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Analysis of MIMO AntennaSystems for 5g Applicationsand OFDM

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ABSTRACT
In this research paper, we have proposed the concept of MIMO and related some recent technologies like Wi-Fi &GPRS for 5g application. MIMO can be used as MIMO multiplexing,MIMO diversity for transmitting and receiving signals from multiple antennas.We have further discussed the concept of beam forming. MU-MIMO ,MASSIVE MIMO. By analysing recent technologies we can see that Wi-Fi allows uses to access network resources from anywhere,it has both analog and digital past & provide high productivity &speed.By inspecting the evaluation of various generation from 1g to 5g we can encounter various technologies such as GPRS ,GSM, etc. LTE and VOLTE concepts which have made the cellular communication very advanced GPRS is a packet oriented mobile data standard. We have concluded our results to solve some real life challenges in the implementation of 5g. As high frequency waves are used in 5g which can't travel larger distances we have to enhances the coverage area of 5g towers &modem to ease the 5g infrastructure .This can be done by using the beam forming in MIMO by which we can produce high gain beam and MODULATION concept in which by using carriers wave we can send modulation signal through long distances.
Keywords:EM Waves: Electromagnetic Waves,GPRS: General Packet Radio Service, GSM: Global System for Mobile Communications, MIMO: Multiple Input Multiple Output,Wi Fi: Wireless Fidelity

I. INTRODUCTION

What is 5g technology and how it works?.5g is the fifth generation of cellular technology.it is designed to increase the speed,reduce latency and improve flexibility.it is a new global wireless standard after 1g,2g,3g,4g networks.5g enables a new kind of network that is designed to connect virtually everyone and everything including machine,objects and devices.Now need of 5g, while we need 5g phones to access a 5g network.it doesn’t mean you need One to reap some Its speed benefits.As the new network rolls out you may experience fast speed on 4g as well.5g is not replacing 4g altogether.Country who introduced 5g is SouthKorea.Will 5g replace wi-fi.While it certainly possible that 5g can replace wi-fi there is a good chance that it won’t.5g has too many limitation like capacity and coverage issuesplus,5g and wi-fi are better as complement rather than competition.Challenges for 5g .Five biggest challenges facing 5g.The frequency band through 4G lite already operates on established frequency band below 6ghz.5G requires frequencies all the way upto 300Ghz.Deployment and coverage. Cost to build,cost to buy. Regulation and standards.Security and privacy.Advantages and disadvantages of 5g network.Advantages: 1.increased bandwidth for all.2.more bandwidth means faster speed. Disadvantages: 1.An increase bandwidth means less coverage.2.The radio frequency may become a problem.What will 5g bring?.It is the next generation of mobile internet connection and offers much faster data download and upload speed.Through greater use of radio spectrum.it will allow far more devices to access the mobile internet at the same time.Can we use wi-fi in 5G devices, As there are not many 5GHz devices,the network congestion in the band is less. Most dual band routers offer both 2.4GHz and 5GHz connection capabilitiesthis makes it possible to connect old and new generation wi-fi devices without any trouble.Telecommunication and networking has been and will be one of the core technologies in helping the evolution of mankind and technology itself.in an ancient time there is no way to connect with any source of technology, but later on the first generation came and we start connecting to people with new generation and technology.Let us introduce the first of all the generation in the world of technology and communication which as first introduced in 1980s and completed in early.It name called 1G.It allows the voicecalls in one country to another use the analogsignals .AMPS was the first launched in USA in 1G mobile system.Poor voice quality ,battery life ,limited capacity poor handoff,reliability.After adapting the whole world of this technology or first generation people wants good voice quality and the latency in signals would also be remove.As to overcome this problem at all. Finland launched 2G in year 1991 (refer t0 2nd generation which is based on GSM.2G network use digital signals because as we saw the problem occurring by using analog signal to overcome from this problem. It's data speed was upto 64kbps. It enables services such as text message, pictures,message and MMS(multimedia message).Now ,it provides better quality and capacity.if there is some benefit than it will be a chance of disadvantages also, 2G requires strong digital signal ,it totally depends on the area of network (range) these system are unable to handle complex data .There were quite few advancement made within the spectrum itself such as GSM,GPRS,and EDGE.GSM:short for Global systems for mobile Communication enabled data transfer on top of voice communication at speeds that seen .It played a critical role in the evaluation as mobile technology. GPRS : General Packet Radio Service operated on the similar 2G technology as GSM with a few refinement with gave it higher data speeds (110kbps).3G:This was a big revolution in terms of technology advancement for network and data transmission .3G had and has speed capabilities of upto 2MBPS.It enabled smartphones to provide faster communication send/receive large emails and texts,provide fast web browsing.Video streaming and more security amongst others.It is totally based on CDMA(code division multiple access) and EDGE technologies. Providing faster communication send/Receive large emails ,11sec-1.5min to download a 3min mp3 song.Expensive fee for 3G generation and license Service it was challenge to build the infrastructure for 3G High bandwidth Requirement Expenses 3G phones.4G generation came with very highspeed data access,high quality streaming video connotation of wi-fimax.The next generation of wireless technology that promises higher data rates and expanded multimedia services .Capable to provide speed 100Mbps-1Gbps,higher securitysoon after 4G,GLTE was introduce .LTE stands for Long term Evolution and it isn't is path followed to achieve $G speeds. Hand to implement, need complicated hardware expensive equipment.

II. H0W INTERNET WORKS?

In electromagnetic waves, there are various types of waves ,in communication we use radiowaves in various areas likeAM Radio GPS, FM Radio WIFI, satellites,Bluetooth mobile Phones. Are all radio waves same?.All radiowaves are different as when we go to FM and tune to different frequencies we get different programmes.Frequency:Every EM wave travels in a particular pattern.If the frequency of wave is less, then with even low power it can travel larger distances. High frequency waves cannot travel larger distances with low power and we have to apply more power to send it through larger distances.A high frequency wave can carry more data as if we relate that one cycle can carry 1 unit of data. Then as many cycles we get in one second we can send as much data. Therefore, larger frequency waves have more data transmission capabilities.Internet Cables: Internet is accessible to us through mobile towers or through wires/optical fibers from outside to in the routers installed in our houses.But the connectivity worldwide is based on the cables we have submerged deep in the sea.The network of these cables can be easily seen on the internet from countries to countries or continents to continents.Why don’t we provide security to them and what will happen if they damage?. Actually, the main cable is inner material of the whole cable and is hardly 1 inch thick, from all the side there are various protections applied on this like steel wires, plastics. So that if any damage occurs then it won’t be able to penetrate into the inner fib er core. As we have a very large and advanced network of these cables if anyone of it gets damaged it won’t affect our internet significantly as internet is basically a network where we are transferring data. if one route gets damage we can transfer our data by another route as we have backup options available with us.

2.1MIMO TECHNOLOGY

MIMO has multiple input and multiple output where we have multiple antennas at the transmitter and the receiver.4*4 MIMO means 4 antennas at the receiver and 4 antennas at the transmitter.Transmitting antennas can be on BTS or AP.MIMO can be used as1)MIMO multiplexing.In MIMO each transmitting antenna transmits different streams or data and hence increase throughput.Each receiving antenna is receiving signals from all transmitting antennas.2)MIMO diversity.In MIMO diversity, we transmits same data from each transmitting antenna. Each receiving antenna receives the signal from all transmitting antennas. So reliability goes high but data rate is same as SISO.3)BEAM FORMING.It is efficient when number of antennas is more. So 8*8 MIMO is more efficient than 4*4 MIMO as beam can be formed efficiently. In MIMO we can form a high gain beam and hence coverage is more with high spectral efficiency.4)MU-MIMO(Multi User- MIMO)In this different transmitting antennas transmits signals to different receiving antennas. As her multiple users can be connected simultaneously so latency is low and throughput is high.5)Massive MIMO.Massive MIMO is extension of MIMO as here we are using excessive number of antennas in the range of hundreds.

III. WI-FI TECHNOLOGY AND MIMO SYSTEMS

Wi-fi stands for wireless fidelity and is the same thing as saying WLAN which stand for wireless local area network. Wi-Fi works off the same principal as the other wireless devices.it uses radio frequency to send signals between devices.Benefits of wi-fi:Convenience –wi-fi allows user to roam the business and access network resources from nearly anywhere.Mobility-with the emergencies of public wi-fi networks, user can access the internet outside their normal work environment.Productivity high.Easy deployment.Good speed.Low cost.Is wi-fi analog or digital? .Answer is both. Analog part of the wi-fi is electromagnetic waves used to carry the data. Meanwhile the digital part is data transferred you will need analog to digital is converter to receive the data and vice-versa digital to analog transmit.

IV. MIMO CHANNEL EQUALIZATION

The primary advantage of Optical OFDM over single-carrier schemes is its ability to cope with severe channel conditions (for example, attenuation of such high frequencies in a single mode or multimode fibers, narrowband interference and frequency-selective fading due to multipath) without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate inter symbol interference (ISI) and utilize echoes and time-spreading to achieve a diversity gain, i.e. a signal-to-noise ratio improvement. This mechanism also facilitates the design of single frequency networks (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.
In a typical communication system we have: Symbols received at time *k*=(Fading channel coefficient)*(Transmitted symbols at time *k*) + Noise sample at time *k*.

$y(k) = hx(k) + v(k)$ In this equation we observe that current output or symbol *y(k)* depends only on the current input symbol.
But actually

$$y(k) = h(0)x(k) + h(1)x(k-1) + v(k)$$

Basically we analyzed that output or symbol *y(k)* not only depends on the current input symbol but also on previous symbol *x(k-1)*. Essentially *x(k-1)* is interfacing with *x(k)*. This is termed as inter symbol interference (ISI).
ISI leads to performance degradation and is undesirable. Removing ISI is termed as equalization.

4.1.1 Interface of inter symbol interference

One of the key principle of OFDM is that since low symbol rate modulation schemes (i.e., where the symbols are relatively long compared to the channel time characteristics) suffer less from inter symbol interference caused by multipath propagation; it is advantageous to transmit a number of low-rate streams in parallel instead of a single high-rate stream. Since the duration of each symbol is long, it is feasible to insert a guard interval between the OFDM symbols, thus eliminating the inter symbol interference. For a general scenario,

$$y(k) = h(0)x(k) + h(1)x(k-1) + h(2)x(k-2) + \ldots\ldots h(L)x(k-L-1) + v(k)$$

And
$h(0), h(1), \ldots\ldots h(L-1)$ are L channel taps. As L increases, the sensitivity of ISI increases.
For equalization of x(k), with L=2 let we employ
$y(k+2), y(k+1), y(k)$
r =3 symbols or 3 tap equalizer.

$$y(k+2) = h(0)x(k+2) + h(1)x(k+1) + v(k+2)$$

$$y(k+1) = h(0)x(k+1) + h(1)x(k) + v(k+1)$$

$$y(k) = h(0)x(k) + h(1)x(k-1) + v(k)$$

L-2 Taps and r=3 Tap equalizer.

$$\begin{bmatrix} y(k+2) \\ y(k+1) \\ y(k) \end{bmatrix} = \begin{bmatrix} h(0), h(1), 0, 0 \\ 0, h(0), h(1), 0 \\ 0, 0, h(0), h(1) \end{bmatrix} \begin{bmatrix} x(k+2) \\ x(k+1) \\ x(k) \\ x(k-1) \end{bmatrix} + \begin{bmatrix} v(k+2) \\ v(k+1) \\ v(k) \end{bmatrix}$$

4.1.2 Removal of inter symbol interference

Our goal is to design the equalizer which can be removed (or suppressed) ISI. To do so, we translate the continuous-time communication system model to an equivalent discrete-time model that is easier to work with. The following steps describe the translation process: For equalization of x(k), with L=2 let we employ
$y(k+2), y(k+1), y(k)$

r =3 symbols or 3 tap equalizer.

$$y(k+2) = h(0)x(k+2) + h(1)x(k+1) + v(k+2)$$

$$y(k+1) = h(0)x(k+1) + h(1)x(k) + v(k+1)$$

$$y(k) = h(0)x(k) + h(1)x(k-1) + v(k)$$

L-2 Taps and r=3 Tap equalizer.

$$\begin{bmatrix} y(k+2) \\ y(k+1) \\ y(k) \end{bmatrix} = \begin{bmatrix} h(0), h(1), 0, 0 \\ 0, h(0), h(1), 0 \\ 0, 0, h(0), h(1) \end{bmatrix} \begin{bmatrix} x(k+2) \\ x(k+1) \\ x(k) \\ x(k-1) \end{bmatrix} + \begin{bmatrix} v(k+2) \\ v(k+1) \\ v(k) \end{bmatrix}$$

$$\bar{y}(k) = rx1 \quad H = rx(r+L-1) \quad \bar{x}(k) = (r+1)x1$$

$$\bar{v}(k) = rx1$$

As we know

$$\bar{y}(k) = H\bar{x}(k) + \bar{v}(k)$$

Let the equalizer weight

$$c_0, c_1, c_2$$

$$\bar{c} = \begin{bmatrix} c_0 \\ c_1 \\ c_2 \end{bmatrix}$$

$$Equalizer = c_0 y(k+2) + c_1 y(k+1) + c_2 y(k)$$

Weighted linear combination of $y(k+2) + y(k+1) + y(k)$ to remove interference of *x(k).*

Equalizer operation will be

$$\bar{c}^T \bar{y}(k) = [c_0, c_1, c_2] \begin{bmatrix} y(k+2) \\ y(k+1) \\ y(k) \end{bmatrix}$$

Substituting y(k) we get

$$\bar{c}^T \bar{y}(k) = \bar{c}^T (H\bar{x}(k) + \bar{v}(k)) = \bar{c}^T H \bar{x}(k) + \bar{c}^T \bar{v}(k)$$

We desire $\bar{c}^T H = [0,0,1,0]$ as best approximation as possible

Taking transpose $[0,0,1,0]^T = (\bar{c}^T H)^T$

Therefore,

$$[0,0,1,0] \begin{bmatrix} x(k+2) \\ x(k+1) \\ x(k) \\ x(k-1) \end{bmatrix} = x(k)$$

Let $\bar{1}_2 = \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix} = H^T \bar{c}$

Minimum error $\left\| \bar{1}_2 - H^T \bar{c} \right\|^2$

Best equalizer $\bar{c}$

$$\min \left\| \bar{1}_2 - H^T \bar{c} \right\|^2$$

$$\left\| \bar{y} - X\bar{h} \right\|^2$$

Let $h = \left(X^T X \right)^T X^T y$

$$\bar{y} = \bar{1}_2$$

$$X = H^T$$

$$\bar{c} = ((H^T)^T H^T)^{-1} (H^T)^T \bar{1}_2$$

$$\bar{c} = (HH^T)^{-1} H \bar{1}_2$$

Therefore, equalized symbol

$$xhet = \bar{c}^T \bar{y}(k)$$

$$xhet = c_0 y(k+2) + c_1 y(k+1) + c_2 y(k)$$

4.1.3 Approximation error for equalizer

Consider the ISI system

$$y(k) = h(0)x(k) + h(1)x(k-1) + v(k)$$

L=2, h(0) and h(1) are channel taps

Consider r=3 tap equalizer, model can be formulated as

$$y(k+2), y(k+1), y(k)$$

$$\begin{bmatrix} y(k+2) \\ y(k+1) \\ y(k) \end{bmatrix} = \begin{bmatrix} h(0), h(1), 0, 0 \\ 0, h(0), h(1), 0 \\ 0, 0, h(0), h(1) \end{bmatrix} \begin{bmatrix} x(k+2) \\ x(k+1) \\ x(k) \\ x(k-1) \end{bmatrix} + \begin{bmatrix} v(k+2) \\ v(k+1) \\ v(k) \end{bmatrix}$$

$$\bar{y}(k) = H\bar{x}(k) + \bar{v}(k)$$

Equalizer vector

$$\bar{c} = \begin{bmatrix} c_0 \\ c_1 \\ c_2 \end{bmatrix}$$

Equalizer operation will be

$$\bar{c}^T \bar{y}(k) = [c_0, c_1, c_2] \begin{bmatrix} y(k+2) \\ y(k+1) \\ y(k) \end{bmatrix}$$

Substituting y(k) we get

$$\bar{c}^T \bar{y}(k) = \bar{c}^T (H \bar{x}(k) + \bar{v}(k)) = \bar{c}^T H \bar{x}(k) + \bar{c}^T \bar{v}(k)$$

We desire $\bar{c}^T H = [0,0,1,0]$ as best approximation as possible

Taking transpose $[0,0,1,0]^T = (\bar{c}^T H)^T$

Therefore,

$$[0,0,1,0] \begin{bmatrix} x(k+2) \\ x(k+1) \\ x(k) \\ x(k-1) \end{bmatrix} = x(k)$$

Minimum error $\left\| \bar{1}_2 - H^T \bar{c} \right\|^2$

Best equalizer $\bar{c}$

$$\min \left\| \bar{1}_2 - H^T \bar{c} \right\|^2$$

$$\bar{c} = (HH^T)^{-1} H \bar{1}_2$$

Approximation error

$$= \left\| H^T \bar{c} - \bar{1}_2 \right\|^2$$

Substitute c bar

$$= \left\| H^T (HH^T)^{-1} H \bar{1}_2 - \bar{1}_2 \right\|^2$$

$$= \left\| P_H \bar{1}_2 - \bar{1}_2 \right\|^2$$

Where

$$P_H = H^T (HH^T)^{-1} H$$

$$= \left\| (P_H - I) \bar{1}_2 \right\|^2$$

As we know

$$\left\| \bar{u} \right\|^2 = \bar{u}^T \bar{u}$$

$$= \left((P_H - I) \bar{1}_2 \right)^T \left((P_H - I) \bar{1}_2 \right)$$

As we know

$$(AB)^T = B^T A^T$$

$$= \bar{1}_2^T (P_H - I)^T (P_H - I) \bar{1}_2$$

Where

$$P_H = H^T (HH^T)^{-1} H$$

Its transpose will be

$$P_H^T = (H^T (HH^T)^{-1} H)^T$$

As we know

$$(ABC)^T = C^T B^T A^T$$

$$P_H^T = H^T (HH^T)^{-1} (H^T)^T$$

$$(A^{-1})^T = (A^T)^{-1}$$

$$P_H^T = H^T (HH^T)^{-1} H = P_H$$

Which says that

$$P_H^T = P_H$$

Similarly

$$P_H^2 = P_H . P_H$$

$$P_H^2 = H^T (HH^T)^{-1} H . H^T (HH^T)^{-1} H$$

$$P_H^2 = H^T (HH^T)^{-1} H = P_H$$

$$P_H^T = P_H$$

$$P_H^2 = P_H$$

P_H is known as projection matrix of H^T

4.2.4 Bit Error Rate (BER) performance of OFDM

We proposed that system model can be expressed as received sample $y = h \otimes x + w$ w is Gaussian noise.

Once we take the FFT at the receiver we have

$$Y(k) = H(k) X(k) + W(k)$$

Y(k) is the kth FFT point of the received samples *[y0,y1,.....y(n-1)]*

W(k) is the kth FFT point of the noise samples *[w0,w1,.....w(n-1)]*

In time domain we have the received signal $y = h \otimes x + w$

In other words $W(k) = \sum_{l=0}^{N-1} w(l) e^{-j2\pi \frac{kl}{N}}$

Each *w(l)* is IID Gaussian in nature with zero mean, therefore.

Mean $E\{w(l)\} = 0$

Variance $E\left\{ |w(l)|^2 \right\} = \sigma^2$

Covariance $E\left\{ w(l) w^*(\tilde{l}) \right\} = 0$

Now let us look the property of *W(k)*

$$W(k) = \sum_{l=0}^{N-1} w(l) e^{-j2\pi \frac{kl}{N}}$$

$$E\left\{W(k)\right\} = E\left\{\sum_{l=0}^{N-1} w(l)e^{-j2\pi\frac{kl}{N}}\right\}$$

$$E\left\{W(k)\right\} = \sum_{l=0}^{N-1} E\left\{w(l)\right\} e^{-j2\pi\frac{kl}{N}}$$

$$E\left\{W(k)\right\} = 0$$

Which says that expected value of each *W(k)* is zero. Since the FFT is a linear combination, the input of noise samples is zero mean. Naturally at the output of the FFT *W(k)* is also zero mean.

Let us look the variance of each noise samples.

$$E\left\{\left|W(k)\right|^2\right\} = ?$$

$$E\left\{W(k).W^*(k)\right\} = E\left\{\left(\sum_{l=0}^{N-1} w(l)e^{-j2\pi\frac{kl}{N}}\right)\left(\sum_{\tilde{l}=0}^{N-1} w(\tilde{l})e^{-j2\pi\frac{k\tilde{l}}{N}}\right)^*\right\}$$

$$E\left\{W(k).W^*(k)\right\} = E\left\{\sum_{l=0}^{N-1}\sum_{\tilde{l}=0}^{N-1} w(l)w^*(\tilde{l})e^{-j2\pi\frac{k(l-\tilde{l})}{N}}\right\}$$

Noise sample *w(l)* are independent and therefore uncorrelated. Therefore expected value will survive only if $l = \tilde{l}$.

$$E\left\{W(k).W^*(k)\right\} = \left\{\sum_{l=0}^{N-1}\sum_{\tilde{l}=0}^{N-1} E\left\{w(l)w^*(\tilde{l})\right\}\right\} e^{-j2\pi\frac{k(l-\tilde{l})}{N}}$$

$$E\left\{w(l)w^*(\tilde{l})\right\} = \begin{cases} 0 \ldots if, l \neq \tilde{l} \\ \sigma^2 \ldots if, l = \tilde{l} \end{cases}$$

$$E\left\{W(k).W^*(k)\right\} = \sum_{l=0}^{N-1} \sigma^2.1$$

$$E\left\{W(k).W^*(k)\right\} = N\sigma^2$$

Hence

$$E\left\{\left|W(k)\right|^2\right\} = N\sigma^2$$

Therefore, noise at the output can be characterize as

Mean $E\left\{W(k)\right\} = 0$

Variance $E\left\{\left|W(k)\right|^2\right\} = N\sigma^2$

Similarly for channel coefficient:

Each *h(l)* is Rayleigh fading coefficient

$h(0), h(1), \ldots\ldots h(L-1), 0, 0, 0$

$N - L, Zeros$

$$H(k) = \sum_{l=0}^{L-1} h(l)e^{-j2\pi\frac{kl}{N}}$$

Each *h(l)* is Rayleigh fading coefficient, which mean each *h(l)* is complex Gaussian with mean zero.

$$E\left\{h(l)\right\} = 0$$

$$E\left\{h(l).h^*(\tilde{l})\right\} = 0 \text{ if } l \neq \tilde{l}$$

Each *h(l)* are uncorrelated. This is known as uncorrelated scattering assumption.

Similarly power of each Rayleigh fading is

$$E\left\{\left|h(l)\right|^2\right\} = 1$$

If $h(l)$ is Rayleigh in nature then $H(k)$ will also be Rayleigh in nature.

That is

$$E\left\{H(k)\right\} = 0$$

$$E\left\{\left|H(k)\right|^2\right\} = \sum_{l=0}^{L-1} E\left\{\left|h(l)\right|^2\right\}$$

$$E\left\{\left|H(k)\right|^2\right\} = \sum_{l=0}^{L-1} 1$$

$$E\left\{\left|H(k)\right|^2\right\} = L$$

Now if we see our system model across subcarrier

$Y(k) = H(k)X(k) + N(k)$

$H(k)$ is Rayleigh fading with average power (Variance) L $E\left\{\left|H(k)\right|^2\right\} = L$

$N(k)$ with average power (variance) $N\sigma^2$

$$E\left\{\left|W(k)\right|^2\right\} = N\sigma^2$$

Let us assume $X(k)$ with average power (Variance) be P $E\left\{\left|X(k)\right|^2\right\} = P$

Therefore SNR for this problem will be $SNR = \dfrac{\left|H(k)\right|^2 P}{N\sigma^2}$ at the receiver.

And average of the received power at the receiver

$$SNR_r = \frac{\left|H(k)\right|^2 P}{N\sigma^2} = \frac{LP}{N\sigma^2}$$

$$SNR_r = \frac{LP}{N\sigma^2}$$

Similarly as the channel Rayleigh fading BER of OFDM for BPSK transmission will be

$$BER = \frac{1}{2}\left(1 - \sqrt{\frac{\frac{L}{N} SNR}{2 + \frac{L}{N} SNR}}\right)$$

As transmit $SNR = \frac{P}{\sigma^2}$

$$BER = \frac{1}{2}\left(1 - \sqrt{\frac{\frac{L.P}{N\sigma^2}}{2 + \frac{L.P}{N\sigma^2}}}\right)$$

Example: Let us calculate BER of OFDM system with L=16 channel taps and N=256 subcarriers and SNR =35dB which means $35dB = \frac{P}{\sigma^2}$. For this system what is the BER.

$$10\log_{10} SNR = 35dB$$

$$SNR = 10^{3.5}$$

$$BER = \frac{1}{2}\left(1 - \sqrt{\frac{\frac{L}{N} SNR}{2 + \frac{L}{N} SNR}}\right)$$

$$BER = \frac{1}{2}\left(1 - \sqrt{\frac{\frac{16}{256}10^{3.5}}{2 + \frac{16}{256}10^{3.5}}}\right)$$

$$BER = 2.5x10^{-3}$$

Which says the BER is $2.5x10^{-3}$ which is derived from the relation of transmit power and received power in respect of SNR. Therefore, in this chapter we conclude that channel equalization is done with the help of $y(k) = hx(k) + v(k)$. Inter symbol interference, has been discussed with its advantages and disadvantages with respect of channel taps. How we can remove the ISI, has also been discussed. Error for the equalizer and its estimation for the communication is reviewed here. A model for the optical OFDM has been discussed, and its channel estimation is derived with the help of PDF and joint PDF.

V. CONCLUSION

As the major challenge in implementing the 5g services is to install large number of 5g towers and modems due to small range or coverage area (of 5g towers) in which they may operate .This issue can effectively be solved/reduced by by using the concept of MIMO and MODULATION in the field oif communication. MIMO: In MIMO,by using the concepts of beam forming, we can form a beam with high gain which can go at larger distances. Hence, our coverage area is high in that particular direction. This beam forming can have only one stream or may have multiple streams and is efficient when number of antennas is more.Modulation:By using the concept of modulation, we can send the modulating signal through larger distances using a carrier wave.If we relate the concepts of MIMO and modulation, we can deal with multiple signals simultaneously to bring advancements in the field of 5g.

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