Bandwidth Selection for Block IV SDA

R. B. Crow
R.F. Systems Development Section

A review of the bandwidth selection for the Block III Subcarrier Demodulator Assembly (SDA) is given, along with the design philosophy as implemented in the engineering model of the Block IV SDA.

Historically, the Block III SDA bandwidths were chosen for a number of reasons. The $wl_0 = 0.03$ Hz loop bandwidth was the narrowest loop that could be efficiently obtained in terms of hardware stability, cost, and acquisition time, while the 1.5-Hz loop bandwidth was compatible with the Block III receiver $wl_0 = 152$ Hz and was required for high-acceleration tracking at launch. The $wl_0 = 0.375$ Hz loop bandwidth was a compromise in an effort to retain reasonable noise performance in the presence of dynamic signal input (i.e., doppler rate).

During the past 6 years, mission requirements have undergone considerable change, and S-band doppler rates as high as 180 Hz/s can be expected in close flybys of the larger planets (e.g., Pioneer 1.3-radius, Jupiter flyby).

The basic philosophy regarding bandwidth selection for the Block IV SDA requires

(1) A narrow bandwidth ($wl_0 = 0.03$ Hz), so that no penalty is suffered in using the Block IV SDA at low symbol rates.

(2) A wide bandwidth that is as narrow as possible while still maintaining sufficient gain (at design point) to handle the maximum doppler rate at the highest subcarrier frequency.

(3) An adaptive gain control that can be raised quickly to improve the loop acquisition characteristic but lowered slowly at a rate depending on which bandwidth is being used, thus offering a convenient

means of increasing the loop gain (i.e., bandwidth), which can be smoothly reduced (to reduce the phase transient due to loop gain change).

(4) A loop gain increase of 10:1 to give a reasonable increase in tracking/acquisition performance without increasing the loop jitter beyond usable limits. (At design point, the narrow-bandwidth loop has a jitter of 4 deg RMS, while the narrow-acquisition-bandwidth loop will have 11 deg RMS phase jitter.)

Figure 1 is a plot of loop bandwidth vs. input sideband signal-to-noise energy ratio per bit (ST_{sy}/N_0) for both the Block III and IV SDAs. It can be noted that a more adaptive bandwidth is available in the Block IV design because of a different IF bandwidth and a different ratio of input limit level/virtual input signal (i.e., ν) (Ref. 1). It is also apparent that the narrow bandwidth is approximately the same for Blocks III and IV up to $ST_{sy}/N_0 \simeq +10$ dB, while the Block III medium bandwidth is approximately the same as the Block IV wide bandwidth.

From Fig. 1 and Tables 1 and 2, it is apparent that many missions previously handled by the Block III medium bandwidth can now be handled by the Block IV narrow-bandwidth loop (because of increased gain).

All other missions requiring high doppler rate tracking can use the Block IV wide bandwidth (with little increase in noise degradation compared to the Block III medium and with large improvement in rate tracking error).

Reference

1. Brockman, M. H., "An Efficient and Versatile Telemetry Subcarrier Demodulator Technique for Deep Space Telecommunications," Paper No. A-1, 2, Fourth Hawaii International Conference on System Science, Jan. 1971, University of Hawaii, Honolulu, Hawaii.

Table 1. Gain comparison between Block III and IV SDAs at design point

Loop bandwidth	Design point loop gain, s^{-1}	
	Block III	Block IV
Narrow	10	56.8
Narrow-acquisition	10	568
Medium	250	–
Wide	500	59,700
Wide-acquisition	–	597,000

Table 2. Gain comparison between Block III and IV SDAs at $ST_{sy}/N_0 = +25$ dB

Loop bandwidth	Loop gain at $ST_{sy}/N_0 = +25$ dB, s^{-1}	
	Block III	Block IV
Narrow	23	2,756
Narrow-acquisition	–	27,560
Medium	2,675	–
Wide	2,549	329,544
Wide-acquisition	–	3,295,440

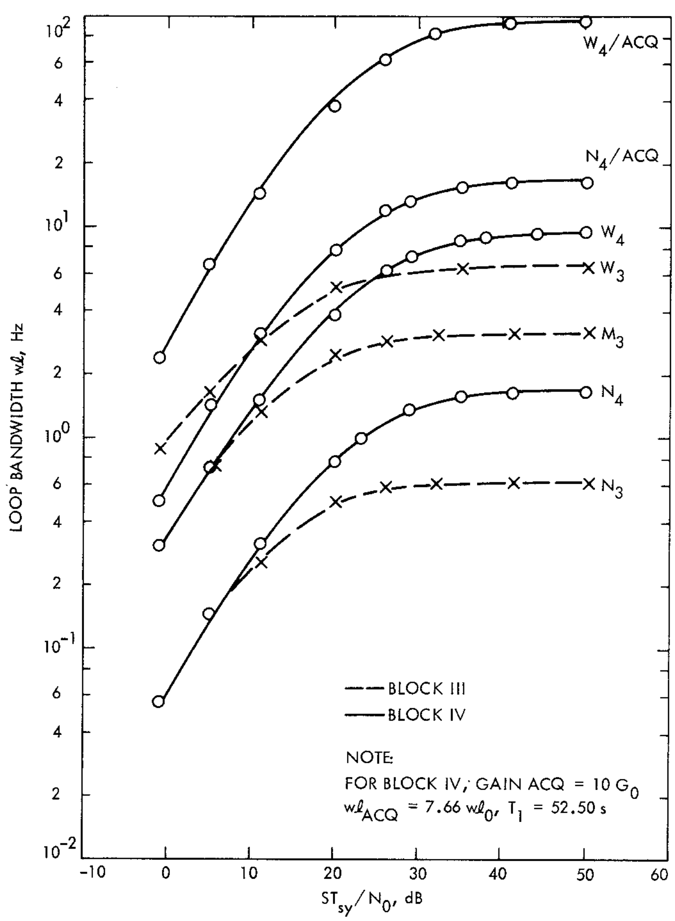

Fig. 1. ST_{sy}/N_0 vs. $w\ell_0$ for Block III and IV SDAs for R_{sy} = 40 SPS