PULSE SHAPED CONSTANT ENVELOPE 8-PSK MODULATION STUDY

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ABSTRACT

The most bandwidth-efficient communication methods are imperative to cope with the congested frequency bands. Pulse Shaping methods have excellent effects on narrowing bandwidth and increasing band utilization. The position of the baseband filters for the pulse shaping is crucial. Filters after the modulator will have non-constant envelope and before the modulator will have constant envelope. These two types have different effects on narrowing the bandwidth and producing bit errors. The constant envelope 8 PSK is used throughout the simulations and is compared with the non-constant envelope results. This work provides simulation results of spectrum analysis and measure of bit errors produced by pulse shaping in an AWGN channel.

KEY WORDS

8-PSK Modulation, Pulse Shaping, Bit Error Rate, Band Utilization Ratio, Bit Rate(R_b)

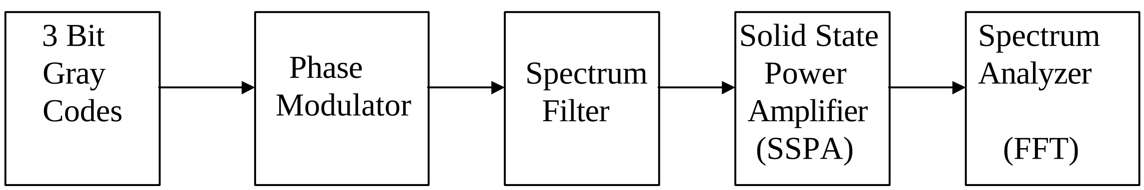
INTRODUCTION

This paper provides simulation results for constant envelope pulse shaped 8 Level Phase Shift Keying (8 PSK) modulation for end to end system performance. In order to increase bandwidth utilization, pulse shaping is applied to signals before they are modulated. This paper provides simulation results of power spectra and measurement of bit errors produced by pulse shaping in a non-linear channel with Additive White Gaussian Noise (AWGN). The constant envelope 8 PSK pulse shaping techniques will be used throughout this paper and will be referred to as Type B. Three kinds of baseband filers, 5th order Butterworth, 3rd order Bessel and Square-Root Raised Cosine with different BTs or roll off factors, are utilized in the simulations. An End-to-End system performance, including the Intersymbol Interference (ISI) and the Bit Error Rate (BER) as a function of Eb/No on 8PSK modulation was conducted on SPW software. This work gives a comparison of simulation results between non-constant envelope (Type A) and Type B modulation techniques on spectrum and bit error rates. The simulations were performed on a Signal Processing Worksystem (SPW: software installed on a Hewlett Packard Model 715/100 UNIX Station). This project was conducted at New Mexico State University (NMSU) in the Space Communication and Telemetry Laboratory in the computer and Electrical Engineering Department.

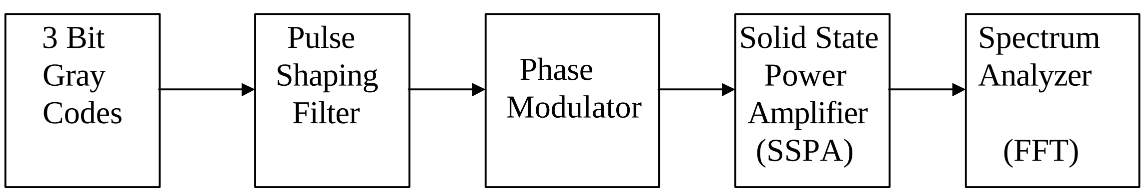
First, a simulation block diagram will be described. Secondly, the results of the simulations on power spectrum, bandwidth utilization and bit error rates for different types of pulse shaping filters are given. Finally, conclusions of the work on pulse shaped 8-PSK are given at the end of this paper.

PULSE SHAPED 8-PSK SIMULATION TEST SYSTEM

Figure 1 shows the block diagram that was simulated on SPW for power spectra for 8PSK and shows the two possible locating for the phase filtering. Figure 1a shows the implementation for non-constant envelope pulse shaped 8 PSK (Type A) and Figure 1b shows the configuration for constant envelope pulse shaped 8 PSK (Type B).



(a) Modulation Type A



(b) Modulation Type B

Figure 1 Block Diagram for Spectrum Analysis

Power Spectra Analysis

A random binary signal is combined via a Gray code, then the 8-level signal passes through a pulse shaping filter, is modulated, passed through a Solid State Power Amplifier (SSPA), and then a spectrum Analyzer.

The random data source provides ideal data with a data rate of 256 Hz, and the sample frequency, Fs, is 131072 Hz. For the spectrum shaping, three types of pulse shaping filters are used. They are 5th order Butterworth with BT=1, 2, 2.8, 3, 3rd order Bessel with BT=1, 1.2, 2, 3, and square-Root Raised Cosine with roll off factor a =1. The BT represents the product of the bandwidth with the symbol time. The constant envelope 8 PSK signal which comes from the modulator goes to the input of the Solid State Power Amplifier(SSPA).

The SSPA model for simulation is based upon specifications provided by the European Space Agency (ESA) for 10 Watts, solid state, S-band power amplifier. Since the SSPA is operating at saturation level and constant envelope 8PSK is used, the spectra of the signals at the input of the SSPA are almost the same as that of the signals output from the SSPA. The Spectrum Analyzer is taken from the Interactive Simulation Library(ISL) of SPW. The power spectrum is obtained by taking the Fast Fourier Transform(FFT) of the input signals of the Spectrum Analyzer.

Bit Error Rates

The bit errors produced are due to the ISI and AWGN. Figure 2 shows the system block diagram for measuring bit error rates.

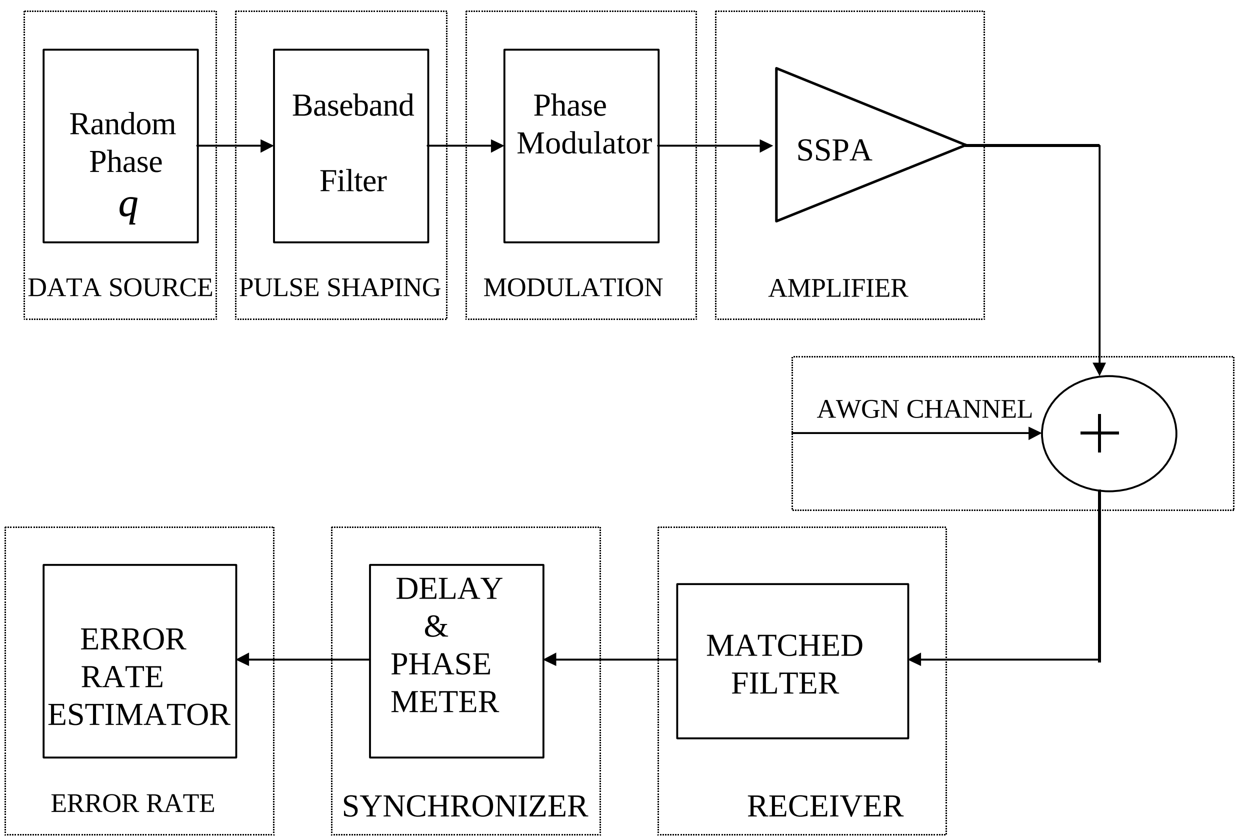


Figure 2 Simulation System Block Diagram

AWGN is added to the signals out of the SSPA to simulate channel noise. The AWGN is taken to have zero mean and with variance $\sigma_n^2 = N_o/2$. $N_0/2$ is the power spectral density of the white noise. Ideally, to give maximum SNR, a matched filter is usually used as a receiver. In this project, an integrate and dump block is used as the matched filter(matching to the NRZ data). Since the actual signal is fairly complex (due to the pulse shaping), an actual matched filter was not attempted at this time. The synchronizer performs a correlation between the reference signals and received signals (delayed and distorted), and gives an estimate of the number of samples of delay and the phase between the two samples. The reference signal and received signals now are adjusted to have the same delay, and are put into the error rate estimator to count the number of bit errors.

SIMULATION RESULTS

Power Spectrum Simulations: Figure 3 shows the output of the SSPA without a pulse shaping filter being used. Figure 4 shows the output of the SSPA when a 5th Order Butterworth (BT=1) is used as a pulse shaping filter (type B). Figure 5 shows a comparison between the output of the SSPA for Type A and Type B modulations. It can be seen that Type B has a spectrum that falls off faster than Type A.

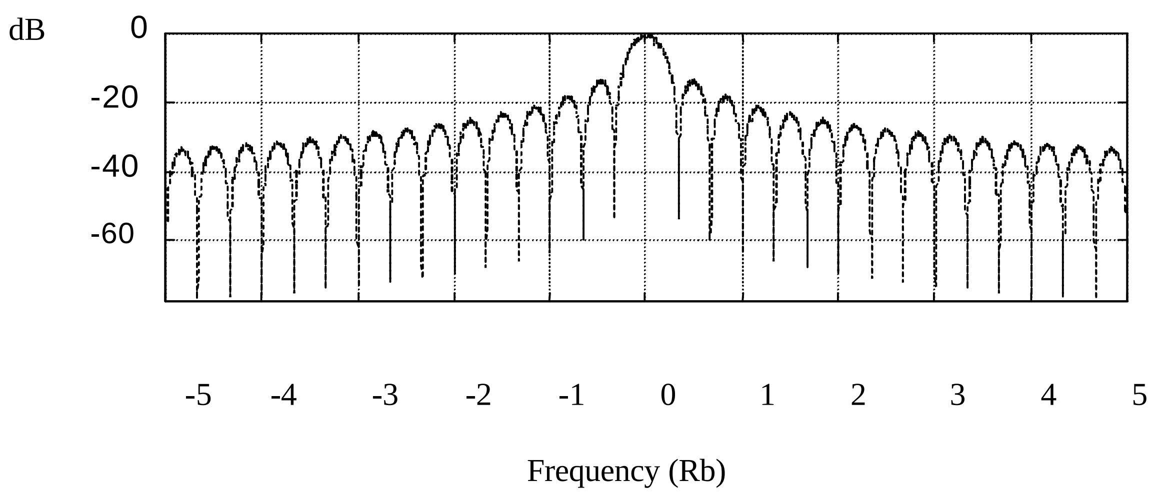


Figure 3 Unfiltered 8-PSK Power Spectral Density

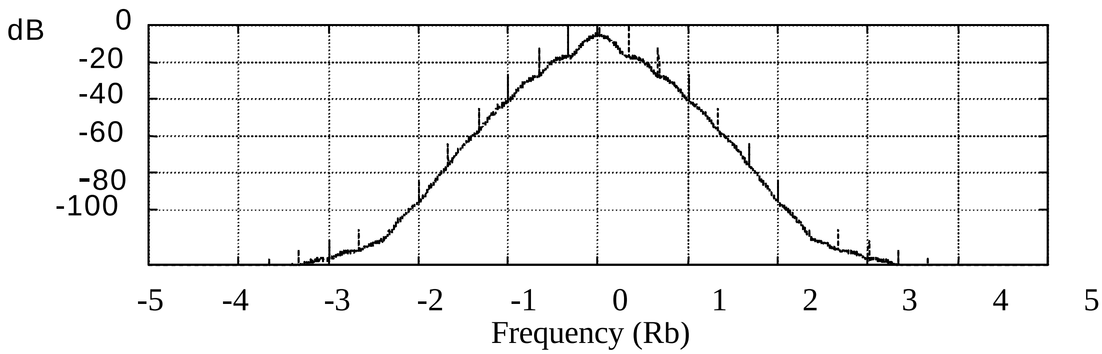


Figure 4 5th Order Butterworth Filter (BT=1), 8-PSK Power Spectral Density

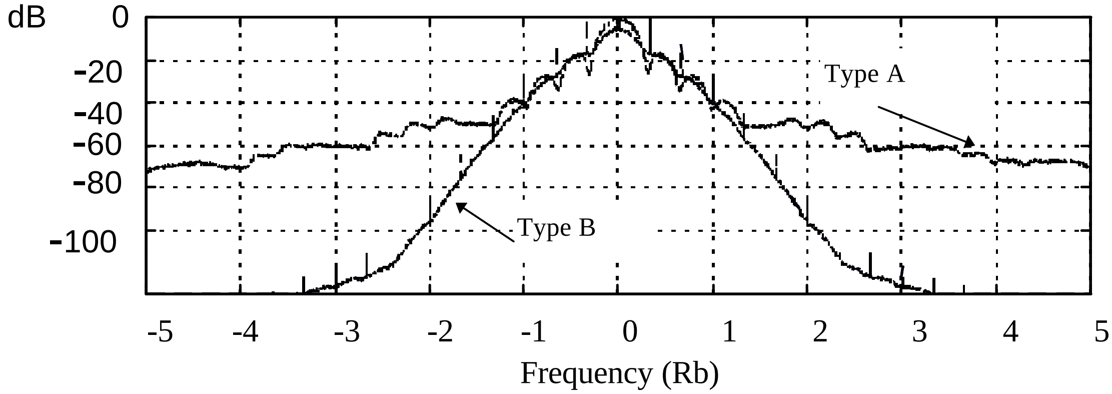


Figure 5 5th Order Butterworth Filter (BT=1), 8-PSK Power Spectral Density
(Type A and Type B)

Frequency Band Utilization Ratio (ρ)

The frequency band utilization ratio can be defined as:

$$r = \frac{\text{Number of spacecraft with Filtering Accommodated in Frequency Band}}{\text{Number of spacecraft without Filtering Accommodated in Frequency Band}}$$

From the simulations, the utilization ratios for type B were calculated from the power spectra and listed in Table 1 along with the utilization ratio for Type A[5]. From the utilization ratio table, for the same BT and baseband filters, modulator type B has higher band utilization ratios than type A.

Utilization Ratio (Type B)

Filter Type	-50 dB point		utilization	
	with spikes (R_b)	no spikes (R_b)	with spikes	no spikes
None	35		1	1
Butterworth(5th order) BT=1	1.22	1.28	28.7	27
Butterworth(5th order) BT=2	2.38	2.43	14.7	14.4
Butterworth (5th order) BT=2.8	3.2	3.23	11	10.8
Butterworth (5th order) BT=3	3.45	3.45	10.1	10.1
Besssel (3rd order) BT=1	1.625	1.75	21.5	20
Besssel (3rd order) BT=1.2	1.88	2.04	18.6	17.1
Besssel (3rd order) BT=2	3.1	3.22	11.3	10.8
Besssel (3rd order) BT=3	4.5	4.53	7.8	7.7
SRRC rolloff=1	1.11	1.23	31.5	28.5

Utilization Ratio (Type A)

Filter Type	-50 dB point	utilization
None	35Rb	1
Butterworth(5th order)BT=1	2.5Rb	14
Besssel (3rd order) BT=1	2.95Rb	11.86
SRRC rolloff=1	2.5Rb	14

Table 1 Utilization Ratio of Type A and Type B 8 PSK

Bit Errors Rates Simulations

This paper provides the measure of bit errors according to the bit energy to noise ratio (Eb/N_o). The system block diagram for measuring bit error rates was shown in Figure 2. For different filter types and their positions (type A or B), the BERs are put together for comparison. The plots of the BER are given in Figures 6-8.

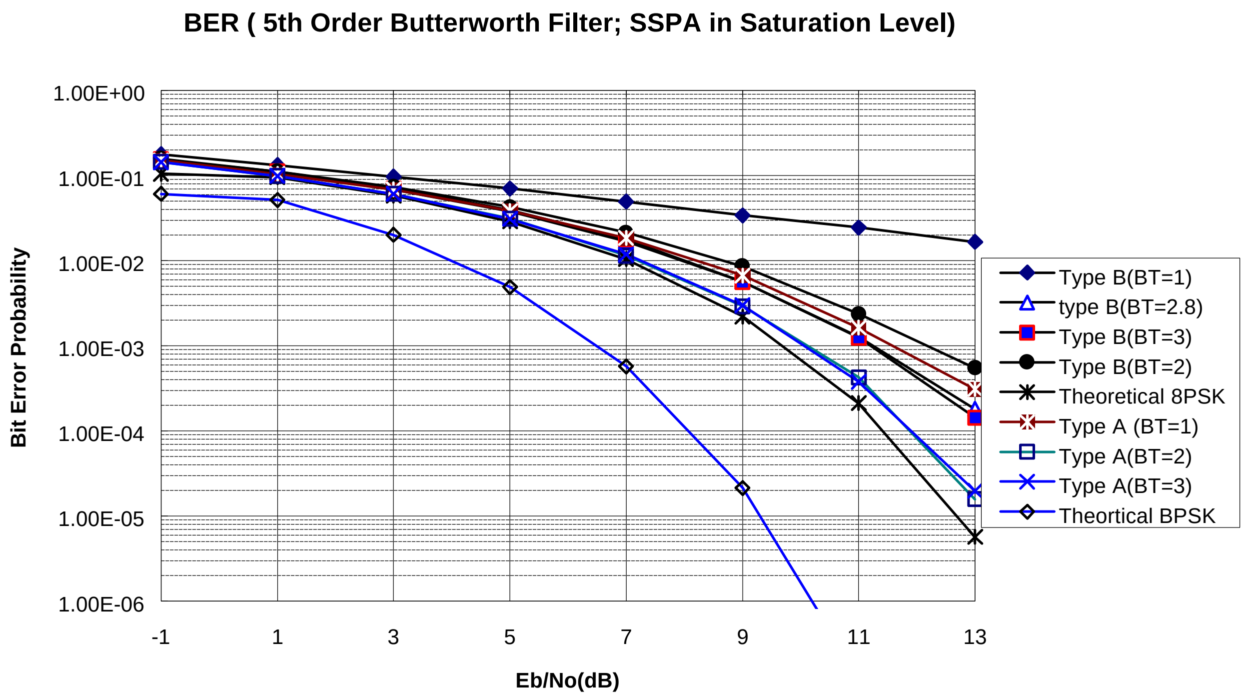


Figure 6 BER For 5th Order Butterworth Filters (Type A and B)

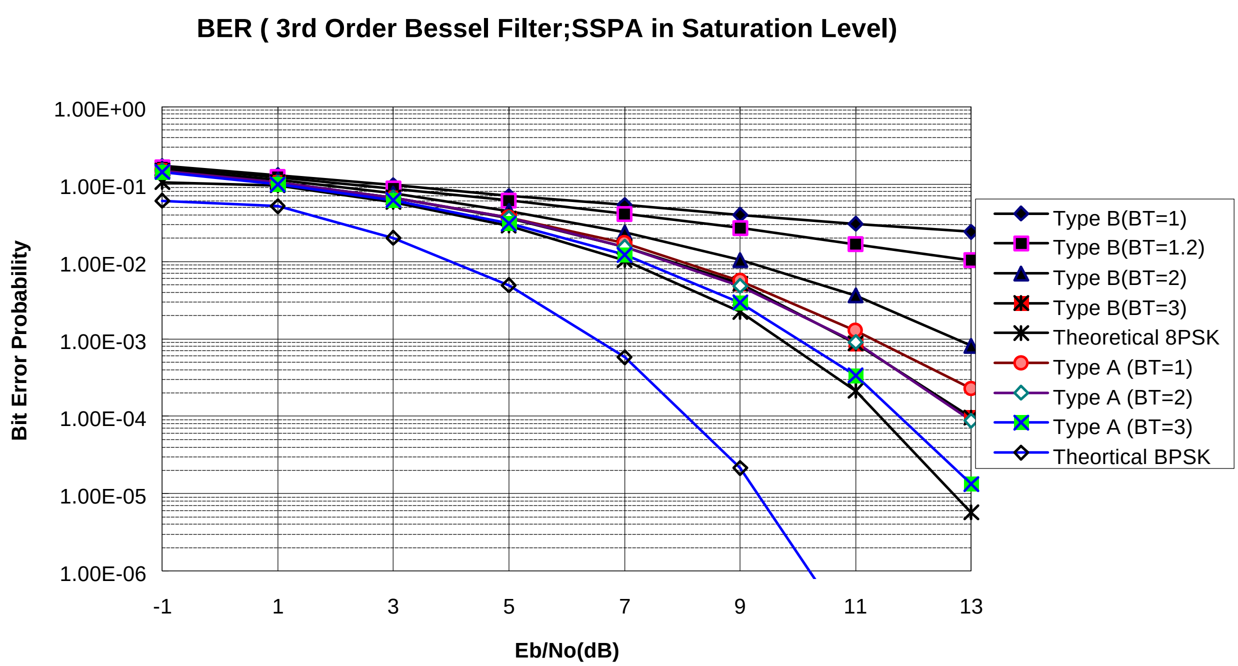


Figure 7 BER For 3rd Order Bessel Filters (Type A and B)

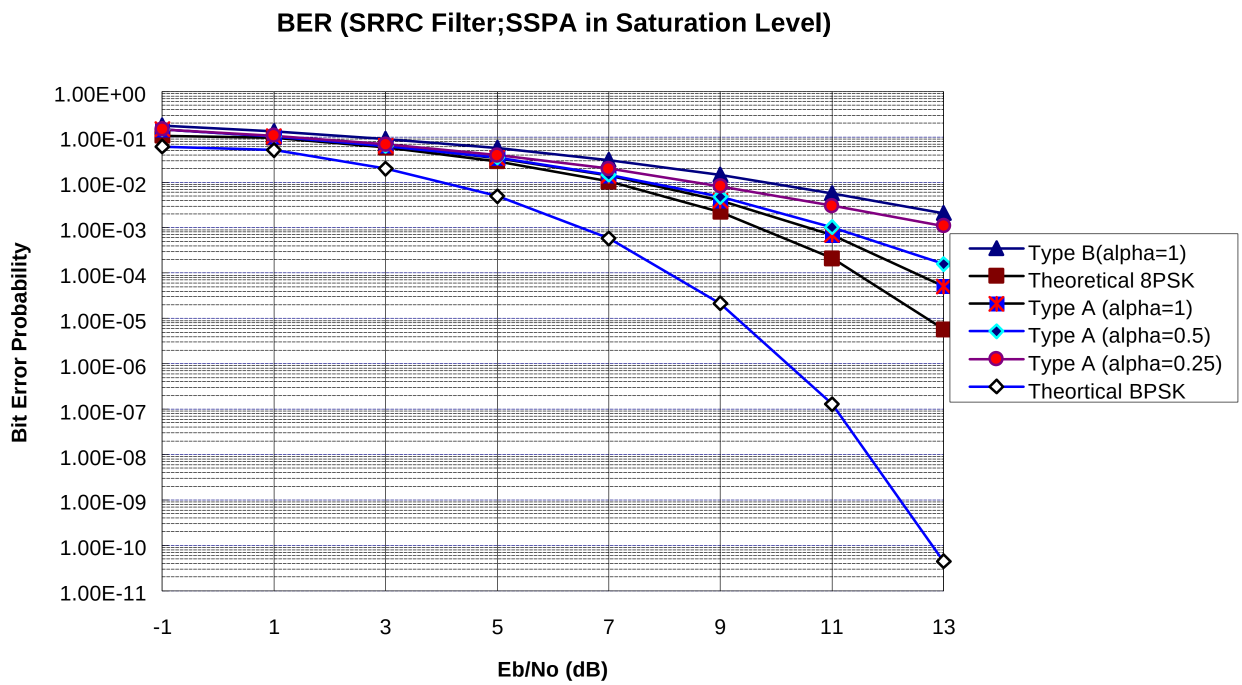


Figure 8 BER Plots For SRRC Filters (Type A and B)

ISI Losses Due To The Filter

The ISI losses due to the pulse shaping filter can be determined by the BER simulations. The following tables give the results of baseband filter ISI losses at 10^{-3} BER for theoretical 8 PSK (or BPSK) and the filtered 8 PSK.

Filter Type	Loss (dB) BT=1	Loss (dB) BT= 1.2	Loss (dB) BT=2	Loss (dB) BT=2.8	Loss (dB) BT=3
Butterworth 5th Order	22.5-10= 12.5	-----------	12.32-10= 2.32	11.48-10= 1.48	11.48-10= 1.48
Bessel 3rd Order	----------	20-10= 10	12.85-10= 2.85	-----------	11.20-10= 1.20
SRRC (a =1)	14.22-10= 4.22	----------	----------	----------	----------

Table 2 Baseband Filters ISI Loss Measurements at 10^{-3} BER (Compared to ideal 8PSK)

Filter Type	Loss (dB) BT=1	Loss (dB) BT= 1.2	Loss (dB) BT=2	Loss (dB) BT=2.8	Loss (dB) BT=3
Butterworth 5th Order	22.5-6.8= 15.7	-----------	12.32-6.8= 5.52	11.48-6.8= 4.68	11.48-6.8= 4.68
Bessel 3rd Order	----------	20-6.8= 13.2	12.85-6.8= 6.05	-----------	11.20-6.8= 4.88
SRRC (a =1)	14.22-6.8= 7.42	----------	----------	----------	----------

Table 3 Baseband Filters ISI Loss Measurements at 10^{-3} BER (Compared to ideal BPSK) (Dashes indicate that the simulation was not performed)

As stipulated in [4], the optimum filter should have the smallest BT value and provide losses<0.4 dB. Thus a higher order of BT should be simulated to find an optimum BT.

CONCLUSIONS

The simulations conducted in the Space Communication and Telemetry Laboratory at NMSU on the pulse shaped 8 PSK modulations were concluded with the following results.

Different types and positions of baseband filters have different effects on narrowing the bandwidth and on the frequency band utilization ratio. In general, type B had narrower power spectra than type A did for the same BT value.

Different types and positions of baseband filters also have different effects on the bit error rates. In general, type A had lower bit error rates than type B. That means that the narrower the bandwidth, the larger the bit error rate. For the 3rd Order Bessel filter, the BER produced by type A(BT=2) is almost the same as that produced by type B (BT=3). For the 5th Order Butterworth filters, the BER produced by type B (BT=2.8 or 3) is between those produced by type A (BT=1) and type A (BT=2).

A matched filter is crucial for receiving the signal to lower the BER. Integrate and dump circuits can exactly match pulse signals, but for pulse shaped signals it could not match perfectly. A new matched filter which can match these Type B pulse shaped signals is needed so that the BER can be reduced further. More filter types and larger BT (BT>4) should be simulated to find an optimal filter and BT. The Spikes that are prevalent in the power spectra should be investigated and ways to reduce or eliminate them should be found.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. Sheila Horan for her help and direction in the development and preparation of this paper. The author would like to thank the National Aeronautics and Space Administration (NASA) for their support under Grant NASA# NAG 5-1491. Also a special thank to the people in the Center for Space Telemetry and Telecommunications Systems at New Mexico State University for their assistance.

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