Radiometrix

99% is good enough

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Radiometı

Radios are specified using a number of simple laboratory measurements which give an ind performance to be expected of them. Their eventual operating environment is usually far f additional design considerations to achieve a reliable radio link. This paper examines the in-building propagation, looks at common sources of radio interference, and suggests dive techniques as a means of improving reliability.

The laboratory

The primary function of a transmitter is to generate RF power, usually as much as the reg constraints permit. The receiver is designed to detect as weak a signal as is possible i.e. l sensitivity. The path loss capability of the pair is the ratio of transmit power to receive se 433MHz transmitter of 10mW power output (+10dBm) and a matching receiver with a 2.2 (-100dBm) have a path loss capability of 110dB, i.e. they can overcome 110dB of attenua

The ideal world – free space

If we now connect this 433MHz transmitter and receiver to a pair of ideal isotropic antenn directions) and assume free space propagation (spreading losses only), we can calculate tl

$$\text{Range} = \frac{\lambda}{4\pi}\sqrt{\frac{P_{tx}}{P_{rx}}} = \frac{23.87\times 10^{\frac{L}{20}}}{f}$$

where R = range in meters
f = frequency in MHz
L = path loss in dB

This figure is far higher than the 200 metres or so that can be expected as a working range and serves to illustrate just how hostile the "real world" is.

Propagation within a building

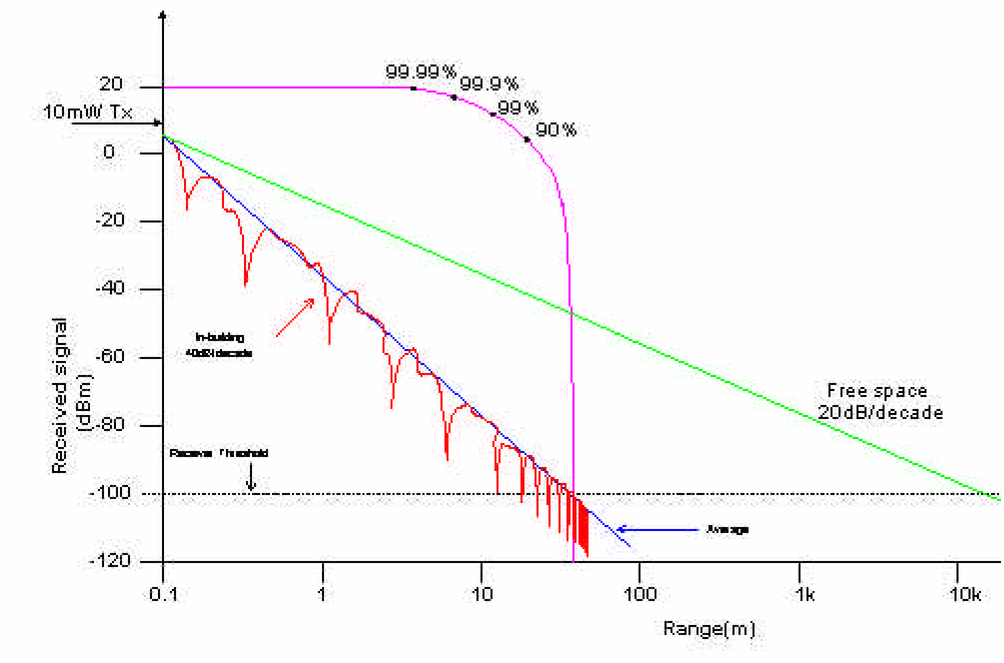
Signal propagation within a building is strongly dependent upon the topology, constructior building and is influenced by the following:

1. Reflection from flat conducting surfaces such as metal cladding, gal backed plasterboard, metal coated anti-reflection glazin

than a wavelength in size.

2. Re-radiation from thin conductors such as pipe work, electrical wirin any conductor of greater than a half wave in length.

3. Absorption by lossy materials such as damp concrete, stonework an



curve for a 433MHz 10mW TX (unity gain antenna)

Multipath interference

Reflection and re-radiation of the signal causes a strong 3-dimensional standing wave patt building. The signal strength at any particular point in space is determined by the sum in a both the directly transmitted signal and all the passively re-radiated signals. It follows tha cancellation will occur. These positions are known as "null spots" and appear as localised when compared to the average strength in the surrounding space.

A receiver placed at random, has:

- a 10% probability of being in a >10dB null.
- a 1% probability of being in a > 20dB null.
- a 0.1% probability of being in a > 30dB null ……..etc.

This effect is bad enough, however it gets worse. The standing wave pattern will change - of the null spot - as the objects that contribute to it are moved. Some of these objects, suc cabinets, power cords etc, are moved infrequently. Others such as people, vehicles and ve move rapidly and regularly. Perhaps the nastiest variable re-radiator is the fluorescent ligl a conductor which appears and disappears at twice the mains frequency and gives rise to ' null spots that have a 100Hz amplitude modulation. In many applications of in-building ra transmitter or receiver or both are mobile, and may at any time be moved through a signal

Sometimes these effects are beneficial. For example, reflections between floor and ceiling buildings act as a waveguide and will enhance propagation across a floor at the expense c

Re-radiation can often provide good coverage in areas which would otherwise lie in shado
There may also be benefits in terms of antenna cross-polarisation losses - since the re-rad
indeterminate polarisation, there is no discernible need to orientate antennas in the same p
polar diagram have any significant importance since re-radiated signals are arriving from

From the foregoing it can be concluded that signal levels within a building cannot be deter
precision, but may only be expressed statistically in terms of averages and probabilities. '
possibility of exceeding the path loss capability of a radio link even at very short range.

Radio interference within a building

In many ways, local interference has the same effect upon a radio link as being in a propa
of signal in a particular area. Depending upon the source the interference can vary from n
around a computer), to denial of the entire building where the interference is a strong on-f
signal propagation nulls which are static or slow moving, interference is often intermittent
occasional 'clicks' from light switches etc to a few minutes from a nearby cell-phone, or i
whilst a computer is turned on.

Sources of interference to beware of:

Computers and other digital electronics can produce broadband noise and weak clock har
above. It is worth noting that even EMC-approved equipment could still be legally radiati
are 40-50dB above our example receiver's noise threshold.

An extremely common and particularly difficult variation on the above is interference fro
within the product in which the receiver is used. Since the interfering source is usually wi
receive antenna and is always present, it masks all incoming signals below a certain level
receiver is permanently "deaf".

Microwave ovens and industrial heaters - multiple unstable 2.4GHz carriers.

Switch mode power supplies - harmonics up to 100MHz and above.

Amateur radio transmissions on 433 MHz.

Other low power radio systems in the local area.

Strong near-frequency transmitters: Unlike all of the above, which occur on the frequency
been designed to respond to, response to this type of interference is a common receiver w
heavily on its selectivity and strong signal handling abilities. It is becoming increasingly i
868MHz with the adjacent cell phone band, and the introduction of TETRA at 410-430 M
870MHz.

Designing for uncertainty

From the foregoing it can be seen that operating range within a building is both unpredict
variable. Since our aim is to design a reliable radio link with a reproducible working rang
examine the various techniques available to improve reliability.

The simplest and by far the most common approach is to use excess signal levels (transm
the maximum working range the average signal level is at least 30dB above the receiver's
is simply checked by attenuating the transmitter output by 20dB and verifying at least 90
desired range.

The figure of 30dB is chosen for a null probability of 0.1%, or conversely a 99.9% link re
may be acceptable for an uncritical application such as a wireless door chime, or a manu
higher safety margin for critical applications such as fire alarms or help call devices.

Excess signal above detection	Signal null probability	Link reliability	Range de-rating	Applications
0dB	>50%	<50%	1.0	car locking, toys
10dB	<10%	>90%	0.5	door chimes, DI
20dB	<1%	>99%	0.3	monitoring syste
30dB	<0.1%	>99.9%	0.2	professional tele
40dB	<0.01%	>99.99%	0.1	critical radio lin

This method of de-rating the range or increasing TX power to gain reliability is both wast is simple. From the above it can be seen that methods to gain higher reliability without ex interest, particularly for more professional / critical radio links.

Redundancy and Diversity

From the simple null spot probabilities stated earlier it follows that if one receive antenna being in a >20dB null, then the probability of two receive antennas both being in nulls is (reliability for 20dB less excess signal. Put another way, a threefold improvement in range can be achieved.

The use of two antennas (and usually two receivers) in an "OR" configuration is known a antenna spacing and orientation is uncritical - provided it is sufficient to prevent significa ensure that that both are not in the same null, any spacing from a quarter wave to many w The technique may be extended to 3 or even more antennas / receivers "OR"ed together, l diminishing returns applies.

Spatial diversity is economically most viable when used at the master or hub of a star net diversity, where a message is sent using a combination of two or more separate transmitte possible and provides similar benefits. In this case the message must be sent twice, first o repeated on a second antenna sited in a different position to the first. Since the message is some immunity to impulse interference.

Finally, transmit and receive diversity may be employed together in bi-directional links to reliability for only 10dB excess signal.

Time diversity is a commonly employed and very effective technique. Simply repeating a with random off periods, or using bi-directional links with intelligent hand shaking, gives a to impulse interference. Clearly, if the receiver is permanently in a null this method canno reliability in a static environment - but if either end of the link is moving, time diversity h spatial diversity in improving link reliability.

Frequency diversity is an excellent method of improving interference immunity. It can als spatial diversity, since the position of null spots is frequency dependent and with sufficie can be moved out of a null spot. Calculating the required shift can become quite complex quarter wave shift in null spot position (minimum effective) at a range of R metres:

$$\text{Required frequency shift} = \frac{300}{4 \times R}\ \text{MHz}$$

This gives a figure of 1.875MHz shift at 40 metres range – just achievable in the 868MH achieved at 2.4 GHz.

Finally

There is no such thing as a 100% reliable radio link. However, redundancy and diversity considerable improvements to in-building link reliability and ensure a good reputation for products.