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REVIEW ON CHARACTERISTICS OF WIRELESS COMMUNICATION SYSTEMS

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Abstract – *The paper gives a comprehensive overview of the approved propagation models for wireless communication system. The wireless propagation system faces different challenges like multipath-propagation, fading, energy limitation, co-channel and adjacent channel interference and Doppler shift. Various propagation models have been derived by analytical and empirical approaches for different ranges having advantages and disadvantages.*

***Key Words*: Fading, Interference, Doppler shift, Path loss, Okumura model, Egli's model.**

1. INTRODUCTION

The sudden increase in the mobile communication environment in the past few decades has increased the dependency on the wireless communication system with the consistent improvement in the quality of signals. The wireless communication involves sensing, processing and networking with different nodes however suffers unwanted phenomena like fading, path loss, Doppler shift, shadowing, co-channel and adjacent channel interference and multi path delay losses that attenuate the signal power and reduce the quality of the transmitted signal. The identified impairments will be defined in detail that cause the variations in the power of received signal over a distance. Different propagation models have been developed to predict radio propagation behavior and are categorized into fully empirical models, semi empirical, deterministic models and stochastic models. The Empirical models include Hata model, Okumura model and COST-231 Hata model, whereas the deterministic models include Ray Tracing and Ikegami model.

2. WIRELESS COMMUNICATION SYSTEM

The wireless communication system uses the method of transmitting information from the transmitter to the receiver which may be placed a few meters or a thousand kilometers apart in the form of electromagnetic waves. It does not use any kind of physical medium such as coaxial cable, optic fiber or twisted pair cable to transmit. The space-time frequency signal ordinarily known as the radio frequency signals is transmitted and received by antennas with the help of propagation medium. The signals' come across various objects and is forced to diffract, scatter, reflect and refract. Consequently, the accumulative effect results in the signal getting absorbed, signal passes across multiple paths, signal's frequency being shifted due to relative motion between the source and objects (Doppler Effect). A correct estimation of the path loss needs to be calculated before deploying a wireless network or cell planning.

The commonly used wireless communication systems include RFID, GSM(mobile phones), infrared, GPS, Bluetooth, Wi-Fi and RF.

3. TYPES OF WIRELESS COMMUNICATION

Major types of wireless communication system are:

1. Bluetooth communication
2. Satellite communication
3. Mobile communication
4. Wireless network communication
5. Infrared communication
6. Microwave communication
7. Wi-Fi communication

4. CHARACTERISTICS OF WIRELESS CHANNEL

The prominent features of the wireless communication channel are:

1. Doppler shift
2. Interference
3. Fading
4. Path loss

4.4.1 Doppler Shift

The Doppler effect was proposed by an Austrian physicist Christian Doppler in 1842 and is stated as the change in frequency or wavelength of a wave for an observer who is in relative motion to the wave source. This effect is seen for any kind of wave – water wave, sound wave or light wave. It is often commonly observed with sound waves particularly at subways where the sound when the train approaching, passing and receding away is perceived differently by the observer.

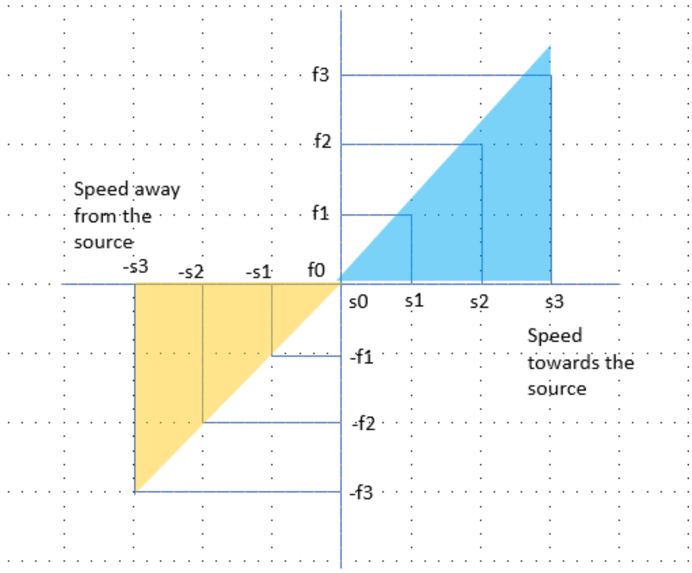

Fig -1: Doppler shift

According to the above figure when the source of frequency and the observer are stationary (s0) the frequency perceived by the observer is similar to the actual frequency (f0). But when the source of frequency is moves towards or away from the observer, the perceived frequency by the observer will be different (at speed s1, Frequency is s1 and so on).

The change in frequency can be calculated by the following formula

$$f = \left(\frac{c \pm v_o}{c \pm v_s}\right) fo$$

where,

f = Apparent frequency
fo = Actual Frequency from the source
v_o = Speed of observer
v_s = Speed of source
c = Speed of sound

Doppler effect is normally seen in radar, flow measurement, aerospace navigation, astronomy etc.

With reference to the mobile communication the user is never considered to be stationary and hence causes a shift in the transmitted signal path due to its velocity and the angle made by the reception radio wave and moving direction. This is known as Doppler shift. Signals travelling in different paths may undergo different Doppler shifts with different phase changes. A single fading channel consisting of various Doppler shifts is called as Doppler spread.

4.4.2 Interference

Interference is considered to a inseparable part of the wireless communication system. The congestion of frequency spectrum and sharing of frequency has made interference to be an integral part of wireless network analysis and calculations. Interference can be defined as any type of noise or unwanted signal which may reduce the reliability and throughput of the system.

4.2.1 Sources of Interference

1. Natural Radiators like lightning, snow storm and electromagnetic discharge.
2. Unintentional Radiators like DC motors, transformers, arc welders, power lines, microwaves and power cables.
3. Intentional radiators (54 Mhz – 698 MHz) like digital and analog TV transmitters, cellular services, wireless microphones and FM/AM radio boosters.
4. Intentional radiators (900 MHz - 2.4 Ghz) like ZigBee devices, Wi-fi devices, cordless phones, RFID readers, intercoms and remote controls.

Sources of Interference between Mobile cells

With respect to the cells, the sources of interference may be defined when:

1. Base stations operate on the same frequency.
2. Another mobile is present in the same cell in close vicinity.
3. A call is in progress in another cell

Some characteristics with respect to cell interference are:

1. Cells having similar frequency suffer more interference as compared to the cells having different frequency.
2. Cells having similar reference signal location tend to have more interference between cells as compared to cells having different reference signal locations.

4.2.2 Types of Interference

Mainly there are two types of interferences:
1. Co-channel Interference
2. Adjacent channel interference

4.2.2.1. Co-Channel Interference

1. Consider two or more access points (APs) are operating and using the same frequency channel then interference may occur. This interference is called as co-channel interference.
2. In case of mobile cells, different cells using the same frequency also known as co- channel cells suffer from this type of interference.

3. It is responsible for causing unnecessary and unwanted contention which forces the clients and access points to adjourn transmission until the medium is clear.
4. This interference is normally influenced by antenna height, type and directionality. The performance is normally hampered by the wait times, but as the bandwidth is controlled and handled correctly, every device or client gets a chance to talk to its designated AP.
5. The co-channel interference can be minimized by placing or separating the cells by a minimum distance to reduce the footprint of the cell. 120° sectoring can also reduce co-channel interference.
6. The use of 3 to 6 directional antennas at the base station by dividing each cell into 3 to 6 sectors will definitely reduce the co-channel interference to a certain extent.

4.2.2.2. Adjacent Channel Interference

1. Inadequate or incomplete filtering, improper tuning or low frequency causes a signal to gain redundant power in an adjacent channel. This interference is called as adjacent channel interference.
2. Another reason for the rise of adjacent channel interference is the leaking of frequencies into the pass band due to imperfect receiver filters which give rise to adjacent interference.
3. Accurate channel assignments, correct filtering techniques and separating the frequency in a particular cell to a maximum extent can minimize the adjacent channel interference.

4.4.3 Fading

In the broadcast media when a signal experiences deviation in attenuation or variation in strength when received at the receiver it is called as fading. Fading is considered to be a random process that occurs due to multipath propagation or shadowing.

Generally fading is based on:

1. Multipath time delay
2. Doppler shift

4.4.1 Based On Multipath Time Delay

1. Multipath fading is caused by multiple radio propagation paths and multiple copies of the same signal received at the receiver having different time delay, phase and amplitude.
2. With the help of multipath propagation signals can travel through many paths between transmitter and receiver by reflection, scattering and diffraction effectively increasing the radio coverage area and moreover with the use of smart or adaptive antennas, usable received power could be increased.
3. It is normally characterized by Ricean or Rayleigh distribution and commonly observed in indoor or urban areas.

4.3.1.1. Effects Of Multipath Time Delay

1. As the signal comes over different paths of various lengths, the signal disperses over time which causes interference with neighboring symbols and is called as Inter Symbol Interference (ISI)
2. The signal reaching a receiver is phase shifted because of reflections and is perceived by the receiver as a distorted signal. This type of fading is called Rayleigh fading which depends on the phases of different paths. It is responsible for fast variations of the received signal and is also known as fast fading.

4.3.1.2. Fading Based On Multipath Time Delay

There are generally two types of fading based on multipath time delay:

1. Flat Fading

   i) In this type of fading the bandwidth of the signal is much smaller than the bandwidth of the channel.
   ii) Delay spread is lower than the symbol periods.

2. Frequency Selective or Non-flat fading

   i) The bandwidth of the signal is much larger as compared to the bandwidth of the channel.
   ii) Delay spread is higher than the symbol periods.

4.4.2 Based On Doppler Shift

Doppler shift fading is caused by the movement of cell phones which results in change of incident plane wave given by the formula.

$$f_D = f_m \cos\theta_n$$

Where

$$f_m = \frac{v}{\lambda}$$

1) Maximum doppler effect occurs at θ=0. The waves coming from the direction of motion result in a positive shift and the waves coming from the opposite direction result in a negative shift. The effect can be mitigated by using a baseband signal of wide bandwidth greater than the maximum Doppler shift.
2) Doppler Shift Spectrum - As seen in the below figure received signal spectrum is limited in range to fm about the carrier frequency and implies that fading occurs at $\lambda/2$ distance apart,

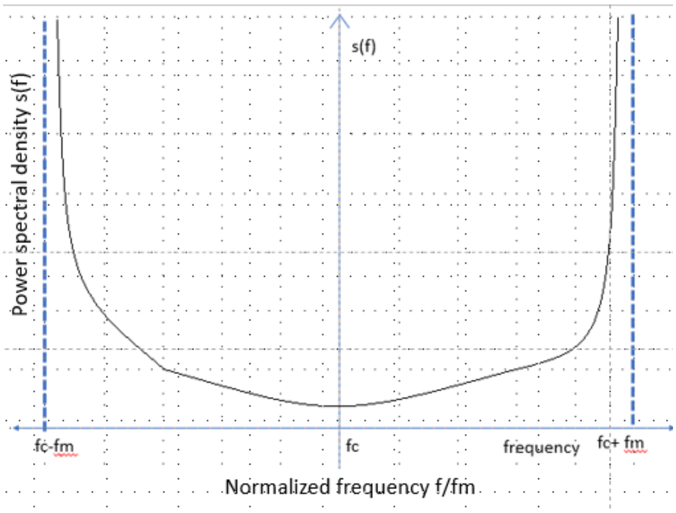

Fig -2: Doppler spectrum

4.3.2.1. Effects of Doppler Shift Based Fading

1) Time-frequency duality – There is an increase in the bandwidth occupancy also known as the frequency dispersion which is created by the doppler spread. This is similar to the time selective fading in the received signal.
2) Coherence Time – The shift in the doppler frequency can be represented in the form of coherence time Tc. If symbol time is less than Tc, it is called slow fading. Otherwise it is fast fading.

4.3.2.2. Types Of Doppler Shift Based Fading

There are two types of doppler shift based fading, namely:

1) Slow fading

i) This fading shows that the signal fades slowly where the duration of the fade may last for few seconds or minutes.
ii) Slow fading normally occurs because of the objects that partially absorb transmission are present between the sender and receiver.
iii) Slow fading causes less doppler spread and the channel variations are slower as compared to the baseband signal variations.
iv) The coherence time is larger than the symbol period in this type of fading.
v) It encounters problems like inter-symbol interference which can be mitigated by equalization and use of directional antenna.

2) Fast fading

i) Different versions of the same transmitted signal interfere with each other and arrive at the receiver at different time intervals. This causes fluctuations in the phase, amplitude or multipath delays of the received signal which is called as fast fading.
ii) Variations in the channel as high as compared to the variations in the baseband signal.
iii) High doppler spread is observed in fast fading
iv) The coherence time for fast fading is very less than the symbol period.
v) It encounters problems like frame error and bit rate error which can be mitigated by diversity techniques, error correction coding and frequency hopping.

4.4.4 Path Loss

i. Path loss is essential for calculating, designing and deploying the wireless communication networks and is expressed as the ratio of transmitted signal power to the power of the same signal received by the receiver over a particular path.
ii. Path loss is the function of propagation distance.
iii. Path loss is dependent on factors like nature of the landform and the radio frequency used in transmission.
iv. Received signal strength also known as RSS is proportional to d^{-n}
n is the path-loss exponent
(n=2 ~ 8 in typical propagation scenarios
n=4 is usually assumed in cellular system study)

4.4.1 Types of path loss models

Types of Path loss models include:

i) Smooth transition model
ii) Two-ray-ground model
iii) Free-space model
iv) Egli's model
v) Okumura model

4.4.1.1 Smooth transition model

Smooth transition model is an improvement over the simple distance-power relationship. Typically, n is of smaller value in near-field and has a greater value in far-field.

- $g(d)=d^{-n1}$ $0 \le d \le b$
- $g(d)=d^{-n1}(d/b)^{-n2}$ $b \le d$

4.4.1.2 Two ray ground model

Two-ray ground model also known as two path models is a commonly used path loss model. In this model the signal reaches the receiver through two paths, one through a line of sight (LOS) path and the other through a non-line of sight (NLOS) path through which the reflected wave is reaches the receiver. Power received in the two-ray model is given by:

$$P_r = G_t G_r P_t \left(\frac{h_t h_r}{d^2}\right)^2$$

Where,

- P_r is the received power
- P_t is the transmitted power
- G_t represent the antenna gain at the transmitter

- G_r represent the antenna gain at the receiver
- d is the distance between the transmitter and receiver
- h_r are the height of the receiver
- h_t is the height of the transmitter

4.4.1.3 Free Space model

Free space propagation model is the easiest path loss model where a direct-path signal exists between the sender and the receiver with no significant atmospheric attenuation or multipath components.

Received power is given by:

$$P_r = G_t G_r P_t \left(\frac{\lambda}{4\pi d}\right)^2$$

Where,

- λ is the wavelength of the signal.
- Gt is the transmitter antenna gain.
- Gr is the receiver antenna gain.
- d is the distance between the transmitter and receiver.

4.4.1.4 Egli's model

Egli's model proposed in 1957 is very efficient over smooth and plane terrains as it measured an increase in the path loss over the range of 1-50km with a carrier frequency of f_c. Egli also gave a frequency dependent correction $(40Mhz/fc)^2$ for the carrier frequency ranging from 30Mhz to 1Ghz.

Received power is given by:

$$P_R = \left(\frac{40Mhz}{f_c}\right)^2 \frac{(h_T h_R)^2}{d^4} P_T G_T G_R$$

Where ,

- G_T is the transmitter antenna gain.
- G_R is the receiver antenna gain.
- h_R are the height of the receiver
- P_R is the received power
- P_T is the transmitted power
- h_T is the height of the transmitter
- f_c is the carrier frequency
- d is the distance between the transmitter and receiver.

4.4.1.5 Okumura model

Okumura model is one of the widest used models for signal prediction for mature cellular and land mobile radio systems which is applicable over frequencies ranging from 150MHz to 1920Mhz covering a distance up to 100km. The path loss estimation is given by the following:

$$L_{50}(dB) = L_F + A_{mu}(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA}$$

Where,

- L_{50} is the 50% value of propagation path loss
- L_F is the free space propagation loss
- $A_{mu}(f,d)$ is the median attenuation relative to free space
- $G(h_{te})$ is the base station antenna height gain factor
- $G(h_{re})$ is the mobile antenna height gain factor
- G_{AREA} is the gain due to environment

5. CONCLUSION

With the increase in demand of mobile and wireless communications, new techniques have emerged to improve the quality of service and capacity. Smart antennas, sectoring higher frequencies and appropriate cell sizes are designed taking into consideration the factors already discussed in this paper like fading, path loss, Doppler effect and multi-path propagation. On the basis of ray-tracing based models and path loss empirical formulas different propagation models need to be implemented and existing models need to be improved by understanding the importance of the effects of fading and path-loss and including them in the smallest of calculations while designing a wireless communication network.

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