Assignment 3. Uniform Amplitude Array Design

Assigned: Tuesday, 28 November 2023
Due: Tuesday 12 December 2023 at class start
Type: **individual**
Software: Matlab™ (suggested)

QUESTIONS

a) Why do we consider that min complexity corresponds to min number of radiating elements? (1 line max)
b) Explain why the presence of grating lobes makes the (max) directivity of the AF decrease (2 lines max)
c) What is the main limitation of uniform arrays? (1 line max)
d) How can we overcome the main limitation of uniform arrays? (2 lines max)
e) By using examples, explain the trade-off between (max) directivity and SLL of the AF. (2 lines max)
f) In a tapered array, for a given N and SLL we choose the min value of tapering t (i.e. closest to 1): why?
g) For a given spec on beamwidth (e.g. HPBW) and min n. of elements, a uniform array (with no option of SLL) will require less elements than a tapered array with SLL requirement better than 13dB; why? Hint: look at the SLL of a uniform amplitude array (in ψ) for N=4-10 on the slides, or beyond 10 using your scripts (see below)

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Problem no. 1- Array Factor Script

1. Write a matlab script to compute the array factor (AF) $AF(\psi)$ as a function of the global variable ψ for a general set of (complex) excitation coefficients $[I]=[I_1,...,I_N]$. Input: $\psi, [I], N$. Output: $AF(\psi)$
2. Write a matlab script to compute the array factor (AF) $AF(\alpha)$ as a function of the observable angle α for a general set of (complex) excitation coefficients $[I]=[I_1,...,I_N]$, for linear phase progression[1] with inter-element phasing Φ. Input: $\alpha, d/\lambda, \Phi, [I], N$. Output: $AF(\alpha)$. Hint: ideally, it should call the function of point 1 above.
3. Repeat (1) (i.e. $AF(\psi)$) above for uniform amplitude $I_n = 1\ \forall n$ and linear phasing Φ
4. Repeat (2) (i.e. $AF(\alpha)$) above for uniform amplitude $I_n = 1\ \forall n$ and linear phasing Φ
5. Test your matlab script against the graphs on the slides of the course, as detailed in Appendix below; must report your figures with clear indication of reference

[1] Having understood the physical meaning of a linear phase progression (i.e. beam pointing), it is convenient to factor that out, $I_n = A_n \exp(j(n-1)\Phi)$

Problems 2-3: Antenna Array for broadcasting

The overall task is to design an antenna for broadcasting for horizontal polarization, with AF pattern directive pattern in the vertical plane with max radiation in the horizontal plane.

Problem no. 2- Array Factor Design

Design the array with AF pattern with omni-directional coverage in the horizontal plane, and directive pattern in the vertical plane with max radiation in the horizontal plane. The design should yield: N, d/lambda, Phi.

1. Design a Broad-Side uniform linearly-phased array with min complexity, with first-null beam width FNBW $\leq 20^{\circ}$; to verify your design, draw the array factor pattern in the horizontal and vertical planes and check specs are complied width.
2. Repeat the design considering the HP beamwidth as HPBW $\leq 16^{\circ}$, and verify your design against the specs as above.

Problem no. 3- Complete Antenna Verification

Using the array layout designed above in p. 1.2 (HPBW spec) at the frequency of 850 MHz, use dipoles[2] to realize horizontal polarization[3]; the AF design will give you inter-element spacing and N.
We consider the z axis along the dipoles, and the array axis along x.

1. Do a drawing of the envisioned antenna (with dipoles sketched); you must **draw** also **your** chosen **coordinate system**.
2. To verify the overall radiation pattern, use the dipole pattern approximation sin^1.5 seen in previous assignments; plot the overall radiation pattern in the three coordinate planes.
   Hints:
   a. Write the explicit expression of $\hat{u}$ in your coordinate system and for your choice of the array axis;
   b. Write the explicit expression of $\hat{r} \cdot \hat{u} = \cos\alpha(\theta, \varphi)$ with respect to your coordinate system and for your choice of the array axis;
   c. Write the explicit expression of $\psi = \psi(\theta, \varphi)$ for your designed array and for your chosen coordinate system;
   d. Write the coordinate planes in terms of θ, φ; recall that all three Cartesian coordinate planes correspond setting one angle constant and finding the interval of variation of the other, e.g. xy plane: $\theta = \pi / 2, \varphi \in [0, 2\pi]$
   e. Now you can write the explicit expression of $AF(\psi) = AF(\psi(\theta, \varphi))$ in the three coordinate planes plane by inserting your expression of the AF and what found above…
   f. (optional) Which are the E and H planes of the array antenna?

Materials:
Course handouts

[2] It is noted that the choice of dipoles here is not necessarily a good one, so it has to be mainly considered for its didactic value.
[3] Recall that in absence of other specs "polarization" refers to the direction of max radiation

Appendix to Problem no. 1- validation cases

In the following, the slide numbering refers to the file `linear_AF_<version>.pdf`
With version=7.0 or higher

1. N=9, amplitude: cosine over pedestal expression on the slides, t=1 and t=0.7;) (as a function of ψ)
2. N=2,…10, uniform amplitude; (as a function of ψ)
3. N=8, uniform amplitude; $\Phi = 0$, $d/\lambda = 1 - 1/N$; reference: figure below (as a function of α)
4. N=8, uniform amplitude; $\Phi = -kd$, $d/\lambda = 0.5(1 - 1/N)$; reference: figure below (as a function of α)