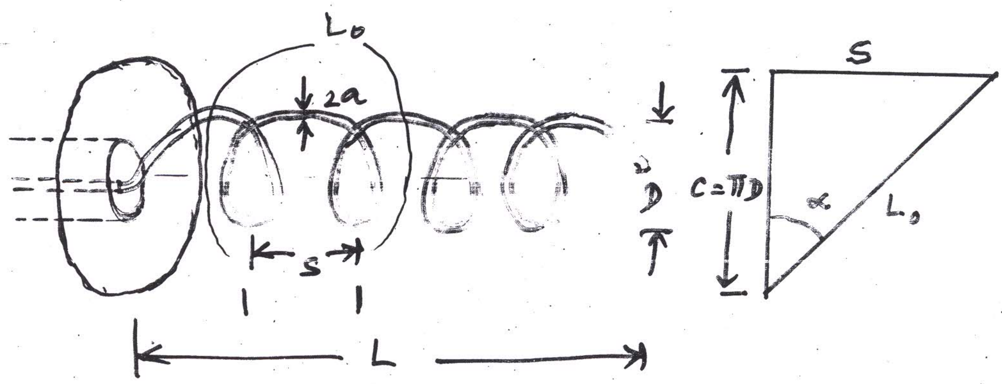
HELICAL ANTENNA

** Exhibits greater broadband characteristics than those of dipoles.

** A conducting wire wound in the form of a screw thread forming a helix.
In most cases helix is used with a ground plane.



** Ground plane can take different forms of which flat ground plane is common.
Typically the diameter of the ground plane should be at least $3\lambda/4$.

** Helix is usually connected to the center conductor of a coaxial transmission line
at the feed point with the outer conductor of the line attached to the ground plane.

** Geometrical configuration:

* N turns, diameter D and spacing S between each turn.
* The total length of the antenna is L=NS, while
* The total length of the wire is $L_n = NL_0 = N\sqrt{S^2 + C^2}$

  Where $L_0 = \sqrt{S^2 + C^2}$ is the length of the wire between each turn

  $C = \pi D$ is the circumference of the helix.
* Another important parameter is the pitch angle α which is the angle formed by a line tangent to the helix wire and a plane perpendicular to the helix axis.
* The pitch angle is defined by

$$\alpha = \tan^{-1}(S/\pi D) = \tan^{-1}(S/C)$$

* When $\alpha = 0^0$, then the windings is flattened and the helix reduces to a loop antenna of N turns.
* On the other hand, when $\alpha = 90^0$ then the helix reduces to a linear wire.
* When $0^0 < \alpha < 90^0$, then a true helix is formed with a circumference greater than zero but less than the circumference when the helix is reduced to a loop($\alpha = 0^0$).

** The radiation characteristics of the antenna can be varied by controlling the size of its geometrical properties compared to the wave length.

** The input impedance is critically dependent upon the pitch angle and the size of the conducting wire, especially near the feed point, and it can be adjusted by controlling their values.

** The general polarization of the antenna is elliptical.

** However circular and linear polarizations can be achieved over different frequency ranges.

** The helical antenna can operate in many modes. However the two principal ones are the normal(broad side) and the axial(end fire) modes.

** The axial (end fire) mode is usually the most practical because it can achieve circular polarization over a wider bandwidth(usually 2:1) and it is more efficient.

** Because ~~an~~ elliptically polarized antenna can be represented as the sum of two orthogonal linear components in time-phase quadrature, a helix can always receive a signal transmitted from a rotating linearly polarized antenna.

** Helices are usually positioned on the ground for space telemetry applications of satellites, space probes, and ballistic missiles to transmit or receive signals that have undergone Faraday rotation by travelling through the ionosphere.

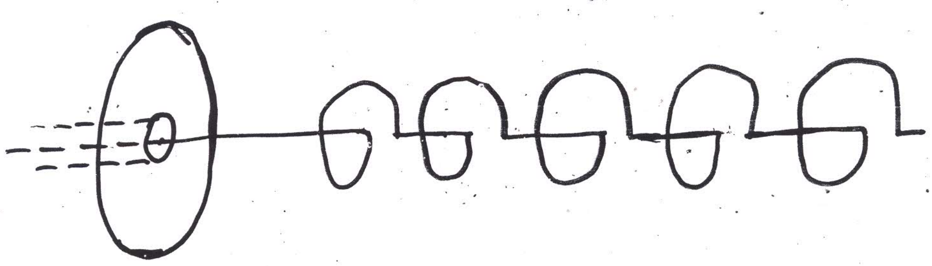
NORMAL MODE

** In the normal mode of operation the field radiated by the antenna is maximum in a plane normal to the helix axis and minimum along its axis.

** To achieve the normal mode of operation, the dimensions of the helix are usually small compared to the wavelength (i.e., $NL_0 << \lambda$).

** Since the limiting geometries of the helix are a loop and a dipole, the far field radiated by:
a small helix in the normal mode can be described in terms of E_θ and E_ϕ components of the dipole and loop, respectively.

** In the normal mode, it can be thought that the helix consists of N loops & N short dipoles connected together in series as shown below.



** The fields are obtained by superposition of the fields from these elemental radiators. The planes of the loops are parallel to each other and perpendicular to the axes of the vertical dipoles. The axes of the loops and dipoles coincide with the axis of the helix.

** Since in the normal mode the helix dimensions are small, current throughout its length can be assumed to be constant, and its relative far-field pattern to be independent of the number of loops and short dipoles.

** Thus its operation can be described accurately by the sum of the fields radiated by a small loop of radius D and a short dipole of length S, with its axis perpendicular to the plane of the loop, and each with the same constant current distribution.

** The far-zone electric field radiated by a short dipole of length S and constant current I_0 is E_θ, and is given by

$$E_\theta = j\, \eta k\, I_0\, S \exp(-jkr) \sin\theta / 4\pi r$$

** The electric field radiated by a loop is E_ϕ and it is given by,

$$E_\phi = \eta k^2\, I_0\, (D/2)^2 \exp(-jkr) \sin\theta / 4r$$

** A comparison of the above two equations indicates that the two components are in time-phase quadrature, a necessary but not sufficient condition for circular or elliptical polarization.

** The ratio of the magnitudes of the field components is defined as the axial ratio(AR), and is given by

$$AR = |E_\theta| / |E_\phi| = 4S / \pi k D^2 = 2\lambda S / (\pi D)^2$$

** By varying the D and/or S the axial ratio attains values of $0 \leq AR \leq \infty$.

** The value of AR=0 is a special case and occurs when $E_\theta = 0$ leading to a linearly polarized wave of horizontal polarization (the helix is a loop). When $AR = \infty$, $E_\phi = 0$, and the radiated wave is linearly polarized with vertical polarization (the Helix is a vertical dipole).

** Another special case is the one when AR is unity (AR = 1) and occurs when

$$2\lambda S / (\pi D)^2 = 1$$

or

$$C = \pi D = \sqrt{2S\lambda}$$

For which $\tan\alpha = S / \pi D = \pi D / 2\lambda$

** When the dimensional parameters of the helix satisfy the above relation, the radiated field is circularly polarized in *all directions* other than $\theta = 0$ where the fields vanish.

* When the dimensions of the helix do not satisfy any of the above special cases, the field radiated by the antenna is not circularly polarized.

* The progression of polarization change can be described geometrically by beginning with the pitch angle of zero degrees ($\alpha = 0^0$) which reduces the helix to a loop with linear horizontal polarization.

* As α increases, the polarization becomes elliptical with the major axis being horizontally polarized.

* When, α is such that $C / \lambda = \sqrt{2S/\lambda}$, AR = 1 and we have circular polarization.

* For greater values of α, the polarization again becomes elliptical but with the major axis vertically polarized.

* Finally when $\alpha = 90^0$ the helix reduces to a linearly polarized vertical dipole.

* Because of the critical dependence of its radiation characteristics on its geometrical dimensions, which must be very small compared to the wavelengths, this mode of operation is very narrow in bandwidth and its radiation efficiency is very small.

* Practically this mode of operation is limited, and it is seldom utilized.

** A more practical mode of operation, which can be generated with great ease, is the axial mode or end-fire mode.

** In this there is only one major lobe and its maximum radiation intensity is along the axis of the helix, as shown below. The minor lobes are at oblique angles to the axis.

** To excite this mode, the diameter D and spacing S must be large fractions of the wavelength.

** To achieve circular polarization, primarily in the major lobe, the circumference of the helix must be in the $3/4 < C/\lambda < 4/3$ range (with $C/\lambda = 1$ near optimum), and the spacing about $S = \lambda/4$.

** The pitch angle is usually $12^0 < \alpha < 18^0$ (with 14^0 near optimum).

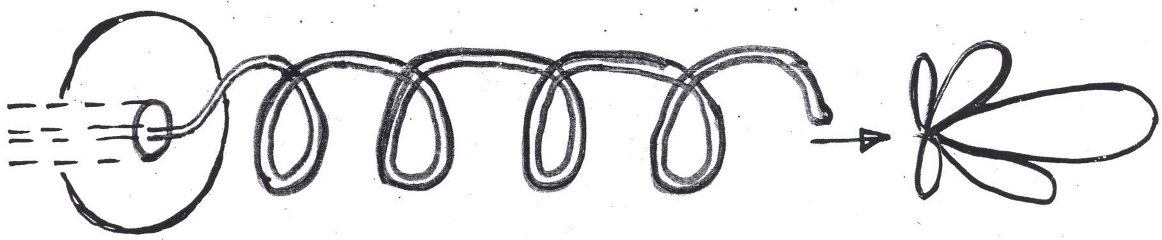
** Most often the antenna is used in conjunction with a ground plane, whose diameter is at least $\lambda/2$, and it is energized by a coaxial line.

** Other types of feeds (such as wave guides and dielectric rods)are possible, especially at microwave frequencies.

** The dimensions of the helix for this mode of operation are not as critical, thus resulting in a greater bandwidth.

** The terminal impedance of a helix radiating in the axial mode is nearly resistive with values between 100 to 200 ohms.

** Empirical expressions, based on a large number of measurements which are used to determine a number of parameters are given below.



** The input impedance is obtained by

$$R = 140(C/\lambda) \quad \text{which is accurate to} \pm 20\%$$

** The half power beam width is given by

$$HPBW(\text{degrees}) = 52\,\lambda^{3/2} / (C\,\sqrt{NS}\,)$$

The beam width between nulls by

$$FNBW(\text{degrees}) = 115\,\lambda^{3/2} / (C\,\sqrt{NS}\,)$$

The directivity by

$$D_0\ (\text{dimensionless}) = 15N\,C^2\,S / \lambda^3$$

** The axial ratio (for the condition of increased directivity) by

$$AR = (2N+1)/(2N)$$

** The normalized far-field pattern by

$$E = \sin(\pi/2N)\cos(\theta)\{\sin[(N/2)\psi]\} / \{\sin[\psi/2]\}$$

where $\psi = 2\pi[(S/\lambda)(1-\cos\theta)+(1/(2N)]$

** All these relations are approximately valid provided $12^0 < \alpha < 15^0$, $3/4 < C/\lambda < 4/3$, and $N > 3$.

** The far field pattern of the helix has been developed by assuming that the helix consists of an array of N identical turns(each of uniform current and identical to that of the others), a uniform spacing S between them, and the elements are placed along the z-axis.

** The cos θ term in the normalized field pattern equation represents the the field pattern of a single turn, and the last term in the same equation is the array factor of a uniform array of N elements.

** The total field is obtained by multiplying the field from one turn with the array factor (pattern multiplication).

** The normal impedance of a helical antenna operating in the axial mode is 100 -200 ohms. However many of our practical transmission lines have characteristics of about 50 ohms.
In order to provide a better match, the impedance of the helix can be adjusted to a value of about 50 ohms by increasing the size of the helix near the feed point.

** A simple and effective way of increasing the thickness of the conductor near the feed point will be to bond a thin metal strip to the helix conductor.

** For example, a metal strip 70-mm wide was used to provide a 50-ohm impedance in a helix whose conducting wire was 13-mm in diameter and it was operating at 230.77 MHz.