S-Band Non-uniformly distributed Slotted waveguide linear & planar array antenna with enhanced sidelobe level (Travelling wave type)

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***Abstract*– This paper describes the design and development of non-uniform slotted waveguide linear and planar array (SWA) antenna in s-band. Linear array produces fan beam narrow in azimuth and wide in elevation, while planar array produces narrow beam in both azimuth and elevation. Conventional SWA antenna offers high sidelobe level, which can be enhanced, theoretically down to (-40) dB, using chebyshev distribution technique which redistribute the slots around the center of one column by transforming the weights of Chebyshev numbers into dimensions by using certain equations.**

We discuss the concept to achieve low sidelobe level of SWA antennas, design, development, and characterization of edge fed slotted waveguide linear array antenna in s-band, and high efficiency broadband slotted waveguide array. The developed SWA antennas are characterized and their measured results are presented. The developed prototype of proposed SWA antenna demonstrates measured sidelobe level better than -28 dB over. Planar array SWA is also introduced producing narrow beam

Keywords—[SWA], slotted waveguide antenna, linear array antenna, planar antenna, low side lobelevel

I. INTRODUCTION

slotted waveguide antennas [SWA] are ideal solutions for many applications such as many radars, communications, and high-power microwave applications due to Geometric simplicity, efficiency, polarization purity, conformal installation, and ability to radiate broadside beams and vertically polarized E-plane beams at very near grazing angle above a ground plane [1-4]. A waveguide is a very low loss transmission line. It allows to propagate signals to a number of smaller antennas (slots). Each of these slots allows a little of the energy to radiate. Slot impedance and resonant behavior for a single slot are dependent on slot placement and size. The process to determine the locations of individual slots along a waveguide to create a desired aperture excitation is an iterative one [4-6].

chebyshev distribution technique is used. slots of traveling-wave arrays are spaced by one-half waveguide wavelength. WR-284 (7.214 cm × 3.404 cm in cross section) waveguide has been selected and the design of broadband SWA has been carried out at 3.275 GHz center frequency. Design and demonstration of SWA with conventional feeding techniques, i.e., edge feeding.

For the planar antenna columns are spaced by more than one-half waveguide length and less than waveguide length to avoid coupling. In the next chapters, conventional design of slotted waveguide antennas in s-band, non-uniformly spaced elements design technique, comparison between uniform linear array and non-uniform linear array in s-band and finally planar array design in s-band.

II. SUBARRAY: CONVENTIONAL DESIGN TECHNIQUES FOR SLOTTED WAVEGUIDE ANTENNA IN S-BAND

Inter-element slot spacing is selected to be close to one-half waveguide wavelength (lamg /2). Therefore, the polarity of adjacent slots is of the opposite sense. For example, adjacent longitudinal shunt slots are on opposite sides of the guide centerline, and adjacent edge-wall shunt slots are inclined to opposite sides of the vertical centerline. The alternating displacement or rotation with respect to the waveguide axis of successive slots may produce grating lobes. If the main beam of the traveling-wave slotted array is pointing far away from broadside, the upcoming grating lobe level may exceed the desired sidelobe level. The grating lobes can be pushed out of the visible array space by choosing a suitable inter-element spacing. There are two types of traveling-wave slot-antenna arrays: (1) the uniformly spaced element array that produces a low-sidelobe pencil beam and (2) the non-uniformly spaced element.

For the number of slots, when it's further increased, the reactive part of admittance starts to destabilize near zero and eventually provides strong resonant behavior 16 slots has been chosen as optimum number.

GUI matlab has been developed to calculate all dimensions according to frequency and number of slots based on the following equations;

$$G2\_slot = \frac{1}{Nslots}$$

$$New_{G1} = 2.09\left(\frac{lam_{guide}}{lam_{zero}}\right)\left(\frac{WG_a}{WG_b}\right)\left(\frac{cmath.\cos\left(\frac{0.464 * PI * lam_{zero}}{lam_{guide}}\right) - }{cmath.\cos(.464 * pi)}\right) ** 2$$

$$New\_Y = \frac{G\_2\_slot}{New\_G1}$$

$$slot\ offeset = \frac{WG_a}{PI}\left(\sqrt{|(cmath.asin(New_Y)|}\right)$$

$$Slot\ Lengh = .210324 * G_{2_{slot}} ** 4 - 0.338065 * G_{2_{slot}} ** 3 + 0.12712 * G\_2\_slot ** 2 + 0.034433 * G\_2\_slot + 0.48253$$

$$Slot\ width = \frac{WG\_a * 0.0625}{0.9}$$

This applies uniformly distributed slotted waveguide linear array antenna that has measured parameters using CST software showing reflection coefficient and farfeild in both azimuth and elevation**, as shown in the following figures**.

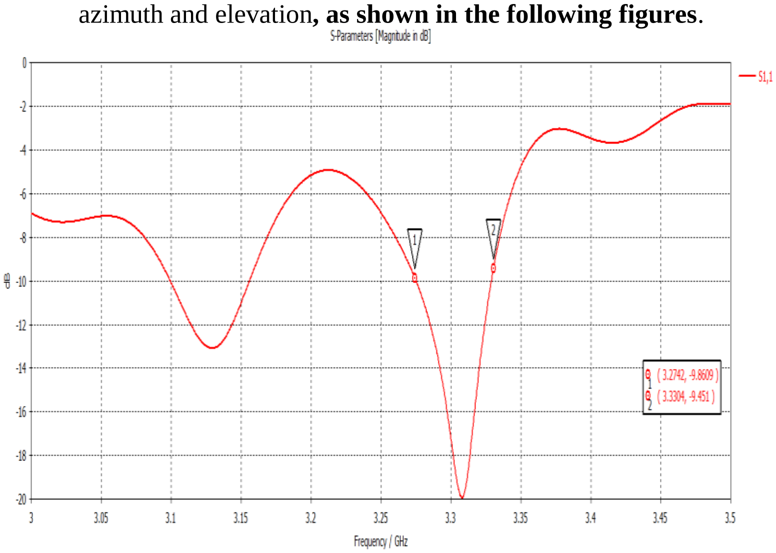

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Figure1, reflection coefficient

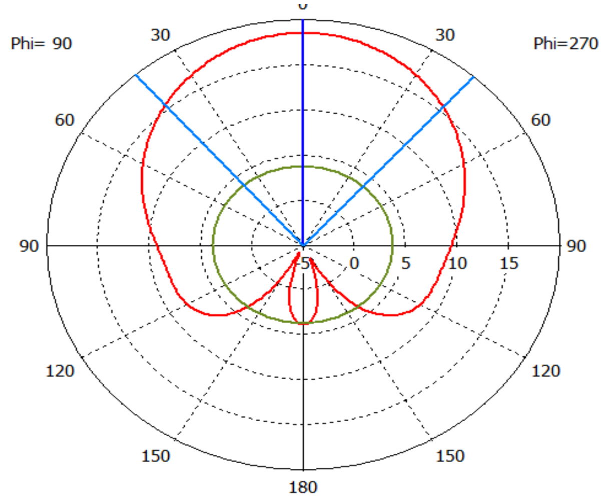


figure 2, farfeild pattern in elevation

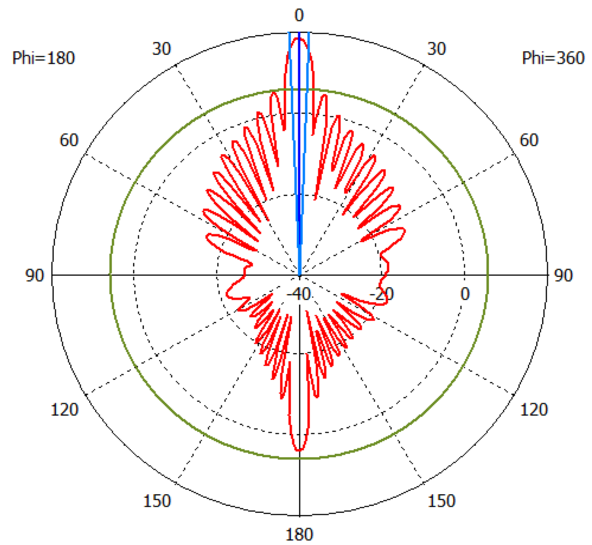
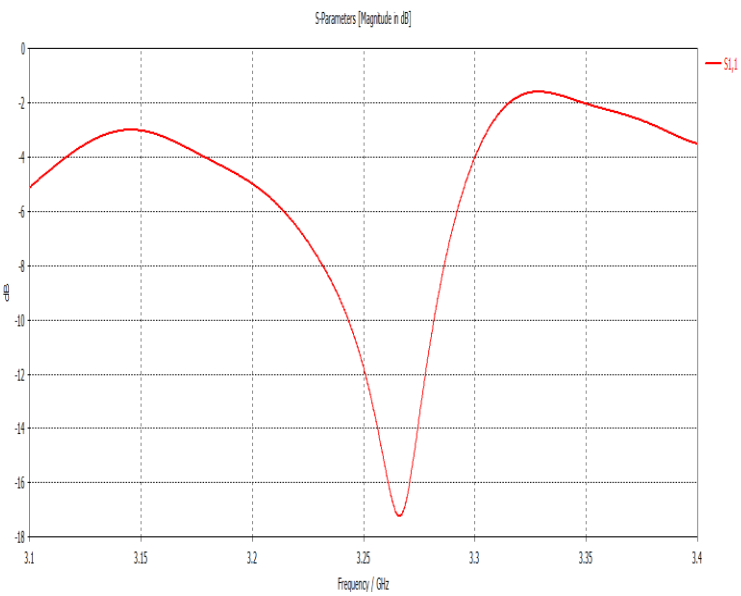


figure 3, farfeild pattern in azimuth

III. nonuniformly spaced element for the number of slots

Some special applications, such as in air traffic control, need the shaped beam to scan over a sector. The aperture illumination of a shaped beam requires, in general, both amplitude and phase variations across the aperture. Therefore, it is desirable to know whether and how a linear slot array can produce a shaped beam. This requires nonuniformly spaced element. Moreover, nonuniformly spaced elements reduce sidelobe level. Non-uniform techniques redistribute slots around the centre of one column with different dimensions.

There are many distribution techniques that can be used such as Binomial distribution, Butterworth and Chebyshev. Each distribution technique has its privilege. Choosing which technique is trade-off between beam width and sidelobe level. Chebyshev distribution technique has been chosen since it's optimum solution. GUI MATLAB has been performed to



transform Chebyshev weights into dimensions around the centre of one column, the expected sidelobe level -40 dB. Measured sidelobe level is -28 dB. measured parameters of nonuniform design using CST software simulation, noticed that great enhancement in sidelobe level has been achieved, are **as shown in the following figures.**

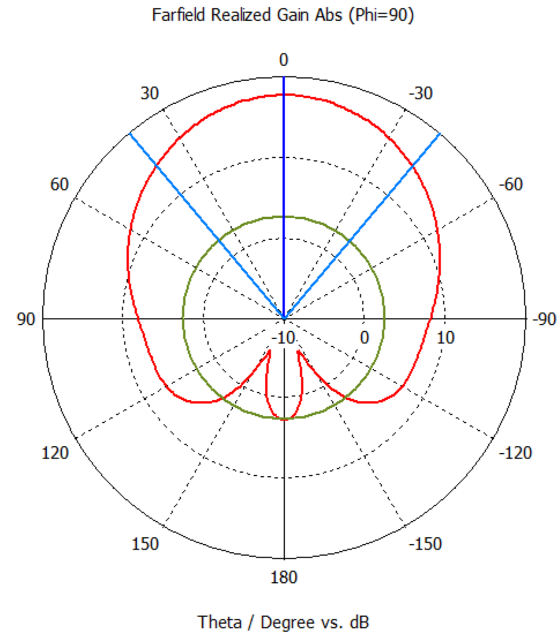


Figure4, reflection coefficient

Figure5. farfeild pattern in elevation

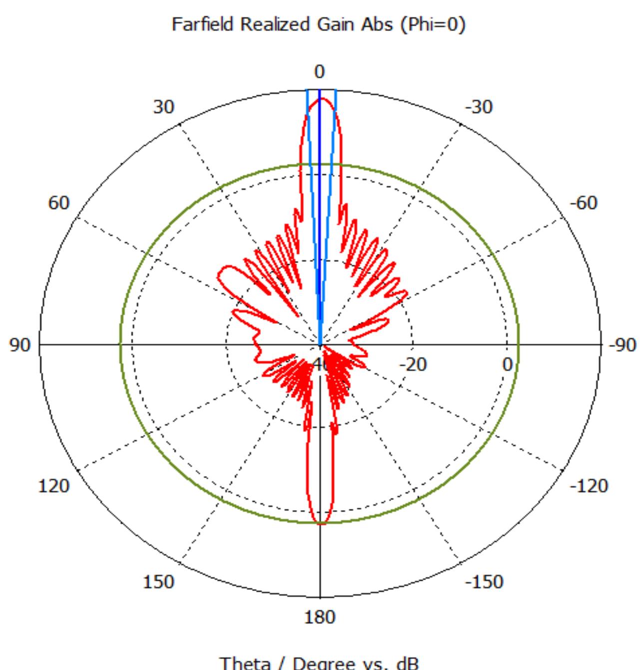
Figure6. farfeild pattern in azimuth

IV. COMPARISON BETWEEN UNIFORMLY DISTRIBUTED AND NONUNIFORMLY DISTRIBUTED DESIGN

From the simulated designs for both uniform and non-uniform design, it's noticed that sidelobe level has been greatly enhanced in the non-uniform design but this enhancement is on the count of azimuth angle and reflection coefficient has increased 2 dB

The following table shows the numeric comparison between uniform and non-uniform designs, based on simulated designs using CST simulation software.

Type size (pts.)	Difference between uniform design and nonuniform design		
	P.O. V	Uniform design	Nonuniform design
1	Reflection coefficient on resonant frequency	-20 dB	-17 dB
2	Sidelobe level	-14 dB	-28 dB
9	Azimuth angle	4.7°	6.1°
10	Elevation angle	82.3°	79.6°



NOTE: THESE RESULTS GIVEN A FAN BEAM SO, WE WILL ENHANCE THE DESIGN TO BE NARROW IN ELEVATION & AZIMUTH, THAT ACHIEVED BY PLANAR ARRAY DESIGN IN THE NEXT CHAPTER.

V. PLANAR ARRAY DESIGN OF SLOTTED WAVEGUIDE ANTENNA IN S-BAND

In this design we must take in our calculations the spaces between columns to avoid the coupling between them to ACHIEVE INSTRUCTIVE interference which the spaces more than one-half waveguide length and less than one waveguide length. the planar array design in our case 30 columns are chosen to achieve the required directivity. that calculated by next laws:

$$D = 3600\lambda \div (\theta 1d * \theta 2d)$$

$$n = 2N(d/\lambda)$$

that achieved a great development in the elevation to get narrow beam as shown in the next Figueres that simulated CST SOFTWARE:

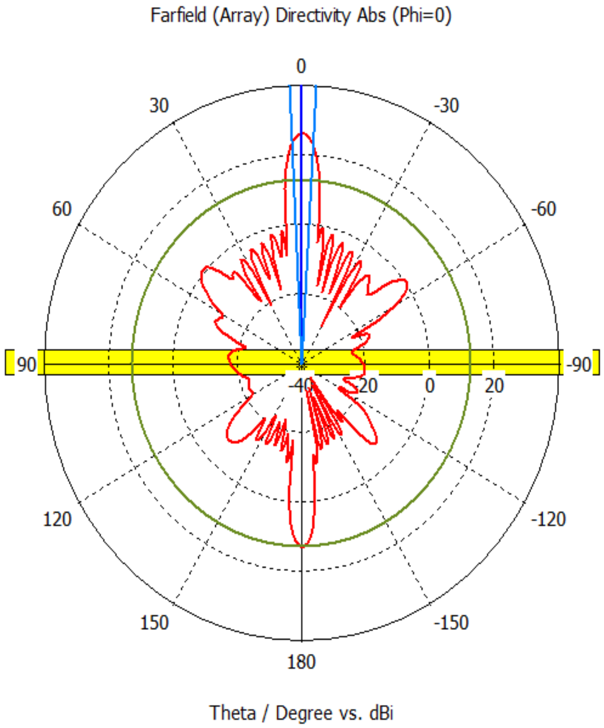


FIGURE 7: FARFIELD PATTERN IN THE ELEVATION

VI. CONCLUSION

In this chapter, high efficiency 16-element linear SWA integrated with nonuniform distributed slots discussed in detail and also compared with uniformly distributed SWAs. The chebyshev distribution technique has been proposed to reduce the high sidelobe level of conventional SWAs excited with edge feeding and. Mathematical justification of design dimensions has been presented and validated. 16-element linear SWAs employed with edge feeding have designed and simulated. The simulated results are also compared to validate the proposed advantages of uniform design. About -28 dB return sidelobe level has been achieved using chebyshev technique. Planar array with 30 columns design has been proposed to develop the HPBW in the elevation to get a narrow beam instead of fan beam in non-uniform design to enhance the directivity.

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