IAC-11.B6.2.4

THE EUROPEAN DATA RELAY SYSTEM (EDRS): OPERATIONAL CHALLENGES

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This paper will illustrate the challenges and preliminary solutions in operating the EDRS constellation.

The EDRS network will include two communication payloads, one hosted on a dedicated spacecraft and one as piggy-back on a commercial satellite. The two satellites will be positioned in geosynchronous orbit to provide near-global coverage for satellites in low earth orbit (LEO). EDRS is designed to reduce time delays in the transmission of large amounts of data and to allow faster access for the end users. This is achieved by using an optical Laser Communication Terminal (LCT) for the link between the LEO and the EDRS payload and a Ka-band link between the EDRS payload and the ground. The latter will be established via three dedicated feeder link ground stations in Europe from where the data is distributed to the users. The users may also use their own ground stations to receive the data directly.

By using the EDRS infrastructure extended capabilities for TM/TC operations will be possible with LEO satellites. This will enable short-time changes to the payload timeline and better reactions to anomalies while optimizing the number of necessary ground stations.

DLR with its German Space Operations Center (GSOC) plays a major role in the EDRS operations. This role includes design, development and integration of ground infrastructure and operations of the satellites and ground stations.

The EDRS concept of operations differs from the conventional communication satellites. Two challenging new technologies will be integrated in order to provide faster data turnaround times and downlink capabilities of up to 1800 Mbit/s:

1. Laser-Optical Inter-satellite link: The large distance between a satellite in GEO and one in LEO makes the pointing of both laser terminals very difficult. Good attitude information and control of both satellites is required. A good quality orbit determination and time synchronisation is vital for good Laser acquisition times and both payloads need to keep accurately track of their fast moving counterparts. Thus, development of the operations concept requires consideration about establishing the interfaces and coordination of operations with the low flying satellites, which are operated by different control centres.

2. Ka-band downlink: The wavelength of the Ka-band signal leads to significant atmospheric and rain attenuation. Thus, requirements for ground stations (for front- and back-end) in terms of pointing accuracy and the specific hardware are very challenging compared to standard S/X/Ku-band ground stations. Careful consideration has to be taken designing the ground stations and during link establishment and station operations.

I. INTRODUCTION

Observation and monitoring of the earth with satellites is an important source of information for various applications.

With the increase in numbers of satellites and the increase of sensor resolution onboard the satellites, the amount of data that has to be transferred from the satellites to the users of the data is increasing drastically. With the implementation of the joint European Commission/ESA Global Monitoring for Environment and Security programme (GMES) it is estimated that the Sentinel (-1, -2, -3) system will produce approx. 4 Terabytes per day (equivalent to a continuous downlink from space at 400Mbit/sec). Also, the users require near real time applications, which means availability of the data at the user in less than 3 hours after generation[1].

These requirements pose a great challenge to our present data transfer infrastructure. The conventional means of communication may not be sufficient to satisfy the quality of service required by users of Earth observation data[2], due to the following shortcomings.

- Conventional ground stations are only able to contact the LEO satellite when the spacecraft passes over the given station. Depending on the orbit and ground station location this might only happen 4 times within 24 hours. Also, the contact times are only in the order of 10 minutes per pass. Given these two factors, the amount of data that can be transferred e.g. per day is very limited and there may be a delay of various hours between the sensing and the availability of the data to the user.
- Commanding of the LEO satellites can only be performed when over a ground station. This implies that quick-reaction commanding is not possible for anomalies or payload operations.
- Given the typical nature of the orbit (often of a polar orbit type) these conventional LEO ground stations often end up in very remote areas. The data received at these premises also need to be transferred to processing and archiving centers before the end product can be made available to the end Users. These processing centers are usually located in more accessible areas with more established infrastructures[3].

These shortcomings could be overcome by the installation of a geostationary relay satellite with high data rates, such as EDRS, the European Data Relay System. GSOC is going to take over various roles in this mission which is the motivation for the considerations contained in this paper, that is structured as follows: Chapter II introduces the concept of a geostationary data relay for earth-orbiting satellites pointing out the advantages as compared to the conventional approach. Chapter III gives some information on the Laser Communication technology which will be used for the inter-satellite communication, while chapter IV contains a description of Ka-band technology which will be used for the space to ground communication. Finally chapter V explains the design and concept of the EDRS mission.

II. DATA RELAY CONCEPT

A schematic showing the concept of a geostationary data relay for earth observation data can be seen in Figure 1.

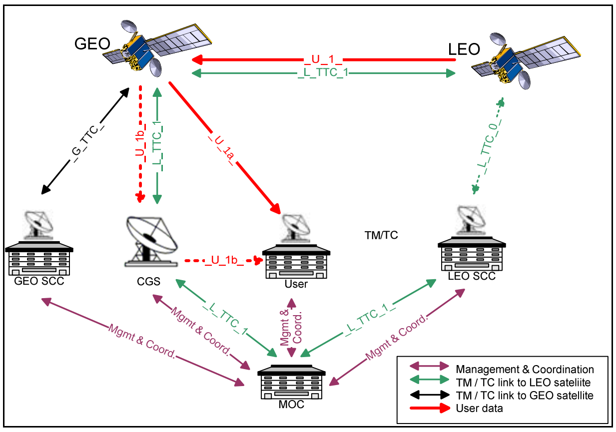

Fig. 1: Concept of a geostationary data relay for earth observation data.

II.I Components

The components of the system are described in the following sections.

Low-Earth-Orbiting satellite (LEO)

The LEO is typically an earth observation satellite carrying one or more instruments that generate user data which have to be transferred to ground. In the conventional approach the data is transmitted to ground through ground stations for example in X-band (not shown in Fig. 1). In the case of a relay satellite the LEO transfers the data to the GEO satellite (link “U_1” in red). Consequently the LEO has to be equipped with a high-data rate LEO to GEO communication device. In order to be able to transfer large amounts of data, at least two technologies might be used:

1. Optical Communication with a Laser Terminal (“Laser Communication Terminal”, LCT). Key

figures and operational aspects are described briefly in chapter III.

2. Radio-Frequency Communication in Ka-Band. This technology and related operations are described briefly in chapter IV.

Note: for the sake of clarity, only one LEO is shown. In fact, various LEOs may use the relay satellite either in parallel or one after the other depending on the technical implementation.

LEO Satellite Control center (LEO SCC)

The LEO satellite control center operates the LEO satellite. It is responsible for housekeeping and payload operations. Among these tasks is the correct pointing and activation of the LEO to GEO communication device. For a correct pointing of the communication device towards the GEO the GEO orbit has to be known to the LEO SCC.

Geostationary Relay satellite (GEO)

The GEO receives the user data from the LEO satellite and relays it to ground. For this purpose it needs a receiver, which is compatible with the terminal of the LEO. Therefore the same technologies come into consideration, namely LCT or Ka-band. As for the LEO, these devices are usually steerable and have to be pointed towards the LEO, depending on the used technology.

To complete the relay function, the GEO needs a high data rate terminal to send the data to ground. The technology that can be used for this purpose is not dependent on the LEO to GEO link. Usually Ka-band is used. The space to ground beam for a geostationary satellites may cover a very large portion of the earth which enables various ground stations spread over large distances to receive the data in parallel (link U_1a and U_1b in red).

GEO Satellite Control center (GEO SCC)

The GEO satellite control center operates the GEO satellite. It is responsible for housekeeping and payload operations. Among these tasks is the correct pointing and activation of the receiver. In order to correctly point the receiver to the direction of the LEO, the LEO orbit has to be known to the GEO SCC.

User Center

In the user center the data generated by the user platform aboard the LEO is processed. The data may be received at the user center directly with the user ground station (link U_1a) or from a central ground station from which it is transferred via conventional telecommunications infrastructure to the user (link U_1b).

Central Ground Station (CGS)

The central ground station receives and stores all data from all users. This enables checking of the correct execution of the data relay and storage of all data. Also, if a user does not have his own ground station, the user data may be transferred from the CGS to the user using conventional telecommunications infrastructure.

Mission Operation Center (MOC)

The MOC is the core component in the system. It interfaces with all other components and coordinates them. Its main purpose is to receive all the link requests from the different users and generate a link session timeline taking all known constraints into account. In addition it monitors and controls all involved infrastructure.

II.II Link Session Process

In the preparation of the TDP#1 mission (see chapter III.III) GSOC developed a concept for the link session process. Adapted to the definitions as laid down in Figure 1, this process is as follows:

1. The GEO SCC and LEO SCC send information required for planning to the MOC, which is at least:
    a. The times where no links are possible because of other operations
    b. Orbit information
    c. Other constraints
2. The MOC calculates the possible link times between the GEO and the LEOs and distributes this information to all users. The inputs received in 1) as well as any other possible constraints are the basis for this calculation.
3. The users request their preferred links at the MOC
4. Based on all available information, the MOC plans the links.
5. The information to establish the links from the GEO to the LEO is sent to the GEO SCC and the information to establish the links from the LEO to the GEO is sent to the LEO SCC. This information contains as a minimum:
    a. Terminal configuration commands, e.g. heater activations, mode configuration
    b. Exact time of link establishment and termination
    c. Orbit information of counterpart
6. From the inputs received from the MOC, the GEO SCC and the LEO SCC calculate parameters that have to be sent to the spacecraft (e.g. pointing angles of the terminal, time-tag times…). With this information the satellites can be commanded to establish the link.
7. The link is established and the data is transferred from the LEO via the relay to ground.
8. The success of the link session is evaluated.

II.III Functionalities

The system as shown in Fig. 1 is able to provide the following functions.

Longer and more frequent data reception times

Data can be received whenever there is visibility between the LEO and the GEO satellite. The GEO has a visibility of roughly half of the earth's surface (depending on the Field of view of the Inter-Satellite-Link (ISL) terminal). Consequently, the average visibility per orbit between the GEO and a LEO shows to be around 40 minutes which is roughly half the orbit duration of usual LEO orbits[1].

This number has to be compared to the average contact time per orbit when using conventional ground stations. A typical ground station pass lasts approximately 10 minutes. With a polar ground station one contact per orbit can be achieved. This gives the relay system an advantage of a factor of four. In case no polar station is used, the advantage of the relay system is even higher since there are less ground station contacts in a given time period. An additional benefit is that on-board memory capacity can be smaller if the data can be downloaded directly after the data take.

Transfer of user data from LEO via GEO directly to the users

One big advantage of the concept is that a user can decide to receive the data directly from the GEO satellite. This is schematically shown by the links U_1 and U_1a (in red). In this case the user needs his own data receive station which ideally is collocated with the data processing center. Transfer of data from remote ground stations (often polar ones) to the users is obsolete.

Since the user data is transmitted through a beam covering a large area (e.g. whole Europe), it is also possible to send the data directly to various users.

Transfer of user data via CGS to the user

A central ground station (CGS) may be implemented which receives all user data from all users. If an user opts to rather not have his own receiving station, the user data may be obtained from the CGS (links U_1 and U_1b in red) using conventional telecommunications infrastructure. Since the CGS is usually located in a facility with existing telecommunications infrastructure, the transfer of data to the user is usually less expensive than the transfer from a conventional ground station located in a remote region.

Completion of lost user data

If the data received at the user station is incomplete or corrupted, the user can request to complete the data with the data received at the CGS. This possibility enhances the availability of the data.

LEO satellite control using the relay

In addition to the use for payload data transfer as described above, the relay can also be used for LEO TM/TC activities. If the LEO is appropriately equipped, the increased contact possibilities (see above), can also be brought to use for the LEO SCC (link L_TTC_1 in green). For example short-time changes to the payload timeline and better reactions to anomalies while reducing the number of conventional TM/TC ground stations are possible.

III. LASER COMMUNICATION TERMINAL (LCT)

III.I Technology

The LCT being used on TerraSAR was developed by TESAT Spacecom of Germany with funding by the German Space Agency DLR. It was designed with the goal of a high-rate data transfer from space to space and space to ground. Data rates of 5.625 GBit/s have been successfully demonstrated between the NFIRE and TerraSAR-X satellites. The distance between these satellites was 1000 km to 5000 km. The key figures for the LCTs which were verified in orbit are as follows[4]:

Mass:	35kg
Power:	120 W
Dimension:	0.5x0.5x0.6 m^3
Telescope diameter:	125 mm
Max Optical Transmit Power:	0.7 W
Bit Error Rate:	$< 10^{-9}$
Link Distance:	1000–5100 km
Link Duration	< 8 min
Data rate:	5.625 GBit/s

Table 1: Key LCT parameters

For the concept as described in chapter II, the LCTs have to be modified such, that large communication distances (45000 km) as required for the LEO to GEO communication are possible. Data rates of 1.8 GBit/s are targeted for this distance.

III.II TerraSAR-X

GSOC became involved in LCT operations for the first time with the program TerraSAR-X, which hosted a Laser Communication Terminal as a secondary Payload. A second LCT is flying onboard the US satellite NIFIRE. GSOC is the operator of the TerraSAR-X and also commanding the LCT.

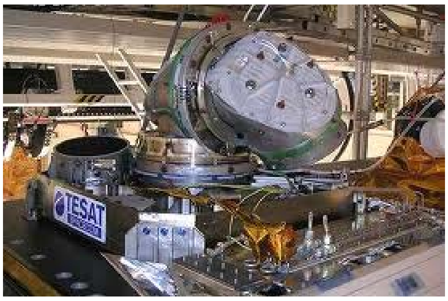

Fig. 2: LCT during the integration

The TerraSAR LCT is designed for two types of contacts, a satellite to ground link and Inter-Satellite-Links. As the objective in this case is test and evaluation of LCT operations the responsibilities are divided between GSOC as the satellite operator and the LCT manufacturer TESAT. In case of a space- to-ground-link (SGL) the input for the links comes from TESAT based on the location of the optical ground terminal, which is mobile. GSOC then coordinates the uplink-times for the commands and prepares the command files to configure the LCT. This involves ensuring the correct operating temperatures, commanding it out of "standby" to "ready mode" and loading the pointing information for the acquisition and tracking. TESAT then delivers files to configure the LCT internally, meaning setting bandwidths for acquisition scans, receiving signal strengths etc. After an experiment GSOC then dumps the generated science data and forwards them to TESAT for evaluation. GSOC verifies that the hardware functions were correctly executed e.g. temperature, heat pipes and returning to park position after the link.

In the case of the ISLs the NFIRE operator provides GSOC with a list of link possibilities and GSOC selects after consulting TESAT the favorable links and provides this feedback to NFIRE. From that point on the activities are the same as in case of a SGL. TESAT provides the configuration files also to the NFIRE operator Orbital.

As the LCT on TerraSAR-X was classified as a secondary payload, it was assumed by the mission control team, that efforts to operate the terminal would be negligible and that there would be no interference to the main payload. Therefore the LCT payload was e.g. not integrated into the TerraSAR-X Mission Planning System (MPS). But mechanical issues required more operational attention than anticipated and a timing issue caused us to coordinate corrective actions closely with the primary payload operations. The timing problem could be solved and de-coupled from the rest of the spacecraft by several software uploads. Overall timing crystallized as one of the more crucial aspects of operations. The Laser terminals have their own timing device that tends to drift from the onboard clock. On TerraSAR-X a time synchronization was required every third day at the beginning of the mission, until a software upload adjusted the drift and corrective action is only occasionally required.

III.III Technology Demonstration Program 1 (TDP#1)

TDP#1 is an experimental mission being the proof of concept of a relay for earth observation data from LEO spacecraft via a GEO satellite using LASER as a transfer media. It is considered a precursor mission to the European Data Relay System (EDRS) project. The TDP#1 payload hosted on a geostationary satellite consists of a laser communication terminal, mainly for the inter-satellite-link to a low earth orbiting spacecraft, but also capable of contacting a laser terminal on ground as well as a Ka-Band payload for the data downlink from the geostationary satellite.

The participating agencies are the German Aerospace Center DLR as the contracting entity or customer, with its institutes GSOC and DFD, the European Space Agency, INMARSAT and TESAT.

In detail ESA hosts the laser terminals on their Sentinel 1A and 2A satellites with the European Space Operations Center (ESOC) serving as the LEO SCC for all spacecraft operations including the LCT.

INMARSAT will provide the platform for the geostationary relay with their ALPHASAT satellite, acting as the GEO SCC except for TDP#1 related operations.

The German Remote Sensing Data Center (DFD) operates the Ka-Band receive antenna and disseminates the data, equivalent to a CGS.

The GSOC will be involved in various functions. First, as the operator of the TDP#1 instrument it is an extension of the GEO SCC. GSOC is responsible for generating all LCT related operational products for INMARSAT and monitoring of the instrument. Second, by coordinating the inter-satellite links together with ESA, GSOC fulfils in part the role of a MOC.

In the background TESAT, as the LCT manufacturer, will provide ESOC and GSOC with LCT configuration files whenever necessary.

The main task at GSOC will be the development of a tool that automates all functions of the operations team, e.g.:

- collect the information from the Sentinel spacecraft concerning relay requests
- integrate possible constraints from the ALPHASAT satellite
- generate all products for INMARSAT to command the LCT
    - time of command uploads
    - time of actual data transfer

    - commands for instrument configuration
- notification of DFD about expected downlinks.

III.IV GSOC long-term goal/development

In the long-term, GSOC's goal is to develop a system that will offer future customers an End-to-End solution for data transfer. The customer will provide the data to be down linked to the LCT terminal onboard the originating spacecraft and GSOC will coordinate and execute all other activities to deliver the data to its final destination within the requested time span. This involves also supporting multiple LEO customers with a variety of requirements and interfaces at the same time. At latest at this time LCT operations will also need to find entry into the standard GSOC Mission Planning System. This would include operations of terminals on satellites operated by GSOC, as well as on satellites controlled by other centers. In this role GSOC would function as MOC, SCC or part thereof and operate the CGS, if so desired. Parts of these efforts will be used in the EDRS program as described in more detail in chapter V.

IV. KA-BAND TECHNOLOGY

IV.I GSOC Ground Station Heritage

The Weilheim Ground Station Complex was established in 1968 and has variety of ground station antennas and supporting infrastructure. The complex is located approx. 70 km southwest of Munich and provides communications for LEO, GEO and Deep space missions. The following ground station antennas are located on an area of approx. 0.15 km^2 at Weilheim/Lichtenau (Germany):

	Telemetry				Tracking				Command			
	S	X	Ku	Ka	S	X	Ku	Ka	S	X	Ku	Ka
15 meter	x				x				x			
15 meter	x				x				x			
30 meter	x	x			x	x			x			
11 meter			X				x				X	
9 meter	x								x			
13 meter[1]				x				x				X

Table 2: List of Weilheim ground station antennas

Although the ground station can support S-, X- and Ku-band frequencies, today the data flow between the satellites and Weilheim ground station is mostly done in S-band for TT&C and S/Ku-band for LEOP support. A full motion Ka-band antenna is under construction and is planned to support Ka-band payload IOT activities. The ground station provides support to LEO, GEO and Deep Space missions and is open for new missions and projects, which could also be Data Relay Ground Stations. All important equipment and components of each ground station antenna are controlled by DLR's self-developed Monitoring and Control System. The ground station is illustrated in Figure 3.

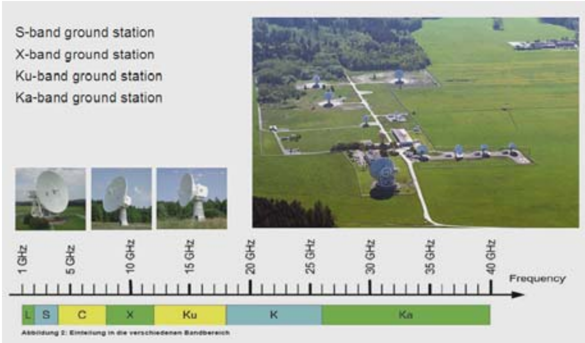

Fig. 3: Weilheim Ground Station Complex

The station uses standard baseband equipment for different antennas and applications. This concept has been realized by building up a pool of TTC baseband units, which can be connected to the different antenna- and RF-systems by means of a switch matrix. This solution allows flexible and cost-effective usage of equipment in conjunction with a high grade of redundancy.

IV.II Ka-band applications

Overview and advantages

Currently, there are several commercial satellite missions worldwide which provide high rate communication services at Ka-band frequencies (18-40 GHz) to various ground-based users. Putting in service higher frequencies allows several advantages. For example, Ka-band brings up to 600% link advantage over X-band. This advantage could be translated either into high data rate communication, longer distance of communication or smaller in size and therefore much more cost effective ground stations. Additionally, a smaller antenna beam of Ka-band ground station considerably reduces RF interference with other systems. In this respect, from one side the Ka-band technology is an inevitable part of the modern ground station complex which could be employed for future data relay satellites, but still a lot of effort is required to design, install and operate such a system.

Hardware problems and manufacturing challenges

Currently a 13-m Ka-band ground station is being constructed in Weilheim. In order to make use of the advantages of this new technology, one has to solve several problems. First problem is that commercially available components for Ka-band systems today are still limited in their performance, bandwidth, power and accuracy.

The following hardware and manufacturing problems seriously affect the performance of existing Ka-band systems:

- A lot of effort is required to assure high mechanical stability of the ground station
- Sophisticated tracking systems are required (feed system, antenna control unit, tracking receiver)
- Surface accuracy and gain stability (elevation, temperature and wind dependencies).
- Wideband systems are required
- Limited power of currently available Ka-band HPAs (High Power Amplifier)
- High Doppler shifts
- High data rate handling problems (modems, storage, communication lines)

Due to the small wavelengths (10-15 mm), Ka-band signals are very sensitive and the requirements to such systems are often driven by mechanical precision and sophisticated tracking and control sub-systems. Very often the requirements for such ground stations (for front- and back end equipment) in terms of pointing accuracy are extremely high. Pointing and tracking accuracy problems could be solved by solving several mechanical problems related to the antenna structure and by the use of high performance tracking systems, such as monopulse tracking. The mechanical problems are mostly affected by the soil characteristics, foundation dimensions, wind magnitude and direction, temperature, by antenna stiffness and by the use of high performance ACUs (Antenna Control Unit) which can correct the errors. Also the hardware shall support very high bandwidth and data rates. This makes the requirements to the specific Ka-band hardware very challenging compared to traditional S/X/Ku-band ground stations.

Operational challenges - atmospheric attenuation

It is well known that the radio signals of frequencies above 10 GHz all suffer from various limiting effects such as rain attenuation, scintillation and depolarization, which affect the satellite links significantly. Time varying random weather events, like rain and clouds, increase the moisture in the atmosphere and consequently the noise temperature and the attenuation. The major attenuation contribution at Ka-band frequencies is a rain fade, which seriously affects the link availability. To deal with this problem in a long term, there are various rain attenuation models, which have been developed by different authors. Most of these models are able to predict the stochastic fluctuation of the rain attenuation based on long-term statistics, which are successfully used within systems where a large fixed link margin is employed.

For the annual availability of 95%, the total attenuation due to atmospheric effects for frequencies between 26 and 30 GHz at an elevation angle of 10º in Weilheim is estimated to be 3.6 dB and 3.9 dB, respectively using ITU models.

The existing ITU models by their nature are limited in accuracy and cannot provide near real-time information about the attenuation. For real-time applications the open loop fade detection concept is used, which relies on the estimation of the link impairment from the measurements of propagation conditions.

A single detection source may not be accurate enough due to errors in the measurement. For example, in case of the observations of a beacon signal transmitted by the satellite repeaters, the measurements do not always provide reliable attenuation observations due to onboard instrumental drifts. Radiometric measurements on the other hand usually have a limited dynamic range and are therefore blind to rain scattering (approximately 20% of total attenuation) and tropospheric scintillation. Therefore, comparing and testing several measurements and estimation sources in parallel allows precise estimation and short-term (near real-time) prediction of atmospheric attenuation. This process is illustrated in Fig. 4.

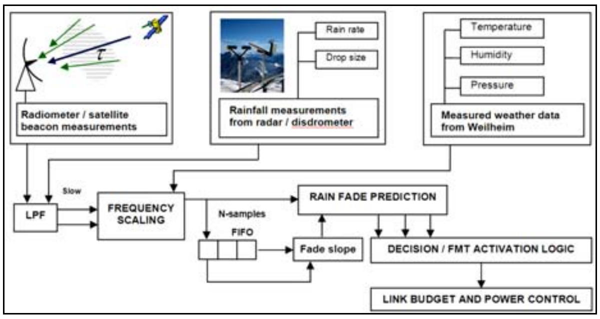

Fig. 4: Fade detection, processing, prediction and fade mitigation technique

The following detection methods can be used in parallel for Ka-band fade mitigation at DLR ground station[5]:

- Sky brightness temperature measurements collected by radiometer
- Fade measurements obtained by Ka-band satellite beacons
- Rain rate measurements obtained by means of disdrometer and radar

- Temperature, pressure, humidity and rain intensity measurements using a meteo-station.

Uplink power control, site diversity, variable coding and modulation – are the methods which could be used in order to cope with rain and atmospheric attenuation problems.

Operational Challenges - Scanning and tracking

Since the antenna's 3 dB beam-width in Ka-band becoming considerably narrow (for example 54 mdeg for a 13-meter antenna), it is becoming difficult to scan and track the satellites. Tracking accuracy is also often affected by weather. Different techniques are usually implemented within the antenna control unit, tracking receiver and feed system which allow accurate scanning and satellite tracking.

The purpose of a scanning is to find the direction of the satellite transmitter, which allows a ground station to acquire the satellite signal. Depending on the situation various signal scanning techniques are used: spiral scan, conical scan and combined methods.

Each of the scan methods has its parameters, like scan radius, spacing, slew rate, orientation. These parameters may vary depending on the mission requirements. The example of a typical spiral scan with its parameters is illustrated on the Fig. 5. When the satellite is scanned and its angular position is located, the ground station antenna will start the tracking process in order to keep precise pointing to the satellite.

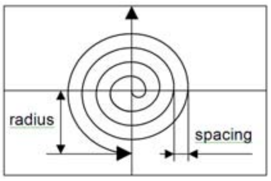

Fig. 5: Spiral scan

Depending on the particular requirements different signal tracking techniques could be used for Ka-band systems: monopulse tracking and program track.

Monopulse tracking is considered to be one of the most accurate tracking methods, but requires a complicated multimode feeds system design. With a wideband tracking receiver and monopulse feed system it is possible to use wideband signals transmitted by the satellite as reference for precise tracking - by closing the tracking loop. This tracking allows operation of the antenna autonomously in case that the orbital vectors are not available. One of the critical factors of this system is the minimum C/No – the ratio of carrier power to the noise power spectral density - that the tracking receiver is able to process[6].

With the programmed track approach, antenna pointing and tracking is achieved by providing the control system - tracking receiver and Antenna Control Unit (ACU) – with the corresponding values for azimuth and elevation angles at given instances. These Az and El angles are calculated in advance – by taking into account the predicted apparent movement of the satellite - and these values are then stored in the memory of the Tracking receiver. The pointing is then performed in open loop without determination of the error of the space angle difference between the direction the antenna communication RF axis points towards and the actual position on the display of the ACU.

Therefore, in order to fully utilize the capabilities of the Ka-band operations, adequate and accurate tracking methods shall be selected and designed and very careful attention shall be paid during the operations of Ka-band systems.

V. THE EDRS MISSION

The experience of GSOC gained in the field of high-data rate technologies and its long-standing background in mission planning, ground stations and satellite operations makes it a valuable partner in establishing a concept as described in chapter II. The first non-experimental mission in which GSOC plays a major role is EDRS. Since currently contract negotiations are ongoing between all involved parties the description below summarizes public available information[3,7,8]. Please note that the design and setup of the project might be changed in the future.

EDRS is an ESA program for which the phase A studies were completed end 2009. Based on these studies a Mission Description and technical specification were issued in February 2010. In January 2011 ESA has selected Astrium Services to manage development and operations of EDRS that would feature one dedicated satellite (EDRS-C) and one piggyback payload (EDRS-A). Both of them will be positioned in the geostationary orbit with visibility over central Europe. This is an advanced concept as the one described in chapter II adding additional flexibility and redundancy. The dedicated satellite EDRS-C will be based on the new SmallGEO platform by OHB. The EDRS-A payload will be hosted on a EUTELSAT satellite. ESA will act as a major customer for Astrium paying for relay services of data from SENTINEL satellites. However the system is designed such that more customers can be integrated.

The link between the LEOs and the GEOs will be established through a Ka-band HF transponder and an optical laser communication terminal (LCT). For these links a data rate of 300Mbps (Ka-band) and 600 Mbps to 1800 Mbps is targeted (LCT). The data transfer between the GEO and ground will be established through a high a bandwidth Ka-Band link.. Besides the main task, which is to relay earth observation data to ground (return link), the system will also feature the possibility to relay data from ground to the LEO spacecrafts (forward link)..

In the EDRS mission the MOC will be operated by the prime contractor Astrium while GSOC will be in charge of performing the following tasks:

- Build-up and operations of the EDRS central ground stations in various places in europe. All stations are operated from the DLR facilities in Weilheim. Stations located outside Weilheim are operated remotely using dedicated software developed at GSOC.

- Build-up and operations of the control centers for the EDRS-A payload and the EDRS-C satellite. In the EDRS-A case, the TM/TC interface is connected to the Eutelsat SCC, from which the TM/TC data is transferred to the Eutelsat ground station controlling the EDRS-A host satellite. GSOCs role is to operate the EDRS payload onboard the host satellite. The EDRS-A GEO SCC is thus shared between Eutelsat and GSOC. In case of the EDRS-C the TM/TC interface is connected to the EDRS ground station in Weilheim with the Redu station as backup. To this respect, GSOC fulfils the role of the EDRS-C GEO SCC.

[1] "*The Sentinels/EDRS Operations Constraints and Concept"* , ESTEC, 2010,
[2] "*European Data Relay System (EDRS) Factsheet* ", ESA 2009,
[3] "*EDRS Phase A study output summary document* ", ESTEC, 2010,
[4] Gregory M., *„Tesat laser communication terminal performance results on 5.6 GBit coherent intersatellite and satellite to ground links",* International Conference on Space Optics, 4 -8 October 2010.
[5] Gataullin Y., "*Real-time fade mitigation using radiometric measurements for future Ka-band services at DLR*" 15th Ka-band and Broadband Communications, Navigation and Earth Observation Conference, 23-25 September 2009, Cagliari, Italy
[6] *RFI for Pointing/Tracking solutions for Ka-Band Antenna for MTG*, EUM/MTG/TEN/10/0264, 7 July 2010, EUMETSAT, Eumetsat-Allee 1, D-64295 Darmstadt, Germany
[7] http://www.spacenews.com/civil/110624-data-relay-project-battling-headwinds.html
[8] http://www.spacenews.com/civil/110114-astrium-build-operate-edrs.html