BELLCOMM, INC.
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B70 05031

SUBJECT: Expected Communication Performance of the Apollo Subsatellite - Case 320

DATE: May 18, 1970

FROM: R. L. Selden

MEMORANDUM FOR FILE

A small subsatellite is now scheduled to be part of the Service Module (SM) science package on the Apollo 16 and 18 missions. The satellite will be launched from the SM into lunar orbit after operations on the lunar surface have been completed. The scientific purposes of the satellite are three-fold; they are to investigate (1) the formation and dynamics of the Earth's magnetosphere, (2) the boundary layer of the solar wind as it flows over the moon, and (3) by doppler tracking, the gravitational field of the moon. The original intent in the design of this satellite's communications system was that it would be provided support from an MSFN station equipped with an 85 foot diameter antenna system. Because of the higher support requirements placed on the 85 foot antenna systems of the MSFN, it is of interest to determine the communication performance of this subsatellite when being supported by a station of the MSFN equipped with a 30 foot diameter antenna. It will be shown that adequate support can be provided by the 30 foot antenna stations of the MSFN assuming nominal values for all parameters.

The salient characteristics of the subsatellite communication system, obtained from Messrs. B. H. Hood and C. T. Dawson of MSC's Telemetry and Communications System Division, are:

Transmit Frequency	2282.5 MHz
Effective Isotropic Radiated Power	-2.0 dBW
Data Rate	128 bits per second
Modulation Technique	PCM/PM/PM
Subcarrier Frequency	32.768 kHz
Subcarrier Modulation Index	1.0 radian

The subsatellite transmitter is part of a transponder that is similar to those used on the CSM and LM. The downlink carrier is coherently related to the received uplink carrier in the ratio of $\frac{240}{221}$. The transponder will be the same type as that used in the GSFC Test and Training Satellite. This transponder, in its present design, has the capability for psuedo-noise ranging; however, for this application, this capability will be deleted to minimize the effects of turn-around noise and modulation products.

(NASA-CR-112717) EXPECTED COMMUNICATION PERFORMANCE OF THE APOLLO SUBSATELLITE (Bellcomm, Inc.) 10 p

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Table 1 presents an evaluation of the subsatellite downlink performance when being supported by stations of the MSFN equipped with (1) an 85 foot antenna system, (2) a 30 foot antenna system and a cooled parametric preamplifier, and (3) a 30 foot antenna system and an uncooled parametric amplifier. The results show that a 10^{-4} bit error rate performance can be supported by the first two configurations when nominal parameters are assumed.* Of particular interest is the 2.5 dB margin that exists when the support is provided by a station equipped with a 30 foot antenna and a cooled parametric amplifier. It may also be of interest to note that the demodulator required to support the subsatellite subcarrier will be a new black box.

R. L. Selden

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Attachment
Table 1

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*Worst case values could make the margin negative at a 30 foot MSFN station using a cooled parametric amplifier.

TABLE 1

NOMINAL SUBSATELLITE DOWNLINK COMMUNICATIONS PERFORMANCE

A. Performance when Supported by an 85 Foot MSFN Station

1.	Effective isotropic radiated power	- 2.0 dBW
2.	Free space loss (215,000 nm)	-211.6 dB
3.	Receive antenna gain (85')	52.5 dB
4.	Total received signal power	-161.1 dBW
	<u>Carrier Channel</u>	
5.	Modulation loss [Cos^2 (1.0)]	- 5.3 dB
6.	Received carrier power	-166.4 dBW
7.	Noise spectral density (T = 210°K)	-205.4 dBW/Hz
8.	Carrier tracking loop bandwidth (2Bw = 50Hz)	17.0 dB
9.	Total noise in carrier bandwidth	-188.4 dBW
10.	Signal-to-noise ratio	22.0 dB
11.	Required signal-to-noise ratio	12.0 dB
12.	Margin	10.0 dB
	<u>Data Channel</u>	
13.	Modulation loss [Sin^2 (1.0)]	- 1.5 dB
14.	Filter loss (filtering a squarewave subcarrier about its fundamental frequency)*	- 1.2 dB
15.	Received subcarrier power	-163.8 dBW
16.	Noise spectral density (T = 210°K)	-205.4 dBW/Hz
17.	Bit rate bandwidth (128 bps)	21.1
18.	Total noise in bit rate bandwidth	-184.3 dBW
19.	Data channel signal-to-noise ratio	20.5 dB
20.	Required SNR for 10^{-4} bit error rate (includes detector degradation)	10.5 dB
21.	Margin	10.0 dB

*The output of the product detector in the MSFN receiver is a squarewave with amplitude K sin(Θ); where K is proportional to the system gain and Θ is the modulation index of the squarewave subcarrier on the r.f. carrier. The filter selects only the fundamental of the squarewave providing to the demodulator a sine wave with amplitude 4 K sin(Θ)/π. The power reduction between the original squarewave and the filtered sine wave is $\frac{16K^2 \sin^2(\Theta)}{2\pi^2 K^2 \sin^2(\Theta)}$ or $\frac{8}{\pi^2}$ (1.2 dB).

TABLE 1 (Continued)

B. Performance when Supported by a 30 Foot MSFN Station

(with cooled paramp)

1.	Receive antenna gain change (from 85')	- 8.5 dB
2.	Receiver noise density change (T = 135°K)*	+ 1.9 dB
3.	IF limiter suppression	- 0.9 dB
4.	Net change from 85' station performance	- 7.5 dB
	Data Margin	2.5 dB

(with uncooled paramp)

1.	Receive antenna gain change	- 8.5 dB
2.	Receiver noise density change (T = 289°K)	- 1.4 dB
3.	IF limiter suppression	- 1.0 dB
4.	Net change from 85' station performance	- 10.9 dB
	Data Margin	- 0.9 dB

*The noise temperature of an MSFN station equipped with a 30 foot diameter antenna and a cooled parametric amplifier is less than that of an 85 foot diameter antenna station similarly equipped because the moon subtends less than the 3 dB beamwidth. The moon can completely fill the beamwidth of an 85 foot antenna system.

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