Satellite Multibeam Signaling for Multimedia Services

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ABSTRACT
In this paper, we[1] constructed a scenario, using AGI's Satellite Toolkit, simulating a Geostationary Satellite and several Base Stations. The purpose was to measure and investigate the reliability of such a satellite system for data rates up to 1000 Mbps. The satellite transmitter used QPSK modulation and a multibeam antenna for accomplishing real-time satellite access and coverage over the various facilities under test. Also the validation of the certain system was performed under rain conditions, taking into consideration the need of QoS, giving results for the needed hardware to be implemented in a future construction. This system can be a part of a larger communication system involving 3G/4G, VoIP and multimedia services.

Keywords
Satellite, Base Station, multibeam antenna, EIRP, Bandwidth, Signal to noise ratio, Carrier-to-noise Ratio, BER, AGI STK

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1. INTRODUCTION
The future in satellite communications is very promising as it will bring new services and applications besides emergency call location and navigation in cars and on mobiles phones. New network features, will probably include high data rate online-gaming, home zone billing and probably applications that will demand the existence of satellite networks unified under a greater network. The keys to all this technological success will be accuracy, real time satellite accessing with low probability of errors, and the reliability of a high data rate transmission under various conditions [1].

In satellite communications, the previous conditions involve rain model analysis, computation of cloud and fog fade, computation of tropospheric scintillation fade and finally gaseous absorption simulation and modeling. In our scenario all these parameters where studied carefully in order to find the degree of reliability of the proposed satellite network.

Our scenario was constructed using AGI's Satellite Toolkit (STK) for simulating the proposed satellite network model. The certain software suite incorporates complex relations between image data and higher-level concepts and designs.

In order to evaluate properly our scenario, various antenna types were used in the transmitter which is located in the satellite body and we concluded that the best antenna type for the proposed network is a multibeam antenna as it can transmit in various angles, establishing real-time access in various facilities located on the surface of the Earth. Also a large number of sensitivity levels of receivers were tested for the purpose of finding the one that really gives low Bit Error Rate (BER) in conjunction with a QPSK modulation system capable of outputting 1000 MBits per second.

Our work has been broken down in three stages. The first stage involved the design and simulation of the satellite network using the graphic interface of STK. The second stage involved the selection of certain hardware to be included in the various transmitters and receivers. In the third stage a link budget analysis of all the Base Stations under test is presented and evaluated.

2. SYSTEM OVERVIEW

An example of how the satellite and various Base Stations were placed it appears in figure 2. The main concept was to obtain the highest possible distance between facilities that it could provide valid telecommunications links through satellite.

Especially a new geostationary satellite was designed giving theoretically the highest possible coverage for all the facilities, which for our purposes should be real-time. The satellite propagator that it was selected was Two Body. The most important elements that describe the Two Body propagator are Period, Eccentricity, Inclination, Argument of Perigee, RAAN, and True Anomaly [2,3].

The satellite under test has a period of 86400 sec, an eccentricity which equals to zero and implies that it has a circular trajectory. Its inclination is 30 degrees and the argument of perigee equals to 5 degrees. Also right ascension of the ascending node (RAAN) equals to zero. Previous propagator settings place its trajectory, in 2D-graphics representation, over Africa.

As it appears from figure 2, real-time access appears graphically as lines that join all the facilities with the satellite at any time of the duration of the scenario. For example, STK indicated us through calculations that real-time access was 259200 sec, for a period of three days.

3. HARDWARE USED IN VARIOUS TELECOMMUNICATION STAGES

3.1 Transmitter

The Multibeam Source Transmitter model that was used has the feature of setting up multiple antenna beams, each with its own specifications, its own polarization and orientation properties. The following parameters can be set for this model:

- Multibeam Antenna: Adding, defining and configuring one or more antenna beams.
- Data Rate - Specifying the data rate in the selected unit
- Post-Transmit Gains & Losses: During communications time, it is often necessary to take into consideration gains and losses that can alter performance and are not defined by any built-in analytical models. The certain transmitter allows modelling these by specifying miscellaneous gains and losses that can be added to the equation [4].
- Modulation: Selection among a number of various modulation types. In addition CDMA (Code Division Multiple Access) spread can be enabled and, if so, specification of the CDMA gain is enabled [5].

The transmitter is based on a QPSK modulator in order to transmit a modulated carrier with a bit rate of 1000 Mbps. Also, post-transmit has a value of -20 dB, for including additional losses in the calculations. Furthermore, the frequency of the carrier is set to 4.5 GHz.

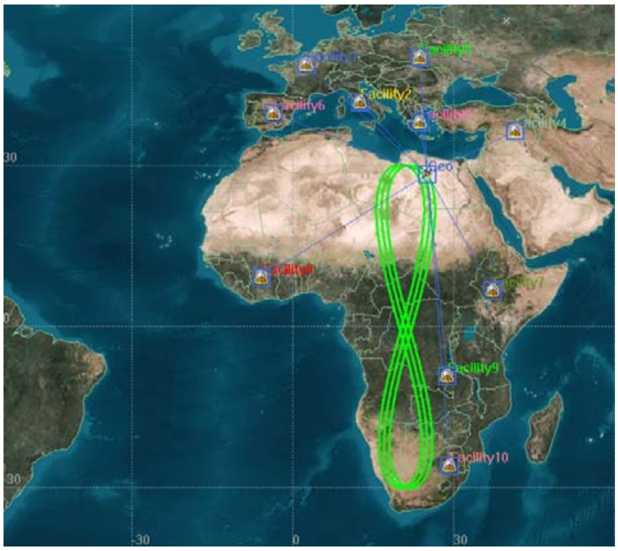

Figure 1. Satellite link with various facilities

3.2 Multibeam Antenna and Receiver

The type of the proposed antenna is a Multibeam antenna because it can transmit in various directions and in such a way that can be specified by the creator of the scenario. The designed antenna can transmit in eight directions generating a well-proportioned radiation pattern giving better access times and generally RF-measurements. Each beam has a power of 2 dBW concurring in the total power of 16 dBW for eight lobes. Also, the antenna patterns that were used included pattern ITU-R S-465-5. The type of the antenna beams that were based on Az-EI mask format, were designed containing the key values shown in table 1 [4].

Table 1. Antenna Beams key values

Frequency	Power	Azimuth	Elevation
4.5 GHz	2 dBW	-135 deg	85 deg
4.5 GHz	2 dBW	-90 deg	85 deg
4.5 GHz	2 dBW	-45 deg	85 deg
4.5 GHz	2 dBW	0 deg	85 deg
4.5 GHz	2 dBW	45 deg	85 deg
4.5 GHz	2 dBW	90 deg	85 deg
4.5 GHz	2 dBW	135 deg	85 deg
4.5 GHz	2 dBW	180 deg	85 deg

A 3D-graphical representation of the transmitted antenna lobes is shown in figure 2, where in this example the radiation orientation is from the geostationary satellite to various facilities located on the surface of the Earth.

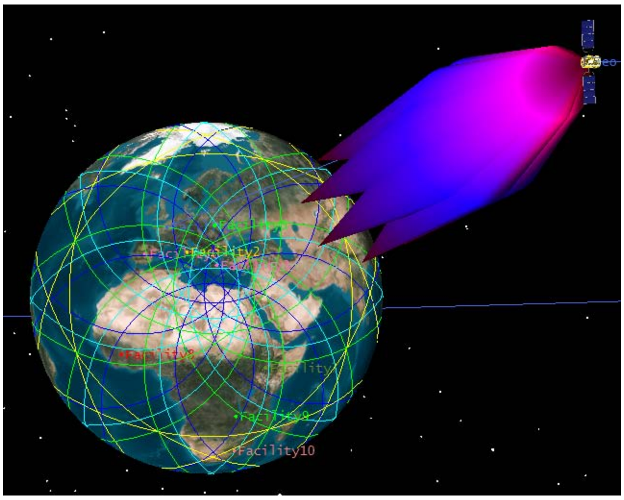

Figure 2. 3-D Radiation representation of multibeam antenna towards facilities

The receiver part was selected to have a sensitivity of -80 dB in order to detect low-powered signals coming from satellite. Furthermore, system temperature was set to 290 K. The system temperature refers to the system's inherent noise characteristics. These can help simulate real-world RF situations more accurately.

4. LINK BUDGET ANALYSIS - RESULTS

STK allows determining how many times one object can access another object. In addition, constraints on accesses can be imposed between objects in order to define what constitutes a valid access. These constraints are defined as properties of the objects whose accesses are being calculated [4].

In this final stage of evaluation and measurement, several RF constraints had to be calculated in order to show clearly that the proposed scenario could work in real world. The constraints that were found, coming from different RF environmental settings, are shown below and their values in tables 2,3,4 and 5.

- EIRP in medium transmitter module:

$$G_U + P_U + G_{POST} \quad (1)$$

where G_U is the user specified antenna gain, P_U is the user specified output power and G_{POST} is the total of the post-transmit losses specified.

- Bandwidth of the transmitted signal is calculated by multiplying modulation specific spectrum efficiency ratio by the data rate. The spectrum ratio is the required bandwidth per bit per second (Hz/bps). For QPSK modulation bandwidth is defined as 1 Hz per bps.

- C/N: Carrier-to-noise ratio

- Eb/No: Bit energy to noise power density ratio

- BER: Bit error rate

- g/T: Receiver gain divided by the system noise temperature. Describes the performance of a receiver.

Table 2. Measurements for clear sky for all facilities (average values)

EIRP dBW	BW MHz	g/T dB/K	C/N dB	Eb/No dB	BER
14	1000	55.37	10-11	10-11	10^{-7}

Table 3. Measurements including rain model ITU-R P.618-8 (Surface temperature 300 K) for all facilities (average values)

EIRP dBW	BW MHz	g/T dB/K	C/N dB	Eb/No dB	BER
14	1000	55.37	9-11	9-11	10^{-7} - 10^{-6}

Table 4. Measurements including rain model ITU-R P.618-8 (Surface temperature 300 K) and gaseous absorption model ITU-R P.676-5 for all facilities (average values)

EIRP dBW	BW MHz	g/T dB/K	C/N dB	Eb/No dB	BER
14	1000	55.37	8-11	8-11	10^{-7} - 10^{-5}

Table 5. Measurements including Cloud and fog fade and tropospheric scintillation fade including deep fade (average values)

EIRP dBW	BW MHz	g/T dB/K	C/N dB	Eb/No dB	BER
14	1000	55.37	(-20) - 11	(-20) - 11	10^{-7} - 10^{-1}

5. CONCLUSIONS

Through link budget analysis we came across with some very important facts. The proposed scenario gave satisfactory results for clear sky, rain and gaseous absorption model even with 20 dB margin for additional losses, but when we included cloud, fog fade and tropospheric scintillation BER wasn't very low giving a large number of errors in QPSK transmission as it ranged between 10^{-7} and 10^{-1} which is a large fluctuation. The certain problem can be overcome by boosting EIRP to higher power levels and also a better receiver with lower levels of sensitivity. Generally, the proposed network can provide real-time accessing and consequently low information loss and valuable QoS in multimedia content [6,7].

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