Introduction to Wireless System

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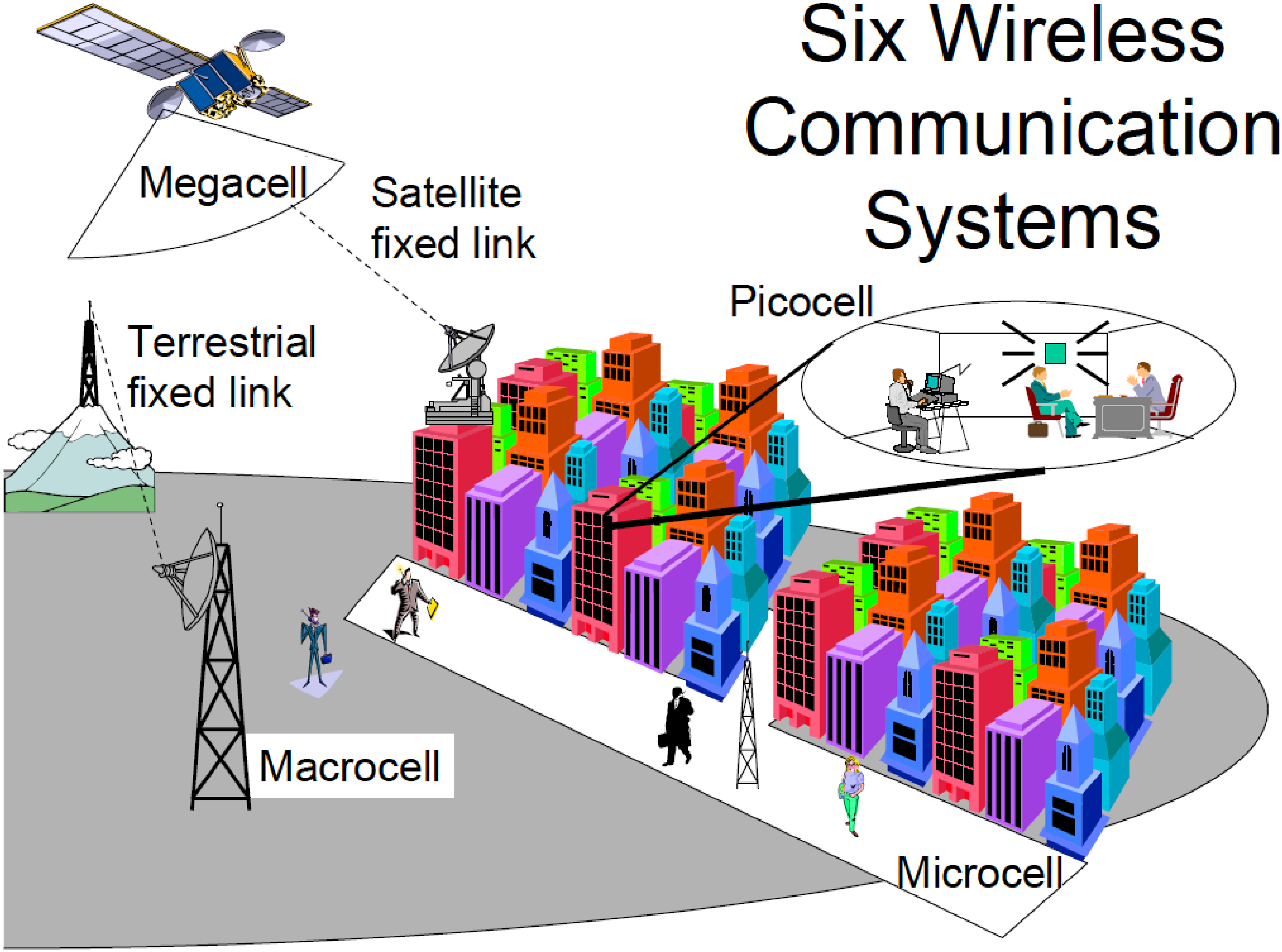
Six Wireless Communication Systems



Wireless systems

- 1980 AT&T estimate: only 900,000 users at 2000 in USA.
- 1998 the number of cellular subscribers in the United States was over 60 million (already an error of more than 6000 percent).

- Many wireless system around us:
  - DBS, Direct Broadcast Satellite
  - WLAN, wireless local area networks
  - Paging, GPS (global positioning system)
  - RFID…
  - Mobile phones

1.1 Wireless systems and markets

Classification of Wireless Systems

- Wireless system: communicate between two points without wired connection
- Sonic, infrared (but is easily blocked by even small obstructions), optical (but require a line-of-sight path), are possible media.
- Wireless system rely on RF or microwave signals in 100MHz to 30GHz.

<u>the nature and placement of the users</u>

- Point-to-point: dedicated data communication
- Point-to-multipoint: broadcast, AM, FM, LMDS
- Multipoint-to-multipoint: need base stations, mobile phone, WLAN.

1.1 Wireless systems and markets

Classification of Wireless Systems

directionality of communication

- Simplex: broadcast and TV
- Half-duplex: walkie talkie, citizen band or called "push-to-talk."
- Full-duplex: simultaneous two-way, need duplexing techniques such as FDD or TDD

ground based v.s. satellite

- GEO, geosynchronous earth orbit, 36000km
- LEO, low earth orbit, 500~2000km

according to their operating frequency.

TABLE 1.1 Wireless System Frequencies

Wireless System	Operating Frequency
Advanced Mobile Phone Service (AMPS)	T: 824–849 MHz R: 869–894 MHz
Global System Mobile (European GSM)	T: 880–915 MHz R: 925–960 MHz
Personal Communications Services (PCS)	T: 1710–1785 MHz R: 1805–1880 MHz
US Paging	931–932 MHz
Global Positioning Satellite (GPS)	L1: 1575.42 MHz L2: 1227.60 MHz
Direct Broadcast Satellite (DBS)	11.7–12.5 GHz
Wireless Local Area Networks (WLANs)	902–928 MHz 2.400–2.484 GHz 5.725–5.850 GHz
Local Multipoint Distribution Service (LMDS)	28 GHz
US Industrial, Medical, and Scientific bands (ISM)	902–928 MHz 2.400–2.484 GHz 5.725–5.850 GHz

T/R = mobile unit transmit/receive frequency.

Cellular Telephone system

The cellular radio concept introduced by Bell Laboratories solved this problem by dividing a geographical area into non-overlapping hexagonal cells, where each cell has its own transmitter and receiver (base station) to communicate with the mobile users operating in that cell.

- Cells for larger capacity
- NTT, NMT, AMPS, all use analog FM modulation

- Later changed to digital modulation

Motorola C-Netzgerät PRX-451

Details:

Netz:	C-Netz
Baujahr:	1988/89/90
Gewicht:	4170g (4,17kg)
Karte:	groß
Höhe:	345/520mm
Breite:	240mm
Tiefe:	67mm
Akku:	NI-CD
Spannung:	12V
Kapazität:	N/A
Besonderheiten:	Festeinbaugerät
	Datenfähig
Zustand:	gut
	funktionstüchtig
Bemerkung:	Bei der Abnahme der Maße wurden die Kabel nicht berücksichtigt!
Anleitung:	vorhanden

Zurück

Cellular system

These PCS standards all employ digital modulation methods and provide better quality service and more efficient use of the radio spectrum than analog systems.

Digital systems also provide more security, preventing eavesdropping through the possible use of encryption.

- PCS: personal communication system, digital modulation,
- IS-136, TDMA, IS-95, CDMA in US
- GSM in Europe and Asia
- Unified vs. non-unified standards in different region/generations.
- 3G and 3.5G systems

Cellular system

TABLE 1.2 **Major Worldwide Cellular and PCS Telephone Systems**

Standard	Country	Year of Introduction	Type	Frequency Band (MHz)	Modulation	Channel Bandwidth
NTT	Japan	1979	Cellular	860–940	FM	25 kHz
NMT-450	Europe	1981	Cellular	453–468	FM	25 kHz
AMPS	United States	1983	Cellular	824–894	FM	30 kHz
E-TACS	Europe	1985	Cellular	872–950	FM	25 kHz
C-450	Germany	1985	Cellular	450–466	FM	20 kHz
NMT-900	Europe	1986	Cellular	890–960	FM	12.5 kHz
JTACS	Japan	1988	Cellular	860–925	FM	25 kHz
GSM	Europe	1990	PCS	890–960	GMSK	200 kHz
IS-54	United States	1991	PCS	824–894	DQPSK	30 kHz
NAMPS	United States	1992	Cellular	824–894	FM	10 kHz
IS-95	United States	1993	PCS	824–894	QPSK	1.25 MHz
PDC	Japan	1993	Cellular	810–1513	DQPSK	25 kHz
NTACS	Japan	1993	Cellular	843–922	FM	12.5 kHz

Satellite system

The key advantage of satellite systems is that a relatively small number of satellites can provide coverage to wireless users at any location, including the oceans, deserts, and mountains-areas for which it would otherwise be difficult to provide service.

In principle, as few as three geosynchronous satellites can provide complete global coverage, but the very high altitude of the geosynchronous orbit makes it difficult to communicate with handheld terminals because of very low signal strength.

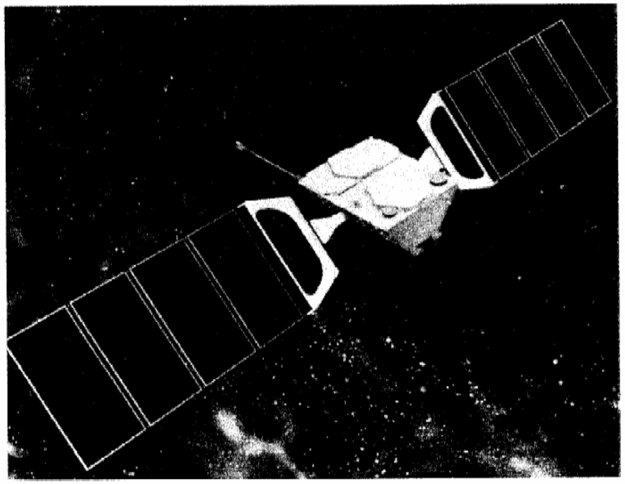
Satellites in lower orbits can provide usable levels of signal power, but many more satellites are then needed to provide global coverage.

GEO satellite systems, such as INMARSAT and MSAT, provide voice and low-data rate communications to users with 12" to 18" antennas. These systems are often referred to as very small aperture terminals (VSATs), and in 1997 were being deployed at the rate of about 1500 per month to business users

Satellite system

TABLE 1.3 Commercial Wireless Satellite Systems

System	Organization	Number of Satellites	Orbit	Operational Date
INMARSAT-M	Inmarsat	5	GEO	1996
MSAT	AMSC, TMI	2	GEO	
Iridium	Motorola	66	LEO	1998
Globalstar	Loral, Qualcomm	48	LEO	2000
ICO Global	Hughes	10	MEO	2000
Odyssey	TRW	12	MEO	2000



Satellite system

Iridium, financed by a consortium of companies headed by Motorola, was the first commercial satellite system to offer handheld wireless telephone service. It consisted of 66 LEO satellites in near-polar orbits. The Iridium system cost was approximately $3.4 B, and it began service in 1998.

Globalstar, proposed by Lord and Qualcomm, is another LEO satellite system intended for wireless telephone, fax, and paging. This system uses 48 satellites to provide global coverage, and became operational in 2000.

One drawback of using satellites for telephone service is that weak signal levels require a line-of-sight path from the mobile user to the satellite. It cannot be used in buildings, automobiles, or even in many wooded or urban areas.

An even greater problem with satellite phone service is the expense of deploying and maintaining a large fleet of LEO satellites, making it very difficult to compete economically with land-based cellular or PCS service. The typical cost of a cellular or PCS call is $0.10 to $0.20 per minute, while in 1999 the estimated cost of a call placed through the Iridium or Globalstar satellite was about $2.00 per minute.

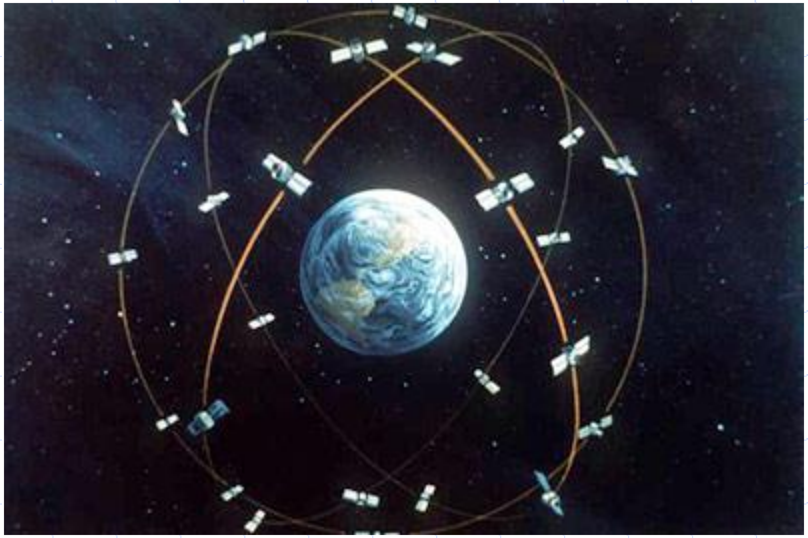
In August 1999 both Iridium LLC and the ICO Global Communications companies *declared bankruptcy.*

SNG: satellite news gathering

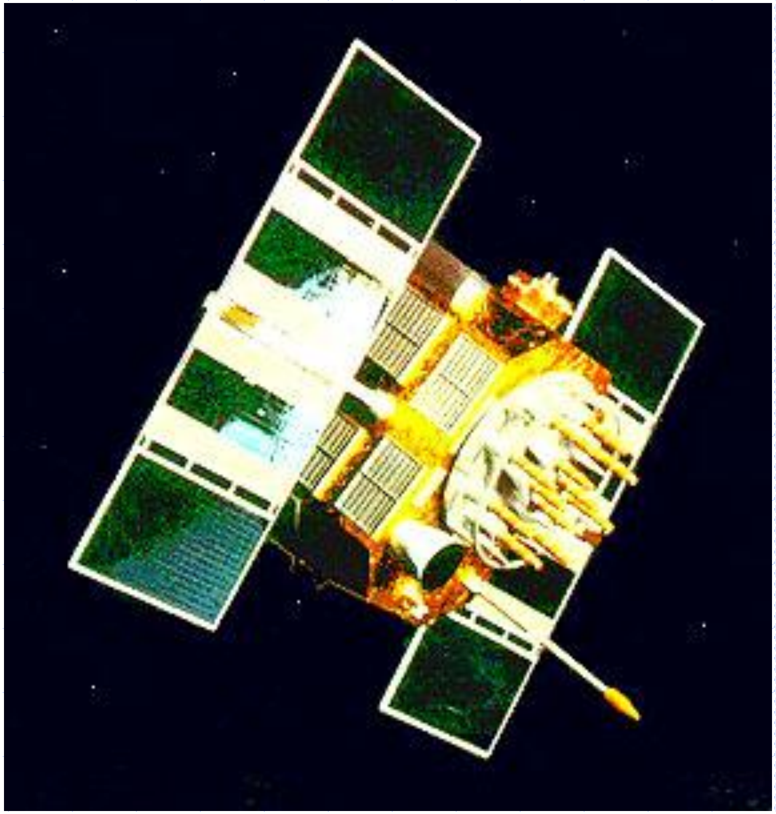
Satellite communication in 921 earth quake

Global Positioning Satellite System

- **http://electronics.howstuffworks.com/gps.htm**

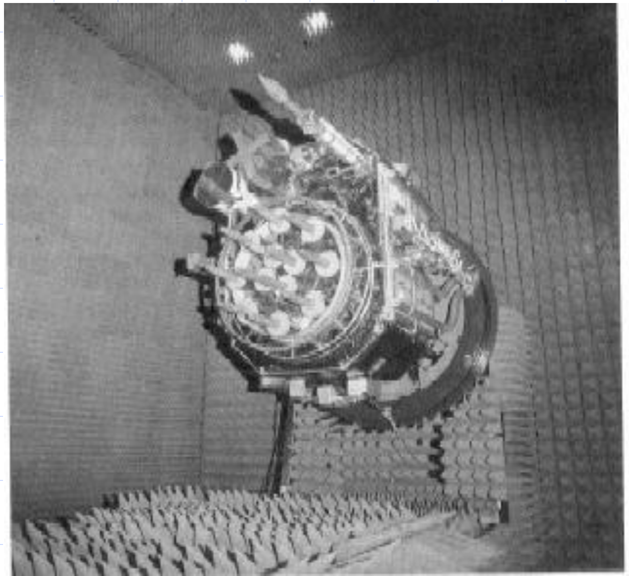


- **Built by U.S. Army for military purpose, later allowed for commercial use.**



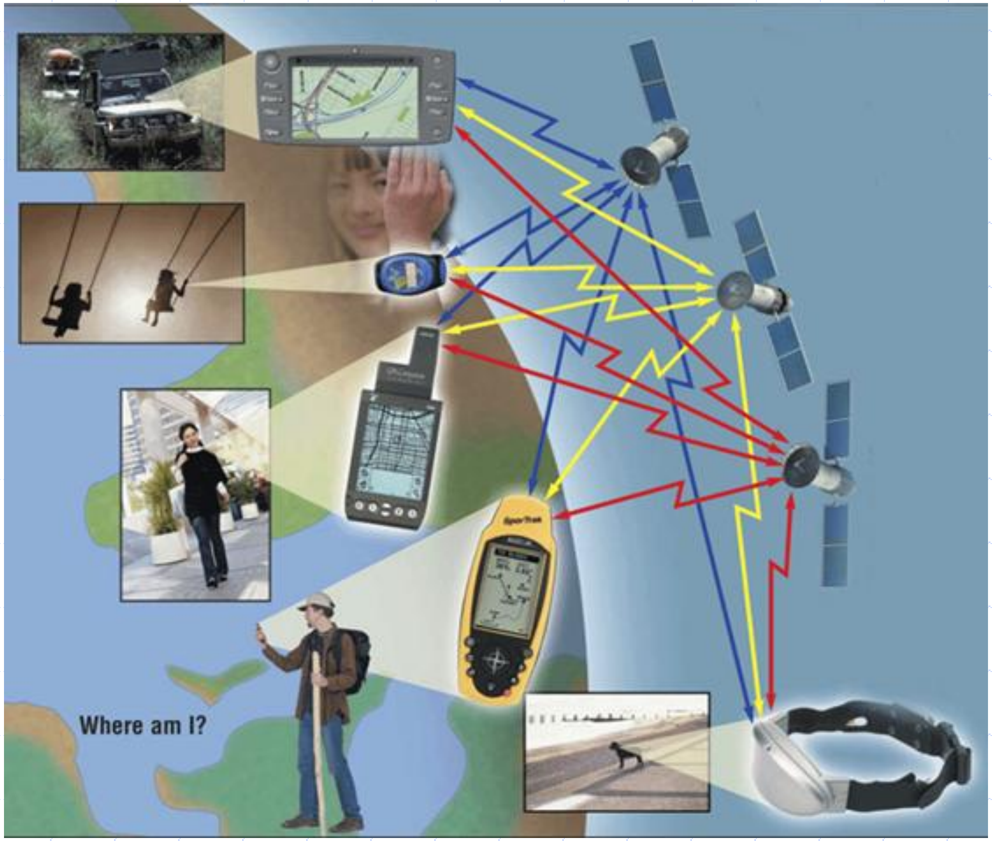
Global positioning satellite system

- NAVSTAR by the US military
- L1: 1575.42 MHz, open to public C/A code
- L2: 1227.60 MHz, P code
- Atmospheric and ionic
- Propagation error when using L1 only.
- Differential GPS



Global positioning satellite system

Step 1.
GPS satellites orbit Earth. Every thousandth of a second, each satellite sends a signal that indicates its current position to the GPS server.



Step 2.
A GPS receiver (such as in a car, a PDA, a watch, a handheld device, or a collar) determines its location on Earth by analyzing at least 3 separate satellite signals from the 24 satellites in orbit.

Global positioning satellite system

The GPS positioning system operates by using triangulation with a minimum of four satellites. GPS satellites are in orbits 20,200 km above the Earth, with orbital periods of 12 hours.

Distances from the user's receiver to these satellites are found by timing the propagation delay between the satellites and the receiver. The positions of the satellites, (ephemeris) are known to very high accuracy; in addition, each satellite contains an extremely accurate clock to provide a unique set of timing pulses.

A GPS receiver decodes this timing information and performs the necessary calculations in order to find the position ,and velocity of the receiver. The GPS receiver must have a line-of-sight view to at least four satellites in the GPS constellation, although three satellites are adequate if altitude position is known (as in the case of ships at sea).

Because of the low gain antennas required for operation, the received signal level from a GPS satellite is very low, typically on the order of -130 dBm (for a receiver antenna gain of 0 dB). This signal level is usually below the noise power at the receiver, but spread spectrum techniques are used to improve the received signal-to-noise ratio.

- **Car navigation:**
- **GPS receiver with map and voice guidance**



- **Differential GPS:**
- **Handset, for up to few cm accuracy.**
- **Better safety, but privacy issues.**

http://www.garmin.com.tw/products/flash/nuvi200w/index.html

WLAN

Wireless local area networks (WLANs) provide connections between computers over short distances.

- Wireless local area network
- Bluetooth
- ISM: 802.11b and g at 2.4GHz,
- 802.11a at 5.2GHz,
- HIPERLAN in Europe

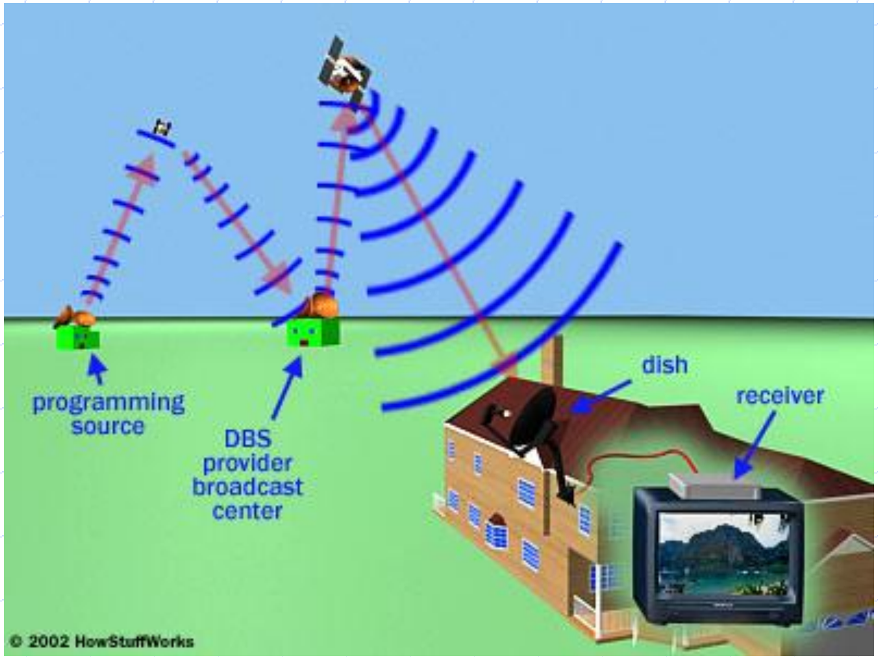
A major new WLAN initiative is the Bluetooth standard, where very small and inexpensive RF transceivers will be used to link a wide variety of digital systems over relatively short distances.

Possible Bluetooth applications include wirelessly networking printers, scanners, cell phones, notebook and desktop computers, personal digital assistants (PDAs), and even household appliances.
Current Bluetooth systems operate in the ISM band at 2.4 GHz, and offer data rates up to 1 Mbps.

Other Wireless Systems

Direct broadcast satellite (DBS)

- Very wide coverage, will not be blocked by mountains …



Reflector antennas for satellite TV broadcast reception

Other Wireless Systems
Direct broadcast satellite (DBS)

The Direct Broadcast Satellite (DBS) system provides television service from two geosynchronous satellites directly to home users with a relatively small 18" diameter antenna. The DBS system uses quadrature phase shift keying (QPSK) with digital multiplexing and error correction to deliver digital data at a rate of 40 Mbps.

Two satellites, DBS-1 and DBS-2, located at 101.2' and 100.8" longitude, each provide 16 channels with 120 W of radiated power per channel.

These satellites use opposite circular polarizations to minimize loss due to precipitation, and to avoid interference with each other (polarization duplexing), DBS-1 transmits with left-hand circular polarization (LHCP), while DBS-2 uses right-hand circular polarization (RHCP).

DBS competes directly with wired cable TV service, but within one year of its introduction in 1994, DBS sold over 1 million units to break all previous records and become the consumer electronics product with the fastest market growth in history. The initial cost of a DBS antenna and receiver was about $700, but after 2.5 million units were sold the price had dropped to about half this value.

- LMDS: local multipoint distribution systems
- Broadband fixed wireless

These systems are poised for rapid market growth because of the strong demand for the 'last mile connectivity', where wireless systems offer one of the few economical solutions to the problem of providing high data rate connections to small businesses and homes for Internet access, telephone, television, and data communications.

LMDS and MMDS systems typically operate in the 2.1-2.7 GHz band, the 3.4-3.7 GHz band, or the 28 GHz millimeter wave band, and may offer two-way full-duplex data rates ranging from 50 Mbps to over 110 Mbps for each channel.

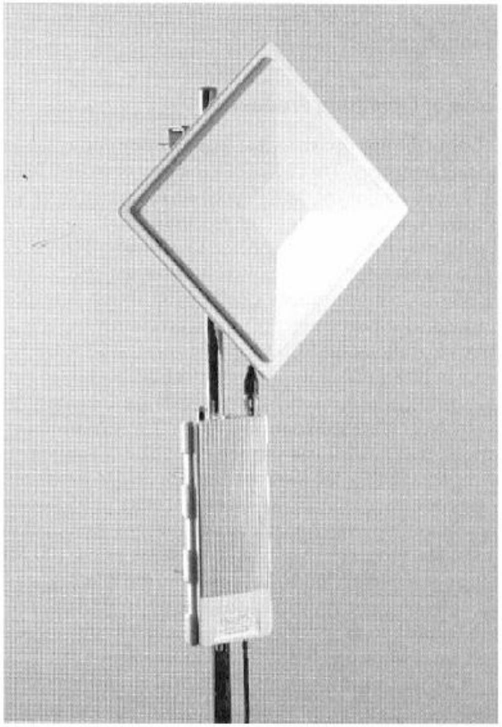


FIGURE 1.3 Photograph of the subscriber antenna and outdoor unit of an MMDS system operating at 2.4–2.6 GHz, providing a data rate of 20 Mb/sec. (Courtesy of N. Herscovici, Spike Technologies, Nashua, NH.)

Other Wireless Systems

Point-to-point radio

Point-to-point radios are used by businesses to provide dedicated data connections between two points. Electric utility companies use point-to-point radios for the transmission of telemetry information for the generation, transmission, and distribution of electric power between power stations and substations.

Point-to-point radios are also used to connect cellular base stations to the public switched telephone network, and are generally much cheaper than running high-bandwidth coaxial or fiber-optic lines below ground.

Such radios usually operate in the 18, 24, or 38 GHz bands, and use a variety of digital modulation methods to provide data rates in excess of 10 Mbps. High gain antennas are typically used to minimize power requirements and avoid interference with other users.

◆Point-to-point radios

Other Wireless Systems
RFID

Radio frequency identification (RFID) systems are used for inventory tracking, shipping, toll collection, personal security access, and other functions.

- Read the data in an ID tag by wireless method.
- Non-contact, non-pointing required

1.2 Design and Performance Issues

Choice of operating frequency

Available of Spectrum.

•In the United States, the Federal Communications Commission (FCC) is responsible for assigning frequency spectrum to competing users.

•(ISM) bands, which reserve three microwave frequency bands for a variety of uses not covered under other spectrum allocations.

Noise, antenna gain, bandwidth, and cost.

•Noise power, for example, increases sharply at frequencies below 100 MHz due to a variety of sources that include lightning, ionospheric ducting, and interference from engine ignitions and other electrical equipment.

• At frequencies above 10 GHz, however, noise power steadily increases due to thermal noise of the atmosphere and interstellar radiation.

• the use of higher frequencies is an advantage for point-to-point wireless systems where high antenna gain is required.

• Higher gain antennas also receive less noise power.

• a wireless system capable of high data rates will require a correspondingly high RF bandwidth, and this is easier to obtain at high frequencies than at low frequencies.

•The efficiency of RF transistors decreases with frequency, which increases the prime power required to operate wireless transmitters and receivers.

1.2 Design and Performance Issues

Choice of operating frequency

electromagnetic propagation characteristics

At lower frequencies, however, signals can more easily pass through or around obstructions such as foliage, buildings, and vehicles. Thus lower frequencies give better propagation characteristics for wireless applications such as cellular and PCS telephone.

As arough estimate, operating range decreases by 5% to 10% **as frequency** increases from 900 MHz to 2.4 GHz, and another 10% at 5 GHz.

1.2 Design and Performance Issues
Multiple Access and Duplexing

Multiple access and duplexing
- FDMA,
- TDMA
- CDMA

Because of the high sensitivity of most wireless receivers, the isolation between transmitter and receiver is typically required to be on the order of 120 dB.

Often it is convenient to use a single antenna for both transmit and receive, in which case a *duplexing filter is used to pass receive frequencies* from the antenna to the receiver, and transmit frequencies from the transmitter to the antenna, while providing enough attenuation between the transmit and receive bands to achieve the necessary isolation.

In half-duplex wireless systems, as used in many TDMA telephones and wireless LANs, duplexing can be accomplished by using a *transmit/receive (T/R) switch*.

1.2 Design and Performance Issues

Circuit Switching versus Packet Switching

Both hard-wired and wireless (cellular and PCS) telephone systems are based on centralized networks that provide a direct physical circuit between the communicating parties for the duration of the call. This is referred to as a *circuit-switching network*. *The* circuit-switched telephone network has proven to be extremely reliable for voice communications, with a very high *quality of service (QoS).*

Packet Switching: interconnected routers are used to provide multiple paths between any two points in the network. Messages and data are divided into packets of fixed length that are independently routed through the network from the sender to the receiver.

The Internet is the most prevalent packet-switched network, and is used extensively for data, email, and multimedia communication between computers.

Safety issues

The most recent U.S. safety standard for human exposure to electromagnetic radiation is given by ANSVIEEE Standard C95.1-1992. In the RF-microwave frequency range of 100 MHz to 300 GHz, exposure limits are set on the power density (in watts/cm2)as a function of frequency

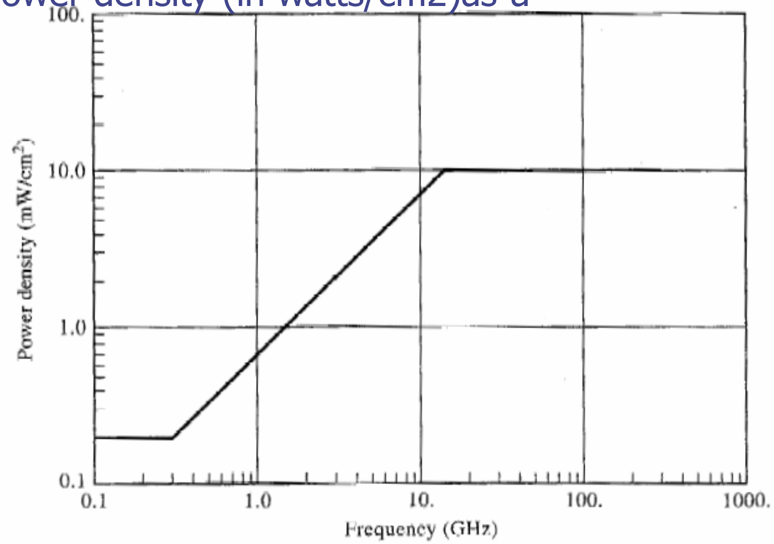


FIGURE 1.5 IEEE Standard C95.1-1991 recommended power density limits for human exposure to RF and microwave electromagnetic fields.

FCC sets limits on the total radiated power of some specific wireless equipment. Vehicle-mounted cellular phones (using an external antenna) are limited to a maximum radiated power of 3 W.

For handheld cellular phones, the FCC has set an exclusionary power level of 0.76 W.

Cellular and PCS base stations are limited to a total effective radiated power of 500 W, depending on antenna height and location, but most urban base stations radiate a maximum of 10 W.

Wireless products using the ISM bands are limited to a maximum radiated power of 1 W.

1.3 wireless system components

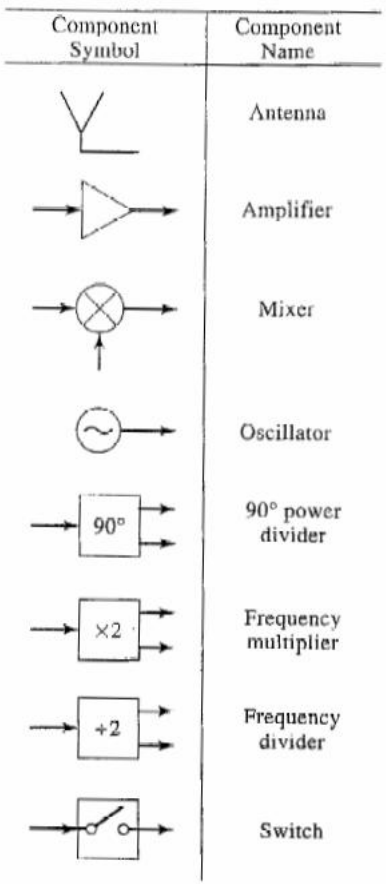


FIGURE 1.6 Block diagram symbols for commonly used RF and microwave components. (Filter symbols are shown in Figure 1.7.)

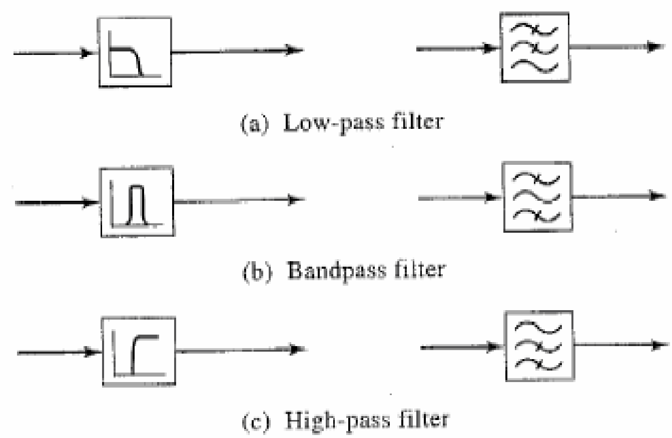


FIGURE 1.7 Symbols for filters: (a) low-pass, (b) bandpass, (c) high-pass.

1.3 wireless system components

Basic Radio System

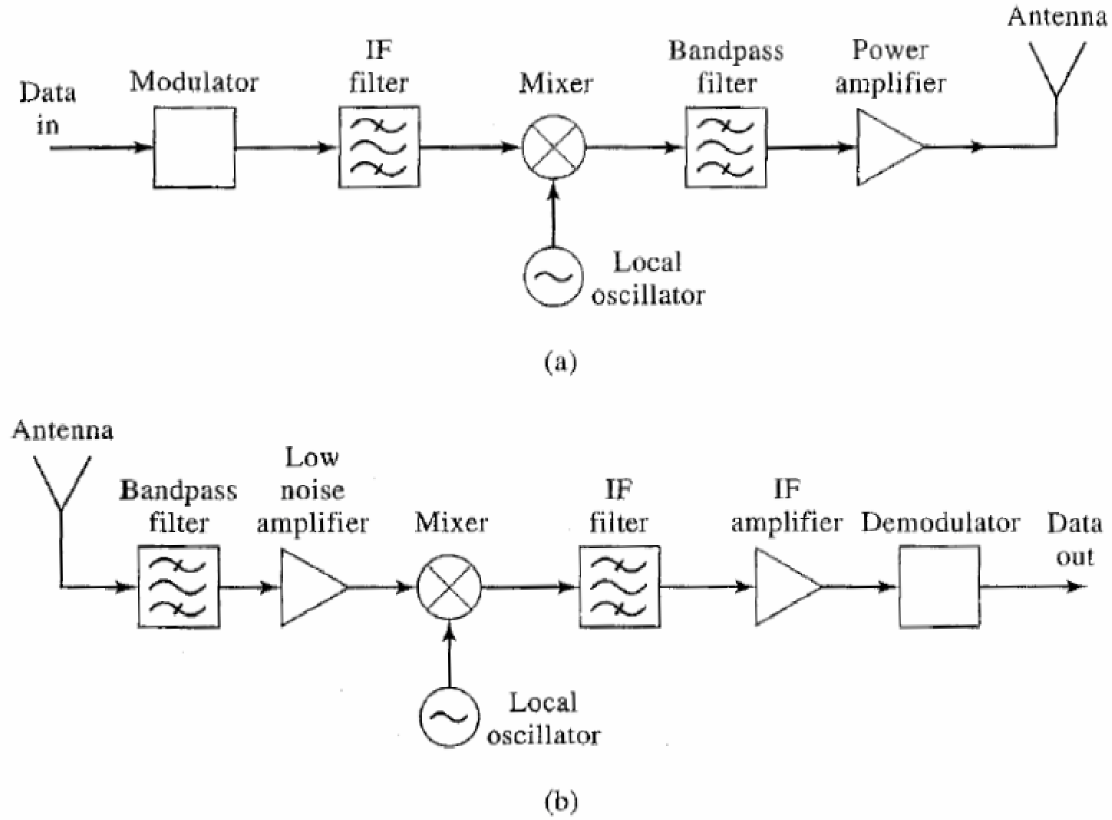


FIGURE 1.8 Block diagram of a basic radio system: (a) radio transmitter, (b) radio receiver.

1.3 wireless system components

Antenna

Important characteristics – include operating frequency, size, and gain.

Low-gain antennas: Examples include dipoles, monopoles, and whip antennas. Their radiation patterns are nearly omni-directional.

High-gain antennas: Examples include reflector antennas (parabolic disk) and patch arrays. Their radiation patterns are highly directional.

Smart antennas: Examples include phased arrays and adaptive arrays. Their main beams of radiation patterns can be changed electronically.

1.3 wireless system components

Filter

Important parameters – include cut-off frequency, insertion loss, out-of-band attenuation rate (skirt factor).

Low integrability with IC: For example, in a GSM RF module the band-select, image-reject, and channel-select filters are usually off-chip components.

Dielectric Resonator (DR) band-pass filters – are dominant in use at RF and microwave frequencies for selecting the receive or transmit frequency range. They have features of moderately sharp cut-off (high Q), low insertion loss, and small size.

Surface Acoustic Wave (SAW) band-pass filters – are dominant in use at intermediate frequency (IF) for selecting the channel frequency range. They have features of extremely sharp cut-off but high insertion loss.

Waveguide resonator band-pass filters – are dominant in use at millimeter-wave frequencies. They have features of sharp cutoff and extremely low insertion loss but relatively large size and high cost.

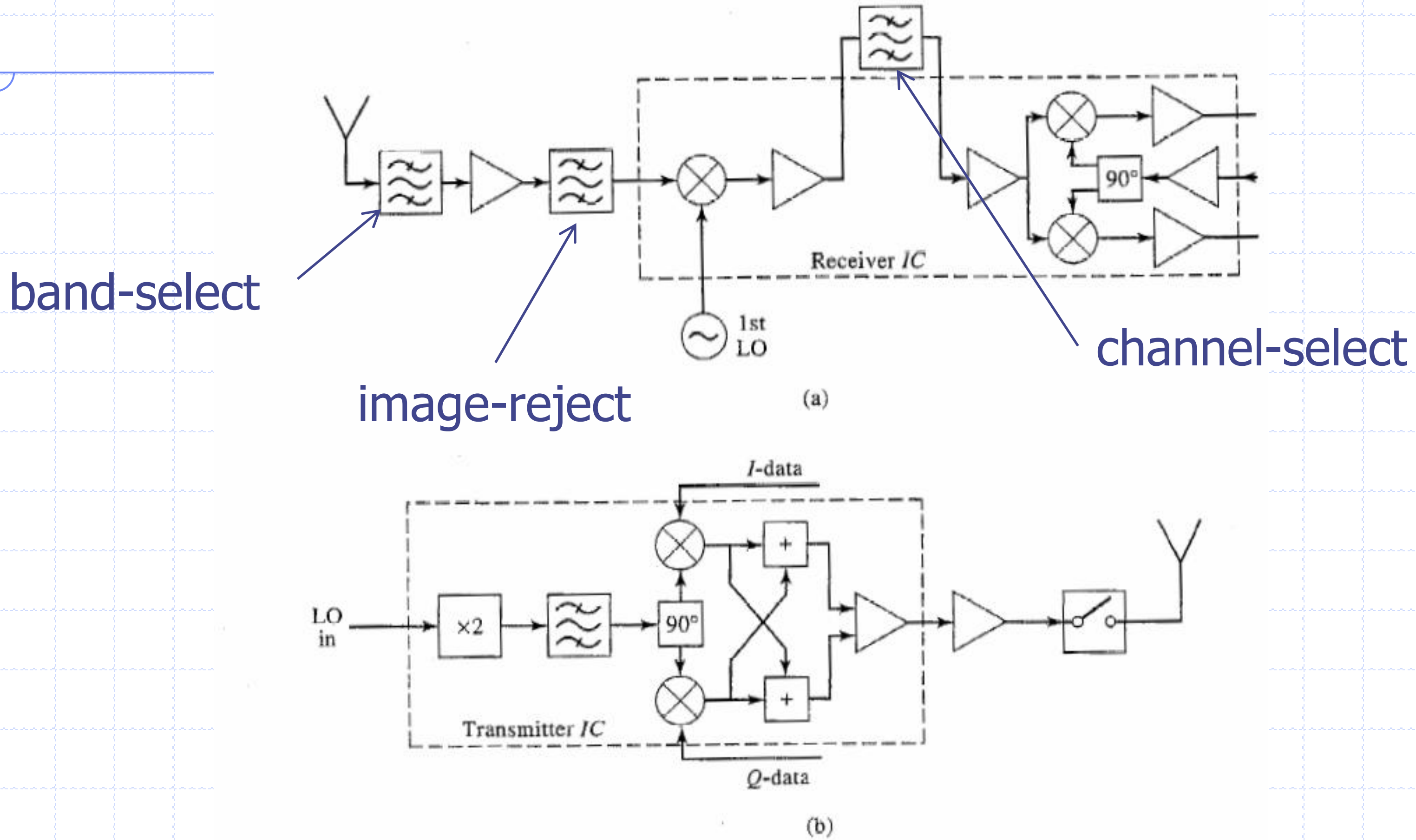
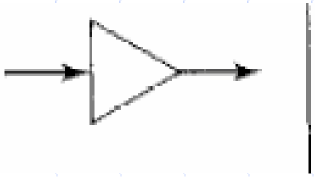


FIGURE 1.9 RF block diagrams for a 900 MHz GSM cellular telephone receiver and transmitter. Each subsystem is highly integrated with commercial RF integrated circuits, but note that the required bandpass filters are not part of the integrated circuit packages: (a) receiver block diagram, (b) transmitter block diagram.

Amplifier

- Amplifiers:
  - Low noise amplifier (LNA)
  - Power amplifier (PA)
  - IF amplifier
- Importance parameters:
  - Gain
  - Noise
  - Intercept point
- Saturation and harmonic distortion



Mixer

A mixer is a three-port component that performs frequency conversion to ideally form the sum and difference frequencies from two sinusoidal inputs.

Two main categories: Passive (diode) mixers and active (transistor) mixers.

Important parameters – include conversion loss/gain, noise figure, intercept points, port-to-port isolation, low dc supply voltage and power consumption.

OSC and PLL

An oscillator is constructed by active component (transistor) to provide the power of oscillation and passive component (resonator) to select the frequency of oscillation. Choice of resonator – includes LC tank and crystal.

Resonator	Advantages	Disadvantages
LC tank	Wide tuning range	Output frequencies are very susceptible to variations in temperature, supply voltage, and load impedance.
Crystal	Very accurate and stable output frequencies	Very narrow tuning range

Frequency synthesizers (Phase locked loops, PLLs) – can provide output frequencies that are tunable with very high accuracy and are dominant for use in the local oscillators (LO) in modern wireless systems.

Important parameters of frequency synthesizers (PLLs) – include frequency tuning range, frequency switching time, frequency resolution, phase noise, cost, low dc supply voltage and power consumption.

Baseband

After down conversion to an IF signal (which may occur in two or more stages), the received signal must be demodulated.

The majority of wireless systems today utilize coherent digital modulation methods (discussed in Chapter 9), for which demodulation requires a local oscillator synchronized in both frequency and phase with the down-converted carrier signal.

These processes, called *carrier acquisition and carrier synchronization, have* traditionally been very difficult to implement, but the advent of powerful digital signal processing (DSP) chips allows these functions to be performed easily and inexpensively.

Demodulated baseband data can then be obtained from the output of the DSP stage, perhaps even including error correction

1.4 Cellular phones and standards

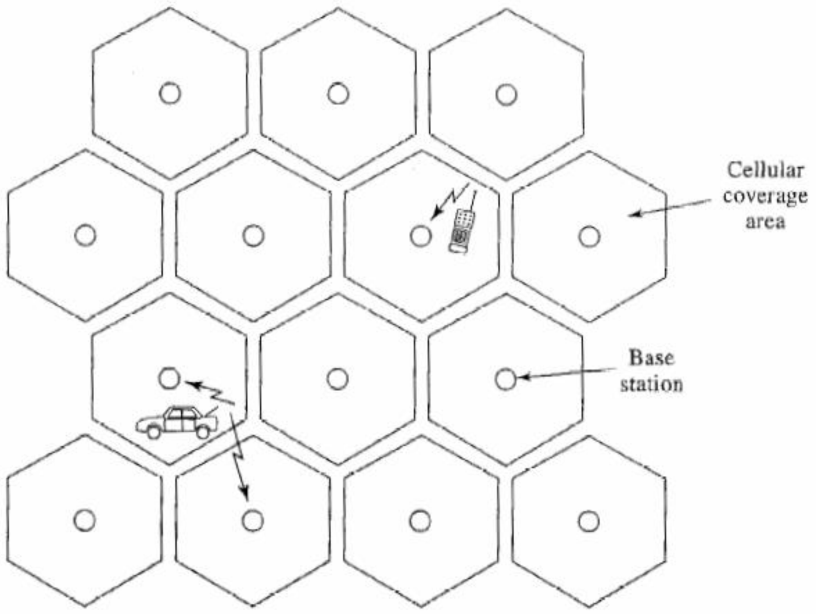


FIGURE 1.10 Layout of hexagonal cell areas and base stations for cellular radio systems.

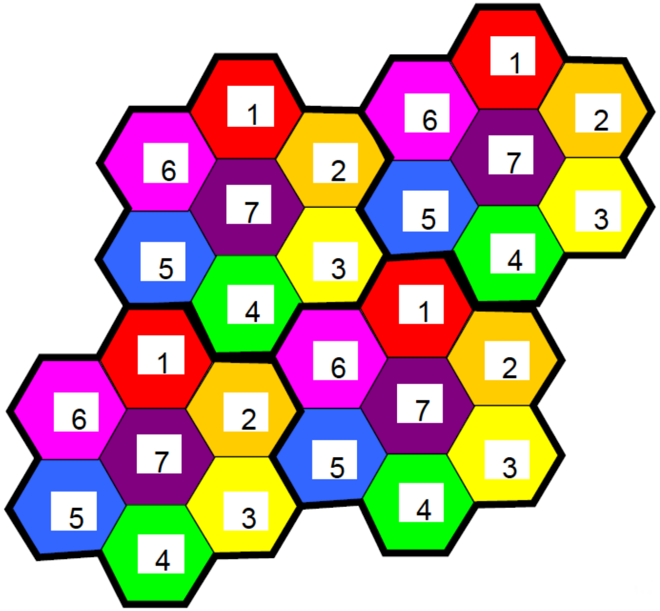
A cellular telephone user communicates with the closest base station, even though it is likely that an adjacent base station may receive a weaker signal from the same user.

If the user is mobile, a hand-off from one base station to the next will occur when the received signal power from the closer base station becomes greater than the received signal power at the original base station.

Cellular reuse concept

7-cell cluster

Coverage area 'tiled' with 7-cell clusters



To avoid co-channel interference, adjacent cells are assigned different sets of channel frequencies.

Frequency reuse is one of the key advantages of cellular radio systems because it permits more efficient utilization of valuable radio spectrum. This method is generally used for FDMA, TDMA, and CDMA multiple access systems.

All the base stations within a given geographical area are connected to a mobile telephone switching office (MTSO), which typically can handle several thousand simultaneous telephone calls.

The PSTN includes high-capacity fiber-optic lines between cities, as well as transoceanic lines between countries.

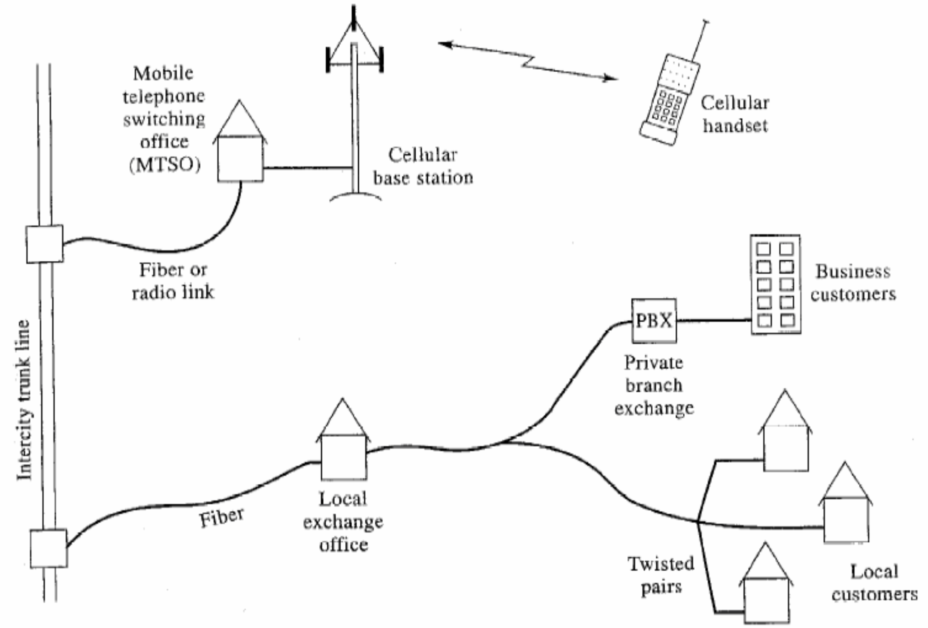


FIGURE 1.11 Pictorial diagram showing the connection of a cellular telephone and base station to the public switched telephone network.

AMPS

- Rx: 869~894MHz, Tx: 824~849MHz for handset
- 832 channels with 30kHz wide
- FM modulation to 25kHz with 5kHz guard band.

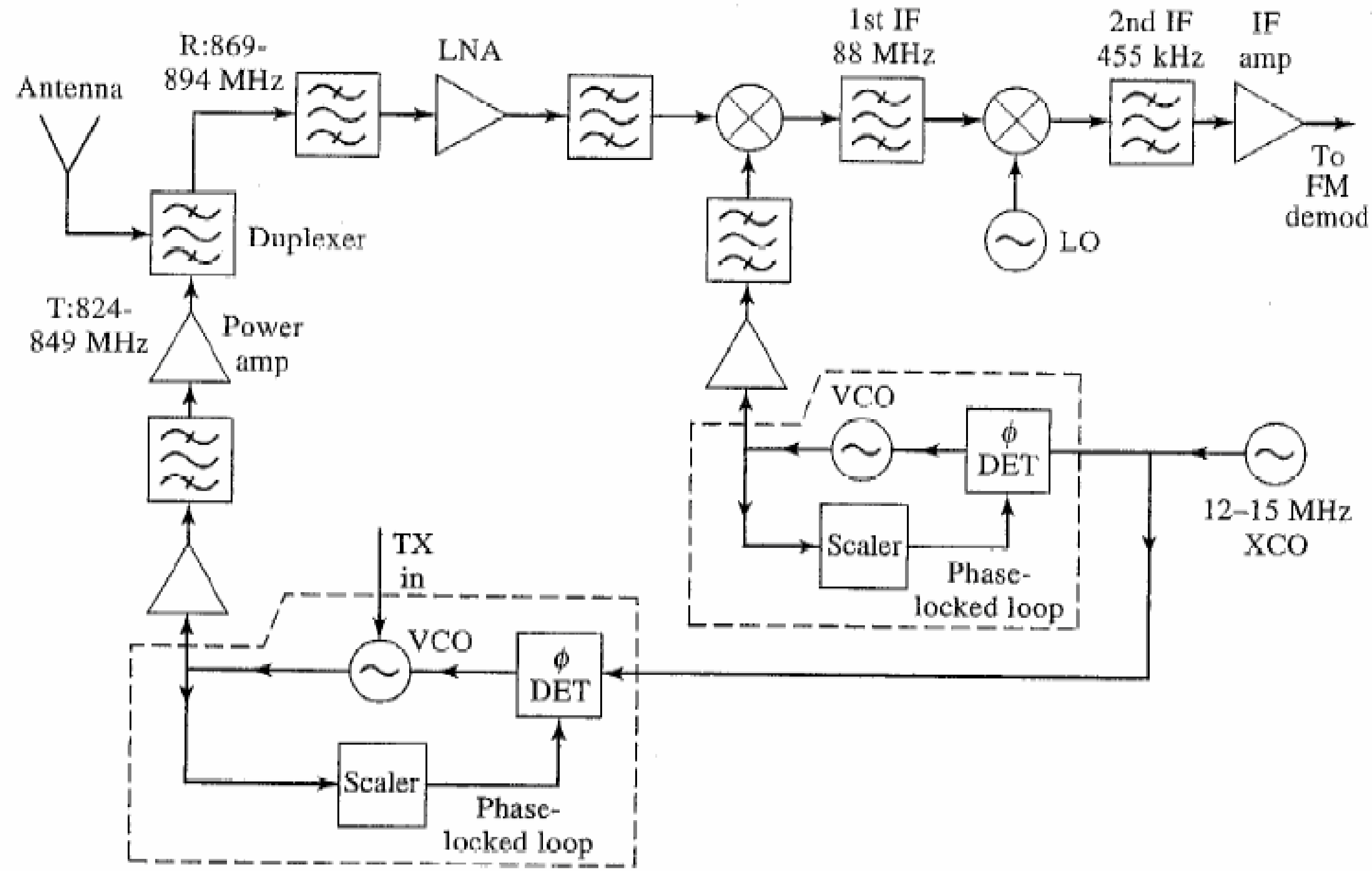


FIGURE 1.12 Block diagram of an AMPS mobile transceiver.

Digital cellular systems

TABLE 1.4 International Digital PCS System Standards

PCS System	IS-54/IS-136	IS-95	GSM
Transmit Frequency (RVC)	824–849 MHz	824–849 MHz	890–915 MHz
Receive Frequency (FVC)	869–894 MHz	869–894 MHz	935–960 MHz
Duplexing Method	FDD	FDD	FDD
Multiple Access Method	TDMA	CDMA	TDMA
Channel Bandwidth	30 kHz	1.25 MHz	200 kHz
Modulation	QPSK	QPSK	GMSK
Channel Bit Rate	48.6 kbps	1,228.8 kbps	270.833 kbps
Users per Channel	3	64	8
User Bit Rate	8 kbps	1.2–9.6 kbps	13 kbps
Number of Users	2,496	15,960	992