ORIGINAL ARTICLE

Estimate Better Channel from Additive White Gaussian Noise (AWGN) and Rician Channel for Minimum Shift Keying (MSK) Signal

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Abstract

The demand for high-speed mobile wireless communication is rapidly growing. Minimum Shift Keying (MSK) based modulation technology can be used for achieving high accuracy data transmission and for high data capacity. Phase Shift Keying (PSK) is used for MSK and Gaussian Minimum Shift Keying (GMSK). In this paper, we consider only MSK based signal and two channels; Additive White Gaussian Noise (AWGN) channel and Rician fading channel. MSK based modulated signals transmit through the AWGN channel with varying Signal to Noise Ratio (SNR) and signal power. Also MSK based modulated signals transmit through Rician fading channel with varying Doppler shift (fd) and the Rician K-factor. We analyze the properties of MSK based transmitted signal for each varying factors in both AWGN and Rician fading channel. A comparison has been made between the MSK based signal through AWGN and the MSK based signal through Rician fading channel. Finally, we investigate the BER performance of the MSK - based system for AWGN channel and Rician fading channel. Here, we propose that the AWGN channel is better than Rician fading channel for transmitting the MSK based modulated signal.

Keywords: AWGN noise, bit error rate, rician k-factor, signal power.

I. INTRODUCTION

In wireless communication, the modulated signal must propagate through a channel. In a real channel, the signal is modified during transmission. The received signal consists of a combination of attenuated, reflected, refracted, and diffracted replicas of the transmitted signal [1]. MSK is an important concept in digital communications [2]. The performance of transmission modes is evaluated by calculating the probability of BER versus the SNR under the frequently used three wireless channel models (AWGN, Rayleigh and Rician) [3],[4]. The performance of wireless devices depends on the transmission characteristics, wireless channel parameters and device structure. The performance of data transmission over wireless channels is well captured by observing their BER, which is a function of SNR at the receiver [5]. The BER is minimum for AWGN and maximum for Rayleigh and Rician. For Rician, the BER is less than AWGN and Rayleigh except in case of 16- Differential phase shift keying (16-DPSK) and the 16-QAM is performing better than 64- Quadrate Amplitude Modulation (64-QAM) [6]. In wireless channels, several models have been proposed and investigated to calculate SNR. All the models are a function of the distance between the sender and the receiver, the path loss exponent and the channel gain. Several probabilistically distributed functions are available to model a time-variant parameter. We describe the two important and frequently used distributions; AWGN, and Rician models.

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The paper organized as follows: In the section 2.1 we give the mathematical description of MSK. In section 2.2 we discuss about AWGN channel with distribution and its parameters. In section 2.3 we discuss about Rician channel with distribution and its parameters. In section 4 we give our experimental analysis. Finally, we discuss our results and future suggestion.

II. MSK AND RESPECTIVE AWGN AND RICIAN FADING CHANNEL

In this section we discuss about MSK, AWGN and Rician fading channel.

A. Minimum Shift Keying (MSK)

AMSK is an important concept in digital communications [2]. It is a form of continuous phase frequency shift keying. MSK encodes each bit as a half sinusoid. This results in a constant-modulus signal, which reduces problems caused by non-linear distortion. In minimum phase shift keying, two key concepts are used. (a) The frequency separation of the sinusoidal used for representing bits 1's and 0's are, 1/2T where T is the symbol period. (b) It is ensured that the resulting waveform is phase continuous.

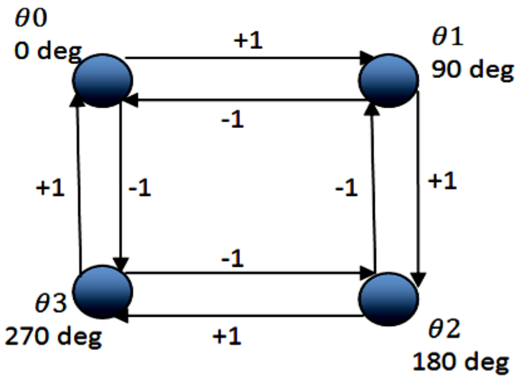


Fig. 1. Phase transition diagram for MSK.

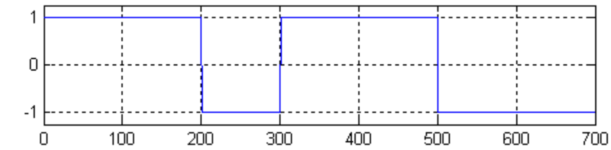
The signal is represented by the following equation.

$$s(t) = a_1(t)\cos\left(\frac{\pi t}{2T}\right)\cos(2\pi f_c t) - a_Q(t)\sin\left(\frac{\pi t}{2T}\right)\sin(2\pi f_c t) \qquad (1)$$

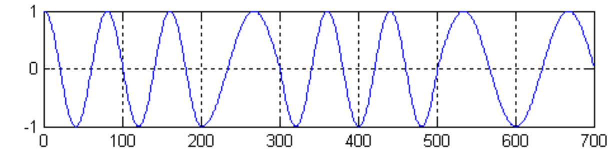
Where $a_1(t)$ and $a_Q(t)$ encode the even and odd information respectively with a sequence of square pulses of duration 2T. Using the trigonometric identity, (1) can be rewritten in a form where the phase and frequency modulation are more obvious,

$$s(t) = \cos\left[2\pi f_c t + b_k(t)\frac{\pi t}{2T} + \phi_k\right] \qquad (2)$$

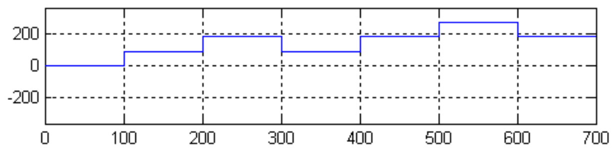
Where $b_k(t)$ is +1 when $a_1(t)$=$a_Q(t)$ and -1 if they are of opposite signs, and ϕ_k is 0 if $a_1(t)$ is 1, and π otherwise. Therefore, the signal is modulated in frequency and phase, and the phase changes continuously and linearly. Simulating and plotting binary MSK, a form of continuous phase frequency shift keying is given as follows.



a) Digital sample signal



b) Analog sample signal



c) MSK signal

Fig. 2. Transition waveforms of an MSK signal.

B. AWGN channel

AWGN is a channel model in which the only destruction of communication is a linear addition of wideband or white noise with a constant spectral density and a Gaussian distribution of amplitude [7]. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion. Wideband Gaussian noise comes from many natural sources, such as the thermal vibrations of atoms in conductors, shot noise, black body radiation from the earth and other warm objects, and from celestial sources such as the sun. The simplest practical case of mobile radio channels is an AWGN channel. When the signal is transmitted over such channels, the signal arriving at the demodulator is perturbed only by the addition of some noise and by some fixed, multiplicative path loss (including shadowing).

When we add AWGN noise with power 1 to the digital modulation signal with in-phase channel data vectors and quadrature-phase channel data vectors then idata and qdata are used respectively, the output data of I channel is iout and Q channel is qout. However, in the simulation, we sometimes calculate the BER performance by varying the noise power, where we define the noise power as variable and the npow, idata and qdata are voltages, not powers. Therefore, we must change npow from power to voltage as follows.

$$\text{attn}= \frac{1}{2}\sqrt{\text{npow}} \qquad (3)$$

Therefore the revised output data after contamination from noise with power of npow become as follows.

$$\text{iout}(t)= \text{idata}(t) + \text{attn} \times \text{randn}(t) \qquad (4)$$

$$\text{qout}(t)=\text{qdata}(t) +\text{attn} \times \text{randn}(t) \qquad (5)$$

Add white Gaussian noise to an MSK based modulated signal and passes through the AWGN channel. The following function is used for this purpose.

y = awgn(x,snr) (6)

Add white Gaussian noise to the vector signal x. The scalar snr specifies the signal-to-noise ratio per sample in dB. If x is complex, then awgn adds complex noise. If we consider the signal power then the above function become as like following.

y = awgn(x,snr,sigpower) (7)

Here sigpower is the power of x in dBW. We change the value of snr from 17 to18 with change the value of sigpower. Both snr and sigpower are the parameter of awgn.

C. Rician channel

Rician channel is a transmission channel that may have a line-of-sight component and several scattered of multipath components [4]. Rician fading is a stochastic model for radio propagation anomaly caused by partial cancellation of a radio signal by itself — the signal arrives at the receiver by two different paths, and at least one of the paths is changing (lengthening or shortening). Rician fading occurs when one of the paths, typically a line of sight signal, is much stronger than the others. In Rician fading, the amplitude gain is characterized by a Rice or Rician distribution [9]. Rician distribution is given by the following equation.

$$p(r) = \begin{cases} \frac{r}{\sigma^2}\exp\left(-\frac{(r^2-4)}{2\sigma^2}\right) I_0\left(\frac{Ar}{\sigma^2}\right) & for (A \geq 0, r \geq 0) \\ 0 & for (r < 0) \end{cases} \qquad (8)$$

The parameter A denotes the peak amplitude of the dominant signal and I0 is the modified Bessel function of first kind and zero-order. The Rician distribution is often described in terms of a parameter K which is defined as the ratio between the deterministic signal power and the variance of the multipath. It is given by K= A2 / (2σ2) or in terms of dB.

K (dB) =10log A2 / (2σ2) (9)

The parameter K is known as the Rician factor and completely specifies the Rician distribution. As A →0, K →-α dB, and as the dominant path decreases in amplitude, the Rician distribution degenerates to a Rayleigh distribution.

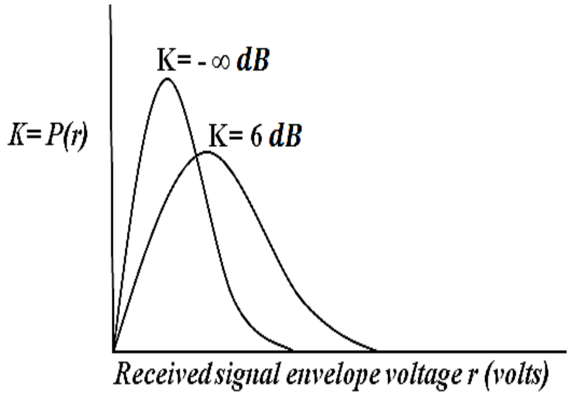


Fig. 3. Probability density of Rician distribution.

For very large values of k, the line-of–sight component dominates completely, very little fading is encountered, and the channel reverts to AWGN behavior. As the k factor increases, the probability of encountering a deep fade reduces, so the mean error rate will decrease. In simulation, when we use Rician fading channel for transmitting the MSK based modulated signal then we have to use the following function.

chan= ricianchan(ts,fd,k) (10)

This function constructs a frequency-flat ("single path") Rician fading channel object. Here ts is the sample time of the input signal in seconds, fd is the maximum Doppler shift in Hertz and k is the Rician K-factor. The range of the fd is 10 Hertz to 100 Hertz. The range of the Rician K-factor is 5 to 11. In this channel, the specular component has zero phase and the phase does not change with the Doppler shift. The effect of the channel on signal x is modeled as follows.

y = filter(chan,x) (11)

chan = ricianchan constructs a frequency-flat channel object with no Doppler shift and a

K-factor of 1. This is a static channel. The sample time of the input signal is irrelevant for frequency-flat static channels.

III. Experimental Results and Discussions

In this paper, one of the important topics in wireless communications that is the concept of fading is demonstrated by the approach available in MATLAB. As explained earlier, one of the important aspects of the path between the transmitter and receiver is the occurrence of fading. MATLAB provides a simple and easy way to demonstrate fading taking place in wireless systems [8]. Simulink is a graphical extension to MATLAB for the modeling and simulation of systems. In Simulink, systems are drawn on screen as block diagrams. Many elements of block diagrams are available (such as transfer functions, summing junctions, etc.), as well as virtual input devices and output devices. Simulink is integrated with MATLAB and data can be easily transferred between the programs. Firstly we simulate the MSK based signal transmission for rician channel. Secondly, we simulate the MSK based signal transmission for AWGN channel.

A. MSK based signal transmission though Rician channel

When we use the raician function for transmitting the MSK modulated with parameters ricianchan (1e-5, 10, 5). We use the parameters ts=1e-5, fd=10, k=5. Here we use the lowest values of the parameter fd and k. The obtained simulated curve represented by pink color and the theoretical curve represented by blue color as in Fig. 4. We use MATLAB software for the simulation. There is a very high difference from theoretical curve.

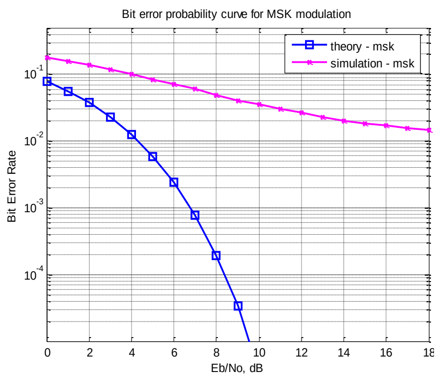


Fig. 4. Bit error probability curve for MSK modulation in Rician fading channel (fd=10, k=5).

Here, BER is calculated from the number of bits received in error divided by the number of bits transmitted. In digital transmission, the errors come from noise, interference, distortion or bit synchronization errors.

$$\text{BER}=(\text{Bits in error})/(\text{Total bits received}) \quad (12)$$

SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation.

$$\text{SNR}=10\log_{10}(\text{Signal power}/\text{Noise power})\ \text{dB} \quad (13)$$

Eb/No is an important parameter in digital communication or data transmission. It is a normalized SNR measure, also known as the "SNR per bit". It is especially useful when comparing the BER performance of different digital modulation schemes without considering bandwidth.

When we use the parameters ts=1e-5, fd=50, k=8. Then the channel becomes as ricianchan(1e-5,50,8). There is so far the difference between simulated curve and a theoretical curve as in Fig. 5.

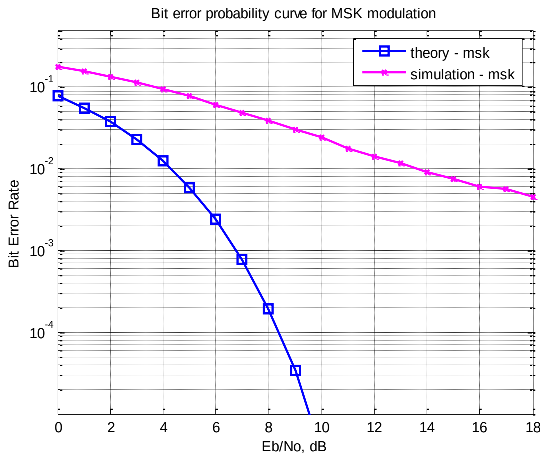


Fig. 5. Bit error probability curve for MSK modulation in Rician fading channel (fd=50, k=8).

When we use the raician function for transmitting the MSK modulated with parameters ts=1e-5, fd=100 and k=11. Then the channel becomes as ricianchan (1e-5,100,11). Here we use the highest values of the parameter fd and k.

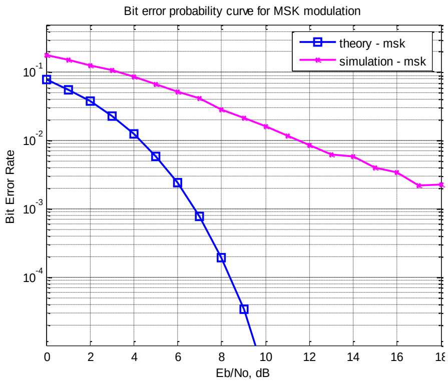


Fig. 6. Bit error probability curve for MSK modulation in Rician fading channel (fd=100, k=11).

Though, the curve is declining as compared with the previous two simulated results. Here also the difference between simulated and theoretical curve is very high as in Fig. 6. So it can be concluded that the bit error rate (BER) is high, when transmitting the MSK based modulated signal through Rician fading channel.

B. MSK based signal transmission though AWGN channel

At first we use the awgn function with the parameter SNR=17. Then the resultant curve is represented by blue color and the simulated curve is represented by pink color as in Fig. 7. Initially the curve matches with the theoretical derived curve and small mismatch when the value of Eb/No is increasing.

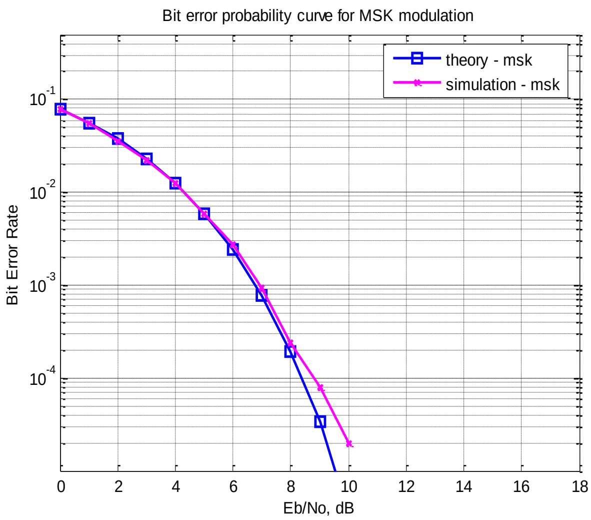


Fig. 7. Bit error probability curve for MSK modulation in AWGN channel (SNR=17).

Now the parameters of the awgn function has changed such as SNR=17 and the sigpower= 0.5. Initially the simulated curve matches with the theoretical derived curve as in Fig. 8. The BER is not alike when the value of Eb/No is increasing.

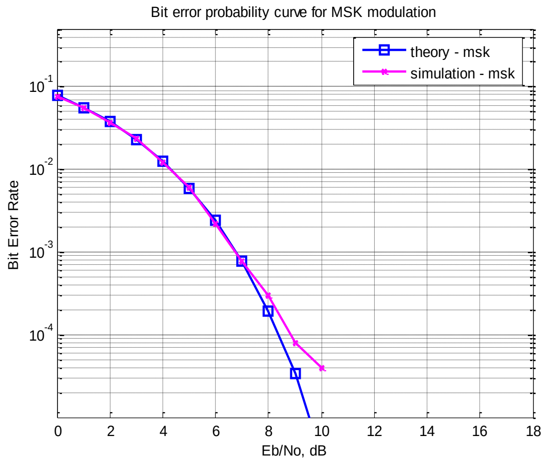


Fig. 8. Bit error probability curve for MSK modulation in AWGN channel (SNR = 17, sigpower= 0.5).

When the parameters of the AWGN function has changed such as SNR=18 and the sigpower= 0.1 then the resultant curve is represented by blue color and the simulated curve is represented by pink color. The curve is matched with the theoretical derived curve, but slimly dissimilar with the theoretical curve at the end of the curve as in Fig.9. The BER is similar initially. Dissimilarity is minimized as compared with the previous two figures.

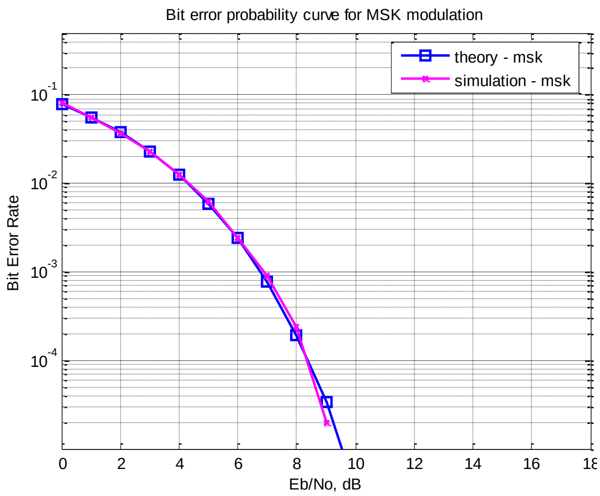


Fig. 9. Bit error probability curve for MSK modulation in AWGN channel(SNR = 18, sigpower= 0.1).

When the parameters of the AWGN function has changed such as SNR=18 and the sigpower= 0.5. Then the resultant curve is represented by blue color and the simulated curve is represented by pink color line.

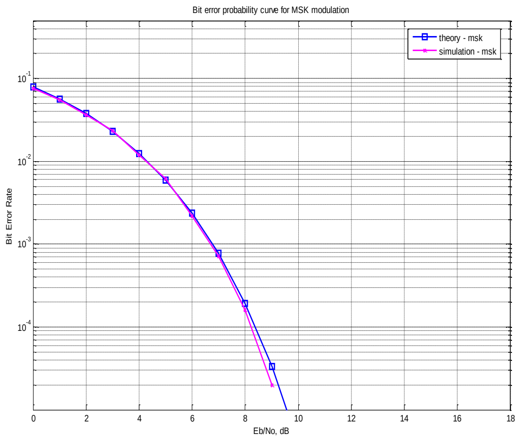


Fig. 10. Bit error probability curve for MSK modulation in AWGN channel (SNR = 18, sigpower= 0.5).

The curve is matched with the theoretical derived curve. The BER is similar to the theoretical curve as in Fig.10. Here theoretical and simulated curve almost coincides.

However, when we consider the AWGN channel for transferring the MSK based signal then in every case, the theoretical curve and the simulated curve is almost similar. When we consider Rician channel for transferring the MSK based signal then, the simulated curve and a theoretical curve always apart in every case.

IV. CONCLUSION

In this paper we have presented that the MSK based modulated signal has a high BER when it is passing through the Rician fading channel. However, we are varying the parameters (fd and k) of this channel. But when the MSK based signal is passing through the AWGN channel then a low BER as compared with the signal passes through the Rician fading channel. The BER decrease with the increase of (Eb/No) in AWGN channel. On the contrary, the BER slightly decrease with the increase of (Eb/No) in Rician fading channel. In AWGN channel, the simulated curve is as alike as the theoretical curve in every case. The BER is decreasing in all the fading channels due to the increasing value of Eb / No for different modulation schemes. This paper is significant and informative especially for the MSK based signal transmission in wireless communication. This paper demonstrates that the better channel from AWGN and Rician fading based on the transmission and analysis of BER performance with respect to various SNR for MSK based modulated signal transmission. Through analytical and practical simulations, the AWGN channel is better than Rician fading channel for transmitting the MSK based modulated signal. In case of Rician fading channel, there is very much difference between the analytical and simulated curve. In case of AWGN channel, for low SNR environments the curve of analytical and simulated is similar, but in high SNR environments there is very small difference between the analytical and simulated curve.

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