General Sir John Kotelawala Defence University

ET3122 Antennas and Propagation
Wideband Antennas

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Outline

Introduction

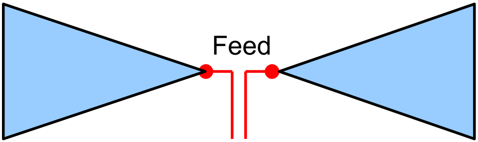
Motivation

- Modern communication technologies require wide bandwidth
  - Mobile communication devices with backward compatibility
  - CDMA
  - Wideband satellite communication
- Most antennas have a limited bandwidth
  - Degradation of radiation pattern
  - Sensitive feed impedance
- How can wideband operation be achieved?

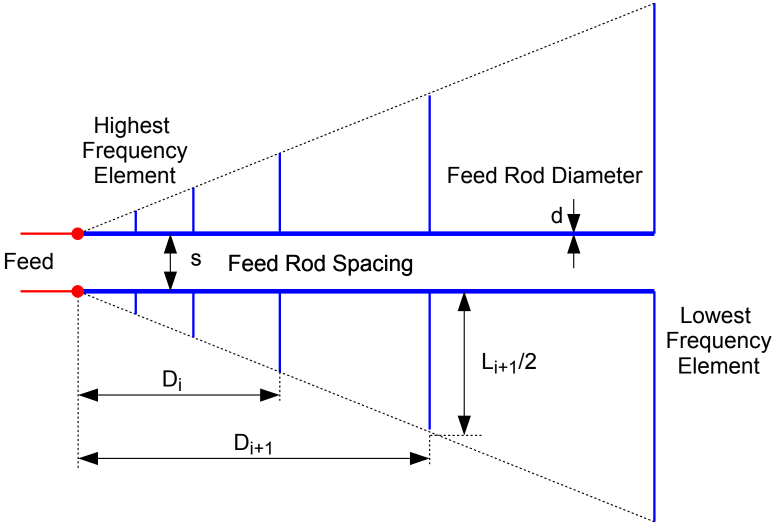
Log Periodic Arrays

Rationale

- Use multiple elements of different length
  - Design so that the current distribution is frequency independent
  - When this happens, elements do not interfere with each other
- Can also use a continuous structure



Log Periodic Dipole Antenna



Design Procedure

Design Parameters

- Range f_{min} to f_{max}
- Number of elements N

Take the *geometric ratio* τ,

$$\tau = \sqrt[N-1]{\frac{f_{min}}{f_{max}}}$$

The spacing between two elements is given by $D_{i+1} - D_i$ where

$$\tau = \frac{D_i}{D_{i+1}}$$

This results in a total antenna length of D_N with D_1 chosen.

Design Procedure (Contd..)

The spacing factor (σ),

$$\sigma = \frac{D_{i+1} - D_i}{2L_{i+1}}$$

The iteration is started with $L_N = \lambda_{max}/2$ (for f_{min}).

The feed spacing s for a transmission line with characteristic impedance z_0 is given by,

$$s = d \cosh\left(\frac{z_0}{120}\right)$$

Log Periodic Antenna Design

Design Specification

A software defined radio unit requires a log periodic antenna to cater a frequency range between 1 - 3.6 GHz. The total length has to be at most 15 cm.

- What makes a good design?
- What is missing?
- Requires antenna theory, mathematics and programming skills to solve

Design Parameters

- Range f_{min} to f_{max} (a requirement)
- Maximum length L (a constraint)
- Number of elements N
  - Has to be *maximized* for best bandwidth response
- Minimum distance between two elements (δ)
  - If too close, they will appear as a *single element*
  - This value is missing (found to be 5 mm)

Design Procedure

Take the *geometric ratio* τ,

$$\tau = \sqrt[N-1]{\frac{f_{min}}{f_{max}}}$$

The geometric ratio also gives the relationship between the distance of two successive elements to the feed end. i.e., D_i and D_{i+1} where

$$\tau = \frac{D_i}{D_{i+1}}$$

Design Procedure (Contd..)

- Need to relate δ and L into the design
- Minimum distance is between D_1 and D_2

$$\begin{aligned} D_1\left(\frac{1}{\tau}-1\right) &\geq \delta \\ D_1 &= \tau^{(N-1)}L \\ L\left(\tau^{(N-2)}-\tau^{(N-1)}\right) &\geq \delta \\ L\left(\left(\frac{f_{min}}{f_{max}}\right)^{\frac{(N-2)}{(N-1)}}-\left(\frac{f_{min}}{f_{max}}\right)\right) &\geq \delta \end{aligned}$$

- How to find N?

Design Procedure (Contd..)

- To find maximum N evaluate the inequality for $N > 2$ until the inequality is no longer satisfied (write a simple program)

$$L\left(\left(\frac{f_{min}}{f_{max}}\right)^{\frac{(N-2)}{(N-1)}} - \left(\frac{f_{min}}{f_{max}}\right)\right) \geq \delta$$

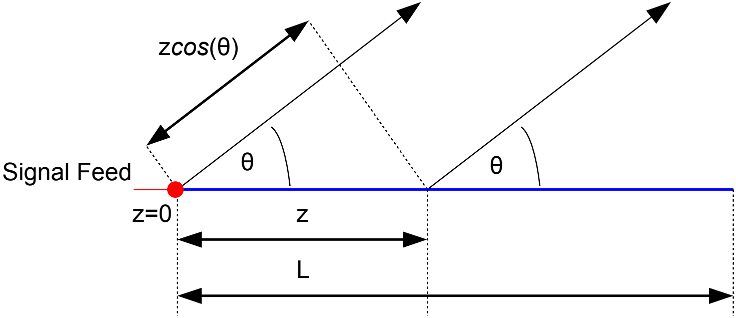
- The result

$$\begin{aligned}
N &= 3 \qquad 0.0373903 \\
N &= 4 \qquad 0.0221925 \\
&\vdots \qquad \vdots \\
N &= 12 \qquad 0.0051458 \\
N &= 13 \qquad 0.0046937 < 0.005 \text{ (Answer } N = 12)
\end{aligned}$$

Biconical Arrays

Traveling Wave Antennas

- Traveling wave current distribution like in a transmission line
- A standing wave may be generated depending on the reflection
- Derivations of the longwire antenna $(L \gg \lambda)$



Traveling Wave Antennas

Assuming the end of the line is perfectly matched and lossless,

$$J = I_0 e^{-\gamma z} = I_0 e^{-(\alpha + j\beta)z} = I_0 e^{-j\beta z}$$

Approximate the longwire as a summation of infinitesimal dipoles. Therefore, the path difference becomes,

$$R = r - zcos(\theta)$$

Therefore,

$$dE = \left[\frac{j\eta k sin(\theta) I_z e^{-jk(r - zcos(\theta))}}{4\pi r} dz \right] \underline{\theta}$$

Traveling Wave Antennas (Contd..)

Thus, the integral of the current distribution becomes,

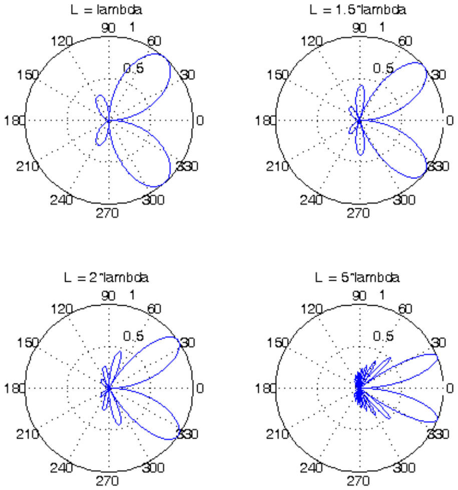
$$E = \left[\frac{j\eta k e^{-jkr} sin(\theta)}{4\pi r} \int_0^L I_0 e^{-jkz} e^{jkzcos(\theta)} dz\right] \underline{\theta}$$

This simplifies to,

$$E = \left[\frac{j\eta I_0 e^{-jk\left[r+\frac{L}{2}(1-cos(\theta))\right]} sin(\theta) sin\left[\frac{kL(cos(\theta)-1)}{2}\right]}{2\pi r(cos(\theta)-1)}\right] \underline{\theta}$$

$$H = \left[\frac{j I_0 e^{-jk\left[r+\frac{L}{2}(1-cos(\theta))\right]} sin(\theta) sin\left[\frac{kL(cos(\theta)-1)}{2}\right]}{2\pi r(cos(\theta)-1)}\right] \underline{\phi}$$

Traveling Wave Antennas - Radiation Patterns



Standing Wave Antennas

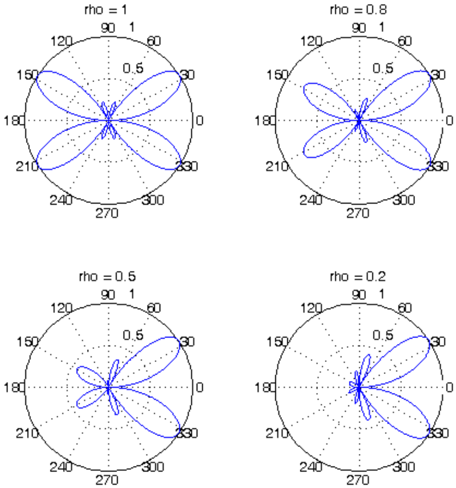
When the longwire has a reflection coefficient of ρ,

$$J = I_0 e^{-jkz} + \rho I_0 e^{jkz}$$

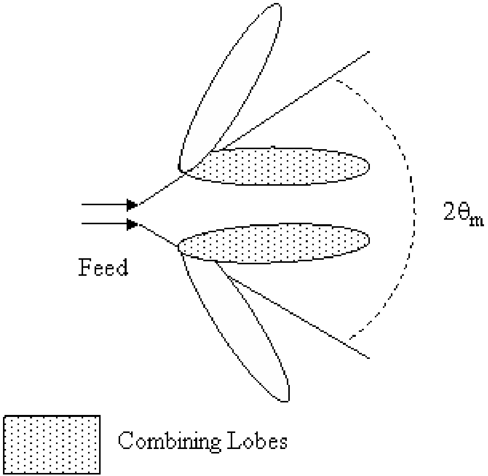
Therefore,

$$E = \left[\frac{j\eta k e^{-jkr} sin(\theta)}{4\pi r} \int_0^L \left(I_0 e^{-jkz} + \rho I_0 e^{jkz}\right) e^{jkzcos(\theta)} dz\right] \underline{\theta}$$

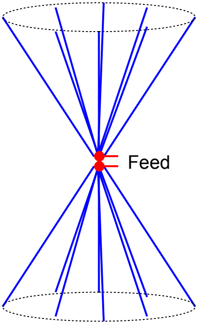
Standing Wave Antennas - Radiation Patterns

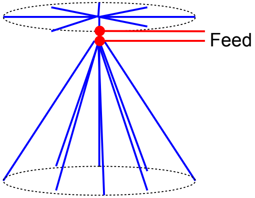


V Antenna



Biconical and Discone Antennas

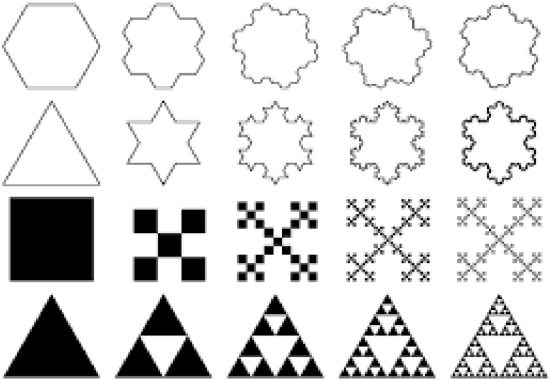




- A composite of multiple V antennas
- Can be made solid at microwave frequencies

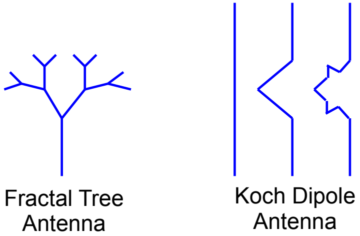
Fractal Antennas

Self Similarity and Fractals



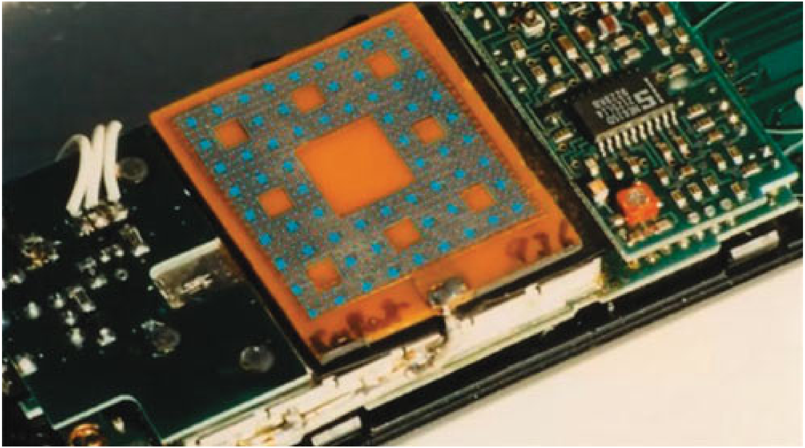
Wolfram Mathworld

Fractal Antennas



- Scale invariant
- Can be an iterative feed like the Fractal Tree or compacting like the Koch dipole

Fractal Antennas (Contd..)



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Conclusion

Summary

- Most antennas are reasonably wideband
  - However, insufficient for modern communication applications
- The main issues of narroband antennas are
  - Degradation of radiation pattern
  - Sensitivity of feed impedance to wavelength
- The main solutions include:
  - Multiple elements to handle multiple frequencies
  - Scale invariant structure
  - Frequency independant current distributions