International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

WiMAX Performance Analysis under the Effect of Doppler's Shift

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Abstract: ***In this paper, an effort has been made to illustrate the performance of WiMAX communication system under the effect of Doppler's Shift for the Multipath fading channel using MATLAB Simulink. An end-to-end baseband model of the physical layer of a Wireless Metropolitan Area Network (WMAN) over the Multipath Rician Fading environment has been used. Doppler Shift is one of the salient factors considered while designing a mobile wireless communication system for prescribing the different standards of the communication system like data rates according to the speeds of the mobile user. By analyzing the scatter plots of received signal prior to demodulation, a frequency range has been found within which the fading effects on the received signal can be overcome for proper signal recovery.***

Keywords: Doppler Shift, IEEE 802.16 Physical Layer, Inter Symbol Interference, LOS, NLOS, 16-QAM, Multipath Rician Fading, WiMAX

1. Introduction

In the last two decades, wireless communication has evolved from a technology of esoteric availability to commercial applications. Recent development of the WiMAX technology has opened several new paths for its implementation. WiMAX is an acronym, meaning "Worldwide Interoperability for Microwave Access". It is a part of the IEEE 802.16 standards and was developed by the Institute of Electrical and Electronics Engineers (IEEE). WiMAX refers to interoperable implementations of the IEEE 802.16 family of wireless-networks standards ratified by the WiMAX Forum. WiMAX is a wireless networking technology which aims for addressing interoperability across IEEE 802.16 standard-based products. It includes the definition of the medium access control (MAC) and the physical (PHY) layer. A white paper for creating an executable specification has been provided by Mathworks which serves as a useful resource to build a simulation model for the WiMAX Physical layer [1].

In wireless signal propagation, the biggest challenge is to overcome the effects of fading. The multipath nature of channel leads to ISI (Inter Symbol Interference) and as bandwidth is increased, ISI affects the channel severely. Some unpreventable circumstances attenuate the signal energy and make it difficult to achieve the desired results from the communication system. The radio link between the Base Station (Transmitter) and User (Receiver) can be a simple LOS (line-of-sight) or it can be a NLOS (non line-of-sight), the latter being severely obstructed by the environmental objects and features like buildings, weather conditions etc. In wireless communication, user has the freedom of mobility and can change its location with respect to the base station. As a result of this relative motion, received signal strength is affected by three major fading phenomena – Scattering, Diffraction and Reflection. [2]

The relative motion between base station (Transmitter) and mobile user (or receiver) & the speed of mobile user results in temporal fading. If there is a relative motion between base station and the user, then there is also a phase difference between the received components, which leads to shift in the frequency. In the high mobility scenario, the relative motion between the transmitters and receivers results in rapid time variations and significant Doppler shift [3]. Accumulating dynamically changed multipath effects and noise, a significant fluctuation in the received signal strength is observed in the channel. Due to this, transmitted signal frequency is not identical to the received signal frequency, resulting in difference between transmitted and received signal. The purpose of this paper is to analyze and estimate the range of frequencies within which the received signal (prior to demodulation) can be recovered for the chosen WiMAX Simulink Model parameters. This range has been estimated for both the cases i.e. when mobile user is moving away from the Base Station and when it is moving towards the Base Station. Fading channel environment is modelled using Multipath Rician Fading channel having 1 LOS and 4 NLOS signal paths. The scatter plots of received signal and BER readings are analysed for the purpose.

Remainder of the paper is divided in following sections. Section 2 shows the WiMAX Simulink model used and lists the WiMAX specifications used for implementing IEEE 802.16 Physical Layer in MATLAB. Section 3 explores the Rician fading channel model. Section 4 explores Doppler's effect. Section 5 lists and analyses the results. Section 6 concludes the work.

2. The WiMAX Model

Following are the parameters used in this paper for implementing WiMAX Physical Layer Simulink [3]:

Table 1: WiMAX Profile Parameters

Standard	IEEE 802.16e
Carrier Frequency	Below 11GHz
Frequency Bands	2.5GHz, 3.5GHz, 5.7GHz
Bandwidth	1.5 MHz to 20 MHz
Radio Technology	OFDM
Distance	10 Km
Modulation	16 QAM

Table 2: Model Parameters used for simulation

Channel Bandwidth	3.5MHz
No. of OFDM symbols per burst	2
Cyclic prefix factor	1/8

Block wise description of WiMAX Simulink:

- Data Source: Bernoulli Binary Generator is employed to generate a vector output with the Probability of a zero of 0.5 and Boolean Output data type.
- 16 QAM Modulator is a Rectangular QAM Modulator Baseband using Reed-Solomon Encoder.
- IFFT Input Packing to concatenate input signals of the same data type to create a contiguous output signal.
- Space-Time Block Coding using an Alamouti code [4]. This implementation uses the OSTBC Encoder and Combiner blocks in the Matlab.
- Orthogonal Frequency Division Multiplexed (OFDM) transmission using 192 sub-carriers, 8 pilots, 256-point FFTs, and a variable cyclic prefix length.
- Digital Pre-distortion Nonlinear Amplifier, a memory less non-linearity that can be driven at several back off levels with digital pre-distortion capability that corrects for the non-linearity.
- Multipath Rician fading channel with AWGN for the STBC model. Rician channel for different Doppler frequency will be tested here. OFDM receiver that includes channel estimation using the inserted preambles.
- Receiver constellation to analyze the received signal constellation prior to 16QAM Demodulator.

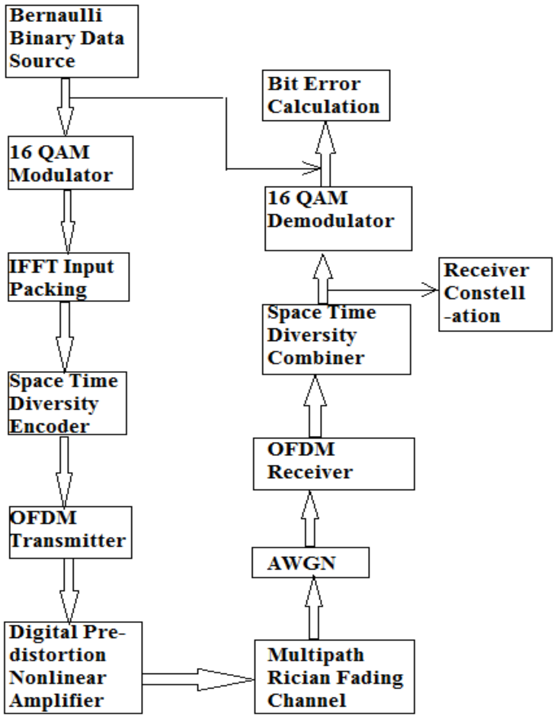

Figure 1: WiMAX OFDM Physical Layer Link

3. Multipath Rician Fading

When a LOS propagation path exists between Base Station or Transmitter and Mobile User or Receiver, there is a dominant signal component. In this case the small-scale fading distribution follows Rician fading model. At the receiver, the signal appears as a continuous component added with a random multi- path component. The Rician distribution is given by:

$$p(r) = \frac{r}{\sigma^2}\exp-\left(\frac{r^2+A^2}{2\sigma^2}\right)I_0\left(\frac{Ar}{\sigma^2}\right), \qquad r \geq 0 \qquad (1)$$

where ‘r’ is the received signal, σ^2 is the variance of received signal, ‘A’ denotes the peak amplitude of the dominant signal and $I_0()$ is the modified Bessel function of the first kind and zero order. The Rician distribution is often described in terms of parameter ‘K’, which is the ratio between the deterministic signal power and the variance of the multi-path component.

$$K = \frac{A^2}{2\sigma^2} \qquad (2)$$

The parameter K completely specifies the Rician distribution. For K=0, the Rician distribution reduces to a Rayleigh distribution.

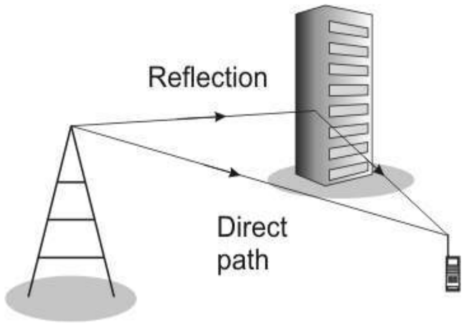

Figure 2: Depicting LOS (Direct Path) and NLOS (Reflected Path)

4. Doppler Shift

When a Base Station or transmitter and receiver is/are moving, the frequency of the received signal will not be the same as that of the transmitted signal. This is called Doppler's Shift. When they are moving towards each other or only mobile user is moving towards the Base station, the frequency of the received signal is higher than the transmitted signal frequency. However, the frequency of received signal will be lower than that of the transmitted signal, when either both of Mobile user and Base station are moving towards each other or only Mobile user is moving towards the base station. The total signal at receiver tends to fade or distort. For proper decoding of received signal, we must have the correct frequency [5]. Such change in frequency can be understood from Doppler's effect depicted in Fig. 3 below. The same is applicable to wireless communications.

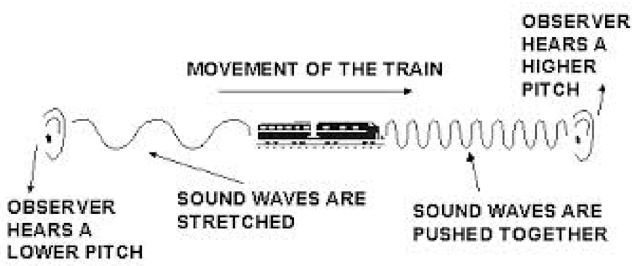

Figure 3: Dopplers Effect

Received Signal frequency f_r, is given by following equation,

$$f_r = f_c \pm f_d \quad (3)$$

where 'f_c' is the source carrier frequency and 'f_d' is the doppler's shift in frequency. Doppler's shift will be positive or negative depending on whether the mobile is moving towards or away from the BS. Therefore, f_d will be added to f_c when mobile is moving towards BS and subtracted from f_c when mobile is moving away from BS.

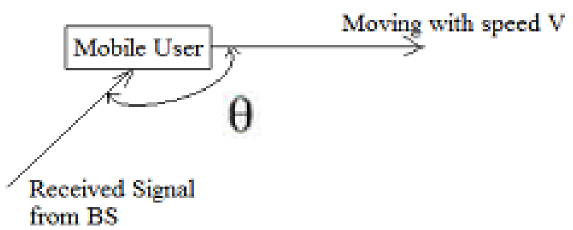

Figure 3: Mobile User

For Mobile user moving with speed v, receiving signal from Base Station at an certain angle ϴ, the doppler shift is given by following equation,

$$f_D = \frac{V}{\lambda} cos\theta \quad (4)$$

5. Simulation Results

Simulation Approach - Suppose a continuous wave is sent at frequency 'f_1' and it undergoes fading i.e. the received signal strength is lowered than the strength of transmitted signal. We have taken the scatter plots of received signal and analyzed the constellation for 16 symbols of 16 QAM to decide whether fading effects can be removed or not. Let at this frequency 'f_1', the fading effects can be removed i.e. ISI between 16 symbols of QAM is less. Now with the increased transmitted signal frequency, say from 'f_1' to 'f_1+Δf', the received signal constellation is again analyzed. The same process has been repeated until a certain frequency 'f_2' at which the effects of fading cannot be removed. Then this gives us the range 'f_1 –to- f_2' between which we can de-correlate the effects of fading and recover the transmitted signal. All the following readings have been taken for a fixed SNR, taken as 21db. Extensive Matlab simulations were conducted to evaluate the performance of WiMAX communication system. Following are the simulation results,

Case 1: When Mobile User is moving towards the Base Station

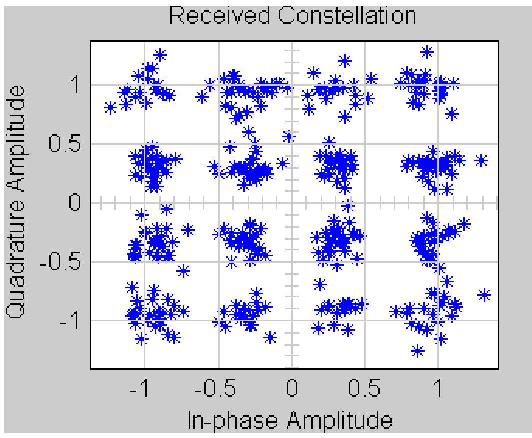

Figure 4(a): f_D=10Hz BER = 0.00013

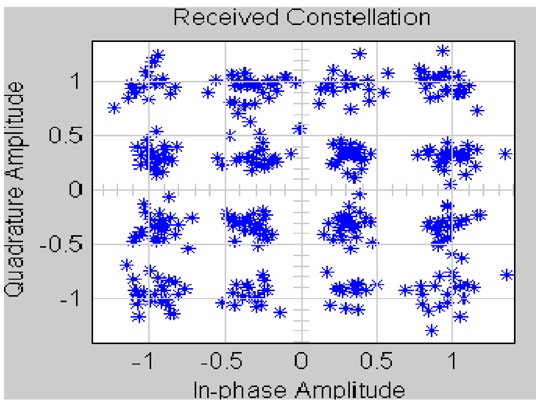

Figure 4(b): f_D=100Hz BER = 0.00037

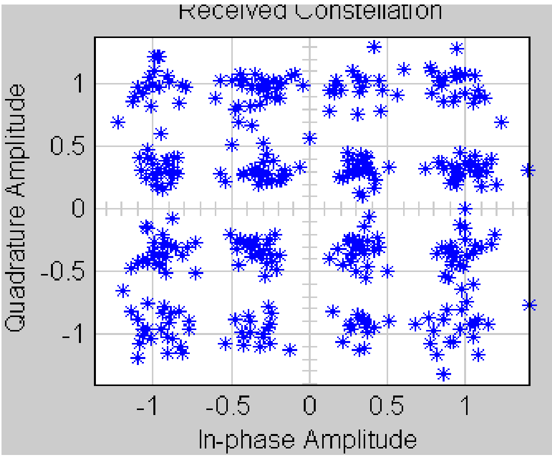

Figure 4(c): f_D=200Hz BER = 0.00047

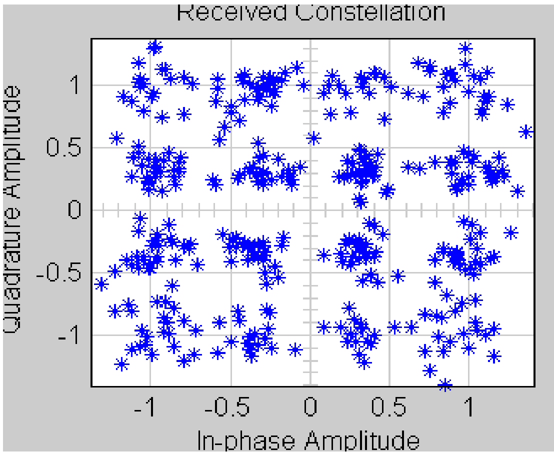

Figure 4(d): f_D=400Hz BER = 0.00088

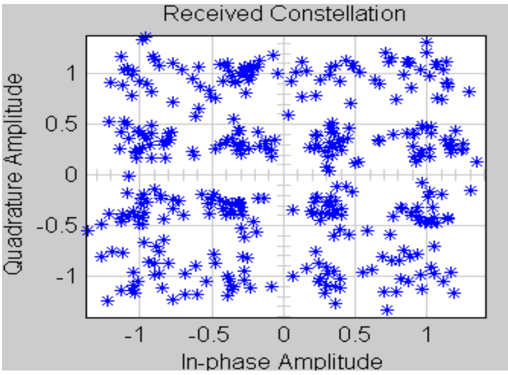

Figure 4(e): f_D=600Hz BER = 0.02892

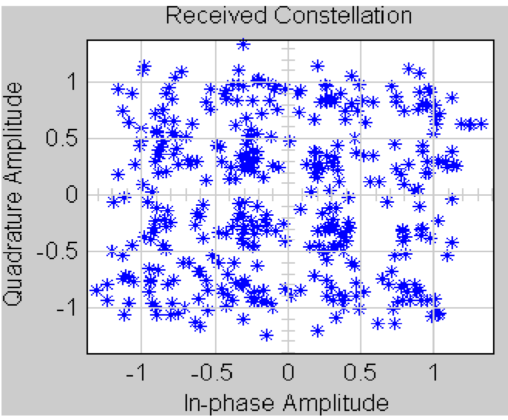

Figure 4(f): f_D=800Hz BER = 0.08053

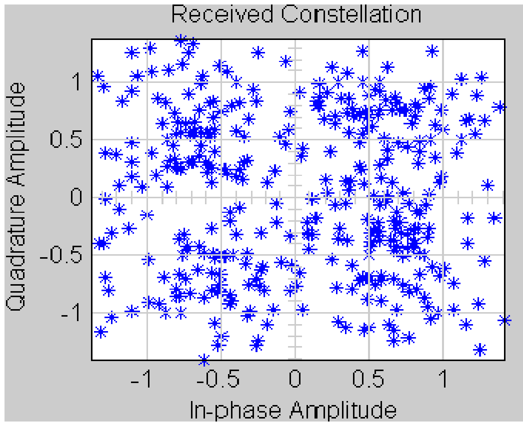

Figure 4(g): f_D=1000Hz BER = 0.09061

Figure 4: Received signal Constellations for Case1

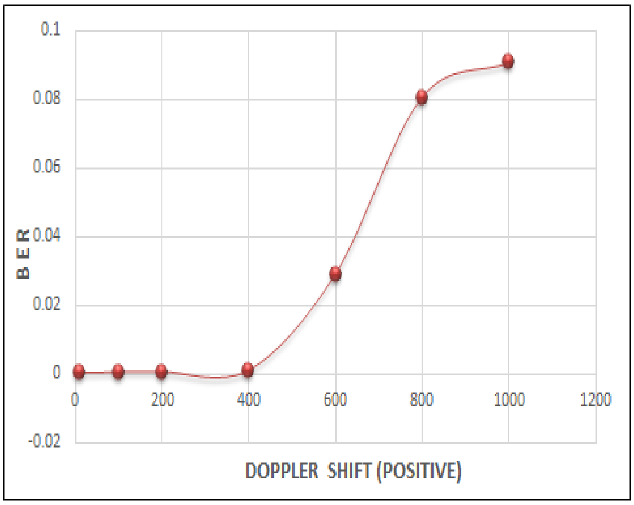

Figure 5: BER Curve for Doppler Shift for Case 1

Case 2 - When Mobile User is moving away from the Base Station

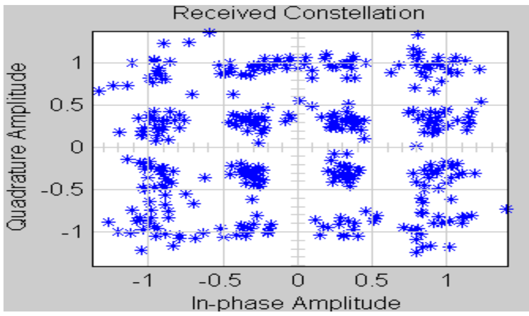

Figure 6(a): f_D=10Hz BER = 0.000125

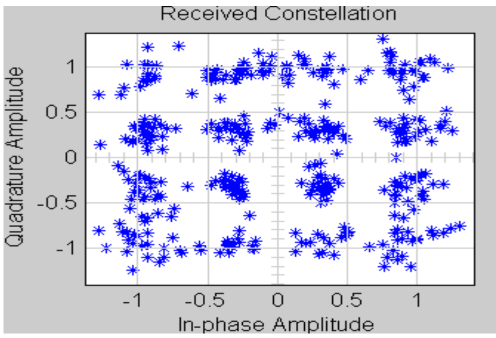

Figure 6(b): f_D=100Hz BER = 0.000218

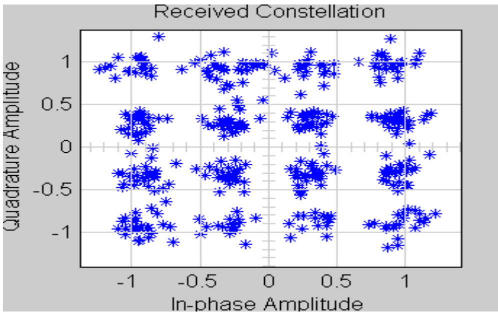

Figure 6(c): f_D=200Hz BER = 0.000526

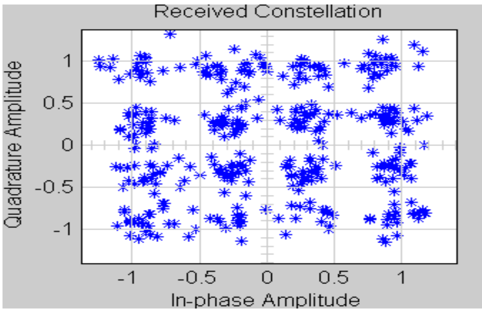

Figure 6(d): f_D=400Hz BER = 0.003138

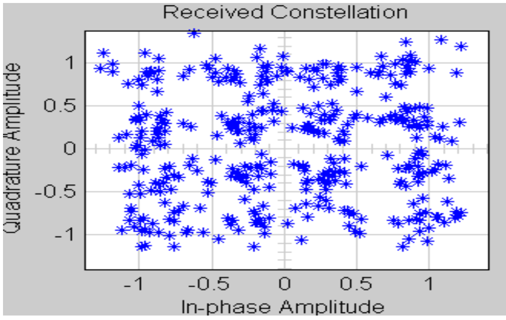

Figure 6(e): f_D=600Hz BER = 0.03062

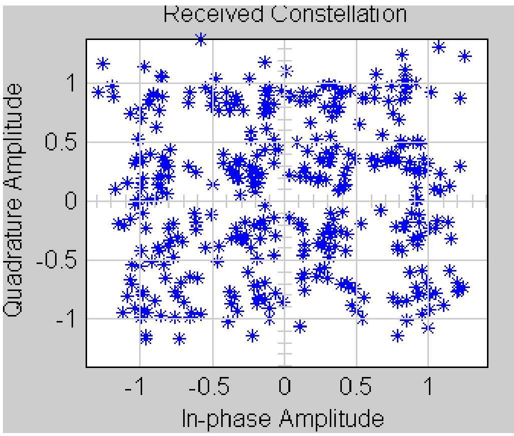

Figure 6(f): f_D=700Hz BER = 0.04846

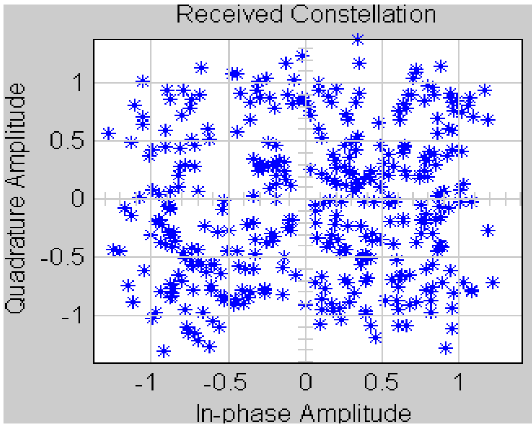

Figure 6(g): f_D=800Hz BER = 0.06840

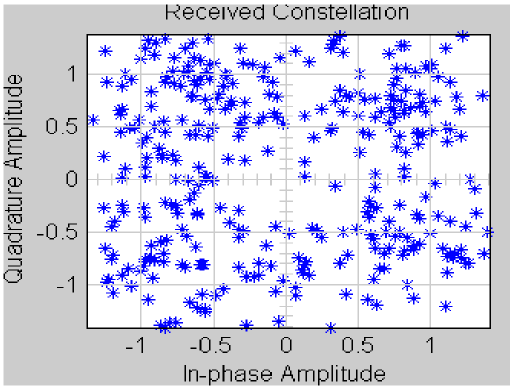

Figure 6(h): f_D=850Hz BER = 0.09830

Figure 6: Received Signal Constellations for Case 2

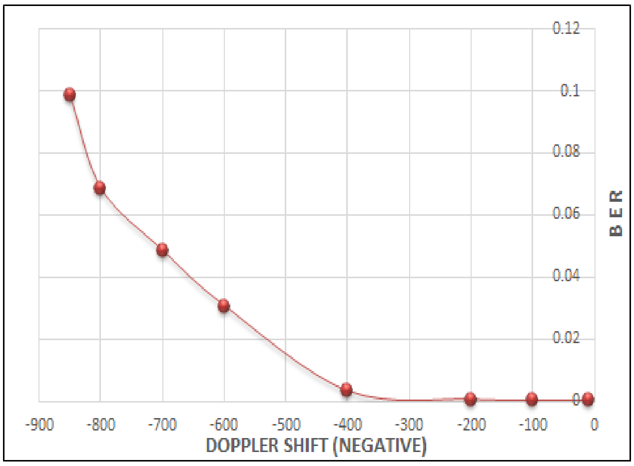

Figure 7: BER Curve for Doppler shift for Case 2

6. Conclusion

Fig. 5 concludes that when Mobile user moves towards the Base Station, BER increases with increase in Doppler Shift**.** The received signal constellations in Fig. 4 suggest that for Doppler Shifts beyond around 400Hz, the Inter Symbol Interference starts severely affecting the received signal strength for the chosen WiMAX profile (i.e. for operation at 3.5GHz). Thus, the de-correlation of fading effects from received signal beyond 400Hz (approximately) becomes inconvenient for the receiver.

Fig. 7 concludes that when Mobile user moves away from the Base Station, BER increases with increase in Doppler Shift. The received signal constellations in Fig. 6 suggest that for Doppler Shifts beyond around -400Hz, the Inter Symbol Interference starts severely affecting the received signal strength for the chosen WiMAX profile (i.e for operation at 3.5GHz). Thus, the de-correlation of fading effects from received signal beyond -400Hz (approximately) becomes inconvenient for the receiver.

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