Phased Arrays

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Introduction

A phased array is an array of transmitting or receiving elements, such as speakers, microphones, or antennae. By utilizing multiple elements, the array is capable of spatially restricting the transmission or reception of signals. Further, adjusting the phase or time delays to these elements enables ***beamsteering***, in which the direction of greatest sensitivity or radiation can be aimed.

Principles of Operation

Phased arrays depend on the wave-like nature of the radiation transmitted and received - be it sound, radio frequencies, or light.

Superposition

Phased arrays depend on superposition, or the addition of many different entities to produce a net effect. In a process known as ***beamforming,*** each array element produces a radiation pattern that constructively and destructively interferes with others around it to produce a focused "beam." The beam, which is known as the ***mainlobe***, radiates with the largest amount of power. Adjacent to the mainlobe is a series of smaller peaks known as sidelobes, which are a result of the imperfect cancellation of the individual antenna patterns.

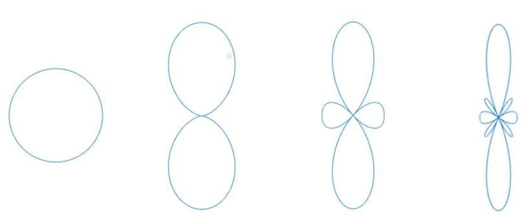

Figure 1 Radiation patterns for linear arrays consisting of one, two, three, and five omnidirectional radiators. Note: the mainlobe extends upward, and a "backlobe" of equal magnitude downward is also formed.

Beamsteering

Steering of the mainlobe can be accomplished by applying a phase or time delay between adjacent elements. By adding this delay, one effectively skews the wavefront formed by the elements, which steers the mainlobe in the desired direction.

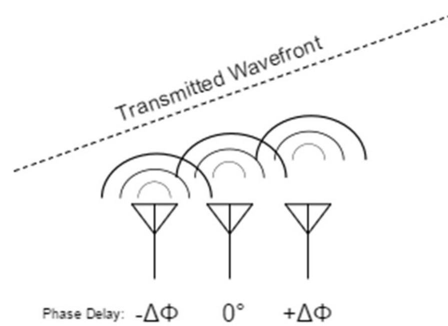

Figure 2 Wavefront skewing due to phase delays

For receiving arrays, one can steer the direction of sensitivity in a similar fashion. When the signal is received, a phase or time delay can be applied incrementally between receivers. When the set of delays is "aligned" with the direction of the signal, the sum of the received inputs is the strongest (Veen, Buckley, 1988).

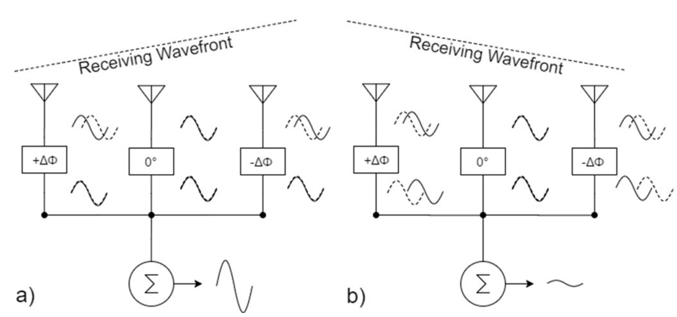

Figure 3 a) Reception of a signal from the target direction b) Receiving signal from non-target direction

Architecture

The simplest phased arrays are linear. That is, elements are placed along a line with equal spacings between elements. Typical element spacings are less than or equal to half of the wavelength of the received or transmitted signal.

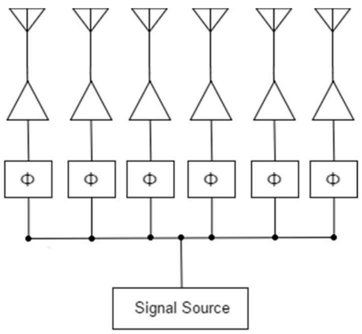

Figure 4 A Linear Phased Array Topology. Top to bottom: Antenna, Amplifier, Phase Delay Generator, Signal Source

Linear arrays can steer the mainlobe of radiation in a single direction. By combining multiple linear arrays into a square planar array, better spatial selectivity as well as steering in two directions is also possible. Directional selectivity, or ***directivity***, is typically expressed in decibels (dB), and compares the array's radiation pattern to an omnidirectional antenna. Another similar measure, ***antenna gain***, is the product of the directivity and the power efficiency of the array (Mailloux, 2005).

A phased array's gain can be improved by increasing the number of elements in the array, as well as through adjusting the geometry of its elements, and careful selection of the individual radiators (Milligan, 2005). Increasing the number of elements decreases the mainlobe's beamwidth, while special array geometries can help attenuate the amount of power transmitted in the sidelobes. An example of a special geometry is a raised cosine distribution, which gives an attenuation of 32dB from the mainlobe to the first sidelobe. The tradeoff lies in that while the first sidelobe is attenuated well, the overall pattern results in a directivity of about 2/3rds of that of the simple linear array (Mailloux, 2005).

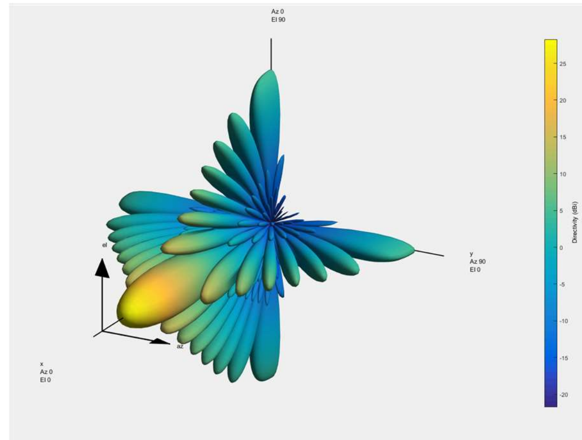

Figure 4 Radiation pattern produced by a planar array.

Applications

Medical Ultrasound

Phased arrays are particularly useful in medical ultrasound, where spatially restricting the path of a signal is desired. A typical ultrasound scanner will consist of an array of transducers that, when placed atop tissue, can send ultrasound in a desired direction, and the receive signals coming back from the same direction with minimal interference (Veen, Buckley, 1988).

Sonar and Radar

Sonar and radar systems take advantage of the beamsteering and spatial filtering capabilities of phased arrays; using electronically adjustable phase or time delay generators, beamsteering can be done without the need for mechanical assemblies, which can be cumbersome and slow, and spatial filtering allows for both localization of the determination of detected objects (Veen, Buckley, 1988).

References

1. Mailloux, R. J. (2005). *Phased array antenna handbook*. Boston: Artech House.
2. Milligan, T. A. (2005). *Modern antenna design*. Hoboken, NJ: IEEE Press.
3. Veen, B. V., & Buckley, K. (1988). Beamforming: a versatile approach to spatial filtering. *IEEE ASSP Magazine*, 5(2), 4-24. doi:10.1109/53.665