**Reference Data for Radio Engineers**, 4th edition, 1956. ITT corp.
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## Helical antennas

Helical antennas can be classified either as to shape (such as cylindrical, flat, or conical) or as to type of pattern produced (such as normal or axial mode). Data will be given here only for the cylindrical helix radiating in the normal or axial mode.

### Normal-mode helix

When the diameter is considerably less than a wavelength and the electrical length less than a wavelength, the helix radiates in the normal mode (peak of the pattern normal to the helix axis). In contrast with the ordinary dipole, where the radiating electromagnetic wave appears to travel on the dipole with the velocity of light in the surrounding medium, the velocity of the wave along the axis of the helix is lower and depends on the frequency, diameter, and number of turns per unit length. The velocity can be decreased by large factors with a corresponding decrease in axial length for quarter-wave or half-wave resonance.

**Velocity of propagation:** The phase velocity along the helix axis is

$$(c/v)^2 = 1 + (M\lambda/\pi D)^2 \tag{17}$$

where

$c$ = velocity of light in surrounding medium
$v$ = axial velocity
$\lambda$ = wavelength in surrounding medium
$D$ = mean helix diameter (same units as $\lambda$)
$M$ = value obtained from Fig. 16.

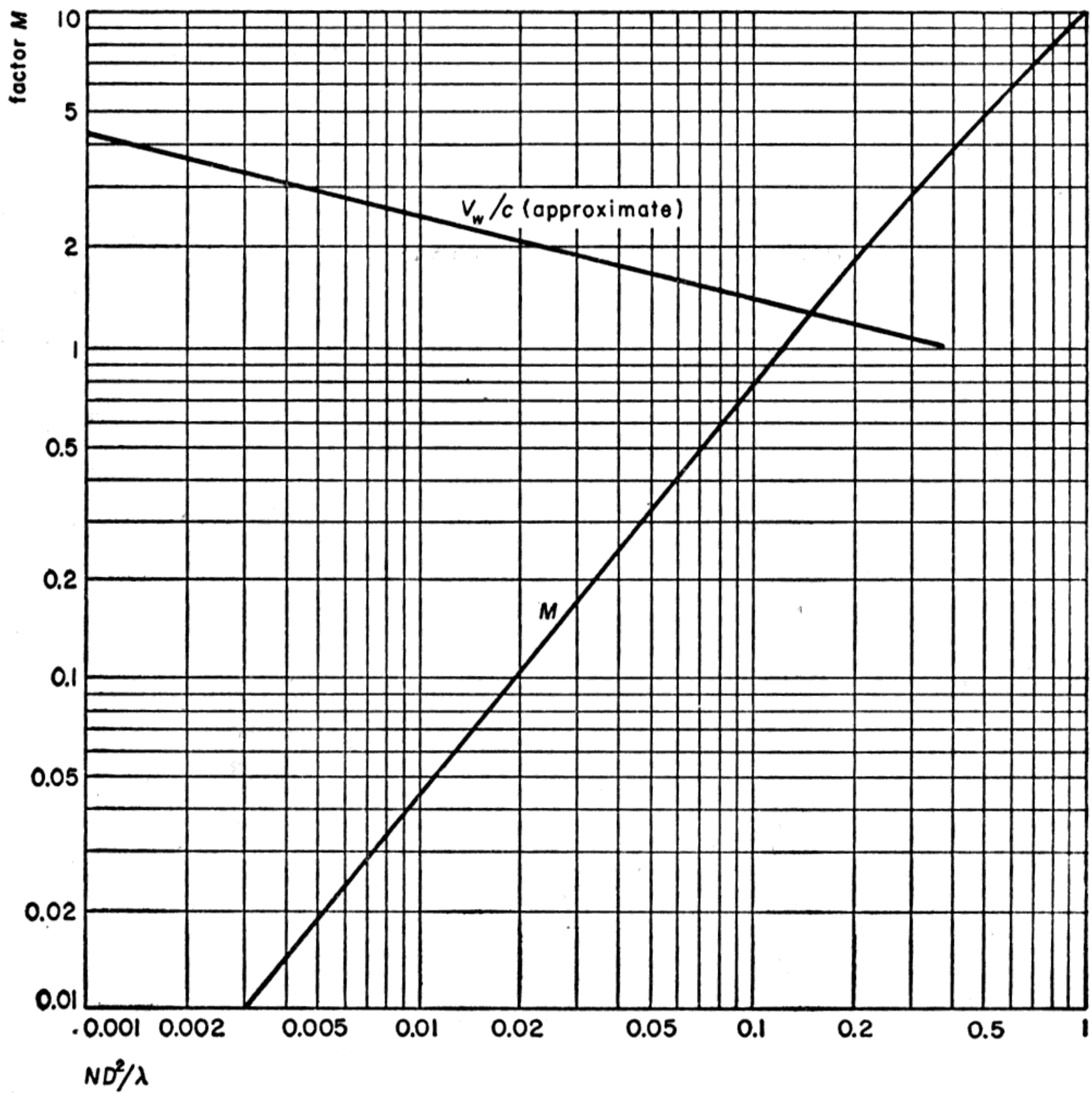


**Fig. 16—Chart giving *M* for (17) and (18) and also showing apparent phase velocity $V_w/c$.**

The apparent phase velocity in the direction of the wire is equal to the axial velocity divided by the sine of the pitch angle, or

$$\left(\frac{V_w}{c}\right)^2 = \frac{1 + (N\pi D)^2}{1 + (M\lambda/\pi D)^2} \tag{18}$$

Where $N$ is the number of turns per unit length. Fig. 16 shows the variation of $V_w/c$ when the terms in (18) are much greater than unity. Fig. 17 shows, for a particular case, how the frequency for quarter-wave resonance varies with the number of turns per unit length for constant wire length. When $ND \geqslant 1$ and $ND^2/\lambda \leqslant 1/5$, this reduces to

$$V_w/c \approx (1.25)\ (h/D)^{1/5} \tag{18A}$$

where $h$ = height of the quarter-wavelength helix.

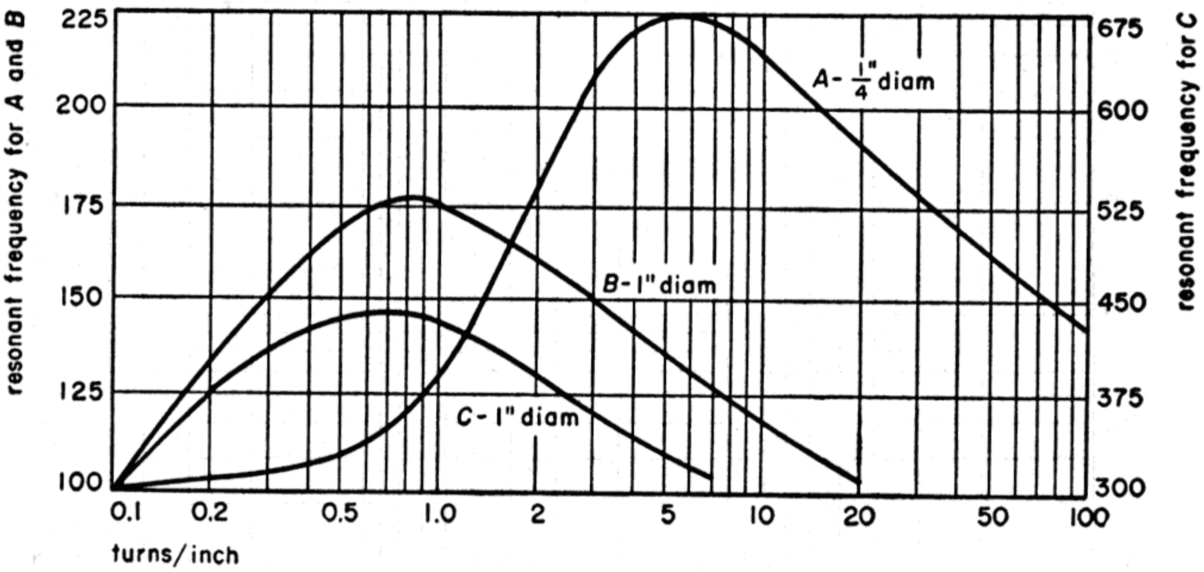


**Fig. 17—Resonant frequency for various helix configurations with same length of wire.**

To obtain a real input impedance (resonance), each half of the helical antenna must be a quarter-wavelength long at the velocity given above or for $ND^2/\lambda < 1/5$

$$\frac{h}{\lambda} = \frac{1}{4\,c/V} = \frac{1}{4\,[1 + 20\ (ND)^{5/2}\ (D/\lambda)^{1/2}]^{1/2}} \tag{19}$$

where $h$ is the length of each half.

**Effective Height:** The effective height of a resonant helix above a perfect ground plane is $2\,h/\pi$ because the current distribution is similar to that of a quarter-wave monopole. A short monopole has an effective height of $h/2$ due to its triangular current distribution.

**Radiation resistance:** The radiation resistance of a resonant helix above a perfect ground plane is $(25.3\ h/\lambda)^2$, while the radiation resistance of a short monopole is $(20\ h/\lambda)^2$.

**Polarization:** The radiated field is elliptically polarized and the ratio of the horizontally polarized field $E_h$ to the vertically polarized field $E_v$ is

$$\frac{E_h}{E_v} = \frac{(N\pi D)\ J_1\ (\pi D/\lambda)}{J_0\ (\pi D/\lambda)} \approx \frac{5\ ND^2}{\lambda} \tag{20}$$

where $J_0,J_1$ = Bessel functions of the first kind.

The approximation is valid for diameters less than 0.1 wavelength. Circular polarization is obtained with a resonant helix when the height is about 0.9 times the diameter.

The horizontal polarization is decreased considerably when the helix is used with a ground plane. The vertical pattern of the horizontally polarized field then varies as $2\ (h/\lambda)\ \sin\theta\ \cos\theta$, while the vertical pattern of the vertically polarized field varies as $\cos\theta$.

**Losses:** For short resonant helixes, the loss may be appreciable because the wire diameter must be much smaller than the diameter of a dipole of the same height. Neglecting proximity effects, the ratio of the power dissipated $P_l$ to the power radiated $P_r$ is

$$\frac{P_l}{P_r} = \frac{2 \times 10^{-4}\ (V_w/c)}{d\ (h/\lambda)^2\ F_{\mathrm{mc}}^{1/2}} \tag{21}$$

where

$d$ = diameter of copper wire in inches

$F_{\mathrm{mc}}$ = frequency in megacycles/second

The efficiency is thus $1/(1 + P_l/P_r)$. Fig. 18 is a plot of height versus resonant frequency for three wire diameters for 50-percent efficiency, assuming that $V_w/c = 1$.

**Q and tap point:** The Q factor† can be calculated‡ approximately:

† Unloaded Q. When the antenna is driven by a zero-resistance generator, the 3-db bandwidth is $f_0/Q$. When driven by a generator whose resistance matches the resonant resistance of the antenna, the 3-db bandwidth is $2\ f_0/Q$.

‡ A. G. Kandoian and W. Sichak, "Wide-Frequency-Range Tuned Helical Antennas and Circuits," *Electrical Communication,* vol. 30, pp. 294–299; December, 1953: also, *Convention Record of the IRE 1953 National Convention,* Part 2—Antennas and Communication; pp. 42–47.

$$Q = \pi Z_0/4R_{\text{base}} \tag{22}$$

where

$Z_0$ = characteristic impedance
= $60\ (c/V)\ [\ln\ (4h/D)\ -\ 1]$
$R_{\text{base}}$ = radiation resistance plus wire resistance
= $(25.3\ h/\lambda)^2 + 0.125\ (V_w/c)/dF_{\text{mc}}^{1/2}$

where $d$ = wire diameter in inches.

The input resonant resistance $R_{\text{tap}}$ with one end of the resonant helix connected to a perfectly conducting ground plane is

$$R_{\text{tap}} = (4/\pi)\ Q\ Z_0 \sin^2\theta \tag{23}$$

where $\theta$ = angular distance between tap point and the ground plane.

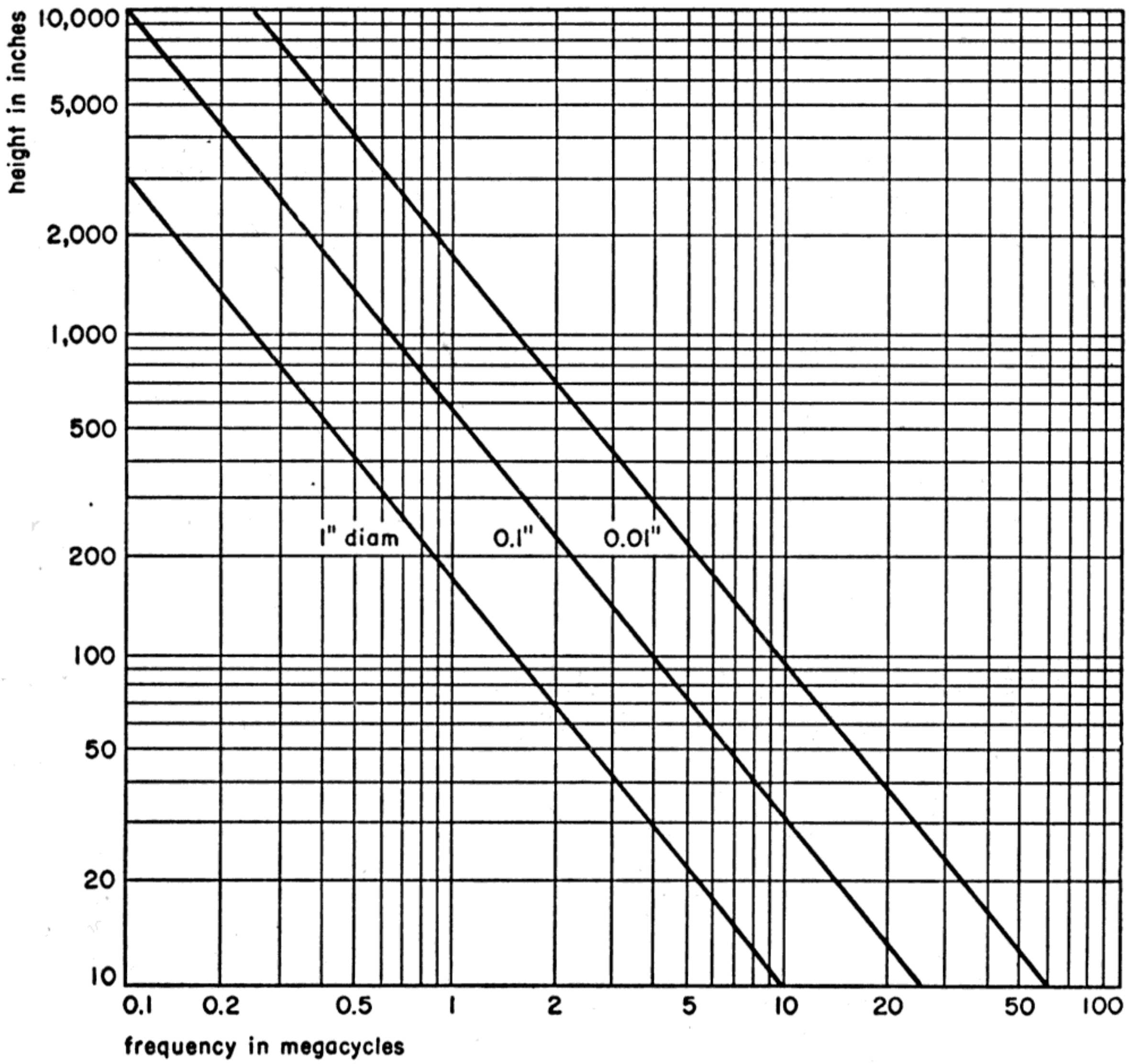


**Fig. 18—Helix height versus frequency for 50-percent efficiency assuming $V_w/c = 1$.**

## Axial-mode helix

When the helix circumference is of the order of a wavelength, an end-fire circularly polarized pattern (axial ratio less than 6 decibels) is obtained.*

Equations (24) give approximately the properties when the diameter in wavelengths is between 1/4 and 4/9, the pitch angle is between 12 and 15 degrees, the total number of turns is greater than 3, and the ground-plane diameter greater than a half-wavelength.

$$\left.\begin{aligned}\text{Half-power beamwidth} &= 17\lambda^{3/2}/D\,h^{1/2}\ \text{degrees}\\ \text{Gain} &= 150\,d^2h/\lambda^3\\ \text{Input resistance} &= 440\,D/\lambda\ \text{ohms}\end{aligned}\right\}\qquad(24)$$

* J. D. Kraus, "Antennas," McGraw-Hill Book Company, Incorporated, New York, New York; 1950: see p. 213.