IEEE 802.11
Wireless Access Method and Physical Layer Specifications

Title: GFSK As a Modulation Scheme for a Frequency Hopped Phy

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Abstract

This paper proposes using binary GFSK with BT=0.5 and frequency deviation, h = 0.36 as a modulation scheme. A low complexity receiver can be implemented for this set of modulation parameters.

1. Introduction and Summary

The use of continuous phase frequency shift keying (CPFSK) has tentatively been selected as the prefered modulation scheme for the the frequency hopped Phy. There are a number of advantages to using CPFSK which include good spectral efficiency and the ability to use limiting amplifiers. To completely define the CPFSK modulation scheme the pulse shape, modulation index, h, and number of levels of the baseband signal, M need to be defined. The proposed parameters are based on practical considerations. This paper proposes a possible set of modulation parameters that can be implemented with a low complexity receiver and transmitter and also meet the FCC transmit spectrum requirements. The proposed modulation parameters are a binary level (M=2), and Gaussian pulse shape with BT = 0.5 and frequency deviation h = 0.36.

For a low complexity (and low cost) implementation a binary (M=2) signaling scheme is a good choice. In addition, for reasons of complexity the modulation scheme should allow for a noncoherent receiver implementation. The noncoherent implementation implies that the receiver recovers a baseband waveform which is proportional to the instantaneous frequency modulation, as opposed to the instantaneous phase modulation. For the noncoherent implementation it is desirable to select a baseband pulse shape that results in minimal intersymbol interference (ISI). A Gaussian pulse (GFSK) with BT=0.5 results in minimal ISI and is also used in existing equipment such as DECT.

For M=2, and GFSK with BT=0.5, the frequency deviation can be adjusted until the FCC transmit spectrum requirements are met. The FCC requirements are interpreted to mean that the -20 dB (with respect to the maximum spectral density) RF bandwidth is 1 MHz. Based on simulation results a value of h = 0.36 will meet the FCC requirements.

2. Simulation Results

Simulations were performed to generate the transmit spectrum for binary GFSK modulation. Random binary data was used as the data source to a GFSK modulator. The parameters h and BT are selectable in the simulation. The power spectrum was estimated by computing the magnitude squared of a complex FFT of the transmit waveform and then averaging over multiple FFT's.

The simulation was verified by generating an MSK signal and comparing the power spectral density (PSD) generated from the simulation to theoretical results which is easily computed for an MSK signal. The MSK signal for the simulation was generated by setting BT>>1. The simulation and theoretical results for the MSK signal shown in Figure 1 agree closely.

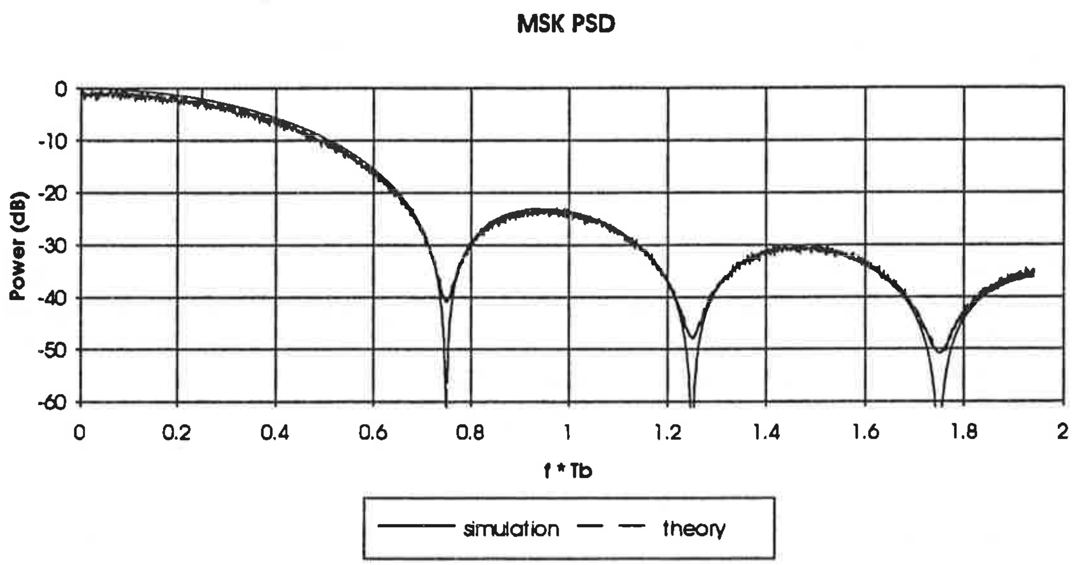


Figure 1 MSK Power Spectral Density

Figure 2 shows the results of the simulation for h = 0.3, 0.36, 0.4 and 0.5 with BT=0.5. The spectral occupancy is reduced as the deviation is decreased. A value of h =0.36 results in a transmit spectrum which meets the FCC transmit spectrum requirements. As h is decreased the amplitude of the eye pattern for the baseband waveform is reduced linearly with h.

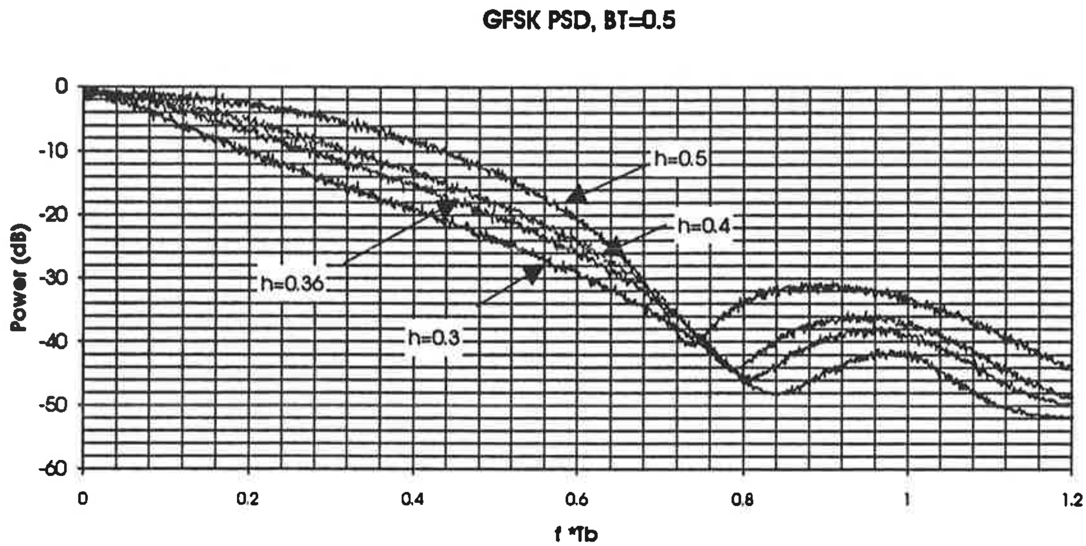


Figure 2 Transmit Power Spectrum For GMSK with BT=0.5

Another logical choice of modulation parameters is to select h=0.5 and adjust the value of BT to meet the FCC spectral requirements. Figure 3 is a plot of the transmit power spectrum for h=0.5 and BT= 0.25 and 0.3. Based on simulation results a value of BT= 0.25 is required to meet the FCC transmit spectrum requirements.

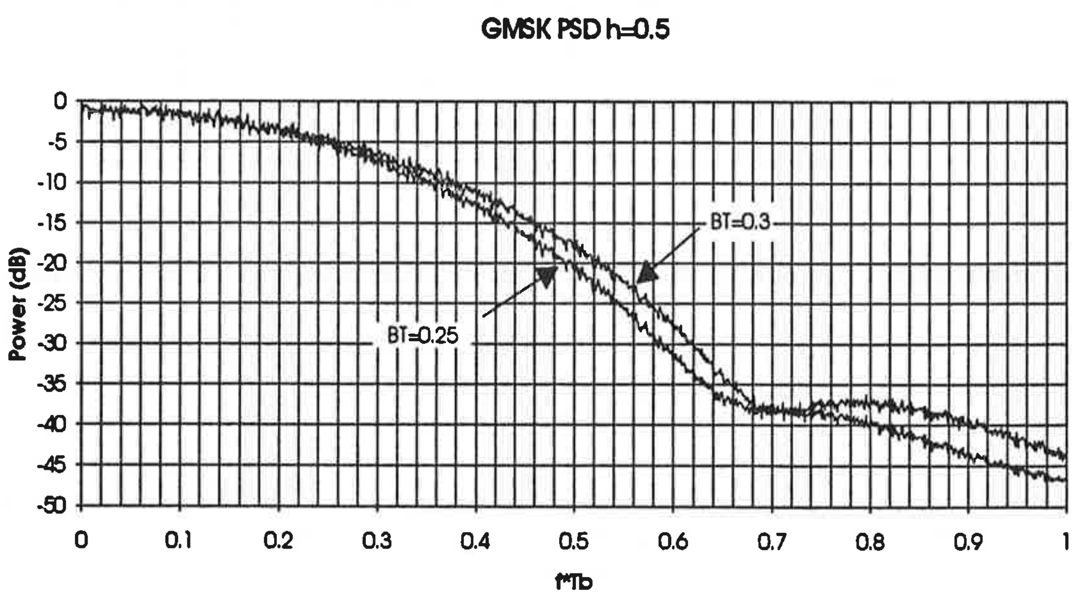
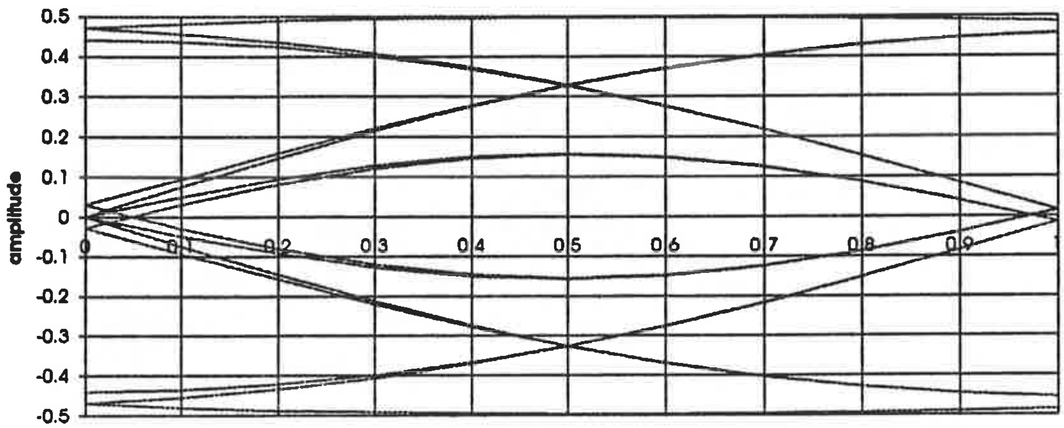


Figure 3 Transmit Power Spectrum For GMSK with h = 0.5

Figure 4 compares the eye pattern for these two candidate schemes. The patterns are properly

Eye Pattern BT=0.25, h=0.5



Eye Pattern BT=0.5, h=0.36

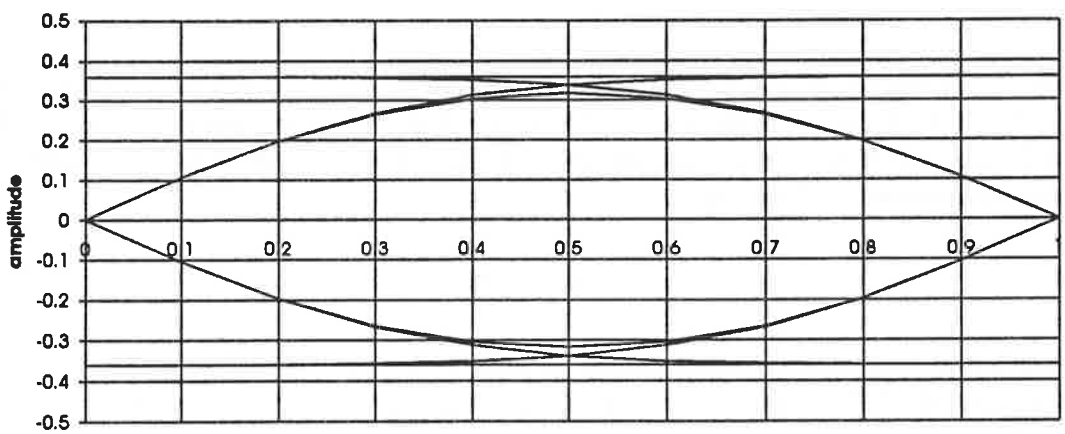


Figure 4 Eye Diagram comparing GFSK BT=0.25, h=0.5 and GFSK BT = 0.5, h=0.36

scaled relative to each other. For BT=0.5, h=0.36 the eye pattern shows minimal intersymbol interference (ISI) and the eye opening is approximately +/- 0.34. The eye for BT=0.25, h=0.5 shows significant ISI although this ISI must be evaluated with respect to the value of the eye opening. Evaluating the eye opening, 50 % of the samples have an eye opening approximately equal to that for BT=0.5, h=0.36, 25 % have an eye opening of +/- 0.5 and 25 % have an eye opening of approximately +/- 0.15. The eye opening gives an indication of the expected bit error rate (BER) performance. Not taking account of any additional lowpass filtering of the baseband waveforms or any forms of equalization in the receiver for BT=0.25, h=0.5 then intuitively

BT=0.5, h=0.36 would seem to give better BER performance. However, further analysis or simulation should be performed to verify this.

3.0 Adjacent Channel Interference

The simulation results result in spectral plots that are accurate to a normalized f*Tb of approximately 1.2. For larger values of f*Tb the accuracy of the estimate is poor. This is probably an artifact of the the windowing function used or is due to limitations in numerical accuracy of the FFT computation. The adjacent channel interference (ACI) has been calculated by Murota [1] for BT=0.5, h=0.5. The results were computed by taking the ratio of the out of band power to the total power in the desired channel. The power is computed in an ideal rectangular filter with BT = 1. The results are shown in Figure 5. Since the spectrum for BT=0.5, h=0.36 is narrower than the spectrum for BT=0.5, h=0.5 then the results in Figure 5 are an upper bound. Examining the spectral plots in Figure 2, the ACI should be 8 to 10 dB lower for h=0.36 compared to h=0.5. The selected parameters of BT=0.5 and h=0.36 provide good adjacent channel interference performance.

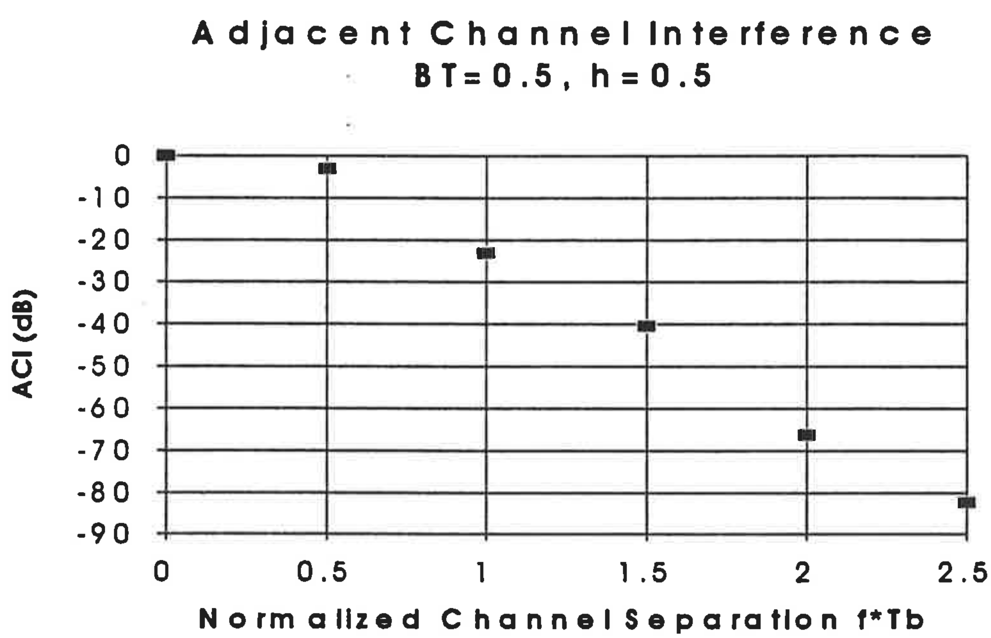


Figure 5 Adjacent Channel Interference for BT=0.5 and h =0.5

References

[1] Murota, K. and Hirade, K., "GMSK Modulation for Digital Mobile Radio Telephony", IEEE Transactions on Communications, Vol. COM-29, No. 7, July 1981, pp 1044-1050.