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Comparison of Rayleigh & Ricean Fading Channels using BPSK, QPSK & 16-QAM Modulation Techniquesin terms of BER Vs. SNR using RRC FIR Filter with DT OFDM Technique

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***Abstract*—Wireless communication is one the fastest growing communication industry. The commonly used wireless communication is the mobile communication. In mobile communication there are many problems that must be overcome that are Doppler effect, ISI, ICI, Fading, Shadowing, Propagation path losses. The orthogonal frequency division multiplexing is well defined technique for removing this problems and also for achieving the high quality services. In this paper, the performance of transmission mode are evaluated by BER/SNR under frequently used Rayleigh and Ricean multipath fading channels. In this paper, we have also assumed Rayleigh and Ricean channels as a noisy channels and also used different modulation techniques (BPSK, QPSK & 16-QAM). DT OFDM transmitter and receiver are implemented using IFFT and FFT to convert the spectrum to time domain to frequency domain and vice versa and also used Root Raised Cosine FIR Filter for better performance of the system. Finally we have compared different modulation technique BPSK, QPSK and 16-QAM over Rayleigh and Ricean multipath fading channels using OFDM system with RRC FIR transmit & received filter.**

Keywords-OFDM,RRC FIR Filter, Modulation techniques, ISI, ICI, Propagation path loss, Doppler shift, BER, SNR, shadowing, Cyclic Prefix.

I. INTRODUCTION

OFDM was invented more than 40 year ago. Orthogonal frequency division multiplexing is a multichannel multicarrier multiplexing modulation technique in which lower order data transmitted via number of parallel frequency sub channels. OFDM overcome the problems like:- multipath fading, ICI, ISI etc. OFDM system makes the effectively use of available spectrum in a contiguous manner. OFDM has been adopted by several technologies are:- DAB, ADSL, DTTB, ISD, 3G, 4G, IEEE 802.11 a/g/n, IEEE 802.16 a/d/e, IEEE 802.20 and many more.

The main reason to use the OFDM wireless technique is, it solve the problem of ICI, Multipath fading and ISI etc. The use of OFDM is just like a water coming from the shower. There is many small-small streams are present by which water is coming out. This concept is also applicable with the OFDM, if one link fail in a single tone carrier system the entire data will be lost but in case of multi-tone carrier system if one or two link goes failed still we are able to recover the data because we have another copy of the original data. It is same as water coming out from the shower.

The OFDM method can use M-PSK or M-QAM mapping for assigning amplitude and phase to the subcarrier. In OFDM system, appropriate to use coding, channel coding and encryption method can be incorporated to have good error handling. Pulse shaping and windowing techniques can improve the OFDM spectral efficiency. OFDM can be used with CDMA which make the system more secure and reliable.

The main objective to write this paper is, the use of RRC FIR filter with the Cyclic prefix, IFFT, FFT, S/P conversion in a OFDM system, which make the system more reliable, robustness and increase the efficiency of the system and decreases the BER by the effective use of Root Raised Cosine Filter at the transmitter end as well as at the receiver end.

A. Different versions of OFDM System

- Flash OFDM:- Flash OFDM(FOFDM) has been patent by Flarion. It uses for spread signals by using multi-tone & fast hopping over a available spectrum.
- Vector OFDM:- VOFDM has been provided by CISCO system, which uses the MIMO(multiple input-multiple output) technology. This technology used for increasing the efficiency of the system.

- Wideband OFDM:- It is a wideband orthogonal frequency division multiplexing technology which is useful for Wi-Fi systems. The mainconcept behind the WOFDM is that it uses degree of spacing between the channels.
- Adaptive OFDM:- The multipath channels effects the received OFDM signal due to the frequently change in the parameters as well as present SNR condition at that movement. The changes in the FFT points, pilot position, no. of subcarriers, this all are the main parameters of the OFDM system whose directly or indirectly effect the system performance. Due to distance variation between the transmitter and receiver, SNR variation also take place which degrade the performance of the system. If the system may be adaptive OFDM in terms of such parameters than system performance increases and it works effectively.

B. *Differences between FDM & OFDM techniques*

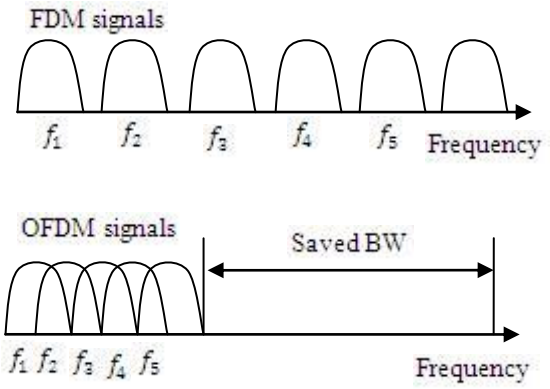

Fig. 1. OFDM VS. FDM System [1]

FDM signals are not time & frequency synchronized where this is must be with OFDM signals. Frequency division multiplexing(FDM) is a single-tone co-channel oriented system where as orthogonal frequency division multiplexing is a multi-tone, multi-channel,multi-carrier, modulation technique(system). Too large cyclic prefix and guard time must be used in FDM signals to prevent ICI interference but it is not necessary in OFDM system. Pulse shaping and windowing problems is involved with the FDM where as OFDM doesn't have it. OFDM consist the concept of orthogonal where this concept is not applicable with FDM. OFDM is the advancement of the FDM technique. FDM doesn't have the relationship between the carrier but OFDM consist.

II. A BRIEF LITERATURE SURVEY

The main concept of orthogonality of the two signals has been given by Bell laboratory in the year 1966. How orthogonality concept can be used with the mobile communication has been given by L. Cimini. Wastage of the spectrum found in the FDM technique which is not in the OFDM. Many technology has been adopted the OFDM technique e.g. DVB-T. The concept of IFFT and FFT with OFDM which makes easy computation and it easily implemented with IFFT and FFT algorithms, this idea has been provided by Weistein in 1971. OFDM uses guard time & CP which came in 1980 & proposed by Ruiz.

The interferences which is caused by multipath co-channels can be overcome by using pilot based method which is provided by Cimini in 1985. Later on, OFDM is adopted by many wireless devices or communication system are:- DAB, HDSL, ADSL, HDTV, VDSL in 1990. Now we proposed that by using Root Raised Cosine Filter(RRCF), the system performance has been upgraded and BER ratio also decreased which makes the system more reliable and effective in terms of BER.

A. *Root Raised Cosine Transmit & Receive Filter*

The RRC FIR transmit & received filter used at the receiver end as well as at the transmit end which up-samples and filter the input signals & output signals by using a normal RC FIR filter or square root RC FIR filter.

The impulse response of the normal RC FIR filter with roll of factor β and the symbol time period T is given by the equation(1) [2] which is given below:-

$$h(t) = \frac{\sin\left(\frac{\pi t}{T}\right)}{\left(\frac{\pi t}{T}\right)} \cdot \frac{\cos\left(\frac{\pi \beta t}{T}\right)}{\left(\frac{1-4\beta^2 t^2}{T^2}\right)} \qquad (1)$$

where, roll of factor β is lies between 0 & 1 which is given below:-

$$0 < \beta < 1 \qquad (2)$$

The impulse response of a square RRC FIR filter is given by the equation(3) [2] which is:-

$$h(t) = 4\beta \frac{\cos\left((1+\beta)\frac{\pi t}{T}\right) + \frac{\sin\left((1-\beta)\frac{\pi t}{T}\right)}{\left(\frac{4\beta t}{T}\right)}}{\pi\sqrt{T}\left(1-\left(\frac{4\beta t}{T}\right)\right)} \qquad (3)$$

The input and the output signals of the RRC FIR filter should be a discrete-time signals.

III. PROPOSED SYSTEM MODEL

OFDM has two types of models:- DT & CT models. CT models are very simple kind of models are multiple phase shift keying/multiple frequency shift keying. In this types of models, the modulated carrier are orthogonal to each other and summed up directly without the stage of IFFT or IDFT. But in our proposed OFDM model is DT model which is shown in the figure(2)[3].

According to block diagram of OFDM DT model which is shown in figure(2), the transmitter end link start from random data generator. Thereafter, the serial to parallel stage starts, which convert the generated data into parallel symbol forms. To having OFDM signals successfully, the orthogonality should be maintain of the carrier and relationship between all the subcarrier should be controlled carefully. The phase and the amplitude of the subcarrier is calculated by the modulation scheme such as

BPSK, QPSK & QAM. Than the samples of the signal is feed to IFFT stage which perform the transformation very fast and converted the input sample frequency data into the output sample time domain data. After that, the received signal which is in time domain and in parallel form converted again back into serial form by parallel-to-serial convertor.

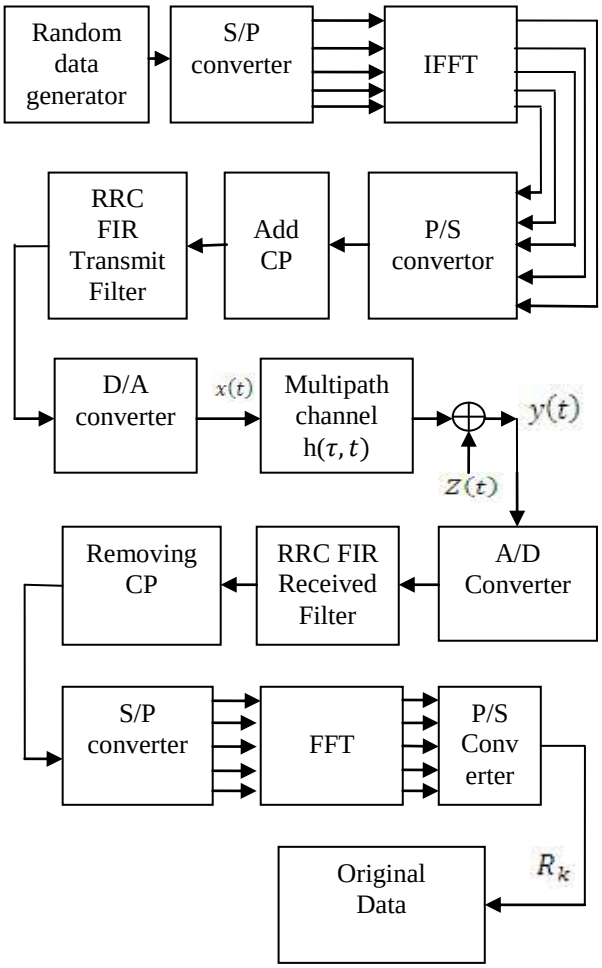

Fig. 2. Proposed DT OFDM Model [3]

Thereafter, CP should be added to the signal which mitigate the effect of multipath, ISI & ICI. Thereafter, the serial data is feed into the Root Raised Cosine FIR filter stage, which shaped the signal and improve the system performance and reduces the BER effectively. The output data of the RRC FIR transmit filter is in discrete samples form which has to convert in analog form which has done by digital-to-analog convertor, before the signal transmitted. The receiver side of the DT OFDM model work totally opposite as transmitter side do. We use FFT at the receiver side of OFDM model to again convert back the time domain data into the frequency domain. This is how DT OFDM model works and it also improve the overall performance of the DT OFDM model with effective use of RRC FIR transmit & receive filter.

A. DT OFDM Model Flowchart

The first step which we take to making any kind of software or methodology is the making of a simple and easier understandable flowchart. The flowchart shown in figure (3) [4] which is developed in the MATLAB, is a DT OFDM system flowchart.

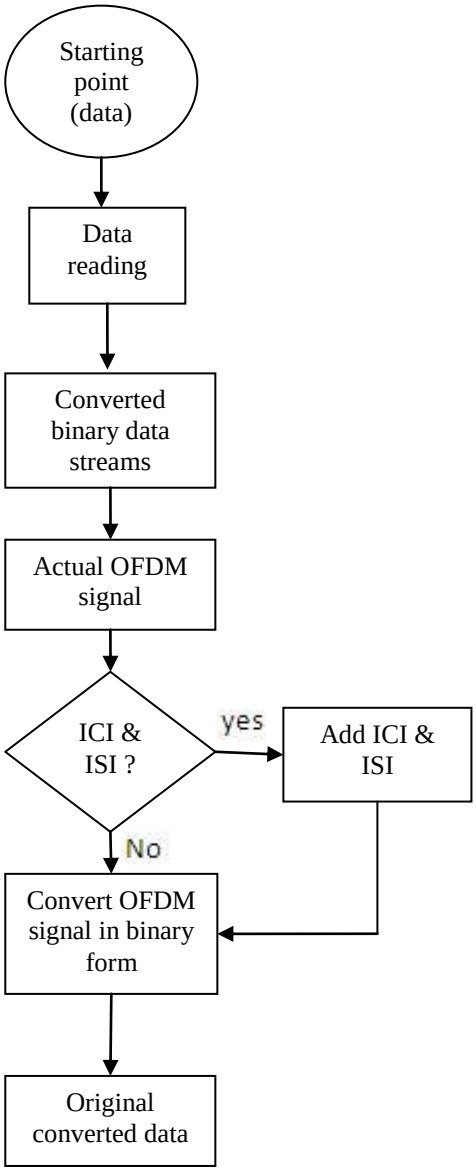

Fig. 3. Flowchart of DT OFDM Model [4]

- The data which may be a sound or picture file and it is necessary to arranged the data into a $1 \times N$ array format before we take further step, which is generated by the random data generator stage.
- Now, in this stage the data is converted into the binary form by pulse code modulation which is a standard A/D method. Each data is quantized by quantizer to a binary & placed in a binary stream which represents the entire data.
- This stage is the most difficult & complicated stage in the DT OFDM model. The binary stream is then

converted into an actual OFDM waveform. In this stage IFFT plays a vital role which converted the data streams into a actual OFDM waveforms also convert the frequency domain data into the time domain.

B. *Orthogonality Principle*

The orthogonality of a two signals or two sinusoids means that they are independent to each other over a time interval and do not interfere or interact with each other. It is very-very necessary to understand the orthogonality of the two signal to understanding the OFDM. Orthogonality allows the multiple signals to be transmitted over a single channel and detected without any interfere. Loss of the orthogonality, causes the information lost & degraded the performance of the communication system.

The two periodic signals are said to be orthogonal if the integral of their product over a time period T is equal to zero, that means the peak of the first carrier is the null of the next carrier.

Mathematically representation of CT & DT OFDM models are shown in the equation (4) [5] & equation (5) [5]; which are the necessary condition for orthogonality.

Continuous time:

$$\int_0^T \cos(2\pi n f_0 t) \times \cos(2\pi m f_0) dt = 0 \quad (n \neq m) \qquad (4)$$

Discrete time:

$$\sum_{k=0}^{N-1} \cos\left(\frac{2\pi kn}{N}\right) \times \cos\left(\frac{2\pi km}{N}\right) = 0 \quad (n \neq m) \qquad (5)$$

Where, $N =$ period of k samples.

Orthogonality of two signals is given below by the equation (6) [5]:-

$$\frac{1}{T}\int_0^T e^{j2\pi f_k t} . e^{-j2\pi f_i t} dt = \begin{cases} 1, & k = i \\ 0, otherwise \end{cases} \qquad (6)$$

The orthogonality is must for the DT OFDM signal to be ICI & ISI free.

C. *IFFT & FFT*

IFFT produces a time domain signal where FFT produces frequency domain signals. As we know that the data which we feed in IFFT is already in the time domain then how IFFT produces a time data into the time domain data. It is very simple, we pretend like that the data which we feed in IFFT is not in time domain, it is in frequency domain by doing such a way the frequency domain data is converted into the time domain data which is actually a time domain OFDM signal.

The mathematically IFFT & FFT are given by the equation (7) [6] & equation (8) [6]:-

The equation for IFFT is

$$x(n) = \sum_{n=0}^{N-1} x(k) \sin\left(\frac{2\pi kn}{N}\right) - j \sum_{n=0}^{N-1} x(k) \cos\left(\frac{2\pi kn}{N}\right) \quad 7)$$

The equation for FFT is

$$x(k) = \sum_{n=0}^{N-1} x(n) \sin\left(\frac{2\pi kn}{N}\right) + j \sum_{n=0}^{N-1} x(n) \cos\left(\frac{2\pi kn}{N}\right) 8)$$

Where, $x(n)$ are the co-efficient of the sine & cosine of frequency $\frac{2\pi k}{N}$, k is the index of the frequency over the N frequencies &n is the time index.

The difference between the FFT &inverse FFT equation is the minus sign and type of the co-efficient of sinusoids, that's all.

The IFFT & FFT are just mathematical concept not more than that, it doesn't care what goes in and what goes out. IFFT & FFT produces the identical results on the same input. IFFT & FT computes the signal very fast in frequency domain to time domain & vice versa.

IV. SIMULATION PARAMETERS & RESULTS

A. *Simulation Parameters*

TABLE I. SIMULATION PARAMETERS

No. of symbols	30,000
FFT size	64
Fading Channels	Rayleigh & Ricean channels
No. of used sub-carrier	52
No. of bits per symbol	52
Signal constellation	BPSK, QPSK, 16-QAM
CP duration, T_{cp}	0.8 μs
SNR	0-12
FFT sampling frequency	20 MHz
Subcarrier spacing	312.5 KHz
Data symbol duration, T_d	3.2 μs
Total symbol duration, T_s	.4 μs

B. *Results*

As we already know that if BER decreases than BER performance will be increases or we can say that BER performance increases than SNR also increases or vice versa.

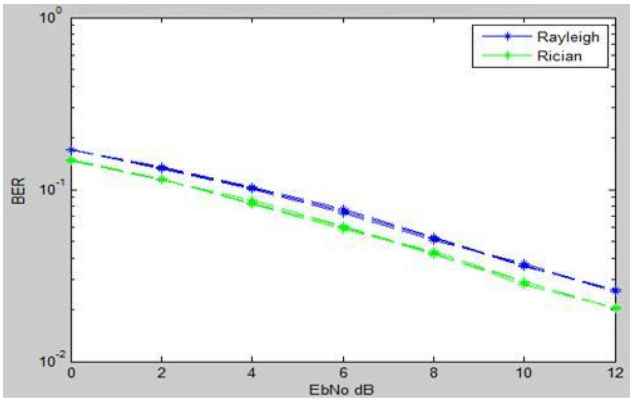

Fig. 4. BER performance of BPSK over Rayleigh and Ricean channel

As we know that BER is decreases in all three modulation technique are BPSK, QPSK & QAM. It means that for good performance, signal to noise ratio must be high, it means that noise must be low for better communication.

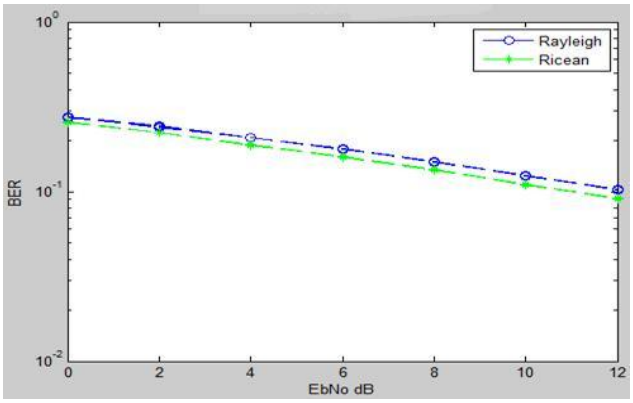

Fig. 5. BER performance of QPSK over Rayleigh and Ricean channel

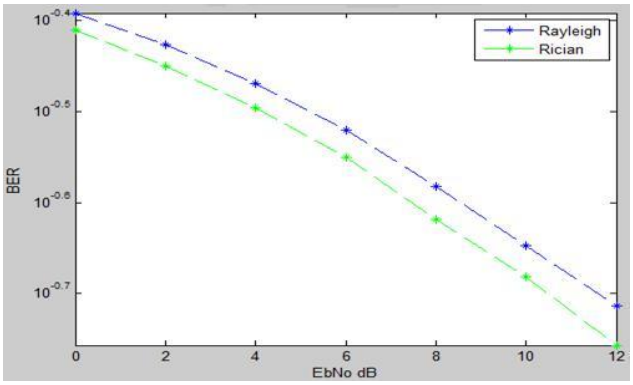

Fig. 6. BER performance of 16-QAM over Rayleigh and Ricean channel

From the figure 4 to 6, we found that the performance of BPSK, QPSK & 16-QAM over Rayleigh & Ricean channel, we conclude that there is no drastic effect of Rayleigh & Ricean channel. All modulation technique give close results between them but still we conclude or compare that Ricean fading channel is better than Rayleigh fading channel on the same parameters and we considered as shown in table 2 given below :-

TABLE II. COMPARISON BETWEEN RAYLEIGH AND RICEAN CHANNEL

SNR (in dB)	*BPSK (BER)*		*QPSK(BER)*		*QAM(BER)*	
	Rayleigh	Rician	Rayleigh	Ricean	Rayleigh	Rican
0	0.4	0.1	0.4	0.2	0.5075	0.40
2	0.3	0.1	0.3	0. 2	0.5197	0.37
4	0.3	0.08	0.3	0.1	0.5340	0.34
6	0.3	0.05	0.3	0.1	0.5489	0.30
8	0.2	0.04	0.2	0.1	0.5630	0.26
10	0.2	0.03	0.2	0.11	0.5747	0.22
12	0.1	0.02	0.1	0.09	0.5833	0.19

From the above table we notice that in comparison of modulation and channel with each other we can say that BPSK BER in Ricean channel much lesser than rest of all blocks.

V. CONCLUSIONS

In this paper, the study of BER/SNR have been analyzed using OFDM over different modulation techniques are BPSK, QPSK and 16-QAM over Rayleigh and Ricean fading channels. Also implemented OFDM system in terms of operation at transmitter end and receiver end. Cyclic prefix id added to OFDM system to overcome the effect of ISI and ICI. We conclude that increasing the SNR decreasing the BER and vice versa. At the last we also conclude that there is no large differences between Rayleigh and Ricean fading channels over a BPSK, QPSK and QAM modulation techniques, but still we conclude that Ricean fading channel is better modulation technique as compare to Rayleigh fading channel on the same parameters.

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