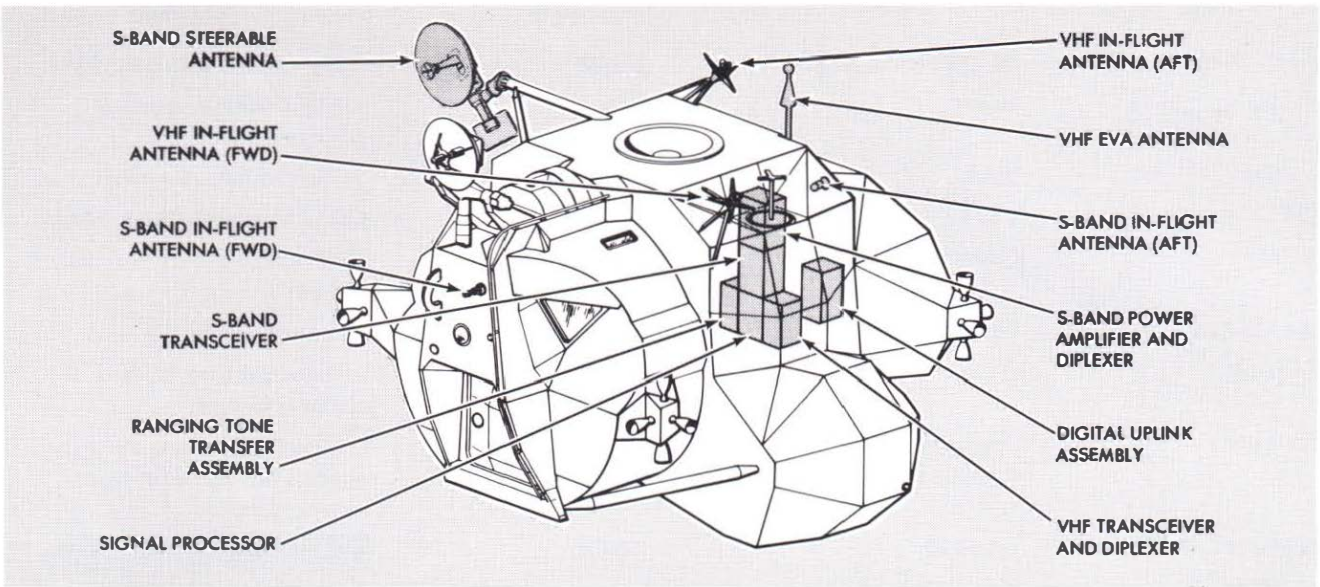
COMMUNICATIONS

QUICK REFERENCE DATA

RF electronic equipment	
S-band transceiver assembly	
Frequency	
Transmit	2282.5 mHz (downlink)
Receive	2101.8 mHz (uplink)
Output power	0.75 watts (minimum)
Input power requirement	36 watts
Application	LM-MSFN communications
S-band power amplifiers	
Frequency	2282.5 mHz
Output power	
Primary amplifier	18.6 watts (minimum)
Secondary amplifier	14.8 watts (minimum)
Input power requirement	72 watts
Application	Amplify S-band transmitter output
VHF transceiver assembly	
Frequency	
Channel A	296.8 mHz
Channel B	259.7 mHz
Output power	5.0 watts
Input power requirement	
VHF A transmitter	30 watts
VHF A receiver	1.2 watts
VHF B transmitter	31.7 watts
VHF B receiver	1.2 watts
Application	LM-CSM and LM-EVA communications
Signal-processing equipment	
Signal processor assembly	
Input power requirement	12.7 watts
Application	Switching center for most signals in the Communications Subsystem
Digital uplink assembly	
Input power requirements	12.5 watts
Application	Processes MSFN signal to update LM guidance computer and provides MSFN voice backup
Ranging tone transfer assembly	
Input power requirements	5.0 watts
Application	Provides CSM-LM ranging in conjunction with VHF transceiver assembly
Microphones	Noise-cancelling, dynamic
Headsets	Dual muff (suits) Ear plug (lightweight)

Signal-processing equipment (cont)

Television camera	
Bandwidth	10 Hz to 500 kHz
Scan	10 fps, 320 lines
	5/8 fps, 1,280 lines
Input power requirement	7.5 watts
Antenna equipment	
S-band steerable antenna	
Operating frequency	
Transmit	2282.5 mHz
Receive	2101.8 mHz
Type	Cross-sleeved dipoles over ground plane with parabolic reflector
Slew movement	
Azimuth	174°
Elevation	330°
S-band in-flight antennas	
Operating frequency	
Transmit	2282.5 mHz
Receive	2101.8 mHz
Type	Omnidirectional, right-hand circularly polarized
VHF In-flight antennas	
Operating frequency	259.7 and 296.8 mHz
Type	Omnidirectional, right-hand circularly polarized
VHF EVA antenna	
Operating frequency	259.7 to 296.8 mHz
Type	Omnidirectional, conical, 8-inch monopole with 12-inch radials



R-98

Major Communications Equipment Locations

The Communications Subsystem (CS) provides in-flight and lunar surface communications links between the LM and CSM, the LM and MSFN, and the LM and the extravehicular astronaut (EVA). When both astronauts are outside the LM, the LM relays communications between the astronauts and MSFN. When the astronauts are in the Lunar Roving Vehicle (LRV), the Lunar Communications Relay Unit (LCRU), mounted on the LRV, is the communications relay. The CS consists of S-band and VHF equipment.

IN-FLIGHT COMMUNICATIONS

In flight, when the LM is separated from the CSM and is on the earth side of the moon, the CS provides S-band communications with MSFN and VHF communications with the CSM. When the LM and the CSM are on the far side of the moon, VHF is used for communications between them.

EARTH SIDE (LM-MSFN)

In-flight S-band communications between the LM and MSFN include voice, digital uplink signals, and ranging code signals from MSFN. The LM S-band equipment transmits voice, acts as transponder to the ranging code signals, transmits biomedical and systems telemetry data, and provides a voice backup capability and an emergency key capability.

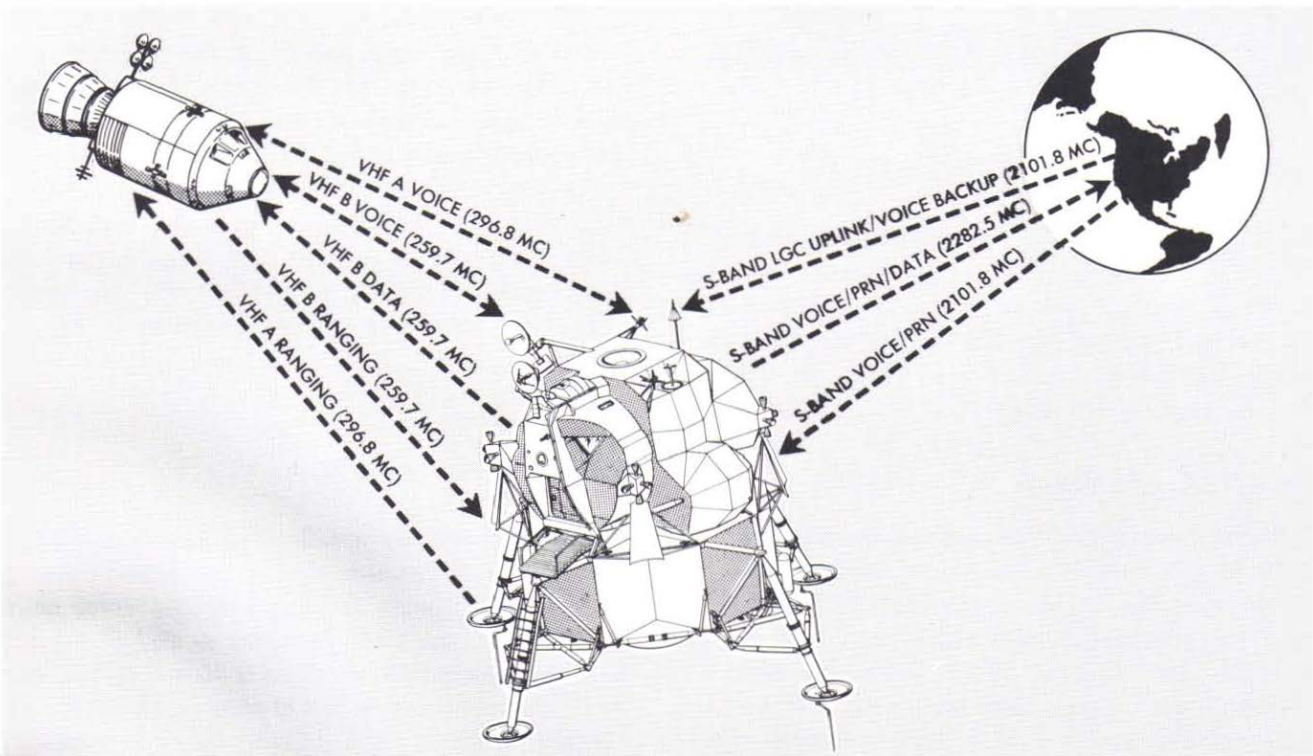
S-band voice is the primary means of communication between MSFN and the LM. Backup voice communication from MSFN is possible, using the digital uplink assembly, but this unit is normally used by the MSFN to update the LM guidance computer. In response to ranging code signals sent to the LM, the S-band equipment supplies MSFN with a return ranging code signal that enables MSFN to track, and determine the range of the LM. The LM transmits biomedical data pertinent to astronaut heartbeat so that MSFN can monitor and record the physical condition of the astronauts. The LM also transmits systems telemetry data for MSFN evaluation; voice, using redundant S-band equipment; and, in case there is no LM voice capability, provides an emergency key signal so that the astronauts can transmit Morse code to MSFN.

EARTH SIDE (LM-CSM)

In-flight VHF communications between the LM and CSM include voice, backup voice, and tracking and ranging signals. Normal LM-CSM voice communications use VHF channels A and B duplex. Backup voice communication is accomplished with VHF channel B simplex or channel A simplex VHF ranging, initiated by the CSM, uses VHF channels A and B duplex.

Link	Mode	Band	Purpose
MSFN-LM-MSFN	Pseudorandom noise (PRN)	S-band	Ranging and tracking by MSFN
LM-MSFN	Voice	S-band	In-flight and lunar surface communications
LM-CSM	Voice	VHF duplex	In-flight communications
CSM-LM-MSFN	Voice	VHF and S-band	Conference (with LM as relay)
LM-CSM	Low-bit-rate telemetry	VHF (one way)	CSM records and retransmits to earth
CSM-LM-CSM	Ranging	VHF duplex	Ranging by CSM
MSFN-LM	Voice	S-band	In-flight and lunar surface communications
MSFN-LM	Uplink data or uplink voice backup	S-band	Update LM guidance computer or voice backup for in-flight communications
LM-MSFN	Television	S-band	Provides lunar color television
LM-MSFN	Biomed-PCM telemetry	S-band	Transmission of biomedical and vehicle status data
LM-MSFN-CSM	Voice	S-band	Conference (with earth as relay)
EVA-EVA-LM	Voice and data; voice	VHF duplex	EVA direct communication
EVA-LM-MSFN	Voice and data	VHF, S-band	Conference (with LM as relay)
CSM-MSFN-LM-EVA	Voice and data	S-band, VHF	Conference (via MSFN-LM relay)

Communication Links



R-99A

In-Flight Communications

FAR SIDE (LM-CSM)

When the LM and CSM are behind the moon, contact with MSFN is not possible. VHF channels A and B are used for duplex LM-CSM voice communications. VHF channel B is used as a one-way data link to transmit system telemetry signals from the LM, to be recorded and stored by the CSM. When the CSM establishes S-band contact with MSFN, the stored data are transmitted by the CSM at 32 times the recording speed.

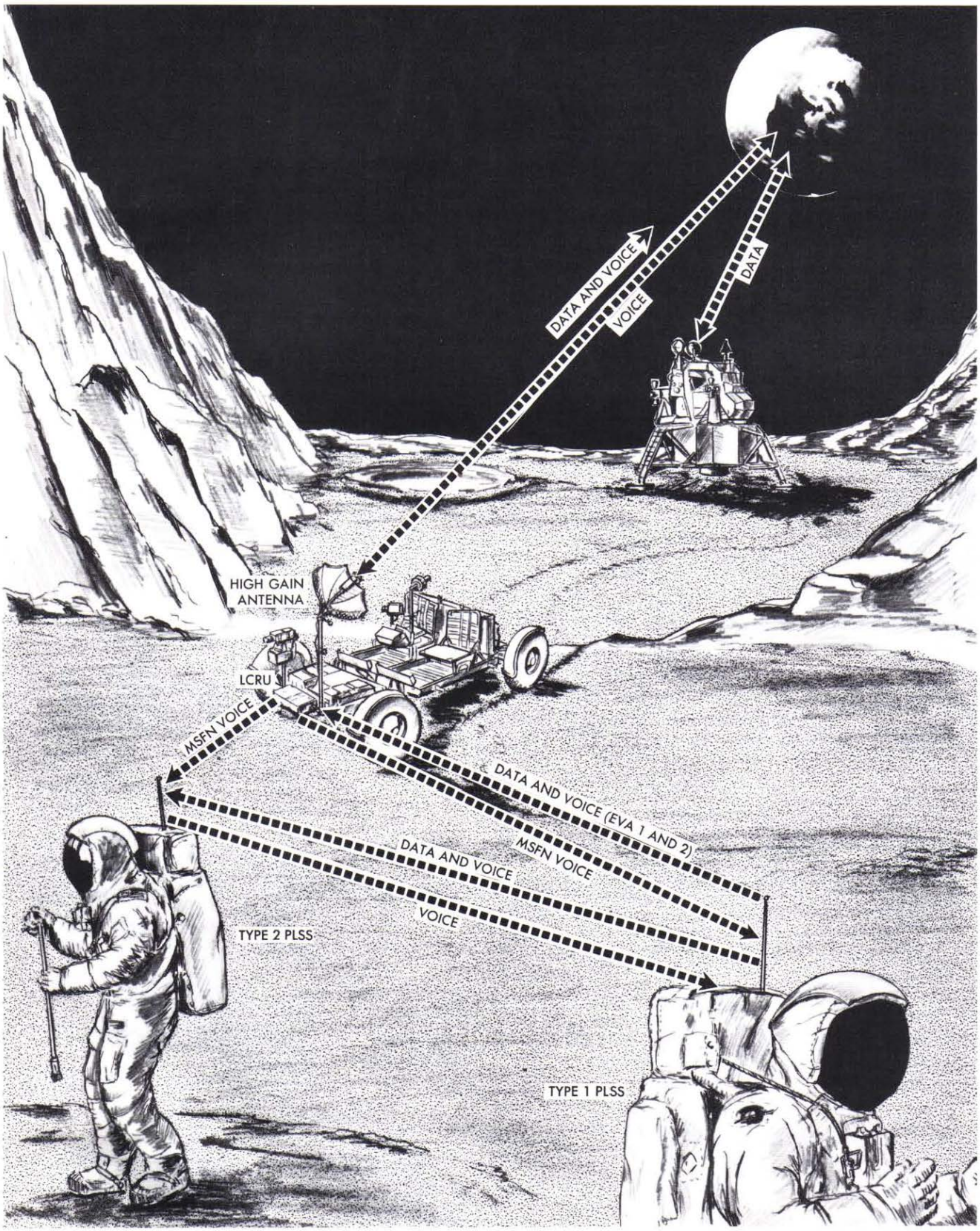
LUNAR SURFACE COMMUNICATIONS

When the LM is on the lunar surface, the CS provides S-band communications with MSFN and VHF communications with the EVA. The LM relays VHF signals to MSFN, using the S-band.

Communications with the CSM may be accomplished by using MSFN as a relay. LM-MSFN S-band capabilities are the same as in-flight capabilities, except that, in addition, TV may be transmitted from the lunar surface in an FM mode.

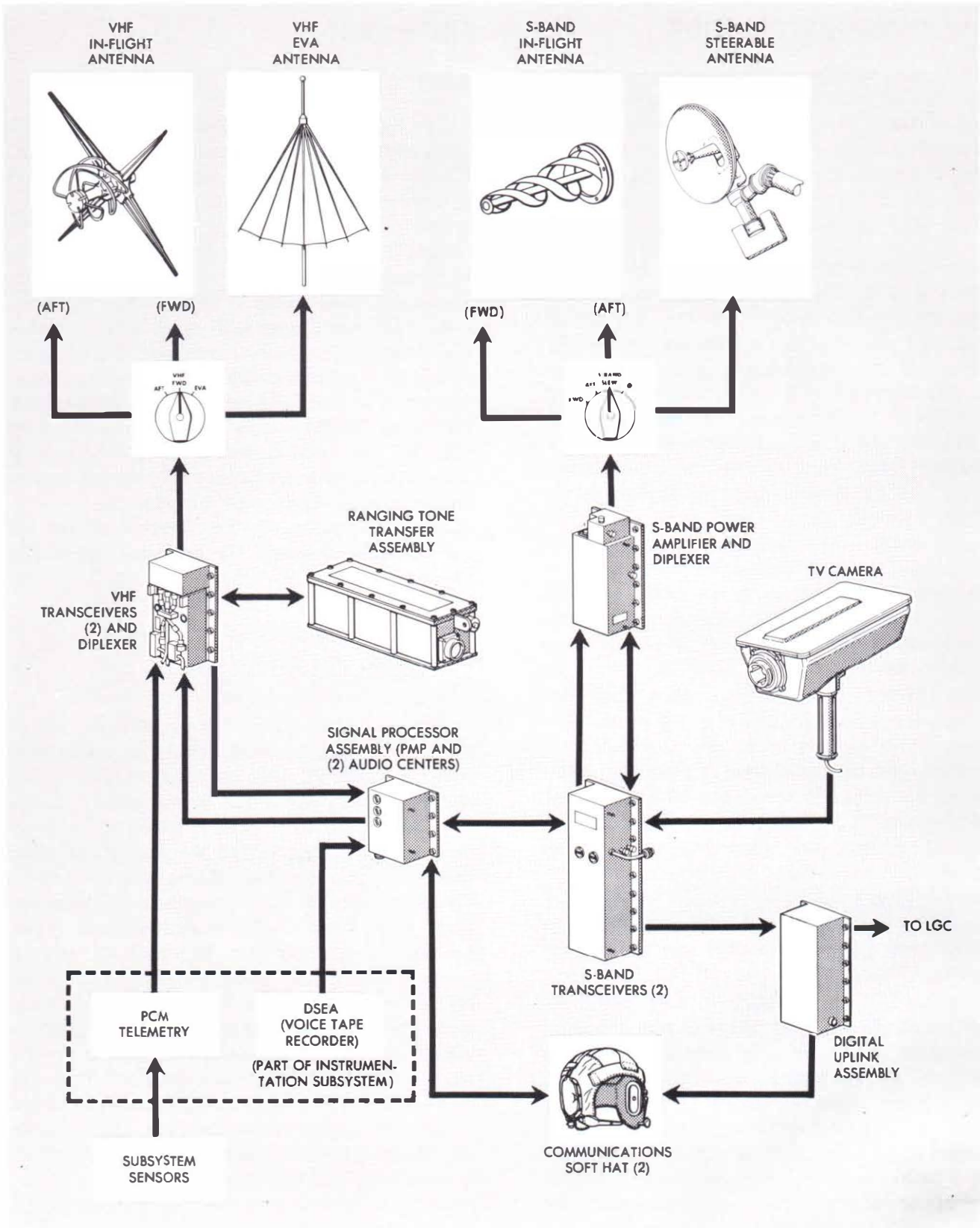
Information	Frequency or Rate	Subcarrier Modulation	Subcarrier Frequency	RF Carrier Modulation
	UPLINK: 2101.8 mHz			
Voice	300 to 3000 Hz	FM	30 kHz	PM
Voice backup	300 to 3000 Hz	FM	70 kHz	PM
PRN ranging code	990.6 kilobits/sec			PM
Uplink data	1.0 kilobits/sec	FM	70 kHz	PM
	DOWNLINK: 2282.5 mHz			
Voice	300 to 3,000 Hz	FM	1.25 mHz	PM or FM
Biomed	14.5-kHz subcarrier	FM	1.25 mHz	PM or FM
Extravehicular mobility unit	3.9-, 5.4-, 7.35- and 10.5-kHz subcarriers	FM	1.25 mHz	PM or FM
Voice	300 to 3000 Hz	None	None	Direct PM baseband modulation
Extravehicular mobility unit	3.9-, 5.4-, 7.35-, and 10.5-kHz subcarriers	None	None	Direct PM baseband modulation
Voice backup	300 to 3000 Hz	None	None	Direct PM baseband modulation
PRN ranging code (turnaround)	990.6 kilobits/sec			PM
Emergency keying	Morse code	AM	512 kHz	PM
Pulse-code-modulation nonreturn-to-zero data	High bit rate: 51.2 kilobits/sec or Low bit rate: 1.6 kilobits/sec	Phase shift keying (PSK)	1.024 mHz	PM or FM
TV	10 to 500 Hz			FM baseband modulation

S-Band Communications Capabilities



R-100A

Lunar Surface Communications



R-101A

Diagram of Communications Subsystem

FUNCTIONAL DESCRIPTION

Each astronaut has his own audio center. The audio centers have audio amplifiers and switches that are used to route signals between the LM astronauts, and between the LM and MSFN or the CSM. The centers are redundant in that each one can be used by either astronaut, or both astronauts can use either audio center if necessary.

In a transmission mode, the output of the audio centers goes to the VHF transceivers, or to the premodulation processor or to the data storage electronics assembly in the Instrumentation Subsystem (IS). If an audio center output is routed to the VHF transmitter, the transmission is through the diplexer to the selected VHF antenna. If an audio center output is routed to the premodulation processor (PMP) and then to the S-band transceivers, the transmitter output is applied to the diplexer, or to the S-band power amplifier, depending on power output requirements. The output from the transmitter or the power amplifier goes through the diplexer to the selected S-band antenna. If an audio center output is routed to the data storage electronics assembly, the voice transmission is recorded.

The inputs to the S-band transceivers are from the premodulation processor or the television camera. The outputs from the premodulation processor (to be transmitted by S-band transmitters) are processed voice, and PCM, EMU and biomed data. For television transmission, the S-band power amplifier is used. In normal flight, and on the lunar surface, the steerable antenna is used. When the LRV is in use, transmission is through the S-band antenna mounted on it. The S-band omni antennas are used in any one of a number of backup modes.

External RF inputs to the S-band equipment are MSFN voice, either uplink data or an uplink backup voice signal, and ranging. Received MSFN voice is routed through the premodulation processor to the audio centers. Received uplink data signals are routed to the digital uplink assembly to be decoded and sent to the LM guidance computer. MSFN backup voice is routed to the digital uplink assembly where it is decoded and then sent to the Commander's microphone amplifier input.

EQUIPMENT

S-BAND TRANSCEIVER

The S-band transceiver assembly provides deep-space communications between the LM and MSFN. S-band communications consist of voice and pseudorandom noise ranging transmission from MSFN to the LM and voice, pseudorandom noise ranging turnaround, biomed, and subsystem data transmission from the LM to MSFN. The assembly consists of two identical phase-locked receivers, two phase modulators with driver and multiplier chains, and a frequency modulator. The receivers and phase modulators provide the ranging, voice, emergency-keying, and telemetry transmit-receive functions. The frequency modulator is primarily provided for video transmission, but accommodates pulse-code-modulation telemetry (subsystem data), biomed, and voice transmission. The frequency modulator provides limited backup for both phase modulators. The operating frequencies of the S-band equipment are 2282.5 mHz (transmit) and 2101.8 mHz (receive).

S-BAND POWER AMPLIFIER

The S-band power amplifier amplifies the S-band transmitter output when additional transmitted power is required. This assembly consists of two amplitrons, an input and an output isolator (ferrite circulators), and two power supplies, all mounted on a common chassis. The RF circuit is a series interconnection of the isolators and amplitrons. The amplitrons (which are characteristic of saturated, rather than linear, amplifiers) have broad bandwidth, high efficiency, high peak and average power output, but relatively low gain. The isolators protect both amplitrons and both S-band transmitter driver and multiplier chains. The isolators exhibit a minimum isolation of 20 db and a maximum insertion loss of 0.6 db. Each amplitron has its own power supply, One amplitron is designated primary; the other, secondary. Only one amplitron can be activated at a time. When neither amplitron is selected, a feedthrough path through the power amplifier exists with maximum insertion loss of 3.2 db (feedthrough mode).

VHF TRANSCEIVER

The VHF transceiver assembly provides voice communications between the LM and the CSM and, during blackout of transmission to MSFN, low-bit-rate telemetry transmission from the LM to the CSM, and ranging on the LM by the CSM. When the LM mission profile includes extravehicular activity, this equipment also provides EVA-LM voice communications, and reception of EVA biomed and suit data for transmission to MSFN over the S-band. The assembly consists of two solid-state superheterodyne receivers and two transmitters. One transmitter-receiver combination provides a 296.8-mHz channel (channel A); the other, a 259.7-mHz channel (channel B), for simplex or duplex voice communications. Channel B may also be used to transmit pulse-code-modulation data from the IS at the low bit rate and to receive biomed and suit data from the EVA during EVA-programmed missions.

SIGNAL PROCESSOR ASSEMBLY

The signal processor assembly is the common acquisition and distribution point for most CS received and transmitted data, except that low-bit-rate, split-phase data are directly coupled to VHF channel B and TV signals are directly coupled to the S-band transmitter. The signal processor assembly processes voice and biomed signals and provides the interface between the RF electronics, data storage electronics assembly, and pulse-code-modulation and timing electronics assembly of the IS. The signal processor assembly consists of an audio center for each astronaut and a premodulation processor. The signal processor assembly does not handle ranging and uplink data signals. The premodulation processor provides signal modulation, mixing, and switching in accordance with the selected mode of operation. It also permits the LM to be used as a relay station between the CSM and MSFN, and, for EVA-programmed missions, between the EVA and MSFN. The audio centers are identical. They provide individual selection, isolation, and amplification of audio signals received by the CS receivers and which are to be transmitted by the CS transmitters. Each audio center contains a microphone amplifier, headset amplifier, voice operated relay (VOX) circuit, diode switches, volume control circuits, and isolation pads. The VOX circuit controls the microphone amplifier by activating it only when required for voice transmission. Audio signals are routed to and from the VHF A, VHF B, and S-band equipments and the intercom bus via the audio centers. The intercom bus, common to both audio centers, provides hardline communications between the astronauts. Voice signals to be recorded by the data storage electronics assembly are taken from the intercom bus.

DIGITAL UPLINK ASSEMBLY

The digital uplink assembly decodes S-band uplink commands from MSFN and routes the data to the LM guidance computer. The digital uplink assembly provides a verification signal to the IS for transmission to MSFN, to indicate that the uplink messages have been received and properly decoded by the digital uplink assembly. The LM guidance computer also routes a no-go signal to the IS for transmission to MSFN whenever the computer receives an incorrect message. The uplink commands addressed to the LM parallel those inputs available to the LM guidance computer via the display and keyboard assembly. The digital uplink assembly also provides a voice backup capability if the received S-band audio circuits in the premodulation processor fail.

RANGING TONE TRANSFER ASSEMBLY

The ranging tone transfer assembly operates with VHF receiver B and VHF transmitter A to provide a transponder function for CSM-LM VHF ranging. The ranging tone transfer assembly receives VHF ranging tone inputs from VHF receiver B and produces ranging tone outputs to key VHF transmitter A.

The VHF ranging tone input consists of two acquisition tone signals and one track tone signal. Accurate ranging is accomplished when the track tone signal from the CSM is received and retransmitted from the LM.

S-BAND STEERABLE ANTENNA

The S-band steerable antenna is a 26-inch-diameter parabolic reflector with a point source feed that consists of a pair of cross-sleeved dipoles over a ground plane. The prime purpose of this antenna is to provide deep-space voice and telemetry communications and deep-space tracking and ranging. This antenna provides 174° azimuth coverage and 330° elevation coverage. The antenna can be operated manually or automatically. The manual mode is used for initial positioning of the antenna to orient it within ±12.5° (capture angle) of the line-of-sight signal received from the MSFN station. Once the antenna is positioned within the capture angle, it can operate in the automatic mode.

S-BAND IN-FLIGHT ANTENNAS

The two S-band in-flight antennas are omnidirectional; one is forward and one is aft on the LM. The antennas are right-hand circularly polarized radiators that collectively cover 90% of the sphere at -3 db or better. They operate at 2282.5 mHz (transmit) and 2101.8 mHz (receive). These antennas are the primary S-band antennas for the LM when in flight.

VHF IN-FLIGHT ANTENNAS

The two VHF in-flight antennas are omni- directional, right-hand, circularly polarized antennas that operate at 259.7 and 296.8-mHz.

VHF EVA ANTENNA

The VHF EVA antenna is an omnidirectional conical antenna, which is used for LM-EVA communications when the LM is on the lunar surface. It is mounted on the LM and unstowed by an astronaut in the LM after landing.