THE SPACE GROUND LINK SUBSYSTEM (SGLS) DOWNLINK DETECTION IMPROVEMENT

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ABSTRACT

The Space Ground Link Subsystem (SGLS) downlink signals are a PM/PSK modulation and have been detected at VAFB by detuning the receivers to the subcarrier frequency or by using cascaded demodulators. A recent demodulator enhancement by SEMCO allows a single box solution by internally routing the signals between FPGAs. This paper discusses the test methods and compares the results of the legacy methods of demodulation with the new demodulators.

INTRODUCTION

The SGLS is a communications system and its set of standards for satellite uplink and downlink systems. SGLS is used for US Government and military satellites.

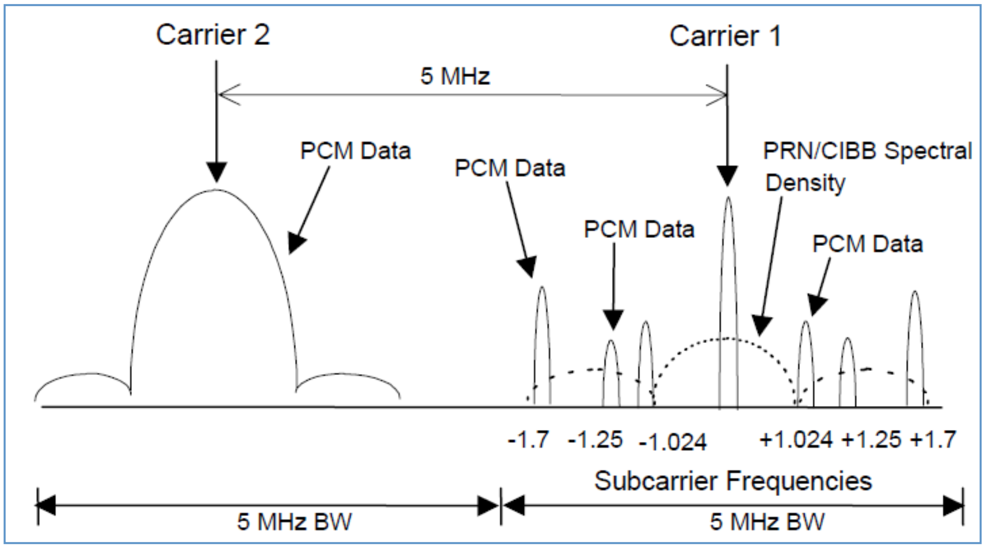
SGLS is not a common aircraft or missile test modulation and additional equipment besides telemetry receivers is required for optimum demodulation.

SGLS OVERVIEW

There are two downlink SGLS carriers. Carrier 1 can have up to two of three possible subcarriers at once. These subcarriers can carry Pulse Code Modulated (PCM) data, voice, or FM/FM data. We concentrated on testing the PCM data, which would be demodulated by the receivers rather than external equipment. The PCM data is Biphase Shift Key (BPSK) modulated, then mixed with other data and PM modulated onto the S-Band Carrier 1.

Carrier 1 and Carrier 2 can also be directly modulated with data. The normal receiver demodulators will cover these cases. See Figure 1.

Figure 1: SGLS Downlink Spectrum (from Ref. 1)



DEMODULATOR OPTIONS

a. SGLS specific demodulators

b. There are companies that make modulators/receivers with SGLS-specific demodulators: RT Logic and GDP, to name a couple. We wanted to avoid the expense of additional receivers, the use of additional rack space, additional patching, and cabling.

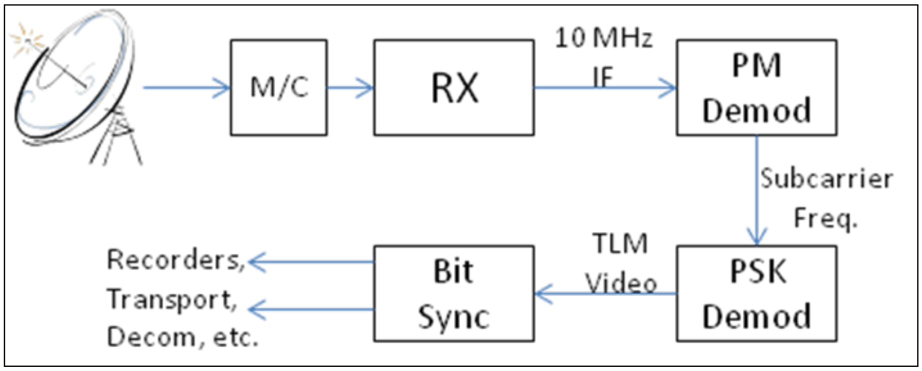
c. Legacy demodulation

   The Western Range has supported SGLS missions in the past. Different methods of demodulation have been used.

   i. Cascaded demodulators

      The signals have been demodulated by taking the IF output from an RF receiver into an external phase demodulator, then into an external BPSK demodulator tuned to the subcarrier frequency. This method works well, but requires additional equipment and rack space. See Figure 2.

Figure 2: Legacy Configuration



ii. Frequency Detune

Using the property that phase modulated (PM) sidebands are frequency stable, we can tune the receiver for the carrier frequency plus (or minus) the subcarrier frequency and BPSK demodulate the signal. We expect a performance degradation using this method because we are only using the power from one of the subcarrier sidebands.

iii. Additional PCI Card in Receiver

SEMCO has a drop-in card for their RC600a chassis available to perform the SGLS demodulation. These cards were removed with the demodulator upgrades.

d. SEMCO DSP Demodulators

The SLRS contract chose SEMCO receivers. We still had a SGLS requirement that we couldn't meet without external equipment or performance degradation. Since the SEMCO demodulators are DSP-based, they were able to perform both demodulations internally with just a software upgrade.

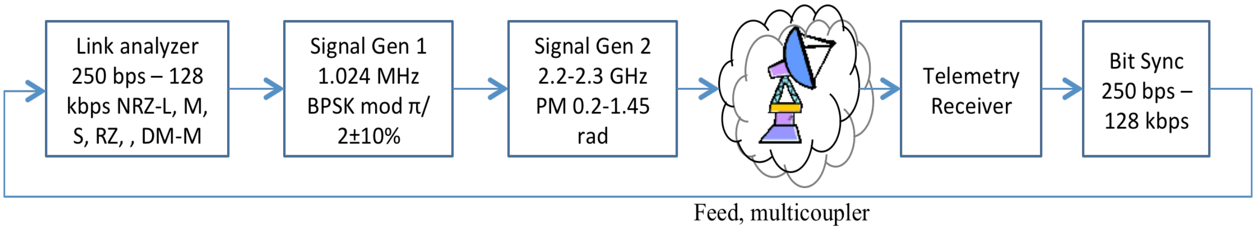
In the receivers, we set our IF bandwidths wide enough to pass the sidebands, then set bit rate and subcarrier frequencies. Settings are shown in Table 1. Other parameters were set to optimize the bit error performance.

At low bit rates, there is excessive jitter with the SEMCO DSP bit syncs, they advertise down to 2 kbps for PM/PSK. We require lower bit rates, so we take the analog telemetry video output to an external bit sync. Here we can get good data at 250 bps.

TEST SETUP

The test setup is shown below in Figure 3. The RF output from Signal Generator 1 is put into the external input of Signal Generator 2.

Figure 3: Test Setup



The question arises as to what output level to set Signal Generator 1. One can set the deviation on Signal Generator 2, and the external input should have a signal of 1 Vp into a 50 Ω input. We found that setting the signal level with an oscilloscope (50 Ω impedance) did not give the correct modulation deviation. We found that we needed to monitor the relative levels of the carrier and subcarrier and adjust the output level of Signal Generator 1 to get the correct modulation.

The modulation loss of the carrier (from Ref. 1) would be:

$MLc = 10 \log Pc$ (Equation 1)
$= 10 \log [J_0(\beta)]^2$
For $\beta = 1$ radian, (Equation 2)
$MLc = 20 \log [0.765]$ (Equation 3)
$= 2.3$ dB

The modulation loss for the first order PM sideband would be:

$MLsc = 10 \log Psb$ (Equation 4)
$= 10 \log 2[J_1(\beta)]^2$
For $\beta = 1$ radian, (Equation 5)
$= 10 \log 2[J_1(1.0)]^2$
$= 10 \log 2[0.4401]^2$
$= 10 \log (.3874)$
$= 4.1$ dB

Where Psb is the sideband power, β is the modulation index, and J_n is the nth order Bessel function of the first kind. The loss is compared to the unmodulated carrier. So, we look at the RF output of signal generator 2 with modulation ON using a spectrum analyzer and adjust the power output of signal generator 1 with modulation OFF until the difference in the carrier and sideband levels is 4.1-2.3 = 1.8 dB.

PERFORMANCE COMPARISON

We cannot measure the output from the first demodulator to find the zero carrier to noise. We found the carrier 0 C/N level using the 3 dB method by routing the output of signal generator 2, with an unmodulated signal generator 1 input, through the system and connecting the receiver IF output to a power meter. To convert this to the subcarrier data 0 Eb/No, we apply the total correction below:

Table 1: Conversion from Carrier Zero C/N to Subcarrier Zero Eb/No

Subcarrier Frequency	Receiver IF Bandwidth	Data Rate	FIR BW	Bandwidth Correction IF to FIR (dB)	Bandwidth Correction FIR to Data Rate (dB)	Subcarrier Modulation Loss (dB)	Total Correction (dB)
1.024 MHz	2.4 MHz	128 kbps	128 kHz	-63.8 + 51.1	51.1-51.1	4.1	-8.6

The Bandwidth Correction IF to FIR column is needed because we are experimentally measuring the 0 C/N level of the carrier and its IF bandwidth. Since the signal is further filtered in the second demodulation by Finite Impulse Response (FIR) filters, we need to correct for the difference, shown below.

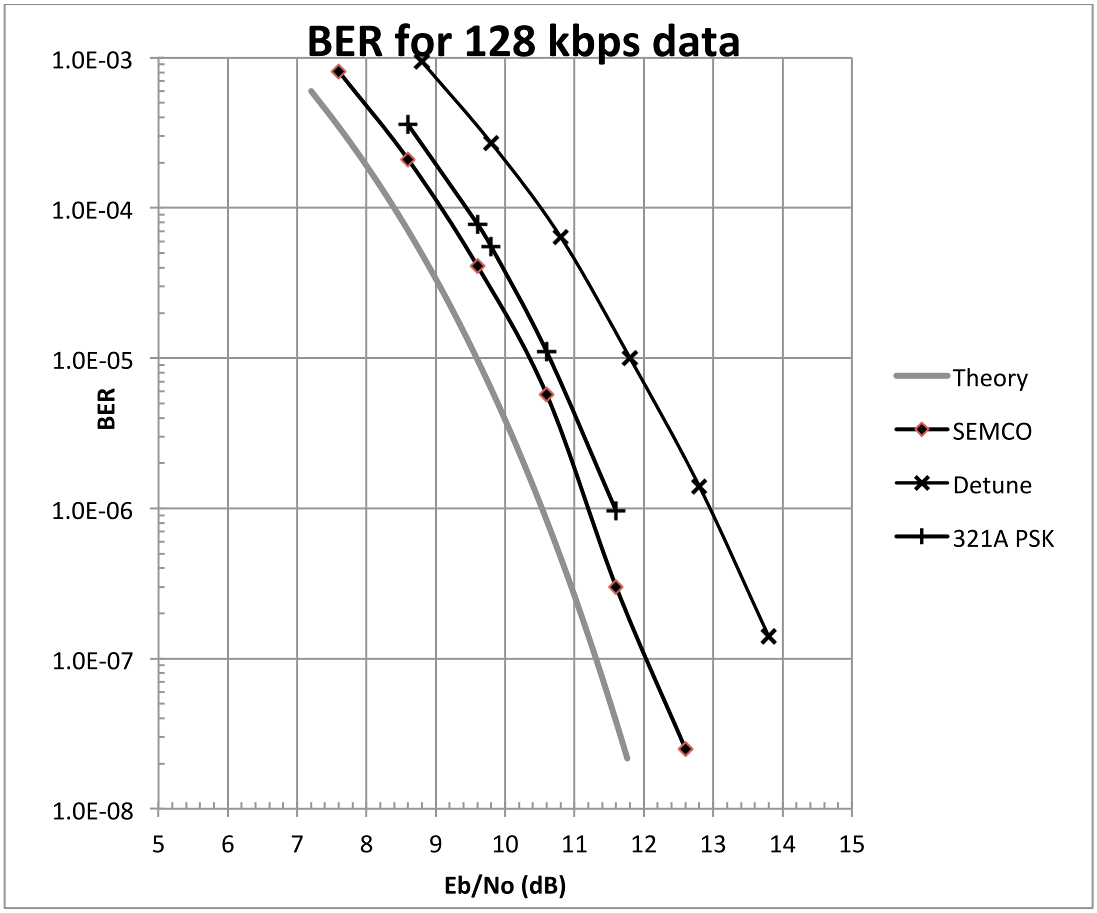
Noise Power in IFBW = 10 log IFBW = 10 log (2,400,000) = 63.8 dB (Equation 6)
Noise Power in FIRBW = 10 log FIRBW =10 log (128,000) = 51.1 dB (Equation 7)

The Bandwidth Correction FIR to Data Rate column converts 0 C/N to 0 Eb/No for a FIR filter bandwidth not equal to the bit rate. In the case of 128 kbps, the data rate is equal to the FIR bandwidth.

The Subcarrier Modulation Loss column is needed because the subcarrier is 4.1 dB lower than the carrier (with 1 radian PM modulation).

Test data is shown in Figure 4 for 128 kbps configuration. The “detuned” data shown is the BER with the same RF levels as the SEMCO tests.

Figure 4: BER for 128 kbps Data



CONCLUSIONS

A method was found to quantitatively test SGLS downlink receiver performance. New and legacy reception methods were tested and compared.

As expected, we found a performance improvement of the new demodulators as compared with the method of detuning the receivers. There was also an improvement over the cascaded demodulator method.

REFERENCES

"Standardized Interface Specification Between Air Force Satellite Control Network, Network Operations Range Segment, and Space Vehicle," SIS-000502D, Network Integration Contract Lockheed Martin Technical Operations, 5 October 2000.