Orthogonal Minimum Shift Keying: A New Perspective on Interference Rejection

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Abstract

Co-Channel Interference is a classical problem in cellular systems that has been studied extensively and several methods have been proposed to overcome it. These include interference rejection techniques as well as joint detection techniques. We have previously proposed a joint detection technique for MSK-type signals that works quite well in certain conditions. In this paper, we formally present what we call Orthogonal MSK and postulate that if two MSK signals have a 90-degree phase offset between them then both can be detected successfully increasing the spectral efficiency two-fold. This technique works well even if the two signals are near equal power and have the same carrier frequency.

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A New Perspective on Interference Rejection

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1. Background

Minimum Shift Keying (MSK) is a type of modulation scheme that has been widely used in communication systems, particularly in GSM systems. It has also found application in defense related communication systems. It's popularity stems from the fact that it's a Continuous Phase Modulation (CPM) scheme which results in a narrower Power Spectral Density (PSD) graph. In addition to this, it has a constant envelope which means that there is no need for an expensive, power hungry, linear amplifier. When a Gaussian filter is used with MSK modulation the side lobe level in the PSD is further reduced resulting in lesser Adjacent Channel Interference (ACI).

However, ACI is not the only interference that a cellular system designer needs to be worried about. There is also Co-Channel Interference (CCI) which is caused by frequency reuse in cellular systems. The problem of CCI in GSM systems has been studied extensively and several techniques have been proposed to overcome this impairment [1]-[4]. The author has himself studied this problem and a joint detection technique has been previously proposed [1]. The scenario that is most challenging and that we would like to discuss in this article is when the frequency and power of the signal of interest and interferer are very similar.

2. Orthogonal MSK

In this article, we consider a special case of CCI where the wanted signal and the interferer are exactly at the same frequency and in the worst case have the same power. However, we assume that we can control the phase offset between the two signals. We show that the most advantageous scenario is when there is a 90-degree phase offset between the two signals. How this is achieved, is left to a later discussion but one way that this can be achieved is by using Reconfigurable Intelligent Surfaces (RIS), assuming that the signals originate from geographically disparate locations. If the signals originate from the same source then we can easily control the phase offset between them. Since in MSK modulation, the information is carried alternatively by the I-carrier and the Q-carrier the vacant carrier can be used to accommodate the other signal. We refer to this as Orthogonal Minimum Shift Keying or OMSK.

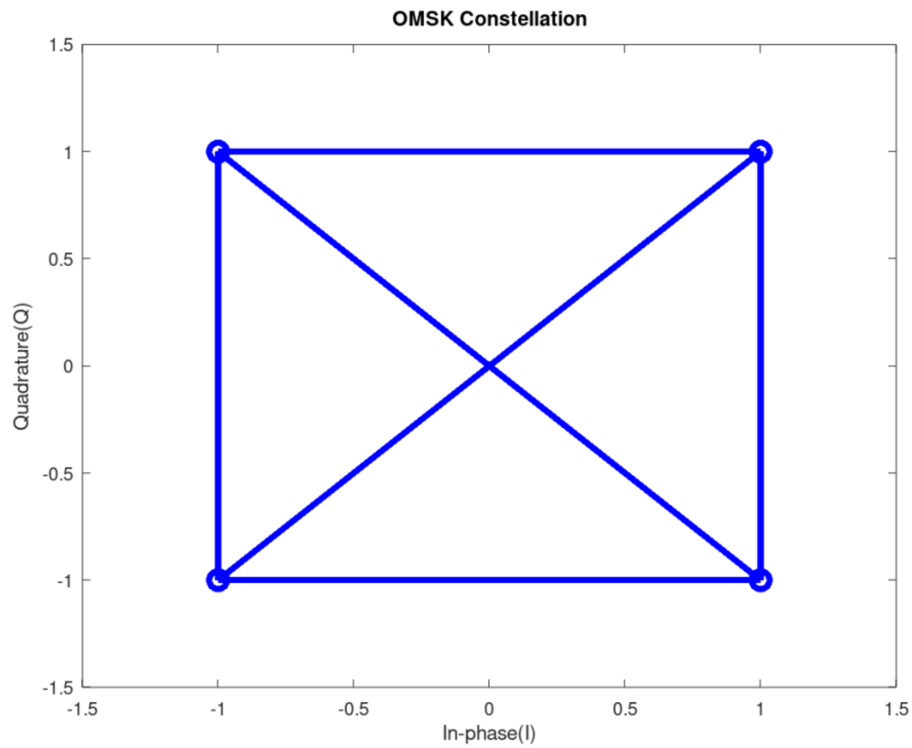

Fig 1. OMSK constellation with no oversampling

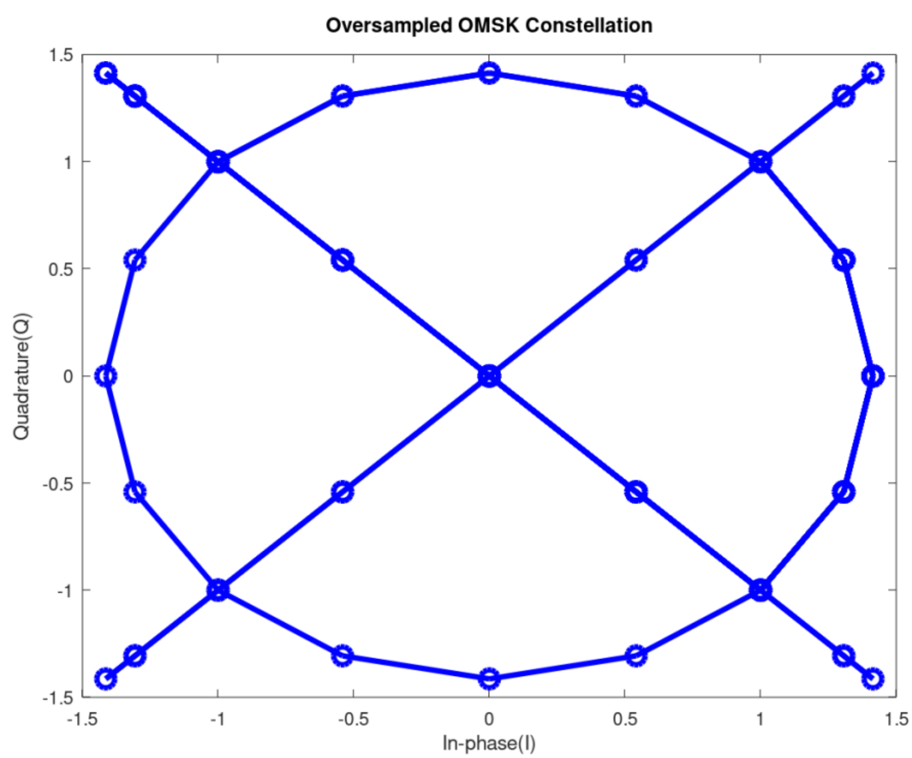

Fig 2. OMSK constellation with oversampling (Ns=4)

3. Simulation Results

Bit Error Rate simulation of the above scenario was carried out for Signal to Interference Ratio (SIR) of 0dB and 3dB. AWGN and Rayleigh faded channels were considered. It was observed that for a single sample per symbol (Ns=1) there was no difference in performance from that for BPSK modulation. This can be easily understood by looking at the constellation diagram for MSK where the symbol lies either on the x-axis or on the y-axis and the other axis can be used to transmit the interferer. However, this orthogonality breaks down when multiple samples per symbol are transmitted. The reason for this behavior is that there are discontinuities at the symbol boundaries when transmitting multiple samples per symbol. Furthermore, the OMSK signal, unlike the MSK signal, undergoes Amplitude Modulation (AM) and the constant envelope property also does not hold.

The Bit Error Rate performance of OMSK for multiple samples per symbol is much worse than MSK at an SIR of 0dB. However, the performance greatly improves for SIR of 3dB. In the Rayleigh faded case the Bit Error Rate performance matches quite well with the simple MSK case and there is only 1dB degradation in performance at SIR of 3dB. It must be noted that if we have no control over the relative phase of the two MSK signals the performance is much worse as already reported in [2]. We also plotted the normalized PSD of OMSK and compared it to BPSK and QPSK. It is seen that now that we are transmitting two bits per symbol the width of the main lobe for OMSK is narrower than both BPSK and QPSK. We are tempted to use a Gaussian filter to further bring down the side lobes of OMSK but this would be at the expense of loss of orthogonality.

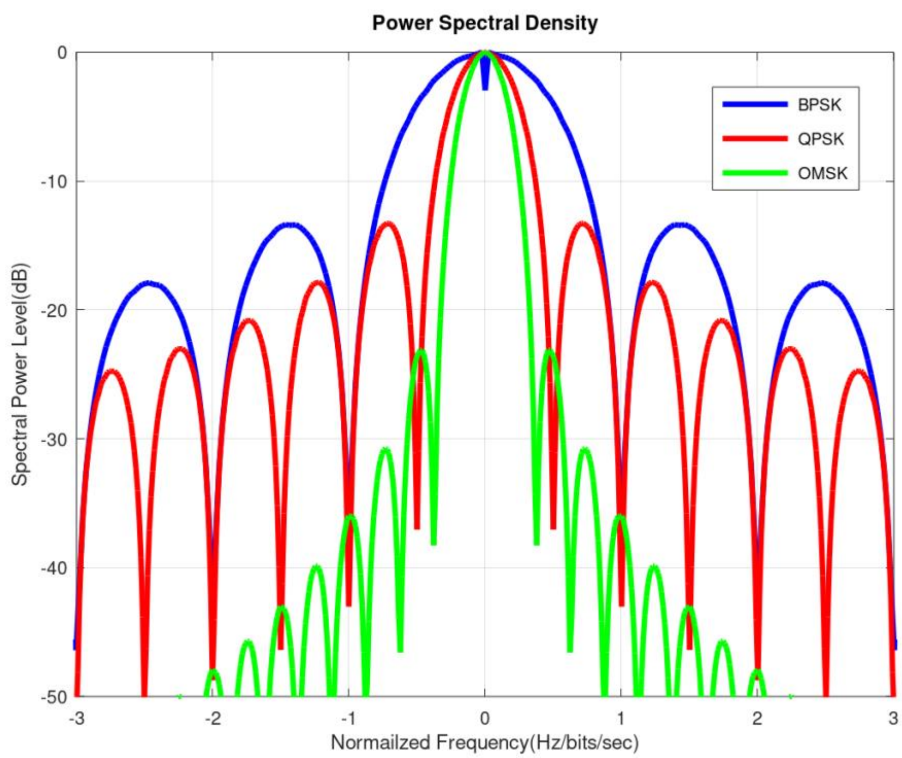

Fig 3. OMSK Power Spectral Density

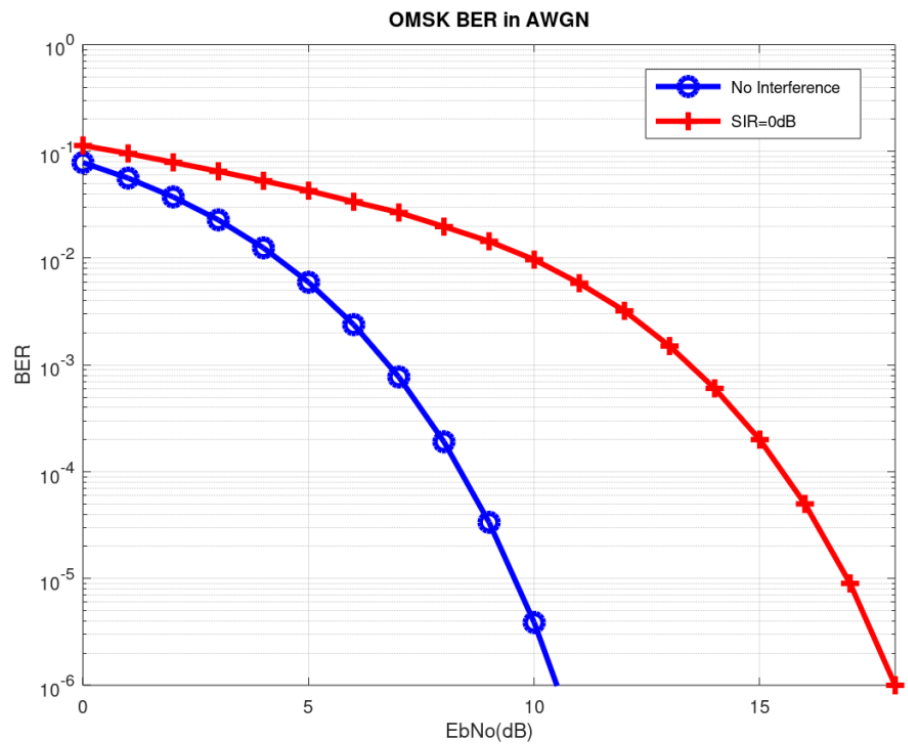

Fig 4. OMSK BER in AWGN and Interference SIR=0dB (Ns=4)

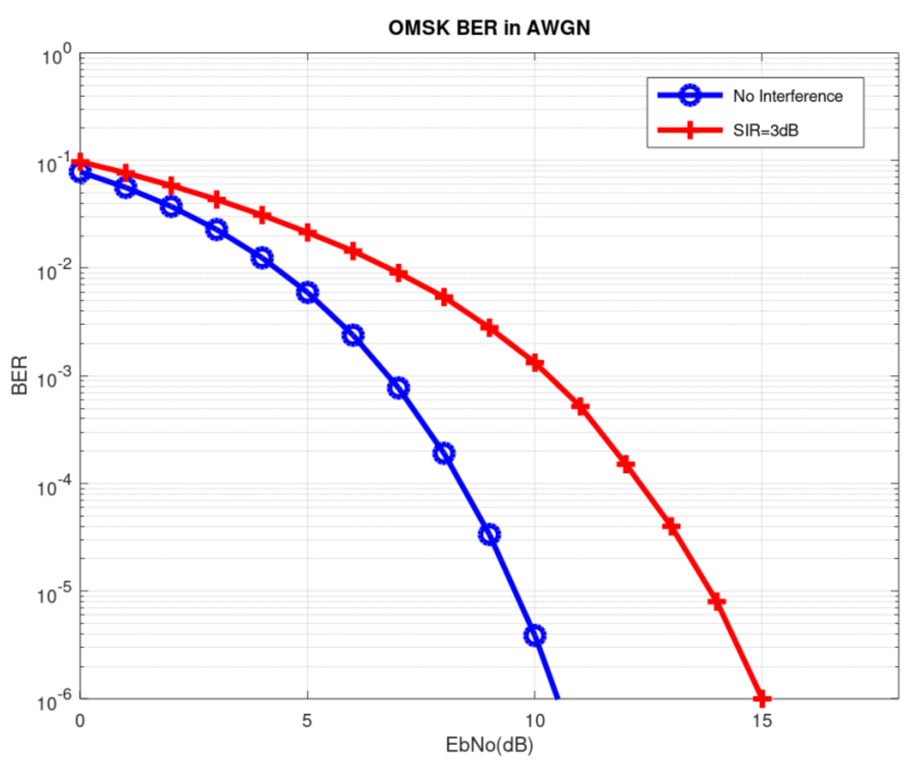

Fig 5. OMSK BER in AWGN and Interference SIR=3dB (Ns=4)

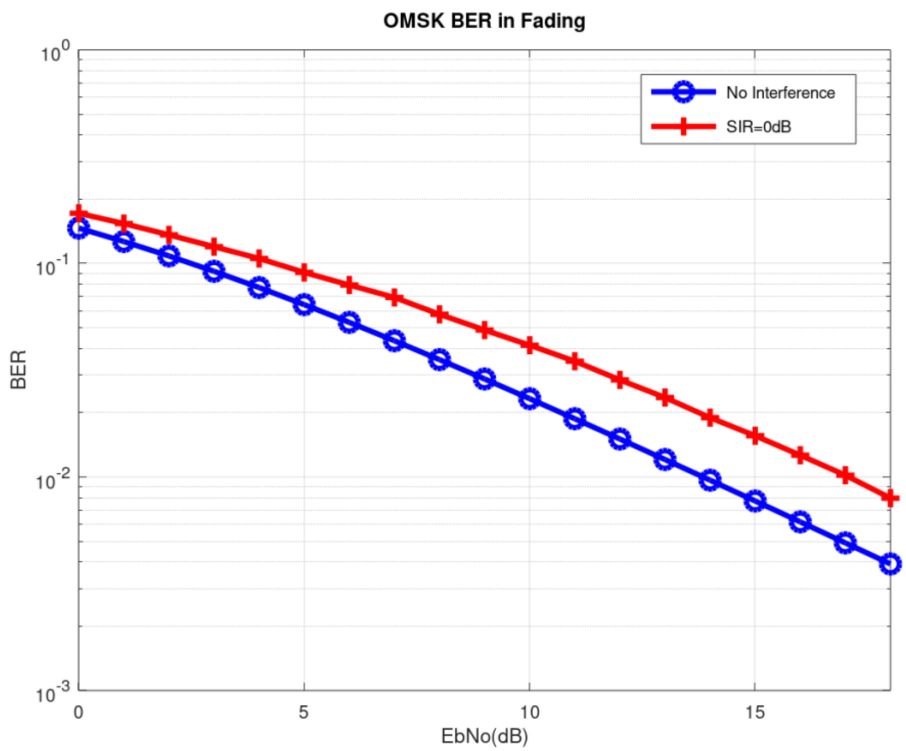

Fig 6. OMSK BER in AWGN, Fading and Interference SIR=0dB (Ns=4)

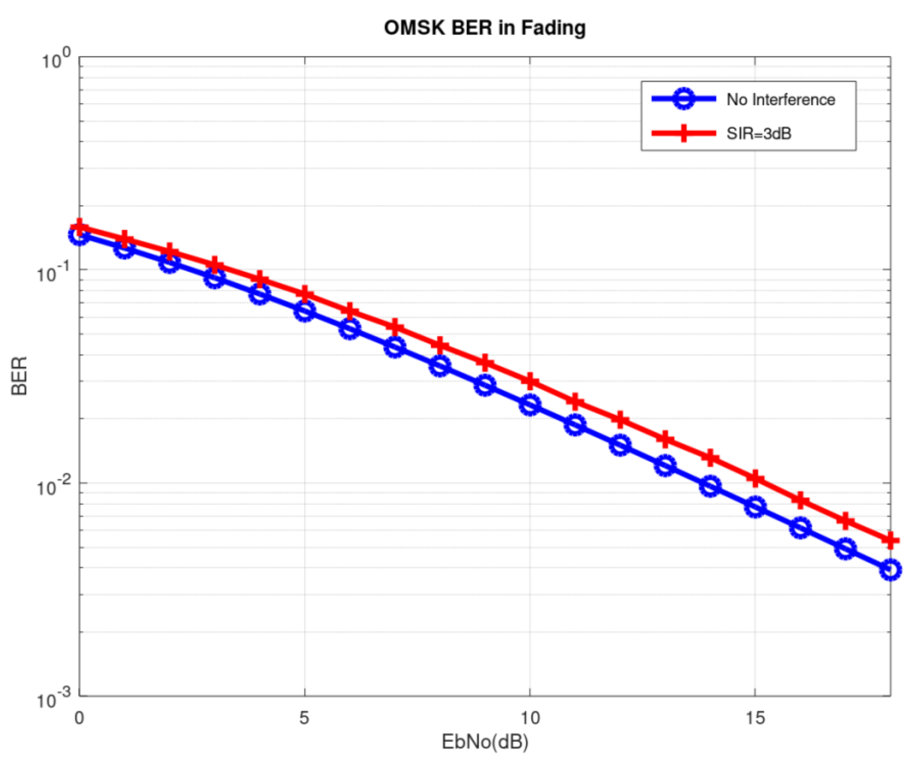

Fig 7. OMSK BER in AWGN, Fading and Interference SIR=3dB (Ns=4)

Concluding Remarks

1. We have ignored pulse shaping here. With ideal pulse shaping the PSD of QPSK improves while its BER remains the same.
2. We have assumed that in OMSK both the signal of interest and interferer undergo similar fading. However, the performance of OMSK might degrade if the fading of the two channels is dissimilar. This would be explored in a future article.
3. In future we would also like to study what performance gains can be achieved by using Successive Interference Cancellation (SIC).

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