

BELLCOMM, INC.

955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 10057

SUBJECT: Proposed Changes in Fra Mauro
Traverses to Obtain Significant
VHF Communications Performance
Data on Apollo 14 - Case 320

DATE: October 5, 1970

FROM: I. I. Rosenblum

ABSTRACT

Traverse changes are proposed for the Fra Mauro mission which would generate VHF signal strength data for definable terrain situations (at or near Star and Cone Craters) which are relevant to future missions. A plan is advanced for collecting data which will help resolve the applicability of the several mathematical models available for describing VHF transmission loss on the lunar surface and will assist in establishing the adequacy and accuracy of particular model use in signal strength prediction.

Instrumentation requirements are discussed.

Implementation of the test plan (or parts as possible) is suggested in view of the significant bearing the data would have for future mission planning.



(NASA-CR-111181) PROPOSED CHANGES IN FRA
MAURO TRAVERSES TO OBTAIN SIGNIFICANT VHF
COMMUNICATIONS PERFORMANCE DATA ON APOLLO 14
(Bellcomm, Inc.) 14 p

Unclas

00/32 11939

FE No. 6 CR-111181
(NASA CR OR TMX OR AD NUMBER) (CATEGORY)
RESEARCH CENTER

SUBJECT: Proposed Changes in Fra Mauro
Traverses to Obtain Significant
VHF Communications Performance
Data on Apollo 14 - Case 320

DATE: October 5, 1970

FROM: I. I. Rosenblum

MEMORANDUM FOR FILE

A. INTRODUCTION

The prediction of VHF communications performance on the lunar surface is a difficult task associated with all lunar exploration. On the early missions (Apollo 11 and 12), the mathematical models available for use in predicting VHF communications proved to be adequate largely because the traverse distances away from the LM were short and prediction with great accuracy was not required. As longer traverses are undertaken on advanced lunar exploration missions into quite variable terrain environments, the adequacy and accuracy of signal strength prediction will become more and more critical.

Several analytical models have been advanced for predicting field strength of communications signals on the lunar surface. Good cases have been or could be made for the application in a particular lunar situation for each of the following prediction models:

1. B. van der Pol-H. Bremmer Series -- A residue series believed good at all ranges requiring the calculation of many terms for high accuracy at short range -- provides phase and attenuation for smooth sphere. (1,2)
2. The calculation of ground wave field intensity by series or graphically according to the method of K. A. Norton. (3)
3. L. E. Vogler method for predicting ground wave attenuation for lunar surface using curves and graphs in parametric form for zero height antennas. (4)
4. Graphical attenuation calculations in the far diffraction region for irregular terrain on homogeneous sphere per method of Raymond F. Hartman. (5)
5. Geometric Optics -- An analysis model incorporating wave reflections from terrain as a function of

divergence, surface roughness, and surface electric characteristics. Results valid over limited range of distances within line-of-sight. (2,6)

6. Edge Diffraction Loss Calculation (with respect to free space field strength). (7,9)
 - a. Single knife-edge model
 - b. Double knife-edge model
 - c. Rounded obstacle model
 - d. Multiple obstacle model
 - e. Obstacle with ground reflection model
7. Straight Line-of-Sight -- The tacit assumption with the line-of-sight model is that communications is present whenever the visual sight line is unobstructed. Visibility regions are determined typically by reference to detail topography or more expeditiously from shadow maps. (8) (Also see Figure 1.)

Often, on the points of a lunar traverse, the terrain geometry between transmitter and receiver appears to clearly fit one model while at other points, such as over a crater rim or hill, a different model or several models may appear appropriate. The essence of the current difficulty with lunar surface signal prediction is that the choice of the appropriate model is not always self-evident and the different models, generally, give different results. Actual performance data capable of being correlated with prediction theory using different propagation models would be invaluable in identifying the appropriate models to use in the various terrain situations and in refining the accuracy of signal strength prediction.

One of the Apollo 13 detailed objectives (MSC Ident. -G-, "EVA Communication System Performance") at the Fra Mauro site was to determine the effects upon communication of obstructing lunar surface features between EVC-1 and the LM (see Appendix A). The test plan was to obtain a record of received VHF signal strength under conditions in which the line-of-sight to the LM was to be deliberately interrupted by having EVA move behind obstructing surface features of opportunity. Unfortunately, it appears that the priority of the objective (priority #8) was so low that the experiment aims were not advanced through definitive impact on traverse planning and of course the lunar surface landing on that mission was aborted. With the NASA decision to return,

after delay, to Fra Mauro on Apollo 14, it is suggested that a more comprehensive VHF experiment be conducted that is more systematically planned.

B. PROPOSED TESTS AT FRA MAURO

An extraordinary opportunity to advance the lunar communications knowledge arises on the Apollo 14 mission which the writer believes should not be forfeited. The terrain at the Apollo 14 site includes isolated craters and cone formations with dimension and characteristics resembling more rugged future Apollo sites. It is almost an exemplary "in situ" communications testbed. Furthermore, on this mission, the proximity of the terrain obstacles is close enough to the LM so that instrumentation of signal strength values is readily practical and the probability of long duration EVA communications loss is minimum. A study of the terrain features of the site and of shadow maps of the region (see Figure 1) indicates that essentially all of the nominal traverses and desirable extensions are within line-of-sight (and presumably within communications range), but that points of possible communications difficulty are very close by.

Revisions to the currently planned Apollo 13 traverses would make it possible to generate quantitative communications data of value in refining and improving the prediction models. Specifically, five changes, some modest, to the EVA-2 and EVA-1 extended traverses currently planned, as illustrated in Figure 2 and as outlined below would, generate meaningful test data supporting or diminishing the usefulness of the current models for predicting, in a practical way, communications signal levels in the lunar surface environment. Such test data will facilitate communications predictions on future missions with considerably more confidence.

The proposed propagation tests are listed in Table I along with applicable models against which the signal strength test data will be collated. The estimated increase in traverse distances are first-cut estimates and can possibly be considerably reduced by more detailed traverse study.

In Test 1, traverse into and across Star Crater, a small but relatively deep crater, will generate signal attenuation data covering a wide range of diffraction angles. In Test 4, similar data will be collected for the situation in which the line-of-sight is obstructed by two (2) crater rims.

In Test 5, the terrain profile between EVA and LM will contain a major line-of-sight obstacle (cone), an order of magnitude greater in dimension than the LM or EVA antenna heights. Which model will best predict the signal attenuation as the EVA descends toward the base of the cone is not known; it could be that the Bremmer series as well as some of the diffraction models will show applicability.

Test 2 and Test 5 (final return leg) present an opportunity to correlate actual and theoretical signal values for relative flat regions devoid of exceptional features. An attempt can be made to reduce this signal strength data in terms of Bremmer series as well as geometric optics calculations. Included in the latter, hopefully, would be confirmation of the very low Fra Mauro surface roughness values in the geometric optics computation model which are currently based on terrain power spectral density information derived from photoclinometric data. Such confirmation would be a significant finding.

The terrain covered by the traverse changes proposed above appears to present slopes well within EVA capability limits; however, the total traverse deltas are regarded by personnel at Bellcomm who are directly involved in EVA operations engineering as being prohibitive from the time-line standpoint, i.e., direct conflicts with the assigned priority tasks would arise in considering the proposed traverse changes. Accordingly, it is suggested that:

1. First consideration or priority be given to the conduct of test items 3 and 4, the estimated total increase in the traverse for which is only .6 km. This would cover calibration for "Free Space loss," single and double knife-edge data.
2. If consumable usage permits, second priority be given to conduct of test items 1 and (if possible) 2 which will generate large diffraction angle knife-edge data and (if 2 is undertaken) an important collection of "smooth surface" signal strength data.
3. Priority should be given next to shortened paths for descent from the cone peak (paths 5A and 5B in Figure 1). These paths would provide at least some quantitative VHF data for propagation over this prominent isolated rounded obstacle; and these paths would not be without redeeming geologic values.
4. The original test item 5 merits last priority because its traverse length is large.

C. INSTRUMENTATION REQUIREMENTS

A necessary concomitant to the proposed tests is adequate instrumentation of the LM VHF received signal strength provide the detailed record of the communications test data. The sensor range and calibration techniques should be established with the view of optimizing the accuracy of the reduced signal strength data. To the best knowledge of the writer, the LM instrumentation needed for all or any part of the above proposed tests is not in the current plan for Apollo 14. (NOTE: Measurement GTO 625V -- VHF B receiver AGC -- had been incorporated in the Apollo 13 measurement list.)

Another approach to collecting equivalent signal strength data is to obtain readings of the LM-to-EVA link (instead of EVA-to-LM signal) relayed back to LM on the EVCS along with PLSS telemetry. This technique would be subject to loss of AGC data at time of low or lost signal whereas the LM received AGC would be a continuous signal. Implementation would not impact on LM hardware; however, it would entail a wiring change in the EVCS equipment to connect up an available AGC voltage and possibly would require some re-qualification testing.

In the absence of suitable instrumentation, it does not appear worthwhile to undertake the specific traverse changes suggested here since only qualitative performance indications would be obtained. Therefore, if, for reasons of lack of instrumentation or time-line conflicts, these tests cannot be conducted on Apollo 14, then it is suggested that the necessary telemetry wiring and planning for equipment tests be started for a subsequent mission.

A limited amount of photography also appears desirable to aid in reconstructing EVA location and recording unusual or unexpected terrain features.

D. RECOMMENDATIONS

The opportunity is tangible.

The required traverse changes appear to be reasonably modest.

The cost in schedule and funds is very small.

The potential payoff in aiding future mission planning through improved communications prediction is appreciable.

Accordingly, it is recommended that as many of the proposed tests as possible be included in the Fra Mauro mission. And, it is suggested that equivalent tests of signal prediction in definable terrain situations be planned for another site if those proposed herein cannot be completed on Apollo 14.

I. I. Rosenblum

2034-IIR-ms

I. I. Rosenblum

Attachment
References
Figure 1
Table 1
Appendix A

BELLCOMM. INC.

REFERENCES

1. Bremmer, H., Terrestrial Radio Waves, Elsevier Publishing Company, 1949.
2. Lindsey, Jefferson F., III, "Lunar Surface Transmission Loss for the Apollo Astronaut," NASA TN D-4915, NASA, Washington, D. C., December, 1968.
3. Norton, K. A., "The Calculation of Ground Wave Intensity over a Finitely Conducting Spherical Earth," Prol. I.R.E., pp. 623-639, December, 1941.
4. Vogler, L. E., "A Study of Lunar Surface Radio Communications," NBS Monograph 85, U. S. Department of Commerce, NBS September, 1964.
5. Hartman, Raymond F., "Graphical Attenuation Calculations for Irregular Terrain," Institute for Environmental Research, Boulder, Colorado, Technical Report R-27-ITSA-27, January, 1967.
6. Schmid, K. H., "Propagation Characteristics of the Apollo Dual-EVA Communication Link," Bellcomm TM-68-2034-13, August, 1968.
7. Rosenblum, I. I., "EVA Communications from Surveyor III Site on Apollo 12," Bellcomm Memorandum for File, October 8, 1969.
8. Rosenblum, I. I., "Use of Shadow Map Techniques to Estimate LM/EVA Line-of-Sight," Bellcomm Memorandum for File, April 6, 1970.
9. Rice, P. L., et al, "Transmission Loss Predictions for Tropospheric Communication Circuits," NBS Technical Note No. 101 (revised) Volumes I and II, U. S. Department of Commerce, NBS, CPRL, Boulder, Colorado, Volume I (revised) January 1, 1967; Volume II (original issue) May 7, 1965.
10. Schroeder, N. W., "Path Loss for a Communications Link on the Lunar Surface," Bellcomm Memorandum for File, June 1, 1970.
11. Lee, P. H., "Lunar Surface Studies Interim Report No. 1", TRW Systems Group, Project Technical Report No. 11176-H440-R0-00 January 16, 1970. Prepared for NASA, MSC, Houston, Texas.

BELLCOMM. INC.

REFERENCES CONT.

12. Lee, P. H., "Apollo 13 Mission Spacecraft-EVA VHF Coverage," TRW Systems Group, Project Technical Report No. 11176-H520-R0-00 March 31, 1970. Prepared for NASA, MSC, Houston, Texas.
13. Rosenblum, I. I., "Screening of line of sight to LM by Craters at Apollo Site 2 - Mission G," Bellcomm Memorandum for File, June 30, 1969.

FRA MAURO



FIG. 1. PROPOSED CHANGES IN TRAVERSES AT FRA MAURO TO OBTAIN VHF TEST DATA

TABLE I

<u>Test Item</u>	<u>Traverse</u>	<u>Traverse Departures</u> (from present plan)	<u>Assumed Applicable Signal Prediction Model</u>	<u>Approx. Increase in Traverse Distance</u>
1	EVA 1 (Extensions)	EVA descend into Star Crater and walk across Star Crater	a) Knife-edge diffraction theory over sharp crater rim	0.5 km
2	EVA 1 (Extensions)	EVA continue from Star Crater to flat region NE of Star Crater and return to LM	a) Bremmer series b) Geometric optics with reflections a function of surface roughness and electrical characteristics	0.9 km
3	EVA 2	EVA ascend to highest point on western rim of Cone Crater	a) Signal strength calculated from free space path loss values	0.2 km
4	EVA 2	EVA walk along Cone Crater rim to point on rim directly opposite LM, then away from rim approx. 100 meters	a) Single knife-edge diffraction over crater, near rim b) Double knife-edge diffraction over both crater rims	0.4 km
5	EVA 2	EVA descend far side of Cone in south-easterly direction (or on path at right angle to EVA-LM line); return to LM along south wall of Cone	a) Diffraction loss over isolated rounded obstacle b) Double knife-edge diffraction over sharp and rounded rims c) Beyond line-of-sight calculation for hill obstacle using Bremmer series and reduced sphere radius (i.e., hill contour) d) Geometric optics (on return leg)	1.2 km

APPENDIX A

G. EVA COMMUNICATION SYSTEM PERFORMANCE

Investigate communication loss modes of the EVA communication system during lunar surface operations.

Purpose

The purpose is to evaluate the performance of the EVA communication system when line of sight from EVA to LM is obstructed by lunar surface features.

The functional test objective is as follows:

- FTO 1) Determine the effects upon communication of obstructing lunar surface features between EVC-1 and the LM.

Test Conditions

- FTO 1) During any EVA period, the LM commander (EVC-1) will move to a position on the lunar surface such that the PLSS antenna line of sight to the LM is obstructed. Telemetry measurement GT 0625 V will be monitored in real time to provide information that can be relayed to the astronaut and to correlate astronaut comments with the data. The LM pilot (EVC-2) will take photographs of EVC-1, the LM, and the obstruction in such a manner that distances from the LM, the size and height of the obstructions, and surrounding terrain features are obtained. EVC-1 will estimate the distances to the LM and to nearby lunar surface features, provide a description of these surface features, describe the direction he is facing relative to the LM and estimate the angle between the PLSS antenna and the local horizontal.

This procedure will be accomplished at least three times with different lunar surface features at distances of one-half statute mile or greater between EVC-1 and LM. Each test will be conducted with the LM commander facing in the same direction relative to the LM in order to standardize the test configuration.

Success Criteria

- FTO 1) Sufficient data shall be obtained to define the effects of various lunar surface features and distance upon EVA voice and data communications when line of sight between EVC-1 and the LM is obstructed.

Evaluation

- FTO 1) The effects of various lunar surface features upon the EVA communication system performance will be determined. (Astronaut records, photographs, GT 0625 V, GT 0992 B, GT 0993 E, GT 0994 V and GT 9991 U)

Data Requirements

1) Telemetry:

<u>Measurement Number</u>	<u>Description</u>	<u>TM</u>	<u>Mode</u>	<u>Priority</u>
GT 0625 V	VHF B AGC	PCM	2	M
GT 0992 B	Phase, St Ph Er, Slctd SBand Xpndr	PCM	2	HD
GT 0993 E	Power, Selected SBand Xmtr RF Power	PCM	2	HD
GT 0994 V	Volt, Selected SBand Rcvr AGC	PCM	1	HD
GT 9991 U	EMU TM Outputs	FM/FM	N/A	M

2) Astronaut Logs or Voice Records: (M)

Comments on EVA voice communication performance when line of sight to the LM is obstructed to include PLSS antenna attitude, the direction EVC-1 is facing relative to the LM, type of obstructing lunar surface features, and distances under which communication loss or degradation occurred.

3) Photographs: (HD)

Photographs showing the direct path between EVC-1 and the LM to include surrounding surface features that may be related to multipath effects. (Note: Up to approximately five photographs will be required for each set of significantly different lunar surface features.)

G. EVA COMMUNICATION SYSTEM PERFORMANCE

Background and Justification

It is necessary to fully understand the transmission characteristics of the EVA communication system on the lunar surface. Testing similar to that identified by this objective has been accomplished in the earth environment and performance characteristics have been established. Due to the significant differences in the earth and lunar environments, it is necessary to accomplish these tests in the lunar environment. The test data will establish conditions under which EVA communication loss may be predicted for future lunar missions.

Telemetry measurement GT 0625 V (VHF B AGC) will be available only on LM-7 and is the only measurement that can be used to determine LM VHF receiver B signal strength. Marginal conditions will be detectable although communications may not be lost. Data will also be provided when the astronaut-to-LM communication is lost and regained. Distances at one-half statute mile or greater are expected to be required before signals at lower levels and marginal conditions are approached. The requirement for accomplishing the test condition with different lunar surface features is based on the need for data on multipath effects.

Previous Flight Objectives

<u>Objective Number</u>	<u>Title</u>	<u>Mission</u>
None		

BELLCOMM. INC.

Subject: Proposed Changes in Fra Mauro
Traverses to Obtain Significant
VHF Communications Performance
Data on Apollo 14 - Case 320

From: I. I. Rosenblum

DISTRIBUTION LIST

NASA Headquarters

W. B. Evans/MLO
J. K. Holcomb/MAO
A. S. Lyman/MR
C. M. Lee/MA
T. H. McMullen/MA
W. H. Shirey/MAL
J. D. Stevenson/MO
W. E. Stoney/MA

MSC

E. L. Chicoine/EE3
D. S. Eggers/EE3
N. B. Farmer/EE16
E. I. Fendell/FC2
R. L. Hymer/EE2
R. E. Joosten/TJ
E. F. Kranz/FC
H. C. Kyle/EE
C. K. Land/EB2
J. McKenzie/PD4
J. B. Tollison/EE2
P. Vavra/EB
J. Wood, Jr./EE2

Bellcomm, Inc.

W. J. Benden
P. Benjamin
A. P. Boysen, Jr.
R. K. Chen
J. P. Downs*
F. El-Baz
L. A. Ferrara
D. R. Hagner
J. W. Head
J. J. Hibbert
N. W. Hinners
J. E. Johnson

Bellcomm, Inc. (Continued)

H. Kraus
J. A. Llewellyn
J. P. Maloy
K. E. Martersteck
J. Z. Menard
J. T. Raleigh
P. E. Reynolds
I. M. Ross
J. A. Saxton
N. W. Schroeder
P. F. Sennewald
R. V. Sperry
J. W. Timko
R. L. Wagner
A. G. Weygand
M. P. Wilson
W. D. Wynn
Central Files
Department 1024 File
Library

*Abstract Only