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Application note 016

Why those specifications REALLY matter

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Look at the data sheet of any receiver module and you will find a list of (by now) familiar specifications: sensitivity, adjacent channel, other spurious responses, blocking (In fact, Application note 010 describes each in detail). Units with tighter specifications usually cost more, and are often physically bigger, and more power hungry.

It's easy to convince yourself that these figures are no more than 'specmanship' amongst design engineers. This article attempts to show that this is not the case. They directly affect real-world performance, and good specifications are vital for reliable system operation. Unfortunately, to show this, we'll need some **maths**.

Imagine a simple ISM band application: a wideband 433MHz FM transmitter/receiver pair using unity gains whip antennae. To keep things simple, these aerials are 1m from the ground (roughly bench-top height).

Typical radio characteristics will be: tx power 1mW (**0dBm**), rx sensitivity (including decoder) **-100dBm**; link margin for reliable operation **10dB**.

So good reliability will be achieved if the path loss between the aerials is **-90dB** or less.

Using the Egli model (see **Note 1**) d = (1 / (117 x 10^(0.1 x L)))^0.25
for L (loss) = -90dB then d (range) = **54m**

Now consider the addition of an interfering signal. To keep things simple once more this will be an identical transmitter. Taking the simplest case, that the unwanted signal must equal the (wanted level + relevant receiver rejection spec) to jam the system, then:

Taking the receiver adjacent channel rejection of a typical 'single chip' design: **-35dB**
Wanted transmitter is at maximum range (as above) from receiver (so wanted = -90dBm)
Unwanted transmitter is on adjacent channel, so for unwanted signal = wanted, then the path loss from the interfering transmitter to the receiver must be -55dB.

From the same model: -55dB corresponds to a distance of **7.2m**, In other words, if a similar transmitter comes within about 7m of the receiver, the system fails. This is a fundamental limit in how multiple links co-exist in the same area.

(In this case we've taken adjacent channel: for interferers located at greater frequency separations the alternate, or even blocking, figures can be used in the same calculation)

Now let us repeat these calculations (in abbreviated form) for a higher performance, narrowband link (employing the same frequency band and aerials):

tx 10mW (**10dBm**), rx sense **-120dBm**; (link margin again = 10dB).

So: Path loss <-120dB, and for this loss, d (range) = **304m**

Adding in the adjacent channel interferer, assuming rx adjacent rejection is still -35dB
Unwanted path loss must be >-85dB, corresponding to a distance of **40m**

Re calculating for adjacent channel rejection of **-65dB** (more typical of good quality narrowband SRD receivers): unwanted path loss >-55dB, critical distance = **7.2m**

Not surprisingly, if the rejection specifications are not improved in line with the increase in range (and operating path loss) then the minimum distance between receiver and unwanted transmitter increases in direct proportion.

To retain, (or improve) the allowable separation between a receiver and interfering transmitters as receiver sensitivity improves, it is necessary to increase the receiver rejection performance proportionally.

Makers of supposed 'narrow band' single chip radios should take heed: a rejection performance sufficient for a short range wideband radio will **not** prove good enough for a long range, narrowband link.

Note 1: Path loss calculation.

The usable range of a radio system is defined by several basic factors: transmitter power, receiver sensitivity, effectiveness of the aerials (antenna gain), and finally the transmission path loss.

Transmit power and antenna gain are simple constants set by the system components. Receiver sensitivity is a combination of the basic sensitivity of the circuitry (defined by noise factor and signal bandwidth), and the ability of the 'decoder' (which could be a modem chip, or the human ear) to recover meaningful information at a given signal to noise level.

Path loss is more interesting. It is the effective attenuation factor measured between transmitter and receiver. There are numerous different ways of calculating this value, from the basic (and for practical, UHF and VHF terrestrial radios, wildly optimistic) free space model:

$$\text{loss (dB)} = 32.4 + 20\log(F) + 20\log(D)$$

F = frequency in MHz
D = distance in km

up to highly complex, modern, statistical methods. In this case, I have chosen to use the rather traditional Egli propagation model, which attempts to simulate path loss over open, but irregular terrain. This model cannot take into account in-building propagation, fading, or multi path effects; but for simple ISM links in rural and suburban environments I have found it tolerably effective.

$$\text{loss factor} = ((40 / F)^2 \times (Ht \times Hr)^2 \times Gt \times Gr) / d^4$$

F = frequency in MHz
d = distance in meters
Gt, Gr = antenna gain
Ht, Hr = antenna elevation

For our 433MHz system, using unity gain aerials located 1m above ground the G and H terms cancel out and this equation simplifies to:

$\text{loss factor} = 1 / (117 \times d^4)$, or in dB $d = (1 / (117 \times 10^{(0.1 \times L)}))^{0.25}$

(for example: for a -90dB path loss, d = 96m)

For more information about the Egli path loss model, see:

J. J. Egli, "Radio Propagation Above 40 Mc Over Irregular Terrain," Proc. IRE, Oct. 1957
http://en.wikipedia.org/wiki/Egli_Model

Note 2: A more extreme worked example

Consider our second example ISM link when operating in the proximity of a typical vehicle mounted 25watt, 70cm band amateur transmitter, driving a +3dBi gain aerial

In this case, it's the +/- 1MHz blocking spec that is relevant. Again, take a typical performance figure for 'narrowband' single chip designs, at -45dB.

unwanted transmitter power: +47dBm, interferer path loss >-122dB for the link maximum range to remain unaffected. The link range begins to degrade when the unwanted transmitter comes within **340m**

For a good, EN300-220 class 1, module design where blocking exceeds 86dB, this critical distance falls to **32m**. The difference between an interferer in your driveway, compared to an interferer somewhere in the same town!

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