Post-occultation Reception of Lunar Ship Endeavour Radio Transmission

THE reception of radio signals from the orbiting lunar spaceship Endeavour after its occultation behind the lunar limb seems to confirm in part a previous suggestion[1]. Similar observations arranged with the lunar command module during the Apollo 14 mission were unsuccessful because of interference from local emissions.

The transmitter normally used for communication between the lunar command module and the lunar landing party was turned on continuously during a period of lunar orbiting between 0026 and 0132 EST, August 3, 1971. The frequency of this transmission was 259.7 MHz with a steady square-wave modulation at 31.6 kHz. This transmission was received by a special receiver using the Air Force Cambridge Laboratory 150 foot radio telescope as an antenna. This radio telescope is located at Sagamore Hill near Hamilton, Massachusetts, USA (latitude 42°, 37′, 55.6″ N and longitude 70°, 49′, 04.5″ W).

The turning on of the spacecraft transmitter was delayed for several hours from the planned time because of astronaut activity required to ensure satisfactory air seals after the return of the lunar landing party. By the time turn-on was achieved, the Moon was so near to setting, as observed from Sagamore Hill, that unfortunately only one observation could be made.

63 km below the point where the Earth line of sight is tangent to the lunar surface. At the time when the signal finally ended, the "line of sight" from the Earth to the Endeavour passed about 158 km beyond the limb of the Moon. The librations of the Moon were all small at the time of these observations and the relatively insignificant corrections for these librations have been included in these figures.

Several possibilities for explaining these results may be considered. The passage of a refracted wave through the bulge of the Moon, as suggested for much longer wavelengths in previous articles[1,2], seems unlikely because the small refraction angles indicated would require much too small a refractive index for the lunar surface material. Also, the Moon is rather rough in terms of this short wavelength and the attenuation for such a high frequency is much too high, as indicated by measurements of returned lunar material[3]. The possible existence of a temporary ionosphere produced by gas emissions from the spacecraft appears to be unlikely because of the large amount of material required for the necessary deflexion of such high-frequency waves (259.7 MHz).

The most probable explanation seems to be one of two possibilities. First, the signal was received from a surface wave carried around the Moon, in a way similar to the propagation of waves in the broadcast band on the Earth's surface[4,5]. This explanation appears possible because of the extreme

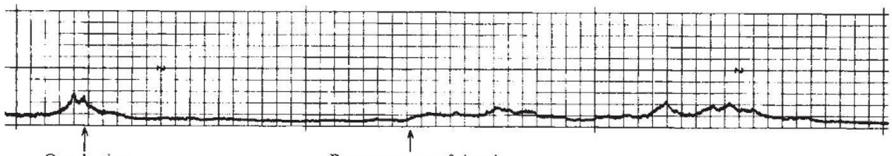

Fig. 1 Record of receiver response (1 division = 5 s).

The interference encountered during the previous mission was not present during this observation, so that the receiver noise level was reduced from about 35 mV on the receiver output to about 2 mV. This improved sensitivity as compared with that of the Apollo 14 test allowed an excellent observation of the occultation of the spacecraft and the signal as the Endeavour transmitter moved behind the edge of the Moon. The signal reappeared 115 s later with an intensity many times the noise level (peaking to about 15 mV) and remained discernible for about 140 s. The reception is shown on the accompanying photograph of the pen-recorded strip chart (Fig. 1). Records were also taken by means of magnetic tape and digital sampling of receiver output voltage. The signal was further observed visually on an oscilloscope, and the characteristic modulation could be clearly seen both before and after occultation.

The height of the Endeavour's orbit above the lunar surface was about 108 km at the time of occultation and was reasonably uniform thereafter. Thus, the Moon ship passed along about 25° of its orbit as measured from the lunar centre during the period between the time that the radius vector from the ship to the lunar centre came perpendicular to the direction toward the Earth and the time of occultation. This represents about 960 km on the lunar surface directly below the Endeavour's orbit. During the 115 s that elapsed between occultation and reappearance of the signal, the ship passed over an additional 177 km of the lunar surface; then, during the renewed signal, the ship passed through 7° more of orbit, or a lunar surface distance of 215 km. Projected on the Earth's direction vector (which does not lie in the plane of orbit, because of the inclination necessary to ensure that the orbit would pass over the relatively northern landing site), this progress is measured by 175 km on the lunar surface.

The surface distance passed over between occultation and the return of the signal when projected on the line of signal is about 135 km. This distance places the Endeavour transmitter

dryness of the Moon and the low electrical conductivity of lunar surface material, as compared with seawater and to soil containing considerable ground water on the Earth. Second, the signal was received from the prismatic refraction of mountain formations in this part of the Moon, where paths through lunar material may be relatively short and the materials may have properties differing somewhat from the average. Work is proceeding to determine, if possible, which is more likely. It is hoped that a repeat test during the Apollo 16 mission can be arranged and that observations can be made for several orbits of the command module. It is also expected that observations during future lunar missions will make possible more definitive data on the radio-frequency properties of the lunar surface, at much longer wavelengths, which will also be important tools in exploring the interior of the Moon.

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