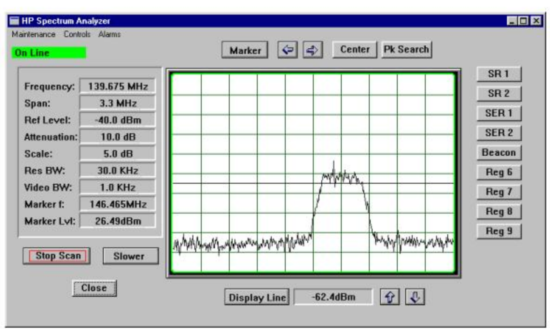
SATELLITE COMMUNICATIONS



Glossary of Satellite Terms

Amplitude Modulation (AM)
The baseband signal is caused to vary the amplitude or height of the carrier wave to create the desired information content.

Amplifier
A device used to boost the strength of an electronic signal.

Analog
A form of transmitting information characterized by continuously variable quantities, as opposed to digital transmission, which is characterized by discrete bits of information in numerical steps. An analog signal is responsive to changes in light, sound, heat and pressure.

Analog-to-Digital Conversion (ADC)
Process of converting analog signals to a digital representation. DAC represents the reverse translation.

ANIK
The Canadian domestic satellite system that transmits Canadian Broadcasting Corporation's (CSC) network feeds throughout the country. This system also carries long distance voice and data services throughout Canada as well as some transponder service to the U.S. and Mexico.

Antenna
A device for transmitting and receiving radio waves. Depending on their use and operating frequency, antennas can take the form of a single piece of wire, a di-pole a grid such as a yagi array, a horn, a helix, a sophisticated parabolic-shaped dish, or a phase array of active electronic elements of virtually any flat or convoluted surface.

Aperture
A cross sectional area of the antenna which is exposed to the satellite signal.

Apogee
The point in an elliptical satellite orbit which is farthest from the surface of the earth. Geosynchronous satellites which maintain circular orbits around the earth are first launched into highly elliptical orbits with apogees of 22,237 miles. When the communication satellite reaches the appropriate apogee, a rocket motor is fired to place the satellite into its permanent circular orbit of 22,237 miles.

Apogee Kick Motor (AKM)
Rocket motor fired to circulate orbit and deploy satellite into geostationary orbit.

Attenuation
The loss in power of electromagnetic signals between transmission and reception points.

Attitude Control
The orientation of the satellite in relationship to the earth and the sun.

Attribute
The form of information items provided by the X.500 Directory service. The directory information

base consists of entries, each containing one or more attributes. Each attribute consists of a type identifier together with on or more values.

Audio Subcarrier
The carrier between 5 MHz and 8 MHz containing audio (or voice) information inside of a video carrier.

Automatic Frequency Control (AFC)
A circuit which automatically controls the frequency of a signal.

Automatic Gain Control (AGC)
A circuit which automatically controls the gain of an amplifier so that the output signal level is virtually constant for varying input signal levels.

AZ/EL Mount
Antenna mount that requires two separate adjustments to move from one satellite to another;

Azimuth
The angle of rotation (horizontal) that a ground based parabolic antenna must be rotated through to point to a specific satellite in a Geosynchronous orbit. The azimuth angle for any particular satellite can be determined for any point on the surface of the earth giver the latitude and longitude of that point. It is defined with respect to due north as a matter of easy convenience.

B-Mac
A method of transmitting and scrambling television signals. In such transmissions MAC (Multiplexed Analog Component) signals are time-multiplexed with a digital burst containing digitized sound, video synchronizing, authorization, and information.

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Beacon
Low-power carrier transmitted by a satellite which supplies the controlling engineers on the ground with a means of monitoring telemetry data, tracking the satellite, or conducting propagation experiments. This tracking beacon is usually a horn or omni antenna.

Beamwidth
The angle or conical shape of the beam the antenna projects. Large antennas have narrower beamwidths and can pinpoint satellites in space or dense traffic areas on the earth more precisely. Tighter beamwidths thus deliver higher levels of power and thus greater communications performance.

BER
Basic Encoding Rules. Rules for encoding data units described in ASN.1. Sometimes incorrectly lumped under the term ASN.1, which properly refers only to the abstract syntax description language, not the encoding technique.

Bird
Slang for a communications satellite located in geosynchronous orbit.

Bit
A binary digit, either a 0 or 1. 8 bits make up on a byte. Bits are used in the measure of transmission capacity.

Bit Error Rate
The fraction of a sequence of message bits that are in error. A bit error rate of 10-6 means that there is an average of one error per million bits.

Bit Rate
The rate at which the compressed bitstream is delivered from the storage medium to the input of a decoder.

Bit Stream
See the description for Multiplex.

Blanking
An ordinary television signal consists of 30 separate still pictures or frames sent every second. They occur so rapidly, the human eye blurs them together to form an illusion of moving pictures. This is the basis for television and motion picture systems. The blanking interval is that portion of the television signal which occurs after one picture frame is sent and before the next one is transmitted. During this period of time special data signals can be sent which will not be picked up on an ordinary television receiver.

Block Down Converter
A device used to convert the 3.7 to 4.2 KHz signal down to UHF or lower frequencies (1 GHz and lower).

BNC Connector (Bayone-Neill-Concelman)
Standard connector used to connect 10Base2 coaxial cable.

BPSK
Binary Phase Shift Keying.

Bridge
A device that connects two or more physical networks and forwards packets between them. Bridges can usually be made to filter packets, that is, to forward only certain traffic. Related devices are: repeaters which simply forward electrical signals from one cable to another, and full-fledged routers which make routing decisions based on several criteria.

Broadband
Refers to networks capable of delivery high bandwidth. Broadband networks are used by Cable Television and range from 550 MHz to 1GHz. A single TV channel requires 6MHz. In the digital domain, all content is digitized and hence the bandwidth is usually measured in bits-per-second (BPS).

Business Television
Corporate communications tool involving video transmissions of information via satellite. Common uses of business television are for meetings, product introductions and training.

Byte
One byte of digital video information is a packet of bits, usually but not always eight. In the digital video domain, a byte is used to represent the luminance or chrominance level. One thousand bytes is one kilobyte (kb) and one million bytes is one megabyte (MB).

C Band
This is the band between 4 and 8 GHz with the 6 and 4 GHz band being used for satellite communications. Specifically, the 3.7 to 4.2 GHz satellite communication band is used as the down link frequencies in tandem with the 5.925 to 6,425 GHz band that serves as the uplink.

Cable
Transmission medium of copper wire or optical fiber wrapped in a protective cover.

Caching
A form of replication in which information learned during a previous transaction is used to process later transactions.

Carrier to Noise Ratio (C/N)
The ratio of the received carrier power and the noise power in a given bandwidth, expressed in dB. This figure is directly related to G/T and S/N; and in a video signal the higher the C/N, the better the received picture.

Carrier
The basic radio, television, or telephony center of frequency transmit signal. The carrier in an analog signal. is modulated by manipulating its amplitude (making it louder or softer) or its frequency (shifting it up or down) in relation to the incoming signal. Satellite carriers operating in the analog mode are usually frequency modulated.

Carrier Frequency
The main frequency on which a voice, data, or video signal is sent. Microwave and satellite communications transmitters operate in the band from 1 to 14 GHz (a GHz is one billion cycles per second).

Cassegrain Antenna
The antenna principle that utilizes a subreflector at the focal point which reflects energy to or from a feed located at the apex of the main reflector.

CCITT
International Consultative Committee for Telegraphy and Telephony. A unit of the International Telecommunications Union (ITU) of the United Nations. An organization with representatives from the PTTs of the world. CCITT produces technical standards, known as "Recommendations," for all internationally controlled aspects of analog and digital communications.

CCR
Commitment, Concurrency, and Recovery. An OSI application service element used to create atomic operations across distributed systems. Used primarily to implement two-phase commit for transactions an nonstop operations.

CDMA
Code division multiple access. Refers to a multiple-access scheme where stations use spread-spectrum modulations and orthogonal codes to avoid interfering with one another.

CD-ROM
Compact Disk Read Only Memory. 5-1/4 inch optional disk, typically used to store text, images, audio, video, and programs which can run on suitably equipped computers.

Channel
A frequency band in which a specific broadcast signal is transmitted. Channel frequencies are

specified in the United States by the Federal Communications Commission. Television signals require a 6 MHz frequency band to carry all the necessary picture detail.

Chrominance
The color information part of the video signal, usually defined in terms of hue and saturation. The video signal is make up of chrominance (color) and luminance (brightness) information. The symbols are Cr and Cb.

Circular Polarization
Unlike many domestic satellites which utilize vertical or horizontal polarization, the international Intelsat satellites transmit their signals in a rotating corkscrew-like pattern as they are down-linked to earth. On some satellites, both right-hand rotating and left-hand rotating signals can be transmitted simultaneously on the same frequency; thereby doubling the capacity of the satellite to carry communications channels.

Clarke Orbit
That circular orbit in space 22,237 miles from the surface of the earth at which geosynchronous satellites are placed. This orbit was first postulated by the science fiction writer Arthur C. Clarke in Wireless World magazine in 1945. Satellites placed in these orbits, although traveling around the earth at thousands of miles an hour, appear to be stationary when viewed from a point on the earth, since the earth is rotating upon its axis at the same angular rate that the satellite is traveling around the earth.

C/N
Carrier-to-noise ratio measured either at the Radio Frequency (RF) or Intermediate Frequency (IF)

Coaxial Cable
Cable consisting of a single copper conductor in the center surrounded by a plastic layer for insulation and a braided metal outer shield.

Codec
Coder/decoder system for digital transmission.

Coding
The third step in the analog-to-digital process in which the information is written in binary form.

Co-Location
Ability of multiple satellites to share the same approximate geostationary orbital assignment frequently due to the fact that different frequency bands are used.

Color Subcarrier
A subcarrier that is added to the main video signal to convey the color information. In NTSC systems, the color subcarrier is centered on a frequency of 3.579545 MHz, referenced to the main video carrier.

Common Carrier
Any organization which operates communications circuits used by other people. Common carriers include the telephone companies as well as the owners of the communications satellites, RCA, Comsat, Direct Net Telecommunications, AT&T and others. Common carriers are required to file fixed tariffs for specific services.

Community Antenna Television (CATV)
Often used to distinguish a decoder, tier, etc., from its Direct Broadcast System (DBS) counterpart.

Companding
A noise-reduction technique that applies single compression at the transmitter and complementary expansion at the receiver.

Component Video
A video signal win which luminance and chrominance information is kept separate rather than being combined as in the composite video signal. Component processing and routing requires three wires to route the signal, and component recording requires the use of separate tracks on magnetic tape Y, R-Y, B-Y, or Y, U, V.

Composite Baseband
The unclamped and unfiltered output of the satellite receiver's demodulator circuit, containing the video information as well as all transmitted subcarriers.

Composite Video
Standard video that combines chrominance and luminance information by encoding the output of the red, green, and blue channels into the Y, I, and Q signals. composite video includes blanking and sync and is the standard for broadcast transmissions of video signals.

Compression
Reduction of dynamic range. Used in broadcasting to achieve greater or more uniform loudness. Digital compression involves the use of algorithms to reduce the bandwidth necessary to store or transmit a digital signal.

Concentrator
A device that provides a central connection point for cables from workstations, servers, and peripherals. Most concentrators contain the ability to amplify the electrical signal they receive

Cross Modulation
A form of signal distortion in which modulation from one or more RF carrier(s) is imposed on another carrier.

CSMA/CA
Carrier Sense Multiple Access Collision Avoidance is a network access method in which each device signals its intent to transmit before it actually does so. This prevents other devices from sending information, thus preventing collisions from occurring between signals from two or more devices. This is the access method used by Local Talk.

CSMA/CD
Carrier Sense Multiple Access with Collision Detection. The access method used by local area networking technologies such as Ethernet.

CSNET
Computer Science Network. A large computer network, mostly in the U.S., but with international al connections.

C/T
Carrier-to-noise-temperature ratio.

DAMA
Demand-Assigned Multiple Access - A highly efficient means of instantaneously assigning telephony channels in a transponder according to immediate traffic demands.

DBS
Direct broadcast satellite. Satellites powerful enough (approximately 120 watts on the Ku-band) to transmit a signal directly to a medium to small receiving dish (antenna). DBS does not require reception and distribution by an intermediate broadcasting facility, but transmits directly to the end user.

dBi
The dB power relative to an isotropic source.

dBW
The ratio of the power to one Watt expressed in decibels.

Decibel (dB)
The standard unit used to express the ratio of two power levels. It is used in communications to express either a gain or loss in power between the input and output devices.

Declination
The offset angle of an antenna from the axis of its polar mount as measured in the meridian plane between the equatorial plane and the antenna main beam.

Decoder
A television set-top device which enables the home subscriber to convert an electronically scrambled television picture into a viewable signal. This should not be confused with a digital coder/decoder known as a CODEC which is used in conjunction with digital transmissions.

Decoder Unit
Refers to the new generation of television set top units that accept digital video as well as analog video.

Decoding (process)
The process that reads an input coded bitstream and produces decoded pictures or audio samples.

Deemphasis
Reinstatement of a uniform baseband frequency response following demodulation.

Delay
The time it takes for a signal to go from the sending station through the satellite to the receiving station. This transmission delay for a single hop satellite connection is very close on one-quarter of a second.

Demodulator
A satellite receiver circuit which extracts or "demodulates" the "wanted "signals from the received carrier.

Deviation
The modulation level of an FM signal determined by the amount of frequency shift from the frequency of the main carrier.

Digital
Conversion of information into bits of data for transmission through wire, fiber optic cable, satellite, or over air techniques. Method allows simultaneous transmission of voice, data or video.

Digital Component Video
Digital video using separate color components, such as YCrCB or RGB. Sometimes incorrectly referred to as D1.

Digital Composite Video
Digital video that is a digitized waveform of composite NTSC or PAL video signals, with specific values assigned to the sync, blank, and white levels.

Digital Speech Interpolation
DSI - A means of transmitting telephony. Two and One half to three times more efficiently based on the principle that people are talking only about 40% of the time.

Downlink
A receiving dish. This can be a passive receiving antenna for a single household, in the case of DBS, or the antenna for the head-end of a cable system.

Dual Spin
Spacecraft design whereby the main body of the satellite is spun to provide altitude stabilization, and the antenna assembly is despun by means of a motor and bearing system in order to continually direct the antenna earthward. This dual-spin configuration thus serves to create a spin stabilized satellite.

Earth Station
The term used to describe the combination or antenna, low-noise amplifier (LNA), down-converter, and receiver electronics. used to receive a signal transmitted by a satellite. Earth Station antennas vary in size from the.2 foot to 12 foot (65 centimeters to 3.7 meters) diameter size used for TV reception to as large as 100 feet (30 meters) in diameter sometimes used for international communications. The typical antenna used for INTELSAT communication is today 13 to 18 meters or 40 to 60 feet.

Echo Canceller
An electronic circuit which attenuates or eliminates the echo effect on satellite telephony links. Echo cancellers are largely replacing obsolete echo suppressors.

Echo Effect
A time-delayed electronic reflection of a speaker's voice. This is largely eliminated by modern digital echo cancellers.

Edge of Coverage
Limit of a satellite's defined service area. In many cases, the EOC is defined as being 3 dB down from the signal level at beam center. However, reception may still be possible beyond the -3dB point.

EIRP
Effective Isotropic Radiated Power - This term describes the strength of the signal leaving the satellite antenna or the transmitting earth station antenna, and is used in determining the C/N and S/N. The transmit power value in units of dBW is expressed by the product of the transponder output power and the gain of the satellite transmit antenna.

Elevation
The upward tilt to a satellite antenna measured in degrees required to aim the antenna at the communications satellite. When. aimed at the horizon, the elevation angle is zero. If it were tilted to a point directly overhead, the satellite antenna would have an elevation of 90 degrees.

Encode/Decode
The process of converting video from its RGB components into composite video, and vice versa.

Encoder
A device used to electronically alter a signal so that it can only be viewed on a receiver equipped with a special decoder.

Encrypt
To scramble the contents of a file or message in such a way as to make it unreadable to everyone except those with a key or code. The code makes it possible to unscramble the encrypted file or message.

Encryption
The science of encoding data so that it cannot be interpreted by anybody or any machine that does not have the key or code. This process is also called "scrambling".

EOL
End of Life of a satellite.

Equatorial Orbit
An orbit with a plane parallel to the earth's equator.

F/D
Ratio of antenna focal length to antenna diameter. A higher ratio means a shallower dish

FDMA
Frequency division multiple access. Refers to the use of multiple carriers within the same transponder where each uplink has been assigned frequency slot and bandwidth. This is usually employed in conjunction with Frequency Modulation.

FEC
Forward Error Correction.

Feed
This term has at least two key meanings within the field of satellite communications. It is used to describe the transmission of video programming from a distribution center. It is also used to describe the feed system of an antenna. The feed system may consist of a subreflector plus a feedhorn or a feedhorn only.

Feedhorn
A satellite TV receiving antenna component that collects the signal reflected from the main surface reflector and channels this signal into the low-noise amplifier (LNA)

Fiber Optic Cable
A cable, consisting of a center glass core surrounded by layers of plastic that transmits data using light rather than electricity. It has the ability to carry more information over much longer distance.

Field
Half of a video frame, 262.5 horizontal lines (NTSC).

Filter
A filter is used to remove spurious data from a search. Typically used when looking for a specific types of data in a list box.

Fingerprinting
The process of visibly or invisibly displaying the RID unit address on the active portion of the video signal. This technique is used to identify the source of the material if recorded and later replayed or distributed.

FM Threshold
That point at which the input signal power is just strong enough to enable the receiver demodulator circuitry successfully to detect and recover a good quality television picture from the incoming video carrier. Using threshold extension techniques, a typical satellite TV receiver will successfully provide good pictures with an incoming carrier noise ratio of 7db. Below the threshold a type of random noise called "sparkles" begins to appear in the video picture. In a digital transmission, however, signal is sudden and dramatically lost when performance drops under the threshold.

Focal Length
Distance from the center feed to the center of the dish.

Focal Point
The area toward which the primary reflector directs and concentrates the signal received.

Footprint
A map of the signal strength showing the EIRP contours of equal signal strengths as they cover the earth's surface. Different satellite transponders on the same satellite will often have different footprints of the signal strength. The accuracy of EIRP footprints or contour data can improve with the operational age of the satellite. The actual EIRP levels of the satellite, however, tends to decrease slowly as the spacecraft ages.

Forward Error Correction (FEC)
Adds unique codes to the digital signal at the source so errors can be detected and corrected at the receiver.

FPM
FEC and Phase Modulator.

Frame
One complete video picture. In NTSC, takes place in one-thirtieth of a second and is made up of 525 lines and two fields.

Frame Rate
The rate at which frames are to be output from the decoding process.

Frequency

The number of times that an alternating current goes through its complete cycle in one second of time. One cycle per second is also referred to as one hertz; 1000 cycles per second, one kilohertz; 1,000,000 cycles per second, one megahertz: and 1,000,000,000 cycles per second, one gigahertz.

Frequency Coordination
A process to eliminate frequency interference between different satellite systems or between terrestrial microwave systems and satellites. In the U.S. this activity relies upon a computerized service utilizing an extensive database to analyze potential microwave interference problems that arise between organizations using the same microwave band. As the same C-band frequency spectrum is used by telephone networks and CATV companies when they are contemplating the installation of an earth station, they will often obtain a frequency coordination study to determine if any problems will exist.

Gain
A measure of amplification expressed in dB.

Gateway
The original Internet term for what is now called router or more precisely, IP router. In modern usage, the terms "gateway" and "application gateway" refer to systems which do translation from some native format to another.

Geostationary
Refers to a geosynchronous satellite angle with zero inclination. So the satellite appears to hover over one spot on the earth's equator.

Geosynchronous
The Clarke circular orbit above the equator. For a planet the size and mass of the earth, this point is 22,237 miles above the surface.

Gigabyte (GB)
One billion bytes of information. One thousand megabytes.

Gigahertz (GHz)
One billion cycles per second. Signals operating above 3 Gigahertz are known as microwaves. above 30 GHz they are know as millimeter waves. As one moves above the millimeter waves signals begin to take on the characteristics of lightwaves.

Global Beam
An antenna down-link pattern used by the Intelsat satellites, which effectively covers one-third of the globe. Global beams are aimed at the center of the Atlantic, Pacific and Indian Oceans by the respective Intelsat satellites, enabling all nations on each side of the ocean to receive the signal. Because they transmit to such a wide area, global beam transponders have significantly lower EIRP outputs at the surface of the Earth as compared to a US domestic satellite system which covers just the continental United States. Therefore, earth stations receiving global beam signals need antennas much larger in size (typically 10 meters and above (i.e.30 feet and up).

Gregorian Dual-reflector antenna system employing a paraboloid main reflector and a concave ellipsoidal subreflector.

G/T
A figure of merit of an antenna and low noise amplifier combination expressed in dB. "G" is the net gain of the system and "T" is the noise temperature of the system. The higher the number, the better the system.

GPS
Global Positioning Satellite - a time base.

Guard Channel
Television channels are separated in the frequency spectrum by spacing them several megahertz apart. This unused space serves to prevent the adjacent television channels from interfering with each other.

Half Transponder
A method of transmitting two TV signals through a single transponder through the reduction of each TV signal's deviation and power level. Half-transponder TV carriers each operate typically 4 dB to 7 dB below single-carrier saturation power.

HDTV
High Definition Television.

Head end
Electronic control center - generally located at the antenna site of a CATV system - usually including antennas, preamplifiers, frequency converters, demodulators and other related equipment which amplify, filter and convert incoming broadcast TV signals to cable system channels.

Hertz (Hz)
The name given to the basic measure of radio frequency characteristics. An electromagnetic wave completes a full oscillation from its positive to its negative pole and back again in what is known as a cycle. A single Hertz is thus equal to one cycle per second.

Hub
The master station through which all communications to, from and between micro terminals must flow. in the future satellites with on-board processing will allow hubs to be eliminated as MESH networks are able to connect all points in a network together.

IBS
INTELSAT Business Services.

Inclination
The angle between the orbital plane of a satellite and the equatorial plane of the earth.

INTELSAT
The International Telecommunications Satellite Organization operates a network of satellites for international transmissions.

Interference
Energy which tends to interfere with the reception of the desired signals, such as fading from airline flights, RF interference from adjacent channels, or ghosting from reflecting objects such as mountains and buildings.

Interlaced Video
Lines of spatial information of a video signal. Interlaced video lines consists of two fields, a top field and a bottom field. One of these fields will commence one field period later than the other.

Isotropic Antenna
A hypothetical omnidirectional point-source antenna that serves as an engineering reference for the measurement of antenna gain.

ITU
International Telecommunication Union

Ka Band
The frequency range from 18 to 31 GHz.

Kelvin (K)
The temperature measurement scale used in the scientific community. Zero K represents absolute zero, and corresponds to minus 459 degrees Fahrenheit or minus 273 Celsius. Thermal noise characteristics of LNA are measured in Kelvins.

Kilohertz (kHz)
KiloHertz. Kilo meaning thousand and Hertz meaning cycles so that 1KHz is equivalent to 1 thousand cycles per second.

Klystron
A type of high-power amplifier which uses a special beam tube.

Ku Band
Operating in the 11 to 14 GHz range, these are medium-power satellites, requiring about 40 to 80 watts per transponder and permitting receiving dishes as small 1 meter across.

L-Band
The frequency range from 0.5 to 1.5 GHz. Also used to refer to the 950 to 1450MHz used for mobile communications.

Low Noise Amplifier (LNA)
This is the preamplifier between the antenna and the earth station receiver. For maximum effectiveness, it must be located as near the antenna as possible, and is usually attached directly to the antenna receive port. The LNA is especially designed to contribute the least amount of thermal noise to the received signal.

Low Noise Block Downconverter (LNB)
A combination Low Noise Amplifier and downconverter built into one device attached to the feed.

LTC
Longitudinal/Linear Time Code.

Luminance
The brightness information part of the video signal. Luminance if often designated by the symbol Y. Luminance level of video signal is measured on a waveform monitor by viewing in the L-Pass or IRE mode.

Margin
The amount of signal in dB by which the satellite system exceeds the minimum levels required for operation.

Mbps
Mega bits per seconds. Millions of bits per second.

MHz
MegaHertz. Mega means million and hertz means cycles so 1 MHz is equivalent to 1 million cycles per second.

Microwave
Line-of sight, point-to-point transmission of signals at high frequency. Many CATV systems receive some television signals from a distant antenna location with the antenna and the system connected by microwave relay. Microwaves are also used for data, voice, and indeed all types of information transmission. The growth of fiber optic networks have tended to curtail the growth and use of microwave relays.

Microwave Interference
Interference which occurs when an earth station aimed at a distant satellite picks up a second, often stronger signal, from a local telephone terrestrial microwave relay transmitter. Microwave interference can also be produced by nearby radar transmitters as well as the sun itself. Relocating the antenna by only several feet will often completely eliminate the microwave interference.

Modem (Modulator/Demodulator)
Devices that convert digital and analog signals. Modems allow computer data (digital) to be transmitted over voice-grade telephone lines (analog).

Modulation
The process of manipulating the frequency or amplitude of a carrier in relation to an incoming video, voice or data signal.

Modulator
A device which modulates a carrier. Modulators are found as components in broadcasting transmitters and in satellite transponders. Modulators are also used by CATV companies to place a baseband video television signal onto a desired VHF or UHF channel. Home video tape recorders also have built-in modulators which enable the recorded video information to be played back using a television receiver tuned to VHF channel 3 or 4.

Motion Compensation
The use of motion vectors to improve the efficiency of the prediction of pel values.   The prediction uses motion vectors to provide offsets into the past and or future reference pictures containing previously decoded pel values that are used to form the prediction error signal.

MPEG
Motion Picture Experts Group. A proposed International Standards organization (IS) standard for digital video and audio compression for moving images.

MPEG-1
1/4 broadcast quality which translates to 352 x 240 pixels. Typically compressed at 1.5 Mbps.

MPEG-2
Similar to MPEG-1, but includes extensions to cover a wider range of applications.   MPEG-2 translates to 704 x 480 pixels at 30 frames per second in North America and 704 x 576 fps at 25 fps in Europe. Typically compressed at higher than 5 Mbps.   The primary application targeted during the MPEG-2 definition process was the all-digital transmission of broadcast TV quality video.

Multiplex
The output signal from an encoder that is divided into two phases. One half is called the I multiplex, and the other is called the Q multiplex. UCS channels 0 through 4 are transmitted in the I multiplex and channels 5 through 9 are transmitted in the Q multiplex. Each multiplex contains control channel messages (messages addressed to the decoders originating from the encoder and the UCS), as well as video, audio, and data information.

Multiplexer
A device that allows multiple logical signals to be transmitted simultaneously across a single physical channel.

Multicast
A special form of broadcast where copies of the packet are delivered to only a subset of all possible destinations.

Multiplexing
A means of transmitting two or more signals over a single wire or carrier wave.

Noise Figure (NF)
A term which is a figure of merit of a device, such as an LNA or receiver, expressed in dB, which compares the device with a perfect device.

NTSC - National Television Standards Committee
The committee formed to determine the guidelines and technical standards for monochrome and color television. Also used to describe the 525-line, 59.95Hz color television signal used in North America and several other parts of the world.

Orbital Period
The time that it takes a satellite to complete one circumnavigation of its orbit.

PAL - Phase Alternation System
The German developed TV standard based upon 50 cycles per second and 625 lines.

Parabolic Antenna
The most frequently found satellite TV antenna, it takes its name from the shape of the dish described mathematically as a parabola. The function of the parabolic shape is to focus the weak microwave signal hitting the surface of the dish into a single focal point in front of the dish. It is at this point that the feedhorn is usually located.

PCM
Pulse Code Modulation. Code where input signal is represented by a given number of fixed-width samples per second.

PCMCIA
An expansion slot found in many laptop computers.

Phase-Locked Loop (PLL)
A type of electronic circuit used to demodulate satellite signals.

QAM
Quadrature Amplitude Modulator.

QPSK - Quadrature Phase Shift Keying
System of modulating a satellite signal.

Rain Outage
Loss of signal at Ku or Ka Band frequencies due to absorption and increased sky-noise temperature caused by heavy rainfall.

Receiver (Rx)
An electronic device which enables a particular satellite signal to be separated from all others being received by an earth station, and converts the signal format into a format for video, voice or data.

Receiver Sensitivity
Expressed in dBm this tells how much power the detector must receive to achieve a specific baseband performance, such as a specified bit error rate or signal to noise ratio.

Repeater
A device which propagates electrical signals from one cable to another without making routing decisions or providing packet filtering. In OSI terminology, a repeater is a Physical Layer intermediate system

Satellite
A sophisticated electronic communications relay station orbiting 22,237 miles above the equator moving in a fixed orbit at the same speed and direction of the earth (about 7,000 mph east to west).

Scalar Feed
A type of horn antenna feed which uses a series of concentric rings to capture signals that have been reflected toward the focal point of a parabolic antenna.

Scrambled
An encryption designation indicating that the channel is fully encrypted. Only DigiCipher decoders can receive the programming.

Scrambler
A device used to electronically alter a signal so that it can only be viewed or heard on a receiver equipped with a special decoder.

SECAM
Sequential Coleur A Memoire. European video standard with image format 4:3, 625 lines, 50 Hz and 6MHz video bandwidth with a total 8 MHz of video channel width. The major difference between PAL and SECAM is that the chrominance is FM modulated in SECAM.

Sidelobe
Off-axis response of an antenna.

Signal to Noise Ratio (S/N)
The ratio of the signal power and noise power. A video S/N of 54 to 56 dB is considered to be an excellent S/N, that is, of broadcast quality. A video S/N of 48 to 52 dB is considered to be a good S/N at the headend for Cable TV.

Single-Channel-Per-Carrier (SCPC)
A method used to transmit a large number of signals over a single satellite transponder.

Skew
An adjustment that compensates for slight variance in angle between identical senses of polarity generated by two or more satellites.

Slant Range
The length of the path between a communications satellite and an associated earth station.

Slot
That longitudinal position in the geosynchronous orbit into which a communications satellite is "parked". Above the United States, communications satellites are typically positioned in slots which are based at two to three degree intervals.

Solar Outage
Solar outages occur when an antenna is looking at a satellite, and the sun passes behind or near the satellite and within the field of view of the antenna. This field of view is usually wider than the beamwidth. Solar outages can be exactly predicted as to the timing for each site.

Spectrum
The range of electromagnetic radio frequencies used in transmission of voice, data and television.

Splitter
A passive device (one with no active electronic components) which distributes a television signal carried on a cable in two or more paths and sends it to a number of receivers simultaneously.

Spot Beam
A focused antenna pattern sent to a limited geographical area. Spot beams are used by domestic satellites to deliver certain transponder signals to geographically well defined areas such as Hawaii, Alaska and Puerto Rico.

Spread Spectrum
The transmission of a signal using a much wider bandwidth and power than would normally be required. Spread spectrum also involves the use of narrower signals that are frequency hopped through various parts of the transponder. Both techniques produce low levels of interference Between the users. They also provide security in that the signals appear as though they were random noise to unauthorized earth stations. Both military and civil satellite applications have developed for spread spectrum transmissions.

Stationkeeping
Minor orbital adjustments that are conducted to maintain the satellite's orbital assignment within the allocated "box" within the geostationary arc.

Stream
A continuous receipt of packets that have an identical packet ID.

Subcarrier
A second signal "piggybacked" onto a main signal to carry additional information. In satellite television transmission, the video picture is transmitted over the main carrier. The corresponding audio is sent via an FM subcarrier. Some satellite transponders carry as many as four special audio or data subcarriers whose signals may or may not be related to the main programming.

Synchronization (Sync)
The process of orienting the transmitter and receiver circuits in the proper manner in order that

they can be synchronized . Home television sets are synchronized by an incoming sync signal with the television cameras in the studios 60 times per second. The horizontal and vertical hold controls on the television set are used to set the receiver circuits to the approximate sync frequencies of incoming television picture and the sync pulses in the signal then fine tune the circuits to the exact frequency and phase.

Synchronous
The instantaneous alignment of two or more events in time. Events may occur at irregular intervals, though at the same instant and still be synchronous.

T1
The transmission bit rate of 1.544 millions bits per second. This is also equivalent to the ISDN Primary Rate Interface for the U.S. The European T1 or E1 transmission rate is 2.048 million bits per second.

T3 Channel (DS-3)
In North America, a digital channel which communicates at 45.304 Mbps.

TDMA
Time division multiple access. Refers to a form of multiple access where a single carrier is the shared by many users. Signals from earth stations reaching the satellite consecutively are processed in time segments without overlapping.

Transceiver
Transmitter-receiver. The physical device that connects a host interface to a local area network, such as Ethernet. Ethernet transceivers contain electronics that apply signals to the cable and sense collisions.

Transmitter
An electronic device consisting of oscillator, modulator and other circuits which produce a radio or television electromagnetic wave signal for radiation into the atmosphere by an antenna.

Transponder
A combination receiver, frequency converter, and transmitter package, physically part of a communications satellite. Transponders have a typical output of five to ten watts, operate over a frequency band with a 36 to 72 megahertz bandwidth in the L, C, Ku, and sometimes Ka Bands or in effect typically in the microwave spectrum, except for mobile satellite communications. Communications satellites typically have between 12 and 24 onboard transponders although the INTELSAT VI at the extreme end has 50.

TWTA
Traveling wave tube amplifier.

Uplink
A sending dish. A transmitter sends its signal to a large parabolic dish antenna that is aimed at the intended relay satellite.

UTC
Universal Time Code.

VSWR
Voltage Standing Wave Ratio. A measurement of mismatch in a cable, waveguide, or antenna system.

VSAT
Very small aperture terminal. Refers to small earth stations, usually in the 1.2 to 2.4 meter range. Small aperture terminals under 0.5 meters are sometimes referred to Ultra Small Aperture Terminals (USAT's)

Waveguide
A metallic microwave conductor, typically rectangular in shape, used to carry microwave signals into and out of microwave antennas.

Zulu Time
Zulu is the military word for the letter "Z". Zulu is the abbreviation for Longitude Zero - Greenwich (England) Mean Time (GMT). Zulu Time is 6 hours later than Central Standard Time and 5 hours later than Central Daylight-Savings Time. Zulu Time (GMT) is always the same worldwide. Communication network switches are coordinated on Zulu Time.

SATELLITES IN GENERAL

Thanks to Dr. Regis Leonard Lewis Research Center

What Keeps Objects in Orbit?

Man has long wondered about questions such as "What holds the sun up in the sky?", "Why doesn't the moon fall on us?", and "How do they (the sun and the moon) return from the west back to the east to rise again each day?" Most of the answers which men put forth in the early years we now classify as superstition, mythology, or pagan religion. It is only in the last 300 years that we have developed a scientific description of how those bodies travel. Our description of course is based on fundamental laws put forth by the English genius Sir Isaac Newton in the late 17^{th} century.

The first of Newton's laws, proposed that every bit of matter in the universe attracts every other bit of matter with a force which is proportional to the product of their masses and inversely proportional to the square of the distance between the two bits. That is, larger masses attract more strongly and the attraction gets weaker as the bodies are moved farther apart.

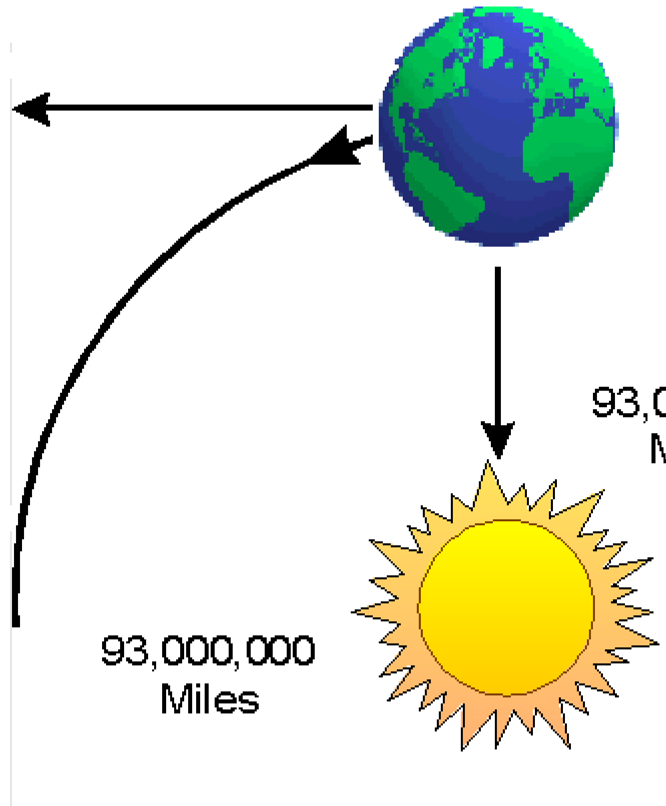
Newton's law of gravity means that the sun pulls on the earth (and every other planet for that matter) and the earth pulls on the sun. Furthermore, since both are quite large (by our standards at least) the force must also be quite large. The question which every student asks is, "If the sun and the planets are pulling on each other with such a large force, why don't the planets fall into the sun?" The answer is simply (are you ready for this?)

THEY ARE!

The Earth is continuously falling into the Sun.

The Moon is continuously falling into the Earth.

However they are also moving "sideways" with a sufficiently large velocity that by the time the earth has fallen the 93,000,000 miles to the sun it has also moved "sideways" about 93,000,000 miles - far enough to miss the sun. By the time the moon has fallen the 240,000 miles to the earth, it has moved sideways about 240,000 miles - far enough to miss the earth. This process is repeated continuously as the earth (and all the other planets) make their apparently unending trips around the sun and the moon makes its trips around the earth. A planet, or any other body, which finds itself at any distance from the sun with no "sideways" velocity will quickly fall without missing the sun. Only our sideways motion (physicists call it our "angular velocity") saves us. The same of course is true for the moon, which would fall to earth but for its angular velocity. This is illustrated in the drawing below.



The Earth Orbits the Sun With Angular Velocity

People sometimes (erroneously) speak of orbiting objects as having "escaped" the effects of gravity, since passengers experience an apparent weightlessness. Be assured, however, that the force of gravity is at work. Were it suddenly to be turned off, the object in question would instantly leave its circular orbit, take up a straight line trajectory, which, in the case of the earth, would leave it about 50 billion miles from the sun after just one century. Hence the gravitational force between the sun and the earth **holds** the earth in its orbit.

The apparent weightlessness experienced by the orbiting passenger is the same weightlessness which he would feel in a falling elevator or an amusement park ride. The earth orbiting the sun or the moon orbiting the earth might be compared to a rock on the end of a string which you swing in a circle around your head. The string **holds** the rock in place and is continuously pulling it toward your head. Because the rock is moving **sideways** however, it always misses your head. Were the string to be suddenly broken, the rock would be released from its orbit and fly off in a straight line.

One question which one might ask is " Does the time required to complete an orbit depend on the distance at which the object is orbiting?" In fact, Kepler answered this question several hundred years ago, using the data of an earlier astronomer, Tycho Brahe.

After years of trial and error analysis (by hand - no computers, no calculators) , Kepler discovered that the quantity R^3 / T^2 was the same for every planet in our solar system. (R is the distance at which a planet orbits the sun, T is the time required for one complete trip around the sun.)Hence, an object which orbits at a larger distance will require longer to complete one orbit than one which is orbiting at a smaller distance. One can understand this at least qualitatively in terms of our "falling and missing" model. The planet which is at a larger distance requires longer to fall to where it would strike the sun. As a result, it takes a longer time to complete the ¼ trip around the sun which is necessary to make a circular orbit.

FOR THE MATHEMATICALLY INCLINED

Kepler's laws and the dependence of period on radius are simple consequences of Newton's second law of motion and Newton's law of gravitation. We know that the second law (which every physics student should recognize) says:

$$F = MA$$

We also know that the F, or force, in this case is the force of gravity, given to us by Newton:

$$F = G(M_{earth}\ M_{sun}) / R^2$$

Finally, we know (or could show fairly easily) that the acceleration experienced by a body moving in a circle of radius R at constant speed (V) is given by

$$A = V^2 / R$$

Putting these two expressions into the F = MA equation, one obtains:

$$G(M_{earth}\ M_{sun}) / R^2 = M_{earth}V^2 / R$$

or just

$$GM_{sun}/ R^2=V^2 / R$$

But the velocity is simply the distance traveled in one orbit (2(pi)R) divided by the time required for one orbit (T). Inserting this quantity (2(pi)R / T) for V, we obtain:

$$GM_{sun}/R^2=(2(pi)R / T)^2 / R$$

- or -

$$T^2 = 4(pi)^2R^3/ GM_{sun}$$

Can We Imitate Nature? (Artificial Satellites)

Very soon after Newton's laws were published, people realized that in principle it should be possible to launch an *artificial* satellite which would orbit the earth just as the moon does. A simple calculation, however, using the equations which we developed above, will show that an artificial satellite, orbiting near the surface of the earth (R = 4000 miles) will have a period of approximately 90 minutes. This corresponds to a sideways velocity (needed in order to "miss" the earth as it falls), of approximately 17,000 miles/hour (that's about 7 miles/second) .

<u>**Launching an Artificial Satellite**</u>

For many years, such a velocity was unthinkable and the artificial satellite remained a dream. Eventually, however, the technology (rocket engines, guidance systems, etc.) caught up with the concept, largely as a result of weapons research started by the Germans during the second World War. Finally, in 1957, the first artificial satellite, called Sputnik, was launched by the Soviets. Consisting of little more than a spherical case with a radio transmitter, it caused quite a stir. Americans were fascinated listening to the "beep. beep, beep" of Sputnik appear and then fade out as it came overhead every 90 minutes. It was also quite frightening to think of the Soviets circling overhead in as much as they were our enemies.

After Sputnik, it was only a few years before the U.S. launched its own satellite; the Soviets launched Yuri Gagarin, the first man to orbit the earth; and the U.S. launched John Glenn, the first American in orbit. All of these flights were at essentially the same altitude (a few hundred miles) and completed one trip around the earth approximately every 90 minutes.

People were well aware, however, that the period would be longer if they were able to reach higher altitudes. In particular Arthur Clarke pointed out in the mid-1940s that a satellite orbiting at an altitude of 22,300 miles would require exactly 24 hours to orbit the earth. Hence such an orbit is called "***<u>geosynchronous</u>***" or "***<u>geostationary</u>***." If in addition it were orbiting over the equator, it would appear, to an observer on the earth, to stand still in the sky. Raising a satellite to such an altitude, however, required still more rocket boost, so that the achievement of a geosynchronous orbit did not take place until 1963.

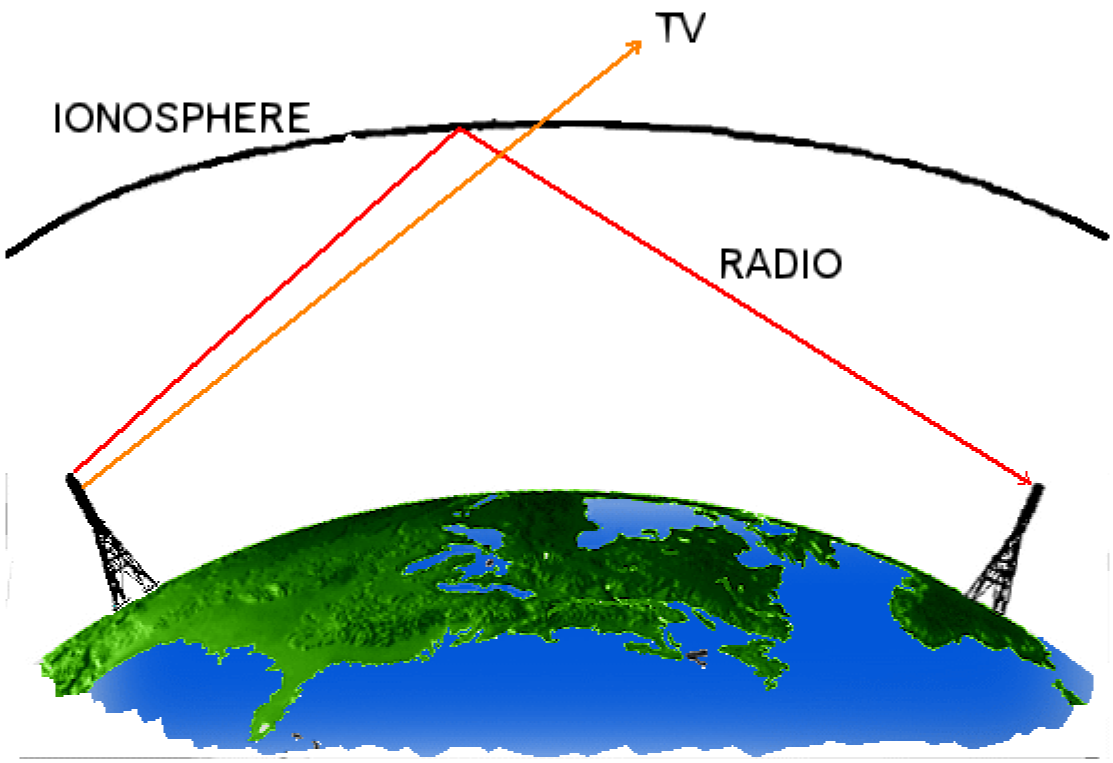
<u>Why Satellites for Communications</u>

By the end of World War II, the world had had a taste of "global communications." Edward R. Murrow's radio broadcasts from London had electrified American listeners. We had, of course, been able to do transatlantic telephone calls and telegraph via underwater cables for almost 50 years. At exactly this time, however, a new phenomenon was born. The first television programs were being broadcast, but the greater amount of information required to transmit television pictures required that they operate at much higher frequencies than radio stations. For example, the very first commercial radio station (KDKA in Pittsburgh) operated (and still does) at 1020 on the dial. This number stood for 1020 KiloHertz - the <u>**frequency**</u> at which the station transmitted. Frequency is simply the number of times that an electrical signal "wiggles" in 1 second. Frequency is measured in Hertz. One Hertz means that the signal wiggles 1 time/second. A frequency of 1020 kilohertz means that the electrical signal from that station wiggles 1,020,000 times in one second.

The expressions "kilo", "mega", and "giga" are used by scientists as a shorthand way of expressing very large numbers. The prefix "kilo" in front of a unit means 1000 of that unit. "Kilo is abbreviated as k. For example, a kilogram (Kg) is 1000 grams. In the same way, "mega" means 1 million. Mega is abbreviated as M. A megawatt (MW) is 1,000,000 watts. The prefix "giga" stands for 1 billion. It is abbreviated as G. Hence a gigabit (Gbit) of data is 1,000,000,000 bits of data.

Television signals, however required much higher frequencies because they were transmitting much more information - namely the picture. A typical television station (channel 7 for example) would operate at a frequency of 175 MHz. As a result, television signals would not propagate the way radio signals did.

Both radio and television frequency signals can propagate directly from transmitter to receiver. This is a very dependable signal, but it is more or less limited to line of sight communication. The mode of propagation employed for long distance (1000s of miles) radio communication was a signal which traveled by bouncing off the charged layers of the atmosphere (ionosphere) and returning to earth. The higher frequency television signals did not bounce off the ionosphere and as a result disappeared into space in a relatively short distance. This is shown in the diagram below.



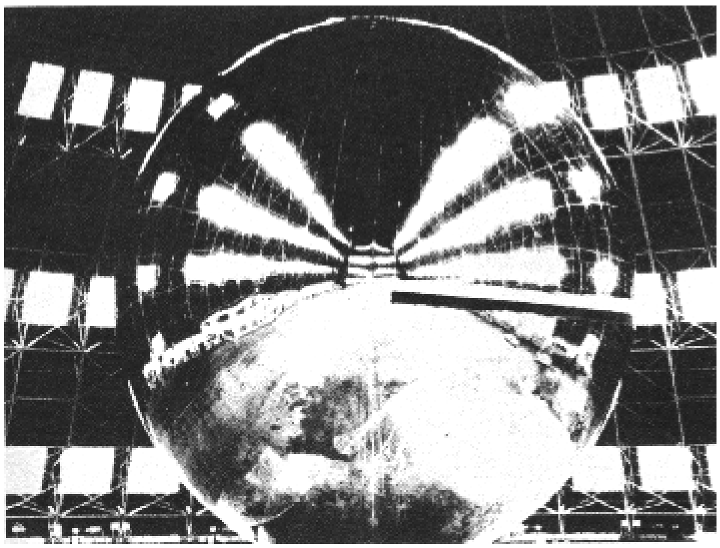
Radio Signals Reflect Off the Ionosphere; TV Signals Do Not

Consequently, television reception was a "line-of-sight" phenomenon, and television broadcasts were limited to a range of 20 or 30 miles or perhaps across the continent by coaxial cable. Transatlantic broadcasts were totally out the question. If you saw European news events on television, they were probably delayed at least 12 hours, and involved the use of the fastest airplane available to carry conventional motion pictures back to the U.S. In addition, of course, the appetite for transatlantic radio and telephone was increasing rapidly. Adding this increase to the demands of the new television medium, existing communications capabilities were simply not able to handle all of the requirements. By the late 1950s the newly developed artificial satellites seemed to offer the potential for satisfying many of these needs.

<u>Low Earth-Orbiting Communications Satellites</u>

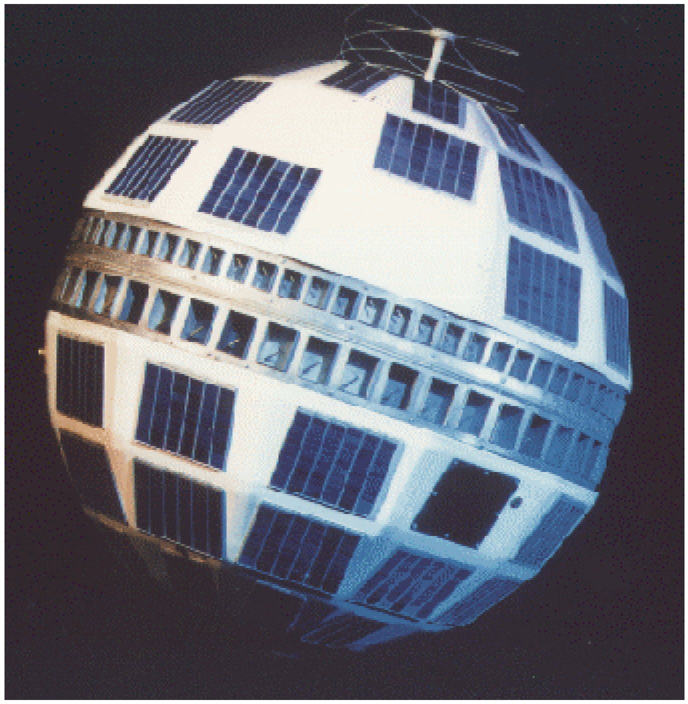
<u>(LEOS)</u>

In 1960, the simplest communications satellite ever conceived was launched. It was called <u>Echo</u>, because it consisted only of a large (100 feet in diameter) aluminized plastic balloon. Radio and TV signals transmitted to the satellite would be reflected back to earth and could be received by any station within view of the satellite.



Echo Satellite

Unfortunately, in its low earth orbit, the <u>Echo</u> satellite circled the earth every ninety minutes. This meant that although virtually everybody on earth would eventually see it, no one person, ever saw it for more than 10 minutes or so out of every 90 minute orbit. In 1958, the <u>Score</u> satellite had been put into orbit. It carried a tape recorder which would record messages as it passed over an originating station and then rebroadcast them as it passed over the destination. Once more, however, it appeared only briefly every 90 minutes - a serious impediment to real communications. In 1962, NASA launched the <u>Telstar</u> satellite for AT&T.

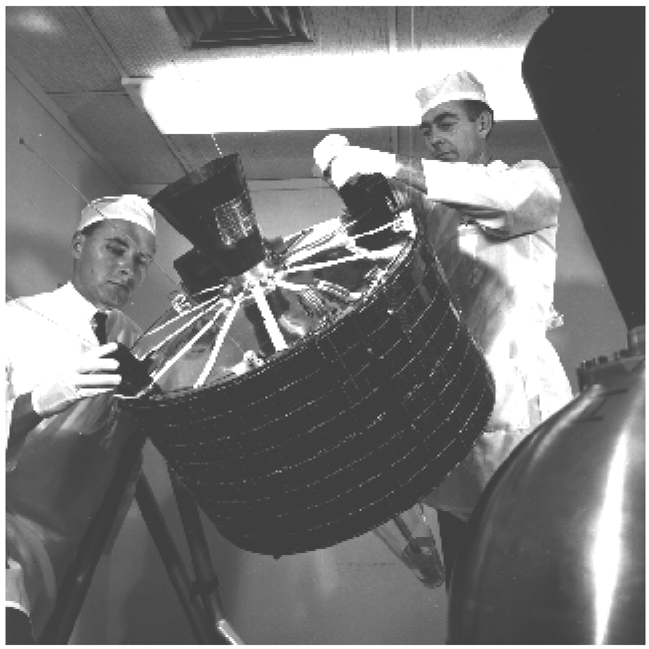


Telstar Communications Satellite

Telstar's orbit was such that it could "see" Europe" and the US simultaneously during one part of its orbit. During another part of its orbit it could see both Japan and the U.S. As a result, it provided real- time communications between the United States and those two areas - for a few minutes out of every hour.

<u>Geosynchronous Communications Satellites</u>

The solution to the problem of availability, of course, lay in the use of the geosynchronous orbit. In 1963, the necessary rocket booster power was available for the first time and the first geosynchronous satellite , <u>Syncom 2</u>, was launched by NASA. For those who could "see" it, the satellite was available 100% of the time, 24 hours a day. The satellite could view approximately 42% of the earth. For those outside of that viewing area, of course, the satellite was NEVER available.



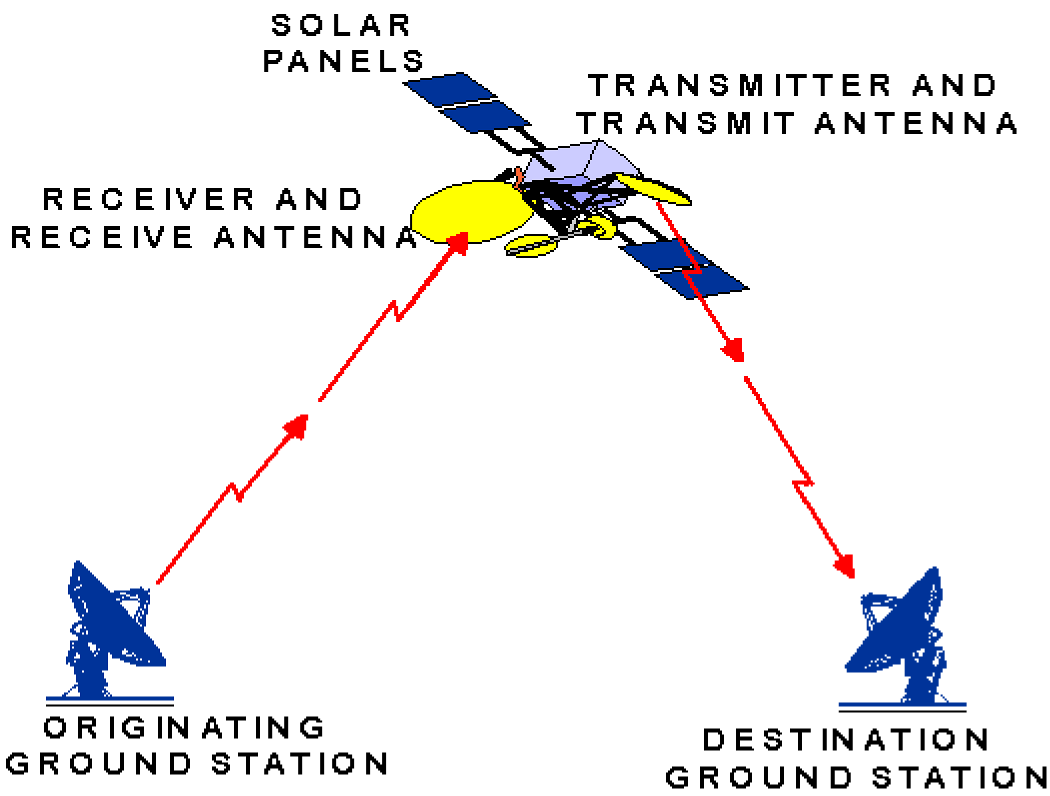
Syncom II Communications Satellite

However, a system of three such satellites, with the ability to relay messages from one to the other could interconnect virtually all of the earth except the polar regions. The one disadvantage (for some purposes) of the geosynchronous orbit is that the time to transmit a signal from earth to the satellite and back is approximately ¼ of a second - the time required to travel 22,000 miles up and 22,000 miles back down at the speed of light. For telephone conversations, this delay can sometimes be annoying. For data transmission and most other uses it is not significant. In any event, once Syncom had demonstrated the technology necessary to launch a geosynchronous satellite, a virtual explosion of such satellites followed.

Today, there are 1000’s of communications satellites in orbit, with over 400 in geosynchronous orbit. One of the biggest sponsors of satellite development was Intelsat, an internationally-owned corporation which has launched 8 different series of satellites (4 or 5 of each series) over a period of more than 30 years. Spreading their satellites around the globe and making provision to relay from one satellite to another, they made it possible to transmit 1000s of phone calls between almost any two points on the earth. It was also possible for the first time, due to the large capacity of the satellites, to transmit live television pictures between virtually any two points on earth. By 1964 (if you could stay up late enough), you could for the first time watch the Olympic games live from Tokyo. A few years later of course you could watch the Vietnam war live on the evening news.

Basic Communications Satellite Components

Every communications satellite in its simplest form (whether low earth or geosynchronous) involves the transmission of information from an originating ground station to the satellite (the uplink), followed by a retransmission of the information from the satellite back to the ground (the downlink). The downlink may either be to a select number of ground stations or it may be *broadcast* to everyone in a large area. Hence the satellite must have a receiver and a receive antenna, a transmitter and a transmit antenna, some method for connecting the uplink to the downlink for retransmission, and prime electrical power to run all of the electronics. The exact nature of these components will differ, depending on the orbit and the system architecture, but every communications satellite must have these basic components. This is illustrated in the drawing below.



Basic Components of a Communications Satellite Link

Transmitters

The amount of power which a satellite transmitter needs to send out depends a great deal on whether it is in low earth orbit or in geosynchronous orbit. This is a result of the fact that the geosynchronous satellite is at an altitude of 22,300 miles, while the low earth satellite is only a few hundred miles. The geosynchronous satellite is nearly 100 times as far away as the low earth satellite. We can show fairly easily that this means the higher satellite would need almost 10,000 times as much power as the low-orbiting one, if everything else were the same. (Fortunately, of course, we change some other things so that we don't need 10,000 times as much power.)

FOR THE MATHEMATICALLY INCLINED

In looking at the relative power requirements of satellites at different distances, it is useful to think of the total power (P_0) radiated as spreading out and striking the surface of a sphere which is centered on the transmitter and has a radius equal to the distance between the transmitter and receiver.
We know that the surface area of a sphere of radius R is given by

$$A = 4(pi)R^2$$

This means that if the power is emitted uniformly in all directions (*isotropically*) then the amount of power which strikes every square centimeter of the sphere is given by

$$P = P_0 / 4(pi)R^2$$

If our receiver has an area of A_r square centimeters, then it will detect an amount of power

$$P_r = A_r P_0 / 4(pi)R^2$$

If then R= 223 miles (it makes the arithmetic easier),

$$P_r = A_r P_0 / 4(pi)(223 \text{ miles})^2$$

On the other hand, if R = 22,300 miles,

$$P_r = A_r P_0 / 4(pi)(22{,}300 \text{ miles})^2$$

Which is 10,000 times smaller, so that in order to have the receiver detect the same amount of power, the transmitter power P_0 must be 10,000 times larger for the geosynchronous system.

For either geosynchronous or low earth satellites, the power put out by the satellite transmitter is really puny compared to that of a terrestrial radio station. Your favorite rock station probably boasts of having many kilowatts of power. By contrast, a 200 watt transmitter would be very strong for a satellite.

Antennas

One of the biggest differences between a low earth satellite and a geosynchronous satellite is in their antennas. As mentioned earlier, the geosynchronous satellite would require nearly 10,000 times more transmitter power, if all other components were the same. One of the most straightforward ways to make up the difference, however, is through antenna design. Virtually all antennas in use today radiate energy preferentially in some direction. An antenna used by a commercial terrestrial radio station, for example, is trying to reach people to the north, south, east, and west. However, the commercial station will use an antenna that radiates very little power straight up or straight down. Since they have very few listeners in those directions (except maybe for coal miners and passing airplanes) power sent out in those directions would be totally wasted.

The communications satellite carries this principle even further. All of its listeners are located in an even smaller area, and a properly designed antenna will concentrate most of the transmitter power within that area, wasting none in directions where there are no listeners. The easiest way to do this is simply to make the antenna larger. Doubling the diameter of a reflector antenna (a big "dish") will reduce the area of the beam spot to one fourth of what it would be with a smaller reflector. We describe this in terms of the *gain* of the antenna. Gain simply tells us how much more power will fall on 1 square centimeter (or square meter or square mile) with this antenna than would fall on that same square centimeter (or square meter or square mile) if the transmitter power were spread uniformly (isotropically) over all directions. The larger antenna described above would have four times the gain of the smaller one. This is one of the primary ways that the geosynchronous satellite makes up for the apparently larger transmitter power which it requires.

FOR THE MATHEMATICALLY INCLINED

Antenna gains, like many power specifications are usually quoted in decibels (dB). The ratio of two power levels in decibels is defined as:

$$R = 10 \log_{10} (P_1/P_2)$$

If the smaller of the two antenna mentioned above concentrated 100 times as much power on the receiver as would an antenna which radiated isotropically, then the gain of the smaller antenna would be

$$10 \log_{10}(100) = 20 \text{ dB}$$

The larger antenna then concentrates 4 times as much power at the receiver as does the smaller one, which is 400 times as much as the one which radiates isotropically. Therefore its gain is

$$10 \log_{10}(400) \; 26 \text{ dB}$$

The power supplied by the larger is (400/100) = 4 times as great as the smaller, therefore its gain should be greater than the small one by

$10 \log_{10}(4)$ 6 dB - which it is.

Power levels are sometimes specified in dBW or dBm. These expressions indicate that the power level in question is being specified as a ratio to 1 watt or 1 milliwatt. For example, 13 dBW means that

$$10 \log_{10}(\text{the power level in watts}) = 13$$

In other words, the given power level is really about 20 watts. Similarly, 13 dBm would correspond to 20 milliwatts of power.

One other big difference between the geosynchronous antenna and the low earth antenna is the difficulty of meeting the requirement that the satellite antennas always be "pointed" at the earth. For the geosynchronous satellite, of course, it is relatively easy. As seen from the earth station, the satellite never appears to move any significant distance. As seen from the satellite, the earth station never appears to move. We only need to maintain the *orientation* of the satellite. The low earth orbiting satellite, on the other hand, as seen from the ground is continuously moving. It zooms across our field of view in 5 or 10 minutes.

Likewise, the earth station, as seen from the satellite is a moving target. As a result, both the earth station and the satellite need some sort of tracking capability which will allow its antennas to follow the target during the time that it is visible. The only alternative is to make that antenna beam so wide that the intended receiver (or transmitter) is always within it. Of course, making the beam spot larger decreases the antenna gain as the available power is spread over a larger area , which in turn increases the amount of power which the transmitter must provide.

Power Generation

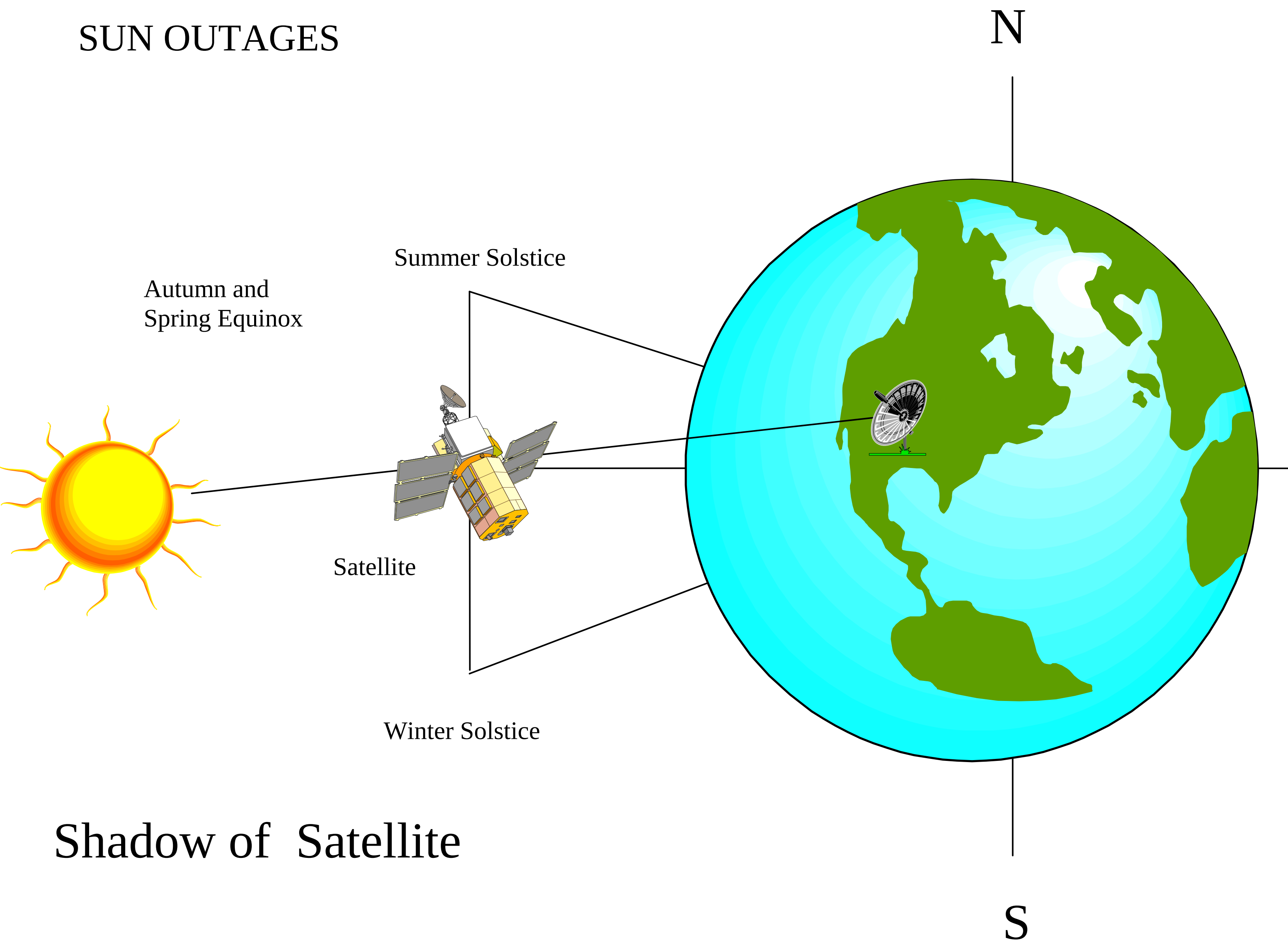
You might wonder why we don't actually use transmitters with thousands of watts of power, like your favorite radio station does. You might also have figured out the answer already. There simply isn't that much power available on the spacecraft. There is no line from the power company to the satellite. The satellite must generate all of its own power. For a communications satellite, that power usually is generated by large solar panels covered with solar cells - just like the ones in your solar-powered calculator. These convert sunlight into electricity. Since there is a practical limit to the how big a solar panel can be, there is also a practical limit to the amount of power which can generated. In addition, unfortunately, transmitters are not very good at converting input power to radiated power so that 1000 watts of power into the transmitter will probably result in only 100 or 150 watts of power being radiated. We say that transmitters are only 10 or 15% *efficient*. In practice the solar cells on the most "powerful" satellites generate only a few thousand watts of electrical power.

Satellites must also be prepared for those periods when the sun is not visible, usually because the earth is passing between the satellite and the sun. This requires that the satellite have batteries on board which can supply the required power for the necessary time and then recharge by the time of the next period of eclipse.

Sun Transit Outage

Another and perhaps bigger problem, although shorter in time duration, occurs when the sun passes behind the satellite and falls within the beamwidth of the earth station antenna. An earth station perceives the sun as a source of thermal noise with a diameter of .48 deg. The nominal noise temperature of the sun is 25,000 Kelvin.

This adds to the thermal noise of the system and causes a communications outage. The length of this outage varies as a function of the antenna beamwidth and the angle the sun makes with the beamwidth of the antenna. This outage occurs for approximately 6 days twice yearly at apparent noon for the satellite longitude. This is commonly called a Sunoutage.



SATELLITE TRANSPONDERS AND BANDWIDTH

Satellite communication systems convey different types of information, such as audio information (telephone calls, radio programs) and video programs (satellite television channels). The amount of information to be transmitted via satellite depends upon the type of signal to be transmitted. For example, one second of a video sequence generates about two hundred times more information than an audio sequence of the same duration.

Each of the various types of information need to be delivered at a certain rate for them to be properly interpreted at the receiving end of the satellite link. Radio and television information, for example, needs to be delivered at the same rate that it is generated, otherwise the radio and television programs will be unintelligible to the recipient. These are examples of "real time" services. Other services do not necessarily require immediate delivery (for example, the transfer of a computer file via satellite, which could take place overnight). Satellite communication systems are designed to handle a wide range of service types and consequently must accommodate a wide range of information delivery rates.

We say that the satellite has a certain capacity to deliver information. In this case, capacity is measured by the bandwidth that we can use to transmit information.

For practical reasons, this usable bandwidth is divided up into a number of segments of the same or different bandwidth. This is equivalent to using several small pipes to deliver water rather than a single, large pipe. Each bandwidth segment is processed individually on-board the satellite by equipment known as a (satellite) transponder. It is common to refer to the satellite's capacity by the number of transponders that it provides and the bandwidth(s) of the transponders. For example, the HOT BIRD™ 2 satellite is equipped with twenty transponders, each with a bandwidth of 33 MHz, providing a total capacity of 660 MHz. Typical transponder bandwidths are 33 MHz, 36 MHz and 72 MHz.

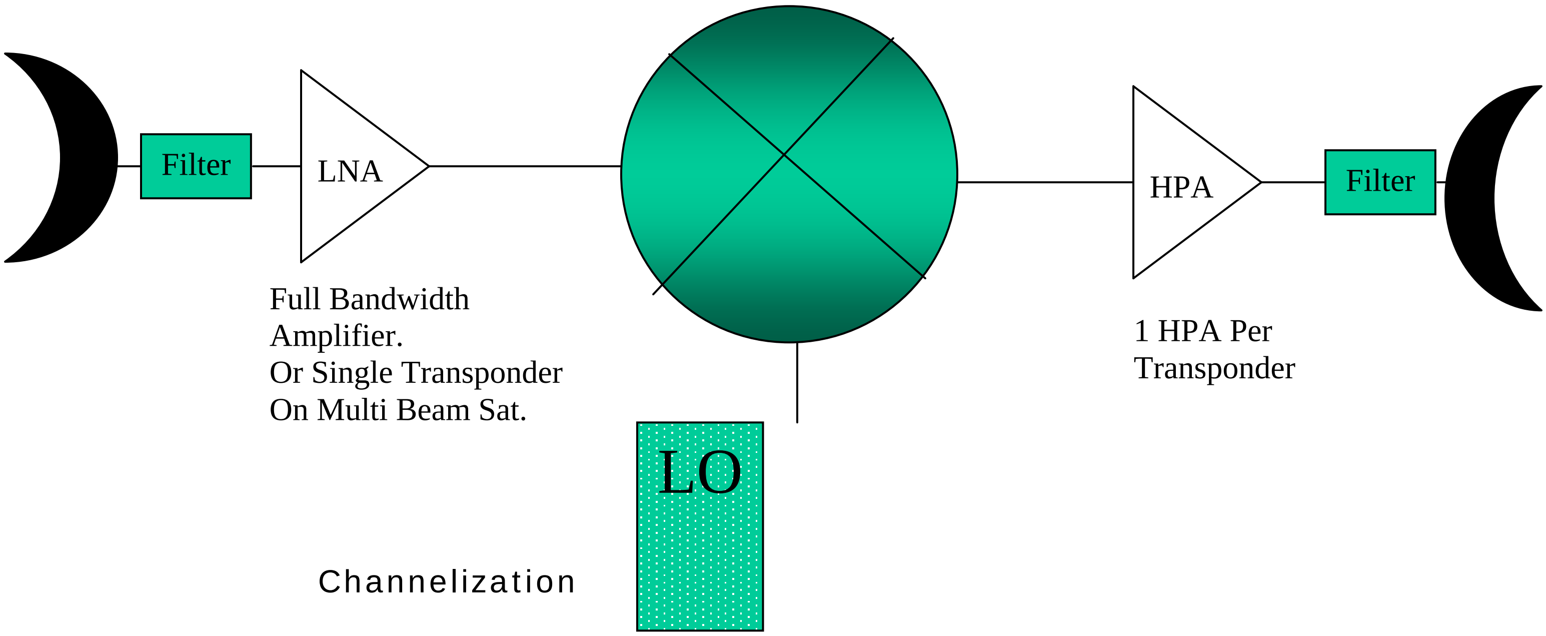
Each service delivered by the satellite uses part of the satellite capacity according to its needs. For example, television program delivery will require significantly greater satellite capacity than radio program delivery, because approximately 200 times more information needs to be sent every second.

The amount of capacity allocated to each communications signal, or carrier, is measured by the signal bandwidth. A signal may require the entire bandwidth of a transponder for transmission, or only a fraction of a transponder's bandwidth. In the latter case the signal would share the transponder bandwidth with other signals (services). The capacity (bandwidth) requirement depends upon the type of service. A telephone channel utilizes only a small fraction of the transponder bandwidth, whereas a television program is commonly transmitted using a dedicated transponder (i.e. it utilizes the entire transponder bandwidth). The new methods of digitally encoding and compressing allows digital MPEG type video to be transmitted to satellites and the same bandwidth of a single Analog Video carrier can now support many digital carries. An example would be the Direct TV satellites transmitting up to 500 channels of digital video would only support 40 or 50 analog video carriers.

The signal bandwidth also depends upon other factors, including the type of technology used (analogue or digital transmission) and the modulation and coding scheme selected for efficient and robust service delivery via satellite.

The satellite transponder and associated antennas are the primary components of the satellite communications system. Transponders differ from LOS microwave in that many signals can arrive at the same instant from widely spaced earth locations

A model of a single transponder is shown below



Channelization

The satellite itself is channelized by the use of frequency selective filters and separate amplifiers.

The application of the channelization is that,

a) The total downlink power can be increased by use of parallel power amplifiers.

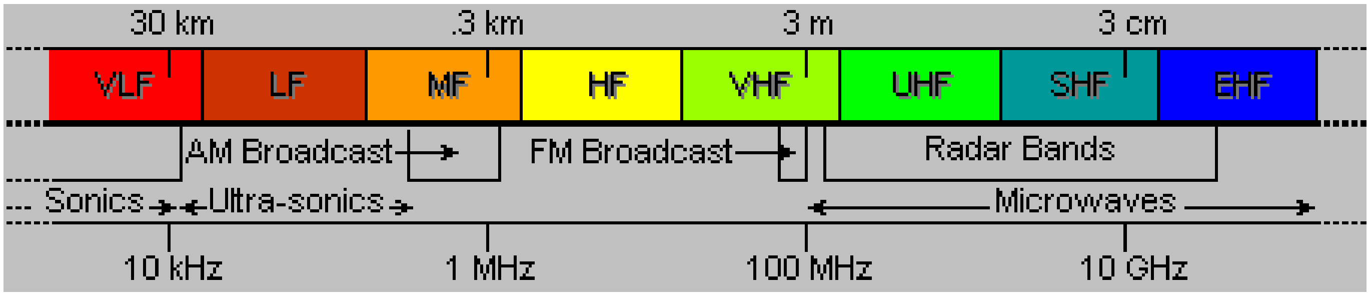
b) Uplink frequency selection can control which downlink polarization or antenna is used.

c) The number of signals can be decreased in each TWT to reduce intermodulation.

Most satellites divide the channels into equal sections to allow a more versatile frequency plan and optimum satellite utilization.

For example, Intelsat IV satellites are divided into 12 or more separate channels (transponders).

Satellite Frequency Bands



- **L BAND 1-2 GHZ MOBILE SERVICES**
- **S BAND 2.5-4 GHZ MOBILE SERVICES**
- **C BAND 3.7-8 GHZ FIXED SERVICES**
- **X BAND 7.25-12 GHZ MILITARY**
- **Ku BAND 12-18 GHZ FIXED SERVICES**
- **Ka BAND 18-30.4 GHZ FIXED SERVICES**
- **V BAND 37.5-50.2 GHZ FIXED SERVICES**

Detailed Frequency Plans

Frequency and Wavelength ... Radio Band designation

30-300 Hz 10-1Mm .....ELF (extremely low frequency)
300-3000 Hz ....1Mm-100 km
3-30 kHz 100-10 km ....VLF (very low frequency)
30-300 kHz 10-1 km ....LF (low frequency)
300-3000 kHz 1 km-100 m ....MF (medium frequency)
3-30 MHz 100-10 m ....HF (high frequency)
30-300 MHz 10-1 m ....VHF (very high frequency)
300-3000 MHz 1 m-10 cm ..UHF (ultra high frequency)
3-30 GHz 10-1 cm ....SHF (super high frequency)
30-300 GHz 1 cm-1 mm EHF(extremely high frequency)
.

Frequency and Wavelength of the IEEE Radar Band designation

1-2 GHz ....30-15 cm ....L Band
2-4 GHz ....15-7.5 cm.....S Band
4-8 GHz ....7.5-3.75 cm.....C Band
8-12 GHz ......3.75-2.50 cm... X Band
12-18 GHz ......2.5-1.67 cm...Ku Band
18-27 GHz .....1.67-1.11 cm....K Band
27-40 GHz 1.11 cm-7.5 mm .Ka Band
40-75 GHz..............................V Band
75-110 GHz............................W Band
110-300 GHz ....mm Band
300-3000 GHz...................u mm Band
.

Satellite bands

S-Band 1700-3000 MHz
C-Band 3700-4200 MHz
Ku1-Band 10.9-11.75 GHz
Ku2-Band 11.75-12.5 GHz (DBS)
Ku3-Band 12.5-12.75 GHz
Ka-Band 18.0-20.0 GHz

Polarization
A technique used by the satellite designer to increase the capacity of the satellite transmission channels by reusing the satellite transponder frequencies. In linear cross polarization schemes, half of the transponders beam their signals to earth in a vertically polarized mode; the other half horizontally polarize their down links. Although the two sets of frequencies overlap, they are 90 degree out of phase, and will not interfere with each other. To successfully receive and decode these signals on earth, the earth station must be outfitted with a properly polarized feedhorn to select the vertically or horizontally polarized signals as desired.

In some installations, the feedhorn has the capability of receiving the vertical and horizontal transponder signals simultaneously, and routing them into separate LNAs for delivery to two or more satellite television receivers. Unlike most domestic satellites, the Intelsat series use a technique known as left-hand and right-hand circular polarization. Circular polarization is also used by Direct broadcast satellites since the one feature of circular that makes it easy to install is that polarization alignment is not necessary in a circular system. Linear systems however require close and careful alignment of the feed system to lower the interference levels between the two signals. The big advantage of linear polarization is that the feed system is less expensive to construct than a circular polarized feed system.

SATELLITE COMMUNICATIONS EQUIPMENT

High Power Amplifiers for the Uplink

Solid State Power Amplifiers (SSPAs)

SSPAs are expected to completely dominate tube-based HPAs in the future. The question is just a matter of when: 5 years or 20 years. Devices have been made that operate over the required Ka uplink frequencies, even though the technology is inherently a narrow band one, with generally 500MHz of instantaneous bandwidth. High volume production is available today for low power devices (1W and less) for point-to-point microwave radios.

Solid state modules are designed by matching and combining individual devices along with a gain stage. The lower power requirements are integrated along with the upconverters to reduce cost and improve manufacturability. Modules are power combined in order to reach SSPA P1dB output power levels of 5W or greater. 40W is currently considered the cutting edge while still reproducible. The additional steps of power combining provides an additional benefit of built in soft-fail capabilities, however it also means more complexity, more difficulties in cooling, larger physical size, and increased cost.

SSPA Advantages

- High volume production capability
- Built in soft-fail capabilities in case of single device or module failure
- No expected RF section sparing requirements
- Inherently good linear performance for multicarrier, digital transmission

SSPA Disadvantages

- Practically limited in the near term to low output powers
- Highly inefficient
- Increased size and weight at the higher power levels due to the added cooling requirements (air flow, heat sinks etc)

Traveling Wave Tube Amplifiers (TWTAs)

TWTAs are prevalent in non-mmWave satellite communication applications requiring instantaneous, broadband coverage with low to high power output. In the case of Ka band, TWTAs again have wide, instantaneous bandwidths (2.5 GHz but tuned for the optimal operation over the required 500 or 750 MHz) at low to medium power levels (10-600W at the flange of the tube). TWTAs have been the historical preferred Ka band communication HPA for any power requirements over 10W.

Current amplifiers are working full-time and proving to be extremely reliable and worry free, with field data MTBF figures of greater than 30k hours.

TWTA Advantages

- Low to medium output power requirements (10W-600W)
- Proven fielded robust performance
- Efficient operation
- Instantaneous, broadband capability
- Long Life
- Improved linearity (~6dB) with an optional linearizer

TWTA Disadvantages

- TWT production limited to 1000's not millions per month
- Physical deterioration requires eventual replacement of TWT
- No soft-fail capability in case of failure (unless the HPA is part of a 1:n or power combined subsystem)

Klystron Power Amplifiers (KPAs)

Klystron power amplifiers have historically been used for high power, narrow band applications such as video uplinking. Klystrons, due to their narrower bandwidths, perform very well in terms of 3rd order intermodulation (IM3) performance. High power also allows more headroom for backoff for optimal linear performance. Klystrons and klystron power amplifiers have developed a reputation as extremely reliable technologies. CPI's C & Ku band klystrons have shown average life spans of 7.5 to 8 years.

Recent KPA developments include:

1. The development of multistage depressed collectors (MSDC) for C & Ku band, which can be leveraged onto the Ka band versions. This increases efficiencies (therefore reducing size, cooling requirements and input power requirements)
2. Development of digital ultrafast tuner for C, Ku and DBS bands providing channel changing times of less than 1 second (virtual instantaneous bandwidth)
3. The availability of an Extended Interaction Klystron (EIK) with an expected 700 W power output and 1 GHz instantaneous bw. Proven power and bandwidths at Ka band include:
    i. 600W & 400 MHz bw
    ii. 300W & 900 MHZ bw

iii. 400W with dual mode bw

4. Proven air cooling capability of standard klystrons (vs. historical water cooled requirements)
5. Standard klystrons are now available with up to 125 MHz instantaneous bandwídth and up to 3kW power level at Ku band frequencies
6. Installed and operating high power communications klystron power amplifiers at Ku band

KPA Advantages

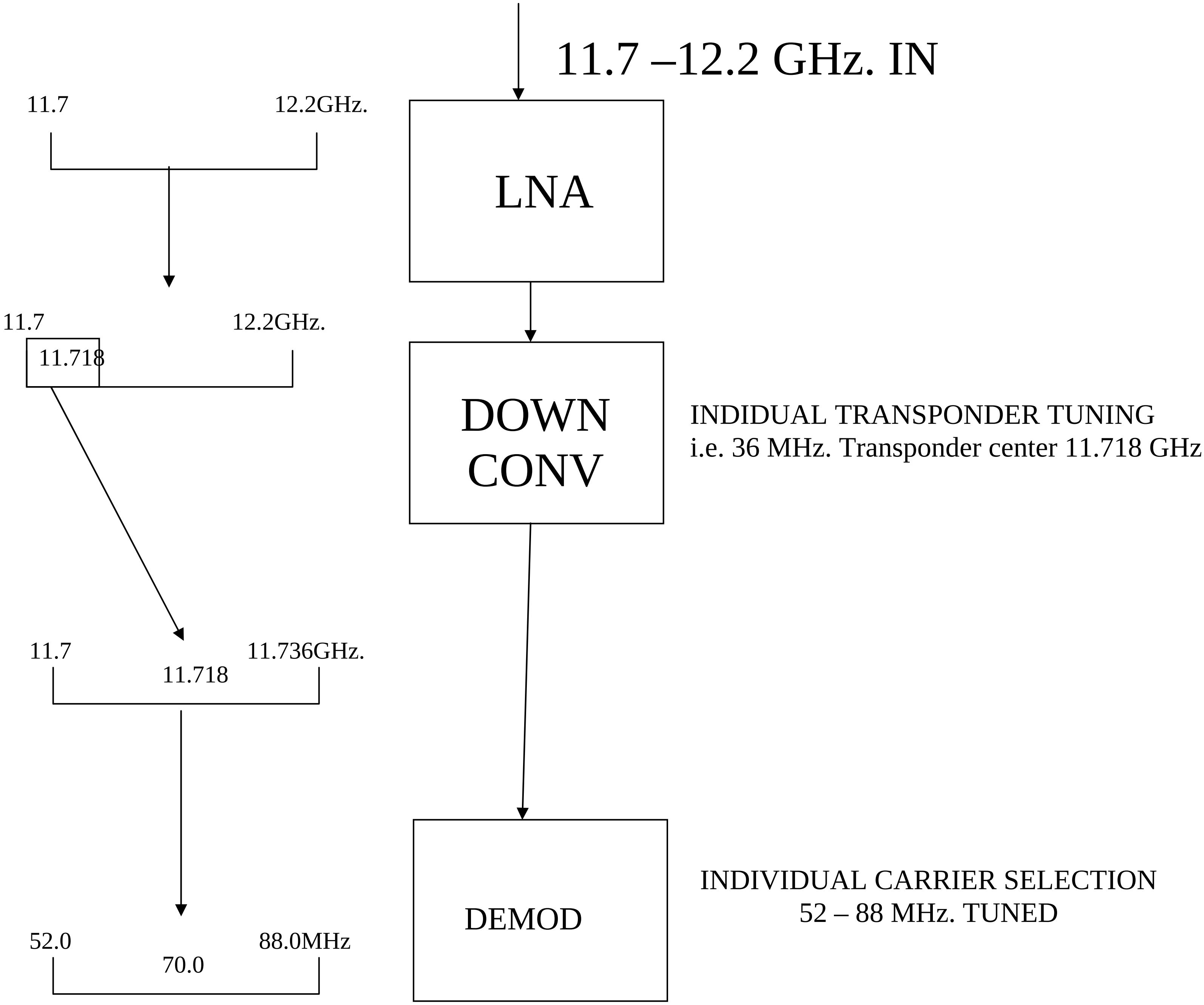
- High power capability to improve availability
- Inherently good linear performance for multicarrier, digital transmission
- Provide a cost effective, lower power solution for applications like tracking, telemetry & control (TT&C)
- Efficient through utilization of MSDC technology
- Broad instantaneous bandwidth through EIK technology

KPA Disadvantages

- Narrower instantaneous bandwidths
- Today's production capability limited to 10s to 100s per month

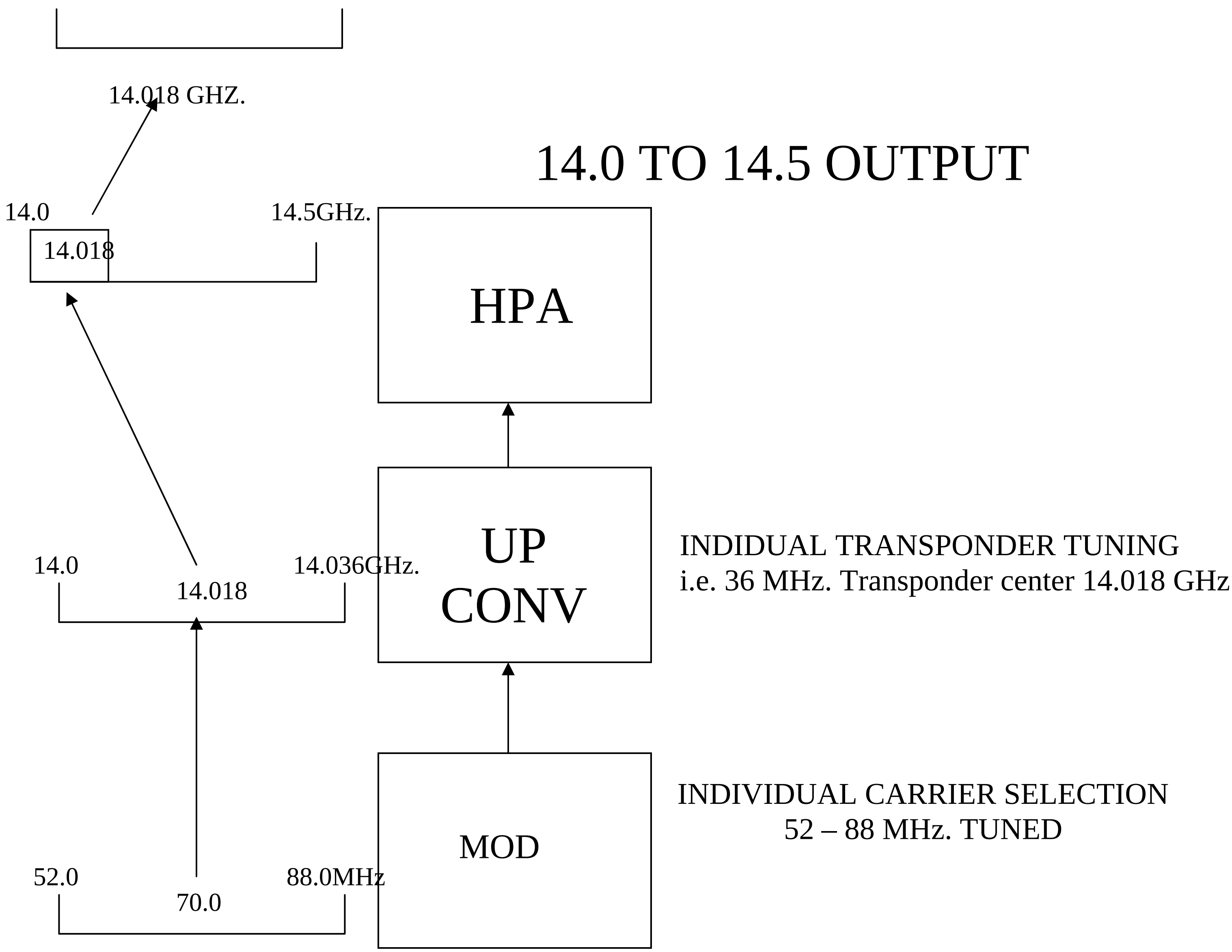
Frequency converters for the Uplink/Downlink

A frequency tunable upconverter converts the 70 (or in some cases 140) MHz signal to an RF. Frequency. Agility of the upconverter is obtained by driving the local oscillator with a synthesizer, and is used in order to center the uplink signal to the assigned portion of the RF transmit band either C or Ku bands. The Downconverter converts signals from the C or Ku bands (or any other satellite frequency band) back to the 70 or 140 MHz. Band.
The devices are in effect block converters from one frequency band to another and are bandwidth limited typically to match the bandwidth of the satellite channel or transponder. The following drawings show the frequency relationships.
This conversion is necessary to get the frequency correct for the modulating and demodulating equipment. This allows you to tune (as you would your car radio) to the proper frequency of the desired signal. The following are typical Ku band Up and Downconverter schematics.



TYPICAL DOWNCONVERTER

TYPICAL UPCONVERTER



LOW NOISE AMPLIFIERS

The LNA amplifies the entire bandwidth of signals coming down from a satellite and presents them as a wide band signal to the downconverter. These amplifiers set the noise temperature Sensitivity) of the entire receive system. Typical noise temperatures vary from a few degrees Kelvin for C band to 500 degrees Kelvin or higher at the upper satellite bands. The typical amplifiers are constructed from Gallium Arsinide Field effect transistors called FET's. In some cases a down converter and LNA are combined in a device called a Low Noise Block Converter (LNB) and is typical in receive only systems. This allows conversion to a lower frequency so the cable loss between the antenna and the receive system will be less.

Typical Ku Band LNB will convert the entire 11.7 – 12.2 GHz. Band to 950 – 1450 MHz. for transport via cable to the receiver.

Modulator/Demodulator

The devices which take information such as data, video, or voice and convert it to an radio signal and convert a radio signal back to data, video, or voice signal. The device Mod/Demod typically generates signals in the 52 –88 or 52 –188 MHz. band to feed the Upconverter system, while the Demod acts like a tunable receiver to tune the proper signal from the downconverter output in the appropriate 52 – 88 or 52 – 188 MHz. band.
Mod/Demod devices are also called video receivers, video encoders for video signals.

OTHER HARDWARE

Other hardware which are part of the system that make a complete satellite station would include IFL (Inter Facility Links) cables, dividers and combiners, waveguide, and air pressure systems (to keep moisture out of waveguides and antenna components, and remote control systems.

COMPLETE SATELLITE LINK DIAGRAM