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Application note 010

There's something they aren't telling you

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Take a look in any ISM band module data sheet and, after the predictable text claiming ease of use, long range and low cost (and the sections detailing the pin out and user interface) you will find an apologetic few paragraphs listing the actual radio specifications.

This is the interesting bit. Radio specifications (and the methods used to measure them) could occupy a small book, but here I plan to focus on a few important measurements, which are all too often omitted.

Most of these are receiver parameters. This is because the commonly encountered ISM or 'low power' radio approval specifications (such as EN300-220, AS/NZ 4268:2003 and the American FCC regulations) define the transmitter parameters fairly closely in terms of power output, spurious radiation and frequency accuracy, to guarantee a minimum of interference, both within the ISM bands and with other services. Unfortunately, the receiver performance limits under these approvals are far less stringent.

To consider a few important parameters:

- **Sensitivity**: The signal level (given in dBm, or sometimes microvolts). Usually 0.1% or 1% errors at a stated data rate (and format), or an equivalent signal to noise or sinad level.

  Always look for a sensitivity measurement which relates to your final application data rate: typical wideband ISM receivers can achieve -115dBm for 12dB SINAD in a 3KHz audio bandwidth, but the same radio at 64kbit/sec is unlikely to exceed -105dBm for 1% errors. And it's the sensitivity with your data format that will define your eventual range (assuming none of these following limits are exceeded).

  

  An 868MHz ISM band receiver

  In the case of units with programmable channel widths (and data rates) the sensitivity, and therefore range claims, are frequency given for the slowest datastream (and therefore narrowest bandwidth).

- **Adjacent channel:** The ability of the receiver to resist interference from a carrier in the next channel.

  These 'rejection' specifications are expressed as a ratio (always in dB) between the level of the interferer on the adjacent channel, and the wanted signal, at the point when the wanted signal has been jammed. It is usual to conduct these test at 3dB above the quoted limiting sensitivity level.

- **Spurious rejection:** The resistance to interference on certain, specified frequencies.

  These should be points where the receiver is particularly susceptible, such as '***image'*** (carrier frequency +/- intermediate frequency x 2), '***half IF***' (carrier +/- intermediate frequency x 0.5) and for dual conversion designs '***second image***' (carrier +/- second intermediate frequency x 2.)

  A responsible designer will usually test for spurious responses at multiples of the reference and processor clocks too, as well as looking for intermediate frequency filter related stopband response defects or 'humps'.

- **Blocking:** The resistance to interference at a series of arbitrarily defined frequencies. (normally +/- 1, 2, 5 and 10MHz from the carrier)

  The final catch-all specification, this relates more to the device's large signal handling ability and the quality of the filter stop-bands, rather than known 'weaknesses' in the design.

- **Intermodulation:** The resistance to multiple interferers, at frequencies which can result in a mixing product on-channel. Normally tested with a pair of interferers at +/- n and +/- 2n from the wanted carrier. ('n' must be equal to or greater than the unit channel spacing. Typically, this test is conducted with n = 2).

  This is an exacting test of receiver large signal handling capability, particularly in the RF amplifier and mixer stages, and is usually where simple, low current designs fail. Unfortunately, in a crowded band, it is intermodulation that eventually limits overall performance, to the point that frequency allocation plans for multiple channel systems are normally arranged to minimise possible intermodulation effects. (In fact, there is a whole market for software which automates this 'intermodulation planning' process).

But why does it matter ?

The receiver sensitivity defines range (with a given power transmitter, at a given channel bandwidth, with given aerials) but only in the absence of other signals.

In the real world, it is the receiver 'rejection' parameters (adjacent, the various 'spurious' and blocking) which will limit performance. A certain degree of planning can minimise the effects of poor intermodulation, and maybe adjacent channel rejection, but deficient spurious, and especially blocking, performance cannot be ignored.

In these cases other transmitters on other frequencies WILL compromise your system. There is no use in having good enough sensitivity to reach out ten miles if a garage door opener in the next street can block you.

If your supplier isn't quoting a particular parameter, then it's usually because it's embarrassingly poor.

Lastly, a few example figures. Tabulated below are the basic receiver specifications for radios in the PMR (radio telephone) bands under EN300-086, for safety critical class 1 and class 2 ISM band radios approved to EN300-220, and one of the better ‘single chip’ receiver designs.

Rx spec.	PMR	‘class1’	‘class 2’	‘single chip’
adjacent	70dB	60dB	(no spec)	30-45 dB
spurious	70dB	60dB	(no spec)	40dB
intermod.	65dB	(no spec)	(no spec)	30dB
blocking	90dB	84dB	30-60dB	50-60dB

Note 1: The term ‘dBm’ refers to ‘power in dB relative to 1mW’. The impedance should be quoted also, but this is usually 50 ohms.

power(dBm) = 10 x log (power in milliwatts) or
power(dBm) = 10 x log (20 x (rms voltage across 50 ohms)^2)

0dBm = 1mW. +27dBm = 500mW. -118dBm = 0.28uV

Note 2: SINAD is a commonly used measurement applied to receiver audio. It is the ratio (expressed in dB) between (signal+noise+distortion) and (noise+distortion)

This is measured by applying a carrier, modulated with a 1KHz sinewave, to the receiver. The recovered audio is filtered (which defines the audio bandwidth, often 300 - 3400Hz, or sometimes a narrower ‘psophometric’ filter with a particularly shaped passband) and then fed through a narrow 1KHz notch filter. The total power levels before and after the notch filter are compared. 12dB sinad is about the noise limit for comfortably intelligible speech.

There are many measurement instruments (dedicated ‘sinadders’, communication test sets) that automate this measurement.

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