Mobile Communication Systems

Part 1 - Introduction & Principles

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Reading List

- Mobile and Data Communications Systems, D Wong, D Britland, Pub: Artech House
- Mobile Communications, A Jagoda, M DeVillepin, Pub: J. Wiley
- Mobile Information Systems, Editor: J. Walker, Pub: Artech House
- Introduction to Digital Mobile Communications, Y Akaiwa, Pub: J. Wiley
- Wireless Communications & Networks – Stallings
- Mobile Communications – Dr. J. Schiller
- 3G Wireless Demystified - Harte
- Introduction to Telecommunications - Anu Gokhale
- Mobile Communication Systems, Parsons J D and Gardiner J G, Blackie USA Halsted Press
- Digital Communications over Fading Channels, S Alouini, J Wiley, 2005

Websites:
- IEC Online Education
- How Stuff works
- Teracom Training Institute
- Telecom Writing
Contents

- Frequency Band
- History
- Principles
- Transmission Properties
- Cellular Concept
- Traffic Engineering
- Propagation
- Modulation
- Performance

Part I
Frequency Bands

- VHF (30 MHz - 300 MHz)
  - VHF Mid Band (70 - 87.5 MHz)
  - VHF High Band (148 - 174 MHz)

- UHF (300 MHz - 3 GHz)
  - UHF Band (403 - 420 MHz)
  - UHF Band (450 - 520 MHz)
  - UHF Band 900 MHz (820 - 960 MHz)
  - UHF Band 1.9 GHz (1880 - 1900 MHz)
Mobile Services

- **Private Mobile Radio (PMR) System**
  - **Conventional Mobile Radio Systems**
    - Simple two-way radio
    - Fixed frequency assignment
    - Generally no privacy
  - **Trunked Mobile Radio Systems**
    - Cellular network architecture
    - Efficient use of the frequency spectrum
    - Intelligent radio equipment

- **Cordless Telephone Systems (e.g. DECT)**
  - Analogue Cellular Phone Systems
  - Digital Cellular Phone Systems
  - Personal Communication Systems
  - Mobile Data Services
# Mobile Communications - History

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1934-</td>
<td>USA</td>
<td>AM based: 1st Generation Analogue Cellular Systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For public safety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 5000 mobiles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Vehicle ignition noise a major problem</td>
</tr>
<tr>
<td>1935</td>
<td>USA</td>
<td>FM based: Frequency bands:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 800 - 900 MHz and 400 - 500 MHz</td>
</tr>
<tr>
<td></td>
<td>Europe</td>
<td>- 120 kHz RF bandwidth, channel spacing of 30 kHz</td>
</tr>
<tr>
<td></td>
<td>Asia</td>
<td>- Data rate 5 - 10 kbps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- No of channels 400 – 1000, half-duplex</td>
</tr>
<tr>
<td>1946-</td>
<td>USA</td>
<td>First Generation Public Mobile Telephone Service:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Coverage distance: 50 km, 60 kHz bandwidth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Single powerful transmitter</td>
</tr>
</tbody>
</table>
History - 1st Generation (1G) Systems

1960  Cellular Radio, developed by Bell Labs.

1970  Cellular Mobile System (USA)

1980  First Generation Analogue Cellular Systems

- Advanced Mobile Telephone Systems (AMPS)
  - Frequency bands: 800 - 900 MHz and 400 - 500 MHz
  - Channel spacing 30 kHz and no of channels 400 – 1000
  - Data rate 5 - 10 kbps
  - FM for speech, FSK for signalling, FDM

- **Systems:**
  - 1991 First Group Special Mobile (GSM) network, Finland
  - 1992 Commercial GSM, all major European operators
  - 1992 Japanese Digital Cellular (JDC) system
  - 1993 GSM1800 system in commercial operation, UK
  - 1994 Commercial operation of D-AMPS (IS-54), US
  - U.S. Digital Cellular (USDC) and CDMA

- **Technology:** TDMA, TDMA hybrid FDMA

- **Characteristics:**
  - Digital voice and low speed data
  - Frequency band @ 900 MHz, RF channel spacing 200 kHz
  - Modulation: GMSK, DPSK, Fixed frequency assignment
  - Speech rate 13 kbps, Speech coding, TDMA
  - High security and higher capacity,
  - Improved speech Quality of service (QoS)

- **GSM 1.8 GHz, and 1.9 GHz – Circuit switching**
- **USDC 1.9 GHz**
- **Digital Cordless Systems (DCS) 1.8 GHz**

1. NEC Cellstar 500 series (1992)
5. Audiovox CDM8300 (2002)

- Support Multimedia Services:
  - Especially Internet Service, 144kb/s (Outdoor and higher velocity),
  - 384kb/s (from outdoor to indoor) and 2Mb/s (indoor);
  - Speech of QoS and other services
  - Packet switching

- First Transitional System: 2 GHz
- 2000 - 2nd Transitional Systems: 2.5 GHz
- 2001 - 1st CDMA Network @ 144 k bps
- 2002 - Handover between GSM and WCDMA by Nokia and Vodafone
- 2003 World's 1st IPv6 over 3G UMTS/WCDMA network, Ericsson
- 2003 World's 1st CDMA2000 high-speed packet data phone call (3.09 Mbps), Nokia
- 2004, World's 1st Enhanced Datarate for Global Evolution
- EDGE-WCDMA 3G packet data handover, Nokia and TeliaSonera
- 2005, 9 Mbps with WCDMA, HSDPA phase 2, Ericsson
- 2005, 1.5 Mbps enhanced uplink WCDMA system, Ericsson
Current - 3G Systems

Are referred to as:

- Universal Mobile Telecommunications System (UMTS) in Europe *
- CDMA 2000 *
- TD-SCDMA *The most common

“UMTS will be a mobile communications system that can offer significant user benefits including high-quality wireless multimedia services to a convergent network of fixed, cellular and satellite components. It will deliver information directly to users and provide them with access to new and innovative services and applications. It will offer mobile personalised communications to the mass market regardless of location, network and terminal used”.

- New technologies within the 3G networks enable significantly higher data transmission speeds than with GSM, GPRS or EDGE.

UMTS Forum 1997
the fourth mobile phone generation did not have a significant market share in 2010 from a global perspective.

LTE (Long Term Evolution) is known as a new 4G mobile phone standard, 
- Higher data speed
- Shorter latency
- Better energy efficiency
- Packet transmission
# xG - Comparison

<table>
<thead>
<tr>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analogue</td>
<td>First used in Europe in 1990s</td>
<td>Support both voice and video</td>
<td>Support both voice and high quality video</td>
</tr>
<tr>
<td>Poor voice quality</td>
<td>Digital narrowband technology – More spectrally efficient</td>
<td>Broadband capacity</td>
<td>Packet transmission</td>
</tr>
<tr>
<td>Poor battery life</td>
<td>Two standards: GSM, TDMA and CDMA</td>
<td>Uses W-CDMA and EVDO, EDGE (iPhone used it)</td>
<td>All IP - IPv6 (128 bits)</td>
</tr>
<tr>
<td>Big phone size</td>
<td>Improved battery life</td>
<td>Reduced complexity</td>
<td>High throughput (3-5 Mbps for moving devices)</td>
</tr>
<tr>
<td>No security</td>
<td>Smaller phone size</td>
<td>Higher data rates: 384 kbps – 3 Mbps</td>
<td>IEEE 802.16m</td>
</tr>
<tr>
<td>Frequent call drop</td>
<td>Improved security</td>
<td>Improved spectral efficiency: 5 MHz</td>
<td>LTE, WiMAX, WiFi</td>
</tr>
<tr>
<td>Limited capacity and range</td>
<td>Improved data rate: Up to 9.6 kbps-270 kbps</td>
<td>Higher bandwidth is still required</td>
<td>Reduced complexity</td>
</tr>
<tr>
<td>Poor hand-over</td>
<td>Improved hand-over</td>
<td>High cost of spectrum</td>
<td>Higher data rates: 20 – 300 Mbps WiFi</td>
</tr>
<tr>
<td>Different systems</td>
<td>Low transmission quality</td>
<td>Huge capacity</td>
<td>Reduced cost</td>
</tr>
<tr>
<td>Deployed in 1980s</td>
<td>Spotty coverage</td>
<td></td>
<td>Faster and more reliable</td>
</tr>
<tr>
<td></td>
<td>Not supporting video</td>
<td></td>
<td>Higher bandwidth is still required</td>
</tr>
<tr>
<td></td>
<td>Abrupt drop calls</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mobile Communications – Spectrum Allocation

- As today's cellular providers attempt to deliver high quality, low latency video and multimedia applications for wireless devices, they are limited to a carrier frequency spectrum ranging between 700 MHz and 2.6 GHz.
- As shown in Table, the global spectrum bandwidth allocation for all cellular technologies does not exceed 780 MHz, where each major wireless provider has approximately 200 MHz across all of the different cellular bands of spectrum available to them.
### Mobile Telephony Standards

<table>
<thead>
<tr>
<th>Access Standard</th>
<th>Company</th>
<th>Provides</th>
<th>What’s Coming</th>
<th>Will Provide</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDMA / TIA 95</td>
<td>Verizon</td>
<td>Voice, Data, PTT, 1xRTT</td>
<td>1XEV-DO CDMA-2000</td>
<td>300-500 kbps, to 2.4 Mbps</td>
</tr>
<tr>
<td>TDMA / TIA 136</td>
<td>Cingular / AT&amp;T</td>
<td>Voice, Data</td>
<td>Edge</td>
<td>384 kbps data</td>
</tr>
<tr>
<td>CDMA / PCS</td>
<td>Sprint</td>
<td>Voice, Data</td>
<td>1XEV-DV</td>
<td>to 3.1 Mbps</td>
</tr>
<tr>
<td>TDMA / iDEN</td>
<td>Nextel</td>
<td>Voice, Data, PTT</td>
<td>Spectrum change</td>
<td>Address public safety concern</td>
</tr>
<tr>
<td>GSM</td>
<td>T-Mobile, AT&amp;T</td>
<td>Voice, Data</td>
<td>GPRS, W-CDMA, PTT</td>
<td>115 kbps data</td>
</tr>
</tbody>
</table>

Source: IEEE
Technologies - Multimedia Messaging Service (MMS)

It send and receives:
- Text messages
- Graphics and Photos
- Audio, video clips

It supports:
- Image: GIF, JPEG,
- Video: MPEG4
- Audio: MP3, MIDI

For high transmission speed uses:
- 3G
- GPRS: General Packet Radio Service
Mobile Phone Networks

GSM 80.4% (GSM, GPRS, EDGE)
CDMA 10.3%
UMTS, HSPA 8.6%
Others 0.7%

Source: http://www.mobileworldlive.com (as of 2010)
Market forecasts show exponential growth of data traffic, most of it from indoor users.

approximately 80% of data traffic will come from indoor locations.
Most mainstream mobile and fixed mobile operators in the UK make use of the 700 MHz (TBA for 5G), 800 MHz, 900 MHz, 1800 MHz, 1900 MHz, 2100 MHz, 2.6 GHz, 3.4 GHz and 3.5 GHz radio spectrum bands. These frequencies do not strictly have to be technology specific. For example, 900 MHz use to only be for 2G services but then it was made available for 3G and operators could eventually even use it for 4G etc.
Mobile Technology - Applications

- **Transport**
  - transmission of news, road condition, weather, music via DAB
  - personal communication using GSM
  - position and tracking via GPS
  - local ad-hoc network with vehicles close-by to prevent accidents, guidance system, redundancy
  - vehicle data (e.g., from buses, high-speed trains) can be transmitted in advance for maintenance

- **Emergencies**
  - early transmission of patient data to the hospital, current status, first diagnosis
  - replacement of a fixed infrastructure in case of earthquakes, hurricanes, fire etc.
  - crisis, war, ...
Mobile Technology - Applications

- Business - Traveling salesmen
  - direct access to customer files stored in a central location
  - consistent databases for all agents/clients
  - mobile office

- Entertainment, education
  - outdoor Internet access
  - intelligent travel guide with up-to-date location dependent information
  - ad-hoc networks for multi user games

- Healthcare
  - Health Care Support
Mobile Communications - Definition

- Designed to operate over a very large area with a limited bandwidth
- A cellular mobile comms. system uses a large number of low-power wireless transmitters (100 W or less)
- Offers larger capacity through cell splitting
- Variable power levels allow cells to be sized according to subscriber density & demand within a particular region
- As mobile users travel from cell to cell, their conversations are handed off between cells
- Channels (frequencies) used in one cell can be reused in another cell some distance away
Mobile Communications - Principles

- Wave propagation mechanism is closely affected by the wavelengths of the propagating frequency
- Uses a separate radio channel to talk to the cell site
- Cell site talks to many mobiles at once, using one channel per mobile

- Channels use a pair of frequencies for:
  - forward link for transmitting from the cell site
  - reverse link for the cell site to receive calls from the users

- Radio energy dissipates over distance, so mobiles must stay near the base station to maintain communications
- Basic structure of mobile networks includes telephone systems and radio services
Internet Speed

- 384 Kbps to 20-40Mbps + downstream via the most common 3G (3rd Generation) based High Speed Packet Access (HSPA) technology
- Much faster with the latest 4G based LTE-Advanced (1000 Mbps) and future 5G (10 Gbps) services.

- Best possible theoretical download speeds by mobile standard
  
  *Basic GSM (2G) – 14.4 Kbps*
  *GPRS (2G) – 48 Kbps*
  *EDGE (2G) – 236 Kbps*
  *UMTS (3G / IMT-2000) – 384 Kbps [64 Kbps upstream]*
  *HSPA (3G / IMT-2000) – 14.4 Mbps [5.8 Mbps upload]*
  *HSPA+ (3G / IMT-2000) – 84 Mbps [22M bps upload]*
  *WiMAX 802.16e (3G / IMT-2000) – 128Mbps [56Mbps upload]*
  *LTE (3G / IMT-2000) – 100 Mbps [50 Mbps upload]*
  *WiMAX2 802.16m (4G / IMT-Advanced) – 1Gbps*
  *LTE-Advanced (4G / IMT-Advanced) – 1Gbps*
  *5G - 10Gbps*

- The current UK average download speed is just 6.1Mbps (1.6Mbps upload) for 3G and rising to 15.1Mbps (12.4Mbps upload) for 4G.
Mobile Communs. - Cellular Spectrum

Phone Transmit

<table>
<thead>
<tr>
<th>824-825 MHz</th>
<th>835 MHz</th>
<th>845 MHz</th>
<th>846.5 MHz</th>
<th>849 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>A' band</td>
<td>B band</td>
<td>A' band</td>
<td>B' band</td>
<td></td>
</tr>
<tr>
<td>A band</td>
<td>B band</td>
<td>A' band</td>
<td>B' band</td>
<td></td>
</tr>
<tr>
<td>10 MHz</td>
<td>10 MHz</td>
<td>10 MHz</td>
<td>10 MHz</td>
<td></td>
</tr>
<tr>
<td>333 channels</td>
<td>333 channels</td>
<td>333 channels</td>
<td>333 channels</td>
<td></td>
</tr>
<tr>
<td>30 kHz</td>
<td>30 kHz</td>
<td>30 kHz</td>
<td>30 kHz</td>
<td></td>
</tr>
</tbody>
</table>

1 MHz         | 1.5 MHz | 2.5 MHz |
33 chs        | 50 chan | 83 chs  |

Base Transmit

<table>
<thead>
<tr>
<th>869-870 MHz</th>
<th>880 MHz</th>
<th>890 MHz</th>
<th>891.5 MHz</th>
<th>894 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>A' band</td>
<td>B band</td>
<td>A' band</td>
<td>B' band</td>
<td></td>
</tr>
<tr>
<td>A band</td>
<td>B band</td>
<td>A' band</td>
<td>B' band</td>
<td></td>
</tr>
<tr>
<td>10 MHz</td>
<td>10 MHz</td>
<td>10 MHz</td>
<td>10 MHz</td>
<td></td>
</tr>
<tr>
<td>333 channels</td>
<td>333 channels</td>
<td>333 channels</td>
<td>333 channels</td>
<td></td>
</tr>
<tr>
<td>30 kHz</td>
<td>30 kHz</td>
<td>30 kHz</td>
<td>30 kHz</td>
<td></td>
</tr>
</tbody>
</table>

1 MHz         | 1.5 MHz | 2.5 MHz |
33 chan       | 50 chs  | 83 chs  |
Fixed Wireless Access

- Use specific frequencies of the radio spectrum to transmit their signals through the air (radio waves) and in a similar way to how mobile phone networks operate, doing away with wires.
- Most only offer very limited coverage in specific/niche areas (e.g. rural villages), although their price and performance tends to be good.
- Presently there are two primary consumer technology types:
  - **Wi-Fi (IEEE 802.11)** - is a far more domestic technology and can often be found in home networks, indoor business environments and Hotspots.
  - **WiMAX (IEEE 802.16)** - has been specifically designed for wider area high-speed networking and can even extend to Mobile Broadband operators (802.16e - see the related section linked above).

**Common Wireless Standards (Speed in Megabits):**
- *Wi-Fi 802.11a (up to 2Mbps)* - Frequency: 2.4GHz or 5GHz
- *Wi-Fi 802.11b (up to 11Mbps)* - Frequency: 2.4GHz
- *Wi-Fi 802.11g (up to 54Mbps)* - Frequency: 2.4GHz
- *Wi-Fi 802.11n (up to 600Mbps)* - Frequency: 2.4GHz or 5GHz
- *Wi-Fi 802.11ac (up to 1700Mbps)* - Frequency: 5GHz
- *Wi-Fi 802.11ac-2013 (up to 7000Mbps)* - Frequency: 5GHz
- *Wi-Fi 802.11ad (up to 7000Mbps)* - Frequency: 60GHz (short range)
- *WiMAX 802.16/d (up to 1Gbps+)* - Frequency: 2.3GHz, 2.5GHz, 2.6GHz, 3.5GHz
- *4G TD LTE (up to 1000Mbps+)* - Frequency: 3.5GHz, 3.6GHz
Mobile Comms. - System

- Mobile Unit
- Mobile Base Station
- Mobile Switching Centre
Mobile Comms. - Components

- **Mobile Base Station (MBS):** – includes
  - an antenna
  - a controller
  - a number of receivers

- **Mobile telecommunications switching office (MTSO):**
  - connects calls between mobile units

- **Channels between mobile unit and MBS:**
  - Control channels: to exchange information related to setting up and maintaining calls
  - Traffic channels: to carry voice or data connection between users
MTSO Controlled Call between Mobile Users

Steps:-
- Mobile unit initialization
- Mobile-originated call
- Paging
- Call accepted
- Ongoing call
- Handoff

Functions:-
- Call blocking
- Call termination
- Call dropping
- Calls to/from fixed and remote mobile subscriber
Mobile Radio Environment

- Propagation Path Loss
- Multipath Fading
- Frequency-Selective Fading
- Doppler Shift
- Co-Channel Interference
- Adjacent Channel Interference
- Man-Made Noise
- Urban Environment
- Suburban Environment
- Rural Environment
System Characteristics

- Frequency sharing amongst users
- Multipath interference environment
- Line-of-sight coverage (UHF)
- High base station antenna (30m)
- Low mobile antenna (1.5m - 3m)
- Beyond Line-of-sight (VHF)
- Long distance (HF)
Early Mobile Systems

- Traditional mobile similar to TV broadcasting

  One very powerful transmitter located at the highest spot would cover an area with a radius of up to 50 km.

- Cellular concept re-structured the mobile telephone network in a different way:
  - Using low power transmitters to cover larger area.
    *E.g. dividing a metropolitan region into 100 different cells, 12 channels each*
Digital Cellular- what does it offers?

- Best quality compared with analogue system

- Improved bandwidth efficiency
  - Reduced from 30 kHz to 10 kHz, and then to 5 kHz.
  - This is achieved via 3-time-slot Time Division Multiple Access (TDMA) (i.e. three pairs of people using a 30 kHz radio channel simultaneously)

- Use of micro-cellular technology to accommodate smaller and smaller cells particularly around the new frequency band of 2 GHz

- Improved frequency reuse
Transmission Types

Simplex

Tx: $f_1$
Rx: $f_2$

Half Duplex

Tx: $f_1$
Rx: $f_2$

Tx: $f_1$, Rx: $f_1$
Transmission Types - Full Duplex

Tx : $f_1$
Rx : $f_2$

Tx : $f_3$
Rx : $f_4$
Transmission - Duplex Operation

Rx ($f_1$) — Dup — Tx ($f_2$)

Antenna

Duplex Operation

Rx

Tx

Load

Transmission

Reception
Typical Wide-Area System

- Dispatcher: Communicates with the vehicles.
- Communication mode: Half Duplex.
- Mobile-to-mobile communication is possible using a Talk-Through Repeater (half-duplex) or direct using Simplex mode.
Mobile Transmission Environment

- Deep Radio Shadow + Radio Horizon
- Reflection, Refraction and Scattering
- Fading
  - Frequency-Selective
  - Multipath
- Propagation Path Loss (Attenuation)
- Doppler Shift
- Delay Distortion
- Noise and Interference
- Urban, Suburban, and Rural Environments
Radio waves at low frequencies can diffract (bend) around objects quite well.
In high-frequency wireless communications, wave diffraction does not take place well, therefore a *deep radio shadow* occurs on the un-illuminated side of the obstruction (e.g., building, hill, truck, or even human being).
Transm. Env. - Radio Horizon (1/2)

• Is 30% farther from the transmitting antenna than the equivalent visible horizon due to the reduction of the refraction in the upper atmosphere as compared to that at ground level.

*Beyond radio horizon, the signal strength falls very rapidly so that in areas well beyond the horizon the same frequency can be reused without causing interference.*

• The higher the transmitter antenna, the further away is its radio horizon.
The coverage area (not the radius) is approximately proportional to the antenna heights of both transmitter and receiver.

With a higher transmitter tower, the far flung horizon prevents close reuse of the same frequency.

Between the transmitter and horizon, in open, flat country, the received power reduces approximately as the inverse fourth power of distance from the transmitter (as we see later on).
Transmission Env. – contd.

Free space line of sight

Reflection at large obstacles
- Object size $>> \lambda$

$E_r = \alpha E_i$, where $\alpha$ is the absorption coefficient $< 1$

Scattering at small obstacles
- Object size $>> \lambda$

$E_{r1} = \alpha E_i$
$E_{r2} = \alpha E_i$
$E_{rk} = \alpha E_i$

Diffraction at edges
- Makes possible to go round corners
Dispersion: signal is dispersed over time, thus interfering with “neighbor” symbols --> Inter Symbol Interference

Distortion: signal reaches a receiver directly and phase shifted: distorted signal depending on the phases of the different parts
In a multipath propagation environment signal are:

- Generally added to strengthen the received signal
- At some point they subtract from one another, thus causing **fading**, (at approximately half wavelength intervals).
- The fade power level is typically 20 dB weaker than the local average field strength. Fades that are 40 dB weaker are not uncommon.
- The combination of shadowing and multipath fading results in a radio field that varies wildly over a short ranges (up to 60 or 70 dB difference between the maximum and minimum street level value within a 100 m2).
The strength (amplitude) of the signals reduces as it propagate through the channel. This is called signal attenuation or loss, which is due to:

- Absorption of energy
- Scattering of energy
- Limits the maximum coverage distance.
- Can be overcome by in line amplification.

High frequencies penetrates building fairly well, mostly through doors, windows, and thin non-metallic roofs. Typical mean building penetration losses are 10 to 20 dB, but penetration losses as high as 40 dB have been encountered.
Transm. Env. - Bandwidth

- All real channels have a limited bandwidth.
- Not all the frequency components of transmitted signal will pass through the channel.
- At the receiver, exact regeneration of the original signal becomes quite difficult.
- Resulting in the received signal distortion
Transm. Pro. - Delay Distortion

- Critical in complex waveform transmission, such as Digital Signals, where different frequency components of the same signal travel at slightly different speeds.

- As the propagation link increases, fast components of one bit (edges) may eventually catch up the proceeding slow moving components of the bit (flat top). Thus resulting in distortion.
Transm. Pro. - Noise & Interference

- Thermal noise
- Amplifier noise
- Man made noise
- Inter-modulation: noise from other transmitters at different frequencies
- Co-channel interference: noise from other transmitter at the same frequency
- Electromagnetic interference in a vehicle
Mobile Phones Technology - Disadvantages

Although the development of mobile phones brought convenient and advantages to the world. But the disadvantages brought along with the fast grown technology cannot be ignored. These problems not only influenced people personally but also the society at large.

- Symptoms caused by the radiation of mobile phones are:
  - headache, earaches, blurring of vision and even causing cancer. Though, these problems are still under research. Mobile phone users are advice to reduce the usage on mobile phones if it is possible.

- Mobile phone addiction.
  - Mobile phone addiction is becoming one of the biggest non-drug addictions in the 21st century in particular among the teenagers.
  - New models of mobile phones are released almost everyday. In order to get up-to-date, people tend to change their mobile phones once in a while. These became habits among the mobile phone users causing them to spend unnecessary cost on mobile bills and
Mobile Phone Technology - Future Development

- Mobile phones are getting more and more sophisticated, just like computer
- The technology is growing everyday with different functions and usage
- From the network system from mobile phones, it is still developing.
  - The new 3G system had just been launched not long ago,
  - 4G system expected in 2010. It is expected that the 4G system will be able to deliver
    • a much faster speed up to 100Mb per second during connection,
    • tighter network security
    • High quality during communication no matter on voice or video calls.
    • security system, and surveillance on certain items. The 4G system will be expected to be launched in 2010.
Mobile Phone Technology - Future Development

- Mobile phone, the piece of communication device itself is also becoming a multi functioned device. Smartphones and PDA phones are already launched in the market.
- Mobile phone with computing functions replacing lap-tops
Summary

- History
- Mobile technologies
- Principle
- Characteristics
- Transmission properties
Next Lecture

Cellular Concept