ANTENNAS

Array Antennas - Uniform Linear Arrays

Javier Leonardo Araque Quijano
Of: 453 – 204, Ext. 14083
jlaraqueq@unal.edu.co
Universidad Nacional de Colombia

Antenna Arrays

- Gain - determines link range, SNR and spatial selectivity:

  :-) grows with antenna size (large paraboloidal reflectors)

  :-(Too large antennas impractical (fabrication/support)

- Antenna arrays → performance comparable to that of a single antenna with the same footprint:

  :-) Lightweight, may conform to arbitrary surfaces

  :-) Electrically steerable

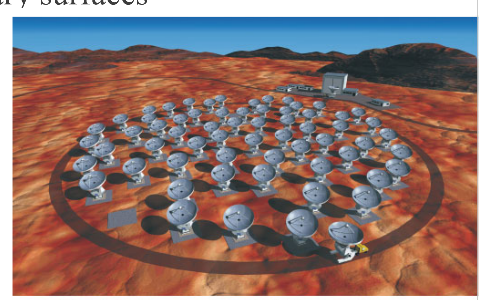
  :-) Modular design, easier upgrading

  :-) Simpler power handling

  :-(Complex feeding networks

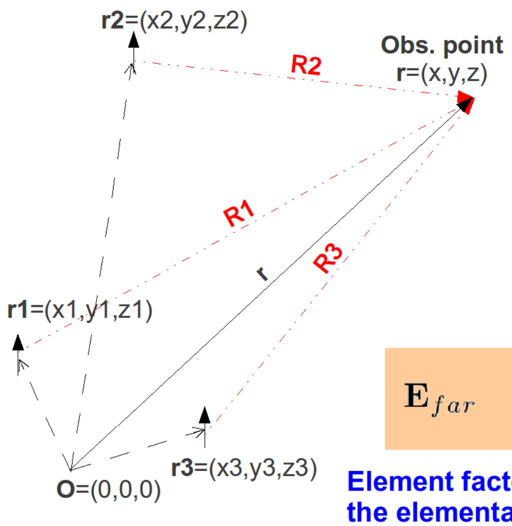
  :-(Inter-element coupling

  :-(Broadband performance difficult



3. This artist's conception shows the ALMA array in its most compact configuration. (Image courtesy of NSF/NRAO/AUI and ESO.)

Array of Elementary Sources



Field radiated by a set of point sources along z with known locations and amplitudes Cn:

$$\mathbf{E}_{far} = \sum_n C_n jk\eta \frac{e^{-jkR_n}}{4\pi R_n} \sin\theta_n \hat{\theta}_n$$

$$\begin{aligned} r &>> r_1, r_2, r_3 \\ R_n &\approx r - \mathbf{r}_n \cdot \hat{\mathbf{r}} \ \ \text{(phase)} \\ R_n &\approx r \ \ \text{(amplitude)} \\ \hat{\theta}_n &\approx \hat{\theta} \end{aligned}$$

$$\mathbf{E}_{far} \approx \boxed{jk\eta \frac{e^{-jkr}}{4\pi r} \sin\theta\hat{\theta}} \boxed{\sum_n C_n e^{jk\mathbf{r}_n \cdot \hat{\mathbf{r}}}}$$

Element factor: Pattern of the elementary source located at the origin

Array factor: Depends only on location and excitation amplitude of elements

Arrays of General (identical, co-oriented) Elements

$$\mathbf{E}_{far} \approx \boxed{\frac{e^{-jkr}}{4\pi r}} \boxed{\mathbf{e}(\theta, \phi)} \boxed{\sum_n C_n e^{jk\mathbf{r}_n \cdot \hat{\mathbf{r}}}}$$

Radial dependence

Element pattern (depends only on angles)

AF, can be shaped to obtain the desired performance

According to the geometric disposition of elements arrays may be:
- linear, anular, planar, conformal, …

A number of excitation schemes can be employed:
- Uniform, tapered, Chebyshev, Butterworth, etc.

Uniform Linear Array (2)

- Elements placed along a line with equal spacing
- Equal excitation amplitudes, linear phasing

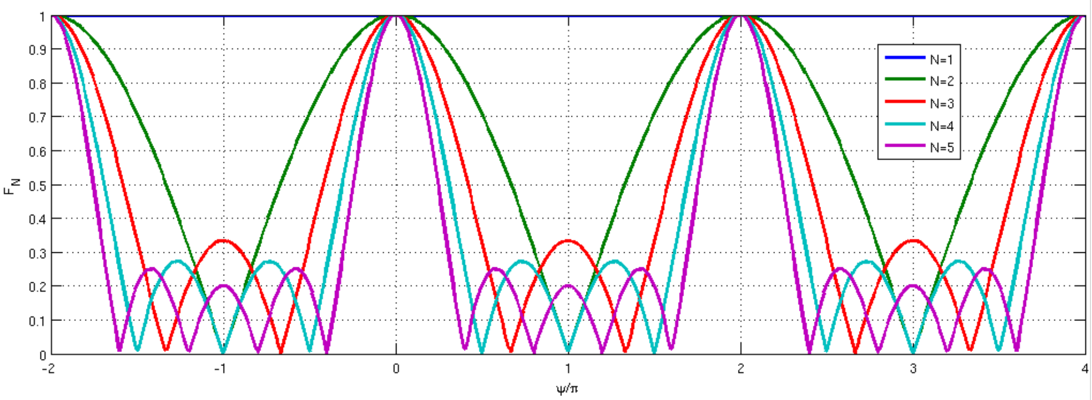
$$\mathbf{r}_n = \hat{z}\,(n-n_0)\,d$$
$$C_n = e^{j(n-n_0)\delta} \Rightarrow AF_{ULA} = e^{-jn_0\delta}\sum_{n=1}^{N} e^{j(kd\cos\theta+\delta)n}$$
$$n_0 = \frac{N-1}{2}$$

$$F_N(\psi) = \frac{1}{N}\left|\frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)}\right|$$

Normalized modulus of array factor

$$\psi = kd\cos\theta + \delta$$

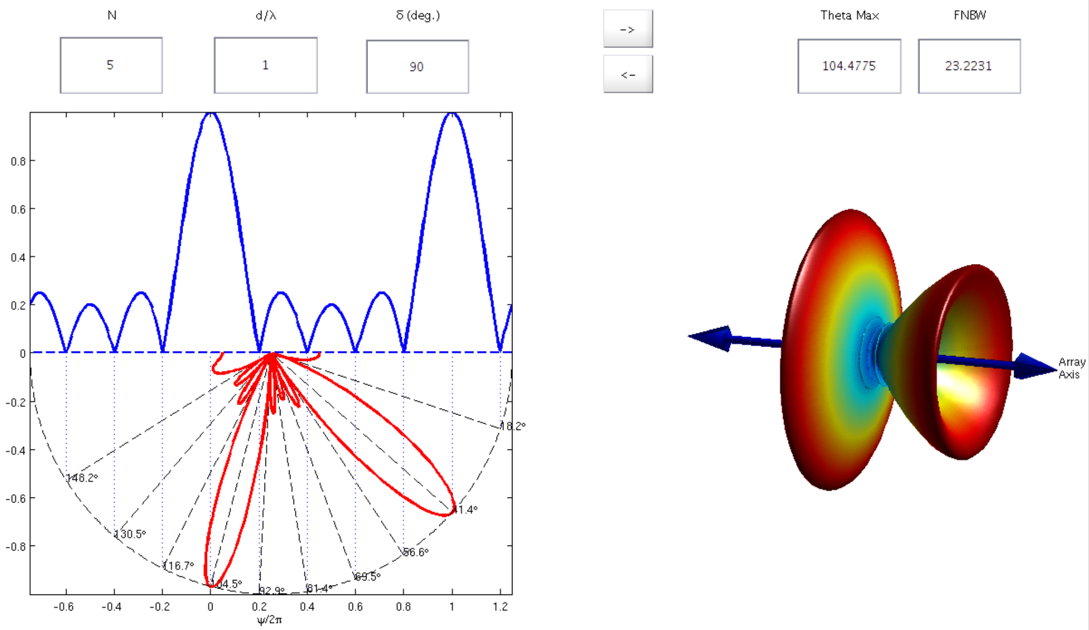
Uniform Linear Array



These "universal" curves work for any linear array, independently from parameters d, phi.

How does AF look in space (as a function of theta, phi)?

Uniform Linear Array

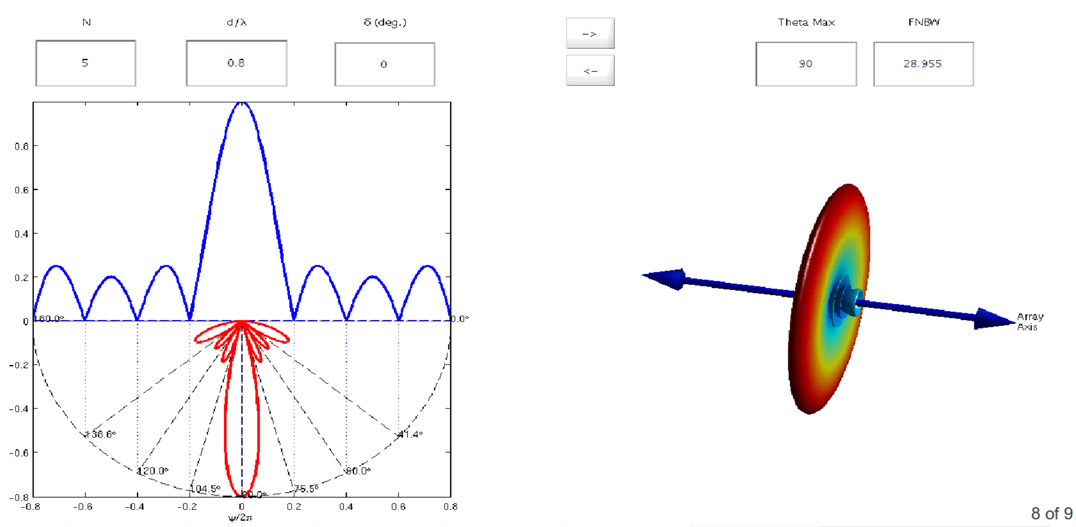


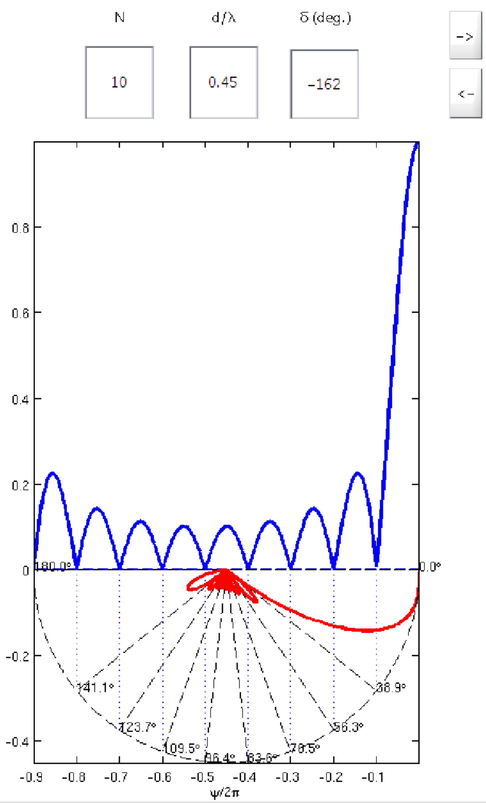
- Recalling the transformation psi = k d cos(theta) + phi gives an aid in visualizing the converstion from FN into the array factor in space.
- Note that AF does not depend on phi

Types of Uniform Linear Array Broadside (Normal)

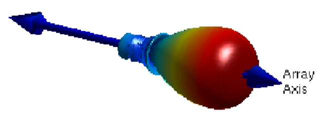
- Maximum occurs at directions normal to array axis. Pattern is constant in the normal plane (omni-directional), useful for broadcasting. Condtions:

  delta = 0 , No grating lobes: d <= 1-1/N





Types of Uniform Linear Array End-fire (Axial)



- Pattern has a maximum for theta = 0, useful for point-to point communications. Conditions to achieve maximum at desired location and avoid grating lobes:

  d = (1-1/N)/2, delta = 2*pi*(1+1/N)/2