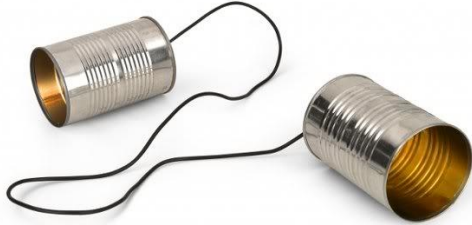
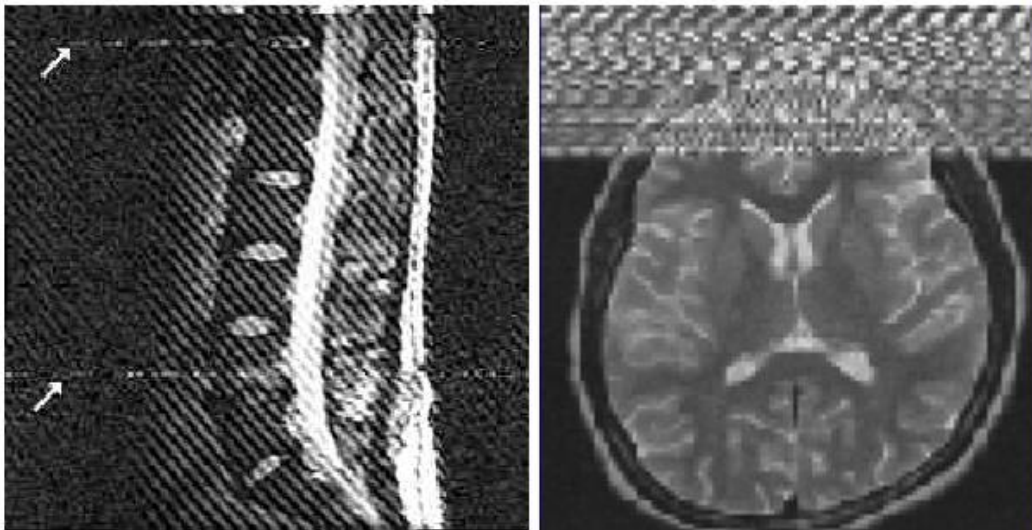


Bitesize Physics - Wave Guides

Matthew Benbow, Superintendent Radiographer CT & MRI, Royal Bournemouth Hospital
BAMRR Policy Board Member



Almost certainly near to your scanning console you will have one or more waveguides leading into the scan room. These give an open channel through which you can pass ventilation tubing, infusion lines or oxygen to your patient whilst they are having an MRI scan. But how is this possible? We spend a great deal of effort, not to mention money, in ensuring we have a leak proof RF cage around our scanners with the aim being to prevent stray radio frequencies entering the scan room. Leaked RF is likely to be detected by the receive coils and ultimately form unwanted artefacts in our images as it overpowers the relatively weak signal being received from the patient. The answer is that a waveguide is not simply any hole. There are some important mathematical design features that are necessary to ensure it does its job.



RF Interference

Unlike in MRI rooms, industrial waveguides are in fact usually employed for the exact opposite - that being to confine and *assist* the passage of signals in the similar way that sound passes well along a hollow tube, or, through a taught wire such as guitar string or kids bean-can intercom. So as the name suggests, they guide waves. This works at its most efficient at high frequencies where the wavelength of the signal approaches the cross sectional dimension of the waveguide. They should be thought of as being channels to direct electromagnetic energy rather than conductors of it. In open space, electromagnetic waves propagate in all directions and as such their power intensity decreases greatly with distance (the familiar inverse square law). Waveguides operate by preventing the waves from spreading out and losses resulting from this effect are therefore almost eliminated.



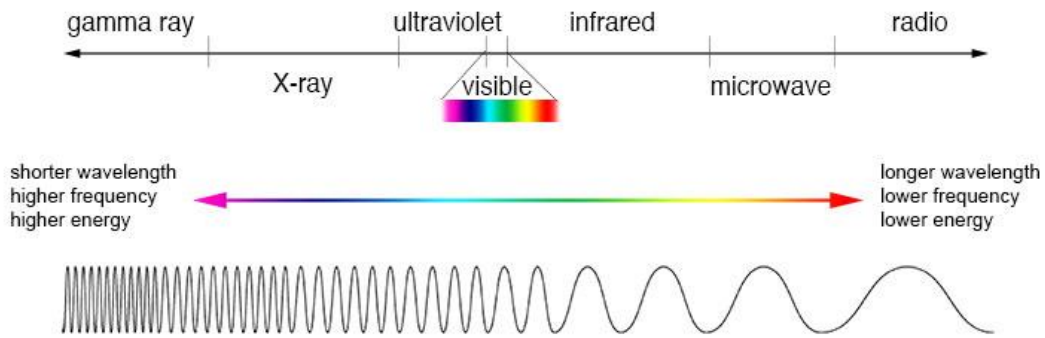
Industrial waveguide

There is therefore a cut-off point where higher frequencies will get through but those below will be blocked, and this can be exploited for the purpose needed in MRI, i.e. to maintain the integrity of the RF cage. This cut-off frequency depends on the shape and size of the cross section of the waveguide. The larger the waveguide is, the lower the cut-off frequency for that waveguide. Waveguides can have either a circular or rectangular cross section, but those commonly used in MRI RF cages are commonly circular and the cut-off frequency for a waveguide with a circular cross section of radius α is given by:

$$\text{Cut-Off Frequency } f_c = \frac{1.8412}{2\pi\alpha\sqrt{\mu\epsilon}} = \frac{1.8412c}{2\pi\alpha}$$

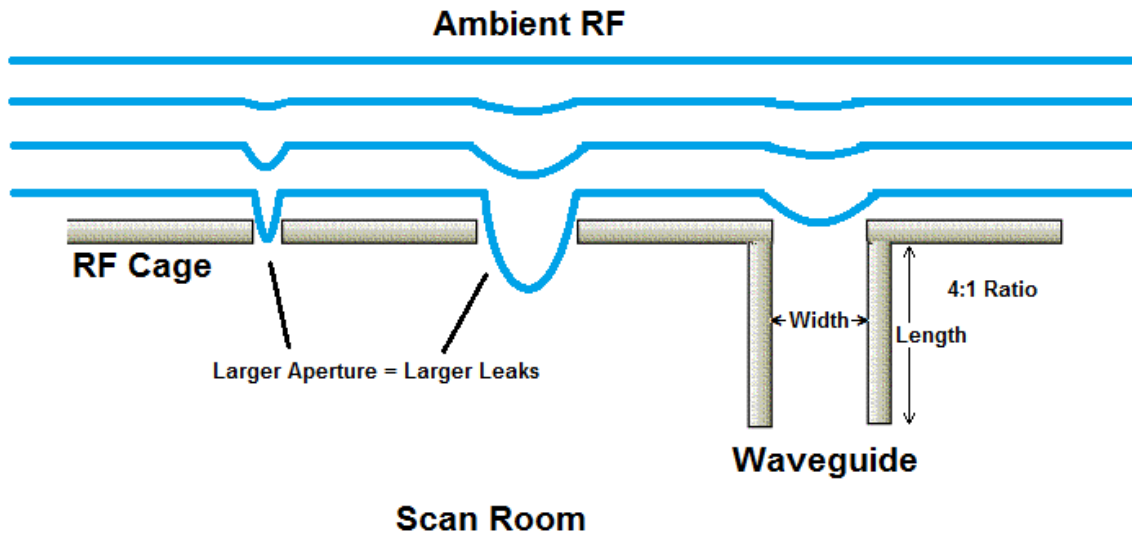
Where c is the speed of light within the waveguide, μ is the permeability of the material that fills the waveguide and ϵ is the permittivity of the material that fills the waveguide.

An MRI waveguide must therefore be built to have a certain diameter relative to the wavelength of the signal. It needs to be sufficiently narrow to ensure that the relevant electromagnetic fields cannot propagate, and this diameter is consequently dependent on the frequency of the RF that needs blocking.



Electromagnetic Spectrum

The range of frequencies used in MRI (10-300 MHz) are relatively low - from the radio wave end of the electromagnetic spectrum and so a cylinder with a length : width ratio of 4:1 or greater will be effective at blocking radiofrequencies in the desired range.



RF Cage

So, by designing a waveguide to be purposely too small for the wave to propagate however, it can be made to become a blocker of waves, rather than a channel to assist their passage. As such we can be provided with a channel that allows activities such as general anaesthetic MRI examinations without the expense of highly specialist MRI conditional equipment within the scan room.