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Application note 009

Listen to your radio module

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To the non-specialist, even the simplest of radio modules can seem a strange and demanding device. It requires ripple free power, proper mounting on a good groundplane, and the provision of a carefully selected and located aerial. And even then, exacting interface requirements must be met, often the datastream must be specifically coded, and bandwidth and timing restrictions worked within.

And then everything is guaranteed to work ?

Unfortunately, no. Even when good practice has been followed, and the module is being used well within it's parameters, there will occur occasions when the implemented link achieves nothing like it's calculated, or promised, range. (In rare cases it may fail to operate at all).

Sometimes, this can be due to simple bad practice. Like using an inappropriate aerial, a noisy power supply, a badly coded datastream, or occasionally even a defective radio. These cases are relatively easy to diagnose. But sometimes even when every guideline and rule has been followed, and the radio modules have been re-tested by the manufacturer and found good, the link does not perform.

The problem is most likely not in the module itself at all, but rather it is the result of an interfering signal. An interferer can originate from outside the customer's equipment (from nearby electronic equipment, or from other radio systems) or from within (from switch mode power supply oscillators, and from digital clock signals). It can be a single frequency 'spur', it can be the modulated carrier of another radio, or it can be a 'forest' of unstable, digital noise.

A 433MHz ISM band receiver

A typical ISM band radio receiver can have an input sensitivity better than -115dBm (about 400nV). An unwanted signal on channel of this order of magnitude will be undetectable on a scope, or a simple spectrum analyser, but will still compromise the link range significantly.

So how do you go about identifying, and solving, such interference?

There are a few simple diagnostic methods that can save a great deal of heart ache and lost time:

Once you've got the suspicion that 'things are not all they ought to be' you need to be able to reliably reproduce your findings. A repeatable test set-up will be needed in your lab if you are to make any meaningful conclusions.

Conducted tests (where a signal generator connected to the aerial port replaces the transmit end of the link) are useful, but only if interference is entering the radio by radiation through the casing, or conduction through the interface.

Otherwise, a radiated test will be needed. Placing a large value attenuator on the transmitter output, or replacing the transmitter aerial with a dummy load will reduce the range to manageable proportions (or, if available, a signal generator feeding an aerial can replace the transmitter-end of the link).

Monitor the receiver audio: You can tell a lot about a link by looking at (on a scope) or better, listening to (with a small audio amplifier and speaker) the analogue AF output of the receiver.
The output of a simple FM receiver in the absence of a signal should be white noise. Anything else is symptomatic of problems. Warbles, tones or 'burbling' noises should suggest either digital noise from a cpu, or another transmitter in your vicinity, while the absence of noise ('quieting') when you remove your wanted signal indicates an un modulated interfering carrier (typically a harmonic of a stable clock oscillator).

Monitor the channel: Use an inexpensive 'scanning' receiver set to your operating channel frequency (or, better, build yourself a monitor receiver from another, identical radio module and aerial. Add a voltmeter on the "signal strength" output, and an audio amp and speaker on "AF out". Power it from batteries)

- Check that there are no unexpected signals present on your channel.
- Conduct this survey both in the lab, and at your final installation location if possible, and be aware that external interferers are frequently intermittent.

Eliminate your own hardware: Observe the output of your receiver when your entire design is operating, and when only the receiver itself is powered (preferably from a temporarily connected battery).

By replacing the monitor receiver aerial with a small 'search coil' (2-4 turns of 1mm diameter wire, wound around a 5mm former), it can be used at shorter range to 'sniff out' an interfering device.

If the signal is found to have an external origin (another radio system, or a piece of equipment over which you have no control) then you have very few options:

- Accept the reduced range, or change frequency to a 'clear' channel.
- Module manufacturers now often provide several frequency versions of even the simplest modules, in identical pin outs, while many of the more sophisticated units are multiple-channel by design.
- Occasionally, the radio design itself will be found to have a 'blocked' channel, when the channel frequency falls onto a harmonic of one of the internal reference oscillator frequencies. Your module manufacturer should be able to advise you of this, although all too few will actually admit it.

If the interferer originates in your hardware, then there are certain modifications and tests that may help:

Improve general decoupling and filtering: This ought to be general good practice, but ensure:

- HF decoupling (47p-1n, surface mount) caps are provided adjacent to all fast logic devices.
- PCB tracks carrying fast digital or high frequency analogue signals are short and direct
- Good grounding practices (groundplanes or low-impedance earths) are used.
- The interface connections to the radio module are clean, and add filtering networks if necessary

Conduct an 'audit' of all the clock sources in your design: If the harmonic of a processor clock or other oscillator falls on the channel frequency (even if it is a very high order multiple: I've seen trouble from the 35th harmonic of a crystal clock!) then this is a possible culprit. Temporarily stopping the clock should be seen to remove the interferer, and changing to a different frequency clock (if system design permits) can be a cure (But beware: the interferer is still present: it's just moved, and if serious enough could still be a general EMC problem).

Locate the circuitry inside a shielded enclosure: if the mechanical design constraints permit, locate the circuitry inside a shielded enclosure (i.e. metal, or treated plastic) with the aerial outside. Sometimes, the addition of internal shield cans over especially ‘active’ circuits can be effective

Carefully examine external connections: Power supply or interface cables are frequently found to radiate interference generated inside a unit, so it is good practice to limit the slew rate of external signals, and include filtering (RC, LC or ferrite) wherever possible

If the interference originates from the hardware and no easy cure can be found, then there are some considerations for the (inevitable) redesign.

- Identify noisy sub-assemblies (displays, power supply modules). Conduct radio interference tests of alternative units.
- When re-draughting the pcb, put series ‘stopper’ resistors on fast logic lines (100 ohms is frequently sufficient to reduce radiation without corrupting the logic waveforms), include a groundplane, and filter all connections at the board edges
- 'Sleep' as much of the digital hardware as possible. Modify the operation of the software so as little as possible that could cause noise (such as updating displays, or reading e2proms) happens during the receiver’s operating time window.

And, as always: test everything.

Good luck

Footnote: Range testing the radio alone.

Sometimes, it will seem that a radio link isn’t “quite right” (range is not quite what was hoped for, but isn’t unusably poor) but no absolute cause can be identified.

In such a case it is useful to conduct a range test on the radio/aerial/environment that is independent of the possibly interference producing customer hardware. This will give an estimate of what the modules themselves are capable of. The easiest way to conduct this test is to use a proprietary encode/decoder chip pair to replace the customer hardware. The coder/decoder should be operated at approximately the same data-rate as that used in the final design, and a simple ‘push button/flash light’ interface

Suitable devices for such a test would be the Holtek H12 type coder, the Radiometrix CTR44, or it’s evaluation kit: http://www.radiometrix.co.uk/products/nbek.htm

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