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Performance Analysis of Power Budget Management for Satellite Design under Ka Band Frequency Band

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Abstract: In the manuscript, a power budget analysis is performed for the estimation of the link budget between satellite and ground station. Various parameters have been considered for this estimation that includes aperture efficiency, operating wavelength, earth station antenna diameter. Several calculations have been performed for the assessment of link budget related to the transmitted power with respect to various carrier-to-noise (C/N) ratio.
Keywords: C/N, Aperture, Ka, VSAT

I. INTRODUCTION

In today's era satellites are playing dominant role and severely affecting the communication capability of every person. There are several frequency bands which are used for up-linking and down-linking of satellite's transceivers [1]. Table-1 is presenting the information of various bands used for the communication. The Ka stands for "K-above". The Ka band covers the frequencies from 27 to 40 GHz, many systems now work in the Ka band to decrease the size of the antenna and increase the data rate. Thus, with a higher frequency, we can extract more bandwidth from a Ka-band system, resulting in a higher data transfer rate and higher performance [2]. The Ka band is advantageous compared to L, S, C, X, Ku, K because of its very high bandwidth for the transmissions. With the flexibility offered by Ka-band technologies, we have entered a new pattern in planning, design, and the development of commercial satellite systems. Two-way broadband internet, VSAT networks, enterprise applications, rural or remote area communications, cellular backhaul, defense applications, satellite news gathering, crisis management, and so on are all applications of Ka band systems [4].

Table 1: Various Satellite frequency bands

S. No	Bands	Frequency (GHz)
1	L	1 to 2
2	S	2to 4
3	C	4 to 8
4	X	8 to 12
5	Ku	12 to 18
6	K	18 to 27
7	Ka	27 to 40

The link budget accounts for all gains and losses of the transmitter, by the means used for the receiver in a telecommunications system. The term satellite link is associated with the radio connection between the earth station and the satellite, i.e., uplink, and satellite at the earth station. i.e., downlink. The linked budget is a set of calculations which is a brief analysis of the performance and feasibility of a particular communication link. A satellite link budget is the calculation of various factors to estimate the amount of power transmitted from the earth station to the satellite to and fdro to have a reasonable amount of power reception at both ends. This computation for the designing of an appropriate link is called a link-power budget. The calculation of the satellite link power budget consists of two quantities, namely transmission power and receiving power. As the high-speed wireless communication is a backbone of the new generation of communication [4-6] and their modelling is also a key section to decide the behavior of the communication model. The manuscript is divided in to four sections. Second section is revealing the mathematical modelling of the of the communication model for up-link and down-link satellite channel. The third section is result and analysis followed by the conclusion.

II. MATHEMATICAL MODEL

A. *Uplink Power Budget*

The modelling of up-linking is little bit easier than the downlink, since an accurately specified carrier power must be presented at the satellite transponder, and earth station transmitters can often use much higher power than can be used on a satellite. Following are the factors affecting the channel model.

B. *Parameters of Transmitted Antenna*

It includes the calculation of Operating wavelength, Antenna diameter, Antenna aperture efficiency, Path loss, Carrier-to-noise ratio.

1) *Operating Wavelength (λ):* $\lambda = c/f$ for Ka-band frequency ranges between 27-40GHz.
2) *Antenna Diameter (D):* A small antenna diameter limits the size of a small earth station. Demonstrating a good satellite link with a small antenna is tricky. In the transmit frequencies, the smaller antenna has a less antenna gain.
3) *Carrier-to-Noise Ratio(C/N):* The ratio of the carrier power C to the noise power density N_0, expressed in dB-Hz. In our calculations, we have considered as C/N Transponder ratio = 30 dB.
4) *Antenna Aperture Efficiency (A_e):* Aperture effectiveness of an antenna is the ratio of the effective radiating area (or effective area) to the physical area of the aperture. The power is transmitted through an antenna's aperture. A_e is the Effective Aperture, which is always less than the physical aperture of the antenna A_{phys}. An aperture antenna's aperture efficiency is expressed in form of ratio for these two areas:

$$e_a = \frac{A_e}{A_{phys}} \tag{2}$$

C. *Path Loss*

The signal intensity of a transmission decreases as it passes through free space, which is known as free space path loss. The free space path loss (FSPL) is used to estimate the theoretical value of power for an RF signal at a given distance. The FSPL, on the other hand, is a good approximation for calculating signal loss when travelling across open space.

$$Lp_1 = 10 * log10(\left(\frac{4\pi R}{\lambda}\right)^2) \tag{4}$$

Where, Lp_1= Path Loss, R = Antenna radius, λ = Operating wavelength. The gain on the receiving and transmission antennas is taken into account in the above calculation by calculating the patch loss of free space.

III. RESULT & ANALYSIS

The results are obtained using MATLAB simulations and verified using analytical calculations. Ka frequency band is used with the input parameters. The result presented in Table (2) is revealing that when the operating wavelength and antenna diameter increases the transmitted power decreases shown in (Fig-1) that draws a Comparison for various Diameter and Operating Wavelength between carrier to noise ratio versus Transmitted power. Table (3) is representing the effect of Aperture Efficiency on uplink power budget .It is clearly seen that by increasing aperture efficiency the transmitted power tends to decrease which is revealed in (Fig-2)drawing Comparison for various Aperture Efficiency between carrier to noise ratio versus Transmitted power.

Table 2: Effect Of Operating Wavelength And Antenna Diameter On Uplink Power Budget

				INPUT	OUPUT
S.No.	Operating Wavelength	Aperture Efficiency (Ae)	Antenna Diameter(D)	C/N Ratio	Transmitted Power (MW)
1	0.0075	18.09	1.4	55	2.29
2	0.01	18.09	1.7	55	1.54
3	0.0111	18.09	1.2	55	3.10

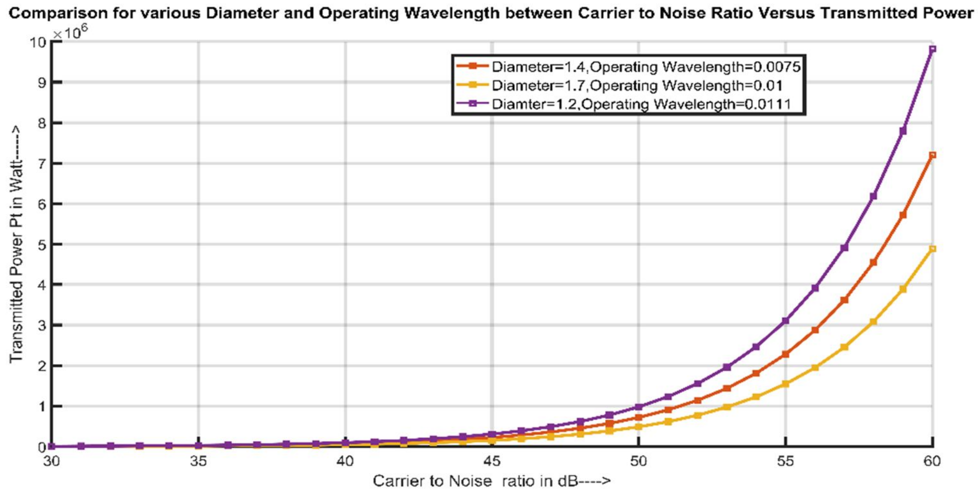

Fig-1: Comparison for various Diameter and Operating Wavelength between carrier to noise ratio versus Transmitted power

Results from Fig-1 revealing that the diameter of the antenna and the operating wavelength are the key factors that affects the transmitted power. On increasing Diameter and operating wavelength the transmitted power is minimized.

Table 3: Effect of Aperture Efficiency on Uplink Power Budget

				INPUT	OUPUT
S.NO.	Aperture Efficiency (Ae)	Antenna Diameter(D)	Operating Wavelength	C/N Ratio	Transmitted Power (MW)
1	18.09	1.2	0.0111	51	0.0464
2	26.8	1.2	0.0111	51	0.0417
3	20.1	1.2	0.0111	55	0.0313

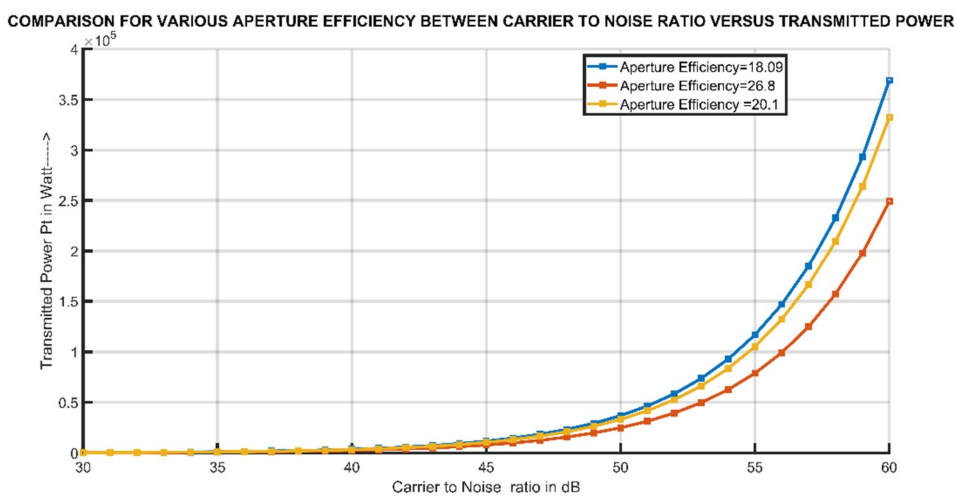

Fig-2:Comparison for various Aperture Efficiency between carrier to noise ratio versus Transmitted power

Results in Fig-2 are revealing that with increase in aperture efficiency the transmitted power gradually decreases.

IV. CONCLUSION

A number of parameters is considered for the performance analysis of power budget analysis for a Ka band satellite system. The necessary key factors for a strong satellite connection are summarized in the satellite link design approach. The analyses are made for satellite-linked architecture, overall transmitted power by utilizing the C/N ratio as an input. In this study, an optimization methodology for a link budget optimal parameters design is presented. The received power is maximized when diameter and the aperture efficiency is minimum which results in efficient communication between ground station and satellite.
2

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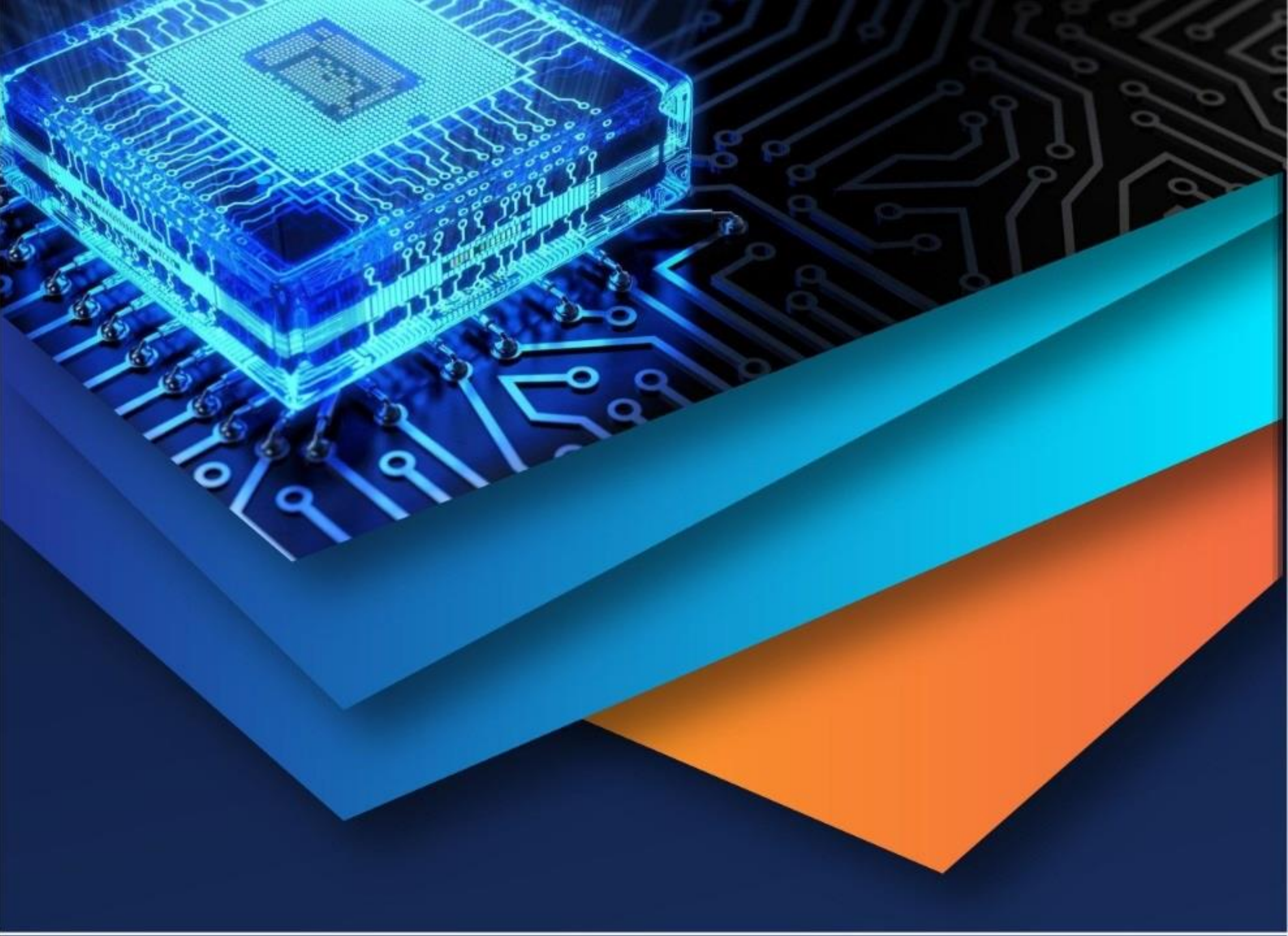

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