World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:6, No:4, 2012

Configuration and the Calculation of Link Budget for a Connection via a Geostationary Satellite for Multimedia Application in the Ka band

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***Abstract*—**In this article, we are going to do a study that consist in the configuration of a link between an earth station to broadcast multimedia service and a user of this service via a geostationary satellite in Ka- band and the set up of the different components of this link and then to make the calculation of the link budget for this system. The application carried out in this work, allows us to calculate the link budget in both directions: the uplink and downlink, as well as all parameters used in the calculation and the development of a link budget. Finally, we will try to verify using the application developed the feasibility of implementation of this system.

***Keywords*—**Geostationary satellite, Ground station, Ka band, Link budget, Telecommunication

I. Introduction

In the context of future satellite communications systems, the deployment of the Ka band is a requires, particularly because of the saturation of the L, C and Ku bands. This operation will provide the advantage of wider channels that support a greater number of users; it also allows reducing the size of the user terminal and antenna [1].

Adding to this that, the realization of a satellite meets a need which results in the definition of the objectives of the space mission. Thus for example a communications satellite is the product of needs expressed by users working in fields varied such as mobile telephony, television and internet by satellite, radio navigation, and systems of localization...Etc [2]. For this, and given the complexity and the cost of space projects, their implementation is divided into phases to have a good understanding and good control on the project.

The work presented in this article between in the first phase of the design of a satellite and which consists in the contribution to the analysis of mission of a telecommunications satellite for the internet or mobile phone by satellite for example, and that in geostationary orbit [3].

We will in what will follow, do the configuration of a system which consists of a link between a broadcast station and a user through a satellite in geostationary orbit, and then do the calculation of the link budget the latter in the order to see if this link can be achieved in the future.

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II. Problem Statement

The calculation of the link budget is a very important step in the design phase of any satellite in order to ensure the proper functioning of the latter up after the launch, our work is within this context, or we will set a link in Ka-band between a station of emission of service and a receiver (user) via a geostationary satellite and to ensure that the system normally works with these parameters we should do the calculation of the link budget in the end leaving a margin of error sufficient as a guarantee for the proper functioning of the system. We cannot take this margin large because this causes additional costs and an over-sizing of the system and a lesser margin can lead to an excessive error rate which may caused the loss of the bond, so it must adjust the parameters of entry until a margin, at least 8 dB [4] greater than the value of the quality of the link estimated, the calculation of the link budget consists in the determination of the ratio of signal to noise at the level of the satellite for the uplink and at the level of the reception station for the downlink, this report is given by the following equations [5]:

A. For the uplink

$$\left(\frac{C}{N_0}\right)_U = \frac{\dfrac{\left(\dfrac{P_{out,b}}{L_{feed,b}}G_{t,b}\right)G_{r,s}/L_{feed,s}}{L_f}}{kT_{s,s}} = \frac{\dfrac{\left(P_{t,b}G_{t,b}\right)G_{r,s}/L_{feed,s}}{L_f}}{kT_{s,s}} \tag{1}$$

$$= \frac{\dfrac{EIRP_b \cdot G_{r,s}/L_{feed,s}}{L_f}}{kT_{s,s}} = \frac{EIRP_b}{L_f}\left(\frac{G_{r,s}/L_{feed,s}}{T_{s,s}}\right)\frac{1}{k}$$

$$\begin{aligned}(C/N)_U &= P_{out,b} - L_{feed,b} + G_{t,b} - L_f + G_{r,s} - T_{s,s} - k - Ls \\ &= EIRP_b - L_f + G_{r,s} - T_{s,s} - Ls + 228.6 \quad dBHz\end{aligned} \tag{2}$$

B. For the downlink

$$\left(\frac{C}{N_0}\right)_D = \frac{\dfrac{\left(\dfrac{P_{out,s}}{L_{feed,s}}G_{t,s}\right)G_{r,b}/L_{feed,b}}{L_f}}{kT_{s,b}} = \frac{\dfrac{\left(P_{t,s}G_{t,s}\right)G_{r,b}/L_{feed,b}}{L_f}}{kT_{s,b}} \tag{3}$$

$$= \frac{\dfrac{EIRP_s \cdot G_{r,b}/L_{feed,b}}{L_f}}{kT_{s,b}} = \frac{EIRP_s}{L_f}\left(\frac{G_{r,b}/L_{feed,b}}{T_{s,b}}\right)\frac{1}{k}$$

$$\begin{aligned}(C/N)_D &= P_{out,s} - L_{feed,s} + G_{t,s} - L_f + G_{r,b} - T_{s,b} - k - Ls \\ &= EIRP_s - L_f + G_{r,b} - T_{s,b} - Ls + 228.6 \quad dBHz\end{aligned} \tag{4}$$

For the calculation of Lf losses mentioned in (2) and (4), say the losses in the free space that is a basic step in the calculation of a link of communication especially satellite in geostationary orbit because of the large distance between the satellite to Earth. Losses in the free space can be expressed by the following report:

$$L_f = \left(\frac{4\pi d}{\lambda}\right)^2 \text{(dB)} \tag{5}$$

At the same time, it is necessary also to take into account all sources of losses that can cause degradation of the link budget. Thus, it is affected by a set of losses that will degrade it, all sources of degradation are accumulated in the term Ls, mentioned in the equations (2) and (4), and it is defined as follows:

$$Ls = L_{Em}.L_{Atm}.L_{Pol}.L_{Poin}.L_{feed} \tag{6}$$

Among these sources of degradation, we find the losses due to the depointing antenna [6], noted by Lpoin and defined by the following equations:

$$L_{\theta_T} = 12.\left(\frac{\theta_T}{\theta_{-3dB}}\right)^2 \quad \text{(dB)} \tag{7}$$

$$L_{\theta_R} = 12.\left(\frac{\theta_R}{\theta_{-3dB}}\right)^2 \quad \text{(dB)} \tag{8}$$

We have the atmospheric losses (LAtm) due to the diverse atmospheric phenomena, we have [7]:

A. Absorption by oxygen molecules γo (dB/km):

$$\begin{cases} \left[\dfrac{6.6}{f^2+0.33} + \dfrac{0.19}{(f-118.7)^2+2}\right] f^2 10 & \text{For } f = 57\text{GHz} \\ 14.9 & \text{For } 57 \le f \le 63\text{GHz} \\ \left[2.10^{-4} r_t^{1.5}(1-1.2\times10^{-5} f^{1.5}) + \dfrac{4}{(f-63)^2+1.5 r_p^2 r_t^5} + \dfrac{0.28\ r_t^2}{(f-118.75)^2+2.84 r_p^2 r_t^2}\right] & \text{For } 63 \le f \le 350\text{GHz} \end{cases} \tag{9}$$

Where: f: frequency (GHz),
rp= p / 1013,
rt = 288/ (273 + t),
p: pressure (hPa),
t: temperature (°c).

B. Absorption by water vapor:

$$\gamma_W = \left[3.27.10^{-2} r_t + 1.67.10^{-3}\frac{\rho}{r_p} + 7.7\times10^4 f^{0.5} + \frac{3.79}{(f-22.23)^2+9.81 r_p^2 r_t} + \frac{11.73 r_t}{(f-183.31)^2+11.85 r_p^2 r_t} + \frac{4.01 . r_t}{(f-325.153)^2+10.44 r_p^2 r_t}\right] f^2 \rho r_t r_p 10^{-4} \tag{10}$$

Where: ρ is the density of the water vapor (g/cm3).

C. Attenuation due to the rain:

$$\gamma_R = k.R^{\alpha} \tag{11}$$

Where: K and α are coefficients which depend on the frequency and polarization.
R is the intensity of rainfall in mm/h.

D. Attenuation due to clouds and fog:

$$\gamma = \text{Af2M} \tag{12}$$

Where: γ : The weakening in dB/Km,
F: The frequency in GhZ,
M: The water content in g/m3,
A: Coefficient which depends on temperature.

We also have other sources of loss, such as:

1) LEM: Corresponds to the losses between the output of the transmitter and the antenna (line, duplexers, filters...).
2) Lfeed: Corresponds to the losses between the receiving antenna and the input of the receiver.
3) Lpol: Corresponds to the polarization losses from a bad adaptation of polarization between two antennas.

III. Context Of Study

For our study which consists in the configuration of a communication link for a multimedia service such as the internet by satellite for example between an transmit earth station (the one that offers the service) and receiver (user service) via a telecommunications satellite on geostationary orbit, we will take the case that is shown in figure 1 which consist in a link between a ground station equipped with a fixed parabolic antenna installed on the site of Arzew (Oran, Algeria) and a user found anywhere in Algeria via a satellite in geostationary orbit telecommunication at a defined position [8].

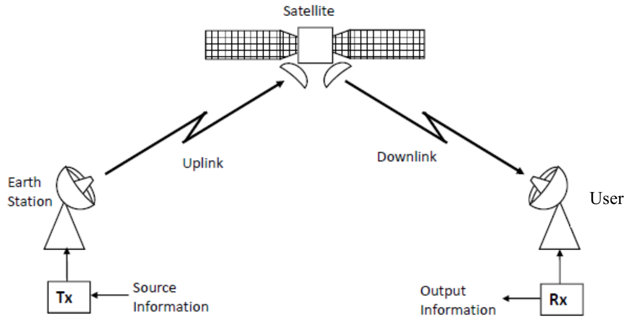

Fig. 1 Connection between ground station and user via geostationary satellite (Case of study).

IV. Working Methodology

A procedure for the design of a satellite link is given by the following steps [9]:

1) Choice of carrier frequency based on the availability and allocation of spectrum by the ITU.
2) Selection of the transmission powers.
3) Estimation of losses between the transmitter and the antenna.
4) Estimation the maximal depointing angle.
5) Calculating the gain of the antennas.
6) Calculation of free space losses.
7) Estimation of atmospheric absorption.
8) Estimation of the noise temperature of the system (clear sky).
9) Calculation of Eb/N0 for the data rate required.
10) Report search Eb/N0 required to satisfy the BER based on the type of modulation and coding.
11) Adding 1 or 2dB to compensate the errors of implementation. Calculation of the margin error of the link.
12) Calculation of the margin error of the link.
13) Adjustment of the input parameters until a margin of at least 8 dB greater than that estimated with degradation due to rain.

The margin of the system is given by:

$$M = (\frac{E_b}{N_0})_{Calc} - (\frac{E_b}{N_0})_{Req} \tag{13}$$

With

$$\left(\frac{E_b}{N_0}\right)_{Calc} = \frac{1}{R} * \left(\frac{C}{N_0}\right) \tag{14}$$

Where: R is the bit rate

If this margin is respected then the transmission may be made, otherwise it must either change the settings or resize some essential parameters to improve the quality of the bond.

V. Developed Software

The software developed in our study is designed under the environment Matlab 7.8; it is structured in four main parties (Figure 2), calculation of the UPLINK budget (Figure 3), and the calculation of the DOWNLINK budget (Figure 4), calculation of the depointing angle of satellite antenna, calculation of depointing losses. In addition, it has a menu that contains all the different calculations that fit into the development of the link budget as antenna settings, the Earth satellite distance, atmospheric losses, and the orientation of the antenna of the station … etc.

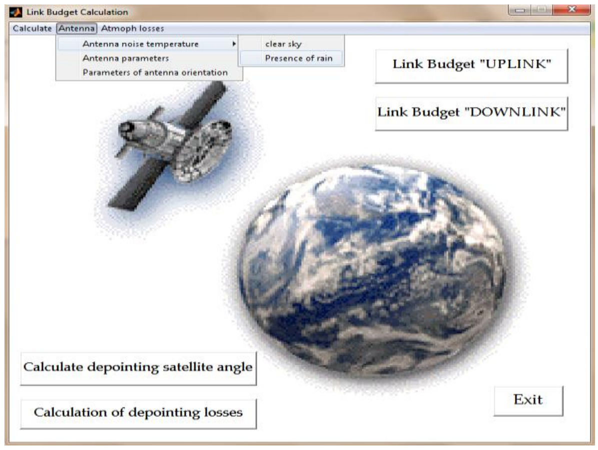

Fig. 2 Principal window of the application

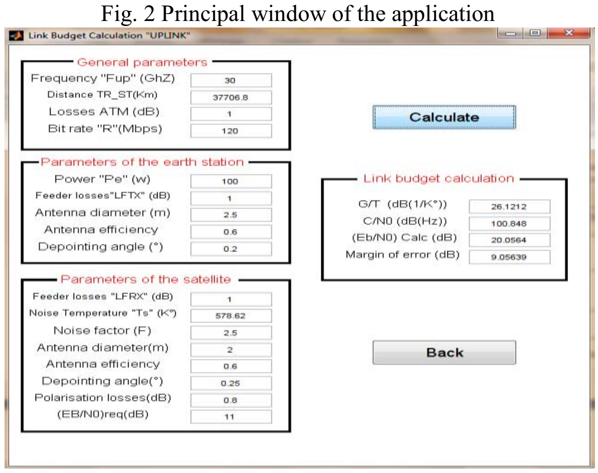

Fig. 3 Calculation of the uplink budget

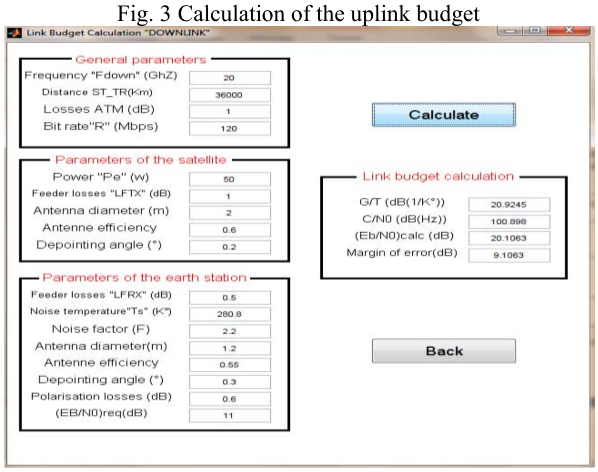

Fig. 4 Calculation of the downlink budget

VI. Simulation And Results

For any satellite link, we have a set of parameters that characterize it, for our case, we will configure a connection in Ka-band between a transmit earth station that is installed at the level of the city of Arzew (Oran, Algeria) and a user found anywhere in Algeria via a geostationary satellite and this for a multimedia application (Internet or Television by satellite, mobile phone).

Among these parameters, there are already presets such as: the coordinates of the station and the longitude of the satellite [9] to calculate the exact distance between the Earth and the satellite (this calculation is integrated in the application), the frequency…etc.

And we have parameters that we will define: the diameters of antennas, their gains, bit rate….etc.

Our contribution is to find an optimal combination between these different settings in the goal to establish a link with a margin of error quite sufficient (>8dB) [4], to ensure the proper functioning of our system. After several trials during what we have tried to take all the constraints into consideration (size, power, cost, access), we have arrived to the data summarized in the following tables:

A. For the uplink

TABLE I
Parameters of the uplink connection

Parameters	Value
General data	
Frequency	30 GhZ
Longitude of the satellite	35.867° N
Latitude of the station	0.321° O
Longitude of the satellite	24.8°
Atmospheric losses	1 dB
Binary rate	120 Mbits/s
Polarization losses	0.8 dB
(Eb/No) req	11 dB
Earth station data	
Power	100 W
Feeder losses	1 dB
Diameter antenna	2.5 m
Antenna efficiency	0.65
Max depointing angle	0.25°
Satellite data	
Feeder losses	1 dB
Noise factor	2.5 dB
Diameter antenna	2 m
Antenna efficiency	0.6
Max depointing angle	0.2
T° noise of the system	578

B. For the downlink

TABLE II
Parameters of the downlink connection

Parameters	Value
General data	
Frequency	20 GhZ
Distance earth satellite	40000 Km
Longitude of the satellite	24.8°
Atmospheric losses	1 dB
Binary rate	120 Mbits/s
Polarization losses	0.8 dB
(Eb/No) req	11 dB
Satellite data	
Power	50 W
Feeder losses	1 dB
Diameter antenna	2 m
Antenna efficiency	0.6
Max depointing angle	0.2°
Earth station data	
Feeder losses	0.5 dB
Noise factor	2.2 dB
Diameter antenna	1.2 m
Antenna efficiency	0.55
Max depointing angle	0.3
T° noise of the system	280

For both cases, we have taken a bit error rate “BER=10^{-7}” [10] and a Viterbie coding with QPSK modulation. With the parameters detailed in the table before and using our software, we have obtained the following results:

TABLE III
Results obtained with the calculation software

	UPLINK	DOWNLINK
Figure of Merit G/T (dB/K°)	26.12	20.92
Signal to noise ratio C/N0 (dBHz)	99.96	99.99
Margin of error (dB)	8.17	8.2

From this, we can see that we can set up a system consisting of a link between an Earth station broadcasting and a receiver via a geostationary satellite with the parameters of the table (1) and (2), because we can guarantee and ensure the proper functioning of our system and this through the margin of error that we have left, despite the fact that it is costly in terms of weight and power but it is essential to know the sensitivity of the link in band Ka to atmospheric disturbances especially rain.

VII. Conclusion

Through this article, we have tried to bring a personal contribution which consists of an adds in the design of future satellite communication system for Ka band that propose a multimedia application, first we have tried to choose an architecture to our system, we have chosen a simple architecture for our study consisting of a transmit earth station a receiver and a geostationary satellite, In the practice case this architecture is spread on several users (multi-user) especially with the use of satellite equipped with multibeam antenna. Secondly we developed software that enables the link budget calculation of any satellite link. Then, we have set up the different parts that make up the system.

Finally, we use the developed software for checking the feasibility of implementing such system with the proposed parameters and the results are very satisfactory because at the end of calculation, we conclude to a margin of error at 8.17 dB for the uplink and at 8.2 dB in the downlink, for both cases is a fairly comfortable margin since it is higher than the limit that was set previously and which is 8 dB, so even if we will have to strong atmospheric disturbances (especially the case of strong rain) or other unexpected sources of losses, our system will function normally and the service will be provided.

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