Performance Evaluation of a Smart Antenna with Fading Environment for WiMAX Application

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Abstract : This paper presents adaptive beamforming of smart antenna for WiMAX application with Rayleigh and Rician fading channels and a comparative study between two fading channels namely Rayleigh and Rician fading channel with different Rician factors. Adaptive beamforming for smart antenna is done using least mean square algorithm with application to WiMAX.

***IndexTerms* – Smart antenna, Rayleigh fading, Rician fading, beamforming, WiMAX.**

I. INTRODUCTION

A remarkable development has been seen in the wireless industry in few years by improving the infrastructures to meet the demand of users and significant advancements for the implementation of wireless technology have been made ,but some unavoidable conditions attenuate the signal energy and make obstructions for obtaining the best desired outcomes from the system. Information is transmitted from source to destination, by a communication channel or a radio link. This communication channel can be either a simple line-of-sight or the one in which the transmission or reception of data is severely hurdled by the obstacles like buildings, mountains etc and this results in multipath fading. Multipath fading is one of the significant factors that affect the performance of a wireless communications link. Fading affects the output strength over a time interval. One of the most important parameter for characterizing a fading channel is the use of PDF (probability density function) which represent the probability density of the received signal power.

Smart antenna uses an array of antenna elements with smart signal processing algorithms and the signals received at each antenna element is adaptively combined to improve the overall performance of the system. [1-3]. The algorithms identify the direction of arrival of signal. After identification of DOA of signal the beamforming network of antenna array locates the antenna beam towards the target. Smart antenna produces main beam along the desired direction and eliminates interference by producing null towards the undesired direction [4-5]. Digital beamforming network of smart antenna system is as shown in Figure (1).Smart antenna is responsible for producing radiation beam along DOA of signal, thus appreciable power saving is achieved. It improves the wireless system performance by increasing the network capacity and signal quality. [6-7]. There are various types of algorithms available for beamforming. A sequential quadratic programming based algorithm is used for multi lobe pattern and for adaptive nulling of the pattern in [8]. A beamforming technique for precise DOA estimation based on hybridization of soft computing methods is reported in [9]. Recently, a complex quaternion LMS algorithm is used [10] for beamforming of polarization-sensitive electromagnetic vector sensor. Smart antenna technology is moving directly into maturing markets that are ready and waiting to imbibe add-on features to existing products. Smart antenna has been around for decades, WiMAX is one of the strongest drivers for smart antenna technology that has made smart antenna even smarter today. Knowledge about WiMAX technology its security and applications is reported in [11-12]. Information about threats in different layers of WiMAX is reported in [13]. Rician K-factor and RMS Delay Spread (RDS) are two main parameters those characterize a multipath fading channel. Effects of antenna beamwidth, RDS, Rician-K and other channel parameters on LTE-OFDM channels are investigated and presented in this paper [14] through theoretical analysis and simulations of channel models. This paper shows simulation of a wireless channel using AWGN, path loss, flat fading channel and frequency selective fading [15].

In this paper, smart antenna is designed for WiMAX application considering multipath fading channel. In section II, brief discussion on beamforming algorithms is done. Section III covers different fading channels like Rayleigh fading and Rician fading. In section IV, simulation results are added. Section V is conclusion and future scope of work.

II. ADAPTIVE BEAMFORMING ALGORITHMS

There are numerous adaptive beamforming algorithms for smart antenna. Some of the commonly used algorithms are least mean square (LMS) and its variants, recursive least mean square (RLS) algorithm, sample matrix algorithm (SMI) etc. In this work, LMS algorithm is used because of relatively easy implementation, computational simplicity and efficient use of memory, robust performance and with limited knowledge about the input signal and desired signal the user can easily set up the system for adequate performance.

Adaptive algorithm is used to minimize the error err(n) between desired signal S(n) and array output y(n) [7]

$$err(n) = S(n) - y(n) \qquad \text{.....(1)}$$

Output of adaptive beam former, at time n, is a linear combination of the data at the N antenna elements, can be expressed as [7]

$$y^H(n) = w^H x(n) \quad \text{...(2)}$$

Where w^H refers to Hermitian transpose of complex weight vector w.

Signal received by array of antenna is [7]

$$x(n) = [x_1(n), x_2(n), x_3(n), \ldots\ldots\ldots\ldots x_n(n)] \quad \text{.......................................(3)}$$

Least Mean Square (LMS) algorithm is a steepest descent method, where iterative procedure is used making successive corrections to the weight vector in the direction of the negative of the gradient vector which eventually leads to the minimum mean square error.

The weight updating equation for LMS algorithm is given by [7]

$$w(n+1) = w(n) + \mu x(n) e^*(n) \quad \text{...(4)}$$

Where μ is the step size parameter.

Figure 1 shows block diagram of LMS algorithm.

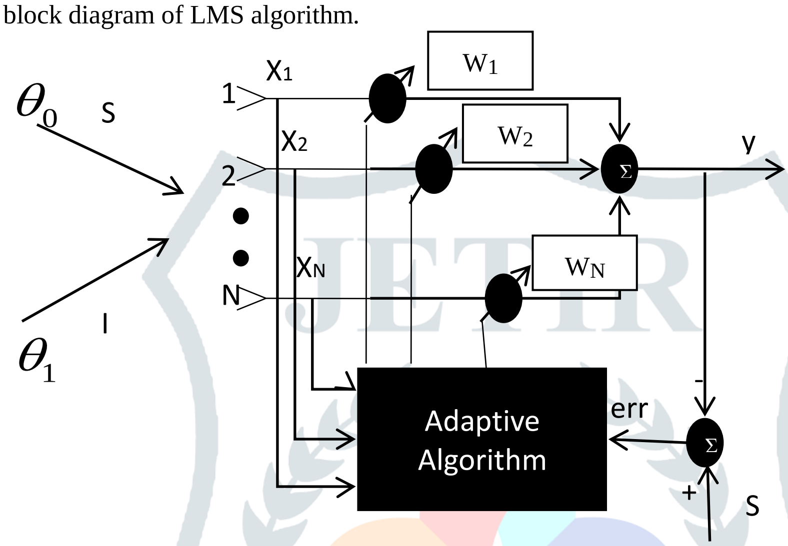

Figure 1: Block Diagram of LMS algorithm

III. Rayleigh And Rician Fading Channels

In case of non line of sight (NLOS) communication between transmitter and receiver, signals may attenuate, reflect, refract and diffract. A Rayleigh fading channel occurs when there are various signal paths between the transmitter and receiver, but none of them is dominant, i.e., all the paths will fluctuate and have an effect on the overall signal at the receiver. The probability density function of Rayleigh channel with received signal envelope $f(r)$ is $f(r) = (re^{-r^2/2\sigma^2})/\sigma^2$ where σ^2 is the time average power of received signal before envelope detection. r is the envelope of Rayleigh fading [7].

If there is line of sight between transmitter and receiver then the propagation environment follows Rician distribution. In this distribution the strongest component goes into deeper fade compared to multipath components. A Rician fading channel occurs when the received signal is a combination of a significant line of sight path and multiple fading paths between a transmitter and receiver. The line of sight path is the strongest signal path that travels directly from the transmitter to receiver. The probability density function of Rician channel is [6-7]

$$p(r_0) = \frac{r_0}{\sigma^2} \exp\left[\frac{(-r_0^{\,2} + A^2)}{2\sigma^2}\right] I_0\left[\frac{r_0 A}{\sigma^2}\right] ; \; r_0 \geq 0, A \geq 0 .$$

Where $I_0(.)$ is the modified Bessel function of zero order. A is the peak magnitude of line of sight signal component. In Rician channel fading K factor is one of that input that defines ratio of power of line of sight component and multipath components $(K = A^2/2\sigma^2)$ when K is zero, Rician fading channel becomes Rayleigh fading.

IV. Adaptive Beamforming Of Planar Antenna Array With Fading Channel For WiMAX Application

The Array factor of MxN planar array can be written as [7],

$$AF = AF_{xM} . AF_{yN} \quad \text{..................(5)}$$

Where,

$$AF_{xM} = \sum_{m=1}^{M} I_{m1} e^{j\,(m-1)\,(kd_x \cos\psi_x + \beta_x)} \quad \text{................(6)}$$

$$AF_{yN} = \sum_{n=1}^{N} I_{n1} e^{j\,(n-1)\,(kd_y \cos\psi_y + \beta_y)} \qquad \text{.................}(7)$$

Here, the directional cosines i.e.ψ_x and ψ_y are considered as equal.

Normalized Array Factor is

$$AF_{norm} = \frac{AF}{AF_{\max}} \qquad (8)$$

Figure 2 shows a uniform planar antenna array (UPA) of MxN elements with inter-element spacing of d_x and d_y along x and y axis respectively.

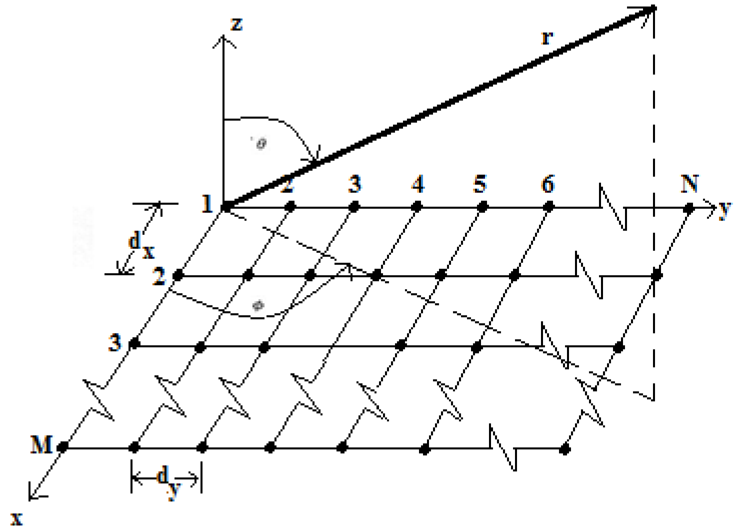

Figure 2: Uniform Planar Array Geometry

WiMAX (Worldwide Interoperability for Microwave Access) technology is having the advantage of low latency, advanced security, QoS (Quality of Service), cost effective, high speed connectivity [11-12].

Different bands are available for WiMAX applications in different parts of the world. The frequencies commonly used are 3.5 and 5.8 GHz for 802.16d and 2.3, 2.5 and 3.5 GHz for 802.16e. Smart antenna is designed for WiMAX application at a frequency of 3.5 GHz.

Block diagram of BPSK fading channel is shown in figure 3.

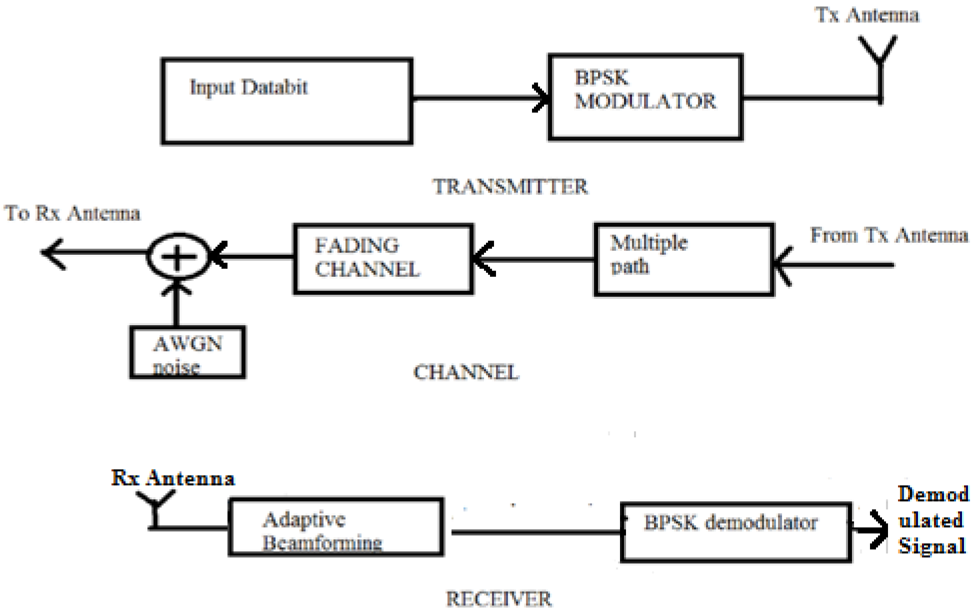

Figure 3: Block Diagram of BPSK Fading Channel

V. RESULTS AND DISCUSSION

In this section simulation results are carried out using MATLAB. SNR Vs Bit error rate is plotted for Rayleigh channel and Rician channel with Rician factors K=1 and K=10 which is shown in figure 4 and SNR Vs Bit error rate is potted showing comparison between Rician factors K=1,K=5,K=10 which is shown in figure5.

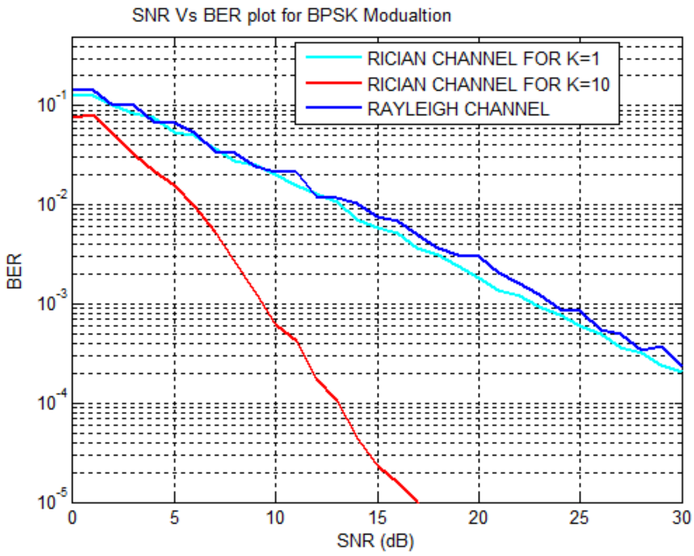

Figure 4: SNR Vs BER plot for different fading channels

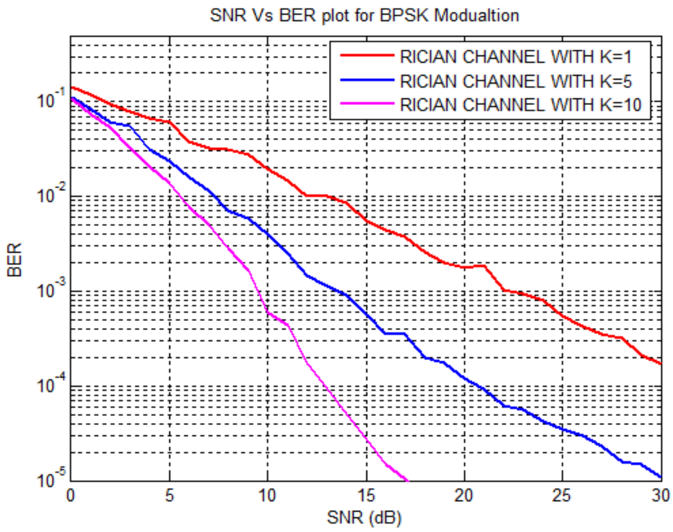

Figure 5: SNR vs BER Plot For Different Rician Factors

It is observed in figure 4 the bit error rate decreases with increase in SNR value and with increase in Rician factor 'K' bit error rate decreases faster. If we compare Rayleigh fading channel and Rician fading channel, bit error rate decreases faster in case of Rician fading channel and in figure 5 it is observed that with increase in rician factor bit error rate decreases faster. If we compare the rician factors K=1,K=5 and K=10 ,for K=10 BER decreases faster .

The radiation pattern is simulated for Rayleigh channel and Rician channel with Rician factor K=1 and K=10 with 10 array elements, Step size=0.02 and multiple interferers . Two such cases are taken and results are shown in from figure (6-7).

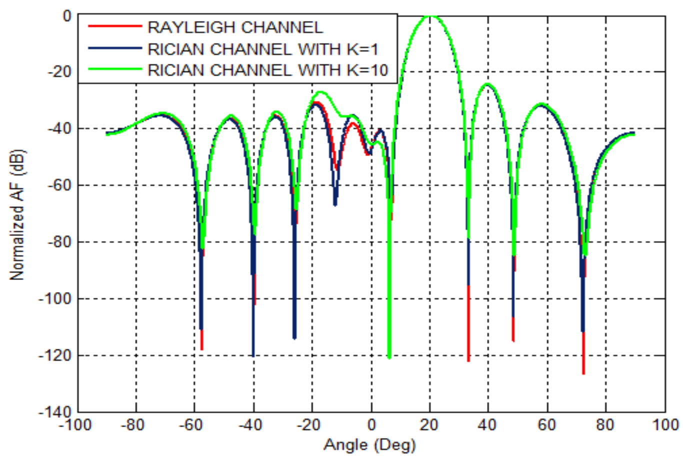

FIGURE 6: Normalized AF for N=10, µ=0.02, AOA=20^0, AOI1=0^0, AOI2= -10^0

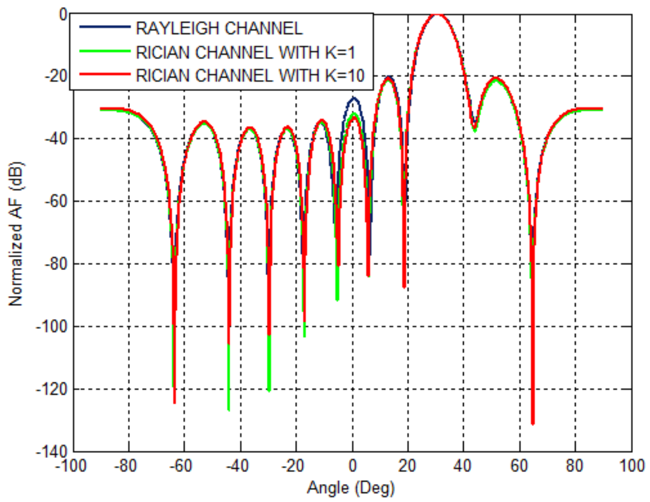

FIGURE 7: Normalized AF for N=10, µ=0.02, AOA=30^0, AOI1=20^0, AOI2= 45^0

Table 1: Performance evaluation of LMS algorithm for beamforming with Rayleigh and Rician channel

	Channel	Desired Main Beam Direction in Degree	Main Beam Direction in Degree	Desired null1 Direction in Degree	Null1 Direction in Degree	Desired null2 Direction in Degree	Null2 Direction in Degree	SLL_{max} in dB	FNBW in Degree
Set-1	Rician Channel for K=1	20	20	-10	-11.8	0	-1.8	-25.2	26.2
	Rician Channel for K=10	20	20	-10	-9	0	-2	-24.9	26
	RAYLEIGH	20	20	-10	-10.8	0	0	-24.69	26.4
Set-2	RAYLEIGH	30	30	20	19	45	44.6	-21.54	25.4
	RICIAN FOR K=10	30	30	20	18.8	45	44.2	-20.64	25.4
	RICIAN FOR K=1	30	30	20	18.8	45	44.2	-21.57	25.6

Smart antenna is designed for WiMAX application. Adaptive beamforming is done for multiple interferers for Rayleigh fading and Rician fading with rician factors K=1 and K=10. It is found that main beam is achieved as desired and nulls are achieved at a deviation of less than 20% from desired direction for both the cases.

V. CONCLUSION

In this paper a comparative study between Rayleigh fading channel and Rician Fading channel with different Rician factors and adaptive beamformation of smart antenna for WiMAX application with different fading channels is presented. It is found bit error rate performance of rician fading channel is better than Rayleigh fading channel and with increase in K value it approaches to AWGN channel, i.e., with increase in 'K' BER decreases faster. For all the fading channels main beam is achieved as desired and nulls are achieved at a deviation of less than 20% from desired direction.

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