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Application note 008

Get the best out of your ISM band radio module

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So you've decided that your product needs a radio link ?
Maybe you've waded through dozens of data sheets, decoded bewildering specifications, negotiated pricing and deliveries and finally unwrapped the first samples in their gleaming, tiny glory.

Job done ? No!

Commercially available radio modules are designed to be easy to use, and to isolate the customer from at least some of the peculiarities and complexities of designing practical RF circuitry. However, there is still a certain amount of care to be taken if the full performance and reliability of what can be a very expensive "component" is to be realised.

The circuitry of a radio system, by it's very nature, includes significant amounts of gain in some very sensitive circuitry. The receiver handles sub-microvolt signal levels, while some transmitters are putting out over half a watt of radio frequency energy. Treated incautiously a receiver can be seriously de-sensitised (resulting in greatly reduced range), while a transmitter may produce unexpected spurii (contravening statutory regulations, with all that entails).

So what needs to be kept in mind ?

1. Mount your module with good RF practice in mind:

- Use a groundplane. Mount the module directly on it and (if possible) solder the screen can to it, ensuring a good, low impedance, earth path. Do not use tall sockets. It may be convenient to plug your modules in, but the considerable inductance resulting from the extended pin length will degrade performance.
- Keep pcb tracking to the module short and direct, and provide EMC filtering wherever possible (series chokes or 'stopper' resistors at least, T section filters are better) to minimise pickup on sensitive lines.
- Take special care of the aerial (RF in/out) tracking: as short as possible, and as good an approximation to a 50 ohm stripline as you can achieve (2.5mm thick tracking on 1.6mm epoxy board is a good start-point). If more than a centimetre or so of track is needed, then seriously consider using a coaxial cable.

2. Beware of interference, coupling and pickup:

- Do not run aerial tracks or locate aerials near other circuitry. Receivers will pick up interfering signals, while the transmitter can 'inject' RF energy into your potentially sensitive circuitry.
- Do not locate the module near interference generators (high speed CPUs, fast backplanes, switch mode power supplies or other radio sub-systems). Be aware that external interference can degrade the selectivity of a receiver (it's ability to reject unwanted signals) even if the apparent sensitivity is unaffected. This nightmare manifests as good 'under test' performance on the lab bench, but unexplained performance deficiencies in the field. Physical separation is often the best form of 'screening'
- Provide a clean power supply, within the specified operating voltage range. DC-DC converter ripple is a particular problem, while battery voltage 'droop' under load can cause some very

unpredictable behaviour. Even wideband noise from older designs of low dropout regulator (the LP2931 series are especially guilty here) has been seen to cause problems. It is usually unwise to share a common power rail with noisy digital circuitry.

3.Design your system to minimise it's interference 'footprint':

- Choices made early in a product's lifetime can make it much more 'radio friendly' in the long run. Obviously noisy techniques can be avoided, and sufficient suppression of unavoidable noise designed in from the start. (This also has the advantage of improving your product's overall EMC performance, for a trouble free CE approval process later)
- Lay out all your circuit boards as if they are radios: keep fast data and clock tracks short, decouple for high and low frequencies (put 100pF caps across your 10 or 100nF decouplers), always use a groundplane, and be generous with ground vias.
- Choose the lowest clock rates that your system design can tolerate, and make doubly sure that none of the clock frequencies (or harmonics of them) fall on or near your radio's channel frequency. (An industrial PC with a 433MHz processor is a poor choice in a system where the radio link operates in the popular 433MHz ISM band).
- Minimise the bit rate of external communication signals, and where possible use balanced, low voltage standards like LVDS in preference to 'raw' logic waveform.
- Use linear regulators if you can. When a switch mode must be used, a constant frequency type should be used in preference to a constant on-time or variable frequency design. If more than one switch-mode is present, arrange for them all to run at the same frequency (many designs now offer external frequency synchronisation inputs). Keep the external fields of power inductors and transformers to a minimum. Choose toroidal core units or screened parts where possible.
- Avoid inherently noisy components. Stepper or brushless motors are better than commutator (brush) types, LED or incandescent lamps are better than fluorescent or electro luminescent types, and semiconductor power switches are less noisy than mechanical contact relays.

4. Read the small print:

- All modules are designed to be easy to use. In theory. But they all have unexpected little interface details that can trap the unwary user:
- 'Raw' data or baseband radios connect your datastream directly to the radio channel, which is prone to interference and noise, and which is rarely (if ever) dc coupled. This requires your datastream to be coded in a way which: a) Balances the overall 1 and 0 durations and b) Allows a decoder to identify a valid data burst. Typically the user data must be formatted into packets, including address and framing/identifier sequences, and the whole stream then biphase (Manchester) coded.
- In addition to coding the data, the radio will impose timing restrictions, as the transmitter requires a specified delay between 'enable' and valid data to turn on, while the receivers usually also require time to settle. These timings can vary from less than 1mS to over 50mS, depending on the design and manufacturer, but will invariably require a 'preamble' sequence to be added to the data packet
- 'Data links' or 'radio modems' take care of the coding and framing functions, and frequently offer some data error handling too. In these cases the module is simply connected to a UART and treated like a serial cable, but the user must be alert to the necessary control or set-up commands needed by the modem and by possible hand shaking restrictions (Often 'buffers full' or 'link busy' signals require a pause in the datastream, while few simple radio modems offer true full duplex working).
- Additionally, some modules will require further interface signals to be handled, ranging from simple channel select inputs to quite complex SPI bus operations. Read the maker's data sheet extra carefully at the selection stage.

5. Remember to consider the non-electrical environment:

- Radio systems rarely operate properly outside their specified temperature range, as they rely on accurate frequency references, subject to thermal drift.

- Some radios (synthesised multi-channel units primarily) are subject to a certain degree of microphony, and are not suitable for use in high-vibration environments.
- RF circuitry is not tolerant of liquid contamination. Even condensation will frequently disable a module, and if assembly requires the unit to be potted then the encapsulating compound must be excluded from the module housing.

6. Pay attention to your aerial:

A radio system depends on the aerial to function, yet it is surprising how little care is usually taken in specifying or designing this part of the link.

Some modules are offered with built in aerials. These are easy to use, but are usually (electrically) quite inefficient. They also require the module to be mounted away from conducting or lossy (= wet) objects, and obviously not inside a metal equipment housing.

Most manufacturers give simple aerial designs in their data sheets, but with the exception of the quarter wavelength whip (a straight piece of wire of specific length: about 16cm for the 433MHz band) the self-made helical and loop aerial designs can require a good deal of specialist knowledge and test equipment to optimise.

The final option is a commercially manufactured aerial. There are a very wide range of these available, and your module's manufacturer should be able to recommend suitable parts. A ready-made aerial is the most expensive option, but it offers some advantages: it is electrically predictable and requires no adjustment; it is robust and can be mounted externally to the product casing; and aerials can be obtained with connector mounting (SMA, BNC, N and similar) allowing easier testing or replacement.

In any case, the link performance is maximised if the aerial is:

- a) Mounted free from interfering objects;
- b) Located as high up as possible (to get the best radio 'horizon' distance);
- c) Connected to the module by the shortest length of the best cable that the application will allow. (In some cases the module is best mounted with the aerial, at some distance from the rest of the system, with interface and power wires instead of an RF cable)

7. And lastly: TEST EVERYTHING.

Do not assume that 'everything will be OK'. The only meaningful proof of design is to use it successfully in it's final intended environment. Conduct range tests, and ensure your design has sufficient range 'in hand'. Use the prototypes in the field and ensure the radio link reliability is good. Time spent here buys product reliability, and customer respect, later.

If the performance of the radio in your completed system isn't what you were anticipating: do not give up. Contact your module supplier's technical support department and get them involved. In many cases a single overlooked detail is the difference between success and failure, and the support engineers have probably seen 'your' problem before..

Good Luck.

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The Intrastat commodity code for all our modules is: 8542 6000