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The bit of wire on the end

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Somewhere, and in some form, there's got to be something that radiates the RF energy that makes your data link actually 'wireless'. Your radio module needs an **aerial**.

Now, to address the brave few readers who haven't already run off: I'm not going to deal with antenna theory, Maxwell's equations, or any scary vectors. The subject of aerial design is a huge one, and ranges from the simplest free-field dipole, to complex, phased multiple-element directional arrays. For the typical low power radio application there is a far more limited choice of configurations, so at a practical level, lets look at the options, and more importantly the pitfalls, awaiting the ISM band radio user.

The antenna can be considered as a transducer. It converts RF current into electromagnetic waves, and radiates them into space. The theoretically simplest antenna is the *isotropic radiator* : an infinitely small point source that radiates radio waves equally in all directions. No real antenna is ever so perfectly non-directional. Even practical "omni-directional" antennas only radiate equally in a single plane. (The radiation pattern of a vertical half wave dipole (an omnidirectional type) in three dimensions looks like a donut: almost no energy is radiated up or down.)

Antennas are specified according to their radiation pattern (and directivity, if any) their effective gain (which is expressed in dB relative to an isotropic radiator), and their range of operating frequencies or bandwidth.

Directional antennas usually have positive gain (a a result of radiating the power over a limited arc, instead of everywhere), as do a few omni-directional types (by compressing the vertical axis of the radiation pattern, or by combining the signal from multiple antenna elements). On the other hand, power losses in the aerial can reduce the gain below that predicted by the radiation pattern, as can imperfect tuning, and incorrect matching.

Most ISM band regulations have transmitted power limits which preclude the use of (positive) gain aerials, at least at the transmit-end of the link. This, combined with the portable or mobile nature of many of the likely target applications, limits the usual choice of antenna to a small sub-set of the simpler types. (which may be just as well: the ARRL publish a simple "Antenna Book" which is 944 pages long).

The same 'mobile' nature of ISM applications also simplifies the choice of aerial polarisation patterns: to achieve a practical omni-directional performance from simple aerial designs, vertical mounting, and hence vertical polarisation, is almost obligatory

To concentrate on the aerial types frequently used in the ISM bands, there are:

Whips. The most common form of antenna used with radio modules is the quarter-wave whip. It's simple, cheap, and can be made in a moment out of wire (length in mm = 71250/frequency in MHz). It also presents a near 50ohm feed-point impedance, without extra matching parts.

But to operate according to theory this aerial needs to be mounted on a groundplane (or on a sufficiently large conducting object to mimic one). With luck, this can be easy to arrange (for instance on a car's roof) but it's all but impossible on a hand-held, plastic box. It's often inconveniently long, too (8cm at 869MHz isn't especially onerous, but at 173MHz the length is about 40cm. They aren't nicknamed "eye-pokers" for nothing).

There are other varieties of monopole (base loaded types, with shorter physical lengths, and longer 5/8 or 1/2 wavelength types with higher gain) which are only usually encountered as commercially made parts.

Dipoles. The centre-fed half wave dipole is theoretical start point of any analysis of aerial theory. The commercially produced units, when mounted from a pole, or off a building wall by the proper bracket are a good choice for a *relatively* inexpensive 'base station' antenna. But they are large, and need to be mounted clear of obstructions.
Also encountered are end fed and co-linear dipole antennas. These look physically like (very long) monopoles, and offer excellent omni-directional gain characteristics, with some co linear types offering over 6dB of gain (by virtue of a

vertically compressed radiation pattern, and multiple aerial elements). But they are big, very expensive, and rarely encountered in low power radio implementations.

Helicals. A development of the whip, this is a monopole wound into the form of a ‘spring’. It can be hand-made (most module manufacturers optimisitically provide a recipe for one in their data sheets. Compare them: they’re all totally different) and is both considerably shorter than a whip, and theoretically operates independent of any groundplane.

Unfortunately, the dimensions are critical, and correct behaviour is hard to verify without proper RF test equipment. This this type of aerial de-tunes badly in the presence of conducting masses (like your body).
Inexpensive factory made helicals do take a lot of the guesswork out of using this class of aerial, and those fitted with a coaxial connector (SMA, BNC or TNC) permit neat, trouble free mounting through bulkheads and case walls.

As a rule of thumb, the shorter a helical is for a given frequency (for the popular 144MHz amateur band I’ve seen helicals between 3cm and 20cm long), the more lossy it will be.

Loops. In the simplest case, this is just a single turn inductor, tuned to resonance by a capacitor. The loop area needs to be maximised, or aerial efficiency will be low (At UHF, it is usual to add extra series capacitors at intervals around the loop to drop the resonant frequency).
Although physically simple, this aerial can be very tricky to use. It presents a higher than 50 ohms impedance at the feed point, requiring further matching parts, and almost certainly will need to be manually tuned on each unit (the bandwidth of this type of aerial is very narrow). Additionally, the efficiency of such loop antennas can be un acceptably low. Still occasionally seen below about 200MHz are ferrite loaded loops, where the aerial is a coil wound onto a ferrite block or rod. Such units are a black art: composition of the ferrite is critical for high frequency operation, the aerials are highly directional, very narrow in bandwidth, and (owing to increasing losses in the ferrite at higher field strengths) almost the only aerial type that is usable only on ‘receive’.

Patches. Best considered as a ‘flattened monopole’, a patch antenna looks like a specific area of conductor, spaced off a groundplane and suitably matched at the feed point.

The patch isn’t a useful ISM application antenna as it is (at the frequencies of interest the area of the patch is considerable, and they can be awkward to tune), but a variant of it is becoming quite common: the ceramic loaded antenna.

By fabricating the antenna elements on a substrate with a very high dielectric constant combined with low RF loss characteristics (such as a carefully formulated ceramic, or a teflon/glass composite) the physical dimensions of the aerial can be reduced without incurring unacceptable losses. (This is probably the antenna in your cell phone, as a ceramic 900MHz band aerial can be shrunk to under 2cm long).

This class of antenna is becoming more readily available on the ISM frequency bands, and as the price of these originally expensive components falls they are likely to be seen built into more and more modules.

Sometimes it is “just a bit of wire”.
But it’s probably the most important part of your radio.

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