Wireless & Mobile Communication (EEC-801)

UNIT-I

Evolution of mobile radio communication fundamentals.Large scale path loss: propagation models, reflection, diffraction,scattering,Practical link budget design using path loss model.Small scale fading & multipath propagation and measurements,impulse response model and parameters of multipath channels.Small scale Multipath Measurements, Parameters of Mobile MultipathChannels types of small scale fading.

INTRODUCTION

Communication is one of the integral parts of science that has always been a focus point for exchanging information among parties at locations physically apart. After its discovery, telephones have replaced the telegrams and letters. Similarly, the term `mobile' has completely revolutionized the communication by opening up innovative applications that are limited to one's imagination. Today, mobile communication has become the backbone of the society. All the mobile system technologies have improved the way of living. It's main plus point is that it has privileged a common mass of society. In this chapter, the evolution as well as the fundamental techniques of the mobile communication is discussed.

EVOLUTION OF MOBILE RADIO COMMUNICATIONS

The first wire line telephone system was introduced in the year 1877. Mobile communication systems as early as 1934 were based on Amplitude Modulation (AM) schemes and only certain public organizations maintained such systems. With the demand for newer and better mobile radio communication systems during the World War II and the development of Frequency Modulation (FM) technique by Edwin Armstrong, the mobile radio communication systems began to witness many new changes. Mobile telephone was introduced in the year 1946. However, during its initial three and a half decades it found very less market penetration owing to high costs and numerous technological drawbacks.

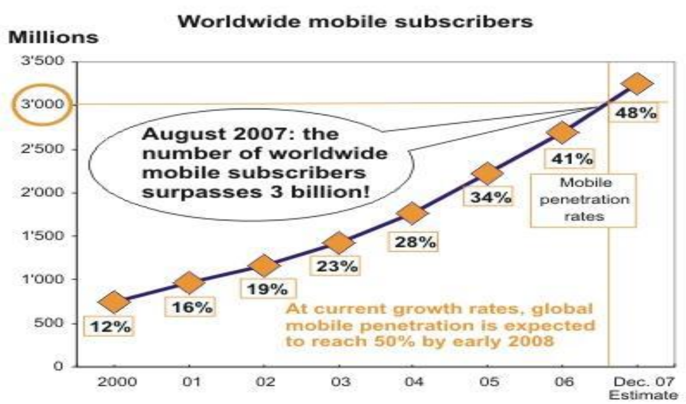


Fig: 1.The worldwide mobile subscriber chart

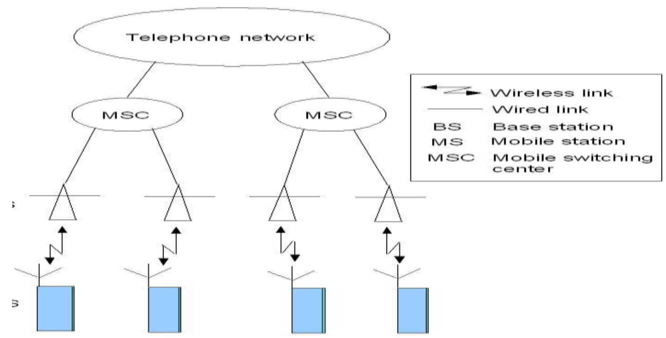


Fig. 2 Basic mobile communication structure

But with the development of the cellular concept in the 1960s at the Bell Laboratories, mobile communications began to be a promising field of expanse which could serve wider populations. Initially, mobile communication was restricted to certain official users and the cellular concept was never even dreamt of being made commercially available. Moreover, even the growth in the cellular networks was very slow. However, with the development of newer and better technologies starting from the 1970s and with the mobile users now connected to the Public Switched Telephone Network (PSTN), there has been an astronomical growth in the cellular radio and the personal communication systems. Advanced Mobile Phone System (AMPS) was the first U.S. cellular telephone system and it was deployed in 1983. Wireless services have since then been experiencing a 50% per year growth rate. The number of cellular telephone users grew from 25000 in 1984 to around 3 billion in the year 2007 and the demand rate is increasing day by day. A schematic of the subscribers is shown in Fig. 2.

MODERN WIRELESS COMMUNICATION SYSTEMS

At the initial phase, mobile Communication was restricted to certain official users and the cellular concept was never even dreamt of being made commercially available. Moreover, even the growth in the cellular networks was very slow. However, with the development of newer and better technologies starting from the 1970s and with the mobile users now connected to the PSTN, there has been a remarkable growth in the cellular radio. However, the spread of mobile communication was very fast in the 1990s when the government throughout the world provided radio spectrum licenses for Personal Communication Service (PCS) in 1.8 - 2 GHz frequency band.

- **1G: FIRST GENERATION NETWORKS**

The first mobile phone system in the market was AMPS. It was the first U.S. cellular telephone system, deployed in Chicago in 1983. The main technology of this first generation mobile system was FDMA/FDD and analog FM.Ex:-AMPS,ETACS etc.

- **2G: SECOND GENERATION NETWORKS**

Digital modulation formats were Introduced in this generation with the main technology as TDMA/FDD and CDMA/FDD. The 2G systems introduced three popular TDMA standards and one popular CDMA standard in the market. EX:-GSM,CDMA etc. These are as follows:

- **TDMA/FDD STANDARDS**
- **GLOBAL SYSTEM FOR MOBILE (GSM):**

The GSM standard, introduced by Groupe Special Mobile was aimed at designing a uniform pan-European mobile system. It was the first fully digital system utilizing the 900 MHz frequency band. The initial GSM had 200 KHz audio channels, 8 full-rate or 16 half-rate TDMA channels per carrier, encryption of speech, low speed data services and support for SMS for which it gained quick popularity.

- **INTERIM STANDARD 136 (IS-136):**

It was popularly known as North American Digital Cellular (NADC) system. In this system, there were 3 full-rate TDMA users over each 30 KHz channel. The need of this system was mainly to increase the capacity over the earlier analog (AMPS) system.

- **PACIFIC DIGITAL CELLULAR (PDC):**

This standard was developed as the Counter part of NADC in Japan. The main advantage of this standard was its low transmission bit rate which led to its better spectrum utilization.

- **CDMA/FDD STANDARD**

- **INTERIM STANDARD 95 (IS-95):**

The IS-95 standard, also popularly known as CDMA One uses 64 orthogonally coded users and code words are transmitted simultaneously on each of 1.25 MHz channels. Certain services that have been standardized as a part of IS-95 standard are: short messaging service, slotted paging, over-the-air activation (meaning the mobile can be activated by the service provider without any third party intervention), enhanced mobile station identities etc.

- **2.5G MOBILE NETWORKS**

In an effort to retrofit the 2G standards for compatibility with Increased Throughput rates to support modern Internet application, the new data centric standards were developed to be overlaid on 2G standards and this is known as 2.5G standard. Here, the main up gradation techniques are:

- supporting higher data rate transmission for web browsing
- supporting e-mail traffic
- enabling location-based mobile service

2.5G networks also brought into the market some popular application, a few of which are: Wireless Application Protocol (WAP), General Packet Radio Service (GPRS), High Speed Circuit Switched Dada (HSCSD), Enhanced Data rates for GSM Evolution (EDGE) etc.

- **3G: THIRD GENERATION NETWORKS**

3G is the third generation of mobile Phone standards and technology,superseding 2.5G. It is based on the International Telecommunication Union (ITU) family of standards under the International Mobile Telecommunications-2000 (IMT-2000).

ITU launched IMT-2000 program, which, together with the main industry and standardization bodies worldwide, targets to implement a global frequency band that would support a single, ubiquitous wireless communication standard for all countries, to provide the framework for the definition of the 3G mobile systems. Several radio access technologies have been accepted by ITU as part of the IMT-2000 framework

RADIO TRANSMISSION TECHNIQUES

Based on the type of channels being utilized, Mobile radio transmission systems may be classified as the following three categories which is also shown in Fig:

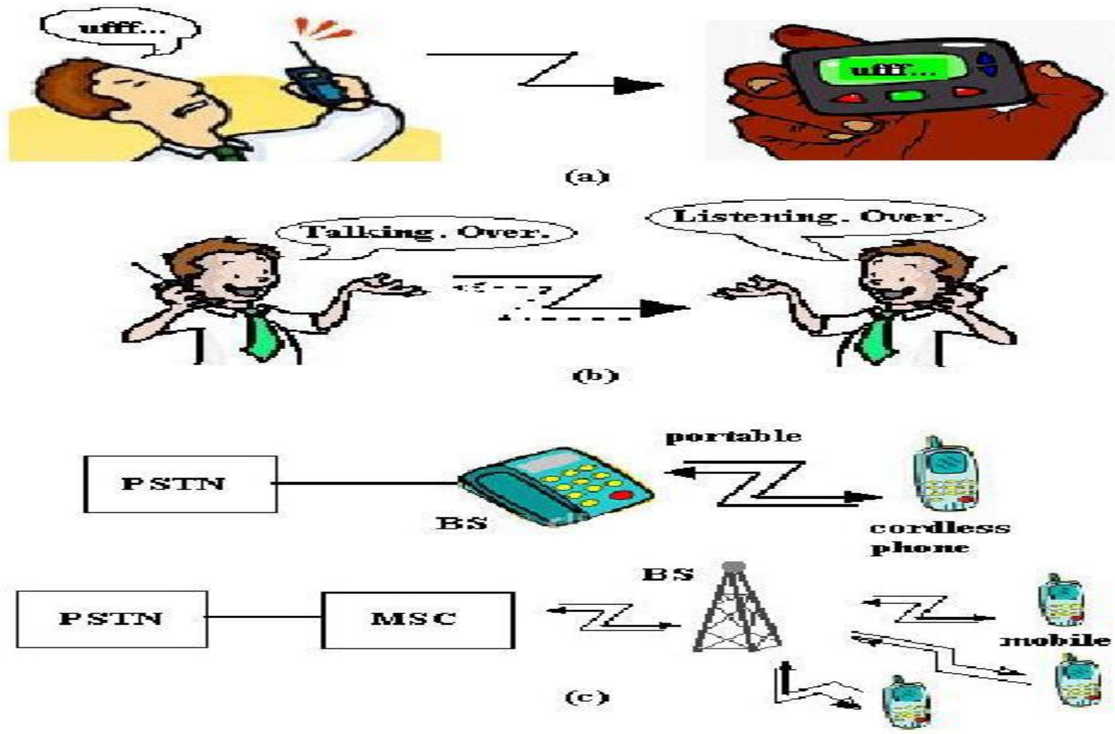


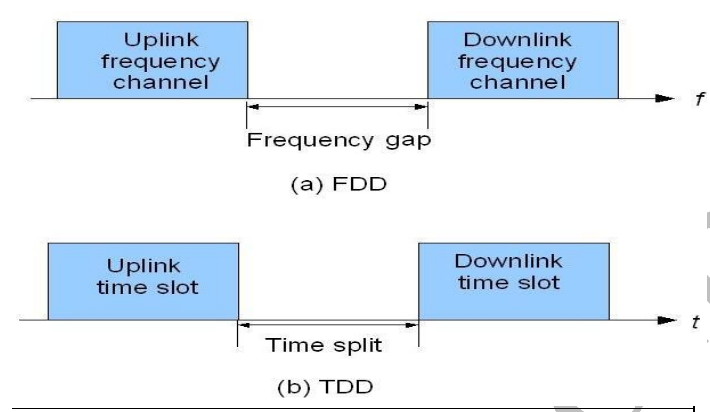
Fig:The basic radio transmission techniques:(a) simplex,(b) half duplex(c) full duplex.

- **Simplex System**: Simplex systems utilize simplex channels i.e., the communication is unidirectional. The first user can communicate with the second user. However, the second user cannot communicate with the first user. One example of such a system is a pager.
- **Half Duplex System**: Half duplex radio systems that use half duplex radio channels allow for non-simultaneous bidirectional communication. The first user can communicate with the second user but the second user can communicate to the first user only after the first user has finished his conversation. At a time, the user can only transmit or receive information. A walkie-talkie is an example of a half duplex system which uses `push to talk' and `release to Listen' type of switches.
- **Full Duplex System**: Full duplex systems allow two way simultaneous communications. Both the users can communicate to each other simultaneously. This can be done by providing two simultaneous but separate channels to both the users. This is possible by one of the two following methods.

  - **Frequency Division Duplexing (FDD):**

FDD supports two-way radio communication by using two distinct radio channels. One frequency channel is transmitted downstream from the BS to the MS (forward channel).

A second frequency is used in the upstream direction and supports transmissionfrom the MS to the BS (reverse channel). Because of the pairing of frequencies, simultaneous transmission in both directions is possible. To mitigate self-interference between upstream and downstream transmissions, a minimum amount of frequency separation must be maintainedbetween the frequency pair, as shown in Fig.



ime Division Duplexing (TDD):

TDD uses a single frequency band to transmit signals in both the downstream and upstream directions.TDD operates by toggling transmission directions over a time interval. This toggling takes place very rapidly and is imperceptible to the user. A full duplex mobile system can further be subdivided into two category: a single MS for a dedicated BS, and many MS for a single BS. Cordless telephone systems are full duplex communication systems that use radio to connect to a portable handset to a single dedicated BS, which is then connected to a dedicated telephone line with a specific telephone number on the Public Switched Telephone Network (PSTN). A mobile system, in general, on the other hand, is the example of the second category of a full duplex mobile system where many users connect among themselves via a single BS.

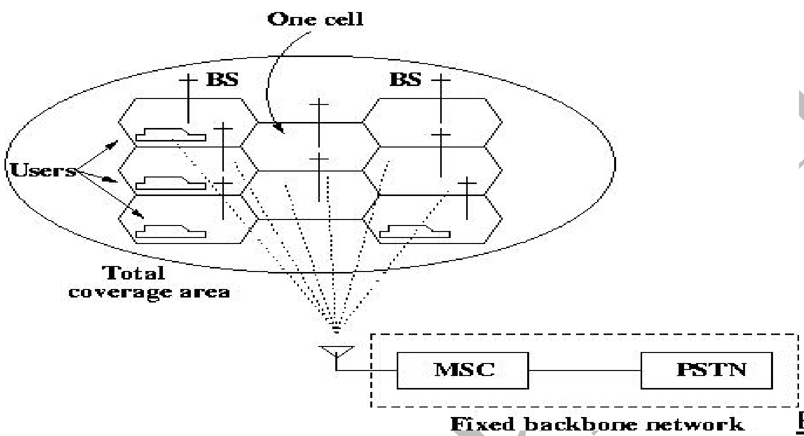


Fig. Basic Cellular Structure

BASIC METHODS OF PROPAGATION

Reflection, diffraction and scattering are the three fundamental phenomena that cause signal propagation in a mobile communication system, apart from LoS communication. The most important parameter, predicted by propagation models based on above three phenomena, is the received power. The physics of the above phenomena may also be used to describe small scale fading and multipath propagation.
The following subsections give an outline of these phenomena.

- **Reflection:**

Reflection occurs when an electromagnetic wave falls on an object, which has very large dimensions as compared to the wavelength of the propagating wave. For example, such objects can be the earth, buildings and walls. When a radio wave falls on another medium having different electrical properties, a part of it is transmitted into it, while some energy is reflected back. Let us see some special cases. If the medium on which the e.m. wave is incident is a dielectric, some energy is reflected back and some energy is transmitted. If the medium is a perfect conductor, all energy is reflected back to the first medium. The amount of energy that is reflected back depends on the polarization of the e.m. wave. Another particular case of interest arises in parallel polarization, when no reflection occurs in the medium of origin. This would occur, when the incident angle would be such that the reflection coefficient is equal to zero.

- **Diffraction**

Diffraction is the phenomenon due to which an EM wave can propagate Beyond the Horizon, around the curved earth's surface and obstructions like tall buildings. As the user moves deeper into the shadowed region, the received field strength decreases. But the diffraction field still exists and it has enough strength to yield a good signal. This phenomenon can be explained by the Huygen's principle, according to which, every point on a wave front acts as point sources for the production of secondary wavelets, and they combine to produce a new wave front in the direction of propagation. The propagation of secondary wavelets in the shadowed region results in diffraction. The field in the shadowed region is the vector sum of the electric field components of all the secondary wavelets that are received by the receiver.

- **Scattering**

The actual received power at the receiver is somewhat stronger than claimed by the Models of reflection and diffraction. The cause is that the trees, buildings and lampposts scatter energy in all directions. This provides extra energy at the receiver. Roughness is tested by a Rayleigh criterion, which defines a critical height h_c of surface protuberances for a given angle of incidence θi, given by,

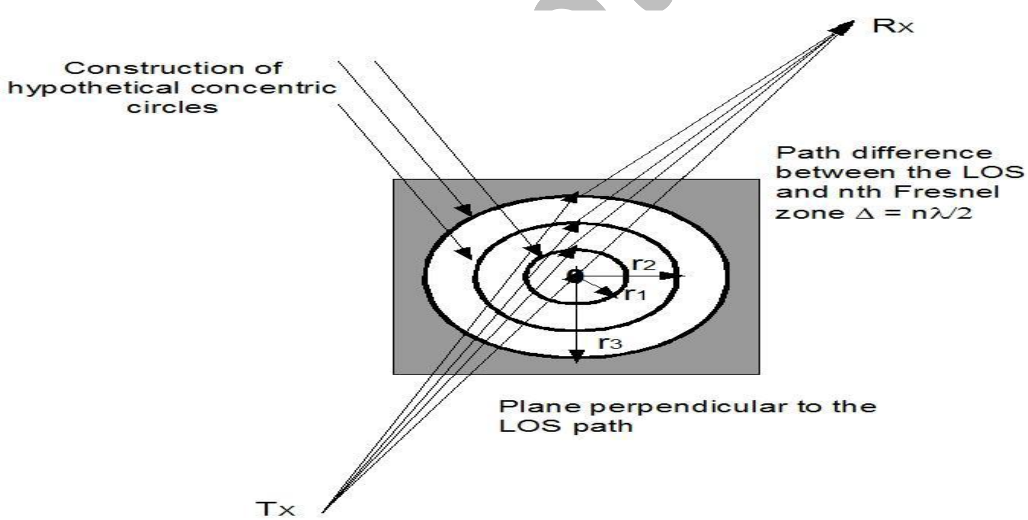
$h_c = \frac{\lambda}{8 sin\theta i}$

DIFFRACTION MODELS:

- **Fresnel Zones: the Concept of Diffraction Loss**

The more is the object in the shadowed region greater is the diffraction loss of the signal. The effect of diffraction loss is explained by Fresnel zones as a function of the path difference. The successive Fresnel zones are limited by the circular periphery through which the path difference of the secondary waves is nλ/2 greater than total length of the LOS path, as shown in Fig. Thus successive Fresnel zones have phase difference of π which means they alternatively provide constructive and destructive interference to the received the signal. The radius of the each Fresnel zone is maximum at middle of transmitter and receiver (i.e. when d1 = d2) and decreases as moved to either side. It is seen that the loci of a Fresnel zone varied over d1 and d2 forms an ellipsoid with the transmitter and receiver at its foci.

Now, if there's no obstruction, then all Fresnel zones result in only the direct LOS prorogation and no diffraction effects are observed. But if an obstruction is present, depending on its geometry, it obstructs contribution from some of the secondary wavelets, resulting in diffraction and also the loss of energy, which is the vector sum of energy from unobstructed sources. please note that height of the obstruction can be positive zero and negative also. The diffraction losses are minimum as long as obstruction doesn't block volume of the 1st Fresnel zone. As a rule of thumb, diffraction effects are negligible beyond 55% of 1st Fresnel zone.



Fresnel zones.

- **Knife-edge diffraction model:**

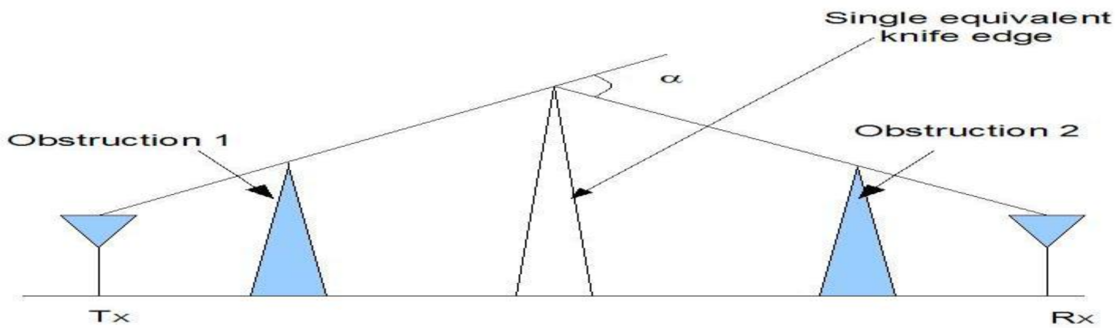
Knife-edge diffraction model is one of the simplest diffraction model to estimate the diffraction loss. It considers the object like hill or mountain as a knife edge sharp object. The electric field strength, Ed of a knife-edge diffracted wave is given by

$$\mathbf{Ed/Eo = F(v) = (1 + j)/2}\int_{v}^{\infty}(\mathbf{exp}\left(\left(-\frac{j2\pi ft}{2}\right)\right)\boldsymbol{dt}$$

The diffraction gain due to presence of knife edge can be given as

Gd(db) = 20logIF(v)I
Gd(db) = 0 v <= -1
Gd(db) = 20log(0:5 - 0:62) - 1 <=v <= 0
Gd(db) = 20log(0:5exp(-0:95v)) 0 <= v <= 1
Gd(db) = 20log(0:4 – sqrt (0:1184-(0:38 - 0:1v2))) 1 <= v <= 2:4
Gd(db) = 20log(0:225=v) v > 2:4

When there are more than one obstruction, then the equivalent model can be found by one knife-edge diffraction model as shown in Fig.



Knife-edge Diffraction Model

LINK BUDGET ANALYSIS

- **Log-distance Path Loss Model**

According to this model the received power at distance d is given by,**PL(d)(d/d0)^n = PL(dB) = PL(d0) + 10nlog(d/d0)**

The value of n varies with propagation environments. The value of n is 2 for free space. The value of n varies from 4 to 6 for obstruction of building, and 3 to 5 for urban scenarios. The important factor is to select the correct reference distance d0. For large cell area it is 1 Km, while for micro-cell system it varies from 10m-1m.

Limitations:
Surrounding environmental clutter may be different for two locations having the same transmitter to receiver separation. Moreover it does not account for the shadowing effects.

- **Log Normal Shadowing**

The equation for the log normal shadowing is given by,
PL(dB) = PL(dB) + X_ = PL(d0) + 10nlog(d/d0) + Xσ
Where X$\sigma$is a zero mean Gaussian distributed random variable in dB with standarddeviation σalso in dB. In practice n and σ values are computed from measured data.

- **Outdoor Propagation Models**

There are many empirical outdoor propagation models such as Longley-Rice model, Durkin's model, Okumura model, Hata model etc. Longley-Rice model is the most commonly used model within a frequency band of 40 MHz to 100 GHz over different terrains. Certain modification over the rudimentary model like an extra urban factor (UF) due to urban clutter near the reciever is also included in this model. Below, we discuss some of the outdoor models, followed by a few indoor models too.

MULTIPATH PROPAGATION

In wireless telecommunications, multipath is the propagation Phenomenon that results in radio signals reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric ducting, ionosphere reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings. The effects of multipath include constructive and destructive interference, and phase shifting of the signal. In digital radio communications (such as GSM) multipath can cause errors and affect the quality of communications.

MULTIPATH & SMALL-SCALE FADING

Multipath signals are received in a terrestrial environment, i.e., where different forms of propagation are present and the signals arrive at the receiver from transmitter via a variety of paths. Therefore there would be multipath interference, causing multipath fading. Adding the effect of movement of either Tx or Rx or the surrounding clutter to it, the received overall signal amplitude or phase changes over a small amount of time. Mainly this causes the fading.

Fading

The term fading, or, small-scale fading, means rapid fluctuations of the amplitudes,phases, or multipath delays of a radio signal over a short period or short travel distance. This might be so severe that large scale radio propagation loss effects might be ignored.

Multipath Fading Effects

In principle, the following are the main multipath effects:

1. Rapid changes in signal strength over a small travel distance or time interval.
2. Random frequency modulation due to varying Doppler shifts on different multipath signals.
3. Time dispersion or echoes caused by multipath propagation delays.

Factors Influencing Fading

The following physical factors influence small-scale fading in the Radio propagation channel:

(1) Multipath propagation {Multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. The effects of multipath include constructive and destructive interference, and phase shifting of the signal.

(2) Speed of the mobile {The relative motion between the base station and the mobile results in random frequency modulation due to different doppler shifts on each of the multipath components.

(3) Speed of surrounding objects {If objects in the radio channel are in motion, they induce a time varying Doppler shift on multipath components. If the surrounding objects move at a greater rate than the mobile, then this effect dominates fading.

(4) Transmission Bandwidth of the signal { If the transmitted radio signal bandwidth is greater than the \bandwidth" of the multipath channel (quantified by coherence bandwidth), the received signal will be distorted.

TYPES OF SMALL-SCALE FADING:

The type of fading experienced by the signal through a mobile Channel depends on the relation between the signal parameters (bandwidth, symbol period) and the channel parameters (rms delay spread and Doppler spread). Hence we have four different types of fading. There are two types of fading due to the time dispersive nature of the channel.

Fading Effects due to Multipath Time Delay Spread

- **Flat Fading**

Such type of fading occurs when the bandwidth of the transmitted signal is less than the coherence bandwidth of the channel. Equivalently if the symbol period of the signal is more than the rms delay spread of the channel, then the fading is at fading. So we can say that at fading occurs when **BS << BC** where BS is the signal bandwidth and BC is the coherence bandwidth. Also **TS** >>$\boldsymbol{\sigma_T}$where TS is the symbol period and $\boldsymbol{\sigma_T}$ is the rms delay spread. And in such a case,mobile channel has a constant gain and linear phase response over its bandwidth.

- **Frequency Selective Fading**

Frequency selective fading occurs when the signal Bandwidth is more than the coherence bandwidth of the mobile radio channel or equivalently the symbols duration of the signal is less than the rms delay spread.

BS >> BC and TS << σ_T

At the receiver, we obtain multiple copies of the transmitted signal, all attenuated and delayed in time. The channel introduces inter symbol interference. A rule of thumb for a channel to have at fading is if σ_T/Ts ≤ 0.1

FADING EFFECTS DUE TO DOPPLER SPREAD

- **Fast Fading**

In a fast fading channel, the channel impulse response changes rapidly within the symbol duration of the signal. Due to Doppler spreading, signal undergoes frequencydispersion leading to distortion. Therefore a signal undergoes fast fading ifTS >> TC where TC is the coherence time and BS >> BD where BD is the Doppler spread.Transmission involving very low data rates suffers from fast fading.

- **Slow Fading**

In such a channel, the rate of the change of the channel impulse response is much less than the transmitted signal. We can consider a slow faded channel a channel inwhich channel is almost constant over at least one symbol duration. Hence

TS <<TC and BS >> BD We observe that the velocity of the user plays an important role in deciding whetherthe signal experiences fast or slow fading.

IMPULSE RESPONSE MODEL OF A MULTIPATH CHANNEL

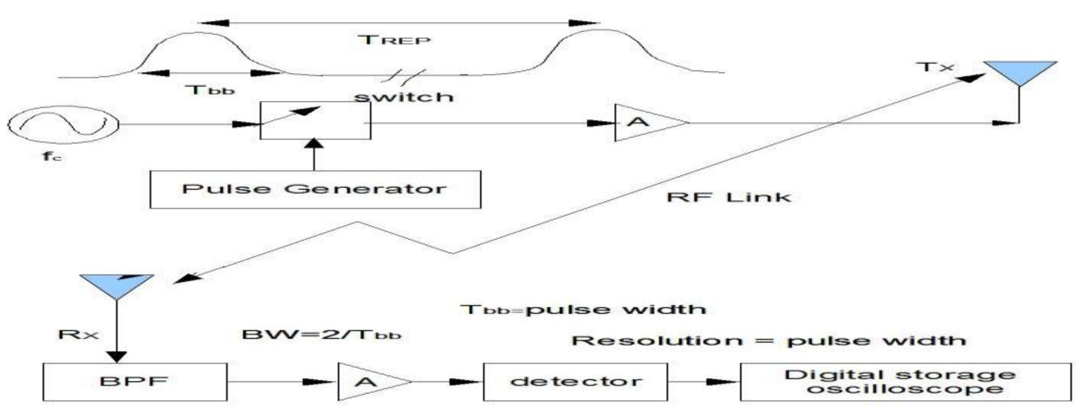
Mobile radio channel may be modeled as a linear filter with time varying impulse response in continuous time. To show this, consider time variation due to receiver motion and time varying impulse response h(d; t) and x(t), the transmitted signal. The received signal y(d; t) at any position d would be

$$\mathbf{y(d, t) = x(t) * h(d; t)} = \int_{-\infty}^{\infty} x(\tau) h(d, t-\tau) d\tau$$

SMALL-SCALE MULTIPATH MEASUREMENTS

- **Direct RF Pulse System**

A wideband pulsed bistatic radar usually transmits a repetitive pulse Of width T_{bb} s, and uses a receiver with a wide bandpass filter .The signal is then amplified, envelope detected, and displayed and stored on a high speed oscilloscope. Immediate measurements of the square of the channel impulse response convolved with the probing pulse can be taken. If the oscilloscope is set on averaging mode, then this system provides a local average power delay profile.



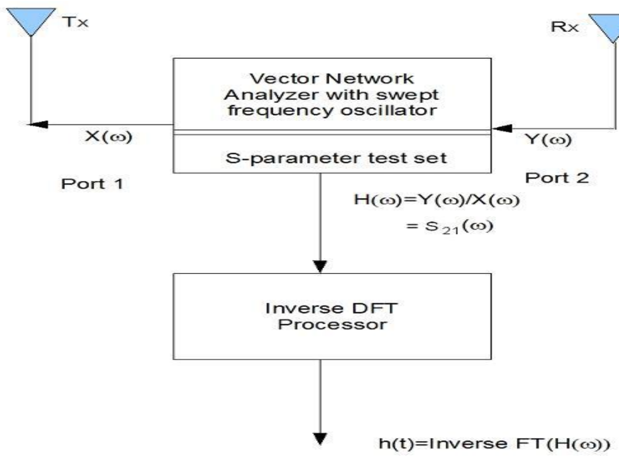
Direct RF pulsed channel IR measurement.

This system is subject to interference noise. If the first arriving signal is blocked or fades, severe fading occurs, and it is possible the system may not trigger properly.

- **Frequency Domain Channel Sounding**

In this case we measure the channel in the frequency domain and then convert it into time domain impulse response by taking its inverse discrete Fourier transform (IDFT). A vector network analyzer controls a swept frequency synthesizer. An S parameter test set is used to monitor the frequency response of the channel. The sweeper scans a particular frequency band, centered on the carrier, by stepping through discrete frequencies. The number and spacing of the frequency step impacts the time resolution of the impulse response measurement. For each frequency step, the S-parameter test set transmits a known signal level at port 1 and monitors the received signal at port 2. These signals allow the analyzer to measure the complex response, $S_{21}(w)$, of the channel over the measured frequency range. The $S_{21}(w)$ measure is the measure of the signal flow from transmitter antenna to receive antenna (i.e., the channel).

This system is suitable only for indoor channel measurements. This system isalso non real-time. Hence, it is not suitable for time-varying channels unless thesweep times are fast enough



Frequency domain channel IR measurement.

Multipath Channel Parameters

To compare the different multipath channels and to quantify them, we define some parameters. They all can be determined from the power delay profile. These parameters can be broadly divided in to two types.

- **Time Dispersion Parameters**

These parameters include the mean excess delay, rms delay spread and excess delay spread. The mean excess delay is the first moment of the power delay profile and is

$$\bar{\tau} = \frac{\sum a_k^2 \tau_k}{\sum a_k^2} = \frac{\sum P(\tau_k)\tau_k}{\sum P(\tau_k)}$$

Where a_k is the amplitude, τk is the excess delay and $P(\tau k)$ is the power of theindividual multipath signals

- **Frequency Dispersion Parameters**

To characterize the channel in the frequency domain we have the following parameters.

(1)Coherence bandwidth: It is a statistical measure of the range of frequenciesover which the channel can be considered to pass all the frequency components with almost equal gain and linear phase. When this condition is satisfied then we say the channel to be at. Practically, coherence bandwidth is the minimum separation over which the two frequency components are affected differently. If the coherence bandwidth is considered to be the bandwidth over which the frequency correlation function is above 0.9, then it is approximated as $\mathbf{BC} \approx \frac{1}{50\sigma_\tau}$

However, if the coherence bandwidth is considered to be the bandwidth over whichthe frequency correlation function is above 0.5, then it is defined as$\mathbf{BC} \approx \frac{1}{5\sigma_\tau}$

The coherence bandwidth describes the time dispersive nature of the channel in the local area. A more convenient parameter to study the time variation of the channel is the coherence time. This variation may be due to the relative motion between the mobile and the base station or the motion of the objects in the channel.

(2) Coherence time: This is a statistical measure of the time duration over which the channel impulse response is almost invariant. When channel behaves like this, it is said to be slow faded. Essentially it is the minimum time duration over which two received signals are affected differently. For an example, if the coherence time is considered to be the bandwidth over which the time correlation is above 0.5, then it can be approximated as

$$TC \approx \frac{9}{16\pi f_m}$$

Where fm is the maximum Doppler spread given be fm = v/λ another parameter is the Doppler spread (BD) which is the range of frequencies over which the received Doppler spectrum is non zero.

HOW A MOBILE CALL IS ACTUALLY MADE?

In order to know how a mobile call is made, we should first look into the basics ofcellular concept and main operational channels involved in making a call. These aregiven below.

Cellular Concept:

Cellular telephone systems must accommodate a large number of users over a large geographic area with limited frequency spectrum, i.e., with limited number of channels. If a single transmitter/ receiver is used with only a single base station, the Sufficient amount of power may not be present at a huge distance from the BS. For a large geographic coverage area, a high powered transmitter therefore has to be used. But a high power radio transmitter causes harm to environment. Mobile communication thus calls for replacing the high power transmitters by low power transmitters by dividing the coverage area into small segments, called cells. Each cell uses a certain number of the available channels and a group of adjacent cells together use all the available channels. Such a group is called a cluster. This cluster can repeat itself and hence the same set of channels can be used again and again. Each cell has a low power transmitter with a coverage area equal to the area of the cell. This technique of substituting a single high powered transmitter by several low powered transmitters to support many users is the backbone of the cellular concept.

Operational Channels

In each cell, there are four types of channels that take active part during a mobile call. These are:

- Forward Voice Channel **(FVC):** This channel is used for the voice transmission from the BS to the MS.
- Reverse Voice Channel (**RVC):** This is used for the voice transmission from the MS to the BS.
- Forward Control Channel **(FCC):** Control channels are generally used for controlling the activity of the call, i.e., they are used for setting up calls and to divert the call to unused voice channels. Hence these are also called setup channels. These channels transmit and receive call initiation and service request messages. The FCC is used for control signaling purpose from the BS to MS.
- Reverse Control Channel **(RCC**): This is used for the call control purpose from the MS to the BS. Control channels are usually monitored by mobiles.

Making a Call

When a mobile is idle, i.e., it is not experiencing the process of a call, then it searchesall the FCCs to determine the one with the highest signal strength. The mobile then monitors this particular FCC. However, when the signal strength falls below a particular threshold that is insufficient for a call to take place, the mobile again searches all the FCCs for the one with the highest signal strength. For a particular country or continent, the control channels will be the same. Soall mobiles in that country or continent will search among the same set of control channels. However, when a mobile move to a different country or continent, then the control channels for that particular location will be different and hence the mobile will not work.

Each mobile has a *mobile identification number (MIN*). When a user wants to make a call, he sends a call request to the MSC on the reverse control channel. He also sends the MIN of the person to whom the call has to be made. The MSC then sends this MIN to all the base stations. The base station transmits this MIN and all the mobiles within the coverage area of that base station receive the MIN and match it with their own. If the MIN matches with a particular MS, that mobile sends an acknowledgment to the BS. The BS then informs the MSC that the mobile is within its coverage area. The MSC then instructs the base station to access specific unused voice channel pair. The base station then sends a message to the mobile to move to the particular channels and it also sends a signal to the mobile for ringing.

In order to maintain the quality of the call, the MSC adjusts the transmitted power of the mobile which is usually expressed in dB or dBm. When a mobile moves from the coverage area of one base station to the coverage area of another base station i.e., from one cell to another cell, then the signal strength of the initial base station may not be sufficient to continue the call in progress. So the call has to be transferred to the other base station. This is called handoff. In such cases, in order to maintain the call, the MSC transfers the call to one of the unused voice channels of the new base station or it transfers the control of the current voice channels tothe new base station.