International Telecommunication Union

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Use of very small aperture terminals (VSATs)

S Series

Fixed satellite service

International Telecommunication Union

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R S.2278

Use of very small aperture terminals (VSATs)

(2013)

TABLE OF CONTENTS

Page

1 Introduction

This Report provides a normative base describing technical and operational characteristics for very small aperture terminals (VSAT) networks. Among the topics included are features of VSAT operation, VSAT networks topologies, and control and monitoring functions.

It is emphasized that VSATs, while in motion (e.g. on board vessel, on land vehicle and on board aircraft), are not encompassed by this Report.

2 Characteristics of VSATs

2.1 Overview

VSATs could be described as earth stations that share satellite resources among a large number of similar terminals. Individual VSAT terminals typically have small aperture sizes, transmit at relatively low equivalent isotropically radiated power (e.i.r.p.) levels, and use relatively small equipment that allows flexible installation of a satellite network earth station directly at a wide variety of user locations and platforms.

Technical and operational characteristics of VSATs are provided below.

2.2 Operational characteristics of VSATs

Some of the advantages of VSAT operational characteristics are:

– local supervision of the terminal is not required;

– allows for efficient use of shared satellite resources;

– performance of the station is remotely monitored by a VSAT network control centre;

– deployment in a geographical area without restrictions on installation density;

– so as to ensure the VSAT is operating with the correct satellite and frequency, the VSAT transmitter can only be enabled after having received authorization to do so via a signal from the VSAT network control centre.

As a consequence of these characteristics, many administrations around the world allow blanket licensing or simplified licensing procedures to allow quick deployment and easy operation of VSAT networks.

2.3 Technical characteristics of VSATs

Technical characteristics of VSATs are:

– while most VSAT networks make use of a star topology where a large hub is at the centre of the star which communicates with remotes, other topologies are possible (see § 3);

– dynamic assignment of satellite capacity to accommodate variable demand by a VSAT;

– capability that allows compatibility with closely spaced satellites;

– capability of VSAT to dynamically adapt to changing channel conditions in order to improve link reliability by manipulation of the station's characteristics such as signal parameters, data rate and power;

– typically designed so as to be able to carry TCP/IP traffic. The VSAT may also be designed to carry other multimedia applications;

– may make use of air interfaces appropriate for satellite communications (DVB-S2, DVB-RCS, etc.) which allow very diverse coding and modulation techniques corresponding to the most effective information technologies;

– typically operated in the 4/6 GHz, 11-12/14 GHz and 20/30 GHz frequency bands (see § 2.4);
– suitable for applications involving frequent relocation given the developments in control and monitoring functions.

2.4 Antenna diameters

VSATs are generally distinguished from the other types of earth stations by the use of smaller antenna apertures, which are nonetheless capable of operating with closely spaced satellites. They are most often designed to operate in the 6/4 GHz, 14/11-12 GHz and 30/20 GHz frequency bands. The actual values of their antenna diameters might vary based on the standards of regional or national regulatory bodies (TIA, ETSI, etc.), satellite spacing and coordination agreements reached with adjacent satellite operators.

NOTE – For example, the ETSI standards EN 301 459 or EN 301 428 state that apertures for VSATs should not exceed 3.8 m for the 14/11-12 GHz band and 1.8 m for the 30/20 GHz band or corresponding equivalent diameters in case of non-circular apertures. In these cases, the equivalent diameter can be calculated using the equation in Recommendation ITU-R S.1855.

2.5 ITU-R Recommendations concerning technical and operational characteristics for VSATs

VSATs should meet the technical and operational characteristics described in ITU-R Recommendations, summarized in Table 1.

TABLE 1

ITU-R Recommendations for technical and operational characteristics of VSATs

a) General technical and operational characteristics

ITU-R Recommendations for VSATs	ITU-R Recommendations for FSS earth stations including VSATs	Comments
S.725		This Recommendation defines that VSAT technical parameters should comply with Recommendations ITU-R S.726, ITU-R S.727 and ITU-R S.728. The monitoring and control functions of VSAT networks should comply with Recommendation ITU-R S.729.
	S.1709	This Recommendation proposes air interface characteristics which can be used as guidance for designers of broadband satellite networks (BSN) including summaries of TIA-1008-A, DVB-RCS (ETSI EN 301 790) and ETSI BSM/RSM-A.
	S.1782	Technical and operational requirements for VSAT and USAT earth stations have been determined, including HDFSS, for global broadband Internet access (USAT – ultra-small aperture terminal).

TABLE 1 (*continued*)

ITU-R Recommendations for VSATs	ITU-R Recommendations for FSS earth stations including VSATs	Comments
	S.1783	This Recommendation presents the technical characteristics of the existing and planned HDFSS networks. Technical characteristics are provided in the form of an EXCEL database for systems employing geostationary satellites.

b) Antenna/Radio frequency characteristics

ITU-R Recommendations for VSATs	ITU-R Recommendations for FSS earth stations including VSATs	Comments
S.728	S.524	These Recommendations provide requirements for maximum permissible level of off-axis e.i.r.p. density: – in any direction within 3° of the GSO in the 14 GHz band and for the cross-polarized component (Rec. ITU-R S.728); – for 2.0-2.5° or more off the main lobe axis of the earth station antenna in any direction within 3° of the GSO in the 6 GHz, 14 GHz and 30 GHz bands (Rec. ITU-R S.524). For VSATs transmitting in the 14 GHz band, Recommendation ITU-R S.728, which is 6 dB more rigid than Recommendation ITU-R S.524, should be used.
S.726		This Recommendation provides maximum permissible level of spurious emissions outside the band allocated to the FSS (Earth-to-space) within which the VSAT operating frequency is assigned, such that the off-axis spurious e.i.r.p. from VSATs shall be below the provided limits for off axis angles greater than 7°, and inside the band allocated to the FSS (Earth-to-space) within which the VSAT operating frequency is assigned.

TABLE 1 (*continued*)

ITU-R Recommendations for VSATs	ITU-R Recommendations for FSS earth stations including VSATs	Comments
	SM.329 SM.1540 SM.328	These Recommendations provide requirements for unwanted emissions in the spurious domain and in the out-of-band domain. NOTE – While applying Recommendations ITU-R SM.329 and ITU-R SM.1540, Recommendation ITU-R SM.328, which gives definitions, analytical models and other considerations of the values of emission components for various emission types as well as the usage of these values from the standpoint of spectrum efficiency, should be taken into account.
S.1844	S.731	These Recommendations address requirements for a reference cross-polarized radiation pattern for the earth-station antenna. It may be useful for coordination studies and for the assessment of mutual interference between radiocommunication satellite systems and between earth stations of such systems and stations of other services sharing the same frequency band. For VSATs, Recommendation ITU-R S.1844 should be used.
	S.1855 S.465 (Note)	These Recommendations provide reference radiation patterns for earth station antennas in the frequency range from 2 to 31 GHz which may be utilized for coordination and/or interference assessment between systems in the FSS. Recommendation ITU-R S.465 may be used for circular antennas while Recommendation ITU-R S.1855 may be used both for circular and non-circular antennas.
	S.580	This Recommendation provides the design objectives of new symmetric aperture antennas such that the gain (*G*) of at least 90% of the side-lobe peaks does not exceed the provided limits.

TABLE 1 (*continued*)

ITU-R Recommendations for VSATs	ITU-R Recommendations for FSS earth stations including VSATs	Comments
	S.732	This Recommendation provides the method for statistical processing of earth station antenna side-lobe peaks to determine excess over antenna reference patterns and conditions for acceptability of any excess.
	S.1428	This Recommendation provides reference FSS earth station radiation patterns for use in interference assessment involving non-GSO satellites in frequency bands between 10.7 GHz and 30 GHz. The reference antenna pattern covers all off-axis angles from 0° to ±180° in all planes which include the principal axis.
	S.1594	Maximum emission levels and associated requirements of high density FSS (HDFSS) earth stations have been provided for earth stations transmitting towards geostationary FSS space stations in the 30 GHz range. This Recommendation should be used for carrying out sharing studies between HDFSS earth stations and other services.

NOTE – Recommendation ITU-R S.1855 should be used as a reference antenna radiation pattern since it would result in improved sharing conditions by minimizing the interferences to adjacent GSO FSS networks.

c) Protocol

ITU-R Recommendations for VSATs and ITU-T Recommendations	ITU-R Recommendations for FSS earth stations including VSATs	Comments
	S.1711	Various techniques collectively referred to as “TCP performance enhancements” were developed in order to overcome some shortcomings of the transmission control protocol (TCP) when used in satellite networks.
	S.1061	This Recommendation presents an overview of strategies and countermeasures for rain attenuation in the satellite link in the FSS, to provide high-speed multimedia services in Ku- and Ka-bands.

TABLE 1 (*end*)

ITU-R Recommendations for VSATs and ITU-T Recommendations	ITU-R Recommendations for FSS earth stations including VSATs	Comments
ITU-T I.571		This Recommendation describes different interconnection scenarios between VSATs based on private networks and public ISDNs, and specifies the requirements that VSATs should satisfy when connecting to the public ISDN.
ITU-T I.572		This Recommendation covers the technical functional requirements for the interconnection of VSAT networks to the national telephone networks.

3 Topologies of networks with VSATs

There are several topologies of networks with VSATs as discussed below. The difference in network topology may affect the control and monitoring function of VSATs.

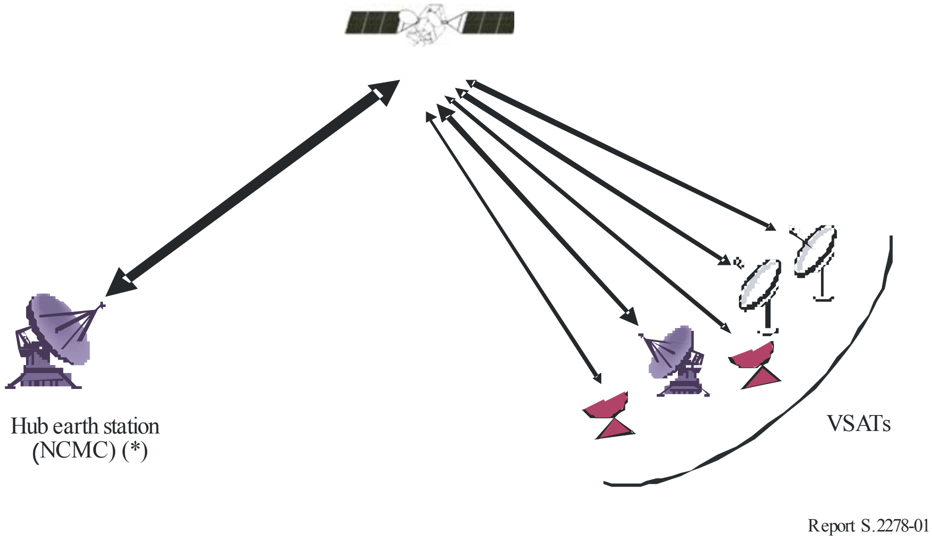
3.1 Star type topology

In this topology, there is a “hub” earth station where the user traffic from a group of VSATs is concentrated and which assumes control of the VSATs, as depicted in Fig. 1. However, more than one hub earth station may be utilized in the network for redundancy purposes (i.e. primary and backup hub earth station). When communicating between VSATs, the “double hop” path must be employed (order 2N latency).

In many cases, the frequency spectrum is shared between VSATs based on a demand driven protocol. The transmission speed of outbound (i.e. hub to VSAT) and inbound (i.e. VSAT to hub) traffic is often asymmetric for such networks in order to avert bottlenecking of data traffic at the hub. It should also be noted that VSATs with different characteristics (i.e. antenna diameter, transmission power and so forth) may operate in the same network.

FIGURE 1

Star type topology



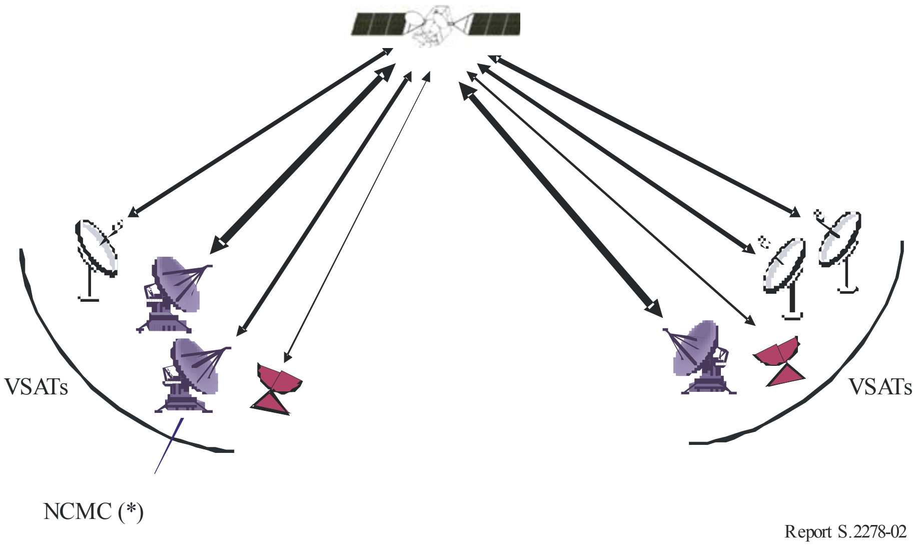
(*) There may be more than one hub earth stations in the network (i.e. primary hub earth station and backup hub earth station).

3.2 Mesh type topology

In this topology, a group of VSATs can communicate with each other without involving a hub earth station (i.e. "single hop" connection) as depicted in Fig. 2 (order N latency). There is a network control and monitoring centre (NCMC) earth station (or more than one NCMC earth station in redundancy) for management and control of the group of VSATs. Yet the user traffic need not be concentrated to the NCMC earth station. In many cases, the frequency spectrum is shared between VSATs on demand basis. The transmission speeds may vary from station to station independent of type. It should also be noted that VSATs with different characteristics (i.e. antenna diameter, transmission power and so forth) may operate in the same network.

FIGURE 2

Mesh type topology



(*) There may be more than one NCMC in the network (i.e. primary NCMC and backup NCMC).

3.3 Hybrid topology

A network with a hybrid topology uses characteristics of both star and mesh topologies. For example, depending on the number of stations in the network, it may be more efficient to have the edges of the network use a star topology while connecting the "centres" of the stars by means of a mesh network.

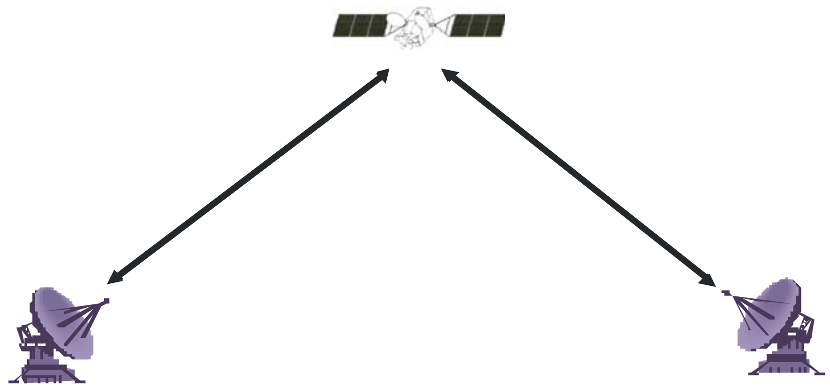
NOTE – Any combination of topology and multiple access may be used in VSAT networks.

3.4 Point-to-point topology

In this topology, only two earth stations on a point-to-point connection are associated as depicted in Fig. 3. Either one end or both ends of the connections are VSATs. Basically, the frequency spectrum is not shared but dedicated to the connection and VSATs operate in stand-alone mode without control by other earth stations. However, one earth station plays a role of "master" earth station that controls the other earth station ("slave") in some cases.

FIGURE 3

Point-to-point topology



(*) Either one end or both ends of the point-to-point connection are VSATs.

4 Features of operation of VSATs

In association with the combination of network topologies mentioned above, the following elements are described in this section:

i) initialization of the operation of a VSAT;

ii) control and monitoring functions during the operation of a VSAT;

iii) other control and monitoring functions (management of the profiles of VSATs (location, satellite beam contour and beam handover), dynamic power control function during the operation of a VSAT and adaptive coding and modulation (ACM) function).

4.1 Initialization of the operation of a VSAT

When a VSAT is powered on, its operational status is assessed by both the NCMC as well as the command processor on the terminal. The VSAT transmission is enabled when the following conditions are met:

i) the VSAT determines that it is correctly receiving and interpreting a specified command signal generated by the NCMC;

ii) the VSAT confirms that no faults have been detected that could result in harmful interference;

iii) the initial transmission parameters such as frequency, power, modulation, timing and coding schemes and so forth are in compliance with expected performance.

Conditions i) and iii) are not applicable in a point-to-point topology when a VSAT operates in a stand-alone mode.

In determining the initial transmission parameters of a VSAT, the NCMC may take into account some of the following profiles:

– geographical location of the VSAT (to establish transmission timing, propagation loss and if the terminal is authorized for operation at that location);

– satellite gain in the direction of the VSAT (to determine transmission power towards and from the VSAT);

– local rain statistics;

– service subscription profiles of the VSAT (e.g. maximum transmission speed of outbound/inbound direction);
– the current number of terminals already authorized or currently in operation (to prevent overloading of satellite resources).

4.2 Control and monitoring functions during the operation of a VSAT

During its operation, the VSAT is continuously assessed by the NCMC and its own command processor for correct operation, and it is usually possible for the NCMC or an equivalent facility to monitor the health of a VSAT and to determine if a VSAT has failed.

The VSAT should cease its transmission when one of the following events occurs:

i) the VSAT loses the control carrier from the NCMC;[1]

ii) the VSAT detects a fault that could result in harmful interference being produced;[2]

iii) a command is received from the NCMC that directs the VSAT to change the transmit frequency;[1]

iv) the angle between the orbital location of the target satellite and the axis of the main lobe of the VSAT antenna exceeds allowed limits;

v) the VSAT has been relocated to a geographic area where it does not have administrative permission to operate.

The VSAT may resume transmission once the issue that caused the shutdown as listed above has been cleared. However, a VSAT network with "point-to-point topology" and stand-alone VSAT operation may continue transmission after its local malfunction is cleared without receiving the carrier from the other VSAT because otherwise the network will never restore after rain fades if both sides stop transmission.

In addition, the VSAT should accept the commands for "enable transmission"/"disable transmission" from the NCMC or an equivalent facility (e.g. in a case of emergency).

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[1] In a point-to-point topology, when a VSAT operates in a stand-alone mode, this condition is not applicable. But, when one VSAT plays a role of "Master", this condition may be applied.

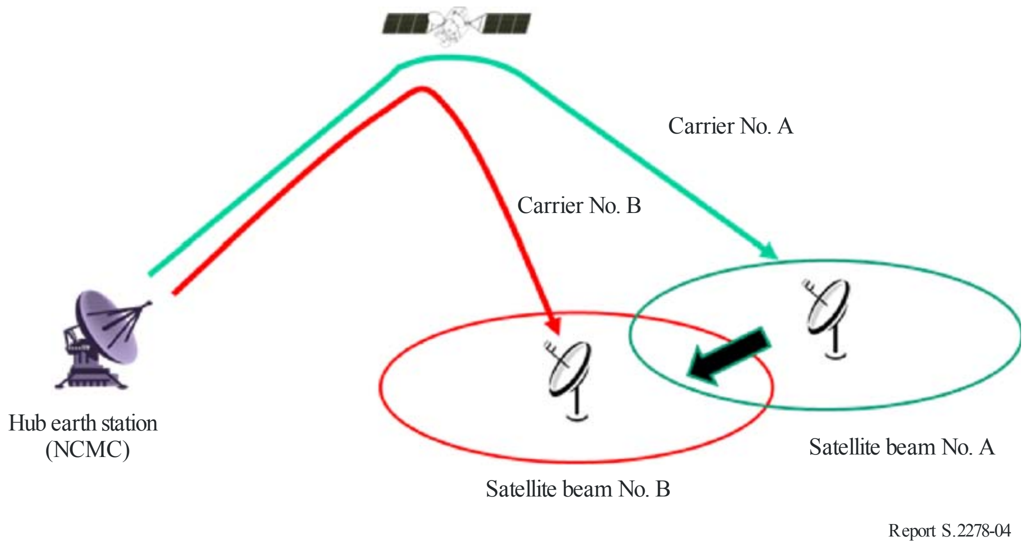
[2] Some faults that do not impact RF performance should not result in the disabling of the transmitter.

4.3 Other control and monitoring functions

4.3.1 Management of the profiles of VSATs (location, satellite beam contour and beam handover)

FIGURE 4

Management of the profiles of VSATs



For some types of VSAT, it may be useful for the NCMC to continuously manage the profiles of the VSAT such as geographical location and satellite beam contour since they may vary during its operation.

If such a VSAT is relocated from one satellite beam to another, the commands from the NCMC direct the frequency and power in the new satellite beam in the manner described in condition iii) in § 4.2. For example, if the VSAT is relocated from satellite beam #A to satellite beam #B as shown in Fig. 4, it ceases its transmission when the VSAT is located at the edge of satellite beam #A. Subsequently, it may search and acquire the carrier from the NCMC in satellite beam #B and start its transmission. Alternatively, in order to minimize the service interruption due to the relocation, it may lock to the carrier in satellite beam #B before the carrier is reassigned from beam #A.

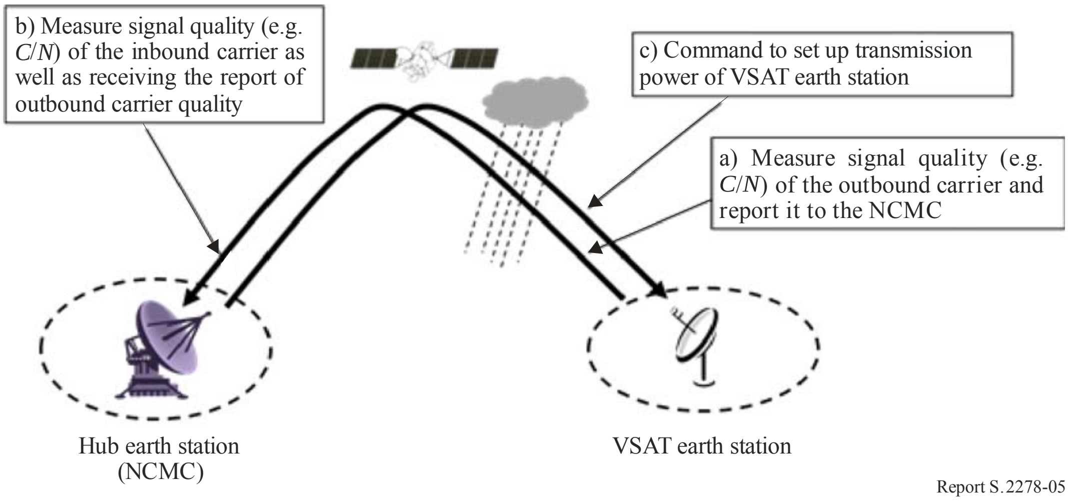
4.3.2 Dynamic power control function during the operation of a VSAT

In order to achieve the efficient use of transmission power of satellites and VSATs, dynamic power control mechanisms may be employed.

Figure 5 shows an example of dynamic power control of a VSAT (in star topology). In this example, it is assumed that the uplink power of the hub earth station has already been properly adjusted in advance. The VSAT periodically measures the signal quality (e.g. C/N) of the outbound carrier and reports it to the NCMC. The NCMC determines the transmit power requirement of the VSAT based on the quality report from the VSAT and its own measurement on the signal quality of the inbound carrier and command it to the VSAT accordingly. The VSAT will then carefully adjust its transmit power in order to avoid excess power emission.

FIGURE 5

Example of dynamic power control (in star topology)



4.3.3 Adaptive coding and modulation function

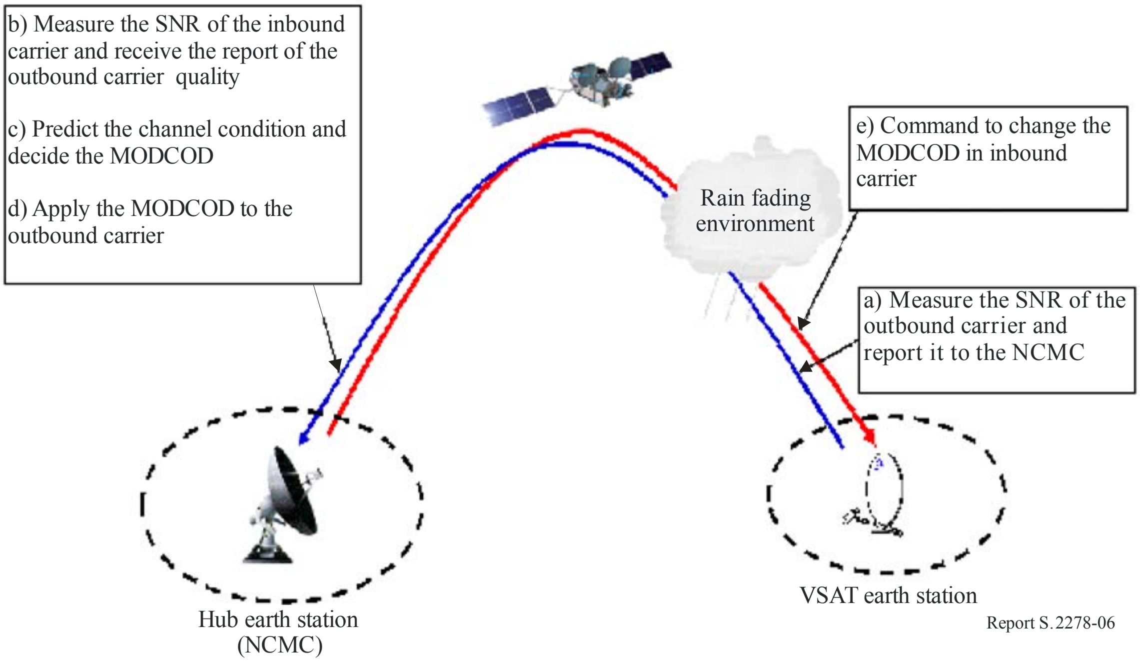
In order to improve the link availability and spectral efficiency, the ACM function may be effective in a VSAT system. With ACM, a VSAT system can change its modulation and coding (MODCOD) rates adaptively depending on the channel condition. In clear sky conditions, a spectrally efficient MODCOD (e.g. 16APSK 4/5 FEC) is used, and in rain fading conditions, a more power-efficient MODCOD (e.g. QPSK ½ FEC) is used.

In order to implement adaptive rain fade compensation according to the channel conditions, it is required to predict the channel condition. For this purpose, an ACM control algorithm may also be combined with a dynamic power control algorithm. The detailed ACM control algorithm is provided in Recommendation ITU-R S.1061.

Figure 6 shows an example of ACM of a VSAT (in star topology). In this example, the VSAT periodically measures the SNR of the outbound carrier and reports it to the NCMC. Also the NCMC measures the SNR of the inbound carrier and predicts the channel condition based on Recommendation ITU-R S.1061. The NCMC determines the modulation schemes of the outbound and inbound carriers and finally changes its own MODCOD adaptively. Then, the NCMC commands the VSAT to change the MODCOD. When implementing the ACM function, it should be taken into account that the MODCOD needs to be carefully adjusted in order to prevent packet loss caused by unwanted oscillation in choice of the MODCOD.

FIGURE 6

Example of adaptive coding and modulation (in star topology)



5 Conclusion

This Report may be used as a guide for e.g. manufacturers, operators and regulators involved with building, using or authorizing VSAT networks.

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