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Satellite Ground Station Antenna and Earth Station Maintenance Principles- N2 Satellite Experiences, Challenges and Future Directives.

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ABSTRACT

Launching satellites and maintaining a mission while in orbit is a procedural and expensive activity. It is therefore imperative satellite operations are designed to suit mission requirements so that operational activities are planned and managed properly. The earth station design and mission control planning are con-currently conducted with satellite payload and platform design and development. This strategy will ensure adequate testing of both satellite and ground facilities prior launching into the desired orbit. To sustain a successful mission ground facilities including the hardware and software components maintenance is a key requirement hence critical issues involved are discussed in this paper. Antenna systems with its peripherals electronic components must be maintained using a given standard procedure provided by the manufacturers or obtained from operational experiences of Nigeriasat-2 and challenges, This Research highlighted general standard Satellite systems in space and earth station mandatory maintenance principles for operational continuity.

Key Words: *Satellite, Earth station, Maintenance, NigeriaSat-2(N2).*

1. Introduction

Satellite mission project involves several number of activities from mission requirement specifications up to the end of the vehicle life time in orbit. Space system engineering project will require the system modules specification, design and manufacture, modules integration and testing and finally launching the spacecraft into the designed orbit. The satellite design and mission operation design are two activities that move con-currently up to a final stage when the manufactured and integrated satellite is functionally tested and launched into space.

However, achieving a satellite in orbit could not meet a mission objective without successful designed mission operation centre for the life time of the vehicle in orbit. In space mission operations centre design, tasking challenges are involved in driving the required hardware and software modules that are conforming with the designed payload and platform. Basic operations involve payload mission control, attitude control and stabilisation, frequent and scheduled spacecraft updates and daily monitoring of spacecraft health and functionality. Space mission operation remains an on-going activity to the end of mission lifetime and passivation of the space vehicle. The ability to continue to maintain and sustain the functionality of an earth station is the key factor enabling achieving the mission objectives. All tested, experienced and standard principles must be employed for effective mission continuation. To achieve maximum mission objectives, Satellite Ground segment is required to be functional and alive throughout satellite design for early spacecraft test and to the period of passivation of the spacecraft to naturally decay. Communication links, payload functional test, spacecraft modules temperature test may be conducted prior launch.

There are four standard operational plans required for a spacecraft mission. Launch and Early Orbit Operation (LEOP), Commissioning Operations, Mission Operations and the End of Life operational activities. LEOP is the initial phase of operation which includes launch operations, signal acquisition, initial attitude acquisition to place the spacecraft into safe mode. LEOP operations usually last within a week. Commissioning Operations activities include functional platform testing, payload testing and performance measurements, and validation of customer requirements. This operational phase can last up to thirteen weeks and can be less when a pair of control stations are used. Mission Operations activity include routine operations, periodic payload characterisation and orbit maintenance. Mission operations are continuous activity up to the end of the designed life. End of Life activity involve passivation of spacecraft and expelling unused fuel to reduce debris risk. This activity usually last for a week.

Satellite ground segment(GS) can either be for communication or earth observation (Remote sensing) satellite. Satellite earth stations (ES) are designed and built to achieve a specific mission objective. However modern Es stations function and operate for a number of satellite missions. This technology will require several number of software and hardware configurations that allow implementation of operations for a mission at an instance. Software programs are automatically set and configured to prepare for a particular spacecraft operation such as tracking at its specific or prioritised time. This process is usually applied by sending pre-configured commands to the spacecraft to allow its resources to be utilised at a specified time. Satellite missions are basically classified based on mission objectives and the type of hosting orbit in space. Two basic ESs types are described in section 1.1 and 1.2. This paper is organised into five sections, apart from section 1 which is introduction, the remaining sections include section 2 ES maintenance requirement, section 3 General Earth Station Key maintenance measures, section 4,5 and 6 are N2 Challenges and issues, conclusion and references respectively.

1.1 Satellite communication Earth's station.

The ground segment of a communication satellite employ a several and different design nodes and network configurations in order to provide and manage services delivered to end users. The design nodes in the networks ranges from large earth stations used as gateways in a telephone network via VSATS (Very Small aperture terminals) that deliver data communication application to remote business locations. These VSATS can be in the range of 60cm to 2.8m. Also, included are low-cost end user communication devices such as desktop, mobile handheld telephones and direct broadcast satellite home receivers. The broad range of ground components and systems employ many of the same hardware/software technologies found in modern telecommunication and broadcasting networks that are the core of terrestrial wireless and internet services. Figure 1 illustrates a typical satellite communication ground segment. The space segment consisting of orbiting communication satellite and the control system.

Operators of geostationary (GEO) space ground segment includes INTELSAT,Society of European Satellite (SES), GEAmerican communications, Panitmsat , EUTELSAT, companies such as GlobalStarLLLC, ICO Teledesic and Japan satellite Telecommunication (JSAT) [1].

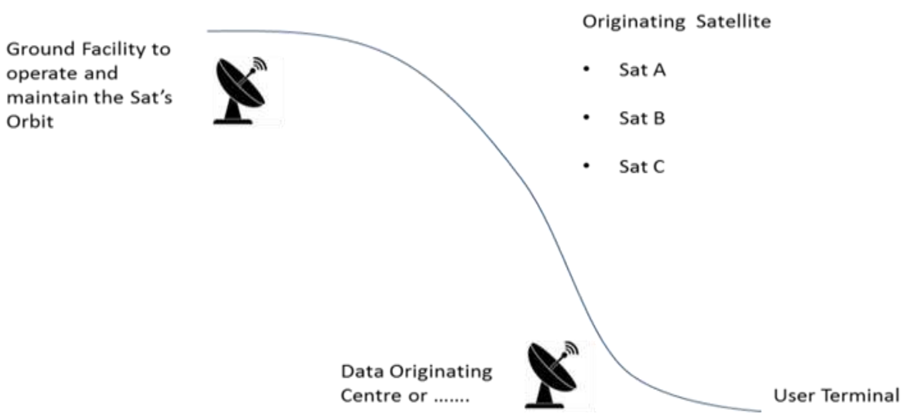


Figure 1 Typical satellite communication ES

1.2 Remote sensing satellite(RS) Earth's station..

The RS operational ground segment refers to satellite for earth observation missions. Majority of these satellites are sun-synchronous orbiting satellite at low earth orbit. The space segment of earth monitoring satellite can be controlled using one or more ground segment. It's ground segment basically perform payload or mission activities which allows earth images to be captured by the satellite. The Segment also monitor the health status of the space segment using telemetry, telecommand and control operations. Major components of a complete RS Earth's Station include antenna systems and the control electronics, spacecraft control and monitoring software and hardware systems, payload and mission control systems and data processing and archiving systems. The number of these components and configurations usually changes depending on the mission objectives and number of satellites that are hosted by the ES. Modern ground segment is designed to be configured for automated operations with reduced amount of human intervention. The automation of the system functionalities has increase safety in the operational functions with reduced cost.

Ground segment can be linked with other ground segment for data collection to efficiently maximize the satellite capacity of mission activities.

Figure 2 shows that maximum utilization of Sat- A with on-board memory capacity of 4GB is obtained by employing a second GSN-A-2 for data downloading activity at target TA1.

Figure 2 can be improved by employing spacecraft with real-time download capability. In this situation, the spacecraft power, it's configurations and station location are the limitations in the ground station. Power requirements are calculated and specified for the entire space craft lifetime. The antenna facility may be an X–band or S–band or other different frequency bands which determines the bandwidth for download.

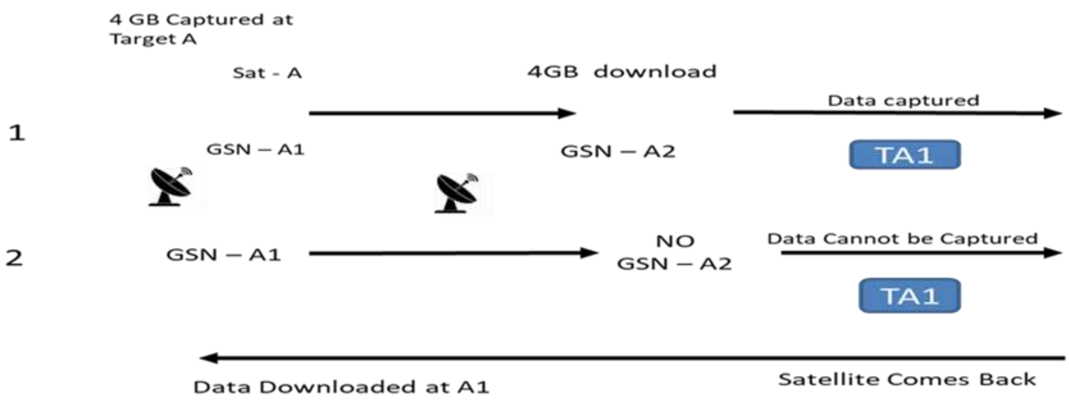


Figure 2 - 1. Two ES(GSN-A1 and GSN-A2) for download 2. One ES (GSN-A1) for download

The facility location is useful in determining how many times in a day spacecraft can be at a latitude with high elevation angle that can allow data download.

Another aspect that can influence an optional compression from payload planning systems is the application; for instance, compression can be chosen for A1, A2 and A3 group of application but not group A4, A5 and A6. This will actually depend on the final user request. Users for geological investigation, environmental monitoring, mapping and agricultural activities may differ in data format requirement. An algorithm to implement this functionality is proposed in section 4.

2. Earth Station maintenance requirements

The maintenance of hardware and software functionalities of an earth station requires several number of scheduled activities. The activities are scheduled on daily, weekly or quarterly basis depending on the importance of the activity with regard to the mission and control operations. A number of functionality and system continuity test are designed to hold on frequent basis which include antenna to operation room cables check, RF loop test, Bit Error rate (BER) of the system ,G/T measurement to ensure quality and optimum performance of the receiving systems. Onboard orbit data download and displaying the status of the spacecraft or vehicle component is a daily activity of an earth station. Although modern stations are configured to alert abnormal conditions of all downloaded telemetry data to the operators. This has reduced the task of manual checking and processing of the orbit data values. Other important tests include calibration of the image data to ensure of the standard and accurate performance. Also various configurations are performed on processing and payload control systems to conform with the spacecraft components ageing changes and functionalities. Other configurations are necessarily considered when new operational applications or equipments are replaced. Equipments are regularly checked to ensure parts replacement are properly planned and done when due.

2.1 Cable Run and Operations room

All cables that run from the antenna usually enter the operation room through a Cable Entrance Box (CEB). CEB is hardware interface between the inside operation building and outside of the building. Control, power and signal cables connecting the antenna to the operations equipment are laid in a trench specially prepared to offer protection from the weather elements as well as from rodents. Cables must be neatly positioned either on a raised floor such as planks to allow water to run beneath or on the side of the walls on specially available cable clamps. All cables must be labelled at both ends and record kept. regular inspection must be done to establish proper condition of the cables and all their supporting structures. The bulk head connectors accommodate all coaxial cables and terminal strips all the control multi-core cables. A convention for layering down cables can be adopted if suitable for the particular tracking station. It is also a standard practice to position signal cables in front of the rack and power cables behind the rack as practice in Nigeriasat2 Ground segment. All rack must have a signal ground separate o the rack ground that is eventually joined to the station grounding grid. The prescribed standard arrangement and procedures make easy access to the long length cables for maintenance purposes such as power and signal measurements or fault tracing.

2.2 Testing the System

Tracking satellites involves the use of sophisticated equipment and performing complex functions live. In addition data received from every satellite is unique and cannot be recovered if lost because (i) the satellite will repeat the same track a number of days later and consequently (ii) the ground conditions will have changed drastically. However, modern technology allow data to be stored and data download is completed in the next pass. In this situation subsequent imaging is restricted due to un-availability of onboard storage resources.

It has therefore become obvious that the system assigned to support a mission be it a launch, a Low Orbiting Earth Resources satellite or a geostationary orbit maintenance campaign must be thoroughly prepared in order to eliminate any possibility of losing that priceless information.

2.3 RF Loop Test (Test Injection)

This is commonly known as continuity test whereby RF signal is injected in the antenna feed and acquired by the receiver demonstrating that there is no discontinuity in the signal path. The test signal is generated by a Signal Generator (SG) at the frequency of the satellite to be tracked and sent up to the feed via a low loss coaxial cable and into the LNA input using directional couplers. The SG, the Coaxial cabling and directional couplers make up what is termed the Test Injection (TI).

The signal leaving the generator travels up to the point where the signal from the satellite will be entering the system and return into the receiving equipment closing the loop establishing this way continuity and the complete signal path is called the RF Loop. The RF Loop test is necessary before every support. if any component in the RF path is faulty the signal will not be received at the receiver and the cause of failure rectified.

2.4 Tracking Loop Testing (TLT)

Auto-track mode is the most used technique in tracking satellites especially for high resolution data payloads. This is essential to ensure that the ground antenna is always pointing accurately at the spacecraft for the highest quality data and on time capturing. In this procedure the CW signal enter the receive system not at the input of the LNA but at the antenna front end. This means the signal must be radiated by a source away from the antenna this way simulating the signal source as the satellite.

2.5 Testing System Bit Error Rate (BER)

A more thorough system check is performed to establish the system continuous quality at less frequent interval by the maintenance personnel. This test is termed the BER test and uses same principle as the RF loop but the Carrier Wave (CW) signal is being modulated by a signal generated by a specially designed BER test generator, and the demodulated output of the receiver is compared against the original modulating signal and check for errors at predefined signal levels.

BER test is a necessary maintenance procedure to keep track of the system performance and anticipate degradation or detect problems in time. The BER system consists of a signal generator, modulator and a BER tester and a counter. The signal generated can be digital or analog, it modulates a carrier, injected in the system via the test injection at the antenna front end like the input to the LNA then returned into the receiver demodulated and the video out of the receiver sent to the BER tester where it is compared against the original signal and inconsistencies between them are detected, counted and displayed as errors.

Once the performance of the system has been established and a reference recorded a regular BER test will show any system deterioration by a higher number of errors to the reference figure. BER plots of error rate against S/N as a function of bit rate are a quick graphical aid to establishing a system's performance.

2.6 G/T Testing

G/T stands for System Gain over System Temperature and is expressed in logarithmic value (In dB/0K). The G/T test is the total and comprehensive system test including the antenna hardware and receiving elements ahead of the LNA. It is called the System's Figure of Merit. G/T is calculated using the following formula

G/T = (8*π*K*L/F1*λ^2)*(Yn -1)

L = (1+ 0.18[Ɵd/Ɵh] ^2) ^2

Yn =10^(YdB/10)

where Ɵd is the angle subtended by the source. In this case the sun is the source with a constant value of 0.53 deg and Ɵh is the beam-width of the antenna under test. π is Pi with the value 3.1415, K is Boltzmann's constant(1.38*10^-23 watts Hz^-10K^-1). L stands for Aperture Correction Factor and F1 is the scaled solar flux at test frequency(watts/meter2 * Hz)*10^-22.Yn is the Solar-Y-factor(Numeric value) and YdB is the Y-factor (average sun power - average sky power). λ (lambda) is the wavelength of test frequency (metres). G/T is then expressed in numeric value as

10LogNumeric Value (dB/0K)

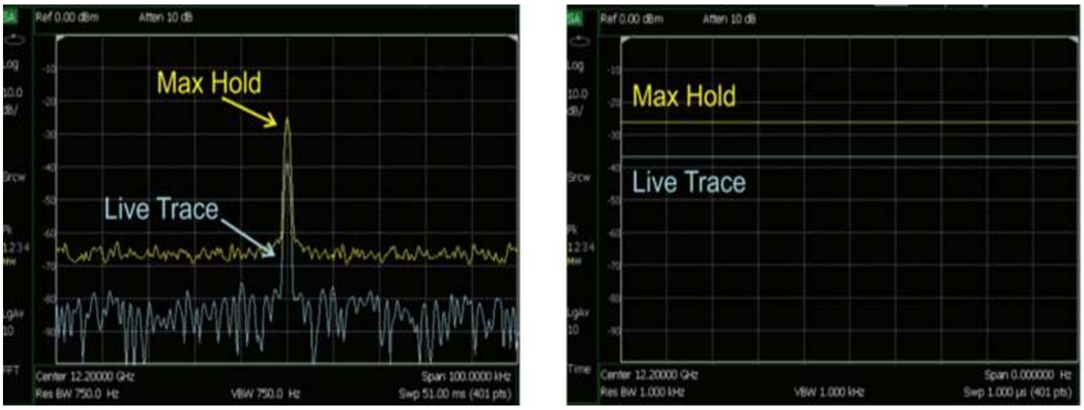
A procedure with three given steps of instructions are followed to obtain the antenna G/T system value. In the first step, a spectrum analyser (SA) is set to the centre frequency, given resolution and video, span and sweep rate values. In the second step procedure, the antenna is then drive using "Sunpose" tracking software to track the sun. In the final step, the signal on the spectrum analyser is set to peak to autotrack the sun. The system is then move off the sun and a marker /delta function of the spectrum analyser is enabled. Tracking to the sun is then returned and the Y-actore is recorded. Step three procedures are repeated few times per polarization for consistency of the results. The values of sunflux are available on the internet from the site http://sec.noaa.gov/ftpdir/lists/radio.rad.txt.

2.7 Antenna Measurements

Earth stations operating with GEO satellites require a fairly simple pointing and tracking system due to the fact that the system Telemetry TeleCommand & Control (TT&C) centre maintains satellite orbit within a fitted angular position. On the other hand, non-GEO satellites can require complex and compound tracking systems in order to follow the satellites' orbit [7]. For case of GEO satellites, antenna pointing can be optimized by tracking a beacon signal transmitted by the satellite. With a new satellite installation, antenna pointing can be manually skilled using a spectrum analyzer connected to a monitor port along the received signal path. As the earth station antenna is moved across a small angular displacement, the measured signal level will increase and decrease as the antenna's boresight direction moves across the direction of the satellite. To optimize the antenna pointing accuracy, Field Fox includes a maximum amplitude hold function, referred as "max hold", that will maintain the highest signal level as the antenna is moved. This max hold measurement can be related to an active measurement as the antenna is moved. The antenna peak is properly pointed when the active trace lines up with the maximum(max) hold trace.

Figure 4 shows two measurement examples when using the max hold trace while simultaneously displaying the active or "live" trace. Both examples were captured using FieldFox with two measurement traces displayed. Figure 3a shows a typical swept spectrum configured with a 100 kHz frequency span. As the antenna was rotated, the peak amplitude of the active trace, shown in blue, moved up and down as the received amplitude changed. The max hold, shown in yellow, maintained a record of the maximum level recorded at each frequency across the span. Pointing was optimized when the peak in the blue trace equalled the max hold peak and no further increase in power level was observed.

A second approach for maximizing the received amplitude uses the "zero span" on FieldFox. Figure 3 shows this measurement with the spectrum analyzer tuned to the centre frequency of the beacon and the instrument display now sweeping in time. Once again, the max hold and an active trace allow a visual aid when optimizing the received signal level and associated antenna pointing. One advantage of the zero span mode is that the sweep rate can be adjusted to approximately the same time it takes for the antenna movement across an axis. This technique is very useful when measuring the antenna sidelobe levels.



a. Narrow Span b. Zero Span

Figure 3 : Measurement of satellite beacon as antenna was rotated using FieldFox set to (a) narrow frequency span and (b) zero span [2]

Due to the fact that geosynchronous satellite orbital slots are specified at every 2 degree of longitude, earth station antennas must have high gain and low sidelobe levels. If the gains of the antenna sidelobes are too high, the earth station antenna will produce high levels of interference to the adjacent satellites, particularly when those systems share the same frequency spectrum and antenna polarization. For example, a single-beam earth station reflector antenna having a diameter greater than 100 wavelengths should have a sidelobe level determined by equation (1) and Figure 3 shows he result of measurement of satellite beacon as antenna was rotated using FieldFox set to (a) narrow frequency span and (b) zero span[2] where the angle θ is specified in degrees relative to boresight and the gain value is relative to an isotropic antenna. One way to measure the relative sidelobe level of an earth station antenna is to transmit a signal from the desired antenna and record the received signal level at another earth station as the desired antenna is rotated over a narrow angular displacement. The displacement should cover the main beam and the peaks of the two adjacent sidelobe levels. The same technique can be applied to capture the receive antenna pattern by using a fixed transmit antenna and a rotated receive antenna. In general, the measurement of sidelobe level in the transmitter antenna is of most importance as this signal potentially creates interference to other satellite systems if the sidelobes are out of specification. Sidelobe levels are typically measured using a similar technique as antenna pointing, where a spectrum analyzer is placed in zero-span mode and the analyzer's sweep time is approximately synchronized with the sweep in angular displacement.

Figure 4 shows the simulated measurement of the received signal as the earth station antenna was scanned over a ±15degree angle from boresight. The measurement was recorded using FieldFox configured with zero-span mode, max hold and a sweep time set to approximately the slew rate of the antenna movement and antenna polarization. The same technique can be applied to capture the receive antenna pattern by using a fixed transmit antenna and a rotated receive antenna. In general, the measurement of sidelobe level in the transmitter antenna is of most importance as this signal potentially creates interference to other satellite systems if the sidelobes are out of specification. Sidelobe levels are typically measured using a similar technique as antenna pointing, where a spectrum analyzer is placed in zero-span mode and the analyzer's sweep time is approximately synchronized with the sweep in angular displacement.

Figure 4 shows the simulated measurement of the received signal as the earth station antenna was scanned over a ± 15-degree angle from boresight. The measurement was recorded using FieldFox configured with zero-span mode, max hold and a sweep time set to approximately the slew rate of the antenna movement.

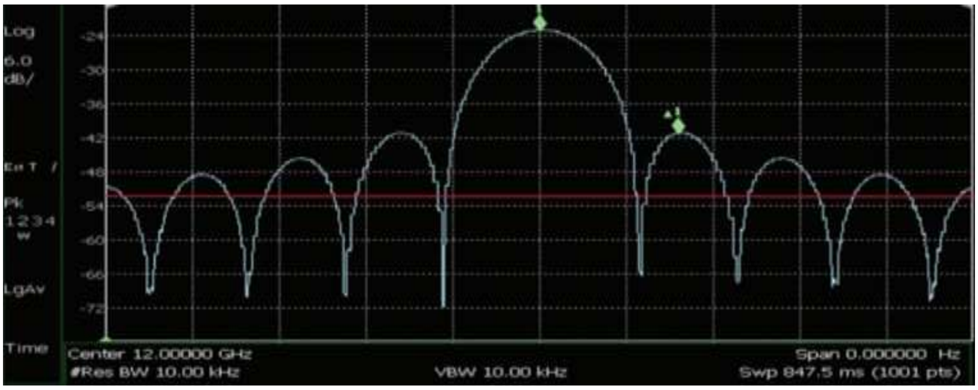


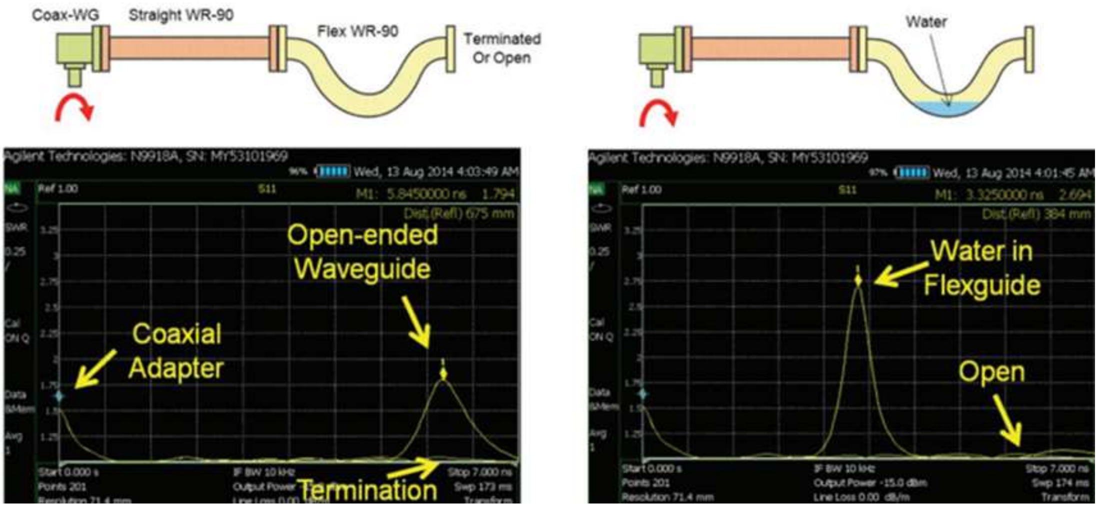
Figure 4: Measured antenna pattern using FieldFox configured in zero span mode with max hold [2]

$$Sidelobe\ Gain\ (dBi) = 29 - 25\ log_{10}\theta, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

In general, unless the antenna becomes damaged or affected by the surrounding environment in some way, pattern measurements are not typically performed on a frequent basis, as the satellite system would be taken out of service. On the other hand, environmental conditions, such as rain and humidity, can affect other parts of the system especially the interconnecting transmission lines including many coaxial and waveguide components. Maintenance and troubleshooting of these transmission lines may occur more frequently and rely on measurement techniques called line sweeping and distance-to-fault, which will be discussed in the section 0

2.8 Line Sweeping and Time Domain Measurements

Line sweeping is a measurement of the frequency response of a long transmission line, such as a coaxial cable or waveguide, connecting a transmitter to its antenna or between an antenna and its receiver. The measurement reports the signal attenuation and return loss of the complete transmission path. Line sweeping may also be used to estimate the physical location of a fault or damage, along a transmission line using the Distance-to-Fault (DTF) measurement available in FieldFox cable and antenna test (CAT) or Vector Network Analyser (VNA) modes. DTF is a mathematical transform of the measured frequency response into the time domain. Figure 8 shows examples of DTF measurements through several sections of WR-90 X-band waveguide. The first section is a coaxial-to-waveguide adapter with the coax port connected to FieldFox. The next part is a connected a 6-inch length of straight rigid waveguide which is then followed by an 18-inch length of flexible waveguide. For these measurements, the flexible waveguide, or "flexguide", is either terminated in a matched waveguide load or the end flange is left open. FieldFox is configured to measure the return loss, as the S-parameter S11, as a function of frequency. FieldFox is switched to the DTF mode, also referred to as the time domain transform mode. In time domain mode, the x-axis is time and the y-axis is amplitude. The time domain result for this simple transmission line system is shown in Figure 5. When examining the DTF display, large peaks are located at the points where discontinuities exist along the transmission line. The measurement in Figure 5 contains two traces, one trace has the flexguide terminated in a matched load and the other trace has the flexguide left open-ended. Both traces show a first peak at the coax-to-waveguide adapter located at time equal to zero. For the measurement with the open-ended flexguide, there is a second large peak at the location of the open. When the flexguide is terminated using a matched load, the amplitude of the peak is very low in comparison. Markers placed at the peak of each reflection report the electrical distance and the associated physical location to the discontinuity. For example, the location of the open circuit at the end of the flexguide is measured at 675 mm, which is the total length through the adapter, straight waveguide and flexguide. FieldFox automatically calculates the dispersion of the waveguide (propagation velocity that changes as a function of frequency) when the WR-90 is selected from the waveguide and cable electrical properties table. This ensures accurate distance to fault. As a comparison, assume that this transmission system was exposed to the environment and water has leaked into the waveguide. For the example shown in Figure 5b, a section of the flexguide was partially filled with water. When examining the time domain response, there was a large peak in the response that corresponds to the location of the water-filled waveguide. Once again, a marker was used to measure the physical distance to the water, which was 384 mm from the input. Obviously, this technique is ideal when troubleshooting problems in the feed lines of an earth station.



a) (b)

Figure 5 : Time domain measurements of a system of waveguide components [2]

2.9 Occupied Bandwidth and Adjacent Channel Power Ratio Measurements

As stated in section 0, the transmitted signals are designed to operate within a specified frequency bandwidth, or channel, in order to not interfere with those signals occupying the adjacent channels. Unfortunately, nonlinearities in the active components of any Radio Frequency (RF) system creates distortion, often called intermodulation distortion or spectral regrowth, resulting in an increase of the signal's occupied bandwidth (OBW) in the surrounding channels and guard bands.

Figure 6 shows an example of a digitally-modulated 44-GHz signal. The test signal was created using a Keysight PXG [2] Vector Signal Generator configured with 64 QAM modulation. This modulated signal was amplified and the spectrum was measured using FieldFox operating in spectrum analyzer mode. The test configuration included a high power attenuator placed between the amplifier and FieldFox to prevent overloading the front end of the analyzer and possibly damaging the instrument. The measurement shows the spectrum of the amplified signal configured to operate just below the amplifiers saturation point. The display also shows that the occupied bandwidth is 52.50 MHz and channel power is 21.08 dBm. The occupied bandwidth measurement is part of the "one button" suite of channel measurements provided by the spectrum analyzer mode in FieldFox. It should be noted that FieldFox can be configured with an external USB power sensor for those test cases requiring the highest accuracy and/or peak power measurements.

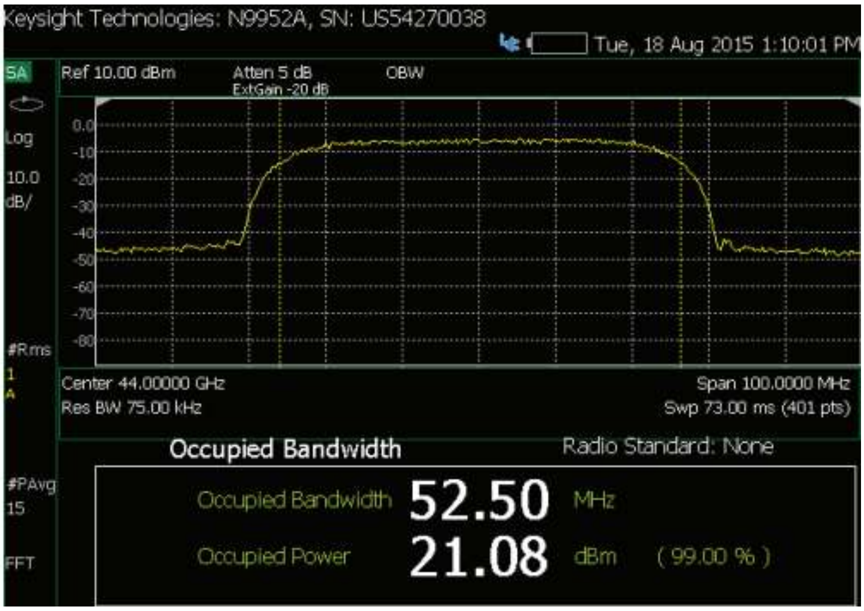
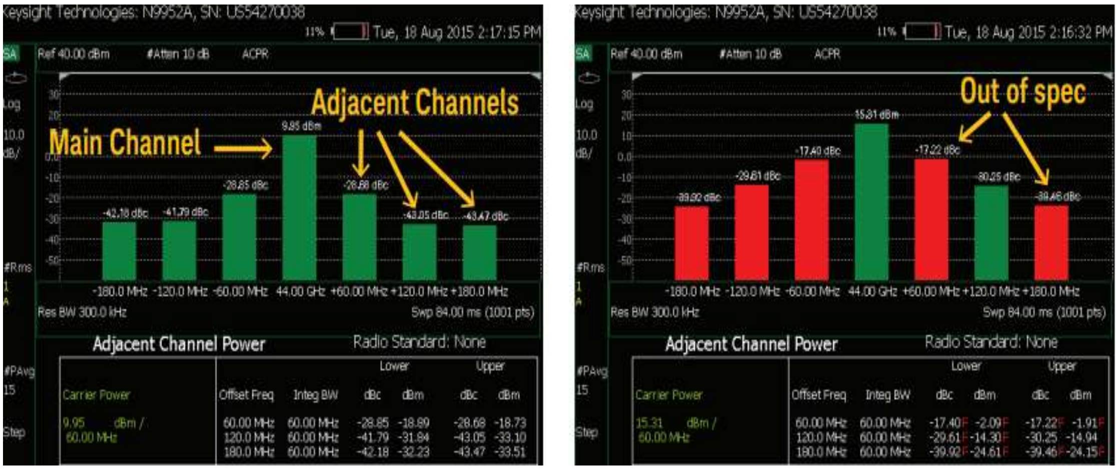


Figure 6 : Measurement of the spectrum and occupied bandwidth from a 44-GHz digitally-modulated input signal [2]

The measurements shown in Figure 7 display the Adjacent Channel Power Ratio (ACPR) for this same amplifier. ACPR reports the amount of unwanted energy in nearby channels relative to the signal power in the main channel. This type of interference is common for modulated signals and primarily created by energy splatter out of the assigned frequency channel and into the surrounding upper and lower channels. This energy splatter can be generated by faulty modulation, switching transients and intermodulation distortion. ACPR levels rapidly increase when an amplifier reaches its output power limit and begins to saturate. For example, the measurement in Figure 7a displays the relative ACPR levels when the amplifier was operating just under its specified saturation level. The power levels in the main channel and the three upper and lower channels are displayed as bar graphs. In this case, the main channel power of the non-saturated amplifier was 9.95 dBm and the relative adjacent channel power in the nearest channels were approximately -29 dBc each. As the amplifier entered saturation, there was a sharp increase in the ACPR as shown in Figure 7b. When the amplifier was saturated, the ACPR of nearest channels increased from -29 dBc to -17.4 dBc, while the main channel power only increased from 9.95 dBm to 15.3 dBm. For this saturated amplifier condition, FieldFox displayed five of the ACPR bars highlighted in red. For this measurement, FieldFox was configured with limits to display an out-of-spec condition when ACPR levels exceeded a predetermined value. In this example, the three adjacent channel limits were entered as -20, -30 and -40 dBc respectively. Measurements below these limits are displayed as green, outside the limits in red.



a. Non saturated amplifier b. Saturated amplifier

Figure 7 a. Non saturated amplifier and b. Saturated amplifier [2]

2.10 Filter Loss and Group Delay Measurements

Filters are used quite extensively in all communication systems. In earth station applications, they are typically integrated into the high-performance upconverters and downconverters. Filters are used primarily for their out-of-band rejection in both uplink and downlink paths. Filter performance is measured using a VNA that displays the scattering parameters (S-parameters) of the two-port device. The measured S-parameters are a function of frequency and are related to specifications of insertion loss, return loss, group delay, and out-of-band rejection. The bandwidth of the filter and its ripple response are measured quantities that are typically determined by using the marker functions on the VNA. The highest measurement accuracy when measuring any two-port device occurs when the S-parameters are measured using a two-port VNA having a full two-port calibration [2,3,4]. FieldFox should be calibrated to remove the effects of the test cable and adapters that are required in order to connect the filter to the analyzer. There are several options for calibrating FieldFox, including the popular “QuickCal” that eliminates the need for an expensive calibration kit to be carried into the field. The measurements shown in Figure 8 display the S21 transmission response of a band pass filter centered at 1 GHz. FieldFox includes a marker search function that automatically determines the filter bandwidth using a target value, in this case at -3 dB. The measured insertion loss is -1.57 dB and the filter 3-dB bandwidth is 15 MHz. Another important characteristic of a filter is its transmission phase, and associated group delay response. In communications systems, it is important to have a linear phase response across the pass band to avoid distortion in the desired signal. Another way to specify a linear phase response is to have a flat group delay response in the pass band. Shown in

Figure 9, as the blue trace, is the measured group delay response of this filter. Markers are placed at the centre and at the peaks near the band edges. In this case, FieldFox was configured with uncoupled markers so different traces can have marker placement at different frequencies. By default, FieldFox configures the markers as coupled so they track each other in frequency on up to four traces at one time.

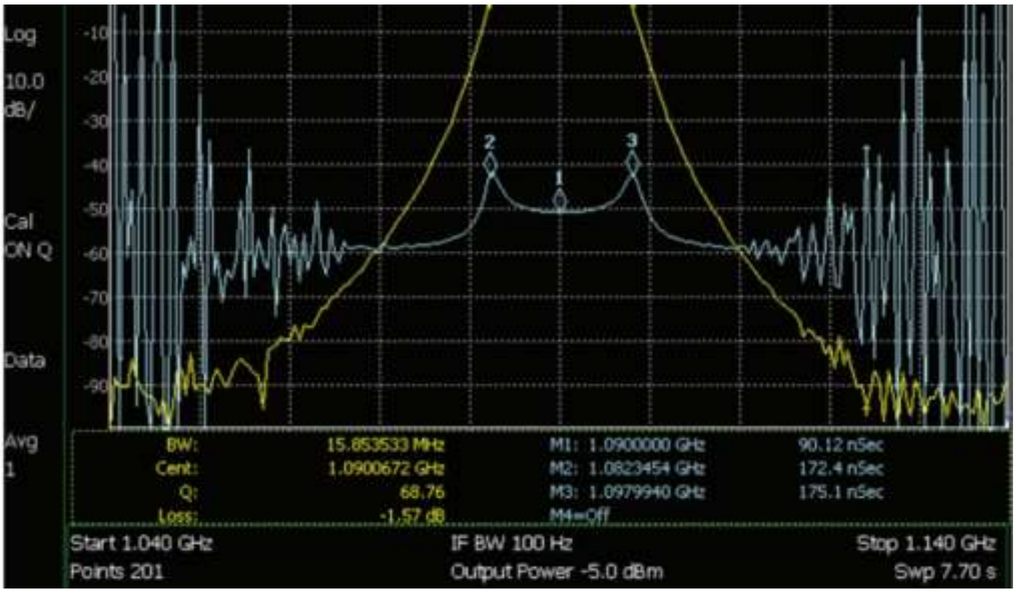


Figure 8: Measured transmission response of band pass filter [2]

2.11 Frequency Converter Measurements

Frequency converters provide translation between a modulated signal's intermediate frequency (IF) and the uplink, or downlink, RF frequency of the system. Figure 12 shows a diagram of a typical block downconverter (BDC). The BDC translates a large block of frequencies captured from the satellite downlink to a lower frequency for additional signal processing and demodulation. BDCs typically use a single internal local oscillator (LO) for frequency translation. The IF from commercial BDCs is typically in the L-band frequency range, 950 MHz to 1450 or 2150 MHz [1]. Other types of downconverters are designed with an IF in the VHF range, typically 70 MHz or 140 MHz. These types of "frequency synthesized" downconverters will have two LOs (double conversion) and can be used to tune to a specific communications channel. Channel bandwidths for these downconverters are typically 40 MHz or 80 MHz wide, providing a high level of dynamic range and adjacent channel rejection

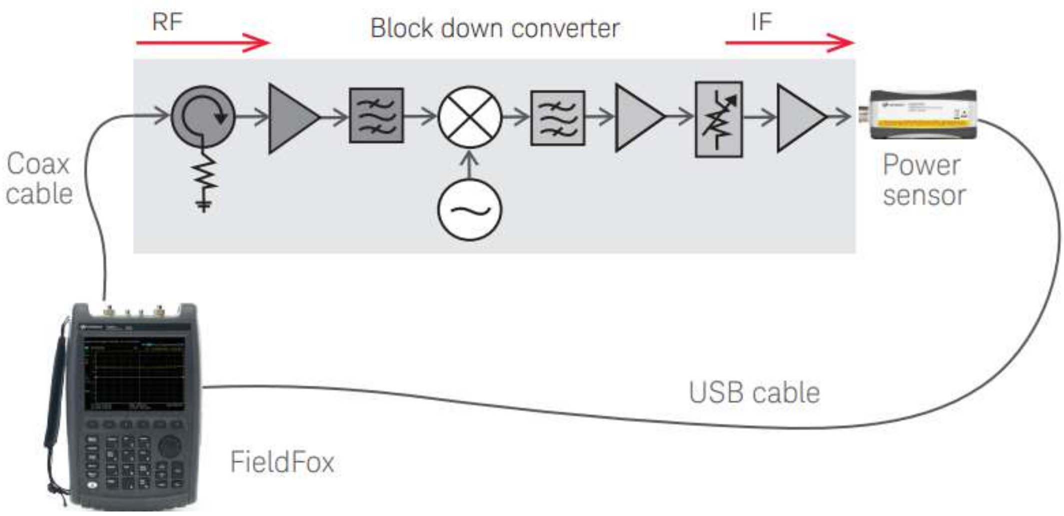


Figure 9 : Frequency block downconverter and associated test configuration [2]

Preferably, a downconverter only changes the center frequency of the signal and does not alter or distort the signal in any way. Unfortunately, the RF/IF components along the converter path create some level of distortion to the signal and it is up to the design engineer to select components that minimize these effects. Several types of test equipment are required to fully characterize the performance of a frequency converter. For example, intermodulation distortion (IMD), harmonic and spurious levels can be measured using a spectrum analyzer whereas return loss is typically measured using a vector network analyzer for its speed and accuracy. FieldFox can be operated in either spectrum analyzer mode or network analyzer mode to perform these required measurements in one single handheld instrument. Other important specifications for any earth station frequency converter include conversion gain, gain flatness and gain stability over temperature. The measurement of these parameters requires test equipment capable of sweeping a signal generator across a range of input frequencies and measuring the amplitude response across the associated range of output frequencies. Fortunately, FieldFox can be configured to measure the frequency conversion parameters using its internal source and a connected USB power sensor. This test configuration is shown in

Figure 9, where FieldFox is connected to the input of the BDC and the power sensor is connected to the output. The same configuration can also be used to measure the conversion gain of an upconverter. In frequency converter mode, FieldFox is configured to operate as a swept source and the USB power sensor, connected to FieldFox, measures the signal level from the output from the converter. To accurately measure the conversion gain, the test configuration is first calibrated across the input frequency range by directly connecting the power sensor to the end of the test cable that connects FieldFox to the converter. FieldFox RF Block down converter IF USB cable Coax Cable Power sensor [2] provides an on-screen wizard, providing step-by-step instructions for performing each part of the process. After RF calibration, the power sensor is connected to the converter output for test. The conversion gain, in dB, or output power, in dBm, is then displayed directly on FieldFox.

10 shows a measurement of the conversion gain of a Ka-band downconverter. The downconverter was tuned to an input channel centered at 20.7 GHz. The FieldFox source was swept over a range of 20.5 GHz to 20.9 GHz and the power sensor measured the IF from 50 MHz to 90 MHz. The measured conversion gain at the center of this band is 45.8 dB as shown by the marker value. While not important for this measurement of a single downconverter, it is possible to place the USB power sensor over 80 meters away from FieldFox. This would be useful when measuring a complete system having the input located at a large distance from the output test location. In this case, the USB power sensor will use a commercially available USB cable extender to extend the distance between the power sensor and FieldFox.

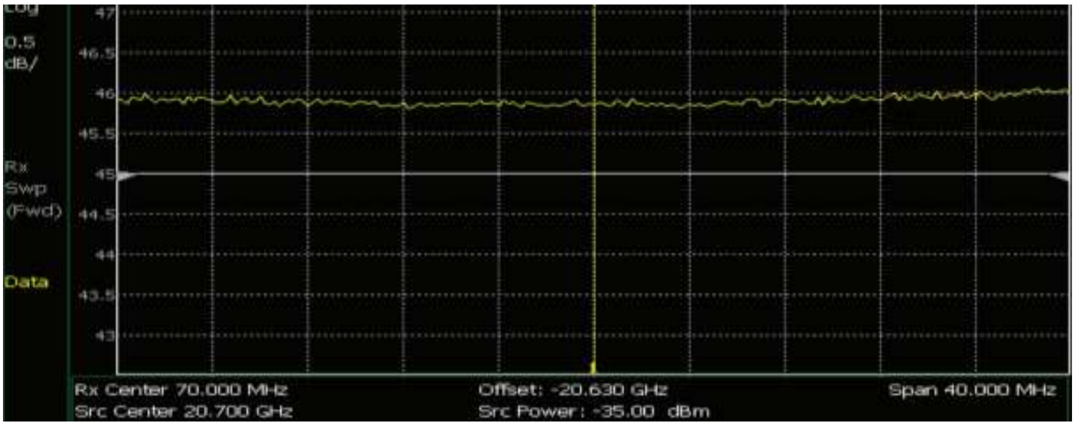


Figure 10 : Measurement of the conversion gain for a Ka-band to 70 MHz earth station downconverter[2]

2.12 Remote Measurements and Control

In section 0, it was mentioned that a USB power sensor can be separated from FieldFox by up to 80 meters; it is also possible to control FieldFox when placed in a remote location. There are several ways to monitor and control FieldFox under remote conditions. For example, when FieldFox is connected to the monitor port of a remote earth station, it is possible to observe live measurement on an iPhone, iPad or PC. It is also possible to control FieldFox wirelessly through the Remote Viewer Application that runs on an Apple iOS device. The iOS interface is configured to show the same instrument panel as FieldFox, allowing the instrument to be directly controlled from the iOS device. In another example, a PC or laptop can be connected to FieldFox either through a wired or wireless internet connection. The Remote Display software running on the PC will display the FieldFox instrument panel allowing live measurements and direct control of the instrument. Wireless connectivity is provided through a USB WiFi hub or similar device connected to the USB port of FieldFox. As the FieldFox is a sealed instrument, it is possible to leave the instrument exposed to a variety of outdoor weather conditions [2].

3. General Earth Station Key Maintenance Measures and Requirements.

In satellite earth station, several number of protective and effective maintenance measures are checked and performed periodically which include the following (i) tracking of expired equipment and replacement of such items before failure and downtime (ii) Upgrading computer systems and peripherals to conform with new installed software programs and applications (iii) upgrading and updating exis Sting programs and applications when similar mission process is performed on spacecraft modules. Similar updates and configuration are performed with the Mission Planning, spacecraft control and monitoring and Image Processing Systems. (iv) spacecraft focussing and adjustment also require updating a number of ground systems for effective operations.

3.1 Antenna Systems Key Maintenance Requirements and Standard

Several number of experienced and manufacturers of Antenna system including Viasat U.S.A. and Anteky Science Technology [12] have addressed number of standard procedures in maintaining (1) Antenna Control System as follows (a)check the beacon receiver and working condition of Antenna Control Unit(ACU) air fan frequently and ensure the cooling part function well (b) Dust the beacon receiver and ACU regularly and ensure the equipment is in normal condition(c) Take effective measures on insect and rat prevention and cover the feed tube port and examine it regularly(d)Long running ACU and beacon receiver have higher requirements for the environmental temperature, so the operator of the system should check if the cooling system is normal or not. The normal phenomenon is that the fan blower will stop working because of aging which can lead to the temperature in the cabinet increasing and make the machine working unstably. Hence the user can replace the fan to eliminate the trouble, similarly in other Systems such as N2 Antenna systems designed by Viasat should be checked regularly. (2) Mechanical Structure as follows (a) check if the drive motor of Antenna Azimuth(Az), (El) or Track(Tr) axis runs normal or has abnormal noise(b) check if the protective jacket of antenna Az, El or Tr jackscrew is aged or damaged, It requires regular inspection and timely replacement. Add MoS2 as required. (c) check if Antenna Az, El, or Tr need to be greased Add grease according to specification (d) check if Antenna Az, El, or Tr limit switch is rusted and aged. Replace if required timely (e)Check if the power cable of Antenna Az, El or Tr drive motor is aged or damaged (f) Check if the reduction gearbox lacks of lube. Add lube according to the requirement usually MoS2 is used as the lube. (g) Check if the metal component are loosen, deformed or rusted. If needed, loosen the components clean the rust and apply paint repair (h) Check if the feed coating is aged or damaged. Change it according to the specification requirement (i) Check if the feed blowing rain system unit is normal. It requires regular checking. (3) Antenna Panels Handling as follows (a) Check if the paint or Antenna reflector falls off and a specialised white paint with high frequency and low insertion loss to be used. Ordinary white paint not to be used. (b)Measure the ground resistance value of the antenna regularly which should be less than 4Ω. Also check the lightening protection and anti-thunder device regularly. (4) Antenna Foundation System as follows (a)choose corresponding model of grease and antiseptic pain to change the grease and do paint mending regularly (b) When the antenna cannot rotate, check if it's the antenna controller's problem after eliminating the trouble of the antenna controller and then mainly check A, El and Tr limit switch. This is the usual part with the normal closed contact This is because the wind and rain corrosion always leads to the poor connection of antenna limit switch contact. It should be checked and changed regularly. (5) Attention for Antenna maintenance as follows (a) If there must be someone standing on the main reflector, only 1-2 light person can be allowed. The standing persons must wear soft-soled shoes and try to stand on the steel bar of beams so that the reflector won't be damaged or deformed. (b) when doing paint repair and painting grease, the fasteners should be untied. If there is strong wind the loosen fasteners must be tightened in time and then resume when the wind stops. (c) Most Antenna Driving Unit(ADU) are with high voltage of 380V. Hence when doing maintenance all functional electricity must be shut down. (d) The user should avoid that somebody stays on the antenna working site.

4. N2 Ground segment issues and Challenges

It is obvious to deduce that the design of functional system must follow a maintenance procedure policy. This policy will allow the system to continue to function effectively to the expiration of any of the designed components lifespan and beyond. A required standard must be maintained in all the system services and especially in the services and maintenance of electronic equipment as in [1]. Clean and effective power source is one important and necessary component that must be planned prior the system operation. Among the maintenance policy is the regular in-house G/T test, BER test and system in the loop test. Others include replacement of faulty or expired components and upgrade together with the calibration of all functional software and reconfigurations when required. System maintenance funding stand to be one important provision that must be made during the initial design of the ground segment and costing. The funding which is estimated considering the design components and their requirements must be budgeted for the entire life of the Ground segment operation. The above mentioned issues remain the main challenges encountered with the ground segment operated with the 7.3m Antenna system. The N2 Ground Segment Antenna is a robust system design, automated and built to last for many years hosting multiple satellite data with effective maintenance principles observation.

Other components requiring maintenance that have been key issues with system continuity of N2 Ground segment is processing software calibration and updates. A number of systems are affected and will continue to generate inaccurate data when spacecraft continue to age and sensors degrade and the system focussing results and control adjustments are not effected on the ground systems. Also ground electronic systems require regular checks and inspection to ensure signal is not impaired due to the distance of the equipment to the receiving dish, cable losses or the equipment deterioration. There are several number of methods and procedures described in this paper that are used to measure the system continuity and validity of output. These procedures if strictly adhered to will guarantee proper functionality of earth station for the entire design life time and beyond. It is always the fact that the level of maintenance of an earth station is directly proportional to the functional life time of the station.

5. Conclusion

In this research work, a significant industrial experience on satellite mission maintenance is reviewed and discussed. It serves as an essential reference and documentation for satellite operators and Earth Stations maintenance personnel. Important measures that are important for effective mission maintenance are also reviewed and discussed. This will familiarise engineers when designing new earth stations to be flexible in their systems and document necessary points of maintenance and upgrade. Maintenance for satellite antenna system and its control components is necessary for the guarantee, safe and quality mission operation for remote sensing satellite and communication satellite and broadcasting system. The maintenance requires high technology and professional practice for mission continuity and long time performance. This practice prolongs life time of the whole system. Hence there is need to regularly test and examine the system performance so that problems are solved before occurrence and did not reach adverse situations. Mastering the maintenance procedures and methods thereby identifying and isolating fault quickly and accurately are all required to ensure normal and reliable running of the satellite earth station components and all its control systems in both Hard and Software mode.

Satellites earth stations are complex systems requiring high performance and reliability. New broadband technologies, including frequency re-use and spot beams, are greatly improving system capacity while achieving lower service cost and higher reliability. In order to assure the highest uptime for the earth stations, routine maintenance and occasional troubleshooting and repair must be done quickly, accurately and in any weather condition. Breakthrough technologies have transformed the way these systems can be tested in the field while providing higher performance, improved accuracy and capability. In this paper experimental reviews and discussions, has shown that a single FieldFox handheld analyzer can replace multiple instruments including a spectrum analyzer, vector network analyzer, signal generator and power meter with frequency coverage up to 50 GHz. FieldFox's lightweight portability substitutes traditional methods of transporting multiple benchtop appliances and instruments to the earth station location. Future Earth station beyond N2 must adhere to the discussed principles for better mission performance and continuity. A well scalable designed Ground segment and well maintained earth station can serve multiple missions and can be upgraded to suit other functionalities for different missions.

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