Network Planning and Link Budget Analysis

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Presentation Outline

Satellite Network Topologies

Access Schemes

C-Band vs Ku-Band

Digital Communication Techniques

Modulation

Introduction to Link Budget Analysis

Satellite Network Topology 1/9

Topologies

Satellites networks have various topologies. We can enumerate the following :

- Star Networks
- Mesh Networks
- SCPC

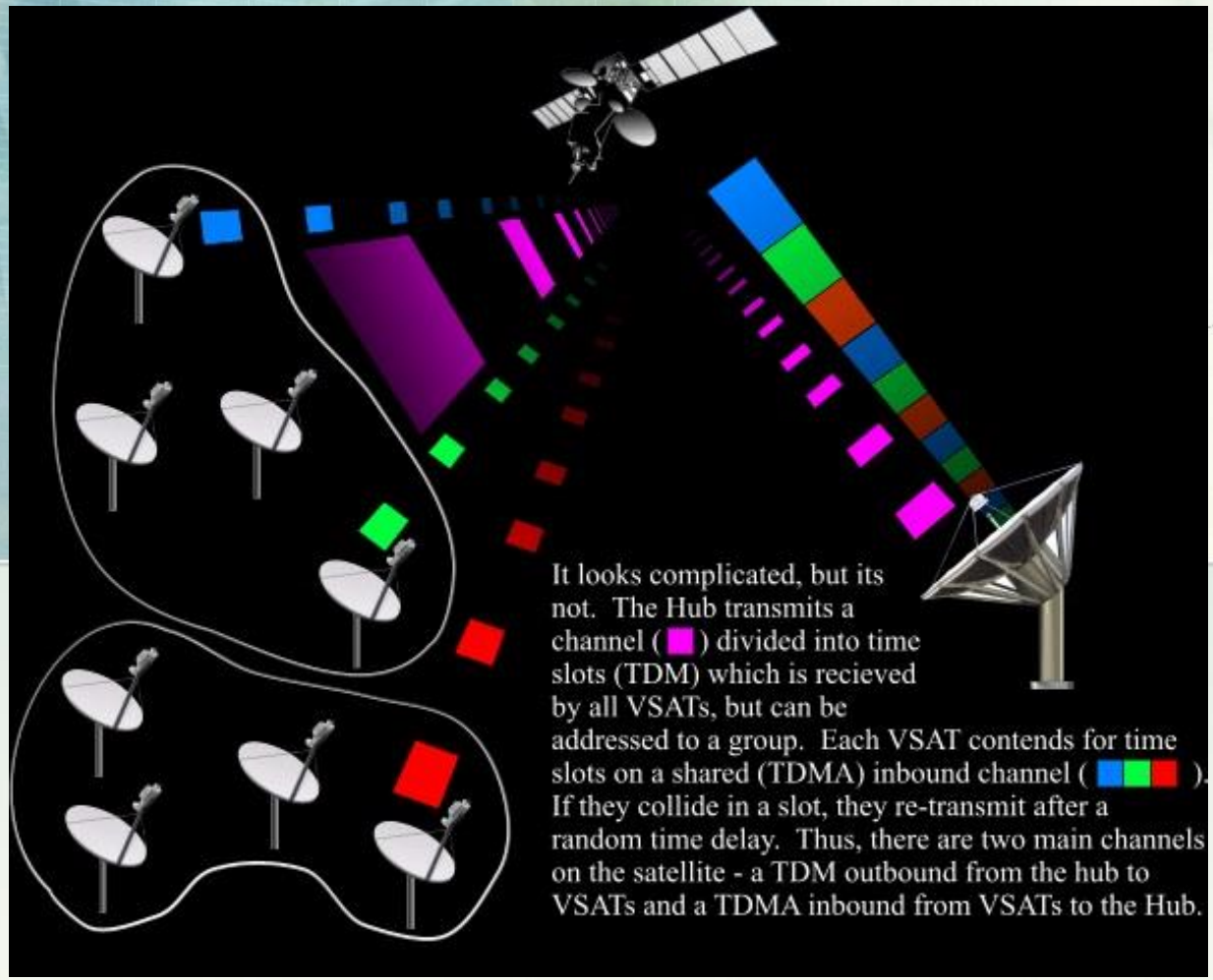
Satellite Network Topology 2/9

Star Network

The next Slide shows how a star data, TDM/TDMA VSAT network works using a hub station, usually six metres or more in size and small VSAT antennas (between 75 centimetres and 2.4 metres). All the channels are shared and the remote terminals are online, offering fast response times. Historically, TDM/TDMA systems competed with terrestrial X.25 or frame relay connections, but as VSAT transmit data rates have risen to 2 Mbps or more and receive rates begin approaching 100 Mbps DSL and MPLS services have become the main competitors in most markets.

Satellite Network Topology 3/9

Star Network



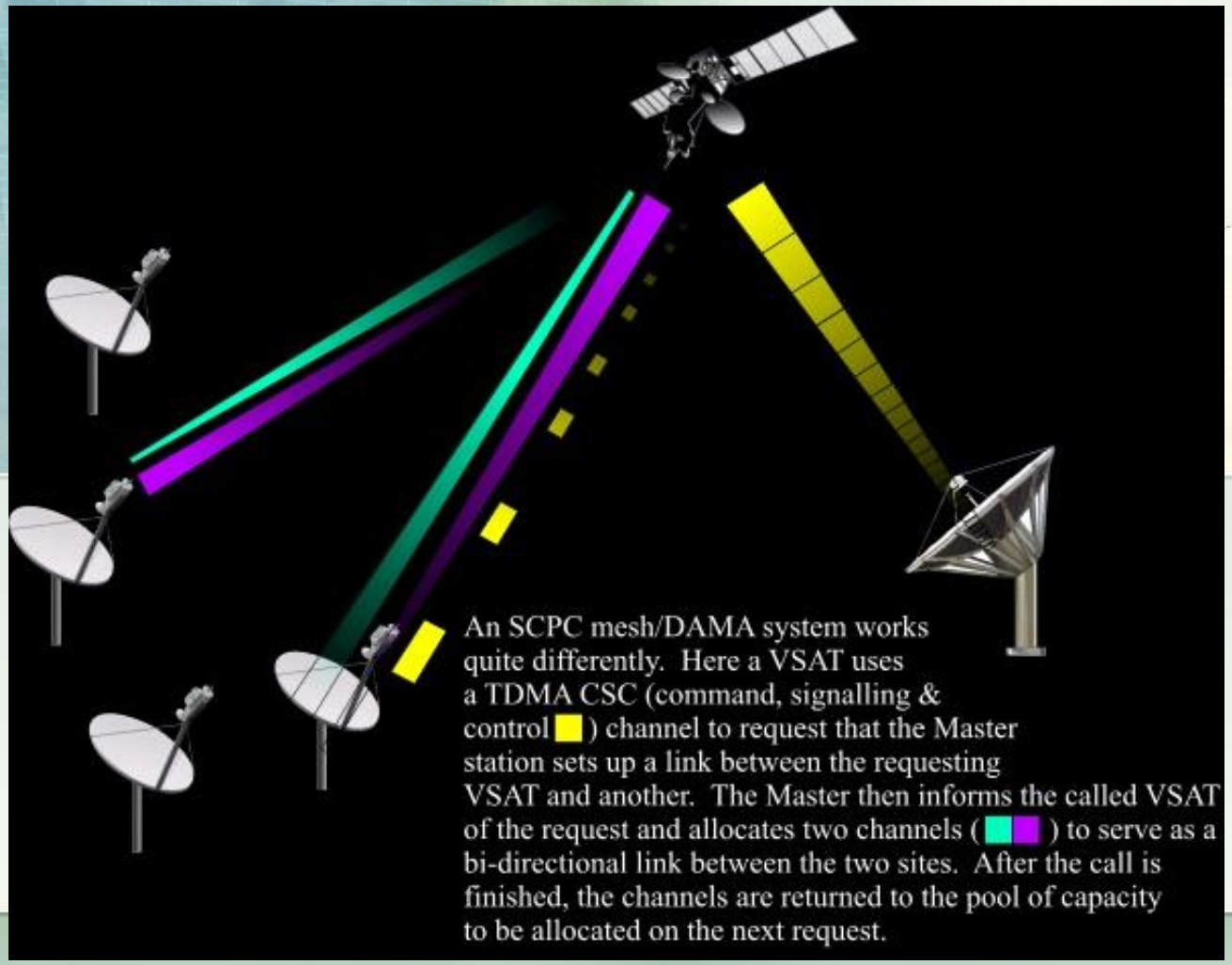
Satellite Network Topology 4/9

Mesh Network

However, mesh networks which use capacity on a demand assigned multiple access (DAMA) basis take a different approach. The master control station merely acts as a controller and facilitator rather than a hub through which traffic passes as in a star network. However, these connections take a little time to set-up and thus, mesh/DAMA systems are often equated to a terrestrial dial-up connection.

Satellite Network Topology 5/9

Mesh Network



Satellite Network Topology 6/9

Mesh Network (Cont'd)

There are also mesh systems which use a TDMA access scheme where all of the terminals in a network receive and transmit to the same channel, selecting different time slots because each terminal is aware of what the others have reserved. In the past this type of system has been costly and therefore, reserved for large scale trunking applications, but, more recently, costs have come down considerably and now they can be cost competitive with SCPC/DAMA systems for thin route applications as well.

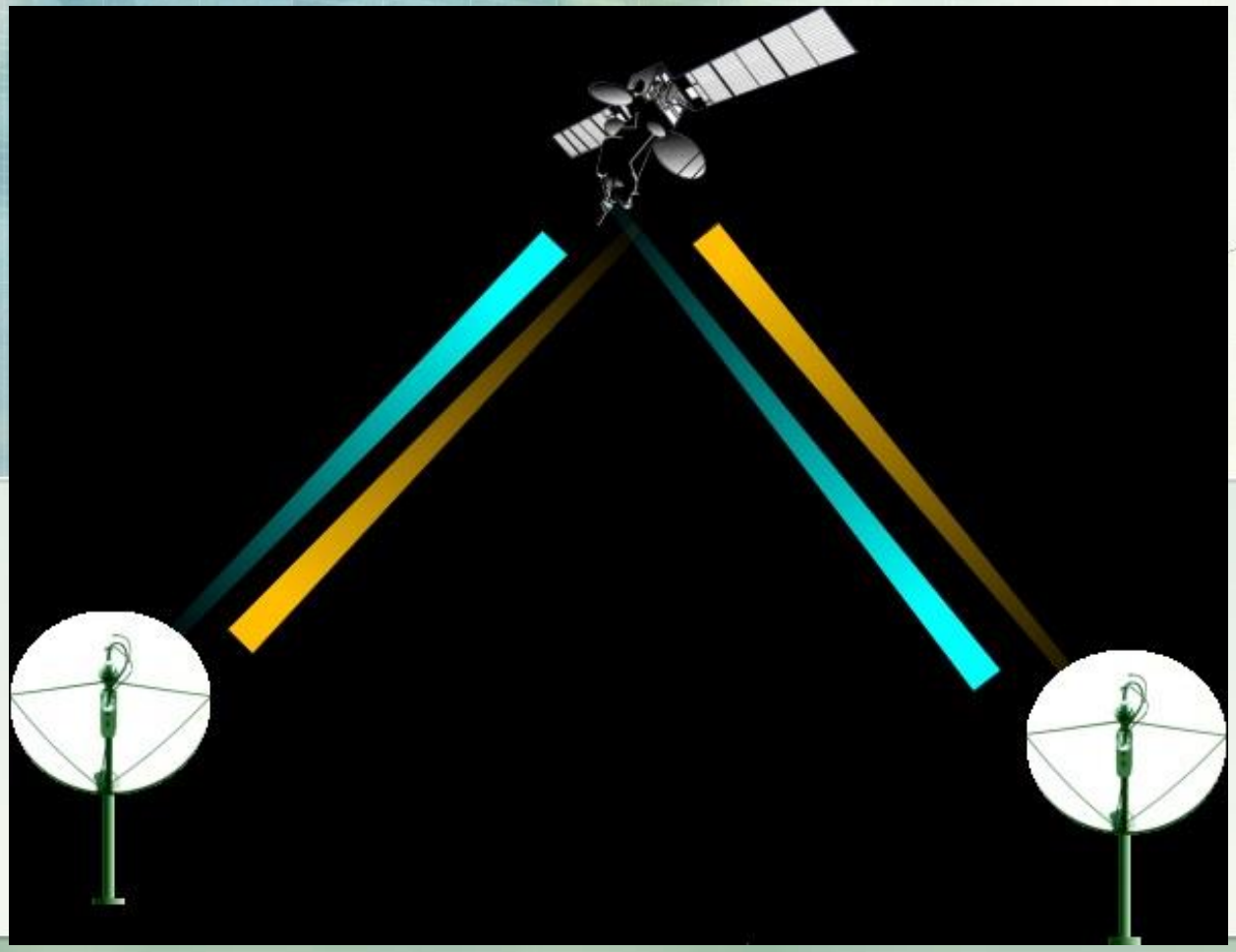
Satellite Network Topology 7/9

SCPC Network

Point-to-point SCPC (single channel per carrier) links are the satellite equivalent of a terrestrial leased line connection. They are usually set-up on a permanent, 24 hour basis and are thus more costly in satellite capacity and less efficient if not used all the time. However, they do support dedicated high bandwidth links without any sharing or contention. Typically we only classify terminals running rates from 9.6 kbps to 2 Mbps as VSATs and can easily be used to carry data, voice and even video traffic.

Satellite Network Topology 8/9

SCPC Network



Satellite Network Topology 9/9

Other Network Topologies

All other systems are usually a variation on one of the themes described above, either in a star, mesh or hybrid (star and mesh) configuration. Most of the TDM/TDMA manufacturers also offer a mesh product which can be deployed in a hybrid-ised configuration, sharing common components such as antennas and RF units, at a remote site.

Access schemes 1/13

The methods by which VSAT networks optimize the use of satellite capacity, and spectrum utilization in a flexible and cost-effective manner are referred to as satellite access schemes. Each topology is associated with an appropriate satellite access scheme. Good network efficiency depends very much on the multiple access schemes. Examples of Access Schemes discussed in this Module are: SCPC, TDMA, FDMA, DAMA, CDMA

Access schemes 2/13

Single Channel Per Carrier (SCPC)

SCPC may be looked as both a topology and an access. Dedicated satellite communications via SCPC networks are an integral part of large business, ISP, and enterprise network operations worldwide. This is because advanced reliability, security, and flexibility enable SCPC (single channel per carrier) satellite service to provide vital, private communications links over VSAT networks in a variety of operating configurations.

Access schemes 3/13

SCPC

SCPC satellite backbone connectivity provides constant dedicated communications to deliver one way, full duplex or asymetrical service in point to point, point to multi-point, star, mesh, or hybrid network configurations.

In these designs, an SCPC network can deliver high bandwidth to easily support the most demanding service applications, such as, video-conferencing, voice communications, and data transmission. Dedicated bandwidth connectivity is offered on SCPC, iSCPC, DVB and DVP-S2 platforms.

Access schemes 4/13

SCPC

Important Satellite SCPC features

- Supports true multimedia capabilities - voice,video,data
- Replacement of terrestrial circuits
- Backup circuits for redundancy or diversity
- Remote access where high-speed terrestrial connectivity isn't available

Potential SCPC applications

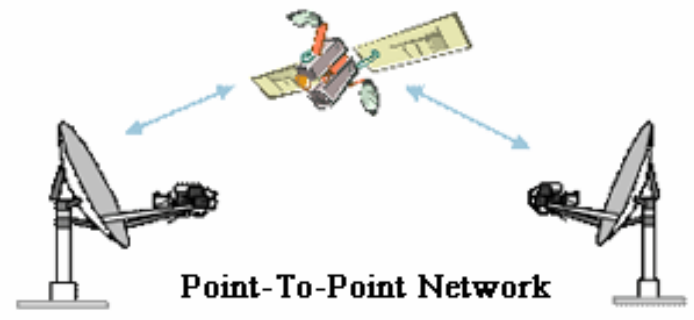
- High-speed access to IP networks
- Replacement of terrestrial circuits
- Credit authorizations and inventory management
- Corporate operations and account management
- WAN connectivity

Access schemes 5/13

SCPC

Point-To-Point Dedicated

Satellite Communications



Provide a direct link between two sites that are located on the same satellite footprint.

Depending upon the satellite and provider, some links can deliver high speeds of up to 155Mbps which is comparable to a terrestrial leased line connection.

Access schemes 6/13

SCPC

These networks easily support voice, video, and data transmissions utilizing a standard data/voice multiplexer, an SCPC satellite modem, and a VSAT terminal at each site. This is a very simple approach for point-to-point networks as communications are only between the two sites. Similarly, Point-To-MultiPoint satellite connectivity is a network configuration composed of multiple Point-To-Point SCPC connections.

There is no connectivity to the teleport which requires the satellite signal to make a double hop. More important, the quality of real time applications is not affected.

There are no costs associated with the usage of a teleport or backhaul which makes this a less expensive solution!

Access schemes 7/13

TDMA

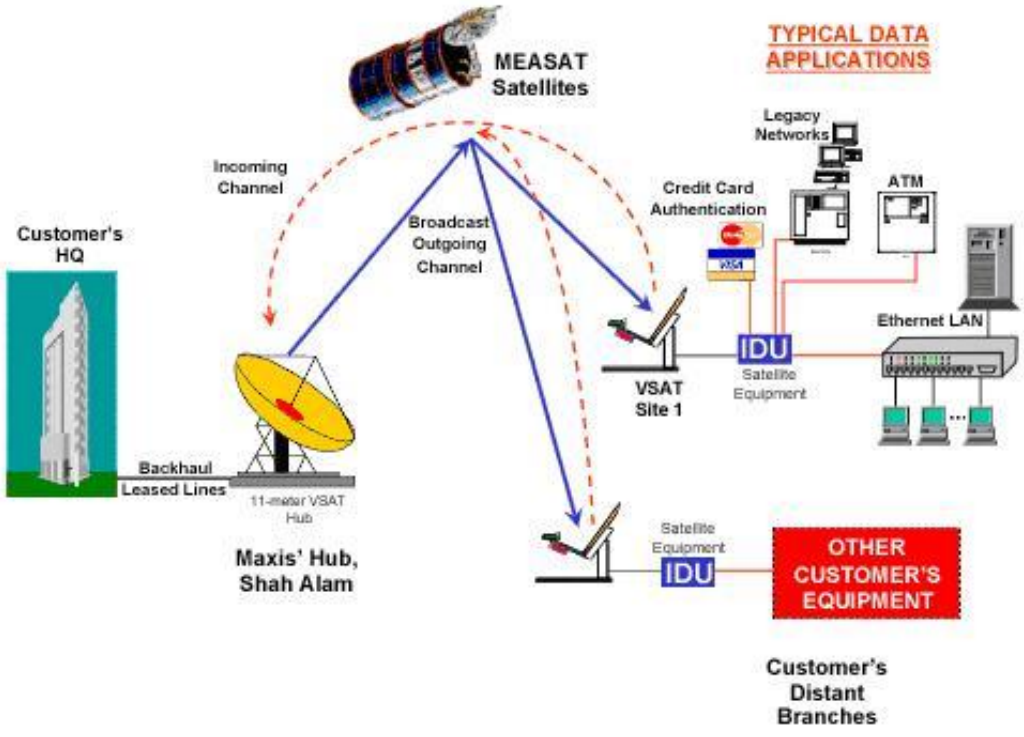
With TDMA networks, numerous remote sites communicate with one central hub – a design that is similar to packet-switched networks.

Remote sites in a TDMA network compete with one another for access to the central hub, restricting the maximum available bandwidth.

In a TDMA network, all VSATs share satellite resource on a time-slot basis. Remote VSATs use TDMA channels or inroutes for communicating with the hub. There could be several inroutes associated with one outroute. Several VSATs share one inroute hence sharing the bandwidth. Typical inroutes operate at 64 or 128 Kbit/s. Generally systems with star topology use a TDMA transmission technique. Critical to all TDMA schemes is the function of clock synchronization that is performed by the TDMA hub or master earth station.

Access schemes 8/13

TDMA



Typical SkyNet (TDM/TDMA) configuration supporting various interactive data applications

Access schemes 9/13

FDMA

It is the oldest and still one of the most common methods for channel allocation. In this scheme, the available satellite channel bandwidth is broken into different frequency bands for different earth stations. This means that guard bands are needed to provide separation between the bands. Also, the earth stations must be carefully power-controlled to prevent the microwave power spilling into the bands for the other channels. Here, all VSATs share the satellite resource on the frequency domain only. Typically implemented in a mesh or single satellite hop topology, FDMA has the following variants:

- **PAMA (Pre-Assigned Multiple Access)**
- **DAMA (Demand Assigned Multiple Access)**
- **CDMA (Code Division Multiple Access)**

Access schemes 10/13

PAMA

It implies that the VSATs are pre-allocated a designated frequency. Equivalent of the terrestrial leased line solutions, PAMA solutions use the satellite resources constantly. Consequently, there is no call-up delay what makes them most suited for interactive data applications or high traffic volumes. As such, PAMA connects high data traffic sites within an organization.

SCPC (Single Channel Per Carrier) refers to the usage of a single satellite carrier for carrying a single channel of user traffic. The frequency is allocated on a pre-assigned basis in case of SCPC VSAT which is also synonymously known as PAMA VSAT.

Access schemes 11/13

DAMA

The network uses a pool of satellite channels, which are available for use by any station in that network. On demand, a pair of available channels is assigned so that a call can be established. Once the call is completed, the channels are returned to the pool for an assignment to another call. Since the satellite resource is used only in proportion to the active circuits and their holding times, this is ideally suited for voice traffic and data traffic in batch mode.

DAMA offers point-to-point voice, fax, and data requirements and supports video-conferencing.

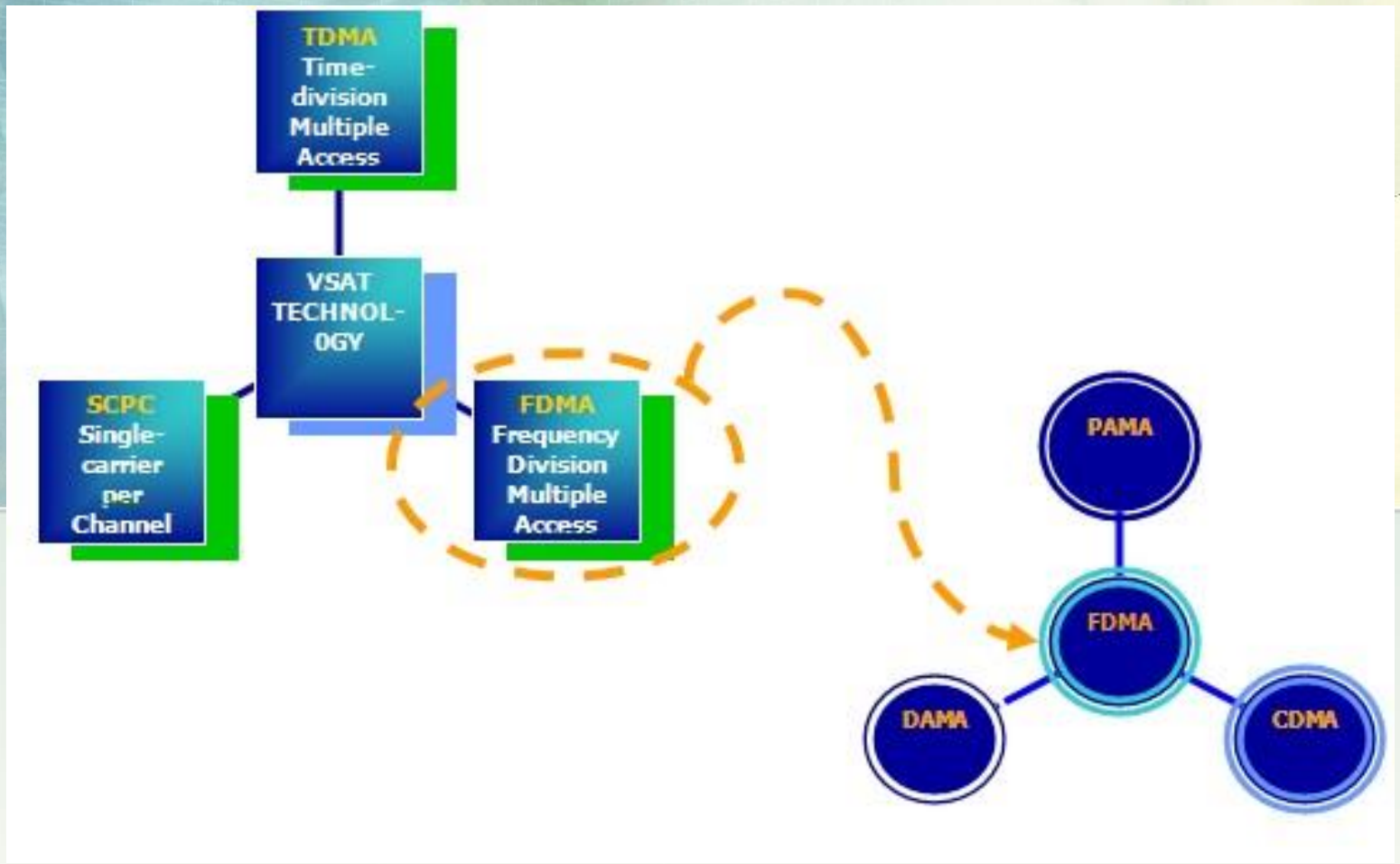
DAMA systems allow the number of channels at any time be less than the number of potential users. Satellite connections are established and dropped only when traffic demands them.

Access schemes 12/13

CDMA

Under this access scheme, a central network monitoring system allocates a unique code to each of the VSATs enabling multiple VSATs to transmit simultaneously and share a common frequency band. To permit this to be achieved without undue interference between the users CDMA employs spread-spectrum technology.

Access schemes 13/13



C Band vs. Ku Band 1/4

C Band: For satellite communications, the microwave frequencies of the C-band perform better in comparison with K_u band (11.2 GHz to 14.5 GHz) microwave frequencies, under adverse weather conditions, which are used by another large set of communication satellites. The adverse weather conditions all have to do with moisture in the air, such as during rainfalls, thunderstorms, sleet storms, and snowstorms.

- Downlink: 3.7 – 4.2 GHz
- Uplink: 5.9 – 6.4 GHz

C Band vs. Ku Band 2/4

C Band

`C-Band Variations Around The World		
Band	Transmit Frequency (GHz)	Receive Frequency (GHz)
Extended C-Band	5.850-6.425	3.625-4.200
Super Extended C-Band	5.850-6.725	3.400-4.200
INSAT C-Band	6.725-7.025	4.500-4.800
Russian C-Band	5.975-6.475	3.650-4.150
LMI C-Band	5.7250-6.025	3.700-4.000

C Band vs. Ku Band 3/4

Ku Band

The K_u band is a portion of the electromagnetic spectrum in the microwave range of frequencies. This symbol refers to "K-under" (in the original German, "Kurz-unten", with the same meaning)—in other words, the band directly below the K-band. In radar applications, it ranges from 12 to 18 GHz according to the formal definition of radar frequency band nomenclature in IEEE Standard 521-2002.

- Downlink: 11.7 – 12.2 GHz
- Uplink: 14.0 – 14.5 GHz

C Band vs. Ku Band 4/4

	Advantages	Disadvantages
C Band	✓ Less disturbance from heavy rain fade ✓ Cheaper Bandwidth	❖ Needs a larger satellite dish (diameters of minimum 2-3m) ❖ Powerful (=expensive) RF unit ❖ More expensive hardware ❖ Possible Interference from microwave links
Ku Band	✓ No interference from microwave links and other technologies ✓ Operates with a smaller satellite dish (diameters from 0.9m) -> cheaper and more easy installation ✓ Needs less power -> cheaper RF unit	❖ More expensive capacity ❖ Sensitive to heavy rain fade (significant attenuation of the signal) / possibly can be managed by appropriate dish size or transmitter power.

Digital Communications techniques 1/15
Protocols supported by VSAT Networks

- A summary of the protocols in general use and their support over typical VSAT networks is provided in Table 8.2.
- When first introduced in the 1980s, VSATs played heavily on the traditional IBM proprietary protocol, Systems Network Architecture (SNA), which followed the same centralized approach as the VSAT star network.
- While still in existence in some legacy environments, it has been replaced with the more open Internet Protocol suite (TCP/IP).
- Transporting TCP/IP over VSAT has its shortcomings, which are being addressed by standards bodies and major vendors like Cisco.
- Employing TCP/IP in a private network is very straightforward and is well within the means of any organization or individual.

Digital Communications techniques 2/15

Protocols supported by VSAT Networks

Table 8.2 Network Protocols and Applications in Common Use for IT Networks and Their Availability over VSATs

Protocol	*Applications*	*Availability on VSATs*
Internet (TCP/IP)	Web, e-mail, file transfer, VoIP, streaming video, videoconferencing	Supported since 1995, now becoming the standard for access and data handing
Frame Relay (ISDN)	Wide area network, private voice networks	Limited (may be substituted by TCP/IP)
Ethernet (MAC layer)	Virtual LANs	Supported since 1992
Novell NetWare (IPX/SPX)	Wide area network	Supported in early VSAT implementations; being replaced by TCP/IP which is provided by NetWare 6

Protocols supported by VSAT Networks

- However, the complexity comes when an organization wishes to interconnect with the global Internet and with other organizations.
- This is due to the somewhat complex nature of routing protocols like the Border Gateway Protocol (BGP) and a new scheme called Multi Protocol Label Switching (MPLS).
- Frame Relay has been popular in WANs for more than a decade, thanks to its ease of interface at the router and availability in (and between) major countries.
- It is capable of near-real-time transfer and can support voice services. With access speeds generally available at 2 Mbps or less.
- Satellite provision of Frame Relay has been limited to point-to-point circuits as the protocol is not directly supported in VSATs currently on the market.
- The best approach would be to use TCP/IP in lieu of Frame Relay when VSAT links are interfaced at the router.

Digital Communications techniques 4/15

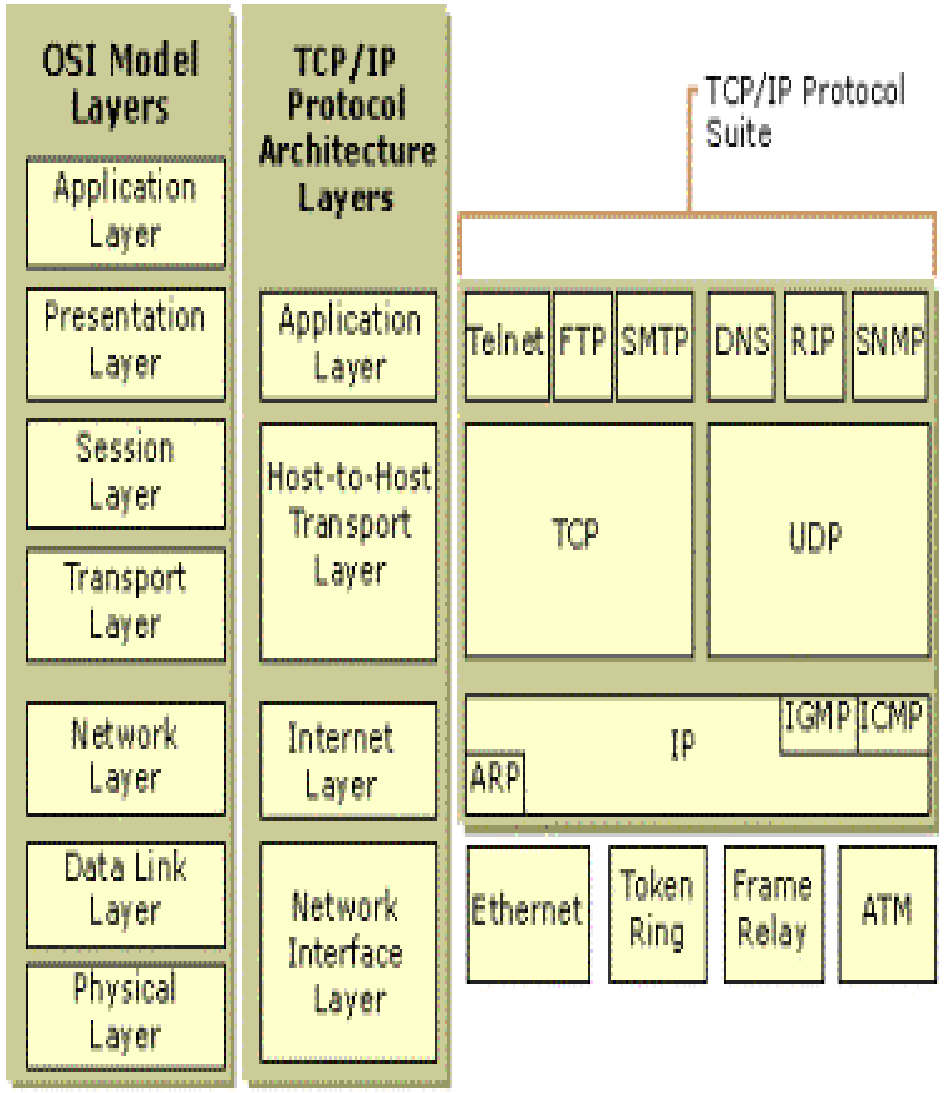
- Modern data communications theory and practice is literally built upon the concept of protocol layering, where the most basic transmission requirement is at the bottom and more complex and sophisticated features are added one on top of each other.
- While this concept is abstract, it is important to understanding how the data in a network is assembled, processed, and reliably transferred between sender and receiver.

Digital Communications techniques 5/15

- The layering concept is embodied in the Open Systems Interconnection (OSI) model shown in the figure on next page and contained in relevant standards of the International Organization for Standardization (ISO) and the ITU-Telecommunication Sector (ITU-T).

OSI and TCP/IP (DARPA) Model

	OSI Layer	TCP/IP Layer
7	Application	HTTP, STMP, FTP, and so forth.
6	Presentation	
5	Session	
4	Transport	TCP (or UDP)
3	Network	IP
2	Data Link	Logical link control (LLC) – 802.2 Media access control (MAC) – 802.3
1	Physical	Twisted pair, T1/E1, VSAT



TCP/IP Protocol

The immense influence of the Internet caused its communications protocol to become the world standard. Almost all networks, except for the circuit-switched networks of the telephone companies, have migrated to TCP/IP.

TCP/IP is a robust and proven technology that was first tested in the early 1980s on ARPAnet, the U.S. military's Advanced Research Projects Agency network, the world's first packet-switched network. TCP/IP was designed as an open protocol that would enable all types of computers to transmit data to each other via a common communications language.

Multiple Layers

TCP/IP is a layered protocol, which means that after an application initiates the communications, the message (data) to be transmitted is passed through a number of software stages, or layers, until it actually moves out onto the wire, or if wireless, into the air. The data are packaged with a different header at each layer. At the receiving end, the corresponding software at each protocol layer unpackages the data, moving it "back up the stack" to the receiving application.

TCP and IP

TCP/IP is composed of two parts: TCP (Transmission Control Protocol) and IP (Internet Protocol). TCP is a connection-oriented protocol that passes its data to IP, which is connectionless. TCP sets up a connection at both ends and guarantees reliable delivery of the full message sent. TCP tests for errors and requests retransmission if necessary, because IP does not.

UDP

An alternative protocol to TCP within the TCP/IP suite is UDP (User Datagram Protocol), which does not guarantee delivery. Like IP, UDP is also connectionless, but very useful for transmitting audio and video that is immediately heard or viewed at the other end. If packets are lost in a UDP transmission (they can be dropped at any router junction due to congestion), there is neither time nor a need to retransmit them. A momentary blip in a voice or video transmission is not critical.

Compression

Analog Video Compression

In communications, data compression is helpful because it enables devices to store or transmit the same amount of data in fewer bits, thus making the transmission of the data faster.

A hardware circuit converts analog video (NTSC, PAL, SECAM) into digital code and vice versa. The term may refer to only the A/D and D/A conversion, or it may include the compression technique for further reducing the signal.

Compression

Digital Video Compression

Hardware and/or software that compresses and decompresses a digital video signal. MPEG, Windows Media Video (WMV), H.264, VC-1 and

QuickTime are examples of codecs that compress and decompress digital video.

VoIP

Definition

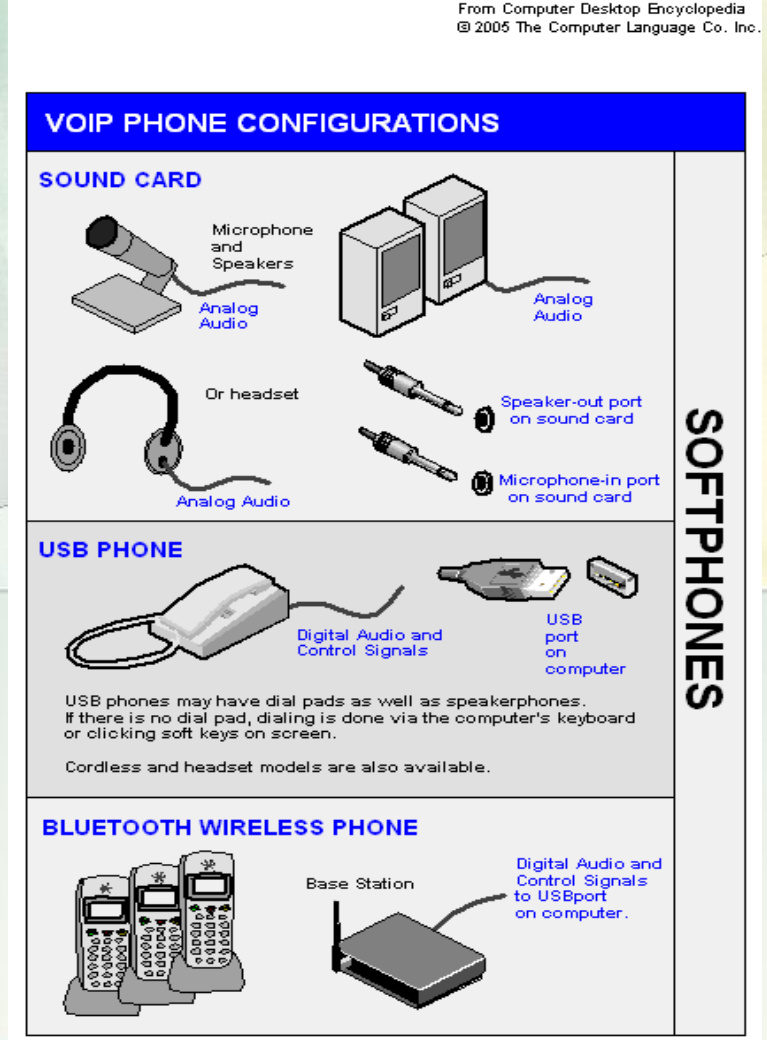
Referring to voice communications over the public Internet or any packet network employing the TCP/IP protocol suite. Specifically, VoIP operates in datagram mode, employing the Internet Protocol (IP) for addressing and routing, the User Datagram Protocol (UDP) for host-to-host data transfer between application programs, and the Real Time Transport Protocol (RTP) for end-to-end delivery services.

VoIP also typically employs sophisticated predictive compression algorithms, such as low delay code excited linear prediction (LD-CELP), to mitigate issues of latency and jitter over a packet-switched network.

Digital Communications techniques 13/15
VoIP

Softphone based

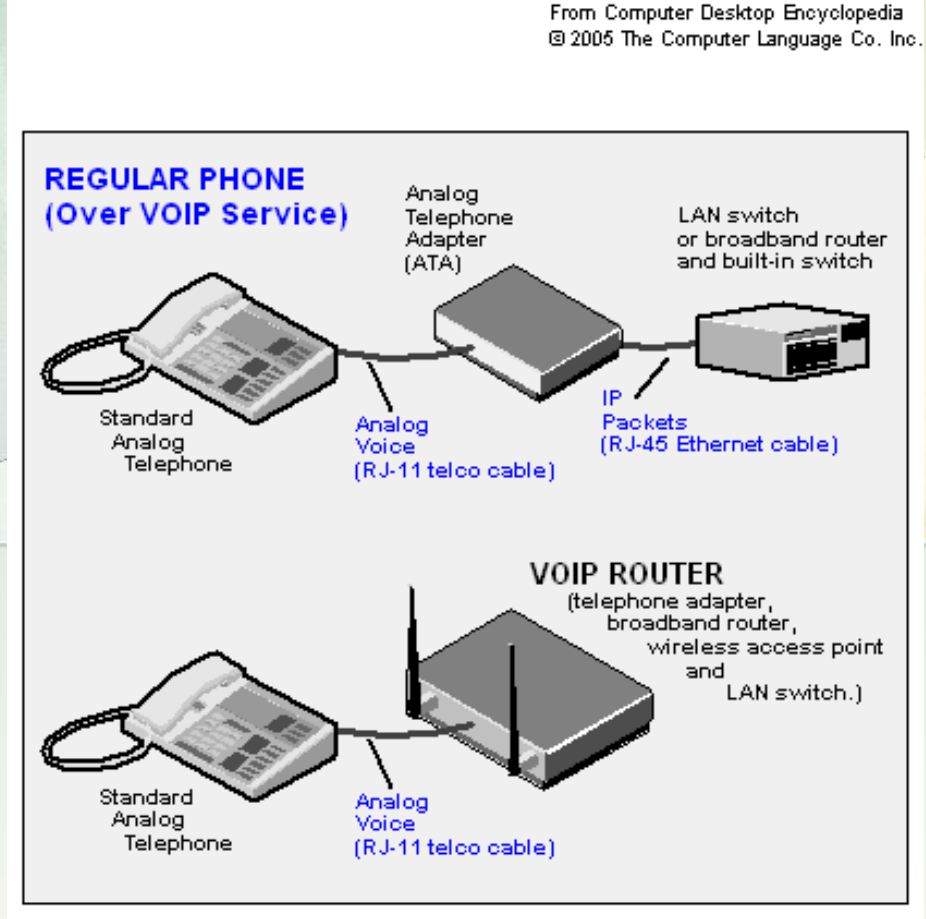
VoIP providers may be entirely softphone based, which requires a computer, phone software and microphone and speakers (or headset) to make and receive calls. Usually free of cost if both sides are on the same service, softphones let users call any phone in the world from their laptops and an Internet connection. Per-minute charges apply to call a regular phone number, but calls from a regular phone may not be possible



VoIP

Handset based

Regular phones can be used with many VoIP services by plugging them into an analog telephone adapter (ATA) provided by the VoIP provider or purchased from a third party. The ATA converts the phone to IP packets. IP phones can also be used that have built-in IP packet support.



VoIP

IP Phone Built in VoIP

IP Phones can be directly connected to the IP network.

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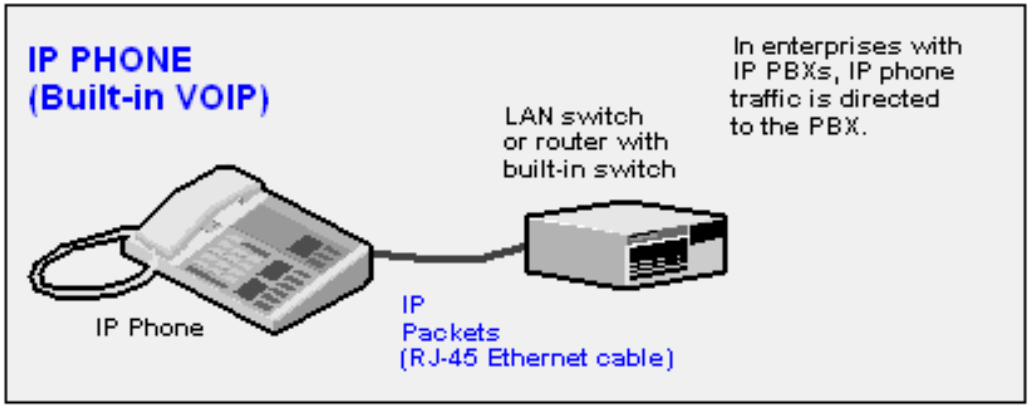


Modulation 1/10

In telecommunications, **modulation** is the process of conveying a message signal, for example a digital bit stream or an analog audio signal, inside another signal that can be physically transmitted. Modulation of a sine waveform is used to transform a baseband message signal to a passband signal, for example a radio-frequency signal (RF signal). In radio communications, cable TV systems or the public switched telephone network for instance, electrical signals can only be transferred over a limited passband frequency spectrum, with specific (non-zero) lower and upper cutoff frequencies.

Modulation 2/10

The three basic types of modulation are :

- Amplitude Shift Keying (ASK)
- Frequency Shift Keying (FSK)
- Phase Shift Keying (PSK)

All of these techniques vary a parameter of a sinusoid to represent the information which we wish to send. A sinusoid has 3 different parameters that can be varied. These are amplitude, phase and frequency.

Modulation 3/10

Amplitude Modulation (AM)

Varying the voltage of a carrier or a direct current in order to transmit analog or digital data. Amplitude modulation (AM) is the oldest method of transmitting human voice electronically. In an analog telephone conversation, the voice waves on both sides are modulating the voltage of the direct current loop connected to them by the telephone company.

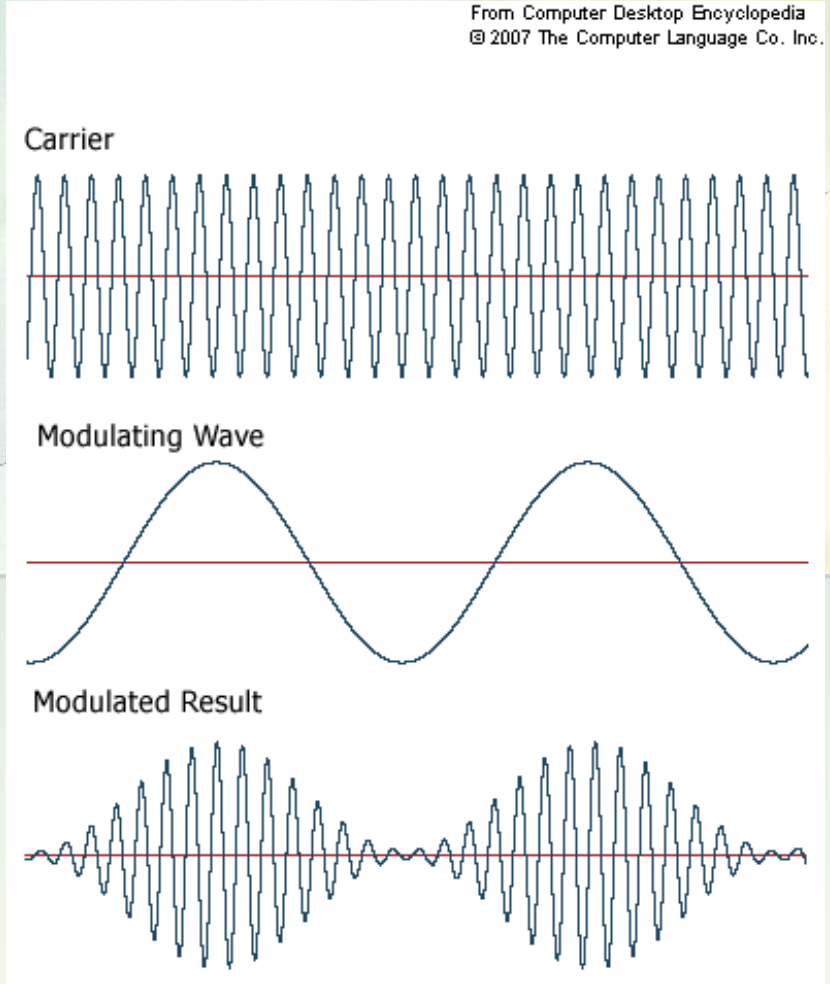
AM is also used for digital data. In quadrature amplitude modulation (QAM), both amplitude and phase modulation are used to create different binary states for transmission.

Modulation 4/10

Amplitude Modulation (AM)

Vary the Amplitude

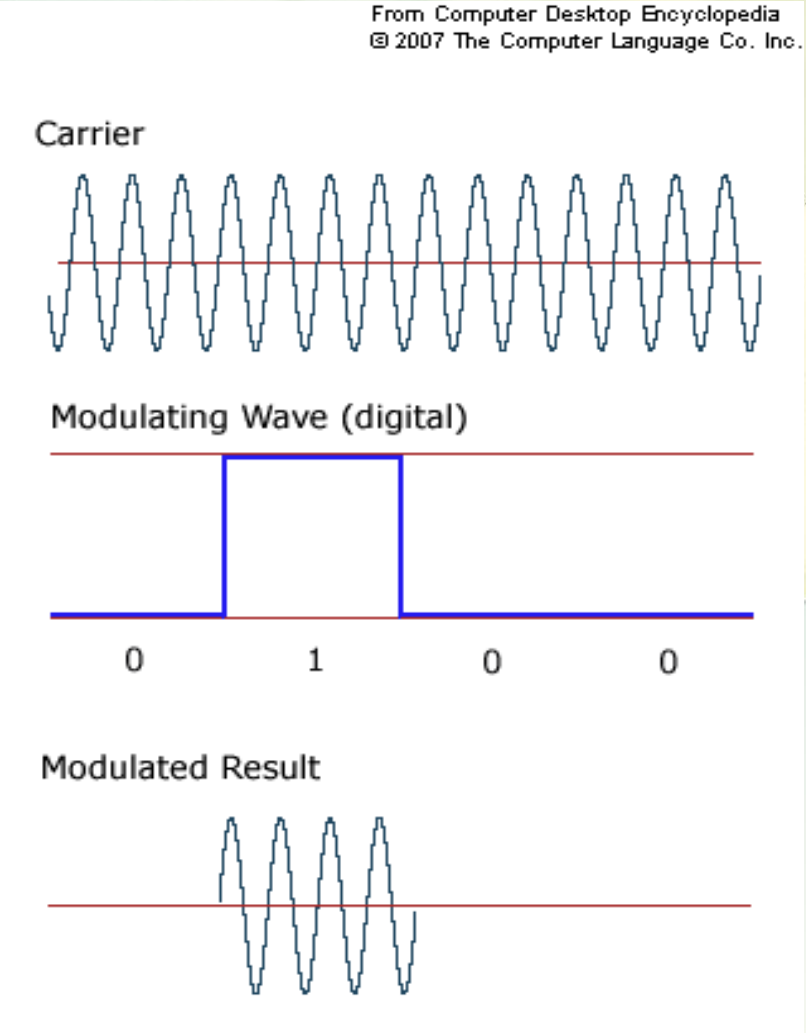
In AM modulation, the voltage (amplitude) of the carrier is varied by the incoming signal. In this example, the modulating wave implies an analog signal.



Modulation 5/10

Digital Amplitude Shift Keying (ASK)

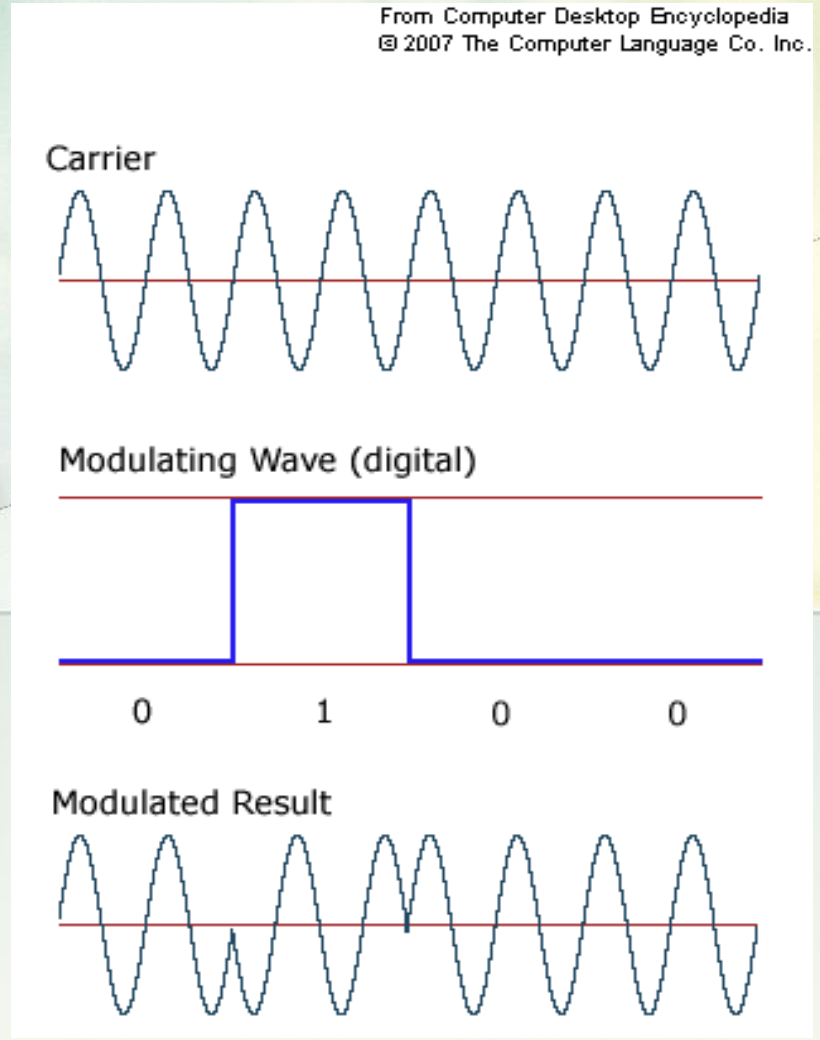
For digital signals, amplitude shift keying (ASK) uses two voltage levels for 0 and 1 as in this example.



Modulation 6/10

Phase Shift Keying (PSK)

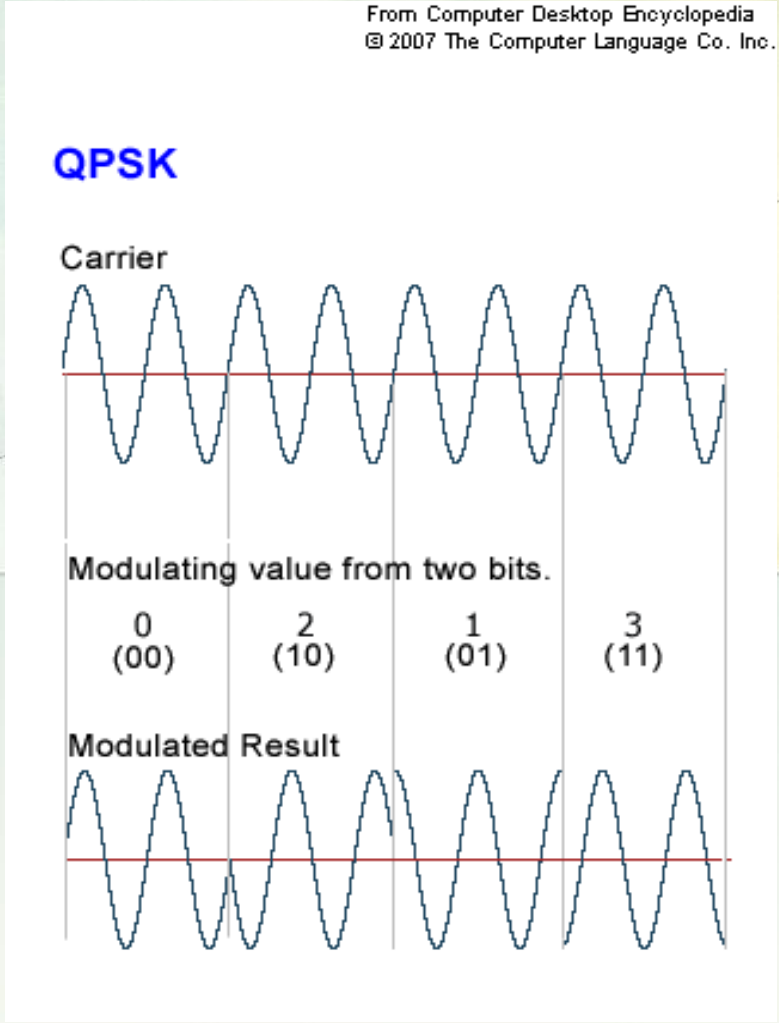
For digital signals, phase shift keying (PSK) uses two phases for 0 and 1 as in this example.



Modulation 7/10

Quadrature Phase Shift Keying (QPSK)

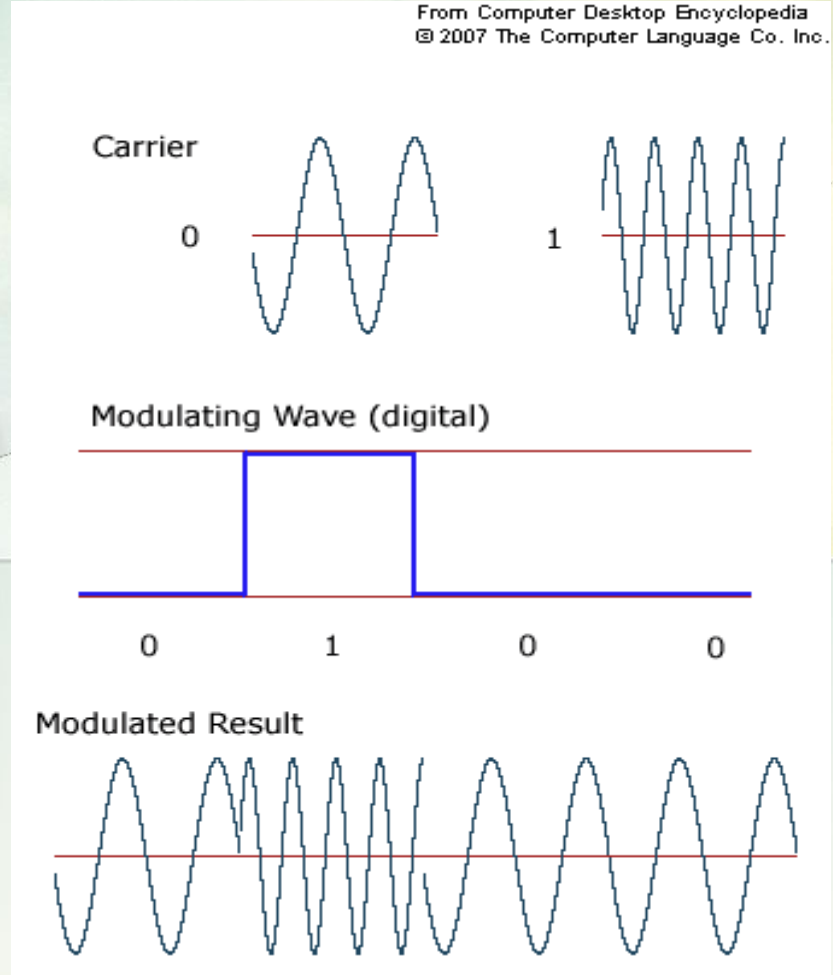
QPSK uses four phase angles to represent each two bits of input; however, the amplitude remains constant.



Modulation 8/10

Frequency Shift Keying (FSK)

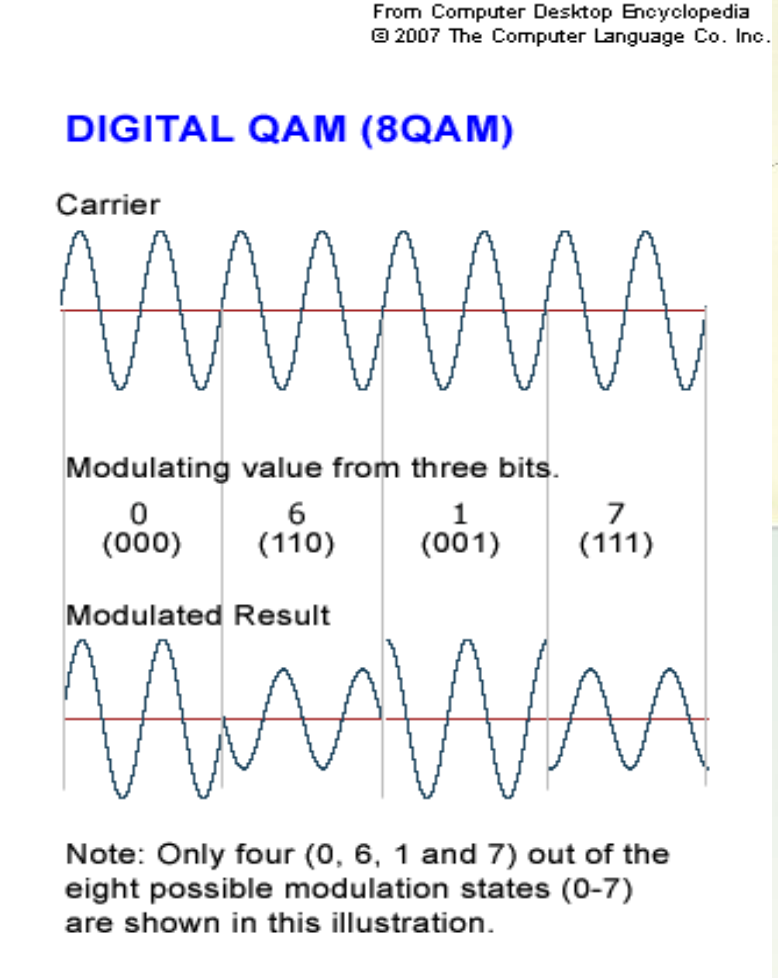
FSK is a simple technique that uses two frequencies to represent 0 and 1.



Modulation 9/10

Digital 8QAM

In this 8QAM example, three bits of input generate eight different modulation states (0-7) using four phase angles on 90 degree boundaries and two amplitudes: one at 50% modulation; the other at 100% (4 phases X 2 amplitudes = 8 modulation states). QAM examples with more modulation states become extremely difficult to visualize.



Modulation 10/10

Popular Modulation schemes used in satellite

Popular modulation types being used for satellite communications:

- Binary phase shift keying (BPSK);
- Quadrature phase shift keying (QPSK);
- 8PSK;
- Quadrature amplitude modulation (QAM), especially 16QAM.

Questions so far?