BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Verification of Adequate Bandwidth in the Apollo VHF Ranging Receiver - Case 320

DATE: October 23, 1968

FROM: K. H. Schmid

ABSTRACT

Frequency variations, caused by oscillator drift and doppler shift, are expected to occur at the IF input of the Apollo VHF ranging receiver. It is shown that the worst case, corresponding to the frequency variation of the third harmonic of the ranging mid tone, is ±28.939 KHz referenced to the nominal IF center frequency of the ranging receiver. Since the receiver IF bandwidth (3 db) is ±32.5 KHz, adequate bandwidth is available to pass the critical frequencies for all ranging tones used in this system.

(NASA-CR-100299) VERIFICATION OF ADEQUATE BANDWIDTH IN THE APOLLO VHF RANGING RECEIVER (Bellcomm, Inc.) 4 p

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MEMORANDUM FOR FILE

I. Introduction

The Apollo VHF ranging system consists of a Digital Ranging Generator (DRG) which interfaces with a VHF transceiver aboard the CSM and a Range Tone Transfer Assembly (RTTA) which interfaces with a similar transceiver aboard the LM. The transceivers are modified versions of ones previously used for voice/data communications. The new transceivers have been modified to process the ranging signals, but otherwise operate in the same manner and on the same frequencies, and are used to establish the two-way communications link between the LM and the CSM.

Under dynamic flight conditions, frequency variations are expected to occur at each receiver IF input. These frequency variations are caused by master oscillator drift at the transmitter, local oscillator drift at the receiver, and doppler shift due to the relative velocity between the LM and CSM. Thus, the receive IF carrier frequency usually is displaced from the receiver's nominal 30 MHz IF center frequency. Since the IF bandwidth is much narrower than the RF bandwidth, the IF is the constraining factor on the overall receiver bandwidth.

The purpose of this memorandum is to investigate and verify that adequate IF bandwidth is provided in each receiver to accommodate worst case frequency variations such that all required spectral components of the receive ranging signal can pass through the receiver IF to the envelope detector.

II. Determination of Worst Case IF Carrier Frequency Offset from Nominal IF Center Frequency

For purposes of this investigation, the LM to CSM link is chosen for the worst case because it operates at the higher RF frequency (296.8 MHz nominal vs. 259.7 MHz for the CSM to LM link). This choice results in both a larger doppler shift for a given relative velocity between the LM and CSM, and larger oscillator drifts (allowable drift is specified in terms of percent of the nominal frequency). Since the IF bandwidth characteristic of the LM and CSM ranging receiver is identical, satisfactory performance of the LM to CSM link will insure satisfactory performance of the lower frequency, CSM to LM link.

System parameters of the LM to CSM link are presented below.

Transmitter Frequency:	296.8 MHz ±0.003%
Receiver L.O. Frequency:	266.8 MHz ±0.003%
Maximum Allowable Doppler Shift: (corresponding to ±600 feet/second)	±181 Hz

A worst case offset of the IF carrier frequency from the nominal 30 MHz IF center frequency can be calculated by adding these factors algebraically. Thus:

Maximum Offset of Transmitter Frequency:	±8.904 KHz
Maximum Offset of Receiver L.O. Frequency:	±8.004 KHz
Maximum Offset of IF Carrier Frequency: (No Doppler)	±16.908 KHz
Maximum Allowable Doppler Shift:	±0.181 KHz
Maximum Offset of IF Carrier Frequency from Nominal IF Center Frequency:	±17.089 KHz

Measurement of IF bandwidths by RCA have yielded typical values of 65 KHz (3 db) and 85 KHz (6 db).* Thus, more than adequate bandwidth is provided to pass the receive IF carrier. Now it is necessary to determine if all required spectral components of the ranging signal can pass the filter while operating in the above worst case condition.

III. Determination of Worst Case Spectral Component Offset from Nominal IF Center Frequency

During ranging operation of the system, one of three square wave tones is amplitude modulated onto the LM to CSM link. The desired square wave tone is selected according to a sequence programmed into the ranging system. The square wave tone frequencies are listed below.

Mid Tone	3.950 KHz
Mid and Coarse Tone	3.950 KHz ⊕ 247 Hz
Fine Tone	31.596 KHz

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*Per telephone conversation with J. Connelly of RCA, September 24, 1968.

The mid tone, and the mid and coarse tone, are used during the acquisition phase of the ranging sequence. These signals, 100% AM modulated on the carrier, must pass the IF bandpass filter. Assuming that the first and third harmonics are required for adequate performance, a required spectral component (third harmonic of the 3.950 KHz square wave) exists at ±11.850 KHz referenced to the IF carrier frequency.

When the fine tone is received, the early/late gate of the receiver generates an error signal having spectral components at ±5.266 KHz referenced to the IF carrier frequency. These spectral components also must pass the filter.

From this cursory analysis, it is evident that the worst case spectral component is the third harmonic of the 3.950 KHz mid tone. Thus, the worst case offset of this spectral frequency is determined as follows:

Maximum Offset of IF Carrier Frequency from Nominal IF Center Frequency:	±17.089 KHz
Third Harmonic of Mid Tone	±11.850 KHz
Maximum Offset of Third Harmonic from Nominal IF Center Frequency	±28.939 KHz

IV. Conclusions

Since measured values of IF 3 db bandwidths yield typical values of ±32.5 KHz from the nominal IF center frequency, all required spectral components can pass through the receiver IF even under worst case conditions. These results are predicated, of course, on the actual equipment meeting the above characteristics. From the above calculations, it is evident that approximately 3.5 KHz bandwidth margin is available at each end of the bandpass to provide for minor equipment irregularities; e.g., imperfect centering of the bandpass filter characteristic on 30 MHz. Therefore, acceptable system performance should be attained even when operating this equipment under worst case conditions.

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From: K. H. Schmid

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