Performance Of DQPSK With MRC Diversity Reception Technique In Tropospheric Communication

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Abstract

This paper presents the effectiveness of MRC space diversity technique in the performance of differential quadrature phase shift keying (DQPSK) modulation in tropospheric communication. Tropospheric communication system employs the frequency selective time varying channel as the propagating media. Tropospheric communication is often hindered by the rain and dust particles in addition to the cloud and oxygen layer. Due to the ever changing cloud condition and rain pattern, always there is a change in refractive index of the tropospheric layer which results in multipath fading. With the severity of rain and dusty wind, the communication gets impaired to a large extent. To mitigate this effect MRC diversity technique is undertaken to check the performance of the DQPSK modulation. Error probability rate curves are simulated for the case of DQPSK in different rain conditions. The fading channel is modeled as frequency selective tropospheric channel corrupted by additive white noise also. The variations of error rates with respect to MRC space diversitiy is found, which is also plotted. The analytical results found in this paper are expected to solve the problems related to the tropospheric communication.

Keywords— *MRC Diversity, Rain Attenuation, Dust Attenuation, BER Curve, DQPSK modulation .*

1. Introduction

Tropospheric communication is a type of communication where the tropospheric layer acts as a reflecting media for signals upto ultra high frequency range and in case of microwave propagation, the same layer act as a ducting media. It is very widely used in air traffic controlling, satellite communication, television broadcasting, navigational aids and mobile taxicab. But the rain, dust, cloud, oxygen and water vapour act as the major constraints in this low cost and very long distance signal communication. The fading of signal due to rain is mainly dependent on the rain rate and frequency of signal. The prime reason behind this is the absorption and scattering properties of the rain drops. The effect of rain is severe when the frequency of radio waves under communication is more than 10 GHz. Besides it, wind and dust are the other contributing factor to the signal impairments. Even though the effect of dust is not that significant, with the visibility less than 200 m can degrade the signal to a large extent. Again in case of tropical zones like northeast India, the humidified air with dust storm causes havoc. Again the dust storm preceded by rain causes very high attenuation to the very high frequency (VHF) signal as the dielectric constant of the dust particle increases with water content [7].

In this paper, we demonstrate the tropospheric channel considering the attenuation due to rain and dust. Apart from these factors, additive white gaussian noise (AWGN) is also added to corrupt the signal further and thereby estimating a proper channel. The performance of the modulation scheme is evaluated by using maximal ratio combining (MRC) technique. The comparison of bit error probability against signal to noise ratio (SNR) is done to check the performance, by simulating the system in MATLAB 7.11. The distributions of the symbols are shown by scatter plots.

The remaining portion of the paper is organized as follows:
In Section 2 we illustrate the basic theoretical background, the system model is shown in Section 3, the simulated results and discussions are given in Section 4, Section 5 depicts the conclusion and Section 6 covers the references.

2. Basic Theoretical Background

2.1 Rain Attenuation

Rain is a critical factor responsible for fading in tropospheric communication. It is mainly due to the properties- absorption and reflection of electromagnetic waves by rain drops. The extent of attenuation is mainly dependent on four components viz. the rain fall rate, rain drop size, frequency and polarization of propagating signal [2].
The rain attenuation is given by

$$A_r = A_{s(0.01)} L_{eff} \tag{1}$$

where $A_{s(0.01)}$ is the specific attenuation with rain rate percentage exceeding by 0.01% and L_{eff} is the effective path length. The effective path length is measured because the signal path length is slanted by the rain drops and so it is slanted path length. Again $A_{s(0.01)}$ is obtained from the following

$$A_{s(0.01)} = KR_{0.01}^{\alpha} \tag{2}$$

where K and α are coefficients dependent on polarization and frequency. After several experiments in this area, the proven data of coefficients given by Ippolito is considered. Table 1 shows the horizontal and vertical polarization coefficients with respect to frequency. The rain function in tropospheric communication is computed from these coefficients.

Table 1. Horizontal and vertical polarization coefficients vs. frequency

Frequency GHz	K_h	K_v	α_h	α_v
1	0.0000387	0.0000352	0.912	0.88
2	0.000154	0.0000138	0.963	0.923
5	0.00100	0.00095	1.28	1.21
7	0.00301	0.00265	1.332	1.312
10	0.0101	0.0088	1.276	1.264

In the table 1, the subscript h and v denotes the horizontal and vertical polarization respectively.

2.2 Dust Attenuation

Dust attenuation occurs due to the scattering of the radio waves dust particles whose dielectric constants are different from one another. The effect is dependent on the number concentration (measured in terms of the number of dust particles per unit volume of air), polarization of signal transmission and the visibility [7]. Since the dust particle absorbs the water vapour present in the troposphere, the dielectric constant of the dust particles changes with the change in the cloud condition. This results in the change of refractive index. Dust particles also cause the diffraction of the radio waves. Considering these factors the dust attenuation is given by [4]

$$A_d = 1.02 \times 10^6 (N/\lambda)\, G \sum P_i r_i^3 \tag{3}$$

where N is the volume fraction, λ is the wavelength of the signal , P_i is the probability that a particle with radius r_i lies within the range Δr_i ;

$$G = \varepsilon'' / \left[\left(\varepsilon' + 2 \right)^2 + \varepsilon''^2 \right] \tag{4}$$

where G is the complex dielectric constant, ε' is the dielectric constant of dust and ε'' is the dielectric constant of medium.

2.3 DQPSK Modulation

Due to the complexity and cost of the coherent modulation schemes, differential modulation schemes are preferred in wireless communications. They do not require a coherent phase reference at the receiver Differential modulation falls in the more general class of modulation with memory, where the symbol transmitted over time $[kT_s, (k+1)T_s]$ depends on the bits associated with the current message to be transmitted and the bits transmitted over prior symbol times. The basic principle of differential modulation is to use the previous symbol as a phase reference for the current symbol, thus avoiding the need for a coherent phase reference at the receiver. DQPSK is the digital modulation technique. DQPSK is a form of Phase Shift Keying in which two bits are combined to form a symbol. The number of symbol in DQPSK can vary from four to twelve depending on the phase difference between successive symbols. For a phase rotation of $\pi/4$, the numbers of symbol will be eight. This type of modulation is bandwidth efficient if the tradeoff between power needed and bandwidth is considered [10].

2.4 Rayleigh Fading Channel

Rayleigh fading channel is commonly used to describe the statistical time varying nature of the received envelope or the envelope of an individual multipath component. It is characterized by the random and scattered distribution of the received signal with zero mean, due to reflection, refraction and diffraction. In tropospheric communication, the signal undergoes multipath due to these phenomena. So it can be

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estimated by Rayleigh fading channel. It also results in the arrival of delayed versions of the signal at the receiver. These irresolvable components combine at the receiver and give rise to the phenomenon known as multipath fading. Due to this phenomenon, each major path behaves as a discrete fading path. In addition to these causes, the motion of the receiver and transmitter causes a phenomenon called Doppler shift which also leads to Rayleigh fading. The envelope of the sum of two quadrature Gaussian noise signal also obeys Rayleigh distribution.
The probability distribution function (pdf) of Rayleigh distribution is given by

$$p(r) = \frac{r}{\sigma^2}\exp\left(-\frac{r^2}{2\sigma^2}\right)(0 \le r \le \infty) \qquad (5)$$

else P(r)=0;

Typically, the fading process is characterized by a Rayleigh distribution for a non line-of-sight path and a Ricean distribution for a dominant line-of-sight path. If the fading observed in wireless channels do not have a line of sight (LOS) component it is called a Rayleigh fading [10].

2.5 MRC Diversity

In this method, the signals from all the branches are weighted according to their individual signal voltage to noise power ratios and then summed as mentioned in [5]. Here the signals must be cophased before being summed which generally requires an individual receiver and phasing circuit for each antenna element. Maximal ratio combining produces an output SNR equal to the sum of the individual SNRs. So it has an advantage of producing an output with acceptable SNR even if none of the components are individually acceptable. Assuming the same noise PSD N_0 in each branch yields a total noise PSD
N_{tot} at the combiner output of

$$N_{tot} = \sum_{i=1}^{M} {a_i}^2 N_0 \qquad (6)$$

Thus, the output SNR of the combiner is

$$\gamma_\Sigma = \frac{r^2}{N_{tot}} = \frac{1}{N_0}\frac{\left(\sum_{i=1}^{M} a_i r_i\right)^2}{\sum_{i=1}^{M} {a_i}^2} \qquad (7)$$

where the envelope of the combiner output is $r=\sum^M a_i r_i$ and a_i is the amplitude of transmitted signal of i th branch. The block diagram of MRC diversity is shown in Figure 1.

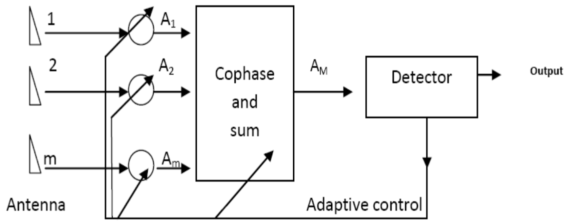

Figure 1. Block diagram of maximal ratio combiner

3. Proposed System Model

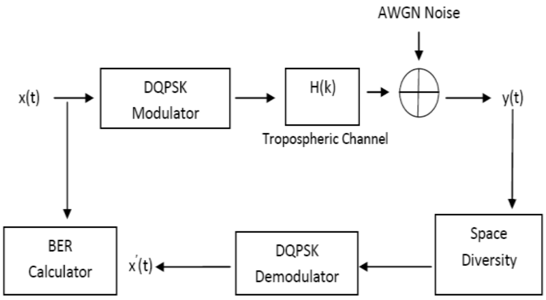

Figure 2. Block diagram of proposed system model

In Figure 2 it is shown that the transmitted signal in the form of bits of size 10000 are taken to be modulated using DQPSK modulation scheme to check the performance. The modulated symbols are transmitted through the tropospheric channel, which is characterised by the effects of rain, dust, oxygen and water vapour. To further corrupt the signal gaussian white noise is also added, which make the condition more realizable tropospheric channel condition. The transfer function of the tropospheric channel is given by

$$H(f)=H_0\exp\{j0.002096f[10^6+N(f)]l\} \qquad (8)$$

and

$$N(f)= N_0 +D(f)+jN''(f) \qquad (9)$$

where H_0 is a constant, N_0 is the frequency dependent refractivity, D(f) is the refractive absorption, N_0(f) is the absorption, and l is the distance in km. These parameters are dependent on frequency and atmospheric conditions such as temperature, barometric pressure, and relative humidity.

Since the tropospheric channel causes the multipath fading to the signals, it will reach the receiver with different delay and with different phase shift. Here in

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this work space diversity technique is used. The performance of MRC diversity scheme is done by calculating the bit error rate for the defined modulation scheme.

Scatter plots are also obtained for the DQPSK modulation without diversity and using MRC diversity. Similarly the BER curve is also simulated for the same modulation in different weather conditions. In this work three different climate conditions are chosen to carry out the performance evaluation in tropospheric communication. Rain rate upto than 15 mm/ hr is considered as mild rain, rain rate in the range of 50 mm/ hr is considered as medium rain, rain rate more than 75 mm/ hr is considered as heavy rain. Again stormy condition is considered by the number concentration of dust particles more than $10^8/m^3$ of air.

4. Results and Discussions

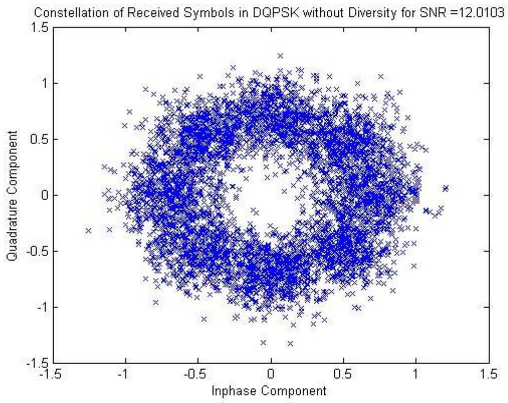

Figure 3. Scatter plot of DQPSK without diversity

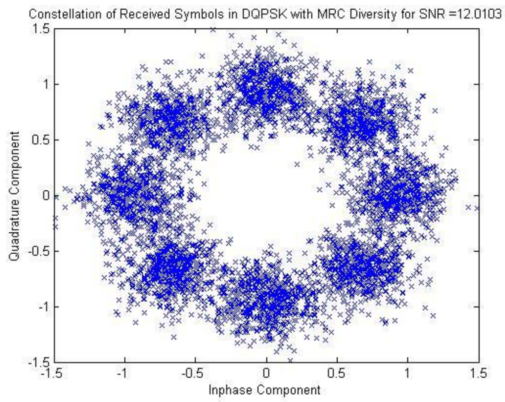

Figure 4: Scatter plot of DQPSK with MRC diversity

From Figure 3 and 4 it is found that for the same SNR and modulation scheme (DQPSK), there is observable difference with the MRC diversity scheme. When MRC method is used the symbols can be obtained with much lesser errors. In this work 10000 bits are transmitted through the tropospheric channel using DQPSK modulation.

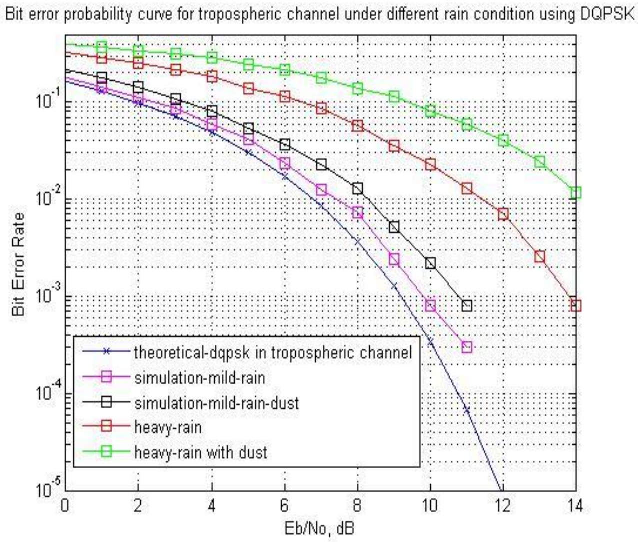

Figure 5. BER vs. Eb/No of tropospheric channel using DQPSK modulation with angle of elevation π/ 4.

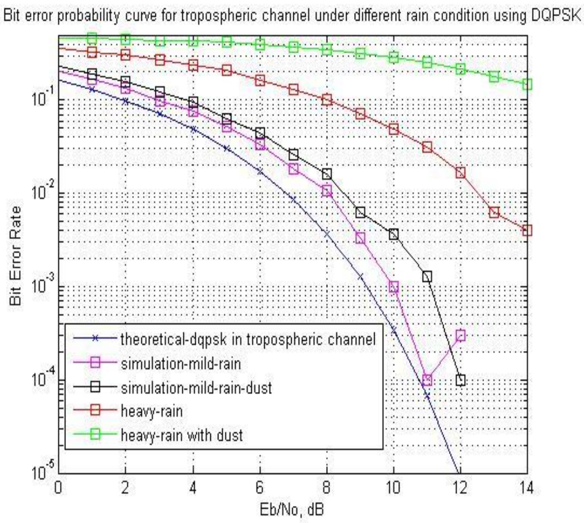

Figure 6. BER vs. Eb/No of Tropospheric channel using DQPSK modulation with angle of elevation π/8

It is evident from Figure 5 and 6 that the bit error rate is also dependent on the angle of antenna elevation. As the angle of elevation is low, the fading is more. It is seen that in case of heavy rain added with dust, the error rate is quite high. So as the rain rate and number concentration of dust gets higher, error probability will be more.

In these extreme weather conditions, to have a more faithful communication, space diversity scheme is used. The effectiveness of the MRC diversity scheme is shown in Fig 7. In this work, the bit error rate is evaluated using three receiver antenna whilst only one transmitter is used

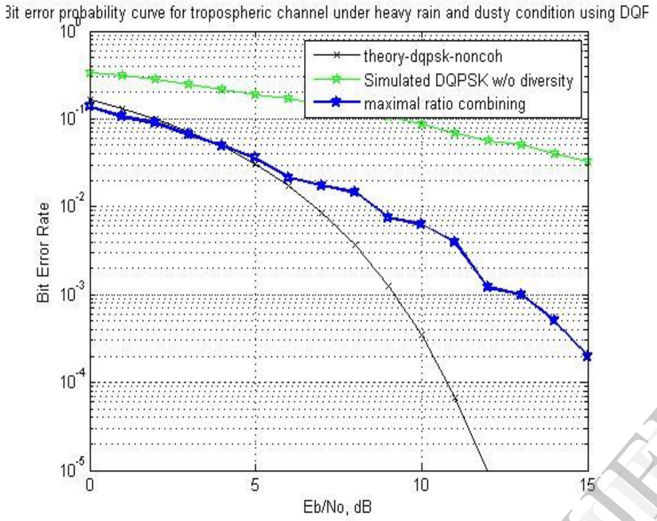

Figure 7. BER curve for DQPSK without diversity and with MRC diversity scheme for heavy rain and dusty condition

The evaluation of the diversity scheme is shown for the extreme weather condition i.e. in heavy rain alongwith dust storm case. It is because the impairment is significant only in case of medium to heavy rain with dust storm.

From Fig 6 it is observed that the bit error is very high if no diversity method is used in case of heavy rain condition. The bit error can be significantly lowered by employing the diversity scheme with higher numbers antenna. It is evident from the curve that the MRC is very effective in such conditions.

Table 2. Variation of BER with diversity schemes.

Diversity method used	BER in heavy rain and dusty condition
No diversity	0.062
MRC	0.0019

From Table 2 it is clear that the MRC can very effectively reduce the bite error in tropospheric communication under extreme weather conditions.

5. Conclusion

The tropospheric communication system is modeled in this paper considering the rain and dust factors. The performance of DQPSK with and without MRC diversity technique is carried out to check their performance in the worst weather condition. BER and Scatter plots are simulated as the performance tools. The MRC space diversity is found very effective under adverse weather condition in tropospheric communication. Our future objective is to implement angle and frequency diversity for this communication. With the use of angle diversity, system is expected to be less bulky and reduced equipment size due to the use of single antenna. But the question lies with the performance of angle and frequency diversity as far as bit errors are concerned.

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7. References

[1] M. S. Alouni, M. K. Simon, “Performance of coherent receivers with hybrid SC/ MRC over Nakagami-m-fading channels,” *IEEE Transactions On Vehicular Technology*, Vol. 48, Issue-4, pp. 1155-1164, 1999.

[2] E. Al Hussaini, A. Al Bassiouni, “Performance of MRC Diversity Systems for the Detection of Signals withNakagami Fading,” *IEEE Transactions On Communications*, Vol. 33, Issue-12, pp. 1315-1319, 1985.

[3] K. A. Norton, “Point to point radio relaying via the scatter mode of tropospheric propagation,” *IRE Transactions On Communication Systems*, Vol. CS-4, pp. 39-49, 1956.

[4] T. S. Chu, "Effect of sandstorms on microwave propagation, ”*Bell Syst. Tech. J., pp. 549-555. 1978.*

[5] T. S. Rapaport, *Wireless Communications- Principles and Practice*, 2nd ed., Prentice Hall, 2011.

[6] S. A. Kanellopoulos, A. D. Panagopoulos and J. D. Kanellopoulos, "Calculation of the Dynamic Input Parameter for aStochastic Model Simulating Rain Attenuation":A Novel Mathematical Approach, IEEE Transactions on Antennas and propagation, Vol. 55, No. 11, 2007.

[7] S. I. Ghobrial and S. M. Sharif., "Microwave Attenuation and Cross Polarization in Dust Storms", IEEE Transactions on Image Processing, Vol. 9, No. 9, pp. 1532-1546, Sep 2000, IEEE, DOI, pp. 209-212, Oct. 2010.

[8] B. Maruddani, A. Kurniawan, Sugihartono and Achmad Munir, IEEE, Dali Zhang, and Wenli Xu,"Rain Fade Modelling Using Hidden Markov Model for Tropical Area", PIERS Proceedings, Cambridge, USA, July 5, 2010.

[9] M. Singh Jit Singh, S. Idris Syed Hassan and Md. Fadzil Ain, "Rainfall Attenuation and Rainfall Rate Measurements in Malaysia - Comparison with Prediction Models," Vol. 4 no.1, pp. 5-7, 2007.

[10] S. Haykin, *Communication Systems*, 4th ed., John Wiley and Sons, New York, 2001.

[11] J. S. Ojo and M. O. Ajewole, "Rain Rate and Rain attenuation prediction for satellite communication in Ku and Ka bands over Nigeria", Progress in Electromagnetics Research B, Vol.5,207–223,2008.