

## THE MOON AS A SCATTERER OF RADIO WAVES

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Radio echoes from the moon at 120 Mc./s. have been obtained with a pulse length of 30 msec. and a pulse interval of 1·8 sec., using a fixed aerial directed due south. Their study has given information about the nature of the scattering function of the lunar surface.

The intensity of moon echoes is proportional to the quantity  $g\rho\pi a^2$ , where  $a$  is the radius of the moon,  $\rho$  the mean power reflectivity of its surface for radio waves at normal incidence, and  $g$  a directivity factor, which depends on the way in which the intensity of waves scattered backwards from an element of the surface varies with the angle of incidence.

For a lunar surface in which any irregularities are very small compared with the wave-length, so that the moon is smooth, the reflexion is specular, and the directivity  $g = 1$ . If the irregularities are of the order of a wave-length in size, the scattering function is given by Lambert's cosine law, the moon appears limb-‘darkened’, and the directivity  $g = 8/3$ . When the irregularities are all very large compared with the wave-length, the scattering function is given by the Lommel-Seeliger law, the moon appears uniformly ‘bright’, and the directivity  $g$  is of the order of 5. In the optical case, as is well known, the moon roughly obeys the Lommel-Seeliger law, and the directivity  $g = 5\cdot7$ .

From measurements of the echo intensity alone, it is possible to deduce only the value of the product  $g\rho$ . However, moon echoes show a rapid fading of intensity, with a quasi-period (at 120 Mc./s.) of the order of 0·5 sec. This, it is believed, is caused by the libration of the moon, because the changing angle of libration introduces variations into the phase-paths of the rays scattered by various parts of the moon, resulting in changes in the resultant echo signal. If this explanation is correct, the amplitudes of a series of echo pulses should follow a Rayleigh distribution, while the rate at which the echo fades should be proportional to the rate of change of the angle of libration, taking into account the librations in longitude, and in

latitude, as well as the diurnal and physical librations. (The rate of fading is conveniently measured by the autocorrelation function for echo amplitude, regarding the amplitudes of echoes as a time series.) These predictions agree well with the observations made at Jodrell Bank. The form of the power spectrum of the fluctuations in echo amplitude will depend, not only upon the rate of libration, but also upon the scattering function for the lunar surface, and hence also with the directivity  $g$ . The power spectra and their associated auto-correlation functions (given by the square of the Fourier cosine transforms of the power spectra) have been computed for four models representing different possible scattering laws for the lunar surface, namely: (i) specular reflexion, (ii) Lambert's law (limb 'darkening'), (iii) Lommel-Seeliger law (uniform 'brightness'), and (iv) a model showing limb brightening. From a comparison with the observed form of the auto-correlation function, it appears that the assumption of Lommel-Seeliger scattering gives the best approximation, though in this case the fading rate is greater than predicted by some 50%. The discrepancy has not been fully accounted for.

A value of 5.7 has accordingly been assumed for the directivity  $g$ . Assuming further that the reflectivity  $\rho$  of the lunar soil is 0.1, a value characteristic of dry terrestrial rocks, it becomes possible to compare the intensity of the observed echoes with that predicted. A comparison is made below for two days on which the slow fading of echoes (produced by the rotation of the plane of polarization of the waves during their passage through the ionosphere) permitted reliable measurements of echo intensity. The values given are averages over one minute.

	10 August 1955	17 August 1955
Observed mean signal-to-noise power of echoes	27.2 ± 1 db.	24.3 ± 2 db.
Predicted signal-to-noise power of echoes	31.8 ± 1 db.	31.0 ± 1 db.

It can be seen that the agreement is fair. It is improved by 3 db. if the assumed value of reflectivity  $\rho$  is taken as 0.05. This value is characteristic of dry dusty soils, suggesting that the moon's surface may be covered with such a layer, to a depth of several centimetres.

Full details of these measurements and their probable errors are being published elsewhere, together with an account of the effects produced by the ionospheric rotation of the plane of polarization of the radio waves during their passage to and from the moon (Browne, Evans, Hargreaves and Murray, 1956) [1].

#### REFERENCE

- [1] Browne, I. C., Evans, J. V., Hargreaves, J. K. and Murray, W. A. S. 'Radio Echoes from the Moon', *Proc. Phys. Soc. B*, **69**, 901, 1956.