



How far will it go: When only the longest range will do

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Low power ISM band modules are well established in a wide variety of short range, high and low data-rate applications. Often referred to as 'SRDs' ('Short Range Devices'), it is commonly assumed that these solutions are usable only over very limited distances.



Fig 1: An ISM band transceiver

Well, it all depends on what you mean by 'short range'. Simple, wideband ISM implementations rarely exceed 100m range. Popular 2.4GHz network devices don't even approach that figure. And rarely need to. But there are a sub-set of low power radio tasks where longer ranges are desirable.

Alarms and high value asset tagging systems can need to cover extensive industrial sites, agricultural monitoring and control devices frequently need ranges exceeding a kilometre, and maritime telemetry calls for even longer ranges. While there are existing infrastructure based wireless systems (such as GPRS, or even ARGOS), or high power licensed band radios, that guarantee far longer range by design, there is a lot that can be achieved with very simple ISM modules, provided a few simple considerations are taken into account.

So what defines range ? The range expected of a radio link is the point at which the path loss between the aerials equals rx_sensitivity - tx_power (the 'link budget'). A margin for fading and uncertainty, of usually 10 - 20dB, is normally added to the path loss.

From the path loss model (see footnote) we can see that the path loss is proportional to $10 \times \log(1/d^4)$, where 'd' is the range in meters.

As a rough rule, this suggests that to double the range, it is necessary to improve the link by about 12dB.

1. Start with an RF friendly design: The most sensitive receiver is totally wasted if all it can pick up is noise from the processor, power supplies and displays. The first step is to provide adequate shielding, decoupling and avoidance of EMI generation.

2. Keep the data rate as low as possible: Range is all about receiver sensitivity, which in turn relates to channel bandwidth. For a given transmitter power, and system noise figure, a 64kbps link will have a lower sensitivity, and hence inferior range, to a 1kbps link.



Fig 2: A narrow band receiver

A lower data rate will also allow the use of narrow band radios, with higher sensitivity and better rejection performance than simple wideband modules (refer to note

2). To make best use of very low data rates, special techniques must be employed, processing the AF output before squaring, or in some cases the IF signals. Some implementations use DSP techniques to achieve sub-10Hz effective band widths, and sensitivities better than -150dBm.

3. **Use an efficient decoder:** For a given level of received signal to noise ratio, the data error rate (and hence usable sensitivity) can vary markedly for different decoder algorithms. Edge triggered, asynchronous decoders (such as simple UARTs) require a much ‘cleaner’ baseband signal than a good biphasic (Manchester) decoder. Tone decoders (slower modem devices, DTMF devices) offer even better performance, at the price of more hardware, and much slower communication.



Fig 3: CTR44 bi-phase encoder/decoder

4. **Choose your band carefully:** Different nations have different regulations, and different permitted power levels. Selecting the band permitting the highest output power is part of, but not all, the issue:

Path loss increases with frequency, proportional to $-10 \times \log(1/f^2)$. Which means that, (assuming the same aerial gain, transmit power, and receiver sensitivity) a 173MHz VHF link will see 14dB lower path loss than an 869MHz one. In other words, a 10mW, 173MHz link will have similar range to an 80mW 458MHz one, a 250mW 869MHz one, or a (hypothetical) 2 watt system at 2.4GHz!

But lower frequencies require larger aerials for a given aerial gain performance, which can be an issue in the mechanical design of the product. (An 869MHz whip aerial is 9cm long. The same 1/4 wave antenna at 173MHz is 43cm).

A good rundown of the available UK frequency allocations can be found here:

http://www.ofcom.org.uk/static/archive/ra/publication/ra_info/ra114.htm

http://www.ofcom.org.uk/static/archive/ra/publication/ra_info/ra365.htm

5. **Pay attention to the aerials:** The best radio on earth won't give good results if it's sited down a manhole, or uses an inefficient aerial.

For long range links, plan to use a good quality helical (not a compressed 'stub' design) or a quarter wave whip as a minimum. If space (and cost) constraints permit, then a true dipole or a 5/8 wavelength design will offer superior performance.

But pay especial attention to radiated power limits in the chosen band, which will prohibit the use of an antenna with more than unity (0dBi) gain at the transmitter. The receiver antenna can, however, have as high a gain as circumstances permit. On fixed links even highly directional 'Yagi' arrays can be used, with gains sometimes exceeding 20dBi.

6. **Height matters:** Mount the aerials as high up as feasible. Referring to the path model again, the loss is directly proportional to $-10 \times \log((H_r \times H_t)^2)$.

Mounting the aerials 2m above ground level will improve the path loss by 12dB, and double the expected range. 4m elevation of both (the height of a first floor window ledge) should quadruple the range.

7. **Test is everything:** At the risk of labouring a point I've made before, only a practical test of your application, in the eventual environment, will confirm for certain your design assumptions. Egli's model is only an approximation, and path losses can be much less (over sea or rivers for instance) or far higher (in buildings, around tall structures, in difficult terrain). Interference can ruin receiver performance. An error in aerial mounting can reduce transmit power.

Go out and try it.

