ITM 1010
Computer and Communication Technologies

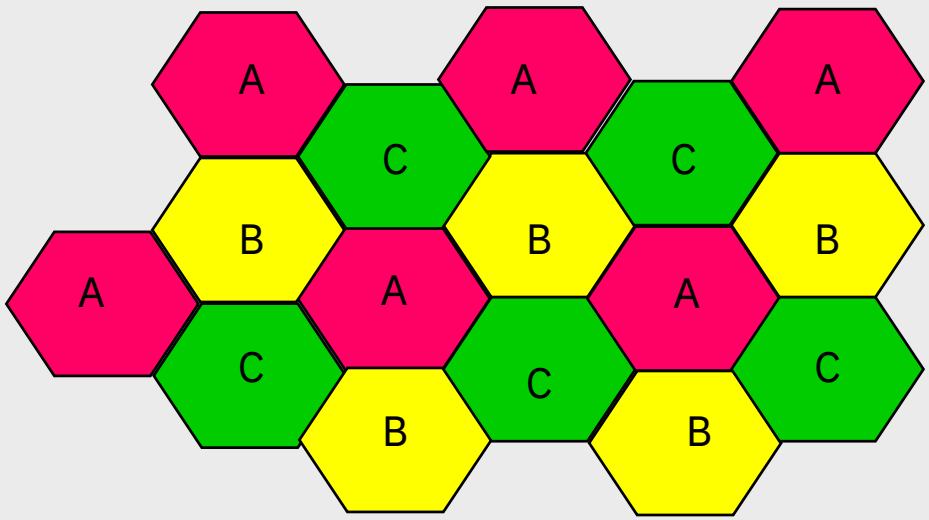
Lecture #18

Part II Introduction to Communication Technologies:

Communication Systems:
Wireless, Optical and Satellite

Cellular Networks

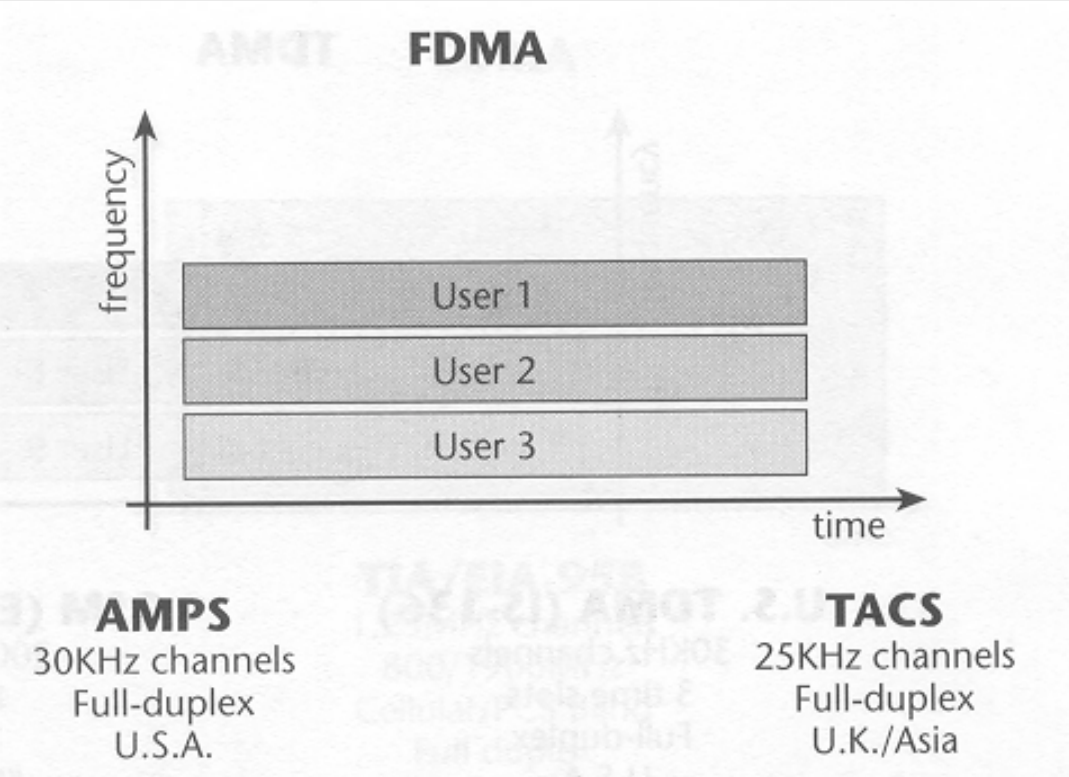
- Problem: Radio frequency spectrum is limited: How can we support many mobile users in a limited bandwidth?
  - A clever solution is a cellular network
  - Basic idea: Divide a region (e.g. in a city) into small cells. Transmitters in each cell has a limited range, allowing the same radio frequencies to be re-used in a distant cell without interference



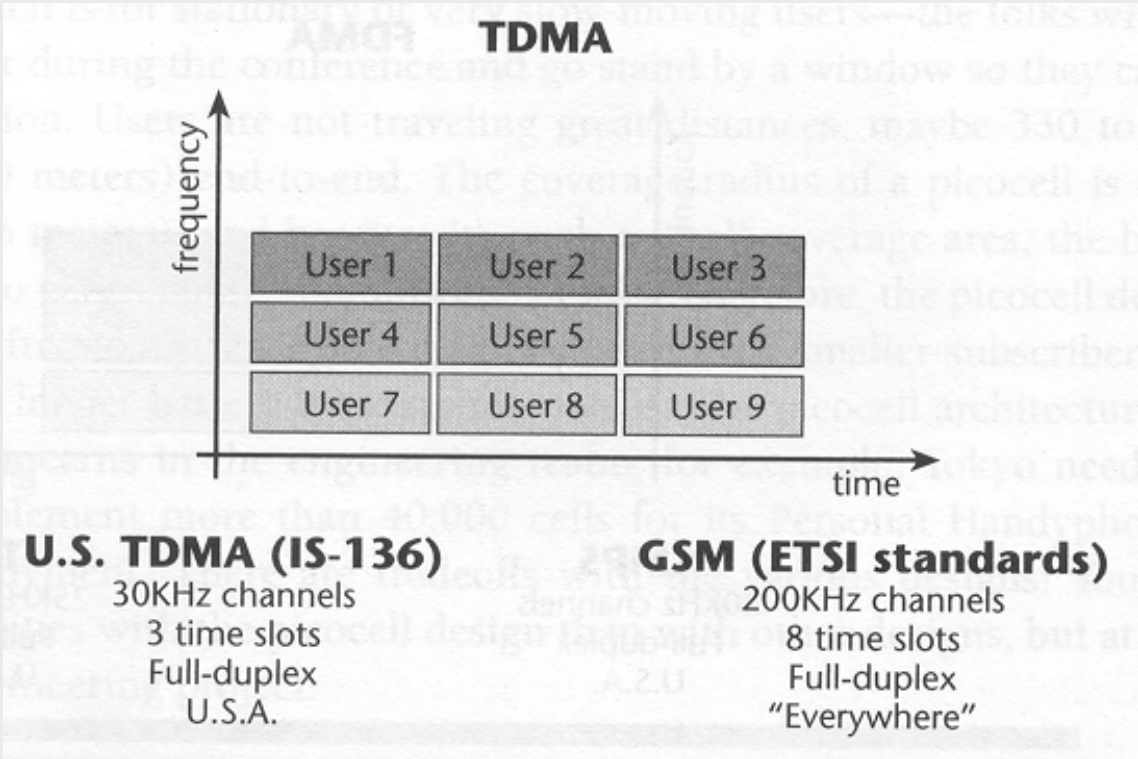
Frequency reuse with three sets of frequencies A, B and C.

In practice more than 3 sets of frequencies (e.g. 6 or 7) are used for larger distance separation between cells with the same frequency

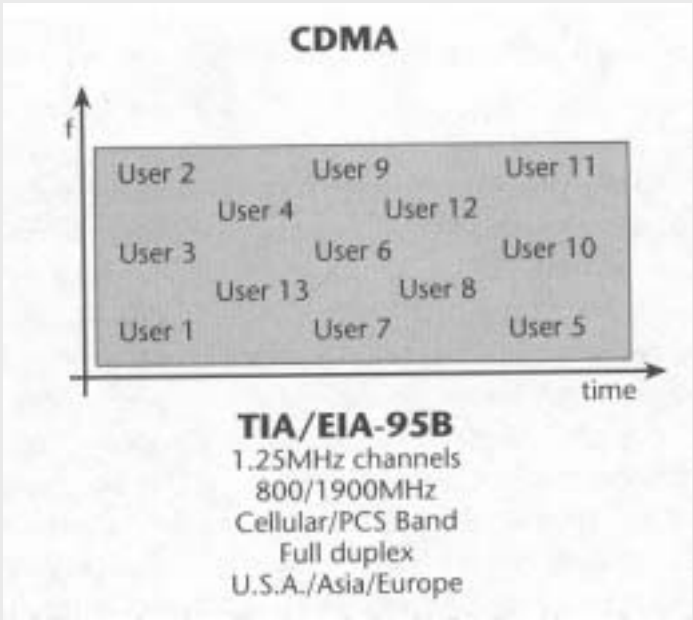
FDMA in Cellular Systems

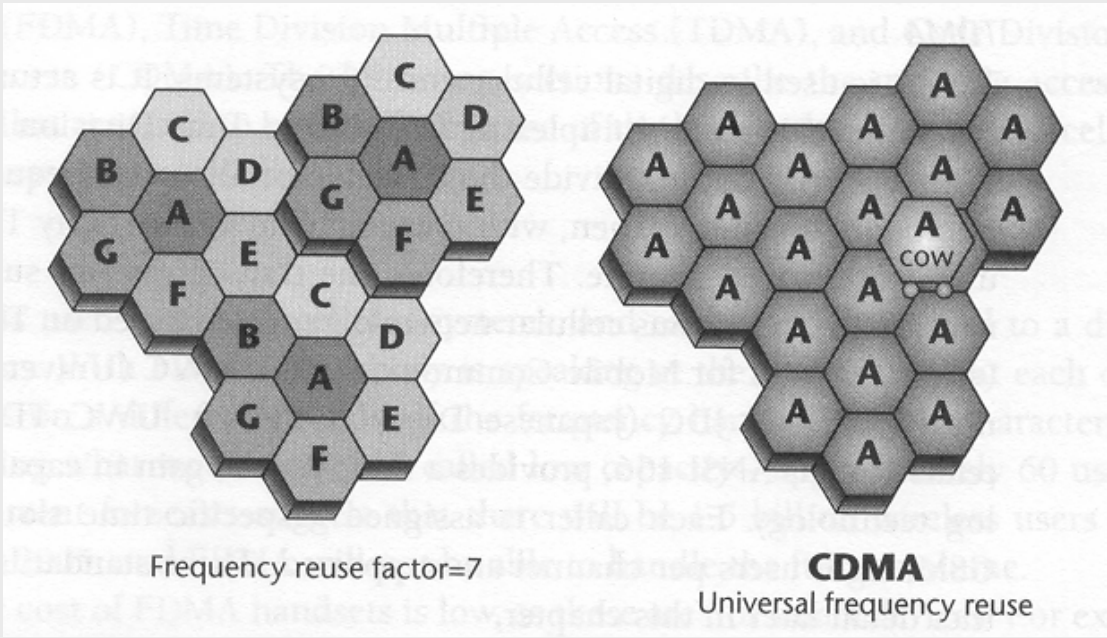


TDMA in Cellular Systems



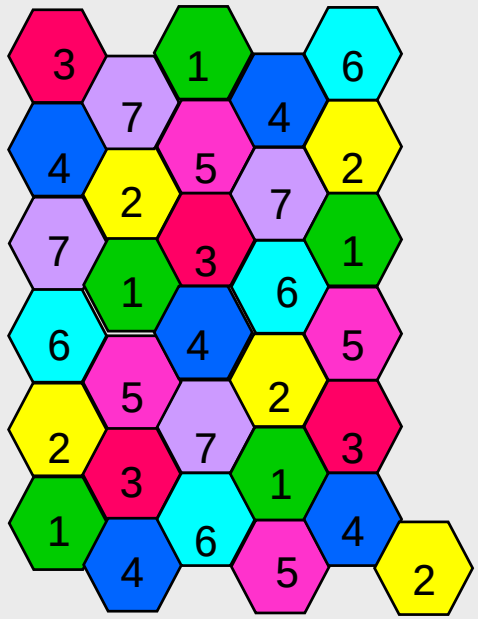
CDMA in Cellular Systems





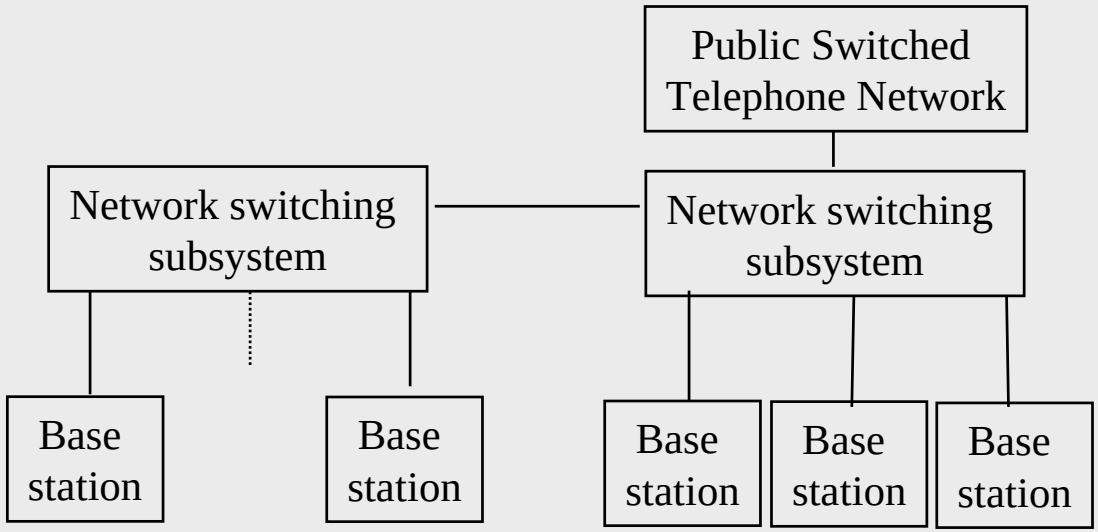
GSM Cellular networks

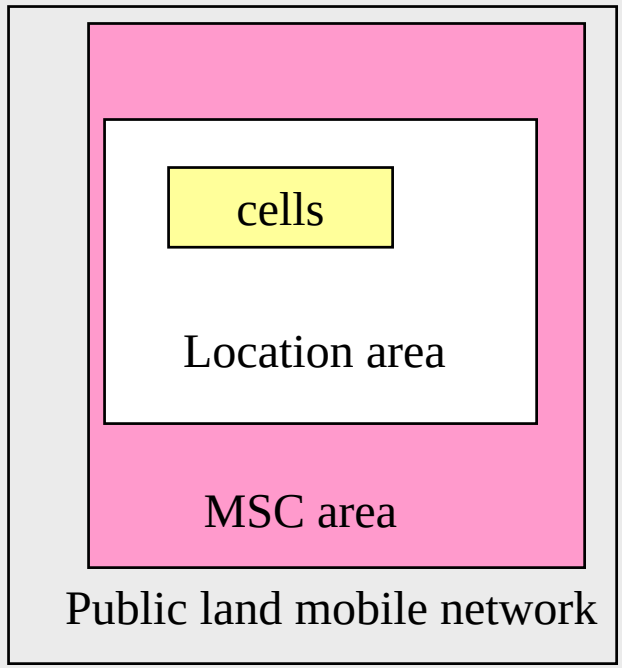
- Each cell has a set of frequencies different from neighboring cells
- GSM (Global System for Mobile communications) uses 900MHz band:
  - Phone to base station (mobile transmit) 890-915MHz
  - Base station to phone (base transmit): 935-960MHz
  - spectrum divided into 124 carriers using FDMA (200kHz spacing)
  - each carrier divided into eight time slots using TDMA
  - Speech is coded at 13kb/s (more efficient than PCM)
  - Minimum shift keying (MSK) used (similar to FM)
- Network control functions use common channels e.g.:
  - Request to use network is made via RACH (random access channel) which uses a slotted Aloha scheme
  - Incoming calls alert is via PCH (Paging Channel)
  - AGCH (Access grant channel) allocates a dedicated channel to a phone which has made a RACH



Cell Organization

- Base-stations are located at the center of each cell, and are basically low cost radio transceivers
- Many base-stations are connected to a single Network Switching Subsystem (NSS). NSS components include mobile switching center (MSC), home location register (HLR), visitor location register (VLR), authentication center (AuC) & Equipment Identification register (EIR)





GSM Phones

GSM mobile telephone consists of 2 distinct parts:

- Subscriber information module (SIM) which contains:
  - International Mobile Subscriber Identity (IMSI) number which is a 15 digit number unique to each card
  - Temporary mobile subscriber identifier (TMSI) assigned during roaming
  - Encryption keys
  - Other data (e.g. phone numbers)

- Phone hardware (identified by a 15 digit number, International Mobile Equipment Identity, IMEI), usually accessible by pressing *#06# on a phone

  IMEI = 111111-22-333333-4

  (TAC - FAC - SNR - CD)

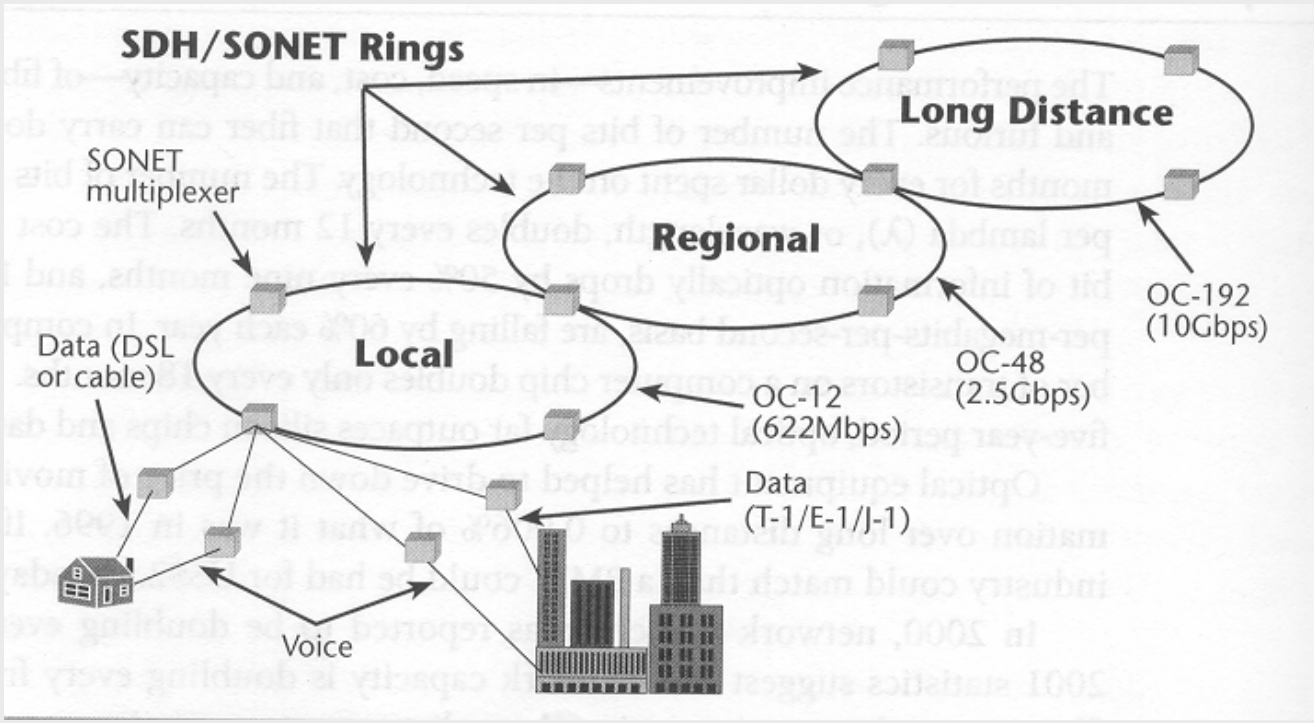
  Where TAC = Type Approval Code, FAC = Final Assembly Code, SNR = Serial Number, CD = Check Digit

Overview of Optical Communications

- Optical systems form the main backbone of choice for today's data networks - no other technology can economically support transmission rates of 40Gbit/s over transoceanic distances.

- Brief overview of the technology in optical communications
  - Components for optical communications
  - Optical fibers
  - Dispersion and intersymbol interference
  - Dense Wavelength division multiplexing

An Example of Today's Optical Networks



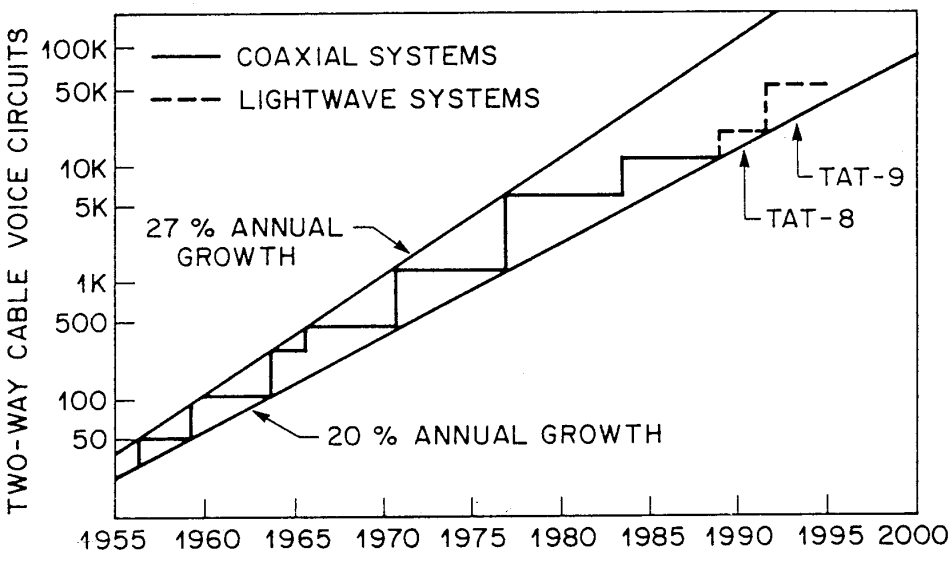
SDH: Synchronous Digital Hierarchy

Some Trans-oceanic Fiber Optic Links

Name	Capacity	Year	Station locations
TAT-8	280Mb/s	1988	USA, UK, France
TPC-3	560Mb/s	1989	California, Hawaii, Guam, Japan
G-P-T	280Mb/s	1989	Guam, Philippines, Taiwan
H-J-K	280Mb/s	1990	Hong Kong, Japan, Korea
TAT-9	1.12Gb/s	1992	USA, UK, France, Spain, Canada
TAT-10	1.12Gb/s	1992	USA, Germany, Netherlands
TPC-4	1.12Gb/s	1992	California, Japan Canada
TAT-11	1.12Gb/s	1993	USA, UK, France
PacRim	1.12Gb/s	1994	Australia, Guam
TAT-12	4.8Gb/s	1995	USA, UK
TAT-13	4.8Gb/s	1995	USA, France
TPC5	4.8Gb/s	1996	USA, Guam, Hawaii, Japan
FLAG	10Gb/s	1997	Europe, N.Africa, Asia (including China)

Growth of Telecommunications Networks

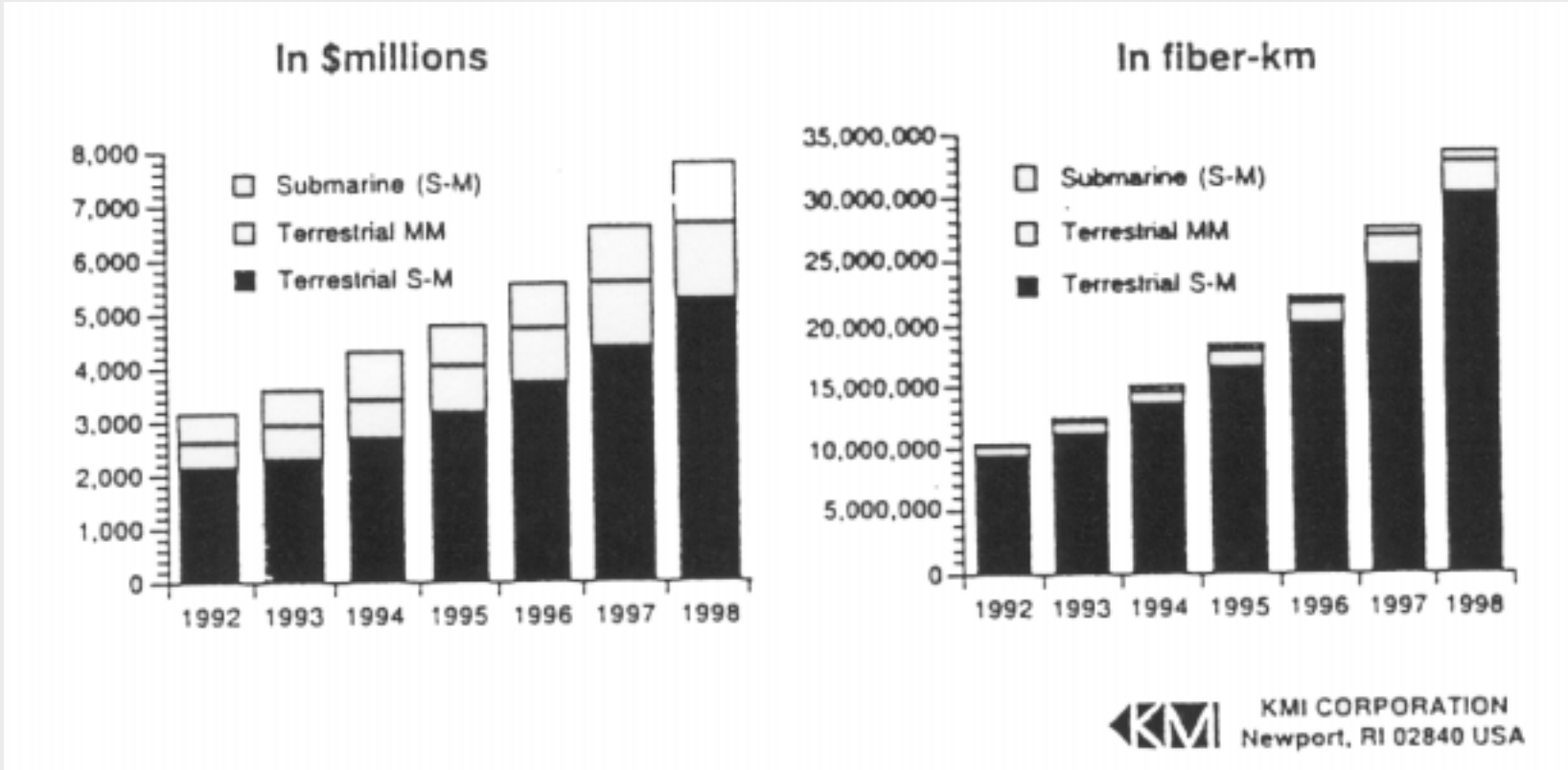
- 20-27% compound annual growth seen in voice networks since 1955 (network doubled in capacity every 4 years)



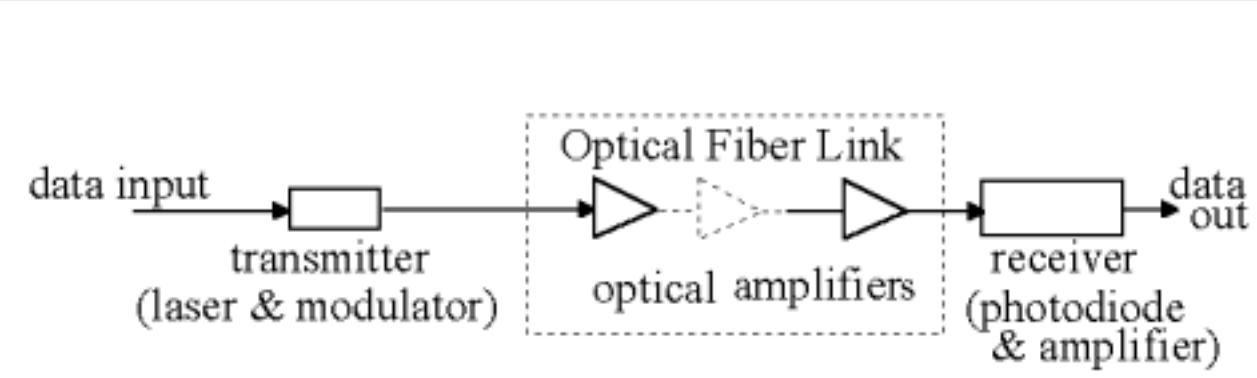
Cumulative trans-atlantic telephone circuits installed by AT&T.

- Since 1993 network growth has accelerated: e.g. One US local exchange carrier (LEC) reported growth of 32 times in capacity during 1994-98. Another LEC reported doubling in capacity every 6 months.
- Internet traffic has grown by about 300% per year since 1993

Worldwide Installation of Fiberoptic Cables



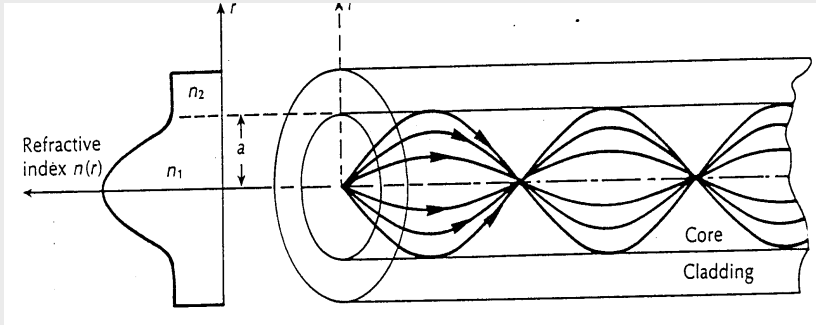
Elements of an optical network



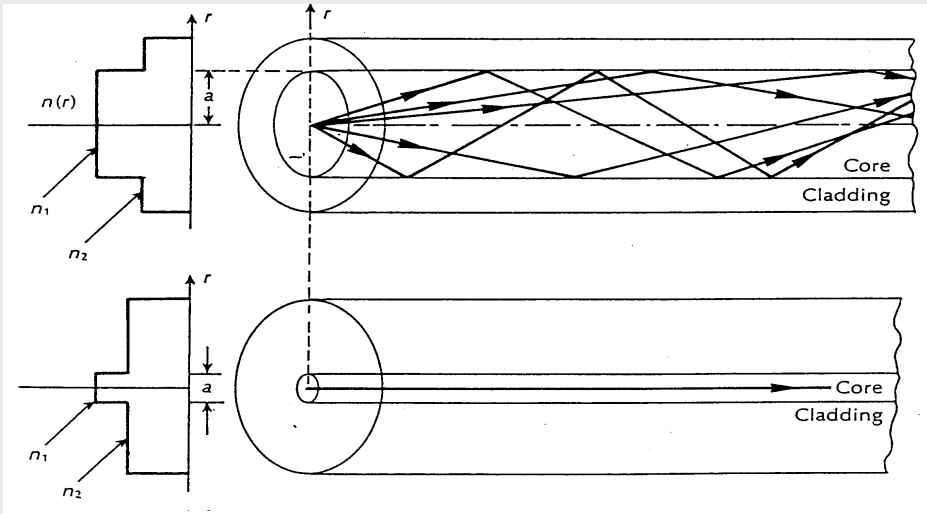
- Transmitter components:
  - optical isolators, data encoding & control electronics
  - laser diode, temperature control
  - optical modulators
- Optical Fiber Link
  - Optical cable, optical couplers, isolators, connectors
  - Erbium doped optical fiber amplifiers
- Optical Receiver components
  - Photodiode, low noise amplifier
  - clock recovery electronics, data decoding

Single and Multimode Optical Fibers

- Graded index fibers have a gradual refractive index transition from core to cladding (multimode graded index fiber is employed in LANs)



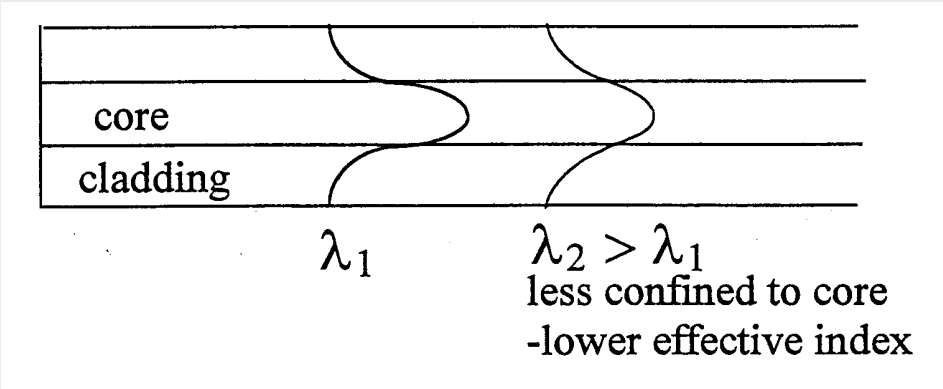
- Step index fibers have an abrupt index change between core and cladding. A large core diameter (e.g. 50mm) can support many possible ray paths resulting in a multimode fiber.



- Single mode fiber have a small core (typically about 10 mm in diameter), and only one mode is transmitted.

Dispersion

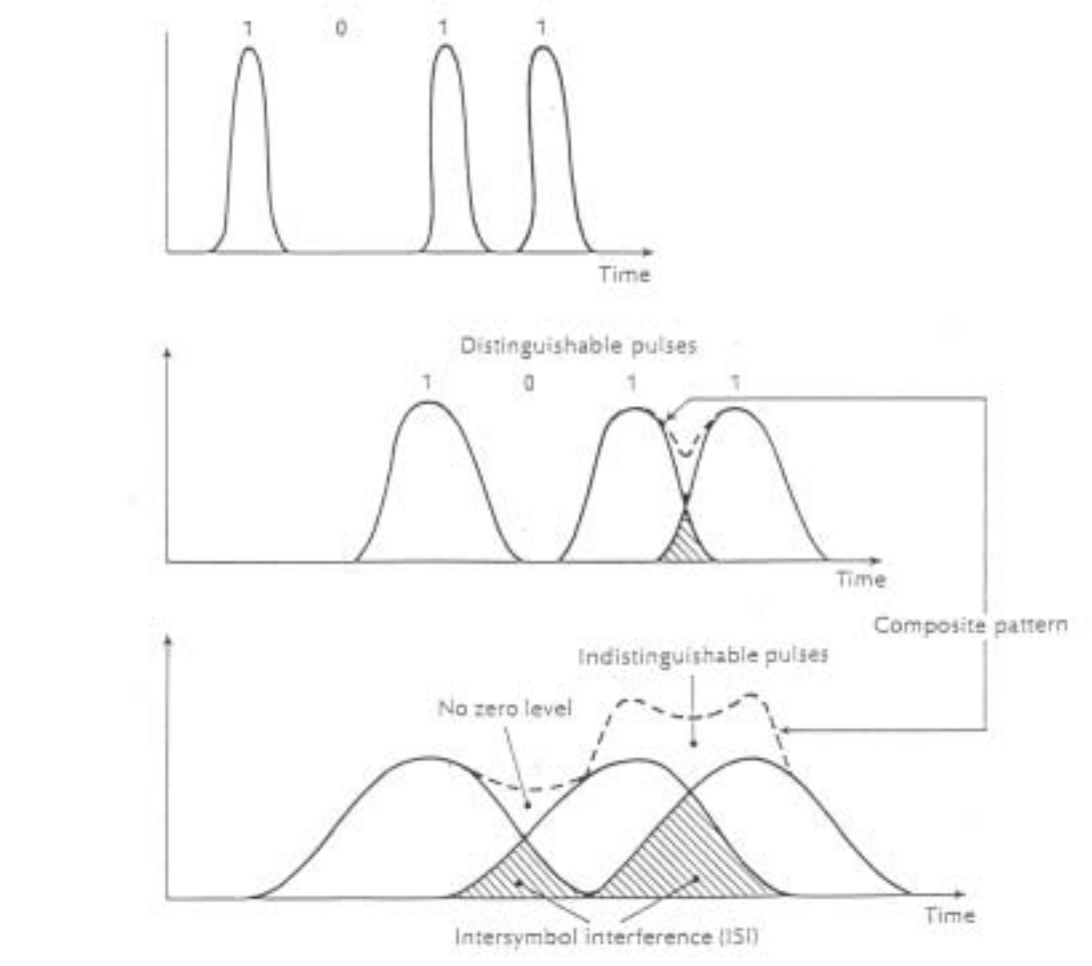
- Dispersion can be of three types:
  1. Modal Dispersion: different modes travel at different group velocities
  2. Material Dispersion: different wavelengths have different refractive index
  3. Waveguide Dispersion: different wavelengths have different waveguiding



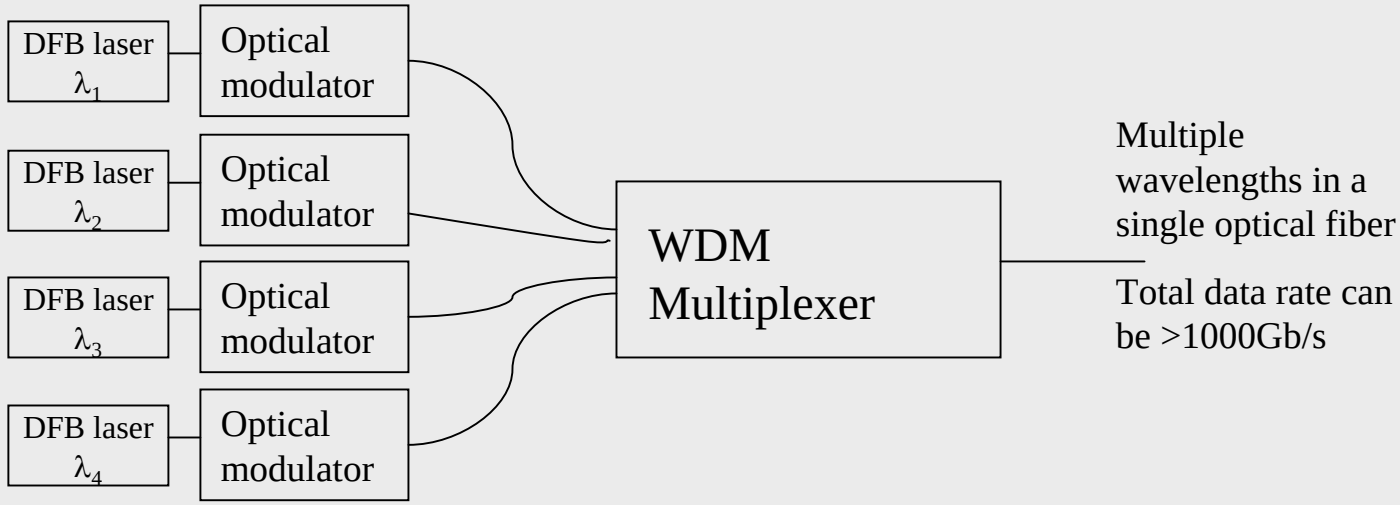
Waveguide dispersion

- Dispersion causes pulse broadening leading to intersymbol interference
- Intersymbol interference limits the maximum bandwidth of a fiber link

Intersymbol interference

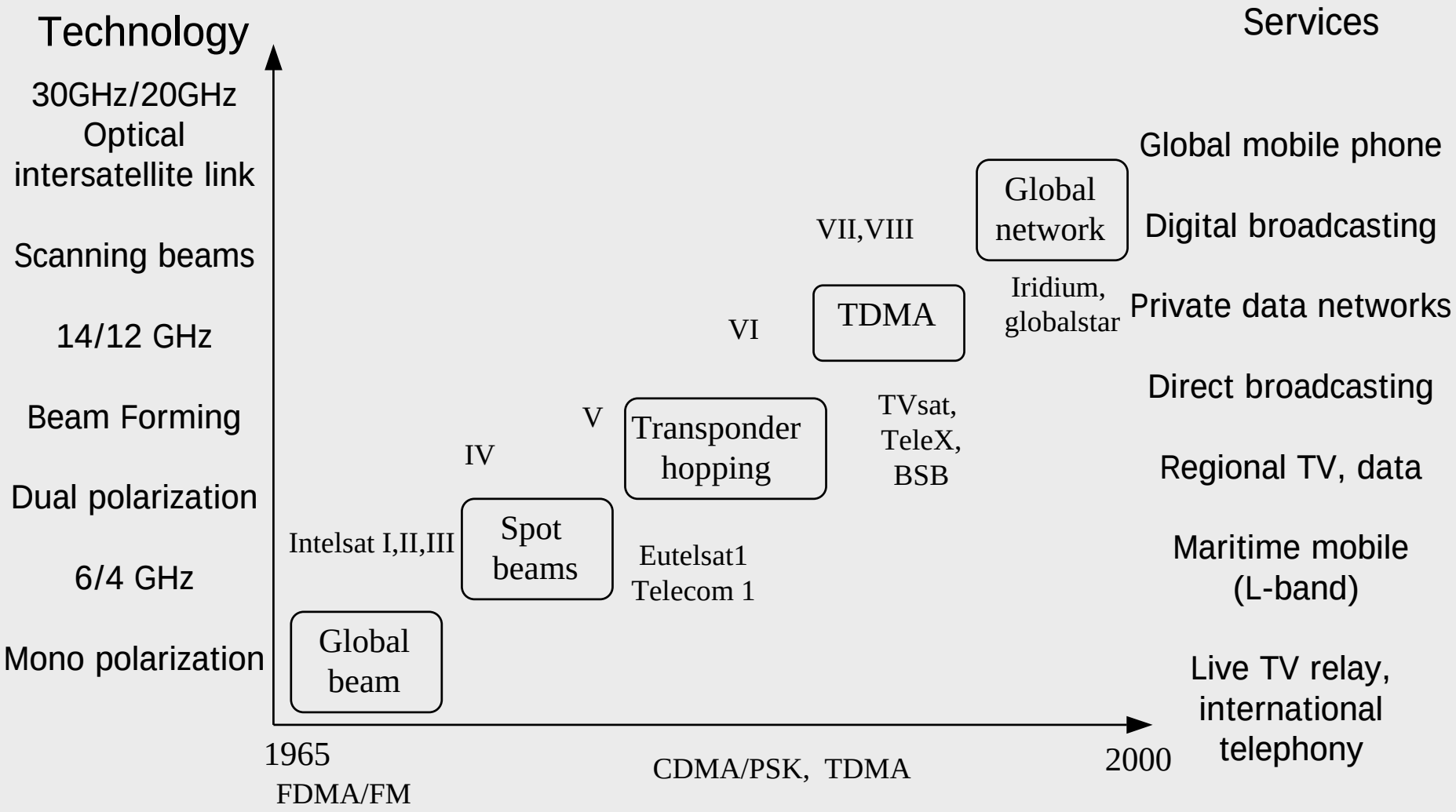


Dense Wavelength Division Multiplexing



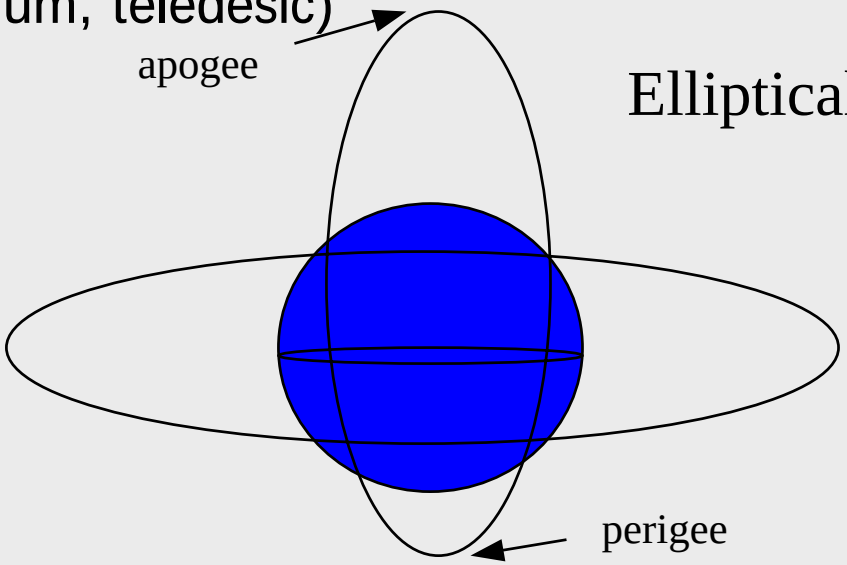
- DWDM increases the information carrying capacity of a single fiber
- Additional components needed include:
  - Multiplexer and demultiplexer to combine and separate different wavelengths
  - Wavelength add/drop modules are needed to add/drop only a single wavelength from the fiber link
  - Wavelength routed networks also need wavelength converters and filters

Satellite Communications



Satellite Orbits

- Geostationary satellites, orbiting above a fixed point over the equator at a distance of 22300 miles (0.27 seconds transmission time delay).
- Low earth orbit satellites move rapidly, with variable speeds around the earth in elliptical orbits and can approach 1000 km of surface at perigee. Many such satellites are needed to provide 24 hour coverage at a single location (e.g. Molnya, iridium, teledesic)



Elliptical orbit

Circular Geostationary orbit over equator

Frequency Bands for satellite communication

- Choice of carrier frequency must take into account the dependence of loss with frequency in the earth's atmosphere

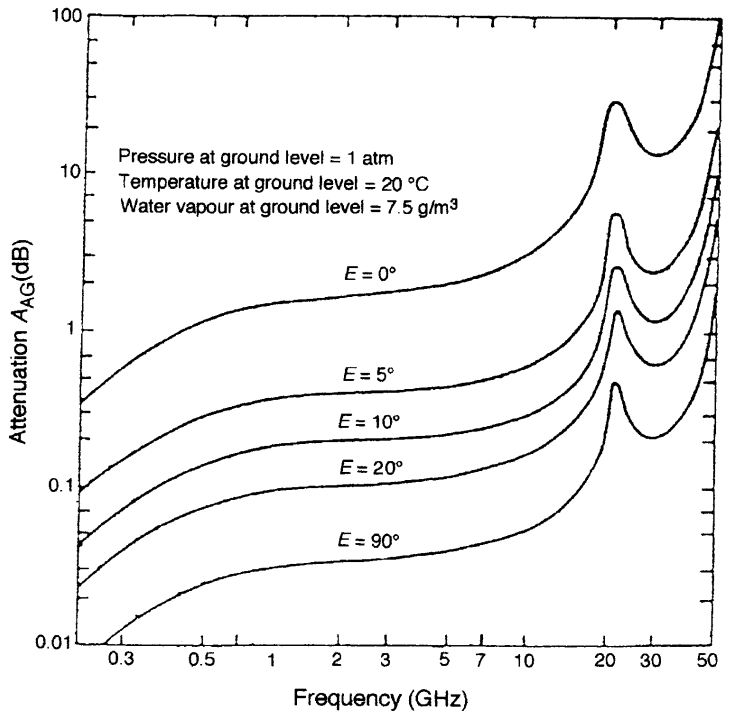


Figure 2.25 Attenuation due to atmospheric gases as a function of frequency and elevation angle E for a standard atmosphere.

Uplink and Downlink

- Transmission of signal from satellite is the downlink, while uplink is the transmission from the ground station
- Downlink and uplink usually employ different carrier frequencies. Commonly used downlink/uplink frequencies are 4GHz/6GHz; 12GHz/14GHz and more recently 20GHz/30GHz.
- Maximum data rate is limited by the carrier frequency and attenuation in the atmosphere
  - Satellites complement rather than compete with optical fiber
  - Provide different services e.g. broadcasting, navigation (GPS), global coverage for mobile phones

Summary

- Mobile Phone Networks
  - Cellular architecture to allow frequency reuse
  - GSM standard uses both TDMA and FDMA
- Fiber Optic Networks
  - Bitrate - distance product limited by dispersion
  - DWDM allows high data throughput in a single fiber (>1000Gbit/s)
  - Expanding rapidly because of demand from internet
- Satellite communications
  - Bitrate limited by carrier frequency
  - Very high carrier frequencies (>30GHz) problematic because of loss