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PROGRESS REPORT: LUNAR SURFACE MAGNETOMETER - C.P. Sonett, B.F. Smith, D.S. Colburn, NASA Ames Research Center, Moffett Field, Calif. 94036, G. Schubert, Univ. of California, Los Angeles, Calif. 90024, and K. Schwartz, American Nucleonics Corp., Woodland Hills, Calif. 91364.

Using Apollo 12 data our earlier determination (Sonett et al., 1971a and 1971b) of the lunar electromagnetic transfer function from Fourier transforms of both the Lunar Surface Magnetometer (LSM) data and the Explorer 35 interplanetary magnetic field data has been extended downwards in frequency by approximately one decade. The frequency range of the transfer function now extends from half the Nyquist limit of Explorer 35 ($f=4\times10^{-2}$Hz) down to periods of about 2 hours ($f=5.0\times10^{-4}$Hz). The transfer function still displays the asymetric response between the north-south and the east-west directions even at the lowest frequencies. The data has been inverted using the Newton-Raphson technique and least squares fitting as before. The very low response in the neighborhood of two hour periods suggests that a limit has been reached such that no significant data can be obtained from extensions of the analysis to lower frequencies.

Detailed consideration of the response of the Moon to higher order modes of excitation by the solar wind indicates that the high frequency plateau region behavior of the transfer function, including its slope and variability, may well be explained by excitation of higher order modes (Schubert and Schwartz, 1972). In order to assess this effect it is important to consider the polarization and direction of propagation of the incident waves on the Moon and the position of the LSM with respect to the incident wave vectors. This problem is still under investigation but it seems likely that the low frequency asymmetry in the lunar transfer function cannot be explained in this way. Another potential source for the asymmetry, i.e., transverse magnetic (TM) excitation, also does not seem likely since the very low frequency response is symmetric. Electric multipole radiation due to TM excitation appears to be below the level of detectibility.

Another candidate for the source of the asymmetry lies in excitation of the permanent magnetic field at the Apollo 12 site by variations in the dynamic pressure of the solar wind (Clay et al., 1971). Tests for this effect are presently under way and begin with rotation of the basic coordinate system in the plane tangent to the surface of the Moon. Directions of the maximum in the lunar response appear to be related to the direction of the permanent field at the site in a complicated manner. Above 1.7 mHz a monotonic change in the direction of maximum tangential response takes place as the frequency is increased. This indicates that if a pressure effect is present it must be frequency dependent or mixed with wave polarization effects which vary

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with frequency. Minimum variance determinations of the wave vector directions in the solar wind have been made to assess the effects of polarization and direction of propagation. There is a definite tendency for the solar wind to contain fluctuations with k vectors aligned with the mean magnetic field, while the central angle between the wave vector and the LSM tends to cluster broadly about 90 degrees showing that polarization effects and higher order modes of excitation in the Moon may all be important in a final assessment of the induction. Study of plasma pressure effects and separation of this from higher order mode excitation effects is still under way.

Time series taken from the lunar darkside period of the first lunation comprising 18 swaths of 1 and 2 hour lengths have been analyzed. Theoretical calculations have been completed of the response for a vacuum Moon so that comparison can be made between data and theory. The tangential component of the transfer function near the antisolar point deviates strongly at low frequency from the theoretical vacuum response. The source of the departure is likely currents lying in the diamagnetic cavity boundary or possibly flowing in the lunar cavity above the surface of the Moon. The radial transfer function seems to track the theoretical value closely with minor departures.

The determination of the heat flux from the Moon based upon thermal gradient calculations show that the dominant effects are due to field line compression, and that such effects as change in the multipolarity spectrum (relative dipole and higher order excitation) are masked. The angular resolution on the Moon is very poor due to smearing of the relative contributions as well as the dominance of the magnetic dipole interaction. Therefore the results are a good quasi-global average, but still subject to contamination from effects connected with field line containment or additional noise sources. Such sources have not been identified but could arise from the current sheath which conceptually may add or subtract noise from the scattered wave field depending upon coherence and phase. Tests for this effect are associated with the angular dependence of the complex transfer function and are still under way. Although a noise contaminant of this type could alter our values for the heat flux, the present values are consistent with the determination of the deep interior temperature and the latter rests upon very low frequency data which is less likely to suffer this type of contamination.

The permanent magnetic field value from Apollo 15 site is 5±5 gamma; a final value will depend upon normalization to Explorer 35 and perhaps the Apollo 15 subsatellite. The approximate value reported here is substantially lower than any previous report from other sites. The geological complexity of the Hadley site makes any guess as to the reason for the low value speculative especially in view of the very local nature of the measurement. On the other hand Explorer 35 shows that large regions of the Moon are magnetized at a presumably low level with a preference shown statistically for localities in the highlands, therefore favoring the backside of the Moon. A map has been

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prepared showing the incidence of these features (Mihalov, et al.,1971; Sonett and Mihalov, 1972). The existence of large scale fossil magnetism ubiquitously over the Moon together with the evidence for a background field present over the whole span of Rb/Sr ages indicates the possibility that the Moon was endowed with a dynamo field till at least 3.2 Aeons ago. For a conventional planetary dynamo then the spin history becomes an important factor. Finally this leads to speculation that spin damping of the Moon took place less than some 3.2 Aeons ago. In that event a capture hypothesis based upon a time of capture some 3.2 Aeons ago becomes attractive. Using the Singer "soft" prograde capture a potential strong dynamical coupling with the earth at that time becomes possible in accord with the marginal geological record available from that time, though serious difficulties remain with a dynamo source (Sonett and Runcorn, 1971c).

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