

Broad Bandwidth Feeds for Reflector Antennas

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Challenges for FASR:

- **Extremely wide bandwidth (100 MHz to 30 GHz)**
- **Small size of the antenna (diameter of 3 – 5 meters)**
- **Dual polarization**
- **“Acceptable” G/T**
- **Minimize number of moving parts**

Gain of Reflector Antennas

$$G = \frac{4\pi A}{\lambda^2} \eta$$

$$\eta = \eta_I \eta_S \eta_P \eta_X \eta_B \eta_E$$

η_I = Illumination Efficiency

η_S = Spillover Efficiency

η_P = Phase Error Efficiency

η_X = Crosspolarization Efficiency

η_B = Blockage Efficiency

η_E = Surface Error Efficiency



Gain of Reflector Antennas

Feed pattern is symmetric (E and H plane patterns are identical)

$$\eta_x = 1$$

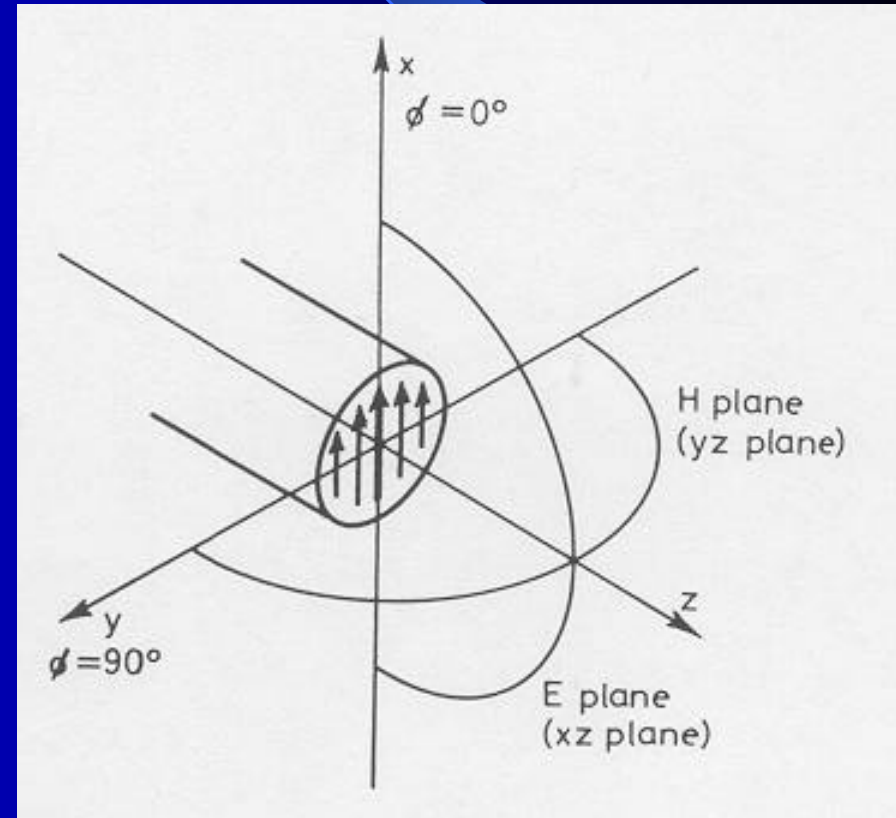
Common phase center for both planes

$$\eta_P = 1$$

Illumination and spillover losses are the principal causes of gain degradation.

There is usually a compromise between the illumination and spillover.

If $\eta_I = 1$, then η_S is too low for a realizable feed.
This results in increased sidelobes.



Types of Feeds Presented Here

- **Hybrid-Mode**
- **Dipole Above Ground Plane**
- **Frequency Independent Structures**

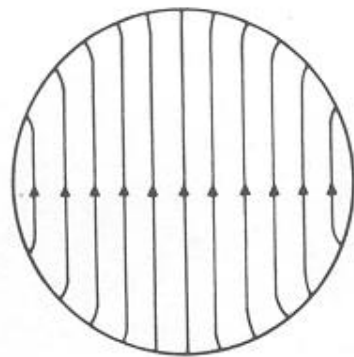
Hybrid-Mode Feeds

The Hybrid-Mode Feed offers a means to approach all of the objectives simultaneously.

$$E = AJ_o(Kr)\hat{i}_x - \left(\frac{X - Y}{4}\right)\frac{U_o^2}{kr_1}J_2(Kr)(\cos 2\phi \hat{i}_x + \sin 2\phi \hat{i}_y)$$

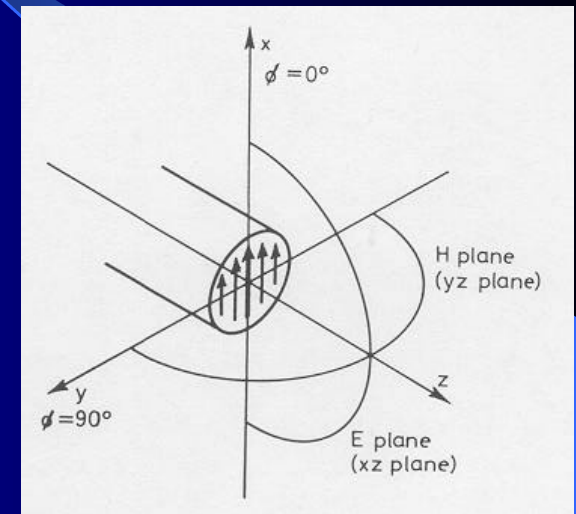
Normalized reactance and admittance of the boundary at $r = r_1$

$$X = -j\frac{Z_\phi}{Z_o} = -j\frac{E_\phi}{H_z}\left[\frac{\epsilon_o}{\mu_o}\right]^{\frac{1}{2}} \quad Y = -j\frac{Z_o}{Z_z} = +j\frac{H_\phi}{E_z}\left[\frac{\mu_o}{\epsilon_o}\right]^{\frac{1}{2}}$$



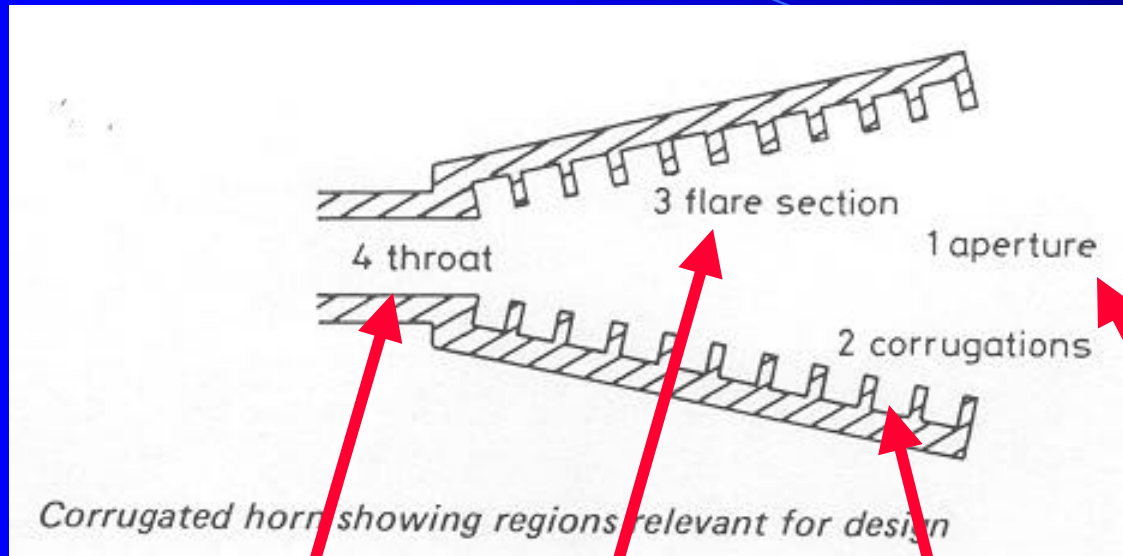
Transverse field patterns for dominant HE_{11} mode in cylindrical waveguide of radius

r_1



Clarricoats, P.J.B. and A.D. Olver, Corrugated Horns for Microwave Antennas, Peter Peregrinus, Ltd., London, UK, 1984, p. 7.

Hybrid-Mode Feed – Corrugated Waveguide



$$X = 0$$

$$Y = \tan\left(m \frac{\pi}{2} \frac{\Delta f}{f_o}\right) = 0 \quad \text{when} \\ m \text{ is an odd integer.}$$

Co-polar bandwidth

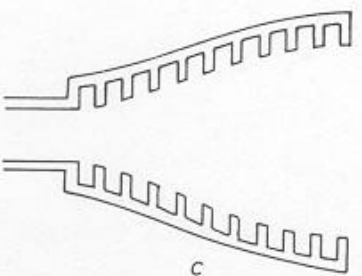
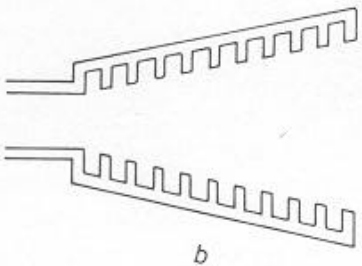
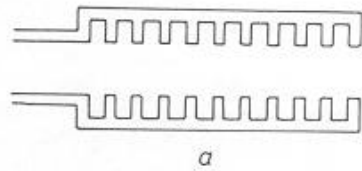
Position of the phase
center and generation of
higher order modes

Pattern symmetry and
cross-polar characteristics

Impedance matching to the waveguide
and mode conversion level

Clarricoats, P.J.B. and A.D. Olver, Corrugated Horns for Microwave Antennas, Peter Peregrinus, Ltd., London, UK, 1984, pp. 99-100.

Hybrid-Mode Feed – Corrugated Waveguide



Types of cylindrical corrugated waveguide feeds
a Open-ended waveguide
b Narrow flare angle horn
c Profiled horn

Large flare angle horn (scalar feed) gives a relatively large bandwidth with nearly constant co-polar radiation characteristics.

Thomas, James, and Greene (1986):

Scalar feed having 2.1:1 bandwidth.

James (1984):

Compact profiled horn having 2.4:1 bandwidth (requires some focus adjustment)

Hybrid-Mode Feed - Corrugated Waveguide

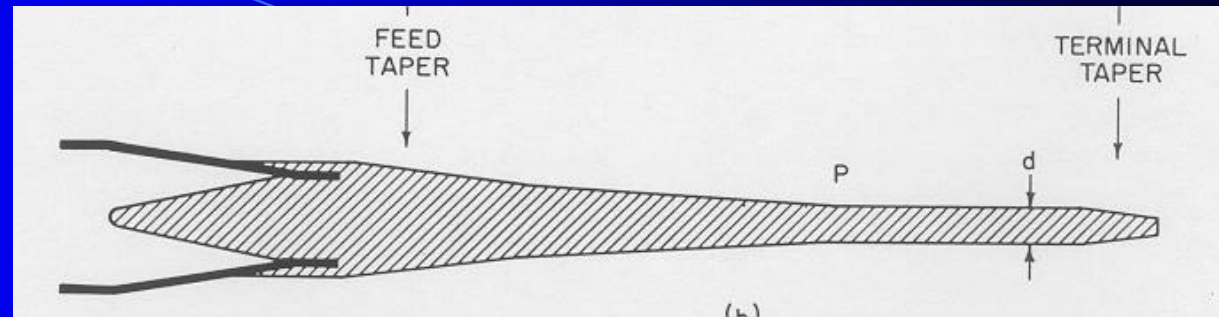
Absorber Lined Horn

Knop, Cheng, and Ostertag (1986)

Demonstrated nearly balanced HE_{11} mode operation in a horn reflector. $\epsilon' = 1.4$ and $\epsilon'' = 0.56$ lined the upper part of the cone. Operation from 4 - 12 GHz was demonstrated (upper frequency limited by waveguide launcher.) Ohmic loss was 0.5 dB over the band.

Hybrid-Mode Feed – Surface-Wave Antenna

**Dielectric
Waveguide (rod)**



If $kr_1 \gg 1$ and if the refractive index differs by only a small amount, Δn , from unity, then

$$X = \frac{1}{\sqrt{(2\Delta n)}}; \quad Y = \frac{1}{\sqrt{(2\Delta n)}}(1 + 2\Delta n)$$

Thus,

$$(X - Y) = -\sqrt{(2\Delta n)}$$

This condition is frequency independent if the dielectric is free from dispersion over the operational bandwidth.

Unless Δn is sufficiently large it is impossible to effectively launch the dominant mode of the dielectric waveguide – loose energy in the launcher.

Corrugated waveguide: Lower cross-pol over 2.5:1 bandwidth.

Dielectric waveguide: higher cross-pol over a **much wider band.**

BW= 4:1

Hybrid-Mode Feeds

Disadvantages for FASR:

- Big and bulky (corrugated)
- High machining cost (corrugated)
- Bandwidth not large enough
- Polarizer bandwidth about 2.5:1
- Loss associated with dielectric material

Dipole Above a Ground Plane

Conventional half-wave dipole

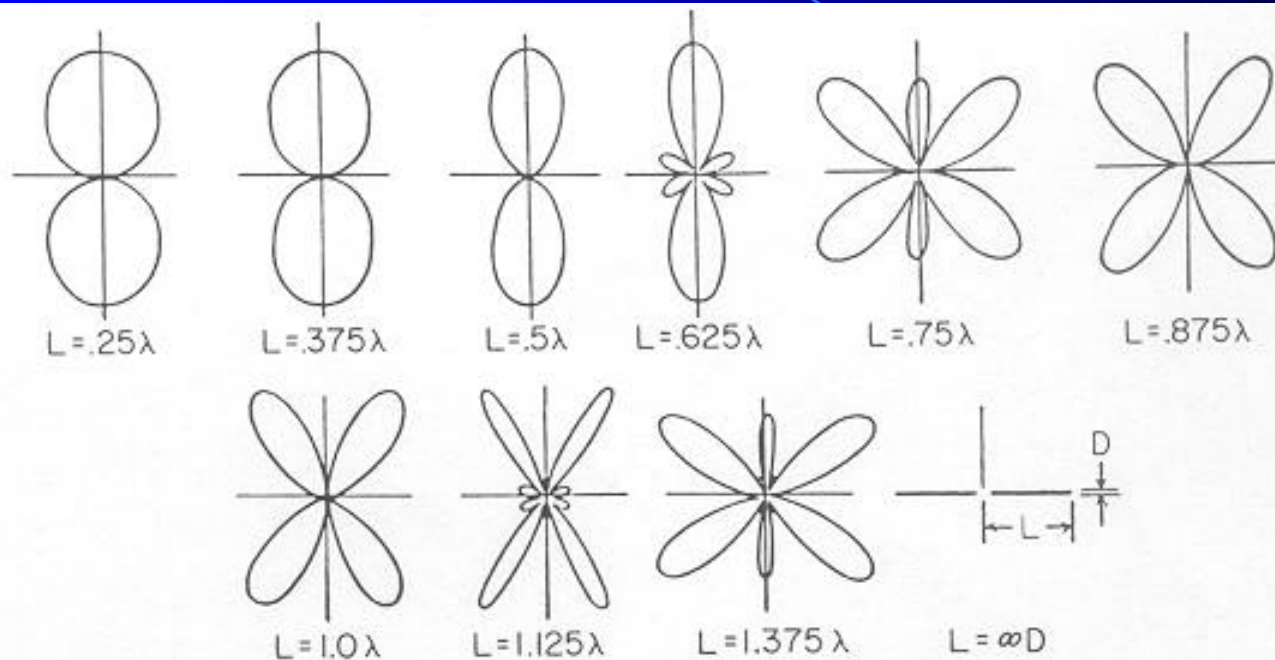


FIG. 4-8 Radiation patterns of center-driven dipoles if sinusoidal current distribution is assumed.

Dipole Above a Ground Plane

Conventional half-wave dipole

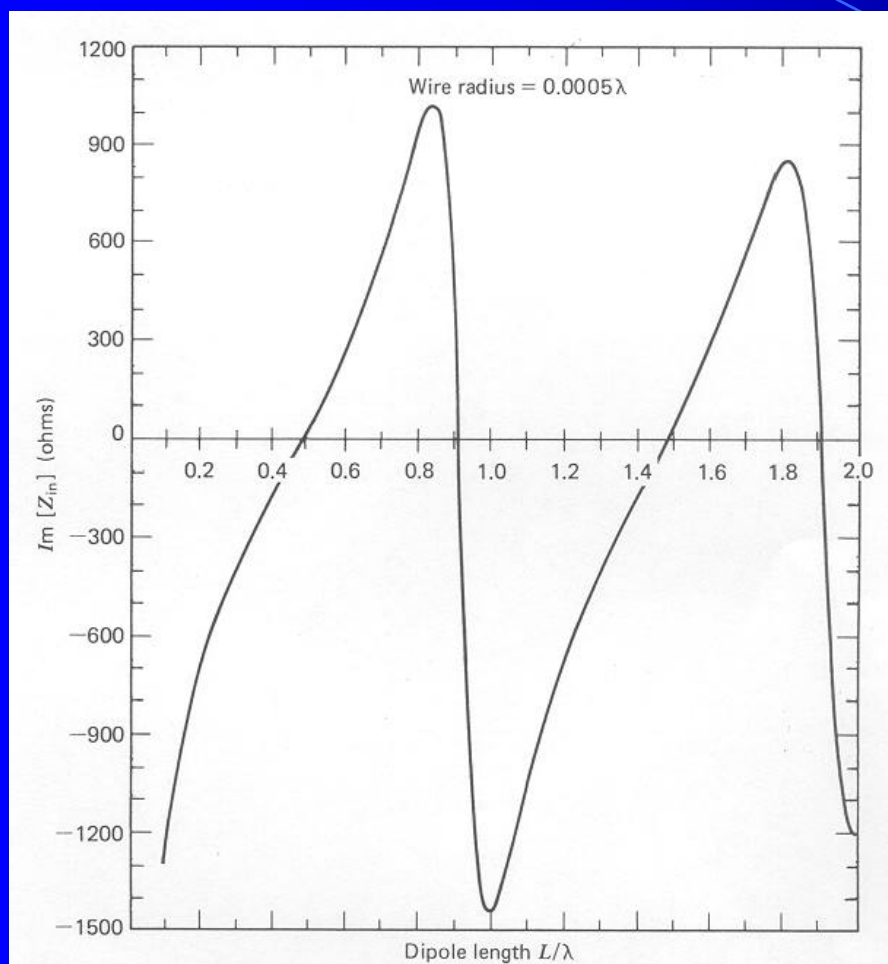


Figure 5-6 Calculated input reactance of center-fed wire dipole of radius 0.0005λ as a function of length L .

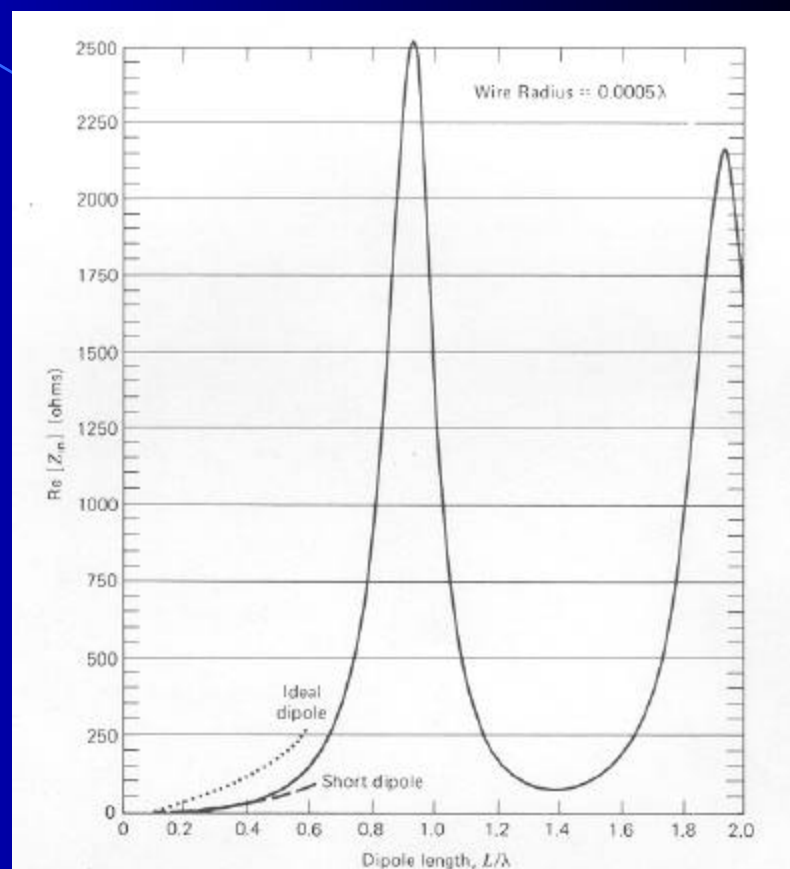
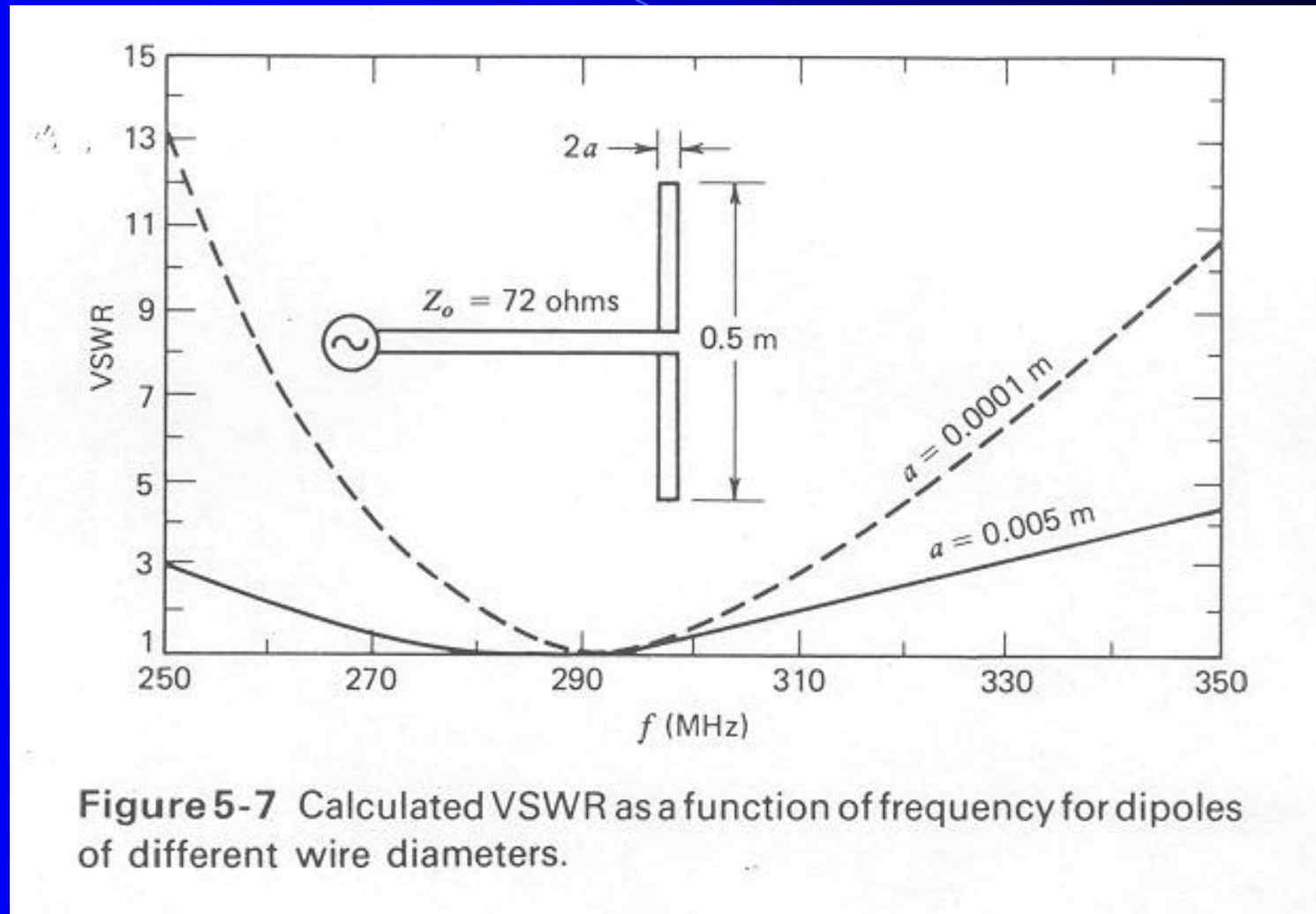


Figure 5-5 Calculated input resistance of a center-fed wire dipole of 0.0005λ radius as a function of length L (solid curve). Also shown is the input resistance $R_{in} = 80\pi^2(L/\lambda)^2$ of an ideal dipole with a uniform current distribution (dotted curve) and the input resistance $R_{in} = 20\pi^2(L/\lambda)^2$ of a short dipole with a triangular current distribution approximation (dashed curve).

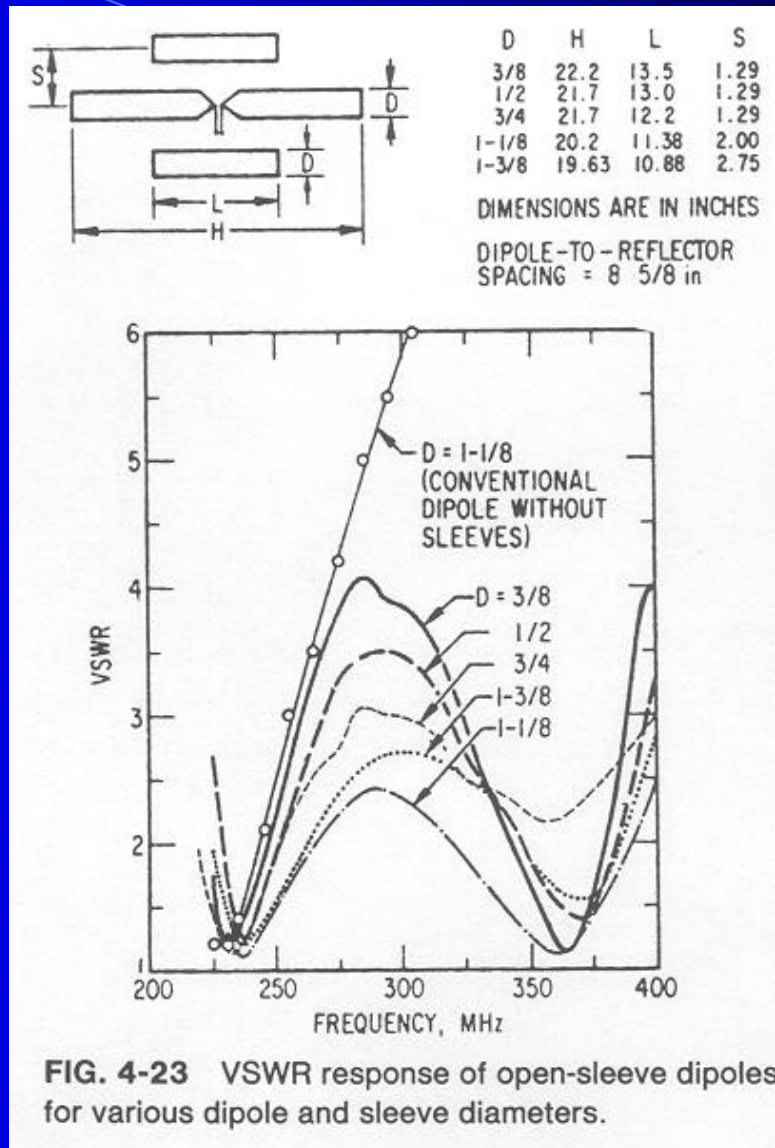
Dipole Above a Ground Plane

Fat Dipole



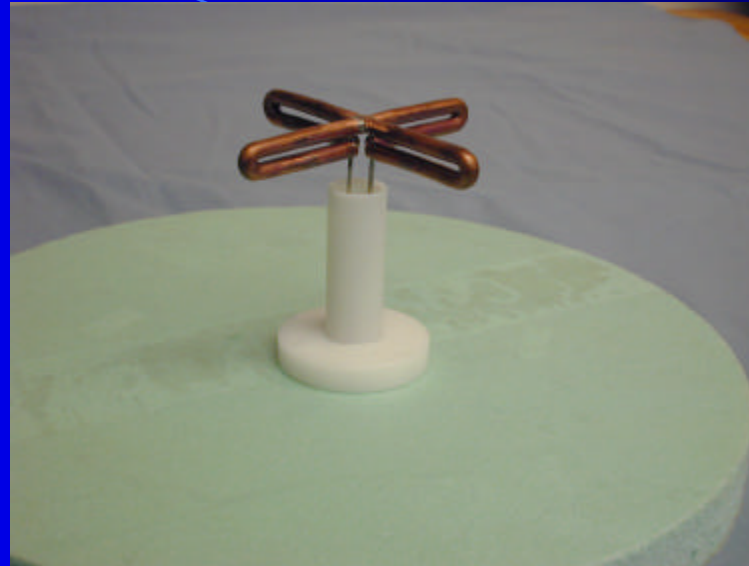
Dipole Above a Ground Plane

Sleeve Dipole

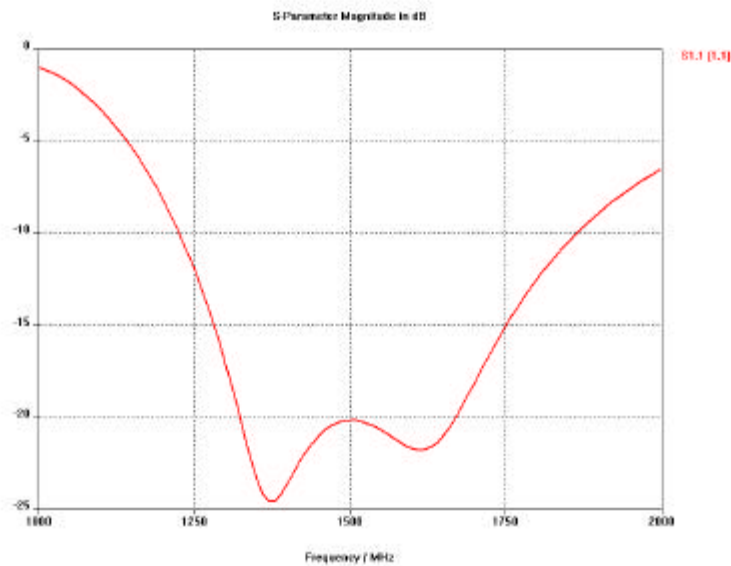


Dipole Above a Ground Plane

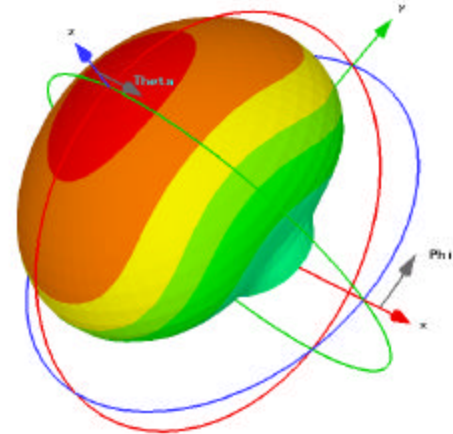
Folded, Fat Dipole



BW= 1.53:1



Type = FarField
Monitor = PF_1420 11.13
Component = dBi
Output = Directivity
Frequency = 1420
Rad. effico. = 1.000
Int. effico. = 1.001
Dir. = 7.913 dBi



-32.1 0 7.913 dBi

Dipole Above a Ground Plane

Short Backfire Antenna

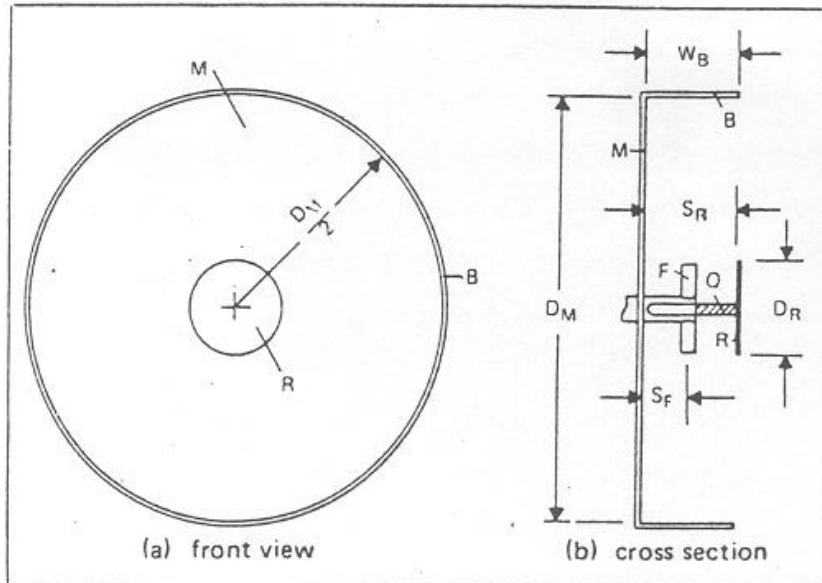


Fig. 1 3 GHz model of SBF antenna.

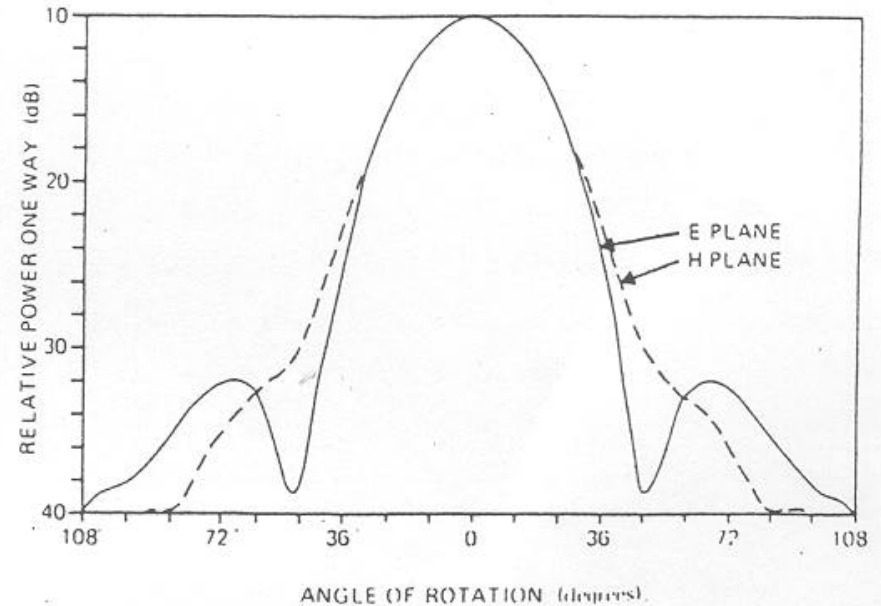


Fig. 2 Radiation patterns of 3 GHz SBF antenna.

Ehrenspeck, H.W. "The Short Backfire Antenna," *Proc. of the IEEE*, v. 53, Aug. 1965, pp.1138-1140.

Srikanth, S. and G. Behrens, "A New Short Backfore Antenna as a Prome Focus Feed for the GBT", GBT Memo. #187, May 13, 1998.

BW= 1.35:1

Dipole Above a Ground Plane

Disadvantages for FASR:

- Bulky
- Narrow bandwidth
- Large spillover



Frequency Independent Antennas

Provided the antenna is made of practically perfect conductors and dielectrics, the impedance, polarization, pattern, etc. are invariant to a change in scale that is in proportion to the change in wavelength.

If the shape of the antenna is determined entirely by angles (invariant to scale), the performance would have to be independent of frequency.

Truncation of the shape from that of infinite extent should also give good performance (current should decrease with distance from the terminals).

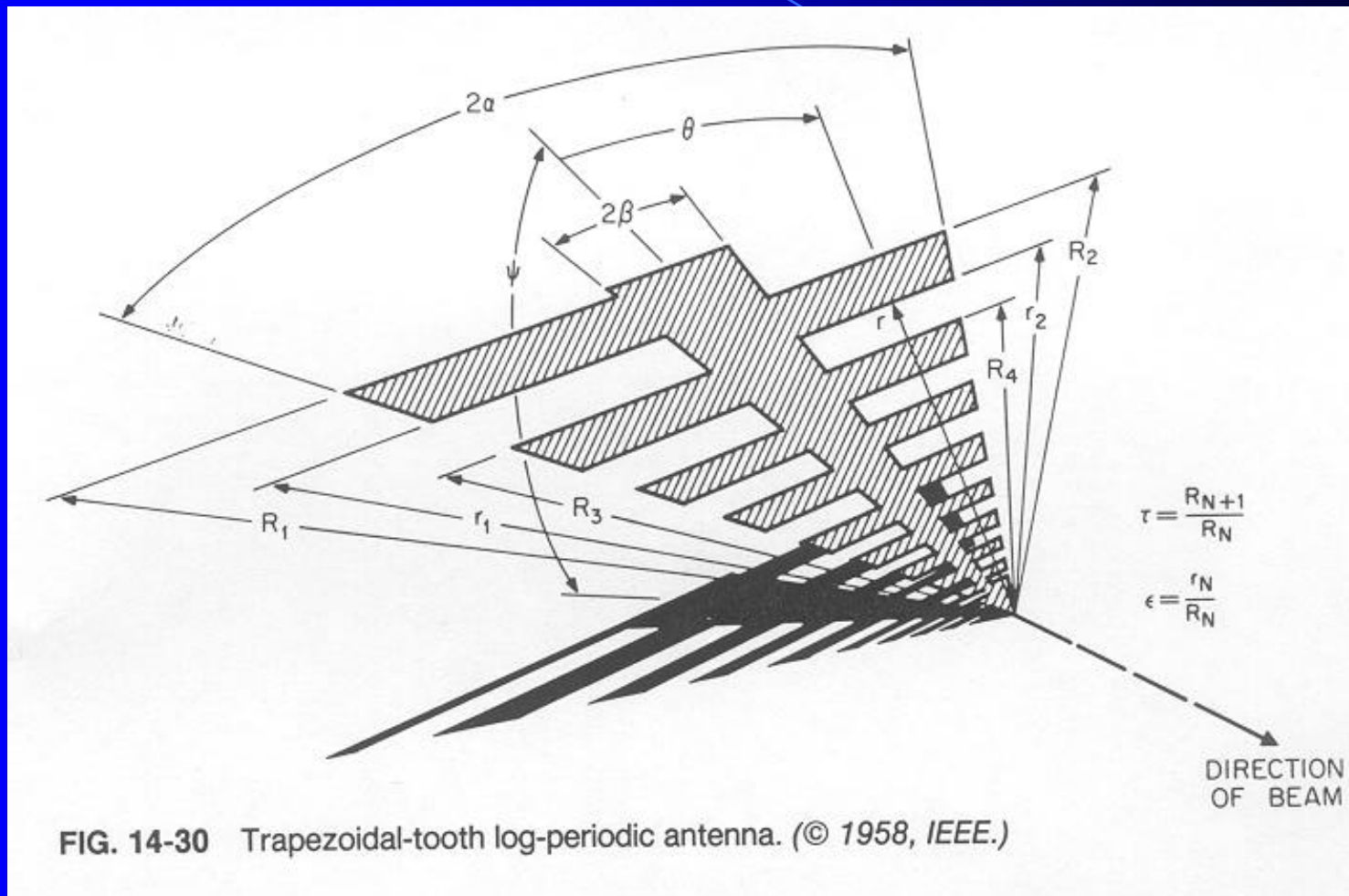
$$\text{Self - Complementary Design} \Rightarrow Z_{AIR} = Z_{METAL} = \frac{\eta}{2} = 188.5 \Omega$$

Operational bandwidth:

- lowest frequency limited by the maximum dimension
- upper frequency limited by the input terminal region
- bandwidths can be 10:1 or greater.

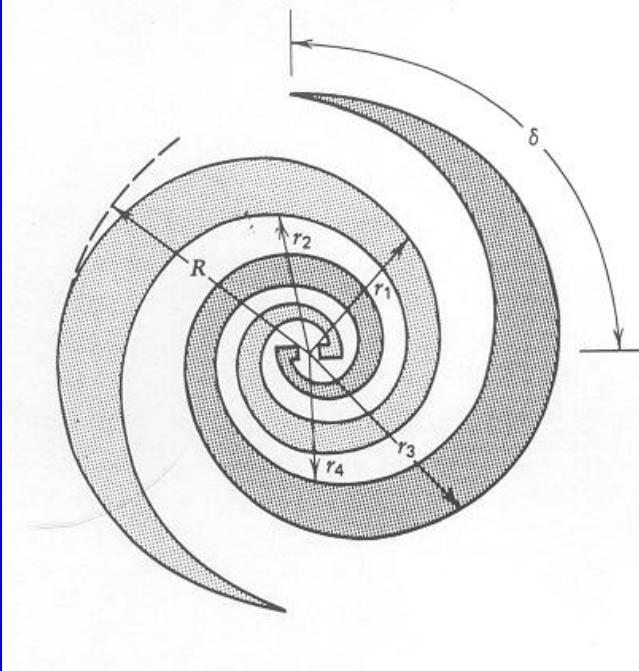
Frequency Independent Antennas

Log Periodic



Frequency Independent Antennas

Spirals



Stutzman, W. and G. Thiele, Antenna Theory and Design, Wiley, New York, 1981, p. 284.

Johnson, R. C. Antenna Engineering Handbook, 3rd ed., McGraw-Hill, New York, 1993, p. (14-25).

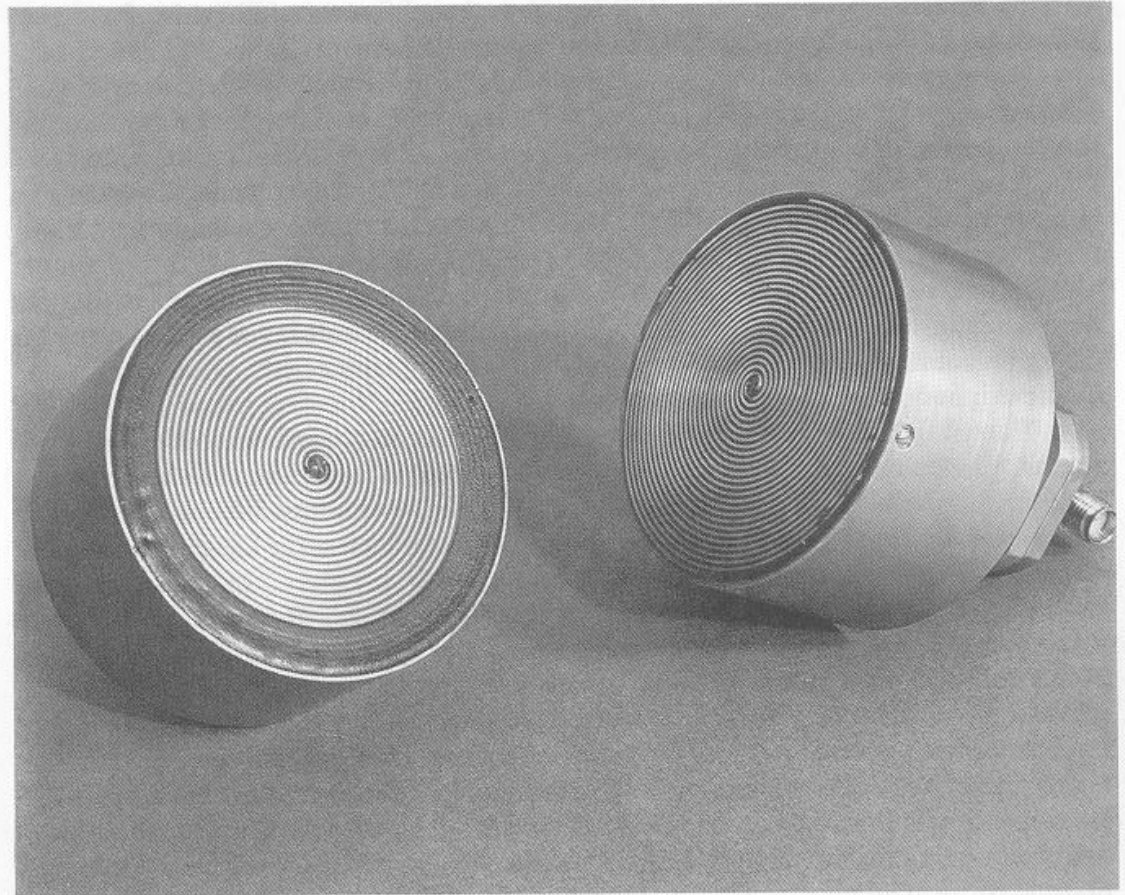


FIG. 14-22 Two 2-in-diameter complementary archimedean spirals terminated with absorber paint and a 100- Ω resistor; arm width $W = 0.022$ in. (Courtesy Loral Randtron Systems.)

Frequency Independent Antennas

Absorber Loaded Cavity

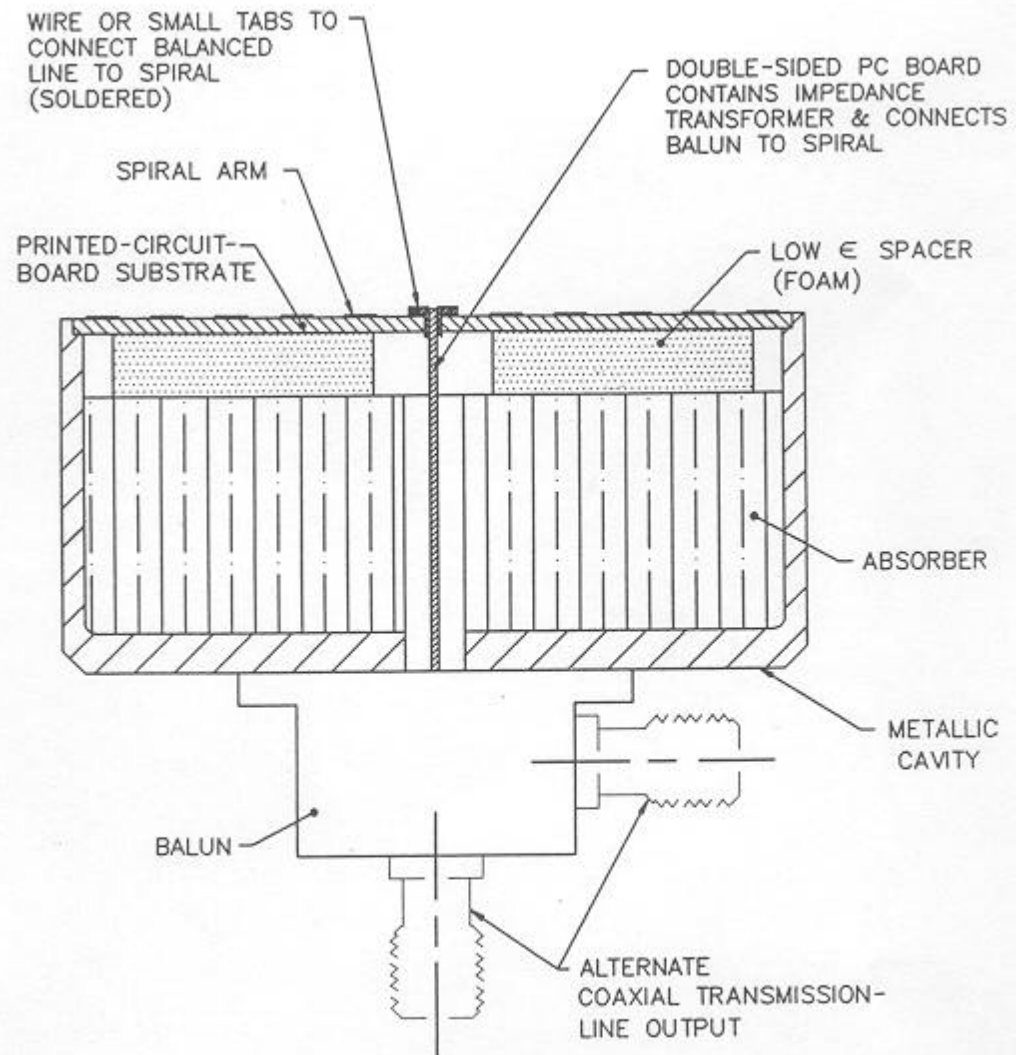


FIG. 14-14 Absorber-loaded cavity-backed two-arm archimedean-spiral antenna.

Johnson, R. C. Antenna Engineering Handbook, 3rd ed., McGraw-Hill, New York, 1993, p. (14-18).

Frequency Independent Antennas

Conical Log-Spiral

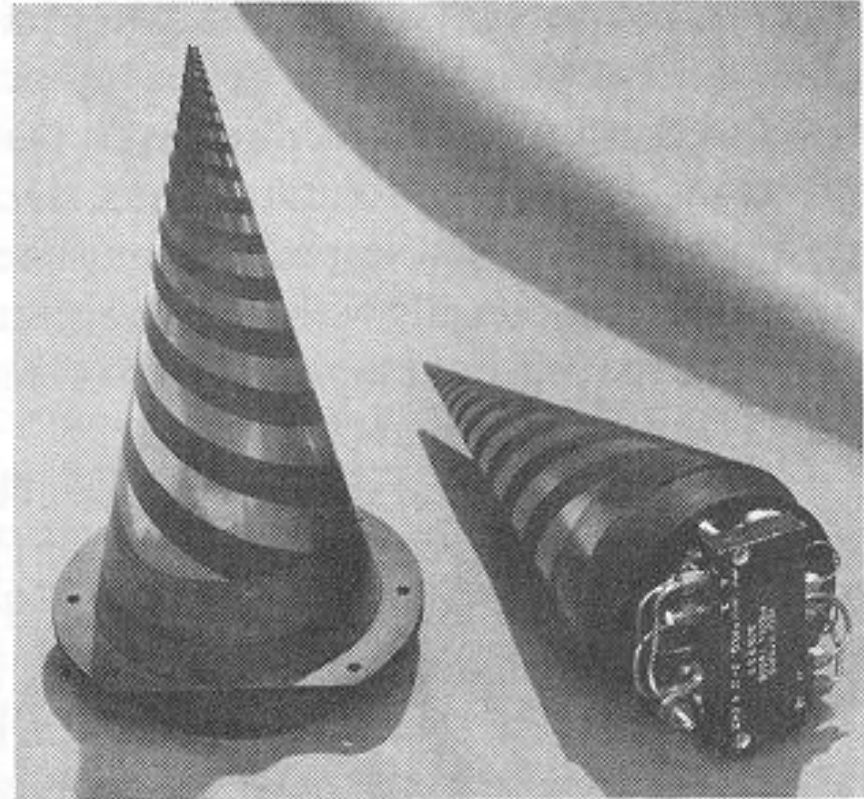


FIG. 14-29 Four-arm conical log-spirals excited in mode 2 for circularly polarized omnidirectional pattern, 2 to 12 GHz. (Courtesy of GTE Sylvania Systems Group.)

Johnson, R. C. Antenna Engineering Handbook, 3rd ed., McGraw-Hill, New York, 1993, p. (14-33).

Frequency Independent Antennas

Sinuuous

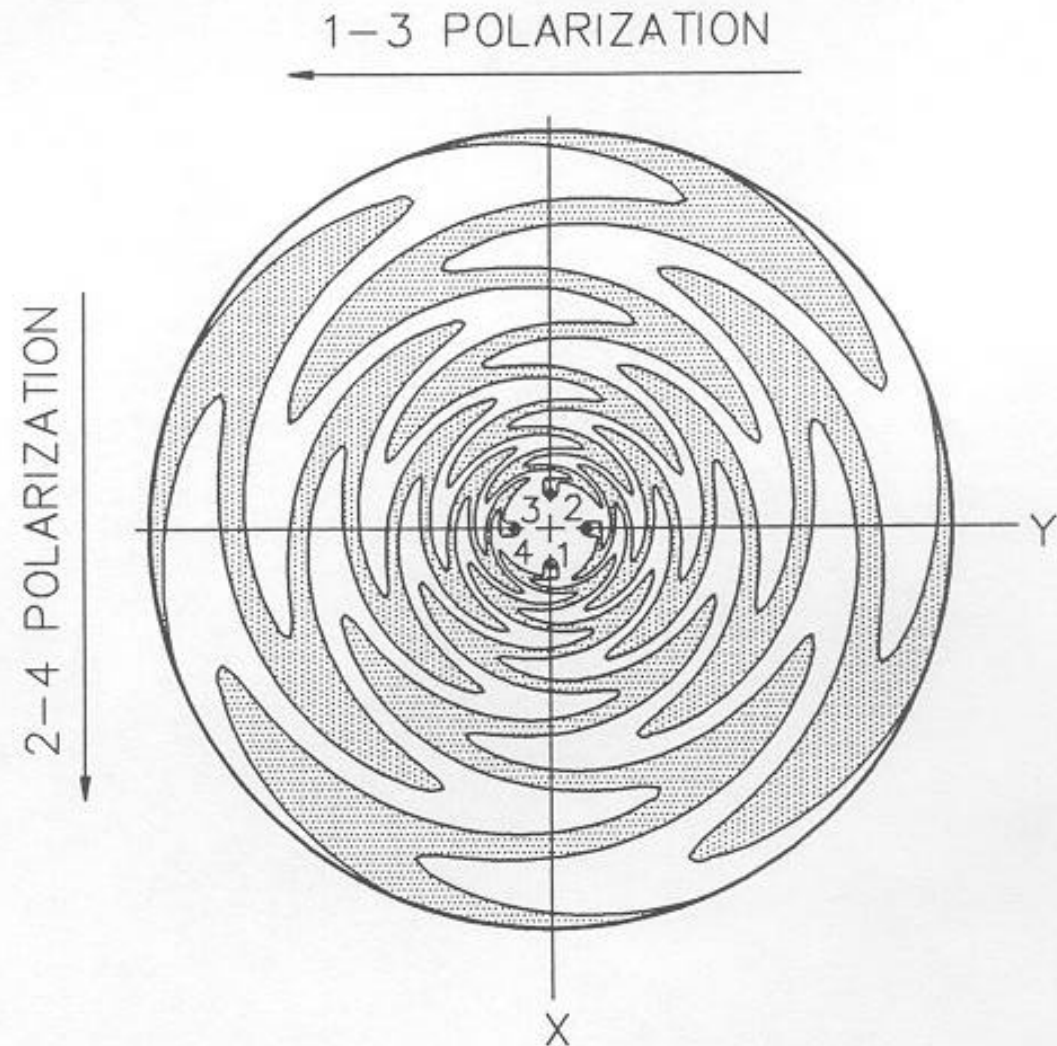


FIG. 14-52 Four-arm sinuous aperture.

Johnson, R. C. Antenna Engineering Handbook, 3rd ed., McGraw-Hill, New York, 1993, p. (14-56).

Frequency Independent Antennas

Sinuous

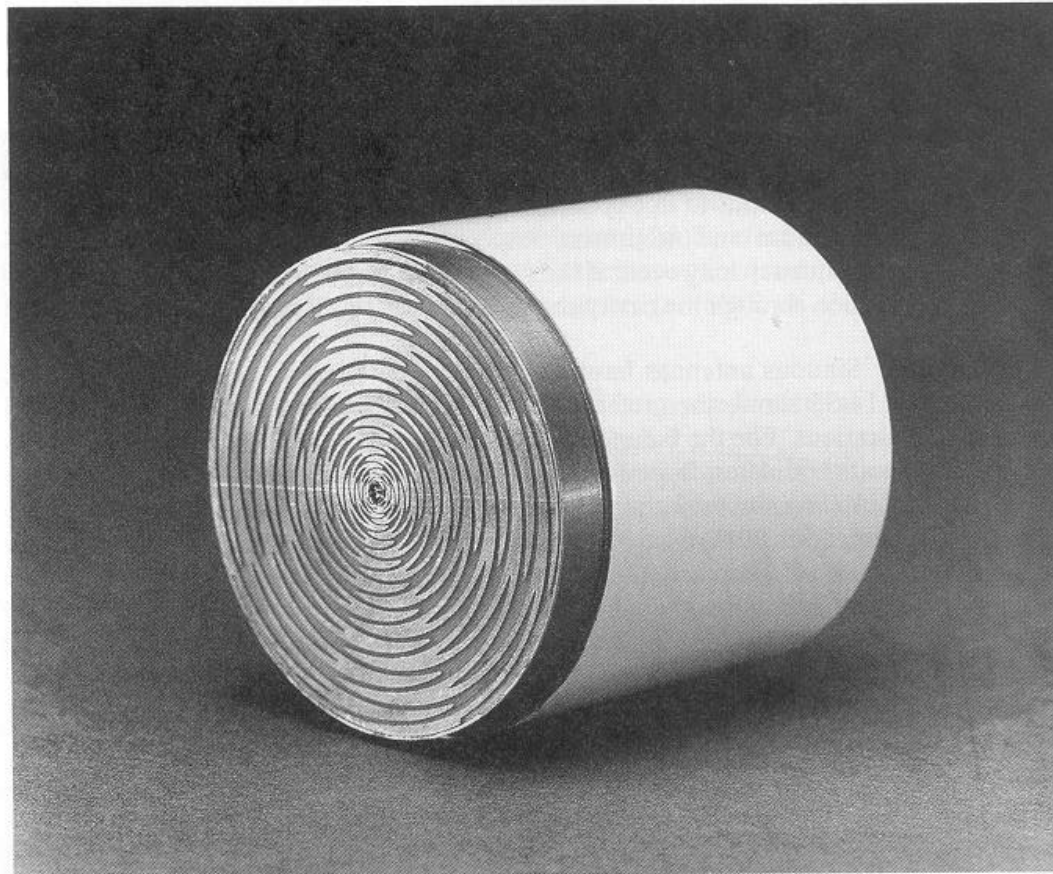


FIG. 14-54 A 2-in-diameter sinuous antenna, $\tau = 0.75$, $\alpha = 45^\circ$, and $\delta = 22.5^\circ$. (Courtesy Loral Randtron Systems.)

Frequency Independent Antennas

Sinuous

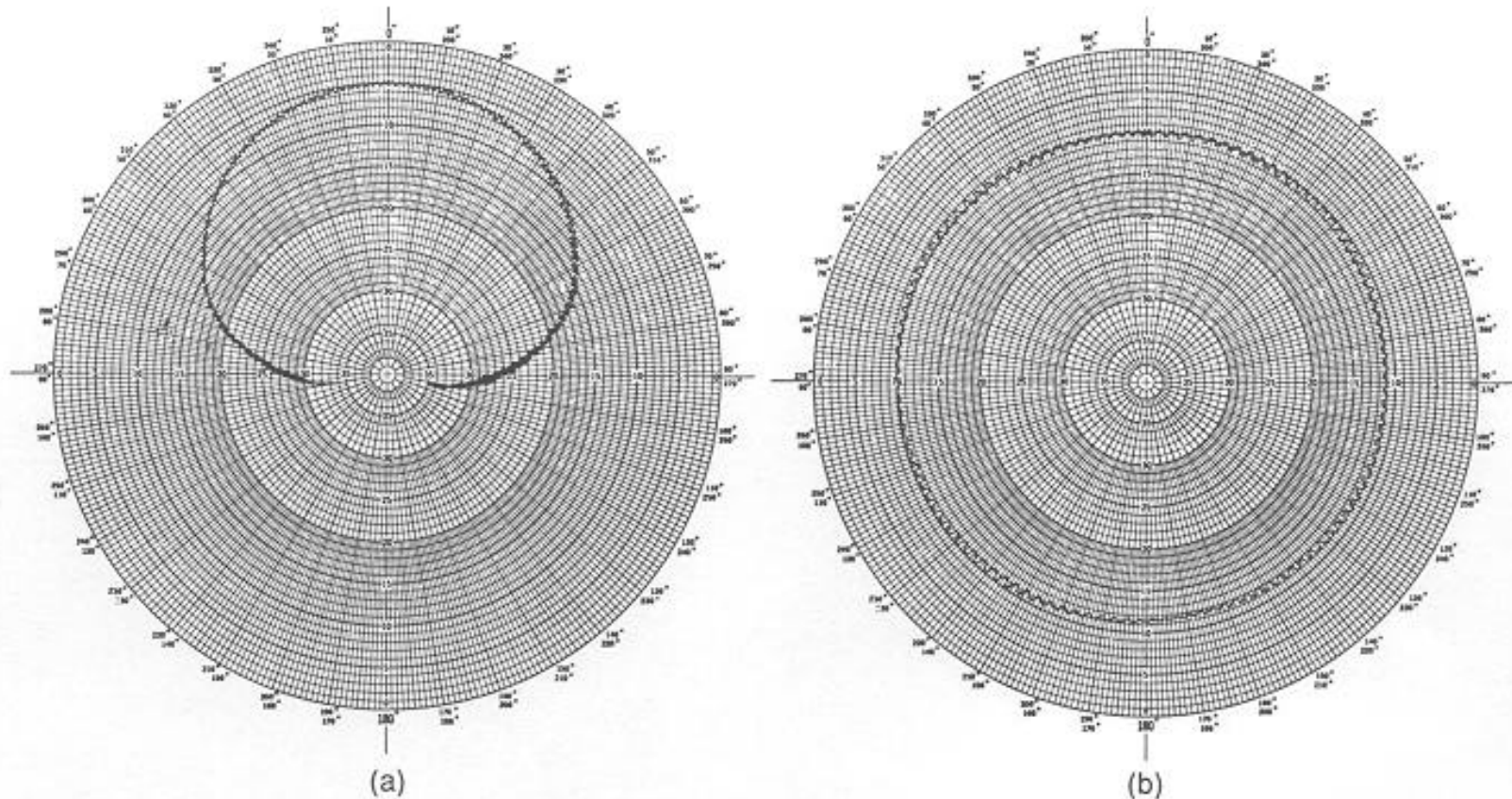


FIG. 14-55 (a) Principal-plane pattern of a 2-in-diameter sinuous antenna at 10 GHz. (b) 60° conical-cut pattern of a 2-in-diameter sinuous antenna at 10 GHz.

Frequency Independent Antennas

Sinuous Antenna on a Cone

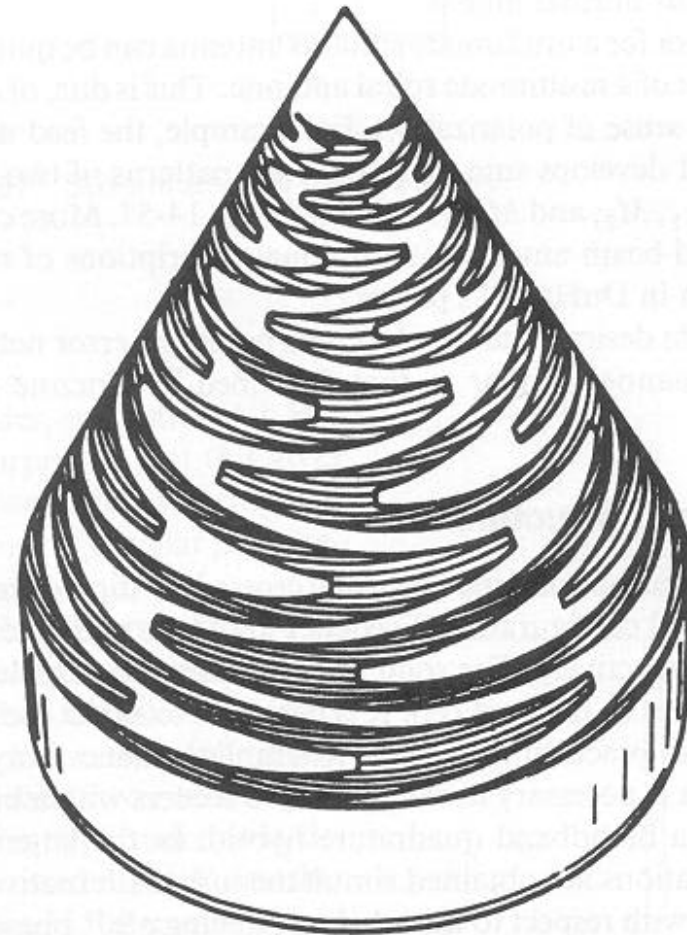


FIG. 14-56 Six-arm conical sinuous antenna.

Frequency Independent Antennas

Disadvantages for FASR:

- Integration of feed, LNA and balun
- Could be lossy (affect G/T)
- Dual-polarization
- Gain varies with frequency for fixed position conical



Conclusions

For FASR:

- Frequency independent antennas are the only practical option to cover FASR frequency range.
- Use a cavity backed structure for wide instantaneous bandwidth.
- Accept gain reduction associated with fixed position cone.
- Consider sinuous version of frequency independent structures.
- Integration of feed terminals with LNAs and balun.
- Prototyping highly recommended!

