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# LINK BUDGET CALCULATION

## *Generic methodology for Propagation calculations*

This document presents a generic methodology for the calculation of microwave Link Budgets in Line-Of-Sight (LOS) conditions and Point-to-Point radio links, based on physical propagation and Friis formula.

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## The Friis Formula

The generic formula that describes the link budget of a radio system is:

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - FSL - L_{M} + G_{RX} - L_{RX} \qquad (1)$$

All quantities in the equation above are expressed in logarithmic dB.

Reminder: for a quantity Q expressed in a certain unit U, its corresponding expression in logarithmic dB looks like Q(dBu)=10logQ(U).

Example: if $P_{TX}$=5W, the corresponding is $P_{TX}$(dBW)=10log(5)=6.99dBW. If the original quantity has no unit, a ratio for instance, the corresponding logarithmic unit is dB. For example, when Q is doubled, its corresponding logarithmic quantity increases by 10log (2)=3 dB.

In the expression (1), the different parameters are as follows:

| | |
|---|---|
| $P_{RX}$ | Signal Power received by the receiving station |
| $P_{TX}$ | Signal Power transmitted by the transmitting stations |
| $G_{TX}$ | Antenna Gain on the transmitting station |
| $L_{TX}$ | Passive losses on the transmitting site (cables, connectors, etc.) |
| **FSL** | Free Space Losses (path losses) |
| $L_{M}$ | Miscellaneous and generic Losses (fading margins, body losses, etc.) |
| $G_{RX}$ | Antenna Gain on the receiving station |
| $L_{RX}$ | Passive Losses on the receiving site (cables, connectors, etc.) |

In the generic form of the link budget equation, one station acts a transmitter while the other acts as a receiver. In technologies that support bidirectional links, such as AerDOCSIS, the link budget should be performed for both Forward and Return links (Downlink and Uplink). Usually the result is the same, because the equipment used in both sides is the same.

## Interpretation of the Friis Formula

The Equation (1) describes the Signal Power that will be received at the receiving side for a given set of parameters. In a communications system, for the signal to be demodulated at the receiving side, and thus the message decoded, the received power $P_{RX}$ must be higher than a certain threshold. The value of this threshold is called *Sensitivity* of the receiver and is expressed in the same unit as $P_{RX}$.

In a digital communications system such as aerDOCSIS, the Sensitivity depends on various parameters such as:

- **mSINR**: minimum SINR (Signal-to-Interference and Noise Ratio) required by the demodulator so as to correctly decode the signal
- **BW**: channel bandwidth of the signal (increasing the BW also increases the Sensitivity).
- **NF**: Noise Figure of the receiving chain. This value depends on the implementation of the receiving chain and is a parameter that is equipment-dependent.

The equation (1) can be written as:

$$(FSL + L_M) = EIRP_{TX} - L_{TX} + G_{RX} - L_{RX} - P_{RX} \qquad (2)$$

Where $EIRP_{TX}$ is the Equivalent Isotropic Radiated Power at the Transmitter side, and is given by $EIRP_{TX} = P_{TX} + G_{TX}$.

The received signal power $P_{TX}$ must be higher than the Sensitivity (S) in order to correctly demodulate and decode the signal. Therefore, the Free Space Losses ***FSL*** must not be higher than a certain maximum value in order to have the minimum that guarantees the correct demodulation of the signal. This maximum value of the ***FSL*** is called ***MAPL*** (Maximum Allowable Path Loss).

In the equation (2), the Miscellaneous losses is a parameter that is not deterministic, as it depends on various factors that can vary in time, such as the losses induced by external elements that affect propagation: human bodies obstruction, terrain obstruction, and most generally, fading effects. It is a decision of the radio engineer to provide a sufficient margin for compensation of these Miscellaneous losses, taking into account the various constraints that are inherent to each particular link budget. This margin, that is to be decided by the engineer, is called the margin of availability: $M_A$.

The equation (2) can be finally written as:

$$MAPL + M_A = EIRP_{TX} - L_{TX} + G_{RX} - L_{RX} - S \qquad (3)$$

In the previous equation the ***MAPL*** represents the maximum path loss that can be accepted, with certain Miscellaneous losses $L_M$, to have a correct reception of the signal. The ***MAPL*** is the maximum value of ***FSL***, with ***FSL*** depending on the distance ***D*** and the frequency ***F*** of the carrier:

$$FSL\,(dB) = 32.45 + 20log[F(MHz)] + 20log[D(km)]$$

Therefore, the equation (3) returns the maximum distance than can be supported in the link, with all other parameters given.

## Trade-off: Distance and Availability

As it can be seen in the left part of Equation (3), there is a trade-off between the maximum distance that can be achieved, and the availability margin ($M_A$) of the radio link.

With all parameters given, the equation (3) returns:

- Either the distance achieved for the link with a certain margin of availability.
- Either the margin of availability achieved for a certain distance.

Albentia Systems cannot commit on an achievable distance since it is a decision of the radio engineer to decide on the trade-off between the margin of availability to be provisioned in the link and the distance to be achieved. Usually, longer links require greater margin, in order to compensate for fading effects.

# Non Line-Of-Sight (NLOS) conditions

In NLOS conditions, the methodology for calculation of the propagation is similar to the LOS case.

In NLOS, the Equation (3) is still valid. In this case, the MAPL is no more assimilated to the Free Space Loss only, but the Path loss is expanded in order to take into account other effects that are inherent to the propagation model chosen.

Such propagation model is nothing else than an empirical formulation that characterizes radio wave propagation in a given scenario. As for FSL, the formula is a function of frequency and distance, but it extends the FSL model by considering other factors such as the presence of buildings, the Earth curvature or the mobility of the stations.

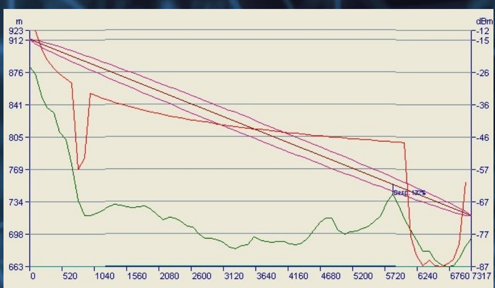
It is up to the engineer to decide on the propagation model to be considered, taking into account the characteristics of the particular environment.

Some typical propagation models are:

- Hata model.
- Okumura model.
- Cost 231 model.
- Longley-Rice model.

Albentia Systems does not advice to operate any microwave equipment in NLOS conditions. As a rule of thumb, you can assume that if the link distance is very short (much less than 1 km) it may work. If the link distance is long, you should not expect proper working.

**LOS Point.Point Link Example**



**NLOS Point-Point Link Example**