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Author: Lee, Dennis

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Co Authors: Lee, Dennis Yan, Tsun-Yee

Abstract Title: Performance of Selected Advanced Bandwidth Efficient Modulations Using Current Ground Station Receivers

Abstract Text

The increased congestion of space frequencies has brought about the necessity for advanced bandwidth efficient modulations. Such modulations often require complex receivers to provide optimal bit error performance. However, due to economics and other factors, many ground stations will not be able to upgrade their receivers in the near future to support these modulations. For this reason, missions using certain bandwidth efficient modulations may not be able to obtain cross support from other space agencies that have older receivers. Thus it is necessary to determine which bandwidth efficient modulations can be demodulated by current ground station receivers, and to quantify the losses due to a sub-optimal mismatched receiver. We present the bit error rate measurements of five different bandwidth efficient modulations using the Block V receiver. The Block V receiver is the primary receiver deployed by NASA throughout the Deep Space Network (DSN) ground stations. It has the capability to demodulate BPSK, QPSK, and Offset QPSK modulations.

The bandwidth efficient modulations tested in this paper represent a wide range of quadrature modulations currently under consideration for recommendation by the Consultative Committee on Space Data Systems (CCSDS) for space-to-earth links in the Space Research Services bands (Category A 2200-2290 MHz, 8450-8500 MHz and Category B 2290-2300 MHz, 8400-8450 MHz). They are Gaussian Minimum Shift Keying (GMSK) BTb=0.25, Feher-patented Quadrature Phase Shift Keying (FQPSK-B), Square Root Raised Cosine Offset QPSK (alpha = 0.5), Trellis-coded OQPSK (T-OQPSK), and Butterworth filtered OQPSK (BTb=0.5). These modulations provide a narrow bandwidth and sharp spectral roll-off with reasonable bit error performance.

This study was divided into three parts. First, computer simulations were conducted using the aforementioned bandwidth efficient modulations and an OQPSK receiver model. The simulation model incorporated integrate-and-dump detection filters, an offset Costas carrier tracking loop, and a digital transition tracking loop (DTTL). Second, a FPGA waveform generator was designed to create the baseband waveforms of the five bandwidth efficient modulations. The design objectives of the waveform generator were low complexity and gate count, with moderate bit rates up to 10 Mbps. A brief discussion of the waveform generator design is given. The spectra and the eye diagrams of the modulations generated by the FPGA are plotted. Finally, bit error probabilities of the efficient modulations generated by the FPGA were measured using the Block V receiver. A summary of the test setup is given below.

The hardware tests were conducted in the Telecommunications Development Laboratory at JPL. A FPGA was used to generate the baseband waveforms of the efficient modulations. After digital-to-analog conversion and anti-aliasing filtering, the baseband waveforms were upconverted to an intermediate frequency (IF) of 437.1 MHz. The spectrum was measured at this point. The IF signal was then upconverted to 8450 MHz and amplified by a 1 Watt solid-stated power amplifier operated at saturation. The spectrum was again measured to determine spectral regrowth of the signal. The RF signal was then downconverted to 2450 MHz, and sent to the input of the Block V receiver. The output of the receiver is compared with the generating PN sequence to determine the bit error probability.

Test results show that the Block V receiver can demodulate and detect all five bandwidth efficient modulations, with losses ranging from 0.7 dB to 3.0 dB Eb/No at 10^-5 bit error probability. Simple modifications to the receiver are proposed which could reduce these losses.

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