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So many transmitters, so small a band

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In an ideal world there would be only one transmitter (mine!) and I would use any frequency I desired, whenever I wished. Unfortunately, the real world of low power radio is far from ideal. There is only a relatively limited amount of spectrum allocated to ISM users, and there are increasingly large numbers of those users.

It is no longer enough to just buy a link on 433.92MHz, and hope that the 'next' user would be out of range of you, or not using their system when yours was operating.

Accommodating multiple users in a limited band is a subject that much work has gone into, and the European low power telemetry bands permit a range of possible approaches:

Multiple channels: Each transmitter uses a different frequency, separated by at least the occupied bandwidth (plus a margin) from the 'next' channel. This method tends to be used by narrowband links, where it is possible to fit a useful number of channels into the available spectrum.

- **Pro**: All links can operate entirely independent from each other, as each is operating on a unique channel. There are no 'channel available' limitations and the full bandwidth of the channel is always available. Channels can be re-used on the basis of the maximum range for any given link (in turn related to the maximum permitted band power output). Frequencies affected by external interference can be avoided.
- **Con**: This mode infers either the inconvenience of ordering and stocking different frequency single channel radios, or complex, expensive multichannel circuitry. Setting up the band usage plan requires either user effort, installation staff, or complex (semi) automatic firmware. With higher transmitter powers (up to 500mW in the UK 458MHz band) intermodulation limits the number of usable channels (and makes frequency planning a skilled job).

Limited duty cycle: No transmitter is permitted to be 'on' for longer than a given (and small) proportion of the time. This is specified as a duty cycle, typically 10% or less (on some bands it is as little as 0.1%). The absolute maximum duration of any transmission is often also limited. This makes it statistically unlikely that any two links will be sending at one time

- **Pro**: Very simple hardware can implement simple, low data throughput links. Many bands specifically require this operating mode (the 433MHz 10mW wideband allocation does in many countries. The 169MHz and large parts of the 868-869MHz bands do)
- **Con**: Only a small fraction of the available channel bandwidth is available, and there is a finite chance that any given transmission will be lost through collision, requiring some manner of acknowledge/re-transmit system, although by using multiple (short) transmissions (separated by a randomly variable time delay to avoid the re-transmission cycles getting into step) the effect of collisions in a crowded bands can be minimised.

Listen before talk: All transmitters are required to also include a receiver, and before any transmission a check is made of the strength of any signal on channel. The transmitter is only key'ed on if the channel is 'empty'. Duty cycle or maximum transmission duration limits are usually also imposed to prevent a single device 'hogging' the channel.

- **Pro**: A greater amount of the channel bandwidth is available to the users, as the usage is 'politely' shared. Lesser requirement for multiple transmissions. This is the specified operating mode for much of the 868-869MHz band.

- **Con**: Requires much more complex (transceiver) radio hardware, and more processing power/programming effort. In presence of other users the time to send a given data packet can be indeterminate, as multiple links compete for the channel. Weak interferers can spoof the receiver into inhibiting transmission.

Generally speaking, high end (narrowband) industrial control units (where reliable, rapid response matters) and high performance radio modems (where data throughput is vital) tend to use multiple channel operation. Very low data throughput tasks (such as alarms and environmental monitors) and simple operator observation feedback ('key-fob' level) remote switches can use limited duty cycle, while LBT operation finds use with the higher data throughput telemetry tasks in-between.

Footnote: I have not mentioned the class of "spread spectrum" radios (either direct sequence of frequency hopping) sometimes encountered in GHz band links or in US market (part 15 approval) 915MHz products.

These can be considered a sub-class of the multiple channel radios, where the operating frequency is varied during operation (at a rate much greater than the data throughput in the case of 'direct sequence', or in between data-packets for the 'frequency hopping' radios).
These interesting, and complicated, operating modes deserve separate consideration.

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