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Review Article

Adjacent and Co-channel Interferences Effect on AWGN Using M-ary PSK Modulation

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Abstract

Instantaneous transmissions is a feature of wireless communication systems, which in turn results in some kind of interference since these transmissions use a common channel. This is phenomenon cannot be eliminated and hence many measures are taken to dampen its effect. Interference in this type of systems is a performance-limiting factor, where it increases the rate of dropped packets, which in turn causes a degradation in system quality. There are many causes for this kind of interference such cell overloading, a call in development in nearby cell or a base station very close that is using the frequency. The main two types of interference are Co-Channel Interference (CCI), and Adjacent Channel Interference (ACI).

In this paper these interferences effect on the performance of a wireless communication system over AWGN channel is investigated using the M-ary-PSK modulation scheme. This investigation covers the effect on Bit Error Rate (BER) and power spectra density of the transmitted signal in an addition to that the constellation diagram of the modulated and demodulated signals. The obtained results indicated that these interference signals have some effect on M-ary PSK modulation technique. The sternness of the effect depends on the modulation level i.e. the higher the level the more severe is effect.

Keywords: Channel; CCI; ACI; PSK; AWGN; BER

Introduction

Modern communication systems nowadays utilize multi-level digital modulation in order to improve bandwidth efficiency. With M-ary, signaling, digital inputs with more than two modulation levels are allowed on the transmitter's input signals. The data is transmitted in the form of symbols, each symbol is represented by n bits, so there are $M = 2^n$ signal levels in M-ary schemes. The M-ary techniques have various variations depending on frequency or phase or amplitude and these schemes known as M-ary FSK, M-ary PSK and M-ary ASK. The combination of both M-PSK and M-ASK construct M- Quadrature Amplitude Modulation (M-QAM)) [1].

The motivation behind M-ary PSK is to increase the bandwidth efficiency of the PSK modulation schemes. In BPSK, a data bit is represented by a symbol. In M-ary PSK, $n = \log_2 M$ data bits are represented by a symbol, thus the bandwidth efficiency is increased to n times. Among all M-ary PSK schemes, QPSK is the most-often-used scheme since it does not suffer from BER degradation while the bandwidth efficiency is increased. Other M-ary PSK schemes increase bandwidth efficiency at the expense of BER performance [2].

Some researchers have investigated the effect of these two interferences on signals modulated by M-QAM technique under AWGN channel and as far as the researchers knowledge, there are not many studies that investigated the effect of these interfering signals on M-PSK modulation techniques. In [3] the authors investigated the effect of the ACI and CCI on AWGN channel using

8-PSK modulation and found out that these noisy signals affect the received signal and this effect can be mitigated by implementing the proper phase and frequency methods with the use of efficient filtration techniques.

The contribution of this paper is to investigate the effect of adjacent and co-channel interference over AWGN channel using the 8, 16, 32 and 64 – PSK since to the authors knowledge there is no previous work investigated the effect of these interfering signals using all the above mentioned modulation techniques.

Communication channels

Electrical systems are effected by undesirable signals known as noise, which is a phenomenon of such systems. The most common type of noise added over the channel in communication systems is the AWGN. It is additive due to the received signal (Rx) is equal to the transmitted signal (Tx) plus the noise. It is white because it has a flat power spectral density. It is Gaussian due to its probability density function, which can be accurately modeled to behave like a Gaussian distribution. It distorts the received signal, since the bandwidth of the signal is much smaller than the bandwidth of the AWGN communication channel. Figure 1 illustrates the AWGN communication channel model [3,4].

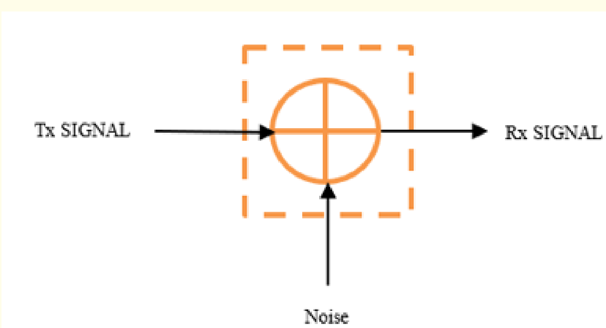

Figure 1: Block Diagram Model of AWGN Channel.

Communication system with interference

Figure 2 represents the basic communication system with ACI and CCI, which includes an input data source, the M-ary PSK modulator/demodulator models, trans-receiver raised cosine filters, AWGN channel, and down sampler.

The applied input data is modulated by M-PSK modulation. After that, the output of the modulator is filtered by raised cosine filter. Then the signal is combined with interference parameters, which construct the noisy signal. That noisy signal is send through AWGN communication channel. When the transmitted signal reached at the receiver side the raised cosine filter was used to filter the signal, then down sampled by down sampler block. In the last stage, M-ary demodulator demodulates the signal [3].

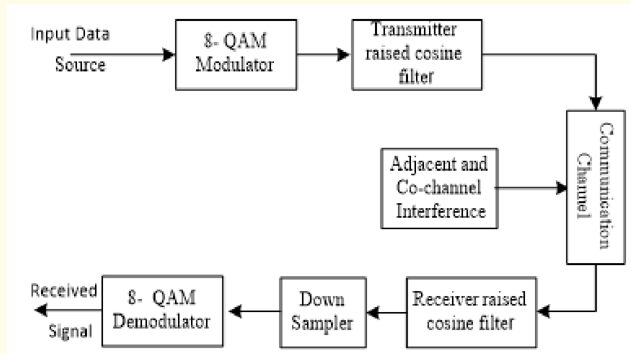

Figure 2: The block diagram of the system showing ACI and CCI signals.

M-Phase shift keying (M-PSK)

The justification behind M-ary PSK is to increase the bandwidth efficiency of the PSK modulation schemes. In M-ary PSK, n = $\log_2 M$ data bits are represented by a symbol, thus the bandwidth efficiency is increased to n times. Among all M-PSK schemes, QPSK (4-PSK) is the most-often-used scheme since; it has a good BER performance as well as a better bandwidth efficiency. Other M-ary PSK schemes increase bandwidth efficiency at the expense of BER performance [5,6].

For example, the phase of 8-PSK changes eight times but amplitude is constant, that means 3 bits can represent each symbol and that why it has eight levels i.e. M = 8. This is true for the other schemes such as 16-PSK, 32-PSK etc. That means the M = 2^n indicates the value representing the number of bits for each symbol which is n and gives the states of phase changes.. This means that, in one cycle it can transmit n bits to represent the M states for M-PSK scheme [7].

The M- PSK equation is given by:

$$v_i(t) = A \cos\left[2\pi f_c t - \frac{(i-1)2\pi}{M}\right], 0 \le t \le T \quad --- (1)$$

Where

T = symbol duration and fc = carrier frequency [8].

M-ary PSK parameters

M-ary PSK has several parameters, in this paper the following parameters will be considered [5,7]: the bandwidth (BW), which can be represented by the relation:

$$BW = \frac{f_b}{Log_2 M} = \frac{f_b}{n} \quad \text{----------} \ (2)$$

Where

$f_b =$ bit rate in bps

n = number of bits per symbol

M = number of phase states, or output levels.

So the BW of 8, 16, 32 and 64 - PSK is given b

$$BW = \frac{f_b}{8}, \frac{f_b}{16}, \frac{f_b}{32} \text{ and } \frac{f_b}{64} \text{ for 8,16,32 and 64-PSK} \quad (3)$$

The bandwidth efficiency (BW_η) that has the following relation:

$$BW_\eta = \frac{\mathbf{f_b}}{\mathbf{BW}} = \mathbf{log_2 M = n} \qquad \mathbf{(4)}$$

For M-ary PSK (M = 8, 16, 32 and 64) the (BW_η) is given by

(BW_η) = 3, 4, 5 and 6 for 8, 16, 32 and 64 –PSK (5) respectively.

Referring to the equation (5) it can be observed that the bandwidth efficiency of M-ary PSK increases as level M increases.

The other important performance measure is the Bit Rate that takes the following form:

$$\text{Bit rate} = = \frac{n(bits)}{T(sec)} = \frac{\log_2(M)}{T} \text{bits/sec} \quad \text{---------} \ (6)$$

Therefore, the bit rate of 8, 16, 32 and 64 - PSK is given by bit rate = 3 baud, 4 baud, 5 baud, and 6 baud for

8, 16, 32 and 64 –PSK respectively. -------- (7)

Finally, one of most important indictors of the modulation technique quality is the Probability of error P(e) that can be mathematically represented by:

$$P(e) = \left(\frac{1}{\log_2 M}\right) \text{erf}\ (z) \quad \text{----------} \ (8)$$

Where erf is the error function

$$z = \sin\left(\frac{\pi}{M}\right)\sqrt{\log_2 M}\sqrt{\frac{E_b}{N_o}}$$

For an M-ary PSK (M = 8, 16, 32 and 64) the P (e) is given by

$$P(e) = \left(\frac{1}{3}\right)\text{erf}\left(\sin\left(\frac{\pi}{8}\right)\sqrt{3}\sqrt{\frac{E_b}{N_o}}\right),$$

$$P(e) = \left(\frac{1}{4}\right)\text{erf}\left(\sin\left(\frac{\pi}{16}\right)\sqrt{4}\sqrt{\frac{E_b}{N_o}}\right)$$

$$, P(e) = \left(\frac{1}{5}\right)\text{erf}\left(\sin\left(\frac{\pi}{32}\right)\sqrt{5}\sqrt{\frac{E_b}{N_o}}\right)$$

$$\text{and } P(e) = \left(\frac{1}{6}\right)\text{erf}\left(\sin\left(\frac{\pi}{64}\right)\sqrt{6}\sqrt{\frac{E_b}{N_o}}\right)$$

For 8, 16,32and 64 –PSK respectively. ------------- (9)

Simulation communication system model with interference using m-ary psk over awgn channel

The simulation system was built using Simulink package as can be seen in figure 3. The simulation system consists of transmitter (Tx), receiver (Rx), channel and 2 interference signals blocks. Following is a brief description for each block [9,10].

Tx block

The Tx block consists of the following

- **Bernoulli Binary Generator:** This part utilizes Bernoulli distribution to generate random binary numbers.
- **M-PSK Modulator Baseband block:** The input, signal is modulated by this block and outputs a complex baseband signal. The modulation level, M (8, 16, 32 and 64), which is equivalent to the number of points in the signal constellation, is determined by the M-ary number parameter. The block accepts scalar or column vector input signal.
- **Q` Raised Cosine Transmit Filter block**: It up samples and filters the input signal using a square root raised cosine FIR filter.

Interference signals blocks 1 and 2

These blocks consists of the extra following units.

Constant value unit: It is responsible for generation of either a real or a complex constant value.

- **Slider Gain unit**: During simulation, this slider unit modifies the scalar gain.
- **Phase/Frequency Offset unit**: This unit offsets the incoming signal frequency and phase.
- **Product unit**: This unit multiplies the input signal and the interference signal.
- **dB Gain unit:** This unit gives the db gain of input signal based on the Gain parameter specified value.

Communication channel

- **AWGN channel unit**: Her the AWGN is added to the modulated signal. The sample time of this new signal same as the input signal.

Receiver part

This part consist of the following units:

- **Raised Cosine Receive Filter unit**: This unit is responsible on the received signal filtration using a square root raised cosine FIR filter. It also down samples the filtered signal.
- **Down sample unit:** The input signal-sampling rate is decreased by removing some of the samples. When this unit performs, frame-based processing then the data in each column of the M_i-by-N input matrix is resampled independently. However, it treats each element of the input as a separate channel and resamples each channel of the input array across time when it performs sample-based processing.
- **M-PSK Demodulator Baseband unit:** The PSK-modulated signal baseband representation is demodulated by his unit s. The modulation level, M (8, 16, 32 and 64), which is equivalent to the number of points in the signal constellation, is determined by the M-ary number parameter. The block accepts scalar or column vector input signals.

Figure 3 shows the simulated system model. By running simulation, the Bernoulli Binary Generator unit generates random binary data, then the 8-PSK modulator modulates this series of binary data; the constellation diagram of the transmitted data can be seen at the output of the 8-PSK modulator then this data is fed to the raised cosine transmit filter. The output of the filter is then mixed with the two interference signals 1 and 2 respectively. The interference signal 1 is generated by adding the phase and frequency offsets to filtered signal at the output of the raised cosine filter. By Similar means, interference signal 2 is generated. The sum of these signals, original interference signals 1 and 2 as well as the noisy signal can be displayed by the spectrum analyzer in the simulation mode in the frequency domain. The resulted noisy signal is then transmitted through AWGN channel then fed through raised cosine receive filter. This signal can be seen at the output of the receiver unit filter stage by a spectrum analyzer. The sampler circuit then down samples the output signal of this stage.

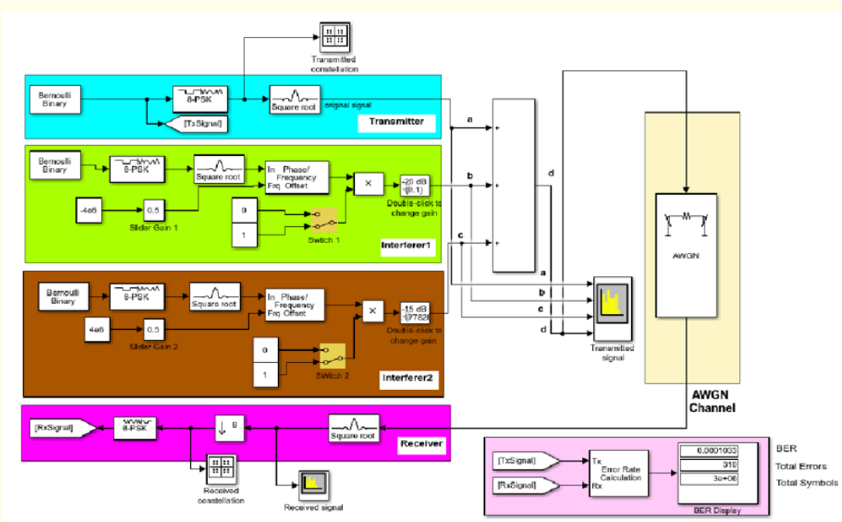

Figure 3: Simulation model with two interference signals using M-PSK.

The constellation diagram of the received signal can be seen at the output of the down sampler circuit. The signal is then demodulated by the 8-PSK demodulator at the receiver unit to retrieve the original signal. These steps are repeated for 16, 32 and 64 - PSK cases.

Simulation result and analysis

BER performances without and with effect of the interferer signals over AWGN channel of the simulated communication system model shown in figure 3 using 8, 16, 32 and 64-PSK modulation techniques are illustrated in figures 4 and 5 respectively.

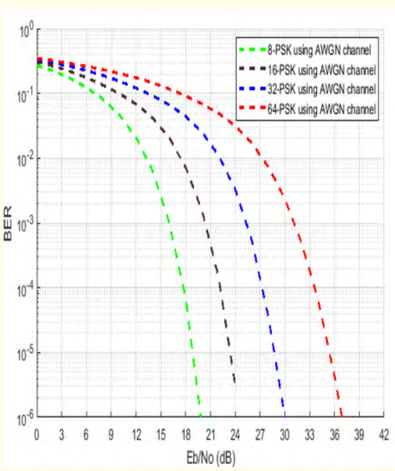

Figure 4: Bit Error Rate vs. Eb/No using 8, 16, 32 and 64 - PSK Over AWGN Channel of the simulated model without interference signals.

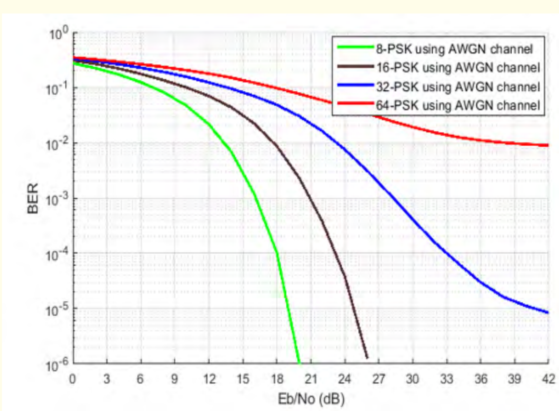

Figure 5: Bit Error Rate vs. Eb/No using 8, 16, 32 and 64 - PSK Over AWGN Channel of the simulated Model with two interference signals.

When examining the plots in figures 4 and 5 BER performance for 8, 16, 32 and 64-PSK modulation, over an open space effect represented by AWGN channel it can be observed that:

- As the number of levels (M) increases the BER increases i.e. More signal energy is needed to get a better BER.
- Consequently, that the best value for BER is for the low level (8-PSK) modulation as can be clearly observed i.e. BER performance is proportional M-PSK level.

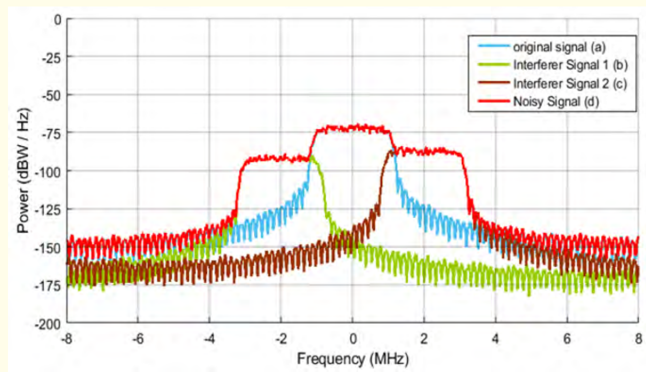

Figure 6: Power Spectrum Density of the Original, Interferer 1 and 2 and Noisy Signals of the Communication System Model using 8 - PSK. Where Eb/No = 18dB.

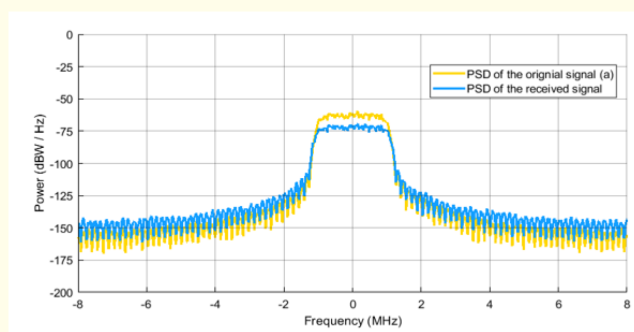

Figure 7: Power Spectrum Density of the Original and Received signals using 8,– PSK Over AWGN Channel of the Communication System Model. Where Eb/No = 18dB.

Figure 6, illustrates the constellation diagrams of the transmitted and received signal of the simulated system model shown in figure 3, with two interfere signals over AWGN channel, using PSK levels 8, 16, 32 and 64. The E_b/N_o is selected to be equal 18 dB since this is the signal energy level at which BER is 10^{-4} dB for the 8-PSK case.

Furthermore, the transmitted signal power spectra density of the two interference signals, the 8-PSK modulated signal and the received signal at the output of the cosine raised filter circuit for the E_b/N_o value of 18 dB are shown in figures 7 respectively. The power spectra density of the 16, 32 and 64 levels are very similar to the 8-PSK case.

From figures, 6 and 7 it can observed that the constellation and the power spectra density diagrams of the received signal over the AWGN channel confirm the BER achieved results in shown in figure 5.

Although to improve the performance of the simulated system model with two interference signals over AWGN channel when using higher level PSK modulation, it is necessary to increase transmitted signal energy.

Conclusion

In this research, a simulated system model with two interferer signals using M-ary PSK (M = 8, 16, 32, 64) was setup and simulated. The obtained results demonstrated the effect on BER performances over AWGN channel. The results indicated that improving system performance in terms of get reasonable BER value requires more transmitted signal energy. Therefore, simulation results convey a clear indication that the lower the PSK level the better is the BER performance and hence the 8-PSK has the best BER value in comparison to the other PSK levels.

Moreover, the constellation and power spectra diagrams of the received filtered signals over the AWGN communication channel have confirmed the lower the M-ary PSK level the lesser-needed signal energy to achieve the desired BER results.

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