Topics in Mathcad:

Electrical Engineering

Platform: Windows
Requires Mathcad 3.1 or higher, 2 MB hard disk space
Available for immediate download (size 783270 bytes) or ground shipment

This Electronic Book introduces useful Mathcad techniques for solving common electrical engineering calculations such as circuit analysis or digital filter design. All of the 24 examples include a background section describing the physics or mathematics of an electrical engineering problem and a step-by-step annotated solution using Mathcad. The variables are highlighted so you can easily customize these examples to your own engineering applications. The index of techniques helps you locate solution methods quickly and the index of terms lets you look up specific engineering problems and terms.

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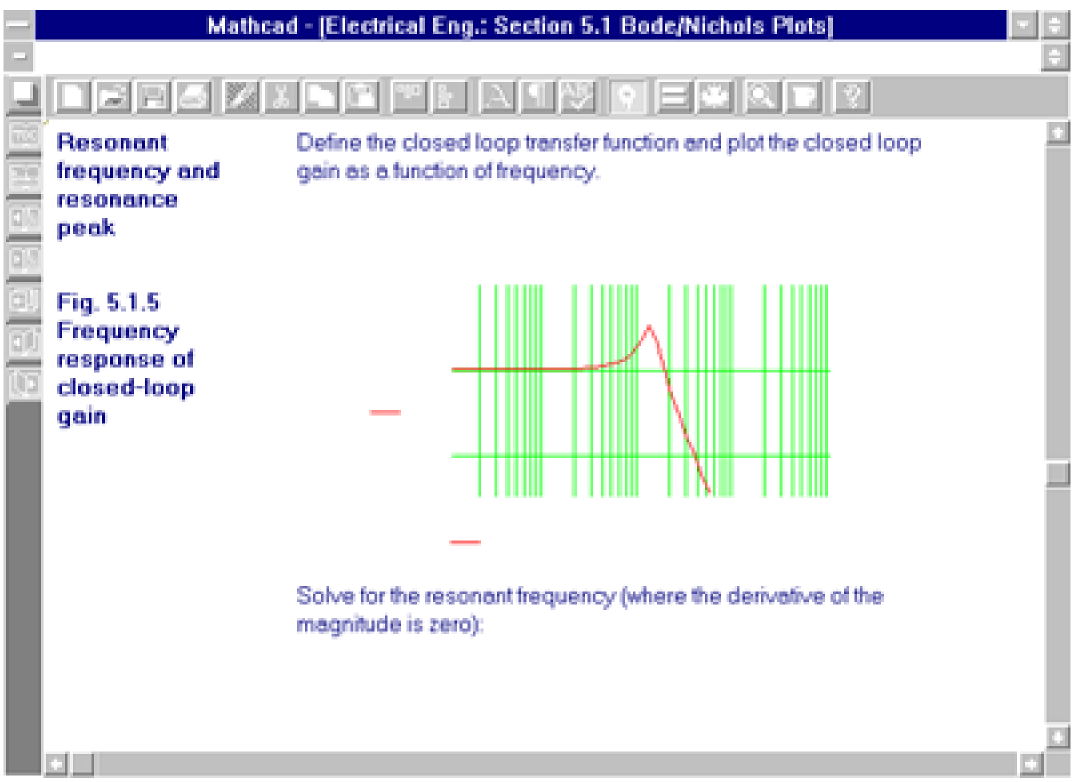

Obtain a comprehensive plot of the closed loop gain as a function of frequency, then use the graph to solve for the numerical value of the resonant frequency.

Topics include: Electromagnetism: Wave Guides and Resonators, Transmission Lines, Smith charts and Antenna Arrays; Circuit Theory: Two-Port Parameters, System/Transfer Functions, Feedback Analysis, Bode plots and Nyquist Diagrams; Signal Processing: Convolution, Fourier Transforms, Delta Modulation and Z-Transforms; Filter Design: FIR, IIR, Analog and Digital Elliptical Filters; and much more.

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Field Patterns of a Uniform Linear Antenna Array

This document calculates the far-field radiation pattern of a uniformly spaced linear antenna array as a function of azimuth angle, and displays the field pattern as both an azimuth distribution and a power pattern. You set the following physical parameters:

- **N**, the number of array elements
- **d**, the interelement spacing
- **f**, the radiating frequency
- **a**, the progressive phase shift from element to element

You can also set **df**, which controls the resolution of the plots.

The document then calculates and plots the radiated far-field pattern in two dimensions for an elevation of 0 degrees, as well as the power pattern as a function of azimuth angle.

References

1. John D. Kraus and Keith R. Carver, *Electromagnetics*, McGraw-Hill Book Company (New York, 1978).

2. Jin Au Kong, *Electromagnetic Wave Theory*, John Wiley & Sons (New York, 1986).

Background

Far-field patterns for an array of uniformly spaced, omnidirectional radiators can be described using the principle of superposition. The energy pattern produced by such an array will be a phase-dependent summation of the individual field patterns. The group behavior of the array is governed by a term known as the array factor, **F(f)**, given by:

$$F(\phi)=\frac{1}{N}\cdot\sum_{array} e^{-j\cdot(k\cdot d\cdot\cos(\phi)-\alpha)}$$

where **a** is the progressive phase shift from element to element in the array, and **k=2pi/lambda** is the wavenumber. The variable **f** is the azimuth angle, defined as the angle in the x-y plane perpendicular to the antennas.

The array factor is a scaling term which multiplies the radiation field from a single antenna to give the group far-field pattern. This model works only in the plane of zero elevation (perpendicular to the direction of the antennas.) Additional terms are necessary to describe different cross sections through the radiation field.

Mathcad Implementation

Units & Constants:

$$\mathrm{Hz} \equiv \frac{1}{\mathrm{sec}} \qquad \mathrm{MHz} \equiv \mathrm{Hz} \cdot 10^{6} \qquad c \equiv 299792458 \cdot \frac{\mathrm{m}}{\mathrm{sec}}$$

First, input the following parameters to define the antenna array and the operating conditions.

Array Parameters:

$N := 6$ <-- number of elements

$d := 50 \cdot \mathrm{m}$ <-- interelement spacing

$f := 3 \cdot \mathrm{MHz}$ <-- frequency

$\alpha := 0 \cdot \mathrm{deg}$ <-- progressive phase shift

Now it is possible to define an expression for the normalized array factor. First, create a range variable for the number of antennas in the array, then the expression for the array factor in terms of the parameters above:

$n := 0 .. N - 1$

$$F(\phi) := \frac{1}{N} \cdot \left| \sum_{n} e^{-\left(j \cdot n \cdot d \cdot \frac{2 \cdot \pi \cdot f}{c} \cdot \cos(\phi) + j \cdot n \cdot \alpha \right)} \right|$$

The array factor can be considered a scaling term for the radiated power, and can be expressed in dB, as follows:

$$P(\phi) := 20 \cdot \log\left(\frac{|F(\phi)|}{N}\right)$$

To plot this expression as a function of azimuth angle, define a range variable, **f**, and the step size, **df**, to be used in the plot. Note that decreasing the step size will increase the resolution of the plot but will take longer to calculate.

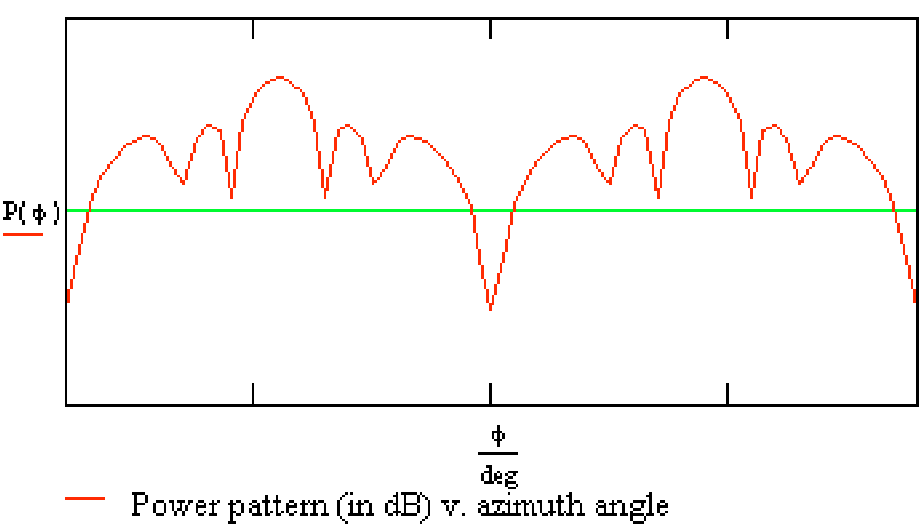
$\delta\phi := 5 \cdot deg$ <-- step size for azimuth angle

$\phi := -180 \cdot deg, -180 \cdot deg + \delta\phi \,..\, 180 \cdot deg$

To see the field pattern, edit the definitions of the four array parameters. Then choose **Calculate Document** from the **Math** menu to plot the power pattern as a function of azimuth.

For the simple case of an antenna array with 6 elements, spaced **lambda/2** apart, the array factor appears as follows:

Fig. 1.1 Power pattern with respect to angle



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The more familiar way to view the power pattern is in two dimensions, which is simply a conversion to polar coordinates from the azimuth angle. This is equivalent to looking at a radiation contour curve in the **x-y** plane. Define the conversion as follows:

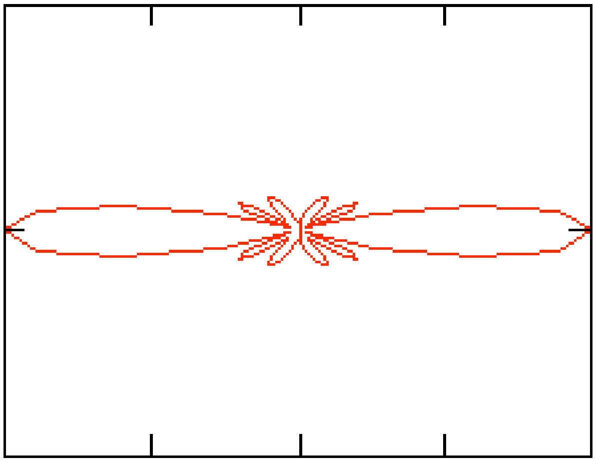
$x(r,\phi) := r\cdot\sin(\phi)$ $\quad\quad$ $y(r,\phi) := r\cdot\cos(\phi)$

are the **x** and **y** coordinates, and

$A(\phi) := |F(\phi)|$

is the value for the radius. The plot appears below.

Fig. 1.2 2-D radiation pattern at zero elevation



Tips

It may also be useful to define additional variables that depend on the array parameters, such as the wavenumber, **k**, defined as follows:

$k := \frac{2\cdot\pi\cdot f}{c}$ $\quad\quad$ $k = 0.063\cdot m^{-1}$

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Or in terms of additional variables...

$$\omega := 2 \cdot \pi \cdot f \qquad k := \frac{\omega}{c}$$

or

$$\lambda := \frac{c}{f} \qquad k := \frac{2 \cdot \pi}{\lambda} \qquad d := \frac{3 \cdot \lambda}{2}$$

Mathcad will display additional variables in any units desired, and new units can be defined if necessary. In this way, constraints for the antenna array can be specified to emphasize particular relationships; special cases can be explored (such as the case of **d=nlambda/2**, where **n** is an integer, or **a=kd**).

Another way to enhance your understanding of the system might be to use global variable definitions, so that the parameters for the problem appear next to the graph. To do this, use the global assignment operator (on the palette), and move the definitions for **N**, **d**, **f**, and **a** next to the graphs.