# Low Transmit Sidelobein Active Phased Array Antenna for Airborne Application

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***Abstract –*** In this paper active phased array antenna design for airborne application is envisaged. In airborne application low sidelobe requirement in transmit mode is required to minimise clutter eco signal. To achieve low sidelobe in transmit mode three different approaches have been studied which are explained herein; (i) antenna aperture shaping by special tapering in quasi elliptical shape, (ii) Use of two type of T/R modules in active array, (iii) reduced power operation in T/R module by applying amplitude weighting in T/R module. Here comparative study has been carried out and appropriate active array architecture selected suiting our airborne application.

**Keywords: amplitude weighting,Phased array, AESA**

## I. Introduction

Active phased-array antennas for radar applications are currently being designed to provide electronic beam scanning throughout wide angular sectors. In phased array beamforming is the combination of radio signals from a set of small non-directional antennas to simulate a large directional antenna. In airborne application low sidelobes in transmit and receive is demanded by radar system to minimize clutter eco signal and low probability of interception of object flying with radar.In active phased array radar each of the radiating elements shall be capable of changing its amplitude/phase and shall able to steer the antenna beam in the desired spatial region. Due to element level complex weighting control active phased arrays can be programmable to achieve different beam types (pencil beam, broadened beam and cosecant square beam). In the design of antenna array, the most important design parameters are usually the number of elements, scan requirements, excitation (amplitude and phase), half power beamwidth, directivity, and sidelobe level [1].

## II. Low Transmit SidelobeConfigurations

An active phased array antenna in X-band using conventional analog Transmit receive (T/R) modules is considered. The analog X-band transmit receive modules are developed based on MMIC (Monolithic Microwave Integrated Circuit) and RF power transistor technology with RF power amplification and Low noise amplification in receive mode. These modules are having MMIC phase shifter for beam formation in transmit and receive mode. Electronically scanned phased array radar technology comprising several hundreds RF T/R modules and associated RF beamforming is employed in the present generation of high performance military radars.

In this paper an active phased array antenna having approximately 400 elements with scan angle requirements of ± $60^0$ in azimuth and ± $50^0$in elevation is configured with appropriate inter element spacing. The number of antenna elements, phase shifters, and associated components are large which has direct impact on cost and complexity of the system. If the number of antenna elements can be reduced by special tapering to achieve required transmit side lobes, the number of phase shifters and associated components can also be reduced resulting in a sizable decrease in cost and complexity of scanning array.

To configure active antenna aperture there can be a number of constraints in terms of modularity, scalability, array weight, array power consumption and available cooling at airborne plateform. In this section different means of satisfying transmit sidelobe requirements have been explained one or another can be suitable for different airborne applications.

### A. Antenna Aperture Shaping by Special Tapering

Active antenna can be shaped in different shapes and sizes it can be square, rectangular, circular, elliptical quasi elliptical, quasi circular or some optimal shape which could meat radar radiation parameters.

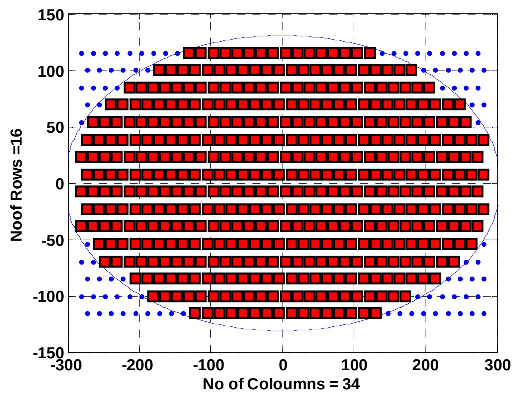

Figure 1 Quasi elliptical antenna aperture to achieve special tapering

In figure 1 elliptical antenna aperture configuration is shown which may be suitable for the airborne application where peak sidelobe requirement may be in the order of 16dB in azimuth and elevation plane. Such configuration will have better average sidelobe by 3dB to5 dB.

Other kind of aperture shaping could be thinning of antenna array. In figure 2 a rectangular aperture of 16 x 32 elements (512 elements) have been chosen for array thing. After running array thing algorithm (genetic algorithm) it has been thinned to 264 radiating element more than 48 % array thing has been achieved. This thinned array will give peak sidelobes in the order of 18dB to 20dB but disadvantage with the thinned array is it will reduce array gain by a 0.5dB to 1.0dB.

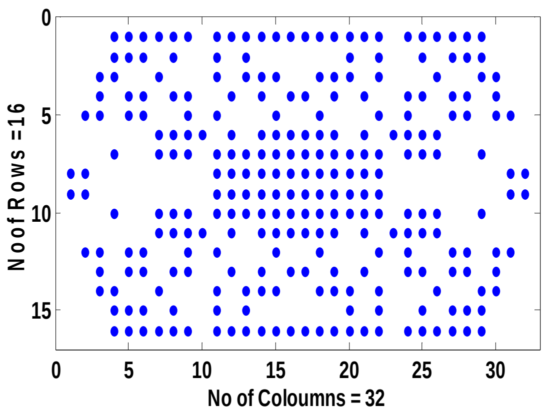


Figure 2 antenna array thing to achieve special tapering to achieve required side lobes

## B. *Step tapering by two different T/R module*

Second type of configuration can be step tapering in transmit mode by using two or three type of T/R module. In figure3 one of the configuration is shown which will have advantage of special tapering and step amplitude tapering. This configuration have been optimise for low side lobe requirements without degrading gain of antenna array. In this explanatory configuration special tapering is used to minimise cost of antenna aperture and keeping narrow beam width for given aperture size. This configuration is having two different type of T/R module with the transmit power difference of 3dB or 6dB. This step excitation will gave additional fix amplitude weighting in transmit mode of operation in addition to spatial tapering.

Disadvantage of such configuration is type of LRUs in active array willincrease; hence such configuration puts constraints on minimum available spare for different kind, interns which increase active array cost. In such kind of active array configuration LRU's becomes location specific not independent from type-1 location to typ,e-2 location.

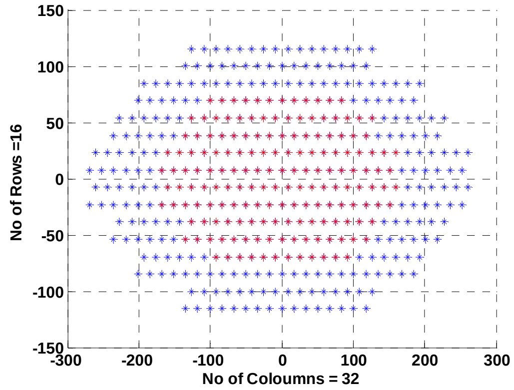


Figure 3 Step amplitude weighting to achievelow transmit side lobes

## C. *Amplitude weighing in T/R module*

Thired kind of aperture configuration could be combination of spatial tapering and amplitude weighing by setting digital attenuator in T/R module. This attenuation is implemented at low input power level of T/R module which does not results into wastage of power and additional cooling requirement. Such king of configuration required single type of LRUs which can be changed in different output power T/R module by increasing or decreasing attenuation. Attenuation setting in driver stage of T/R module will bring T/R module in linear operation which may decrease efficiency of T/R module still power consumption and cooling requirement will remain same as full output power T/R module.

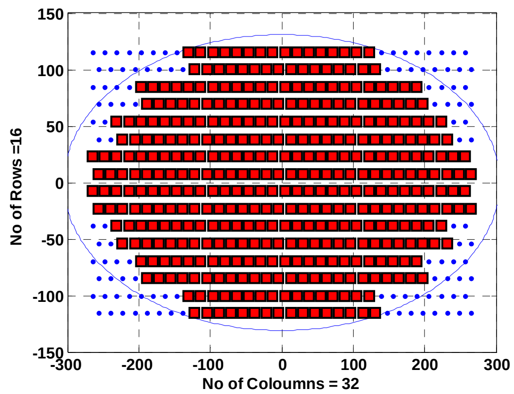


Figure 4 Shaping of antenna aperture in elliptical aperture boundary

In figure 4 an elliptical antenna aperture is shown which has been optimised for low sidelobe requirement by elimination radiating elements falling outside the ellipse. Such configuration shall give side lobes in the order of 16dB to 17 dB and good average side lobes.

In addition to shaping of antenna aperture, amplitude weighting is also applied at element level to improve side lobes in transmit mode to meet radar system requirements.

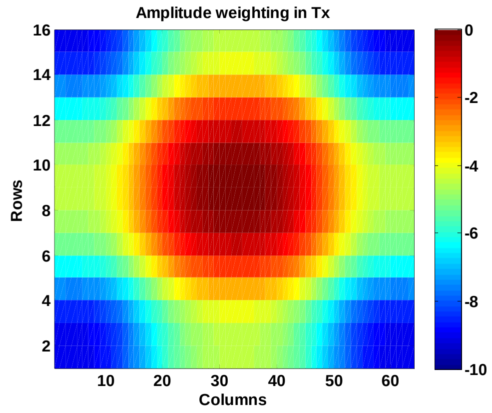


Figure 5Step amplitude weighting to achieve low transmit side lobes

In figure 5 amplitude weighing on antenna aperture is shown. To achieve required side lobes maximum weighting of 8dB is required at the corner elements. Centre elements will not get higher amplitude weighting. Due to amplitude weighting transmit power will reduce by 1.2dB and transmit gain also will reduce by same value.

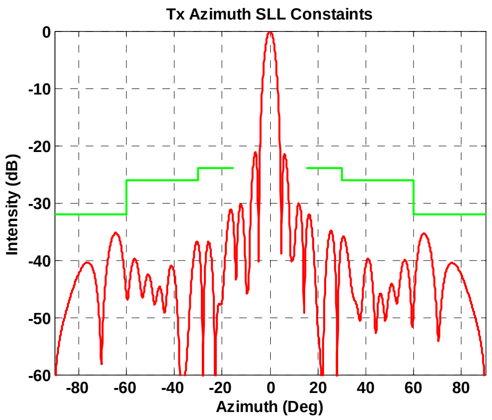


Figure 6 (a) Step amplitude weighting to achieve low transmit side lobes

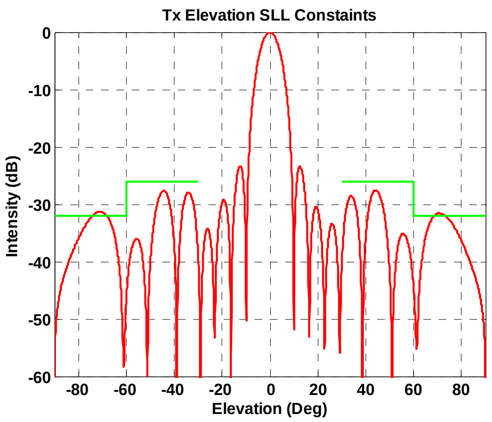


Figure 6(b) Step amplitude weighting to achieve low transmit side lobes

In figure 6 (a), and figure 6 (b) simulated patterns for the combination of special tapering and amplitude tapering is shown. An envelope of requirement of side lobe level is plotted along with the azimuth and elevation pattern respectively.

Table.1 (a)Simulated achieved sidelobes for azimuth in transmit mode

| Azimuth | Transmit Side lobes in angular zone | | |
|---|---|---|---|
| Angles | 10-20 | 20-40 | 40-90 |
| Peak SLL | -22 dB | -28dB | -32dB |
| Ave. SLL | -28 dB | -32dB | -40dB |

Table.1 (b) Simulated achieved side lobes for elevation in transmit mode

| Elevation | Transmit Side lobes in angular zone | |
|---|---|---|
| Angles | 30-60 | 60-90 |
| Peak SLL | -26dB | -30dB |
| Ave. SLL | -34dB | -38dB |

## III. CONCLUSION

An active phased array with the combination of spatial shaping and amplitude weighting is suitable for our application. Simulated figures shows in the configuration of spatial shaping and amplitude weighting peak side lobes are less than 220dB in azimuth and elevation and average side lobes are with the specification and tabulated in table 1(a) and (b). Aperture configurations explained in this paper may be useful in other applications for different requirement.

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## REFERENCES

[1] . Constantine A. Balanis, Antenna Theory analysis and design, 2nd edition, pp.311, John wiley.1997.

[2] . P. J. Kahrilas, "Electronic Scanning Radar System (ESRS)", Design Handbook, Massachusetts, Artech House Inc. 1976, Page – 186-190).

[3] . R. J. Mailloux, Phased Array Antenna Handbook. Boston, MA: Artech House, 2005.

[4] . M. I. Skolnik, Introduction to Radar Systems, 3rd ed. New York, NY

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