The Global VSAT Forum
Education & Training Working Group

VSAT Installation & Maintenance Training

Level 3

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The Global VSAT Forum (GVF) is a not for profit organization comprised of a large number of satellite communications companies from over 60 countries in every major region of the world. The GVF's mission is to act in an independent manner for the general promotion of the global VSAT Industry, whether this be technology or service based. The Global VSAT Forum represents the best interests of its membership at relevant industry symposia, regulatory and legal consultations and forms a single point of contact for any suppliers to the industry or any users of VSAT equipment or services. The Forum's actions are always consistent with the promotion and growth of the VSAT Industry and its membership.

Second Edition February 2006.

Dear Reader,

Everyone knows that modern communications satellites are at the heart of the high quality telecommunications services satellite service provides to our myriad customers around the world. However we sometimes take for granted just how remarkable these satellites and their associated ground systems have become. Weighing about the same as a full size American car, when these satellites roll of the assembly line their fuel tanks will be filled and then they will be subjected to the full force and fury of a controlled explosion known as a launch vehicle. With several additional pushes from an internal rocket, after two weeks they will finally arrive at the proper orbital slot 22,300 miles above the earth. For the next thirteen to fifteen years, in spite of the continuous push from the "solar wind" and the constant pull of gravitational forces, the satellite must be kept in exactly the same position - again using internal rockets under ground control - so that the customers antennas will not have to search to find it. After the antennas and solar panels are unfolded and a short period of testing is completed, the satellites will be expected to run twenty four hours a day, seven days a week for thirteen to fifteen years with no stops at the dealer for repairs or even routine maintenance. They will also be expected to provide continuous communications services between all points on the earth within the antenna "footprints" carrying huge volumes of video, voice and data for your or your company's customers.

One of the goals of this training manual is to make the development, launch and operation of these "modern miracles"" and the installation of ground segment as earth stations look easy to you as a VSAT Technician and ultimately, to your worldwide customers.

Because satellite technology is a rapidly evolving area of technology it cannot be over-emphasized that training should be a continual activity. It is necessary that both the executive and technical staff keep up-to-date with technological developments in this field. As a minimum, VSAT technicians should have good knowledge of RF transmission, digital technology and some knowledge of mechanical systems. Managers need to understand the importance of continuing education for personnel to enhance knowledge, improve skills and keep up with new technology.

This Training Manual provides the reader with an overview of satellite technology and VSAT technology in particular. In addition, it addresses issues typical to all VSAT installations. It should be noted that the issue of human health and safety from electromagnetic radiation is not included in this manual, as compliance with national and regional standards and limits in this area is insured through each national licensing process.

Please take your time to read through the manuals and make notes where required. If necessary, insert comments, remarks or questions.

The Manual is far from perfect but efforts will be made to keep it updated. In addition this paper is written by a non-native English speaker what occasionally may result in funny grammar.

At any time never hesitate to contact me for remarks, suggestions or critics.

Amsterdam, The Netherlands.

August 2003

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Part 2 – Level 3: VSAT Technology Basics

History Edition

Version	Date	Author	Notes
Draft 0.0	30 April 2003	Onno Beemsterboer	Initial set-up
Rev 1.0	22 July 2003	Onno Beemsterboer	Implementation of suggestions
Rev 1.1	10 September 2003	Onno Beemsterboer	Implementation of suggestions
Rev 1.2	18 November 2003	Onno Beemsterboer	Adding copyright clause
Rev 1.3	14 December 2003	Onno Beemsterboer	Update introduction; update charts on page 122 and 125
Rev 1.31	3 February 2006	Onno Beemsterboer	Level split and update

Part 2 – Level 3

VSAT Technology Basics

1. Preparing for a VSAT installation

Before any VSAT installation the installer should receive detailed information regarding the materials awaiting him at the site, used satellite, look angles, equipment settings and other information relevant to the specific job. In most installations, the installer should assume that he or she would be required to program the VSAT terminal. In most of the cases this will require a laptop PC with some form of communications software. Another vital tool for any VSAT job is a spectrum analyzer. Most modern digital receivers do not provide easy, built-in satellite pointing tools. TVRO receivers can be used, but they require knowledge of each satellite's daily program content – which is subject to change. A spectrum analyzer is great for finding the proper satellite, peaking the antenna, setting transmit and receive levels, and setting cross-polarization.

1.1. Typical VSAT installation

A typical Installation shall include:

a. Conducting and documenting one (1) site survey;
b. Optional: assisting with customs clearance, duties, handling charges, taxes and fees arising from the import of VSAT equipment;
c. Optional: administering all local and governmental licensing of earth station equipment,
d. Optional: assisting the local Customer with obtaining construction permits and landlord approvals;
e. Optional: delivery/transport of equipment to Customer site,
f. Assembly and installation of pre-fabricated penetrating or non-penetrating (roof) mount, including ballast;
g. Erecting and pointing antenna;
h. Installation of IF and M&C cables;
i. Assembly and installation of indoor equipment;
j. Proper grounding of all equipment;
k. Assisting with connection of Customer equipment to the VSAT;
l. Performing local, end-to-end, and commissioning tests;
m. Customer instruction, and
n. Completing of technical documentation aka Service Acceptance Test.

The Service Acceptance Test is defined as a technical document what needs to be completed after every new installation, service upgrade and service downgrade. The purpose of the documents is to increase the quality of the services by being better informed about the exact details of an installation and the work that was performed on site. The document is mandatory and requires customer's signature.

1.2. Standard VSAT hardware to be installed

The hardware for Installation shall, in general, include:

- 1.2, 1.5, 1.8, 2.4 or 3.7 meter antenna, occasionally with de-ice incorporated in one or more antenna panels, and preferable a non-penetrating antenna mount with sufficient ballast;
- Satellite transceiver unit including radio and LNB/LNC;
- Satellite modem unit;
- Optional: Multiplexer unit;
- Optional: Router unit;
- Optional: Monitor and Control (M&C) unit;
- Optional: Telephone modem unit to support the M&C unit;
- IF (Inter Facility) and M&C (Monitor and Control) cables and connectors;
- Modular uninterrupted power system (UPS) unit; and
- Equipment rack with internal cables and wiring.

1.3. The VSAT Technician

A VSAT Technician must be capable of:

- Understanding all the technical/network requirements;
- Understanding the basics of RF, networking and satellite technology;
- Understanding the specific satellite modems, radio, multiplexers, UPS, parabolic antenna installation etc;
- Understanding link budget calculation;
- Using a spectrum analyzer to measure absolute power and carrier to noise over noise ratios (C+N)/N.
- Using a bit-error-ratio (BER) tester and a voltmeter.
- Using a PC/ laptop to load and run software (e.g. radio settings and multiplexer settings)
- Using compass, inclinometer and hand tools to re-point the antenna.
- Mounting connectors to a cable in the correct way using the right tools.
- Conversing in understandable English with Network Operations Centers (NOC) and the recording of test results and measurements in English.

2. Site Survey

2.1. The purpose of a site survey:

- To gather site specific information necessary to design and implement the customer contract requirements
- To ensure that the chosen installation site has a clear view to the desired satellite
- To select the best placement for the antenna
- To determine the type of mount needed
- To document the location of the indoor equipment
- To determine and document the path and length of the cable run
- To discover and document any special problems that may affect the installation such as landlord approval or contractor issues
- To identify or confirm interface requirements
- To obtain information needed to procure permits and licenses

2.2. Azimuth and elevation

The longitudinal position into which a geostationary orbit satellite is positioned is called a slot. The satellite's position is expressed in degrees and indicates a point east or west of the prime meridian. As an example Telstar 12 is positioned in the 14.8° West orbital slot. An orbital slot is 75 x 75 x 85 km in size.

The position of GEO satellites is given in degrees of longitude. *Longitude* indicates a point east or west of the prime meridian. Position of an earth station is given in longitude and latitude. *Latitude* indicates a point north or south of the equator.

If you want to point a parabolic antenna to a satellite only two parameters are required:

1. The longitudinal position of the satellite.
2. The longitudinal and latitudinal position of the antenna.

From those parameters the antenna's azimuth and elevation can be determined:

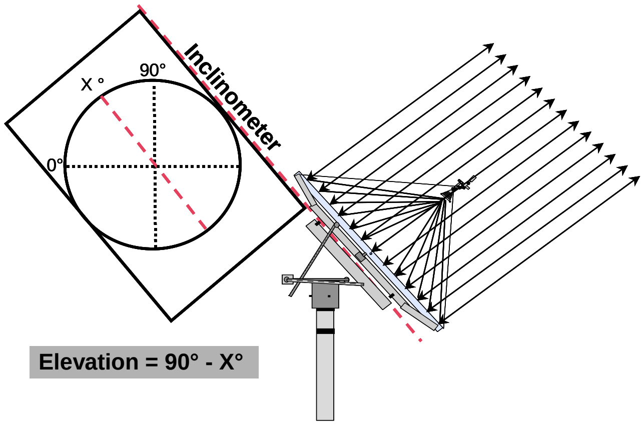
- **Elevation:** The vertical angle measured from the horizon up to a targeted satellite. When the beam axis is parallel to the ground, the elevation is zero. A 90^o-elevation rotation points the beam to the zenith.
- **Azimuth:** Angle between antenna beam and meridian plane (measured in horizontal plane). The zero reference for measuring true azimuth is north, east is 90^o, south is 180^o and west 270^o.

2.2.1. Azimuth and elevation angle measurements

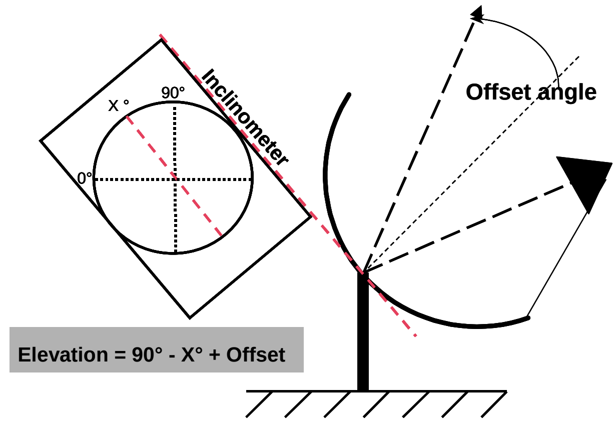
Indispensable in practicing the elevation-over-azimuth pointing system is a compass and an inclinometer. The inclinometer is an instrument used to measure the angle of elevation to a satellite from the surface to the earth. Azimuth can be measured by using a compass. However, a compass doesn't work well near steel obstructions and frameworks commonly found in buildings. Strong magnetic fields dramatically affect compass readings as well. This is called deviation. Besides, a compass always points at the Magnetic North, which is officially the city of Badhurst in Canada. The given azimuth in an Antenna and Radio Configuration Sheet always refers to the Geographic North. This means that you always have to deal with a difference between the Magnetic North and the Geographic North. This is called the variation and depends very much on where you are on Earth.

A simplified procedure to point an antenna is:

- *Step1:* Know the orbital position of the satellite and the geographic location of the antenna. As an example Astra-1A is located in the 19.1° East slot. Be advised that this is ***not*** your compass readout unless your antenna is on the equator.
- *Step2*: Calculate the azimuth and elevation for the specific satellite for your specific location
- *Step3:* Read the compass at ground level. Stay away from motors and large steel constructions.
- *Step4:* To find the true azimuth you first must subtract or add the variation to your compass reading.
- *Step5:* Identify a landmark in the assigned azimuth pointing direction and refer to the landmark when pointing the antenna.



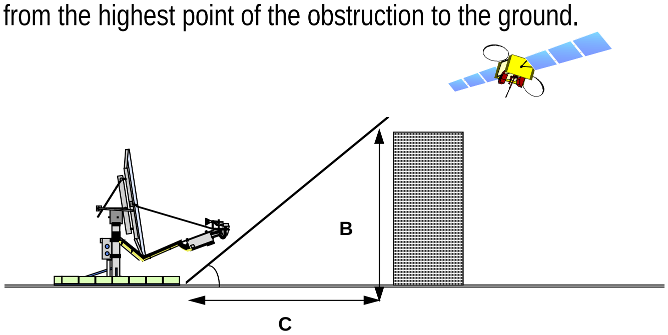
Passive antenna elevation pointing: Prime focus antenna



Passive antenna elevation pointing: Offset antenna

2.2.2. Obstructions

It may happen that there is an obstruction between the antenna and the satellite. For each meter from the center post, the rise (line B on the drawing below) can be calculated from the tangent of the elevation angle. To find out if the height of this obstruction will cause problems for your installation *first* measure/calculate the antenna elevation. *Second* measure the distance C. C is the distance between antenna center post and imaginary line perpendicular from the highest point of the obstruction to the ground.



Elevation (degrees)	Rise B (cm) for each meter C
5	8.74
10	17.63
15	26.79
20	36.39

Example: An obstruction of 4 meters (this could be a tree?) is right in front of the antenna. The elevation is 10 degrees. The distance C between antenna and obstruction is only 25 meters. Is there any problem? No, because the rise B for each meter C is tg (10) = 17.63 cm. The total rise over 25 meters is 25 x 17.63 = 438.73 cm = 4.38 meters. Conclusion: the tree may grow another 38 cm before you face serious problems.

2.3. Site survey process

2.3.1. Necessary equipment and materials to do a Site Survey:

- A compass
- An inclinometer
- A measuring tape
- A marker
- Standard “Site Survey Form” (see Appendix for example)
- (Digital) camera

Step 1. Prior to the site survey
In preparation for the site survey, contact the customer to schedule the survey and to explain the purpose of the survey giving him the details to the best of your knowledge. Review your role and his role in the survey. Advise the customer to request the presence of the building owner, building engineer, and electrician during the site survey. Inform the appropriate program manager of the day and the time you plan to complete the site survey.

Step 2. On site
Notify the customer contact individual when you arrive. Try to provide as detailed information as possible, and feel free to add comments wherever there is a need for it. Do not hesitate to provide alternative solutions for possible problems. Take photographs and make sketches to clarify layouts and diagrams.

Step 3. Locating indoor equipment
Remember you need is at least a meter clearance both to the front and to the rear of the rack, in order to allow access to the equipment. Determine whether the cables, which will be run to and from the customer interfaces, and the power supply should enter the rack from above or below.

Step 4. Reporting
Send completed documentation to the responsible Program Manager as soon as possible after completion of the survey.

Please note
Please take the time to represent your company according to international hospitality standards, respecting local customs and culture. Remember that you often represent an international telecommunications company which is judged by your actions.

2.4. Local restrictions

Some countries ban satellite dishes in an effort to restrict broadcasts from outside their borders, whether for religious, political or purely monopolistic reasons. Even in developed countries barriers to antenna placement may exist at local level. Sometimes these regulatory roadblocks are based on aesthetic or zoning conditions; but in some cases more mercenary reasons come up, such as a deceive to protect the local cable network or capture high fees.

2.5. Equipment importation license and transmit license

At any time check with the local authorities what documentation is required and what the conditions are to import and use telecommunications equipment. Often there are a number of permissions and licenses required to operate a VSAT legally.

2.6. Equipment type approval and homologation

According to (local) law a satellite earth station - and telecommunications equipment usually needs a governmental approval before it can be used. This means that equipment must have been tested and certified by a (national) notified body. However, (technical) requirements for type approval can vary from country to country. It does not automatically mean that the use (or even the importation) of equipment is allowed if this equipment is approved for, or in another country. Especially CE type approvals for transmit equipment (radios and (terrestrial) modems) are very important and often indispensable for obtaining a VSAT license.

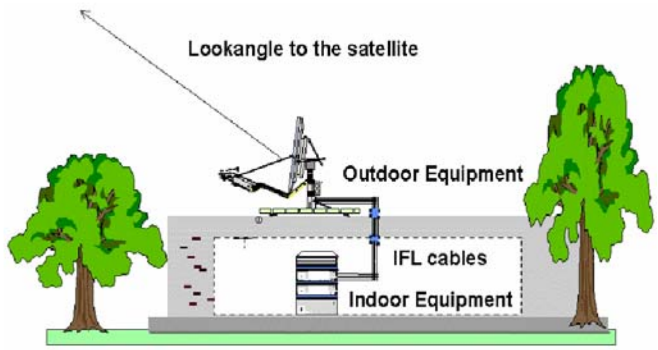
As an example; In Europe, standardizing of telecommunications products and services are handled by the European Telecommunications Standards Institute (ETSI). Any publications can be downloaded from the publications catalogue at their web side: www.etsi.org

3. Typical VSAT Installation

Introduction

A typical VSAT installation consist of three basic hardware sections:

- Outdoor unit (ODU)
- Indoor unit (IDU)
- Inter-facilities link (IFL) cables

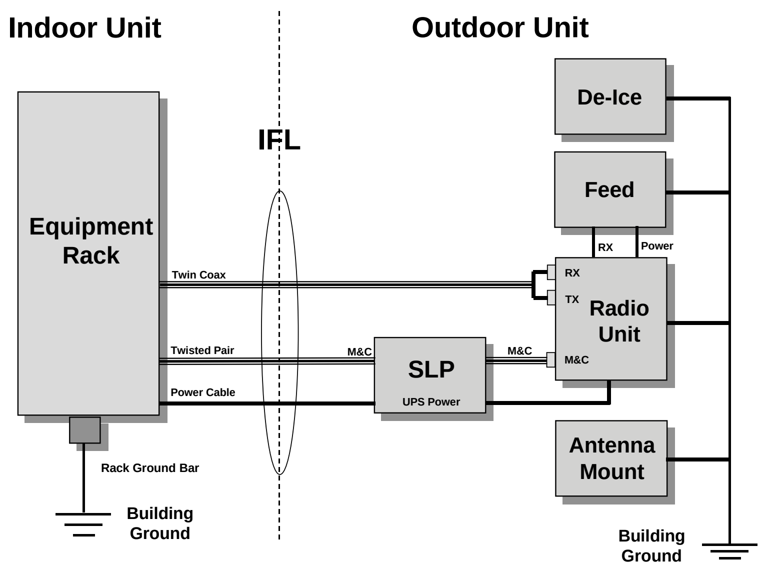


The standard installation includes a standard site survey at the location, local license application(s) (if necessary), IDU/IFL/ODU installation, Customer instruction and hand-over and the return of Service Acceptance Test.

- A 1m - 2.4m antenna installation requires maximum one qualified technician and one assistant on site.
- A 3.8m antenna installation requires one qualified technician and two assistants.

ODU/IDU/IFL installation is defined as

- Installation of a satellite antenna with maximum 3.8m aperture diameter including mount and ballast. Antenna size is specified by the service provider or customer and can be with or without de-icing. Typical mount construction is non-penetrating; Typical de-icing is a de-ice system integrated in one or more antenna panels; and
- Installation of digital low noise block converter (LNB or LNC) and radio transceiver; Installation of power cable, M&C cable and coaxial cable including connectors. Peak and pole of antenna and level check in cooperation with satellite operations center. Programming and testing of digital base band equipment including a 8h BER test; and the installation of the monitor and control (M&C) device.



3.1. VSAT installation sequence

Site Survey (prior to installation)	Download Site Survey Form from the Internet.
Installation Preparation	Check all the licenses. Check shipment and report missing items. Check all the site specific documentation is available. Test and configure equipment. Put modem(s) in loop back test for 15 min.
Installation of IFL	Test connectors. Test IFL (cable loss). Install power on the roof for spectrum analyzer and modem. Check grounding.
Installation of IDU	Mount rack.
Installation of ODU	Install Mount. Install Antenna. Install Radio. Find the satellite using a beacon.
Cross-pol and line up & level setting*)	See chapter 7 of this manual for an example
Perform all the necessary tests	Find absolute receive level at satellite modem input. Perform sync loss and fade margin test. Perform satellite modem-to-modem BER test. Perform multiplexer (if any) voice port test Perform multiplexer (if any) customer voice interface test Perform M & C test (together with NOC)
Clean up	
Hand over to the customer	Complete Service Acceptance Test and forward to the responsible Program Manager.

**) In order to maintain strict control over the transponders, many satellite companies have published the Satellite Access Procedures. These procedures outline the method for a customer to arrange for a service contract and receive frequency assignments. They also provide instructions for a customer to receive authorization to transmit to the satellite and the step-by-step process for verifying performance of their up-link equipment. Most importantly, the Satellite Access Procedures grant the Satellite Operating Center the authority to deny access or terminate the transmission of any customer that is violating the terms of the agreement or is operating in a way that causes interference or threatens the health of the satellite.*

3.2. Before you start

Prior to the installation of a new VSAT the installer should receive from the service provider or customer all the site specific documentation. This should include detailed information regarding the materials awaiting him at the site, satellite location, look angles, equipment settings and other information relevant to the specific job.

3.2.1. Check documentation.

Samples of all the documents listed below can be found in the Appendix. If you believe something is missing immediately contact the responsible Program Manager or Network Engineer.

As a minimum you should have for every node in the network:

- Full equipment list / Bill of Materials
- Schematic installation diagrams
- Antenna related parameters as azimuth and elevation
- Radio configuration sheet clearly indicating the up- and downlink frequencies and carrier ID's
- Satellite Modem and multiplexer (if required) configuration including Timing Diagram
- List of telephone numbers (PM, NOC, Satellite Operations Center)
- IP addresses (if required)
- Link Budget Calculation

3.2.2. Check all necessary equipment is on site.

Use the Bill of Materials/Equipment list for this. This list is to be provided the service provider or customer. It also may be wise to check the electronics if they work properly.

> If you believe something is missing or faulty, immediately contact the responsible program manager or network engineer.

3.2.3. Check all necessary tools and test equipment is available on site.

To meet common standards proper tools, test and measurement equipment required to perform installation and repair of VSAT systems is absolutely indispensable. For those Installers who want to update their inventory of test equipment it is recommend a visit to the following websites:

Companies selling (used) test equipment at often reasonable prices		
Company	Internet address	Language
Telogy Networks	http://www.telogy.com/	English
Electrolab	http://www.electrolab.com/menu.htm	English
The Test Equipment Depot	http://www.testequipmentdepot.com/	English
Planet Test	http://www.planettest.com/	English
Instrumex	http://www.instrumex.de/	German
T.O.P. Electronik	http://www.topelektronik.de/	German
Metric	http://www.metricsales.com/	English

Absolutely Indispensable is:

- Compass and Inclinometer, 0.2% accuracy
- Utility knife and diagonal cutter
- Crimp tool for F, BNC and N connectors (One what fits!!)
- Cell Phone (GSM)
- Set of combination wrenches, Set of Allen wrenches
- Set of screwdrivers, standard blade and cross blade
- Crescent or pipe wrench
- Spectrum Analyzer and Data Analyzer
- Standard service cables

A spectrum analyzer and a data analyzer are absolutely indispensable for people working in the field doing VSAT installations. Without this equipment it is almost impossible to complete the installation and to hand over a proper product to the customer.

The complete list of tools should include:

1 ratchet wrench, 3/8 or 1/2 inch drive
1 socket, ½ inch or 13 mm deep well
1 socket, ¾ inch or 19 mm deep well
1 socket, 1-1/8 inch or 29 mm deep well
1 combination wrench, 5/16 inch or 8 mm
1 combination wrench, 1/2 inch or 13mm
1 combination wrench, 3/4 inch or 19 mm
1 combination wrench, 15/16 inch or 24 mm
1 combination wrench, 1-1/8 inch or 29 mm
1 combination wrench, 1-1/2 inch or 38 mm
1 adjustable wrench, 10 inch
1 Allen wrench set, .05 to 3/8 inch
1 Allen wrench set, 1.5 to 10 mm
1 hex key set, metric short arm
1 screw-starter, 3/16 inch standard blade
1 screw-starter, Phillips
1 screwdriver set, standard blade
1 screwdriver set, cross blade
1 hammer, 16 oz. Or larger
1 metal file, fine
1 metal file, course
1 cutter
1 solder removal tool, soldering iron and solder
1 tweezers
1 fuse puller, midget non-slip, 1/4 to 1/2 inch
1 utility knife w/replacement blades
1 ignition wrench set, 7/32 to 7/16 inch
1 pin insertion/extraction tool, 4-48 pin
1 center punch, 3/32 inch
1 crimp tool for the RF-connectors
1 RJ 11 connector crimp tool
1 RJ 45 connector crimp tool
1 RS-232 pin insertion/extraction tool
1 V.35 pin extraction/insertion tool
1 inclinometer, 0.2 % accuracy
1 compass
1 power drill
1 13" or 76mm wrench (socket, crescent or pipe wrench) for 2" to 4.5" bolds

Additional materials

The following materials can be very useful on site:

- Adhesive caulking compound
- Electrical tape, Scotch 33 +, or equivalent
- Rubber tape, Scotch +C130, or equivalent
- Data connector gender changers- 9, 15, 25, 37 pin
- Data cables, DB9-DB9, DB9-DB25, DB25 null modem, etc.
- Fixed attenuators, 50 and 75 ohm BNC; 1, 2, 3, 5, 10, 20 dB
- Duct seal putty
- Tie wraps, ultra-violet rated, 12 to 24 inch
- Marking pen, fine point, indelible ink
- Cable labels, adhesive and tie-wrap types
- 1/4 and 0.35 inch cable with 9/16 inch connector
- Assorted male and female cable connectors and F, BNC, SMA, & N type adapters

Indispensable test equipment

- Spectrum analyzer; ideal would be 50 MHz to 2 GHz, RBW to 3 KHz or better, sensitivity to -95 dBm or better with +/- 250 MHz frequency accuracy or better (Example: Hewlett-Packard model 8591 or equivalent)
- Data error analyzer, BER, average BER, sync loss, pattern loss recording, with V.35, RS449 data interface capability (Example: TTC Fireberd 6000 with TCC 42522 data interface, or equivalent)
- Laptop computer, 486 or higher CPU, 10baseT network card preferably with Windows 98 or higher with COM-port and terminal emulator software;
- Universal Multimeter including set of probes

A Basic Toolkit

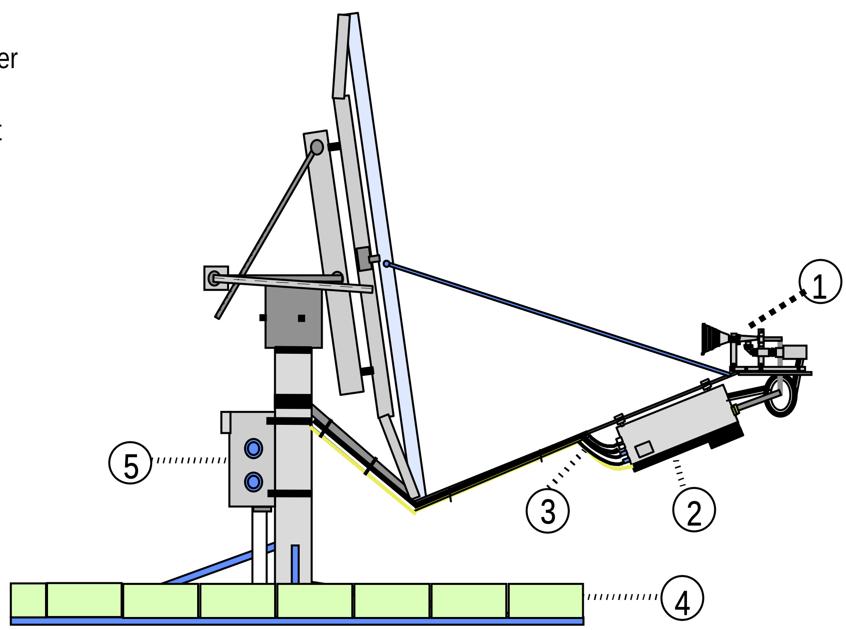
3.3. Typical VSAT Outdoor Unit (ODU)

The outdoor unit is comprised of an antenna, feed system, transceiver and optional an anti-ice system. The antenna is normally installed on a non-penetrating mount. Occasionally specially designed (penetrating) mounts are used.

The use of a non-penetrating mount (NPM) is preferred and provides a method for an antenna to be mounted on the roof (or other flat surface) when penetration of the roof barrier is not feasible. This non-penetrating mount is easy to assemble, offers low uniform load distribution, minimum settlement into the roof barrier, and is compatible with many types of flat roof constructions. Generally, the NPMs are not physically attached to the building and use the weight of ballast (such as concrete blocks or block caps) and specially designed braces to hold the mast vertical and to avoid moving.

The antenna is a passive element and its size is directly proportional to the to be transmitted amount of bandwidth (which is related to power). The main differences between the 1.2m, 1.8m, 2.4m and the 3.7m antenna can be found in the antenna gain (which is determined to a great extent by its diameter) and antenna efficiency.

1 Feed construction
2 Radio unit or transceiver
3 IFL cables
4 Non penetrating mount



Note: An offset reflector contains a X° elevation offset look angle. Therefore, when the reflector aperture is perpendicular to the ground, the antenna is actually looking X° in elevation. X is antenna specific and can be found back in the manufactures manual.

3.3.1. Outdoor Unit installation verification

Verify the following after installing the ODU:

- All equipment is grounded to a proper ground;
- All connectors are taped and protected from moisture;
- All bolts and nuts are tightened firmly;
- Enough ballast on a non penetrating mount;
- IFL is connected to the outdoor unit;
- The roof is clean;
- Is lightning protection installed?

Examples of an Outdoor Unit; 2.4m antenna and a non-penetrating roof mount.

3.4. Indoor Unit (IDU)

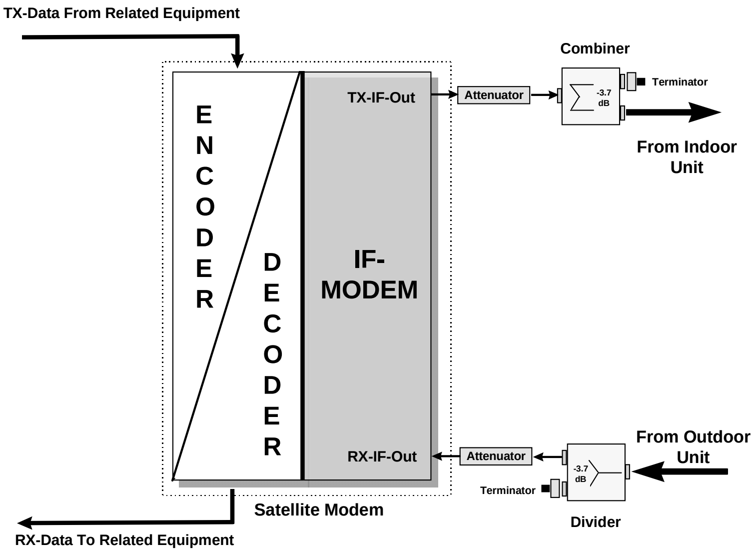
The indoor equipment comes can be integrated in one or more standard 19-inch wide equipment cabinets or racks. The location of this cabinet is selected to minimize cable runs to the local customer's data terminal equipment. The indoor equipment requires an environmentally controlled, reasonably clean area, such as a computer room.

3.4.1. The equipment rack

The heart of every rack is the satellite modem what includes the interface to the customer's equipment, the data encoder/decoder (codec) and a modulator/demodulator. In fact the satellite modem produces the signal for the uplink, and demodulates the received downlink signal. The modem(s) is (are) connected to the Outdoor Unit via the IFL cables. The indoor unit is a rack containing as minimum configuration, all the necessary channel equipment, the monitor & control (M & C) unit and a PSTN modem are optional. Depending on the application, an UPS unit, multiplexer, and router(s) can be installed in addition.

A Monitor and Control (M&C) unit collects status information from the VSAT site including the transceiver and reports to the Network Operations Center via a PSTN modem, either automatically or in response to a query. It also gives the NOC the ability to dial into the site for reading (and changing) the equipment settings without dispatching a technician.

To improve the MTBF (mean time between failure) keep the power always switched on. Never switch off the electrical equipment for the weekend!



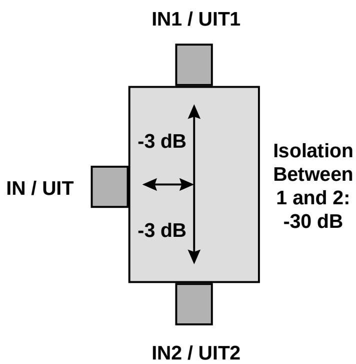
The Indoor Unit is a:

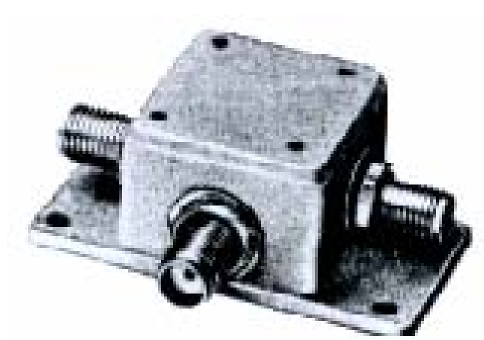
- Satellite Modem(s)
- Fan
- UPS
- Splitters and Fixed Attenuators
- M&C Device
- PSTN Modem
- Multiplexed (optional)
- Router (optional)

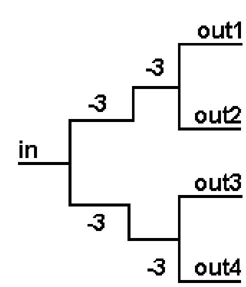
3.4.2. Dividers / combiners

Combiners for TX and dividers for RX make IF-monitoring with a spectrum analyzer or the connection of an additional modem possible. Dividers or combiners are actually the same piece of equipment and also called (power) splitters. Basically they split the signal power into two equal parts. This means that the signal at the output is theoretical 3 dB lower than at the input. Practical loss depends on the used connectors, connected impedance (does it match with splitter in- and output impedance or not) and the frequency. In real life a two-way splitter gives a loss of 3.4-3.7 dB. A three-way splitter also exists as a basic component and has 4.8 dB insertion loss. Out of those two basics it is possible to create every desirable divider or combiner simply by adding them together. The table below shows often used splitters with their theoretical insertion loss.

2-way	3.0 dB
3-way	4.8 dB
4-way	6.0 dB
6-way	7.8 dB
8-way	9.0 dB







A standard two-way combiner / divider. The loss between in ⇔ out is -3.7 dB (this is including the connector losses). The isolation between in1/out1 and in2/out2 is about 30 dB but depends very much on the correct impedance termination. If one of the in/outputs is left unterminated the isolation can drop to 10 dB.

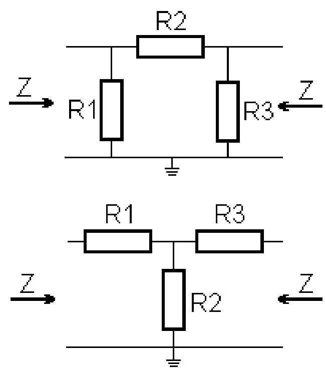
Schematic diagram of a four-way combiner/divider

Be aware, a splitter is directive and cannot be connected in any way you like. Commercial splitters have an in- and output impedance of 50 Ω or 75 Ω and the pass band is flat from 5 MHz to 1 GHz or higher. Many companies uses Mini-Circuits 75 Ω types and are flat to 500 MHz. Unused out- or inputs always have to be terminated with the correct characteristic impedance.

3.4.3. Fixed attenuators

Attenuators are often found in the RF signal path of transmitters and receivers. The use of broadband, rather than narrow band, input filters often results in a considerable amount of unwanted RF energy reaching the first signal stage and mixer, giving rise to overload problems. One method of reducing this type of problem is to provide the option of adding some attenuation in the signal path. This can be effective in improving reception either when the desired signal is strong and is causing overload effects, or when a strong undesired signal is masking a weaker signal. The used attenuator must be of the same impedance as the modem input and the cable. In effect, if the modem input filters are presented with the wrong drive impedance they will not achieve their design performance.

Mini Circuits Fixed Attenuator



The Pi- and T network:
Two simple configurations are available for (unbalanced ⇒ one side is connected to the ground) attenuators

Depending on the quality and the length of the IFL cable run, the cable has a certain attenuation. For example the Olympic Twin coaxial cable has for 70 MHz an attenuation of 6dB/100m. Since the minimum output level of the satellite modem is -25 dBm this attenuation is often not enough to avoid overdriving the radio when connecting the modem output via the IFL cable to the radio. For this reason the use of fixed attenuators is absolutely necessary.

Attenuators in the RX path are often required for not overdriving the input stage of the demodulator.

3.4.4. Indoor Unit installation verification

Verify the following after installing the IDU:

- All equipment located within a common rack is bonded together and grounded to a proper ground;
- Verify the IFL is connected to the indoor unit, and the indoor unit is connected to a pre-tested AC receptacle. A pre-tested AC receptacle is one that has a good ground and no polarity reversals. This may be checked with a standard ac receptacle checker;
- The IDU is secured to a stable flat surface or in an equipment rack with adequate air circulation;
- The IDU is located within a sheltered environment, away from sources of water, extreme cold and heat, vibration, dust or excessive electromagnetic interference (EMI);
- The PSTN modem is connected to a working telephone line. The provider's Network Operations Center (NOC) is informed about the telephone number and should have the possibility to dial up the device;

4. Data interfaces

Data interfaces (Physical Layer or Layer1 from OSI Reference Model) are used to connect user devices into the communications circuit. Most interfaces describe four attributes of the interface:

1. **Electrical** – Electrical describes the voltage (or current) levels and the timing of the electrical changes to represent a “0” or “1”
2. **Functional** - Functional describes the functions to be performed by the interface. As there are control, timing, data and ground;
3. **Mechanical** - Mechanical describes the connectors and the wires;
4. **Procedural** – Procedural describes the sequence of events required to effect actual data transfer across the interface;

Several standards are widely used throughout the world

- The RS series. RS stands for Recommended Standard
- The V. series stipulates recommended standards for data transmission in telephone networks
- The X. series is used for defining data transmission in public or private data networks

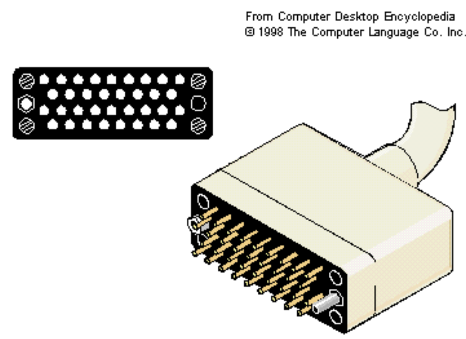
DTE stands for Data Terminal Equipment and is a typical end-user device, such as a terminal or computer.

DCE stands for Data Circuit-terminating Equipment. DCE provides the DTE a connection into the communications circuit. A telephone modem is an example of a DCE.

4.1. Standard data interfaces

V.35 - An ITU standard (1968) for group band modems that combine the bandwidth of several telephone circuits to achieve higher data rates. V.35 standard describes synchronous full duplex data transmission at 48 kbps line speed using 60-180 kHz group bandwidth circuits.

Although not specified in the ITU standard, the V.35 or Winchester connector has become a de facto standard for a serial interface in the 48 to 64 Kbps range.



X.21 - An ITU standard protocol for a circuit-switching network. X.21 describes the interface between DTE and DCE for synchronous operation on public data networks. The physical connector has 15 pins, but not all of them are used.

- **X.21** is a ITU recommendation for operation of digital circuits. The X.21 interface operates over eight interchange circuits(i.e. signal ground, DTE common return, transmit, receive, control, indication, signal element timing and byte timing) their functions is defined in recommendation X.24 and their electrical characteristics in recommendation X.27.
- **X.21-bis** is an ITU recommendation that defines the analogue interface to allow access to the digital circuit switched network using an analogue circuit. X.21-bis provides procedures for sending and receiving addressing information that enable a DTE to establish switched circuits with other DTEs, which have access to the digital network.

X.25 - The first international standard packet switching network developed in the early 1970s and published in 1976 by the CCITT (now ITU). X.25 was designed to become a worldwide public data network similar to the global telephone system for voice, but it never came to pass due to incompatibilities and the lack of interest within the U.S. It has been used primarily outside the U.S. for low speed applications (up to 56 Kbps) such as credit card verifications and automatic teller machine (ATM) and other financial transactions.

X.25 describes the interface between DTE and DCE for terminals operating in the packet mode on public data networks and provides a connection-oriented technology for transmission over highly error-prone facilities, which were more common when it was first introduced. Error checking is performed at each node, which can slow overall throughput and renders X.25 incapable of handling real time voice and video.

RS-232 (equal to V.28) – RS-232 describes the interface between DTE and DCE employing serial binary data interchange. RS-232 is a standard for serial transmission between computers and peripheral devices (modem, mouse, etc.). Using a 25-pin DB-25 or 9-pin DB-9 connector, its normal cable limitation of 50 feet can be extended to several hundred feet with high-quality cable. RS-232 defines the purpose and signal timing for each of the 25 lines; however, many applications use less than a dozen. RS-232 conveys data across the interface by changing voltage levels.

RS-422 - A standard for serial interfaces that extend distances and speeds beyond RS-232. RS-422 is a balanced system requiring more wire pairs than its RS-423 counterpart and is intended for use in multipoint lines. Both use either a 37-pin connector defined by RS-449 or a 25-pin connector defined by RS-530. RS-422 caters for a line impedance of as low as 50 ohm and supports data rates of up to 10 Mbps.

RS-423 - As RS-422 however RS-423 describes the electrical characteristics of unbalanced voltage digital interface circuits. RS423 supports a maximum data rate of 100kbps.

RS-449 – RS-449 is a further enhancement of RS-422 and RS-423 and defines a 37-pin connector for RS-422 and RS-423 circuits. RS-449 caters for data rates up to 2 Mbps.

RS-530 - RS-530 defines a 25-pin connector for RS-422 and RS-423 circuits. It allows for higher speed transmission up to 2Mbps over the same DB-25 connector used in RS-232, but is not compatible with it. See RS-422.

G.70X / G.73X
TBW

4.2. E&M signalling

TBW

5. Inter Facility Link (IFL) cables

The VSAT equipment requires a total of three IFL (Inter Facility Link) cables installed between the antenna location and the selected indoor equipment rack location. The length of the IFL cable, and how it will be strung between the indoor unit (IDU) and outdoor unit (ODU) should be determined during a site survey which normally has taken place several weeks prior to the installation of the equipment. The routing of these cables within the customer's building, as well as any conduit requirements, is selected and approved by the building representative.

Transmit and receive intermediate frequency (IF) signals (50 - 70 MHz) are carried between the indoor and outdoor units by shielded coaxial cable. Failure to use lower loss cable for extended lengths will result in significant reduction in ODU output and excessive signal distortion. This becomes even more critical for L band (1 GHz) applications.

General guidelines to ensure that the IDU to ODU coaxial cables are properly prepared and installed are:

- Prior to installation (and preferable during the site survey) plan the route that the IFL cable will follow. Plan the route to minimize the cable length between the IDU and ODU. Keep in mind that approximately 150 cm (five feet) at both ends should be added for drip loops and service loops.
- Ensure that a strain relief is added to both cable connections.
- Use the correct crimp tool for crimping connectors to the cables.
- Ensure that all the external connectors are sealed and waterproofed.
- With the coaxial cables disconnected from the RF Unit, measure the AC voltage between the shield of the coaxial cable and the proposed ground wire. If no AC voltage is present, change the meter to read resistance and measure the resistance from the IFL shield (still not connected to RF Unit) to the ground wire. The resistance should be 25 Ω or less.

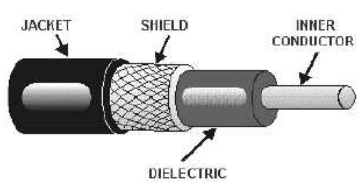
In addition, a twisted pair cable connects the transceiver monitor and control port to the M&C unit indoors. Other cables include a telephone line for the telephone outlet in the SLP box, and a power cable between UPS and RFU.

Be advised that equipment ground wires should be separated from all other conductors, and should not be run through metal conduit unless the conduit and ground wires are bonded at both ends.

The life of an IFL cable depends on many factors. Some of those factors are ultra-violet exposure, migration, high humidity, age, corrosion, power/heat, and voltage. In summation, in general cable can perform to it's maximum designed efficiency an average of seven years to ten years, provided the connectors are appropriately terminated and the cable is installed correctly.

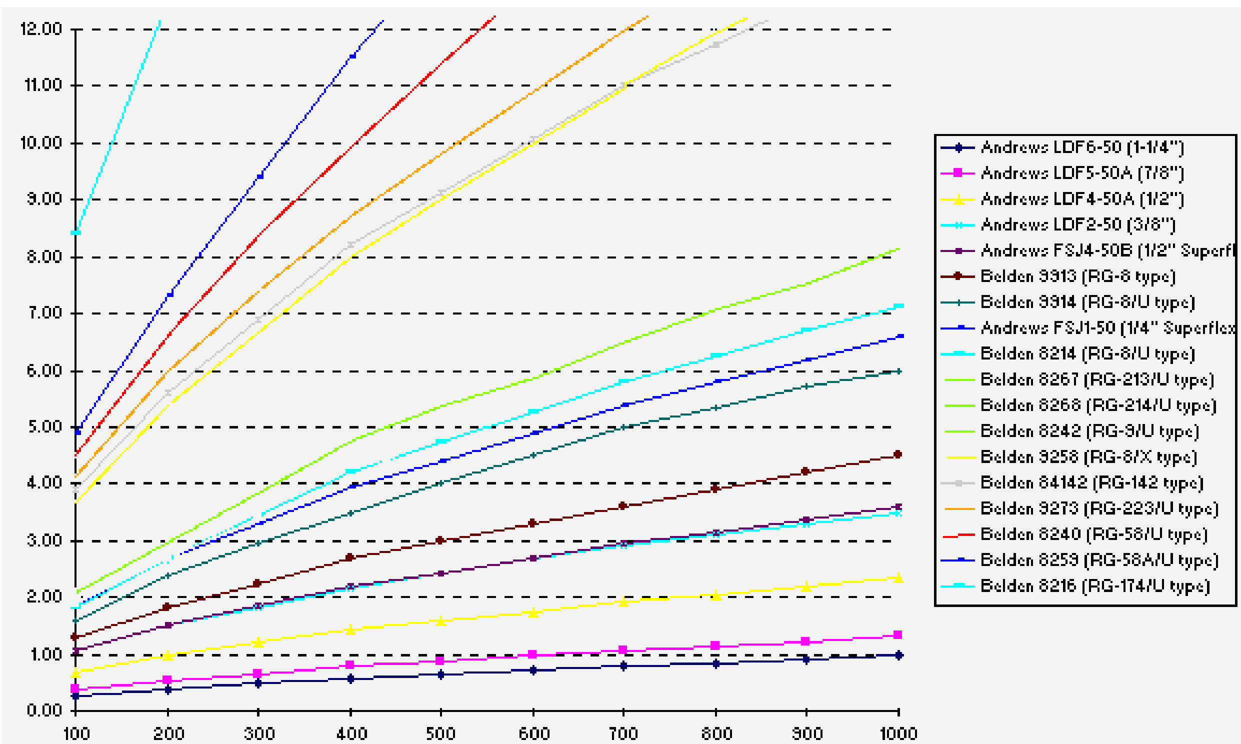
5.1. Coaxial cable

Coaxial cable is defined as two concentric wires, cylindrical in shape, separated by a dielectric of some type. One wire is the center conductor and the other is the outer conductor. A protective jacket covers these conductors. The protective jacket is then covered by an outer protective armor. Coaxial cables are used as transmission lines and are constructed to provide protection against outside signal interference. When installing coaxial cable you should remember that its characteristics depend upon its shape - so don't do anything to bend it sharply or to squash it. Each area of damage introduces reflections in the signal and reduces the efficiency of the cable.



5.2. RF cable loss

The largest single passive device in an RF distribution system is the coaxial transmission cable itself. The purpose of the transmission cable is to carry the RF signal with a minimum amount of loss. At the RF frequencies involved in the different systems, however, characteristics of the cable and losses in the cable must be taken into careful consideration. One of the losses associated with coaxial cable is signal leakage. Signal leakage occurs when the coaxial cable cannot contain the whole RF signal, and allows some of it to leak out into free space. Leakage loss should be identified and corrected. Two other types of cable loss, dielectric loss and resistance loss. All coaxial cables have a specific amount of dielectric and resistance loss. These losses are taken into account when the distribution system is designed and built. Any changes in these parameters after the system is operating, however, may severely affect the performance of the distribution system. For this reason, it is important to briefly review cable loss and its affect on the performance of the system. Resistance loss is by far the largest contributor of losses in coaxial cable. Losses caused by the resistance of the inner conductor vary with the cross sectional area of the conductor. Most of the loss, however, is frequency related, a condition called "skin effect." Skin effect describes the condition where, as the frequency of the signal increases, the signal is carried through the conductor further and further away from the center. Thus, the resistance loss in any given cable type varies in direct proportion to the frequency of the RF signal-the higher the frequency the greater the loss. Typical cable loss is normally specified in dB/100m. Table above lists some commonly used RF distribution cables and the typical losses for each. Any attenuation which differs substantially from typical indicates a problem with the cable, such as a poor connector, physical damage such as a sharp crimp or bend, or moisture in the cable.



Coaxial Cable Loss in dB per 100ft. Horizontal axis represents frequency, vertical axis represents attenuation.

5.3. RF connectors

With all coaxial RF connectors, be sure to consider the dimensions of the cable you'll be using. Coaxial cables come in a variety of diameters that are a function of their transmission properties, "series" ratting, and number of shields and jackets.

5.3.1. BNC connectors

One of the most popular of the coaxial connectors, the BNC was developed in the late 1940's. The name BNC stands for Bayonet-Neill-Concelman. Bayonet describes the interface coupling mechanism, while Neill and Concelman were the inventors of the N and C connectors. The BNC is essentially a miniature version of the C connector which is a Bayonet version of the N connector. BNC connectors are available in both 50Ω and 75Ω versions, both versions will mate together. The 50Ω designs operate up to a frequency of 4 GHz. BNC connectors are used in many applications, some of which are flexible networks, instrumentation and computer peripheral interconnections.

Difference between 50 Ω and 75 Ω BNC connectors

What are the physical differences between 50 Ω BNC connectors and 75 Ω BNC connectors? There are a few physical differences. The 75 Ω plug's center pin has the same diameter in the rear as in the front mating interface area. Whereas, the 50Ω plug's center pin has a thicker diameter in the rear area where it is crimped. Both plugs have the same pin size in the mating area. Regarding the dielectric on each, the 75 Ω connector's dielectric is made of Teflon which has higher impedance properties than Delrin. The 50 Ω connector's dielectric is made of Delrin. Finally, the main physical difference is that the 75 Ω plug does not have extended dielectric around its outer spring fingers. 50 Ω BNC connectors on 75 Ω cable have little effect on the signal with frequencies below 300 MHz.

5.3.2. F connectors

The type of coax connector you are most familiar with is probably the one you have in your home for use with video equipment. F connectors are standard 75 Ω and require a crimp tool for proper mounting to the cable. A cheaper F-type connector available at some retail outlets attaches to the cable by screwing the outer ferrule onto the jacket instead of crimping it in place. These are very unreliable and pull of easily. Their use in residences is not recommended, and they should never be used in commercial applications.

5.3.3. N connectors

The N connector was invented by and named for Paul Neill of Bell Labs. It was the first connector capable of true microwave performance. N connectors have threaded coupling interfaces and are 50 Ω in impedance. There are also 75 Ω versions available, but they will not mate with the more common 50 Ω version. N connectors operate up to 11 GHz in the common 50 Ω impedance design. Although less common, there are also precision versions of the N connector available which operate up to 18 GHz. Applications for the N connector include Local Area Networks (LANs); test equipment; broadcast, satellite and military communication equipment.

BNC Type

F Type

N Type

Always use the correct Crimp Tool

> Only use connectors that fit your cable and always test your cables before final installation. Loose connectors contribute to signal ingress and egress, cause problems with return path services and can affect link availability.

6. Powering of a VSAT unit

The indoor units utilise standard 3-prong, 220 VAC (110 VAC USA) convenience outlets for primary electrical power. The equipment obtains an electrical ground from the third wire (green) that originates at the electrical distribution box ground and is connected internally to the equipment chassis. Improper grounding can cause major problems and makes the installation unsafe. As part of the site preparation work, the customer is to provide an appropriate origination point for grounding (a grounded structural steel building member, a metallic cold water pipe, source side of metallic power service race way, source side of equipment enclosure, or a driven ground rod). Depending upon the terms of a particular contract, an installer may be required to drive a ground rod at additional customer cost if a satisfactory grounding point is not available at the time of installation.

The local authority supplies the power supply facility on a VSAT site in a single phase. When electric power leaves the generating facility it is clean and stable. However, during the transmission and distribution, electrical storms and load variations can cause a variety of power problems. These power disturbances, including voltage sags, high voltage spikes and complete power loss, can interrupt VSAT operation or even damage indoor or outdoor equipment. To protect the installation against outages due to power failures, many providers include an emergency power supply or uninterruptible power system (UPS) in its rack. An UPS is in fact a rectifier and battery back-up system in parallel operation. Depending on the type of UPS, the size of the radio and what's in the rack the UPS keeps the equipment running for 15 to 45 minutes during power outages.

The maintenance of the UPS batteries is very important for a reliable VSAT installation. The antenna de-ice installation (if any) is never powered by the UPS!

6.1. Power consumption typical VSAT

The total power consumption of an overall VSAT installation depends very much on the size (output power) of the used radio and the amount of indoor equipment.

The table below is an *example* and reflects the power consumption of the most popular ODU and rack equipment. Except of the de-ice all the equipment is normally backed up by a UPS.

Type of Equipment	Power Consumption	Type of Equipment	Power Consumption
2 W Ku band Radio	100 - 160 W	10 W C band Radio	150 W (Anacom)
4 W Ku band Radio	125 - 174 W	20 W C band Radio	225 W (Anacom)
8 W Ku band Radio	200 - 275 W	Satellite Modem	35 W
16 W Ku band Radio	300 - 421 W	Nuera Multiplexer	526 W

7. Satellite link analyzes

The objective of a communications system link analysis is to achieve a specific performance for a signal, as it is transmitted from one point to another. For a satellite link, the performance is impaired in transmission capability by satellite downlink power, atmospheric propagation effects, and satellite and earth terminal noise. In most cases, however, satellite downlink parameters are the major concerning factors. For satellite link analysis a proper understanding of link budgets is necessary

7.1. Link budgets

The calculation has to be performed for each satellite channel to ensure good reception for all required channels. It is particularly important where a system is put together from a variety of manufacturer's component parts since, at one extreme, poor results may be experienced and at the other, "over engineering" may unnecessarily add to equipment cost and may look less esthetically pleasing

What is link budget:

What a link budget actually involves is a relatively simple addition and subtraction of gains and losses within a RF link. When these gains and losses of various components are determined and summed, the result is an estimation of end-to-end system performance in the real world. To arrive at an accurate answer, factors such as the uplink power amplifier gain and noise factors, transmit antenna gain, slant angles and corresponding atmospheric loss over distance, satellite transponder noise levels and power gains, receive antenna and amplifier gains and noise factors, cable losses, adjacent satellite interference levels, and climatic attenuation factors must be taken into account.

The link budget will determine the earth station equipment necessary for a given satellite link. A careful link analysis provides the data necessary to specify what size antenna to use, SSPA or TWTA PA power requirements, link availability, bit error rate etc.

7.2. What do you need to compute the link budget:

The next information is absolutely necessary for a proper link budget calculation:

- The saturated EIRP and saturated flux density of the transponder
- The satellite G/T figure appropriates to your planned uplink location
- Satellite transponder bandwidth
- Satellite transponder output back off or attenuation
- Satellite transponder input back off or attenuation

The above information can generally be obtained from the satellite operator, or from a good satellite database such as e.g. http://www.satnews.com on the Internet. Other sources of this data include printed media, such as the Global Satellite Directory from Phillips Publishing.

You will also need the following information:

- Desired **link availability** as agreed with your customer. Link availability is normally taken as 99.5% of an "average year" for single VSAT systems, and 99.9% or greater for redundant systems.
- **Transmission Losses or Free Space Losses**. This is the attenuation that a signal undergoes as it travels over the path between the earth station and the satellite. Losses are due mainly to the spreading out of the signal on its long journey, and are dependent on the distance (GEO, MEO or LEO) and the signal frequency.
  At 12 GHz the path loss equals 205.11 dB when the receiving earth station is located on the equator directly below a GEO-satellite. In other locations the path loss is slightly more. Also different path losses apply for other frequencies as C band and Ka band.

- **Atmospheric absorption or Rain Fade.** The main components, which are difficult to predict, are atmospheric absorption and attenuation due to precipitation. Atmospheric absorption by water vapor and oxygen is basically a clear sky effect (happens whether raining or not) and depends mainly on the absolute humidity or vapor density measured in grams per cubic meter. However, this is a relatively minor contributor below about 7.5GHz.

  The effects of precipitation become significant above about 8GHz. Rain, or to a lesser extent snow, fog, or cloud will attenuate and scatter microwave signals. The magnitude depending more on the size of the water droplets (in cubic wavelengths) rather than the precipitation rate itself. Heavier rain tends to comprise larger droplets so the two are normally related. Thunderstorms are perhaps the main offender in this respect. In addition, rain has a noise temperature similar to that of the earth (260K average) which increases the sky noise temperature over the clear sky value. Based on the long-term statistics of rainfall rates for a particular area a Downlink Degradation (DND) figure corresponding to specified signal availability may be calculated. The DND figure is the total degradation of the signal due to precipitation expressed in dB and, for a given signal availability, consists of the sum of the attenuation due to precipitation and the system noise increase translated to an equivalent dB loss. There is also a small contribution due to the increase in atmospheric gaseous absorption during rain.

  Rain Fade is the major component of the link margin set aside for Ku band and Ka band.

- **Scintillations.** Another clear sky effect is the loss due to tropospheric scintillations. Turbulence caused by wind in the atmosphere cause short duration fluctuations in the refractive index. These translate to small amplitude fluctuations in the received signal that can be significant particularly at low elevations.

  Other indispensable information necessary for link budget calculation is:

  - Latitude and longitude of the uplink and downlink earth stations.
  - Planned data or information rate.
  - Modulation type (BPSK or QPSK)
  - Forward error correction rate (1/2 or 3/4, etc.)
  - Spread Factor - if any (use only for spread spectrum systems)
  - Uplink and downlink frequencies.
  - Uplink and downlink antenna sizes.
  - Uplink and downlink antenna efficiency.
  - Uplink and downlink transmit and receive gains at frequency.
  - Minimum digital signal strength (Eb/No) for desired Bit Error Ratio (BER) performance.

Fortunately in this age of computers and spreadsheet programs, the link budget does not have to be all that difficult to compute. Several companies now market quite sophisticated link budget calculation programs that contain large databases of information regarding satellite performance parameters, ground station antenna performance data, and other information vital to calculation. With one of these programs, all the user must do is fill in the blanks regarding earth station location, planned satellite(s) to use, required link availability, and the program generates a very good estimation of link performance.

In Ku band networks, it is a good rule of thumb to allow 7 or 8 dB of margin above threshold at the receive site with clear sky conditions. This will generally provide link availability in excess of 99.5%. C band networks require much less margin, typically about 3 dB, for the same performance expectation, since there is less atmospheric attenuation with the C band.

Most satellite operators limit satellite received EIRP to a specific maximum level of 6dBW/4kHz, or about minus 140 dBW per square meter on the ground. If spectral density exceeds these limits, you should use better LNB/C's or larger receive antennas to lower the power requirements. You can also spread the signal over greater bandwidth; either by changing FEC rates, changing modulation formats from QPSK to BPSK, or by using some form of additional signal spreading.

7.3. Example of a link budget calculation

CARRIER / MODEM INFORMATION & LINK PERFORMANCE REQUIREMENTS

Ckt Ref #:	5		Modem Make:	Paradise				
			Model:	P300				
Network:	**Alcatel**		Step Size:	2.5	kHz			
			Min. Allocated BW:	25	kHz			
Information Rate:	128	kbps						
Modulation Type:	QPSK		Symbol BW:	85.3	kHz			
Code Rate:	3/4	Sequential	Noise BW:	102.4	kHz	=	1.20	x SBW
			Absolute Min. Alloc. BW:	119.5	kHz	=	1.40	x SBW
Link Availability:	99.62	%	Actual Min. Alloc. BW:	120.0	kHz	=	1.41	x SBW

RFT INFORMATION

	Uplink	Downlink	
Site Code:	Lipljan	Dublin	
City:	Lipljan, Kosovo	Dublin	
Country:	Yugoslavia	Ireland	
Latitude:	42.5	53.3	N
Longitude:	-21.10	6.25	W
CCIR Rain Zone:	K	F	
Satellite G/T & Saturated EIRP:	1.6	50.7	dB/K & dBW
Geographic Advantage:			dB
Azimuth:	227.2	190.9	degrees
Elevation:	29.0	28.5	degrees
Slant Range:	38770	38809	km
A(0.01%):	13.1	5.6	dB
Antenna Diameter:	2.4	2.4	m
HPA & LNA:		110	W & K
Waveguide Loss:	0.5	0.2	dB
Antenna Gain:	49.1	48.2	dBi
Antenna Efficiency:	0.65	0.65	
Antenna Noise Temp. @ 20° elev. angle:		32	dB & K

SATELLITE INFORMATION

				Uplink	Downlink	
Satellite:	Orion-F2					
Xpdr Number:	11		Beam Coverage:	E	E	
Longitude:	15	W	Beam Type:		BB	
Actual BW:	54	MHz	Center Frequency:	14.157	12.657	GHz
			Polarity:	V	H	
			Total Operating Point:	5.0	3.2	dB
			G/T & EIRP Reference Contours:			dB/K & dBW
			Xpdr Constant at Gain Setting of 0 dB:	-96.7		dBW/m2K
			Gain (Pad) Setting:	-10.0		dB
			Effective Xpdr Constant:	-86.7		dBW/m2K

SPACE SEGMENT REQUIREMENTS

	BW must be purchased in multiples of:		10	kHz from	54	MHz of useable xpdr BW	
	Power:	0.1995%	which is	30.2	dB COPBO ref. to	3.2	dB TOPBO
Limited by	BW:	0.2222%	which is	120.0	kHz referenced to	54.0	MHz useable BW
	Equivalent:	0.2222%	which is	29.7	dB COPBO ref. to	3.2	dB TOPBO
	Power & BW:			120.0	kHz referenced to	54.0	MHz useable BW

UPLINK RFT REQUIREMENTS

Power at HPA Flange:	-6.2	dBW	0.24	W
Insertion Loss:	0.5	dB		
Power at Antenna Flange:	-6.7	dBW	0.21	W
Power Density at Antenna Flange:	-20.8	dBW/4kHz		
EIRP Density:	28.4	dBW/4kHz		
EIRP per Carrier:	42.5	dBW		

LINK CALCULATION

		Clear Sky	Rain on U/L	Rain on D/L	
Probability of Rain Loss:			0.35	0.03	%
Uplink:					
Earth Station EIRP:	A	42.5			dBW
Path Spreading Loss:	B	162.8			dBm2
Rain Loss:	C		2.7		dB
Power Flux Density:	D=A-B-C	-120.3	-123.0		dBW/m2
Saturation Flux Density:	E	-88.3			dBW/m2
Carrier Input Backoff:	F=E-D	32.0	34.7		dB
Area of Isotropic Antenna:	G	-44.5			dBm2
Satellite G/T:	H	1.6			dB/K
Boltzmann's Constant:	I	-228.6			
C/No:	J=F+G+H-I	65.4	62.7		dBHz
Noise Bandwidth:	K	50.1			dBHz
C/N:	L=J-K	15.3	12.6		dB
Cross-Pol C/I:	M	28.2	25.5		dB
Adjacent Satellite C/I:	N	25.2	22.5		dB
Total C/I:	O	23.5	20.7		dB
Total C/(N+I):	P	14.7	12.0		dB
Downlink:					
Saturated EIRP:	Q	50.7			dBW
Carrier Output Backoff:	R	30.2	32.9		dB
Carrier EIRP:	S=Q-R	20.5	17.8		dBW
Path Spreading Loss:	T	162.8			dBm2
Rain Loss:	U			3.6	dB
Pointing Error Loss:	V	0.5			dB
Power Flux Density:	W=S-T-U-V	-142.8	-145.5	-146.4	dBW/m2
Area of Isotropic Antenna:	X	-43.5			dBm2
Earth Station G/T:	Y	26.1		23.1	dB/K
Boltzmann's Constant:	I	-228.6			
C/No:	Z=W+X+Y-I	68.4	65.7	61.8	dBHz
Noise Bandwidth:	K	50.1			dBHz
C/N:	A'=Z-K	18.3	15.6	11.7	dB
Xpdr IM C/I:	B'	16.4	13.7		dB
Cross-Pol C/I:	C'	27.2	24.5		dB
Adjacent Satellite C/I:	D'	23.7	21.0		dB
TotalC/I:	E'	15.4	12.7		dB
Total C/(N+I):	F'	13.6	10.9	10.1	dB
Total Link:					
C/N:	I'	13.6	10.8	10.1	dB
C/I:	J'	14.8	12.0		dB
C/(N+I):	K'	11.1	8.4	8.8	dB
Noise Bandwidth:	K	50.1			dBHz
C/(No+Io):	L'	61.2	58.5	58.9	dBHz
Information Rate:	M'	51.1			dBHz
Ebi/(No+Io):	N'=L'-M'	10.1	7.4	7.9	dB
Rain Margin:	O'	2.7	0.0	0.5	dB
Implementation Margin:	P'	0.5			dB
Target Ebi/No:	Q'=N'-O'-P'	6.9			dB

8. Test Equipment

8.1. Oscilloscope

The standard method for observing electric signals is to use an oscilloscope. The horizontal axis of a (CRT) oscilloscope increases by the unit of time; oscilloscopes are sometimes referred to as time-domain instruments. Observation in time domain is useful to obtain signal timings (e.g. clocking) and phases.

8.2. Spectrum analyzer

The performance of certain elements such as amplifiers, oscillators, mixers, modulators, filters and others require the analysis of other characteristics (frequency response, harmonic distortion, noise, etc.). Instruments that display levels of an electric signal as a function of the respective frequencies are called frequency-domain instruments. Typical instruments are the spectrum analyzer and the selective level meter

Spectrum Analyzers are swept-tuned, super heterodyne receivers that provide a CRT display of amplitude versus frequency. It is essentially a frequency-selective, peak-responding voltmeter calibrated to display the rms value of a sine wave. The spectrum analyzer can show the individual frequency components that make up a complex signal. (It does not, however, provide phase information about a signal). Spectrum Analyzers provide frequency-domain signal analysis for numerous applications, including the manufacture and maintenance of microwave communications links, RADAR, telecommunications equipment, cable television systems and broadcast equipment, mobile communications systems, EMI diagnostic testing, component testing, light wave measurements, and signal surveillance.

The following and much more can be made visible and measures with a spectrum analyzer:

- Frequency (accuracy)
- Absolute Power Levels
- C+N/N
- Bandwidth
- Interfering Signals and Spurious Noise
- Antenna Pointing
- Modulation Check

8.2.1. Typical spectrum analyzer functions explained:

- <u>Resolution</u>: The IF filters separate the frequency components of the signals; this capability is called resolution
- <u>Resolution Bandwidth (RBW)</u>: Spectrum analyzer specifications indicate a 3dB bandwidth for the available analyzer filters (this is known as resolution bandwidth). The resolution bandwidth indicates how close two equal carriers can be and still are resolved.
- <u>Video filters</u>: The spectrum signal at the output of the IF filter is detected for final conditioning in the post detection gain and signal processing (known as video filters) which smoothes (or averages) the signal for final presentation. The narrower the video filter bandwidth, the more sweep time is required. If the signal is swept too quickly, there will be a loss of displayed amplitude due to the time that the video filter takes to charge and discharge.

8.2.2. Minimum requirements for typical use

Minimum spectrum analyzer requirements

- Frequency range: 10 MHz to 2 GHz
- Minimum span: 10 kHz/div
- Sensitivity: -95 dBm or better

Example: Hewlett-Packard model 8590 series or equivalent

The HP 8590L is a low cost, but full-featured, frequency accurate RF spectrum analyzer designed to meet general purpose measurement needs. The easy-to-use interface provides access to more than 200 built-in functions.

8.3. Data analyzer - BER test set

In digital communications, bits may disappear or unwanted bits can be generated as a result of noise, jitter or level variations. If such distortions occur, the transmitted information is received in a deformed condition. This usually affects the transmission quality. Transmission quality is in direct relationship with the link availability and is measured in terms of the degree of variation of bits (a.k.a. error rate) over a certain period of time.

Bit Error Ratio (BER) is the most fundamental measure of system performance - how well bits are transferred end to end. While this performance is affected by factors such as signal to noise and distortion, ultimately it is the ability to receive information error-free defines the quality of the link.

$$\text{BER} = \frac{\text{Number of bits received in error}}{\text{Number of bits received}}$$

Is equal to

$$\text{BER} = \frac{\text{Error count in measurement period}}{\text{(Bit Rate) x (Measurement Period)}}$$

A performance guarantee of BER=1E-6 for 99.5% availability means that for all year except 44 hours (of heavy rain, snow, sun outage, interference, etc.) the link will perform at BERs much better than the threshold. During the remaining 0.5% of the time there are more errors received than usual, resulting in more re-transmissions or a ‘noisy’ signal.

To measure the error rate accurately, a sequence of bits simulating the real data is transmitted at a rate equal to the transmission rate. This pattern is called the Pseudo Random Bit Sequence (PRBS). The PRBS is compared with the one generated at the receiver and the ratio of detected mismatched bits to the total number of bits is calculated as the bit error ratio.

The length of the PRBS test pattern is selected according to the transmission rate of the system being tested:

Info. Rate [bit/s]	PRPL [bits]
64k	2047 (2^{11}-1)
192k	2047 (2^{11}-1)
384k	2047 (2^{11}-1)
512k	2047 (2^{11}-1)
1024k	2047 (2^{11}-1)
1544k	2^{15}-1
2048k	2^{15}-1
6312k	2^{15}-1
8448k	2^{15}-1
32064k	2^{15}-1
34368k	2^{15}-1
44736k	2^{15}-1

As an example if the data rate is 64 kbps than the time needed to measure BER greater than:

BER better than	Equal no Errors in at least:
1 E-09	4 h 20 min 25 sec
1 E-08	26 min 3 sec
1 E-07	2 min 37 sec
1 E-06	16 sec
1 E-05	2 sec

In statistics you usually have to take about 25 samples to be sure. The time given in the table above is the equivalent of 1 sample.

8.3.1. What can be measured with a data analyzer

Most data analyzer in general support the following basic functions:

- Average Bit Error Rate (AVG BER): The ratio of the number of bit errors counted on the number of data bits examined since the beginning of the test.
- Average Block Error Rate (AVG BLER): The ratio of the number of bit errors counted to the number of data bits examined since the beginning of the test.
- Pattern Slips (PAT SLIP): The number of occurrences since the beginning of the test where data bits have been added to or deleted from the received pattern
- Clock Slip: Clock Slip is a timing problem that occurs when two networks meet. Sooner or later when signals, which originated in a distant country, are brought into the network there are going to be speed discrepancies because the networks will probably be operating at a rate controlled by their own country's master clock oscillator. When this occurs, the network experiences a problem because one of two situations is possible:

  1. **Incoming traffic is too fast**: The odd incoming traffic bit will be lost occasionally, resulting in errors being created and passed out to end users.
  2. **Incoming traffic is too slow**: In this situation an occasional incoming traffic bit will be repeated resulting in errors being created and passed out to end users.

  There are ways of dealing with these situations to minimize the error rate. One way is the use of BUFFERS which are often installed at the earth station satellite modem.

8.3.2. Problems using a data analyzer

Framed/Unframed - A common cause of problems during test is the option “FRAMED/UNFRAMED” that the test equipment gives. This option means that the PRBS will be transmitted with the frame structure for the transmission rate. For 2048 kbps, this means that the pattern will give time for the Frame Alignment Word and other related information to be transmitted. Both stations should agree on the use of this option

Error Insertion - Another cause of problems is the option “ERROR INSERTION”. This option automatically inserts a certain number of errors in the sequence. This option may not be noticed in the link performance test if the Eb/No is low, because the number of errors generated by the noise is greater than that generated in the equipment.

8.3.3. Typical use of data analyzers

Typical applications for data analyzers include:

- End-to-End Testing: Quickly isolate any problem to a specific direction by analyzing the performance of an entire digital link in both directions. Full-duplex end-to-end testing also serves as an excellent analysis of all circuits and equipment within the network.
- Out-of-Service Testing: Perform precise analysis of your circuits and equipment by removing live traffic from the digital link. The (Fireberd) Data Analyzer offers a variety of bit error results and statistics for the most accurate measurement of circuit performance by any test instrument.
- Loop back Testing: Loop back testing is ideal as a quick check of circuit performance or when isolating faulty equipment. The (Fireberd) Data Analyzer supports all standard T1, DDS, and data communications loop backs.

Minimum requirements BER Tester:

- Must be capable to measure BER, average BER, sync loss and pattern loss
- Data interfaces: V.35, RS449 and RS232

Example analyzer: TTC Fireberd 6000a or equivalent

8.3.4. PRBS tester feature in satellite modem

Many satellite modems support a simple BER tester with limited capabilities. The test patterns are often common with stand-alone BER testers.

9. Typical VSAT link testing

The test procedures are designed as a guideline for the Installer on site. By completing the tests properly the VSAT Technician has the possibility to hand over a perfect VSAT installation to the Customer. The results of each individual test have to be filled in a Site Acceptance Test Form and after signing by the customer send to the responsible Program Manager or Engineer.

The following basic procedures are mandatory for every typical VSAT installation.

	Test To Be Performed	Purpose
1	IFL Cable Loss Measurement	To verify quality of the cable and connectors To verify value of cable attenuation To guarantee correct input level to radio (TX)
2	G/T Measurement - Pointing Of Antenna	To verify that antenna has been correctly installed To guarantee that antenna and electronics meet specs
3	Line Up - Cross-Polarization Measurement This procedure is described in chapter 7 of this manual	To guarantee correct value of EIRP (TX level) To guarantee correct cross-polarization setting
4	Satellite Modem Loop-back Test	To confirm proper modulator and demodulator operation
5	Determine Initial Modem Output Level	To determine Modem output level to compensate cable loss and nominal transmit level To verify value of fixed RX attenuator
6	Absolute RX Level Measurement	To guarantee correct modem RF input level To verify value of fixed RX attenuator
7	1:1 Redundant VSAT, TX Gain and Alarm Check. If any.	To Verify that the TX levels of the individual modulators and transmitters, are configured in such a way that the radiated power will be at the nominal power level regardless of what transmitter or modulator is activated by the redundant subsystem.
5	Margin Test	To verify minimum link margin
6	BER Test	To verify minimum BER and Eb/No values
7	M&C – System Test	To guarantee remote access availability To verify modem/radio access
8	Data and Application Test	Connectivity (IP addresses reachable) Ping response time FTP throughput Customer specific application test
9	UPS Test	To check duration of UPS meets specs
10	Antenna De-icing Test	To check antenna de-icing system
11	Overall Services Test	Connectivity and Availability
12	Submitting of Site Acceptance Test	To be well documented
	Optional Tests (if mux is installed)	
13	Voice Per Node Test	Connectivity Objective quality criteria (drop outs, echo cancellation)
14	Voice Per Network Test	Availability and Connectivity Objective quality criteria (drop outs, echo cancellation) Subjective quality (volume level, background noise)
15	Video Per Node Test	Availability and Connectivity
16	Video Per Network Test	Availability and Connectivity Objective quality criteria (Stability, drop outs, etc,) Subjective quality of video

10. Satellite access and E/S verification

Transmission and modification of a new or existing Earth Station carrier is not allowed on any satellite without the permission of the satellite provider. This is so very important because:

- The new station should not generate any harmful interference with existing services
- The polarization of the transmit carrier must be correct
- Carrier frequencies must be correct
- Transmit power must be according to the link budget results
- The carrier must not exceed its allocated bandwidth
- The ODU must be operating below the radio saturation point (back off)

10.1. Satellite access procedure

In order to maintain strict control over the transponders, many satellite providers have published Satellite Access Procedures. These procedures outline the method for a customer to arrange for a service contract and receive frequency assignments. They also provide instructions for a customer to receive authorization to transmit to the satellite and the step-by-step process for verifying performance of their up-link equipment. Most importantly, the Satellite Access Procedures grant the Operating Center the authority to deny access or terminate the transmission of any customer that is violating the terms of the agreement or is operating in a way that causes interference or threatens the health of the satellite.

An earth station is not allowed to radiate any power towards any satellite without the permission of the Satellite Provider

10.1.1. Performance Verification Procedure

Most anomalous conditions occur on the satellite during the circuit initiation stage. To certify the suitability of a new or reconfigured up-link earth station prior to their operating on a transponder, the Satellite Operation Center controller guides the up-link operators through the Performance Verification. The process prevents any harmful interference to any satellite companies' space segment due to an out of tolerance condition of the earth station equipment.

10.2. Line-up and RF systems performance verification

The purpose of a Line-up and RF Systems Performance Verification is to describe all the necessary procedures for a successful (VSAT) antenna installation. Customers accessing a satellite system must follow the procedures. This includes the measurement of the antenna performance (cross-pol) and the site's transmit and receive performance (radiated and received levels). These procedures have been designed to ensure that the customer operates according to assigned levels and frequencies and to ensure that other customers are protected from interference. The installation technician is supposed to execute the tests in close cooperation with the Satellite Operations Center. The results have to be recorded in the Satellite Acceptance Test form.

10.3. Pointing the antenna using a LNC

Before you start radiating power towards the satellite

- Make sure you have a site specific Antenna and Radio Configuration (ARC) Sheet. This ARC sheet which is a part of the Field Installation Documentation is the full responsibility of the satellite service provider
- Contact the Satellite Control Center at least 24 hours **prior** to the actual antenna line-up to schedule your action. Inform the Satellite Control Center about the site-specific details as name of the customer and the site code (or carrier ID). Confirm transmit and receive frequencies.
- Build the antenna according to the "Antenna Assembly Procedure,"
- Point the antenna to the correct satellite.
- Set azimuth and elevation.
- Allow the radio to warm up for at least 15 minutes before any transmission.
- Call the Satellite Control Center and act in accordance with their instructions.

Procedure Pointing The Antenna Using a LNC

The next procedure describes a method of aligning the antenna towards the satellite using a LNC. The goal is to achieve the best possible elevation, azimuth and cross-pol isolation on receive. Elevation, azimuth and polarization offset are normally given in the Antenna and Radio Configuration (ARC) sheet. In the event you do not have the sheet on site while doing an installation you can easily calculate some of the necessary parameters. Useful software can be the Atlas and Time zone Database (http://www.astro.ch/atlas/) if you don't know your site-specific coordinates and an azimuth/elevation calculator e.g. Swedish Microwave Link (http://www.smw.se/smwlink.htm/).

The elevation and azimuth values for the antenna are given in the "Antenna and Radio Configuration" sheet which is a part of the Field Installation Documentation. Indispensable for setting the elevation is an inclinometer.

Elevation

- Place the inclinometer on the metal frame at the rear of the antenna.
- Adjust the elevation until the inclinometer indicates the correct value. Be advised that if you are off the correct elevation you will never find the satellite. Bigger apertures require more accuracy.

Note: The Antenna and Radio configuration sheet gives you the true elevation (or the elevation for a prime focus antenna). Many companies prefer the use of offset antennas. To achieve the correct inclinometer readout simply subtract the antenna offset from the elevation given in the Field Installation Documentation.

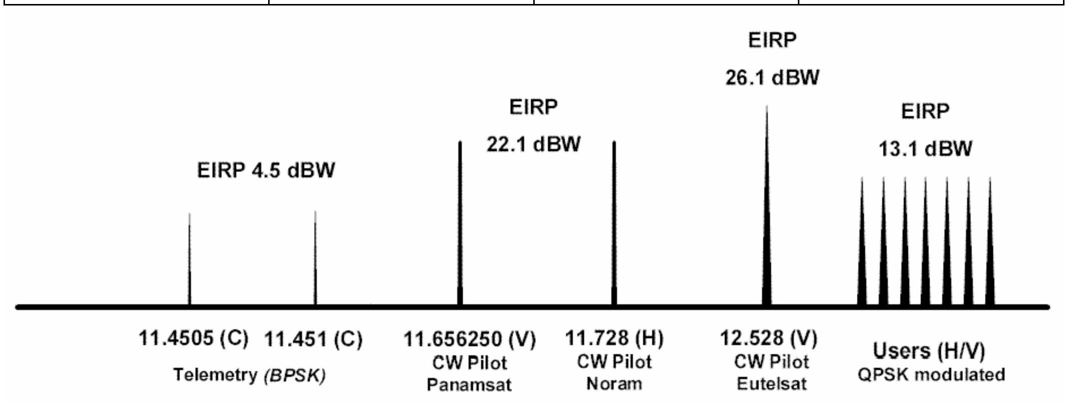
Antenna Offset Examples		
Andrew 0.96m	1 piece 0.875f/d	15.40°
Andrew 1.2m	1 Piece 0.875f/d	16.97°
Andrew 1.8m	1 piece 0.6f/d	22.62°
Prodelin 1.8m	1 piece 0.6f/d	22.30°
Andrew 2.4m	2 piece 0.6f/d	22.62°
Prodelin 2.4m	4 piece 0.8f/d	17.35°
Prodelin 3.8m	4 piece 0.6f/d	22.62°

Azimuth

Azimuth can be measured using a compass. However, a compass doesn't work well near steel obstructions and frameworks commonly found in buildings. Strong magnetic fields dramatically affect compass readings as well. This is called deviation. Besides a compass always points at the Magnetic North which is officially Badhurst, Canada. The given azimuth in the Antenna and Radio Configuration sheet always refers to the Geographic North. This means that you always have to deal with a difference between the Magnetic North and the Geographic North. This is called the variation and depends very much on where you are on Earth. To find the true azimuth you first must subtract or add the variation to your compass reading.

- Read the compass at ground level. Stay away from motors and large steel constructions.
- Identify a landmark in the assigned azimuth pointing direction and refer to the landmark when pointing the antenna.
- Connect the spectrum analyzer to the RECEIVE IF OUTPUT of the radio. Leave the TRANSMIT IF INPUT unconnected preferable terminated.
- Hook up a laptop to the radio.
- Connect power to the radio and program the radio receive center frequency for one of the pilot carriers on the satellite. As an example Telstar 11 pilot carriers can be found on:

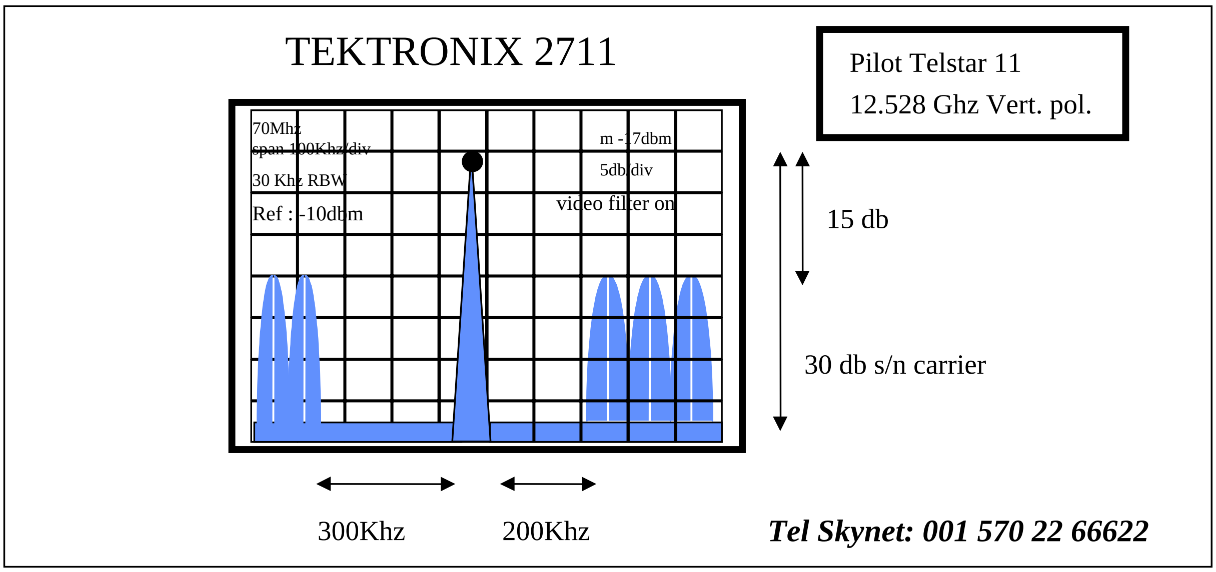
Pilot Frequency [kHz] / polarization	Type of Radio	Radio Center Freq. [kHz]	Spectrum Analyzer Center Freq. [MHz]
12 528 000 / V	Eutelsat	12528000	70.000
11 656 260 / V	Panamsat / Intelsat	11656000	70.260
11 728 000 / H	Noram	11728000	70.000



Telstar 11 Pilot Carriers

- Determine the pilot carrier you need. Set up the spectrum analyzer center frequency according to the table. Use a span of 30 MHz and maximum sensitivity.
- Check all the cables, connectors and check the LNC is working according to your expectations (e.g. a SSE LNC shows you a noise level of -35 dBm on the spectrum analyzer).
- Move the antenna slowly (not faster than two degrees per second) from the left to the right. Do this while looking at the spectrum analyzer.
- If you "hit" the satellite a bunch of signals will appear on the spectrum analyzer. You will also notice that the noise floor is changed. If you don't see any changes at all check the elevation of your antenna and repeat the previous steps.
- Since you are only interested in the pilot carrier, decrease the span of the spectrum analyzer. If the pilot carrier shows up on the spectrum analyzer center frequency you can be pretty sure that you are "on" the Telstar 11 satellite.
- Top the level of the pilot roughly. The C/N should be better than 30 dB.

- Do a side lobe performance test. Turn the antenna very slowly off the satellite (you can do this by either moving the antenna to the left or to the right). The level of the carrier will drop dramatically. As you continue moving in the same direction it will come up again. This is the first side lobe and its level is about 15 dB below that from the main lobe. If you go any further you will find a second lobe and probably a third. Do the same but now for the opposite direction. The antenna radiation pattern should be symmetrical. If this is not the case the antenna is probably mounted in the wrong way or defective. If you leave this situation as it is the antenna will radiate energy in undesired directions, will not meet its cross-pol requirements, and in case of receiving you will face a bad G/T.
- Top the level of the pilot. Go for the best result. Do this by fine-tuning azimuth and elevation. Consider decreasing the dB/div of your spectrum analyzer into 1 or 2 dB/div.
- Secure azimuth and elevation.
- Find a minimum for the pilot level. Do this by adjusting the polarizer (position of the feed) only, In most of the cases you will find two notches. Choose the one, which gives you the best results (the difference between minimum and maximum should be at least 35 dB). Mark this position on the donut and move the feed exactly 90°. The level of your pilot carrier is topped now and you are receiving exactly the polarization in which the pilot carrier comes down.
- If the downlink polarization given in the ARC sheet is opposite of the pilot polarization then set the polarizer in its correct position (90° swing).



Example only: Pilot Level on Telstar 11 with Radio gain 85dB on a 2.4 Prodelin Antenna

10.4. Pointing the antenna using a LNB

The next procedure describes a method of aligning the antenna towards the satellite using a LNB. The goal is to achieve the best possible elevation, azimuth and cross-pol isolation on receive. Elevation, azimuth and polarization offset are normally given in the Antenna and Radio Configuration (ARC) sheet. In the event you do not have the sheet on site while doing an installation you can easily calculate some of the necessary parameters. Useful software can be the Atlas and Time zone Database (http://www.astro.ch/atlas/) if you don't know your site-specific coordinates and an azimuth/elevation calculator e.g. Swedish Microwave Link (http://www.smw.se/smwlink.htm/).

Elevation

- The elevation and azimuth values for the antenna are given in the "Antenna and Radio Configuration" sheet , which is a part of the field installation documentation.
- Indispensable for setting the elevation is an inclinometer. Place the inclinometer on the metal frame at the rear of the antenna.
- Adjust the elevation until the inclinometer indicates the correct value. Be advised that if you are off the correct elevation you will never find the satellite. Bigger apertures require more accuracy.

Note: The Antenna and Radio configuration sheet gives you the true elevation (or the elevation for a prime focus antenna). Many companies prefer the use of offset antennas. To achieve the correct inclinometer readout simply subtract the antenna offset from the elevation given in the field installation manual (FIM).

Antenna Offset Examples		
Andrew 0.96m	1 piece 0.875f/d	15.40°
Andrew 1.2m	1 Piece 0.875f/d	16.97°
Andrew 1.8m	1 piece 0.6f/d	22.62°
Prodelin 1.8m	1 piece 0.6f/d	22.30°
Andrew 2.4m	2 piece 0.6f/d	22.62°
Prodelin 2.4m	4 piece 0.8f/d	17.35°
Prodelin 3.8m	4 piece 0.6f/d	22.62°

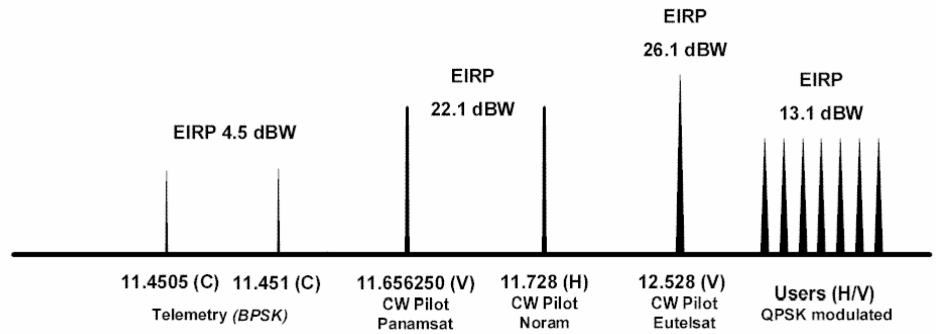
Azimuth

Azimuth can be measured using a compass. However, a compass doesn't work well near steel obstructions and frameworks commonly found in buildings. Strong magnetic fields dramatically affect compass readings as well. This is called deviation. Besides a compass always points at the Magnetic North, which is officially Badhurst, Canada. The given azimuth in the Antenna and Radio Configuration sheet always refers to the Geographic North. This means that you always have to deal with a difference between the Magnetic North and the Geographic North. This is called the variation and depends very much on where you are on Earth. To find the true azimuth you first must subtract or add the variation to your compass reading.

- Read the compass at ground level. Stay away from motors and large steel constructions.
- Identify a landmark in the assigned azimuth pointing direction and refer to the landmark when pointing the antenna.
- Since the LNB is powered with DC over coax it is not possible to connect the spectrum analyzer straight to the LNB. Connect the spectrum analyzer to the monitor output of the receiver. If your receiver does not support a monitor output use a sufficient inserter (ordinary splitters can't be used). Be very careful not to feed the spectrum analyzer with DC power. In most of the cases you will blow up the spectrum analyzer input immediately.
- Program the spectrum analyzer center frequency for one of the pilot carriers on the satellite. Use a wide span and maximum sensitivity.

T11 Pilot Frequency [kHz] / polarization	Type of LNB
12 528 000 / V	Euro High Band
11 656 260 / V	Euro Low Band
11 728 000 / H	Noram

LNB Band	LNB Input Frequency [GHz]	LNB Local Oscillator [GHz]	LNB Output Frequency [MHz]	LNB Bandwidth [MHz]	T11 pilot after down conversion [MHz]
Noram	11.70 - 12.20	10.75	950 - 1450	500	978
Euro Low	10.95 - 11.70	10.00	950 - 1700	750	1656.26
Euro High	12.25 - 12.75	11.30	950 - 1450	500	1228



Example only: Telstar 11 Pilot Carriers

- Move the antenna slowly (not faster than two degrees per second) from the left to the right. Move the antenna while looking at the spectrum analyzer.
- If you "hit" the satellite a bunch of signals will appear on the spectrum analyzer. You will also notice that the noise floor is changed. If you don't see any changes at all check the elevation of your antenna and repeat the previous steps.
- Since you are only interested in the pilot carrier decrease the span of the spectrum analyzer. When using a DRO LNB (a LNB with a free running local oscillator) and you bring your spectrum analyzer back to a very narrow span you will see that the pilot carrier is not stable. This is normal.
- Top the level of the pilot roughly. The C/N of the pilot carrier should now be better than 20 dB.
- If the installation has to transmit as well do a side lobe performance test. Turn the antenna very slowly off the satellite (you can do this by either moving the antenna to the left or to the right). The level of the carrier will drop dramatically. As you continue moving in the same direction it will come up again. This is the first side lobe and its level is about 15 dB below that from the main lobe. If you go any further you will find a second lobe and probably a third. Do the same but now for the opposite direction. This should be symmetrical. If this is not the case the antenna is probably mounted in the wrong way or defective. If you leave this situation as it is the antenna will radiate energy in undesired directions, will not meet its cross-pol requirements, and in case of receiving you will face a bad G/T.
- Top the level of the pilot. Go for the best result. Do this by fine-tuning azimuth and elevation. Consider decreasing the dB/div of your spectrum analyzer into 1 or 2 dB/div.
- Secure azimuth and elevation.

- Find a minimum for the pilot level. Do this by adjusting the polarizer (position of the feed) only, In most of the cases you will find two notches. Choose the one, which gives you the best results (the difference between minimum and maximum should be at least 35 dB). Mark this position on the donut and move the feed exactly 90°. The level of your pilot carrier is topped now and you are receiving exactly the polarization in which the pilot carrier comes down.
- If the downlink polarization given in the ARC sheet is opposite of the pilot polarization then set the polarizer in its correct position (90° swing).

10.5. Antenna cross-pol measurement

The minimum cross-pol isolation for transmit is 30 dB. The cross-pol isolation depends very much on the construction of the antenna, the position of the feed, and the quality of the OMT.

Before you start

- Contact the Satellite Control Center at least 24 hours prior to the actual antenna line-up to schedule the cross-pol adjustment. Inform the Satellite Control Center about the site code (or carrier ID which is on your Antenna and Radio Configuration Sheet) and the name of the customer.
- Confirm the transmit and receive frequencies.
- Check if all the antenna bolts and nuts are tightened firmly. Check all the ballast is in place.
- Allow the radio to warm up for at least 15 minutes before any transmission.
- Program the radio transmit center frequency for the test frequency. TX must be switched off!
- Configure the satellite modem for:

TX frequency: 70 MHz
Pure carrier (switched off)
TX carrier level: -25 dBm

- Check all the cables and connectors. Connect the modulator output to the radio input. Use attenuators, which are easy to remove. At least 30 dB to start with.
- At the scheduled time, contact the Satellite Control Center and ask them to assist you on setting the cross-pol isolation. The Satellite Control Center will provide you with a test frequency.
- If you are in the possibility so see the downlink resulting from the uplink this frequency should be clean. Program the radio for a receive center frequency and the spectrum analyzer for 70 MHz.

The Cross-pol procedure

- Bring up a carrier if the Satellite Control Center tells you to do this. Give the TXON command to radio and modem.
- Adjust transmit level according to the directions of the Satellite Control Center.
- If you can see your own down link, go back to your azimuth and elevation settings. Set your spectrum analyzer for 1 dB/division. Leave the transmitter on and top the level of your own downlink. You probably will gain another 0.5 dB of signal strength. When you are finished call the Satellite Control Center for the final. If you cannot see your own downlink you will do this together with the Satellite Control Center.
- To achieve an optimum in cross-pole isolation the Satellite Control Center will ask you to adjust the position of the feed. Do this very gentle since a small change in the position of the feed gives you an enormous change in cross-pol isolation.
- When a maximum of isolation is achieved (better than 30 dB) secure the feed. The Satellite Control Center will now recheck the isolation. If the results meet the requirements you will be asked to bring the carrier down and to prepare yourself for a level setting test on the assigned frequency.

10.5.1. Line-up at the assigned frequency

Before you start

- Program radio and modem according to the configuration sheets.
- Confirm interconnection (IFL) between the radio and the satellite modem according to the Rack Wire Diagram.
- Measure the losses of the IFL cable.
- Call the Satellite Control Center.

The line-up procedure

- Bring up a pure carrier on the assigned frequency.
- Modulate the carrier if the Satellite Control Center tells you to do this. The Satellite Control Center will measure the bandwidth occupied by your signal and confirm it is within specified limits.
- Set transmit level according to the directions of the Satellite Control Center.
- Your installation is now approved by the Satellite Control Center.
- Make note of the results in the Site Acceptance Test Document

11. Grounding and Lightning Protection

11.1. Grounding

All VSAT equipment is subject to electrical noise and high-voltage surges. These transients occur mainly in the common mode (line-to-ground), and are typically caused by lightning or power switching. They can cause plenty of problems (e.g. unexpected bit errors, equipment damage) that are sometimes hard to trace. The main problem is that currents flowing through a ground line can generate a signal seen by another part of the circuit sharing the same ground. Proper grounding is absolutely necessary. Basically there are three types of grounding:

1. **Power distribution system grounding** (power panels, service entrance equipment, etc.): Power distribution system grounding is essential for protecting occupants from exposure to dangerous shock voltage, providing a path for ground fault current, and limiting excessive voltages due to lightning or utility switching. This type of grounding works well for safety, and may prevent certain problems. However, a misconception exists that it also works as an RF ground, which it does not..
2. **RF grounding:** RF grounds must be short with respect to a wavelength. As an example at 70 MHz, a half wavelength is about 2 meter or 6.5 feet. Existing grounding systems are usually much longer than this. The reason why this situation is typically not a problem for RF grounding is that RF signals will naturally try to return over the coaxial shield. Even if another low DC resistance ground path is present. – that system is long compared to a wavelength, and so presents a relatively high impedance to any RF signals that try to return that way. Trouble might be introduced if you're trying to shield two signals at the same frequency. In that case, some RF ground current may try to return outside of the coaxial cable shield and that's where you get the "loop antenna effects". Another one is poor shield electrical contacts, such as with poorly applied F connectors.
3. **Telecom equipment grounding** (radio, satellite modem, UPS, etc.): Telecommunications equipment requires additional grounding because this (sensitive) equipment must be protected from excessive transients caused by lightning or utility switching and from degraded performance due to electromagnetic noise. Equipment grounding utilizes a ground ring encircling the interior of the building (a.k.a. halo ground ring). Multiple external drops should connect the internal ground ring to the exterior site ground ring (building ground). equipment ground lugs are connected via the central ground lug of the rack to the building ground.

As thick as possible stranded copper wire must be used to bond the RFU and LNC units together and to the earth ground, using the most direct and shortest routes. External ground connection points are provided on the RF Unit and (Prodelin) antenna canister. Appropriate ground wires of #10 gauge (AWG) or larger must be provided for connection to these ground studs at the outdoor equipment site. Some grounding points are:

Grounding Point	Gauge Wire
Building ground	10 gauge or greater diameter
Metallic cold water pipe	10 gauge or greater diameter
Grounded structural steel building member	10 gauge or greater diameter
Metallic power service raceway (source side)	10 gauge or greater diameter
Service equipment enclosure (source side)	10 gauge or greater diameter
Driven ground rod	6 gauge or greater diameter

It should be noted that the next greater diameter gauge wire from number 10 gauge is number 8 gauge, that is, a larger diameter wire has a smaller gauge number.

Do Not…

Do not ground to any branch circuit conduit or any conduit on the load (or output) side of the service equipment enclosure (power distribution panel). The metallic power service raceway is defined as the input power service conduit, which is on the input side of the service equipment enclosure.

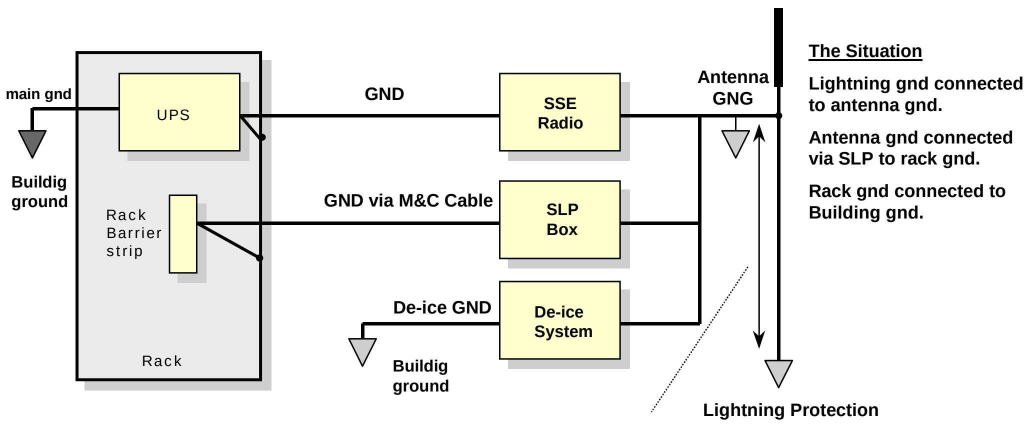
Do not use the shield of the coaxial cable as the main grounding wire between the indoor and outdoor unit.

Do not ground the antenna to an air conditioning unit. Grounding to an air conditioner mounting frame is not recommended because the frame may not be connected to building steel, and may provide a ground loop condition. Ohmmeter measurement will not detect a ground loop condition, since the EFL is connected to ground via the third wire of the indoor unit power cord, and the air conditioner metal frame is connected to ground via the air conditioner third wire. A low resistance value will be measured even though the metal frame is floating. The ground wire should be routed securely to prevent a possible tripping hazard. If possible, route the ground wire along the EFL cable to the point of entry.

Do not connect the building ground to the lightning protection. This is to avoid ground loops.

The building lightning protection is not equal to the building ground!

Ground loops



What is going to happen:

V (lightning discharge) = dV/t. As the length of the lightning earth is a long cable => high impedance for dV/t. This means that our equipment can be damaged.

A VSAT installation must be properly grounded always using the most direct and shortest routes. Grounding should never be undertaken without consulting with a professional licensed electrician. The original grounding installation must be periodically tested to determine whether resistance is remaining constant or increasing.

Antenna mount grounding

11.2. Lightning protection

Lightning is a gigantic electric spark traveling between cloud and earth. Its energy level is difficult to comprehend. A single lightning flash may be on the order of 30 thousand amperes, 200 million volts, and will take place within 30 millionths of a second. Lightning can easily induce a 3000 A transient into a power line. When this transient reaches a building, the building ground at the service entrance can rise to 60,000 volts (assuming a building earth resistance of 20 Ω). The reference potential for ground in the rest of the building would rise proportionately.

Lightning discharges are commonly referred to as "hot" or "cold" bolts. The difference is in the amount of power dissipated and the length of time it takes for this dissipation process. "Hot" bolts have higher current values and longer duration times, thus easily igniting combustible materials. "Cold" bolts on the other hand are characterized by low current values, high voltage and short duration times; thus producing the violent shattering effect.

Many lightning flashes consist of multiple discharges, making this well-known natural phenomenon Nature's Most Destructive Force.

Myths & facts

Many people believe they have lightning protection if the antenna on the building rooftop is "grounded". Even if an expert had properly grounded the antenna, only the antenna would be protected. The major portion of the building is still unprotected. More importantly, when struck by lightning, the grounded antenna may very well introduce side flashing to other grounded metal objects within the building. The ignition of combustibles may result.

Another myth is that tall trees around a building will protect it from lightning. Actually, more often than not, when lightning strikes such a tree it will only follow the tree a short distance before "jumping" to some grounded metal item in or on the building. Larger branches over a house present a double peril, in that they could come crashing into the building should a lightning bolt tear them off.

Lightning does strike the same place twice, sometimes more than once during the same storm. If it has struck once, chances are it will strike again.

11.2.1. Why a lightning protection system?

A properly designed and installed lightning protection system will protect lives and property against lightning damage. Such a system is designed to safely carry lightning currents to ground without damage to the protected structure.

General lightning protection requirements

A typical system will consist of air terminals (lightning rods) and ground terminals, which are connected together with low resistance conductors. These conductors are usually copper or aluminum as are other components of the lightning protection system. These metals and their alloys are specified not only for their electrical conductivity, but also for their corrosion resistance qualities. In addition to these basic items, lightning protection codes require separately grounded systems to be bonded together as well as other metallic items that may provide a short circuit path between grounded items.

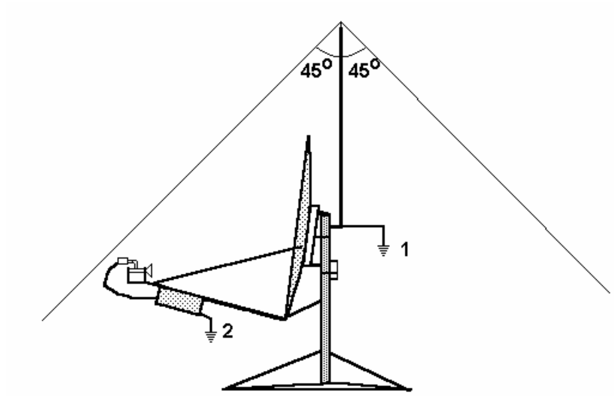
A properly designed lightning protection system will also take into consideration the myriad of electronic devices found in a VSAT installation. Transient voltage surge protection as there is in the SLP box (outdoor unit) should be provided to guard against unwanted electrical disturbances from entering the installation via the antenna.

In order to protect the building against the high voltages surges it is important to establish a low-resistance earth ground at the service entrance. The resistance should be 5 Ω or less.

The building owner is responsible for the lightning protection on his building and in no case the VSAT technician is allowed to commission any lightning protection system.

The next lightning protection requirements are typical for the USA but may very well do in other parts of the world since almost every country has a similar notified body.

A complete lightning protection system shall be installed by a firm actively engaged in the installation of Master Labelled Lightning Protection Systems and shall be so listed by Underwriters Laboratories Inc. The completed system shall comply with the latest editions of the Installation Requirements for Lightning Protection Systems, UL96A and the National Fire Protection Association's Lightning Protection Code, NFPA 780.



1. Connect to the lightning ground
2. Connect to the building ground

Lightning protection is the responsibility of the building owner and is basically a very thick metal pipe on top of the antenna. The minimum height of this pipe is the height where the antenna is covered totally (see drawing). After a lightning strike the equipment is gone anyway but it hopefully will prevent you from fire.

12. (Preventative) Maintenance

Good maintenance, knowledge of the site and well maintained records are the basis for avoiding the unexpected faults. However, an unexpected failure may cause circuit outages and emergency repairs may be necessary by the on-shift technician or VSAT Technicians.

An unwritten law for engineers and technicians in VSAT and satellite broadcasting is, *"Ignore your antenna and pay the price."* The earth station antenna is an *essential* part of satellite communications, especially when sending and receiving signals that cannot be re-created. To meet the guarantee, and to keep the link functioning, you need to have a regularly scheduled, thorough, antenna inspection and maintenance program.

The lack of a well implemented preventive maintenance program could trigger a wave of problems. An electrical or physical failure could lead to a complete antenna failure, causing downtime or even loss of contract. It is known that 50-70 percent of all outages is caused by:

1. Equipment incl. the antenna error
2. Human error
3. Lack of experience on equipment and test equipment
4. Improper or mal-function test equipment

This means that most failures can be avoided and outages can be substantially reduced by the implementation of a good maintenance policy. A proper inspection and maintenance program is a form of insurance.

Maintaining an earth station antenna is much less costly than to repairing one that has failed.

12.1. VSAT maintenance program

Although VSAT sites are varied and come in all sizes and complexities, they are functionally very similar. Functions at an earth station can be divided into those that are administrative and those that are technical. Administrative means that the GVF advises every VSAT Technician to keep a site log. A dated log (started from day one!) with photographs should be prepared when the antenna (and the other parts of the site) are installed. Entries into the log should be made during each inspection so a complete record of the entire antenna system and its condition is available. Maintenance logs should be stored with the equipment or within the equipment rack. Technical functions are typically into two, one being operations and other maintenance. Maintenance is the area, which ensures that all equipment, machinery and circuitry continue to function as designed.

Generally, the maintenance procedure takes from one hour to half a day, depending on the environmental conditions under which the antenna operates. All the maintenance activities must not only be scheduled in advance with the customer but also coordinated with the different support organizations in the same way installation activities are scheduled.

The maintenance program should include maintenance to the following items.

- Inspect the total appearance of the equipment, including radio, LNC, feedhorn and de-ice.
- Inspect the antenna mount hardware
- Inspect the ground connections
- Inspect the power equipment and facilities
- Inspect the IF equipment and terminal equipment (including modems, mux and M&C Equipment)
- Inspect the enclosures
- Inspect the cables and connections
- Inspect areas exposed to the weather to insure they are adequately waterproofed
- Evaluate antenna's overall performance

Reliable and effective maintenance depends upon good test equipment, which is regularly calibrated, in accordance with manufacturer's recommendations.

12.1.1. Check appearance

Inspect all painted and galvanized surfaces of the antenna and its mounting structures at least once a year; however, never paint the coated Prodelin reflector! Note that most of the antenna reflectors do not need much maintenance however a visually pleasing installation helps avoid community opposition to its presence. Local requirements vary among countries, but appearance is a factor.

If the main reflectors are made of painted steel, be sure to follow the manufacturer's instructions for preparation of the surface and for paint specifications. Remember that the wrong paint can affect your signal. Darker colors on the reflector's surface absorb sunlight; the resulting higher noise temperatures could cause signal distortion. Paint with to much lead can cause signal loss through attenuation or scattering. Today most of the reflectors are fiberglass with imbedded mesh. Repainting, therefore, is not necessary.

12.1.2. Check mount hardware

Not surprising, corrosion is the enemy of the nuts, bolts, rivets, and other fasteners used to assemble the antenna mount. Therefore, it is necessary to inspect the mount hardware, tighten loose bolts and replace missing or badly corroded parts. If loose bolts are found, and if they affect the antenna pointing, contact the Satellite Operations Center and notify them that the antenna needs to be re-pointed.

Repair any damage, even if it is minor!

12.1.3. Verify ground connections

The antenna, mount and RF unit should be grounded against possible lightning strikes. The grounding for both mechanical and non-mechanical connections must be verified — a ground loop impedance test unit does very well. After checking mechanical ground connections, replace rusted or corroded hardware to prevent a build-up of resistance.

Grounding System Performance Check means that the original grounding installation must be periodically tested to determine whether resistance is remaining constant or increasing.

12.1.4. Inspect enclosures

Vermin (bees, spiders and spider webs, birds, etc.) can do unbelievable, and costly, damage if left unchecked. If equipment is housed in an antenna enclosure at the rear of the reflector, inspect the enclosure for water retention or infestation by insects or rodents. Repair and seal any suspicious openings.

A hornet's nest on the back of an antenna

12.1.5. Maintain cables

Inspect and verify connector weather sealing and all cable ties. The inter facility link (IFL) cables carry intermediate frequency and monitor and control signals between the roof and the equipment room. If, on inspection, you find or suspect any VSWR and/or insertion loss (IF-cable only), check to see whether any cables need to be replaced or repaired. (Are they waterproof?) With a simple "home, garden, and kitchen" multimeter, the cables and the connectors check the conductivity and continuity of the cables. Also, ensure that support and routing of the cables are consistent with the requirements. Stainless steel cable hangers or clamps are preferable to plastic cable ties for supporting the cables. If plastic ties are used, use only black nylon ultraviolet resistant ones. White or clear ties become brittle and break with prolonged exposure to sunlight.

12.1.6. Maintain equipment

Antenna moves

Whenever the antenna has to be moved or the IFL cable disconnected, the antenna must be taken out of service. Use this opportunity to inspect the antenna.

Monitor and Control (M&C)

Monitoring and Control is an activity of both corrective and preventive maintenance. Regular measuring and recording of essential parameters will help note and identify potential problems and faults. Verify that the NOC can access the site and check for current alarm conditions on all equipment. Also verify that M&C to radio is connected and functional and that telephone access is available on the roof via the M&C line.

Radio, equipment, and rack fan

Check to ensure the fan in the radio, if any is operating properly. If not, repair as soon as possible because radios may fail within a few hours if not properly cooled. Check that all filters, if present, are clear and free from dust build up and inspect chassis air passages openings.

12.2. Checklist for routine antenna inspection and maintenance program

For proper assembly, do not assume that the antenna is assembled correctly because it is in service!

	Inspect	Maintain
Antenna Reflector	Hardware (Painted surfaces)	If galvanized, remove rust: replace or treat with zinc-rich paint. Repaint where peeling, flaking or fading.
Ballast & Roof	All	Install extra ballast if necessary and notify customer or building owner of possible roof damage or leakage.
Mount Hardware	All	Tighten, replace or reinstall hardware.
Ground Connection	Impedance Leads Resistance	Tighten or replace hardware. Remove sharp bends in leads. Verify proper resistance; add grounding if needed.
Reflector and Mount Openings	Water accumulation, infestation	Repair/seal openings as required.
Radio	Fan for proper operation	Repair as necessary.
Cables and Connectors	IF and M&C cables, connectors Cable conductivity and continuity Support hardware	Perform insertion loss tests. Replace cables if out of spec. Replace damaged connector hardware. Replace waterproof tape. Verify with multi-meter Replace if missing, rusted or corroded
Antenna	Azimuth, elevation, cross-pol, feedhorn	Talk to the NOC. Check for moisture, dry out as necessary. Wipe surface with damp cloth to remove dirt and dust.
Indoor equipment	Cables and Connectors, Fans	Clean, repair

12.3. Most common mistakes made in the field

- Inaccurate antenna pointing: The most common causes for antenna deflection and resulting beam pointing errors are:
    - High winds or gusting wind conditions
    - Settling of the antenna mounting
    - Loosening of the assembly due to weather and wind conditions
    - Flexing of the supporting structure. The allowable deflection varies inversely with the size of the antenna reflector. As an example for a 2.4m antenna this is 0.15 degrees
- Loose bolts/nuts on the antenna resulting in:
    - Antenna looses pointing
    - Antenna diagram is not as specified since the reflector is not kept in shape properly with loose bolts
- Loosing pointing when tightening Elevation/azimuth bolts resulting in:
    - Low quality of service
    - Interference with adjacent satellites
- Low cross-polarization isolation resulting in:
    - Signal of the site is also seen in the opposite pole
    - Interference with other systems operating on the other pole
    - Low power efficiency of the VSAT station (only with very bad settings)
- Wrong transmit frequency settings
    - Signal is overlapping with other services
    - Interrupt of other services
- Wrong receive frequency settings
    - Station is not able to receive
    - At least no impact on other systems operating on the satellite