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Application note 020

Lies, damned lies, and datasheets

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Every radio module manufacturer in the world is telling lies. Open deception. Falsehoods. Disambiguations. Porkies.

I am, of course, referring to the operating range claims made by ISM band wireless module manufacturers in their advertising literature and their datasheets.

If you look at the information issued alongside the module you're planning to buy, you will undoubtably find some claim of 'typical' link range. Usually a bald statement like "range exceeds 1000m", or occasionally something slightly more meaningful like "75m indoors, over 150m outdoors".

And it means nothing. Because the author of the datasheet has missed out almost all of the supporting information which would let you know how the module was really performing.

The actual, achievable, range of a wireless data link can be a highly unpredictable thing. In theory, and in unobstructed free space, you can meaningfully calculate a path-loss, relate that to the performance of the radio components, and get an absolute range.

But not in the real world. Firstly, the actual propagation will be nothing even vaguely like the free space model (compare the equations in notes 1 and 2). The presence of obstructions, the curvature of the earth limiting the line of sight "horizon", the proximity of the ground itself (causing diffraction losses) all mess up the propagation of your radio waves.

The quality ("antenna gain") of the aerials obviously makes a difference. So does the elevation of the aerials (height above ground). On top of the basic radio's sensitivity there is the decoding algorithm's efficiency (it's ability to deal with degraded signal to noise ratio. This can vary by over 10dB between edge triggered UARTs and proper biphase decoders) and the actual data rate (on basic -120dBm sensitivity narrowband link hardware I've measured actual decoder performance between -116 and -126dBm simply by changing data rate from 4kbit/sec to 62bits/sec).

And these are just the predictable factors. Reflection from obstacles causes multipath fading (specific localised "nulls" or reductions of signal strength, often by 10 to 20dB, or more) well inside the calculated 'path loss' maximum range. Sometimes, those obstacles are moving vehicles, making these fades time-variable.

The structure of buildings will cause huge variations (wood framed light domestic constructions are almost radio-transparent, but a steel framed industrial unit can resemble a faraday cage. Older brick or stone structures can be totally unpredictable). And environmental factors can intrude (remember: 2.4GHz is a water absorption band. Dew soaked foliage in the morning can add tens of dBs to the path loss, changing as it dries out through the day)

(Of course, unexpected effects can also increase range: reduced path loss is sometimes seen down the "waveguide" formed by straight roads between tall buildings. Range is greatly increased across water, or between the sides of a valley. And at VHF frequencies there are infrequent atmospheric effects such as sporadic-e propagation which can cause greatly extended (shortwave-like) unexpected over-horizon range, for short periods).

My message here is one frequently preached: "test everything". It is never enough to assume the claims made in a manufacturers data sheet can be believed, unless their technical support engineers can actually substantiate the claim with real tests.

Even then, it is vitally important to test your hardware using your aerials in your environment. Nothing else will guarantee a reliable link.

Finally, lets consider a real world example I've actually seen in print

Several distributors sell a particular 2.4GHz Zigbee module as having "up to 24km" range. Adverts and editorials claiming this range have appeared in reputable technical publications, and are repeated on-line.

Closer inspection of the data reveals +20dBm output power and -106dBm sensitivity. So the unit should (optimistically, assuming no fades) function over a 126dB loss path

Calculated free space path loss at 24km = 127dB

(Egli's model suggests 200 meters for 127dB pathloss at 2.4GHz, but this model is only characterised between VHF and 1GHz so shouldn't be relied on at these frequencies)

But then refer to the manufacturers detailed data sheet:

" Indoor/Urban: up to 1200' (370m) " (which is possible, if optimistic)
"Outdoor line-of-sight: up to 15 miles (24km) **w/ high gain antenna** "

So the advertised range is in an open field, unobstructed site with a clear line of sight between two (undefined) high gain aerials either looking across a deep valley or mounted on towers at least 11m high (horizon distance due to earth's curvature).
(and "high gain antenna" at 2.4GHz could well mean a highly directional type with a gain of 15-20dBi, or more)

The only comment I can add after that is "let the buyer beware"

Note 1a: For reference, here is the Egli irregular terrain path loss model, expressed in dB terms : (remember it refers to a path gain, so the answer is always negative)

path gain (dB) = 32.4 - 40 x log(d) - 20 x log(F) + 20 x log ((Hr x Ht)) + Gt + Gr

F = frequency in MHz d = distance in meters
Gt, Gr = transmit and receive antenna gain (dBi)
Ht, Hr =height above ground of transmit and receive aerials (in meters)

Note 1b: And here is the "free space" model

path gain (dB) = - 32.44 - 20log(F) - 20log(D)

D = distance in km

The free space model is "optimistic" in the extreme. Take an imagined 433MHz radio link with a 115dB link budget (-105dBm rx, +10dBm tx).
Eigli's model gives 230m range (assuming 0dBm aerials at 1m elevation), which is typical for measurements on ISM links in this performance catagory
The free space model would predict 31 kilometers !

A good (although necessarily maths-heavy) discussion of propagation modelling can be found here:
http://people.seas.harvard.edu/~jones/es151/prop_models/propagation.html#fsl

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