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Application note 017

Choice of frequency band can really make a difference

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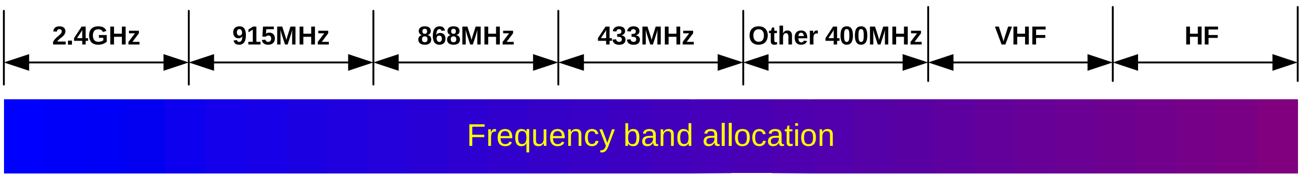
When choosing a module, the typical user starts with the simple requirements at the interface (data rate, power supply); considers physical size limitations and price; worries about the claimed link range; and takes a random stab at the catalogue.
But there is another parameter which influences all the others and which might best be considered first: the operating frequency band of the module.

There is a wide range of frequency bands where ISM band wireless modules are used. Some frequency allocations are available worldwide or across an entire continent, while others are specific to one particular country. Legal transmit power levels, operating modes and usage restrictions are depressingly non-uniform. However, a little examination of the physics of radio transmission reveals certain basic characteristics that should influence the selection of a particular operating band:



2.4GHz

This is definitely the most "fashionable " band currently in the advertising press. This band is dominated by "defined protocol " short—range networks like Zigbee, Bluetooth and their various imitators and lookalikes (Wibree, Zwave, Nanotron and others).

- **Merits**: Truly a worldwide allocation, with materially similar regulations for its use in almost every country (although fine details do vary).The allocation is wide (over 80MHz), which encourages wide bandwidth, high data-rate systems. There is a great deal of heavily marketed available silicon, making the radio design easier. And, the aerials are tiny.
- **Problems**: Path loss per meter is high compared to lower frequencies, and penetration of building materials (and even rain!) is poor, so this is a short-ranged allocation, even ranges over 10m can be difficult to reliably achieve. Band congestion is serious, as this band is shared with WiFi radio-LANs.

915MHz

In the US (also Canada and limited usage in Australia/New Zealand).This is a fairly generous allocation (26MHz total)with tightly defined operating modes (compliant spread spectrum radios are allowed up to 1W transmit power, fixed frequency units are restricted to less than 1mW).

- **Merits**: High-end modules are capable of good range (up to 1km), while simple units can offer the size/cost benefits of "European " type modules. Aerials are small.
- **Problems**: Limited area of use, within which the FCC approval procedures can be difficult. Even well designed spread spectrum modules tend to have long set-up/sync periods and high power consumption. Little penetration of this band by "network "radios.

868MHz

A band harmonised throughout the European Union. To improve band useability, specific areas of the band are assigned to specific applications (fire alarms, security) and in certain sub-bands there are limits to transmit duty cycle or operating mode ("Listen Before Talk " or LBT operations). Transmit power varies from 5mW to 500mW.

- **Merits**: Small aerials, reasonable range. Relatively little band congestion (helped by the sub-band allocations).Wide range of modules available from long range 500mW units to very simple short ranged 1mW devices

- **Problems**: Complicated band plan. Zigbee units on 868MHz are limited to a single channel. Not as wide a range of modules as for the 433MHz band.

433MHz

Probably the widest used ISM band, the 433MHz band is used throughout Europe and much of the rest of the world also (excluding the US).

Both, simple wideband units and sophisticated longer ranged narrowband radios, are offered and in many regions there is simple band planning and duty cycle restrictions.

- **Merits**: Extremely wide choice of modules from a great many manufacturers. Integrated circuit solutions are also available, for even lower costs. Lower path loss than 868MHz band -so less transmit power for the same range.
- **Problems**: Low power (10mW,or 25mW in Australia). Band is overcrowded in some areas and there 's some very low quality hardware on offer, which can make selecting a device hazardous. Aerials tend to be bigger (a 1/4 wavelength monopole is 16cm long). Range rarely exceeds 500m.

Other 400MHz

In addition to the 433MHz allocation, many nations retain other 400MHz band allocations, such as the 458MHz band in the UK, or 448MHz in the Czech Republic. Some nations specify licensed operation, for instance "part 90 " operation in the US.

These allocations are usually intended for high reliability industrial telemetry and telecommand, so higher transmit powers (up to 500mW)are frequently permitted and only narrowband (25KHz or 12.5KHz) radios are usually permitted. Aerial sizes are similar to 433MHz.

- **Merits**: Long range of several km. High quality, reliable, equipment, some units even meet PMR standards. Uncrowded band allocations.
- **Problems**: Limited choice of expensive modules. Frequency allocations are specific to particular countries. Channel bandwidths limit data rates to 10kbit/s or less. Relatively few channels allocated.

VHF bands

There are no worldwide (or even continent-wide) VHF allocations – although a 169MHz allocation is slowly being introduced across Europe.

Where they can be used, VHF telemetry radios are associated with long range applications. Typically, these modules are used for environmental monitoring, agricultural process control, remote meter reading and asset tracking. Almost all VHF modules are narrowband.

- **Merits**: 5-10km range is easily achievable (lower path loss than UHF bands). Modules tend to be cheaper than comparable performance UHF examples. Good penetration into buildings; low power consumption.
- **Problems**: Limited, country specific, frequency allocations; low data rates; large aerials. No "single chip radio " silicon has yet been released.

HF bands

Typically the 27MHz (and 40MHz) bands have so far been limited to model/toy control and very low end short-range data link applications, such as wireless keyboards – although Bluetooth is encroaching on this market. A few operators use them for agricultural process control.

Owing to environmental variations, the propagation of these much lower frequency signals can occasionally be highly unpredictable.

- **Merits**: Very simple, very cheap hardware. Some countries permit high powers (4W in the US). Allocations exist in almost all countries
- **Problems**: Very large aerials are needed to achieve anything but short range operation. Highly overcrowded bands, especially the 27MHz allocation, shared with CB and model control. Low data rates.

What I have detailed here is far from exhaustive, but combined with a little investigation into available products it ought to make choosing a radio module a little more scientific and a little less dependant on extravagant advertising claims.

Good luck!

Note: Path loss is related to frequency, being proportional to 10log(1/f ^2).
This means (aerial gain, transmit power and rx sensitivity being the same) that 10mW at VHF (173MHz), 80mW at 458MHz, 250mW at 869MHz and 2W at 2.4GHz would exhibit similar ranges.

Receiver sensitivity, hence range, is also related to channel bandwidth, and as such data rate. Higher speed links have shorter ranges for the same tx power.

For further information, refer to:
http://www.ofcom.org.uk/radiocomms/ifi/licensing/classes/rlans/short/
http://www.ofcom.org.uk/radiocomms/ifi/tech/interface_req/uk2030.pdf (refer to table 3.1 especially).

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