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The Measurement of Baseband Frequency Range for Military Satellite Terminals

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ABSTRACT

The article concerns problems related to electromagnetic compatibility of military satellite terminal with small VSAT antennas (Very Small Aperture Terminals). The article focuses on the measurement of the frequency range of military satellite terminal work in the basic band for VSAT satellite terminals intended for data transmission. The article presents a laboratory stand and a method for measuring the operating frequency in the basic band for VSAT satellite terminals, which was developed on the basis of European civil standards and a military standard containing requirements on the operating frequency in the basic band for VSAT. In the case of measuring the operating frequency in the basic band for satellite terminals of the tested device, we must remember to estimate the uncertainty of the measurement. The extended value of the uncertainty of measurement for individual frequency ranges is determined from the $f_0 \pm 2 * 10^{-7}$ relationship.

Keywords: Baseband, Frequency range, Satellite terminal, VSAT

INTRODUCTION

VSAT stations (Very Small Aperture Terminals) are small, cheap terrestrial satellite stations, which are equipped with small antennas (typically from 1 m to 2 m), low power RF transmitters (typically from 0.5 W to 2 W) and in modems and signal converters, forming a compact structure. Stations can be very easily installed on the roof, wall or car park in front of the user's office, where the end devices are placed. Stations can be used in a very convenient and economical way to connect end users devices to the main computer located in a remote data center. VSAT stations are usually used to transmit digital data.

VSAT stations often work in a star network, as shown in Figure 1. VSAT stations communicate with a large ground station, called the central station. In this case, the type of modulation, transmission rate, coding and access methods for the outgoing channel (from the central station to the VSAT station) and for the incoming channel (from the VSAT station to the central station) are usually differentiated, in order to use the satellite channel effectively, using methods multiplied access. In this type of VSAT networks, user data is usually processed by VSAT stations and the central station, so as to

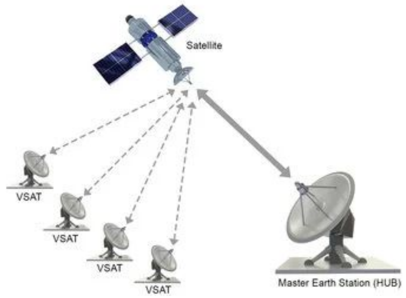

Figure 1: VSAT network - star configuration.

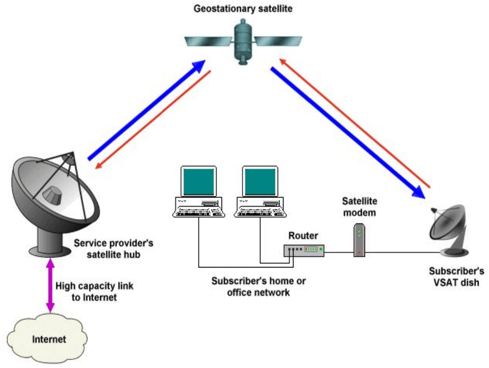

Figure 2: VSAT network with point-to-point configuration.

effectively support various computer network protocols. Point-to-point connections between VSAT stations are also used, as shown in Figure 1. In this case, the type of modulation and the format of the signals transmitted and received by the VSAT station is usually the same, and the user data usually passes through the VSAT network in a transparent manner without protocol processing. To the manage and supervise the configuration and operation of the network is usually used computer.

Point-to-point connections between VSAT stations are also used, as shown in Figure 2. In this case, the type of modulation and the format of signals transmitted and received by the VSAT station is usually the same, and user data usually pass through the VSAT network in a transparent manner, without protocol processing. To manage and supervise the configuration and operation of the network, a management and supervisory computer is usually used.

GENERAL COMMENTS ON METHODS OF MEASUREMENT VSAT TERMINALS

The RF port of an ODU device is usually connected directly to a tube radiator. In this case, the antenna with the radiator must be separated from the rest of the ODU, using the instructions developed by the manufacturer, in order to enable measurements of the antenna parameters and RF parameters at the contact point. Sometimes, it may be necessary to use appropriate adapters or

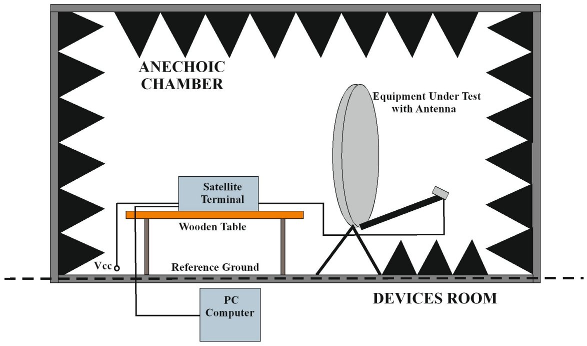

Figure 3: General block diagram of the measurement stand in the anodising chamber used in the study of satellite terminals.

waveguides to connect the measuring instruments with the contact point. The general block diagram of the measuring station in the annealing chamber used during the examination of the VSAT satellite terminals is shown in Figure 3.

There is a control function in the VSAT station that prohibits the RF signal output when the VSAT station operating in the star topology does not receive the appropriate permission signal from the central station. It may be necessary to use the manufacturer's instructions to force the broadcast of the VSAT station - by omitting the control function or by using a central station simulator, equipped with a supervisory computer and its emulator, which generates a control signal During measurements, conditions that could damage the tested devices should be avoided. If this is not specifically indicated, the measurements should be carried out under normal conditions for power supply, temperature, air pressure, humidity and output load. Once the device has been prepared for operation under specified conditions, these conditions should be left unchanged during all measurements, unless these conditions are to be specially changed for a specified period of time or for a specific measurement.

MEASURE OF THE OPERATING FREQUENCY RANGE IN BASE BAND FOR VSAT TERMINALS

The method of measuring the operating frequency range in the basic band for VSAT satellite terminals has been developed on the basis of the following standards: "PN-EN 60835-3-13: 2000 - Methods of measurement for equipment used in digital microwave radio transmission systems - part 3: Measurements on satellite earth stations - section 13: VSAT systems" and "PN-EN 60835-1-2: 2002 Methods of measurement for equipment used in digital microwave radio transmission systems - Part 1: Measurements common to terrestrial radio-relay systems and satellite earth stations - Section 2: Basic characteristics". However, the requirements for the operating frequency band in the basic band for VSAT satellite terminals are contained in STANAG 4484 Edition 2. The requirements are as follows: a intermediate frequency of 140 MHz is recommended and for L band in the range of 450 MHz to

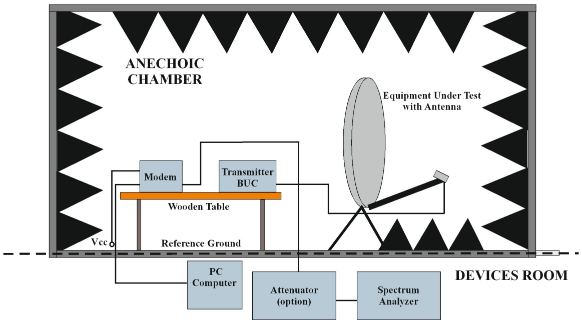

Figure 4: Block diagram of a laboratory stand in an anechoic chamber used in testing satellite terminals when measuring the maximum harmonic level.

2000 MHz with a jump of 25 kHz. In general, within the developed measurement method, it should be possible to transmit a continuous carrier wave through the VSAT terminal, using local setting or remote control. A pseudorandom bit sequence should be fed to the VSAT terminal modulator input and then the spectrum analyzer should be connected to the RF port. Then measure the spectrum of the output signal. The detailed requirements for the operating frequency band in the basic band for VSAT satellite terminals are discussed in the following subsections.

Measuring Systems

According to the PN-EN 60835-3-13: 2000 standard, for the operating frequency in the basic band for VSAT satellite terminals, it is necessary to set up the laboratory stand in the configuration as shown in Figure 4.

Authentication of the Measuring Path

The measurement path should be subject to authentication on the section from the RF output of the tested device to spectrum analyzer. In order to authenticate the track:

a) turn on the power of the measuring instruments and leave them in this state for the time necessary to obtain the proper stability,
b) provide from the signal generator a reference signal of a known level and at a fundamental frequency f_0 equal to the center frequency of a given sub-range of the transmitter. The center frequency should be determined according to the relationship (paragraphs 2.3.10.2 of NO-06-A500: 2012):

$$f_0 = (f_{max} + f_{min})/2 \tag{1}$$

$$f_1 = 0{,}95 f_{max} \tag{2}$$

$$f_2 = 1{,}05 f_{min} \tag{3}$$

in which:
f_0 - the frequency of tuning the device or block,
f_{max} - the upper frequency of the device (block) sub-range,

f_{min} - the lower frequency of the device (block) sub-range.

c) tune the spectrum analyzer to the frequency f0 and check if the frequency of the measured signal is within the range of the allowable measurement error of ± 0,1% with f_0,
d) if the measurement error does not fall within the range of the admissible measurement error ± 0,1 % with f_0, locate the error source and remove the cause of the error before proceeding with the EUT tests.
e) repeat the operations described in item b) to d) for the two extreme frequencies of the sub-range under consideration.

The Main Measurement Procedure

During the measurements, it should be possible to transmit a continuous carrier wave (preferably unmodulated) using a local settings or remote control. Attach the frequency counter to the RF port of the ODU (outdoor device), measure and record the carrier frequency (for the limiting frequencies shown in Table 1). Change the frequency using local settings and/or remote and check if the carrier frequency changes according to the control. If required, accuracy and stability should be measured at several carrier frequencies.

The bandpass filter should only be used in the presence of interfering signals. The use of an amplifier or a silencer is necessary when the levels of the measured signal do not correspond to the levels of signals required by the frequency meter. It is recommended that the tested device and measuring instruments reach the state of thermal stability before starting measurements. The reading from the digital frequency meter follows the end of the counting period, for example, after one second. You can also register the digital frequency meter's indications from several counting periods. The number of counting periods used for measuring depends on the presence of disturbances and on the fact whether interference modulates the measured signal or overlaps it. Statistical analysis of a series of averaged results from several counting periods allows to validate the measurement results.

The above method is also applicable in the case of modulating the RF signal by a baseband signal with a zero mean value, provided that the digital frequency meter does not introduce errors depending on the modulation signal. It is recommended that the period of averaging the digital frequency meter be not less than 100 periods of the modulating signal. However, in cases where we perform frequency measurements in the presence of modulating signals, for which the averaging time should be eg 10 s or more, it is permissible to perform several measurements with a short averaging period, and then to recalculate the average value from the obtained results.

Measurement Procedure

In order to measure the operating frequency band in the basic band for VSAT satellite terminals, perform the following steps:

a) Turn on the power of the measuring instruments and leave them in this state for the time necessary to obtain the proper stability.
b) Set up the tested terminal on a laboratory stand in accordance with Figure 4, run the tested object in accordance with its instruction manual.

c) Switch off the positioning of the antenna system in the terminal.
d) Configure the tested terminal to work with the minimum available signal strength.
e) Set the transmitter frequency to the minimum frequency of the baseband in the tested terminal.
f) Using the spectrum analyzer, measure the center frequency of the signal from the transmitter.
g) Record (save) the result of the measurement.

Points e), f) and g) shall be performed for the maximum frequency of the transmitter in the baseband, respectively.

Display of Test Results

According to the EN 60835-1-2 standard: Methods of measurement for digital infrared radio transmission systems - Part 1: Measurements common to terrestrial radio-relay systems and satellite earth stations - Section 2: Basic characteristics (point 2.3) it is recommended that the measurement protocol be a manual or automatic recording of the digital frequency meter's indications as a function of time. It is also recommended to register the counting period and accuracy of the digital frequency meter. In the case of the result obtained as averaging over several readings, it is recommended to include in the form of a table subsequent readings along with the calculated average value. The measurement accuracy can be expressed as an absolute value, e.g. 50 kHz, or as a relative value, e.g. 10-5. It is recommended that the nominal carrier frequency be saved as well.

EXTENDED MEASUREMENT UNCERTAINTY

When measuring the operating frequency range in baseband for VSAT satellite terminals, estimating measurement uncertainty is a fairly complex element. The total uncertainty budget of the measurement includes components that are associated with various elements of the measurement path. Table 1 presents the components included in the uncertainty budget and how to estimate the expanded measurement uncertainty for the laboratory stand in question.

The extended value of measurement uncertainty for individual frequency ranges is determined from the relationship $f_0 \pm 2 * 10^{-7}$. For example, for a frequency of 14 GHz, the result with extended measurement uncertainty is 14 GHz $\pm 2 * 10^{-7}$.

MEASUREMENT RESULTS

In order to show the practical application of the developed method of measuring the operating frequency range in the base band for VSAT satellite terminals, measurements were carried out for the PARADISE DATACOM PD10L satellite terminal.

The device under test includes the Paradise Datacom modem, the Prodelin 1134 antenna and the BUC NJTS017L transmitter. During the measurements in the Paradise Datacom modem, the SCPC mode was set and the limiting

Table 1. Sample human systems integration test parameters Uncertainty of measuring the maximum harmonics level for satellite terminals.

The component of measurement uncertainty	X_i	Uncertainty x_i			$u(x_i)$	c_i	$c_i u(x_i)$	$(c_i u(x_i))^2$
	–	Hz	Probability distribution function		Hz	–	Hz	
			shape	k =				
Frequency measurement stability	f_0	$1*10^{-7}$	normal	2	$2*10^{-7}$	1	$2*10^{-7}$	$4*10^{-14}$
							$\sum (c_i u(x_i))^2$	$4*10^{-14}$
							$\sqrt{\sum (c_i u(x_i))^2}$	$2*10^{-7}$
Extended uncertainty				k = 2	$u_c(x)$			$2*10^{-7}$
Determined extended measurement uncertainty								$2*10^{-7}$

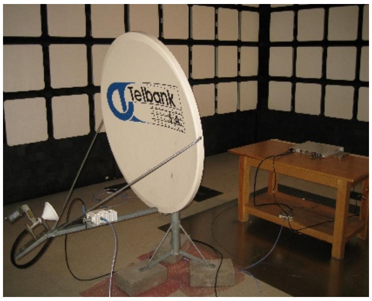

Figure 5: Satellite terminal type PARADISE DATACOM PD10L.

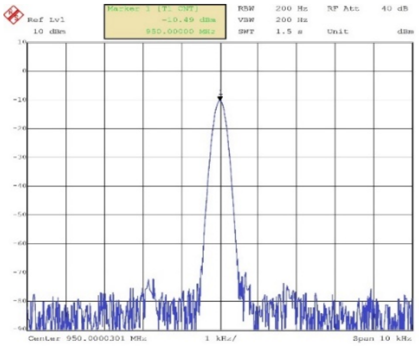

Figure 6: Frequency spectrum near the bottom frequency of 900 MHz from the bandwidth range L for the Paradise Datacom mode.

frequencies in its band L range defined in the NO-58-A217:2009 standard were set. The frequency range for the tested modem in the L band is 950 MHz - 2000 MHz. The appearance of the tested satellite terminal is shown in Figure 5.

Below in Figure 6 and Figure 7 are presented the results of measurements of the operating frequency band in the basic band for VSAT satellite terminals for the PARADISE DATACOM PD10L terminal containing the Paradise Datacom modem.

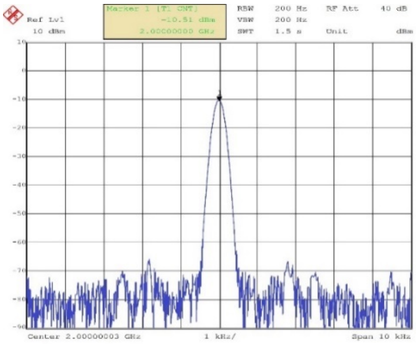

Figure 7: Frequency spectrum near the upper frequency of 2000 MHz from the bandwidth range L for the Paradise Datacom modem.

CONCLUSION

The article presents a laboratory stand and a method for measuring the operating frequency in the basic band for VSAT satellite terminals, which was developed on the basis of European civil standards and a military standard containing requirements on the operating frequency in the basic band for VSAT. In the case of measuring the operating frequency in the basic band for satellite terminals of the tested device, we must remember to estimate the uncertainty of the measurement. The extended value of the uncertainty of measurement for individual frequency ranges is determined from the $f_0 \pm 2 * 10^{-7}$ relationship. For example, for 14 GHz frequencies, the result with an expanded uncertainty of measurement is 14 GHz $\pm 2 * 10^{-7}$.

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