Modeling of OFDM Transmission System under Different Weather Condition

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Abstract: Orthogonal Frequency Division Multiplexing (OFDM) system has been recognized as one of the most popular and competitive technique in a wireless environment nowadays. The performance is calculated in terms of Bit Error Rate (BER) versus the Signal to Noise Ratio (SNR). A fading channel is a communication channel that experiences fading. We will discuss the advantages of using OFDM in fading environment with different fading models, like Rayleigh fading and Rician Fading in the terns of Bit Error Ratio(BER) and Signal to Noise Ratio(SNR).

Keyword: .OFDM, Fading, BER, SNR

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a Digital modulation transmission technique in which it modulates digital signal onto equally spaced subcarriers. The information is modulated onto the subcarrier by varying the phase, amplitude, or both. Each subcarrier then combined together by using the Inverse Fast Fourier Transform (IFFT) to yield the time domain waveform that is to be transmitted. To obtain a high spectral efficiency the frequency response of each of the subcarriers are overlapping and orthogonal. This orthogonally prevents interference between the subcarriers (ICI) and it is preserve even when the signal passes through a multipath channel by introducing a Cyclic Prefix, which prevents Inter-symbol Interference (ISI) on the carriers. This makes OFDM especially suited to wireless communications applications. Two periodic signals are orthogonal when the integral of their product over one period is equal to zero:

For the case of continuous time:
$cos\ T\ O$ (2πnf0t) cos (2πmf0t) dt = 0

For the case of discrete time:
$cos\ N{-}1\ K{=}0\ 2\pi kn\ N$ cos $2\pi km\ N$ dt = 0

Where, m ≠ n in both cases.

To maintain orthogonality between sub-carriers, it is necessary to ensure that the symbol time contains one or more multiple cycles of each sinusoidal carrier waveform. In the case of OFDM, the sinusoids of our sub-carriers will satisfy this requirement since each is a multiple of a fundamental frequency.

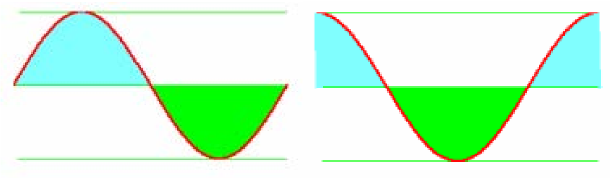

Fig 1: The area under a sine and a cosine wave over one period is always zero

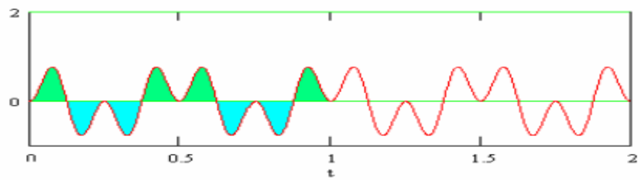

Fig 2: The area under a sine wave multiplied by its own harmonic is always zero

Orthogonality is critical, since it prevents inter-carrier interference (ICI). ICI occurs when the integral of the carrier products are no longer zero over the integration period, so signal components from one sub-carrier causes interference to neighboring sub-carriers. As such, OFDM is highly sensitive to frequency dispersion caused by Doppler shifts, which results in loss of orthogonally between sub-carriers.

II. FADING

In wireless communications, fading is aberration of the attenuation affecting a signal over assured propagation media. The fading may vary with time, geographical position or radio frequency, and is often modeled as a random process. A fading channel is a communication channel that experiences fading. In wireless systems, fading is either be due to multipath propagation, referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading.

- Single and Multi-path Fading :

Most indoor and urban areas do not have direct line of sight propagation between the transmitter and receiver. Multi-path occurs as a result of reflections and diffractions by objects of the transmitted signal in a wireless environment. These objects can be such things as buildings and trees. The reflected signals arrive with random phase offsets as each reflection follows a different path to the receiver. The signal power of the waves also decreases as the distance increases. The result is random signal fading as these reflections destructively and constructively superimpose on each other. The degree of fading will depend on the delay spread (or phase offset) and their relative signal power.

- Fading Effects due to multi-path fading

Time dispersion due to multi-path leads to either flat fading or frequency selective fading:

Flat fading occurs when the delay is less than the symbol period and affects all frequencies equally. This type of fading changes the gain of the signal but not the spectrum. This is known as amplitude varying channels or narrowband channels, since the bandwidth of the applied signal is narrow compared to the channel bandwidth.

Frequency selective fading occurs when the delay is larger than the symbol period. In the frequency domain, certain frequencies will have greater gain than others frequencies.

- Mitigation

The effects of fading can be combated by using diversity to transmit the signal over multiple channels that experience independent fading and coherently combining them at the receiver. The probability of experiencing a fade in this composite channel is then proportional to the probability that all the component channels simultaneously experience a fade, a much more unlikely event. Diversity can be achieved in time, frequency, or space. Common techniques used to overcome signal fading include:

Diversity reception and transmission
MIMO
OFDM
Rake receivers
Space–time codes

III. FADING MODELS

- Rayleigh fading

It is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modeled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed.

Calling this random variable R, it will have a probability density function:[1]

$$p_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, \ r \geq 0$$

where $\Omega = E(R^2)$.

Often, the gain and phase elements of a channel's distortion are conveniently represented as a complex number. In this case, Rayleigh fading is exhibited by the assumption that the real and imaginary parts of the response are modeled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes.

- Rician fading

A channel can be described by two parameters: K and Ω. K is the ratio between the power in the direct path and the power in the other, scattered, paths.[2] Ω is the total power from both paths ($\Omega = \nu^2 + 2\sigma^2$), and acts as a scaling factor to the distribution.

The received signal amplitude (not the received signal power) R is then Rice distributed with parameters

$$\nu^2 = \frac{K}{1+K}\Omega \quad \text{and} \quad \sigma^2 = \frac{\Omega}{2(1+K)}$$

$$f(x) = \frac{2(K+1)x}{\Omega} \exp\left(-K - \frac{(K+1)x^2}{\Omega}\right) I_0\left(2\sqrt{\frac{K(K+1)}{\Omega}}x\right),$$

where $I_0(\cdot)$ is the 0th order modified Bessel function of the first kind.

IV. ADVANTAGES OF OFDM

- OFDM is an efficient way to deal multipath; implementation complexity is significantly lower than single carrier with equalizer.
- In relatively slow time varying channels, performance can be enhanced by the adaptability of the data rate according to the SNR ratio of that subcarrier.
- OFDM is robust against narrowband interference, because such interference affects only a small number of sub-carriers

- OFDM makes single frequency networks possible, which is especially attractive for broadcasting applications

On the other hand, OFDM has the following disadvantages compared to single carrier modulation:

- OFDM is more sensitive to frequency offsets and phase noise
- OFDM has a relatively large peak to average power ratio, which reduces the power efficiency of the RF amplifier.

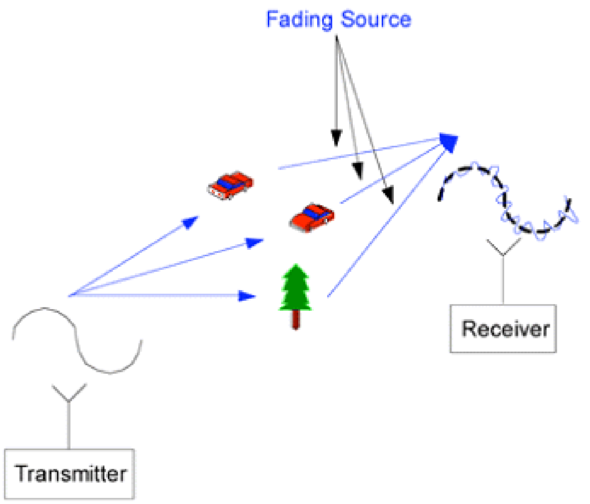

Fig 3: Example of Fading

Our system environment will be wireless indoor and urban areas, where the path between transmitter and receiver is blocked by various objects and obstacles. For example, an indoor environment has walls and furniture, while the outdoor environment contains buildings and trees. This can be characterized by wireless multi-path components as shown below:

V. BIT ERROR RATE (BER) & SIGNAL-TO-NOISE RATIO (SNR)

In digital transmission, the no. of bit errors is the number of receiving bits of a signal data over a communication channel that has been changed because of noise, noise, distortion, interference or bit synchronization redundancy. The bit error rate or bit error ratio (BER) is defined as the rate at which errors occur in a transmission system during a studied time interval. BER is a unit less quantity, often expressed as a percentage or 10 to the negative power.

The definition of BER can be translated into a simple formula:

BER = number of errors / total number of bits sent

Noise is the main enemy of BER performance. Quantization errors also reduce BER performance, through unclear reconstruction of the digital waveform. The precision of the analog modulation/ demodulation process and the effects of filtering on signal and noise bandwidth also influence quantization errors.

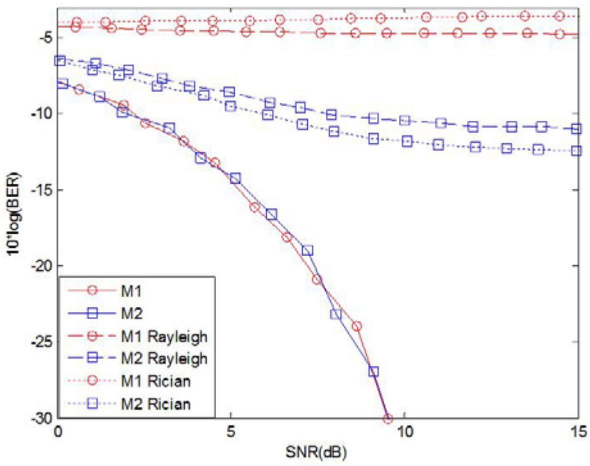

Fig. 4: BER vs SNR for different Fading Models

The SNR is the ratio of the received signal power over the noise power in the frequency range of the process. SNR is inversely related to BER, that is high BER causes low SNR. High BER causes an increase in packet loss, enhance in delay and decrease throughput. SNR is an indicator usually measures the clarity of the signal in a circuit or a wired/wireless transmission channel and measure in decibel (dB). The SNR is the ratio between the wanted signal and the unwanted background noise.

$SNR = Psignal /\ oise$

SNR formula in terms of diversity:

$BER \ \alpha\ 1 /\ (\mathrm{SNR})^{d}$

REFERENCES

[1]. "Performance Analysis of MIMO OFDM System for Different Modulation Schemes under Various Fading Channels" in International Journal of Advanced Research in Computer and Communication Engineering Vol. 2, Issue 5, May 2013