Design and Analysis of Shaped Beam Pattern using Circularly Polarized Broadband Proximity Fed MSA

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Abstract— The objective of this paper is to design and analyze the shaped beam pattern at 2.211GHz frequency. Microstrip patch antenna arrays can be designed to produce shaped pattern, which are advantageous in reduction of the onboard power of satellites by restraining the radiation of the antenna in the desired regions only. However the main disadvantages of using microstrip antenna arrays are their high loss and narrow bandwidth. In this paper the design of array electromagnetically coupled proximity fed patches are designed to operate over a bandwidth of 120MHz with Left hand circular polarization. An efficient null perturbation technique has been applied for the synthesis of flat topped radiation pattern with gain of 15dB and 3dB beamwidth of 55 degree in the region –27o≤Θ≤28o using 4x8 arrays (32 elements) with 0.6 wavelength spacing.

Key words: beam pattern , Fed MSA

I. INTRODUCTION

In satellite communication system, antenna with shaped beam radiation pattern required which illuminates the desired region at constant power with an acceptable variation and a minimal spill over. Different type of synthesis algorithm is used depending on their usability to get desired radiation pattern [5-6]. The majority of the design methods use are based on Woodward's aperture synthesis technique [7].But for small number of elements this technique does not reproduce the desired pattern. This inconsistency was overcome by W.L.Stutzman in 1971.But his technique does not have any control on the specified sidelobe region. Orchard [8] developed an optimization technique which have precise control on sidelobe but often required skill and luck of the designer. The present technique is developed by extending the perturbation technique developed by S.B.Sharma [9] where the exact location of the nulls is determined and utilized directly for particular sidelobe topography without calling for any iteration. The final pattern of the antenna mainly depends on the geometry of the aperture and distribution of the amplitude and phase of excitation across the aperture. In case of array the final pattern is directly influence by number of elements. The number of elements should be more to have finer control of the footprint. Moreover, we have to have an optimal choice between size of array, complexity of the feed network and real estate available.

In this paper, a 32 element microstrip patch antenna array with flat top radiation pattern is presented. Array synthesis has been done using a null perturbation technique and actual element factor has been taken into account in optimization. The basic radiating element is 4x1 array of element fed with equal amplitude and phase. So the overall antenna is effectively a 4x8 array with spacing of 0.6 lambda. The antenna is designed using Ansoft Designer software and HFSS Software.

II. ARRAY ELEMENT

In a circularly polarized microstrip patch antenna ,the narrow bandwidth mostly occur due to not maintaining the appropriate excitation condition for polarization purely, which results in the axial ratio degradation off the resonance[2].Amongst the various broad-band techniques for the microstrip antenna (MSA)multi-resonator/parasitic coupling in both planar as well as in stacked configurations, aperture coupling, electromagnetic/proximity coupling, etc. proximity coupling is preferred, as it is simpler to implement for thicker substrates[1-4].

The antenna is meant for satellite on board application, so the weight of the antenna should be as low as possible. So microstrip patch become one of the prominent choices for the radiating elements. Stacked configuration with proximity gap coupled fed CP antenna is chosen to achieve broadband performance over a bandwidth (-17dB) of 120MHz. The optimized configuration of single element consists of three layers fig1a & fig1b.The lower layer is substrate Rogers RT/duroid 5880(εr=2.2) of height (hl) =62mil.The middle layer is Foam (εr=1.06) of height (hf) =7mm.The upper layer is a substrate Rogers RT/duroid 5880(εr=2.2) of height (hu) =62mil.The dimension of the ground plane is 135mm x 135mm.The radiating element patch and L-strips are etched on upper substrate. The dimension of patch and L-strips are 44mm x 44mm and 10mm x 10mm respectively. To obtain LHCP, dual feed is used. The coaxial probes are connected to two L-strip with orthogonal phase at an optimized distance to match 50ohm impedance as shown in fig 1(b).The patch is electromagnetically coupled from the L-strip which is placed at a proximal distance of 0.5mm to 2mm.

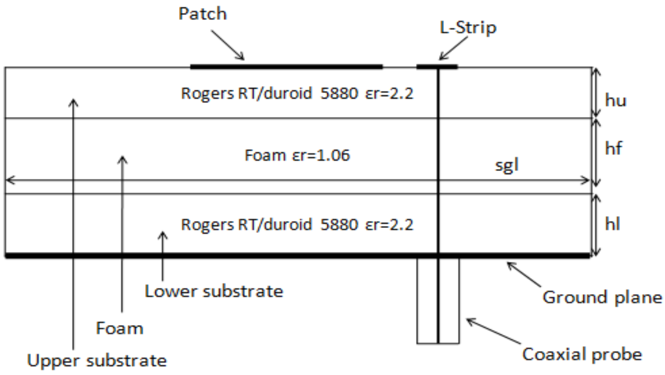

Fig. 1(a) Side view

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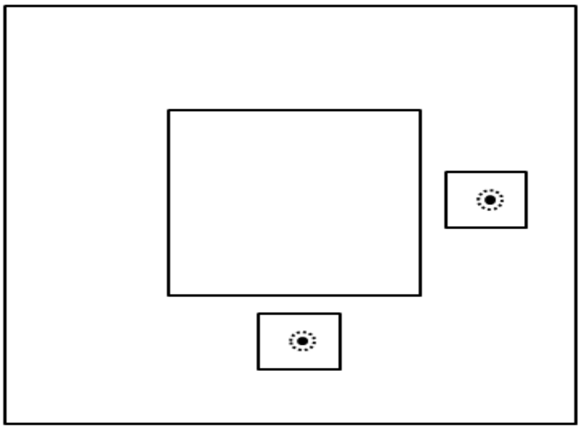

Fig. 1(b): Top view

The centre frequency is controlled by the length and width of patch. Fig 2 shows the simulated |s11| result. It is found that the centre frequency 2.211 GHz is matched when length and width is 44mm.The proximal distance between the patch and L-strip is a key parameter. The circular polarization performance with an optimum axial ratio 1.6503dB can be obtained by fine tuning *Gap and feed location* as shown in Fig 3.The LHCP gain obtained by single element is 7.7632dB as shown in fig 4.

III. Array Synthesis and Optimization

The array synthesis is the reverse process of array analysis. It starts from a given requirement specified on the array radiation pattern and ends with an array design to approximately (or exactly) satisfy the requirement and the other system constraints. The synthesis method depends on the category of requirements. Two categories of requirements are studied: 1.The array radiation pattern exhibits a desired distribution in the visible region beam shaping. 2. The array radiation pattern has low sidelobe and a narrow main beam.

The radiation pattern of an equally spaced linear array distributed along the *X* axis with element spacing *d* = 108mm will be optimized, we begin with the general expression of the far field of an *N*-element (*N* = 8) linear antenna array, given by:

$$E(\theta) = \sum_{n=1}^{N} g_n(\theta) \cdot a_n \exp[j(k(n-1)d\cos\theta + \beta_n)]$$

Here, k = 2π/λ is the free space wave-number, and d denotes the element spacing of the array. The amplitude and phase weights of the nth element are an and βn, respectively. The expression gn (θ) represents the radiation pattern of the nth element. For synthesizing the desired pattern, element excitation (an, βn) will be optimally determined by Null perturbation.

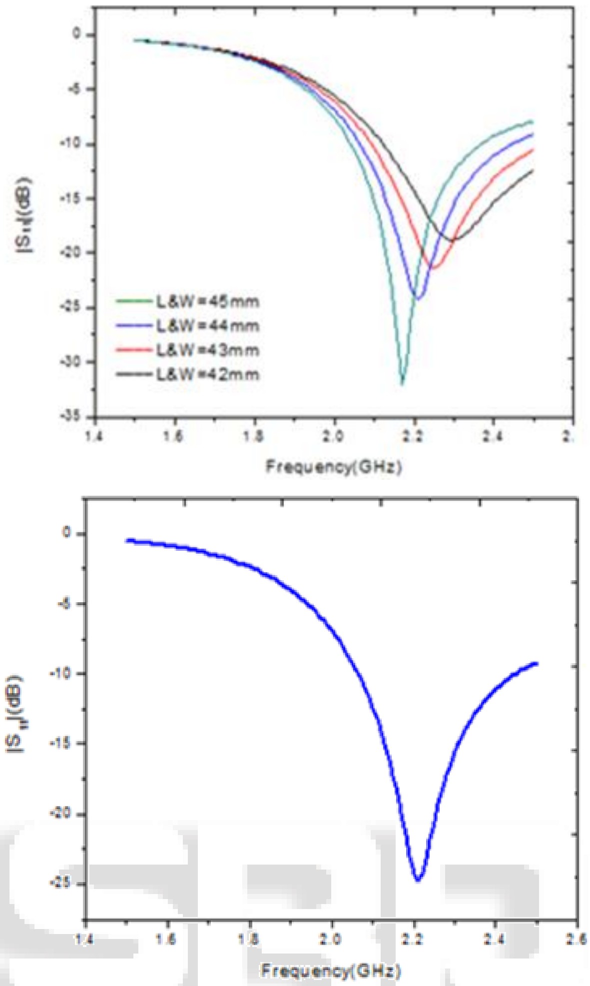

Fig 2: Simulated |S11| parameter (Return Loss (RL))

In this paper null perturbation technique is used for array synthesis. Null Perturbation Technique is a pattern synthesis technique which yields the excitation of an equispaced linear array that will produce a shaped-beam pattern with arbitrary sidelobe topography in the nonshaped region. The technique relied on an generating a suitable starting pattern, which used a polynomial representation of the pattern, with all roots on the Schelkunoff unit circle, the positions of these roots being iteratively adjusted to yield a sum pattern with the height of each sidelobe independently specified.

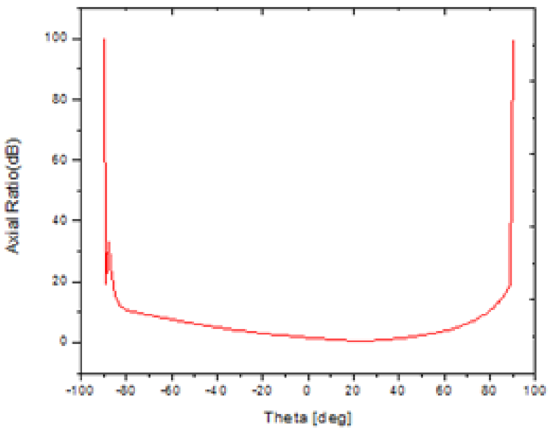

Fig 3: Axial Ratio (AR)

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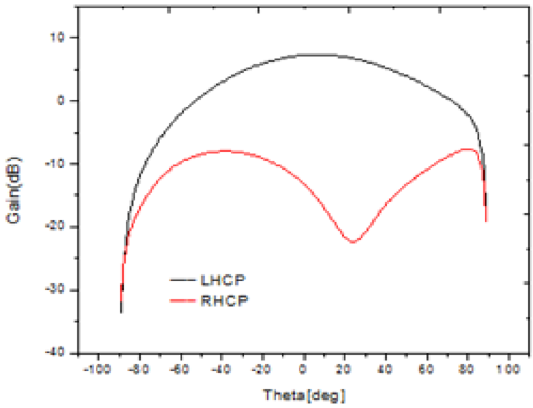

Fig 4: Gain

IV. MEASURED RESULT AND DISCUSSION

The radiation pattern of linear array of 8 elements is shown in Fig 5.From figure we can see that the gain is 12.55dB and 3dB beamwidth is 10^o by applying equal amplitude 1V and 0^o phase to each element. Our requirement is 15dB gain and 3dB beamwidth should be 55^o.we developed the GUI of 8 elements. Null perturbation technique in MATLAB using GUI, we obtained different set of excitation and phase to achieve the desired shaped beam. The basic radiating element is a 1 x 8 array of elements fed with unequal amplitude and phase. Amplitude distribution for most favorable of 8 excitations shown in table 1 that produce Fig 6

From fig 6 we can see that the gain obtained is 8.7573dB and beamwidth equals to 55^o.When we have

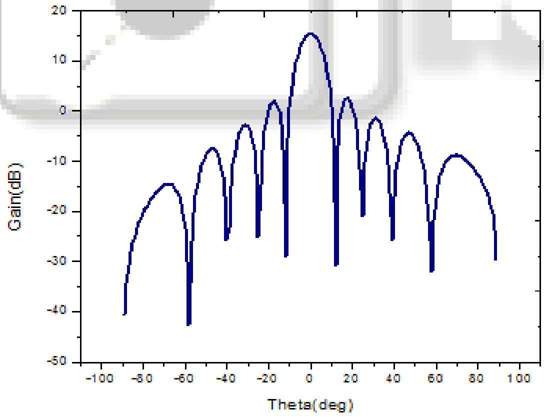

Fig 5: Gain Of 1x8 Arrays With Equal Amplitude And Phase

Element	Magnitude	Angle
1	0.0168	0.8794
2	0.0195	3.3275
3	0.1502	-179.9497
4	0.26	0.2538
5	0.7762	-0.2546
6	0.2605	0.0024
7	0.1203	-3.5928
8	0.0178	179.9779

applied equal amplitude and phase we obtained 12.55dB,while applying unequal amplitude and phase we obtained 9.285 this due to the losses. Now to get the 15dB gain we will form an array of 4x8.Above excitations are given to 4x8 elements such that each column have same amplitude and phase. The radiation pattern of 4x8 elements is shown in fig 7. From fig 7 we can see that the peak gain is 15dB while the 3dB beamwidth is 55^o in the region -27$^o \leq \Theta \leq$ 28^o.

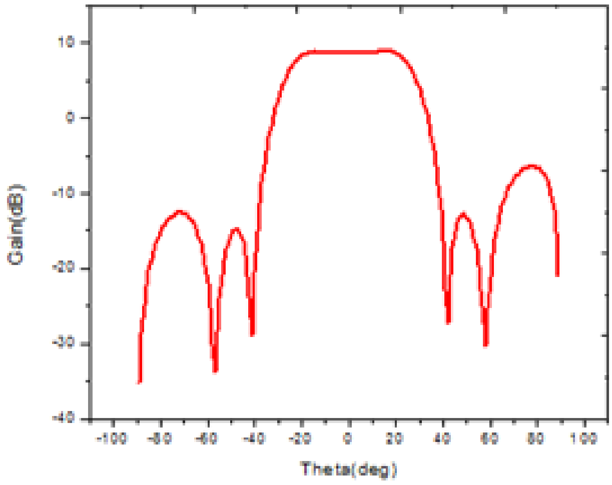

Fig 6: Gain Of 1x8 Element With Unequal Amplitude

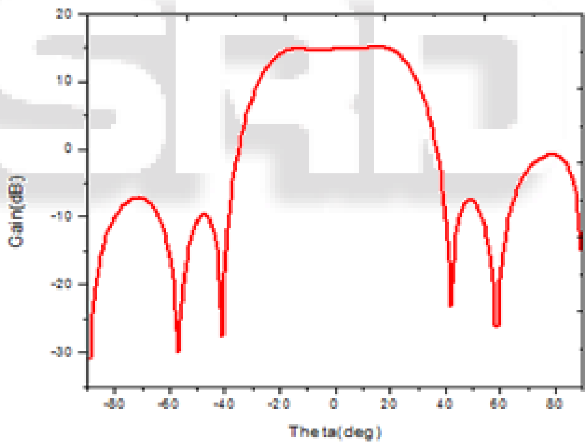

Fig 7: Gain Of 4x8 Element

V. CONCLUSION

In this paper, an array of 4x8 of proximity fed coupled MSA uniformly spaced linear Array using Ansoft Designer Software is synthesized to generate the flat-top radiation pattern by optimizing the excitation coefficients in desired zone. The proposed antenna array is optimized by Null perturbation Technique using MATLAB. The measured radiation patterns show a flat-top shaped-beam region covering $-27^\circ \sim 28^\circ$ and with gain of 15dB with bandwidth of 120MHz at 2.211GHz.

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