



Introduction to Internet satellite connectivity

Escudero-Pascual Alberto <aep@it46.se>

Berthilson Louise <louise@it46.se>

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Brief Historical Introduction

The history of satellite communication starts dates back in 1945 when a RAF electronics officer and member of the British Interplanetary Society, Arthur C. Clarke, wrote a short article in *Wireless World* magazine that described the use of manned satellites in 24-hour orbits. His work was based on ideas of other visioners such as the russian Konstantin Tsiolkovsky *Константин Эдуардович Циолковский* and the slovenian Herman Potocnik.

Telstar, launched by NASA on board a Delta rocket from Cape Canaveral on July 10, 1962, was the first privately sponsored space launch and the first active satellite with a microwave receiver and transmitter to transmit live television and telephone conversations across the Atlantic.¹

In July 2004, one of the biggest communication satellites, Anik F2, was launched on board an Ariane 5G Rocket. With a weight of almost 6 tons, Anik F2 carried 94 transponders (38 Ka-band, 32 Ku-band and 24 C-band transponders).²

1 History of satellite communications, <http://www.hq.nasa.gov/office/pao/History/satcomhistory.html>

2 Telesat Anik F2 pictures and launching http://www.telesat.ca/satellites/photos/satellites_gallery8.htm



Fig 1: Vibration Testing Anik F2, Source: Telesat CA

What is VSAT?

VSAT stands for Very Small Aperture Terminal and it is the term that is normally used to refer to several satellite data communication technologies. The term VSAT assumes the use of a (very) small diameter antenna (terminal) to receive and/or transmit radio signals (data) to/from a satellite.

In a traditional VSAT-based communication, a satellite is used as a mere radio-repeater, where signals that reach the satellite are sent back to the ground to a central earth hub.

Internet connectivity is normally achieved by sharing, with a large number of geographically dispersed sites, a link to a central location (the hub). The hub is normally placed in a highly connected region and operates as the main gateway to the Internet or other data services as voice, fax, or video conferencing.



Fig 2: A C-band VSAT

Communication Architecture with VSATs

There are three main components in a communication architecture with VSATs: (1) a high performance hub earth station, (2) a satellite and a (large number of smaller, lower performance) (3) VSAT stations.

Opposite to the client stations that use a small antenna of (0.8 to 3 meters) a hub station is equipped with a bigger antenna in the range of 10 to 30 meters of diameter. The cost of a hub station ranges between 0.5 and several million USD.

The most common access technology used in VSAT is known as TDM/TDMA. The outbound or outgoing channel (from the hub to the satellite) uses Time Division Multiplexing (TDM). In TDM, numerous signals are combined for transmission on a single communications line or channel. TDM works in a satellite in the same way that a T1 or E1 dedicated phone connection. The line (carrier) consists of 24 or 32 (T1/E1) individual channels, each of which supports 64 Kbps. Each 64 Kbps channel can be configured to carry voice or data traffic.

In the client side, (Time Division Multiplexing Access) TDMA is used by the dispersed VSATs to share the incoming or return channel (from stations to satellite). Each station access the shared channel in a certain number of time slots.

This introductory unit will just cover the elements of a VSAT station (client side). Those interested in how a hub/ground station works can consider the book "The Satellite Communication Ground Segment and Earth Station Handbook", Artech House, 2001³. Fig 2: C-band VSAT



Fig 3: VSAT Antenna Ground Station, Source: telstar

Elements of a VSAT station

A VSAT station is composed of three parts: antenna, outdoor unit (ODU) and indoor unit (IDU). The (parabolic) antenna is normally mounted on the ground or in a roof top and its size varies depending on the frequency of operation to a maximum of 3.8 m at Ku band (tx: 14 Ghz) and 7.8 m at C band (tx: 7 Ghz). The antenna system comprises a parabolic reflector and a “feedhorn” mounted in its focal point. In fact, the “feed horn” is another small antenna (horn-shape) that consists of an array of microwave passive components that is used to convey radio waves between the RF transceiver and the reflector.

Band	UPLINK Ghz	DOWNLINK Ghz
Extended C band (Lower)	3.4 to 3.7	5.725 to 5.925
C band	3.7 to 4.2	5.925 to 6.425
Extended C band (Upper)	4.5 to 4.8	6.425 to 7.075
Ku band	10.7 to 13.25	12.75 to 14.25
Ka band	18.3 to 22.20	27.00 to 31.00

Outdoor Unit (ODU)

The outdoor unit is also known as outdoor electronics and contains a Radio Frequency Transceiver (RFT), transmitter + receiver. The ODU is mounted on the antenna frame and is interconnected to the feed horn. The ODU consists of two different subsystems specially designed to operate when in transmission or reception. The *reception subsystem* consists of a Low Noise Amplifier (LNA) and down converters. This is the reason why sometimes the receiver part is known as low-noise block down converter (LNB). In satellite

TV systems, the LNB is the only subsystem present in the ODU as the antenna acts only as receiver. In a LNB, the LNA is responsible of amplifying the received signal while adding minimum noise and the down converter to perform a frequency conversion to a lower intermediate frequency band. This intermediary frequency is known as IF-band. The IF band was traditionally 70 Mhz but new systems use the current industry standard in L-band (950–1450 Mhz) as RF interconnection⁴.

The *transmission subsystem* consists of upconverters and High Powered Amplifiers (HPA). The upconverters convert frequencies between intermediate frequency (normally L-band) and the final transmission frequency. In satellite TV systems, there is not transmission subsystem in the ODU.

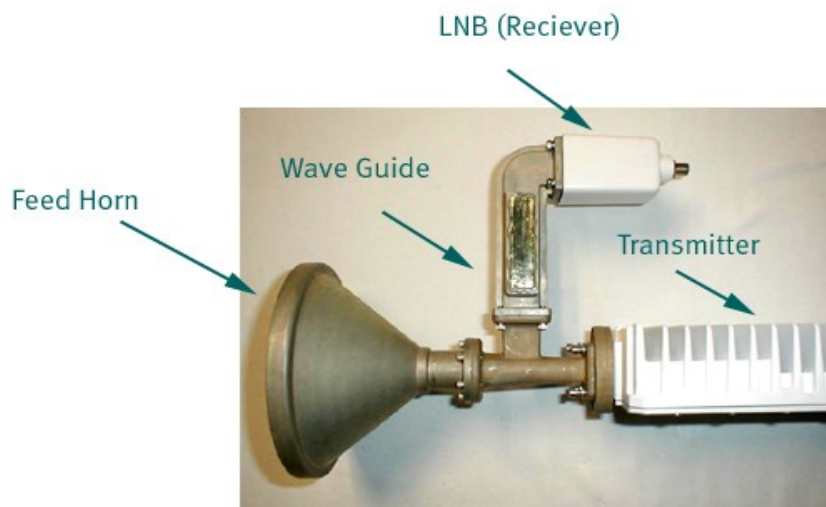


Fig 4: Feedhorn and ODU credit: groundcontrol

Transmission frequencies depend on the radio band in use. For example, for Extended C band, the downconverter receives the signal at 4.5-4.8 GHz and the upconverter converts it to 6.725 to 7.025 Ghz. In Ku Band, the downconverter receives the signal at 10.95-11.7 Ghz and the upconverter converts it to 14 Ghz to 14.50 Ghz.

Indoor Unit (IDU)

The L-band coming from the ODU is coupled to the IDU through a 75 ohm coax cable. The cable that connects the ODU with the IDU is known as Interfacility Link or IFL. When the distance between ODU and IDU is smaller than 100 meters there is no extra need for additional inline amplification.

The Indoor Unit (IDU) is normally placed close to the computer facilities. The IDU is composed of a Multi-Frequency Time Division Multiple Access radio modem (MFTDMA) and built-in IP routing. The IDU unit is both a radio modem and a IP router.

4 ODU Diagram and components: http://www.ssi-iraq.com/kb_vsatsat_terms.html

VSAT media access methods

Opposite to already discussed TDM/TDMA where a carrier includes multiple channels, there are configurations where it is possible to reserve one single channel per carrier. These configurations are known as (Single Carrier Per Channel) SCPC or (Multiple Carrier Per Channel). SCPC uses a Frequency Division Multiple Access (FDMA) scheme in which the input data stream is used to modulate an RF (radio frequency) carrier and assign dedicated carrier frequency to each client.

In a traditional Internet connectivity project in a developing region, we are going to find that the most common of the technologies is TDM/TDMA⁵.

It is not uncommon to find satellite networks based on Demand-assigned multiple access (DAMA). The DAMA protocol is used to share bandwidth in a time division mode (TDM). Typically DAMA transmission is used in Internet projects as highly efficient means of instantaneously assigning carrier channels in a transponder according to immediate traffic demands. By using DAMA, many subscribers can be served using only a fraction of the satellite resources required by dedicated SCPC.

GEO satellites

Although there are other satellites that can be used for Internet connectivity (as the Low Earth Orbit LEOs), the best orbit for a communications satellite is geostationary. A GEO satellite is seen as motionless relative to the ground.

GEO satellites are located at 36000 km above the equator and are placed in line with ITU stipulations. ITU recommends that to avoid interference, all satellites operating the same frequency need to be placed at least 2 degree apart (i.e. A maximum of 180 GEO satellites can be deployed). An alternative to place more satellites is known as co-located satellites. Co-located satellites are separated by 0.1 degree in space (approx. 30 kms) and interference is avoided by using orthogonal polarisations.

GEO satellites normally carry several radio repeaters known as transponders. A communication satellite can carry between 30 to 50 transponders. A transponder (transmit + respond) is responsible of receiving the radio signal from the VSAT and the hub (uplink signals), translate the uplink-signals to a downlink frequency and amplify the downlink signal before transmission. A average bandwidth of a transponder is 36 Mhz.

The amount of bandwidth available in Mbps depends on the modulation, forward error correction coding, and guard band assumptions. The carrier on the satellite is made up of a sequence of joined together pulses to make a continuous signal. Each pulse is a symbol. According to the modulation method each symbol represents 1 or more bits of transmission rate data. Typical VSAT networks use 1 bit per symbol (BPSK) or 2 bits per symbol (QPSK). Forward Error Correction (FEC) used. A Forward Error Correction is a method of increasing the reliability of data communication by sending redundant information with the data in order to allow the receiver to reconstruct the data. A ½ FEC means that one out two bytes that are send out is used for error correction.

A rule of the thumb in VSAT networks is that for a QPSK modulation ½ FEC, 1 bps requires 1 Hz of bandwidth. So a 36 Mhz transponder using QPSK/½ FEC give us a capacity of 36 Mbps.

Ku-band based networks are used primarily in Europe and North America and utilize the smaller sizes of VSAT antennas. C-band, used extensively in Asia, Africa and Latin America requires larger antennas. Although the Ku- Band by virtue of its higher frequency can support traffic with smaller antenna sizes in comparison to C Band. It is, however, susceptible to rain outages.

The market price of a transponder is very dependent on the region, total subscribed capacity and radio band. Just an indication, in 2003 a 36 Mhz transponder in C Band in Africa can cost around 2 M\$/year. The cost of 1 Mbps is 4500 USD/month. When the bandwidth is shared between other users, the term "contention ratio" is used. In a contended or oversubscribed service bandwidth can be share as much as at 20:1.

5 TDM/TDMA is not the only mechanism to share the spectrum in satellite communications, other schemes are based on Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA), Demand Assigned Multiple Access (DAMA), Pre-Assigned Multiple Access (PAMA) or Frequency-Time Division Multiple Access (FTDMA).

Satellite footprints

The satellite footprint is the coverage area where the satellite can provide certain communication service. Satellite footprint maps are used to decide the type of antenna and ODU required⁶. Satellite footprint maps are calculated based on the Equivalent Isotropically Radiated Power (EIRP) of the satellite, EIRP is the sum of output power from the satellite's amplifier, satellite antenna gain and losses. A satellite EIRP footprint map is the result of drawing lines through points of equal EIRP in the service area. The EIRP values increase towards the center of the antenna beam and decrease away from the center. The highest level of EIRP the smallest diameter of antenna is required⁷.

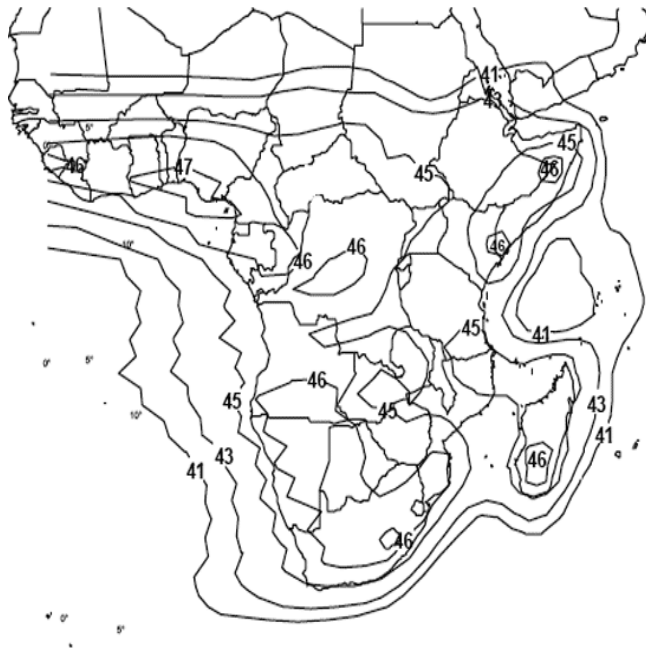


Fig 5: PAS – 10 Footprint

6 Satellite Link Budget Calculator
<http://www.rfdesign.info/doc-desc/14/Satellite-Link-Budget-Calculator.html>

7 Satellite Footprints <http://www.g2sat.com/satellite-bandwidth/managed-network-services.asp> and
http://www.panamsat.com/global_network/map_flash.asp

Internet over Satellite... the next step

With the appearance of digital television over satellite a set of standards have been proposed to be able to send IP data besides audio and video transmission. Some of those standards include DVB and the recent standardized (March 2005) IPOS (IP over Satellite) from Hugues Network Systems (HNS). In the next section we will give a brief introduction to DVB.

What is DVB?

DVB stands for Digital Video Broadcasting and is a set of open standards for digital television. DVB is the result of the work of the DVB Project, an industry consortium with more than 300 members that includes the European Telecommunications Standards Institute (ETSI). DVB standards define the physical and data link layer of a distribution system that can send and receive data by satellite (DVB-S), cable (DVB-C) and terrestrial television (DVB-T).

In the outbound channel all data is transmitted in MPEG-2 transport streams. As many other wireless standards, the distribution system can use different modulation techniques depending on the media. For example while DVB by satellite uses QPSK, DVB by cable uses QAM.

Besides audio and video transmission, DVB also defines data connections with return channels (DVB-RC) for several types of media (DECT, GSM, ISDN, Satellite, etc.)

DVB has standardized a return channel for satellite communications that work together with DVB-S to create bi-directional communication over satellite networks. The standard is known as DVB-RCS Return Channel Satellite, and specifies return channels in C-, Ku- and Ka frequency-bands with return bandwidth of up to 2 Mbit/s.

DVB-S, DVB-RCS Architecture

A short description bi-directional Internet satellite communications by DVB follows:

The forward link between the hub and the satellite station or satellite interface terminal (SIT) uses the DVB-S standard. The DVB-S forward channel is a QPSK modulated TDM broadcast channel. Similar to any other satellite forward links the data of all SIT is aggregated in a single TDM carrier. The IP packets are encapsulated in a MPEG-2 transport stream (MPEG-2 TS) by means of an encapsulation protocol named Multiprotocol Encapsulation (MPE) or the new proposed Unidirectional Lightweight Encapsulation (ULE). The receiver station needs a DVB receiver card and a software capable of extracting the IP packets out of the MPEG-2 stream (typically a Linux-based system).

The return channel uses another standard known as DVB-RCS, opposite to DVB-S where the forward is a broadcast channel, the return channel in DVB is point to point. The return channel uses QPSK and MF-TDMA. The SITs are capable of sending data in multiple carriers (Multi frequency) and in certain time slots.

The return channel uses another encapsulation technique instead of encapsulating IP in MPE/MPEG-2 TS, the IP packets in the return channel are sent as ATM encapsulated with AAL5.

Mixed architectures in developing regions

It is common nowadays to see a mix of all the proposed solutions in developing regions. Due to market reasons and technological push the DVB-S traffic is cheaper than dedicated SCPCs. That situation has forced many ISP to use DVB-S for the downlink channel and use SCPC or TDMA equipment for the return channel.

In the future we can predict an expansion of DVB-based systems⁸.

8 See <http://www.isi.edu/tcpsat/list/archive/0822.html>

Conclusion

This unit provides a primer introduction to traditional VSAT satellite communications including DVB-S. The content should help a system and network administrators in a developing region to understand how a VSAT system works and to provide enough background information to understand to a set of case studies included in the bibliography section.

Advanced topics as link budget, modulation and coding, VSAT topologies etc. have not been included in this introductory document but might be included in future versions.