Link Budget

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Abstract

The term link budget refers to an expression that describes a communication system. This expression accounts for gains and losses throughout the system and simplifies it significantly. The system is typically a signal transmission starting from a transmitter through a medium to a receiver. The expression utilizes power to bridge the relationship between transmission and reception of a signal. The relationship of the system is power received is the sum of the gain and losses along with the signal power initially transmitted.

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1 Introduction

When looking at the link budget of a system, the expression can get really messy and complicated. That is why it is easier to analyze the system starting from the top. This method is the way we will introduce the components of the simplified expression. This will help give some insight and help the designer realize what components of the system to consider when establishing the expression. In addition, one must realize even though the link budget describes a telecommunication system not all systems will have the same components to consider. For example, a system in space will not need to consider atmospheric attenuation of the signal from clouds or rainfall.

2 Link Budget

The following is the simplified expression of the link budget in the general case.

$$P_{rec}(dBm) = P_{tran}(dBm) + Gain(dB) - Losses(db) \quad (1)$$

To start off, we should go over the units of the system. The unit dB is used to describe power levels in terms of decibels. The equation is as follows.

$$dB = 10log(x) \quad (2)$$

Whereas dBm is simply the same decibel value but in reference of milliwatts. This is convenient because it can display both large and small values when compared to other methods. The equation is below.

$$dBm = 10log(\frac{x}{1e^{-03}}) \quad (3)$$

Lastly, dBi is just the gain of the isotropic antenna. The equation is the same for finding the power level in decibels, equation 2 above. There are many more conversions of the dB scale, but these are the ones used in this writing. Notice that only the dBm is different from the other two, so be aware when converting between scales.
Starting with P_{tran}, this is the power of the signal from the transmitter. P_{rec} is then the power received by the receiver. The gain and losses are simply the total gains and losses of the system. The total gains are typically from the antenna gains. however, other components or sources of gain can be introduced to the system.

The losses, however, can come from multiple sources. Typically, outnumbering the sources of gain. For example, looking back at the atmospheric losses from before, imagine a system that has a signal traveling down to Earth from the satellite. We would have to consider the losses from Earth's atmosphere, such as, rain, clouds, oxygen gas. etc. These atmospheric elements will create reflection and absorption which leads to attenuation of the signal. An example of the application with equations would be the following. If this is the power initially received without atmospheric losses.

$$P_{rec} = P_t G_r G_t (\frac{\lambda}{4\pi R})^2 \tag{4}$$

Then the following would be the power received when taking atmospheric losses of the system.

$$P_{ri} = \gamma(\theta) P_{rec} \tag{5}$$

Where $\gamma(\theta)$ is the one-way transmissivity of the atmosphere with zenith angle θ. Also, notice that the equation (4) is the Friss transmission formula.

Putting all of these concepts together, let us now look at a real scenario utilizing the link budget. The following scenario will be design planning of a 5G mobile network utilizing link budget.

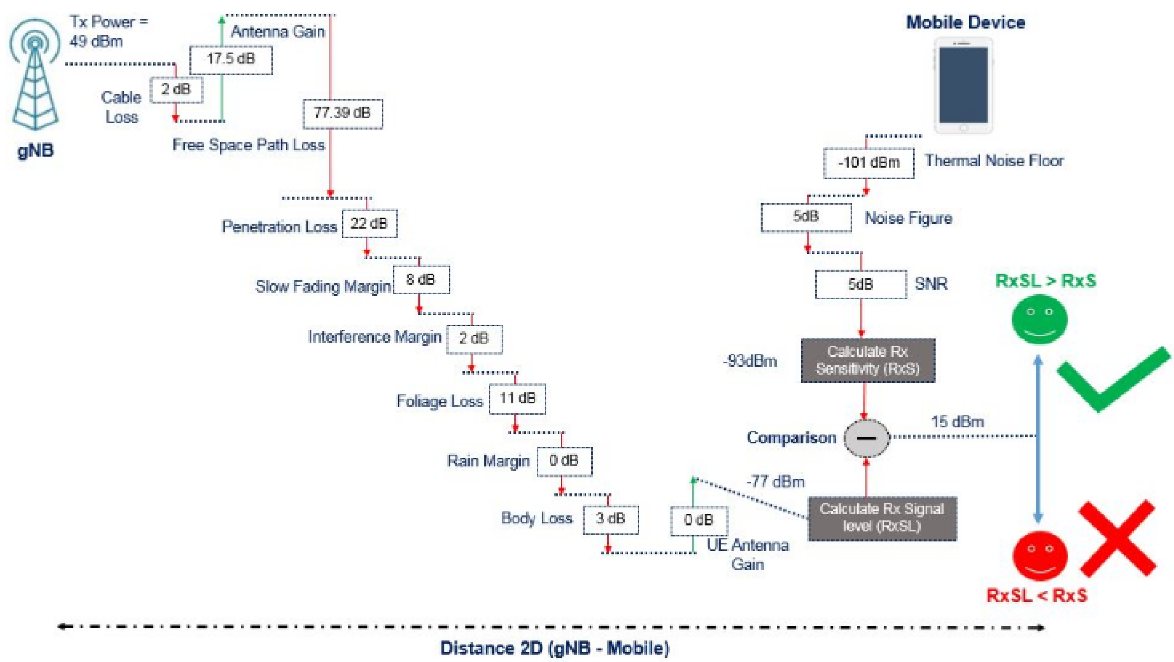

Figure 1: 5G Link Budget Diagram

In the figure above, we can see the transmitter and the receiver, which is the cell tower and the mobile phone respectively. We have a antenna gain from the transmission side, however, there is a gain of 0 dB from the receiving side. Most importantly, in the figure we can several factors or sources for losses. Each of these losses have a value in dB for their respective loss. This next figure shows the expanded expression for power received by the mobile phone.

Received Signal Level at receiver (dBm) = gNodeB transmit power (dBm) – 10*log10 (subcarrier quantity) + gNodeB antenna gain (dBi) – gNodeB cable loss (dB) – **Path loss (dB)** – penetration loss (dB) – foliage loss (dB) – body block loss (dB) – interference margin (dB) – rain/ice margin (dB) – slow fading margin (dB) – body block loss (dB) + UE antenna gain (dB)

Figure 2: Link Budget Expression

This particular example is great because we can see losses from our previous discussion of atmospheric losses along with other losses. These other losses can give some insight as to what may be involved within a communication system and what losses should be considered.

To elaborate further on this design example, after these gains and losses were considered. We can move forward to determine criteria for the system. For example, if the signal power received is greater than a signal sensitivity (system criteria), we can pass the signal. Otherwise, redesign of the system should be considered.

Before we move on to the conclusion, we should briefly mention SNR. This is the signal to noise ratio, which is an important concept of signal integrity. Essentially, what it is is the ratio of the signal power over the power of the noise. This can also be implemented into the link budget as done above, because noise power is considered to lead to attenuation of the signal.

3 Conclusion

So as we have seen above, link budget is the concept of accounting for signal power along with the system's gains and losses. This concept can be an important designing tool that can help in the early stages of a project. If this link budget concept were not to be utilized, we could potentially have an unstable system with undesired outcomes. As seen in the 5G mobile network example, we can then move forward with the design if the outcome is within desired tolerances. Tolerances because some of these earlier losses are variable. For example, it does not rain everyday, but we must still account for it if it does rain occasionally in the system. All in all, the link budget must be considered for an adequate engineering design for telecommunication systems.

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Ryan Nand, is a BS candidate in the Electrical & Computer Engineering department at Portland State University. His research and studies have only just begun.

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