

# EE1002: Part 2

## Lecture 4



香港城市大學  
City University of Hong Kong

專業 創新 胸懷全球  
Professional · Creative  
For The World

- Mobile communication
  - Cellular network
  - Mobile phone
  - Health risks of mobile phone usage
  - Evolution of mobile communication
- Satellite communication
  - Types of satellites
  - Satellite communication
  - Global positioning system (GPS)
- Transmission lines
- Microwave waveguides

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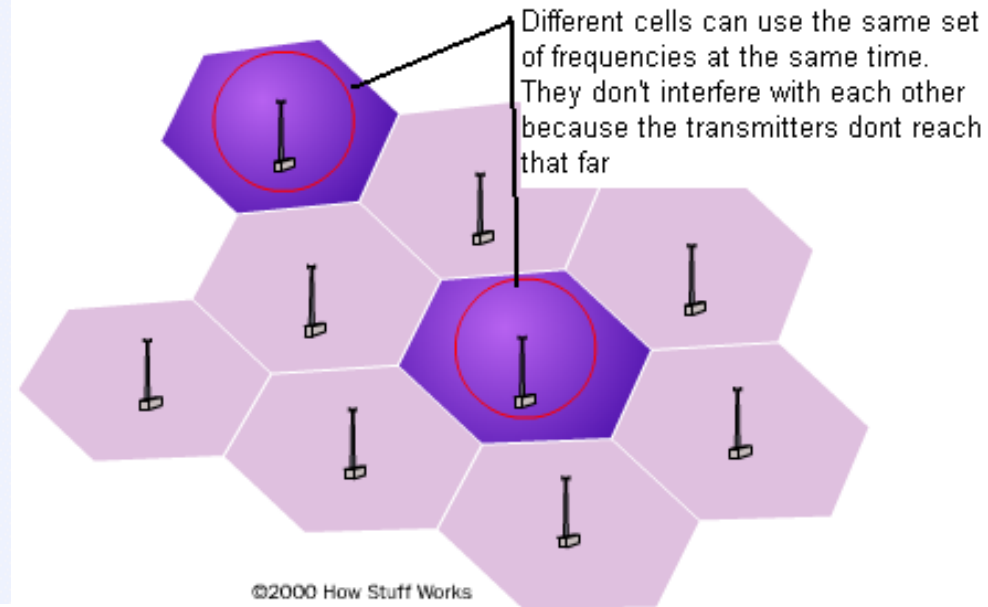
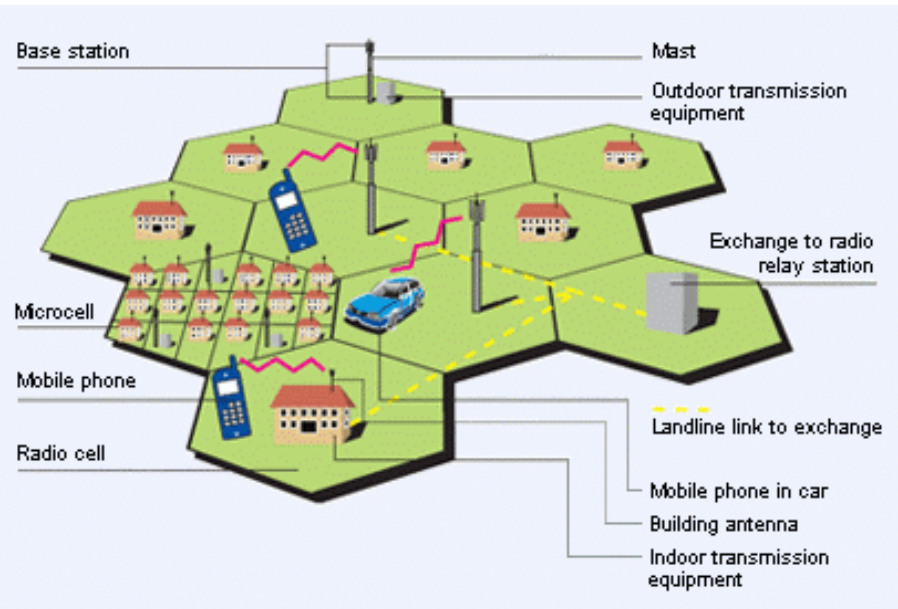
# Mobile Communication

A **mobile phone** (**cell phone**) network is a **cellular network**, where a mobile phone receives or makes calls through a cell site (base station) or a transmitting tower. Radio waves are used to transfer signals to and from the cell phone.

A cellular network divides an area into small cells, which may vary in radius from 1 to 30km. The boundaries of the cells can also overlap between adjacent cells and large cells can be divided into smaller cells. This allows extensive frequency reuse across that area, so that many people can use cell phones simultaneously. Cellular network has a number of advantages, like increased capacity, reduced power usage, larger coverage area, reduced interference from other signals etc.

[http://www.odec.ca/projects/2007/hopp7m2/Cellular\\_Phones.html](http://www.odec.ca/projects/2007/hopp7m2/Cellular_Phones.html)

# Mobile Communication



[http://www.odec.ca/projects/2007/hopp7m2/Cellular\\_Phones.html](http://www.odec.ca/projects/2007/hopp7m2/Cellular_Phones.html)

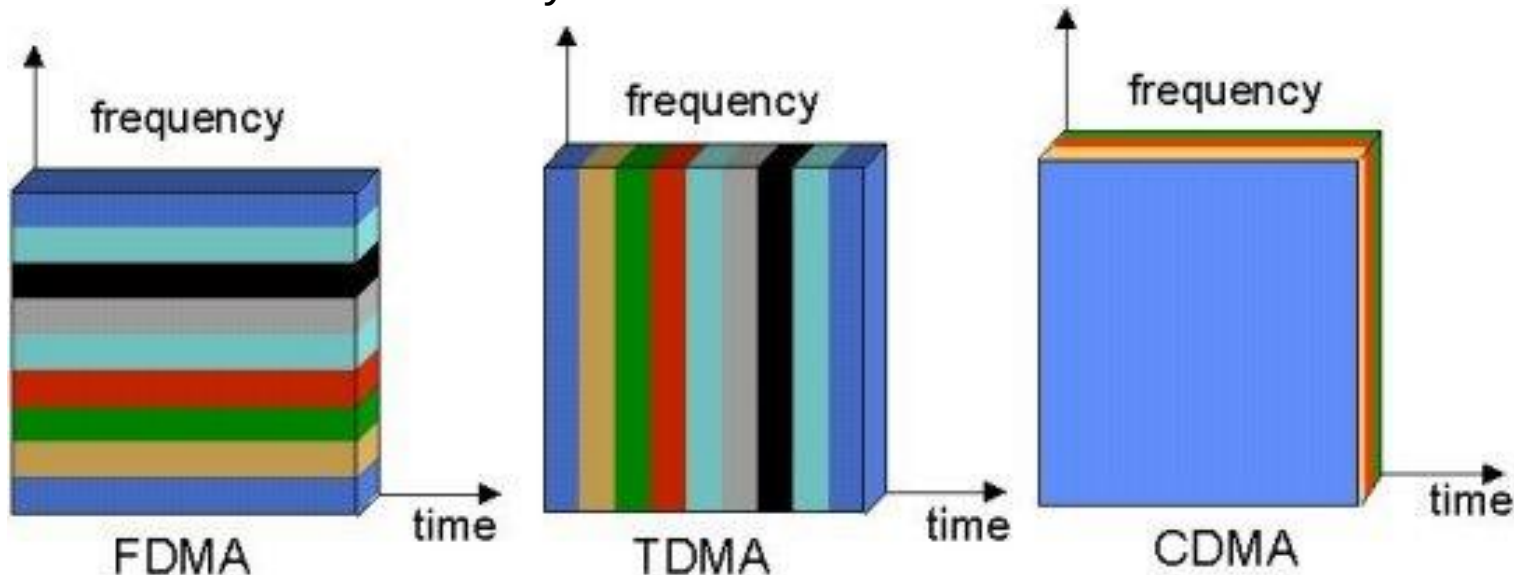
**How Mobile Phone Works (3 min)**

<https://www.youtube.com/watch?v=JepEtbbOyOU>

# Mobile Communication

## Access Schemes:

For radio systems there are two resources, frequency and time. Division by frequency, so that each pair of communicators is allocated part of the spectrum for all of the time, results in **Frequency Division Multiple Access (FDMA)**. Division by time, so that each pair of communicators is allocated all (or at least a large part) of the spectrum for part of the time results in **Time Division Multiple Access (TDMA)**. In **Code Division Multiple Access (CDMA)**, every communicator will be allocated the entire spectrum all of the time. CDMA uses codes to identify connections.



# Mobile Communication

## Mobile phone

A mobile phone is an electronic device used for mobile telecommunications over a cellular network of specialized base stations known as cell sites. A cell phone offers full **Duplex Communication** and transfer the link when the user moves from one cell to another. As the phone user moves from one cell area to another, the system automatically commands the mobile phone and a cell site with a stronger signal, to switch on to a new frequency in order to keep the link.

## SIM card (Subscriber Identification Module)

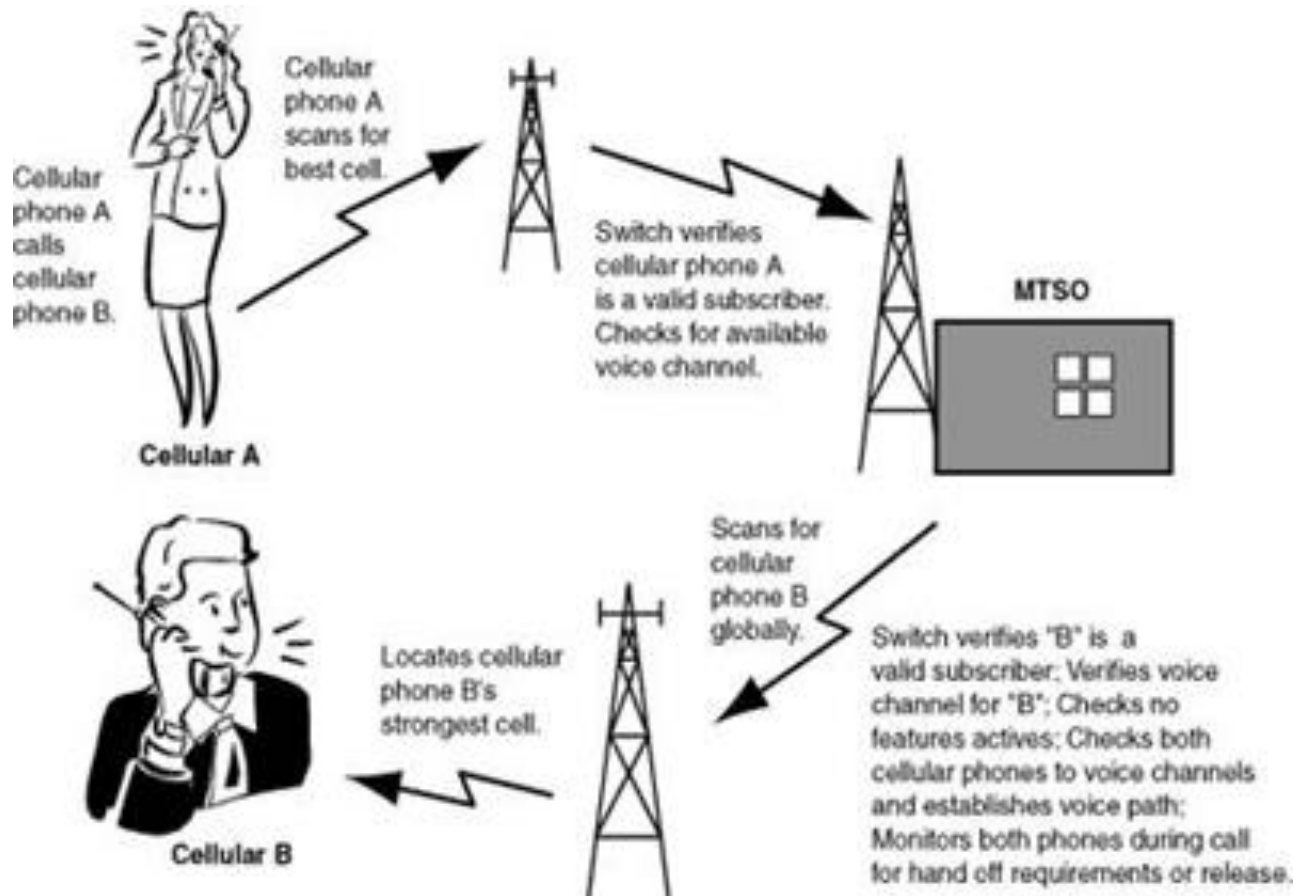
When the mobile phone is used for the first time, it sends a number called International Mobile Subscriber Identity – IMSI present in the SIM card to the network, which looks it up in a database to ensure the card is registered. If the IMSI is recognized, the network creates another number called a Temporary Mobile Subscriber Identity (TMSI), which is encrypted and sent back to the phone. In all subsequent calls, the phone identifies itself by broadcasting the TMSI.

<http://www.electroschematics.com/5231/mobile-phone-how-it-works/>

**Know about SIM card | SIM used in Mobile phone (3.5 min)**

<https://www.youtube.com/watch?v=Xm13AtTysrY>

# Mobile Communication



MTSO: Mobile Telephone Switching Office

<http://www.electroschematics.com/5231/mobile-phone-how-it-works/>

# Mobile Communication

## How Do Cell Phones Work?

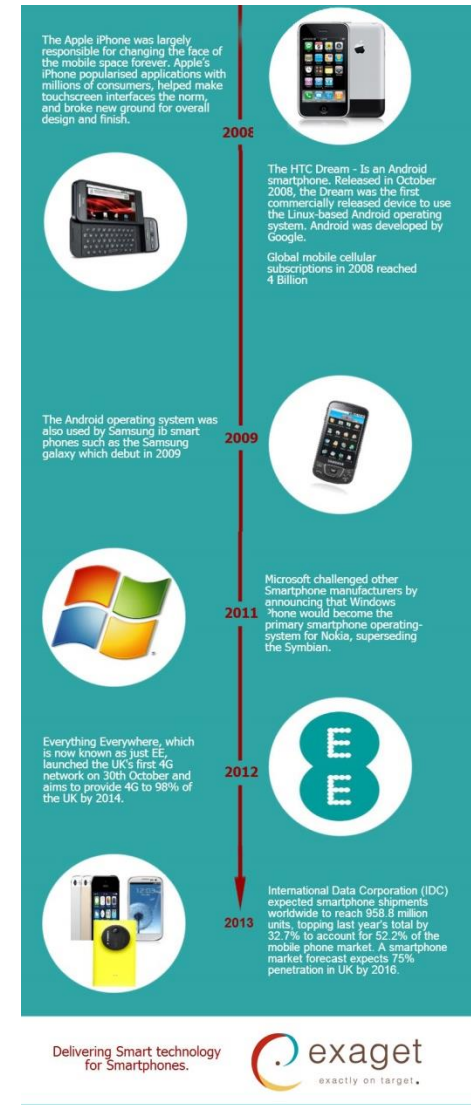
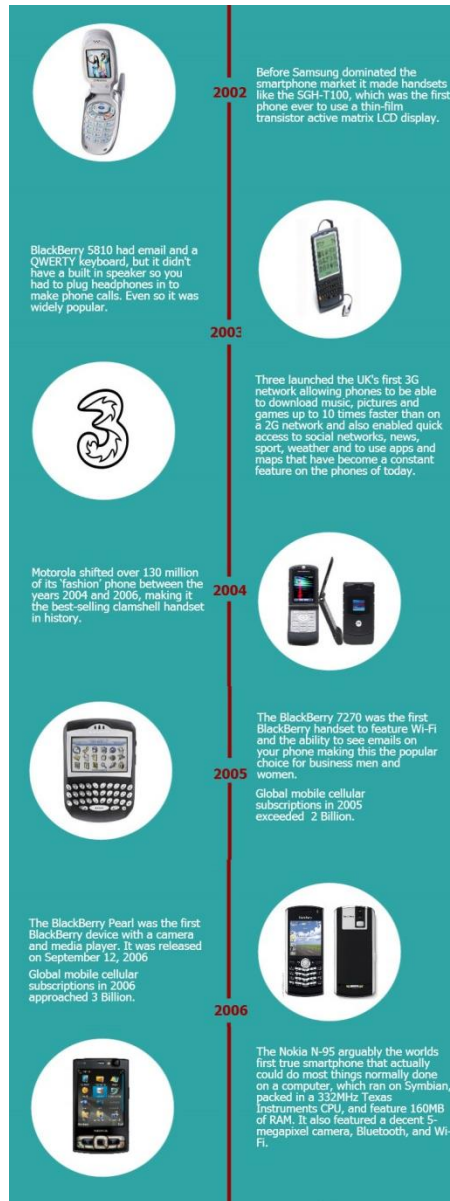
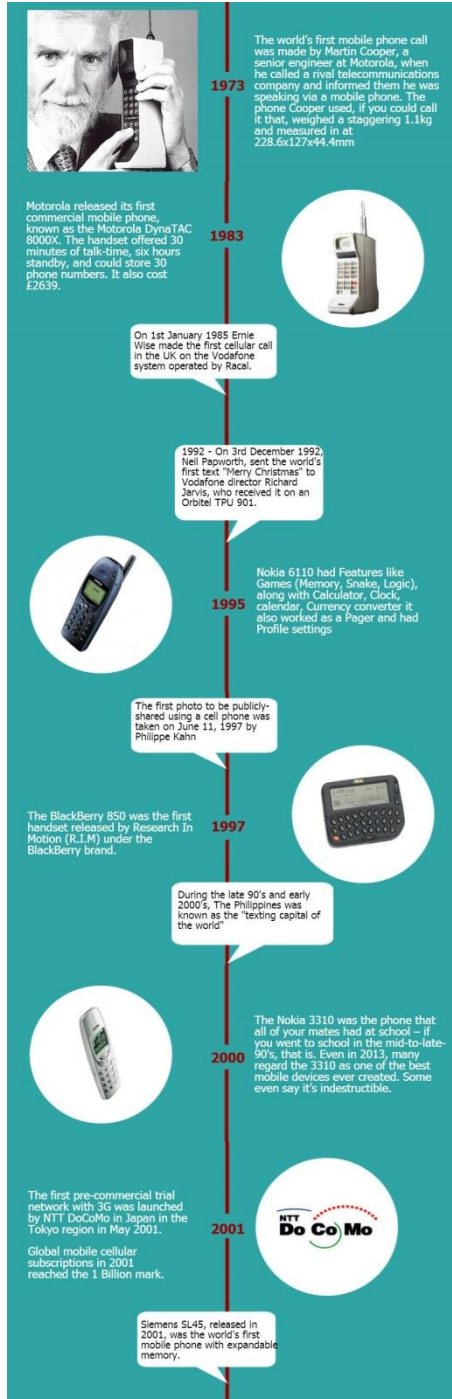
<https://www.youtube.com/watch?v=RhOKTHDHtho>

### **What happens when we make a call?**

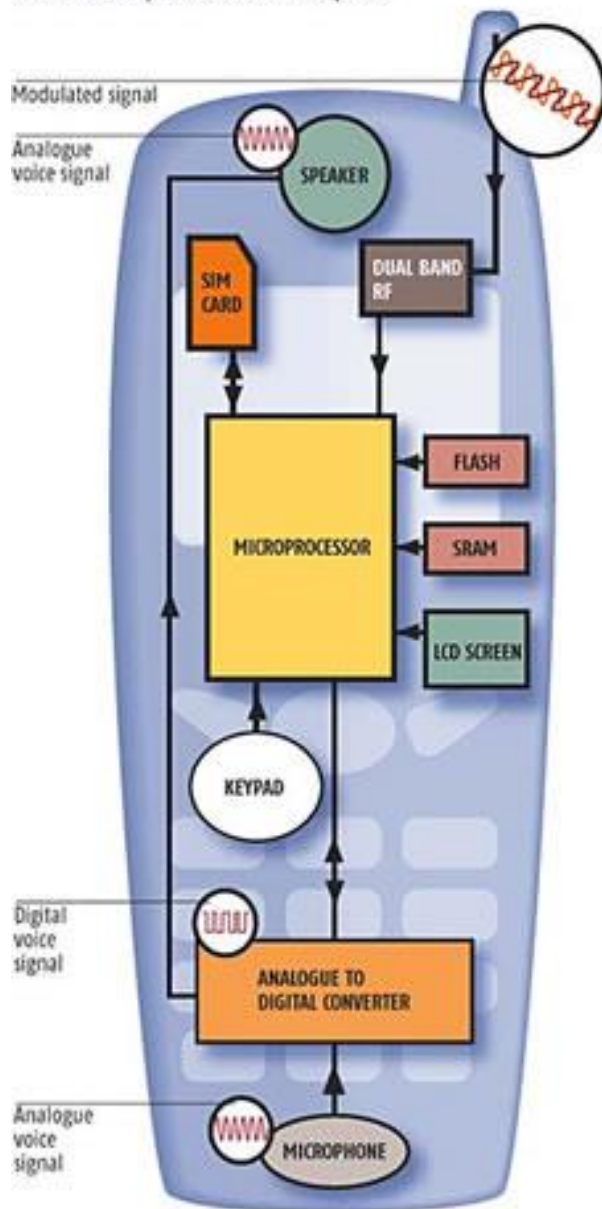
1. When we switch on the mobile phone, it tries for an SID (System Identification Code) on the control channel. The control channel is a special frequency that the phone and the base station use to talk to one another. If the mobile phone finds difficulty to get link with the control channel, it displays a “no service” message.
2. If the mobile phone gets the SID, it compares the SID with the SID programmed in the phone. If both SID match, the phone identifies that the cell it is communicating is the part of its home system.
3. The phone also transmits a registration request along with the SID and the MTSO keeps track of your phone’s location in a database. MTSO knows in which cell you are when it wants to ring the phone.
4. The MTSO then gets the signal, it tries to find the phone. The MTSO looks in its database to find the cell in which the phone is present. The MTSO then picks a frequency pair to take the call.
5. The MTSO communicates with the mobile phone over the control channel to tell it what frequencies to use. Once the mobile phone and the tower switch on those frequencies, the call is connected.
6. When the mobile phone move toward the edge of the cell, the cell’s base station will note that the signal strength is diminishing. At the same time, the base station in the cell in which the phone is moving will be able to see the phone’s signal strength increasing.
7. The two base stations coordinate themselves through the MTSO. At some point, the mobile phone gets a signal on a control channel and directs it to change frequencies. This will switch the phone to the new cell.

<http://www.electroschematics.com/5231/mobile-phone-how-it-works/>

# Evolution of Mobile Phone



<http://www.exaget.com/infograph/>

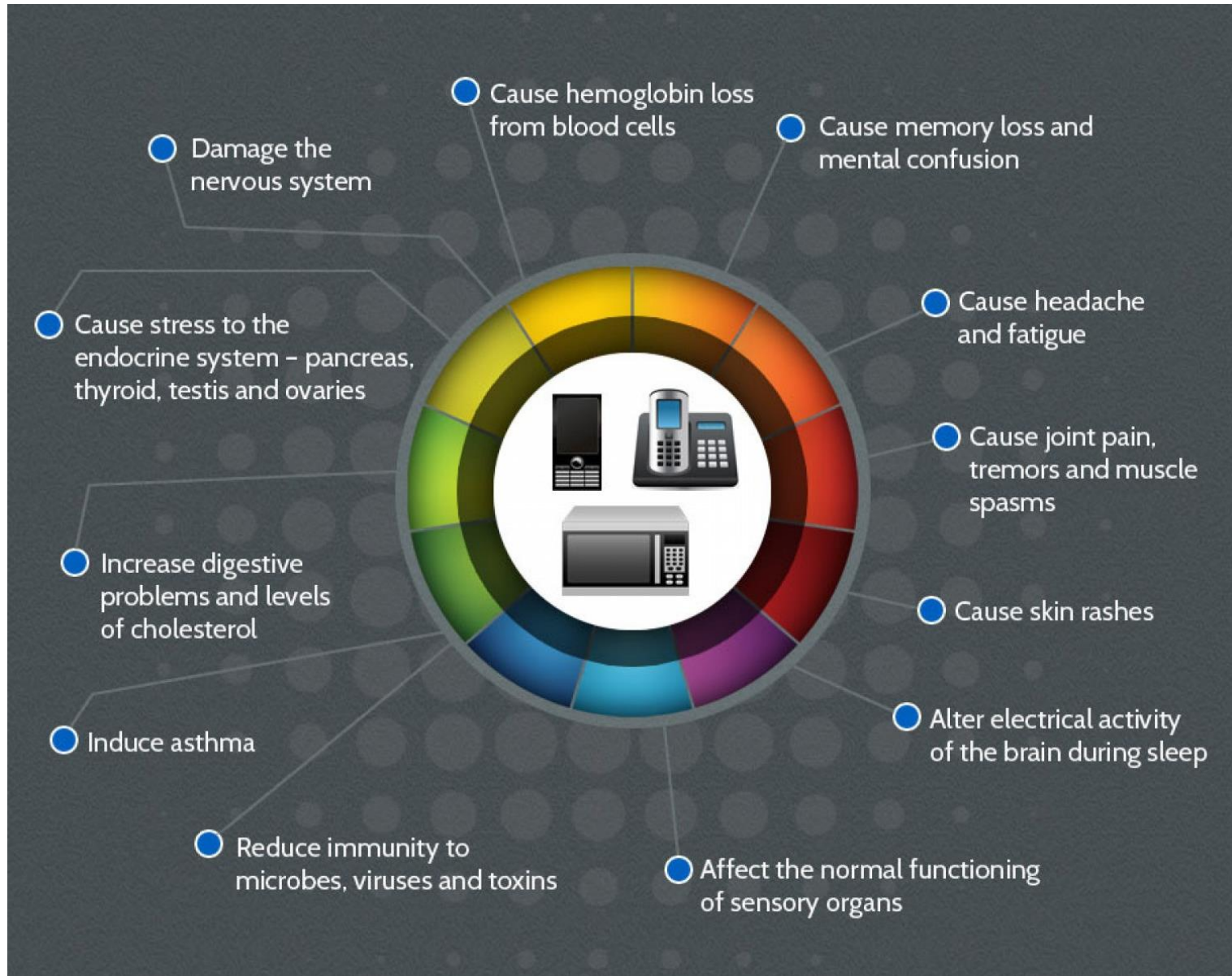


## Inside the Mobile Phone

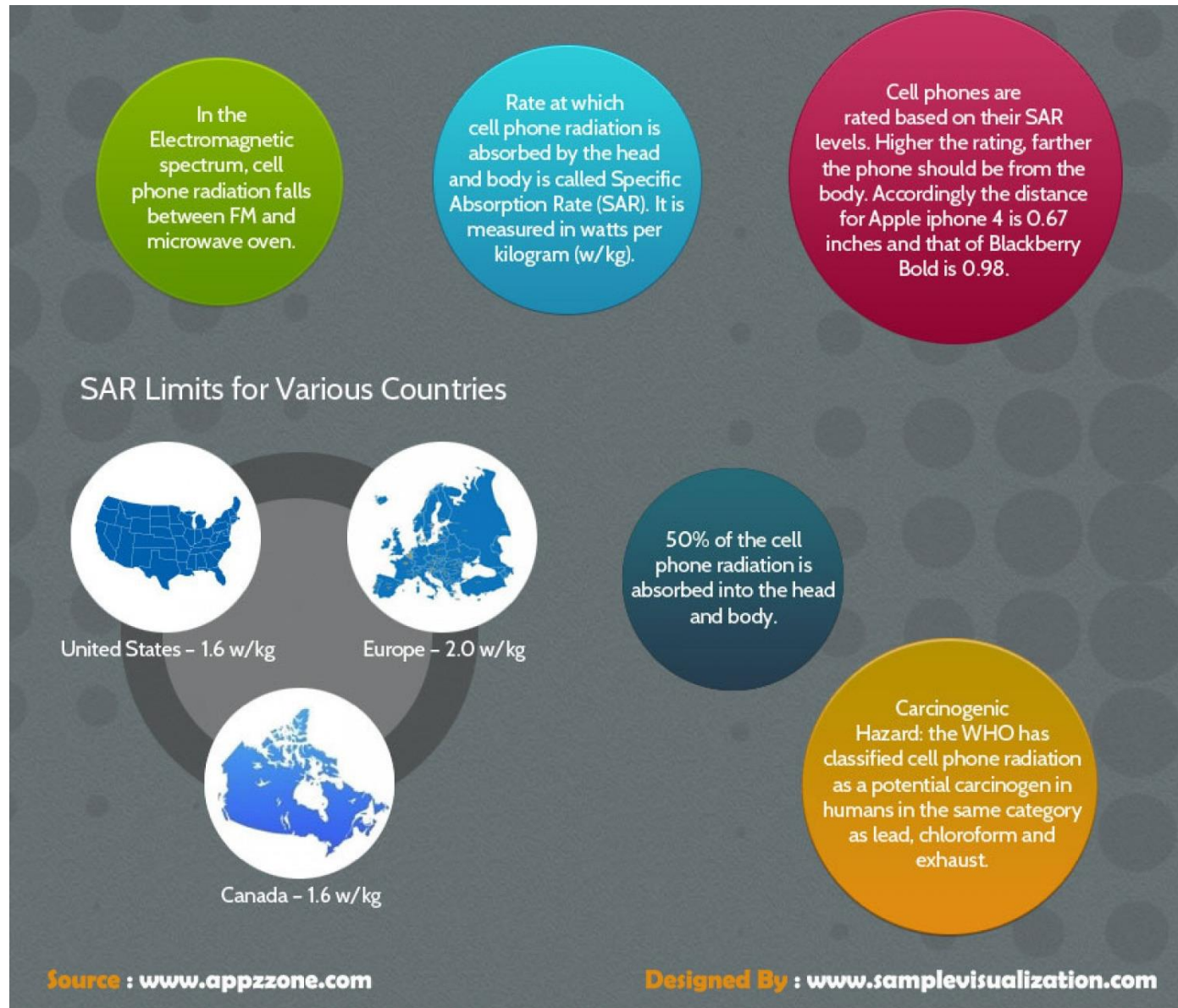
Mobile phone is a sophisticated device using SMD components, microprocessor, flash memory etc. In addition to the circuit board, mobile phone also has antenna, liquid crystal display (LCD), keyboard, microphone, speaker, and battery. The circuit board is the heart of the mobile phone. It has chips like analog-to-digital and digital-to-analog conversion chips that translate the outgoing audio signal from analog to digital and the incoming signal from digital back to analog.

By dumping our mobile phones in landfill sites, we are building up a huge collection of electronic waste. Some ingredients present in our mobile phones that can impact the environment negatively are lead, cadmium, cobalt, and mercury.

# Health Risks of Mobile Phone Usage



# Health Risks of Mobile Phone Usage



# Absorption of RF Radiation by Human Body

**Specific absorption rate (SAR)** is a measure of the rate at which energy is absorbed by the human body when exposed to RF radiation (100 kHz to 10 GHz). It is defined as the power absorbed per mass of tissue and has units of watts per kilogram (W/kg).

$$SAR = \frac{\sigma E_0^2}{2\rho} \quad \text{In W/kg}$$

where  $\sigma$  is conductivity of tissue (S/m),  $E_0$  is electric-field strength (V/m), and  $\rho$  is the density of tissue (kg/m).

## Some safety tips:

- Stay away from the phone
- Store away from body
- Dial and stretch
- Avoid use in moving vehicles
- Avoid weak signals
- Keep in flight mode when not in use
- Use safe case or no case
- Use speaker or safe headset
- Text instead of talk

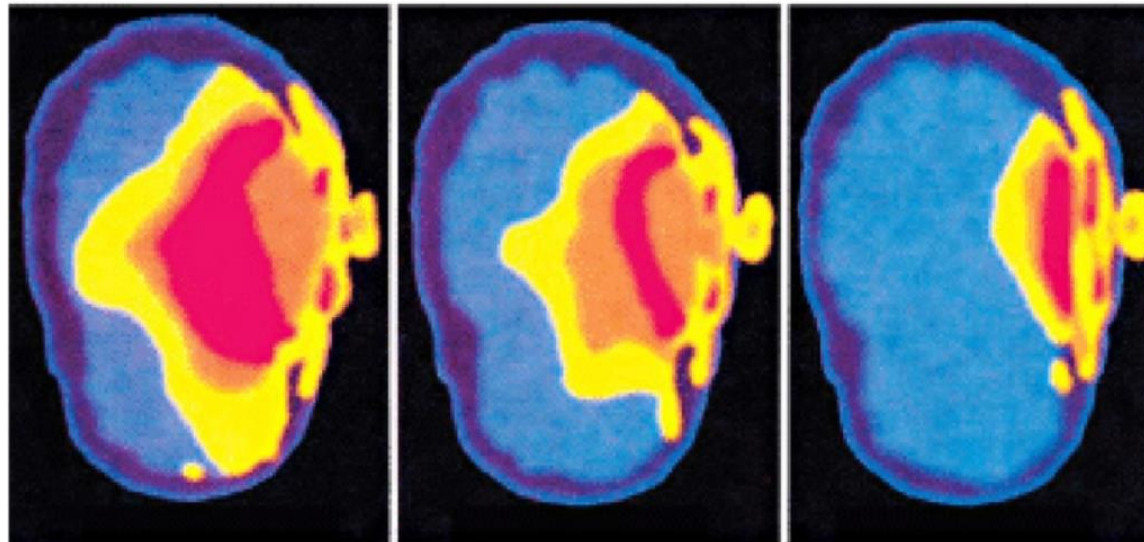
# Absorption of RF Radiation by Human Body

| Model                                                     | SAR [Body]<br>(Over 1gr) | SAR [Head]<br>(Over 1gr) | SAR [Body]<br>(Over 10gr) | SAR [Head]<br>(Over 10gr) |
|-----------------------------------------------------------|--------------------------|--------------------------|---------------------------|---------------------------|
| Limit                                                     | 1.6 W/kg                 | 1.6 W/kg                 | 2.0 W/kg                  | 2.0 W/kg                  |
| <b>iPhone 7 Plus</b><br>(A1661, A1786 /<br>A1785 / A1784) | 1.17 / 1.19 /<br>1.19    | 1.19 / 1.19 /<br>1.19    | 0.95 / 1.29 /<br>1.00     | 1.34 / 0.96 /<br>1.24     |
| <b>iPhone 7 (A1660,<br/>A1780 / A1779 /<br/>A1778)</b>    | 1.19 / 1.20 /<br>1.19    | 1.20 / 1.19 /<br>1.19    | 1.39 / 1.38 /<br>1.34     | 1.37 / 1.32 /<br>1.38     |
| iPhone SE                                                 | 1.19                     | 1.17                     | 0.99                      | 0.97                      |
| iPhone 6S                                                 | 1.14                     | 1.12                     | 0.98                      | 0.93                      |
| iPhone 6S Plus                                            | 1.14                     | 1.14                     | 0.98                      | 0.87                      |
| iPhone 6                                                  | 1.14                     | 1.08                     | 0.97                      | 0.93                      |
| iPhone 6 Plus                                             | 1.16                     | 1.14                     | 0.99                      | 0.91                      |
| iPhone 5S                                                 | 1.18                     | 1.18                     | 0.99                      | 0.93                      |
| iPhone 5C                                                 | 1.19                     | 1.19                     | 0.95                      | 0.99                      |
| iPhone 5                                                  | 1.18                     | 1.25                     | 0.95                      | 0.90                      |
| iPhone 4S                                                 | 1.19                     | 1.18                     | 0.99                      | 0.99                      |
| iPhone 4                                                  | 1.11                     | 1.17                     | 0.74                      | 0.93                      |
| iPhone 3GS                                                | 0.67                     | 1.19                     | 0.45                      | 0.40                      |

# Absorption of RF Radiation by Human Body

## **Microwave Cellphone Effects**

Absorption in the Brain According to Age



**5 Year Old**

**10 Year Old**

**Adult**

Image courtesy of Dr. Om Gandhi, University of Utah, 1996, IEE Publication

**Is Mobile Phone Radiation Harmful? (3 min)**

<https://www.youtube.com/watch?v=mWB1zRxH0Fk>

# Mobile Communication

## Different digital cellular technologies:

- Global System for Mobile Communications (GSM)
- General Packet Radio Service (GPRS)
- cdmaOne
- CDMA2000
- Evolution-Data Optimized (EV-DO)
- Enhanced Data Rates for GSM Evolution (EDGE)
- Universal Mobile Telecommunications System (UMTS)
- Digital Enhanced Cordless Telecommunications (DECT)
- Digital AMPS (IS-136/TDMA)
- Integrated Digital Enhanced Network (iDEN).

**Global System for Mobile Communications (GSM)** is the standard for mobile telephone systems in the world. In GSM, the signaling and speech channels are digital, therefore GSM is considered a 2G (Second Generation) system. Maximum distance the GSM supports is 35 kilometers. Most 2G GSM networks operate in the 900 MHz or 1800 MHz bands while 3G GSM in the 2100 MHz frequency band.



Top of a cellular radio tower



Antennas

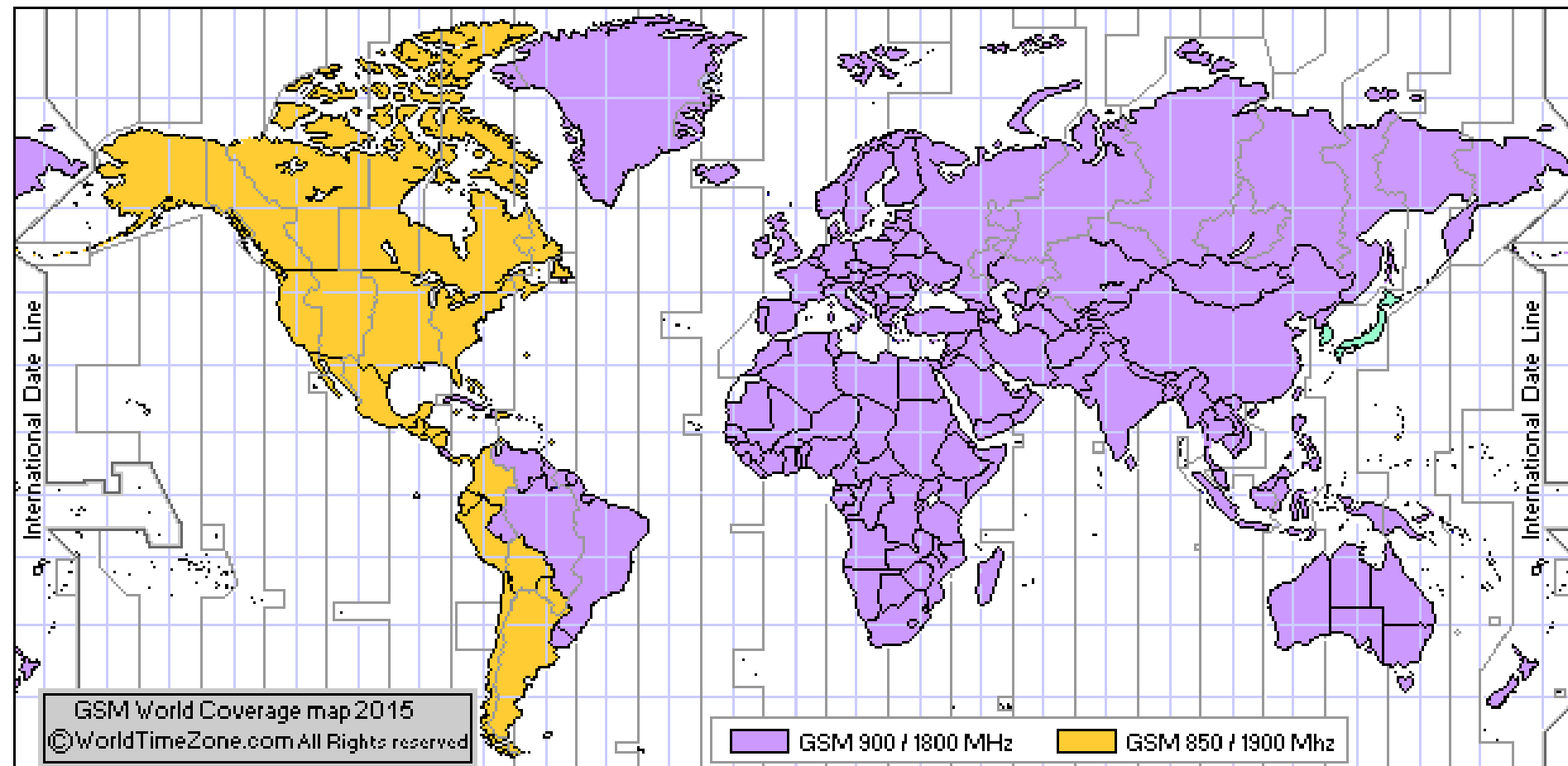
# Mobile Communication

| Attribute                | 3G                                     | 4G                                                                 |
|--------------------------|----------------------------------------|--------------------------------------------------------------------|
| Major Characteristic     | Predominantly voice- data as add-on    | Converged data and VoIP                                            |
| Network Architecture     | Wide area Cell based                   | Hybrid - integration of Wireless Lan (WiFi), Blue Tooth, Wide Area |
| Frequency Band           | 1.6 - 2.5 GHz                          | 2 - 8 GHz                                                          |
| Component Design         | Optimized antenna; multi-band adapters | Smart antennas; SW multi-band; wideband radios                     |
| Bandwidth                | 5 - 20 MHz                             | 100+ MHz                                                           |
| Data Rate                | 385 Kbps - 2 Mbps                      | 20 - 100 Mbps                                                      |
| Access                   | WCDMA/CDMA2000                         | MC-CDMA or OFDM                                                    |
| Forward Error Correction | Convolution code 1/2, 1/3; turbo       | Concatenated Coding                                                |
| Switching                | Circuit/Packet                         | Packet                                                             |
| Mobile top Speed         | 200 kmph                               | 200 kmph                                                           |
| IP                       | Multiple versions                      | All IP (IPv6.0)                                                    |
| Operational              | ~2003                                  | ~2010                                                              |

<http://www.slideshare.net/ponnu16/4g-wireless-4067732>

**4G LTE** (Long-Term Evolution)

# Mobile Communication



Hong Kong  
(SAR)

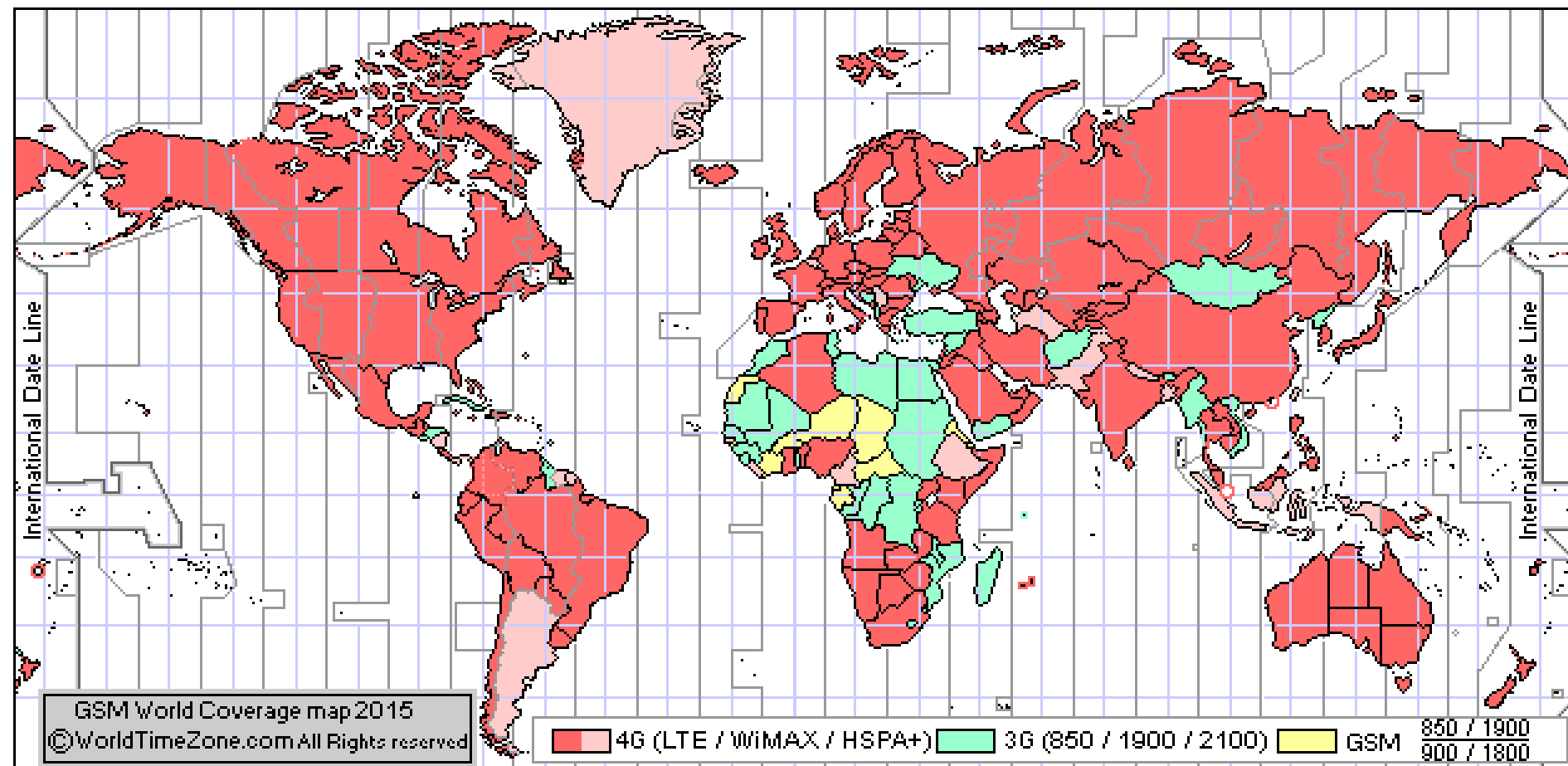
900 1800

3G 2100 CSL Ltd; 3G 2100Mhz  
HKT; 3G 900/2100Mhz Hutchison;  
3G 2100Mhz SmarTone;

4G LTE HKT 1800/2600Mhz; 4G LTE  
Hutchison 1800/2600Mhz; 4G LTE  
SmarTone 1800Mhz;

<http://www.worldtimezone.com/4g.html>

# Mobile Communication



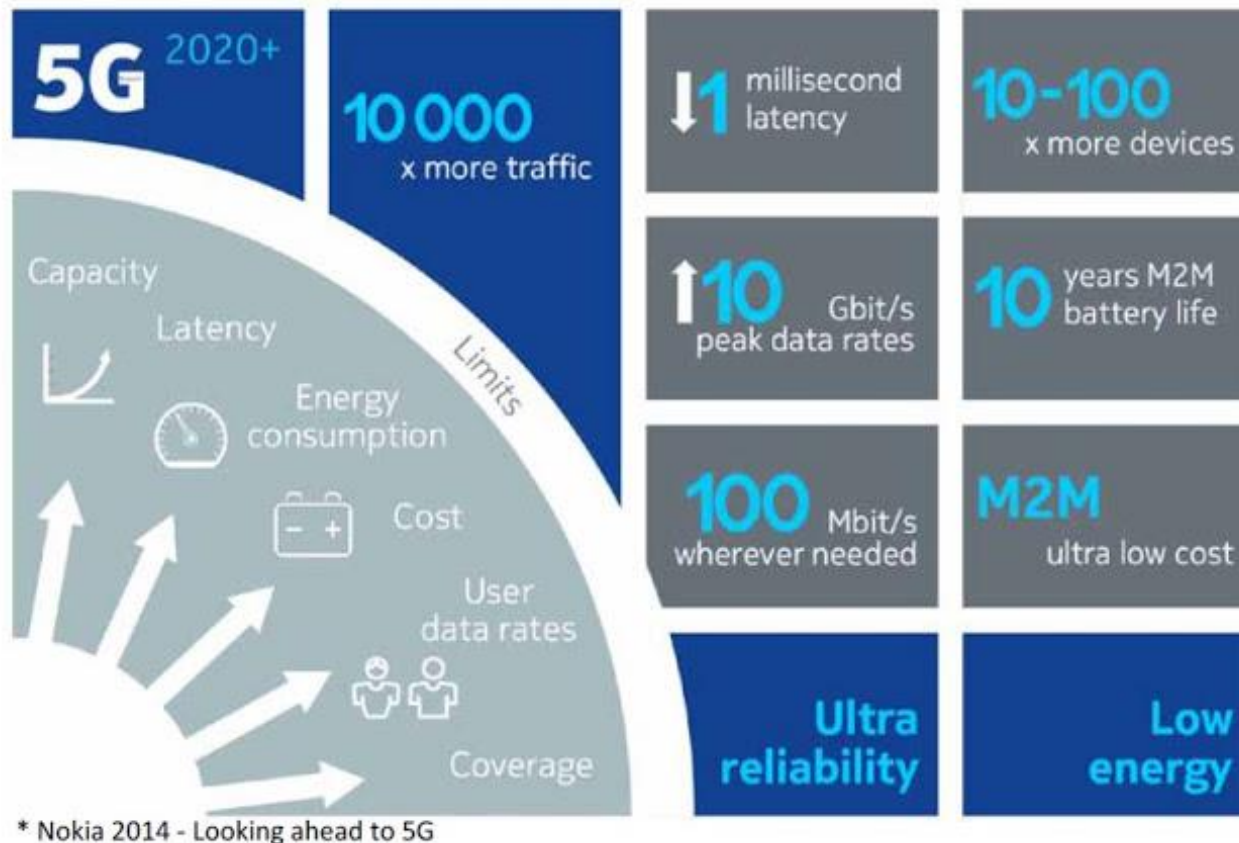
Hong Kong  
(SAR)

900 1800

3G 2100 CSL Ltd; 3G 2100Mhz  
HKT; 3G 900/2100Mhz Hutchison;  
3G 2100Mhz SmarTone;

4G LTE HKT 1800/2600Mhz; 4G LTE  
Hutchison 1800/2600Mhz; 4G LTE  
SmarTone 1800Mhz;

# Evolution of Mobile Communication



<http://www.rfpage.com/how-5g-technology-works/>

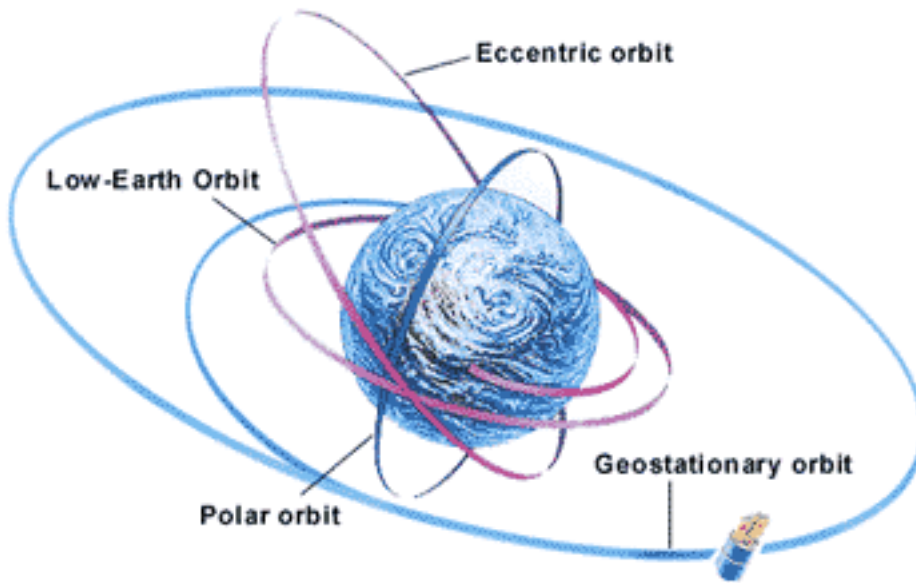
**From 1G to 4G & Towards 5G - Evolution Of Communication (11 min)**

[https://www.youtube.com/watch?v=2nsEAW\\_SirQ](https://www.youtube.com/watch?v=2nsEAW_SirQ)

**Everything You Need to Know About 5G (6 min)**

[https://www.youtube.com/watch?v=GEx\\_d0SjvS0](https://www.youtube.com/watch?v=GEx_d0SjvS0)

# Types of Satellites



## **Low Earth orbit satellites**

Satellites in low Earth orbits are normally military reconnaissance satellites that can pick out tanks from 160 km above the Earth. They orbit the earth very quickly, one complete orbit normally taking 90 minutes. However, these orbits have very short lifetimes in the order of weeks compared with decades for geostationary satellites. Simple launch vehicles can be used to place these satellites of large masses into orbit.

<http://www.telescope.org/nuffield/pas/moon/moon9e.html>

# Types of Satellites

## **Sun-synchronous orbit satellites**

Meteorological satellites are often placed in a sun-synchronous orbit. These satellites are in polar orbits. The orbits are designed so that the satellite's orientation is fixed relative to the Sun throughout the year, allowing very accurate weather predictions to be made. Most meteorological satellites orbit the Earth 15 to 16 times per day.

## **Geosynchronous satellites**

Earth-synchronous or geosynchronous satellites are placed into orbit so that their period of rotation exactly matches the Earth's rotation. They take 24 hours to make one rotation. However, the plane of orbit for these satellites is generally not the equatorial plane. The satellites are used for communications at high latitudes, particularly in Russia and Canada. The satellites are placed in highly elliptical orbits which enable them to appear to hover above one point on the Earth for most of the day.

<http://www.telescope.org/nuffield/pas/moon/moon9e.html>

# Types of Satellites

## **Geostationary satellites**

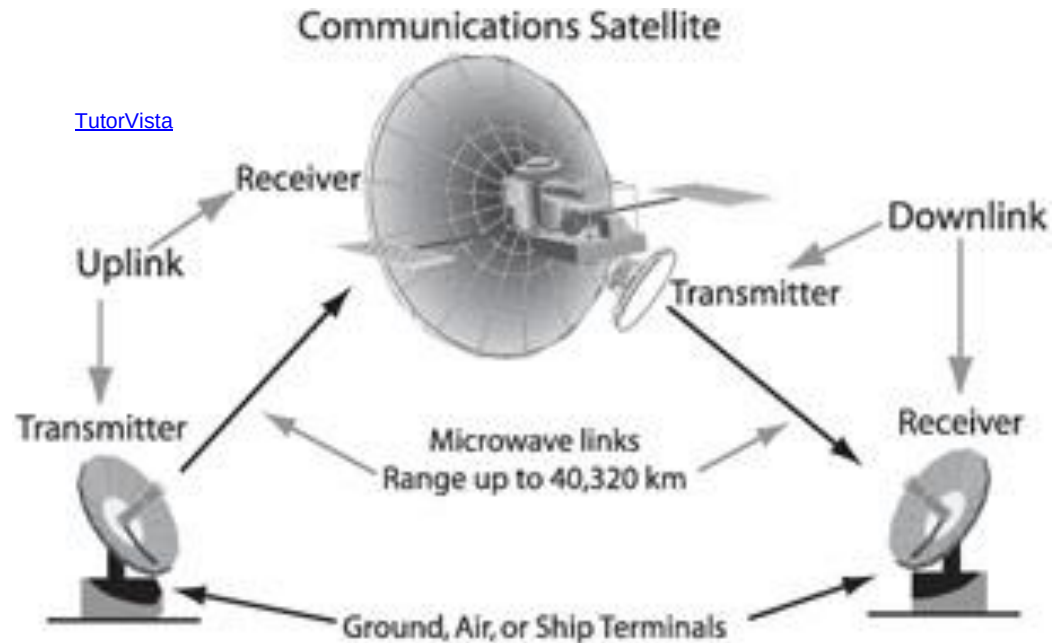
The majority of communications satellites are geostationary satellites. Geostationary satellites like geosynchronous satellites take 24 hours to complete a rotation. However, geostationary satellites are positioned directly over the equator and their path follows the equatorial plane of the Earth. As a result, geostationary satellites do not move North or South during the day and are permanently fixed above one point on the equator of the Earth. Most video or T.V. communications systems use geostationary satellites. Geosynchronous and geostationary satellites are typically orbiting at 35,788 km above the surface of the planet (42,000 km from its centre).

Modern satellites have a mass of several thousand kilograms. They are placed in space using launch vehicles like the Space Shuttle. Once in space, most satellites obtain their power from the Sun using solar panels. Satellites travelling deep into space often carry additional nuclear power supplies.

# Satellite Communication

A **communications satellite** relays and amplifies, through the use of a **transponder**, radio telecommunications signals, between a source and a receiver. Communications satellites are used for television, telephone, radio, internet, and military applications. There are over 2,000 communications satellites in Earth's orbit, used by both private and government organizations.

Passive satellites only redirect (usually via reflection) the signal coming from the source, toward the direction of the receiver. Active satellites amplify the received signal before re-transmitting it to the receiver on the ground.

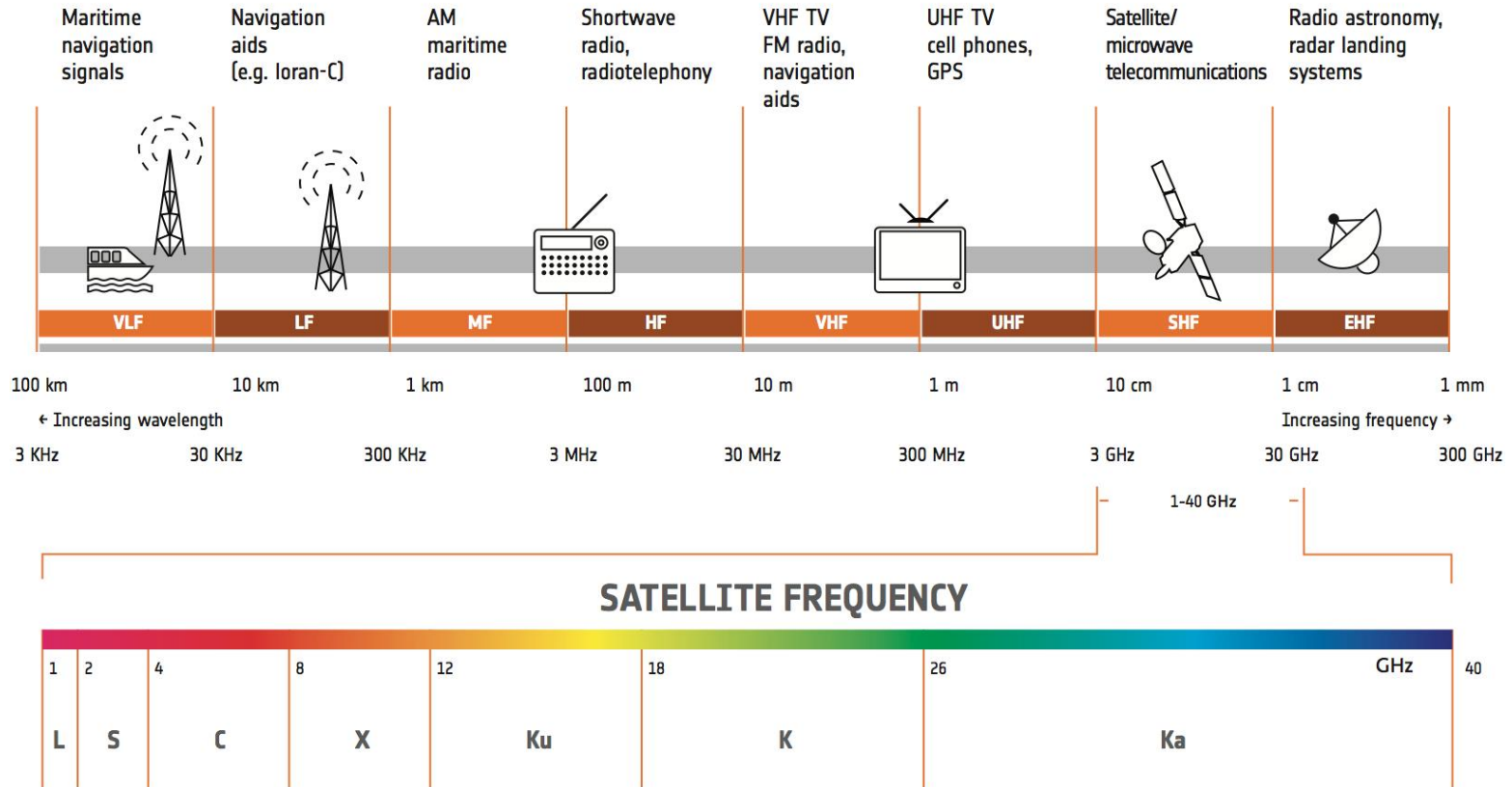


**Satellite Communication (4.5 min)**

<https://www.youtube.com/watch?v=hXa3bTcIGPU>

# Satellite Communication

## Satellite Frequency Bands



The higher frequency bands give access to wider bandwidths, but are also more susceptible to signal degradation due to the absorption of radio signals by atmospheric rain, snow or ice.

# Global Positioning System (GPS)

A position on earth's surface is determined by measuring the distances to three satellites simultaneously. For this task, GPS receivers are used, which decode the information sent by the satellite. The satellites are equipped with atomic clocks, allowing an extremely precise time measurement. The signals sent by the satellite contain encoded information on the exact moment of transmission. A receiver on earth contains a memory with the coordinates of the orbit of each satellite. This allows for the allocation of a received signal to a specific satellite and the calculation of the runtime (and thus, the distance).

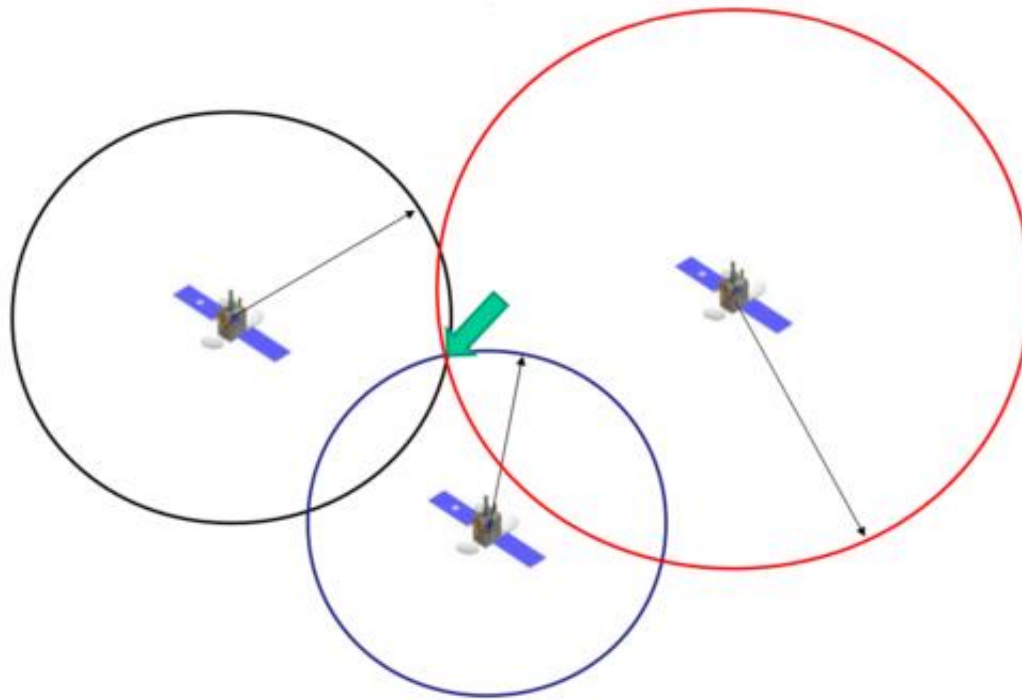
GPS satellites fly in medium Earth orbit at an altitude of 20,200 km. Each circles the Earth twice a day. As of August 17, 2015, there were 31 operational GPS satellites

[http://wiki.awf.forst.uni-goettingen.de/wiki/index.php/Global\\_Positioning\\_System\\_\(GPS\)](http://wiki.awf.forst.uni-goettingen.de/wiki/index.php/Global_Positioning_System_(GPS))

<http://www.gps.gov/systems/gps/space/>

# Global Positioning System (GPS)

A minimum of three GPS satellites (in reality, four GPS satellites) is needed for position determination. The use of more satellites can correct errors and make more precise measurements.



**How Does GPS Work? (5 min)**

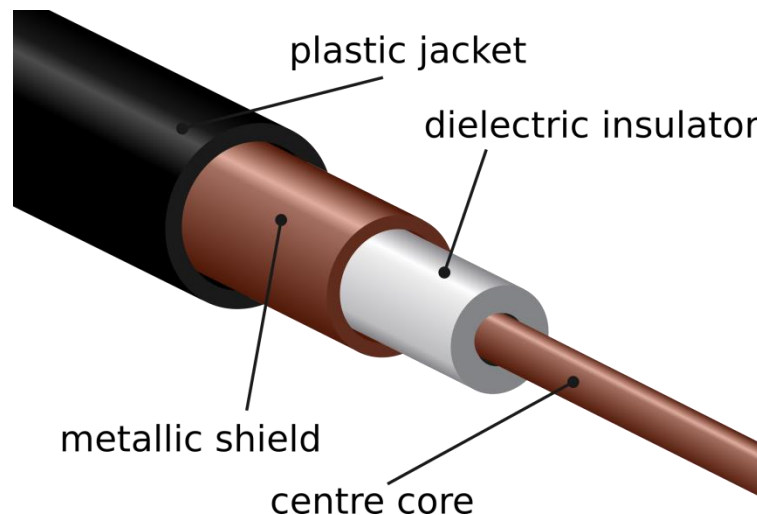
[https://www.youtube.com/watch?v=FU\\_pY2sTwTA](https://www.youtube.com/watch?v=FU_pY2sTwTA)

# Transmission Lines

**Transmission line** is a specialized cable designed to carry alternating electric current at radio frequencies. Transmission lines are used for purposes such as connecting radio transmitters and receivers with their antennas, distributing cable television signals, routing calls between telephone switching centers, computer network connections, and high speed computer data buses.

[https://en.wikipedia.org/wiki/Transmission\\_line](https://en.wikipedia.org/wiki/Transmission_line)

## Coaxial cables



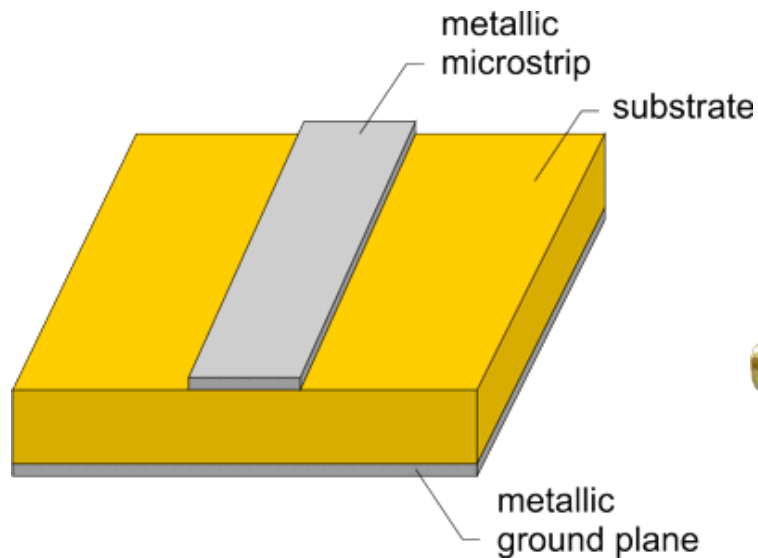
[https://en.wikipedia.org/wiki/Coaxial\\_cable](https://en.wikipedia.org/wiki/Coaxial_cable)



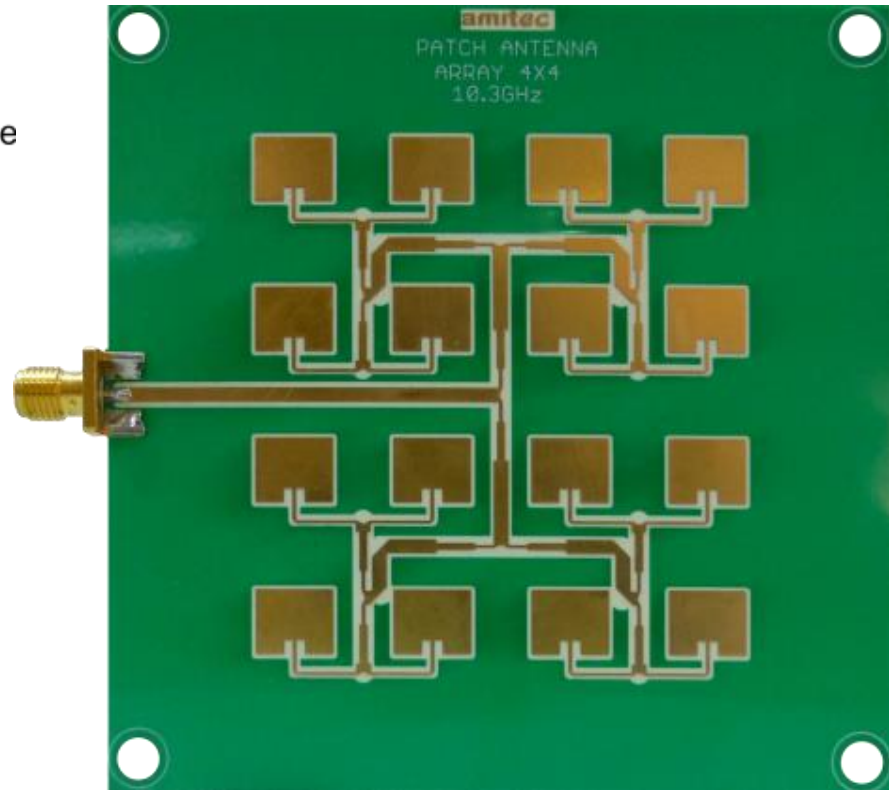
<http://www.zimexy.com/>

# Transmission Lines

A **microstrip** line feeding a patch antenna designed for operation at 10.3 GHz



[http://www.photond.com/products/fimmwave/fimmwave\\_applications\\_09.htm](http://www.photond.com/products/fimmwave/fimmwave_applications_09.htm)



<http://amitec.co/home/antenna-positioner-transmission-line/rf-microwave-antenna>

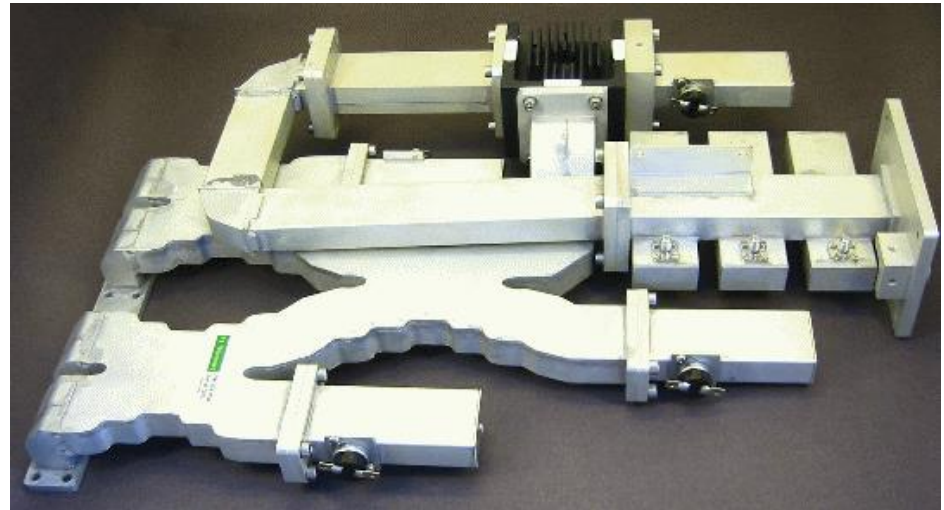
# Microwave Waveguides

**Waveguide** is a structure that conveys electromagnetic waves between its endpoints. The most common waveguide for transmitting radio waves is a hollow metal pipe. This type of waveguide is used as a transmission line mostly at microwave frequencies, for such purposes as connecting microwave transmitters and receivers to their antennas, in equipment such as microwave ovens, radar sets, satellite communications, and microwave radio links.

[https://en.wikipedia.org/wiki/Waveguide\\_\(electromagnetism\)](https://en.wikipedia.org/wiki/Waveguide_(electromagnetism))



<http://www.microwaveengservices.com/waveguide.html>



[http://www.gigacomp.de/A1Microwave\\_en.php](http://www.gigacomp.de/A1Microwave_en.php)

# Exercise

1. A 4G mobile phone operating at a carrier frequency of 2.2 GHz emits an equivalent isotropic power of 6 W to establish communication with the nearby base station. Estimate the line-of-sight distance range of the base station from the mobile phone, if the power received by the base station must be higher than  $-68$  dBm and the receiving antenna of the base station has a gain of 3 dB.
2. Consider transmitting a microwave signal to a distant receiver via a geostationary satellite, which orbits at 35788 km from the surface of the Earth. Estimate the time delay (the latency) of the signal caused by wave propagation, if the receiver is 2500 km away from the transmitter and the satellite is located directly above the receiver.
3. The average electric-field strength generated inside a human brain by a mobile phone operating at 1800 MHz is  $E_0 = 9.0$  V/m. Estimate the Specific Absorption Ratio (SAR) of the brain, given that the conductivity and the density of the brain at 1800 MHz are 1.7 S/m and  $1.030$  g/cm<sup>3</sup>, respectively.