Technique For Monopulse Antenna With Improved Sidelobe Suppression In Both Sum And Difference Pattern

Joita Mukherjee, G.V.R.K.Rao, Dr. A.Ghosh, Dr. V.G.Borkar
Scientists, Research Centre Imarat, DRDO
joita.mukherjee@rcilab.in,gvrkrao@rcilab.in

Abstract -

Last decade has seen the development of slotted-array antenna as they are the most preferred missile antenna, as they offer several significant advantages such as thin profile, light weight and ease of stabilisation. To achieve high speed tracking accuracies within fraction of a beam width, monopulse antenna is the chosen configuration. For look-down mode applications, aperture distributions capable of generating narrow beam along with low side levels are predominantly used to avoid clutter, jamming and possible detection through sidelobes. However, high sidelobes in the difference pattern increases the radar's susceptibility to interference from background clutter or other off-axis sources of radiation which results in tracking error and loss of efficiency. This paper reviews some of the techniques commonly used and demonstrates a simple yet effective technique to achieve low difference sidelobe in the difference pattern without compromising on the gain of the antenna.

Keyword : Monopulse Difference pattern, low side lobe level

I. INTRODUCTION

Monopulse antenna plays an important role in obtaining the maximum detection range. Array antennas offer desired sidelobes with controlled aperture excitation. Aperture distributions such as Taylor distribution & Chebyshev distribution are often used to get maximum beam efficiency which are important to achieve high gain leading to higher range detection. A common approach has been to optimise the sum pattern and accept the resulting difference signal pattern. However, it is essential to optimise the undesirable features of the difference pattern to eliminate significant tracking problems.Some of the popular methods to optimise the difference pattern is by using the Bayliss distribution. Such distribution suffer with problem of optimising the difference signal leading to reduced gain in sum pattern. Another technique as reported in (US Patent 5030960) uses a method of dividing the aperture into 5 sections. Apart from the regular 4 quadrants, the fifth quadrant is created at the center taking a few elements from each quadrant as shown in figure(1a). Removal of elements results in very low side lobe in the difference pattern. The comparator structure is shown in figure(1b). This results in a complicated & heavy RF structure at the back of the antenna rendering it unfit for missile applications.

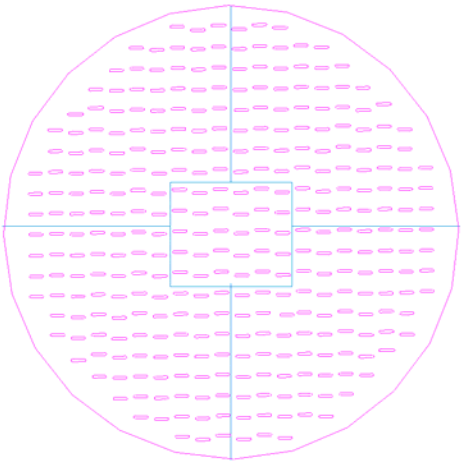

Figure 1 : a) Schematic of 5-quadrant monopulse array configuration

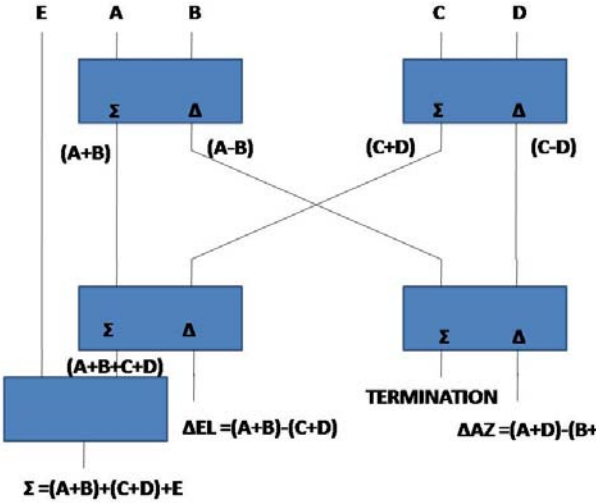

Figure 1b : Schematic of 5-quadrant monopulse array comparator structure

II. DESIGN METHODOLOGY

A very common observation in the design of array antenna using any tapered aperture distribution is that we can achieve low sidelobe level in sum signal and tolerate the difference pattern in the E-plane, along the principal plane (H-plane) cuts ie Ø= 0° plane and Ø= 90° plane . A typical synthesized E-plane sum signal and difference signal pattern with Taylor taper distribution for a circular aperture array antenna given by eqn 1 is shown in figure (2a).

$$F(u) = \frac{2J_1(\pi u)}{\pi u} \prod_{n=1}^{\bar{n}-1} \frac{\left(1 - \frac{u^2}{u_n^2}\right)}{\left(1 - \frac{u^2}{\mu_n^2}\right)} \quad \text{Where } u_n$$

$$= \bar{n}\left[\frac{A^2 + (n-1/2)^2}{A^2 + (\bar{n}-1/2)^2}\right]^{1/2} \quad \text{----------- (1)}$$

Where A is measure of the SLL in that cosh πA = b, with 20 $\log_{10}$ b=SLL. In the conventional configuration as seen in figure (2b), if A(n) is the desired excitation coefficient for the nth radiating element, the conductance gn is given by $g_n = KA(n)^2$ where constant K is chosen such that $g_e = W$, in order for the array to be matched for maximum radiated power. The input match condition for an array of (N+1) slots is given by $g_e = \sum_{n=1}^{N} g_n = \omega$. ω=1 for end fed; ω=2 for center fed. Similarly, the series slot resistance in each branch line is determined by the following equation

$$r_n = K \sum_{m=1}^{M_n} A^2(n,m) \quad \text{----------} \qquad \text{eqn(2)}$$

and

$$\sum_{n=1}^{N} r_n = W \quad where \quad W = 1 \quad for\ end\ feed \quad - \quad W = 2 \quad for\ center\ feed \quad \text{---------------} \qquad \text{eqn (3)}$$

The method by which the match condition is obtained depends how the aperture is divided. In the conventional technique the quadrant is determined along Ø= 0° and Ø= 90° plane ie straight cardinal plane cuts (figure2b). Therefore,

$$W = K \sum_{n=1}^{N} \sum_{m=1}^{M_n} A^2(n,m) \quad \text{---------------------} \qquad \text{eqn(4)}$$

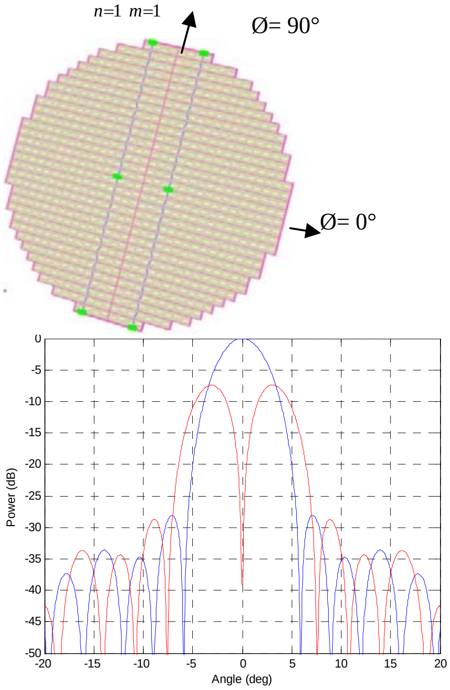

Figure 2: a) Sum & difference pattern of conventional Taylor distribution b) Feed design layout for principal plane

At Ø= 45° cut, we observe that the sidelobe level of the difference pattern is suppressed significantly as seen in figure(3).

The present paper proposes to translate the advantage of Ø= 45° & 135° cut to the principal plane by feeding the radiating elements by inter-cardinal feed design structure as shown in figure (4). The design methodology follows the same design equations as (1),(2),(3). But the difference lies in way of determining the value of the match condition. Here, a inter-cardinal feeding structure is adopted as seen in figure (4) where the method of obtaining the 4 quadrants are in a cross configuration. Therefore, the slots contributing to determine W in eqn (4) is different.

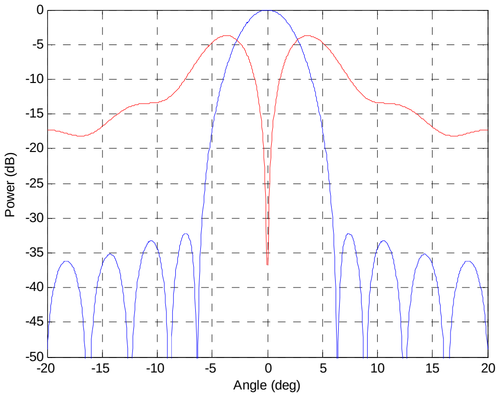

Figure 3: Sum & Difference pattern at Ø= 45° plane

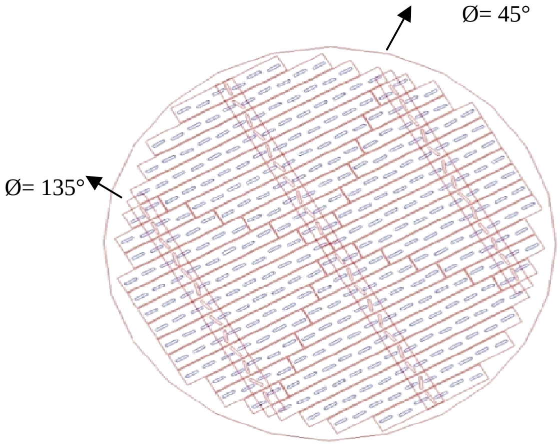

Figure 4a: Feeding Structure of the array at Ø= 45° & Ø= 135° plane

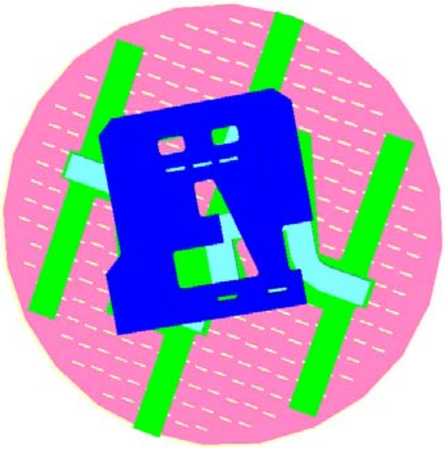

Figure 4b: Inter-cardinal Feed design layout showing the radiating elements fed by coupling slots & reduced height folded magic tee comparator at the back.

Hence, a difference sidelobe suppression of atleast 25dB is achieved with no additional circuitry. Using a single feed design, optimum sum and difference radiation patterns, low side lobe levels, compactness and simplicity were satisfied simultaneously. The only penalty is the reduction of monopulse slope which is acceptable for most on-board applications.

III. HARDWARE EXPERIMENTATION

An array antenna was fabricated using this techniques and its pattern shows the reduced difference sidelobe level. The design at Ku-band was implemented in a reduced height waveguide dimension to keep the overall height and weight of the antenna low.

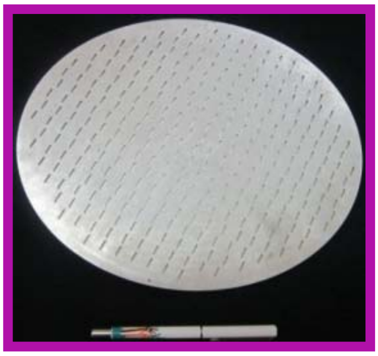

Figure 5: Fabricated and Brazed Antenna

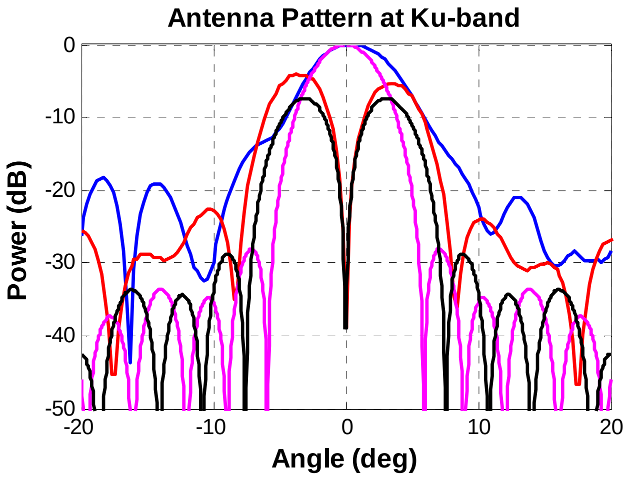

Figure 6: Radiation pattern with inter-cardinal feeding showing reduced difference sidelobe level.

Some deviations are observed in the sum pattern which is attributed to improper brazing at certain points. These problems are expected to be sorted out in the subsequently antennas.

IV. CONCLUSIONS

This form of antenna feed can be easily implemented and used in tracking radar systems without the problem of achieving high sum gain while preserving low sidelobes in difference pattern.

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