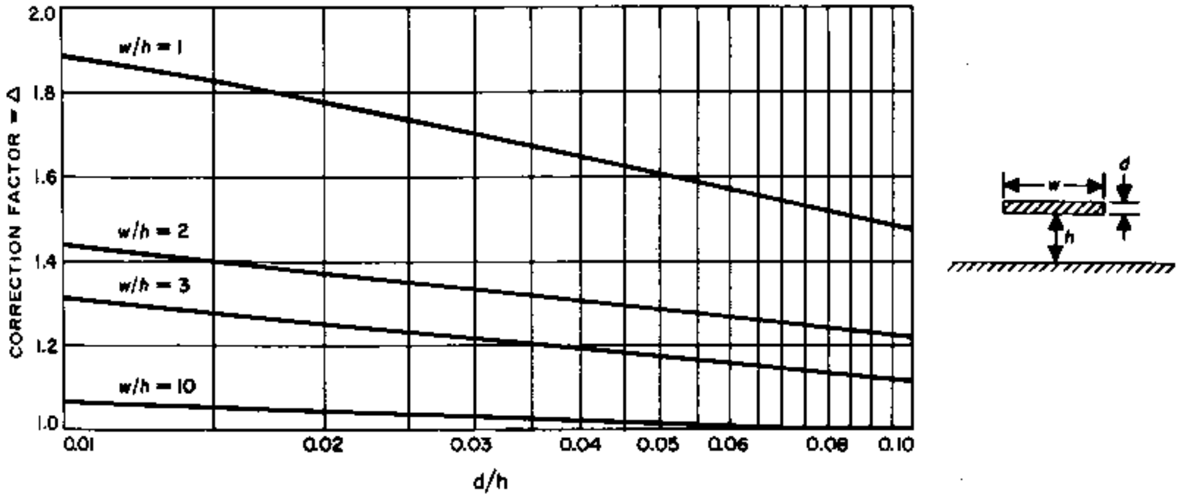

Fig. 28—Correction factor Δ for conductor attenuation (case of wide strip of small thickness above infinite ground plane).

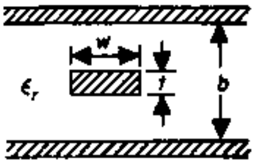

Fig. 29.

Conductor loss in decibels/unit length

$$\alpha_c = (y/b)\,(f_{\mathrm{GHz}}\epsilon_r\mu_r\rho/\rho_{\mathrm{Cu}})^{1/2}$$

where y = ordinate from Fig. 31, and ρ/ρ_{Cu} = resistivity relative to copper.

The unit of length in α_d is that of λ_0, and in α_c it is that of b.

LINES WITH HELICAL INNER CONDUCTOR

Spiral Delay Line

For a transmission line with helical inner conductor (spiral delay line) where axial wavelength and length of line are both long compared with line diameter (similar to Fig. 32 in dimensional symbols):

$$L' = 0.30n^2d^2[1-(d/D)^2]$$

microhenries/axial foot, where d is in inches and $n = 1/\tau$ = turns/inch.

$$C' = 7.4\epsilon_r/\log_{10}(D/d)$$

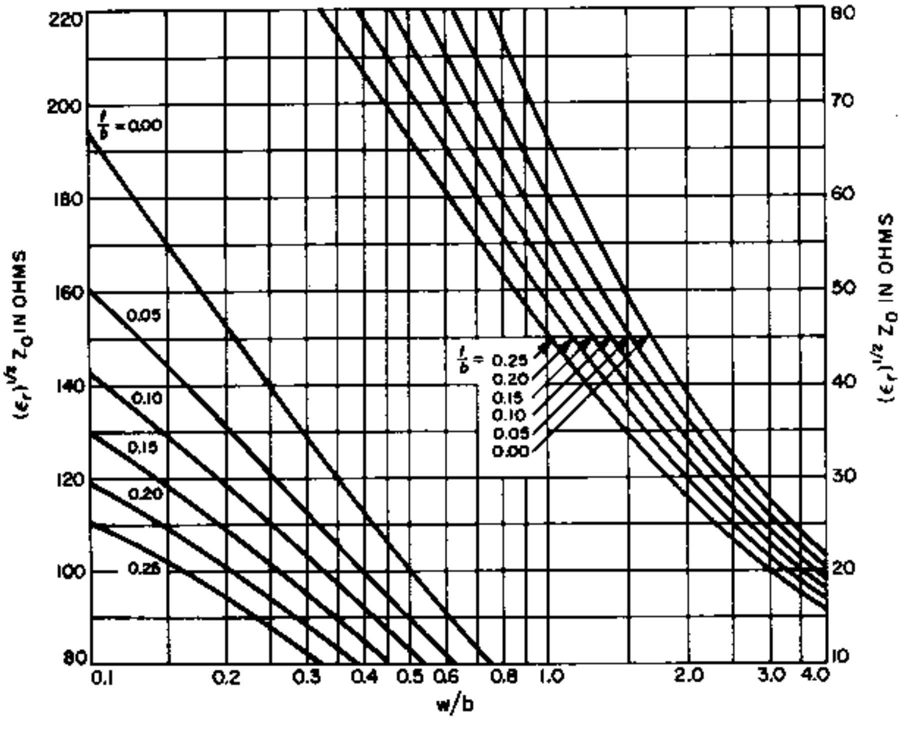

Fig. 30—Plot of strip-transmission-line Z_0 versus w/b for various values of t/b. For lower-left family of curves, refer to left-hand ordinate values; for upper-right curves, use right-hand scale. *Courtesy of Transactions of the IRE Professional Group on Microwave Theory and Techniques.*

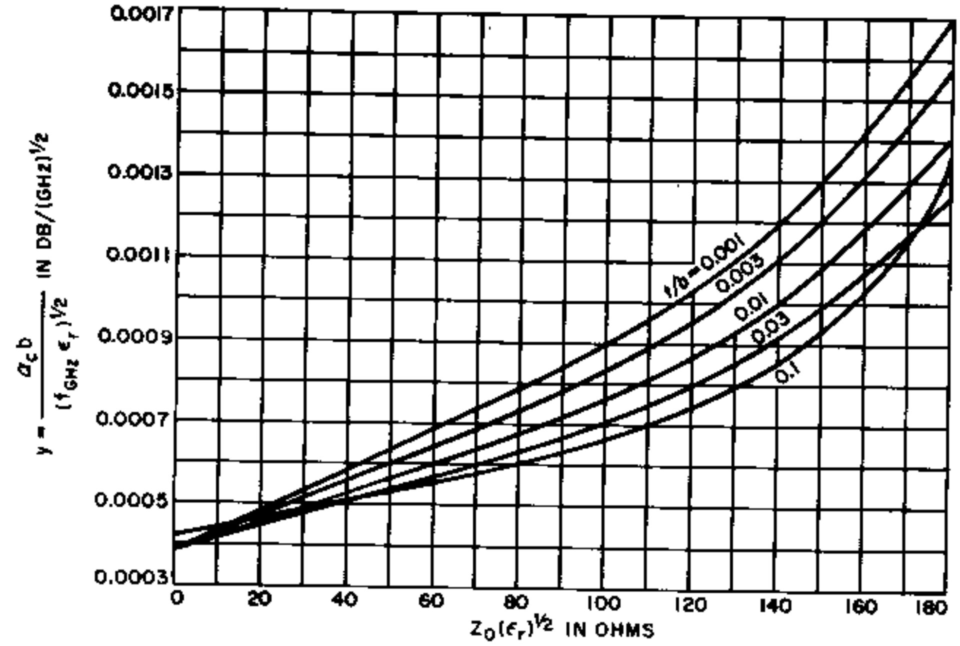

Fig. 31—Theoretical attenuation of copper-shielded strip transmission line in dielectric medium ϵ_r. *Courtesy of Transactions of the IRE Professional Group on Microwave Theory and Techniques.*

picofarads/axial foot.

$$Z_0 = (L'/C')^{1/2} \times 10^3 \text{ ohms}$$

$$T = (L'C')^{1/2} \times 10^{-3}$$

microseconds/axial foot.

$$\alpha_{dB} = 4.34R/Z_0 + 27.3F_p fT$$

decibels/axial foot where R = total conductor resistance in ohms/axial foot, f = frequency in megahertz, F_p = power factor, and ϵ_r = relative dielectric constant of medium between spiral and outer conductor.

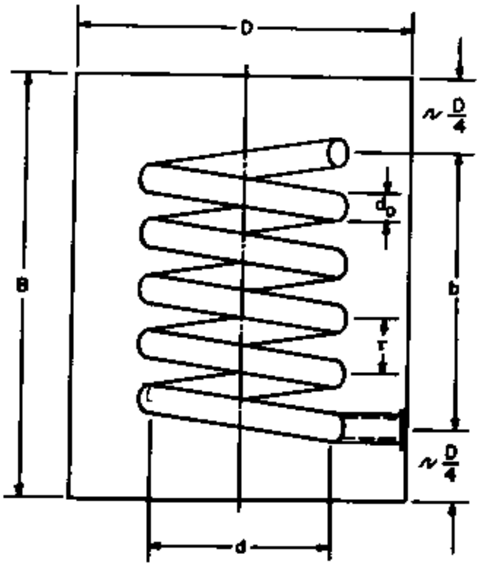

Fig. 32—Outline sketch of resonator. *W. W. Macalpine and R. O. Schildknecht, "Coaxial Resonators with Helical Inner Conductor," Proceedings of the IRE, vol. 47, no. 12, p. 2100; December 1959. © 1959 Institute of Radio Engineers.*

HELICAL RESONATOR*

Symbols

b = axial length of coil, inches
B = inside length of shield, inches
d = mean diameter of turns, inches
D = inside diameter of shield, inches
d_0 = diameter of conductor, inches
f_0 = frequency of resonance, megahertz
n = turns per inch
N = total number of turns of winding
Q_u = unloaded Q

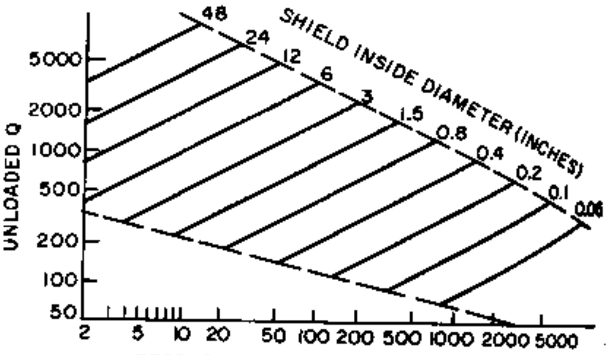

Fig. 33—Unloaded Q of helical resonator. *W. W. Macalpine and R. O. Schildknecht, "Coaxial Resonators with Helical Inner Conductor," Proceedings of the IRE, vol. 47, no. 12, p. 2100; December 1959. © 1959 Institute of Radio Engineers.*

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* W. W. Macalpine and R. O. Schildknecht, "Coaxial Resonators with Helical Inner Conductor," *Proceedings of the IRE*, vol. 47, no. 12, pp. 2099–2105; December 1959. W. W. Macalpine and R. O. Schildknecht, "Helical Resonator Design Chart," *Electronics*, p. 140; 12 August 1960.

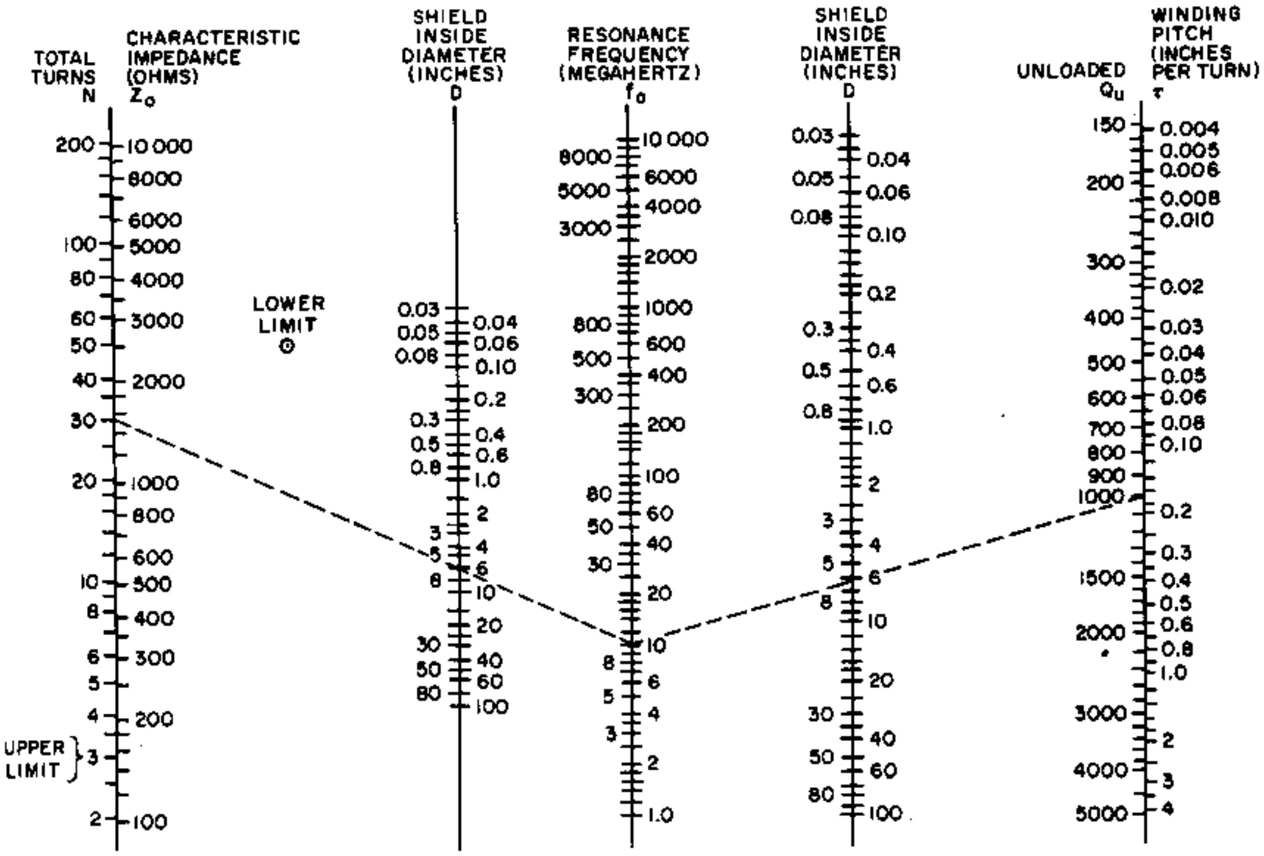

Fig. 34—Design chart for quarter-wave helical resonators. *W. W. Macalpine and R. O. Schildknecht, "Coaxial Resonators with Helical Inner Conductor," Proceedings of the IRE, vol. 47, no. 12, p. 2101; December 1959.* © *1959 Institute of Radio Engineers.*

δ = skin depth, inch
$\tau = 1/n$ = pitch of winding, inches.

Other symbols have the usual meanings, page 22-1.

The helical resonator shown in Fig. 32 consists of a shield (outer conductor) enclosing a coil (inner conductor). One end of the coil is solidly connected to the shield and the other end open-circuited, except possibly for a trimming capacitor. It operates as a distributed-parameter system equivalent to a quarter-wave coaxial transmission-line resonator. Probe, loop, or aperture coupling can be used for input and output circuits, or between adjacent coupled resonators.

Unloaded Q versus resonance frequency and shield diameter is shown in Fig. 33. The region plotted is where the helical resonator gives better Q for a given volume than other types. For higher Q and frequency, a conventional coaxial-line resonator is preferable. When the Q and frequency are lower than the plotted region, a lumped LC resonant circuit is indicated. These conditions are marked on Fig. 34 as "upper limit" (3 turns) and "lower limit," respectively.

Figure 34 is usually accurate to within ±10 percent. It is plotted from the following equations and is limited by the conditions noted.

Unloaded Q is given for a resonator that consists of a single-layer coil of copper conductor on a low-loss form and is enclosed in a shield of seamless copper tubing. A shielded coil below its resonance frequency also has ideally a true Q predicted by this equation. The equation gives a practical working value of Q somewhat below the theoretical maximum.

$$Q_u = 50 D f_0^{1/2}$$

provided:

$$0.45 < d/D < 0.6$$

$$b/d > 1.0$$

$$0.4 < d_0/\tau < 0.6 \text{ at } b/d = 1.5$$

$$0.5 < d_0/\tau < 0.7 \text{ at } b/d = 4.0$$

$$d_0 > 5\delta.$$

Total number of turns

$$N = 1900/(f_0 D) \text{ turns}$$

for $d/D = 0.55$, and $b/d > 1.0$.

Pitch of winding and characteristic impedance:

$$\tau = 1/n = (f_0 D^2)/2300 \text{ inches per turn}$$

$$Z_0 = 98\,000/(f_0 D) \text{ ohms}$$

for $d/D = 0.55$, and $b/d = 1.5$.

General conditions for all equations:

$$B \approx (b + D/2)$$

$$\tau < d/2.$$

Simplified and empirical equations from which

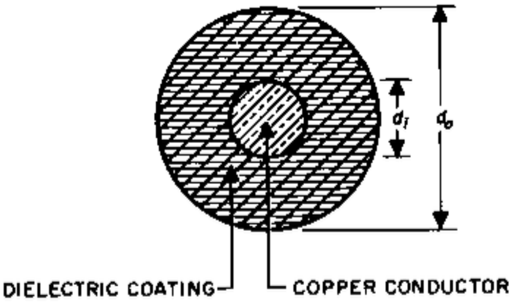

Fig. 35—Cross section of surface-wave transmission line.

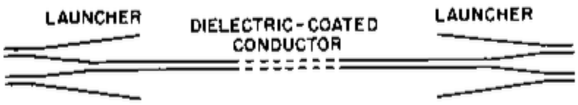

Fig. 36—Surface-wave transmission line with launchers at each end. These form transitions to coaxial line. *Courtesy of Electronics.*

the design equations are developed:

$L=0.025n^2d^2[1-(d/D)^2]$ microhenry per axial inch

$C=0.75/\log_{10}(D/d)$ picofarad per axial inch

$v=f_0\lambda=1000(LC)^{-1/2}$ inches per microsecond

$b=0.94\lambda/4=235f_0^{-1}(LC)^{-1/2}$ inches

$Z_0=1000(L/C)^{1/2}=235\,000(bf_0C)^{-1}$ ohms.

A further useful relationship in terms of the inside volume of the shield (vol) in cubic inches is

$$Q_u=50(\text{vol})^{1/3}f_0^{1/2}$$

provided that $0.4<d/D<0.6$, and $1.0<b/d<3.0$.

SURFACE-WAVE TRANSMISSION LINE*

The surface-wave transmission line is a single-conductor line having a relatively thick dielectric

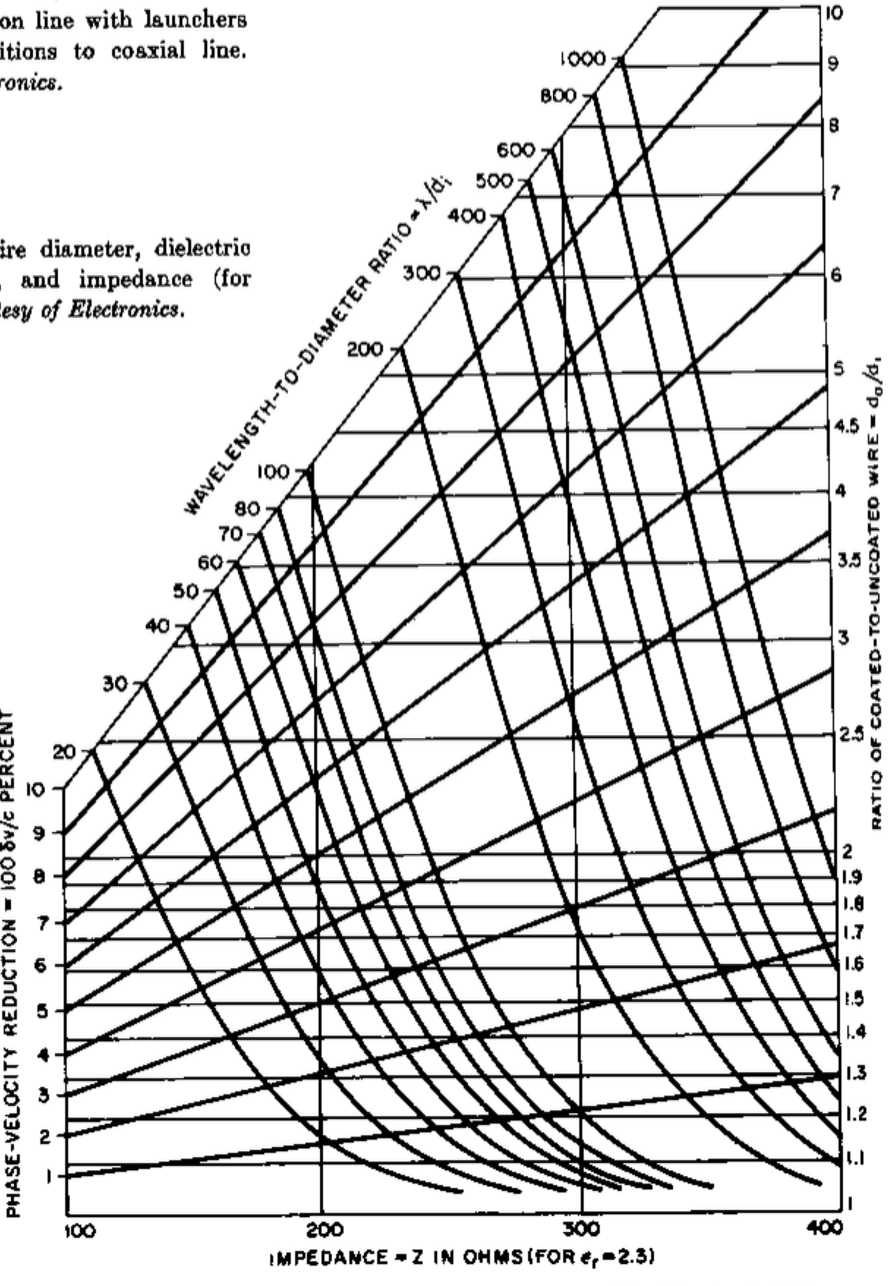

Fig. 37—Relationship among wire diameter, dielectric layer, phase-velocity reduction, and impedance (for brown polyethylene). *Courtesy of Electronics.*

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* G. Goubau, "Designing Surface-Wave Transmission Lines," *Electronics*, vol. 27, pp. 180–184; April 1954.