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## Lunar Module Communications

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The Radio Amateur's Journal

# "Said the Spider in the Sky"

BY HOWARD W. KELLEY,* K4DSN

*"Ideals are like stars, you will not succeed in touching them with your hands, but like the seafaring man on the desert of waters, you choose them as your guides, and, following them, you reach your destiny"*

—CARL SCHURZ

A SPINDLY, ugly, clumsy-looking, insect-like contraption that only the world could love has made its debut. In an age of super-smooth and sleek flying machines, U.S. astronauts will soon be flying an aerodynamic misfit to the moon and back.

The final payoff of the Apollo moon mission is to be carried out aboard the spidery Lunar Module (LM) whose homeliness is offset by its beauty of sophistication and practicality. Though its ability to space-fly is something of amazement about which pages could be written, this discussion is limited to the LM's communication ability.

### In-Flight Communications

The communications subsystem aboard the Lunar Module is capable of three two-way combinations of in-flight or lunar surface radio links: LM to the orbiting Command Module (CM), LM direct to earth, and LM to the astronauts who are roaming about the moon's terrain.

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**Table I—LM Frequencies**

| | |
|---|---|
| S-band Transmit | 2282.5 mc |
| S-band Receive | 2101.8 mc |
| V.H.F. Channel A | 296.8 mc |
| V.H.F. Channel B | 259.7 mc |

As in the Apollo[1], the LM places its communications responsibilities in Unified S-band and v.h.f. equipment.

In flight (fig. 1), when the LM is on the earth side of the moon and separated from the Command Module, communication with earth is handled on S-band, but between the LM and CM information is passed back and forth on v.h.f.

As in the Apollo S-band system a multitude of information sources on the LM can be transmitted and received at the same time, on the same antenna and often on the same frequency. LM-to-earth S-band links contain voice, TV, digital uplink, ranging code signals, biomedical, and systems telemetry data (see Table III).

S-band voice is the primary means of communication between Mission Control and the two men aboard "Spider" (the voice identi-

[1]Kelley, Howard W., K4DSN, "The Voice of Apollo-8," March 1969, p. 17.

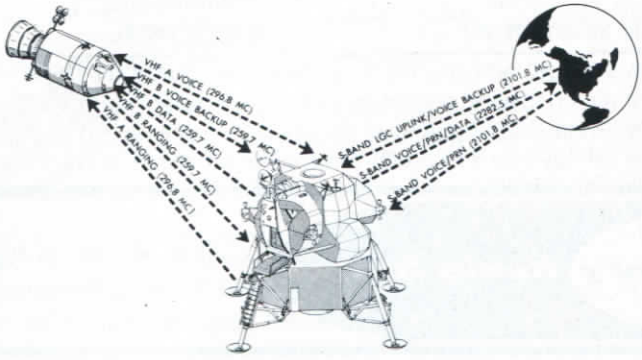


Fig. 1—In-flight communications.



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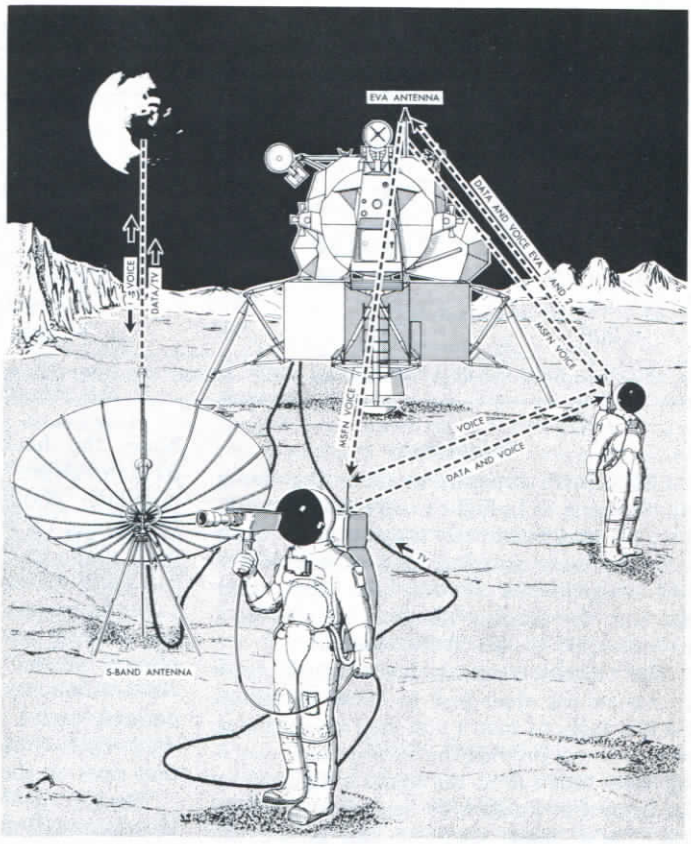


Fig. 2 — Lunar surface communications. The two astronauts roaming about the moon's surface communicate with each other on 296.8 mc. The unattended Lunar Module acts as a repeater to relay to earth the v.h.f. communications via 2282.5 mc (S-band). Television pictures are also transmitted to the Manned Space Flight Network on S-band and biomedical and telemetry go along for the ride on subcarriers.

fier for the Lunar Module). Backup voice from earth is possible using the digital uplink channel, but this is usually tied up keeping the LM's guidance computer up-to-date.

In response to ranging code signals sent to the LM, the S-band equipment supplies earth stations with a return ranging code signal that enables Mission Control to track and determine range of "Spider."

Biomedical data pertinent to astronaut heartbeat is transmitted by the LM (so earthbound doctors can monitor and record the physical condition of the spacemen), as is telemetry, voice (using redundant S-band equipment) and, in case voice capability is lost, an emergency key is provided for c.w. communication to the Manned Space Flight Network.

Most of the same information can be exchanged between "Spider" and "Gumdrop" (voice identifier for the Command Module) that can be sent directly to earth from the LM. However, these communications are carried out on v.h.f. Normal voice chatter goes out on 296.8 mc simplex. Backup is accomplished on 259.7 mc simplex. V.h.f. ranging, which is initiated by "Gumdrop" uses both v. h. f. channels as a duplex operation.

When the two orbiting spacecraft are behind the moon, contact with Mission Control is not possible. Simplex voice is maintained over the 296.8 mc circuit between "Spider" and "Gumdrop" at this time while telemetry data is fed over channel B into tape recorders aboard the command ship to be stored and re-transmitted to earth at 32-times the original recording speed when radio conditions between earth and space improve.

### Lunar Surface Communications

When the 16-ton Grumman Aircraft Spider has planted its legs into the moon's crust, the orbiting CM will use its S-band system to talk to earth and v.h.f. to maintain communications with the astronauts who are on the lunar surface (fig. 2). The Lunar Module then becomes the world's most expensive f.m./a.m. repeater. The LM takes the v.h.f. voice, converts it to S-band and retransmits it to the space network of earth receiving stations.

Should v.h.f. between the moonbound astronauts and the commandship not be satisfactory, earth stations may act as repeaters by re-tranmitting S-band from the moon back into space to the CM.

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**Table II—Frequency Chart of Apollo/Lunar Module**

| *Freq. (mc)* | *Vehicle* | *Mode* | *Information* |
|---|---|---|---|
| 2287.500 secondary | CM | PM | Voice, tracking/ranging, data |
| 2282.500 transmit | LM | PM/FM | Voice, TV, tracking/ranging, data |
| 2272.500 | CM | FM | TV, data |
| 2106.400 primary | CM | PM | Voice, tracking/ranging, data |
| 2101.800 receive | LM | PM | Voice, tracking/ranging, data |
| 296.800 Ch. A | CM/LM | AM | Voice, CM to LM, EVA, data |
| 259.700 Ch. B | CM/LM | AM | Voice, CM to LM, data |
| 243.000 | CM | AM | Recovery beacon |
| 10.006 | CM | SSB | Backup h.f. recovery link |

CM—Command Module of Apollo. LM—Lunar Module. EVA—Extra Vehicular Activity.

### Television

LM-to-earth capabilities from the moon are the same as in-flight except that, in addition, TV may be directly transmitted to earth from the lunar surface. In fact, one of the first assignements of the LM crew, after checking for landing damage, is to erect a 10-foot 2200 mc parabolic antenna.

The television system has a much more utilitarian use than just to show earthlings the spectacle of man's first step on a foreign planet. It will provide the closest, most exacting view thus far of the moon's topography for instant evaluation by scientists in Houston. These same scientists can advise the spacemen which rocks to pick up and bring back, which features are important, and which way to point the camera. There are also plans to set the camera on a tripod a distance away from the LM so that we on earth can see the actual blastoff from the moon when the job is done and Spider returns to space for a rendezvous with the mothership. The television transmitter is located in the base section (descent stage) of the LM—the part that stays behind.

The small hand-held TV camera (fig. 3) designed for the Apollo program weighs only 4½ pounds. It has a bandwidth of 10 cy. to 500 kc and scans 10 frames per second (f.p.s.) at 320 lines and 5/8 f.p.s., 1280 lines. The 1-inch vidicon consumes about 7½ watts of power.

### PLSS—Pronounced Pliss

The well-dressed astronaut who strolls along Lunar Lane wears upon his back an all important unit known as the PLSS—Portable Life Support System (fig. 4). The PLSS is a self-contained, self-powered rechargeable environmental control system. For four hours the back-pack supplies pressurized oxygen, cleans and cools the expired gas, circulates cooling liquids, and contains a transmitter for biomedical information and a dual v.h.f. transceiver for communication.

The PLSS has a contoured fiberglass shell to fit the astronaut's back, and a thermal micrometeoroid protective cover. It has three control valves, and, on a separate remote control unit, two control switches, a volume control, and a five-position switch for the dual v.h.f. transceiver. The remote control unit rests on the chest.

The astronaut has available to him primary and secondary duplex voice communication, and physiological and environmental telemetry all of which must go through the LM to the CM on v.h.f., then from the CM to earth on S-band. The v.h.f. antenna for the

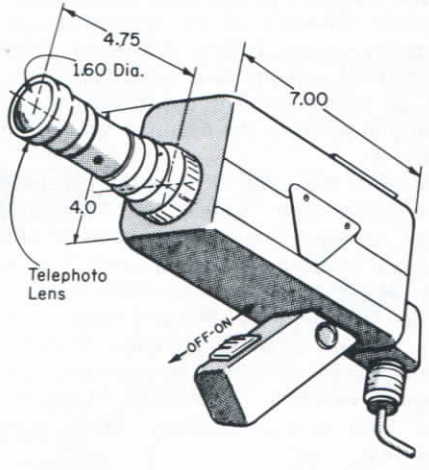


Fig. 3—One-inch Videcon TV camera. The small hand-held camera will give the first glimpse of the men on the moon, but will also allow earthbound scientists to pick and choose what geological samples are to be brought back.



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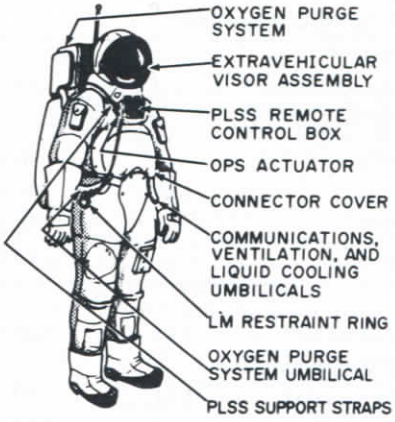


Fig. 4—Integral thermal micrometeoroid garment. What the well-dressed lunar astronaut wears. On his back is the PLSS—Portable Life Support Systems. Included inside the thermal micrometeoroid garment is a dual v.h.f. a.m. transceiver capable of voice communication and constant physiological telemetry.

PLSS is permanently mounted on the oxygen purge system. Two side-tone generators override incoming audio in the headphones to notify of low pressures or low fuel reserve.

### RF Equipment

In several respects, r.f. equipment (fig. 5) on the LM is much like that on its big brother Apollo. (NOTE: Unlike military ships, astronauts don't refer to their spacecrafts as "she", but rather "he".) The S-band assembly consists of two identical phased-locked receivers, two phase modulated (p.m.) transmitters (0.75 watts output) with driver and multiplier chains, and a frequency modulator (f.m.) The receivers and phase modulators provide the ranging, voice, emergency c.w., and telemetry transmit-receive functions. F.m. is primarily used for video transmission, but accomodates pulse-code-modulation telemetry, biomedical, and voice transmission. F.m. also provides limited backup for both p.m. units.

When more r.f. is required amplifiers can be brought into play. This assembly consists of two amplitrons (primary; 18.6 watts output, secondary; 14.8 watts output), an input and output isolator (ferrite circulators), and two power supplies all mounted on a common chassis. The r.f. circuit is a series interconnection of the isolators and amplifiers. The amplifiers themselves (which are saturated, rather than linear) are broadband and exhibit high efficiency, high peak and average output power, but relatively low gain. The isolators protect both amplifiers and both S-band transmitter driver and multiplier chains. The isolators exhibit minimum isolation of 20 db and a maximum insertion loss of 0.6 db. Only one amplifier can be activated at a time and when neither amp is selected, a feedthrough path through the power amplifier exists with a maximum insertion loss of 3.2 db.

### V.H.F. Equipment

Although the Apollo relies heavily on its S-band capabilities, the Lunar Module is oriented toward v.h.f. This equipment consists of two solid-state superhet receivers and two 5-watt a.m. transmitters. One transmitter-receiver combination operates on 296.8 mc (Channel A), the other on 259.7 mc (Channeel B), for simplex or duplex voice communications. Channel B may also be used to transmit pulse-code-modulation (p.c.m.) data from the LM to the CM at a low bit rate and to receive biomedical and space suit data from the astronauts who are outside the ship on the moon.

### Signal Processor

The signal processor unit is the common acquisition and distribution point for most received and transmitted information, except that low bit rate split-phase data are directly coupled to v.h.f. Channel B and TV signals go directly to S-band f.m. The signal process-

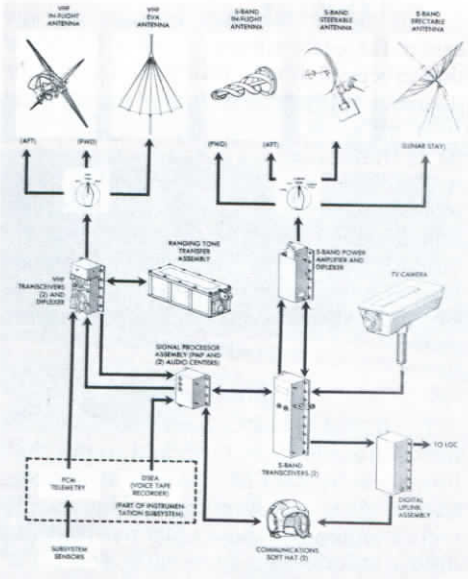

Fig. 5—Lunar Module communications subsystem.

**Table III—Lunar Module S-Band Capabilities**

| *Information* | *Freq. or Rate* | *RF Carrier Modulation* | *Subcarrier Modulation* | *Subcarrier Freq.* |
|---|---|---|---|---|
| *Receive: 2101.8 mc:* | | | | |
| Voice | 300 to 3000 cy. | PM | FM | 30 kc |
| Voice Backup | 300 to 3000 cy. | PM | FM | 70 kc |
| Ranging Code | 990.6 kilobits/sec. | PM | | 70 kc |
| Uplink Data | 1.0 kilobits/sec. | PM | | 70 kc |
| *Transmit:2282.5 mc* | | | | |
| Voice | 300 to 3000 cy. | PM or FM | FM | 1.25 mc |
| TV | 10 to 500 cy. | FM baseband | | |
| Biomedical | 14.5 kc subcarrier | PM or FM | FM | 1.25 mc |
| Lunar Surface Unit | 3.9, 5.4, 7.35, 10.5 kc subcarriers | PM or FM | FM | 1.25 mc |
| Voice | 300 to 3000 cy. | PM baseband | | |
| Biomedical | 14.5 kc subcarrier | PM baseband | | |
| Lunar Surface Unit | 3.9, 5.4, 7.35, 10.5 kc subcarriers | PM baseband | | |
| Voice Backup | 300 to 3000 cy. | PM baseband | | |
| Ranging Code | 990.6 kilobits/sec. | PM | | |
| Emergency Code | Morse Code | PM | AM | 512 kc |
| Pulse-code-mod. non-return zero | High bit rate: 51.2<br>Low bit rate: 1.6 | PM or FM | Phase Shift | 1.024 mc |

or assembly processes voice and medical information and provides the interface to the proper r.f. generator, tape recorder, modulator, or computer.

This signal processor includes an audio center for each astronaut and a premodulation processor where information is switched, mixed, and modulated. It also has a repeater function so that v.h.f. received signals can be re-transmitted on S-band.

The two identical audio center provide individual selection, isolation and amplification of audio received or transmitted from the LM. Each center includes a mike preamp, headset amplifier, VOX circuit, diode switches, audio gain controls, and an intercom system.

### Digital Uplink

The digital uplink assembly decodes 2101.8 mc commands from earth and routes the information to the LM guidance computer. It also provides a verification signal to the pilots that the equipment has in fact received all the needed information from earth and got it in fine shape. However, if for some reason the computer doesn't get all the information it wants or it suspects some of it of being wrong, it will signal through the S-band transmitter "no-go" and ask for a repeat. The uplink commands addressed to the LM parallel those inputs available to the LM guidance computer via the display and keyboard accessible to the spacemen. The digital uplink assembly also provides another means of voice-backup if the received S-band audio circuits in the premodulation processor fail.

### Ranging Tone Transfer

The ranging tone transfer unit operates with v.h.f. receiver B and v.h.f. transmitter A to provide a transponder function between the command and the moon vehicle. The

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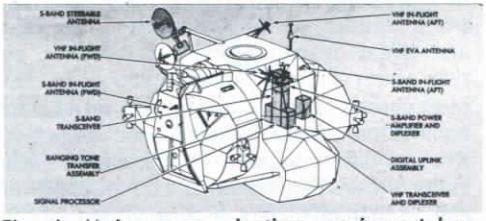


Fig. 6—Major communications equipment locations.



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