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Mr. Md. Mahbubul Hoque Bhuiyan
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Diversity Combining Techniques under Employment of Generalized Receiver in Wireless Communication Systems with Rayleigh Fading Channels

Daina Das¹, Hritom Das², Modar Safir Shbat¹, Vyacheslav Tuzulkov¹

The bit error rate (BER) performance of wireless communication system employing the generalized receiver (GR) under the binary phase shift keying (BPSK) modulation over Rayleigh fading channel with three common diversity combining techniques, namely, the selection combining, equal gain combining, and maximal ratio combining with the purpose to mitigate the effects of multipath fading is investigated. Simulation demonstrates a high performance gain under employment of GR in wireless communication system in comparison with modern approaches.

Keywords: generalized receiver (GR), diversity combining, selection combining (SC), equal gain combining (EGC), maximal ratio combining (MRC), and Rayleigh fading channel.

1. Introduction

In urban and indoor environments, the line-of-sight between the transmitter and receiver has a random character and the transmitted signal is distorted along multiple paths. Each of these bounces can introduce phase shifts, time delays, attenuations, and distortions that can destructively interfere with one another at the aperture of the receiving antenna. Antenna diversity is especially effective at mitigating these multipath situations (Proakis, 1995). This is because multiple antennas offer a receiver several observations of the same signal. Each antenna will experience a different interference environment. Thus, if one antenna is experiencing a deep fade, it is likely that another has a sufficient signal. Collectively such a system can provide a robust link. Diversity combining is the technique applied to combine the multiple received signals of a diversity reception device into a single improved signal. The experimental results of dual and triple diversity are presented in (Wambeck, 1951). The derivation of the combining weights of the optimal linear combiner for dual diversity is discussed in (Kahn, 1954), and generalization of the Kahn’s results for higher orders of diversity is presented in (Brennan, 1955). The technique described by Kahn and Brennan is commonly known as maximal ratio combining (MRC). A thorough treatment of the more commonly-used diversity combining techniques is presented in (Schwartz, 1966). The performance of diversity combiner is measured by diversity gain which is the difference in signal-to-noise ratio (SNR) between the output of a diversity combiner and the signal on a single branch measured at a given probability level. Diversity gain quantifies the improvement in SNR of a received signal that is obtained using signals from different receiver branches. Equalizers or rake receivers employed in wideband radios cannot mitigate flat fading with a single antenna (Benvenuto, 1997), but when combined with

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antenna diversity they can improve performance in both flat fading and frequency-selective fading channels. Predetection combining using space-diversity antenna array is commonly used to combat fading in mobile radio systems. These methods have been extensively studied in (Brennan, 1959) and (Jakes, 1971). The most widely considered predetection combining techniques are selection combining (SC), equal-gain combining (EGC), and maximal-ratio combining (MRC). SC is a suboptimal combining scheme in which the branch signal with the largest amplitude or SNR is selected for demodulation (Altman, 1956), (Mack, 1955), and (Kavehrad, 1985). SC scheme is used to decrease the receiver complexity in terms of the number of radio frequency (RF) chains, proposed in (Chen, 2005) and (Jakes, 1994). The SC scheme has been extended to the cases where the signals on more than one receive antennas with the largest instantaneous SNRs are combined (Eng, 1996), (Kong, 1999), (Win, 1999), and (Bjerke, 2004). This scheme is referred to as hybrid selection/maximal-ratio combining (HS/MRC) (Win, 1999). MRC is one of the most widely used diversity combining schemes in which SNR is the sum of the SNR's of each individual diversity branch. It is the optimal but the most complex combining model, since MRC requires cognition of all channels fading parameters (Suzuki, 1977). The bit error rate (BER) of MRC receiver for BPSK signals in the presence of log-normal and Rayleigh fading is derived in (Nikolic, 2011). The BER of MRC receiver is presented in the presence of log-normal and Rice fading in (Nikolic, 2008); and Nakagami-m fading and shadowing in (Nikolic, 2010). The performance analysis of MRC receiver in the presence of Weibull fading and shadowing are described by both log-normal and Gamma distributions in (Nikolic, 2010). The performance analysis of EGC has been extensively reported for the case when channel information is perfectly known at the receiver (Beaulieu, 1991), (Zhang, 1999), (Annamalai, 2000), (Alouini, 2001), and (Qi, 2003). To evaluate the performance of the EGC, a decision variable based approach is presented in (Annamalai, 2000) and (Alouini, 2003) and the simplifying analysis of that performance is presented in (Beaulieu, 1991). Closed form error probability expressions for the case of dual branch EGC over Rayleigh fading channels have been presented in (Qi, 2003).

In this paper, we employ the generalized receiver (GR), which is constructed based on the generalized approach to signal processing (GASP) in noise (Tuzlukov, 1998), and (Tuzlukov, 2001) in wireless communication system with one transmit antenna and N receive antennas. The multiple-input multiple-output (MIMO) wireless communication system employing GR over Rayleigh fading channel shows high performance gain in comparison with NP receiver (Das, 2012). We study the SC, MRC and EGC techniques used by GR under BPSK modulation over Rayleigh fading channel. The BER performance of wireless communication system over Rayleigh fading channel employing the GR with discussed diversity combining techniques has a great advantage in comparison with widely used receivers, for example, receiver based on the Neyman Pearson criterion employing the same diversity combining procedures.

The paper is organized as follows. In section 2 we describe the generalized receiver (GR). Diversity combining techniques for wireless communication system are discussed in section 3. Simulation results are given in section 4 and some
conclusions are made in section 5.

2. Generalized Receiver

The GR can be simply presented in a form of block diagram shown in Fig.1, (Tuzlukov, 2011). In this flowchart, MSG is the model signal generator (local oscillator), PF is the preliminary filter with the impulse response $h_{PF}(t)$, and AF is the additional filter with the impulse response $h_{AF}(t)$. A resonant frequency of the AF is detuned relative to a resonant frequency of PF on such a value that, at the PF output both the signal and noise can be appeared whereas the only noise is appeared at the AF output. A value of detuning between the AF and PF resonant frequencies is more than $4\div 5\Delta f_s$, where $\Delta f_s$ is the signal bandwidth. In this case the coefficient of correlation is not more than 0.05. If the Gaussian noise $w(t)$ comes in at the AF and PF inputs (the GR linear system front end), the noise forming at the AF and PF outputs is Gaussian, too, because the AF and PF are the linear systems and, in a general case, takes the following form (Tuzlukov, 2001), and (Tuzlukov, 2011):
Figure 1: Principal GR flowchart.

\[
\xi_{PF}(t) = \sum_{i=-\infty}^{\infty} h_{PF}(t_i) \eta(t_i - \tau),
\]

(1)

\[
\xi_{AF}(t) = \sum_{i=-\infty}^{\infty} h_{AF}(t_i) \eta(t_i - \tau).
\]

(2)

If the additive white Gaussian noise (AWGN) with zero mean and two-sided power spectral density \( N_0 / 2 \) is coming in at the AF and PF inputs (the GR linear system front end), then the noise forming at the AF and PF outputs is Gaussian with zero mean and variance given by,

\[
\sigma_n^2 = \frac{N_0\omega_0}{8\Delta_f},
\]

(3)

where \( \Delta_f \) is the AF (or PF) bandwidth and \( \omega_0 \) is the resonance frequency.
The input stochastic process at the output of the PF takes the following form:

\[ X_i(t) = \sqrt{E_b} a_i(t) \xi_i(t) \quad (i \in [1,N]; \quad 0 \leq t \leq T), \]  

(4)

where \( \sqrt{E_b} a_i(t) \) is the signal at the output of the PF; \( N \) is the sample size; \([0, T]\) is the time interval within the limits of which the input stochastic process is observed; \( \xi_i(t) \) is the Gaussian noise with zero mean and the spectral power density \( \frac{N_0}{2} \) at the output of the PF. Further, the correlation channel of the GR is created under the following condition

\[ \sqrt{E_b} a_i^*(t) = \sqrt{E_b} a_i(t), \]  

(5)

Here \( a_i^*(t) \) is the model signal; \( E_b \) is the energy of the model signal. The process at the output of the GR takes the following form:

\[ Z_{\text{out}}(t) = 2E_b + 2\sqrt{E_b} \sum_{i=1}^{N} a_i^*(t)\xi_i(t) - E_b - 2\sqrt{E_b} \sum_{i=1}^{N} a_i(t)\xi_i(t) - \sum_{i=1}^{N} \xi_i^2(t) + \sum_{i=1}^{N} \eta_i^2(t) \]

\[ = E_b + \sum_{i=1}^{N} \left[ \eta_i^2(t) - \xi_i^2(t) \right], \]  

(6)

where \( \eta_i(t) \) is the noise at the output of the AF.

### 3. Diversity Combining

In this paper, we consider one transmit antenna and \( N \) receive antennas over flat fading channel shown in Fig. 2. For the \( i-th \) receive antenna, each transmitted signal is multiplied by a random channel gain \( h_i \). As the channel under consideration is a Rayleigh channel, the real and imaginary parts of \( h_i \) are Gaussian distributed with the mean zero and variance 0.5.
The instantaneous bit energy to noise ratio for NP receiver at the $i$–th receive antenna takes the following form (Brennan, 1955) and (Jakes, 1971):

$$\gamma_i^{\text{NP}} = \frac{|h_i|^2 E_b}{N_0}. \quad (7)$$

For GR the bit energy to ratio at the $i$–th receive antenna takes the following form (Tuzlukov, 2001), and (Tuzlukov, 2011).

$$\gamma_i^{\text{GR}} = \frac{|h_i|^2 E_b^2}{2N_0^2}. \quad (8)$$

In the case of NP receiver the probability density function (pdf) of $\gamma_i$ takes the following form (Brennan, 1955) and (Jakes, 1971):
\[
p(\gamma_i^{NP}) = \frac{1}{(E_b / N_0)} e^{\frac{-\gamma_i^{NP}}{E_b / N_0}}.
\]  \hspace{1cm} (9)

The pdf of \( \gamma_i \) for GR is defined as follows (Tuzlukov, 2001), and (Tuzlukov, 2011):

\[
p(\gamma_i^{GR}) = \frac{2}{(E_b / N_0)^2} e^{\frac{-2\gamma_i^{GR}}{(E_b / N_0)^2}}.
\]  \hspace{1cm} (10)

### 3.1. Selection Combining

In selection combining technique, the receiver selects the antenna with the highest received signal power and ignores observations from the other antennas. Outage probability is the probability that the bit energy to noise ratio falls below a threshold. The outage probabilities on the \( i-th \) receive antenna for NP receiver takes the following form (Kavehard, 1985) and (Chen, 2005):

\[
P_{\text{out}}^{NP} = P[\gamma_i^{NP} < \gamma_s]
= \int_{\gamma_s}^{\infty} \frac{1}{(E_b / N_0)} e^{\frac{-\gamma_i^{NP}}{E_b / N_0}} d\gamma_i^{NP} = 1 - e^{\frac{-\gamma_s}{(E_b / N_0)}}.
\]  \hspace{1cm} (11)

Where, \( \gamma_s \) is the defined threshold for bit energy to noise ratio.

The outage probabilities by GR on the \( i-th \) receive antenna can be defined as follows (Tuzlukov, 2001), and (Tuzlukov, 2011):

\[
P_{\text{out}}^{GR} = P[\gamma_i^{GR} < \gamma_s]
= \int_{\gamma_s}^{\infty} \frac{2}{(E_b / N_0)^2} e^{\frac{-2\gamma_i^{GR}}{(E_b / N_0)^2}} d\gamma_i^{GR} = 1 - e^{\frac{-2\gamma_s}{(E_b / N_0)^2}}.
\]  \hspace{1cm} (12)

In \( N \) antenna case, the probability that all bit energy to noise ratio on all the
receive antennas are below the threshold $\gamma_s$, i.e.

$$P_{\text{out}} = P[\gamma_1 < \gamma_s, \gamma_2 < \gamma_s, \ldots, \gamma_N < \gamma_s]$$

where, $\gamma_1, \gamma_2, \gamma_3, \ldots, \gamma_N$ are the bit energy to noise ratio on the 1st, 2nd, 3rd, and so on till the N-th receive antenna. Since the channel on each antenna is assumed to be independent, the joint probability is the product of individual probabilities.

$$P[\gamma_2 < \gamma_s]P[\gamma_3 < \gamma_s]\ldots P[\gamma_N < \gamma_s] = \prod_{i=1}^{N} P[\gamma_i < \gamma_s].$$

(14)

For NP receiver, the joint probability is as follows (Kavehard, 1985) and (Chen, 2005):

$$P_{\text{joint}}^{\text{NP}} = \left[ 1 - e^{-\frac{\gamma_s}{\frac{E_o}{N_0}}} \right]^N.$$  

(15)

For GR it takes the following form (Tuzlikov, 2001), and (Tuzlikov, 2011):

$$P_{\text{joint}}^{\text{GR}} = \left[ 1 - e^{-\frac{2\gamma_s}{\frac{E_o}{N_0}}} \right]^N.$$  

(16)

$P_{\text{out}}$ also represents the cdf of the output SNR as a function of the threshold $\gamma_s$. Therefore the pdf of the output SNR is as follows:

$$p(\gamma) = \frac{dP_{\text{out}}}{d\gamma}.$$  

(17)

The pdf of the output SNR for NP receiver takes the following form (Kavehard, 1985) and (Chen, 2005):

$$p(\gamma^{\text{NP}}) = \frac{N}{(E_o / N_0)} e^{-\frac{\gamma^{\text{NP}}}{\frac{E_o}{N_0}}} \left[ 1 - e^{-\frac{\gamma^{\text{NP}}}{\frac{E_o}{N_0}}} \right]^{N-1}. $$

(18)
For GR, the pdf of the output SNR is as follows (Tuzlukov, 2001), and (Tuzlukov, 2011):

\[
p(\gamma^{GR}) = \frac{2N}{(E_b / N_0)^2} e^{\frac{-2\gamma^{GR}}{(E_b / N_0)^2}} \left[ 1 - e^{\frac{-2\gamma^{GR}}{(E_b / N_0)^2}} \right]^{N-1}.
\]  

The average output bit energy to noise ratio can be defined as follows:

\[
E(\gamma) = \int_0^\infty \gamma p(\gamma) d\gamma.
\]

In case of NP receiver, the average bit energy to noise ratio is as follows (Kavehard, 1985) and (Chen, 2005):

\[
E(\gamma^{NP}) = \int_0^\infty \gamma^{NP} \frac{N}{(E_b / N_0)^2} e^{\frac{-\gamma^{NP}}{(E_b / N_0)^2}} \left[ 1 - e^{\frac{-\gamma^{NP}}{(E_b / N_0)^2}} \right]^{N-1} d\gamma^{NP} = \frac{E_b}{N_0} \sum_{i=1}^N \frac{1}{i}.
\]

For GR, the average bit energy to noise ratio takes the following form (Tuzlukov, 2001), and (Tuzlukov, 2011):

\[
E(\gamma^{GR}) = \int_0^\infty \gamma^{GR} \frac{2N}{(E_b / N_0)^2} e^{\frac{-2\gamma^{GR}}{(E_b / N_0)^2}} \left[ 1 - e^{\frac{-2\gamma^{GR}}{(E_b / N_0)^2}} \right]^{N-1} d\gamma^{GR} = \frac{1}{2} \left( \frac{E_b}{N_0} \right)^2 \sum_{i=1}^N \frac{1}{i}.
\]

The effective bit energy to noise ratio with selection diversity is the integral of the conditional BER integrated over all possible values of \( \gamma \). The total BER for NP receiver takes the following form (Kavehard, 1985) and (Chen, 2005):

\[
P_e^{NP} = \int_0^\infty \frac{1}{2} \text{erfc} \left( \sqrt{\gamma^{NP}} \right) p(\gamma^{NP}) d\gamma^{NP}
\]

\[
= \frac{1}{2} \text{erfc} \left( \sqrt{\gamma^{NP}} \right) \frac{N}{(E_b / N_0)^2} e^{\frac{-\gamma^{NP}}{(E_b / N_0)^2}} \left[ 1 - e^{\frac{-\gamma^{NP}}{(E_b / N_0)^2}} \right]^{N-1} d\gamma^{NP}.
\]
The total BER for GR takes the following form (Tuzlukov, 2001), and (Tuzlukov, 2011):

\[
P_e^{GR} = \frac{1}{2} \text{erfc} \left( \sqrt{y^{GR}} \right) P(y^{GR}) d y^{GR}
\]

\[
= \frac{1}{2} \text{erfc} \left( \sqrt{y^{GR}} \right) \frac{2N}{(E_b / N_0)^2} e^{-2y^{GR} / (E_b / N_0)} \left[ 1 - e^{-2y^{GR} / (E_b / N_0)} \right]^{N-1} d y^{GR}.
\]  \hspace{1cm} (24)

Finally the bit error probability with selection diversity for NP receiver takes the following form (Kavehard, 1985) and (Chen, 2005):

\[
P_e^{NP} = \frac{1}{2} \sum_{k=0}^{N} (-1)^k \binom{N}{k} \left( \frac{k}{E_b / N_0} \right)^{-1/2}.
\]  \hspace{1cm} (25)

For GR, the bit error probability with selection diversity takes the following form (Tuzlukov, 2001), and (Tuzlukov, 2011):

\[
P_e^{GR} = \frac{1}{2} \sum_{k=0}^{N} (-1)^k \binom{N}{k} \left( \frac{2k}{E_b / N_0} \right)^{-1/2}.
\]  \hspace{1cm} (26)

### 3.2. Maximal Ratio Combining

On the \( i - \text{th} \) receive antenna, the received signal is defined as,

\[
y_i = h_i x + n_i,
\]  \hspace{1cm} (27)

where \( y_i \) is the received signal, \( h_i \) is the channel gain, \( x \) is the transmitted signal and \( n_i \) is the noise on \( i - \text{th} \) receive antenna. The received signal can be presented in the matrix form as follows:

\[
y = h x + n,
\]  \hspace{1cm} (28)
where $y = [y_1, y_2, \ldots, y_N]^T$ is the received signal from all the receive antennas, 
$h = [h_1, h_2, \ldots, h_N]^T$ is the channel gain on all the receive antennas, $x$ is the transmitted signal, and $n = [n_1, n_2, \ldots, n_N]^T$ is the noise on all the receive antennas.

We can define the equalized signal as follows:

$$
\hat{x} = \frac{h^H y}{h^H h} = \frac{h^H y x}{h^H h} + \frac{h^H n}{h^H h} = x + \frac{h^H n}{h^H h},
$$

where $h^H h = \sum_{i=1}^{N} |h_i|^2$ is the sum of the channel powers across all the receive antennas. The effective bit energy to noise ratio for NP receiver takes the following form (Nikolic, 2011):

$$
\gamma^{NP} = \sum_{i=1}^{N} \frac{|h_i|^2 E_b}{N_0} = N \gamma_i^{NP}.
$$

The effective bit energy to noise ratio for GR is defined as follows (Tuzlukov, 2001), and (Tuzlukov, 2011):

$$
\gamma^{GR} = \frac{1}{2} \sum_{i=1}^{N} \frac{|h_i|^2 E_b^2}{N_0^2} = N \gamma_i^{GR}.
$$

The pdf of $\gamma^{NP}$ for the NP receiver is as follows (Nikolic, 2011):

$$
P(\gamma^{NP}) = \frac{1}{(N-1)! (E_b/N_0)^N} (\gamma^{NP})^{N-1} e^{-(\gamma^{NP}/E_b/N_0)}, \quad \gamma^{NP} \geq 0.
$$

For GR, the pdf of $\gamma^{GR}$ takes the following form (Tuzlukov, 2001), and (Tuzlukov, 2011):

$$
P(\gamma^{GR}) = \frac{2}{(N-1)! (E_b/N_0)^{2N}} (\gamma^{GR})^{N-1} e^{-(\gamma^{GR}/E_b/N_0)^2}, \quad \gamma^{GR} \geq 0
$$

The total bit error rate for NP receiver takes the following form (Nikolic, 2011):
\[ P_{e}^{NP} = \int_{0}^{\infty} \frac{1}{2} \text{erfc} \left( \sqrt{\gamma^{NP}} \right) p\left( \gamma^{NP} \right) d\gamma^{NP} \]

\[ = \int_{0}^{\infty} \frac{1}{2} \text{erfc} \left( \sqrt{\gamma^{GR}} \right) \frac{1}{(N-1)!} \left( \frac{E_{b}}{N_{0}} \right)^{N} \left( \gamma^{GR} \right)^{N-1} e^{-\gamma^{GR}} d\gamma^{GR} \]

(34)

The total bit error rate for GR takes the following form (Tuzlukov, 2001), and (Tuzlukov, 2011):

\[ P_{e}^{GR} = \int_{0}^{\infty} \frac{1}{2} \text{erfc} \left( \sqrt{\gamma^{GR}} \right) p\left( \gamma^{GR} \right) d\gamma^{GR} \]

\[ = \int_{0}^{\infty} \frac{1}{2} \text{erfc} \left( \sqrt{\gamma^{GR}} \right) \frac{2}{(N-1)!} \left( \frac{E_{b}}{N_{0}} \right)^{2N} \left( \gamma^{GR} \right)^{N-1} e^{-2\gamma^{GR}} d\gamma^{GR} \]

(35)

Finally we can write the total bit error rate in a simplified form as follows:

\[ P_{e} = p^{N} \sum_{k=0}^{N-1} \binom{N-1+k}{k} (1-p)^{k} \]

(36)

where \( p = \frac{1}{2} - \frac{1}{2} \left( 1 + \frac{1}{E_{b}/N_{0}} \right)^{-1/2} \), for the NP receiver and in case of the GR

\[ p = \frac{1}{2} - \frac{1}{2} \left( 1 + \frac{2}{(E_{b}/N_{0})^{2}} \right)^{-1/2} \]

3.3. Equal Gain Combining

The effective signal to noise ratio with EGC is the channel power accumulated over all receive chains. For NP receiver the effective SNR with EGC takes the following form (Beaulieu, 1991), (Zhang, 1999):

\[ E\left( \gamma_{i}^{NP} \right) = \frac{E_{b}}{N_{0}} \frac{1}{N} \left( \sum_{i=1}^{N} |h_{i}|^{2} \right) = \frac{E_{b}}{N_{0}} \frac{1}{N} \left( \sum_{i=1}^{N} \sum_{k=1}^{N} |h_{i}||h_{k}| \right) \]
\[
E(y_{i}^{GR}) = \frac{1}{2} \left( \frac{E_b}{N_0} \right)^2 \frac{1}{N} \left( \sum_{i=1}^{N} |h_i|^2 \right) = \frac{1}{2} \left( \frac{E_b}{N_0} \right)^2 \frac{1}{N} \left( \sum_{i=1}^{N} \sum_{k=1}^{N} |h_i||h_k| \right) \\
= \frac{1}{2} \left( \frac{E_b}{N_0} \right)^2 \frac{1}{N} \left( \sum_{i=1}^{N} |h_i|^2 + \sum_{k=1, k \neq i}^{N} |h_i||h_k| \right) \tag{38}
\]

where, the first term is a chi-square random variable with 2N degrees of freedom having mean value of \(2N\sigma_h^2\). Hence the first term reduces to the following form:

\[
\sum_{i=1}^{N} |h_i|^2 = N. \tag{39}
\]

The second term is a product of two Rayleigh random variables. The mean of Rayleigh random variable with variance \(\sigma_h^2\) is \(\sigma_h \times \sqrt{\frac{\pi}{2}}\). Hence the second term takes the following form:

\[
\sum_{i=1}^{N} \sum_{k=1, k \neq i}^{N} |h_i||h_k| = N \sqrt{\frac{\pi}{4}} (N-1) \sqrt{\frac{\pi}{4}} = N (N-1) \frac{\pi}{4}. \tag{40}
\]

Simplifying the effective signal to noise ratio with EGC for NP receiver takes the following form (Zhang, 1999) and (Annamalai, 2000):

\[
E(y_{i}^{NP}) = \frac{E_b}{N_0} \frac{1}{N} \left[ N + N(N-1) \frac{\pi}{4} \right] \\
= \frac{E_b}{N_0} \left[ 1 + (N-1) \frac{\pi}{4} \right]. \tag{41}
\]
The effective signal to noise ratio with equal gain combining for GR is simplified in the following form (Tuziukov, 2001), and (Tuziukov, 2011):

\[
E\left(\gamma^G_R\right) = \frac{1}{2} \left(\frac{E_b}{N_0}\right)^2 \frac{1}{N} \left[ N + N(N-1)\frac{\pi}{4} \right] = \frac{1}{2} \left(\frac{E_b}{N_0}\right)^2 \left[ 1 + (N-1)\frac{\pi}{4} \right].
\]

(42)

4. Simulation

The simulation is carried out using MATLAB. The BER performance comparison between NP receiver and GR as a function of signal to noise ratio under BPSK modulation with diversity combining techniques in wireless communication system is presented. We observe that performance improvement can be achieved in wireless communication system employing GR in comparison with NP receiver for different diversity combining techniques. For selection combining with single receive antenna, at \(SNR=10\, \text{dB}\), the employment of GR in wireless communication system gives us \(BER_{GR,SC}^R = 9.315 \times 10^{-3}\) whereas, NP has \(BER_{NP,SC} = 23.07 \times 10^{-3}\), Fig. 3. In the case when the number of receive antenna is 2, NP has \(BER_{NP,SC}^R = 2.966 \times 10^{-3}\) and GR has \(BER_{GR,SC}^R = 0.979 \times 10^{-3}\) for SC technique, Fig. 3. For MRC with single receive antenna, \(BER_{GR,MRC}^R = 9.437 \times 10^{-3}\) is achieved using GR and \(BER_{NP,MRC}^R = 23.39 \times 10^{-3}\) for the NP, Fig. 4. Using antenna diversity, as an example, using 2 receive antennas with MRC, \(BER_{GR,MRC}^R = 0.415 \times 10^{-3}\) is achieved by GR and \(BER_{NP,MRC}^R = 1.578 \times 10^{-3}\) for the NP receiver, Fig. 4. Moreover, using single receive antenna with EGC, we achieve \(BER_{GR,EGC}^R = 9.451 \times 10^{-3}\) by GR and \(BER_{NP,EGC}^R = 23.09 \times 10^{-3}\) for NP receiver, Fig. 5. On the other hand, using antenna diversity with EGC, \(BER_{GR,EGC}^R = 2.158 \times 10^{-3}\) is
Figure 3: BER for BPSK modulation with Selection Combining in Rayleigh channel.

Figure 4: BER for BPSK modulation with Maximal Ratio Combining in Rayleigh channel.
Figure 5: BER for BPSK modulation with Equal Gain Combining in Rayleigh channel.

Figure 6: BER performance comparison between NP and GR for BPSK modulation with SC, EGC and MRC over Rayleigh channel.
achieved using GR and $BER_{NP, EGC}^{GR} = 0.545 \times 10^{-3}$ for the NP receiver, Fig. 5. In Fig. 6, the BER performance comparison between GR and NP receiver as a function of signal to noise ratio under BPSK modulation with SC, MRC, and EGC techniques are presented using 2 receive antennas.

5. Conclusion

In this paper the GR BER performances under BPSK modulation over Rayleigh fading channel in wireless communication system with diversity combining techniques are discussed. The performance comparison between GR and NP receiver with diversity combining techniques such as SC, EGC, and MRC techniques demonstrates the low BER by the employment of GR in wireless communication system. We can observe the lesser losses in SNR caused by implementation of diversity combining techniques in wireless communication system employing GR in comparison with the use of NP receiver.

Reference


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