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Mitigating Communication Fading Using Bit Error Rate Performance of Combining Techniques Simulink Model

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ABSTRACT

Information plays a significant role in the society, industry and business organizations but in spite of the improvement in wireless communication over the conventional communication system, its performance is still degraded by many transmission impairments such as fading, co-channel interference and noise. In wireless communication, diversity techniques are very powerful tools to mitigate the fading impairment. This work presents the investigation of bit error rate (BER) performance of combining techniques in combating fading. To visualize the BER performance of Maximal Ratio Combining (MRC), Equal Gain Combining (EGC) and Selection Combining (SC) techniques, some mathematical modelling develop in MATLAB/Simulink model were performed. The simulation results conform to their corresponding closed form expression. The performance improvement in the Bit Error Rate (BER) is maximum for Maximal Ratio Combining (MRC), while Equal Gain Combining (EGC) and Selective Combining (SC) provide marginally inferior performances. The developed program is tested and found to be reliable and accurate in combating signal fading.

Keywords: Bit error rate, combining techniques, fading, global system, mobile communication, Simulink, Statistical analysis.

INTRODUCTION

Communication fading is defined as any time varying phase, polarization, and/or level of a received signal. The most basic definitions of fading are in terms of the propagation mechanisms involved: refraction, reflection, diffraction, scattering, attenuation, and guiding (ducting) of radio waves [1]. These are basic because they determine the statistical behavior with time of measurable field parameters including amplitude (level), phase, and polarization, as well as frequency and spatial selectivity. Consequently, the overall system performance can be severely degraded. Once these mechanisms are understood, remedies can be developed to avoid or mitigate the effects. In terms of error rate performance, Rayleigh fading converts the exponential dependency of the bit-error probability on the signal-to-noise ratio (SNR) for the classical additive white Gaussian noise (AWGN) channel into an approximately inverse linear one, resulting in large SNR penalty [2].

Transmitting/receiving diversity can enhance better performance of mobile radio system by weighting and combining the receiving signals strength from all branches of antenna to combat fading and co-channel interference [3]. In Maximal Ratio Combining (MRC), the signal from all the branches are co-phased and individually weighted to provide the optimal SNR at the output [4]. In Equal Gain Combining (EGC), all the received signals are co-phased at the receiver and added together without any weighting. This paper focuses performance analysis on three combining techniques: Maximal Ration Combining, Equal Gain Combining and Selection Combining to develop an application program for different diversity combining technique that allows model fading in mobile communication. And to evaluate the system performance of the different techniques using bit error rate as the performance metrics. Various transmit diversity techniques have been proposed in the literature, but the diversity techniques are most frequently applied [5].

Performance of maximum ration combination in conjunction with multiple input multiple output (MIMO) systems as equalizer was presented in [6][7], however, the performance indicator in term of signal to noise ratio or signal to interference was not quantified in comparison with other techniques. In [8], a multicasting Rayleigh fading system with closed form of expression of outage probability by applying diversity combining techniques. Diversity combining techniques under employment of generalized receiver in wireless Communication Systems with Rayleigh Fading Channel was presented in [9]. However, the diversity techniques are suboptimal in performance in term of SNR. In addition, most of the system complexities with receiver MRC concentrate at the receiver' side. Therefore, this paper exploits the combination of three diversity techniques: Maximal Ration Combining, Equal Gain Combining and Selection Combining. The concept, principles and analysis of maximum ration transmission for wireless communication were implemented for comparative analysis and effectiveness of each combining technique.

Significant Statement

- The study established the possibility of improving the quality of service of wireless transmission through the use of diversity combining technique; and provided the performance evaluation of selective combining, equal gain combining and maximum ratio combining based on their bit error rate values.
- The quality of service delivered by wireless communication system is not yet at par with that delivered by wired communication. Fading over wireless communication channel is one of the major factors responsible for this discrepancy. There is need to continue to improve on the service delivery of wireless communication because of its reach advantage over wired communication.
- It is the desire to contribute to the effort of achieving the goal of seamless communication. Being able to combat fading will contribute greatly towards moving the communication industry forward.

MATERIALS AND METHODS

Diversity Combining Methods

The goal of a combiner is to improve the noise performance of the system [10]. After obtaining the uncorrelated signals, there is need to consider the method of processing these signals to obtain the best results. The analysis of combiners is generally performed in terms of SNR [11]. The idea of diversity is to combine several copies of the transmitted signal, which undergo independent fading, to increase the overall received power. Different types of diversity call for different combining methods but in this study, evaluating the bit error rate performance of three combining techniques which are: maximum ratio combining (MRC), equal gain combining (EGC) and selection combining (SC) was adopted.

In MRC, the output of the diversity combiner is the weighted sum of the branched signals making the output optimum. The input signals are co-phased and proportionally weighted to the signal level, signal power or signal-to-noise (SNR). In EGC, the weights are normalized to unity. This implies that the individual strength of a branch signal is not taken into consideration. In SC, the combiner selects the input that has the highest or most desirable signal level. This selection process is based on some quality measurement, which can be signal level, signal power or SNR. Considering a transmitted signal $s(t) = A cos 2\pi f_c t$ through a fading channel. The received signal can be expressed as:

$$y(t) = A \sum_{i=1}^{N} a_i \cos(2\pi f_c t + \theta_i) \qquad (2.1)$$

where a_i is the attenuation of the ith multipath component. θ_i is the phase-shift of the ith multipath component. It must be noted that a_i and θ_i are random variables. The above expression can be re-written as:

$$y(t) = A\left\{\left(\sum_{i=1}^{N} a_i \cos(\theta_i)\right)\cos(2\pi f_c t) - \left(\sum_{i=1}^{N} a_i \sin(\theta_i)\right)\sin(2\pi f_c \mathrm{t})\right\} \qquad (2.2)$$

With the introduction of two random processes $X_1(t)$ and $X_2(t)$, such that the above equation becomes:

$$y(t) = A\{X_1(t)\cos(2\pi f_c t) - X_2(t)\sin(2\pi f_c \mathrm{t})\} \qquad (2.3)$$

If the value of N is large (i.e., a large number of scattered waves are present), invoking the Central-Limit Theorem, we get approximate

$X_1(t)$ and $X_2(t)$ to be Gaussian random variables with zero mean and variance σ^2. The expression (2.3) above can be rewritten as:

$$y(t) = AR(t)\cos\big(2\pi f_c t + \theta(t)\big) \qquad (2.4)$$

where, the amplitude of the received waveform $R(t)$ is given by:

$$R(t) = \sqrt{X_1(t)^2 + X_2(t)^2} \qquad (2.5)$$

Since the processes $X_1(t)$ and $X_2(t)$ are Gaussian, it can be shown that $R(t)$has a Rayleigh Distribution with a probability density function (pdf) given by:

$$f_R(r) = \frac{r}{2\sigma^2} e^{\frac{-r^2}{2\sigma^2}}, \quad r > 0 \qquad (2.6)$$

The phase of the received waveform $\theta(t)$ is given by:

$$\theta(t) = tan^{-1}\left(\frac{X_2(t)}{X_1(t)}\right) \qquad (2.7)$$

Since the processes $X_1(t)$ and $X_2(t)$ are Gaussian, it can be shown that $\theta(t)$ has a Uniform Distribution with a probability density function (pdf) given by:

$$f_\theta(\theta) = \frac{1}{2\pi}, \quad -\pi \le \theta \le \pi \qquad (2.8)$$

Bit Error Rate and Combining Techniques

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unit less performance measure, often expressed as a percentage. The number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference and distortion.

Mathematical Model for Signal Transmission

For a slowly flat fading channel, the equivalent received signal of multiple branches, say the ith branch can be written as:

$r_i(t) = g_i s(t) + n_i(t), \;\; i = 1, 2, \dots L$

where $g_i = A_i e^{j\theta_i}$ is the ith branch fading attenuation with phase θ_i which is assumed uncorrelated; $s(t)$ is the equivalent transmitted signal, $n_i(t)$ is the Additive White Gaussian Noise. L is the total number of branches that lead to the receiver and the received signals.
To be able to visualize the BER performance of Maximal Ratio Combining (MRC), Equal Gain Combining (EGC) and Selection Combining (SC) techniques, some mathematical modelling and numerical simulations were performed using Simulink, a MATLAB modelling tool and graphs plotted-collecting data from sufficient number of independent random realizations of the system's parameters. MATLAB scripts codes were written for each of the three combining techniques using eight different paths from the transmitter to the receiver and the graphs of the BER against the SNR for the paths were plotted. The blocks and description is the same for the three combining techniques, but there are some peculiarities to each of the combining techniques. For Equal Gain Combining, the EGC block performs equal gain combining on received signals. Also, for Maximum Ratio Combining, MRC block performs maximum ratio combining on receive signals and the Converter block converts sample-based vector to frame. The figures below show the Simulink model for the three combining techniques when four multipath signals were combined.

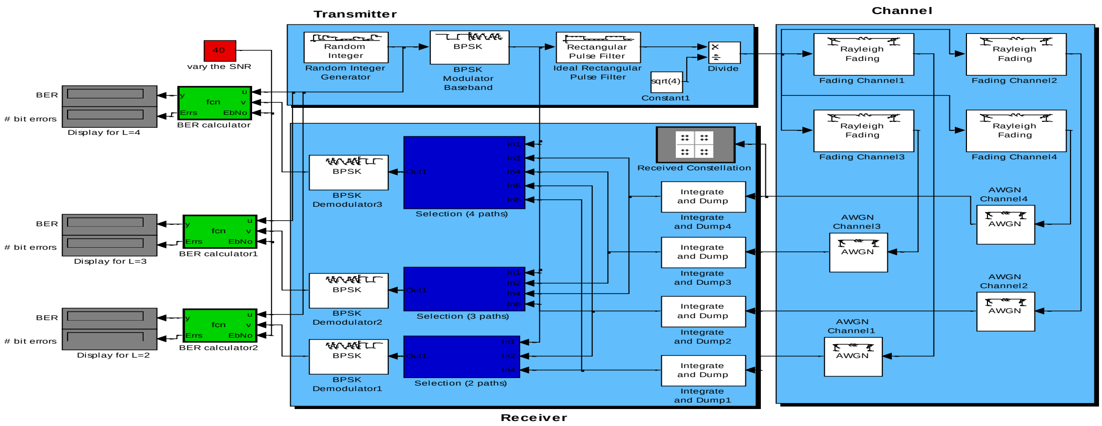

Figure 1: Simulink model of Selection Combining

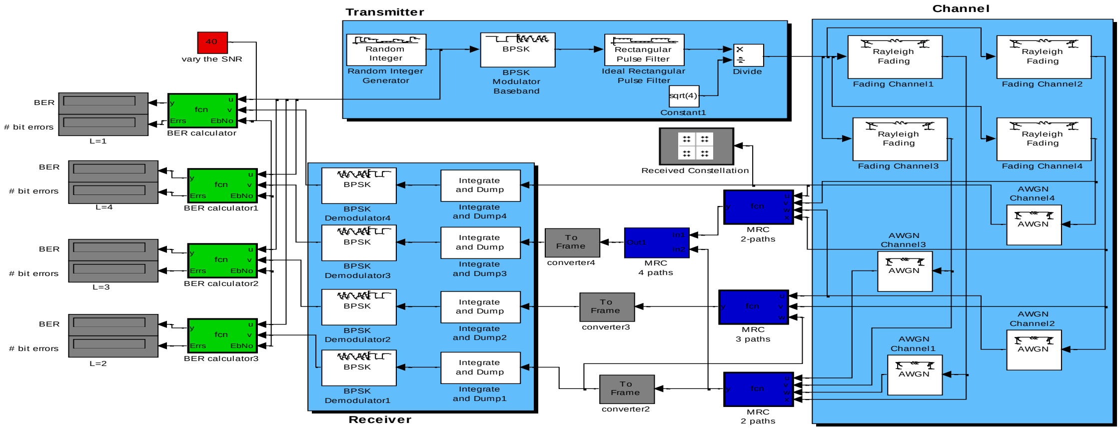

Figure 2: Simulink model of Maximum Ratio Combining

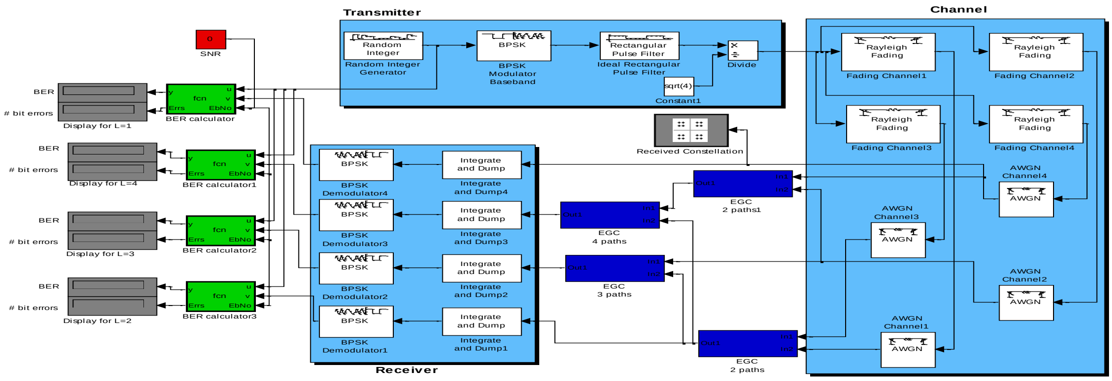

Figure 3: Simulink model of Equal Gain Combining

RESULTS AND DISCUSSION

Simulink Model Results

From the Simulink model in methodology, when it was run in MATLAB, the BER and number of bit errors for the number of paths, L=1 to L=4 was gotten for different SNR value of 0,8,16,24,32 and 40 and the length of the signal (sample size) is 10,000 bits.

$$BER \times 10\,000 = Number\ of\ bit\ errors$$

$$BER = \frac{Number\ of\ bit\ errors}{10000}$$

The results in the Tables 1, 2 and 3 are the Tables for BER and Number of errors for different SNR values of paths for EGC, SC and MRC respectively. When the simulation is run, the 'display' block gives the output of the BER and the number of bit errors. The higher the SNR, the lower the BER which implies that the SNR is inversely proportional to BER.

To get the number of paths that provides best performance, a specific combining technique is analysed and a specific SNR is used. Taking MRC in Table 3 at SNR=16, the BER values of the paths L=1, L=2, L=3 and L=4 are 57.54e-4, 29.94e-4, 19.91e-4 and 15.05e-4 respectively and it can be deduced that the highest number of paths L=4 has the best performance because it has the least BER value. To get the diversity combining technique with the best performance, the technique with the least BER value is needed. From the Tables 1, 2 and 3, taking SNR of 16dB and path L=4, the BER value for EGC in Table 1 is 29.02e-4, the BER value for SC in Table 2 is 69.54e-4 and the BER value for MRC in Table 3 is 15.05e-4. From these three values it can be deduced that MRC has the best performance because it has the least BER value, followed by EGC and then SC. The results discussion in comparison to [1], [3] and [4] showed similarity of performance with MRC having the best performance. However, with a low diversity order, the performance differences among the combining techniques in earlier works are insignificant. This was clearly analysed in this work with BER values as performance indicator.

Table 1: BER and Number of errors for different SNR values of paths for EGC

No of paths		SNR=0	SNR=8	SNR=16	SNR=24	SNR=32	SNR=40
L=1	BER	0.4786	0.07585	0.01202	0.001905	0.000302	4.786 e-005
	Number of bit errors	4786	758.5	120,2	19.05	3.02	0.4786
L=2	BER	0.2288	0.03626	0.005747	0.0009109	0.0001444	2.288 e-005
	Number of bit errors	2288	362.6	57.47	9.109	1.444	0.2288
L=3	BER	0.1486	0.02356	0.003734	0.0005917	9.378e-005	1.486 e-005
	Number of bit errors	1486	235.6	37.34	5.917	0.9378	0.1486
L=4	BER	0.1155	0.01831	0.002902	0.0004599	7.289e-005	1.155 e-005
	Number of bit errors	1155	183.1	29.02	4.599	0.7289	0.1155

Table 2: BER and Number of errors for different SNR values of paths for SC

No of paths		SNR=0	SNR=8	SNR=16	SNR=24	SNR=32	SNR=40
L=2	BER	0.4823	0.07644	0.01211	0.00192	0.0003043	4.823 e-005
	Number of bit errors	4823	764.4	121.1	19.2	3.043	0.4823
L=3	BER	0.3391	0.05374	0.008517	0.10035	0.0002139	3.391 e-005
	Number of bit errors	3391	537.4	85.17	13.5	2.139	0.3391
L=4	BER	0.2768	0.04388	0.006954	0.001102	0.0001747	2.768 e-005
	Number of bit errors	2768	438.8	69.54	11.02	1.747	0.2768

Table 3: BER and Number of errors for different SNR values of paths for MRC

No of paths		SNR=0	SNR=8	SNR=16	SNR=24	SNR=32	SNR=40
L=1	BER	0.4786	0.05248	0.005754	0.006309	6.918e-005	7.585e-006
	Number of bit errors	4786	524.8	57.54	6.309	0.6918	0.7585
L=2	BER	0.2491	0.02731	0.002994	0.0003283	3.6e-005	3.947e-006
	Number of bit errors	2491	273.1	29.94	3.283	0.36	0.03947
L=3	BER	0.1656	0.01816	0.001991	0.0002183	2.394e-005	2.625e-006
	Number of bit errors	1656	181.6	19.91	2.183	0.2394	0.2625
L=4	BER	0.1252	0.01373	0.001505	0.000165	1.81e-005	1.984e-006
	Number of bit errors	1252	137.3	15.05	1.65	0.181	0.01984

CONCLUSION

The Results of this research work has determined the bit error rate performance of selection combining, equal gain combining and maximum ratio combining. It has shown and proved that the maximum ratio combining has the best performance with the highest number of paths L=4

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