International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 5, May - 2013

Performance Analysis Of Rician Fading Channels In MSK And GMSK Modulation Schemes Using Simulink Environment

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Abstract

The need for the estimation of the effects of multipath fading and noise on the mobile channels is mandatory for the developing any communications system. For wireless facilities where there is a relatively free choice of where antennas are to be located, they can be placed so that if there are no nearby interfering obstacles, there is a direct line-of-sight path from the transmitter to receiver. This is generally the case for many satellite facilities and for point-to-point microwave. When a strong stationary path such as a Line of Sight path is introduced into the Rayleigh fading environment, the fading becomes a Ricean or Rice-distributed fading. In this paper, a review about the fading in the mobile environment is discussed followed the performance analysis of Rician fading channels in Minimum Shift Keying modulation scheme and Gaussian Minimum Shift Keying modulation scheme.

1. Introduction to Fading in the Mobile Environment

Usually multipath waves in the radio channel combine at the receiver to give a resultant signal that can vary widely in amplitude and phase over a short period of time or over a small travel distance. This short-term rapid fluctuation of signal strength is superimposed on the local mean slow varying field due to log normal large scale power loss. Mobile radio systems cause time dispersion in the pulse due to their multipath nature. In addition to this, systems mobility modulates the carrier frequency due to random Doppler shift. In such systems, the signal received by the mobile at any point in space may consist of a large number of plane waves having randomly distributed amplitudes, phases, and angles of arrival. These multipath fields combine vectorially to cause the signal strength to fluctuate with time due to the dynamic nature of the surroundings and mobile radios. A repetitive baseband pulse train with very narrow pulse width, T_b, and repetition period, T_s, is sent in a mobile environment. It is assumed that the multipath delay is much larger than T_b but smaller than T_s. It may be observed that if the transmitted signal is able to resolve the multipaths, then the average small-scale received power is simply the sum of the average power received in each multipath component. The amplitudes of the individual multipath components do not fluctuate widely in the local area and thus multipath components in such a wideband signal can easily be resolved. However, if the signal has narrow bandwidth (T_b>T_d) when the multipath is not resolved at the receiver and large fluctuation occurs. Thus, the multipath channel has to be modelled to find the signal at the receiver. Total multipath delay may be resolved in various resolvable multipath delay components as $\Delta\tau$, thus the maximum excess delay would be for N such paths as N$\Delta\tau$. Thus this model will be suitable for signal bandwidths lesser than $2/\Delta\tau$.Thus the prediction of the channel performance by characterizing the impulse response becomes easier. A mobile radio channel can be modelled as a linear filter with a time varying impulse response due to the dynamic nature of the channel. In order to characterize a mobile channel toward time dispersion parameters, one should find power delay profiles to determine the mean excess delay $\bar{\tau}$ as defined below

$$\bar{\tau} = \frac{\sum_k P(\tau_k)\tau_k}{\sum P(\tau_k)} \quad (1)$$

This may provide rms delay spread (σ_τ) as is given as

$$\sigma_\tau = \sqrt{\overline{\tau_k} - (\overline{\tau_k})^2} \quad (2)$$

where $$\bar{\tau}^2 = \frac{\sum P(\tau_k)\tau_k^2}{\sum P(\tau_k)} \quad (3)$$

Here τ_k denotes the arrival time of the K_{th} multipath by assuming τ_0 to be the first detectable signal arrives and $P(\tau_k)$ as the corresponding power. The maximum excess delay (x dB) is defined as $\tau_x - \tau_0$, when τ_x is the delay at which the multipath component is within x dB down to the strongest to arrive multipath signal. These rms delay spread may be typically of microsecond order in the outdoor system but of nanosecond (ns) in the case of indoor mobile systems. These delay spreads in the time domains correspond to coherence bandwidths in the frequency domain for the corresponding channel. Thus, the coherence bandwidth (B_c) is a range of frequencies over which the channel passes all the spectral components with nearly equal gain and linear phases. This provides a strong amplitudes correlation for the signals with B_c, but behaves differently when they are above this. In general, coherence bandwidth defined in terms of frequency correlation function is to be greater than a required value. If this bandwidth is greater than the transmitted signal, then the spectral characteristic of the signal is preserved[4]. However, the strength of the signal changes with time due to strong correlation of multipath amplitudes. When the corresponding B_c of the channel is smaller than the bandwidth of the signal (B_s), then the spectral characteristics of the received signal become selective. In other words, the channel time spread is greater than the symbol time and this causes multiple versions of transmitted waveforms in the delayed time slots inducing intersymbol interference (ISI). Sometimes frequency selective channels are known as wideband channels as the signal bandwidths are narrower than the channel. Usually, for the symbol time $T_s \geq 10\sigma_\tau$ the channel is flat faded. We have seen that delay spread provides the channel dispersive model; however, the time varying nature of the channel can only be predicted by Doppler frequency spread due to relative motion in the mobil environment.

2. A REVIEW ON RICIAN FADING CHANNEL

In designing a communication system, the communications engineer needs to estimate the effects of multipath fading and noise on the mobile channel. The simplest channel model, from the point of view of analysis, is the additive white Gaussian noise (AWGN) channel. In this channel, the desired signal is degraded by thermal noise associated with the physical channel itself as well as electronics at the transmitter and receiver. This model is fairly accurate in some cases, such as space communications and some wire transmissions, such as coaxial cable. For terrestrial wireless transmission, particularly in the mobile situation, AWGN is not a good guide for the designer. Rayleigh fading occurs when there are multiple indirect paths between the transmitter and receiver and no distinct dominant path, such as LOS path. This represents a worst case scenario. Fortunately, Rayleigh fading can be dealt with analytically, providing insights into performance characteristics that can be used in difficult environments, such as downtown urban settings. In mobile radio channels, the Rayleigh distribution is usually used to describe the statistical time varying nature of the envelope detected at the receiver for a flat faded environment. The Rayleigh probability density function (pdf) for a distributed envelope r(t) can be expressed as follows

$$p(r) = \frac{r}{\sigma^2}\exp\left(-\frac{r^2}{2\sigma^2}\right) \quad \text{for } 0 \leq r \leq \infty \quad (4)$$

$$p(r) = 0 \quad \text{for } r < 0 \quad (5)$$

Where σ is the rms value of the received voltage signal and σ^2 is the time average power at the envelope detector respectively. Sometimes the dominant nonfading signal due to line-of-sight in the channel superimposes itself on the random multipath components. The effect of the dominant signal over the weaker multipath weaker signal gives rise to a Ricean distribution. The Rician distribution degenerates to Rayleigh in the absence of a line-of-sight dominant signal. The Rician (pdf) can be expressed as follows

$$p(r) = \left\{\frac{r}{\sigma^2}\exp-\left(\frac{r^2+A^2}{2\sigma^2}\right)I_0\left(\frac{A_r}{\sigma^2}\right)\right\} \text{ for } A \geq 0, r \geq 0 \quad (6)$$

$$p(r) = \{0\} \quad \text{for } r<0 \quad (7)$$

Here A is the peak amplitude of the direct Line of Sight (LOS) signal and $I_0(x)$ is the modified Bessel function of the first kind with zero order. The Rician distribution is described by a parameter K, which is the ratio between the direct signal power and the variance of the multipath. This may be expressed in dB as given below

$$K = 10\log\frac{A^2}{2\sigma^2}\ \text{dB} \quad (8)$$

This shows that for the absence of direct line-of-sight signal $K \rightarrow -\infty$ and Rician distribution degenerates into Rayleigh. In digital wireless systems, channel impairment due to fading is solved using error control codes, equalizers, or appropriate diversity schemes. Random fluctuating signals cause fades which randomly cross a given specific signal level. Thus, the level crossing rate and the average fade duration in a faded environment become important statistical information for system designers. The average fade duration helps to find the lost signalling bits during the deep fades[5]. Obviously, for a fast moving mobile, average fade duration would be very small but the level crossing rate would be high. The small-scale fading caused due to constructive and destructive interference of various multipath components at the receiver also depends on the direction of movement relative to the arrival of multipath. Thus,fading statistics depend on the angular distribution of multipath power and multipath power concentration toward the antenna used. These estimates require second order statistics which include measure of power spectral density, level crossing rate and fade duration and its effect on omnidirectional or directional antenna [6]. Recent measurement and models have shown that arriving multipath in a local area has a little resemblance with onmidirectional propagation assumption. Thus proper modelling of small-scale fading under distribution of non-omnidirectional multipath waves is useful to predict the useful available signal at the receiver and to implement the appropriate modulation or link improvement techniques viz., equalization, error correction coding, or diversity schemes.

3. MSK AND GMSK MODULATION SCHEMES

3.1. MINIMUM SHIFT KEYING:

Minimum Shift Keying (MSK) can be viewed as OQPSK plus half-sinusoidal pulse shaping. MSK encodes each bit as a half sinusoid. The symbol duration for MSK and OQPSK is a one-bit period, while that for QPSK is a two-bit period. The MSK signal is shown to be a special FSK signal with two frequencies f-,f+ = $f_c \pm \frac{1}{4T}$ [1]. The frequency separation is $\Delta f = \frac{1}{2T}$, which is the minimum separation for two FSK signals to be orthogonal; hence the name minimum shift keying. MSK carrier phase is continuous at bit transitions. MSK is a particularly spectrally efficient of coherent CPFSK. It is a CPFSK scheme with modulation index h=0.5. When the MSK signal is realized in this manner, it is called fast frequency shift keying (FFSK). MSK can be implemented in a serial fashion. In this case, the precise synchronization and balancing for the Q-channel is no longer needed, and this is especially suitable for high bit rates. Many MSK-type schemes have been proposed to improve the bandwidth efficiency of MSK. They can be continuous phase modulation with constant envelope, or based on pulse shaping in the Q-channel such as the sinusoidal FSK and many other symbol-shaping pulses. These shaping schemes can generally have better spectral sidelobe roll-offs, but have a wider main lobe than the MSK spectrum and that of conventional PSK. MSK has the advantage of not introducing any ISI. As a binary modulation scheme, the spectral efficiency of MSK is still very low.Unlike FSK, which has spectral lines at certain frequencies, MSK does not have. The power spectrum decreases faster than that of OQPSK, QPSK, and FSK, leading to less out-of-band energy. Thus, MSK provides and advantage over other schemes in case of a more stringent in-band power specification

3.2. GAUSSIAN MINIMUM SHIFT KEYING:

The power spectrum of MSK has a wide mainlobe. GMSK is obtained by narrowing the mainlobe of MSK signals using a predmodulation Gaussian low pass filter, that is, using Gaussian instead of sinusoid pulse shaping [2]. The transfer function of the Gaussian filter is given as follows

$$H(f) = e^{-\frac{2\ln 2 f^2}{B_b^2}} \quad (9)$$

where B_b is the 3-dB bandwidth of the baseband shaping filter. Thus, smaller B_b corresponds to a higher frequency. The impulse response of the Gaussian filter is given by [3]

$$g(t) = Q\left(\frac{2\pi B_b (t - \frac{\tau}{2})}{\sqrt{\ln 2}}\right) - Q\left(\frac{2\pi B_b (t + \frac{\tau}{2})}{\sqrt{\ln 2}}\right) \quad (10)$$

which can be approximated by a Gaussian response. GMSK increases the spectral efficiency of MSK. Like MSK, GMSK signals can also be demodulated by using coherent detection, differential detection, and frequency discriminator techniques. Coherent detection generally gives the best result. Differential detection does not suffer from the threshold effect and cancels the phase distortion between adjacent symbols. Like MSK, GMSK is a constant-envelope modulation scheme that achieves a high power-efficiency MS using a class C amplifier. The GMSK modulator consists of a bit stuffing system, a differential encoder, a Gaussian low pass filter and an FM modulator. The bit stuffing system repeats each bit once to eliminate small and ambiguous phase change sequence patterns and to provide a symmetric detection. The differential encoder encodes information bits using the carrier phase differences. GMSK is used in the GSM, GPRS, EDGE, and CDPD systems. GFSK is similar to GMSK, but it utilizes a Gaussian filter to smooth positive/negative frequency deviations of FSK. Although GMSK is a good choice for voice modulation, it is not desirable for data modulation. This is because a much lower BER is required for data, which limits the value α and consequently reduces the spectral efficiency of GMSK for data. For GMSK, the measured BER can be approximated by the following equation [2]

$$P_b = Q(\sqrt{2\alpha\gamma_b}) \quad (11)$$

Where α is the degradation factor due to the Gaussian filter, α=0.68 for GMSK with B_bT=0.25, α=0.85 for simple MSK ($B_bT \rightarrow \infty$). With coherent detection in the AWGN channel, theoretically α= 1 for MSK.

4. PERFORMANCE ANALYSIS OF RICIAN FADING CHANNELS IN MSK AND GMSK MODULATION SCHEMES

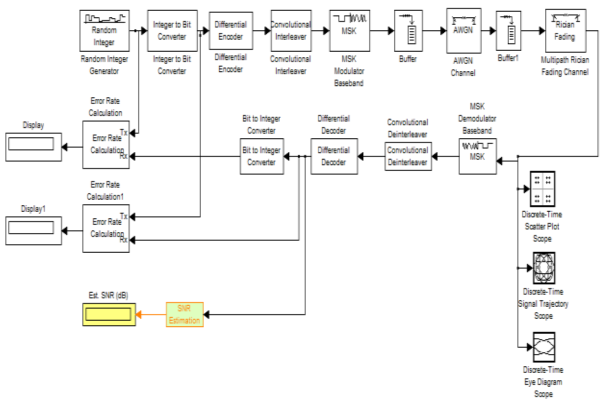


Fig. 1.Simulink Scenario for the performance analysis of Rician fading channels in MSK modulation scheme

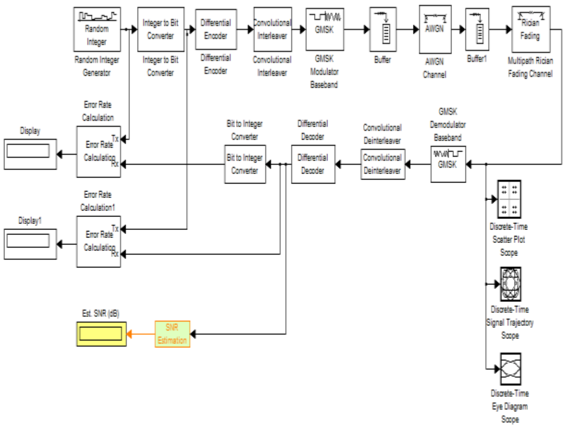


Fig. 2. Simulink Scenario for the performance analysis of Rician fading channel in GMSK modulation scheme

The environment is created as shown in the figures 1 and 2 respectively using Simulink tool.

5.1 RANDOM INTEGER GENERATOR: The random integer generator generates random uniformly distributed integers in the range [0, M-1], where M is the M-ary number.

5.2. INTEGER TO BIT CONVERTER: In the integer to bit convertor unit, a vector of integer-valued or fixed valued type is mapped to a vector of bits. The number of bits per integer parameter value present in the integer to bit convertor block defines how many bits are mapped for each integer-valued input. For fixed-point inputs, the stored integer value is used. This block is single-rated and so the input can be either a scalar or a frame-based column vector. For sample-based scalar input, the output is a 1-D signal with 'Number if bits per integer' elements. For frame-based column vector input, the output is a column vector with length equal to 'Number of bits per integer' times larger than the input signal length.

5.3 DIFFERENTIAL ENCODER: Differential encoder differentially encodes the input data. The differential encoder object encodes the binary input signal within a channel. The output is the logical difference between the current input element and the previous output element.

5.4 CONVOLUTIONAL INTERLEAVER: This block permutes the symbols in the input signal. Internally, it uses a set of shift registers. The delay value of the kth shift register is (k-1) times the register length step parameter. The number of shift registers is the value of the rows of shift registers parameter.

5.5 MSK MODULATOR: The MSK modulator baseband modulates the input signal using the minimum shift keying method.

5.6 MSK DEMODULATOR: The DQPSK demodulator baseband demodulates the MSK modulated input signal using the Viterbi algorithm.

5.7 GMSK MODULATOR: The GMSK modulator baseband modulates the input signal using the Gaussian minimum shift keying method.

5.8 GMSK DEMODULATOR: The GMSK Demodulator baseband demodulates the modulated input signal using the Viterbi algorithm.

5.9 BUFFER: The buffer converts scalar samples to a frame output at a lower sample rate. The conversion of a frame to a larger size or smaller size with optional overlap is possible. It is then passed to the multipath Rician fading.

5.10 CONVOLUTIONAL DEINTERLEAVER: The Convolutional deinterleaver block recovers a signal that was interleaved using the Convolutional interleaver block.

5.11 DIFFERENTIAL DECODER: The differential decoder block decodes the binary input signal.

5.12 BIT TO INTEGER CONVERTER: The bit to integer converter maps a vector of bits to a corresponding vector of integer values. The number of bits per integer parameter defines how many bits are mapped for each output.

5.13 ERROR RATE CALCULATION: The error rate calculation is done by computing the error rate of the received data by comparing it to a delayed version of the transmitted data.

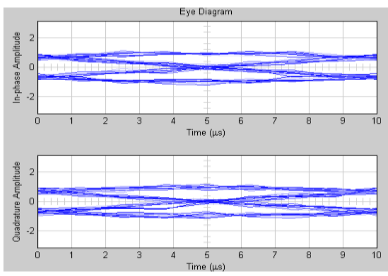
5.14 SIGNAL TRAJECTORY SCOPE: The discrete-time signal trajectory scope is used to display a modulated signal constellation in its signal space by plotting the in phase component versus the quadrature component.

5.15 SCATTER PLOT SCOPE: The discrete-time scatter plot scope is used to display a modulated signal constellation in its signal space by plotting the in phase component versus the quadrature component.

5.16 EYE DIAGRAM SCOPE: The discrete-time eye diagram scope displays multiple traces of a modulated signal to reveal the modulation characteristics such as pulse shaping, as well as channel distortions of the signal.

5.17 SNR ESTIMATION: The SNR estimation block gives the estimated SNR in decibels.

5.18 DISPLAY: This unit gives the total number of bits transmitted, the number of errors and finally displays the Bit Error Rate



ISSN: 2278-0181
Vol. 2 Issue 5, May - 2013

Fig. 3. Eye diagram for Performance Analysis of Rician Fading Channels in MSK modulation scheme

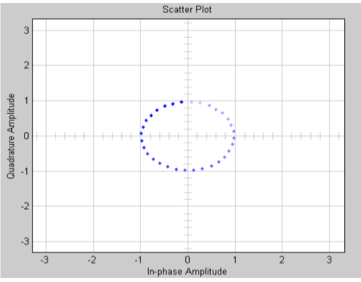


Fig. 4. Scatter plot for Performance Analysis of Rician Fading Channels in MSK modulation scheme

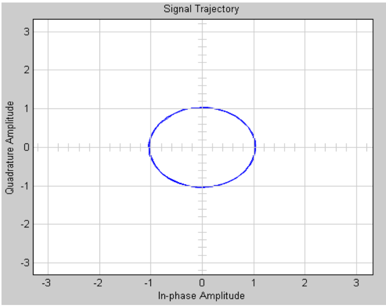


Fig. 5. Signal Trajectory for Performance Analysis of Rician Fading Channels in MSK modulation scheme

Table 1. BER Analysis of Rician Fading Channels in MSK modulation scheme

Ricean factor (K_r)	SNR (dB)	BER
500	100	0.008297
1000	200	0.008236
1500	300	0.008216

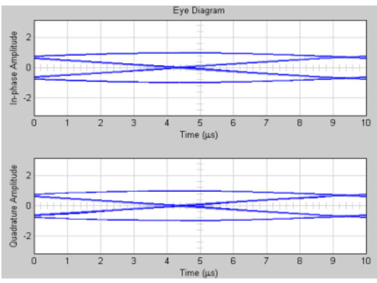


Fig. 6. Eye diagram for Performance Analysis of Rician Fading Channels in GMSK modulation scheme

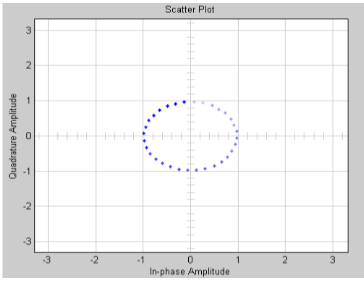


Fig. 7. Scatter plot for Performance Analysis of Rician Fading Channels in GMSK modulation scheme

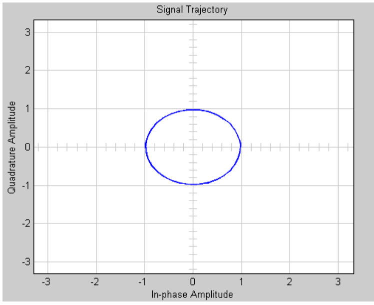


Fig. 8. Signal Trajectory for Performance Analysis of Rician Fading channels in GMSK modulation scheme

Table. 2. BER Analysis of Rician Fading Channels in MSK modulation scheme

Ricean factor (K_r)	SNR (dB)	BER
500	100	0.008255
1000	200	0.008217
1500	300	0.008037

5. CONCLUSION

A short survey on fading in the mobile environment is provided followed by a review on Rician fading channel. It is apparent from table 1 and table 2 that when the Ricean factor and Signal to Noise Ratio increases then the Bit Error Rate decreases in both the Minimum shift keying modulation and the Gaussian Minimum shift keying modulation schemes. When comparing the bit error rates of both the MSK modulation schemes and the GMSK modulation schemes, GMSK produces a very low bit error rate. The eye diagrams, scatter plots and the signal trajectories are also obtained. Future works may include the computation of the Bit Error

Rate by increasing the Rician factor values along with signal to noise ratio and by changing the modulation techniques suitably.

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