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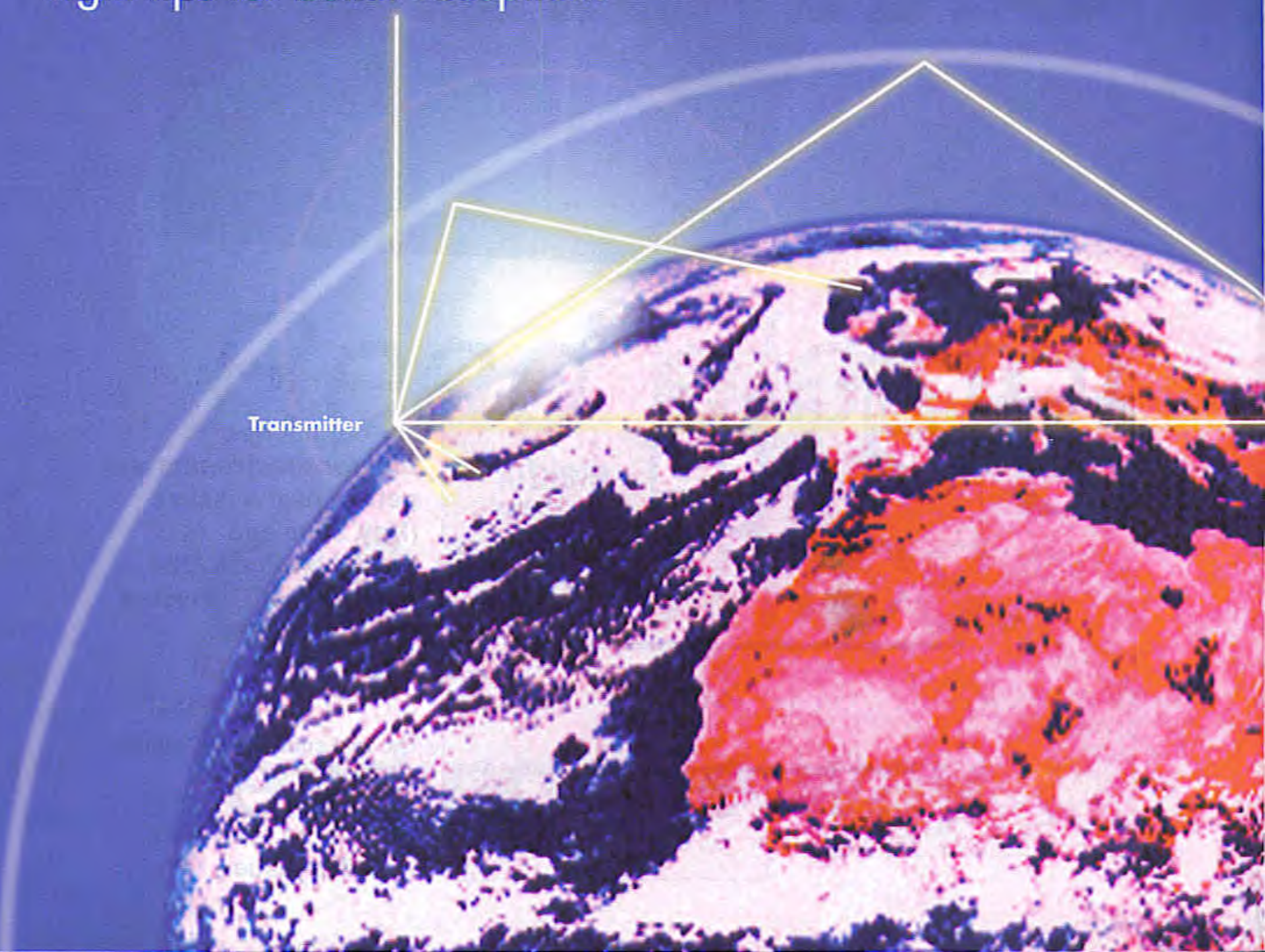
WAVECATCHER

Aerials and preselectors for AM and DRM

For initial experimenting and radio listening with a DIY short-wave or DRM receiver, a simple rod aerial or piece of wire is sufficient. But it's only natural to want something better. This article gives you the right tips for better reception.



In the UHF band, radio waves propagate essentially in a line-of-sight manner, similar to light, and this limits their reception to a range of around 100 km, depending on aerial height. However, radio waves at frequencies below 30 MHz show completely different behaviour, which makes a significantly larger reception range possible. Of course, the complex propagation mechanisms in this frequency range also lead to special problems, such as dependence on the time of day, field strength fluctuations (fading) and selective fading.

Radiation and propagation

The decisive role in the propagation of radio waves in the short-wave bands is played the ionosphere, a set of weakly conductive layers in the atmosphere at great height that are formed by solar ionization. The ionosphere results from collisions between particle radiation and gamma radiation from the sun and air molecules, which become ionized with the release of electrons. Within certain frequency bands and at certain incident angles, the free electrons generated in this manner act like a mirror. At large incident angles and high frequencies, the ionosphere is instead transparent.

A short-wave transmitter can be received in the nearby region via ground-wave propagation over a range of only around 30 to 100 km, depending on the height of the aerial. At greater distances, the transmitter disappears behind the horizon due to the curvature of the earth, making a direct link impossible. However, radio waves reflected from the ionosphere can reach receivers located in a region starting at certain minimum distance away for the transmitter, as illustrated in **Figure 1**.

Between the limit of reception of the ground wave and the start of reception of the reflected signal, there is a region called the 'skip zone' where the signal cannot be received. The reflection angle that would be necessary for the signal to be received in this region is too large. Of course, the transmitter also radiates energy at this angle, but it leaves the atmosphere without being used, perhaps to be received sometime later on by one of our neighbours in outer space.

The minimum distance between the transmitter and the receiver varies with the time of day for each frequency, and it also depends on the level of solar activity, which varies over time.

High frequencies can only be reflected at very shallow angles. Consequently, the ground distance spanned by the reflected signal is generally greater in the higher-frequency bands. The skip zone is also correspondingly larger; during the day it ranges up to around 200 km at 6 MHz and around 1000 km at 15 MHz.

The skip zone expands at night, and with it the reception range. As a result, it often happens that a particular transmitter can be initially received quite well near dusk but then suddenly disappears, since in a manner of speaking it has slid into the skip zone. If the same programme is also being broadcast on other frequency bands (as is customary with BBC, DW, etc.), it is recommended to change to a lower frequency when this happens.

Generally speaking, radio waves arrive at a receiver via more than one path. The differences in the path lengths give rise to phase differences, which lead to partial reinforcement or cancellation of the waves. Especially in the short-wave band, rapid fluctuations in field strength are common. This frequently causes selective fading, which is particularly noticeable with AM transmitters in the form of unpleasant distortion resulting from nearly total loss of the carrier signal, causing it to be overshadowed by the sidebands. DRM (the new digital transmission technique) is also affected by this fading, but the modulation and coding methods used for DRM are especially robust and can tolerate partial loss of data. Thanks to effective error handling, even deep dropouts in the DRM spectrum, such as those caused by cancellation at certain frequencies, generally do not interfere with reception.

DRM restores excitement to radio listening on the medium- and short-wave bands. There are already quite a few stations available (see **Table 1**), and new transmitters are constantly being added to the list.

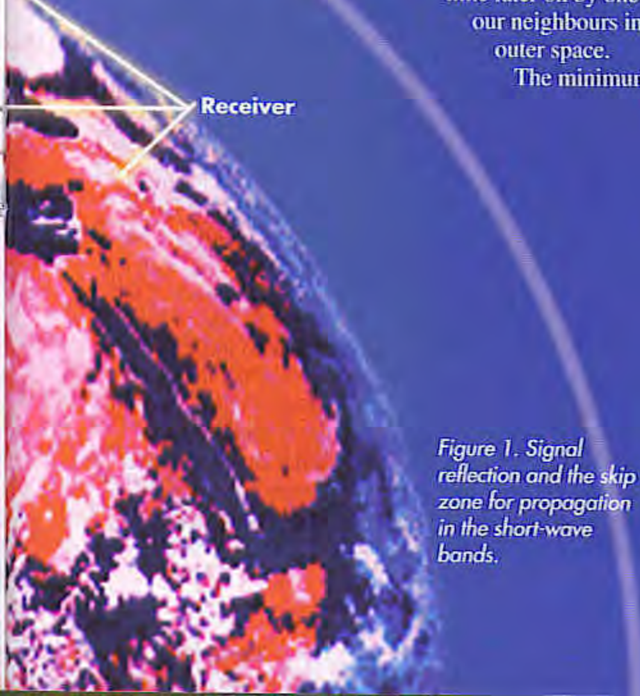


Figure 1. Signal reflection and the skip zone for propagation in the short-wave bands.

A longish wire

Strong short-wave transmitters can be received using an 'aerial system' (rod aerial or piece of wire) with a length of less than a metre. For long-distance reception, it is naturally much better to use a 'longish' wire aerial, which preferably should be strung up outdoors – as widely separated from other objects as possible, as high as possible and sufficiently far away from the house, in order to avoid the 'noise cloud' emanating from the house.

In theory, a wire aerial has a resonant frequency at one quarter of the signal wavelength, although a good earth connection acting as a counterpoise is important for this. In practice, wire aerials with lengths of around 10 metres have proved to be satisfactory.

If the receiver is located close to a window or the outside wall of the house, it is sufficient to connect the end of the wire directly to the inner contact of the aerial socket. However, if the distance between the aerial and the receiver inside the house is relatively long, the connection should be made using coaxial cable, with the opposite pole being provided by an earth connection close to the feed point of the aerial (see **Figure 2**). Here it makes no difference whether you use 50-Ω cable or 75-Ω cable. After all, the base resistance of the aerial varies with frequency, and it has a complex impedance with

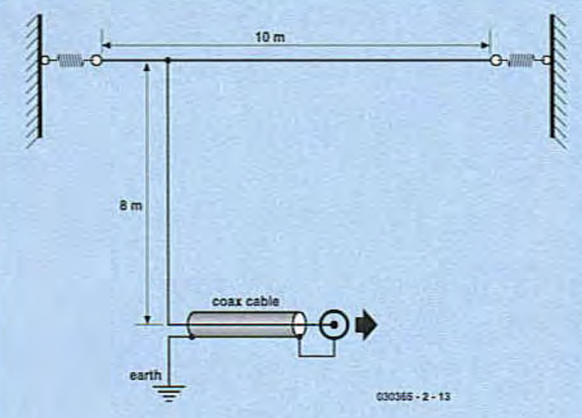


Figure 2. An outdoor wire aerial connected via a coaxial cable.

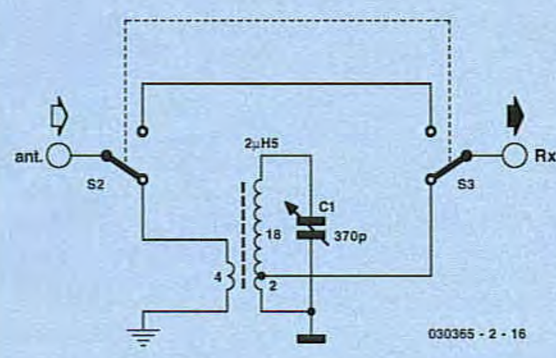


Figure 3. A freely tuneable resonant circuit used for preselection.

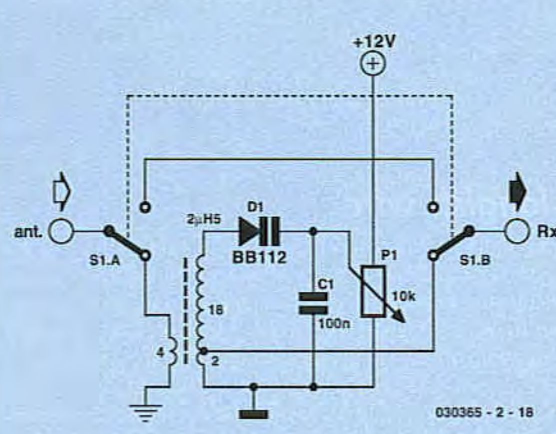


Figure 4. Tuning using a variable-capacitance diode instead of a rotary variable capacitor.

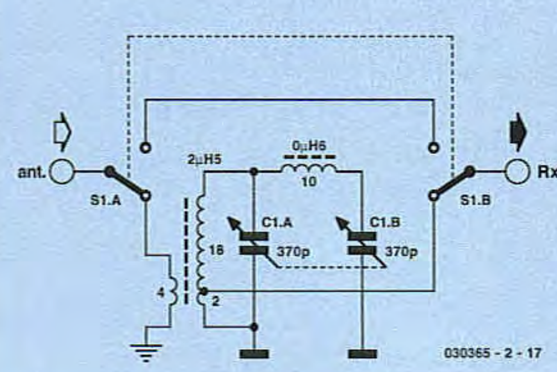


Figure 5. Tuning from 3 MHz to 30 MHz using a dual variable capacitor.

alternating capacitive and inductive components. The coaxial cable also has its own resonances, since it is not being used at its characteristic impedance, and it transforms the aerial impedance, with the net result that resonances other than those to be expected from the length of the aerial can also occur. However, this does not have much of a noticeable effect at the receiver, since signal level variations of around 10 dB hardly matter with DRM.

Outdoor wire aerials are normally made from stranded wire with a sufficiently large cross-sectional area, in order to obtain good mechanical strength as well as low ohmic losses. A lead from a standard mains cable or loudspeaker cable with a cross-sectional area of 0.75 to 1.5 mm_ is suitable for this purpose. It is also possible to use significantly thinner wire. A test using 10 m of thin magnet wire (0.3 mm diameter) yielded usable results for DRM reception, and it has the advantage of being quite inconspicuous.

If you shy away from constructing your own aerial, in many cases you can make use of existing systems or cables. A typical aerial system provides not only television and UHF signals, but also the entire AM range from long-wave to short-wave. It's certainly worth trying.

In many cases, better results can be obtained with a rooftop aerial than with an indoor aerial. Old rooftop aerials are often no longer in use, but the aerial cables leading to the roof are still in place. The cable by itself can also be useful. Such a 'forgotten' aerial cable that has been converted into a 'single lead', which means with the inner conductor and the screen shorted together, forms a usable vertical aerial. The cable usually runs all the way to the roof of the building and thus reaches a greater height than a horizontally strung wire aerial. Especially at relatively high frequencies (above 15 MHz), better results can be achieved using such an aerial than with an outdoor wire aerial.

Preselection

A 'longish' wire aerial has a broadband characteristic and receives the entire AM radio band between 0.5 MHz and 22 MHz relatively uniformly, so no additional tuning is need for the aerial itself. However, preselection is worthwhile if reception is degraded by mirror frequencies.

Practically every receiver that works on the superhet principle has two reception frequencies: the intended frequency and the mirror frequency, which is separated from the intended frequency by twice the intermediate frequency. With the usual IF of 455 kHz (as used in the DRM receiver published in the March 2004 issue), this means the mirror frequency is located 910 kHz above the tuned frequency. For receivers having a switching mixer (such as the diode-ring mixer of the DRM receiver), the received signal is mixed with not only the fundamental frequency of the oscillator signal, but also (with a certain amount of attenuation) with all odd harmonics of the fundamental oscillator frequency. Primarily in case of reception in the medium-wave band, this can lead to interference from mixer products formed by harmonics of the mixer oscillator and strong short-wave signals. Consequently, a medium-wave preselector often provides significant improvement.

A preselector connected between the aerial and the receiver is most commonly used, and such preselectors are generally tuneable. Suitable preselectors are available from specialist (amateur) radio shops, but you can also build your own.

Tuneable

The standard approach to building a preselector is to use a tuneable resonant circuit (**Figure 3**). The coil can be wound as an air-core coil, which means without using an actual core. The wire diameter is not all that important for such air-core coils. For small coils, you can use enamelled copper wire with a diameter of 0.3 to 0.7 mm; somewhat heavier wire should be used for larger coils for the sake of mechanical stability.

A coil having a diameter of 8 mm and 20 turns over a length of 10 mm has an inductance of 2.5 µH. In combination with a 370-pF variable capacitor, it has a lower resonant frequency of approximately 5 MHz. This circuit can thus be tuned across the 49-m band and the higher-frequency bands up to around 16 MHz. A tap at the second turn provides the proper impedance for connection to the receiver.

The aerial can be connected using a coupling coil with two to four turns. If you make the coupling coil such that it can be moved back and forth, the degree of coupling can be adjusted. You can then experimentally determine the best adjustment. Tighter coupling yields a higher signal voltage, but it decreases the Q factor of the resonant circuit and thus reduces the attenuation at the mirror frequency. If it is necessary to use a short aerial (such as a rod aerial), the coupling must be designed to be relatively tight . In this case, the aerial can be connected directly to the hot end of the resonant circuit.

The resonant circuit shown in the figure has a high Q factor (typically 50). This yields a bandwidth of 120 kHz at 6 MHz. As a result, the variable capacitor must be tuned relatively precisely. For DRM reception, the optimum tuning can be recognised by a maximum signal level in the spectrum display generated by DRM software, but the delay in processing the date for this display makes adjustment difficult. It is easier to use direct acoustic monitoring by connecting the receiver output directly to the Line In socket of the sound card. It's then easy to tune for maximum noise volume for the DRM transmitter using the speakers of the PC.

If the preselector is built into an enclosure, the most important frequencies should be marked on a scale.

Figure 4 shows the same type of resonant circuit with the rotary variable capacitor replaced by a high-value variable-capacitance diode, such as the type BB112 (available from Geist Electronic). Here it is important to use a stable, well-filtered voltage for the tuning potentiometer, since otherwise reception can be degraded by phase modulation of the aerial signal.

The tuning range of a simple resonant circuit does not exceed 1:3 with a standard variable capacitor. One solution is to use several coils that can be selected using a rotary switch. Another approach is used by radio amateurs, who are faced with the same problem in the standard amateur radio bands (80 m to 10 m, which corresponds to 3.5–29.7 MHz). This requires a preselector with a tuning range of 1:10. The solution is to use coupled circuits with two fundamentally different resonant frequencies. **Figure 5** shows a proven circuit using a dual variable capacitor and a second coil with 10 turns. Although there are two 'bad' pass frequencies for every setting, they are well separated from the mirror frequency of the receiver.

Good air-dielectric variable capacitors are no longer easy to come by. It is often possible to scavenge them from old

Table 1 DRM transmitters and frequencies.

Time	Frequency	Station	Language
06.00–24.00 Tu–Su	6095	RTL	various
08.00–14.00 daily	15440	DW	English
10.00–12.00 daily	6140	DW	English
10.00–12.00 daily	9850	RNW**	English
10.00–15.00 daily	7320	BBCWS	English
11.00–13.00 Sa & Su	9410	BBCWS	English
12.00–12.57 daily	9850	RNW**	Dutch
12.00–13.00 daily	6140	DW	German
13.00–15.00 Mo–Fr	9410	BBCWS	English
14.00–15.59 daily	6130	DW	German
15.00–16.00 daily	9490	VoR*	English
16.00–17.00 daily	9490	VoR*	German
16.00–17.29 daily	3995	DW	German
16.00–18.00 daily	6140	DW	English
16.00–19.15 daily	1296	BBCWS	English
17.00–18.00 daily	9490	VoR*	French
18.00–19.00 daily	6140	DW	German
19.00–20.00 daily	11925	BBC	Russian
21.00–22.55 daily	11730	RNW**	Dutch
21.15–24.00 daily	1296	BBCWS	English

* Voice of Russia

** Radio Netherlands World Service (Wereldomroep)

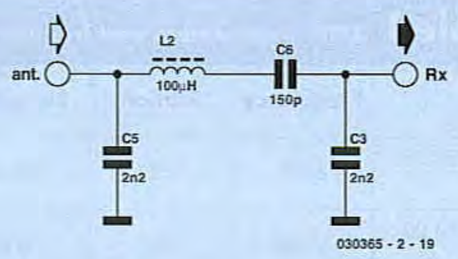


Figure 6. A 1296-kHz aerial filter.

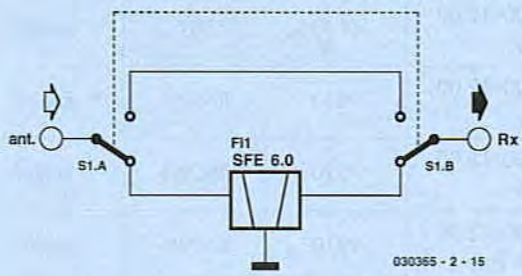


Figure 7. Using a ceramic IF filter for preselection.

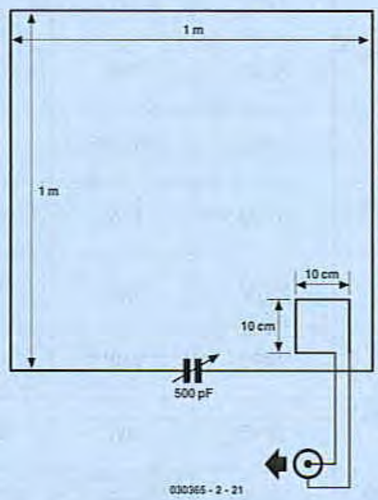


Figure 8. A magnetic-loop aerial.

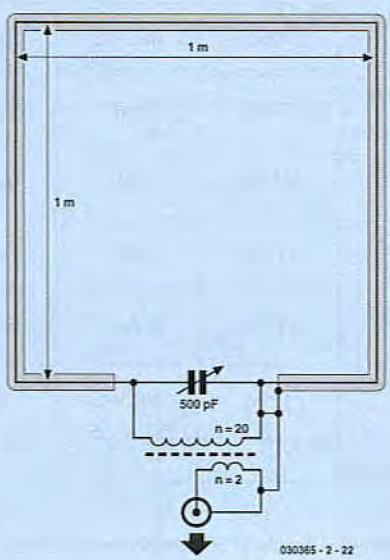


Figure 9. A tuned and screened loop aerial made from coaxial cable.

radios. One source of suitable multi-gang variable capacitors from current production is Geist Electronic (www.geist-electronic.de).

Fixed-frequency

An alternative to a circuit with adjustable tuning is to use a fixed-frequency filter. In the medium-wave band, there is often only one usable reception frequency. Although the relative bandwidth of the input circuit is relatively large, good selectivity is possible thanks to the low frequency. A circuit such as that shown in **Figure 6** can thus manage with a fixed inductor. This fixed-frequency filter for 1296 kHz improves reception of the BBC transmitter in the evening hours. It primarily reduces interference from multiples of the oscillator frequency in the short-wave bands.

For the 49-m band, a quite simple solution is possible using the type SFE 6 ceramic IF filter, which is used for the sound IF in television sets. **Figure 7** shows how to connect the filter to the receiver input so it can be switched in or out as necessary. The specified 3-dB bandwidth of around 100 kHz, which is actually too narrow, is broadened by the low impedances of the aerial and receiver to such an extent that the measured 6-dB corner frequencies are located at 5850 kHz and 6150 kHz. In practice, this filter is primarily useful in the 49-m band when interference occurs from strong transmitters in the 40-m band. At 7 MHz, the filter provides an attenuation of around 40 dB.

Magnetic-field aerials

A 'longish' wire aerial receives electrical energy from both the electrical and magnetic components of the radio waves. By contrast, short aerials such as rod aerials predominantly receive energy from the electrical component. This results in a higher level of interference, especially inside a building. The coupling between the receiver aerial and electrical equipment or the mains wiring is primarily capacitive. Better results can thus be obtained by receiving the magnetic-field component. In principle, all that is necessary for this is a wire loop or a coil. Commonly used solutions are loop aerials with a few turns of wire or single-winding loops, sometimes called 'magnetic loops'. Tuned loops with high Q factors are particularly effective. For instance, you can use a length of copper pipe formed into a circle with a diameter of one metre. However, a broad piece of aluminium foil wound around a cardboard box with suitable dimensions also provides good results.

When connected to a variable capacitor with a maximum capacitance of 500 pF, the loop forms a high-Q resonant circuit and thus delivers a significantly higher aerial voltage than would be expected from an aerial of this size. The receiver should be loosely coupled using a small coupling coil, in order to avoid excessively damping the resonant circuit (see **Figure 8**). The optimum size and position of the coupling coil is best determined experimentally. Due to the high Q factor of the aerial, an additional preselector is in any case unnecessary.

A magnetic loop aerial can also be constructed using normal wire, although this yields a lower Q factor and thus a lower aerial voltage, as well as a larger bandwidth. If it is necessary to make the aerial smaller, two or more turns of insulated wire can be used.

An especially effective solution is an electrically screened loop aerial, which in its simplest form can be made from a length of coaxial cable. Such an aerial can be inconspicuously fitted in a bookshelf, and it provides a relatively good signal to noise ratio. The resonant frequency depends on the size of the loop and the capacitor setting. If the total length of the coaxial cable is four metres, a resonant frequency range extending to below 6 MHz can be obtained with a 500-pF variable capacitor (see **Figure 9**). The primary inductance of the wideband transformer should be greater than that of the wire loop. Good results can be obtained with 20 turns on a ferrite core or toroidal core. In the interest of obtaining a high Q factor, the tuned circuit should not be too heavily damped. Consequently, the secondary has only two to four turns. The best value for the coupling coil should be determined experimentally.

In the medium-wave band, ferrite rod aerials have long since proven their worth. Like magnetic loops, they are relatively insensitive to electrical interference. **Figure 10** shows a ferrite rod aerial followed by an impedance converter. With a 10-mm diameter ferrite rod, the coil requires 70 turns of stranded RF wire ('litz wire') or 0.3-mm enamelled copper wire. Approximately 100 turns are necessary on a thinner rod (8 mm diameter).

Relatively large resonant voltages arise across the tuned circuit, even with distant transmitters. For example, at the author's location in Essen, Germany, at peak reception times an open-circuit voltage of 50 mV can be measured across a ferrite rod aerial with a length of 20 cm for the BBC signal at 1296 kHz. At the low-impedance receiver input, this still amounts to 5 mV, which is more than enough steam for our new digital steam radio.

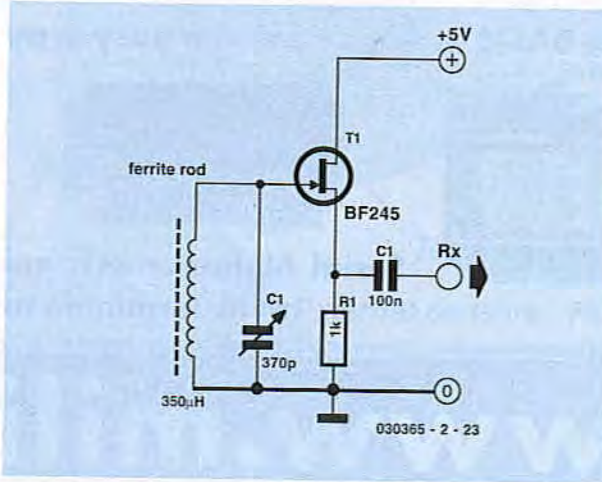


Figure 10. A ferrite rod aerial with an impedance converter.

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