Efficient Phased array antenna with grating lobes

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Abstract:

An antenna Array is a configuration of individual radiating elements that are arranged in space and can be used to produce a directional radiation pattern. Single element antennas have radiation patterns that are broad and hence have a low directivity and wide beam width compared to when the number of element of antennas are increasing, that is not suitable for long distance communications with more directive radiation. A high directivity can still be achieved with single element antennas by increasing the electrical dimensions (in terms of wavelength) and hence the physical size of the antenna. Generally, this paper focuses on uniform linear phased array, an array which consists of equal-spaced elements (d), which are fed with current of equal magnitude (i.e. with uniform weighting) and can have progressive phase-shift (theta) along the array. The existence of grating lobes and the mechanisms that can be implemented to reduce these grating lobes are also the main points of interest in this paper. The impact of variation of phase angle, number of elements and inter element spacing are also described with supportive simulation using MATLAB software.

Keywords: Phased array antenna, gain, directivity, grating lobes

I Introduction

A phased array, in antenna theory, is an array of antennas in which all of the phases of each signal that feeds each antenna are set in such a way that the effective radiation pattern of the entire array is set toward the desired direction and that the signal is emanating toward undesired directions are suppressed. It is a way to direct waves of radiation toward a desired direction. The use of proper antennas, with appropriate radiation pattern, can improve the system performance, allowing eliminating some unwanted interfering signals, increasing gain, efficiency and quality of the signal reception.[1]

Phased array antenna has multiple radiating elements, each having a phase shifter of its own. The beams are then formed through the shifting of the signals phase that is emitted from each radiating element: this serves as constructive interference towards the desired direction for the waves as destructive interference for undesired directions. The main beam in a phased array antenna always points in the direction of the increased phase shift. Because of the phase shifting and directional nature of the application, a phase array antenna usually has a flat surface that can be moved, unless it is meant as a stationary antenna, in which case it always broadcasts in a single direction Phased arrays antennas are used in AM broadcasting to provide more power and range and so that they will only serve their area of licence and not interfere in others.[1]

As we know different antennas are used

for different purposes. So, this process is achieved by either designing or modifying (redesigning) antennas and analyzing their performances by varying the phase angle, number of element, spacing of interelements. In this paper, the results of the performance analysis of the antenna array are discussed and a brief background of the existing antenna array, and simulation results, conclusions and recommendations.

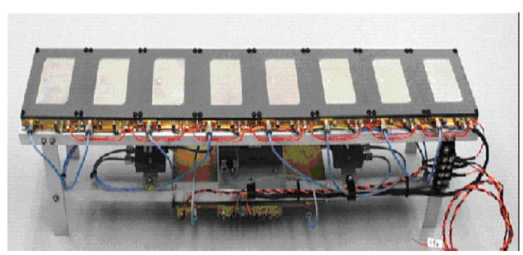
II Existing Phased array antenna systems

Phased array transmission was originally shown in 1905 by Nobel laureate Karl Ferdinand Braun who demonstrated enhanced transmission of radio waves in one direction. During World War II, Nobel laureate Luis Alvarez used phased array transmission in a rapidly steerable radar system for "ground-controlled approach", a system to aid in the landing of aircraft. . Phased arrays were developed at the University of Cambridge. This design is also used for radar, and is generalized in interferometry radio antennas.
The relative amplitudes of and constructive and destructive interference effects among [2] the signals radiated by the individual antennas determine the effective radiation pattern of the array. [3] A phased array may be used to point a fixed radiation pattern, or to scan rapidly in azimuth or elevation. Simultaneous electrical scanning in both azimuth and elevation was first demonstrated in a phased array antenna. Phased arrays are used in optical communication [4] as a wavelength selectivesplitter.

The aim of the proposed algorithm is to obtain the optimum values for inter-element spacing and excitation amplitude for a linear antenna array in a given radiation pattern with suppressed Side Lobe Level (SLL), minimum Half Power Beam width (HPBW), improved directivity and placement of nulls in the desired direction. A variety of design examples are considered and the obtained resultsare validated by benchmarking with results obtained using other nature-inspired meta-heuristic algorithms such as the Real-coded Genetic Algorithm (RGA) and the Biogeographic Based Optimization (BBO) algorithm. The comparative results are shown that optimization of linear antenna array [5]using the PSO provides considerable enhancement in the SLL, the HPBW, the directivity and the null control in the desireddirection.

III Proposed phase array antenna

For an antenna with an efficiency of less than 100%, both the effective area and gain are reduced by that same amount. Therefore the above relationship between gain and effective area still holds. These are thus two different ways of expressing the same quantity. receiving elements could be designed to operate primarily in the direction of the antenna bore sight, and were in the past typically steered in multi-element phased array antennas having hundreds or more elements.
Due to inherent size limitations in spacecraft, these multi-element phased array antennas have not proved feasible. Rather, phased array



antennas having a

Figure 1: Phased-Array Antenna with elements.

relatively small number of elements are needed. As used in the description of the present invention, the phrase “relatively small number of elements” should be construed to mean from five elements to seventeen or more elements, up to twenty or twenty five[6][12]. With the present invention, it has been found that if certain conventional design assumptions are disregarded, surprising and unexpected performance results of small element number phased array antennas are achieved. By choosing the antenna parameters, it is possible to restrict the area covered by the antenna so that the field strength or antenna gain is made more uniform over this beam steering range while also minimizing phase transients as the beam is steered. [7][8]

The assembly is usually contained inside a plastic random, which protects the antenna structure from damage. Patch antennas are simple to fabricate and easy to modify and customize. They are the original type of micro strip antenna the two metal sheets together form a resonant piece of micro-strip transmission line with a length of approximately one- half wavelength of the radio waves. The radiation mechanism arises from discontinuities at each truncated edge of the micro-strip transmissionline.

Figure 2 Shows an overview of the original system. As can be seen from that, the user supplied digital control system provides the RF signal processor with a steering control voltage

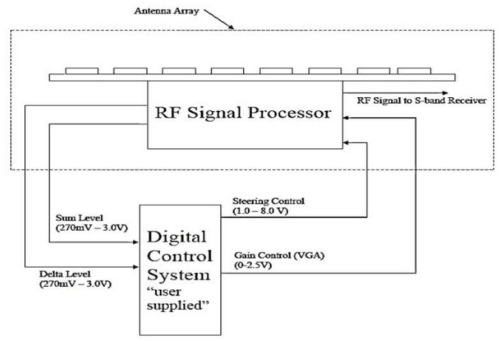


Figure 2 Top Level Block Diagram

Each antenna element consists of a single layer patch antenna. A number of different approaches are available to increase the bandwidth of patch antennas. The most common involve the use of cavities and stacked substrate techniques. However, these techniques increase the complexity, size, and weight of the design[9]. The simplest approach is to increase the height of the substrate. The drawback to this approach is that if the height is made too tall, an increase in the production of surface waves will decrease the antenna’s efficiency[10]
The strategy to be employed is to moderately increase the height of the patch antenna in order to achieve the desired increase in bandwidth. Figure 2 shows the geometry of a typical patch antenna.

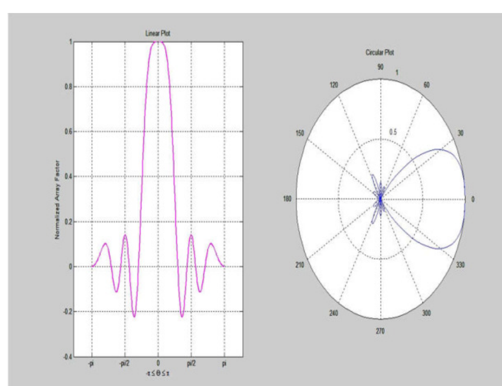


Figure 3 simulation results at 0^0

The final patch dimensions can be

summarized as follows. The dielectric height is 0.25”; the patch width is 6 cm; the probe radius is 0.15 cm; the patch length is 3.913 cm. The patch is fed using an inset of 0.75 cm from the edge (this is the distance from the patch’s edge to the radial centre of the coaxial feed).

The final simulation was made more realistic by using the patch’s true conductor (finite thickness copper). The simulation volume was also expanded to include ~2 wavelength width radiation boundary (compared to ¼ wave length in original simulation). The ground plane was reduced from being infinite in extent. The resulting simulation took ~30 minutes per iteration. The simulated results were not drastically different from the ideal simulations. We now proceed to describe the simulationresults.

IV Results and discussion

Phased Excitation Angle

The performance analysis by varying the phase angle with phase difference in 30^0 each with in linear and polar form. The effect of varying the phase angle will affect the performance of the phase antenna array and this effect is shown as follows. We take the theta values θ=0, π/6, π/3, π/2, 2π/3, 5π/6, and π to analyse it in terms of radiation intensity transmitting capacity. And the results are as shownbelow.

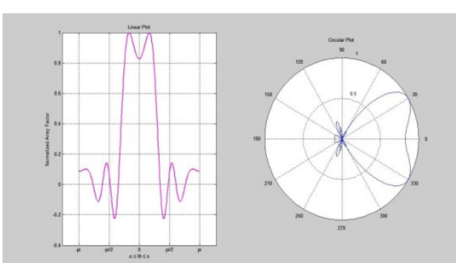


Figure 4 simulation results at30^0

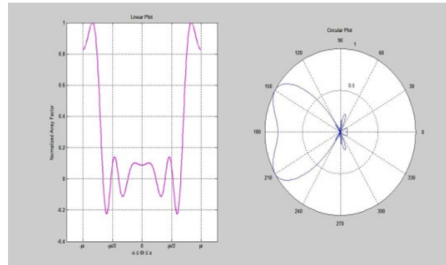


Figure 5 simulation results at 5n/6

Simulation Result with Different Inter-element Spacing

We see the effect by varying the distance between the elements in linear form with constant number of elements and lamda value at theta =pi/3. And the results are as shown below.

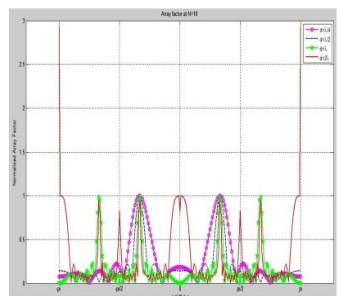


Figure 6 simulation result of comparison of different inter-element spacing.

The element radiation pattern is chosen to be directional. Then in this case, the array radiation pattern will be totally determined by the array factor AF. Therefore the radiation pattern of a uniform linear array antenna which has 10 elements with inter-element spacing d=λ/4 is similar to the plot given in fig.4 for the array factor. Figure 5shown in steering angel increases to cover large area without mechanical movement of the physical part of phased array antenna. This is done by changing excitation angels of phased array antenna to detect signals from all direction of antenna. As shown in Fig6 it is understood that grating lobes exist if d ≥λ disregarding value of βtaken.

The array factor plots sketched for different inter-element spacing indicate that the beam width is inversely proportional to the spacing between the elements for same number of elements. Fig 6 array factor plot shows that beam-width is greater in the first case when d = λ/4 compared to the beam width when d= λ and so on.

V Conclusion

The steering angle of phased array antenna increases to detect signal in all direction of antenna. To maximize the steering angle we used a variety of values of phase angle, number of elements and inter element spacing. From the above specified number of elements, phase angle and inter element spacing we can get the frequency range. By using inter element spacing value equal to 2.5m, the resulting frequency range is equal to frequency= c/ lambda, where lambda is the inter element spacing, which gives the value of 120 M Hz. This frequency range helps us to identify the type of modulation we need to use, the application of the antenna and the beneficiary bodies.

The simulation shows how to detect signal in all direction by changing the excitation angle of phased array antenna to control area around antenna thatspecified for specific application. This is important in radar system to detect signal radiation in any direction. But this is influenced by element spacing between elements and number of elements.

Beam width is inversely proportional to the spacing between the elements for same number of elements, beam-width is greater in the first case when d = λ/4 compared to the beam width when d= λ and so on d ≥ λ, grating lobes exist for all values of β &narrower beam-width is achieved. So to increases beam width without increasing of grating lobes distance between elements must be 0.5 λ < d < λ and phase different between element must be 0 ≤ β < π or π ≤ β < 2π. However, beam width not only depends on distance between element also it depends on number of elements so beam width decreases as the number of elements in the array increases. That means with higher number of elements we can achieve a more directive radiation.

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