Antenna Workshop

TWISTS AND TURNS - TO GETTING A SIGNAL

David Butler G4ASR takes his turn in the 'Antenna Workshop' presenting the helical antenna, which is useful from v.h.f. to microwaves. He also shows you how to build one for the 430MHz band into the bargain!

Antennas such as Yagi beams or a vertical whip antenna have either horizontal or vertical polarisation. This is when the electric vector lies wholly in a single plane. In this mode the wave is said to be linearly polarised. However, there is another polarisation mode, termed circular polarisation, which has unique characteristics that may be useful for certain applications.

During local v.h.f. and u.h.f. communication (especially over 'line of sight' paths) the received signal polarisation is pretty much that propagated by the transmitting station. However, on many 'over the horizon' pathways it's possible that the polarisation of the transmitted signal can rotate or shift by many degrees by the time it reaches the receiving antenna.

Polarisation rotation may be caused by the signals bouncing off large objects, hills, etc. or even by tropospheric or ionospheric effects. The consequence of this polarisation shift will be to reduce the received signal strength. In practice these transitory 'cross-polarisation' losses can be as much as 30dB and that's a lot of signal attenuation!

Circularly Polarised

A circularly polarised antenna will receive any linearly polarised wave, whether it be horizontal, vertical or slant polarisation. Similarly a circularly polarised wave will be received on a linearly polarised antenna regardless of the polarisation (horizontal or vertical) of the latter. There is a 3dB loss associated with contacts between antennas type, but the normal reflection and diffraction losses that occurs to most v.h.f. and u.h.f. signals, will tend to mask out this difference.

Circular polarisation may be used advantageously for communication between a base station and a mobile station. The 'flutter' caused by the polarisation shift due to the motion of the mobile station being greatly reduced when circular polarisation is used at the base station.

The advantages of circular polarisation are more obvious when the communication is with an Orbital Satellite Carrying Amateur Radio (OSCAR). The random tumbling motion of the low earth orbiting satellite provides an ever changing signal of random polarisation at the receive station. Circular polarisation will provide a much more uniform coverage under these circumstances.

Agreed Convention

The agreed convention for the sense of rotation (of the electric vector) is defined in terms of: the direction of rotation 'seen' by an observer looking in the direction of propagation (looking from the transmitter towards the receiver). A circularly polarised wave may be said to be either clockwise or counter clockwise. Clockwise rotation is also called right-hand circular (r.h.c.) and conversely counter clockwise is left-hand circular (l.h.c.) polarisation.

Although a circularly polarised antenna will receive linearly polarised waves (with a 3dB loss), it is essential that if circularly polarised antennas are used at **both ends** of the path, **both must be 'left-handed' or** both must be '**right-handed'**. Opposite circular polarisations will cause a large loss of signal strength. Exactly the same loss as you would encounter if using a horizontal antenna at one end and a vertical one at the other end of a path.

So be aware, don't make the same mistake that some professionals did when trying to receive the initial signals from the Telstar (Intelsat-1) satellite! Unfortunately however, there's no convention for polarisation rotation within Amateur Radio, either for conventional terrestrial usage or for satellite use. This is most noticeable when using OSCAR satellites capable of microwave operation as both clockwise (r.h.c.) and anti-clockwise (l.h.c.) polarisations are currently to be found.

Number Of Ways

There are a number of ways in which to achieve circular polarisation. One common Amateur Radio practice is to use carefully dimensioned phasing lines to couple up two or more dipoles or Yagis so that the individual units fire signals which add in phase in a circulating pattern. The simplest form of this type of antenna uses two antennas set on a common boom with their elements at 90° to each other (often called an 'XY' Yagi).

However, the simplest antenna configuration for a directional beam having circular polarisation, is the helical antenna. This simply consists of a corkscrew-like spiral conductor, working against a reflector plate and fed with coaxial cable as shown in the diagram, **Fig. 1**.

The helix is a very simple means of obtaining high gain and wide-band characteristics (although less gain than a Yagi array of the same boom length). At the design frequency, a six-turn helix will give a power gain (referred to a non-directional circularly polarised antenna) of 12dB and a beam-width of about 50°. An antenna with 20 turns in the helix will give a power gain of 17dB with a beam-width of 24°. It possesses an excellent performance over a frequency range of around ±20% of the design frequency.

Therefore a helix designed for 145MHz will retain its effectiveness over the band 115-175MHz. One designed for

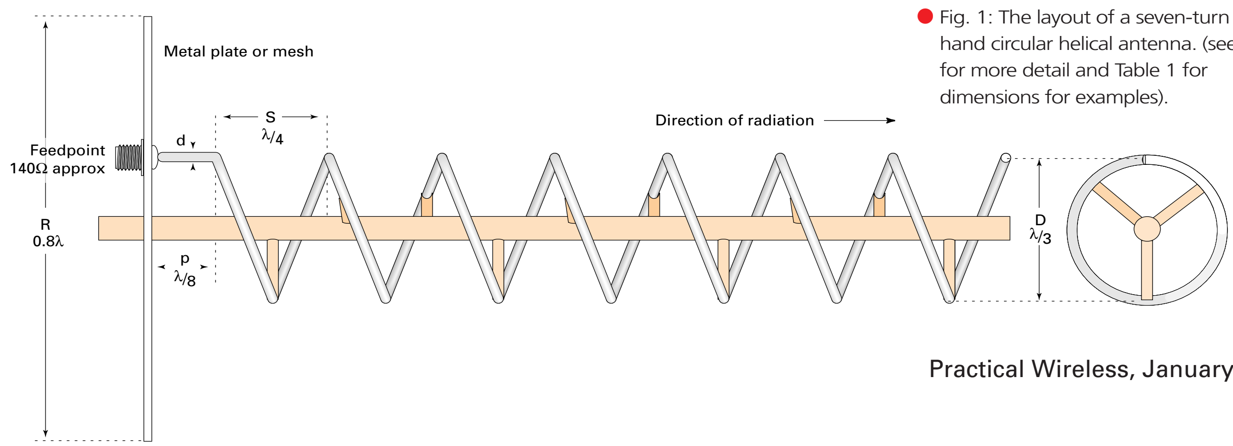


Fig. 1: The layout of a seven-turn right hand circular helical antenna. (see text for more detail and Table 1 for dimensions for examples).

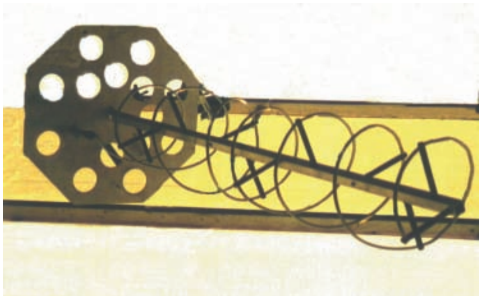


Fig. 2 A completed helical antenna.

435MHz, will work over the band 350-520MHz. Such a wide coverage means dimensions are less critical when the antenna is to be used over a narrow band of frequencies such as an Amateur band. The standing wave ratio (s.w.r.) will also be low over the complete frequency range.

Some Disadvantages

There are some disadvantages with using an helical antenna though, the major one is that it's not omni-directional so, you will need to arrange some method of rotating it.

And as mentioned earlier, there is no convention for polarisation twist. So, if you need to receive both left-hand and right-hand polarisations you will need to construct two antennas. However, if you are only receiving signals from linearly polarised sources then only one helix will be required.

Designing The Helix

Designing the helical antenna is simplicity itself and the most comforting part is, that because of the inherent broadband nature of the helix the dimensions are not at all critical. I've shown the dimensions in **Table 1** for three popular v.h.f. and u.h.f. bands and I'll describe an example for a 433MHz helix antenna.

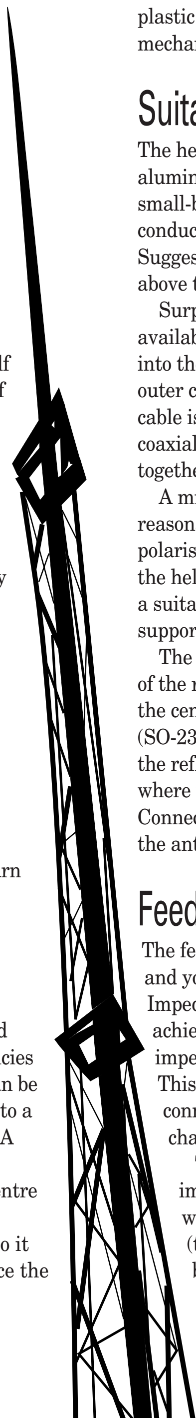
Now you can 'roll your own' for any frequency band of your choice.

First calculate the free-space wavelength
(300/frequency in MHz)
300/433 = 0.69m
The reflector (R) is 0.8λ or greater.
0.69m * 0.8 = 0.55m (550mm).
The helix diameter (D) is 0.33λ
0.69m * 0.33 = 0.23m (230mm).
The turns spacing (S) is 0.25λ.
0.69m * 0.25 = 0.173m (173mm)
The space from the reflector to the first helix turn (p) is 0.125λ.
0.69m * 0.125 = 0.086m (86mm)

Building The Helix

Now let's turn to building your helix, and a good starting point is the reflector plate. For frequencies up to 600MHz or so a suitable ground screen can be made from small-mesh 'chicken' wire, fastened to a round or square frame of either metal or wood. A small metal ground plate (diameter equal to approximately D/2) should be soldered to the centre of the screen.

You could use a solid disc with holes cut into it as shown in the photograph of **Fig. 2**, to reduce the wind loading. A solid disc should be used for frequencies above 1GHz. The central boom support can be made from wood or square section metal tube as shown in the photograph.



Non-Metallic

However, it is important that the helix supports are non-metallic such as wood or plastic. The supports are fixed to the central boom with self-tapping screws and spaced at suitable intervals to support the helix turns at the correct spacing. If you are using a square section boom, the supports should be fitted with alternate 90° spacing. Helix antennas for use above 1GHz can be conveniently wound directly onto a non-metallic central tube. For the 1.3GHz band a three inch (76mm) plastic pipe is ideal.

A helix array on a short boom can conveniently be supported from behind the reflector plate by an extension of the main boom. If you want to support the helix in the centre of the array the stub-mast must be sufficiently rigid and should at the same time be of a non-metallic material such as wood, thick-wall plastic tube or glass-fibre. Ensure that the clamping mechanism is also non-metallic.

Band (MHz)	R (0.8λ) (mm)	D(λ/3) (mm)	S(λ/4) (mm)	P(λ/8) (mm)	MS (mm)
145	1650	680	520	260	340
433	550	230	170	85	115
1300	180	75	55	30	35
2350	102	42	32	16	21

Table 1: Dimensions for some popular bands. The dimension 'MS' is the theoretical length of a λ/4 matching section of 75Ω coaxial cable (see text for more detail).

Suitable Materials

The helix can be made from thick wire, copper, brass, aluminium tube or rod. Suitable materials can include small-bore central heating piping or car brake piping. The conductor diameter 'd' is not particularly critical. Suggested diameters might be 6mm below 1GHz and 3mm above this frequency.

Surplus coaxial cable may also be used. It's readily available, inexpensive, light in weight and easy to shape into the coils required. Hard-line feeder with a solid copper outer conductor such as Andrews LDF4-50 or LDF2-50 cable is ideal in this application. But if you decide to use coaxial cable - solder the centre and outer conductor together at both ends.

A minimum of about five turns are necessary for reasonably 'round' circular polarisation and the polarisation twist is determined by the direction in which the helix is wound. The helix wiring can be close-wound on a suitable former and then fixed onto the insulated supports to give the specified pitch.

The first turn of the helix is started at a point 'p' in front of the reflector and is supported by crossed supports from the central boom. A chassis mounting antenna connector (SO-239 or N-type) should be located on the periphery of the reflector plate, not exactly in the centre as this is where the support boom passes through the ground plane. Connect the end of the helix conductor to the centre pin of the antenna connector.

Feed Impedance

The feed impedance of the helix antenna is about 140Ω and you cannot directly connect it to 50Ω coaxial feeder. Impedance matching is important but not difficult to achieve. It may simply be transformed to the feeder impedance by means of a quarter-wave transformer. This is a quarter-wave length of 75Ω coaxial cable connected in series with the feed line right at the chassis mounting antenna connector.

The formula for calculating the length of the λ/4 impedance transformer is (300*0.25* V_f) / f (MHz), where V_f is the velocity factor of the cable used (typically 0.66). At 433MHz the length will therefore be 114mm.

That's it for this time. Now get building! PW