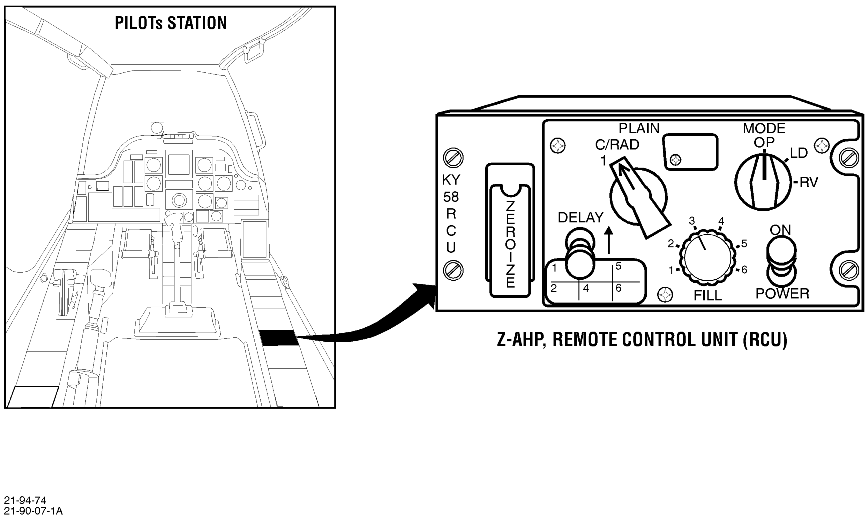
SPACER PAGE
FOR AVIONICS
STUDENT HANDOUT

TSEC/KY-58 REMOTE CONTROL UNIT



Z-AHP, REMOTE CONTROL UNIT (RCU)

NOTES

A. TSEC/KY-58

1. Provides secure voice (ciphony) for all classifications of traffic in tactical environments. The pilot's VHF AM/FM radio is the only device designated to use secure voice transmission and reception.

2. Features

   a. Utilizes a remote control unit (RCU) to interface the pilot crewstation with the TSEC/KY-58 security voice unit in the aft avionics bay.

   b. Operating power comes from the 28 VDC emergency bus through a circuit breaker on the pilot crewstation circuit breaker panel, labeled KY-28.

   c. Two operating modes are available.

      (1) PLAIN mode for clear voice transmission or reception.

      (2) C/RAD 1 (cipher) mode for secure VHF radio transmission or reception.

   d. A crypto alarm is generated and sent to both integrated helmets when secure voice is being used.

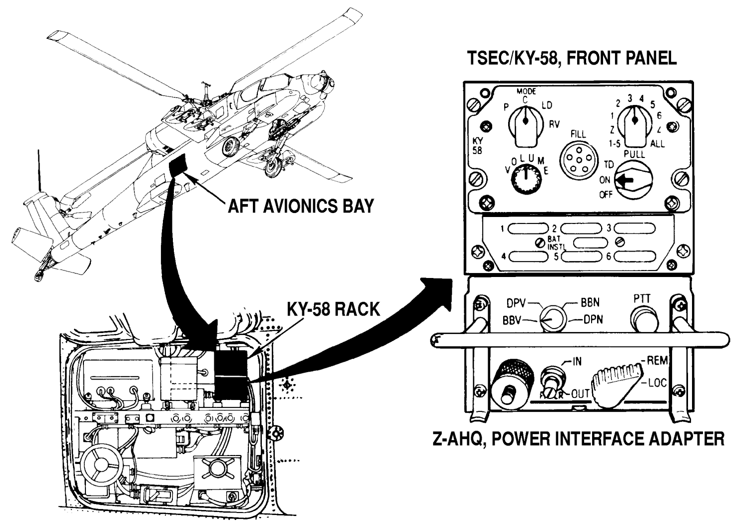
3. Major components

   a. Z-AHP remote control unit

   b. Z-AHQ power interface adapter.

   c. TSEC/KY-58

TSEC/KY-58 AND ADAPTER



21-94-75
21-92-50

NOTES

4. Component purpose, location, description, and operation

a. Z-AHQ power interface adapter

(1) The Z-AHQ power interface adapter provides the interface to use a KY-58 in the aircraft.

(2) Mounted in the aft avionics bay on the mount provided for the KY-28.

(3) The front panel contains the following controls

(a) BBV, DPV, BBN, DPN

1) 4-position switch specifying the type of radio being secured.

(4) Set to BBV for pilot crewstation VHF AM/FM radio.

(a) PTT (push-to-talk) button

1) Clears crypto alarm that occurs upon power up.

2) Alarm can also be cleared by pressing any push-to-talk switch in the pilot compartment.

(b) FILTER IN/OUT selector

1) Prevents adjacent channel interference when using radios with channel spacing of 25 KHZ.

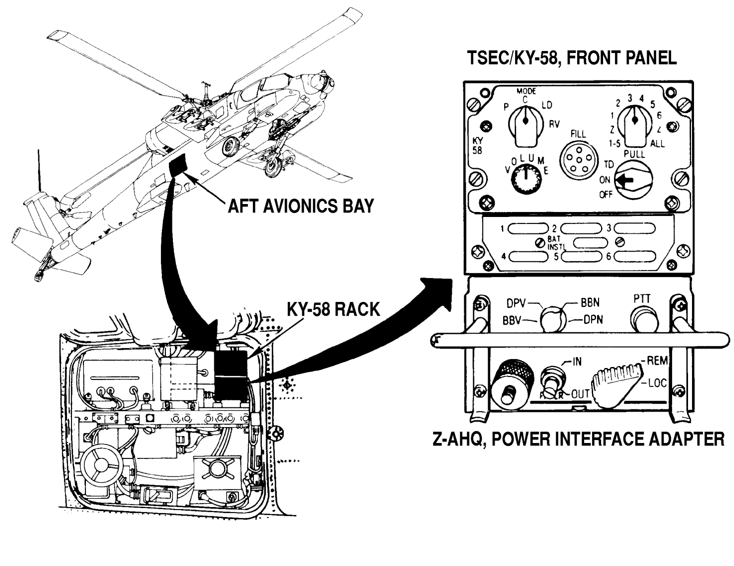
2) Must be set to IN for pilot's AN/ARC-186(V) VHF-FM radio.

(c) REM/LOC switch

1) Sets the Z-AHQ to the local mode.

2) Switch returns to REM (remote) position upon release, but equipment remains in local mode until any PTT is keyed.

TSEC/KY-58



NOTES

b. TSEC/KY-58 voice security unit

(1) Provides secure voice for #1 VHF radio.

(2) Located in aft avionics bay and is interfaced with the aircraft by the power interface adapter.

(3) Description

(a) VOLUME control

1) Sets audio level of pilot's VHF-AM radio.

2) The proper volume level must be set, otherwise the audio to the pilot crewstation VHF is insufficient or excessive.

(b) MODE switch

1) Set to P (PLAIN) to operate pilot's VHF-FM radio in the clear.

2) Set to C (CIPHER) to operate pilot's VHF-FM radio in the ciphered (secure speech) mode.

3) Set to LD (load) when installing cyrpto-net variables (CNV) in the TSEC/KY-58 (TM 5810-262-12&P).

4) SET to RV (receive variable) during manual remote keying (TM 5810-262-12&P).

(c) FILL connector - used to load crypto-net variables (CNV's) into the TSEC/KY-58 registers (TM 5810-262-12&P).

(d) FILL switch

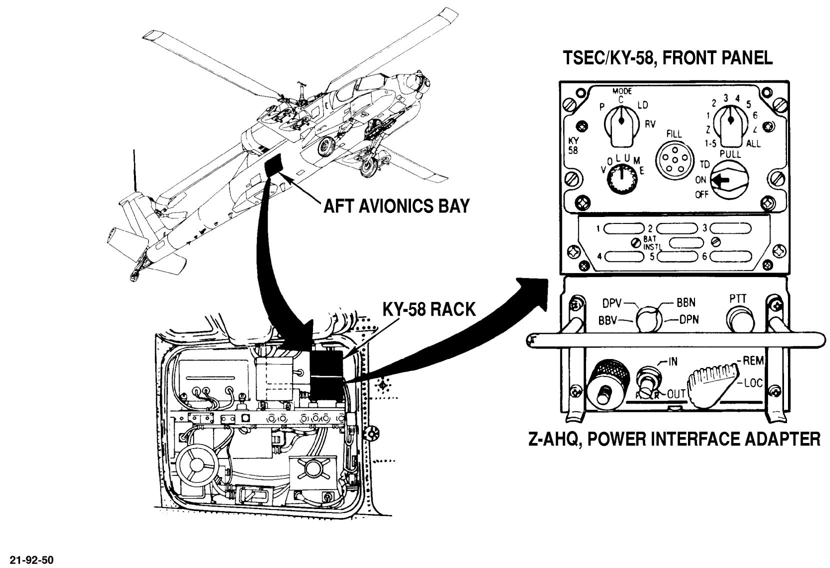
1) Pull knob and set to ZI-5 to zeroize (delete) crypto-net variables (CNV's) in TSEC/KY-58 registers 1-5.

2) Select 1-5 for desired CNV.

3) Pull knob and set to Z-ALL to zeroize (delete) crypto-net variables (CNV's) in all TSEC/KY-58 registers.

4) Zeroizing all registers renders TSEC/KY-58 unusable.

TSEC/KY-58



NOTES

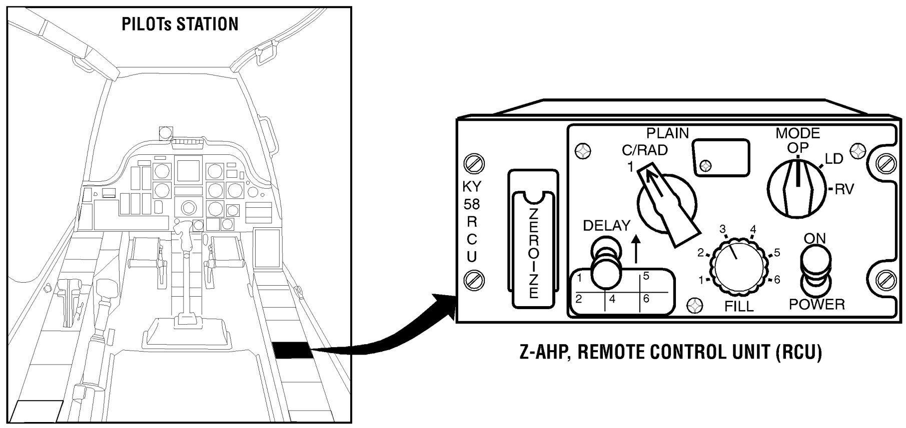
(e) Power switch

1) Set to OFF to turn off both TSEC/KY-58 and the pilot's VHF-FM radio.

2) Set to ON to operate the TSEC/KY-58 and pilot's VHF-FM radio.

3) Set to TD (time delay) when secure voice from pilot's VHF-FM radio is to be retransmitted.

TSEC/KY-58 REMOTE CONTROL UNIT



Z-AHP, REMOTE CONTROL UNIT (RCU)

21-94-74
21-90-07-1A

NOTES

c. Z-AHP remote control unit (RCU)

(1) Provides pilot interface with KY-58.

(2) Located in the pilot crewstation right-hand console.

(3) Description

(a) ZEROIZE switch

1) Two-position toggle switch housed under a spring-loaded cover.

2) Used in an emergency to delete all crypto-net variables (CNV's) from KY-58 registers.

3) Renders KY-58 unusable until new variables are loaded.

(b) DELAY switch

1) Introduces time delay that is necessary when secure signal from pilot's VHF-FM radio is to be retransmitted by receiving station.

2) Switch is normally in the down (off) position.

(c) C/RAD 1/PLAIN

1) Set switch to C/RAD 1 switch (cipher radio 1) to use secure voice.

2) Set switch to PLAIN when operating radio in the clear.

(d) Switch guard - rotates to the left to prevent C/RAD 1/PLAIN switch from accidentally being set to PLAIN.

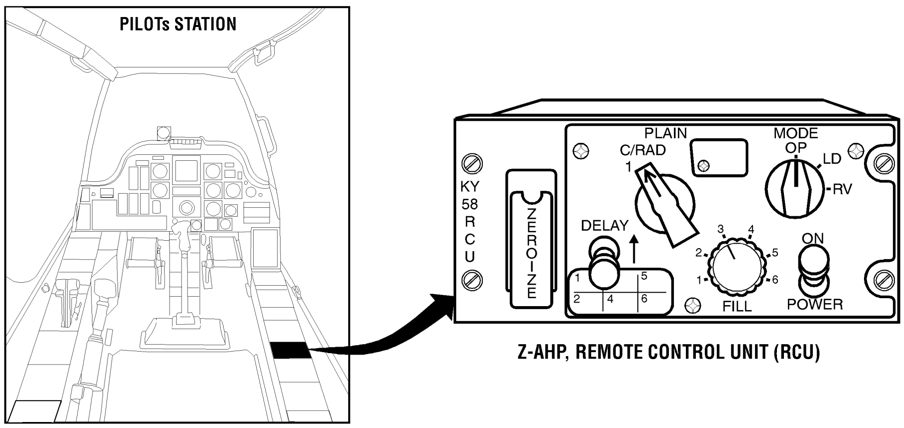
(e) MODE switch

1) Set to OP (operate) to use pilot's VHF radio in either the ciphered or plain mode.

2) Set to LD (load) when installing crypto-net variables (CNV) in the TSEC/KY-58 (TM 5810-262-23&P).

3) Set to RV (receive variable) during manual remote keying (TM 5810-262-12&P).

TSEC/KY-58 REMOTE CONTROL UNIT



Z-AHP, REMOTE CONTROL UNIT (RCU)

21-94-74
21-90-07-1A

NOTES

(f) POWER

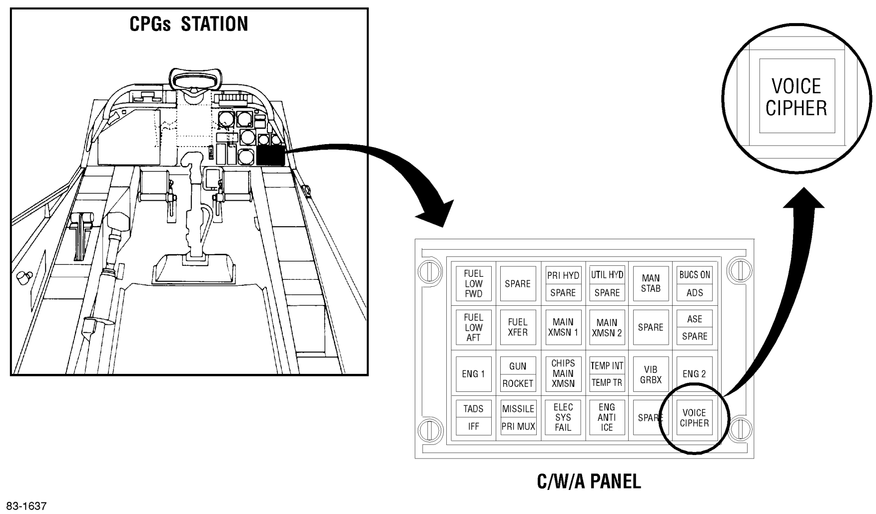
1) Turns KY-58 on and off.

2) Switch must be on (up) for operation in either plain or cipher mode.

(g) FILL switch

Selects desired crypto-net variable (CNV).

CPGs VOICE CIPHER LIGHT

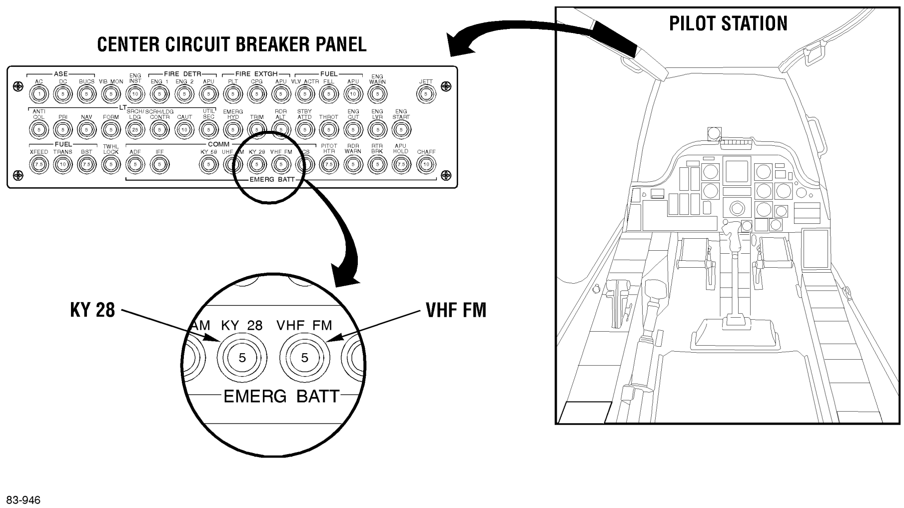


NOTES

d. CPGs voice cipher light

Illuminates when KY-58 secure voice is in operation.

PILOT VHF CIRCUIT BREAKERS



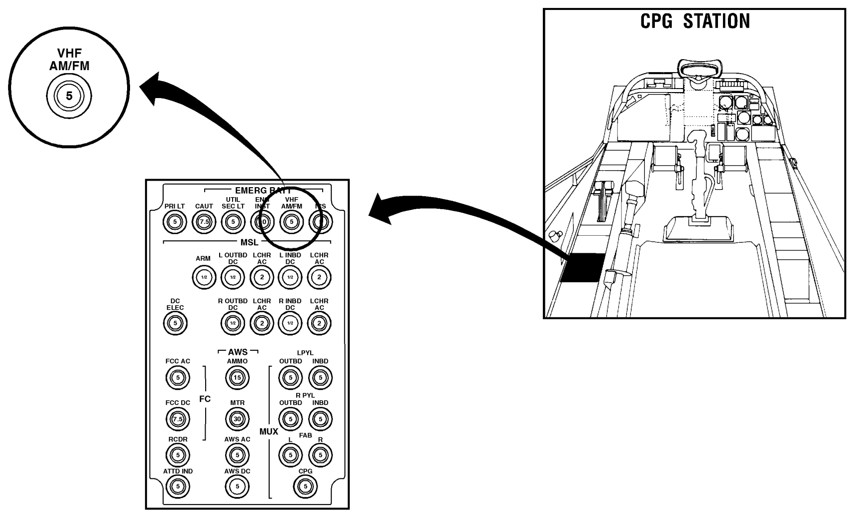
NOTES

e. Pilot VHF circuit breakers

(1) Provides circuit protection for the pilot crewstation VHF and KY-58 secure voice system.

(2) The VHF (No. 1) and KY-58 circuit breakers are mounted in the pilot's center overhead circuit breaker panel.

CPG VHF CIRCUIT BREAKER



83-948

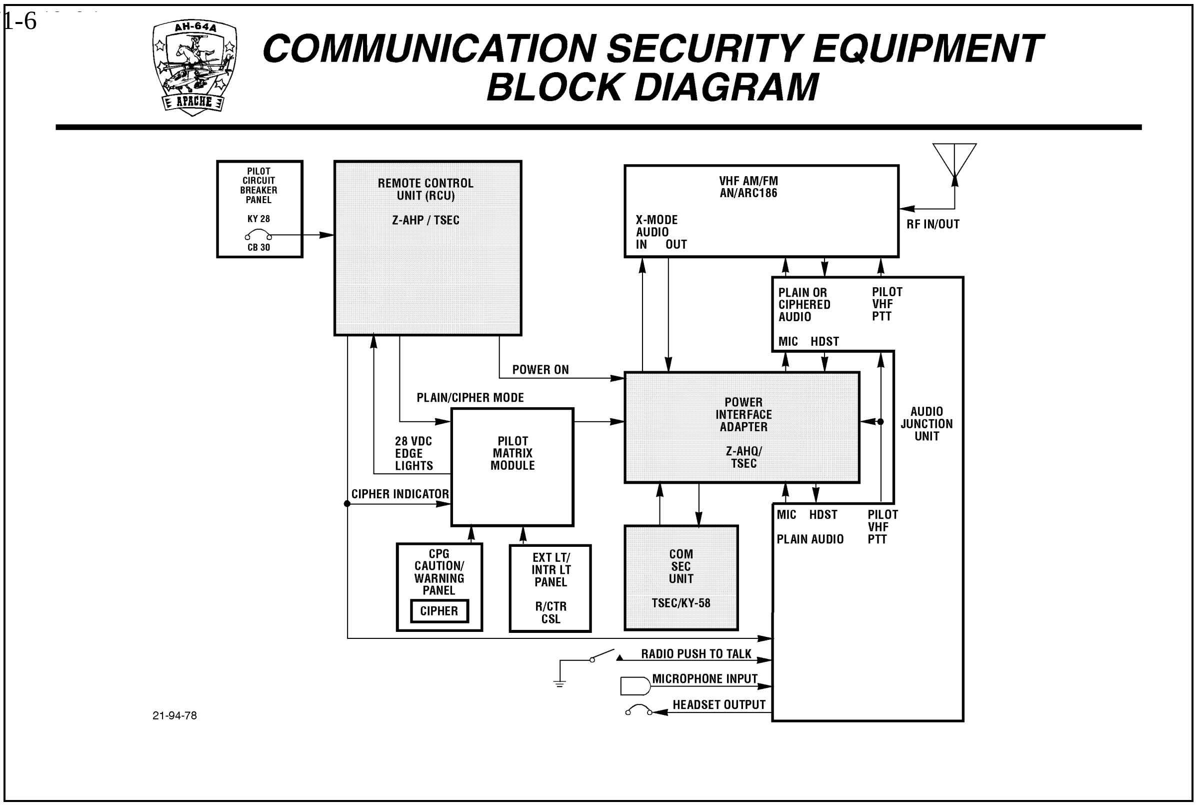
NOTES

f. CPG VHF circuit breaker

(1) Provides circuit protection for the CPG crewstation VHF.

(2) The No. 2 VHF circuit breaker is located on the CPG's No. 1 circuit breaker panel.

(3) All of the VHF circuit breakers are rated at 28 VDC, 5 amps.


AH-64A
APACHE
COMMUNICATION SECURITY EQUIPMENT
BLOCK DIAGRAM
PILOT CIRCUIT BREAKER PANEL
KY 28
CB 30
REMOTE CONTROL UNIT (RCU)
Z-AHP / TSEC
VHF AM/FM AN/ARC186
X-MODE AUDIO
IN
OUT
RF IN/OUT
PLAIN OR CIPHERED AUDIO
PILOT VHF PTT
MIC
HDST
POWER ON
PLAIN/CIPHER MODE
POWER INTERFACE ADAPTER
Z-AHQ/ TSEC
AUDIO JUNCTION UNIT
28 VDC EDGE LIGHTS
PILOT MATRIX MODULE
CIPHER INDICATOR
MIC
HDST
PILOT VHF PTT
PLAIN AUDIO
CPG CAUTION/ WARNING PANEL
CIPHER
EXT LT/ INTR LT PANEL
R/CTR CSL
COM SEC UNIT
TSEC/KY-58
RADIO PUSH TO TALK
MICROPHONE INPUT
HEADSET OUTPUT
21-94-78

NOTES

5. Communication security equipment block diagram

a. Power, control, and interface

(1) Power to the communication security equipment is provided by the aircraft electrical system KY 28 circuit breaker.

(2) RCU output signals

(a) 28 VDC power to the interface adapter.

(b) Selection of the crypto-net variable to the power interface adapter.

(c) Radio re-transmission and zeroizing (dumping) the crypto-net variable memory.

(3) The power interface adapter performs interface functions between the communications security unit and the VHF AM/FM receiver/transmitter.

(a) Receives the control signals from the RCU.

(b) Outputs the signals to the communications security unit and the VHF AM/FM receiver/transmitter.

(c) Selects VHF AM or FM operation, narrow or wide band reception, or fill operation.

(4) The communications security unit accepts, stores, ciphers, and deciphers VHF FM transmissions and receptions.

b. Aircraft system application

(1) Power up

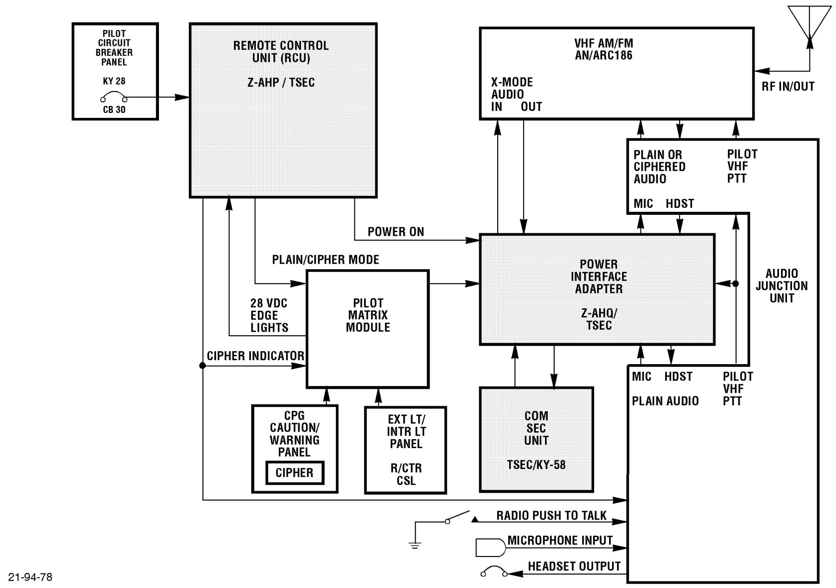
(a) When the KY 28 circuit breaker is closed, 28 VDC is applied to the RCU.

(b) Setting the RCU POWER switch to ON applies power to the power interface adapter and TSEC/KY-58.

(c) Setting the TSEC/KY-58 power switch to ON enables the TSEC/KY-58 circuitry.

(d) The RCU 28 VDC panel edge-lighting is controlled by the pilot EXT LT/INTR LT panel R/CTR CSL switch rheostat through the pilot matrix module.

COMMUNICATION SECURITY EQUIPMENT BLOCK DIAGRAM



NOTES

(2) Plain mode

(a) When the RCU is turned on, a plain (clear voice) MODE signal is sent through the pilot matrix module to the pilot VHF AM/FM receiver/transmitter and to the power interface adapter.

(b) The audio junction unit routes microphone audio to and from the power interface adaptor and the VHF AM/FM radio.

(c) In the plain mode, the VHF AM/FM mic and HEADSET audio are not enciphered/deciphered by the KY-58.

(d) The VHF AM/FM transmits and receives plain voice.

(3) Cipher mode

(a) Cipher indicator signal

1) A cipher indicator signal is sent from the RCU through the pilot matrix module to the CPG caution/warning panel and lights the VOICE CIPHER indicator.

2) The cipher indicator signal is also sent to the audio junction unit and disconnects the LH and RH wing ICS station head set audio during cipher mode.

(b) Cipher on MODE signal

1) A cipher on MODE signal is sent from the RCU through the pilot matrix module to the pilot VHF AM/FM receiver/transmitter and to the power interface adapter.

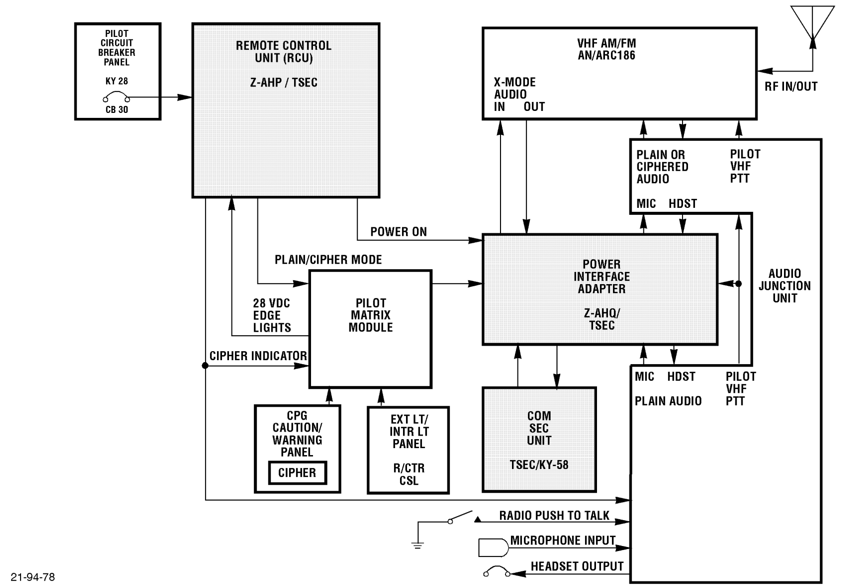
2) The cipher on MODE signal generates an audio tone.

(c) These audio and visual indications indicate secure voice operation.

(d) The audio junction unit routes microphone and headset audio to and from the power interface adaptor.

(e) The power interface adaptor routes microphone and headset audio to and from the VHF AM/FM radio.

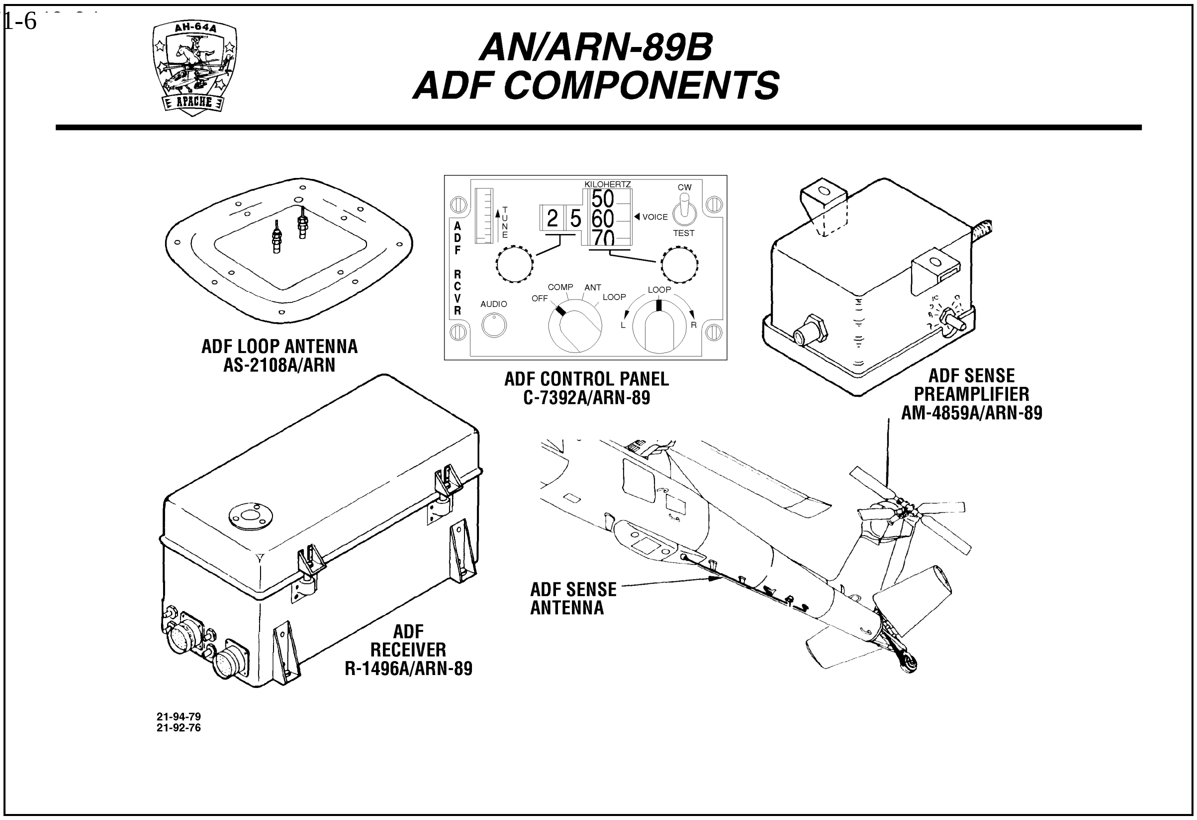
COMMUNICATION SECURITY EQUIPMENT BLOCK DIAGRAM



NOTES

(f) In the cipher mode, the VHF AM/FM mic and HEADSET audio are enciphered/deciphered by the KY-58.

(g) The VHF AM/FM transmits and receives ciphered - voice modulated RF.


AH-64A
APACHE
AN/ARN-89B
ADF COMPONENTS
ADF LOOP ANTENNA
AS-2108A/ARN
KILOHERTZ
CW
2 5
50
60
70
VOICE
TEST
TUNE
ADF RCVR
AUDIO
OFF
COMP
ANT
LOOP
LOOP
L
R
ADF CONTROL PANEL
C-7392A/ARN-89
ADF SENSE
PREAMPLIFIER
AM-4859A/ARN-89
ADF SENSE
ANTENNA
ADF
RECEIVER
R-1496A/ARN-89
21-94-79
21-92-76

NOTES

A. Automatic direction finder (ADF) AN/ARN-89B purpose, features, and major components

1. Provides bearing-to-station information to the pilot's horizontal situation indicator (HSI) and the CPG's radio magnetic indicator (RMI).

2. Features

   a. Provides an automatic or manual compass bearing on any radio signal within the frequency range of 100 to 3000 KHZ.

   b. The ADF displays helicopter bearing relative to a selected radio station.

   c. The ADF has three modes of operation.

      (1) AM reception

         (a) Automatic direction finder

         (b) Manual direction finder

      (2) Continuous wave reception

         (a) Automatic direction finder

         (b) Manual direction finder

      (3) AM broadcast-band receiver

3. AN/ARN-89B ADF major components

   a. C-7392A/ARN-89 ADF control panel

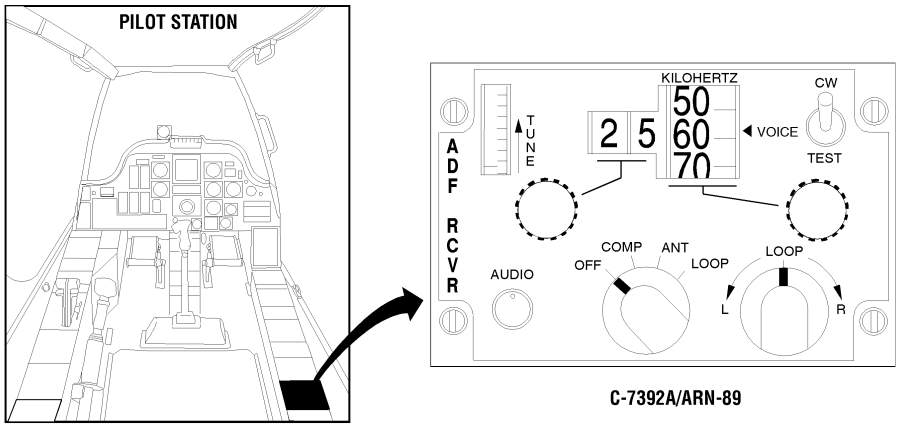
   b. R-1496A/ARN-89 ADF receiver

   c. AS-2108A/ARN-89 ADF loop antenna

   d. AM-4896A/ARN-89 ADF sense preamplifier

   e. ADF wire sense antenna

AN/ARN-89B ADF CONTROL PANEL



21-94-80
83-1324A

NOTES

B. Component purpose, location, description, and operation

1. ADF control panel C-7392A/ARN-89

a. The ADF control panel provides complete control of the ADF system.

b. Mounted in the pilot's right-hand console.

c. The ADF control panel has the following switches and indicators.

(1) OFF/COMP/ANT/LOOP switch (mode selector switch)

(2) Tune indicator

(3) Coarse tune control

(4) Fine tune control

(5) CW-VOICE-TEST switch

(6) LOOP (manual slewing control)

(7) AUDIO (volume control)

d. Operation

(1) OFF/COMP/ANT/LOOP mode selector switch

(a) OFF - removes power from the set

(b) COMP - provides for operation as an ADF

(c) ANT - provides for operation as an AM receiver using the sense antenna

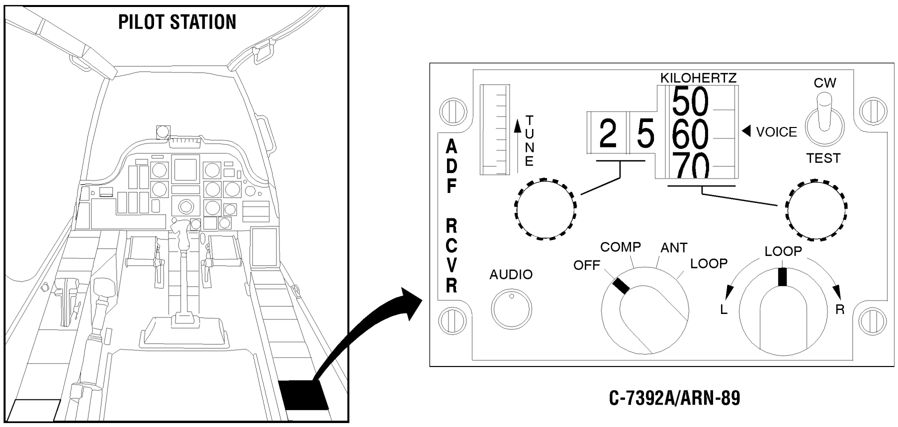
(d) LOOP - provides for receiver operation as a manual direction finder using only the loop antenna

(2) TUNE indicator - indicates relative signal strength while tuning the set to a specific radio signal

(3) COARSE tune control - tunes receiver in 100 KHZ steps as indicated by first two digits of the KILOCYCLES indicator

(4) Fine tune control - tunes receiver in 10 KHZ steps as indicated by last two digits of the KILOCYCLES indicator

AN/ARN-89B ADF CONTROL PANEL



C-7392A/ARN-89

21-94-80
83-1324A

NOTES

(5) CW-VOICE-TEST switch

(a) CW - has 2 modes of operation

1) CW in COMP mode - enables the tone oscillator to provide an audible tone for tuning to a continuous wave (CW) station when the mode selector switch is in the COMP position.

2) CW in ANT or LOOP mode - enables the beat frequency oscillator to permit tuning to a CW station when the mode select switch is in the ANT or LOOP position.

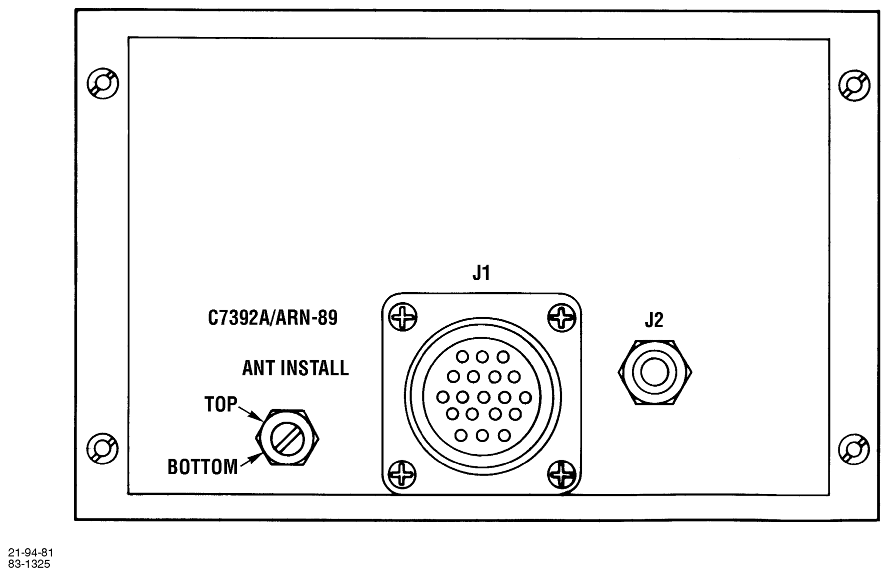
(b) VOICE - permits low frequency receiver to operate as a receiver when the mode selector switch is in any position.

(c) TEST (used in the COMP mode only) - provides for slewing of the loop through 180 degrees to check operation of the receiver in the COMP mode. The TEST position is inoperative in LOOP and ANT modes.

(6) LOOP L-R control knob - provides for manual left and right control of the loop when the mode selector is in the LOOP position.

(7) AUDIO - adjusts audio volume

AN/ARN-89B ADF CONTROL REAR PANEL



NOTES

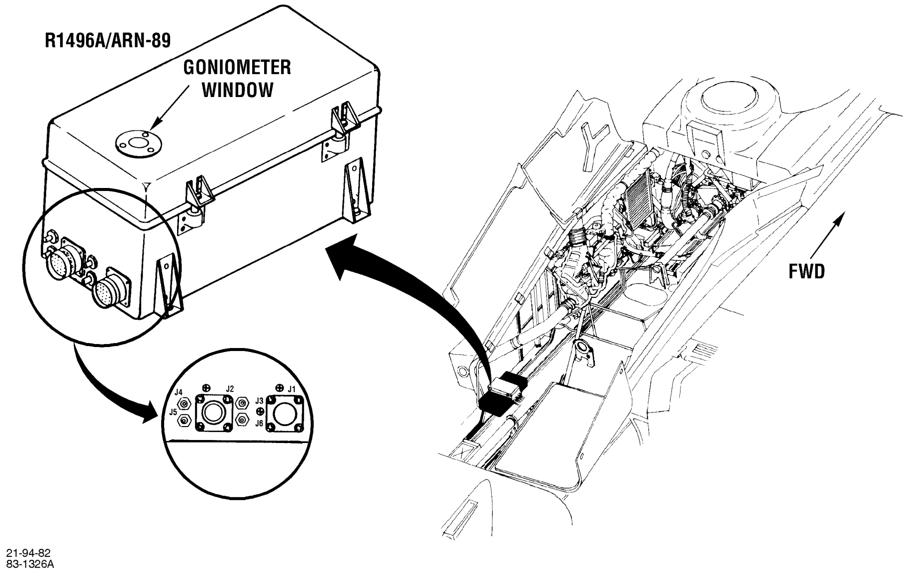
e. ADF control panel connections

(1) ANT INSTALL switch - selects top or bottom antenna (the AH-64A uses the BOTTOM antenna)

(2) Connector J1 - provides connection for signal and control

(3) Connector J2 - provides antenna connection

AN/ARN-89B ADF RECEIVER



NOTES

2. ADF receiver (R-1496A/ARN-89)

   a. The purpose of the loop antenna and sense antenna is to process the inputs to provide bearing-to-station information and audio outputs.

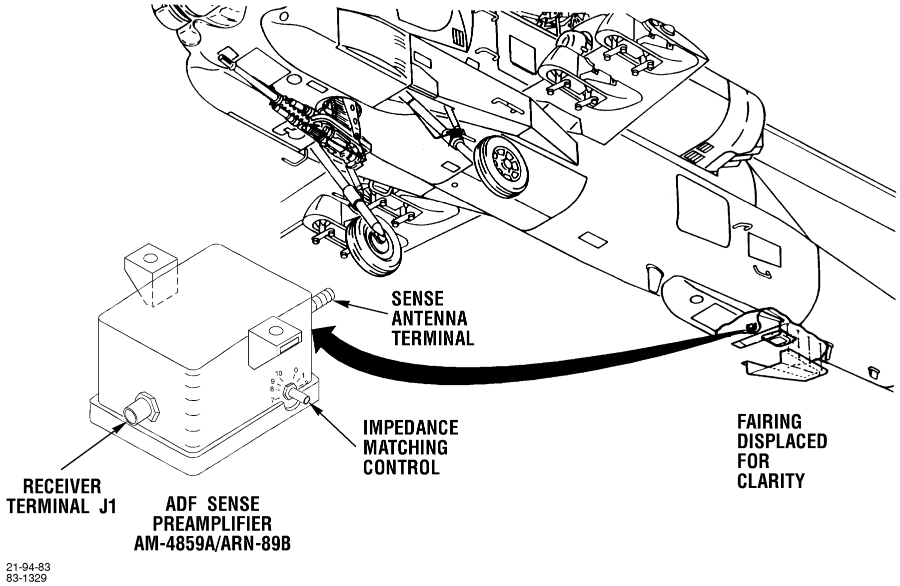
   b. The ADF Receiver is located on the left side of the aft equipment bay, forward of the aft equipment bay access.

   c. Description

      (1) The receiver has two signal and power connectors (J1 and J2), and four coaxial connectors (J3 through J6).

      (2) A circular goniometer indicator window in the top cover of the case shows the angle of the antenna position.

AN/ARN-89B
ADF SENSE PREAMPLIFIER



NOTES

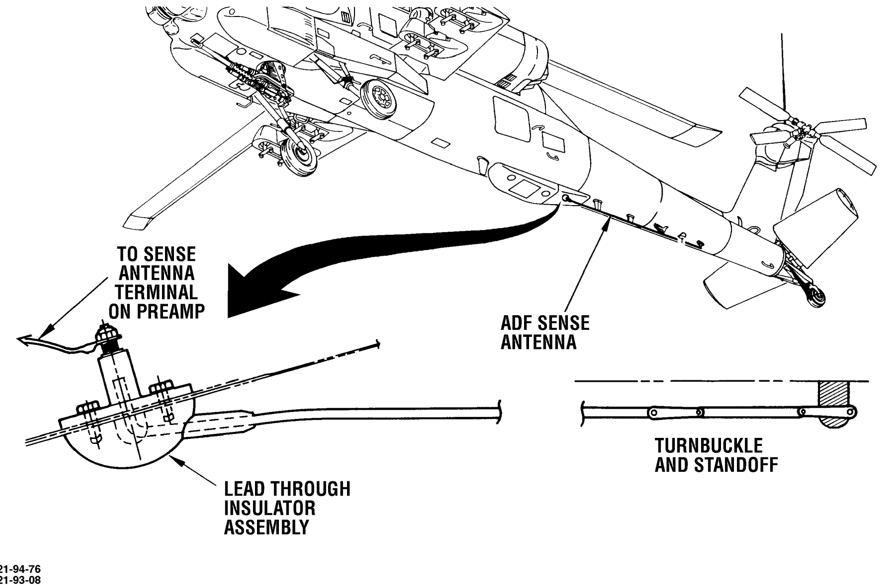
3. ADF sense preamplifier (AM-4859A/ARN-89)

   a. The sense preamplifier provides amplification of signals picked up by the sense antenna. It also provides impedance matching of the antenna to the receiver.

   b. The ADF sense preamplifier is located in the doppler fairing on the bottom of the fuselage.

   c. The sense preamplifier consists of a single electronic chassis with a sense antenna terminal, a coax connector, and the impedance matching potentiometer marked in increments from 0 through 10.

ADF SENSE ANTENNA



NOTES

4. ADF sense antenna

a. The ADF sense antenna provides the ADF receiver with an omnidirectional RF signal via the sense preamplifier. The sense antenna signal is used to resolve the 180E ambiguity of the loop antenna signal.

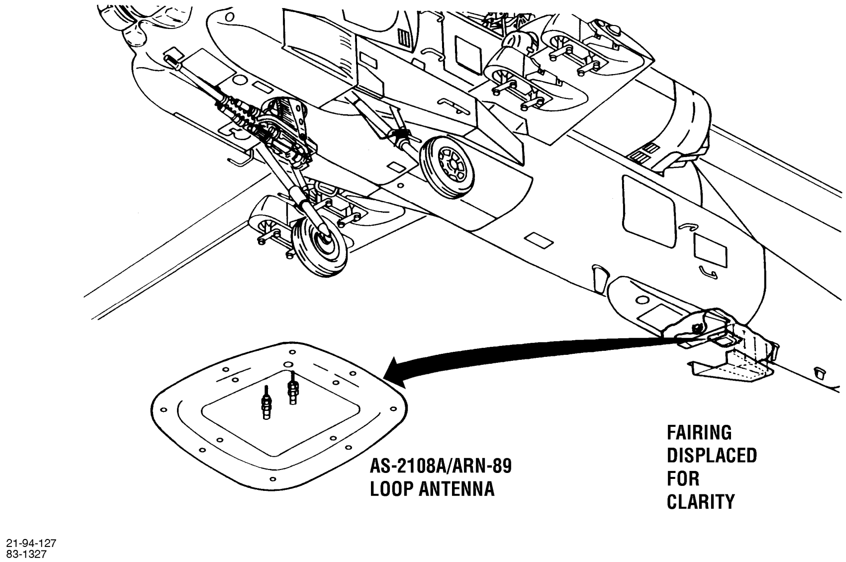
b. The sense antenna is a wire that is suspended on the bottom of the fuselage between the doppler fairing and a 6-inch standoff near the tail wheel.

c. Description

(1) The long wire antenna is attached to the fairing with a lead-through insulator which is attached to the sensor pre-amp.

(2) The trailing end is attached to the fuselage standoff by a turnbuckle.

AN/ARN-89B
ADF LOOP ANTENNA



NOTES

5. ADF loop antenna

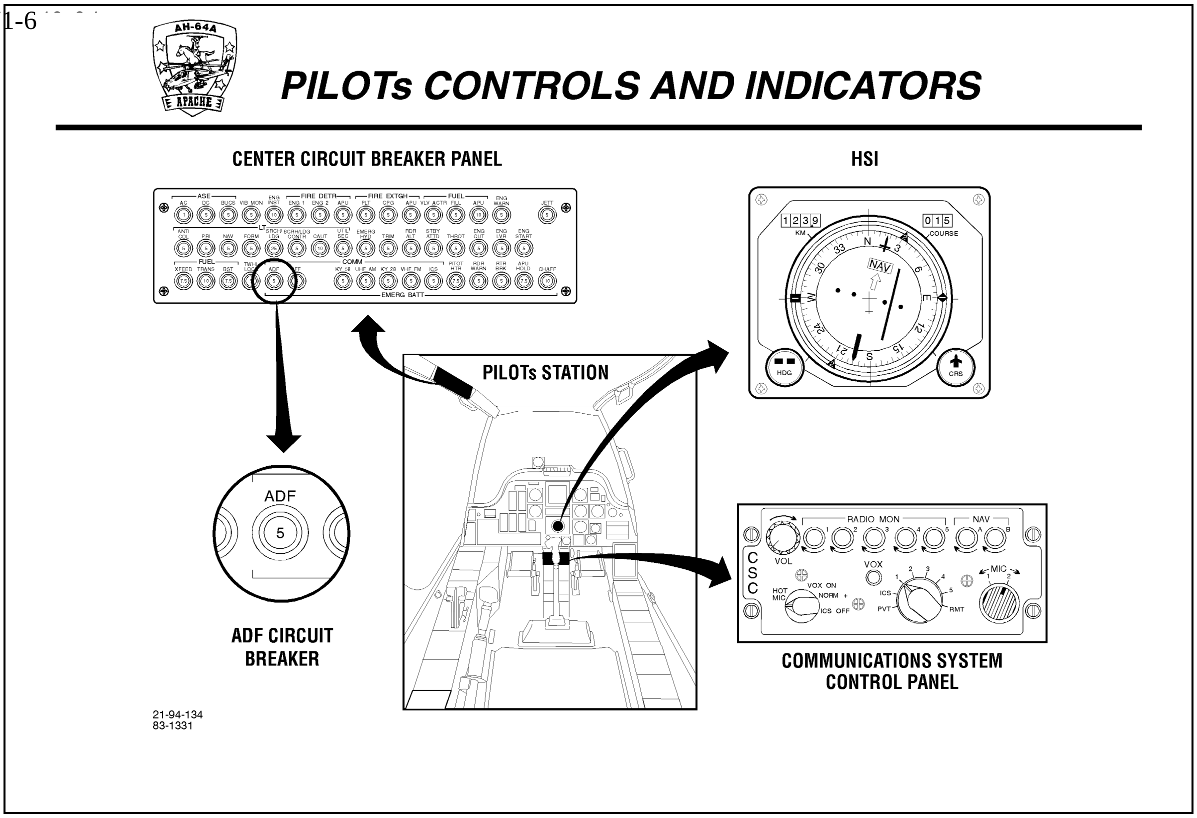
a. The ADF loop antenna provides directional information to the ADF receiver.

b. The ADF loop antenna is mounted in the doppler fairing on the bottom of the fuselage.

c. Description

(1) The loop antenna is an un-tuned system consisting of four ferrite core elements that form an X-loop, Y-loop, and two packaged preamplifiers mounted on a metal base.

(2) The assembly is filled with a polyurethane foam material, and is non-repairable.


AH-64A
APACHE
PILOTs CONTROLS AND INDICATORS
CENTER CIRCUIT BREAKER PANEL
HSI
PILOTs STATION
ADF
5
ADF CIRCUIT
BREAKER
RADIO MON
NAV
VOL
VOX
MIC
COURSE
HDG
CRS
COMMUNICATIONS SYSTEM
CONTROL PANEL
21-94-134
83-1331

NOTES

C. Interface components

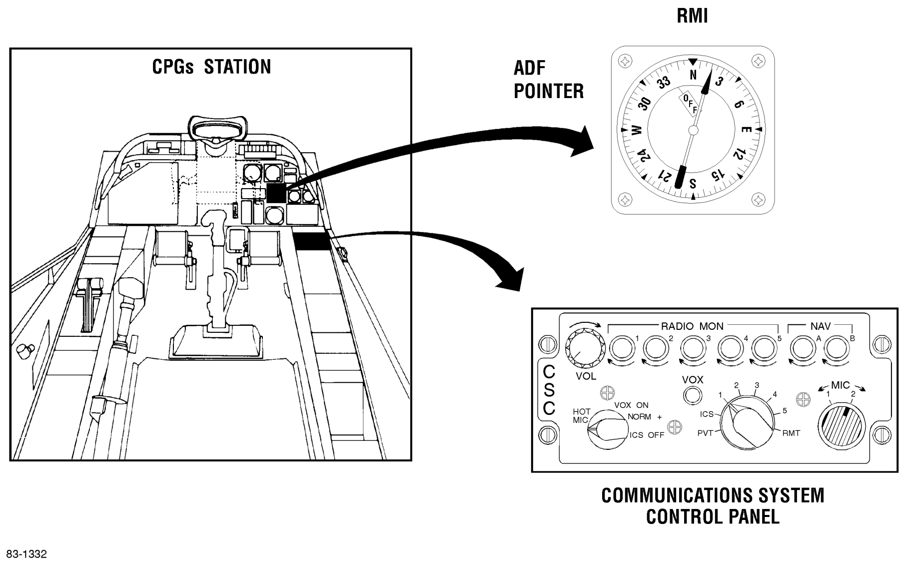
1. Pilot's controls and indicators

a. The ADF circuit breaker is 28 VDC, 5 amp thermal circuit breaker located on the pilot's overhead center circuit breaker panel.

b. Horizontal situation indicator (HSI) no. 2 needle indicates bearing to the station tuned into the ADF receiver.

c. Communication system control panel NAV A MON switch/rheostat controls ADF receive volume to the headset.

CPGs CONTROLS AND INDICATORS



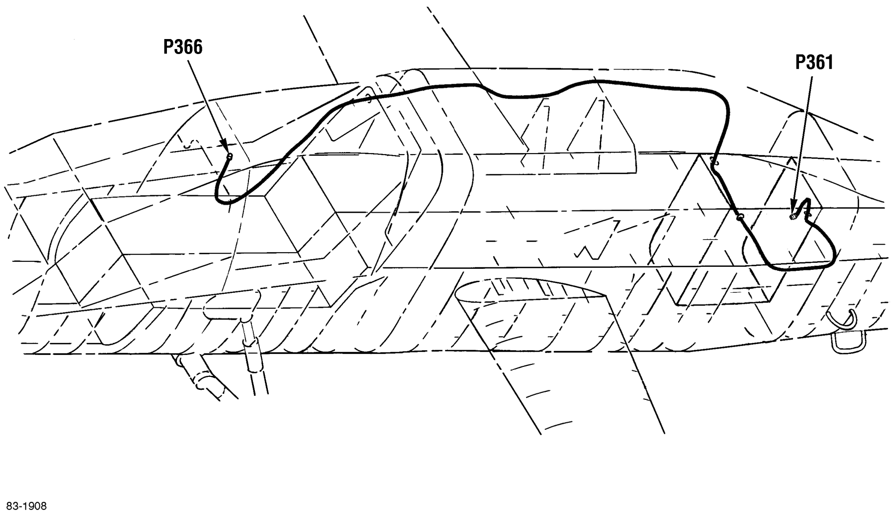
NOTES

2. CPG's controls and indicators

   a. Radio magnetic indicator (RMI) bearing pointer is driven by the ADF.

   b. CSC panel NAV A MON switch/rheostat controls ADF receive volume to the headset.

WIRE HARNESS W224

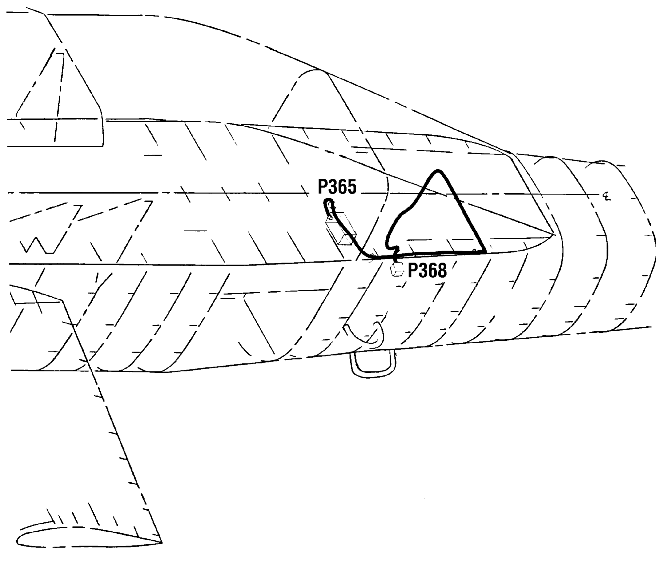


NOTES

3. Wire harnesses

   a. Wire harness W224 - a coaxial cable that carries the local oscillator frequency from the ADF receiver (P361) to the control panel (P366).

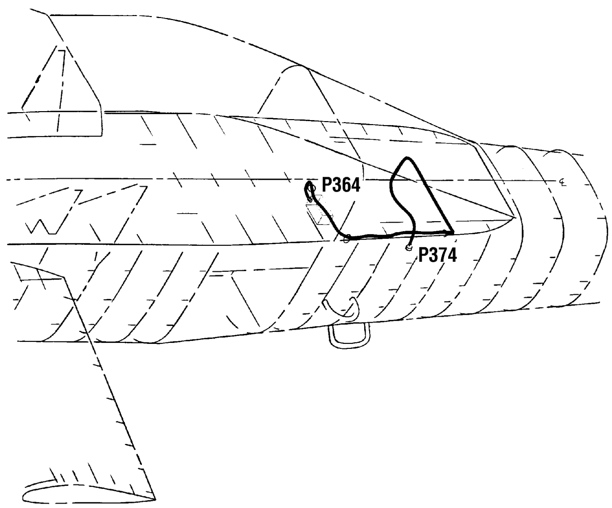
WIRE HARNESS W184



NOTES

b. Wire harness W184 - a coaxial cable between the ADF receiver (P365) and the sense preamplifier (P368).

WIRE HARNESS W182

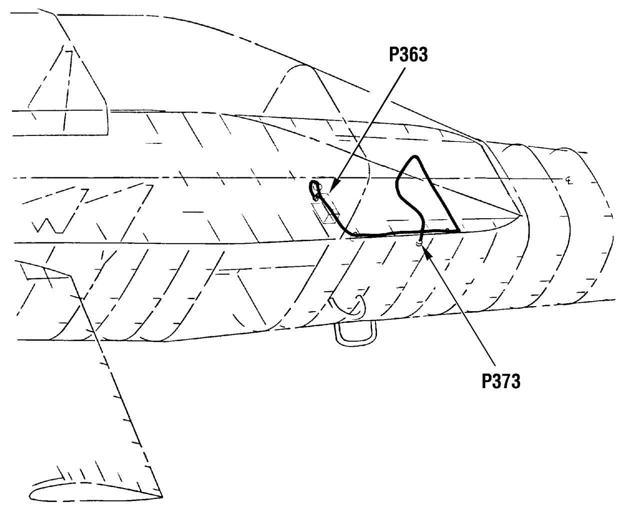


83-1907

NOTES

c. Wire harness W182 - a coaxial cable between the ADF receiver (P364) and the loop antenna Y axis (P374).

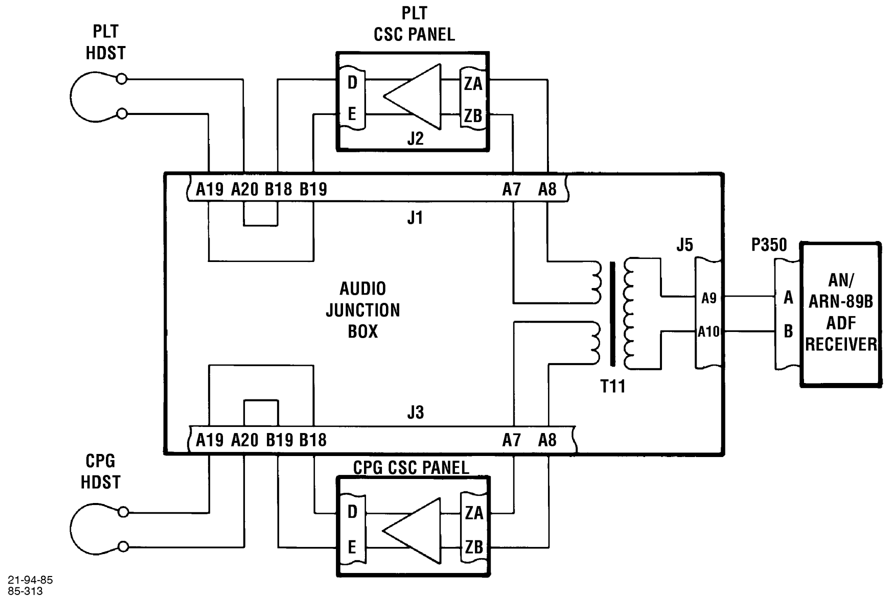
WIRE HARNESS W183



NOTES

d. Wire harness W183 - a coaxial cable between the ADF receiver (P363) and the loop antenna X axis (P373).

ADF AUDIO



NOTES

D. AN/ARN-89B automatic direction finder operation

1. ADF audio

a. The audio signal from the ADF receiver enters the AJB via pins A9 and A10 of J5.

b. The signal is applied to the primary of audio transformer T11.

c. One of the secondary windings supplies the audio signal to the pilot's CSC panel via J1 of the AJB and J2 of the CSC panel.

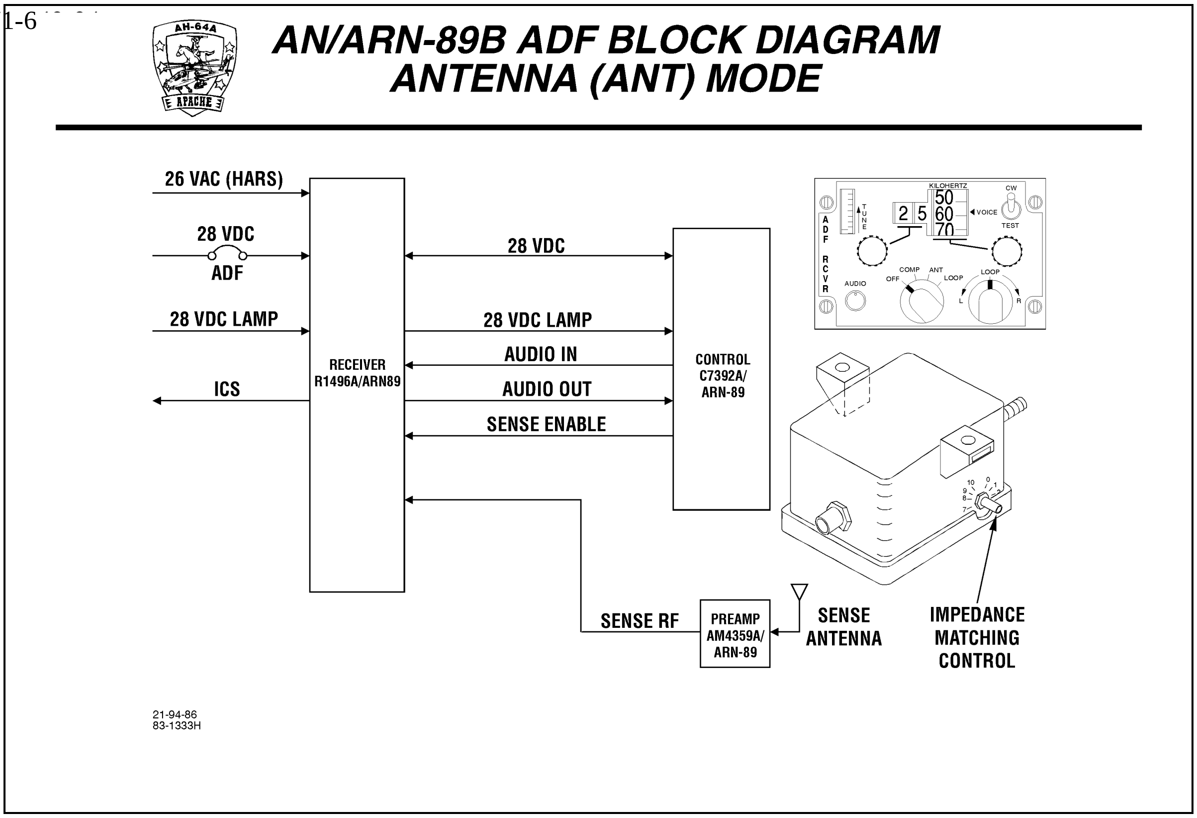
(1) The signal is amplified by the CSC panel and exits on pins D and E of J2.

(2) The signal reenters the AJB through pins B18 and B19 of J1 and is jumpered out to the pilot's headset via pins A19 and A20 of J1.

d. The other secondary winding supplies the audio signal to the CPG's CSC panel via J3 of the AJB and J2 of the CSC panel.

(1) The signal is amplified by the CSC panel and exits on pins D and E of J2.

(2) The signal reenters the AJB through pins B18 and B19 of J3 and is jumpered out to the CPG's headset via pins A19 and A20 of J3.


AH-64A
APACHE
AN/ARN-89B ADF BLOCK DIAGRAM
ANTENNA (ANT) MODE
26 VAC (HARS)
28 VDC
ADF
28 VDC LAMP
ICS
RECEIVER
R1496A/ARN89
28 VDC
28 VDC LAMP
AUDIO IN
AUDIO OUT
SENSE ENABLE
CONTROL
C7392A/
ARN-89
KILOHERTZ
CW
VOICE
TEST
2 5 60
TUNE
ADF RCVR
AUDIO
COMP
ANT
OFF
LOOP
LOOP
L
R
SENSE RF
PREAMP
AM4359A/
ARN-89
SENSE
ANTENNA
IMPEDANCE
MATCHING
CONTROL
21-94-86
83-1333H

NOTES

2. Power inputs (common to all modes)

    a. 28 VDC is applied to the ADF receiver from the DC emergency bus.

    b. 26 VAC synchro-reference voltage is supplied by the HARS.

    c. 28 VDC lamp voltage is supplied by the multichannel dimmer.

3. ANT (antenna) mode operation

    a. When mode select switch is placed in the ANT position, the sense antenna is enabled.

    b. The CW/VOICE/TEST switch must be placed in the CW or VOICE.

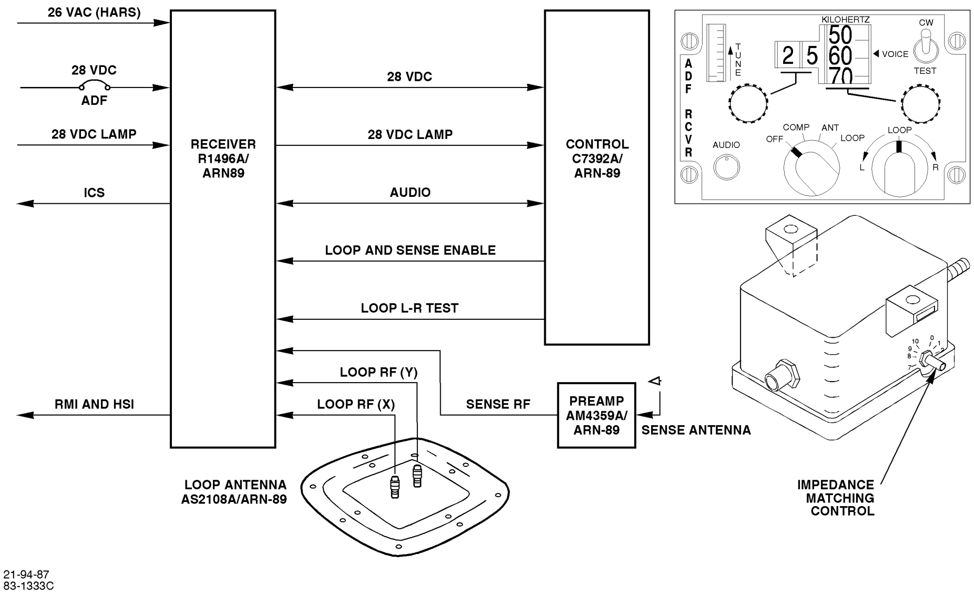
    c. The sense antenna receives the AM signal and applies it to the preamplifier.

    d. The preamplifier matches the high sense antenna impedance to the low ADF receiver impedance, amplifies the RF signal, and applies it to the ADF receiver.

    e. The ADF receiver processes the RF signal and applies the audio portion of the signal to the tune indicator on the control panel, allowing the operator to fine-tune to the transmitting station frequency.

    f. The audio signal is applied back to the receiver for amplification and routing to the ICS.

AN/ARN-89B ADF BLOCK DIAGRAM COMP AND LOOP MODES



NOTES

4. COMP and LOOP modes

a. Sense preamplifier impedance matching

(1) The sense preamplifier has an impedance matching control which is manually adjusted for equal RF signal strength in the LOOP and ANT modes.

(2) This procedure is mandatory if the sense preamplifier or the loop antenna is replaced.

(a) Tune the ADF to a known station in the LOOP mode by peaking the TUNE indicator on the ADF control panel utilizing the LOOP L/R switch.

(b) After a peak is attained, place the MODE SELECT in the ANT position and duplicate the LOOP peak by adjusting the impedance matching control on the sense preamplifier.

b. LOOP mode operation

(1) The LOOP mode is the manual direction finding mode of operation.

(2) The MODE SELECTOR switch is placed to LOOP, enabling both the sense antenna and the loop antenna.

(3) The rotor vane remains stationary until the LOOP/L/R switch is operated. As the LOOP L/R switch is activated, the rotor vane moves.

(4) The operator detects the nulls by listening to the ADF or by observing the TUNE indicator.

(a) The ADF system cannot distinguish between the bearing-to-station null and the false null when operating in the LOOP mode.

(b) The ambiguity must be resolved by the operator, by flight procedures, or the navigational aids.

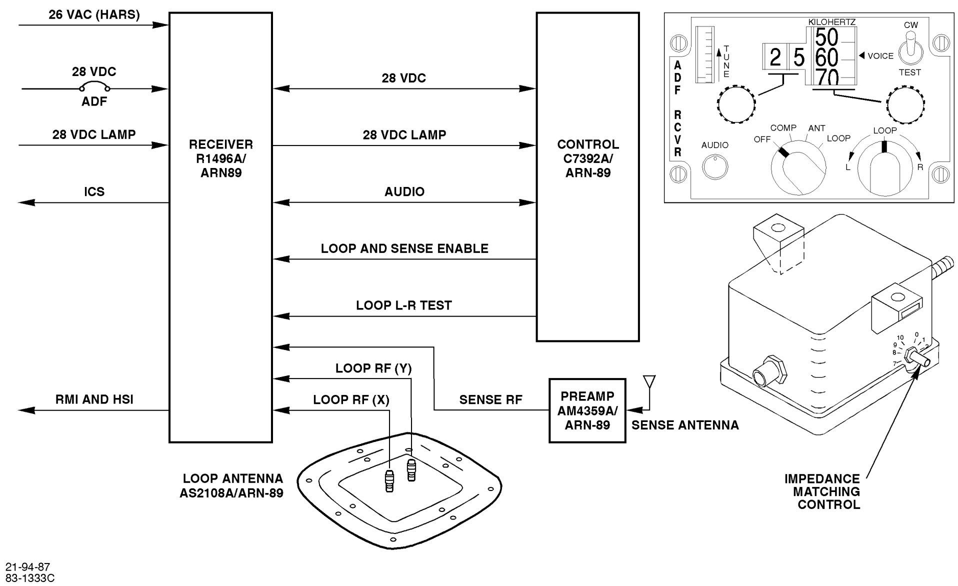
(5) The direction information is displayed on the HSI and RMI.

(6) The LOOP mode audio processing is identical to the ANT mode.

c. Compass (COMP) mode operation

(1) The COMP position of the mode selector switch enables both the sense and loop antennas.

AN/ARN-89B ADF BLOCK DIAGRAM COMP AND LOOP MODES



NOTES

(2) The CW/VOICE/TEST switch must be selected to CW or VOICE.

(3) The two loops in the loop antenna pick up the selected station's RF signal. The RF energy in each loop is amplified separately by pre-amps in the antenna assembly.

(4) The loop input signals are then applied to the ADF receiver.

(5) A loop difference signal is produced in the ADF receiver where it is combined with the sense antenna input.

(6) The combined signal is processed through the ADF receiver and sent to mechanically position the goniometer which mechanically positions the rotor vanes until the loop difference signal is nulled.

(a) The COMP mode is the automatic direction finding mode of operation.

(b) It combines the loop antenna inputs with the sense antenna input to produce automatic and continuous bearing-to-station indications as well as audio.

(7) With no loop difference, the signal is inhibited which prevents further movement of the rotor vane.

(8) The rotor vane is mechanically ganged to the rotor of a synchro transmitter.

(9) The 3-wire stator output of the synchro transmitter is the bearing-to-station signal that drives the HSI and RMI.

(10) Audio routing is the same as ANT mode.

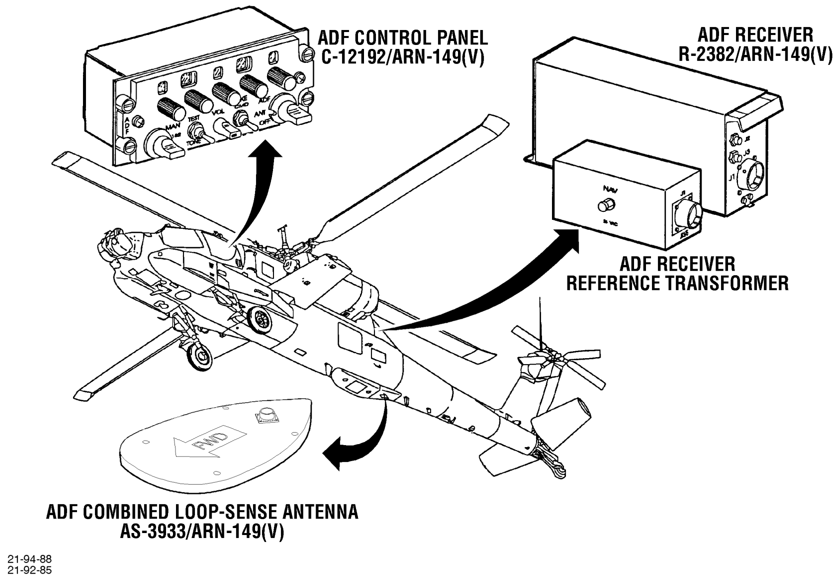
d. TEST position of the CW/VOICE/TEST switch is also used in the COMP mode.

(1) Tune to a known station.

(2) Hold the switch in the TEST position; the needle should rotate 180 degrees to the right to the false null position.

(3) When the test switch is released, the needle should return to the correct null.

AN/ARN-149(V) ADF COMPONENTS



NOTES

A. Purpose and major components of the AN/ARN-149 ADF system

1. AN/ARN-149 ADF system purpose

a. Provides radio reception and direction finding on AM and CW signals in a frequency range of 100 to 2199.5 KHZ, in the automatic direction finder (ADF) mode. May also be used as an auxiliary AM or CW communication receiver (ANT mode) in the same frequency range.

b. The automatic direction finder (ADF) system provides bearing-to-station information to the pilot's HSI and the CPG's RMI.

2. AN/ARN-149 ADF system major components

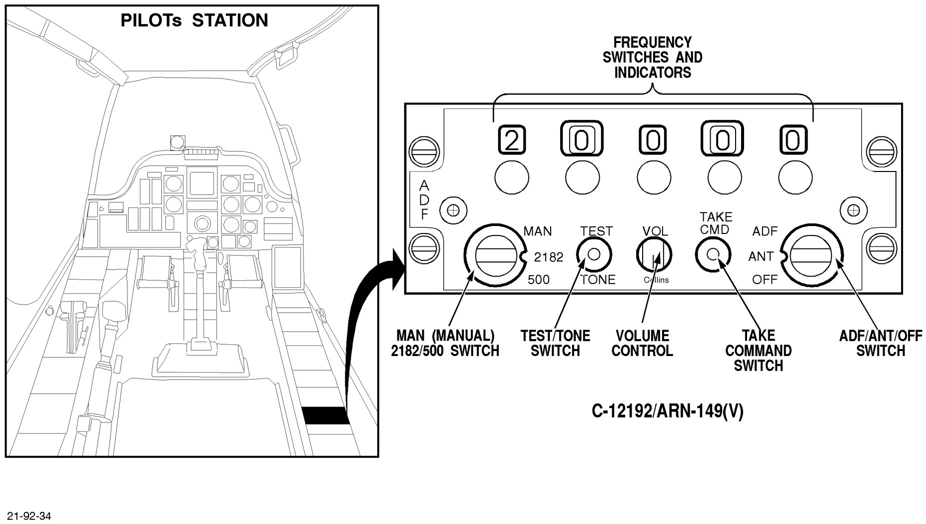
a. C-12192/ARN-149(V) control panel

b. R-2382/ARN-149(V) receiver

c. Reference transformer

d. AS-3933/ARN-149(V)antenna

AN/ARN-149(V)
ADF CONTROL PANEL



NOTES

B. ARN-149 navigation system component purpose, location, description, and operation

1. ADF control panel C-12192/ARN-149 (V)

a. Provides complete control of ADF System.

b. Mounted in the pilot's right console.

c. Front panel controls and indicators

(1) Tune indicator windows

(2) Tuning controls

(3) Tone/test switch

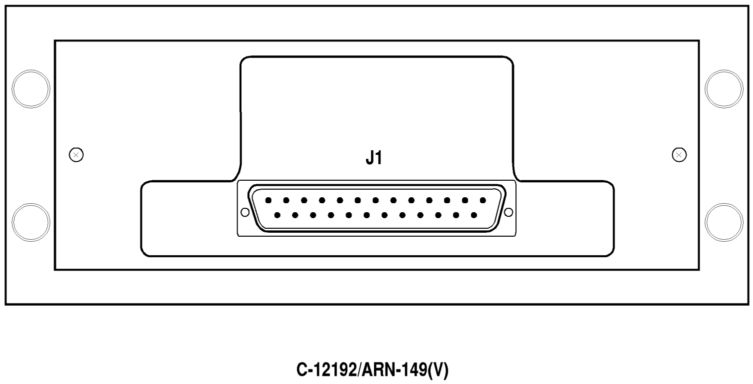
(4) Volume control

(5) Mode selector (OFF/ANT/ADF)

(6) MAN-2182-500 control

(7) Take command switch (not used)

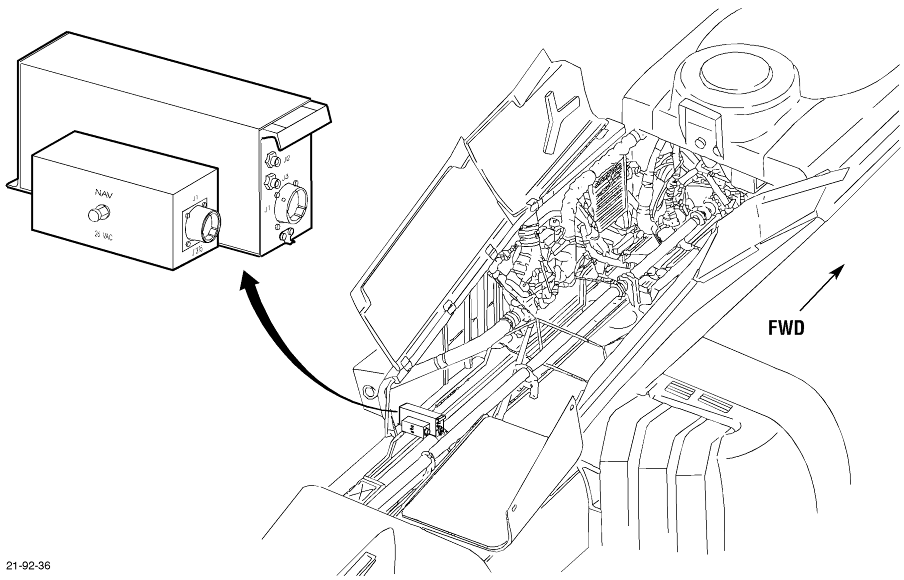
AN/ARN-149(V)
ADF CONTROL REAR PANEL



NOTES

d. The rear panel consist of a single "D" type 25 pin connector which provides all input and output signals, control, data, and power requirements.

AN/ARN-149(V)
ADF RECEIVER AND TRANSFORMER



NOTES

2. ADF receiver (R-2382/ARN-149) and reference transformer

   a. Processes loop/sense antenna inputs.

   b. Provides bearing-to-station information and audio outputs.

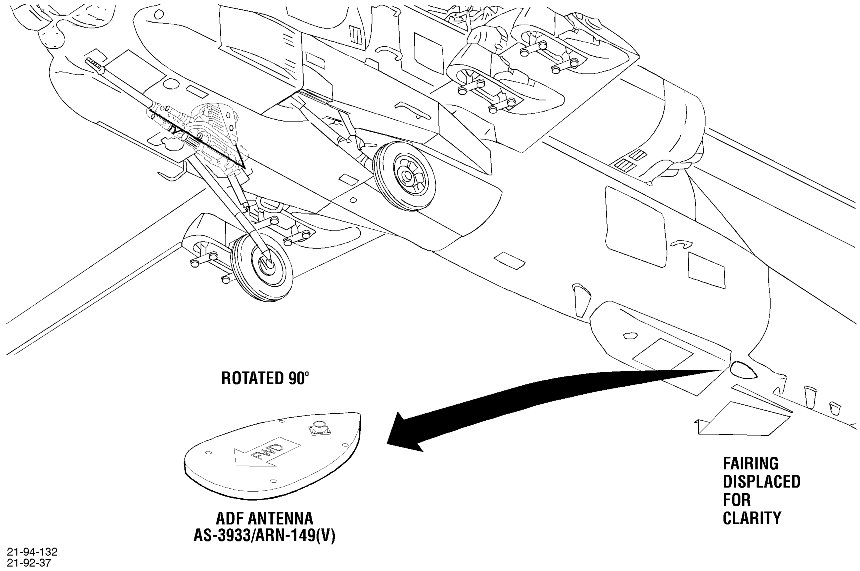
   c. The receiver is mounted on the left aft equipment bay accessed through door L325.

      (1) J1 provides all signal and power connections to the receiver.

      (2) J2 and J3 are not used on the AH-64A and may not be present on some receivers.

   d. The reference power transformer mounted on the same platform as the receiver converts 115 VAC, 400 Hz, "B" phase power to a 26 VAC reference signal for use by the receiver as output reference to the HSI and RMI for bearing information.

AN/ARN - 149(V)
ADF LOOP/SENSE ANTENNA



NOTES

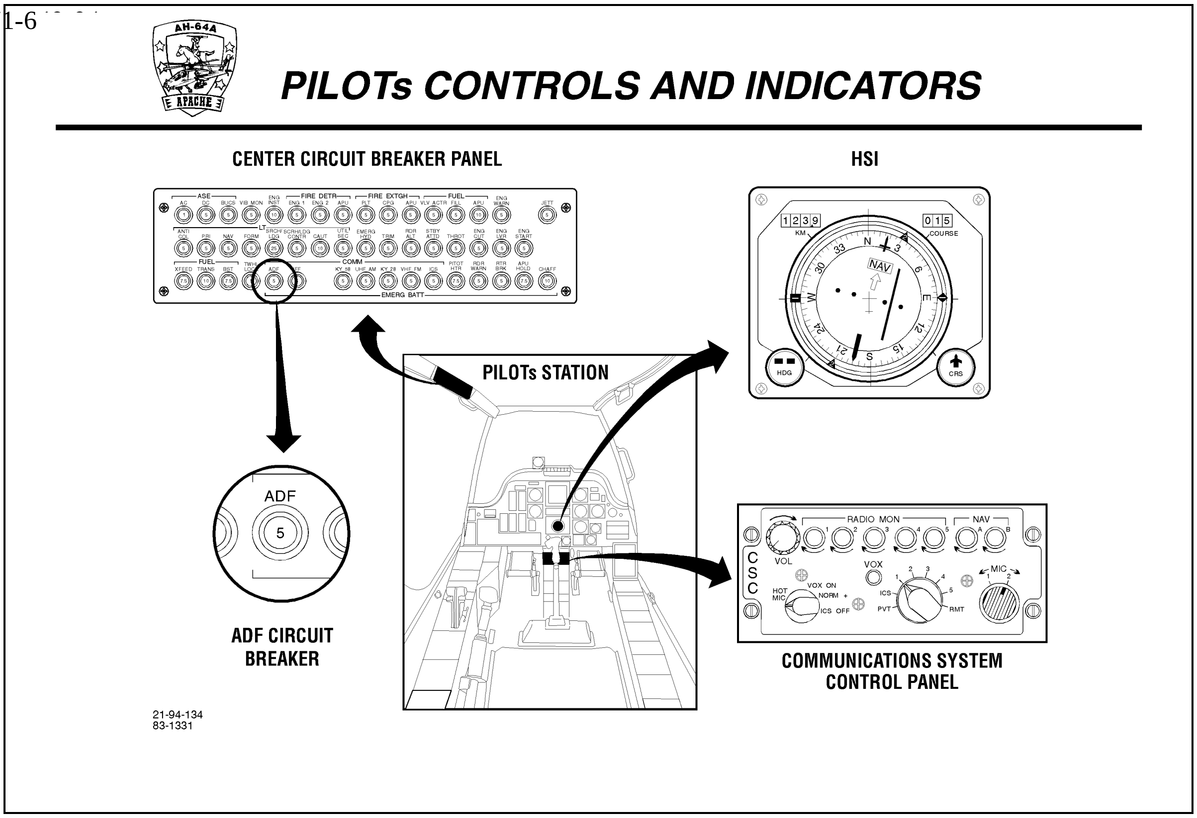
3. AN/ARN-149(V) ADF Loop/Sense Antenna

a. The ADF loop/sense antenna provides directional information to the ADF receiver.

b. The antenna is mounted in the doppler fairing on the bottom of the fuselage.

c. The loop/sense antenna is a combination unit which contains the loop antenna, a SENSE antenna, and electronics for signal processing. It is used to derive directional information from AM or CW radio transmissions.

d. The radio frequency (RF) signals received are modulated with reference signals, one is SINE reference and the other is a COSINE reference. The resulting signals are then phase shifted 90 degrees and amplified. The loop signal thus generated is summed with the sense antenna signal and sent to the receiver.


AH-64A
APACHE
PILOTs CONTROLS AND INDICATORS
CENTER CIRCUIT BREAKER PANEL
HSI
PILOTs STATION
ADF
5
ADF CIRCUIT BREAKER
COMMUNICATIONS SYSTEM CONTROL PANEL
21-94-134
83-1331

NOTES

C. Interface components

1. External controls, indicators, and harnesses

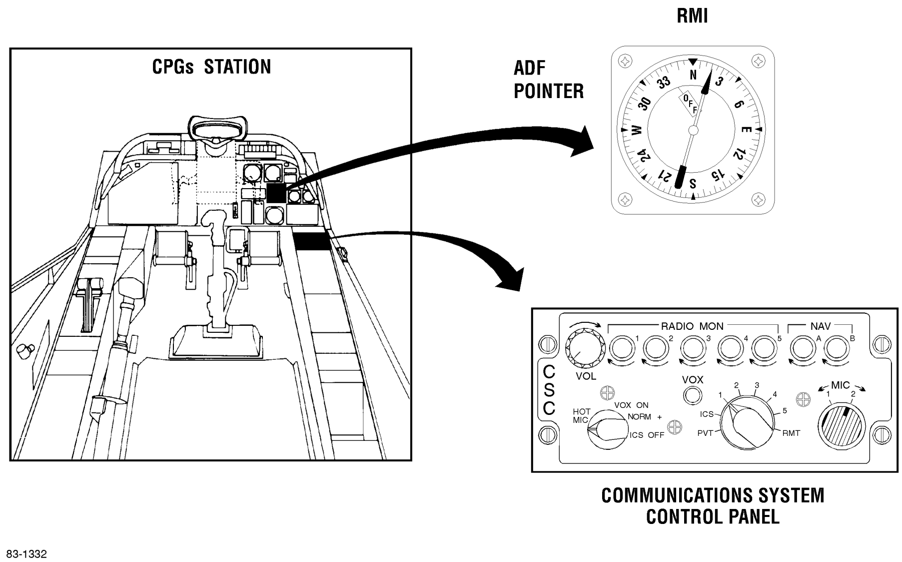
a. Pilot's station

(1) HSI bearing pointer 2

(2) CSC panel NAV A monitor

(3) Center circuit breaker panel ADF 28 VDC, 5 amp circuit breaker

CPGs CONTROLS AND INDICATORS



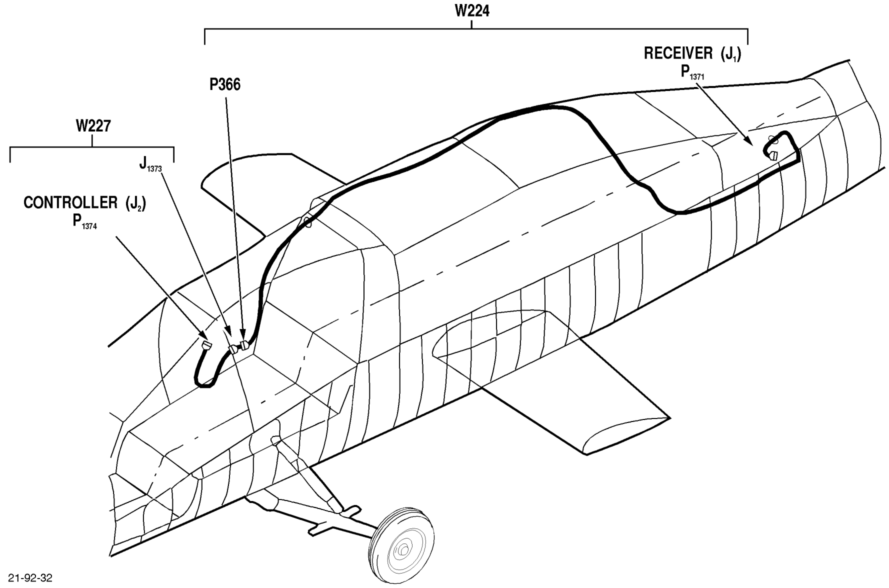
NOTES

b. CPG's station

(1) RMI bearing pointer

(2) CSC panel NAV A monitor

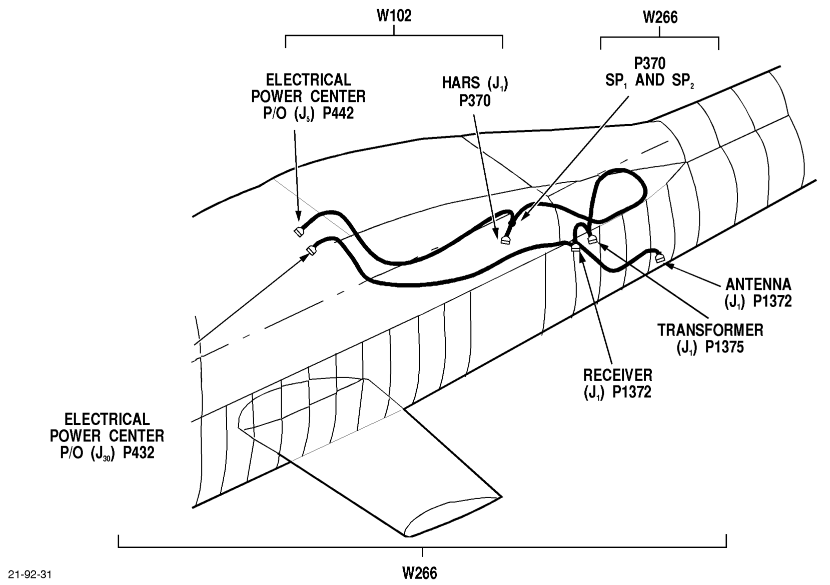
AN/ARN-149(V) WIRE HARNESS W224/W227 (ADAPTER)



NOTES

c. Wire harness W224 and W227 (adapter) - a cable that carries signals and voltage between the control panel (P1374) and the ADF receiver (P1371).

AN/ARN-149(V) WIRE HARNESS W102 AND P/O W266 (AFT)



NOTES

d. ADF wire harnesses W102 and P/O W266 (aft) - harness W102 carries 115 VAC, 400 Hz, B Ø power from the electrical power center (P442) to the HARS unit J1 (P370).

e. Harness W266 (AFT)

(1) Carries 115 VAC, 400 Hz power from the HARS unit J1 (splice P370 SP1 and SP2), to the reference transformer J1 (P1375).

(2) Carries the received RF signals and controls between the antenna J1 (P1372) and the receiver J1 (P1371).

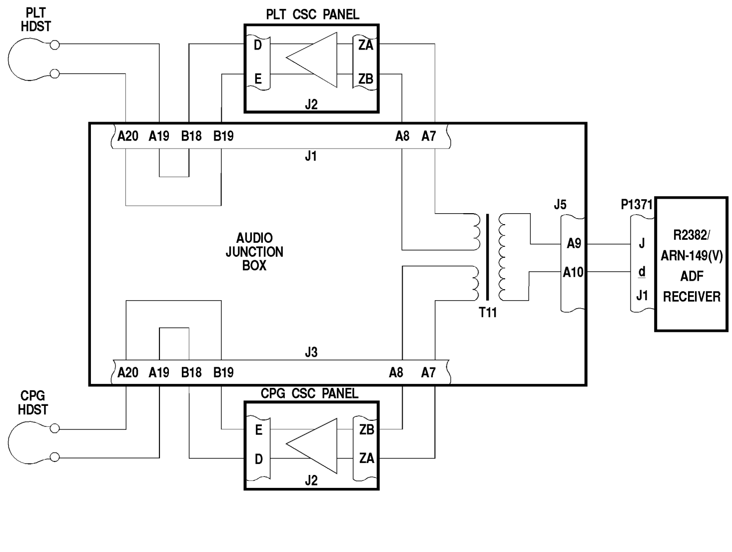
(3) Carries synchro outputs x, y, and z from the receiver J1 (P1371) to the navigation instruments via the electrical power center J30 (P432).

(4) Links the output of the transformer from J1 (P1375) to the receiver J1 (P1371).

(5) Connects the receiver J1 to feed through connector P909/J909 where the 28 VDC power is picked up from harness W119 of the pilot's center C/B panel (ADF 28 VDC 5 amp).

(6) Connects audio signals between ADF receiver J1 and audio junction box J5.

AN/ARN-149(V) ADF AUDIO



NOTES

D. AN/ARN-149 (V) ADF system audio signal flow

1. The audio signal from the ADF receiver J1 (P1371) enters the AJB via pins A9 and A10 of J5.

2. The signal is applied to the primary of audio transformer T11.

3. One of the secondary windings supplies the audio signal to the pilot's CSC panel via J1 of the AJB and J2 of the CSC panel.

    a. The signal is amplified by the CSC panel and exits on pins D and E of J2.

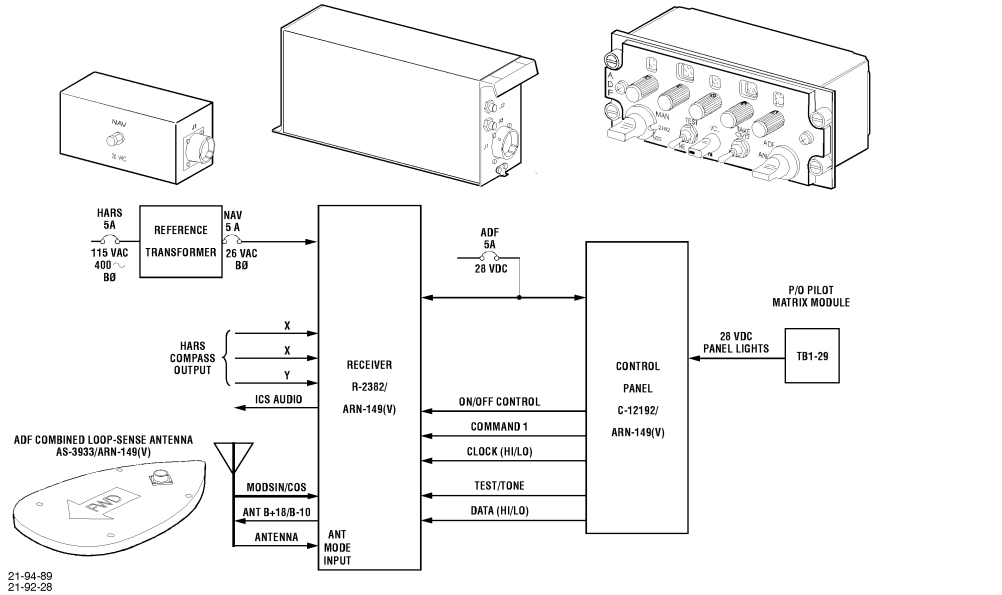
    b. The signal reenters the AJB through pins B18 and B19 of J1 and is jumpered out to the pilot's headset via pins A19 and A20 of J1.

4. The other secondary winding supplies the audio signal to the CPG's CSC panel via J3 of the AJB and J2 of the CSC panel.

    a. The signal is amplified by the CSC panel and exits on pins D and E of J2.

    b. The signal reenters the AJB through pins B18 and B19 of J3 and is jumpered out to the CPG's headset via pins A19 and A20 of J3.

AN/ARN-149(V) ADF BLOCK DIAGRAM
ANTENNA (ANT) MODE



NOTES

E. AN/ARN-149 (V) ADF system operation

1. Power inputs

a. 28 VDC is applied to the ADF receiver from the DC emergency bus.

b. 26 VAC synchro-reference voltage is supplied by the reference transformer.

c. 28 VDC lamp voltage is supplied to the control panel by the multichannel dimmer.

2. Antenna (ANT) mode operation

a. When mode select switch is placed in the ANT position only the aural functions are enabled.

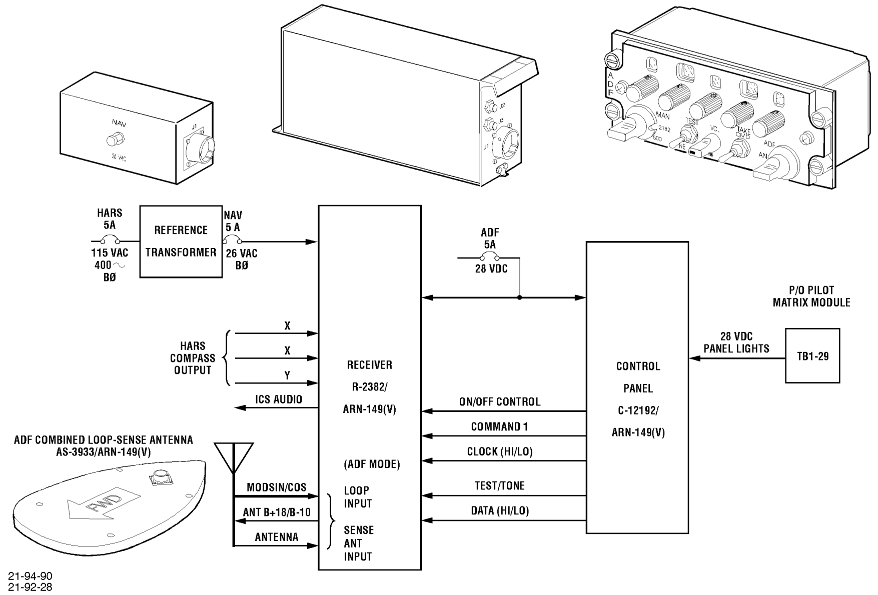
b. When the "TEST/TONE" switch is placed in the "TONE" position a 1000 Hz tone is heard in both headsets.

c. The built-in sense antenna receives AM broadcast-band RF signals and transmits them to the receiver.

d. The ADF receiver processes the RF signal and applies the audio portion of the signal to the communication system control panel, audio monitor volume control, allowing the operator to control the audio output level to the headsets.

e. The audio signal is applied back to the receiver for amplification and routing to the ICS.

AN/ARN-149(V) ADF BLOCK DIAGRAM (ADF) MODE



NOTES

3. ADF mode operation

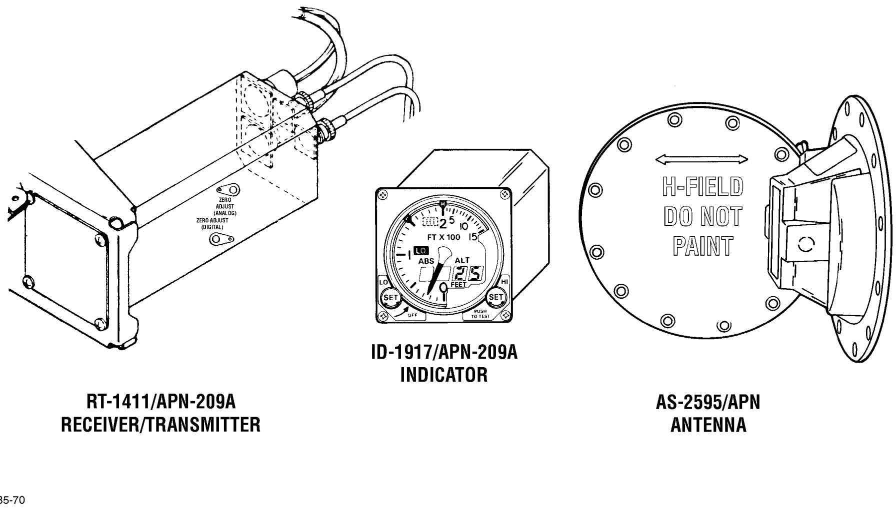
a. When "ADF" is selected on the ADF controller the aural and automatic direction finding functions are enabled, regardless of the position of the man/2182 500 switch.

b. Detected audio from the audio detector passes through a synchronous filter to remove unwanted signals (i.e. noise, etc.). The remaining signal contains phase shift data which reflects angular direction of the transmitter relative to aircraft heading.

c. The signal phase detector determines differences between the sine and cosine references and the received signals. The result is converted to a 400 Hz driver signal for the HSI and RMI bearing indications.

d. If the signal strength drops below a given threshold the flag circuit inhibits digital bearing outputs to the navigation instruments.

AN/APN-209A MAJOR COMPONENTS



NOTES

A. Purpose, features, and major components of the AN/APN-209A radar altimeter

1. The AN/APN-209A radar altimeter provides the pilot with visual indications of aircraft altitude above the ground [absolute altitude above ground level (AGL)] on analog and digital altitude displays.

2. Features

   a. The AN/APN-209A radar altimeter set measures and displays the height of the aircraft above the ground or nearest terrain obstacle, from zero to 1500 feet.

   b. The system operates at any airspeed within the capability of Army aircraft and at pitch and roll attitudes up to 45 degrees.

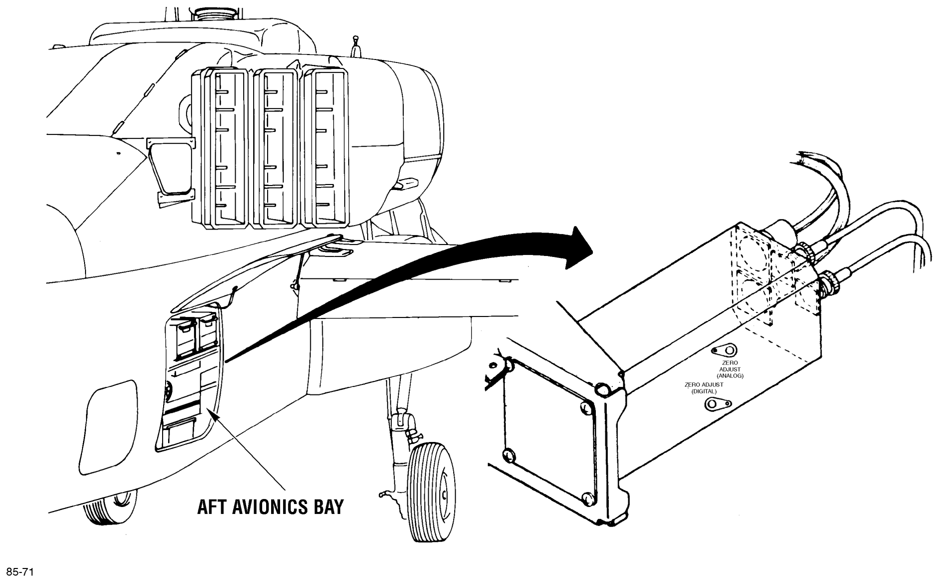
3. Major components

   a. RT-1411/APN 209 receiver/transmitter

   b. ID-1917/APN 209 indicator

   c. 2 each AS-2595/APN antennas (one for transmit, one for receive)

RT-1411/APN-209A RECEIVER/TRANSMITTER



NOTES

B. Component purpose, location, description and operation

1. RT-1411/APN-209A receiver/transmitter

a. The receiver/transmitter transmits, receives, and processes radar signals to provide analog and digital output signals of the helicopter's absolute height above the terrain to the system's indicator and to the multiplex system.

b. The receiver/transmitter is mounted in the aft avionics bay.

c. Receiver/transmitter connectors and adjustments

(1) J1 - signal and power connector

(2) J2 - signal and power connector

(3) J3 - receive coaxial connector

(4) J4 - transmit coaxial connector

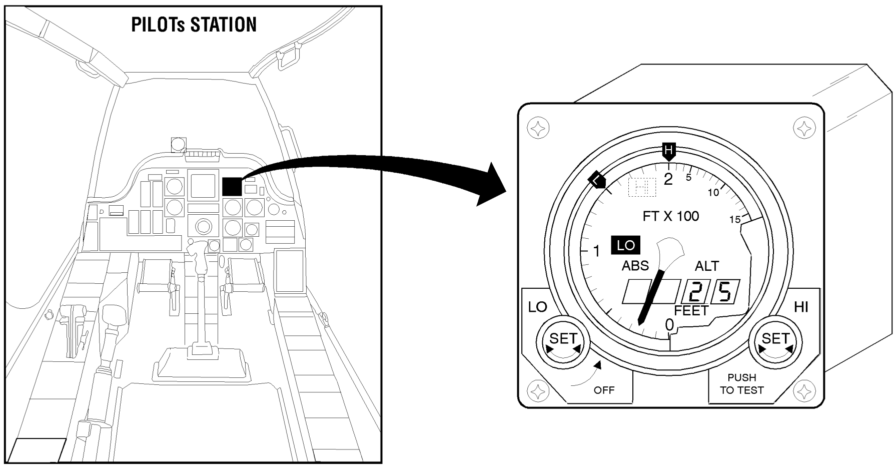
(5) Receiver/transmitter adjustments

(a) Analog zero adjust - adjusted to 0 "3 feet

(b) Digital zero adjust - adjusted to 0 "3 feet

(c) These adjustments, analog and digital zero adjust, must be made whenever the RT-1411 is replaced.

ID-1917 / APN-209A HEIGHT INDICATOR



85-73

NOTES

2. ID-1917/APN-209A indicator

   a. The indicator is a remote indicator providing the pilot with analog and digital displays of the helicopter altitude.

   b. The height indicator is mounted on the pilot instrument panel.

   c. Indicator controls

      (1) LO set knob - sets position of LO index and provides ON-OFF function.

      (2) LO set index - sets trip point for LO warning lamp.

      (3) HI set knob - sets position of HI index and initiates self-test function.

      (4) HI set index - sets trip point for HI warning lamp.

      (5) Dial pointer - provides analog indications of altitude (0 to 200 ft, 10 foot increments; and 200 to 1500 feet, 100 foot increments).

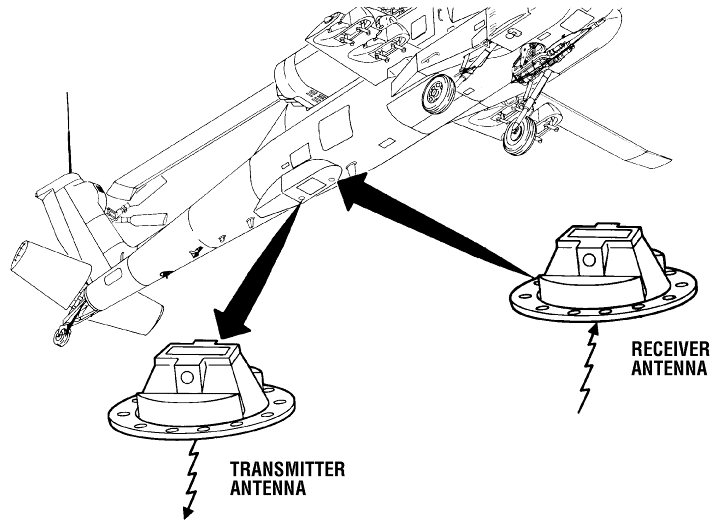
      (6) Digital readout - provides a direct-reading four digit indication of the absolute altitude from 0 to 1500 feet.

      (7) LO warning lamp - illuminates whenever the dial pointer goes below the setting of the LO Set Index.

      (8) HI warning lamp - illuminates whenever the dial pointer goes above the setting of the HI Set Index.

      (9) OFF flag - moves into view whenever unreliable operation (track) is detected, or loss of primary power is detected.

AS-2595/APN ANTENNAS



21-93-07

NOTES

3. AS-2595/APN antennas

a. Purpose

(1) The transmit antenna radiates RF pulses from the receiver/transmitter to the earth.

(2) The receiver antenna collects the reflected RF pulses and applies them to the receiver/transmitter for conversion to altitude display signals.

b. The AS-2595/APN radar altimeter receive and transmit antennas are mounted on the doppler fairing.

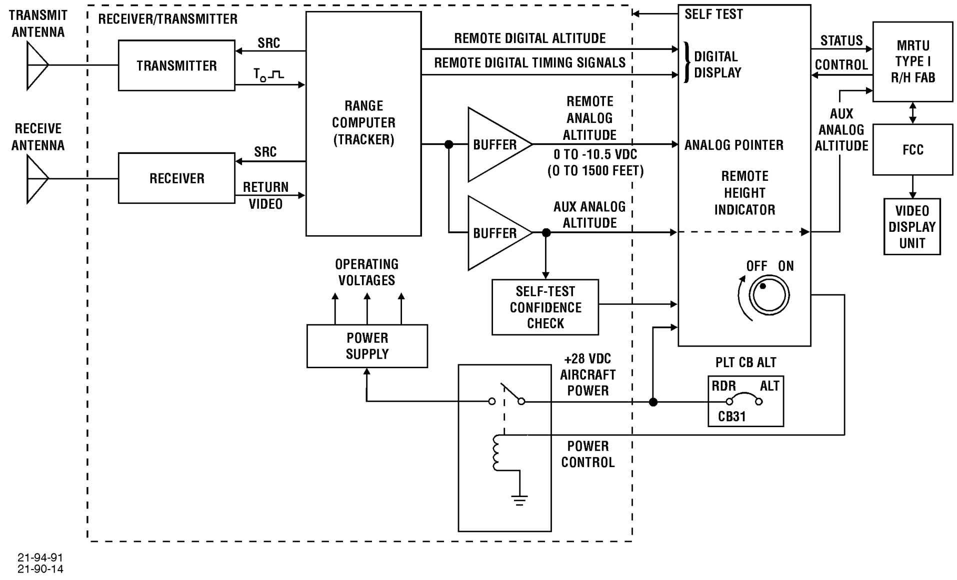
(1) The receive and transmit antennas are identical.

(a) The receive antenna is forward of the doppler fairing.

(b) The transmit antenna is aft of the doppler fairing.

(2) The antenna mounting has off-center holes for orientation during installation.

AN/APN - 209A SYSTEM OPERATION



NOTES

C. AN/APN-209A operation

1. Power to operate the AN/APN-209A is supplied from the DC emergency bus via a 5 amp circuit breaker on the pilot's center circuit breaker panel.

2. RT-1411/APN-209A receiver/transmitter

a. The receiver/transmitter generates radar pulses which are radiated toward the earth through the transmit antenna.

b. These pulses reflect from the terrain to the receive antenna.

c. The receiver/transmitter computes the time from transmission to reception and translates this into auxiliary, digital, and pointer altitude signals.

3. Outputs

a. Remote indicator signals

(1) The digital and pointer signals are used to produce digital and analog altitude displays on the AN/APN 209 height indicator.

b. Auxiliary analog signal

(1) Is sent to the R/H FAB MRTU and to the FCC via the multiplex system as digital information.

(2) Altitude information is required by the fire control computer for ballistic/trajectory computation during weapons delivery.

(3) Altitude information from the auxiliary analog signal is also used to develop symbology to be displayed on the VDU.

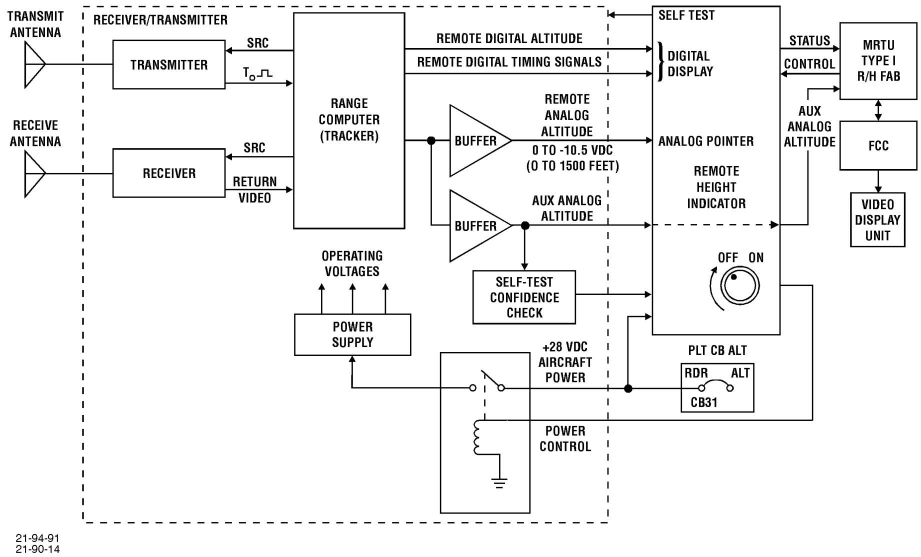
c. Reliability signal

(1) The receiver/transmitter produces a reliability signal which enables all system displays as long as altitude data is valid.

(2) Unreliable data causes the OFF flag to appear.

(3) If the HI or LO altitude limits are exceeded, the HI or LO warning lamp lights.

AN/APN - 290A SYSTEM OPERATION



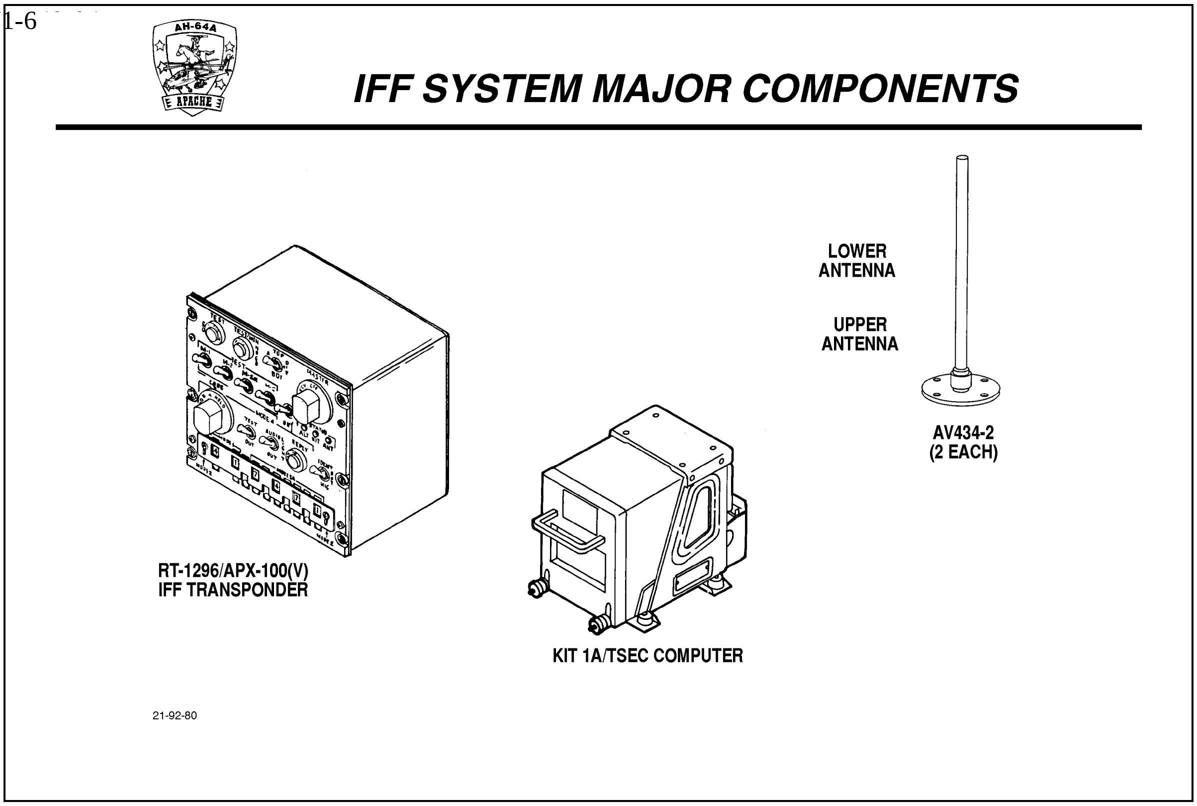
NOTES

d. Self-test

(1) When self-test is initiated, the pointer and digital display should indicate 1000 ft "100 feet.

(2) The OFF flag should not be present.

(3) The HI and LO warning lamps should be lit, depending upon the HI and LO index settings.


AH-64A
APACHE
IFF SYSTEM MAJOR COMPONENTS
LOWER ANTENNA
UPPER ANTENNA
AV434-2
(2 EACH)
RT-1296/APX-100(V)
IFF TRANSPONDER
KIT 1A/TSEC COMPUTER
21-92-80

NOTES

A. AH-64A AN/APX-100 transponder system purpose, features, description, and major components

1. The identification friend or foe (IFF) transponder system signal is issued by air traffic control (ATC) to distinguish between aircraft in the surrounding airspace. The system provides automatic identification when it is interrogated. It also provides emergency identification when selected by the pilot.

2. The IFF system has the ability to decode interrogations and to encode replies in six modes of operation.

   a. MODE 1

   b. MODE 2

   c. MODE 3A

   d. MODE 4

   e. TEST

   f. MODE C (helicopters incorporating MWO 1-1520-238-50-05 barometric altimeter and encoder installation only)

3. Major components

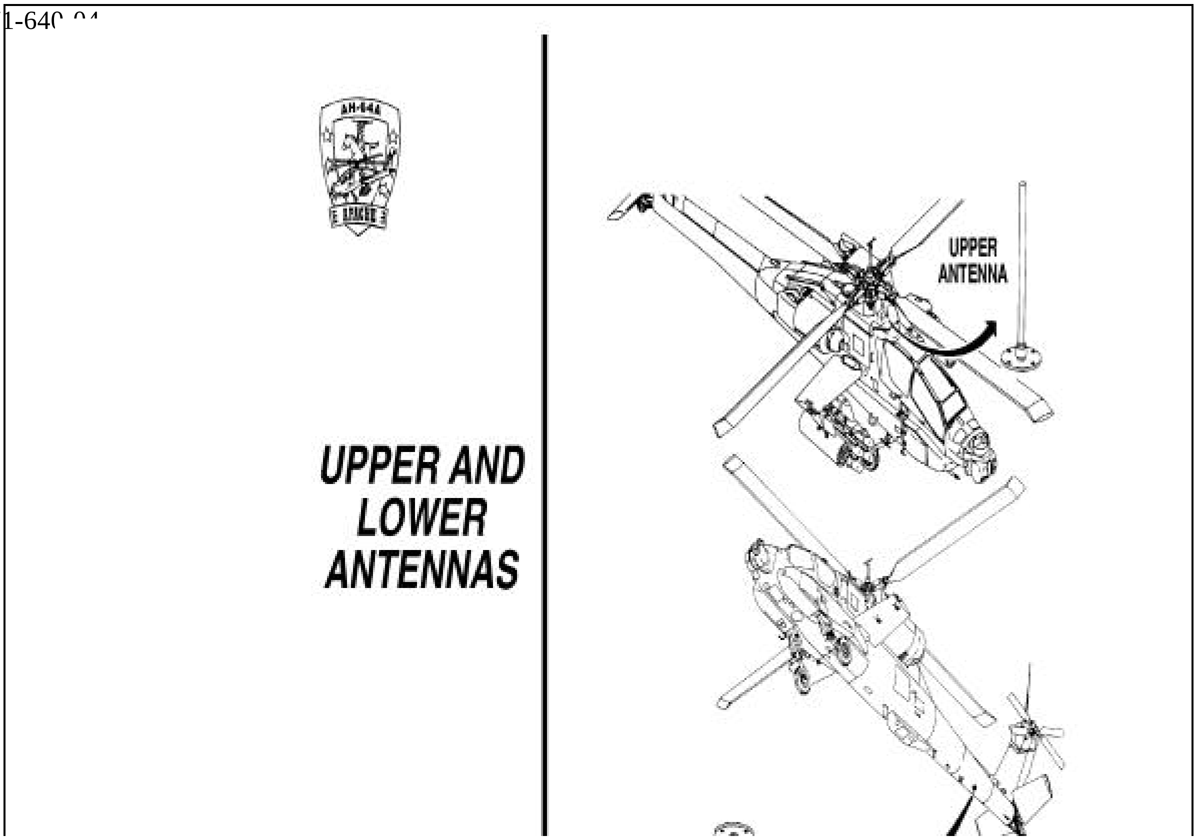
   a. Upper antenna

   b. Lower antenna

   c. KIT-1A/TSEC security computer (as mission requires)

   d. RT-1156/APX-100 IFF transponder

   e. Squat switch and squat relay (not shown)



NOTES

B. AN/APX-100 component purpose, location, description, and operation

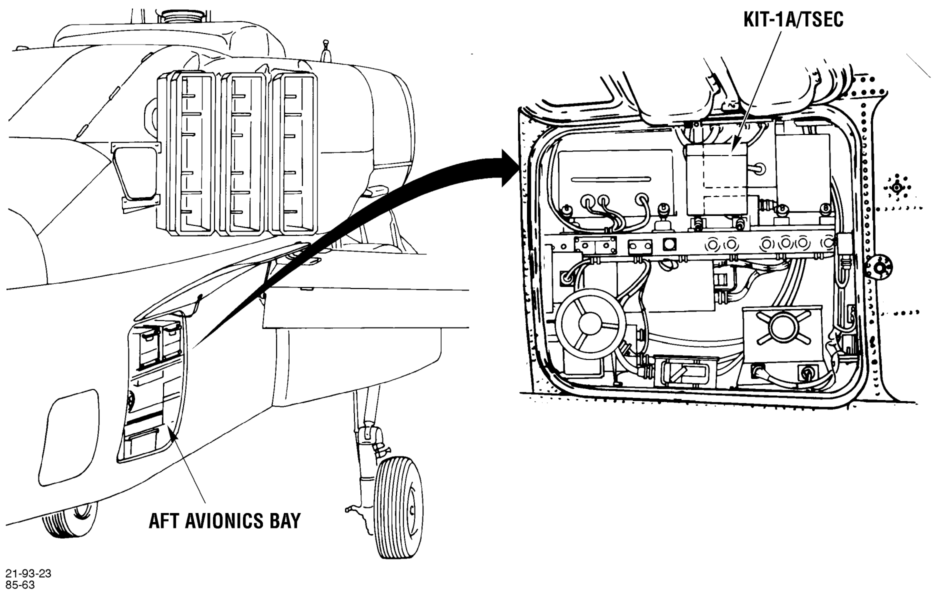
1. Upper and lower antennas

a. The upper and lower antennas receive the incoming interrogation signals and radiate the outgoing replies.

b. The upper antenna is located on top of the upper fuselage fairing section, aft of the canopy.

c. The lower antenna is on the bottom of the tailboom, behind the doppler fairing. It is the aft half of the blade antenna (the forward half is the UHF antenna).

SECURITY COMPUTER



NOTES

2. KIT-1A/TSEC security computer

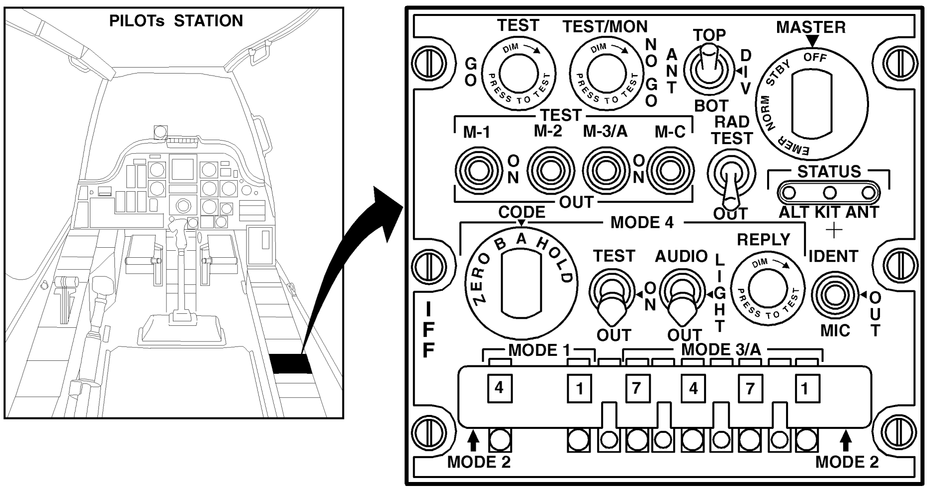
   a. The KIT-1A provides a secure MODE 4.

   b. It processes the MODE 4 challenge signals from the transponder and supplies a secure MODE 4 reply.

   c. Visual and audio warnings are provided to the crew when the transponder is interrogated but does not reply in MODE 4.

   d. The KIT-1A is located in the aft avionics bay on the upper shelf, in the center position.

RT-1296/APX-100(V) IFF TRANSPONDER



21-91-16

NOTES

3. RT-1296/APX-100 transponder

a. The RT-1296/APX-100 transponder provides for reception and decoding of interrogations and it also provides for encoding and transmission of replies. The controls required for operation are on the front panel.

b. The RT-1296/APX-100 transponder is located in the pilot's station on the right console.

c. The RT-1296/APX-100 is a lightweight one-piece unit that has the ability to be interrogated and to reply in 6 MODES.

(a) MODE 1 - aircraft control number. Total of 32 different codes.

(b) MODE 2 - military identification. Total of 4096 different codes.

(c) MODE 3A - special, variable. Total of 4096 different codes.

(d) MODE 4 - secure

(e) TEST - internally generated

(f) MODE C - altitude (helicopters incorporating MWO 1-1520-238-50-05 barometric altimeter and encoder installation)

d. The unit uses space diversity to insure strong reliable transmission and reception.

e. It also has a built-in-test (BIT) feature.

f. Front panel controls and indicators

(1) TEST GO lamp - indicates a successful self-test.

(2) TEST/MON NO GO lamp - indicates a unit malfunction.

(3) ANT/TOP/DIV/BOT toggle switch - selects top or bottom antenna separately or in the centered position selects space diversity.

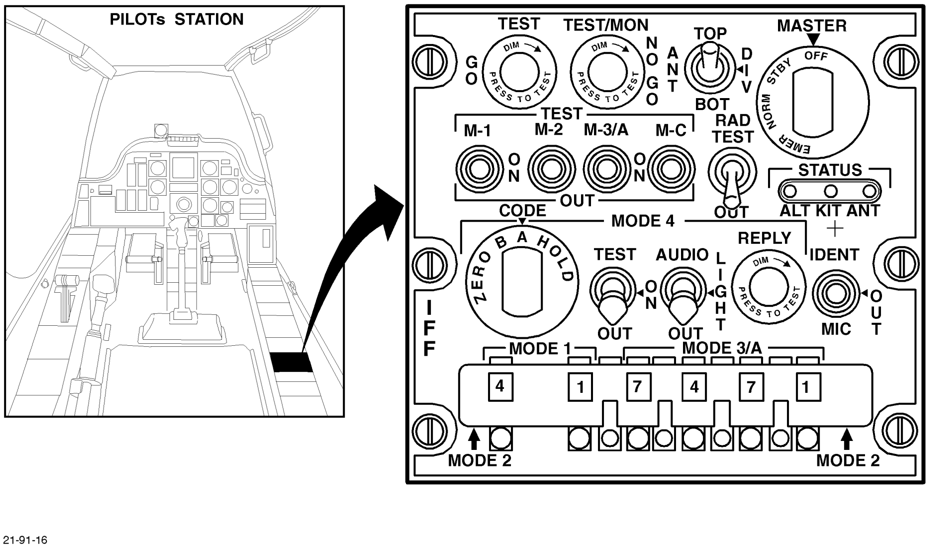
(4) MASTER switch - selects the mode of operation.

(a) OFF - power removed from the transponder.

(b) STBY - used to warm up the system (2 - 3 minutes).

(c) NORM - regular operation, after standby.

RT-1296/APX-100(V) IFF TRANSPONDER



NOTES

(d) EMER - transmits the emergency pulse train for all MODES, even if the MODE is off.

(5) MODE switches M-1, M-2, and M-3/4 are 3-position toggle switches.

(a) Center position - MODE is ON.

(b) Down position - MODE is off.

(c) Up position - MODE is being tested by BIT.

(6) RAD/TEST/OUT switch - enables BIT self-test mode.

(7) STATUS lamps

(a) ALT - indicates a failure of the altitude digitizer (helicopters incorporating MWO 1-1520-238-50-05 barometric altimeter and encoder installation only).

(b) KIT - indicates a failure of the KIT-1A.

(c) ANT - indicates failure due to a high voltage standing wave ratio (VSWR) in one of the antennas.

(8) MODE 4 CODE HOLD/A/B/ZERO switch

(a) CODE A - code of the day for current 24-hour zulu day.

(b) CODE B - code of the day for next 24-hour zulu day.

(c) ZERO - manual clearing of both codes of the day.

(d) HOLD - used to retain the codes of the day when the aircraft lands, by bypassing the squat switch.

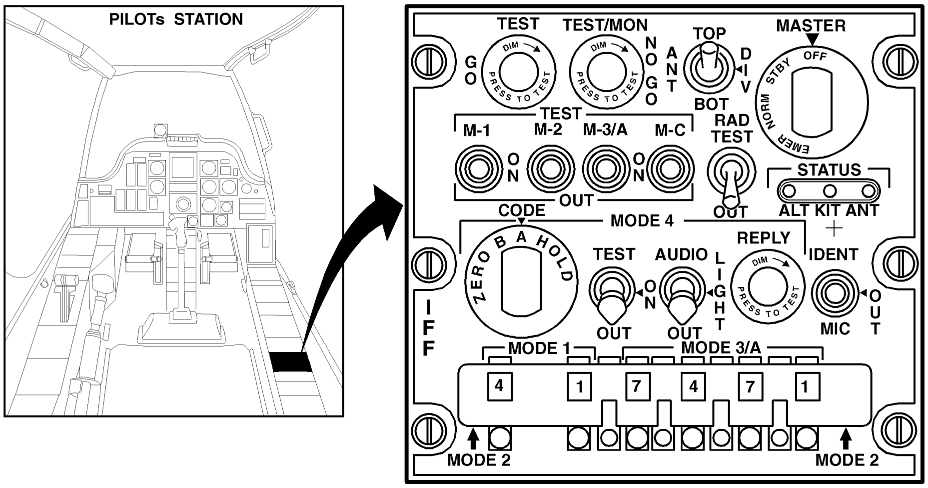
(9) MODE 4 AUDIO/LIGHT/OUT switch - controls the method by which MODE 4 is monitored (alarm system).

(a) OUT position - the alarm generated is a caution light on the pilot's and CPG's caution/warning/advisory panel.

(b) Light position - in addition to the warning lights in the crew stations, the TEST/MON NO GO lamp lights when no MODE 4 is present.

(c) AUDIO position - the warning lights in the crew stations light and there is an audio warning in the crew helmets. The TEST/MON NO GO lamp does not light. The audio is via the NAV A monitor on the CSC panel.

RT-1296/APX-100(V) IFF TRANSPONDER



21-91-16

NOTES

(10) MODE 4 TEST/ON/OUT switch - turns MODE 4 on or off, and also activates BIT for MODE 4.

(11) REPLY lamp - indicates a MODE 4 reply has been generated.

(12) IDENT/OUT/MIC switch - controls the transmission of the I/P pulse.

(a) The center position is off.

(b) When IDENT is selected, it causes the blip to blossom on the scope.

(c) MIC position squawks "ident" each time the radio PTT switch is pressed.

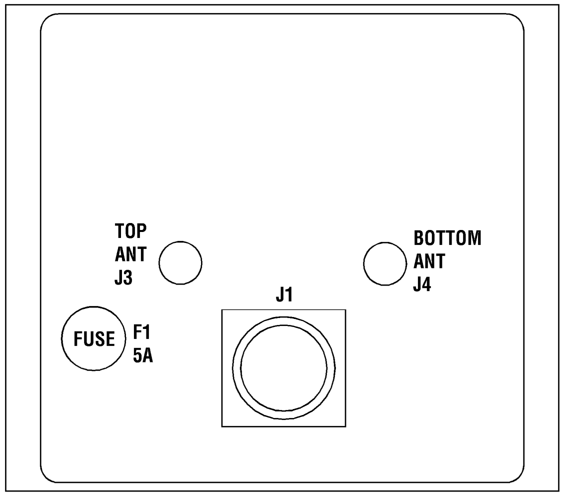
(13) CODE SELECT for MODES 1, 2 and 3A (for transmitting).

(a) MODE 1 - two pushbutton switches used to select codes.

(b) MODE 2 - four pushbutton switches used to select codes. Must loosen two screws and slide the plate upwards to see the numbers.

(c) MODE 3A - four pushbutton switches used to select codes. Plate must be in the lower position to see the numbers.

TRANSPONDER REAR PANEL



85-66

NOTES

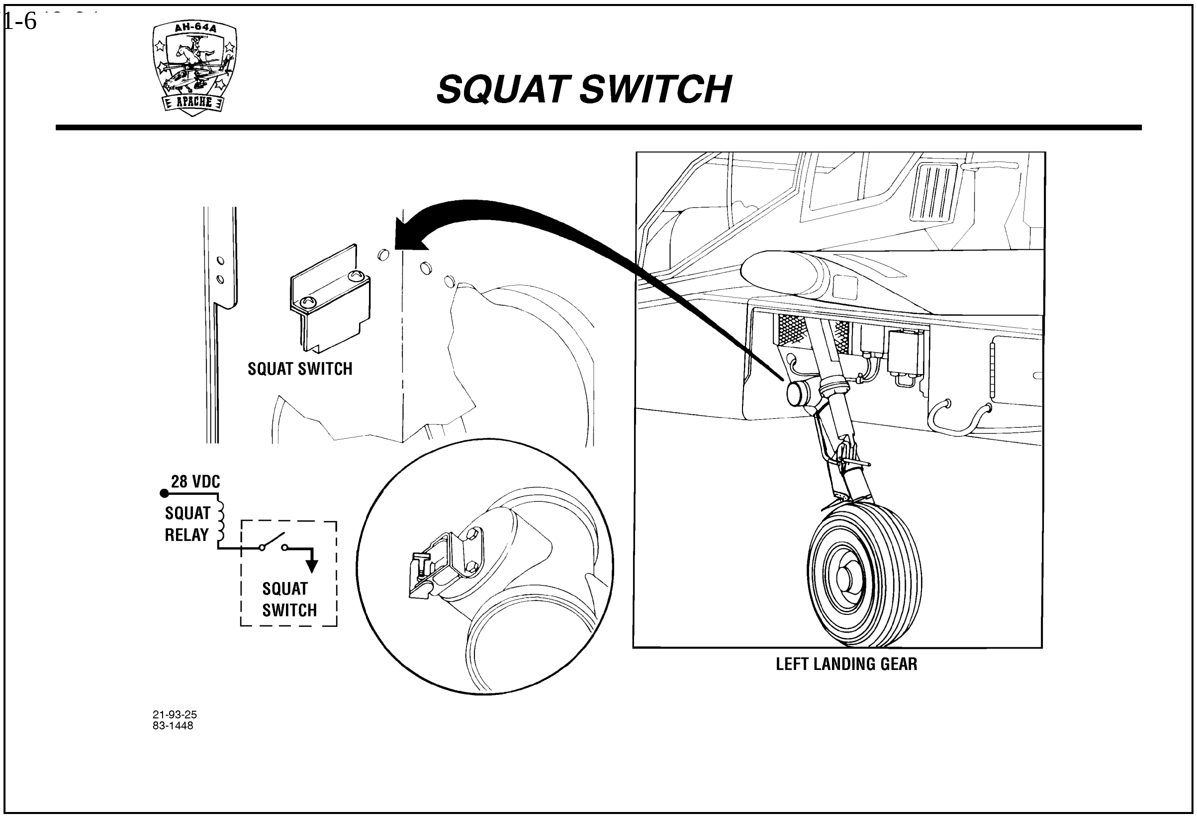
g. Transponder rear panel

(1) J1 - 66-pin power and signal connector

(2) J3 - Top antenna connection

(3) J4 - Bottom antenna connection

(4) F1 - 5-amp fuse


AH-64A
APACHE
SQUAT SWITCH
SQUAT SWITCH
28 VDC
SQUAT
RELAY
SQUAT
SWITCH
LEFT LANDING GEAR
21-93-25
83-1448

NOTES

C. Interface components

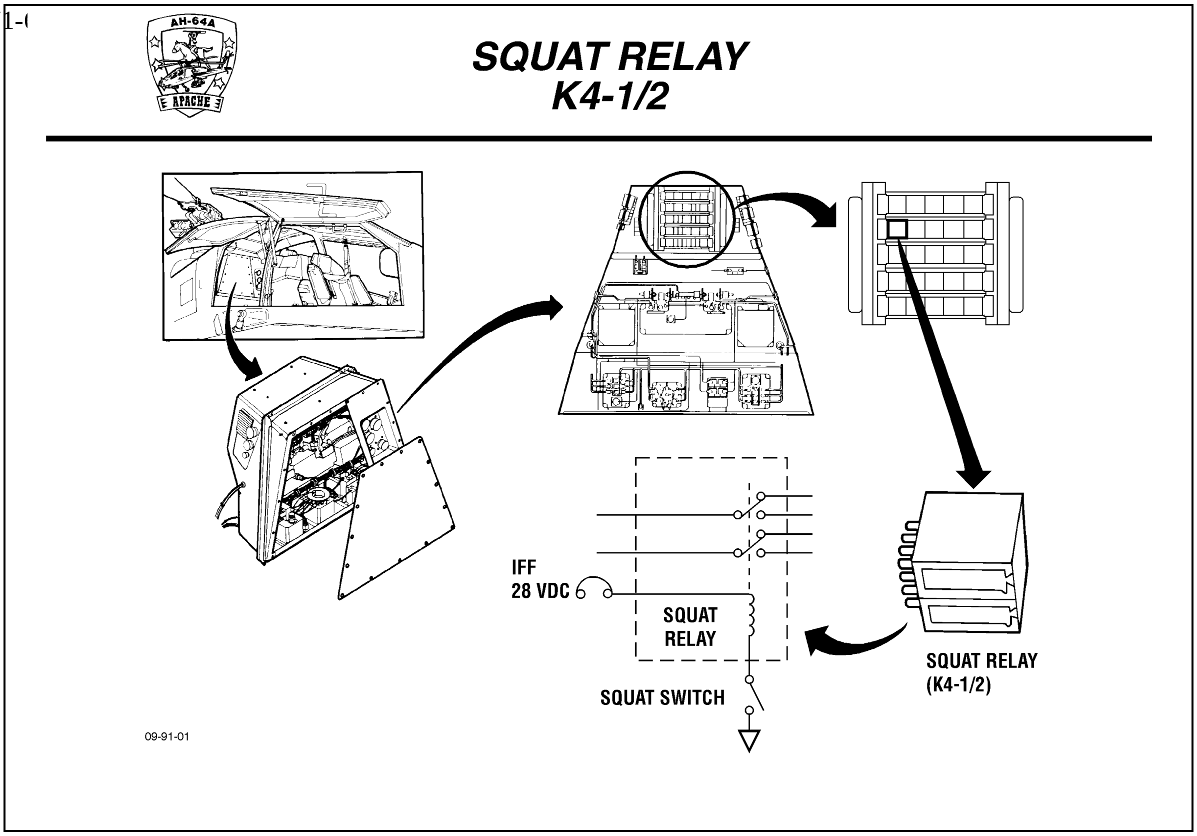
1. Squat switch

a. Removes the electrical ground from the coil of the squat relay when the helicopter is on the ground.

b. Mounted on the top of the trailing arm of the left main landing gear.

c. The squat switch is a 28 VDC magnetic proximity switch.

d. When the helicopter is on the ground the squat switch opens, which removes the ground from the squat relay.


AH-64A
APACHE
SQUAT RELAY
K4-1/2
IFF
28 VDC
SQUAT
RELAY
SQUAT SWITCH
SQUAT RELAY
(K4-1/2)
09-91-01

NOTES

2. Squat relay

   a. The squat relay zeroizes the MODE 4 code when the helicopter lands, if the HOLD function has not been selected.

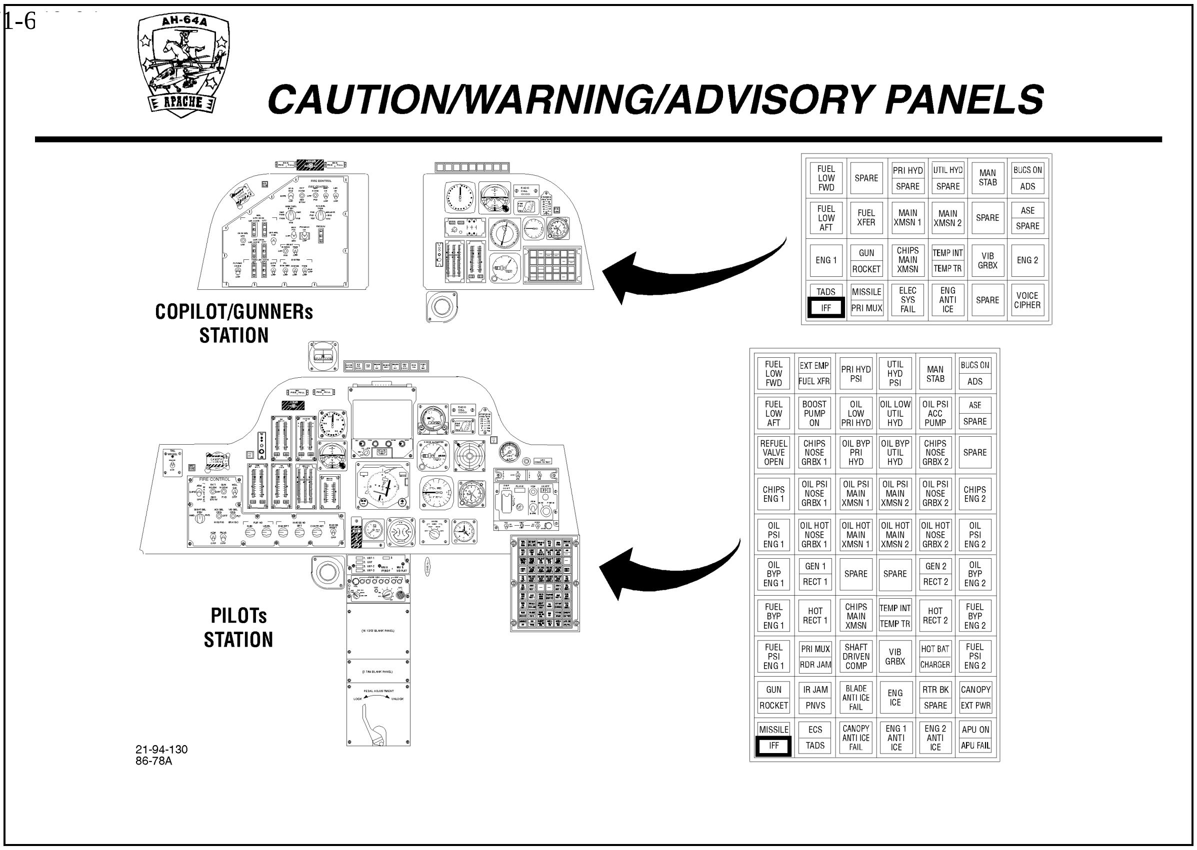
   b. Located in the electrical power distribution center behind the pilot's seat.

   c. A small 1" x 2" lightweight (2.8 ounces) solid-state LRU.

   d. The squat relay is supplied 28 VDC from the emergency DC bus via the IFF circuit breaker.

      (1) When the helicopter touches down, the squat switch opens, which removes the electrical ground from the relay.

      (2) When the relay de-energizes, it provides a ground to the KIT 1A/TSEC, causing it to zeroize any code entered in the KIT 1A.


AH-64A
APACHE
CAUTION/WARNING/ADVISORY PANELS
COPILOT/GUNNERs STATION
PILOTs STATION
FUEL LOW FWD
SPARE
PRI HYD
SPARE
UTIL HYD
SPARE
MAN STAB
BUCS ON
ADS
FUEL LOW AFT
FUEL XFER
MAIN XMSN 1
MAIN XMSN 2
SPARE
ASE
SPARE
ENG 1
GUN
ROCKET
CHIPS MAIN XMSN
TEMP INT
TEMP TR
VIB GRBX
ENG 2
TADS
IFF
MISSILE
PRI MUX
ELEC SYS FAIL
ENG ANTI ICE
SPARE
VOICE CIPHER
FUEL LOW FWD
EXT EMP
FUEL XFR
PRI HYD PSI
UTIL HYD PSI
MAN STAB
BUCS ON
ADS
FUEL LOW AFT
BOOST PUMP ON
OIL LOW PRI HYD
OIL LOW UTIL HYD
OIL PSI ACC PUMP
ASE
SPARE
REFUEL VALVE OPEN
CHIPS NOSE GRBX 1
OIL BYP PRI HYD
OIL BYP UTIL HYD
CHIPS NOSE GRBX 2
SPARE
CHIPS ENG 1
OIL PSI NOSE GRBX 1
OIL PSI MAIN XMSN 1
OIL PSI MAIN XMSN 2
OIL PSI NOSE GRBX 2
CHIPS ENG 2
OIL PSI ENG 1
OIL HOT NOSE GRBX 1
OIL HOT MAIN XMSN 1
OIL HOT MAIN XMSN 2
OIL HOT NOSE GRBX 2
OIL PSI ENG 2
OIL BYP ENG 1
GEN 1
RECT 1
SPARE
SPARE
GEN 2
RECT 2
OIL BYP ENG 2
FUEL BYP ENG 1
HOT RECT 1
CHIPS MAIN XMSN
TEMP INT
TEMP TR
HOT RECT 2
FUEL BYP ENG 2
FUEL PSI ENG 1
PRI MUX
RDR JAM
SHAFT DRIVEN COMP
VIB GRBX
HOT BAT
CHARGER
FUEL PSI ENG 2
GUN
ROCKET
IR JAM
PNVS
BLADE ANTI ICE FAIL
ENG ICE
RTR BK
SPARE
CANOPY
EXT PWR
MISSILE
IFF
ECS
TADS
CANOPY ANTI ICE FAIL
ENG 1 ANTI ICE
ENG 2 ANTI ICE
APU ON
APU FAIL
21-94-130
86-78A

NOTES

3. IFF caution lights

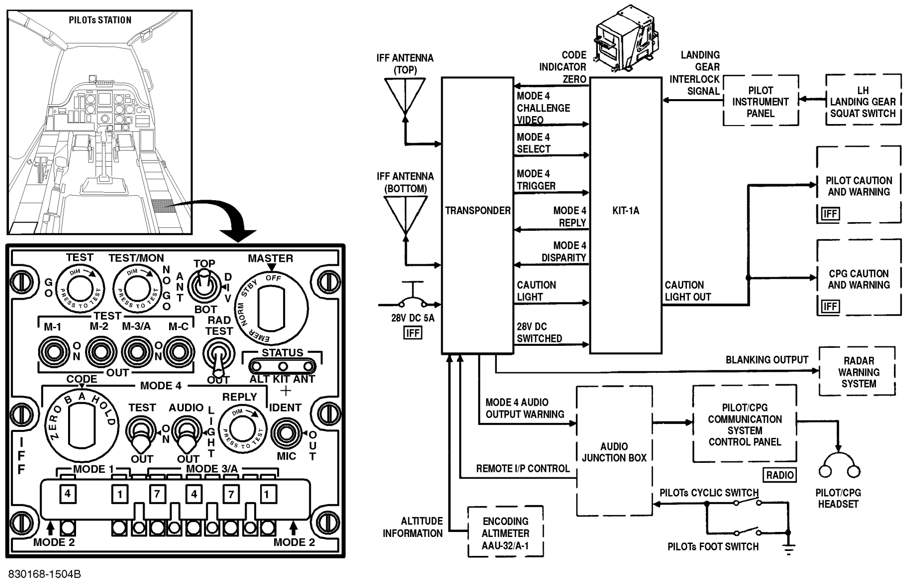
a. Advise the pilot and CPG that MODE 4 has been interrogated but has not replied.

b. One IFF caution light is located in the bottom left corner of both C/W/A panels.

c. A half-segment red caution light with two bulbs

d. When the KIT 1A/TSEC is interrogated, but is unable to reply, the caution lights illuminate. The lights illuminate flashing 2 "1 times per second until the master caution annunciator is reset; then the IFF light comes on in the steady state.

IFF SYSTEM BLOCK DIAGRAM



NOTES

D. AN/APX-100 transponder system operation

1. Primary power

a. The transponder receives 28 VDC from a 5 amp, emergency bus circuit breaker, located on the pilot's center overhead circuit breaker panel.

b. When the KIT-1A/TSEC is installed, primary power is switched through the transponder to power the security computer.

2. Receive

a. The transponder receives interrogation signals (time-pulse trains) via the IFF antennas.

b. The interrogation processing is essentially the same for MODES 1, 2, and 3A.

3. Transmit

a. If the interrogation mode coincides with the preset MODE selected by the pilot, the transponder replies in the same MODE as the interrogation.

(1) The reply contains specific coded information that has been selected by the controls for each of the three MODES.

(2) Due to high transmit power (approximately 500 watts), a blanking output pulse is produced by the transponder to prevent false missile threats in the radar warning system.

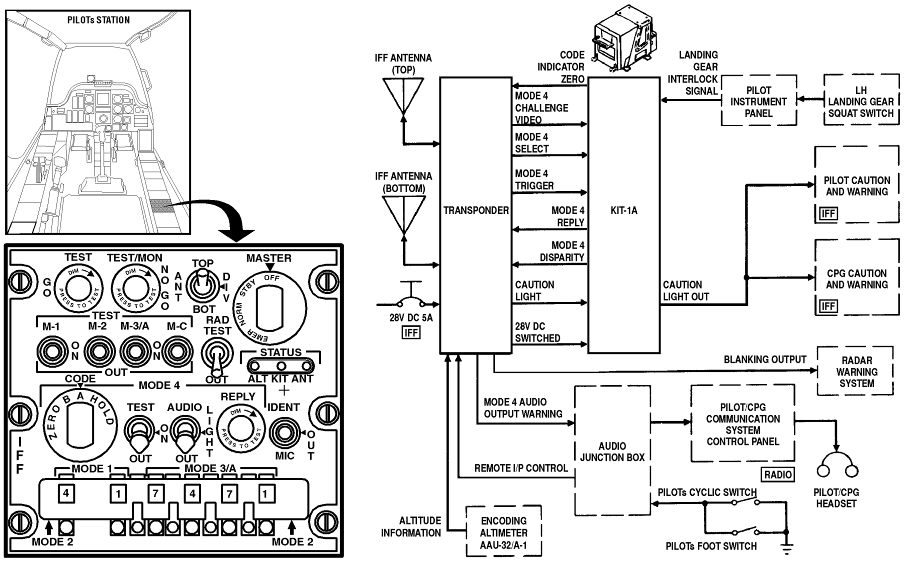
b. Mode C capability is now available. MWO 1-1520-238-50-05 replaced the existing non-encoding altimeter, part number AAU-31/1, in the pilot's station with an encoding altimeter, part number AAU- 32/A-1. It also added data transfer wires between the altimeter and the IFF transponder. The barometric pressure altitude is now digitized by the encoding altimeter and made available to be interrogated with Mode C selected, the transponder responds with the altitude information being supplied by the encoding altimeter. Use caution when replacing the altimeter to ensure that the proper part number is utilized.

c. Identification of position (I/P) - the pilot "squawks I/P" and forces the transponder to transmit through the RADIO push to talk switch or transmit foot switch.

4. MODE 4 processing

a. MODE 4 must be selected on the transponder so the MODE 4 interrogation signal can be applied to the KIT-1A computer.

IFF SYSTEM BLOCK DIAGRAM



830168-1504B

NOTES

b. The interrogation pulse contains

(1) The MODE identification code (trigger).

(2) Special information coding (challenge video).

c. KIT-1A computer - compares the MODE 4 challenge video with the code of the day.

(1) If the codes are the same - KIT-1A encodes the MODE 4 reply, which is sent to the transponder for transmission.

(2) If the codes differ - KIT-1A applies a disparity signal to the transponder, which triggers the MODE 4 alarms.

(3) MODE 4 alarms occur when MODE 4 is interrogated but does not reply (due to an improper interrogation) or if the KIT-1A fails.

(4) Three possible alarm indications.

(a) Caution lights illuminate on the pilot and CPG caution/warning/advisory panels.

(b) Combination of the two caution lights and the TEST/MON NO GO lamps light.

(c) Combination of the two caution lights and an audio warning in both helmets.

d. Zeroing (erasure of the code of the day)

(1) Manual

(a) Rotate the HOLD/A/B/ZERO switch to ZERO.

(b) The command is sent to the KIT-1A on the MODE 4 select line.

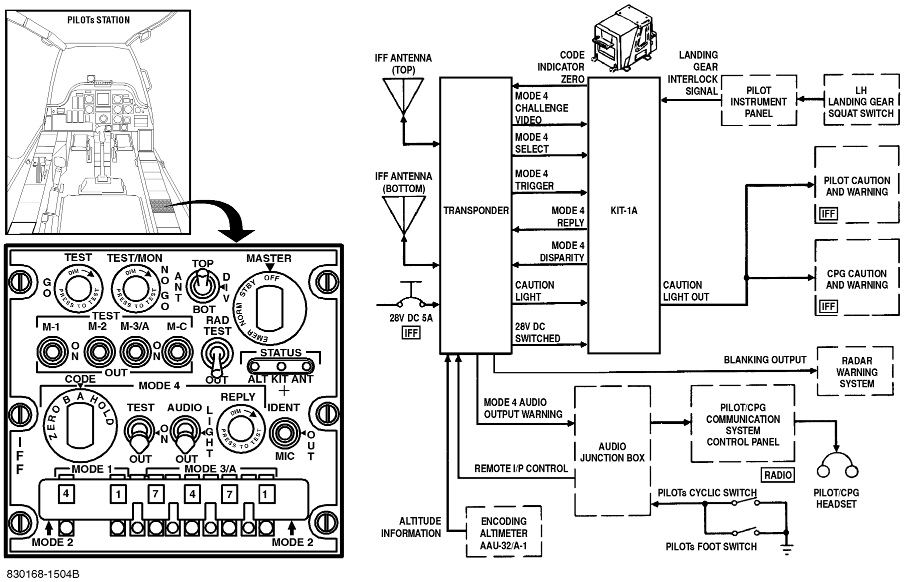
(2) Automatic

(a) Loss of 28 VDC.

(b) When the aircraft lands

1) The squat switch opens which causes the squat relay to de-energize.

IFF SYSTEM BLOCK DIAGRAM



NOTES

2) When the squat relay de-energizes, it causes a ground to be applied to the KIT 1A.

3) The ground causes the KIT 1A to zeroize.

(c) Can be disabled by the HOLD/A/B/Zero switch.

1) Rotate to HOLD momentarily, then release.

2) Wait 15 seconds; rotate MASTER rotary switch to OFF.

5. Built-in-test (BIT)

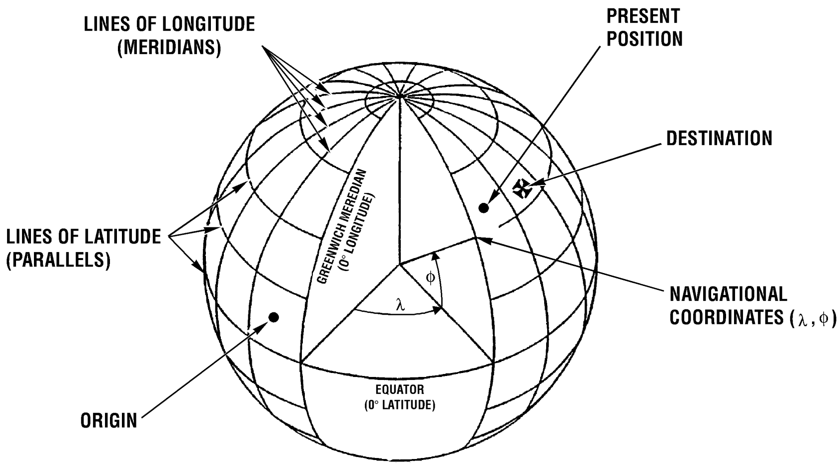
a. Allows for a complete system test.

b. Provides continuous monitoring of critical IFF operations.

c. Conducts operator-initiated self-tests of the IFF system components.

d. MODE 4 cannot be tested unless the KIT-1A is installed.

NAVIGATION



LONGITUDE (λ) AND LATITUDE (φ)

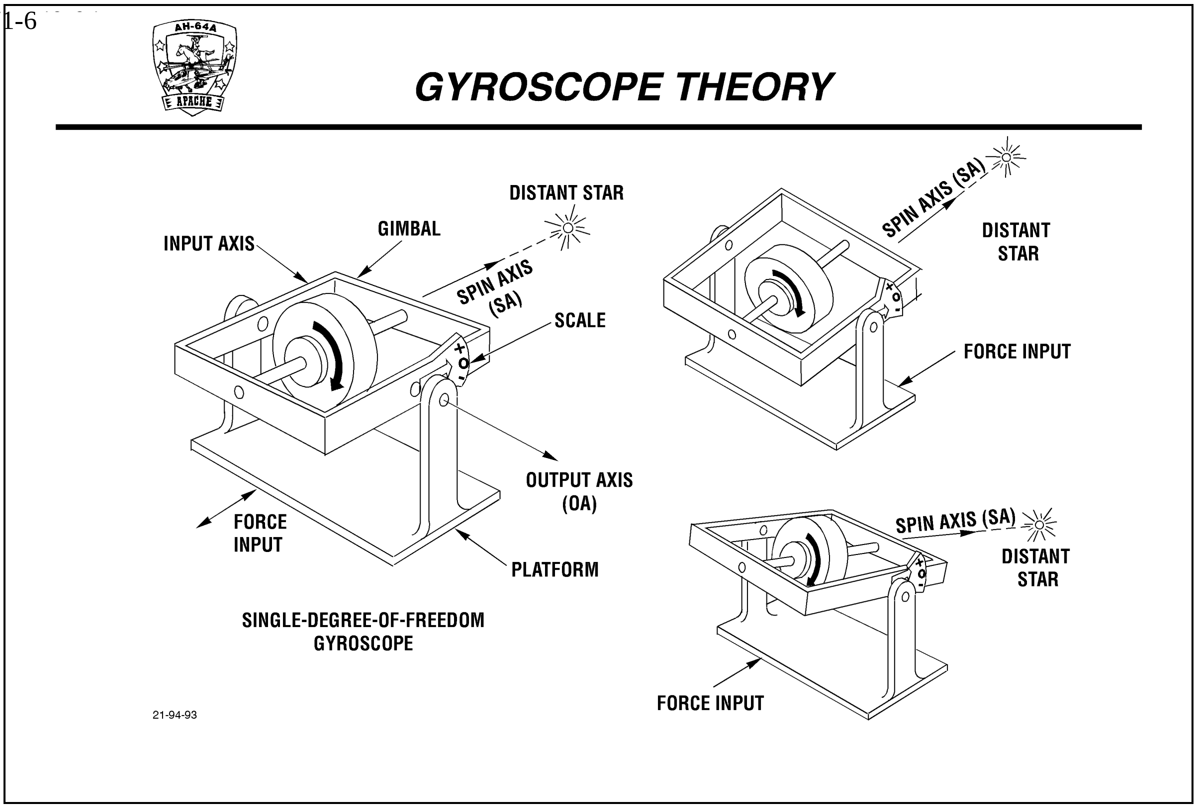
21-94-92

NOTES

A. Navigation

1. Long distance travel and tactical/strategic warfare all share a common need in the realm of navigation, the need to operate and accurately travel to a destination without the need for outside navigation aids.

2. Space can be defined as a grid coordinate or other system where known reference points are used to find the position of other objects. These characteristics are the same as the requirements for an inertial navigation system reference, in which gyroscopes are used to provide a stable platform (or element) for acceleration sensing components. As a result gyroscopes are instruments that are well suited to inertial navigation.


AH-64A
APACHE
GYROSCOPE THEORY
DISTANT STAR
GIMBAL
INPUT AXIS
SPIN AXIS (SA)
SCALE
OUTPUT AXIS (OA)
FORCE INPUT
PLATFORM
SINGLE-DEGREE-OF-FREEDOM GYROSCOPE
21-94-93
SPIN AXIS (SA)
DISTANT STAR
FORCE INPUT
SPIN AXIS (SA)
DISTANT STAR
FORCE INPUT

NOTES

3. A gyroscope is a device that remains angularly fixed in space OR precesses in a predetermined manner. A gyro consists of a wheel having much of its mass concentrated around its rim. The wheel spins on an axis which is free to pivot about one or both of two axes that are perpendicular to the spinning axis and to each other. The spinning mass of the wheel possess the property of rigidity in space which keeps the axis of rotation pointed in the same direction. Newton's first and second laws of motion defines why the axis stays pointed in the same direction.

AN OBJECT CONTINUES IN A STATE OF REST, OR UNIFORM MOTION IN A STRAIGHT LINE, UNLESS ACTED UPON BY AN EXTERNAL FORCE.

a. This law is also the property of INERTIA, of which, MASS IS THE NUMERICAL MEASURE OF THIS PROPERTY.

FOR EVERY ACTION, THERE IS AN OPPOSITE AND EQUAL REACTION.

b. Momentum is also involved in maintaining the rigidity of the spinning gyroscope because mass is involved.

(1) Momentum (linear) is defined as the quantity of motion that a device has and is equal to the product of it's mass (inertia) and velocity vector.

$$\rho = mv$$

(2) Gyroscope momentum is angular momentum because the mass is spinning, not moving in a linear motion.

(3) Angular momentum of a body about it's axis of rotation is equal to the product of it's position vector (which includes the radius of the spinning mass from the axis of rotation) and it's linear momentum.

$$L = r \text{ X } \rho$$

c. Gyroscopes can be made more rigid by

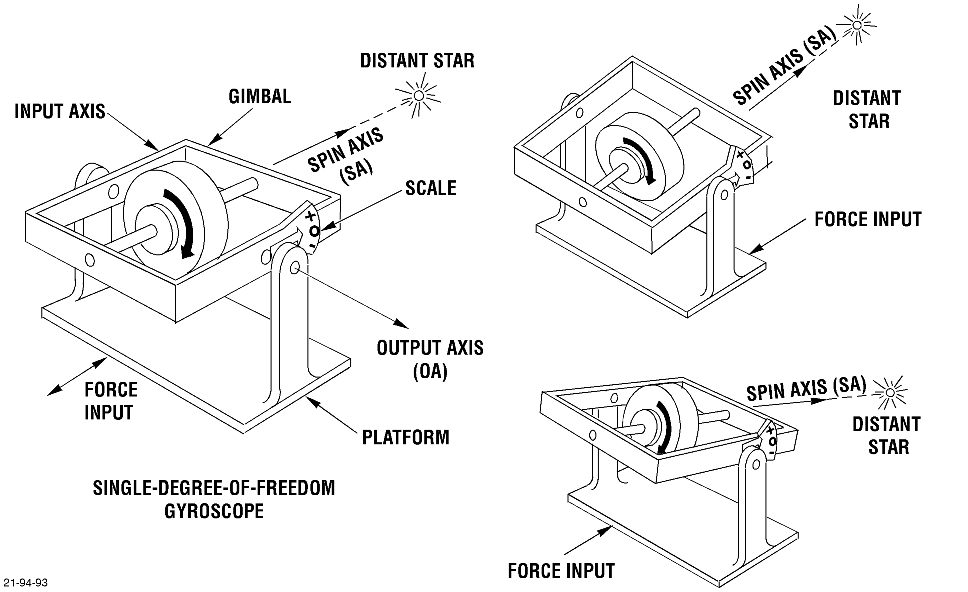
(1) Increasing the mass of the rotor.

(2) Increasing the angular momentum (RPM).

(3) Or a combination of both.

d. Aerospace applications usually tend toward an increase in angular momentum to increase rigidity because of weight constraints.

GYROSCOPE THEORY



21-94-93

NOTES

4. Gyroscopes are classified as to the number of axes, or "degrees-of-freedom" around which an input disturbance may rotate the gyro platform and allow the rotor axis to remain pointed at an object in space. There are two basic types that are used for aerospace applications.

   a. Single-degree-of-freedom gyroscopes

   b. Two-degree-of freedom gyroscopes

5. Single-degree-of-freedom gyroscope

   a. Has one degree of freedom

   b. Consists of the following

      (1) Rotor (the spinning mass and shaft)

      (2) Gimbal

         (a) Supports the rotor

         (b) Allows the axis of the rotor one degree of freedom at a right angle to the axis (up or down in this case)

         (c) The standard against which platform rotation is measured

      (3) Platform

         (a) Attaches the gimbal/rotor to the object that moves

         (b) Allows room for the platform to pivot around the gimbal so that the gyro axis can stay pointed at the fixed point in space to which the rotor spin axis has been initially ALIGNED to.

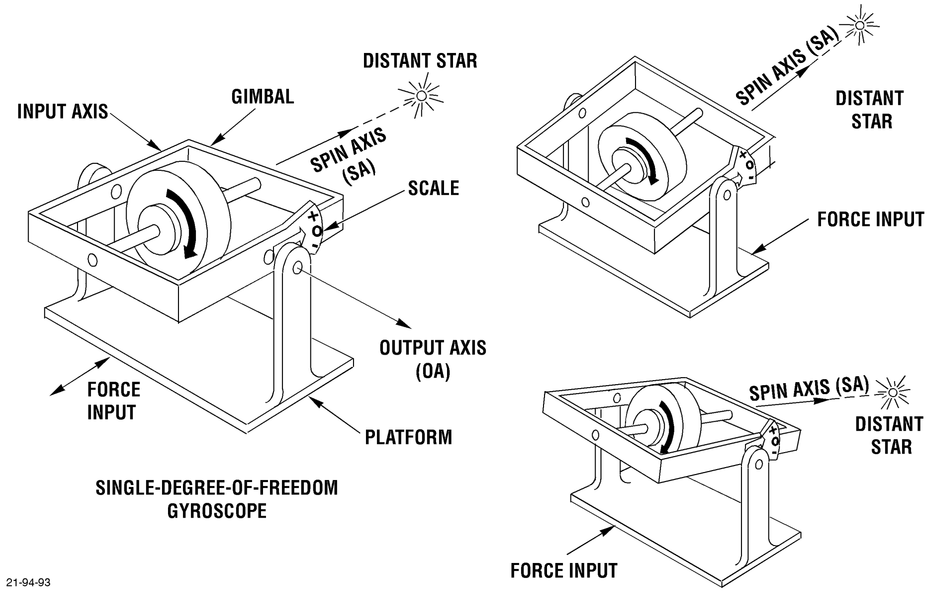
      (4) Input axis is the axis about which input disturbances are sensed.

      (5) Output axis is the axis about which the platform pivots or the gyro may precess.

   c. Single-degree-of-freedom gyroscope operation

      (1) To attain rigidity, the gyro rotor is spun on it's rotational axis at a constant high speed by a motor (air pressure or vacuum are used with some types of gyros).

GYROSCOPE THEORY

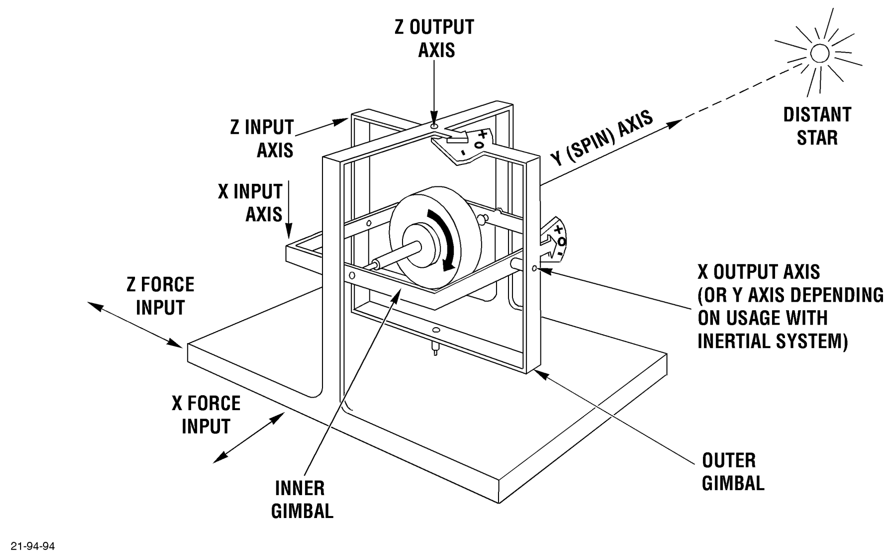


NOTES

(2) If a force is applied to the platform in the direction of the input axis of the gyro, the platform rotates around the output axis. The amount of rotation can be measured when compared to the gimbal.

(3) The single-degree-of-freedom gyroscope has little practical value in inertial navigation because the one axis of movement cannot be used to detect movements in the other two axis in which movement can occur.

TWO-DEGREE-OF FREEDOM GYRO SCOPE



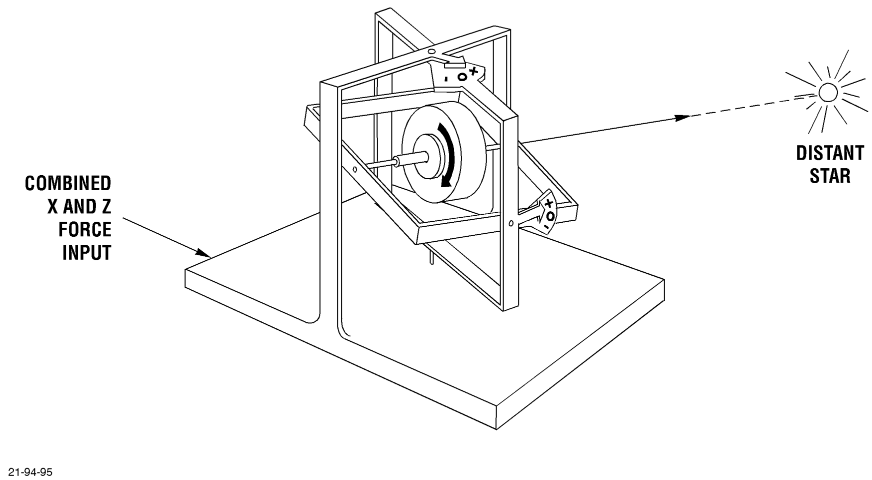
NOTES

6. Two-degree-of freedom gyroscope

a. A two-degree-of freedom gyroscope has two gimbals that can be moved at 90E to each other and both are at 90E to the rotor axis. The two-degree-of freedom gyroscope can measure angular displacement in two axes and more adequately meet the needs of the three axes of displacement that occurs in inertial navigation. In practice, two separate two-degree-of freedom gyroscopes are used to monitor the three axes of displacement (pitch, roll and yaw) in inertial navigation.

b. A two-degree-of freedom gyroscope consists of the same components and they have the same function as in a single-degree-of-freedom gyro. The exception, as noted, is the extra gimbal that provides the additional degree of freedom.

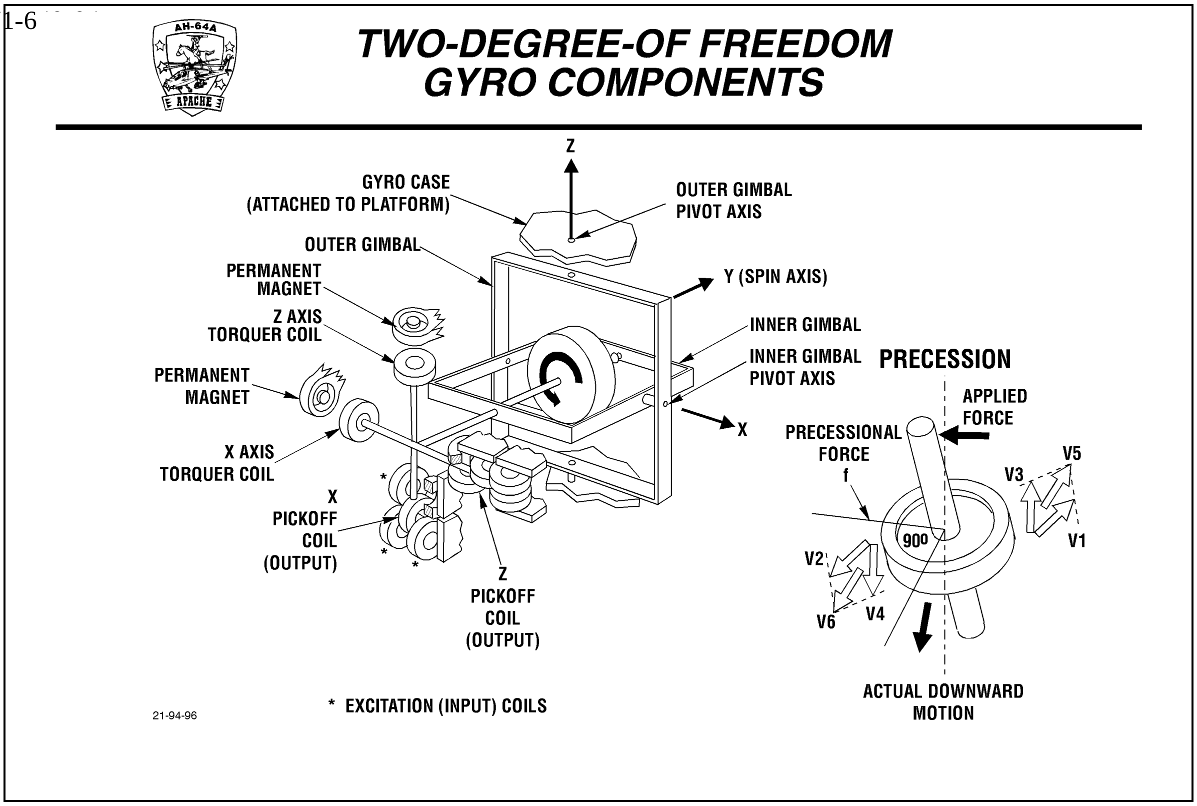
TWO-DEGREE-OF FREEDOM GYRO OPERATION



NOTES

7. Two-degree-of freedom gyroscope operation

   a. If a force is applied to the platform in any direction of the input axes of the gyro, the platform rotates around the output axes. The type and amount of rotation can be measured when compared to the respective gimbals.


AH-64A
APACHE
TWO-DEGREE-OF FREEDOM
GYRO COMPONENTS
Z
GYRO CASE
(ATTACHED TO PLATFORM)
OUTER GIMBAL
PIVOT AXIS
OUTER GIMBAL
PERMANENT
MAGNET
Y (SPIN AXIS)
Z AXIS
TORQUER COIL
INNER GIMBAL
INNER GIMBAL
PIVOT AXIS
PERMANENT
MAGNET
X
X AXIS
TORQUER COIL
X
PICKOFF
COIL
(OUTPUT)
Z
PICKOFF
COIL
(OUTPUT)
PRECESSION
APPLIED
FORCE
PRECESSIONAL
FORCE
f
V3
V5
90°
V1
V2
V6
V4
ACTUAL DOWNWARD
MOTION
21-94-96
* EXCITATION (INPUT) COILS

NOTES

8. Two-degree-of freedom gyroscope components

a. Additional components are required to make the gyro usable in an inertial system.

(1) Excitation coils are used to provide an electrical reference to the pickoff coils.

(2) Pickoff coils electrically measure how far the platform is displaced by an applied force.

(3) The torquer coils work in conjunction with the permanent magnets that are mounted on the gyro case. The gyro has a tendency to mechanically DRIFT from it's initial ALIGNMENT over time because of undesirable precession rates. Precession is the movement of the spin axis of a gyro because of a force applied to it. The actual movement occurs at 90E to the applied force.

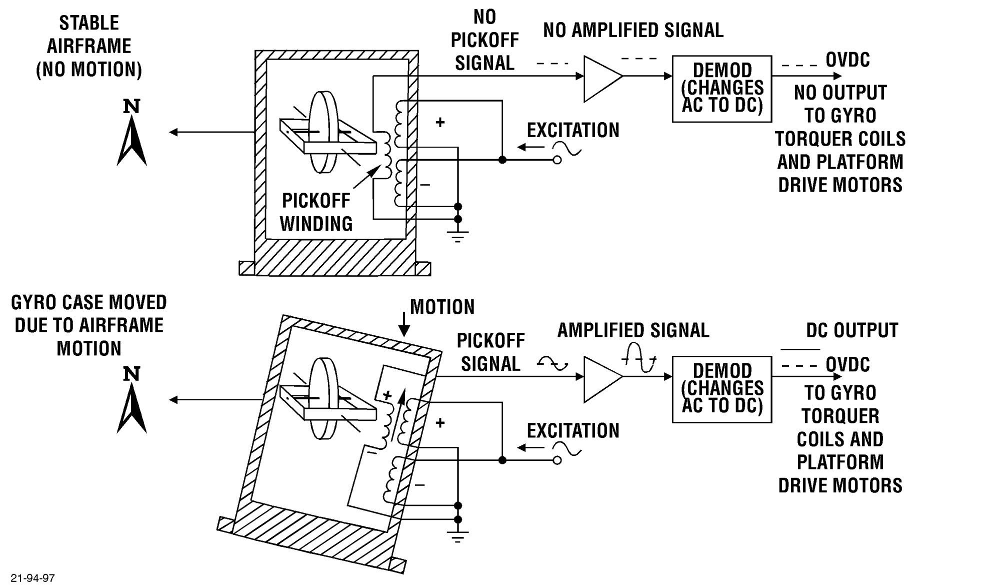
(a) The precession is caused by unwanted torques induced into the system by the motor that spins the gyroscope rotor.

(b) The precession rates are determined during gyro-drift calibration runs.

1) The rates are relatively constant and eliminated by creating a counter torque magnetic field in the torquer coil.

2) More or less current through the coil controls the magnetic field which is attracted to or repelled from the permanent magnet.

GYRO PICKOFF SIGNAL



NOTES

9. Gyro pickoff signal

a. A gyro pickoff system is used to measure stable platform (or element) deviation from an outside source.

b. This pickoff signal is used to electrically measure how far the platform is displaced by an applied force.

c. Several components make up the basic gyro pick off system.

(1) Excitation coils are used to provide an ELECTRICAL REFERENCE to the pickoff coils. Excitation coils are mounted to the gyro case and move in relation to the pickoff coils as the platform is displaced by an outside force.

(2) Pickoff coils are mounted to the gyro gimbal and are used to ELECTRICALLY MEASURE how far the platform is displaced by an applied force (this signal is used in an actual inertial system to control a drive motor to keep the platform ALIGNED with it's initial position; i.e., gyro axis pointed to true north).

(3) An amplifier is used to increase the pickoff signal to a usable level.

(4) A demodulator converts the pickoff signal to a signal usable by the platform stabilization and precession torquer circuit.

d. Gyro pickoff signal operation

(1) Under initial conditions

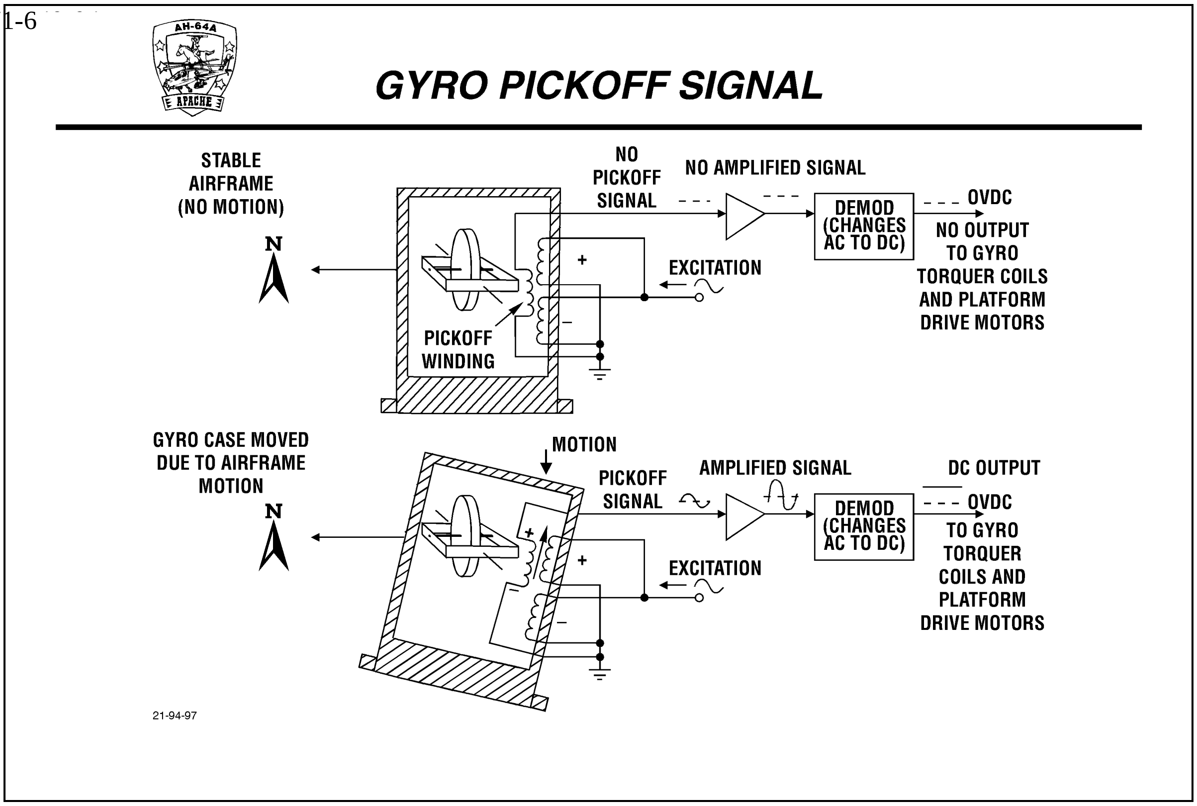
(a) The gyro is spinning and the gyro case is level with the gyro gimbal.

(b) A reference AC voltage is supplied to the two reference transformer windings. The two windings are wound 180E out of phase so that the magnetic fields are of opposite polarity.

(c) The pickoff winding is CENTERED between the two opposite polarity reference magnetic fields, and no pickoff signal is generated by induction.

(2) If an outside force causes the gyro case to tip, the excitation coils move in relation to the pickoff coil.

(a) In this case, the + REFERENCE excitation winding has moved CLOSER to the pickoff winding.


GYRO PICKOFF SIGNAL
STABLE AIRFRAME (NO MOTION)
N
NO PICKOFF SIGNAL
NO AMPLIFIED SIGNAL
DEMOD (CHANGES AC TO DC)
OVDC
NO OUTPUT TO GYRO TORQUER COILS AND PLATFORM DRIVE MOTORS
EXCITATION
PICKOFF WINDING
GYRO CASE MOVED DUE TO AIRFRAME MOTION
N
MOTION
PICKOFF SIGNAL
AMPLIFIED SIGNAL
DEMOD (CHANGES AC TO DC)
DC OUTPUT
OVDC
TO GYRO TORQUER COILS AND PLATFORM DRIVE MOTORS
EXCITATION
21-94-97

NOTES

1) A **+** (positive) pickoff signal is generated.

2) It is in-phase with the excitation signal.

3) The amplitude (height) of the signal indicates how far the gyro case has moved.

(b) If the case had moved in the other direction:

1) A **-** (negative) pickoff signal is generated.

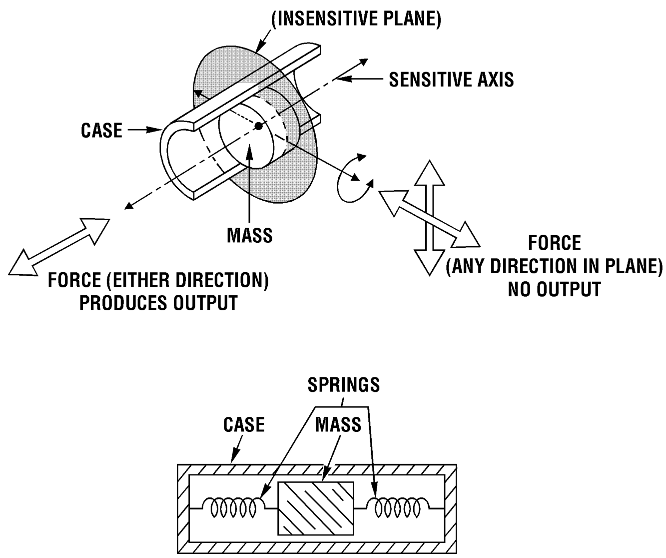
2) It is OUT of phase with the excitation signal.

3) The amplitude (height) of the signal would indicate how far the gyro case moved.

(3) The amplifier is used to increase the pickoff signal to a level usable by the demodulator circuit.

(4) A demodulator converts the pickoff signal to a DC signal usable by the platform stabilization drive motors and the precession torquer circuit.

LINEAR ACCELEROMETER



21-94-98

NOTES

B. Linear accelerometer

1. Accelerometers are the basic sensing elements in inertial navigation that allow a vehicle to operate and accurately travel to a destination without the need for outside navigation aids.

2. Acceleration is a change in the velocity of an object.

   a. It can be a change from an at-rest condition to a velocity, from an existing velocity to a higher or lower velocity, a change in direction, or from a velocity back to an at-rest condition.

   b. When there is no change in velocity or direction, there is no acceleration.

   c. Newton's second and third laws of motion applies to accelerometer theory.

      THE ACCELERATION OF AN OBJECT IS DIRECTLY PROPORTIONAL TO THE SUM OF THE FORCES ACTING ON THE OBJECT

      FOR EVERY ACTION, THERE IS AN OPPOSITE AND EQUAL REACTION.

3. From the acceleration detected by the accelerometers, velocity (from the first integral) and distance traveled (from the second integral), can be determined by using basic calculus.

4. A basic accelerometer consists of a mass and a case.

   a. The case limits the freedom of motion of the mass to a single axis called the sensitive axis.

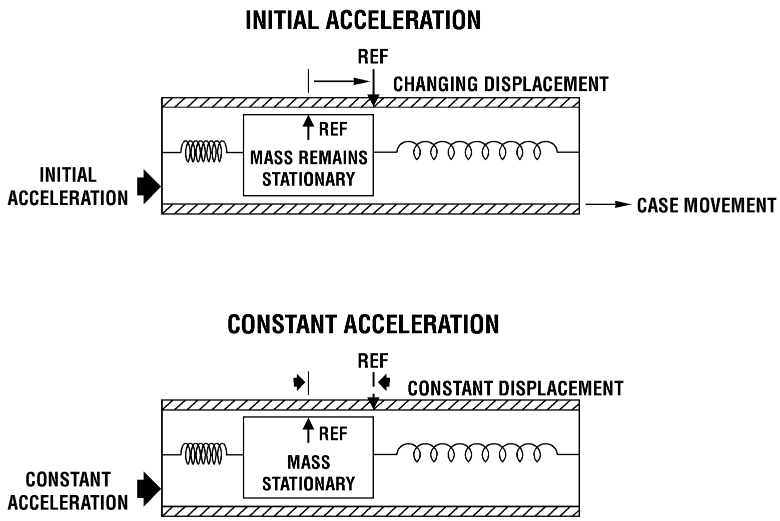
      (1) The mass is free to move inside the case along the sensitive axis.

      (2) The sensitive axis is the direction along which acceleration can be detected.

   b. No accelerations can be detected from any force applied in the insensitive plane.

5. To make the basic accelerometer usable in a practical situation, a way of limiting the mass's travel (which ultimately limits the G force that can be detected), and a means of centering the mass after it has been subjected to an acceleration must be provided. Springs can be used to achieve these requirements.

LINEAR ACCELEROMETER OPERATION



21-94-99

NOTES

C. Linear accelerometer operation

1. When an acceleration is INITIALLY applied to an accelerometer the force is applied to the case which is mounted to the vehicle.

   a. The case begins to move as force is applied.

   b. The mass tends to stay at rest, extending one spring and compressing the other.

   c. A changing displacement occurs between the initial and current position of the mass.

2. As the acceleration reaches and maintains a constant value:

   a. The case continues to be accelerated at the constant rate applied to the vehicle.

   b. The spring force at this displacement is equal to the acceleration force and prevents further movement of the case in relation to the mass.

   c. The mass now moves along with the case, at some displaced distance.

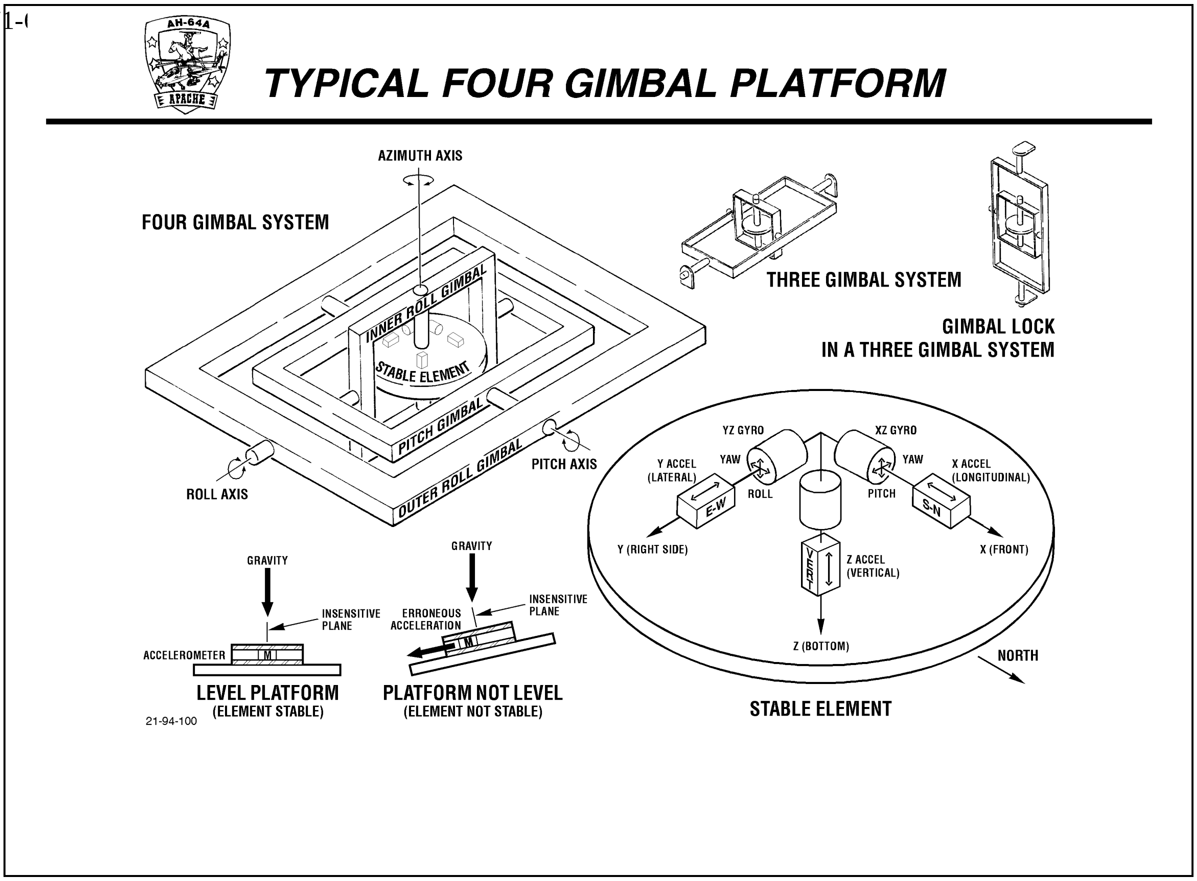
   d. The constant displacement between the case and mass is a measure of the acceleration that the accelerometer is presently subjected to.

   e. The velocity of the vehicle continues to increase as long as the acceleration remains constant.

3. If the acceleration force is removed from the vehicle:

   a. The acceleration is removed from the accelerometer case. The spring force is now greater than the acceleration force and centers the mass as the acceleration decreases and the vehicle attains a constant velocity.

   b. The displacement between the case and mass returns to zero, indicating the zero acceleration state.


AH-64A
APACHE
TYPICAL FOUR GIMBAL PLATFORM
AZIMUTH AXIS
FOUR GIMBAL SYSTEM
INNER ROLL GIMBAL
STABLE ELEMENT
PITCH GIMBAL
OUTER ROLL GIMBAL
PITCH AXIS
ROLL AXIS
THREE GIMBAL SYSTEM
GIMBAL LOCK
IN A THREE GIMBAL SYSTEM
YZ GYRO
XZ GYRO
Y ACCEL
(LATERAL)
YAW
X ACCEL
(LONGITUDINAL)
E-W
ROLL
PITCH
S-N
Y (RIGHT SIDE)
X (FRONT)
Z ACCEL
(VERTICAL)
Z (BOTTOM)
NORTH
STABLE ELEMENT
GRAVITY
INSENSITIVE
PLANE
ACCELEROMETER
M
LEVEL PLATFORM
(ELEMENT STABLE)
ERRONEOUS
ACCELERATION
PLATFORM NOT LEVEL
(ELEMENT NOT STABLE)
21-94-100

NOTES

D. Typical four gimbal platform

1. The accelerometers must be kept aligned in the north-south, east-west, and vertical directions on the gimbal system for accurate acceleration, velocity, and distance traveled information to be obtained by the inertial navigation.

2. Combining the two "two-degree-freedom" gyros and three accelerometers on a common platform and placing them on a four axis gimbal system provides the vehicle with the basic inertial platform.

3. Gimbal functions

   a. Outer roll gimbal - prevents gimbal lock (an axis cannot move) from occurring during some vehicle maneuvers and corrupting the nav information.

   b. Pitch gimbal - allows the stable element to remain aligned to level and pointed to true north in the pitch axis.

   c. Roll gimbal - allows the stable element to remain aligned to level and pointed to true north in the roll axis.

   d. Stable element gimbal - allows the stable element to remain aligned to level and pointed to true north in the azimuth axis.

4. The stable element contains the gyros and accelerometers aligned in north-south and east-west directions on the gimbal system.

   a. The X-Z gyro is matched with two accelerometers.

      (1) One accelerometer is aligned with it's sensitive axis to gyro X axis.

      (2) The other accelerometer is aligned with it's sensitive axis to the gyro Z axis.

   b. The Y-Z gyro is matched with one accelerometer.

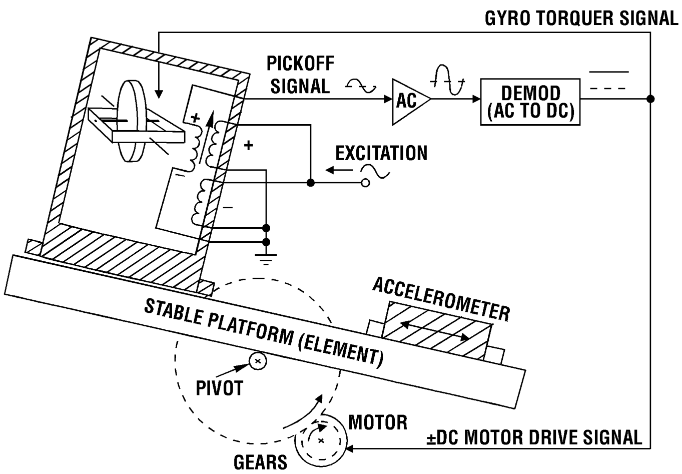
      (1) The accelerometer is aligned with it's sensitive axis to gyro Y axis.

      (2) The other gyro Z axis is redundant and is not used.

5. The accelerometers provide acceleration information to a processor to be integrated in to velocity information (first integral) and distance traveled (second integral).

6. The gyros provide information to the platform stabilization loop system to keep the stable element level and pointed to true north once it has been initially aligned. Erroneous accelerations due to gravity are induced into the system if the stable element is allowed to deviate from level position.

PLATFORM STABILIZATION LOOP



21-94-101

NOTES

E. Platform stabilization loop

1. The addition of a platform stabilization drive motor to each axis of the four axis gimbal system provides the vehicle with the basic STABILIZED inertial platform.

2. The drive motors operate to keep the platform aligned as controlled by the gyros.

3. Platform stabilization loop operation

   a. The demodulated gyro pickoff DC signal is sent to a platform stabilization drive motor.

   b. The platform stabilization drive motor operates and drives the platform toward level.

      (1) As the platform approaches level, the drive signal decreases.

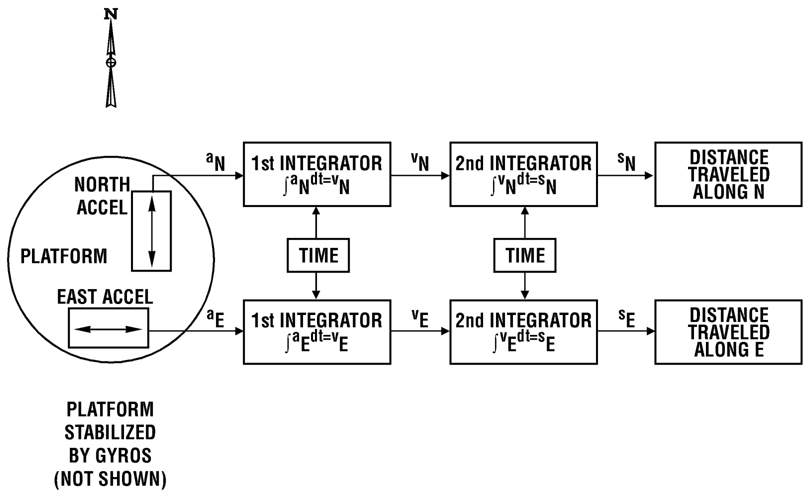
      (2) The platform drive signal becomes zero when the platform is level as detected by the gyro.

      (3) The drive motor stops.

      (4) The drive motor remains stopped until another input from the airframe upsets the platform.

   c. Under actual operating conditions, the platform stabilization drive motor is constantly receiving control signals from the gyro pickoff and demodulator to keep the platform level and aligned to north.

ACCELERATION INTEGRATION BLOCK DIAGRAM



21-94-102

NOTES

F. Acceleration integration block diagram

1. Now that the platform is stabilized, the accelerometers can accurately sense the vehicle accelerations in the north-south and east-west directions.

   a. The north-south accelerometer output is:

      (1) Integrated to become north-south velocity.

      (2) Integrated a second time to become north-south distance traveled.

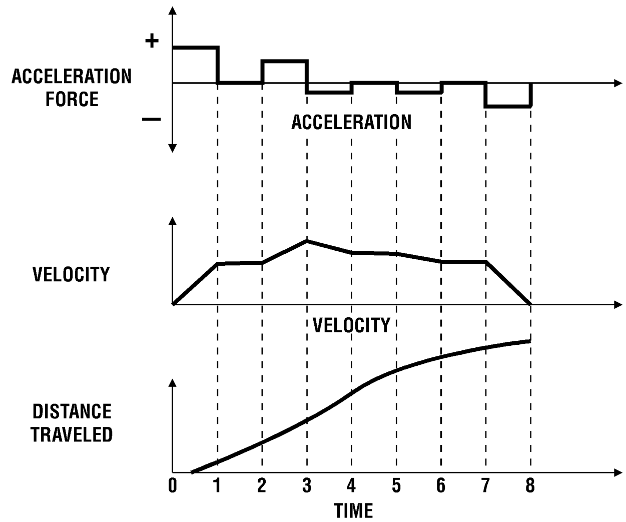
   b. The east-west accelerometer output is:

      (1) Integrated to become east-west velocity.

      (2) Integrated a second time to become east-west distance traveled.

2. The velocity and distance traveled outputs are used directly to give vehicle present position.

ACCELERATION INTEGRATION SIGNALS



21-94-103

NOTES

G. Acceleration integration signals

1. The acceleration force is dependent on the motion of the vehicle and can:

   a. Be a positive acceleration.

   b. Be zero

      (1) The vehicle is at rest.

      (2) The vehicle is traveling at a constant velocity.

   c. Be a negative acceleration (deceleration).

2. Velocity is dependent on acceleration.

   a. The velocity is zero if no acceleration has occurred.

   b. As positive acceleration occurs, velocity increases.

   c. As the acceleration drops to zero, the velocity attains a constant rate.

   d. If a negative acceleration occurs, the velocity decreases.

   e. If the vehicle continues to decelerate the velocity becomes zero.

3. Distance traveled is dependent on acceleration and velocity.

   a. If no acceleration has occurred, the velocity is zero and no distance is traveled.

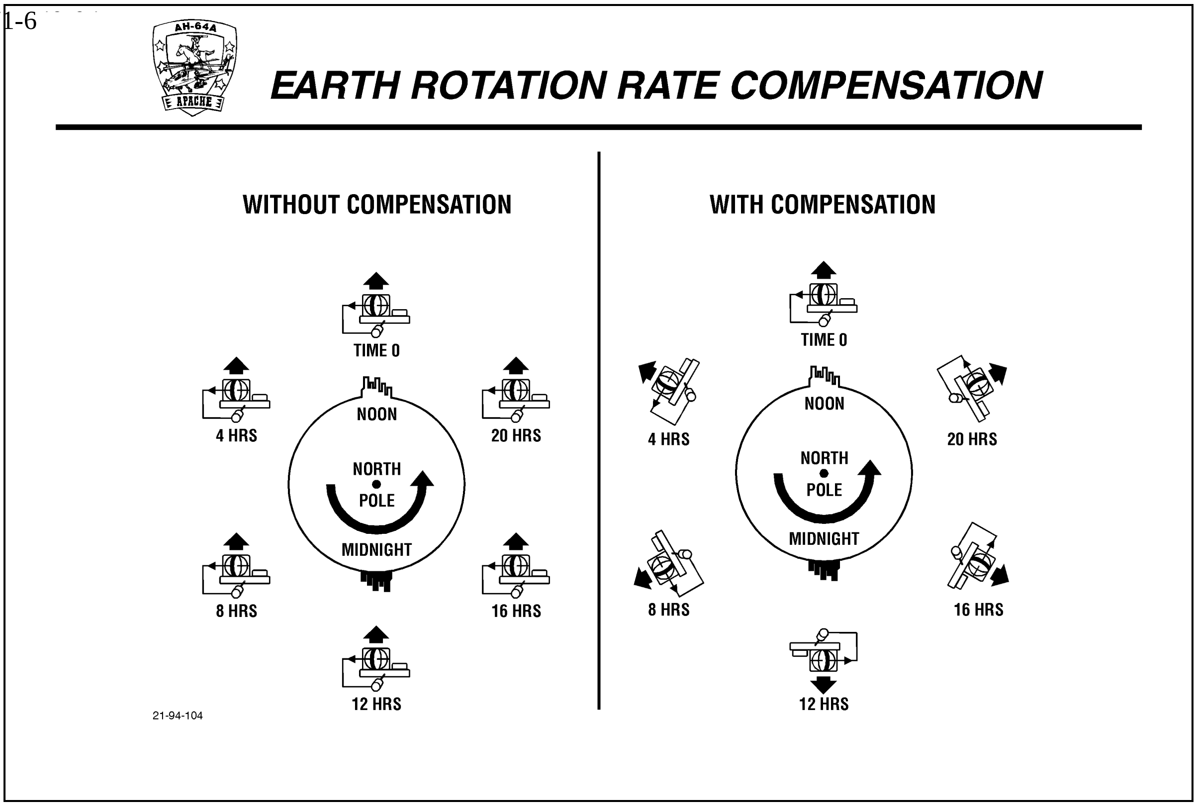
   b. As positive acceleration occurs, velocity increases and distance is traveled by the vehicle.

   c. If a higher positive acceleration occurs, velocity increases again and distance traveled is at a higher rate.

   d. If the acceleration drops to zero, the velocity attains a constant rate and the distance traveled continues at that rate of velocity.

   e. If a negative acceleration occurs the velocity decreases and the distance traveled decreases.

   f. If the vehicle continues to decelerate the velocity becomes zero and the distance traveled stops and remains at that value.


AH-64A
APACHE
EARTH ROTATION RATE COMPENSATION
WITHOUT COMPENSATION
WITH COMPENSATION
TIME 0
NOON
NORTH
POLE
MIDNIGHT
4 HRS
20 HRS
8 HRS
16 HRS
12 HRS
21-94-104

NOTES

H. Earth rotation rate compensation

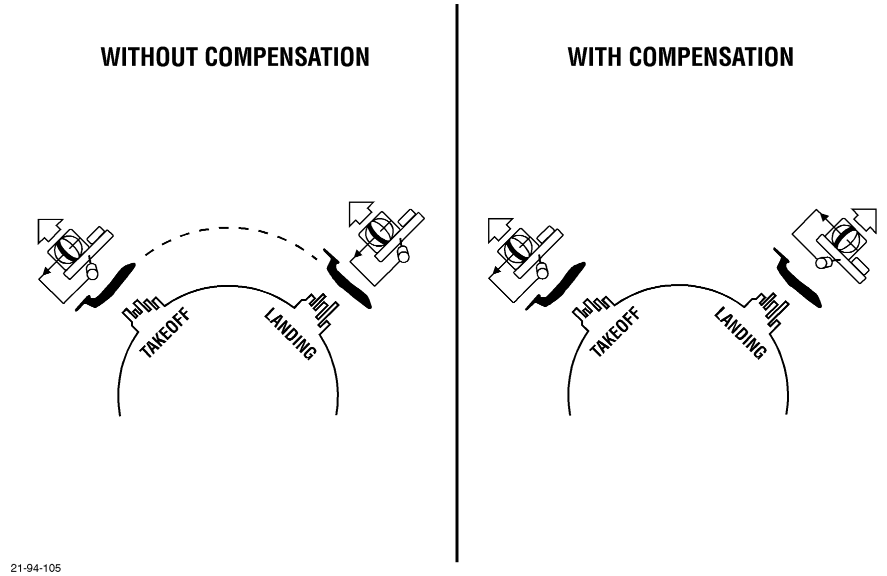
1. A platform appears to precess 360E every 24 hours due to the rotation of the earth.

2. This must be compensated for in order to keep the platform at "local level" at all times.

   a. A conventional stabilized gimbal inertial platform uses the gyro torque loop to keep the platform level.

   b. Computer processing compensates for earth rate in a strapdown inertial system.

TRANSPORT RATE COMPENSATION



NOTES

I. Transport rate compensation

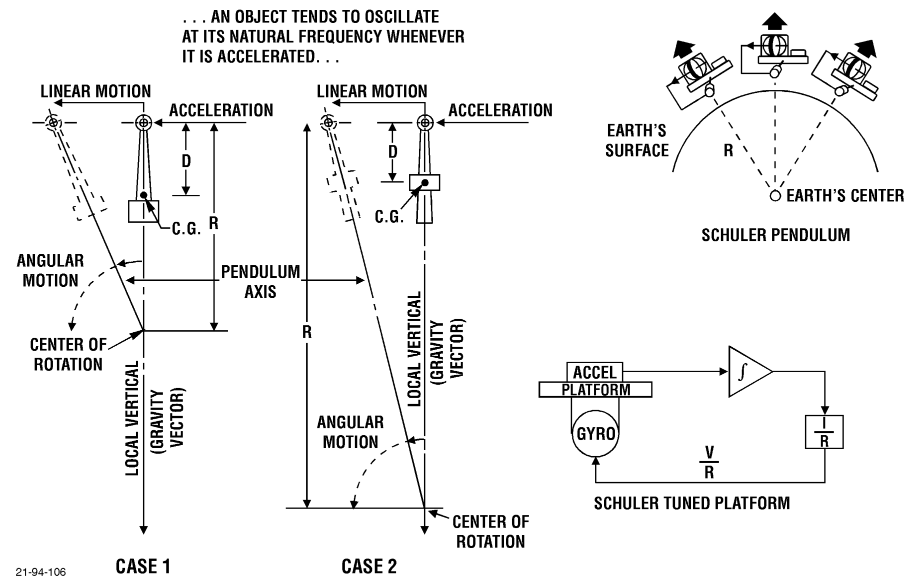
1. A platform appears to precess as a function the velocity at which the platform is transported across the earth.

2. This must be compensated for in order to keep the platform at "local level" at all times.

   a. A conventional stabilized gimbal inertial platform uses the gyro torque loop to keep the platform level.

   b. Computer processing compensates for transport rate in a strapdown inertial system.

SCHULER EFFECT



NOTES

J. Schuler Effect

1. This property is named after Maximillian Schuler, a German engineer, who solved the problem of oscillating shipboard compasses for the German Maritime Commission in the early 1900's.

a. The Schuler Effect can be described by the following properties and conditions.

(1) Any pivoted mass which is not perfectly balanced is a pendulum, this extends to include inertial platforms.

(2) A pendulum aligns with the local vertical when at rest, the pivot and C.G. being in line with the gravity vector.

(3) When the pendulum is accelerated in case 1:

(a) The acceleration is introduced to the pivot axis and moves it out of the gravity vector.

(b) The center of gravity lags behind.

(c) The pendulum axis intersects the gravity vector at a point below it (called the center of rotation) and forms an angle with the gravity vector.

(d) The linear acceleration has caused an angular acceleration of the pendulum.

(e) When the pendulum is established at a constant velocity, the pendulum mass tries to return to the vertical directly under the pivot axis but continually overshoots.

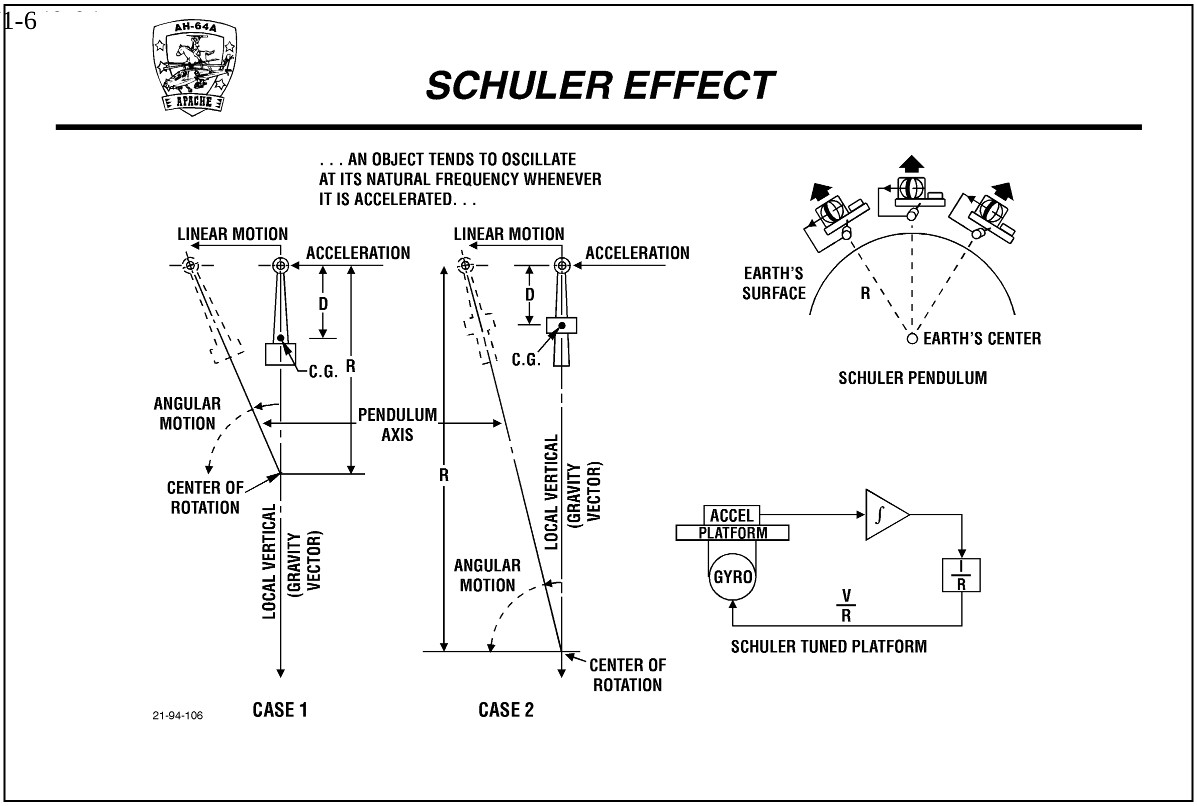
(4) The pendulum tends to oscillate at it's natural period of oscillation.

(5) This oscillation yields false accelerations and velocities in an inertial system.

(6) When the pendulum is accelerated in case 2:

(a) The pendulum mass is closer to the pivot axis causing the pendulum axis to intersect the gravity vector at a point farther below it and forming a smaller angle with the gravity vector.

(b) When the pendulum is established at a constant velocity it oscillates at a lower rate, due to the shift of the C.G., changing the natural period of oscillation.


SCHULER EFFECT
. . . AN OBJECT TENDS TO OSCILLATE
AT ITS NATURAL FREQUENCY WHENEVER
IT IS ACCELERATED. . .
LINEAR MOTION
ACCELERATION
D
R
C.G.
ANGULAR
MOTION
PENDULUM
AXIS
CENTER OF
ROTATION
LOCAL VERTICAL
(GRAVITY
VECTOR)
EARTH'S
SURFACE
EARTH'S CENTER
SCHULER PENDULUM
ACCEL
PLATFORM
GYRO
V
R
SCHULER TUNED PLATFORM
21-94-106
CASE 1
CASE 2

NOTES

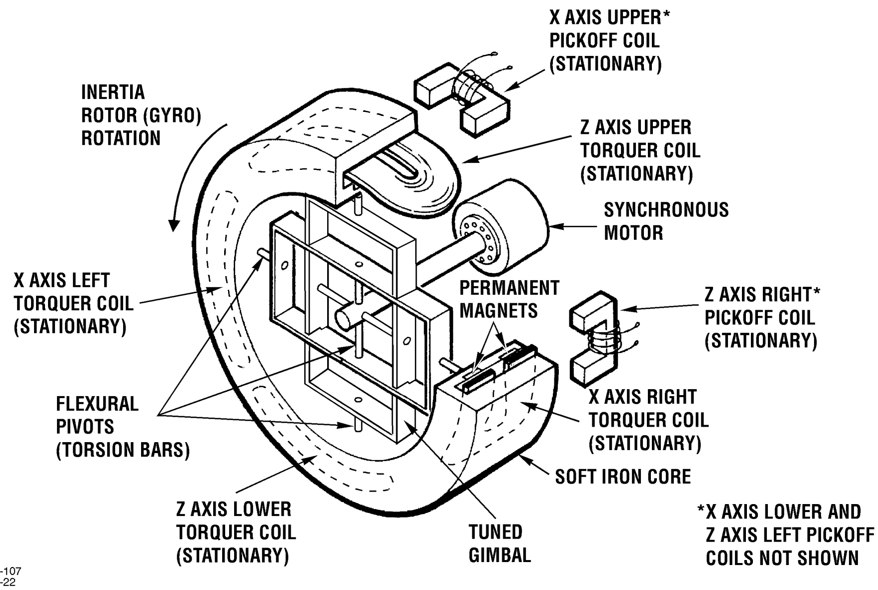
(c) If the pivot axis and C.G. are brought close enough together, the center of rotation coincides with the center of the earth.

(d) Once this pendulum is brought to static rest, accelerations exerted upon the pivot axis cannot cause the pendulums' axis to form an angle with the gravity vector.

(e) All horizontal accelerations cause the proper angular velocities to maintain the alignment of the pendulum axis with the gravity vector.

(f) The pendulum does not oscillate because of the Schuler Effect and impart erroneous accelerations and their related velocities into an inertial system.

STRAPDOWN GYRO



NOTES

K. Strap Down Gyro

1. Most conventional inertial navigation systems are large and heavy. These properties reduce the usable load that the vehicle may carry. The larger system consumes more power because of the size of the drive motors required to keep the platform stabilized. The large systems are prone to high error rates because of the moments involved in the platform. The gimbals of large platforms are in fact long levers that cause large torques to exist when the platform is displaced by vehicle motion. The drive motors have to overcome these large torques when stabilizing the platform to the level. The platform tends to overshoot the level position for the same reason.

2. The weight, power, and high error rates created by these characteristics can be reduced by utilizing a special type of gyro that is called a *Strapdown Gyro*. The gyro requires an inertial measuring unit processor (IMUP) to process the signals from the gyro to put them in a usable format.

3. Strap down gyro rotating components

   a. Synchronous motor

      (1) Powered by 3 phase AC power.

      (2) The inertia rotor and the tuned gimbal rotate at the same RPM as the resonate frequency of the tuned gimbal.

      (3) The frequency of the AC power is the same as the resonant frequency of the tuned gimbal. When disturbed by an outside force it causes the gyro to precess at the same rate as the RPM of the motor and keeps the precession in-phase with the disturbance.

   b. Tuned gimbal assembly

      (1) Flexural pivots (torsion bars)

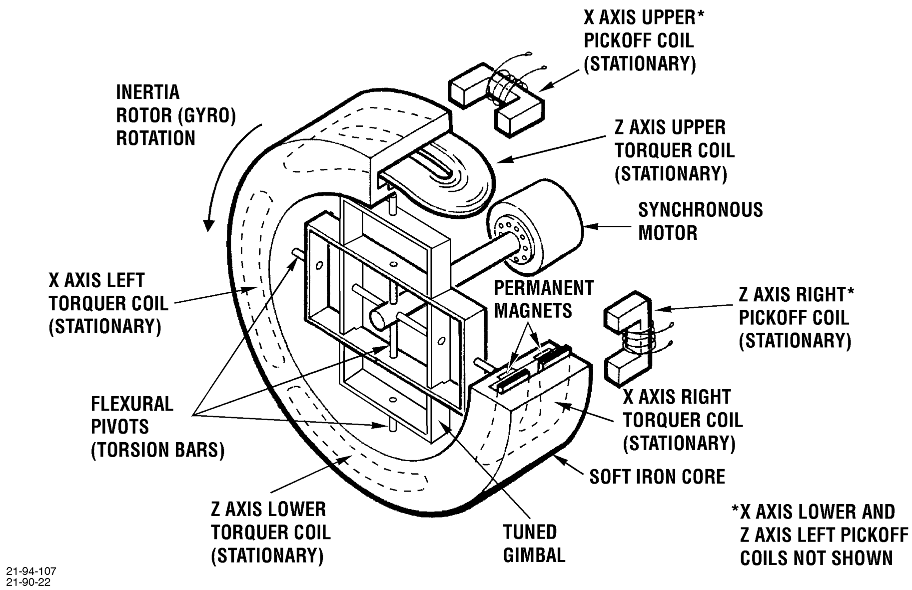
         (a) Connect the motor shaft to the tuned gimbal.

         (b) Connect the tuned gimbal to the inertia rotor.

         (c) In a strapdown gyro, the flexural pivots replace the gimbal pivot bearings that are found in standard gyros.

         (d) The flexural pivots in the gimbal are frictionless in their operation and minimize torque errors that are caused by bearing friction in standard gyro gimbals.

STRAPDOWN GYRO



NOTES

(2) Two gimbals

(a) Attached to the motor shaft via the flexural pivots.

(b) Attached to the motor via the flexural pivots.

(c) The second gimbal keeps the rotor from precessing due to rotor axis and motor shaft misalignment.

(3) Creates an infinitely complaint (flexible) universal joint.

(4) Allows the rotor complete angular freedom about the two gyro output axes and supports it against acceleration forces.

(5) Precesses easily when disturbed by an outside force, a desirable trait in strapdown gyro applications.

(6) Connects motor shaft rotation to the rotor so the rotor can be driven.

(7) Reduces the size of the gyro and further reduces the size of the inertial platform.

c. Inertia Rotor

(1) Provides the mass for gyroscopic operation.

(2) Consists of

(a) Permanent ring magnets, used to excite the magnetic pick off coils.

(b) A soft iron core

1) Main portion of the gyroscope rotating mass.

2) Eliminates magnetic torques.

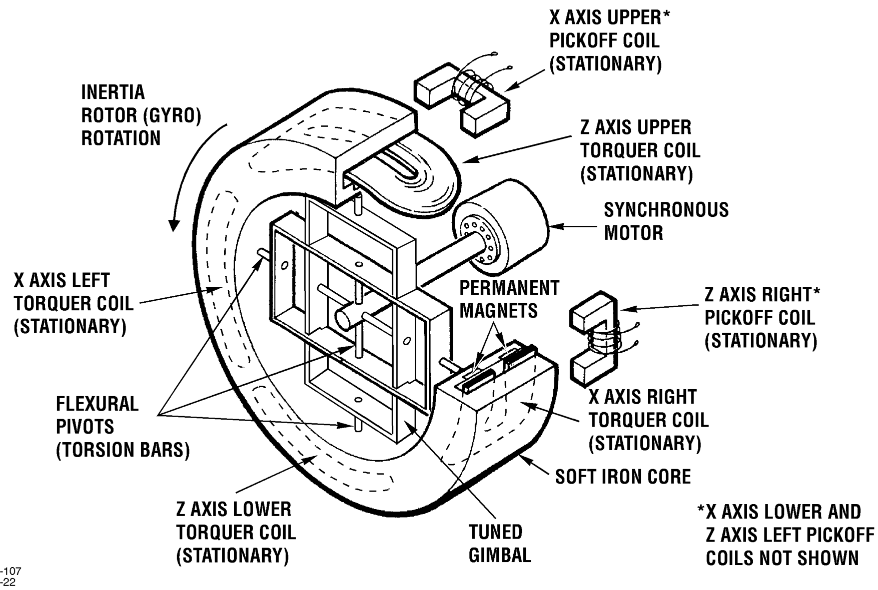
3) Provides mounting for the permanent ring magnets.

4) Has a circumferencial slot.

a) The permanent ring magnets are located next to the slot.

b) The stationary torquer coils fit into the slots.

STRAPDOWN GYRO



NOTES

4. Strap down gyro stationary components

a. Stationary pickoff coils

(1) There are four stationary pickoff coils arranged as two pairs.

(a) Two X axis coils mounted 180E apart near the top and bottom of the inertia rotor (the X axis coils become Y axis coils when the gyro is mounted at 90E to the X axis on the platform).

(b) Two Z axis coils mounted 180E apart near the left and right side of the inertia rotor.

(c) The pairs are mounted in the same plane (in phase) with the axis they serve.

(2) Each coil in a pair is one-half of a differential transformer for that axis. When the gyro is displaced by vehicle motion, the coil-pair senses the difference in the magnetic field strength of the permanent ring magnets due to different distances between the pickoffs and the permanent ring magnets in the rotor.

(3) The outputs are sent to

(a) The gyro re-balance loop circuitry to drive the stationary torquer coils the for that axis.

(b) The IMUP for processing into pitch, roll, and heading signals.

b. Stationary torquer coils

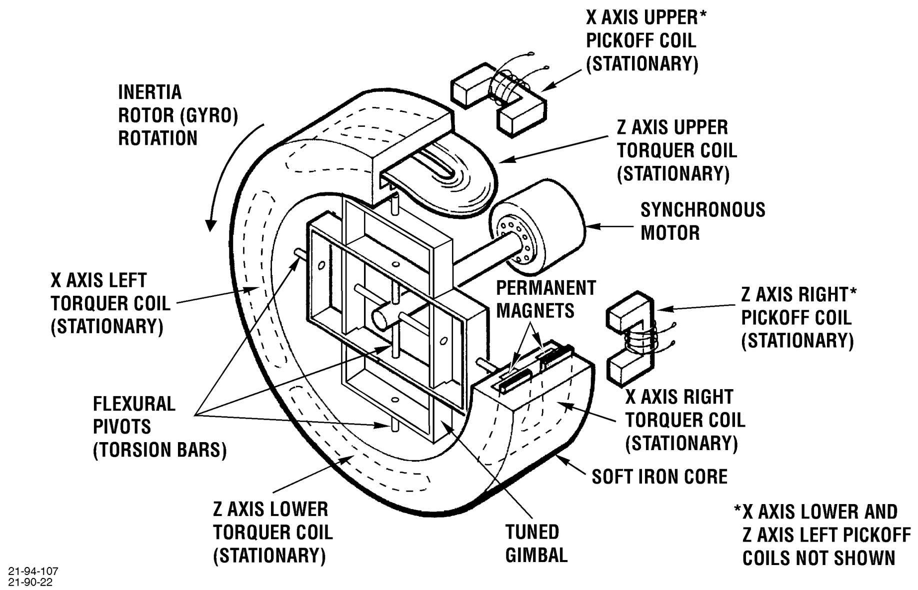
(1) There are four stationary torque coils arranged as two pairs.

(a) Two X axis TORQUER coils are mounted 180E apart near the left and right side of the inertia rotor and fit into the circumferencial slot of the rotor (the X axis coils become Y axis coils when the gyro is mounted at 90E to the X axis on the platform).

(b) Two Z axis TORQUER coils are mounted 180E apart near the top and bottom of the inertia rotor and fit into the circumferencial slot of the rotor.

(2) The pairs are mounted 90E to the plane (90E out of phase) with the axis they serve. This is necessary because the inertia rotor precessed back into position by a torquing magnetic field and it takes 90E for the torquing precession to occur.

STRAPDOWN GYRO



NOTES

(3) When torquer current is applied to an individual pair, the pair becomes an electrically controllable electro-magnet.

(a) The magnetic fields of the torquer pair work in relation to the magnetic fields of the permanent ring magnets in the rotor.

(b) When the gyro is displaced by vehicle motion the magnetic fields of the torquer coils and the permanent ring magnets are no longer in the same plane.

1) Where the fields of the torquer and ring magnets are of the same polarity, they attract.

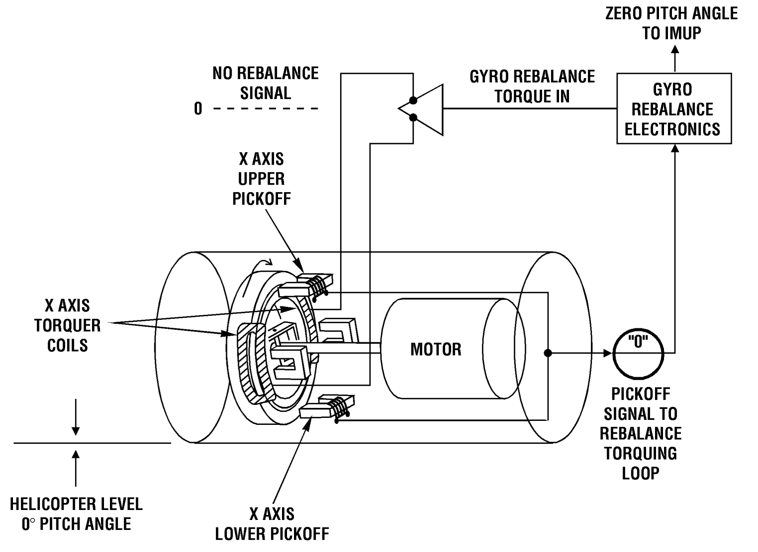
2) Where the fields of the torquer and ring magnets are of opposite polarity, they repel.

3) The magnetic fields place a "torque" on the rotor and cause it to precess on the gimbals until the magnetic fields of the torquer coils and the permanent ring magnets ARE in the same plane.

(4) Under operating conditions, the rotor restoring loop (torquing) rate is on the order of 200E per second for modern strapdown gyros. Traditional gimbaled gyro torquing rates are on the order of only 3/4E per second.

(5) The current inputs to the torquer coils are from the gyro re-balance loop circuitry.

STRAPDOWN GYRO NO PITCH INPUT



NOTES

5. Strap down gyro operation

   a. No pitch input

      (1) With the gyro level and the inertia rotor turning:

         (a) The X axis stationary pickoff coils pairs are at equal distances from the permanent ring magnets in the rotor.

         (b) The strength of the magnetic fields sensed by the pickoff coils is equal.

         (c) The pickoff signal to the gyro re-balance electronics is zero.

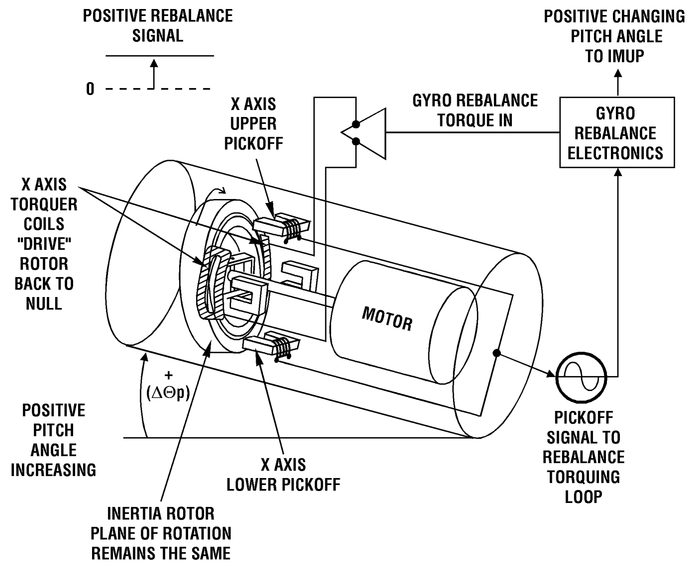
      (2) The gyro re-balance electronics sends a zero torque signal to the X axis torquer.

      (3) The polarities of the permanent ring magnets and the torquer coils provide zero torque to the rotor.

      (4) The inertia rotor continues to rotate in the same plane.

      (5) The gyro re-balance electronics sends a zero pitch angle signal to the IMUP.

STRAPDOWN GYRO POSITIVE PITCH INPUT



21-94-109

NOTES

b. Positive pitch input

(1) When a positive pitch input is applied to the gyro case, it moves upward in relation to the inertia rotor which continues to rotate in the same plane because of gyroscopic effect.

(2) The case mounted X axis stationary pickoff and torquer coils are now at a positive angle to the gimbal mounted rotor.

(a) The X axis stationary pickoff coils are now at unequal distances from the permanent ring magnets in the rotor.

(b) The strength of the magnetic fields sensed by the pickoff coils is unequal.

1) The field sensed by the lower pickoff coil is stronger because it is now closer to the permanent ring magnets in the rotor.

2) The field sensed by the upper pickoff coil is weaker because it is now farther from the permanent ring magnets in the rotor.

(c) The pickoff signal to the gyro re-balance electronics is a positive phase signal.

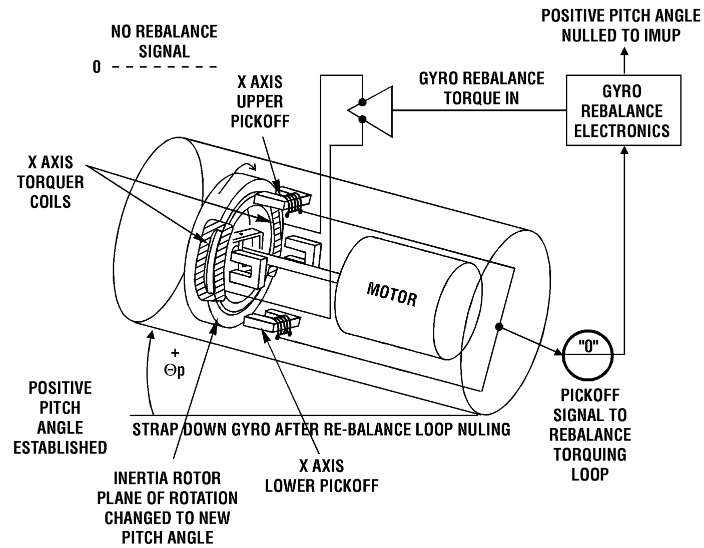
(3) The gyro re-balance electronics sends a positive torque signal to the X axis torquer.

(4) The polarities of the permanent ring magnets and the torquer coils are no longer in the same plane and they provide magnetic torque to the rotor.

(5) The inertia rotor begins to precess in the positive direction to the new positive plane of rotation.

(6) The gyro re-balance electronics sends a positive changing pitch angle signal to the IMUP.

STRAPDOWN GYRO NULLED AT POSITIVE PITCH ANGLE



NOTES

c. Nulled at positive pitch angle

(1) With the gyro case established at the positive pitch angle the inertia rotor continues to precess until it reaches the new positive plane of rotation.

(2) When the inertia rotor reaches the new plane of rotation:

(a) The X axis stationary pickoff coils are again at equal distances from the permanent ring magnets in the rotor. The magnetic torque on the rotor has caused it to align with the magnetic fields of the torquer coils.

(b) The strength of the magnetic fields sensed by the pickoff coils is equal.

(c) The pickoff signal to the gyro re-balance electronics is zero.

(d) The gyro re-balance electronics sends a zero torque signal to the X axis torquer.

(e) The polarities of the permanent ring magnets and the torquer coils provide zero torque to the rotor.

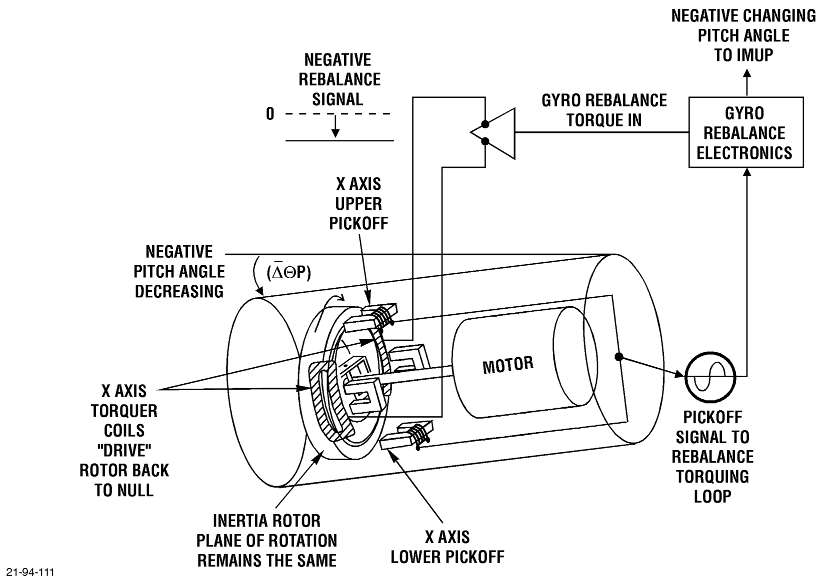
(3) The inertia rotor continues to rotate in the new positive plane of rotation.

(4) The gyro re-balance electronics sends a zero pitch angle signal to the IMUP.

(a) The zero pitch angle signal lets the IMUP know that the gyro has been re-torqued to the new positive pitch angle and that the IMUP can now store the positive pitch angle in the IMUP memory.

(b) The IMUP continues to use this stored positive pitch angle value in it's calculations UNTIL a new pitch change is detected by the gyro re-torque electronics.

STRAPDOWN GYRO
NEGATIVE PITCH INPUT



NOTES

d. Negative pitch input

(1) When a negative pitch input is applied to the gyro case, it moves downward in relation to the inertia rotor which continues to rotate in the same plane because of gyroscopic effect.

(2) The case mounted X axis stationary pickoff and torquer coils are now at a negative angle to the gimbal mounted rotor.

(a) The X axis stationary pickoff coils are now at unequal distances from the permanent ring magnets in the rotor.

(b) The strength of the magnetic fields sensed by the pickoff coils is unequal.

1) The field sensed by the upper pickoff coil is stronger because it is now closer to the permanent ring magnets in the rotor.

2) The field sensed by the lower pickoff coil is weaker because it is now farther from the permanent ring magnets in the rotor.

(c) The pickoff signal to the gyro re-balance electronics is a negative phase signal.

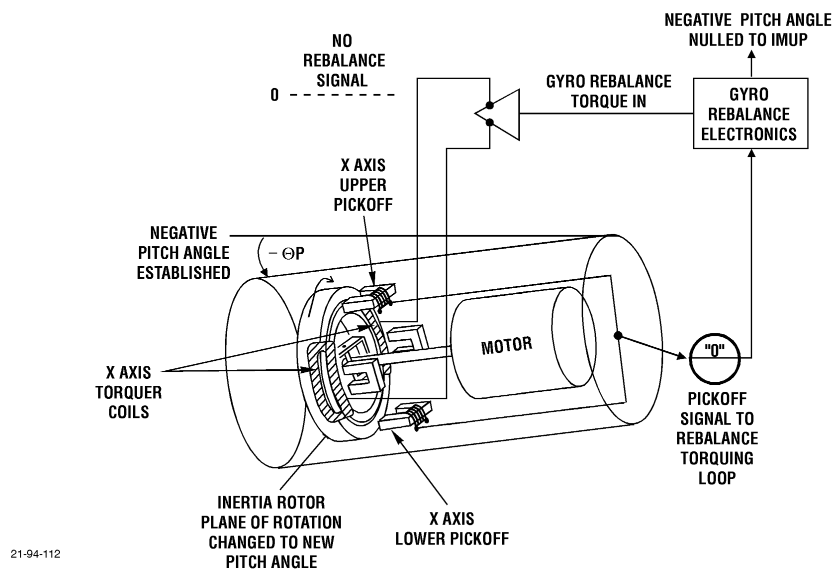
(3) The gyro re-balance electronics sends a negative torque signal to the X axis torquer.

(4) The polarities of the permanent ring magnets and the torquer coils are no longer in the same plane and they provide magnetic torque to the rotor.

(5) The inertia rotor begins to precess in the negative direction to the new negative plane of rotation.

(6) The gyro re-balance electronics sends a negative changing pitch angle signal to the IMUP.

STRAPDOWN GYRO
NULLED AT NEGATIVE PITCH ANGLE



NOTES

e. Nulled at negative pitch angle

(1) With the gyro case established at the negative pitch angle the inertia rotor continues to torque until it reaches the new negative plane of rotation.

(2) When the inertia rotor reaches the new negative plane of rotation:

(a) The X axis stationary pickoff coils are again at equal distances from the permanent ring magnets in the rotor. The magnetic torque on the rotor has caused it to align with the magnetic fields of the torquer coils.

(b) The strength of the magnetic fields sensed by the pickoff coils is equal.

(c) The pickoff signal to the gyro re-balance electronics is zero.

(d) The gyro re-balance electronics sends a zero torque signal to the X axis torquer.

(e) The polarities of the permanent ring magnets and the torquer coils provide zero torque to the rotor.

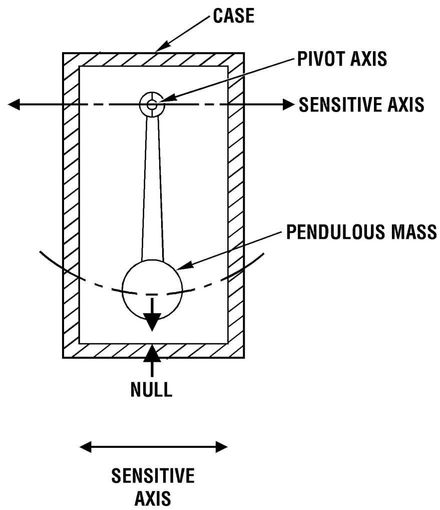
(3) The inertia rotor continues to rotate in new negative plane of rotation.

(4) The gyro re-balance electronics sends a zero pitch angle signal to the IMUP.

(a) The zero pitch angle signal lets the IMUP know that the gyro has been re-torqued to the new negative pitch angle and that the IMUP can now store the negative pitch angle in the IMUP memory.

(b) The IMUP continues to use this stored negative pitch angle value in it's calculations UNTIL a new pitch change is detected by the gyro re-torque electronics.

PENDULUM ACCELEROMETER



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NOTES

L. Pendulum accelerometer

1. Accelerometers are the basic sensing elements in inertial navigation that allow a vehicle to operate and accurately travel to a destination without the need for outside navigation aids.

2. Pendulum accelerometers serve the same function as linear accelerometers, are extremely compact, and lend themselves to miniaturization.

3. As with linear accelerometers, the detected acceleration is used to obtain velocity from the first integral and distance traveled from the second integral by using basic calculus.

4. A basic pendulum accelerometer consists of a pendulous mass and a case.

   a. The case limits the freedom of motion of the mass to a single axis called the sensitive axis.

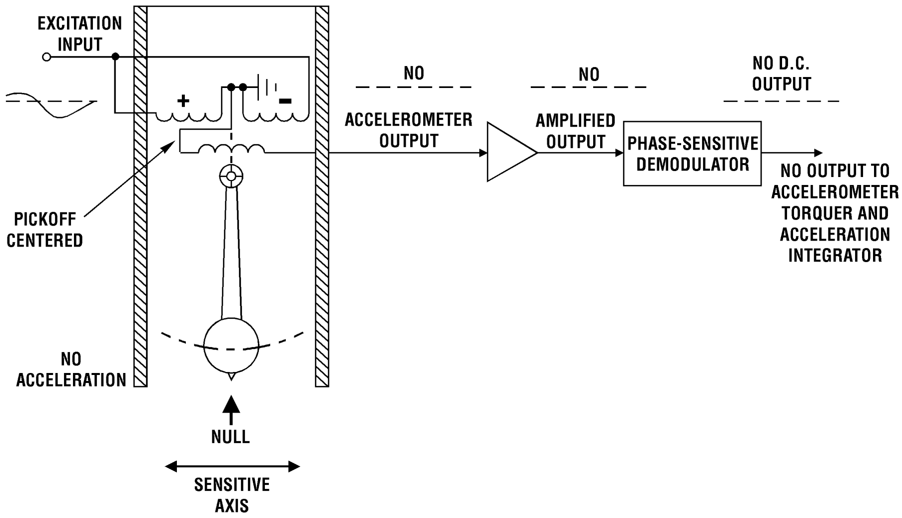
      (1) The mass is free to move inside the case on it's pivot axis along the sensitive axis.

      (2) The sensitive axis is the direction along which acceleration can be detected.

      (3) The case can be fluid filled to dampen the oscillations that pendulum accelerometers are subjected to. The specific gravity if the fluid is chosen carefully to match the mass of the pendulum, so the mass floats and minimizes friction on the pivot-jewel bearings. These steps all add to the sensitivity of the accelerometer.

   b. No accelerations can be detected from any force applied in the insensitive plane.

PENDULUM ACCELEROMETER OPERATION - NO ACCELERATION



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NOTES

5. To make the basic accelerometer usable in a practical situation, a way of sensing the mass's travel in relation to the case must be provided. As in gyro angle sensing, excitation and pick off coils can be used.

M. Pendulum accelerometer operation

1. No acceleration

a. An AC excitation voltage is applied to the two 180E out of phase excitation windings.

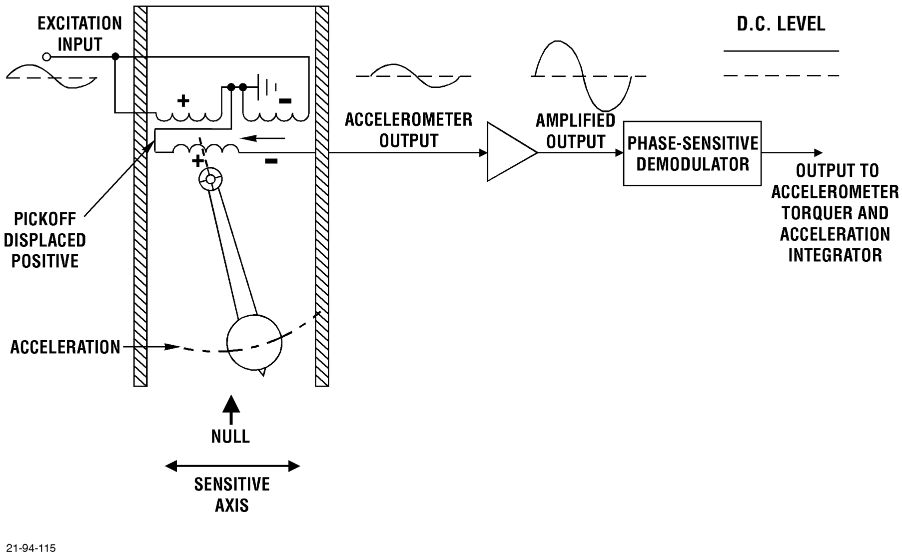
b. The mass is centered, which centers the pickoff coil.

(1) The pickoff coil output is zero.

(2) The amplified output is zero.

c. The phase sensitive demodulator output to the accelerometer torquer and acceleration integrator is zero.

PENDULUM ACCELEROMETER OPERATION - ACCELERATION



NOTES

2. Acceleration

a. When an acceleration is INITIALLY applied to an accelerometer, the force is applied to the case which is mounted to the vehicle.

(1) The mass tends to stay at rest.

(2) This causes rotation and displacement to occur between the initial and current position of the mass, excitation, and pickoff coils.

b. As the acceleration constant value is reached and is maintained:

(1) The case continues to be accelerated at the constant rate applied to the vehicle.

(2) The rotation of the mass and displacement of the excitation and pickoff coils continue until a balance exists between the mass and the acceleration applied to it. The force acting on the mass at this displacement is equal to the acceleration force and prevents further movement of the case in relation to the mass.

(3) The non-rotating angular displacement between the case and mass is a measure of the acceleration that the accelerometer is presently subjected to.

c. The displacement between the excitation and pickoff coil is the electrical measure of the acceleration applied to the accelerometer.

(1) In this case, the + REFERENCE excitation winding has moved CLOSER to the pickoff winding.

(a) A + pickoff signal is generated.

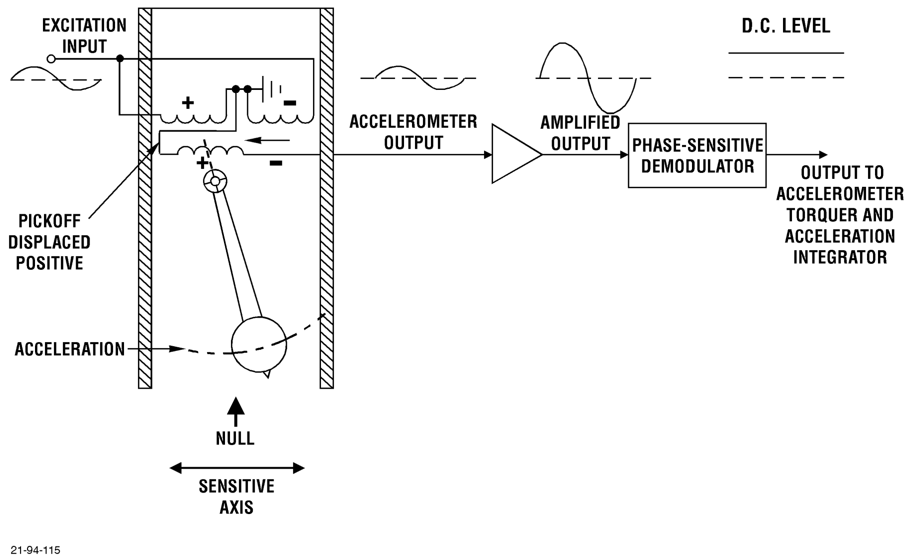
(b) It is in-phase with the excitation signal.

(c) The amplitude (height) of the signal indicates how far the gyro case has moved.

(2) The phase sensitive demodulator output to the accelerometer torquer and acceleration integrator is a D.C. level proportional to the applied acceleration.

d. The velocity of the vehicle continues to increase as long as the acceleration remains constant.

PENDULUM ACCELEROMETER OPERATION - ACCELERATION



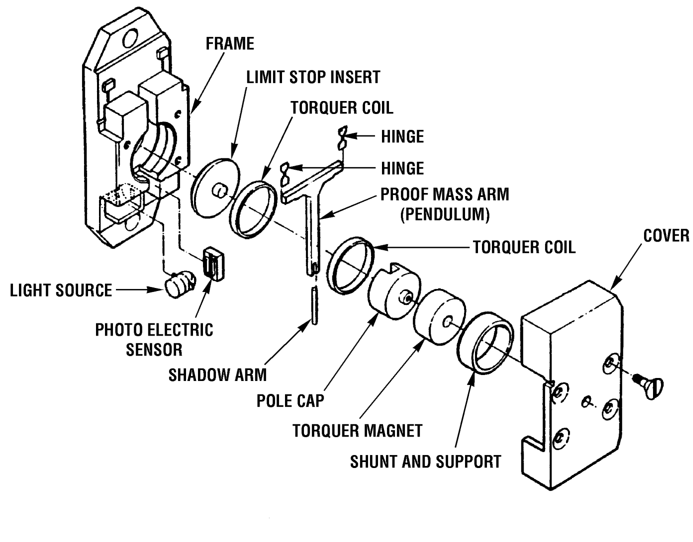
NOTES

3. If the acceleration force is removed from the vehicle:

   a. The acceleration is removed from the accelerometer case and mass. The mass centers as the acceleration decreases and the vehicle attains a constant velocity.

   b. The displacement between the case and mass returns to zero, indicating the zero acceleration state.

STRAPDOWN ACCELEROMETER (PENDULUM TYPE)



NOTES

N. Strapdown accelerometer

1. A strapdown accelerometer is a dry electro-mechanical pendulum accelerometer with a restoring loop with the advantages of small size, light weight, increased sensitivity (10^{-6} g) and a DC output which does not require an AC to DC converter and simplifies the acceleration measurement process.

2. Strapdown accelerometer components

   a. Frame

      (1) Rigid structure that supports and holds the proof mass and it's sensitive axis in precise alignment with the navigation platform.

      (2) Provides mounting for the pickoff and torquer magnets.

   b. Hinges - join the proof mass to the frame in a frictionless connection.

   c. Proof mass assembly

      (1) Proof mass arm - is the basic mass in the strapdown accelerometer.

      (2) Shadow arm - attaches to the proof mass arm and is the mask that controls the amount of light that the pickoff detector detects.

      (3) Two torquer coils - as controlled by re-balance electronics, the coils work in relation to the permanent magnets to return the proof mass arm and shadow arm to the null position when the accelerometer has an acceleration applied.

      (4) Under operating conditions, the proof mass arm and shadow arm motion are MINIMIZED by optimized servo action, keeping the pendulum close to the zero point where the response is linear.

      (5) The amount of current required to keep the pendulum centered is proportional to the acceleration.

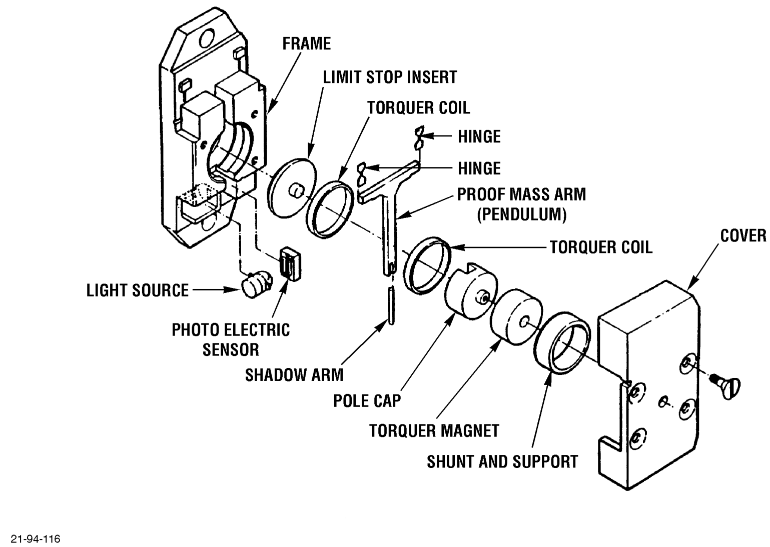
   d. Torquer magnet assembly

      (1) Torquer mass - provides the magnetic fields that the torquer coils work in relation to, in order to keep the proof mass centered.

      (2) Pole cap - orients the poles of the magnet.

      (3) Shunt and support - compensates for the temperature sensitivities of the magnet.

STRAPDOWN ACCELEROMETER (PENDULUM TYPE)



NOTES

e. Pickoff

(1) Detects the amount of acceleration.

(2) Light source - is a highly reliable solid-state emitter.

(3) Detector

(a) Is a highly reliable, dual element, solid-state photo electric sensor.

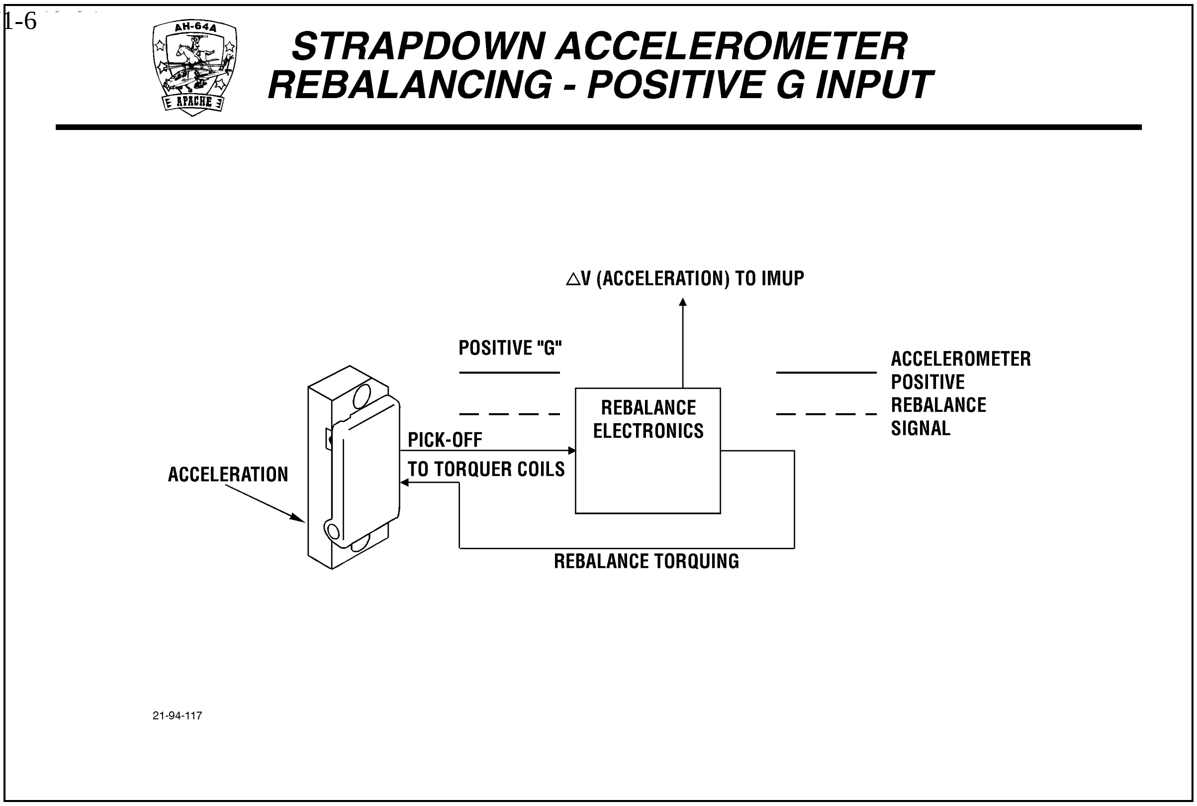
1) One element detects positive "G"

2) The other element detects negative "G"

(b) The strapdown accelerometer detector produces DC directly and does not need AC excitation or demodulation circuitry.

1) This saves space and weight.

2) Also allows acceleration to be measured by a microprocessor without the need for complex excitation and conversion circuits.


AH-64A
APACHE
STRAPDOWN ACCELEROMETER
REBALANCING - POSITIVE G INPUT
△V (ACCELERATION) TO IMUP
POSITIVE "G"
ACCELEROMETER
POSITIVE
REBALANCE
SIGNAL
REBALANCE
ELECTRONICS
PICK-OFF
TO TORQUER COILS
ACCELERATION
REBALANCE TORQUING
21-94-117

NOTES

O. Strapdown accelerometer re-balancing - positive "G" input

1. Acceleration

a. Initially, the proof mass and shadow arm are centered in the accelerometer frame, causing the light from the light source to be equally present on both the positive and negative "G" portions of the dual channel detector.

b. When an acceleration is applied to an accelerometer, the force is applied to the case which is mounted to the vehicle.

(1) The proof mass tends to stay at rest.

(2) This causes a rotation of the proof mass and shadow arm and displacement to occur between the initial and current position of shadow arm and the dual channel pickoff detector in the positive direction.

(3) More of the light is allowed to come in contact with the positive side of the dual channel detector.

(4) The dual channel detector sends a positive "G" pickoff DC voltage signal to the accelerometer re-balance electronics.

(5) The re-balance electronics sends a positive torque signal to the accelerometer torquer coils to create a magnetic field.

(6) The polarities of the torquer magnet and the torquer coils interact and provide magnetic torque to restore the proof mass to it's null position.

(7) The amount of current required to keep the proof mass in it's null position corresponds to the "G" force acting on the accelerometer.

c. The re-balance electronics sends the change in velocity (acceleration) to the IMUP.

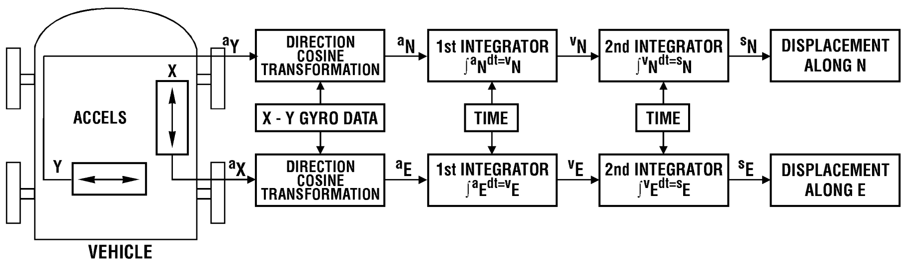
2. If the acceleration force is removed from the vehicle:

a. The acceleration is removed from the accelerometer case. The restoring force is now greater than the acceleration force and causes the proof mass to displace in the opposite direction.

b. The re-balance electronics sends a negative torque signal to the accelerometer torquer coils to create a magnetic field of the opposite polarity and drive the proof mass back to null.

c. When null is reached the re-balance electronics sense the null position and remove the re-balance torque.

STRAPDOWN TWO AXES INERTIAL SYSTEM



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NOTES

P. Strapdown two axes inertial system

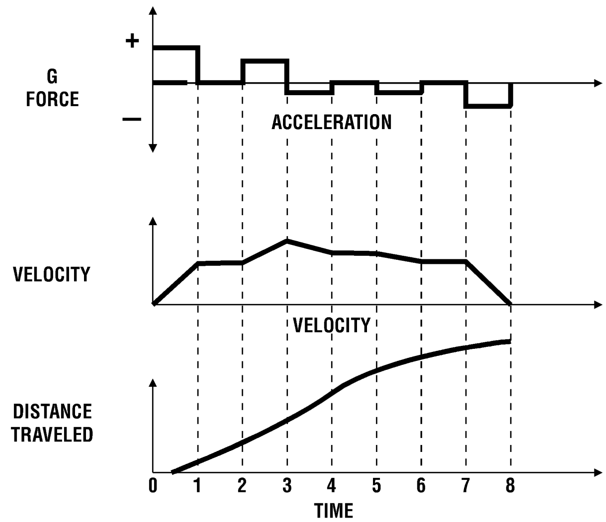
1. In a two axes strapdown inertial system the accelerometers and gyros are effectively strapped down to the vehicle x and y axes.

   a. In a conventional inertial system the platform is oriented to level and points to true north.

   b. In a strapdown inertial system the platform gyros precessions and accelerations from the accelerometers are measured during alignment and are resolved by the IMUP into grid north and south.

   c. The IMUP takes the place of the gimbaled platform in a strapdown inertial system.

ACCELERATION AND INTEGRATED SIGNALS



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NOTES

Q. Acceleration integration signals

1. The acceleration force is dependent on the motion of the vehicle and can:

   a. Be a positive acceleration.

   b. Be zero

      (1) The vehicle is at rest.

      (2) The vehicle is traveling at a constant velocity.

   c. Be a negative acceleration (deceleration).

2. Velocity is dependent on acceleration.

   a. The velocity is zero if no acceleration has occurred.

   b. As positive acceleration occurs, velocity increases.

   c. As the acceleration drops to zero, the velocity attains a constant rate.

   d. If a negative acceleration occurs, the velocity decreases.

   e. If the vehicle continues to decelerate the velocity becomes zero.

3. Distance traveled is dependent on acceleration and velocity.

   a. If no acceleration has occurred, the velocity is zero and no distance is traveled.

   b. As positive acceleration occurs, velocity increases and distance is traveled by the vehicle.

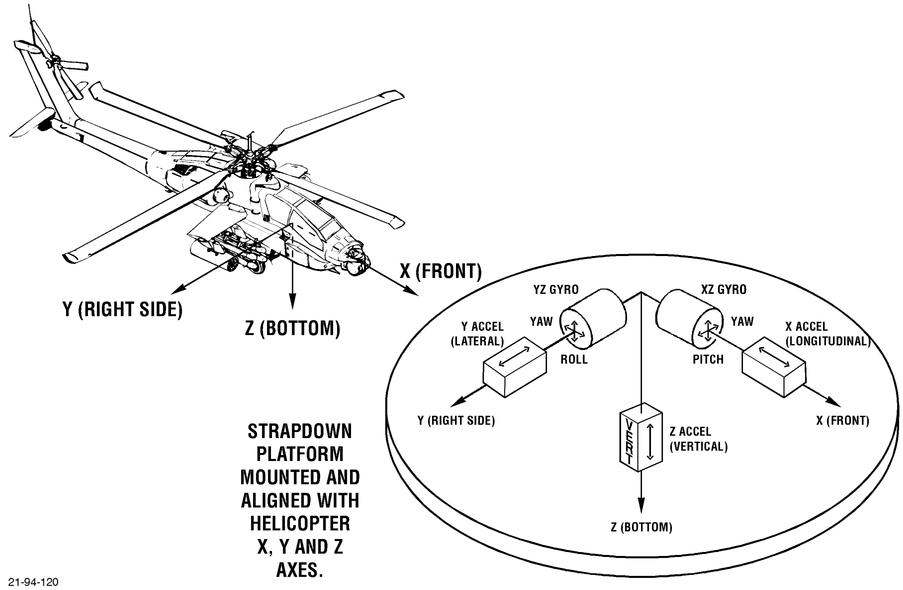
   c. If a higher positive acceleration occurs, velocity increases again and distance is traveled at a higher rate.

   d. If the acceleration drops to zero, the velocity attains a constant rate and the distance traveled continues at that rate of velocity.

   e. If a negative acceleration occurs, the velocity decreases and the rate at which the distance is traveled decreases.

   f. If the vehicle continues to decelerate, the velocity becomes zero and the distance traveled stops and remains at that value.

STRAPDOWN INERTIAL REFERENCE SYSTEM



NOTES

R. Strapdown inertial reference system

1. In a three axes strapdown inertial system

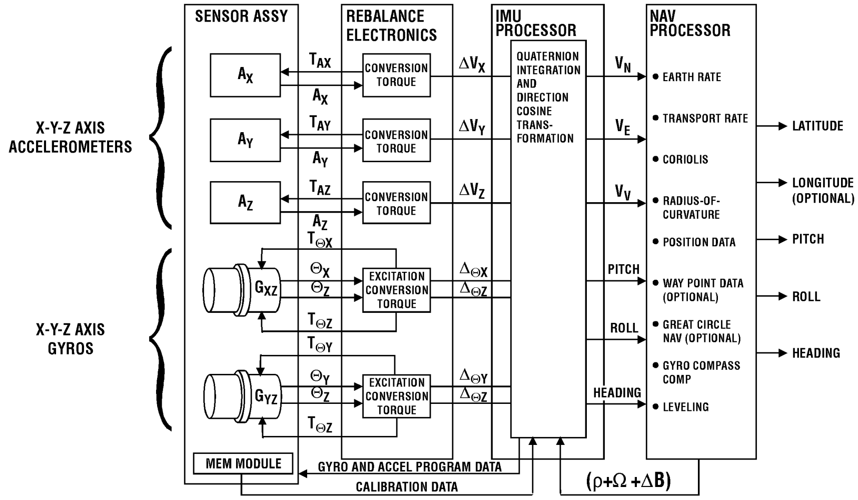
a. The accelerometers and gyros are effectively strapped down to and aligned with the vehicle X, Y, and Z axes.

b. Each axis is monitored by a gyro axis and an accelerometer.

c. The Z axis in the Y-Z gyro is redundant.

d. The alignment of the strap down inertial platform to the airframe is critical, as any misalignment causes acceleration errors to be sent to the IMUP and erroneous velocity, distance traveled, and heading information could result.

STRAPDOWN SYSTEM BLOCK DIAGRAM



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NOTES

S. Strapdown system block diagram

1. A complete inertial navigation system consists of the following.

a. Sensor assembly

(1) Contains the gyros and accelerometers on a strapdown platform.

(2) Detects and sends angular displacement signals from the gyros to the re-balance electronics.

(3) Detects and sends acceleration signals from the accelerometers to the re-balance electronics.

(4) Memory core plane sends gyro and accelerometer system calibration data to the IMUP.

(5) Receives the proper spin frequency signal for each gyro from the IMUP, converts and applies them to the synchronous, 3-phase, gyro drive motors. This ensures that each gyro gimbal is infinitely compliant (frictionless).

b. Re-balance electronics

(1) Contains and provides:

(a) Circuitry for the pickoff excitation, pickoff signal conversion, and torquing of each gyro.

(b) Circuitry for the pickoff signal conversion and torquing of each accelerometer.

(2) Sends:

(a) Changes in the angular displacement of the gyros from the conversion circuits to the inertial measuring processor (IMUP).

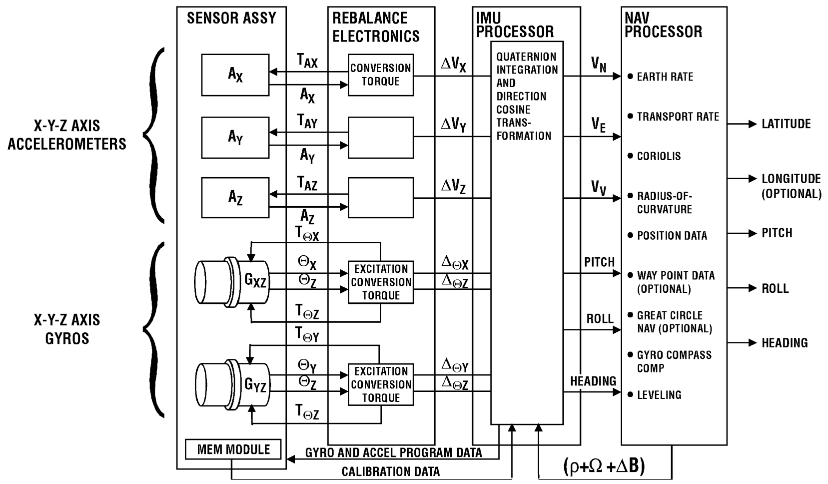
(b) Changes in velocity (acceleration) from the conversion circuits to the inertial measuring processor (IMUP).

c. Inertial measuring processor (IMUP)

(1) Uses cosine transformation to convert the three axis acceleration signals into north-south and vertical velocity signals.

(2) Converts the angular displacement signals into pitch, roll, and heading information.

STRAPDOWN SYSTEM BLOCK DIAGRAM



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NOTES

(3) Sends the information to the NAV processor.

(4) Receives gyro and accelerometer calibration data from the sensor assembly memory.

(a) Calculates the proper spin frequency for each gyro to match it to the tuned gimbal resonant frequency.

(b) Sends it back to the sensory assembly for conversion to 3-phase motor drive voltages.

d. NAV processor

(1) Receives:

(a) 3 axis velocity information from the IMUP.

(b) Pitch, roll, and heading information from the IMUP.

(c) Receives present "position data" as entered by the operator prior to the alignment mode.

(2) Alignment (gyro-compassing) operation

(a) When the strapdown inertial system is placed in the align mode, the system measures initial pitch and roll angles from accelerometer data.

(b) Computes the level platform from these values.

(c) Monitors the pitch and roll rates with the X axis at 0E and at 180E position by using a turntable that rotates the platform about the yaw axis at 0 degrees for a given time, then at 180 degrees for the same period of time during the alignment phase. During the inertial operate mode the platform is strapped down as previously described.

1) This measures earth rate.

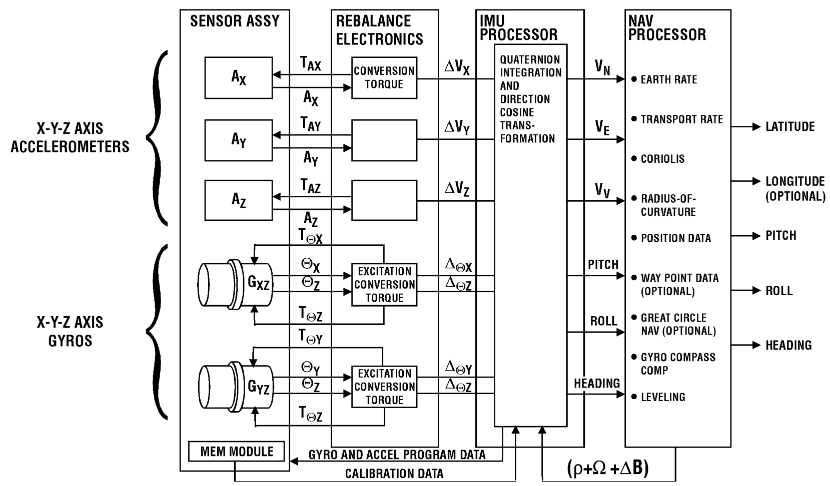
a) The rate a which the earth rotates around it's own polar axis.

b) 15.041088 degrees per hour.

2) It also measures gyro drift.

(d) Initial pitch, roll, heading angle, and gyro biases are now known.

STRAPDOWN SYSTEM BLOCK DIAGRAM



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NOTES

(e) The turntable rotates back to the 000E position.

(f) The NAV processor outputs the current heading information and sends a heading valid signal to pull the heading and attitude flags from view.

(g) The platform is now aligned.

e. Inertial operation

(1) Once the platform is aligned it must be manually switched to the operate mode. In the operate mode the NAV processor continuously corrects the outputs for the following.

(a) Earth rate (Ω)

(b) Transport rate (ρ)

(c) Coriolis acceleration

1) Coriolis acceleration is a deflecting force caused by the rotation of the earth that is exerted on a moving object and causes it to move to the right of course in the northern hemisphere.

2) Coriolis acceleration causes the object to move to the left of course in the southern hemisphere.

(d) Schuler effect

(2) Once the vehicle is placed in motion, accurate doppler velocities are received from the lightweight doppler navigation system (LDNS) via the MUX bus and are used to dampen the inertial system velocities.

(a) The stabilization of the inertial system makes the entire system (doppler/inertial) more accurate than either system by themselves.

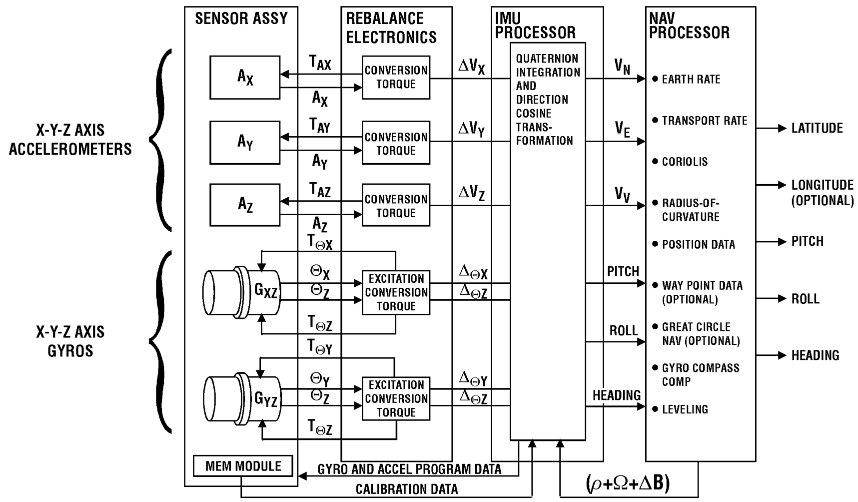
(b) The doppler velocities are applied to stabilize the inertial velocities through part of a computer program called Kalman Filtering.

(c) Kalman Filtering

1) A software program that uses statistical probability and modeling equations to do a computed estimate of the systems errors.

2) These errors are computed in the "state" equations.

STRAPDOWN SYSTEM BLOCK DIAGRAM



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NOTES

3) The state equations are formulated by a process of "updating" whenever measurements are made from an external source, or in between these external measurements by extrapolating them through time.

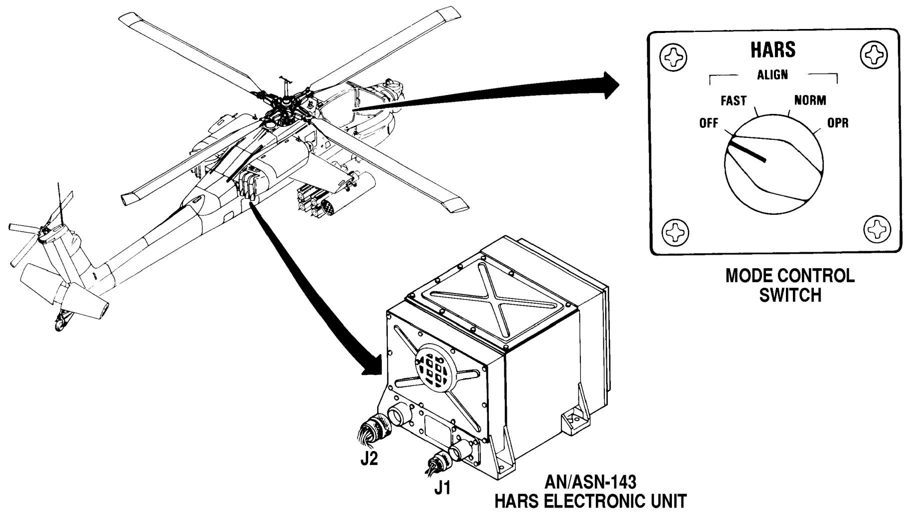
(3) The NAV processor continuously computes latitude and longitude from the north-south and east-west velocities.

(a) The NAV processor calculates the second integral of acceleration, which is distance traveled.

(b) The distance traveled is scaled to nautical miles which also represent latitude and longitude in minutes of arc.

(4) The NAV processor sends earth rate, transport rate, and gyro drift back to the IMUP to update the calculations.

HARS LOCATION



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NOTES