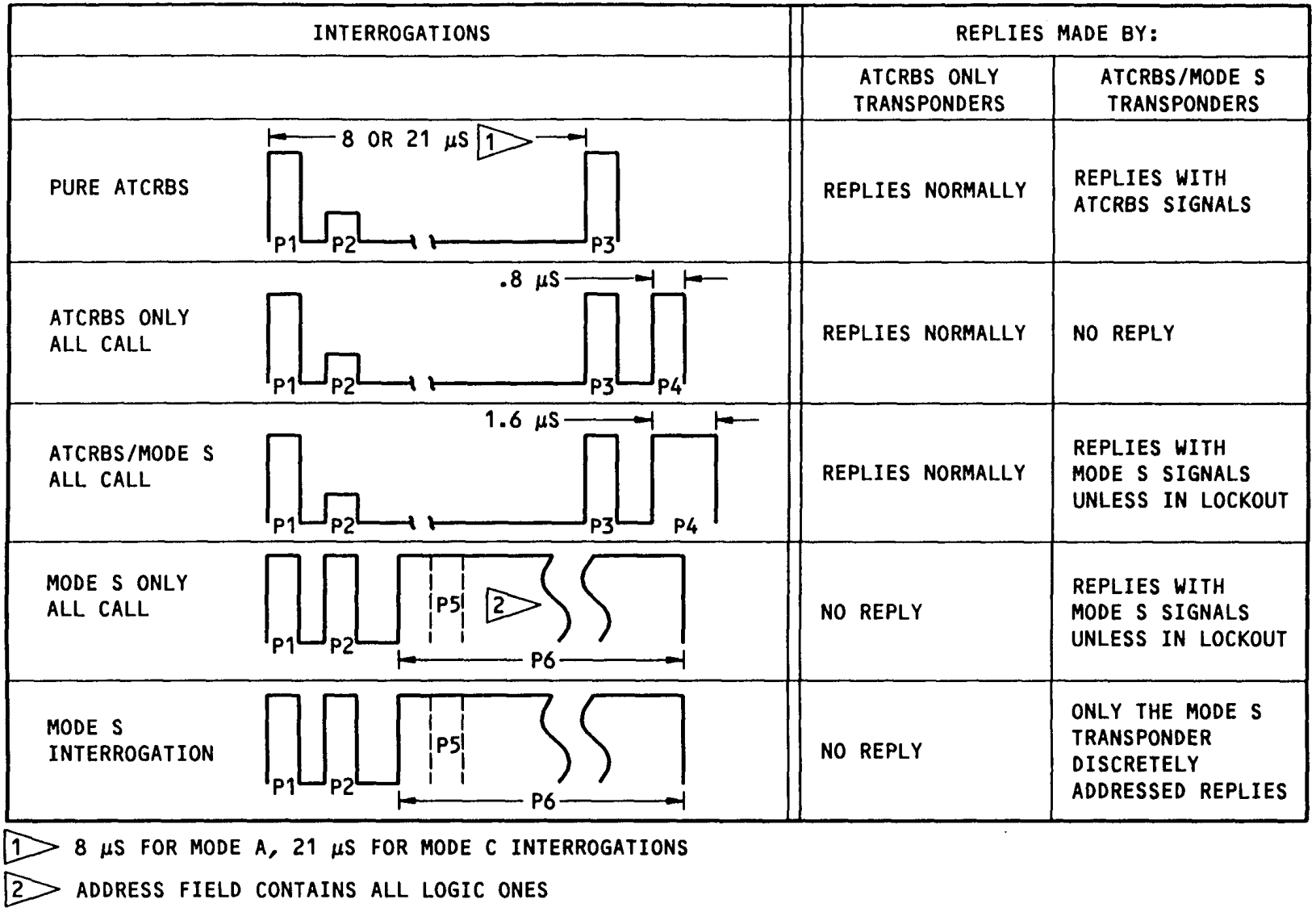


Figure 15 ATCRBS/MODE S INTERROGATION SIGNALS

MODE S UPLINK/DOWNLINK SIGNALS

Mode S Signal Content

Mode S uplink format (UF) or downlink format (DF) transmissions are comprised of either 56 bits for surveillance or 112 bits for extended length messages (ELM). The interrogation messages are formed by the sequence of differential phase shift keying (DPSK) phase reversals within the P6 pulse. The reply messages are represented by the pulse position modulation (PPM) of the mode S reply waveforms.

Information within each message is encoded in fields, each field has a dedicated purpose. All messages contain at least these two essential fields: the format descriptor field, and the address/parity field. The format descriptor is at the beginning of each message, and the address/parity field at the end. The transmitted data are contained in a block of other fields in between. For varied purposes and mission of the mode S and TCAS system, 25 different formats are used. only eight of these fields are presently defined as shown in figure 1 and 2. Figure 3 is a table of field definitions.

Format Descriptor Field

The format descriptor field corresponds to the binary code in the first five bits of UF interrogations and DF replies numbered 0 through 23. Format number 24 of both UF and DF is defined as the format beginning with 11 in the first two bit positions while the following three bits vary with the message content.

Address/Parity Field

The 24-bit address/parity field (AP:24) uses the last 24-bits of the message. In general, (XX:M) denotes a field designated XX which is assigned M bits. Figure 3 shows the field name and meaning of each field designator.

The airplanes 24-bit unique address code in the address/parity field is overlaid with 24 parity check bits that are generated in a special coding algorithm. The combined address/parity field requires fewer bits than would be needed if address and parity were coded separately.

An exception to the above, is downlink format eleven (DF-11), the mode S only all-call reply. In this format the last 24 bits transmitted are called a parity/interrogation reply or (PI:24) field used to report the source of the interrogation.

Data Block Fields

The data within each message are contained in the data block fields between the format descriptor and the address/parity fields. The data block fields are comprised of either 27 or 83 bits to makeup messages of either 56 or 112 bits. The data fields making up the data block carry the same type designation as the address/parity field (XX:M).

Data Error Protection

A data error anywhere in the reception of an interrogation or a reply will change the decoded airplane address.

On the uplink, the transponder will not accept the message and will not reply. On a downlink, the receiver will recognize that an error has occurred and the interrogator will attempt to reinterrogate the transponder a limited number of times.

SEE APPENDIX „A“

Figure 16 MODE S UPLINK/DOWNLINK

TRANSPONDER

General

The ATC transponder is interrogated by pulsecoded signals from air traffic control ground stations. (Reception is on a frequency of 1030 MHz.)

The transponder responds to the interrogations with pulse-coded signals on a frequency of 1090 MHz.

Characteristics

The transponder responds to ATCRBS (Air Traffic Control Radar Beacon System) mode A and mode C interrogations. It can also respond to mode select (mode S) operation.

Thus, it can be discretely addressed and can receive and send data link messages. The transponder can also receive and send from two antennas. Mode S operation is not enabled at the present time.

The ATC transponder has a non-volatile flight fault memory for 63 flight legs.

Displays and Indications

The Light Emitting Diode (LED) status indicators on the front panel show:

- A green PASS LED if there are no LRU failures
- A red FAIL LED if there are LRU failures (all failures other than antenna failures are considered LRU failures)
- A red UPPER ANT or LOWER ANT LED if either antenna fails.
- A red ALT or CTL LED if no altitude or control inputs are received during the selftest sequence

The test switch starts a system test. The LEDs will come on only during a self-test.

CAUTION: DO NOT TOUCH THE TRANSPONDER BEFORE YOU CONNECT THE GROUND STRAP BETWEEN YOUR WRIST AND THE ELECTROSTATIC GROUND JACK. ELECTROSTATIC DISCHARGE CAN CAUSE DAMAGE TO THE TRANSPONDER.

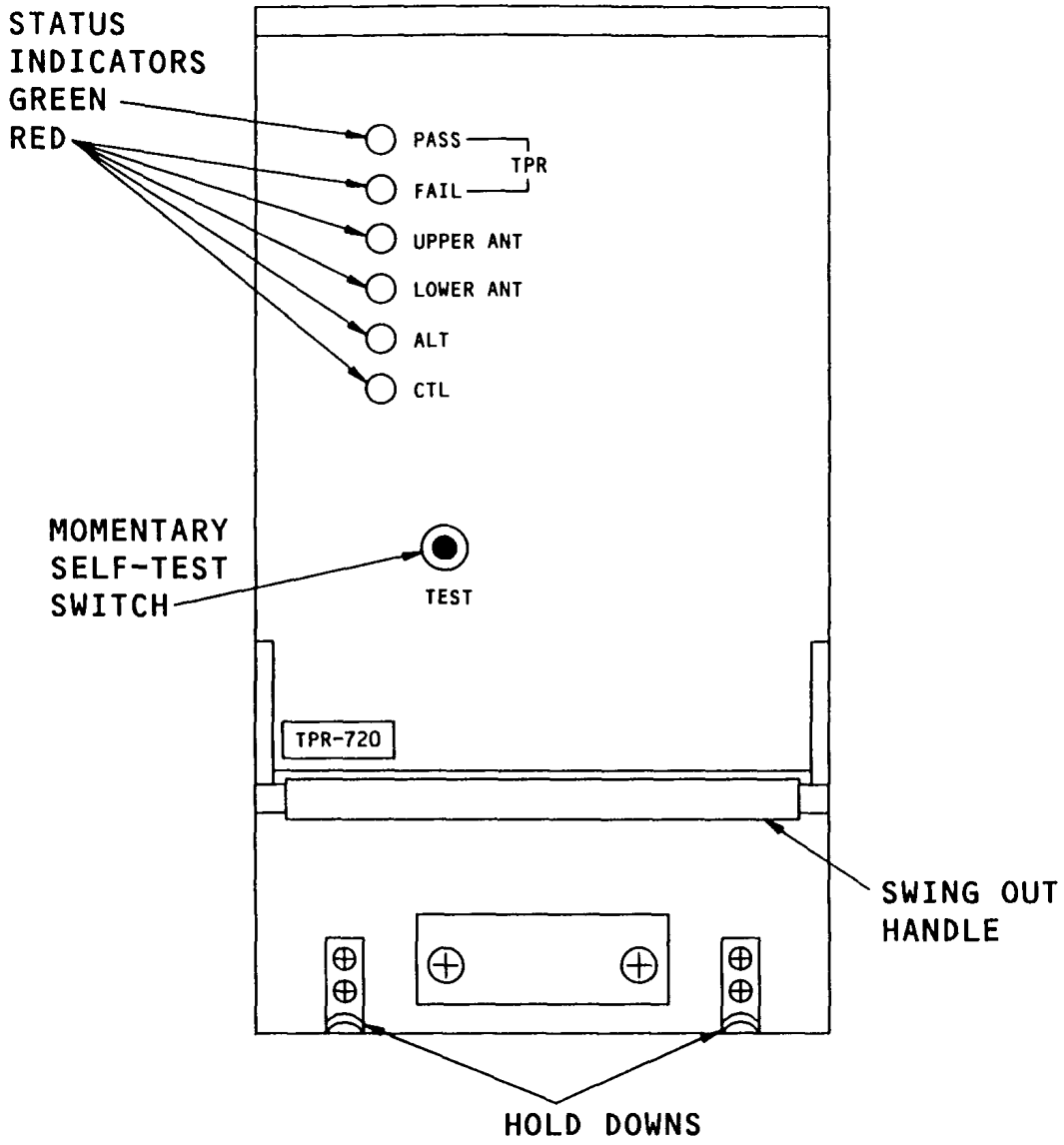


Figure 17 ATC - TRANSPONDER

ATC - CONTROL PANEL

General

The ATC control panel supplies control of the ATC transponders and the WAS computer. The TCAS functions will be discussed in the TCAS lesson.

Power

The ATC control panel has two independent power supplies. Each receives 115v ac from the left and right ATC transponder circuit breakers.

Transponders Select Switch

The XPNDR select switch allows for selection of either the left or right ATC transponder. A ground is sent to the transponder in standby.

Identification Code Select

The four digits of the identity code are set by the rotary switches on the front panel. The code is shown on the

LCD display. Codes are from 0000-7777, with 4096 different selections available.

Function Select Switch

The ATC transponder function select switch positions are:

- The STBY position sends a ground to both transponders when selected. Standby prevents transponder and TCAS operation except for BITE functions.
- The ALT RPTG OFF position disables the mode C altitude reporting function of the transponder.
- XPNDR position is the normal operation position for the selected ATC mode S transponder. TCAS is not available in this position.
- The TA ONLY position activates the TCAS traffic advisory mode. In this mode no resolution advisories will be annunciated. The selected ATC mode S transponder operates normal.
- The TA/RA position activates the normal TCAS mode of operation. Both traffic and resolution advisories are available, and the selected ATC mode S transponder operates normal.

Identification Function

The IDENT pushbutton adds a special position identification (SPI) pulse to any mode A interrogation for the next 18 seconds after it is pushed.

CAUTION: DO NOT SELECT CODES 3100, 7500, 7600 OR 7700. THESE ARE CODES USED ONLY IN EMERGENCY SITUATIONS.

CAUTION: STATIC SENSITIVE. DO NOT HANDLE BEFORE READING PROCEDURES FOR HANDLING ELECTROSTATIC DISCHARGE SENSITIVE DEVICES (REF 20-41-02/201). CONTAINS DEVICES THAT CAN BE DAMAGED BY STATIC DISCHARGE.

CAUTION: CAREFULLY SLIDE THE CONTROL PANEL OUT OF THE CONTROL STAND TO AVOID STRESS AND/OR DAMAGE TO ELECTRICAL CABLE AT REAR OF CONTROL PANEL.

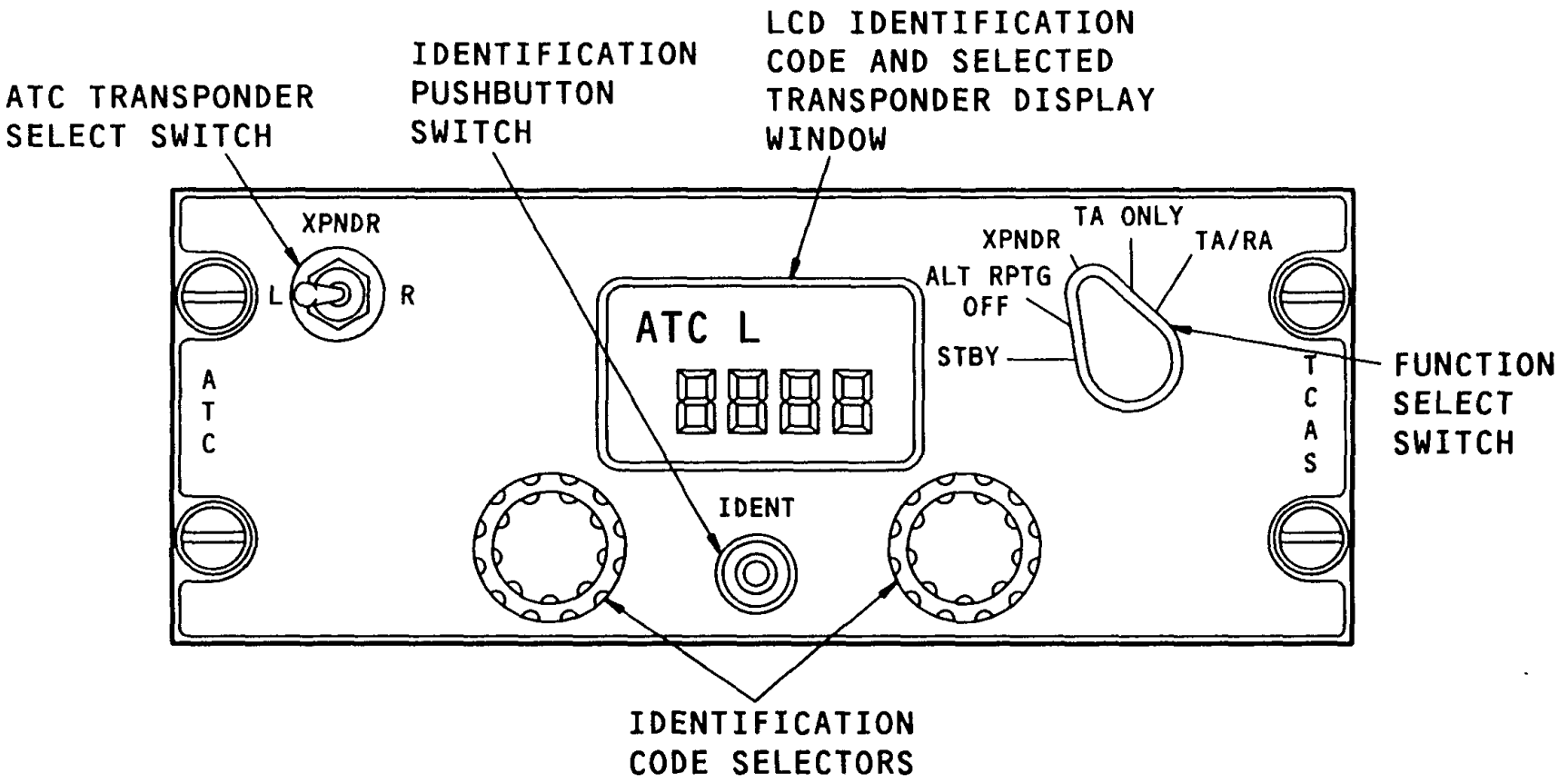


Figure 18 ATC - CONTROL PANEL

ATC - CONTROL PANEL

General

The ATC control panel supplies control of the ATC transponders and the WAS computer. The TCAS functions will be discussed in the TCAS lesson.

Power

The ATC control panel has two independent power supplies. Each receives 115v ac from the left and right ATC transponder circuit breakers.

Transponders Select Switch

The XPNDR select switch allows for selection of either the left or right ATC transponder. A ground is sent to the transponder in standby.

Identification Code Select

The four digits of the identity code are set by the rotary switches on the front panel. The code is shown on the

LCD display. Codes are from 0000-7777, with 4096 different selections available.

Function Select Switch

The ATC transponder function select switch positions are:

- The STBY position sends a ground to both transponders when selected. Standby prevents transponder and TCAS operation except for BITE functions.
- The ALT RPTG OFF position disables the mode C altitude reporting function of the transponder.
- XPNDR position is the normal operation position for the selected ATC mode S transponder. TCAS is not available in this position.
- The TA ONLY position activates the TCAS traffic advisory mode. In this mode no resolution advisories will be annunciated. The selected ATC mode S transponder operates normal.
- The TA/RA position activates the normal TCAS mode of operation. Both traffic and resolution advisories are available, and the selected ATC mode S transponder operates normal.

Identification Function

The IDENT pushbutton adds a special position identification (SPI) pulse to any mode A interrogation for the next 18 seconds after it is pushed.

CAUTION: DO NOT SELECT CODES 3100, 7500, 7600 OR 7700. THESE ARE CODES USED ONLY IN EMERGENCY SITUATIONS.

CAUTION: STATIC SENSITIVE. DO NOT HANDLE BEFORE READING PROCEDURES FOR HANDLING ELECTROSTATIC DISCHARGE SENSITIVE DEVICES (REF 20-41-02/201). CONTAINS DEVICES THAT CAN BE DAMAGED BY STATIC DISCHARGE.

CAUTION: CAREFULLY SLIDE THE CONTROL PANEL OUT OF THE CONTROL STAND TO AVOID STRESS AND/OR DAMAGE TO ELECTRICAL CABLE AT REAR OF CONTROL PANEL.

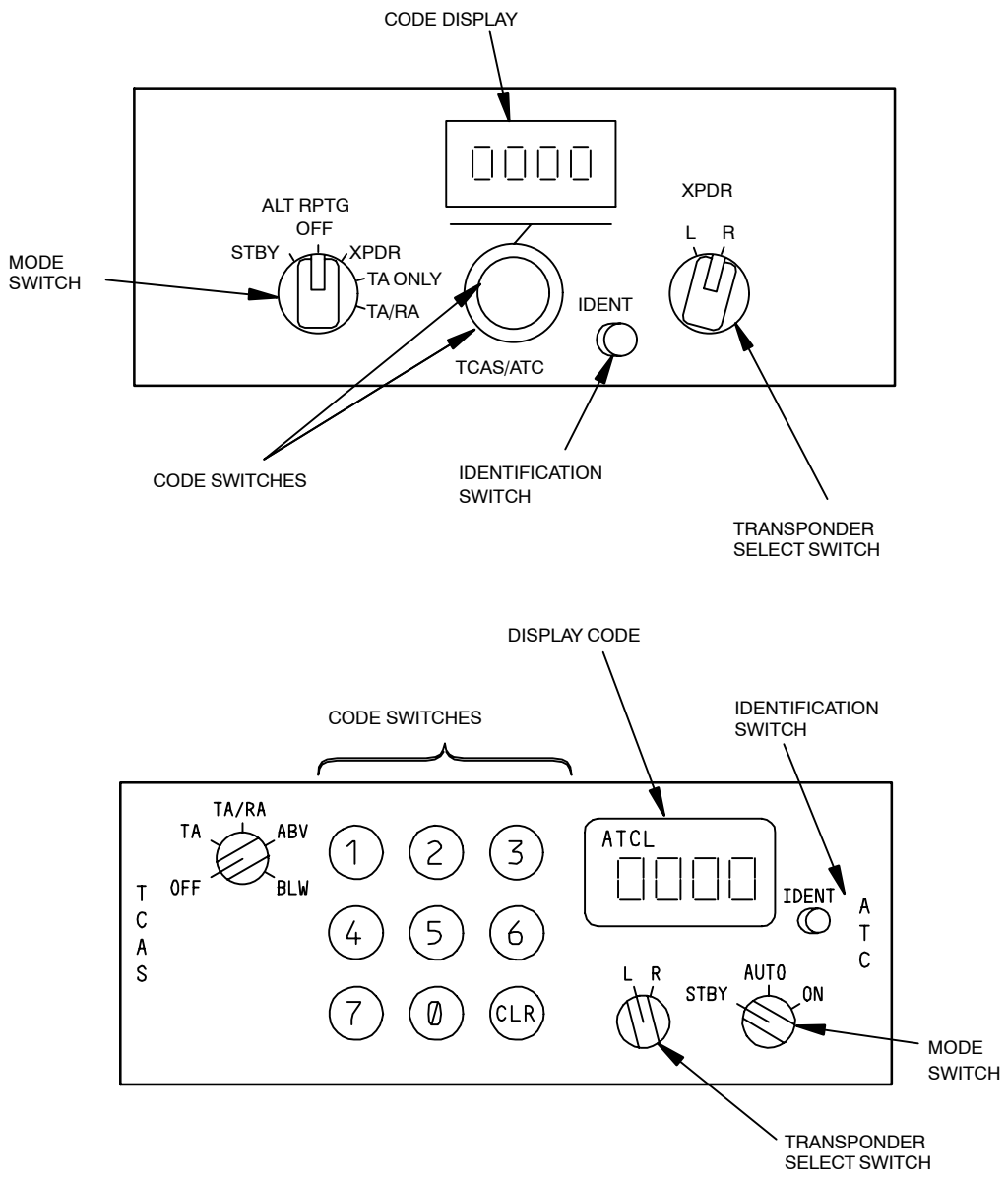


Figure 19 ATC - CONTROL PANEL

ATC - ANTENNA

Purpose

The ATC L-band blade antenna receives the interrogation and transmits the reply signals.

Characteristics

The antenna requires an O-ring moisture seal and is attached to the airplane by four screws. The coaxial cable connector is attached to the antenna before the antenna is installed on the airplane. The ATC and DME antennas are the same and can be changed with each other.

WARNING: EXTRA FORCE ON ANTENNA BASE MAY BE REQUIRED TO BREAK WEATHERPROOFING SEAL. TO PREVENT DAMAGE TO AIRPLANE SKIN OR ELECTRICAL CABLE AT ANTENNA BASE, CAREFULLY PRY AROUND THE ANTENNA WITH SEALANT REMOVAL TOOL.

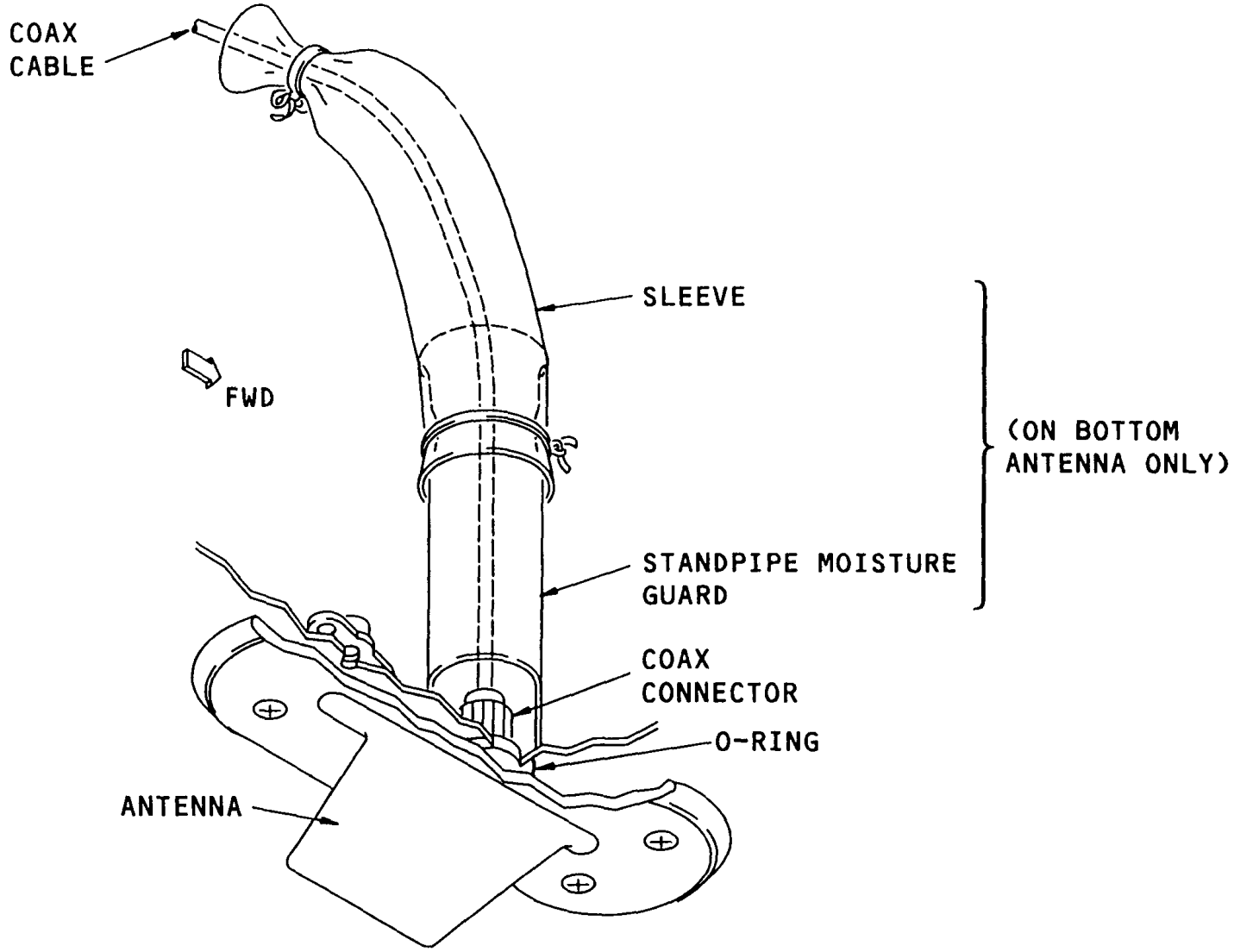


Figure 20 ATC - ANTENNA

ANTENNA SWITCHES

The ATC antenna switch connects the active ATC transponder to the ATC antenna. This permits the two ATC transponders to share the same antenna.

These connectors provide an RF interface for the ATC system interrogation and reply signals:

- Left ATC transponder connector
- ATC antenna connector
- Right ATC transponder connector

The electrical connector has an input from the:

- ATC antenna switch circuit breaker
- ATC control panel

Control of the RF signal switching is supplied by the ATC control panel.

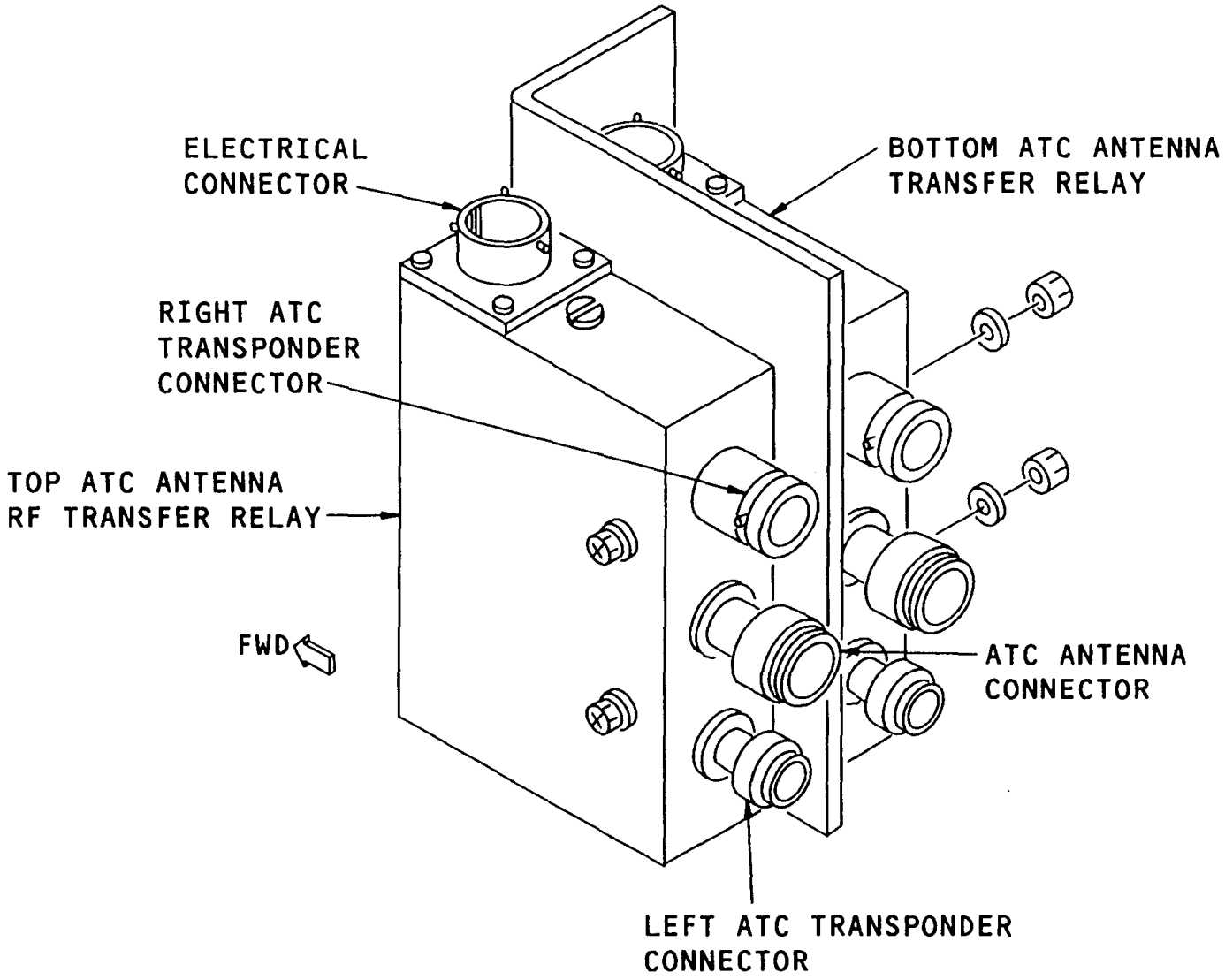


Figure 21 ANTENNA SWITCHES

ANTENNA SWITCHING

The ATC control panel sends a discrete (ground) or (open) to the top and bottom ATC antenna switches. This connects the right transponder or left transponder to the top and bottom ATC antennas.

With power applied and the ATC control panel selected to standby or left position, grounds are removed from R1 relays and R2 relays, & 1 switches are opened and the top and bottom antenna's are connected to the left ATC Transponder.

Selecting the right position applies a ground to Relays R1 & Relays R2 by the relaxation of switches S1. The top and bottom antennas then switch to the right transponder.

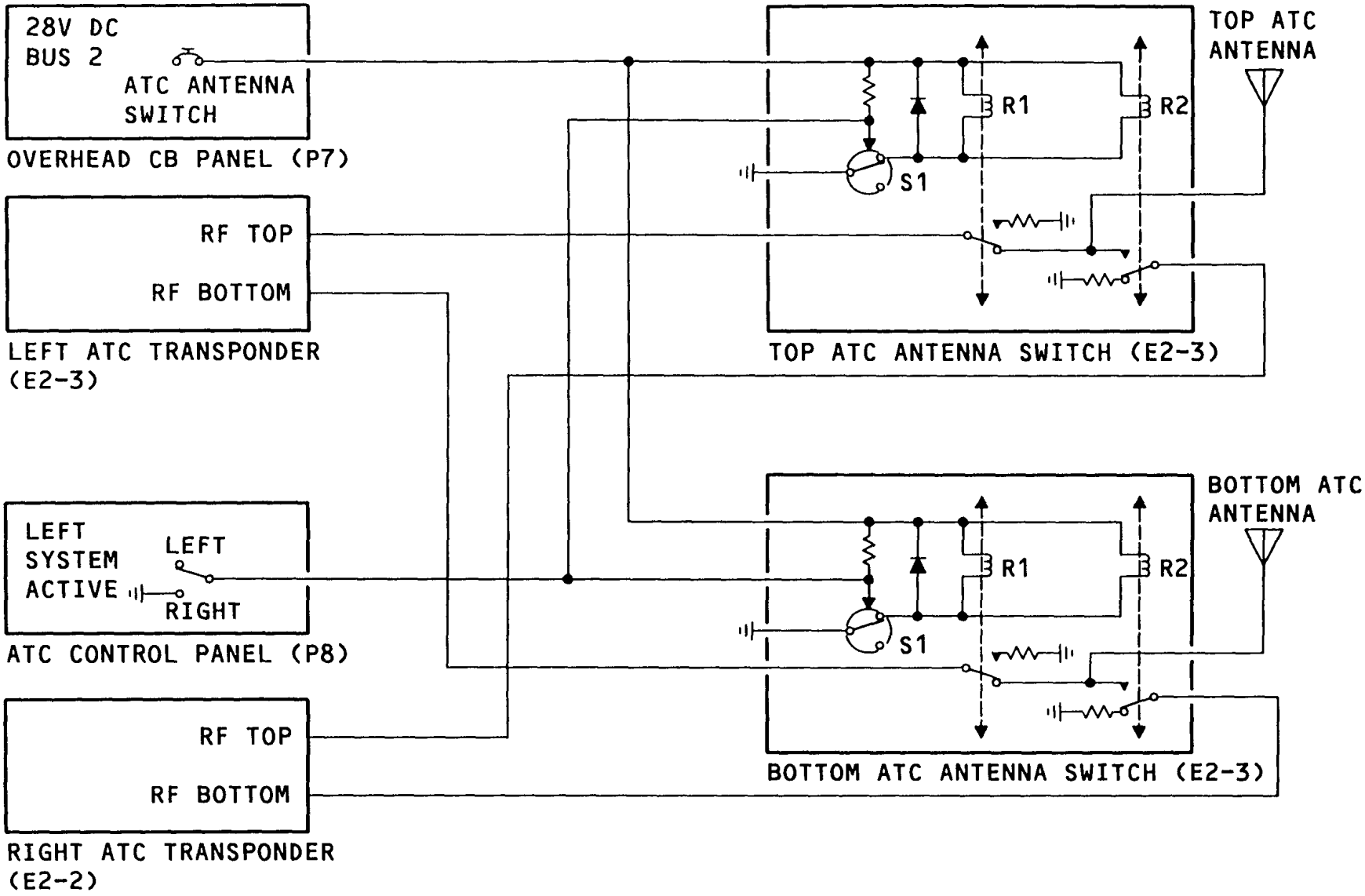


Figure 22 ANTENNA SWITCHING

INPUTS AND CONTROL

Power

115v ac is supplied by the standby bus.

Control

The ATC transponder is controlled by the ATC control panel. Control is supplied with one digital data bus and analog discretes. The digital data bus contains the identity code the flight crew has selected for reply to mode A interrogations.

Also on the data bus are digital discretes for the position of the IDENT switch and the ALT RPTG OFF switch.

When the left or right transponder is selected, and the function switch is selected to standby, a ground discrete goes to the selected transponder and inhibits operation of the unit. A ground discrete is also sent from the ATC control panel to select the top and bottom antenna to either the left or right ATC transponder.

ATC Transponder Inputs

The ATC transponder's Input/Output circuit is an interface to receive ARINC 429 data and discretes. The Central Processing Unit (CPU) supplies the link between the 1/0 and the signal processing circuits.

The digital input data is read by the 1/0 section. The identity code is put in memory for later use.

Standard baro altitude is sent on two digital data buses. The instrument source select module (ISSM) is used to select one or the other digital bus.

Altitude data is also put in memory for later use.

The digital data bus contains two digital discretes. One is the position of the function select switch. If the switch is in ALT RPTG off, the CPU will prevent mode C replies. The other digital discrete is the position of the IDENT switch. This switch is momentarily pushed by the flight crew at the request of the ground station (verbally by radio).

The CPU sends a special position identification (SPI) pulse that is transmitted at the end of every normal mode A reply.

The ATC transponder receives an air/ground discrete from the air/ground relay. The air/ground discrete is used by the CPU to count flight segments in the fault history nonvolatile memory. This discrete also prevents modes A and C replies on the ground.

A transponder fail discrete goes to all three EIU's when a fault is detected in the ATC transponder. This discrete activates the ATC-L or R advisory and status messages.

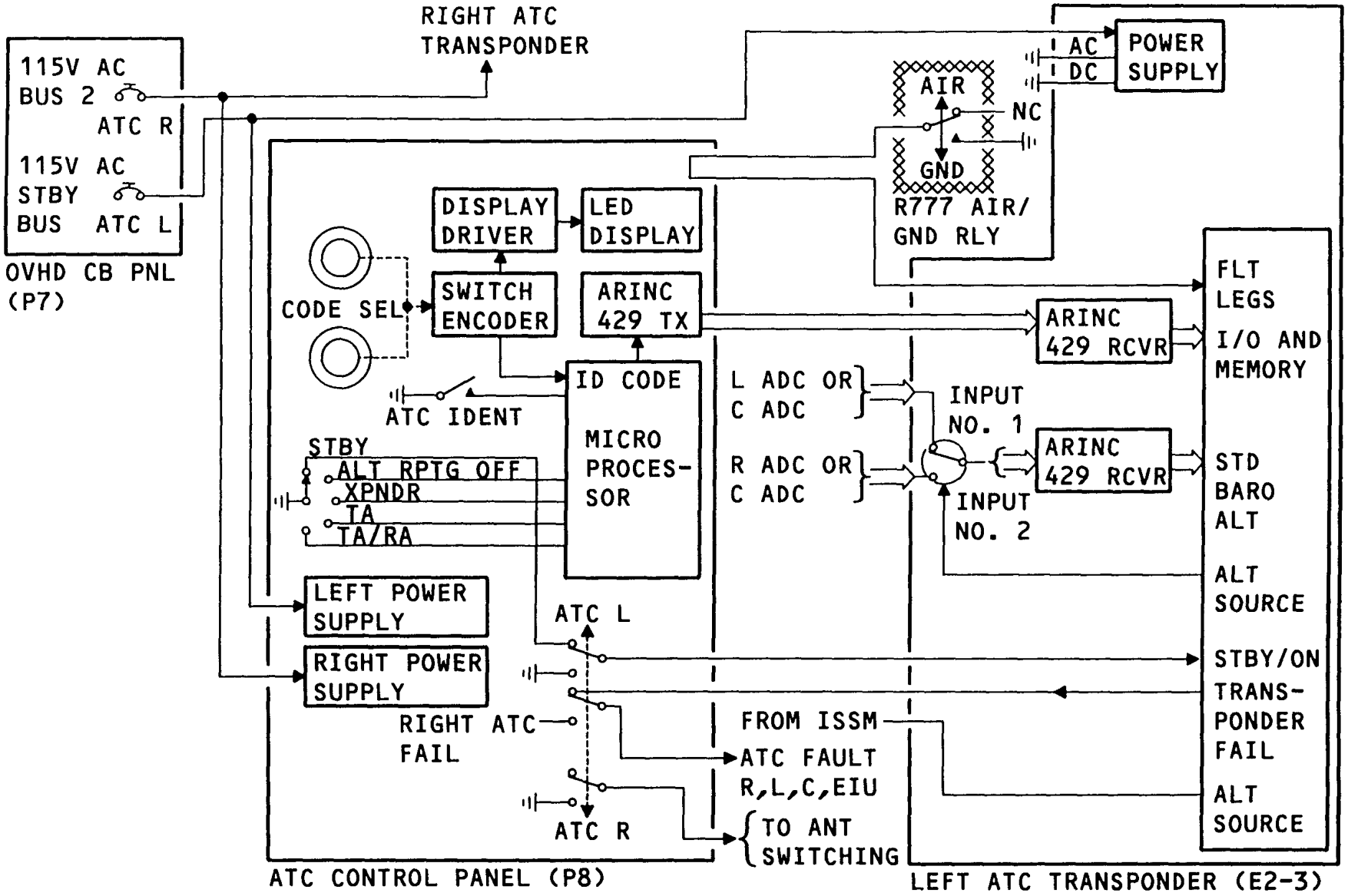


Figure 23 INPUTS AND CONTROL

RECEIVE

Interrogation signals are received at one or both of the antennas. They are sent through diplexing circuits to two individual receivers. The diplexer circuits control the receiver/transmit operation as well as monitor antenna power output. The 1030 MHz rf signal is mixed with a 1090 MHz signal from the local oscillator. This causes an intermediate frequency signal which is sent to the video circuits to be decoded.

The decoded signals are analyzed and it is determined if the signal is a valid interrogation and what the reply mode will be.

The antenna select circuit decides which receiver supplies a stronger signal. The output of this circuit is used for antenna switching. Antenna switching selects the antenna through which the reply will be transmitted.

During the reply process, the signal processor in the transponder sends a suppression pulse to the other L-band equipment. This prevents the operation of the other units while this unit is transmitting.

When the signal processor circuits in the transponder receive a suppression pulse, both receivers are disabled. This prevents the operation of the transponder.

When the system is initialized or the self test push button is pressed, noise is injected into the receivers and monitored and a test interrogation is injected into both top and bottom channels of the signal processor. If the system is valid, the transponder replys, and is monitored and stored in BITE memory. Front panel LED’s are activated to show test fail or pass.

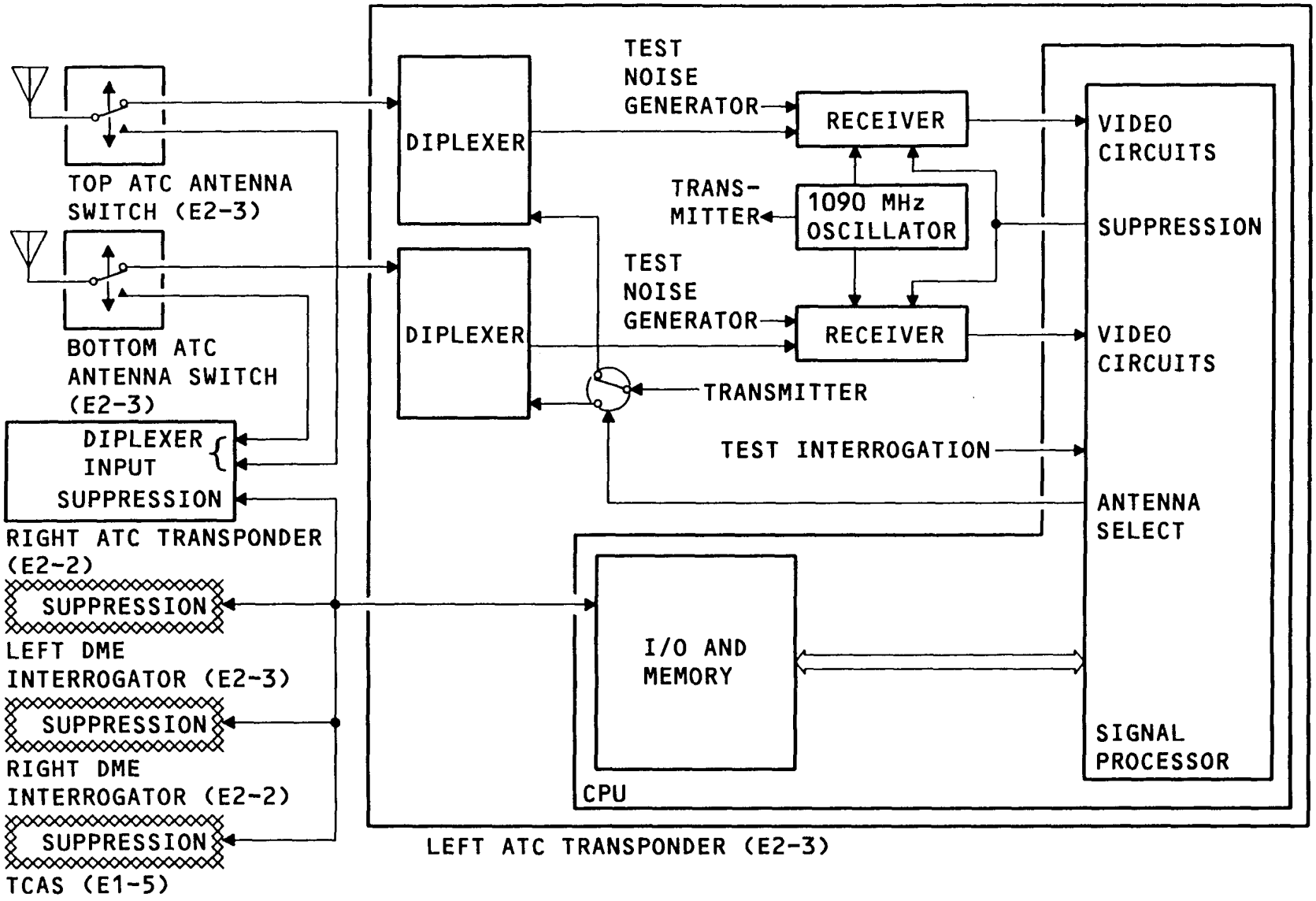


Figure 24 RECEIVE

TRANSMIT AND CMC INTERFACE

Transmit

The CPU signal processor circuit determines if the interrogation is either a valid mode S or ATCRBS mode A or C signal. This is done by comparison of the interrogation pulses.

The identify code and airplane altitude along with the mode S reply data is stored in the memory section of the CPU. This information goes through the mode formatters and the output formated data is sent to the modulator where it is pulse-modulated for transmission.

A 1090 Mhz oscillator is mixed with the modulator output and is amplified for transmission in a power amplifier.

The antenna select circuit sends the reply transmission out on the antenna that received the strongest interrogation signal.

BITE

The ATC transponder operates in a BITE (Built-In Test Equipment) mode which transmits continuous maintenance data

to the CMCs. The transponder detects faults through periodic monitoring. The BITE circuits identify the failure at the SRU (Shop Replaceable Unit) level. This data is stored in non-volatile memory.

CMC Interface

The ATC transponder transmits fault summary data on an ARINC 429 digital data bus to both CMCs. The CMCs supply this data on the CDUs.

A test command is sent from a CDU through the left CMC when a ground test is started.

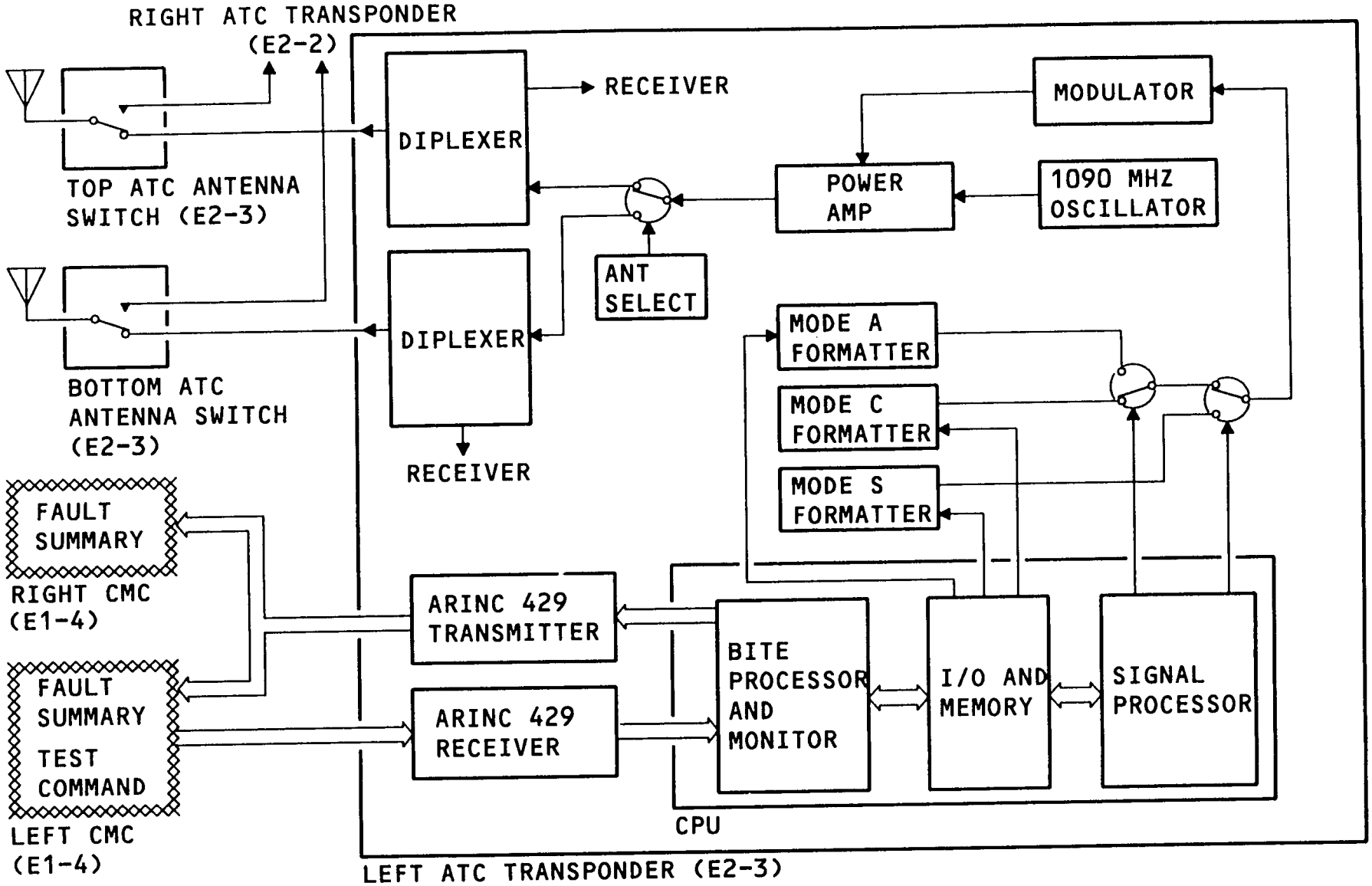


Figure 25 TRANSMIT AND CMC INTERFACE

OPERATIONAL TEST

The TEST pushbutton starts a test of the ATC system. During test, all normal processing stops and the transponder BITE circuits perform:

- Tests of memories
- A monitor of noise sources in each receiver
- An inspection of antenna integrity
- A simulated interrogation, injected into the top and bottom receivers (the transponder then responds with transmission)
- A sampling of the transmitter monitor (after transmission) and verification of the reply
- A sampling of the power monitor
- A test check of all data buses
- A return of the unit to normal operation

All front panel LEDs show for one second after the test is started.

For 10 seconds after all LEDs come on, the LEDs will stay on with these conditions:

- Transponder failure - causes red FAIL LED to come on - all detected failures are an LRU failure but the detected antenna failure is not
- No failures - green PASS LED comes on
- Antenna failures - causes upper and/or lower antenna failure LEDs to come on
- Altitude failure - causes red ALT LED to come on
- Control panel failure - causes red CTL LED to come on

CAUTION: DO NOT SELECT CODES 3100, 7500, 7600 OR 7700. THESE ARE CODES USED ONLY IN EMERGENCY SITUATIONS.

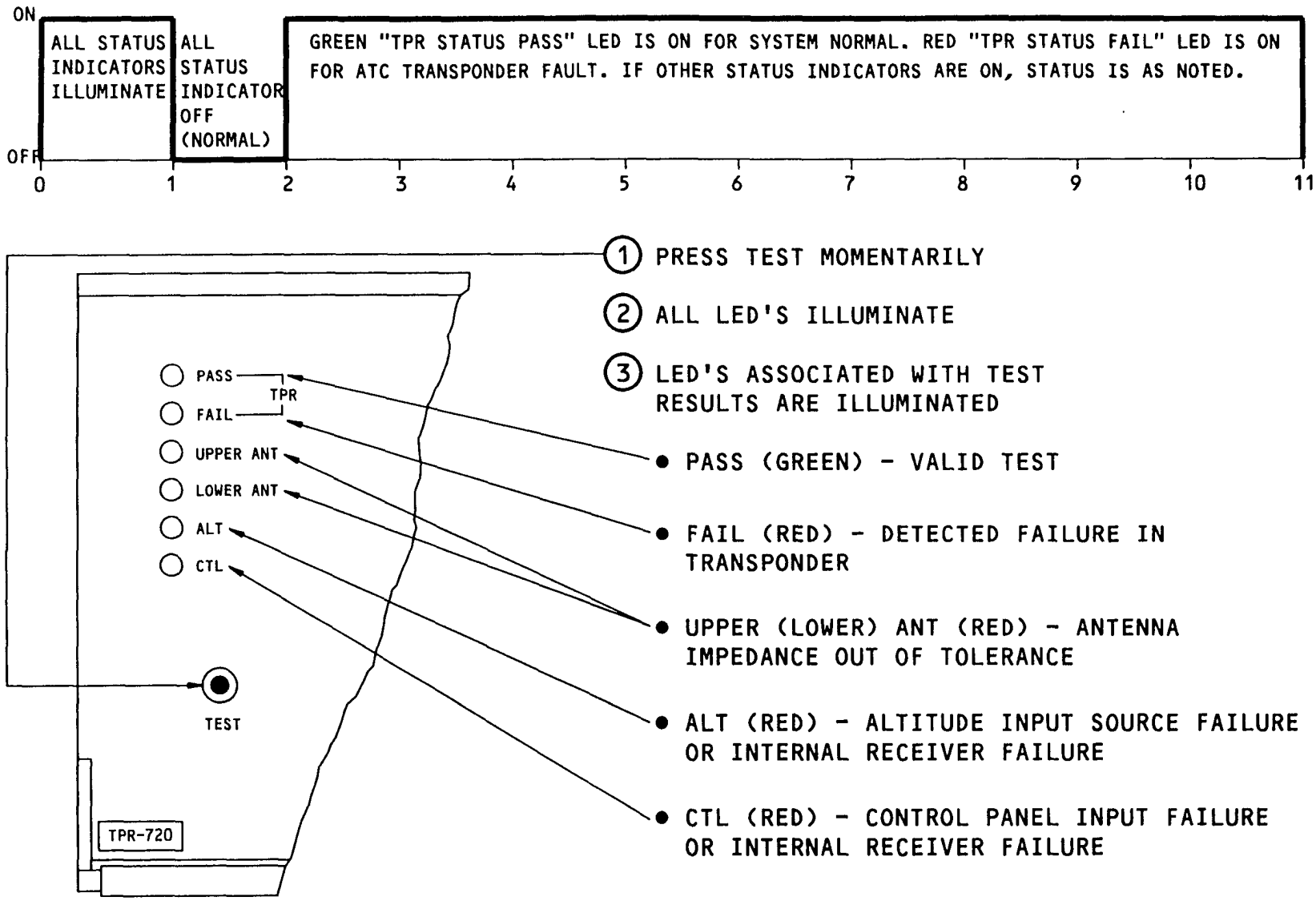


Figure 26 OPERATIONAL TEST

GROUND TEST

Ground Test

The ground test menu page allows ground test of specific line replaceable units (LRUs). The ATC ground test is inhibited under certain conditions. When the line select pushbutton for ground test of either ATC transponder is pushed, an enable test screen comes up. These test conditions must then be satisfied before the ground test can be run. When the conditions are met, push the RETURN LSK and the GROUND TESTS menu screen will come up without the inhibit cue. Push the LSK next to the ATC system to perform the ground test. This test is the same as the self-test performed from the ATC front panel, except it is performed from a CDU. The results show on the CDU.

Ground Test Results

The word PASS shows a valid ground test. Failure of the ground test is shown by the word FAIL. When the LSK next to FAIL is pushed, the ground test message page shows. This page gives special data about the ATC test failure.

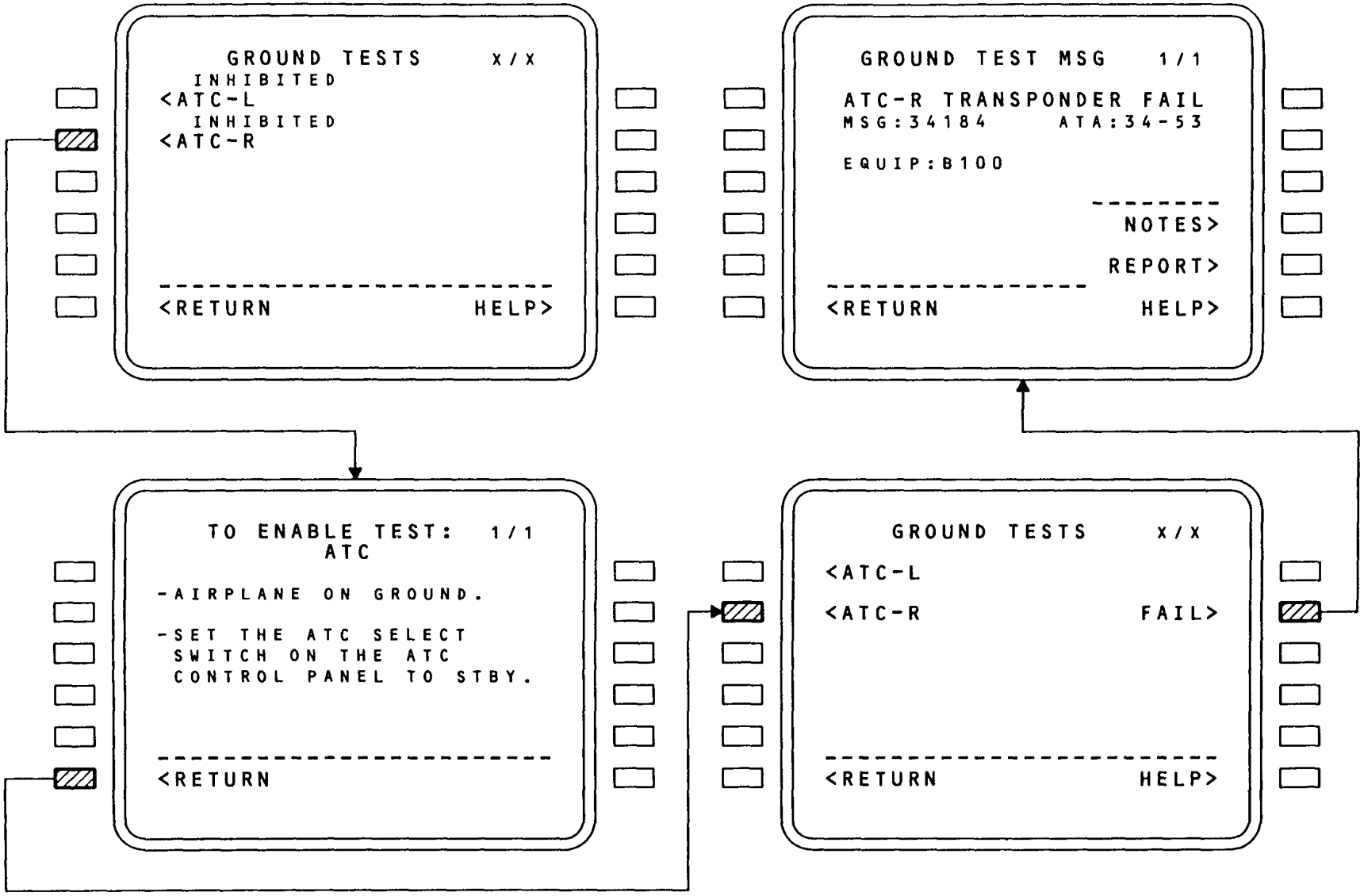


Figure 27 GROUND TEST

FLIGHT DECK EFFECTS AND CMC MESSAGES

Flight Deck Effects

Two types of EICAS messages are displayed for the ATC system. One is an advisory message with a time delay of 10 seconds:

- > ATC-X (ATC transponder fault)

And a level S message for a time delay of 60 seconds:

- ATC-X (ATC transponder fault)

CMC Messages

The different types of CMC messages displayed for the ATC system are:

- ATC-X FAIL OR CMC -- ATC-X BUS FAIL (CMC output bus failure).
- ATC-X -- CMC-X BUS FAIL (ARINC 429 ATC to CMC bus failure)
- ATC-X NO TEST RESPONSE (The ATC-X transponder failed to respond after a CMC ground test was started from the CDU)

ATC-X TRANSPONDER FAIL (ATC-X transponder failure)

UPPER ATC ANTENNA FAIL REPORTED BY ATC-X

LOWER ATC ANTENNA FAIL REPORTED BY ATC-X

ATC CONTROL PANEL -- ATC-X BUS FAIL (ARINC 429 ATC Control panel to ATC -X transponder bus failure)

ATC-X FAIL OR ADC-Z -- ATC-X BUS FAIL (ARINC 429 ADC to ATC bus failure)

TCAS -- ATC-X BUS FAIL (ARINC 429 TCAS to ATC bus failure)

ATC-X FAIL (NO BUS OUTPUTS)

NOTE: X = L (LEFT) OR R (RIGHT) Z = L (LEFT), R (RIGHT), OR C (CENTER)

FLIGHT DECK EFFECT	MESSAGE TYPE	DESCRIPTION
- >ATC-X	ADVISORY MESSAGE	X-AIR TRAFFIC CONTROL TRANSPONDER FAULT
- ATC-X	STATUS MESSAGE	X-AIR TRAFFIC CONTROL TRANSPONDER FAULT

CMC MESSAGES

ATC-X FAIL OR CMC ~ ATC-X BUS FAIL 1
ATC-X ~ CMC-X BUS FAIL
ATC-X NO TEST RESPONSE
ATC-X TRANSPONDER FAIL
UPPER ATC ANTENNA FAIL REPORTED BY ATC-X
LOWER ATC ANTENNA FAIL REPORTED BY ATC-X
ATC CONTROL PANEL ~ ATC-X BUS FAIL
ATC-X FAIL OR ADC-Z ~ ATC-X BUS FAIL 2
TCAS ~ ATC-X BUS FAIL
ATC-X FAIL (NO BUS OUTPUTS)

1 X = L(LEFT) OR R(RIGHT)

2 Z = L(LEFT), C(CENTER) OR R(RIGHT)

Figure 28 FLIGHT DECK EFFECTS AND CMC MESSAGES

APPENDIX A

APPENDIX

FIGURE 1 SUMMARY OF MODE S UPLINK FORMATS

FORMAT NO.

```
                UF
0       (0 0000)-3-(RL:1 )----4----(AQ:1 )---18----(AP:24). . SHORT AIR-AIR SURVEILLANCE
1       (0 0001)-------------27 OR 83 -------------(AP:24). . RESERVED FOR FUTURE USE
2     }
3     } SEE NOTE (4) BELOW
4       (0 0100)( PC:3 )( RR:5 )( DI:3 )( SD:16 )( AP:24 ). . SURVEILLANCE, ALTITUDE REQUEST
5       (0 0101)( PC:3 )( RR:5 )( DI:3 )( SD:16 )( AP:24 ). . SURVEILLANCE, IDENTITY REQUEST
6     )
7     )
8     } SEE NOTE (4) BELOW
9     )
10    )
11      (0 1011)( PR:4 )( II:4 )-----------19----( AP:24 ). . MODE S ONLY ALL-CALL
12    )
13    )
14    } SEE NOTE (4) BELOW
15    )
16      (1 0000)-3-(RL:1 )--4--(AQ:1 )--18--(MU:56)(AP:24). . LONG AIR-AIR SURVEILLANCE
17    )
18    } SEE NOTE (4) BELOW
19    )
20      (1 0100)(PC:3 )(RR:5 )(DI:3 )(SD:16)(MA:56)(AP:24). . COMM-A, ALTITUDE REQUEST
21      (1 0101)(PC:3 )(RR:5 )(DI:3 )(SD:16)(MA:56)(AP:24). . COMM-A, IDENTITY REQUEST
22    }
23    } SEE NOTE (4) BELOW
24      (11)(RC:2 )(NC:4 )(         MC:80         )(AP:24). . COMM-C (ELM)
```

NOTES: (1) (XX:M) DENOTES A FIELD DESIGNATED "XX" WHICH IS ASSIGNED M BITS.
(2) ---N--- DENOTES FREE CODING SPACE WITH N AVAILABLE BITS.
(3) FOR UPLINK FORMATS (UF) 0 THROUGH 23 THE FORMAT NUMBER CORRESPONDS TO BINARY CODE IN THE FIRST 5 BITS OF THE INTERROGATION. FORMAT NUMBER 24 IS DEFINED AS THE FORMAT BEGINNING WITH "11" IN THE FIRST TWO BIT POSITIONS WHILE THE FOLLOWING THREE BITS VARY WITH THE INTERROGATION CONTENT.
(4) THOSE FORMATS FOR WHICH NO APPLICATION IS PRESENTLY DEFINED, REMAIN UNDEFINED IN LENGTH. DEPENDING ON FUTURE ASSIGNMENT THEY MAY BE SHORT (56 BIT) OR LONG (112 BIT) FORMATS. SEE FORMAT NO. 1

Figure 29 MODE S UPLINK/DOWNLINK

APPENDIX

FIGURE 2 SUMMARY OF MODE S DOWNLINK FORMATS

FORMAT NO.	DF		
0	(0 0000)	(VS:1)---7----	(RI:4)----2----(AC:13)(AP:24) . . SHORT AIR-AIR SURVEILLANCE
1	(0 0001)	----------27 OR 83 ----------	(AP:24) . . RESERVED FOR FUTURE USE
2 3	} SEE NOTE (4) BELOW		
4	(0 0100)	(FS:3)(DR:5)(UM:6)(AC:13)	(AP:24) . . SURVEILLANCE, ALTITUDE
5	(0 0101)	(FS:3)(DR:5)(UM:6)(ID:13)	(AP:24) . . SURVEILLANCE, IDENTITY
6 7 8 9 10	} SEE NOTE (4) BELOW		
11	(0 1011)	(CA:3)(AA:24)	(PI:24) . . ALL-CALL REPLY
12 13 14 15	} SEE NOTE (4) BELOW		
16	(1 0000)	(VS:1)--7--(RI:4)--2--(AC:13)(MV:56)	(AP:24) . . LONG AIR-AIR SURVEILLANCE
17 18 19	} SEE NOTE (4) BELOW		
20	(1 0100)	(FS:3)(DR:5)(UM:6)(AC:13)(MB:56)	(AP:24) . . COMM-B, ALTITUDE
21	(0 0101)	(FS:3)(DR:5)(UM:6)(ID:13)(MB:56)	(AP:24) . . COMM-B, IDENTITY
22 23	} SEE NOTE (4) BELOW		
24	(11)--1--(KE:1)(ND:4)(	MD:80)	(AP:24) . . COMM-D (ELM)

NOTES: (1) (XX:M) DENOTES A FIELD DESIGNATED "XX" WHICH IS ASSIGNED M BITS.
(2) ---N--- DENOTES FREE CODING SPACE WITH N AVAILABLE BITS.
(3) FOR DOWNLINK FORMATS (DF) 0 THROUGH 23 THE FORMAT NUMBER CORRESPONDS TO BINARY CODE IN THE FIRST 5 BITS OF THE REPLY. FORMAT NUMBER 24 IS DEFINED AS THE FORMAT BEGINNING WITH "11" IN THE FIRST TWO BIT POSITIONS WHILE THE FOLLOWING THREE BITS MAY VARY WITH THE REPLY CONTENT.
(4) THOSE FORMATS FOR WHICH NO APPLICATION IS PRESENTLY DEFINED, REMAIN UNDEFINED IN LENGTH. DEPENDING ON FUTURE ASSIGNMENT THEY MAY BE SHORT (56 BIT) OR LONG (112 BIT) FORMATS. SEE FORMAT NO. 1

Figure 30 MODE S UPLINK/DOWNLINK

APPENDIX

FIGURE 3 TABLE OF MODE S FIELD DESCRIPTIONS

CODE	FIELD NAME	DOWNLINK (D)/UPLINK (U) MEANING	
AA	ADDRESS ANNOUNCED	D	AIRCRAFT IDENTIFICATION IN ALL-CALL REPLY
AC	ALTITUDE CODE	D	AIRCRAFT ALTITUDE CODE
AP	ADDRESS/PARITY	U/D	ERROR DETECTION FIELD
AQ	ACQUISITION	U	PART OF AIR-AIR PROTOCOL
CA	CAPABILITY	D	AIRCRAFT REPORT OF SYSTEM CAPABILITY
DF	DOWNLINK FORMAT	D	DOWNLINK DESCRIPTOR
DI	DESIGNATOR IDENTIFICATION	U	DESCRIBES CONTENT OF SD FIELD
DR	DOWNLINK REQUEST	D	AIRCRAFT REQUESTS PERMISSION TO SEND DATA
FS	FLIGHT STATUS	D	AIRCRAFT'S SITUATION REPORT
ID	IDENTIFICATION	D	EQUIVALENT TO ATCRBS IDENTITY NUMBER
II	INTERROGATOR IDENTIFICATION	U	SITE NUMBER FOR MULTISITE FEATURES
KE	CONTROL, ELM	D	PART OF EXTENDED LENTGH MESSAGE PROTOCOL
MA	MESSAGE, COMM-A	U	MESSAGE TO AIRCRAFT
MB	MESSAGE, COMM-B	D	MESSAGE FROM AIRCRAFT
MC	MESSAGE, COMM-C	U	LONG MESSAGE SEGMENT TO AIRCRAFT
MD	MESSAGE, COMM-D	D	LONG MESSAGE SEGMENT FROM AIRCRAFT
MU	MESSAGE, COMM-U	U	AIR-TO-AIR MESSAGE TO AIRCRAFT
MV	MESSAGE, COMM-V	D	AIR-TO-AIR MESSAGE FROM AIRCRAFT
NC	NUMBER, C-SEGMENT	U	PART OF ELM PROTOCOL
ND	NUMBER, D-SEGMENT	D	PART OF ELM PROTOCOL
PC	PROTOCOL	U	OPERATING COMMANDS FOR THE TRANSPONDER
PI	PARITY/INTERR. IDENTIFY	D	REPORTS SOURCE OF INTERROGATION
PR	PROBABILITY OF REPLY	U	USED IN STOCHASTIC ACQUISITION MODE
RC	REPLY CONTROL	U	PART OF ELM PROTOCOL
RI	REPLY INFORMATION	D	AIRCRAFT STATUS INFORMATION FOR TCAS
RL	REPLY LENGTH	U	COMMANDS AIR-TO-AIR REPLY LENGTH
RR	REPLY REQUEST	U	COMMANDS DETAILS OF REPLY
SD	SPECIAL DESIGNATOR	U	CONTROL CODES TO TRANSPONDER
UF	UPLINK FORMAT	U	FORMAT DESCRIPTOR
UM	UTILITY MESSAGE	D	PROTOCOL MESSAGE
VS	VERTICAL STATUS	D	AIRCRAFT STATUS, AIRBORNE OR ON THE GROUND

Figure 31 MODE S UPLINK/DOWNLINK

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TABLE OF FIGURES