Link Budget and Noise Calculator for Satellite Communication

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Abstract. MATLAB is widely used in all areas of applied mathematics, in education and research at universities, and in the industry. MATLAB stands for MATrixLABoratory and the software is built up around vectors and matrices. This makes the software particularly useful for linear algebra but MATLAB is also a great tool for solving algebraic and differential equations and for numerical integration. Among MATLAB software main function is to produce a calculator to calculate the Link Budget System and the noise of the system. A link budget is accounting of all of the gains and losses from the transmitter, through the medium used (i.e. free space, cable, waveguide, and fiber) to the receiver in a telecommunication system. The purpose of calculating link budget is to investigate the system performance tied to operation threshold, to get the minimum power, Cmin that should be received at the demodulator input in order for communication to work properly with reading typically of 10 dB. By using this design, all the parameter (i.e. Effective Isotropic Radiated Power (EIRP), Path loss/ Free space path loss, Effective aperture, Flux density, Physical aperture, Transmit gain, Receive gain, Transmit power and Receive power) can be calculated. Lastly, the purpose of calculating noise in satellite link system is to get noise temperature ratio and noise density ratio. A noise temperature ratio is a figure of merit used to represent the quality of a satellite or an earth station receiver. While, noise density ratio is one of the most important and most often used parameters when evaluating a digital radio system.

Keywords-Automatic; Calculator; Space Technology; Link Budget;

1. Introduction
Link analysis is shows in detail how the difference between the transmit power and the receive power is accounted for [1]. The fundamental elements that related in communications satellite Radio Frequency (RF) or free space link are employing in link analysis. The basic link of power equation is exploited from basic transmission parameter which are antenna gain, free space path loss and beam width [2,3]. The development of concept and quantify for system noise on the RF link is to define the parameters such as noise temperature , noise power, noise figure and figure of merit. The
communications link design and performance defined by the carrier-to-noise ratio and related parameters, which are, based on the basic link and system noise parameters [4]. In communications, the carrier-to-noise ratio, is defined as ratio of the strength of received carrier relative to the strength of the received noise and commonly it has written as CNR or C/N. The better quality reception and higher accuracy and reliability are providing by high C/N ratio compare to the low C/N ratios [5, 6]. The C/N ratio between the carrier power of the desired signal and the total of received noise power are specifying in decibels (dB) [7]. If both carrier strength, \( P_c \) and the noise level, \( P_n \) in microwatts, then the carrier-to-noise ratio, \( C/N \) (dB) is given by following equation (1).

\[
C/N = 10 \log_{10} \left( \frac{P_c}{P_n} \right)
\]  

(1)

The C/N ratio is measure in a similar approach to the technique of the signal-to-noise ratio (S/N) measurement and both specifications are performing as the quality of a communications channel. Nevertheless, the S/N ratio specification shows the more significant in practical situations [8]. Commonly, the C/N ratio is use in satellite communications systems to align the receiving dish; so that the best dish alignment is defining by maximize C/N ratio.

The purpose of calculating noise in satellite link system is to determine noise temperature ratio and noise density ratio. A noise temperature ratio is a figure of merit used to represent the quality of a satellite or an earth station receiver [9]. Noise density ratio is the one most important and often use parameters in evaluating a digital radio system [9]. While, Link budget analysis is need to analyze the signal loss factor during the propagation and estimate the required power in a certain transmitter to overcome noise that happen in the receiver [10].

2. Methodology

The link budget and noise calculator is design to ease user to calculate all the signal gains and losses to ensure that the signal intended for a given receiver is sufficiently strong enough to get the job done. The flowchart in Figure 1 shows the overall process of the project.

![Flowchart](image)

Figure 1. Flowchart of the overall project
By refer to Figure 1, the system starts by setting the parameter of each link budget and noise system. Next, design the GUI of the system. By successfully designing the GUI, user may now insert an input based on the chosen parameter. After that, the calculation part took place. User need to wait a while for the system to calculate. Finally, the calculated value will be display in the appropriate box. By displaying the calculated value, the system has successfully calculated the linked budget and the noise of the system.

The noise calculation involving the calculation of the carrier to noise ratio (uplink), carrier to noise ratio (downlink), total carrier to noise ratio, carrier to noise ratio density (uplink), carrier to noise ratio density (downlink) and total carrier to noise ration density. As for link budget that is in Radio Frequency (RF) is to get rough feel of viability and to find tune actual design. Figure 2 below shows the Application of link budget in Radio Frequency.

![RF Link Budget Gains & Losses](image)

**Figure 2. Application of link budget in Radio Frequency**

3. **Result and Discussion**

The design of GUI is show in Figure 3. The user need to insert the input values such as the speed of light (c), frequency (f), efficiency (η), effective area of isotropic antenna (A0), power transmit (Pt), transmitter gain (Gt), aperture antenna (Ar), input backoff (Boi), wavelength (λ), effective aperture (Ae), noise temperature (Tn), losses (L), distance radius (R), Boltzmann constant (k), saturation flux density(Ψs), bandwidth (Bw), figure of merit for uplink and downlink (G/T), output back off (Boo), diameter (D), effective isotropic radiated power (EIRP) and power receive (Pr). Number 1 until 16 is the parameter that available in link budget and noise calculator program. The formula for each parameter of the link budget has been set in the program, hence, user was only need to insert the input for the parameter that need to be calculate and click the “compute” button. Then the value will be display in the appropriate box.
Firstly, to find the wavelength and effective aperture, user must key in the value of speed of light (c), frequency (f), efficiency (ƞ), and aperture antenna (Ar) as shown in Figure 4 below. Here, other parameters will not give an output as the inputs are only involving the wavelength and the effective aperture only.

Figure 3. GUI for link budget and noise system calculator

Figure 4. Output for wavelength and effective aperture
Next, to find the path loss, user must key in the value of wavelength and distance radius (R). The wavelength value that has been calculating earlier also can be use. The interface is as shown in Figure. 5 below. The user must key in the value of Pt and Gt to find the effective isotropic radiated power (EIRP), this calculator will calculate the value in dB as shown in Figure. 6.

![Figure 5: Path loss Output](image)

Next, to find the noise power spectral density (N0), the input that user needed to key in are Boltzmann constant (k) and noise temperature (Tn) as shown in Figure. 7. Lastly, refer Figure. 8 below to find the uplink, downlink and the total carrier power to noise density.

![Figure 6: EIRP Output](image)

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Figure 7. Noise power spectral density Output

Figure 8. Carrier Power to Noise Density Output
4. Conclusion

As a conclusion, the Link Budget and Noise System Calculator is successfully created using the interface in MATLAB software. The link budget items are including transmitter and received power, antenna gain, aperture antenna, effective area of isotropic antenna, antenna feeder losses and path losses. Whereas for noise system the items are noise temperature, figure of merit for uplink and downlink, input back off and output back off. Finally yet importantly, link budget and noise system calculator is important tool to investigate the areas, gain and losses that possibly will occur between transmitter and receiver of satellite communication system.

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