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A LEADING PROVIDER OF STRATEGIC HF ANTENNAS FOR 50 YEARS

Broadband, Horizontally-Polarized, Omni-directional, HF Antenna Operating over Imperfect Ground

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Corporate Overview

Antenna Products Corp. is first and foremost a developer and manufacturer of antennas.

Although the company produces antennas for all frequency ranges, much emphasis is placed on HF antennas.

The company has been designing and manufacturing HF antennas for over 50 years.

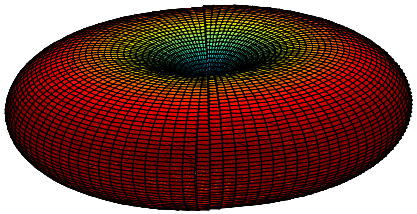
Overview of Presentation

- *Re-examination of old problem in light of new developments*
- *HF Broadcast antenna*
  - *Isotropic in azimuth*
  - *Horizontal polarization—minimal surface wave excitation*
  - *High radiation efficiency in presence of ground*
  - *Good beam efficiency—power primarily in principal lobe*
- *Reducing size*
- *Reducing radiation hazard*
- *Possible new features under software control*
  - *Multi-mode operation*
  - *MIMO*
  - *Adjustable take-off angle*
  - *Adjustable beam width*

Canonical Problem

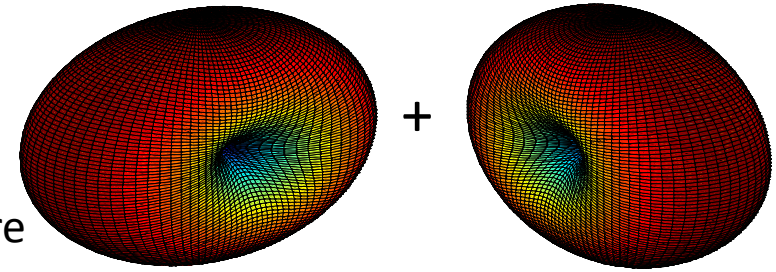
Isotropic azimuthal pattern, horizontally-polarized on horizon:

TE_{01} Spherical Mode



- Loop over ground with vertical axis
- Electrically-small loop—magnetic dipole
- Electrically-large, multiple-feed loop (Alford, Kandoian, Cloverleaf)

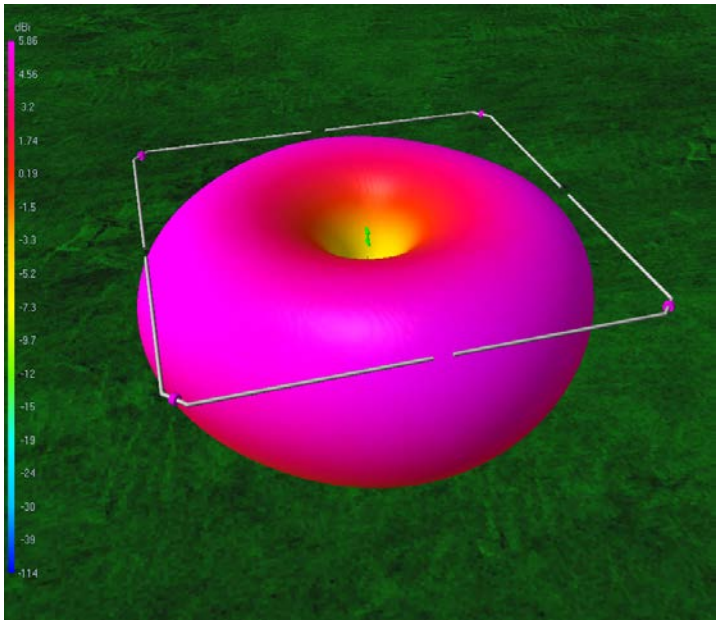
TM_{11}^{odd} and TM_{11}^{even} Spherical Modes in phase quadrature

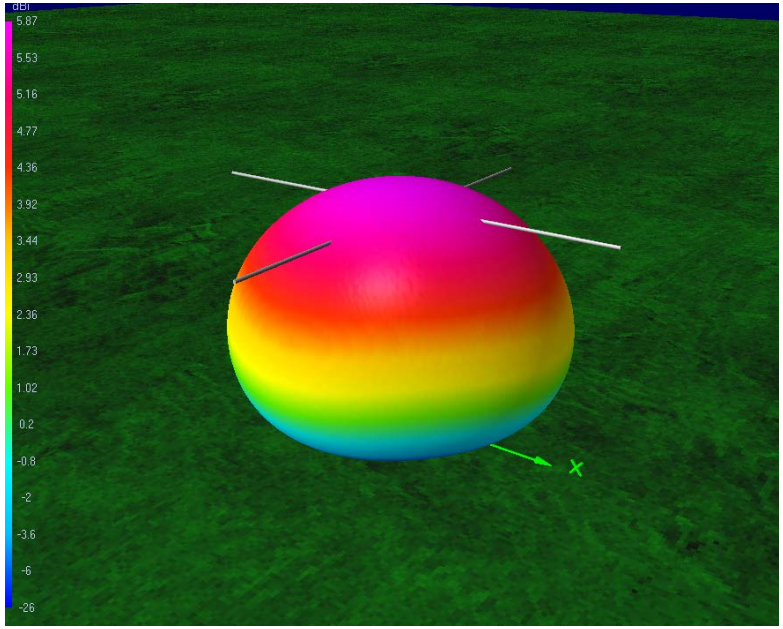


- Crossed-dipoles in phase quadrature (Turnstile) over ground: horizontal polarization on horizon, circular polarization in vertical direction
- Quadrant antenna: similar to crossed dipole in phase quadrature—dipoles not electrically small and pattern is somewhat distorted.

Effect of Imperfect Ground

Compare radiation efficiency of loop and crossed dipoles over ground at same height.





Radiation efficiency 82 %

$\varepsilon_R = 4$

$\sigma = .003$ S/m

Radiation efficiency 81 %

Beam Efficiency

Beam efficiency is a measure of how well an antenna concentrates its radiated power into one lobe or beam

Beam efficiency of antenna with major lobe directed along z-axis

$$\text{Beam Efficiency} = BE = \frac{\text{Power transmitted (received) within cone angle } \theta_1}{\text{Power transmitted (received) by the antenna}}$$

$$BE = \frac{\int_0^{2\pi}\int_0^{\theta_1} U(\theta,\phi)\sin\theta\, d\theta\, d\phi}{\int_0^{2\pi}\int_0^{\pi} U(\theta,\phi)\sin\theta\, d\theta\, d\phi}$$

If beam efficiency is degraded in pursuit of high radiation efficiency, efficacy of antenna is compromised.

Antenna Theory Analysis and Design, Constantine Balanis, John Wiley & Sons New York 1997

Beam Efficiency

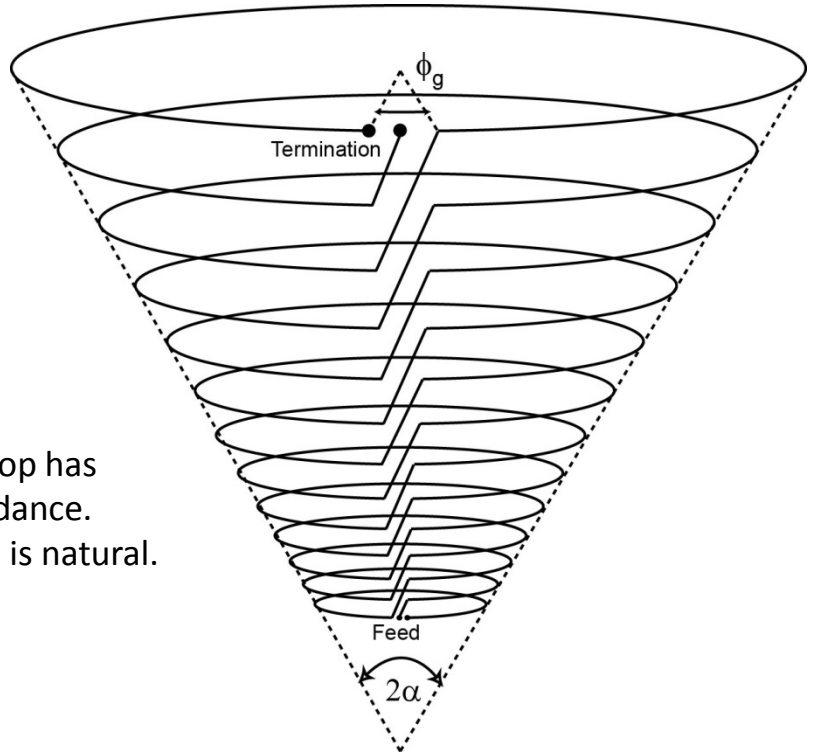
Radiation efficiency is very important, but if beam efficiency is low or polarization state (“polarization loss factor” or “polarization mismatch”) is significantly different from the optimum, the benefits of high radiation efficiency are not realized.

- Antennas having very similar far field patterns can have very different near electromagnetic fields.
- Thus, antennas operating over ground with similar far field patterns can have very different radiation efficiencies.
- Also, antennas with similar far field patterns can generate very different extraneous near fields and hence pose very different radiation hazards to personnel.

Log-periodic Array of Coaxial Loops

- Series-fed
- Shunt-fed
- Multiply-shunt-fed
- Multi-mode operation
- Clamped-mode operation
- Reduced-structure (Tanner)

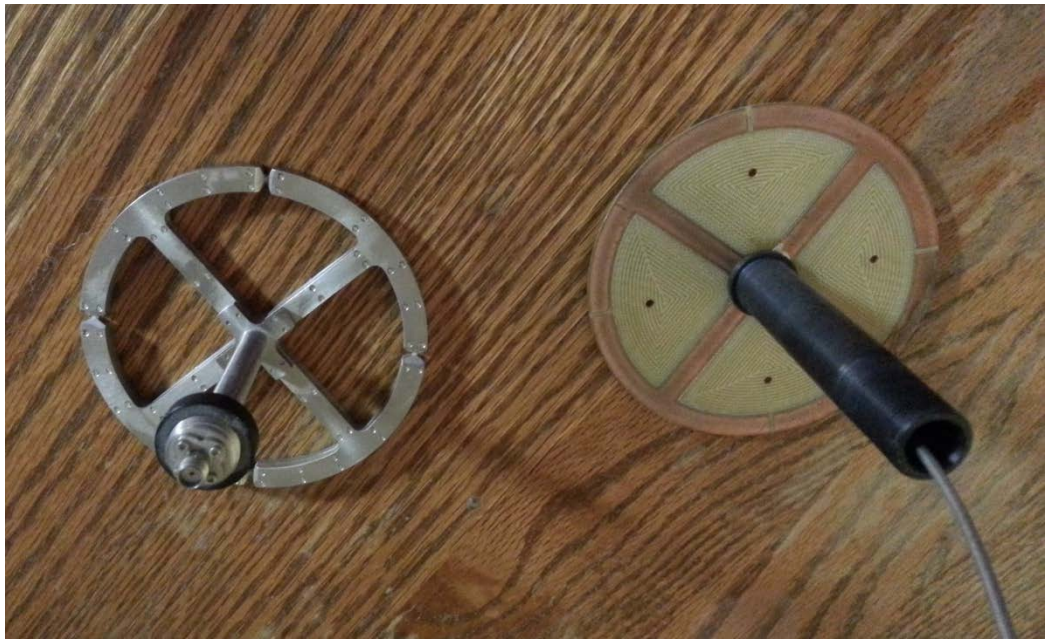
Series-fed Coaxial Array of Loops



A canonical, electrically-small loop has minimum reactance input impedance. Thus, a series feed arrangement is natural.

Series-fed log-periodic array of coaxial loops is circuit dual of conventional LPDA with linear elements. A series fed log-periodic array of folded linear dipoles has been developed and published.

Multiply-fed Loop



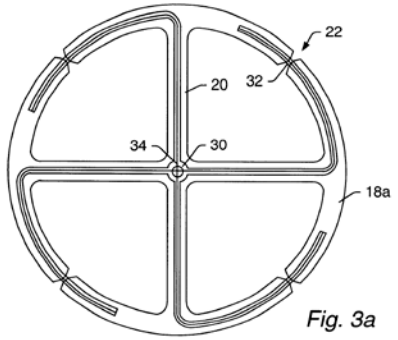


Fig. 3a

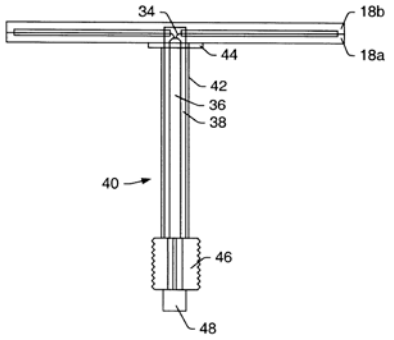


Fig. 3b

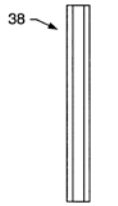


Fig. 3c

Variants of the Cloverleaf/Alford Loop:
Generate azimuthally isotropic pattern for wireless testing in 800-900 MHz range

Multiply-fed Loop

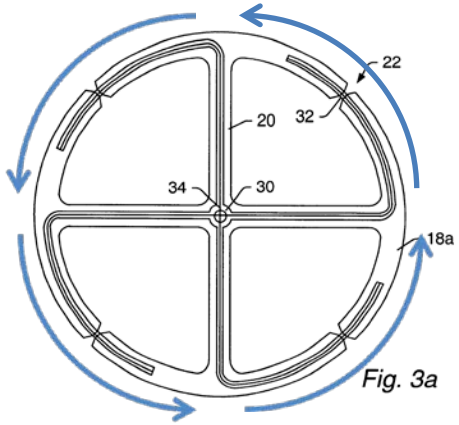


Fig. 3a

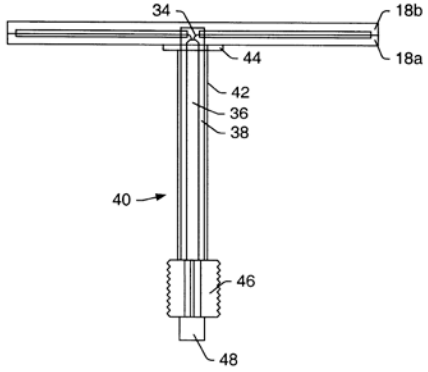


Fig. 3b

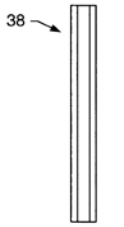


Fig. 3c

- *Current flows in circulatory fashion on exterior of loop.*
- *Capacitive gaps are introduced to facilitate impedance matching.*
- *Impedance transformation is also employed in feed structure, e.g. quarter-wave transformer.*

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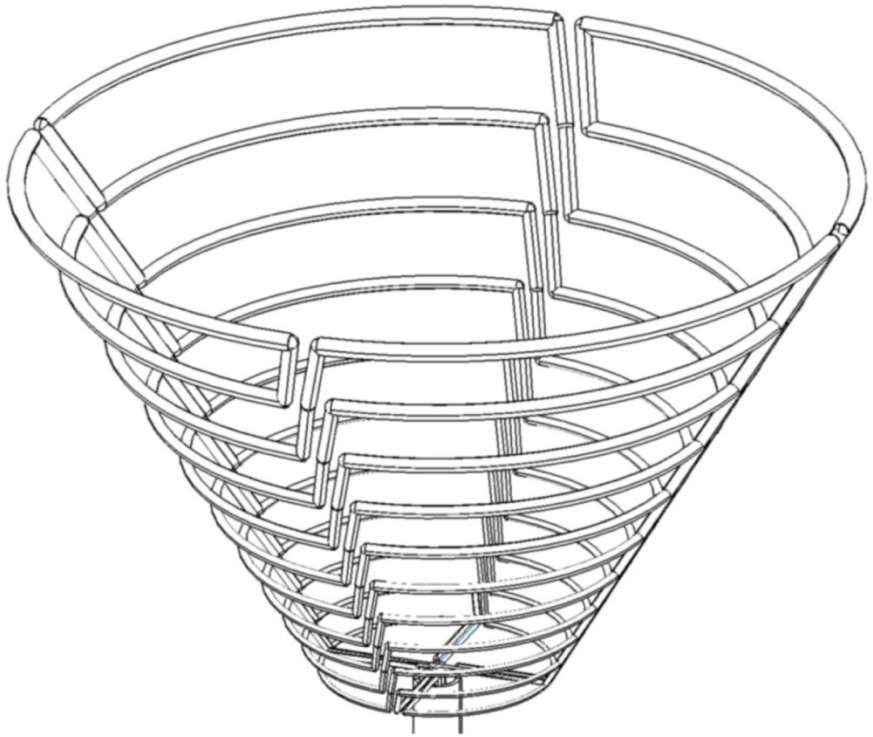
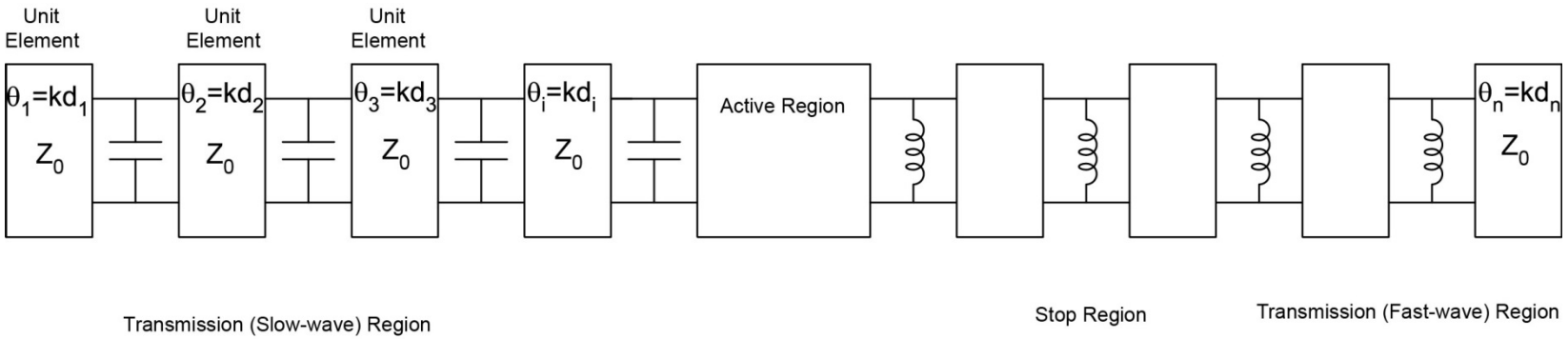
Series-fed Coaxial Array of Loops



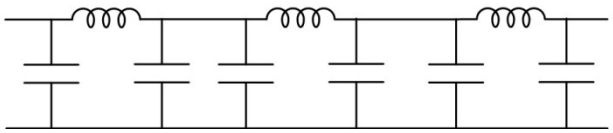
- *Current flows in circulatory fashion on exterior of loop.*
- *Capacitive gaps are not employed and loops are fed in series.*
- *Series-fed array is difficult to implement.*
- *Magnetic loop structure with minimum reactance input impedance provides reduction in near electric field similar to what is obtained with an electrically-small loop.*

Adaptation the Cloverleaf/Alford multiple-feed scheme for series-fed coaxial loop LPDA

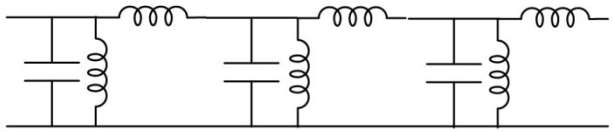
Shunt-fed LPDA



Shunt-capacitively Loaded (Slow-wave) Transmission Line

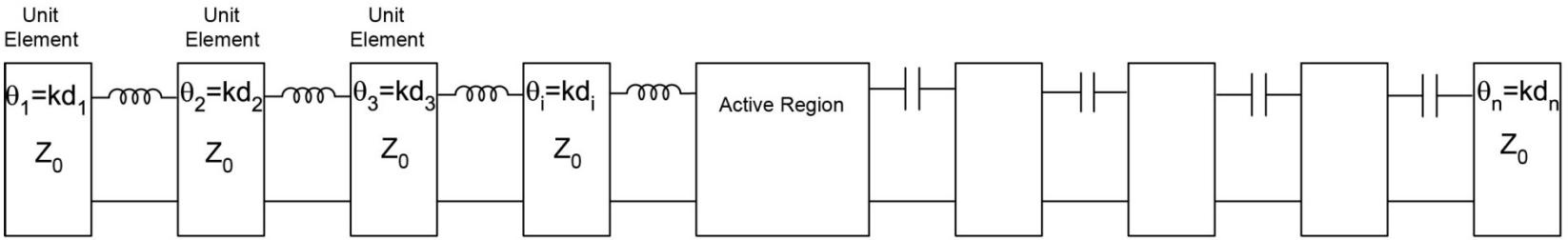


Shunt-Inductively Loaded (Filter-type) Transmission Line

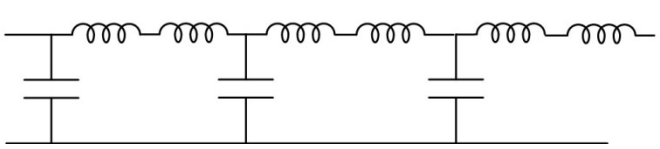


Conventional LPDA has slow-wave network topology in transmission region with shunt capacitive loading. Stop region exhibits shunt inductive loading.

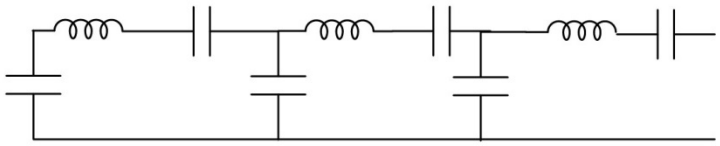
Series-fed LPDA



Series-Inductively Loaded (Slow-wave) Transmission Line

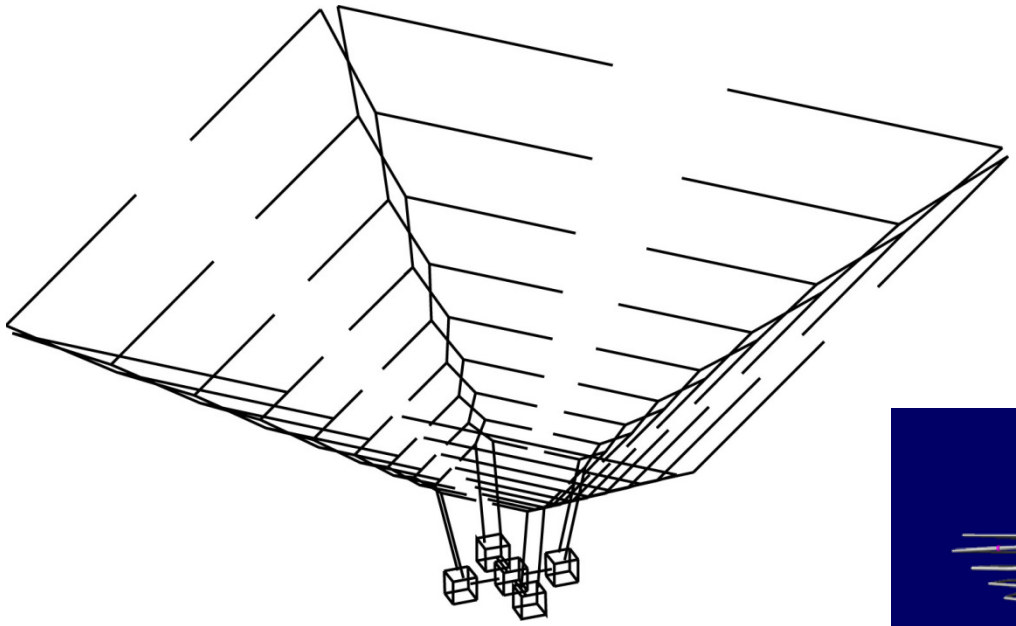


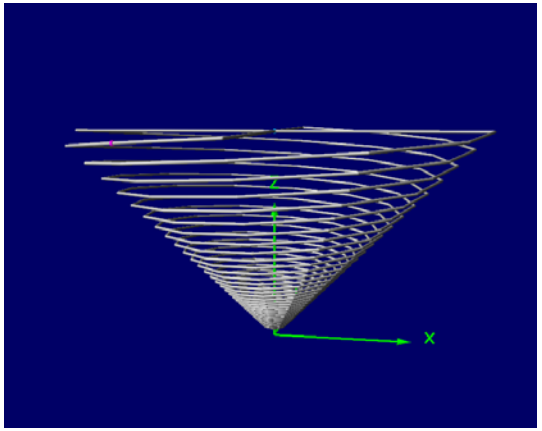
Series-capacitively Loaded (Filter-type) Transmission Line



Series-fed log-periodic array of coaxial loops has network topologies in the transmission and stop regions which are the duals of their counterparts in a conventional LPDA. Transmission region is slow-wave with series inductive loading. Stop region exhibits series capacitive loading.

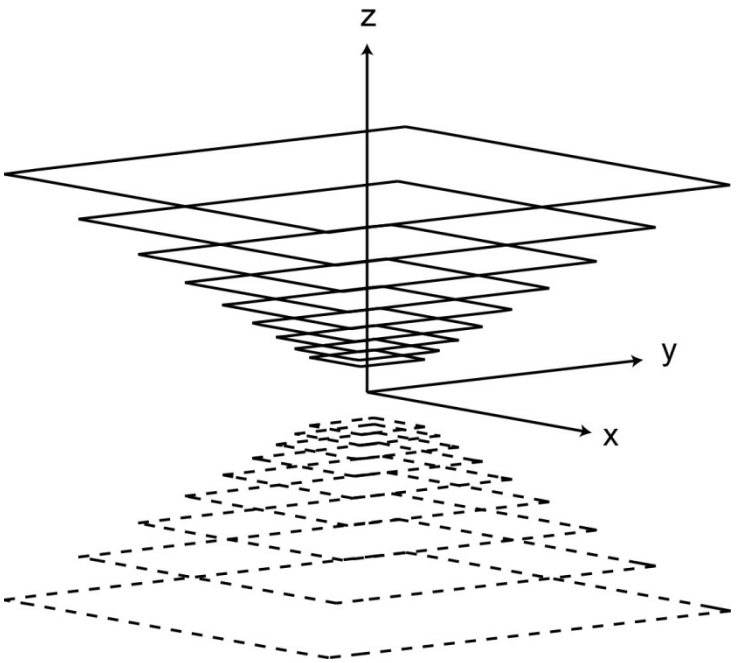
Log-periodic Array of Coaxial Loops Operating Over Ground





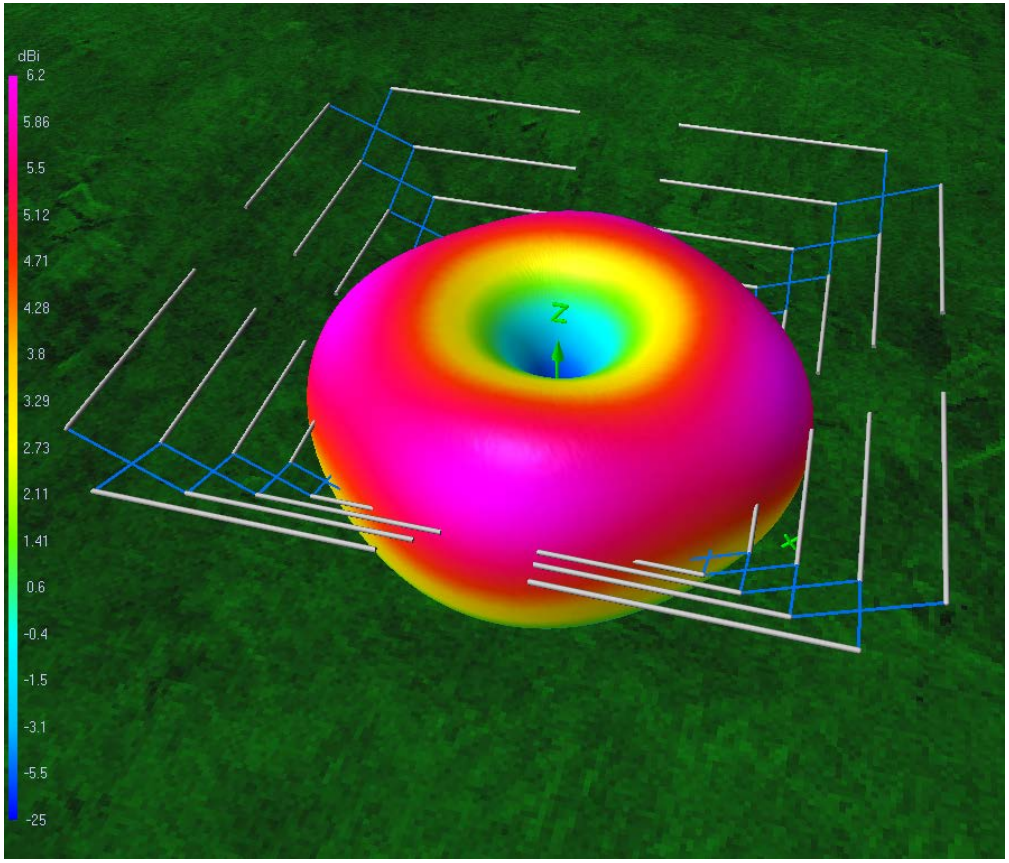
4 Distinct ports: Similar to 4-arm spiral such as AP SRQ-230 or SQQ-230.

Log-periodic Array of Coaxial Loops



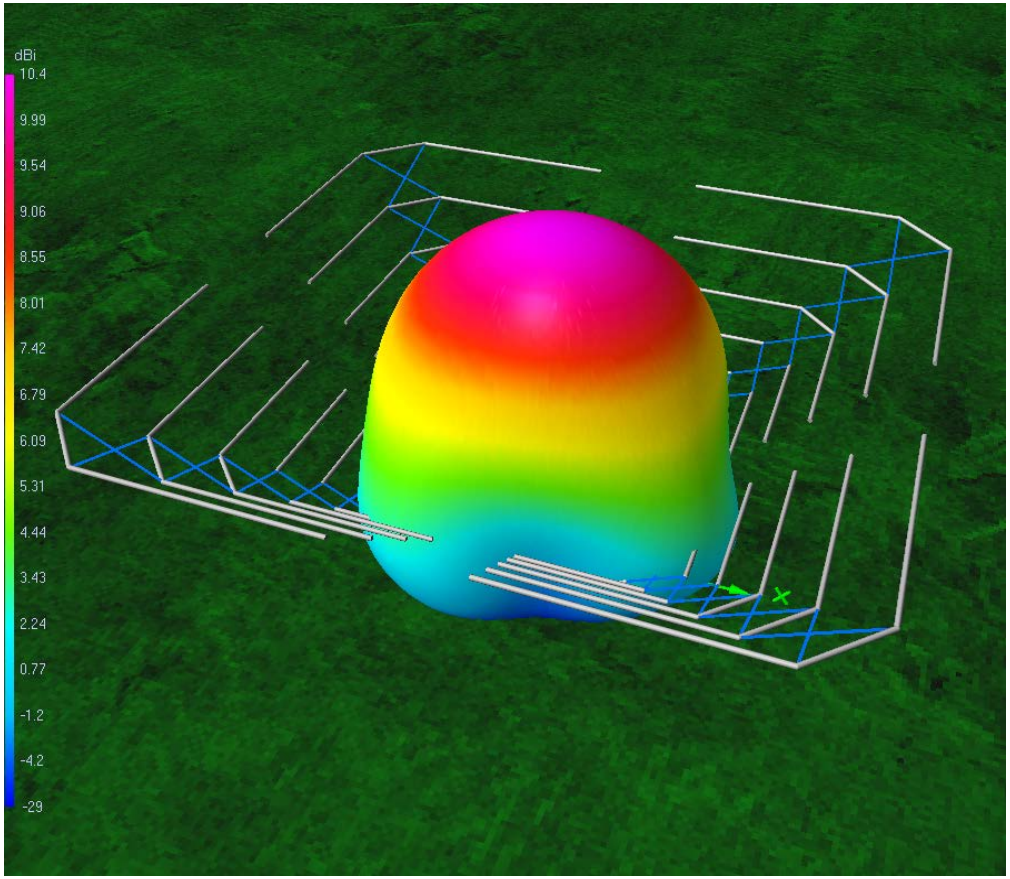
When apex of structure is located at ground, the operation remains quasi-frequency-independent, or more strictly, log periodic. This holds true for the conical log-spiral as well.

Log-periodic Array of Coaxial Loops



Log-periodic Array of Coaxial Loops Operating Over Ground: Low-angle HP mode

Log-periodic Array of Coaxial Loops



See:

"The Importance of Circular Polarization for Diversity Reception and MIMO in NVIS Propagation"
B. A. Witvliet, E. Van Maanen, G. J. Petersen, A. J. Westenberg, M. J. Bentum, C. H. Slump, R. Schiphorst
The 8th European Conference on Antennas and Propagation, The Hague, The Netherlands, 6-11 April 2014

Log-periodic Array of Coaxial Loops Operating Over Ground: High-angle CP mode

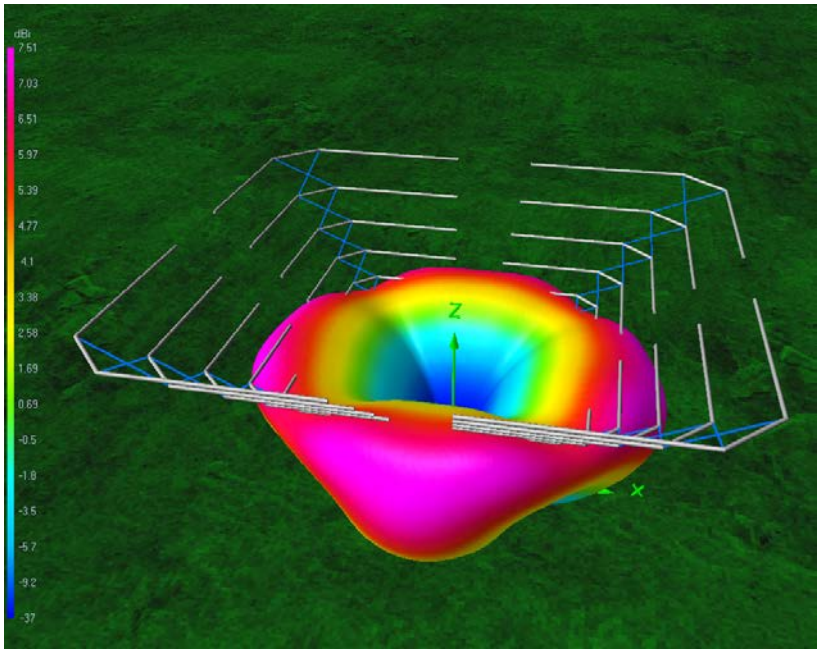
LHCP and RHCP ports are well isolated and can provide MIMO operation for NVIS

Log-periodic Array of Coaxial Loops

- Displacement of frequency independent antenna from ground
- Take-off angle
- Grating lobes
- Vertical arrays of isotropic antennas.
- Coupling between array elements

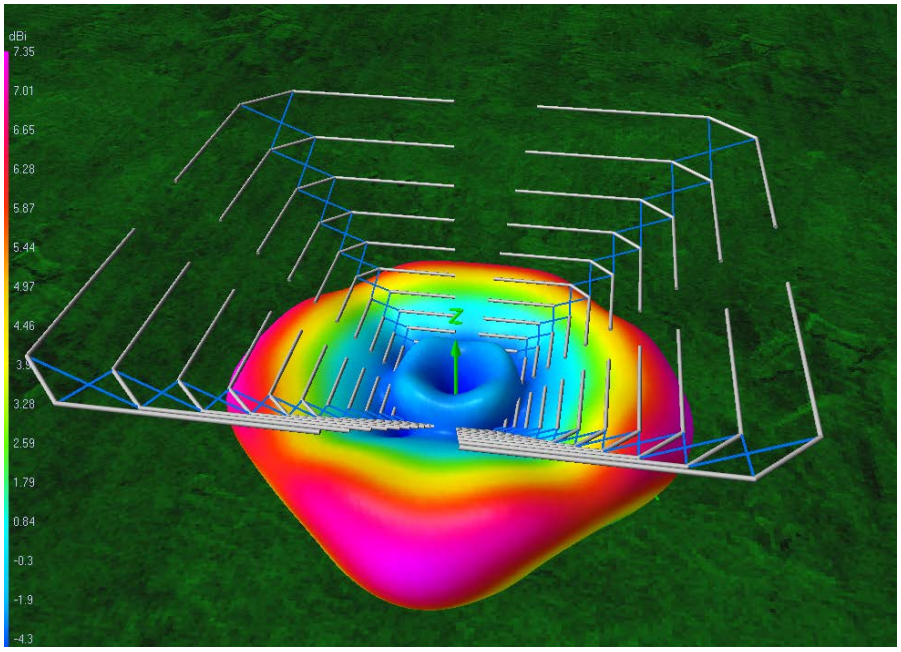
Log-periodic Array of Coaxial Loops

5 meters displacement, 10 MHz



Displacement of the apex of the structure from ground decreases the elevation angle of maximum gain..

8 meters displacement, 10 MHz



However, this incurs grating lobes when the displacement is a large fraction of a wavelength

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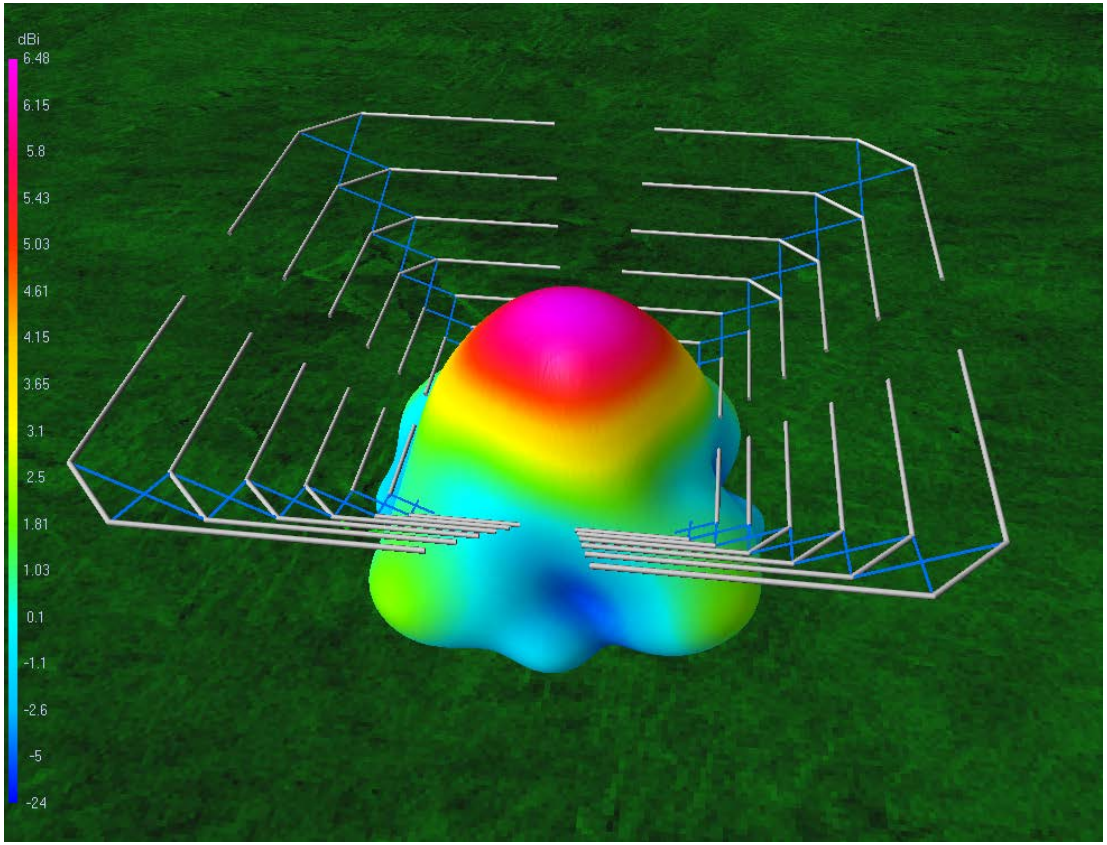
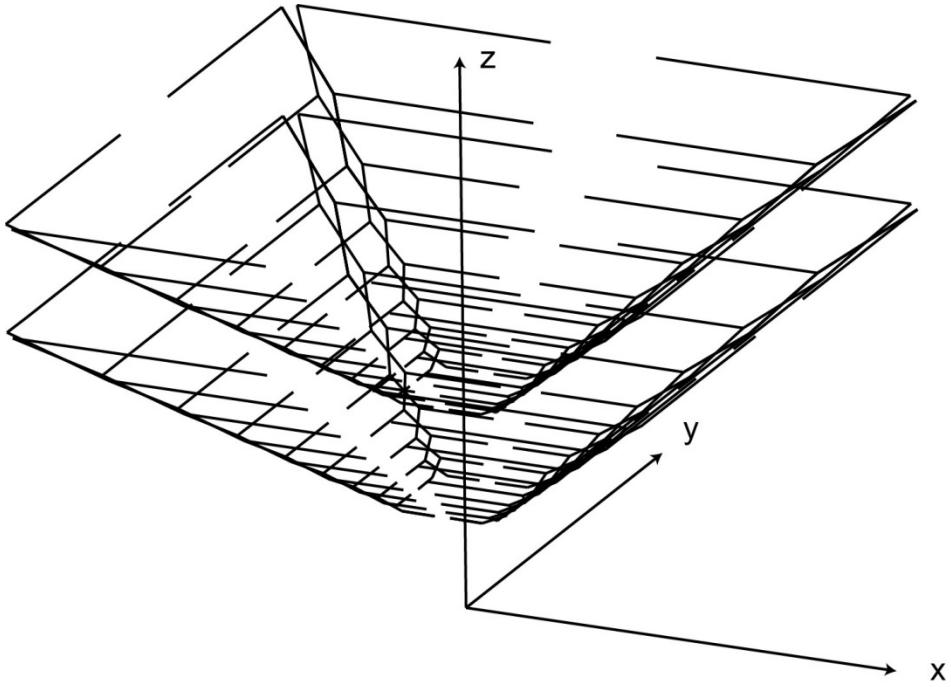
Log-periodic Array of Coaxial Loops



Other modes affected by displacement, but not in the same way

Log-periodic Array of Coaxial Loops

2-Element Array of Log-periodic Arrays of Coaxial Loops Operating Over Ground



8 Distinct ports

Operating modes are not orthogonal, but are nevertheless diverse.

Conclusions

Multiply-fed, log-periodic array of coaxial loops and vertically-stacked arrays thereof provide multiple modes of operation thus facilitating MIMO.

Multiple-arm spiral antennas and vertically-stacked arrays thereof also provide this performance.

The exploitation of these characteristics by software defined/controlled radios would seem to natural.