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■ CREATIVE WIRELESS ELECTRONICS ■

How to unlock the secret of wireless range

Introduction

Wireless systems and devices are being creatively applied in an increasing number of technology areas. Smaller device sizes, reduced radio component costs and increased device performance are some of the factors encouraging more businesses to consider implementing wireless systems.

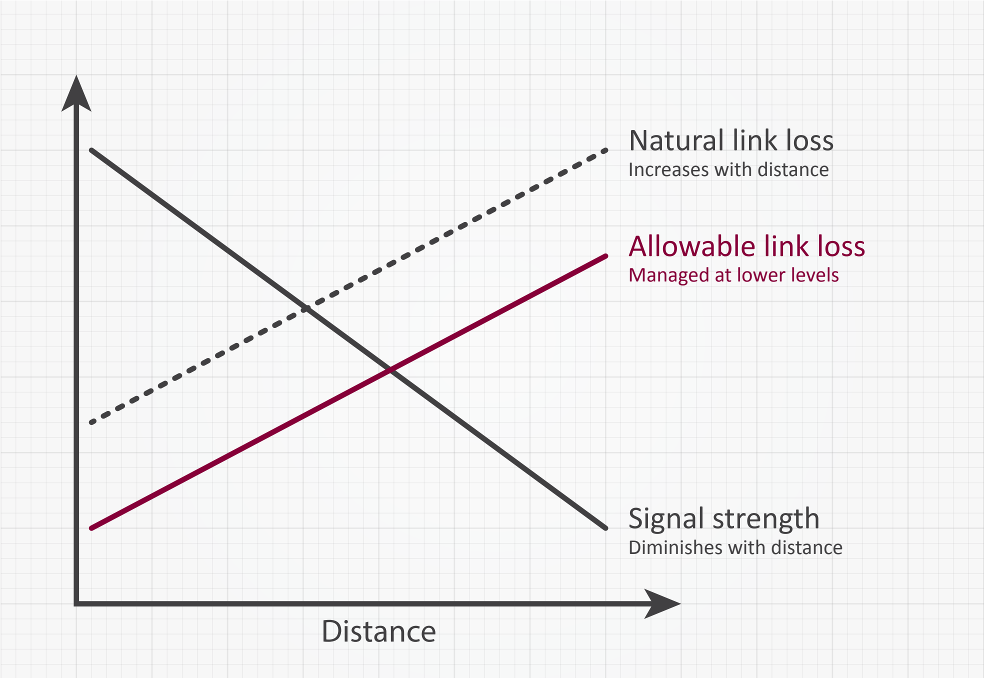
Designing wireless systems requires balancing the optimum levels of usability, performance and cost. Equally, it is important to understand the limitations of what can be achieved and to design solutions which are realistic in their approach. If you are considering utilising wireless communications and have questions about range, this resource looks at some of the key factors including what governs radio range, the physics of wireless communications and what is possible with current technology. These factors will help you understand the opportunities and design limitations of wireless technology.

Overview

What governs radio range?

All wireless communications are governed by a fundamental equation that provides the secret to good wireless system design. It boils down to how loud you 'shout', how hard you 'listen' and what gets 'lost' in between. The allowable reduction in signal strength between two connections (known as link loss) is the ratio between the strength of signal transmitted and the receive sensitivity. The greater the range of transmission required, the larger the link loss.

All wireless system designers must determine the required antenna performance, radio transmitter power levels, and receiver sensitivity. Once these are known it is possible to design the system so that it meets its requirements and performs correctly without being over-designed. Higher transmitter power can add considerably to the cost, so it is necessary to balance this to minimise the cost of the system while still maintaining performance. The following diagram shows the elements involved:



When designing a wireless system it's important to note that all transmissions disperse over distance and that other environmental factors can also affect the strength of the received signal. Link loss increases with range.

Wireless system designers calculate link loss with the help of this equation.

$$L = \frac{G_T P_T}{G_R P_R}$$

Here's what each element means:

L is the link loss
G_T is the transmitter antenna gain
P_T is the transmitter output power
G_R is the receiver antenna gain
P_R is the received power

Therefore, $G_T P_T$ refers to the amount of focused power which is being transmitted from the transmitter and $G_R P_R$ refers to the amount of listening and sensitivity of the receiver.

The goal when designing a wireless system is for the received power level to be higher than the minimum sensitivity of the receiver with a sufficient safety margin. The challenge is to limit how much link loss eats into the system's safety margin, which requires tuning the elements of the equation that affect how loud the system 'shouts' and how hard it 'listens'. If you increase $G_T P_T$ for instance (or just G_T or P_T) the allowable link loss can go up. It's a balancing act that requires expert calculation and system calibration.

The physics involved

The physics behind transmitters and receivers in a wireless network rests on balancing data rate and range. Such physics govern what is practical in real-world applications. To illustrate this we can turn the previous equation into a logarithmic form, so multiplications become additions, and the divisions become subtractions. Unpacking each element will show how it contributes towards calculating what is possible within a wireless system and help reveal the secret to range.

The link loss equation

$$L_{(dB)} = G_T - G_R + P_T - \left\{ R + \left(\frac{E_b}{N_o} \right) + k + T \right\}$$

$$G_T - G_R$$

We start with the ratio of the gain of the transmitter and receiver antennas. Users normally want handheld devices that work in all directions with no focused transmission which requires omnidirectional antennas. Both G_T and G_R then are actually zero and can in effect be forgotten in the calculation.

$$P_T$$

We then add the transmit power, a key element governing how loud the transmitter can 'shout'. If extending wireless range was simply a case of turning up the volume to whatever level was required a designer's job would be much easier. However, the transmit power of any wireless communications system is limited by legal regulations. Licensing arrangements by regulatory bodies mean that the device or network is not allowed to transmit more than ten milliwatts for ISM (Industrial, Scientific and Medical) frequency bands, or one hundred milliwatts from some devices. These are very small amounts but increasing the transmit power higher will break legal regulations in the common 2.4Ghz band. If the device is to be used in close proximity to a person then even less may be allowed.

$$P_R$$

Lastly we subtract the received power. P_R is the section in curly brackets and dictates how sensitive the receiver can be. It is the sum of a number of key elements:

R

R is the data rate, or the rate at which the information is sent. The minimum power required is dependant on the data rate and, unlike other elements that are out of their hands, designers can choose what value this is. They know from the equation that a higher data rate is going to lower the amount of link loss you can have. So, for a higher data rate (often needed for large amounts of information) it is advisable to have a shorter physical range between transmitter and receiver. If only a low data rate is required, the distance can be extended significantly, even when the transmission power is very low. Herein lies the secret to wireless range.

$$\frac{E_b}{N_o}$$

This symbolises the signal to noise ratio and is normally expressed in decibels (dB). Essentially this determines how much noise (other signals) is getting to the receiver. Since much of the dominant noise in a wireless system is actually created inside the receiver itself it is possible to reduce the noise level to about zero dB by processing the data using error detection and correction techniques that enable reconstruction of the original data. For most systems the signal to noise ratio should be be around 10dB to ensure signals are heard by the receiver. Increasing system complexity directly influences the signal to noise ratio and is the only other element wireless designers can significantly influence in the equation.

k

Boltzmann's constant, which is a scientific fundamental relating particle level energy to temperature and designers can't change that.

T

The effective temperature of the radio receiver is T in Kelvin, but can't normally be reduced from a value of 1000K down to less than 290K (room temperature) due to room temperature radiation.

The possibilities of wireless range

Wireless system design is complex and requires many factors to be considered. Problems arise when users want to be able to transmit large amounts of data from multiple places and devices across large ranges. For some users maximising the range is a priority, for others it is transmitting large amounts of data with a high data rate, and for still more it is both. Weighing user priorities with design constraints is a constant challenge.

Unlocking the link loss equation has shown though that the secret to wireless range lies in creating flexibility in **two key elements:**

Changing transmission data rates

Varying data rates allows small improvements to be made where they are needed and wireless systems to be tailored to the specific needs of the application. Simply put, longer range requires a reduced data rate. This is why consumer HD video is not streamed wirelessly over large distances, but text messages can be sent over many kilometres. If range is important to you, be clear about what data you want to send but flexible about the rate at which it can be sent.

The complexity of the system

System complexity is where the biggest gains in range tend to be made in wireless designs. The constituent elements of the radio communications system can have layers of complexity and added or removed that will positively affect performance. Designers will also look to improve how the system operates at low power whenever possible due to the positive effects on range.

Conclusion

When considering a new wireless system design, or a new application of an existing design, understanding data transfer rates and system complexity is crucial. Engage with wireless design partners who have the expertise to tailor these elements of the systems' design to your needs. Most modern wireless standards also offer solutions that target specific range requirements, data rates and levels of system complexity.

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