# Aerials for Confined Spaces

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It is assumed that a length of wire suitably placed, insulated and fed with alternating current from a transmitter acts as an aerial and that the amount of radiation from any portion of it is proportional to the square of the current in that portion.

### Radiation Resistance

As a measure of the amount of radiating power of an aerial a fictitious resistance, called the " radiation resistance," is assumed. This must not be confused with the impedance at the feed point, for only in the special case of centre-fed dipoles are these two almost alike in amount. A comparison of the radiation resistance of an aerial with the loss resistance gives an idea of its efficiency as a radiator, though this does not take into account the direction of radiation.

Aerials are usually compared with a half-wave aerial in free space as a standard and this provides a useful starting point for the consideration of aerials shorter than a half-wave. A half-wave aerial can be considered in two ways. First, it acts as a tuned coil so that its spread inductance and capacitance tune to the frequency for which it is designed. Secondly, it is of such a length that when the travelling wave supplied by the transmitter is reflected out of phase at the far end, the point of maximum current is in the centre, the feeding end being a point of high impedance.

The power radiated by a short section of a half-wave aerial (and hence the contribution of that section to the radiation resistance) is proportional to $\sin^2 \theta$ where $\theta$ is the electrical distance from the free end. To use this to arrive at an approximation to the radiation resistance of a short aerial, without using advanced mathematics, we can plot a curve, letting each 14 ft and a little over represent 10° of a 256 ft half-wave aerial. The area between any part of the curve and the line on which it stands represents the radiation resistance of the part of the aerial represented by that part of the curve.

### Efficiency

" What is the value of this gain in radiation resistance? " might be asked. The value is in the increase in efficiency as the radiation resistance rises compared with the loss resistance. If the radiation resistance is 2 ohms and the loss resistance is also 2 ohms, as it might be for a 40 ft length of wire, only half the power supplied is radiated. If the radiation

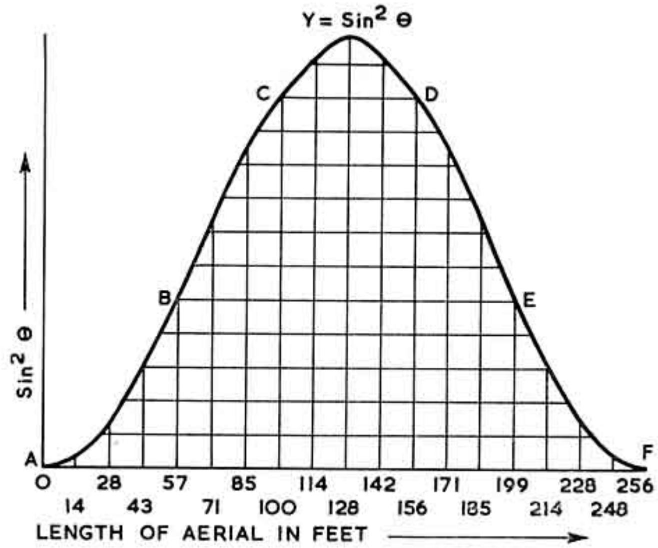


**Fig. 1. Curve plotting sin $\theta$ versus aerial length.**

resistance is raised to 40 ohms by increasing the loss resistance only to 4 ohms, then only one eleventh of the power supplied is lost and ten elevenths radiated.

Aerials on the 160 metre band tend to have low radiation

**TABLE I**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Portion to | 14ft | 28ft | 43ft | 57ft | 71ft | 85ft | 100ft | 114ft | 128ft |
| Area under | 1/8 | 7/8 | 2¼ | 4 | 6¼ | 8½ | 10¼ | 11½ | 12¼ |
| Radiation resistance in ohms of each portion | 0·08 | 0·56 | 1·45 | 2·57 | 4 | 5·5 | 6·6 | 7·4 | 7·9 |
| Radiation resistance in ohms of length from end | 0·08 | 0·64 | 2·1 | 4·6 | 8·6 | 14·1 | 20·7 | 28·1 | 36 |
| Radiation resistance in ohms of length at centre | 8 | 15·8 | 23·4 | 30·6 | 37·5 | 43·8 | 49·5 | 54·8 | 59·1 |
| Times gain | 100 | 12·4 | 11·1 | 6·7 | 4·4 | 3·1 | 2·4 | 1·9 | 1·6 |

In Fig. 1 the curve is drawn. Table I shows the number of squares under each portion of the aerial, but as the curve is symmetrical, only the first quarter wave is shown.

If we take a length of 57 ft of wire, shown in Fig. 1 as AB on the curve, this acts as a length of 57 ft at the end of an aerial, if suitably fed; that is, the portion EF of the curve. It will be seen that the radiation resistance of this portion, even if in free space, would be only 4·6 ohms.

If it could be moved to the centre, to be represented by the curve CD, the radiation resistance would be changed to 30·6 ohms, and the 57 ft would be nearly as good a radiator as 120 ft of wire used ordinarily. A 28 ft length of wire would show a greater gain in radiation resistance, from 0·6 ohm at the end to 15·8 ohms at the centre.

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resistance because they are not usually a quarter wavelength (128 ft) high; below that height the radiation resistance falls almost in proportion to the fraction of a quarter wavelength the height is. For a full half-wave the radiation resistance falls as follows:—

| | | | | |
|---|---|---|---|---|
| Height: | 128 ft | 64 ft | 32 ft | 16 ft. |
| Radiation resistance: | 72 ohms | 30 ohms | 15 ohms | 7·5 ohms. |

The average 66 ft aerial 30 ft high would have a radiation resistance of only 1 ohm, thus being a very inefficient radiator, as its loss resistance would be higher than its radiation resistance.

### Inductive Loading

If the aerial is terminated by an insulator at the end remote from the transmitter it must always act as the end portion of a half-wave, no matter how it is fed. But there is a method by which the portion acting as an aerial can be made to act as the centre portion. This method causes the current, after reflection at the insulator, to build up to maximum in the aerial by putting the required length of wire between the aerial proper and the insulator. Unfortunately this wire cannot be close wound in a conveniently small coil because the wire must retain its " open " self-inductance and it must have as low a loss as possible so as not to increase unduly the loss resistance of the aerial system. This wire must be of the same kind as the aerial (e.g. 14 gauge hard drawn copper) wound non-inductively and spaced at least 1 in. and of a length equal to a quarter wavelength for the band in use minus half the length of the aerial top.

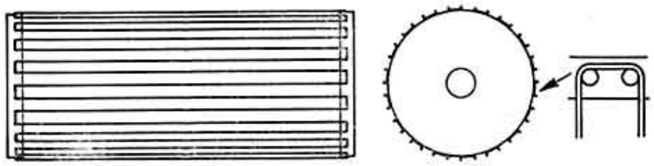

Fig. 2. Method of winding a loading coil for outside use.

The most convenient form for use outside is shown in Fig. 2. This consists of two circular end pieces each 1 ft in diameter, giving a circumference of 37 in. spaced about 3 ft apart. Round the circumference of each end piece, 1 in. apart, insulated pegs are spaced; the loading wire is wound round these pegs from a peg at the top to one below, along 1 in. to the next peg, up to the peg above, along 1 in. to the next peg, then down again to the peg below and so on until the required length is reached.

This former allows for a loading coil of 37 wires each 3 ft long, with 3 ft for the end spacing, giving 114 ft in all, sufficient to load a 14 ft aerial for the 160 metre band. If a shorter length is needed either smaller discs could be used for the ends, or the distance apart of the ends made smaller. This form can be mounted at the top of a pole or slung in the wire next to the insulator. If the loading coil must be accessible in order to disconnect part of the loading for working on another band, it should be remembered that it is at a high voltage point in the aerial and needs good insulation, and must be protected from close investigation by children or animals. Any down-lead to this loading device from the aerial proper should be taken off the length of loading wire and not counted as part of the aerial.

For indoor use the loading wire may more conveniently be wound on a flat frame 3 ft square, suitably insulated. The method of winding is shown in Fig. 3. It is as if the circular loading device were split down one side and opened out. This frame may be hung on the wall if the wire is more than 1 in. from it.

As this loading coil is placed between the end of the aerial remote from the transmitter and the insulator, there still remains the need to match the feeding end of the aerial to the transmitter. This might be done by placing a similar loading

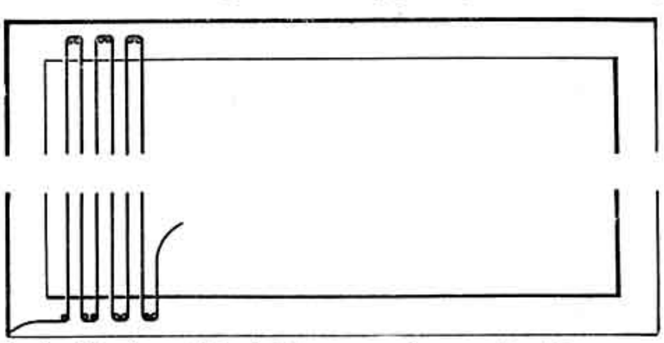

Fig. 3. A loading coil for inside use may be wound in this manner.

coil between the transmitter and the aerial, when the aeria would act nearly like a half-wave and be fed at a high impedance point, but matching is more conveniently achieved by the use of a pi-section coupler, which might be the tank coil itself or a separate unit coupled to the tank coil. The pi-section coupler is very suitable for this purpose because a loaded aerial presents a medium impedance and is easily matched, though any efficient coupling device will suffice.

Table I shows the rise in radiation resistance to be expected by the transfer of various lengths of a half-wave aerial from the end to the centre. The figures given are for an aerial in " free space " and need to be divided suitably if the aerial is less than a quarter-wave above ground. This shows that quite a useful gain may be obtained if the aerial is a quarter-wave or less in length.

The effect of this shortening on the radiation pattern of the aerial is also of considerable importance. As the aerial proper becomes shorter and the loading longer the horizontal pattern of a horizontal aerial becomes more omni-directional, the circles of the polar diagram of a half-wave seeming to be pressed in towards the line of the aerial, giving a conchoidal shape, as shown in Fig. 4. There is still no radiation along the line of the aerial. The vertical pattern, if the aerial is horizontal, is all round if in free space, but varied, as is that of a half-wave, by the nearness of the earth.

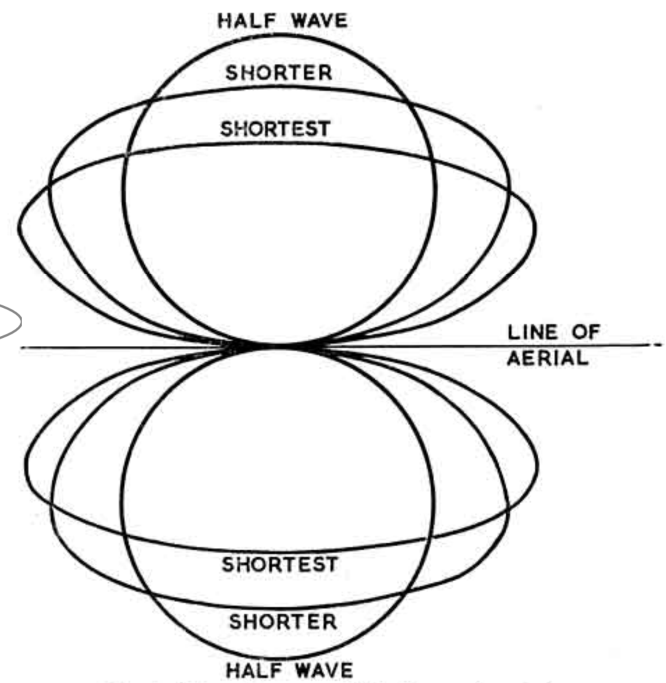


Fig. 4. Polar diagrams of " half-wave " aerials.

If good results are desired for this type of aerial the ordinary rules for good results with any type of aerial must be observed—good insulation, fairly thick copper wire, in the clear as far as possible. Especially, the loading must be of the same kind of wire as the aerial, equally well insulated and at the far end of the aerial. The length of the loading is not very critical, as moving the aerial a few feet from the centre position will not result in a serious radiation resistance loss.

Using a 15 ft aerial indoors in the attic in a house in Bradford, Yorkshire, working on the 160 meter band, the aerial being loaded with wire wound on a square frame hanging on a nail on the attic wall and fed from a p.a. taking 8 watts, pi-section coupled, the writer worked many stations in the British Isles and F8RJ in Paris and had a letter of complaint from the G.P.O. for causing interference to traffic at Blaavand, in Denmark.

(*Continued on page 320*)

is required across C9, as might be expected, the charge leaking off only too readily through the back resistance of CR3 and CR4.

When there is no speech input to the microphone, the control triode (right hand half of V7) is conductive, which activates the relay and applies the negative voltage from the miniature battery B2 to the grid of V4, biasing it beyond cutoff and de-activating the transmitter. When the microphone is spoken into, the control triode is biased beyond cutoff by the negative voltage resulting from rectification of the a.f. by the 1N34s, thereby releasing the relay. This activates the transmitter by removing the cut-off bias from V4 and at the same time mutes the receiver by applying the negative battery voltage to the receiver's a.v.c. system.

Headphones rather than a loudspeaker must be used for reception with this type of voice control. Automatic break-in with a loudspeaker is possible, but considerably more complicated circuitry is necessary since the device must be "intelligent" enough to differentiate between your voice and the voice emanating from the loudspeaker.

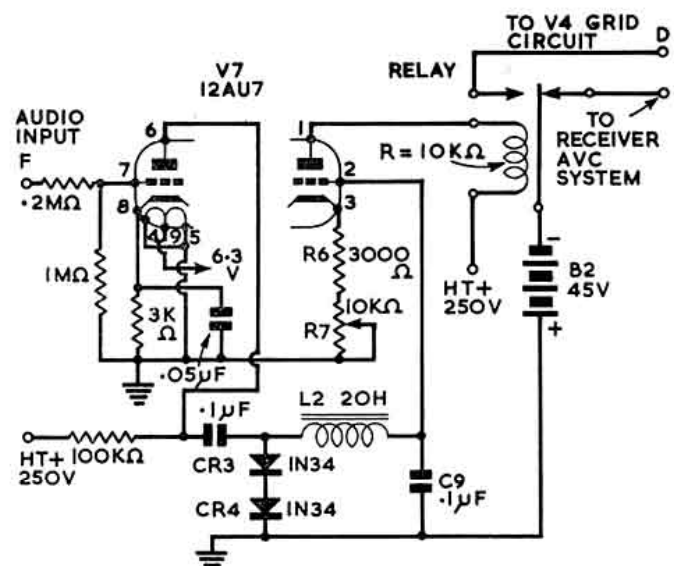

Fig. 3. Voice control circuit.

**First heterodyne oscillator**

In order to produce a signal output in the 80 metre band, the basic s.s.b. exciter must have about three volts of r.f. at around 3500 kc/s injected at connector P2. This voltage is usually supplied by the station v.f.o., but for convenience in tuning up and also for fixed frequency operation it may be internally produced.

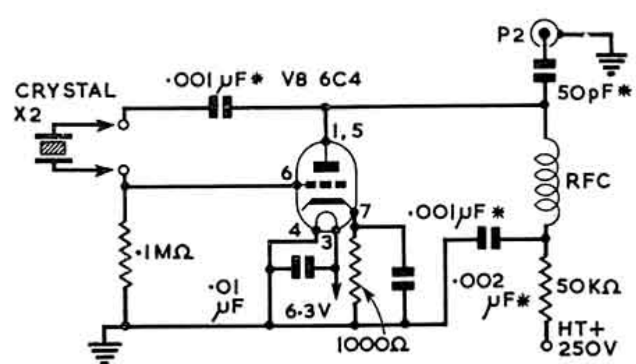

Fig. 4. Heterodyne crystal oscillator.

Referring to Fig. 4, it will be seen that V8, a 6C4 triode, operates as an untuned crystal oscillator whose output is permanently connected to P2. If the crystal filter pass band is centred at 450 kc/s, for example, s.s.b. output at a frequency between 3·5 and 4·0 Mc/s can be obtained with X2 chosen for the appropriate frequency between 3050 and 3550 kc/s. Rather than add a switch to start and stop this oscillator, the crystal is inserted or removed from its socket.

* * *

Each valve, with its associated circuitry, may be added singly at any time its particular function is desired. This is possible because each is independent of the others, although complementary to the basic, four-valve exciter. As the hawker said at the county fair, "Pay your money and take your choice."

### The W3FIU S.S.B. Exciter

IN Fig. 2 of the above article on page 218 of the November BULLETIN, T5 should have been marked T4.

### Wonders of Wireless

THE United States Federal Communications Commission has advised that there is nothing in the law to prevent two licensed amateur radio stations being utilised to consummate a wedding ceremony between a couple separated by the Pacific Ocean!

Who would be a radio amateur in the United States?

### Aerials for Confined Spaces

Continued from page 318

**Magnetic Loading**

During the war another method of shortening a half-wave aerial was brought to the writer's notice, and put into use combined with the end loading method. The principle of this method is to increase the inductance of a piece of wire used as an aerial by increasing the permeability of the surrounding medium. This is done by sleeve-loading the wire with a material of high magnetic permeability but with a high electrical resistance to reduce losses, as shown in Fig. 5.

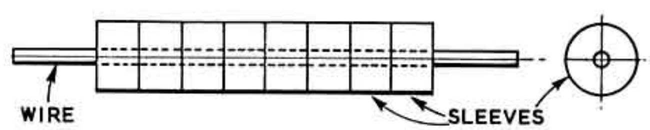

Fig. 5. Sleeve-loading of wire with material of high magnetic permeability.

Using sleeves of outer diameter 9·5 mm and internal diameter 3 mm on 14 gauge wire[redacted]that using separate sleeves did not seriously reduce the permeability of the sleeve material, and a sinusoidal distribution of aerial current along it, the inductance per metre of wire loaded with the sleeving would be increased by 0·208$\mu$, where $\mu$ is the permeability of the sleeving.

If Ferroxcube B2, of permeability about 250 were used, the inductance of one metre of 14 gauge wire would increase from 0·4$\mu$H to 52·4$\mu$H. At the same time the capacity is increased from 7·2$\mu\mu$F. to 8$\mu\mu$F. per metre. Thus the LC ratio increases by

$$\sqrt{\frac{8 \times 52{\cdot}4}{7{\cdot}2 \times 0{\cdot}4}} \simeq 12.$$

The length of a half-wave aerial sleeve loaded is about one twelfth of the length of an unloaded one, using suitable loading material. This brings a half-wave aerial on the 1·8 to 2 Mc/s band within range of most amateurs.