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Performamance Analysis of Slotted Waveguide Antenna for High Power Microwave Applications

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ABSTRACT

Slotted-waveguide antenna arrays find wide applications in communication and radar systems that require narrow beam or shaped-beam radiation patterns, especially when high power, light weight, and limited scanned areas are priorities. Placement of slots in waveguide plays a crucial role for shaping side lobes with desired values. An iterative procedure for calculating the placements of slot positions of slotted-waveguide array, which consists of an arbitrary number of slots, is presented in this paper. The offsets of the slots' positions with respect to the waveguide centerline, which determine the side lobe level, were then obtained from well-known mathematical distributions like Chebyshev, Taylor, Binomial are presented. And the results are simulated in HFSS software.

Keyword: slotted waveguide antenna(SWA) array, side lobe level(SLL)

1. INTRODUCTION

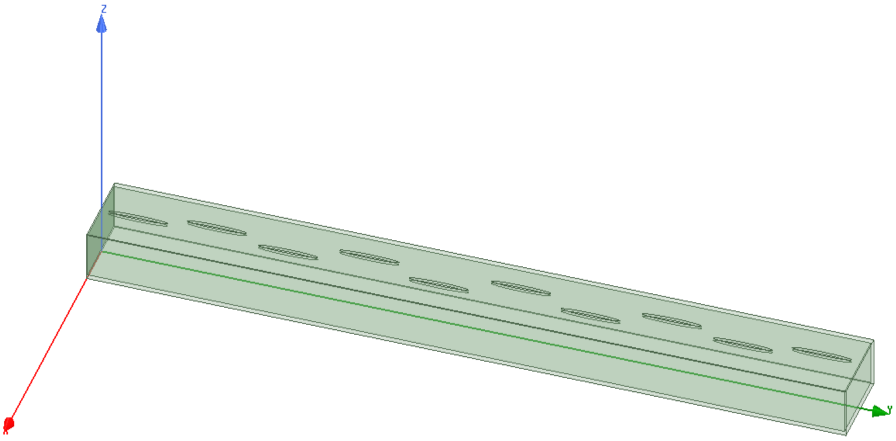
Waveguides are useful for guiding the wave in a particular direction. Mainly used structures to guide the wave are rectangular waveguides and circular waveguides. Antenna arrays are used for high directivity. In radar systems, slotted waveguide antennas are widely used for their lightweight structure, high power, high efficiency, and good reflection coefficient. In rectangular waveguides, slots are made on the broad side of the waveguide to radiate. This avoids the separate inclusion of radiating elements in the structure. Hence, they became the best solutions for radar communications, high power microwave applications [1]. Slots' positions from the center line of the waveguide decides the side lobe level of the radiation pattern.

In [1], the theory of slots offsets is discussed and describes how the resonant frequency depends on the slot offset which depends on the conductance. In [2], the design equations are developed for rectangular slots and various equations are derived for slotted waveguide antenna array. In [3], Elliptical slots specifications are discussed.In [4] for planar structure Taylor distributions coefficients are discussed and variation β with number of slots are given.

2.Design aspects of slotted waveguide antenna array

An S-band WR-284 waveguide with dimensions of waveguide width 72.136 mm and height of 34.798 mm is utilized for the design's illustrations. It's operating frequency ranges from 2.6 Ghz to 3.9 Ghz. In the given design, 3 GHz frequency is the target for the illustration. Ten elliptical slots are made on one broadside wall. At one end, the waveguide is fed, while at the other, it is shorted. Center of elliptical Slot 1 is placed at distance of $\lambda_g/4$, or $3\lambda_g/4$ from the feeding edge of the waveguide. Last elliptical slot is placed at $\lambda_g/4$, or $3\lambda_g/4$ from the short-circuited edge of the waveguide. The distance between each elliptical slot from center to center is $\lambda_g/2$. An example of such Slotted waveguide is as shown in Figure 1.

Figure 1: Slotted waveguide antenna



Usually, the length of rectangular slots is $0.98 \times \lambda_0/2$. Since the elliptical slots narrows the edges, so the length will be slightly greater than $\lambda_0/2$. The length of the elliptical slot is optimized to resonate at 3 Ghz. The elliptical slot length is found to be 54.25 mm. Each elliptical slot has a set width of 5 mm, which is equal to 2 times the minor radius of the ellipse. Ten elliptical slots are made on broad wall side of the antenna.

3. **Non-Uniform displacement calculation procedure**

Non uniform distances from the center line of the waveguide are calculated using the equations [1] and [2] using python.

$$d_n = \frac{a}{\pi} \sin^{-1}\left(\sqrt{\frac{gn}{2.09 \times \frac{\lambda_g}{\lambda_0} \times \frac{a}{b} \times \cos^2\left(\frac{\pi \lambda_0}{2 \lambda_g}\right)}} \right) \qquad 1$$

$$gn = \frac{c_n}{\sum_{n=1}^{N} c_n} \qquad 2$$

3.1 Taylor distribution coefficients

Adopting the N-point Kaiser window coefficients and using the current magnitudes of an N element linear array with symmetric excitations, the equation of the currents is given by equation 3

$$a_m = \begin{cases} I_0\left[\beta\sqrt{1-\left(\frac{m-0.5}{M-0.5}\right)^2}\right], \text{for } N = \text{even} \\ I_0\left[\beta\sqrt{1-\left(\frac{m-1}{M-1}\right)^2}\right], \text{for } N = \text{odd} \end{cases} \qquad 3$$

where:
$1 \leq m \leq M$
$I_0(.)$ represents the zeroth-order modified Bessel function of the first kind
β is the parameter that affects the side lobe level of the Fourier transform of the window.
m represents iteration number
M represents final slot

a_1 is the excitation of the array's center element(s), and a_M is that of the two edge elements. β is the crucial parameter that controls the side lobe level. When β is taken as 3.36, -20dB Taylor coefficients and corresponding slots displacements leading to a slot waveguide antenna side lobe level of -20dB is achieved. And when β is taken as 5.36, -30dB Taylor coefficients and corresponding slots displacements leading a slot waveguide antenna side lobe level of -30dB is achieved.

3.2 Binomial distribution coefficients

Although it is not directly possible to use a binomial distribution to control the SLL, it is interesting to use the coefficients from a Binomial distribution and observe the resulting SWA SLL. The binomial coefficients are obtained from the binomial expansion using the equation 4.

$$(1+x)^n = 1 + \frac{nx}{1!} + \frac{n(n-1)x^2}{2!} \qquad 4$$

4.Results

As discussed in section 2, slots displacements are calculated for 10 slots.

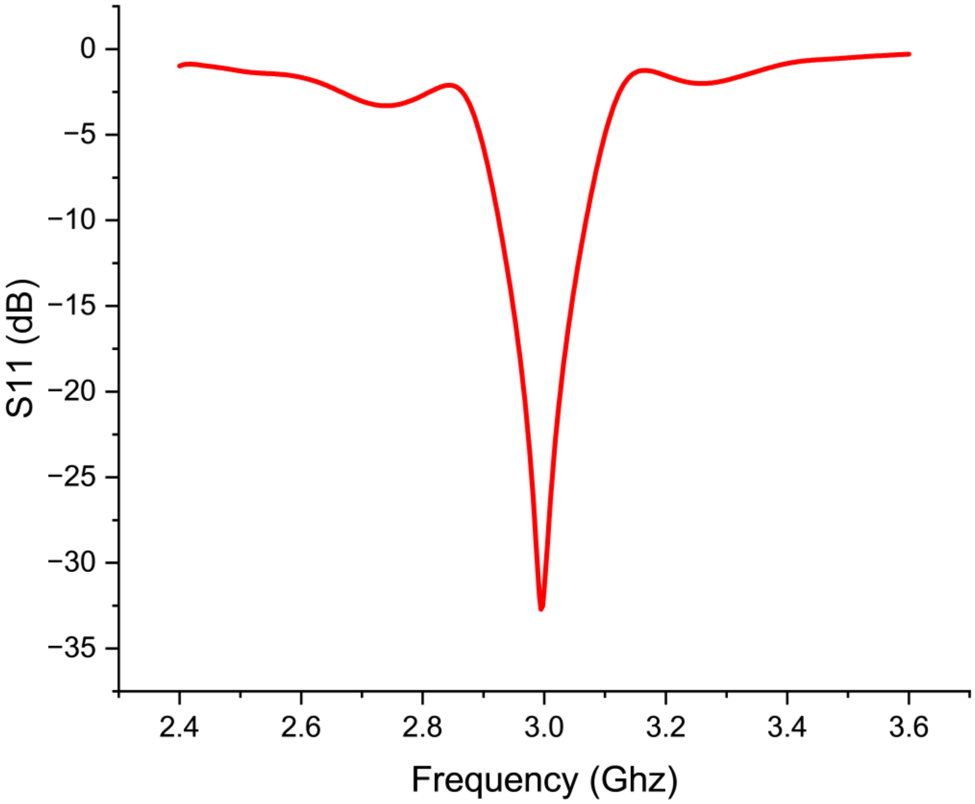
4.1 Binomial

Binomial Coeffcients are generated using the eqauation

Table 1: Binomial coefficients and its displacements

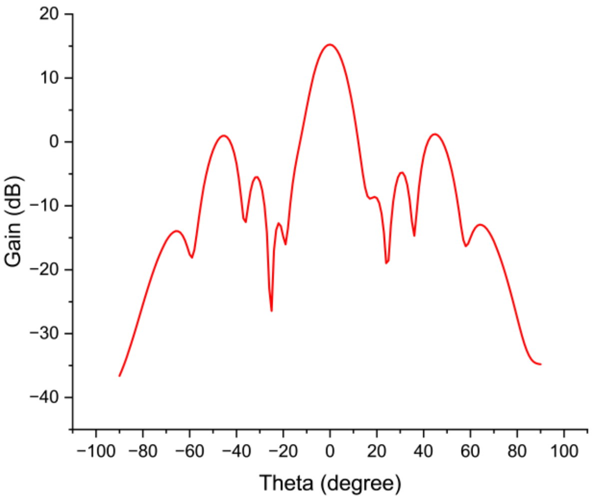
Slot number	Binomial coefficients	Displacements
1	1	0.980
2	9	2.947
3	36	5.943
4	84	9.224
5	126	11.466
6	126	11.466
7	84	9.224
8	36	5.943
9	9	2.947
10	1	0.980

Figure 2**:** Reflection coefficient of the antenna using Binomial distribution



From the obtained values in table-1, rectangular waveguide is designed in with the dimensions as discussed in section 2. This binomial distribution slots make the antenna to resonate at 3 Ghz with reflection coefficient of-32.71dB as shown in Figure 2.

Figure 3:Binomial distribution gain



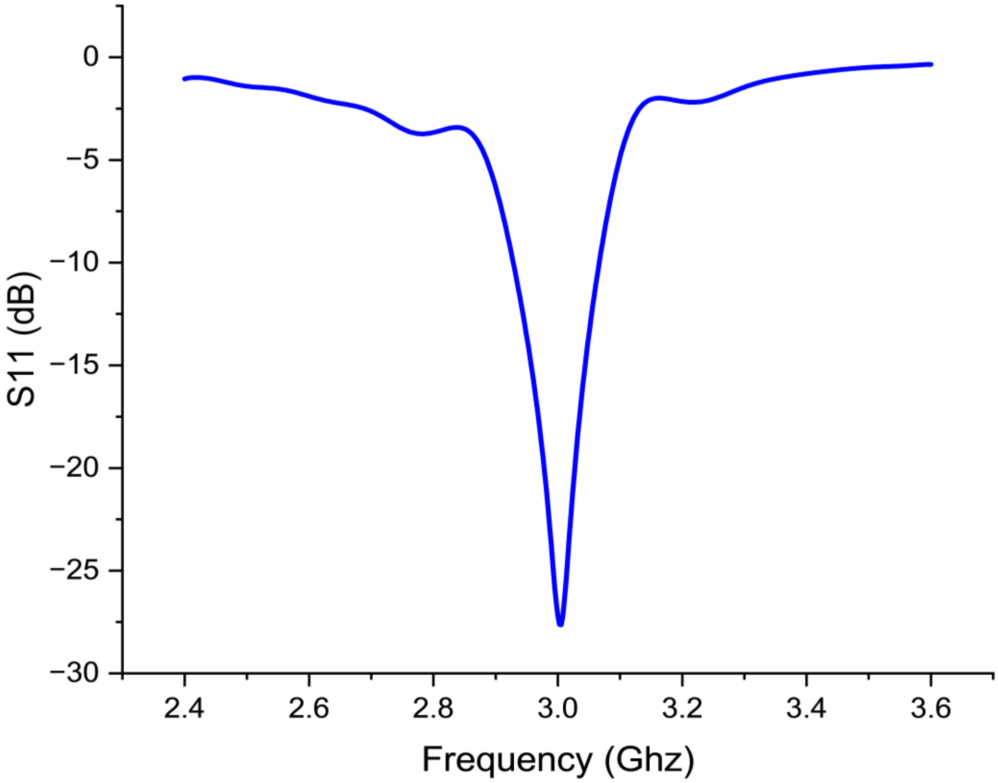
Using the Binomial distribution, peak gain is attained at 15.24 dB as shown in Figure 3. And the SLL is measured as -24.025 dB. Since the displacements are symmetrical, the gain pattern is also symmetrical as the slot radiation is directly depending on conductance(which is directly propotional to slot displacement).

4.2 -20dB Taylor distribution

Table 2: -20dB Taylor coefficients and displacements

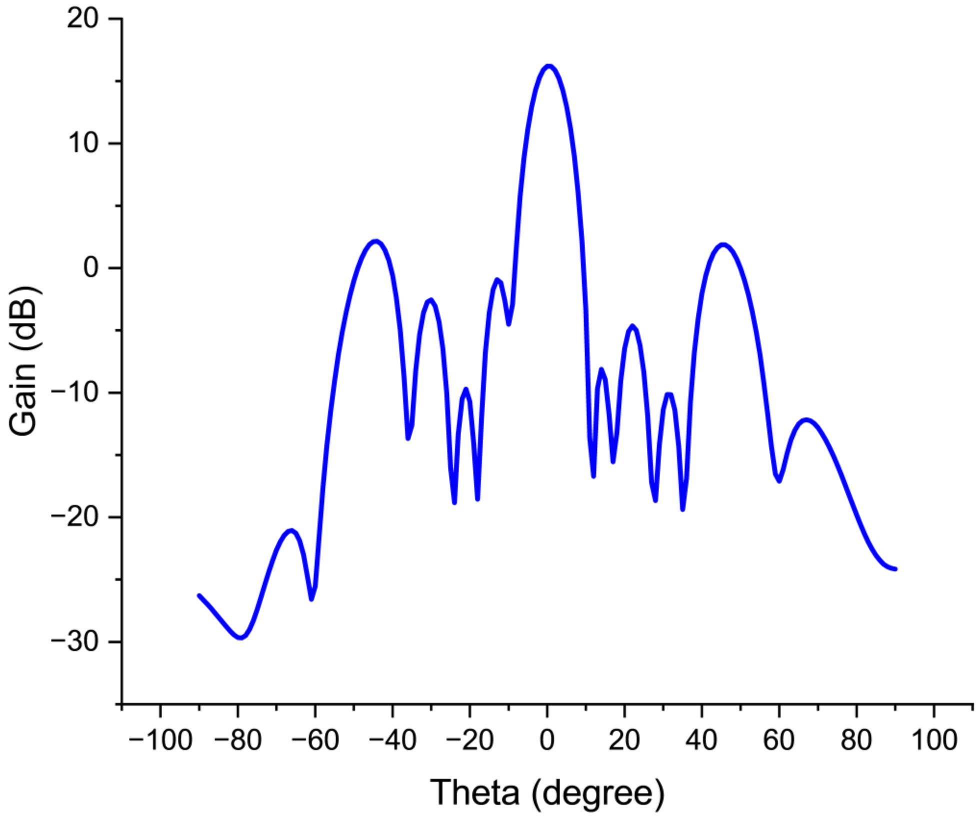
Slot number	Coefficients	Displacements
1	1	3.550
2	2.467	5.609
3	4.137	7.314
4	5.598	8.562
5	6.449	9.225
6	6.449	9.225
7	5.597	8.562
8	4.137	7.314
9	2.467	5.609
10	1	3.550

Figure 4: Reflection coefficient of -20dB Taylor



For the displacements generated in Table-2, waveguide is designed in HFSS software and the reflection coefficient can be observed in Figure 4, it is resonating at 3Ghz with -17.13dB.

Figure 5: -20dB Taylor distribution gain



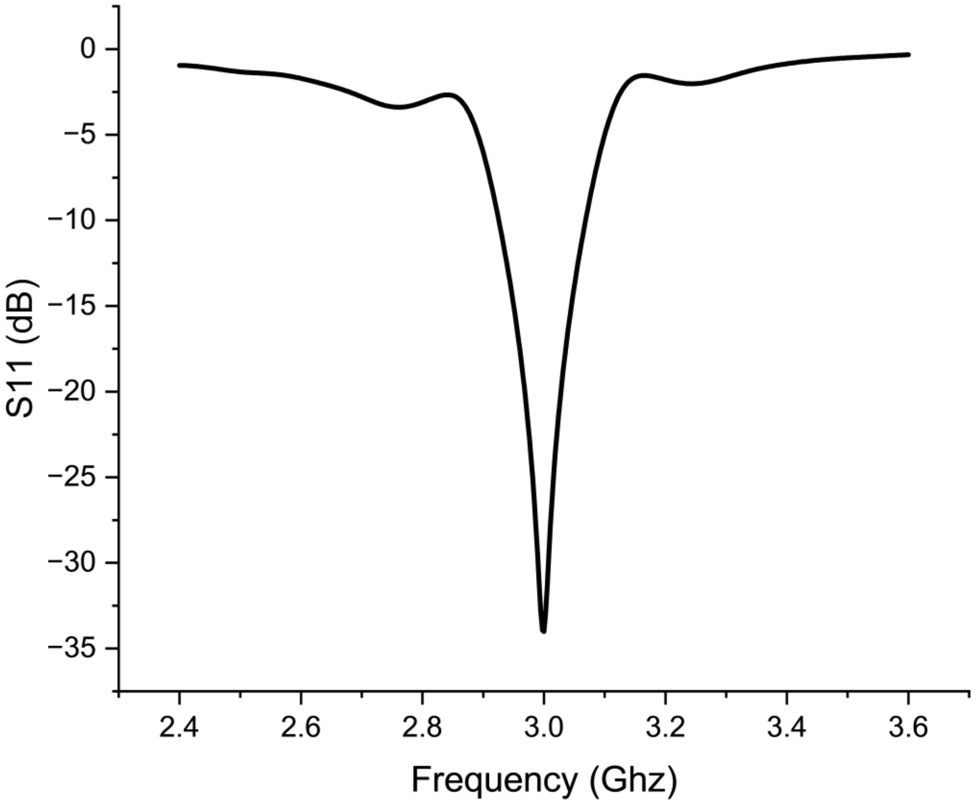
For -20dB Taylor distribution peak gain is attained at 16.202dB.The Figure 5 shows the gain. The side lobe level is -17.13dB where the expected value is -20dB.

4.3 -30dB Taylor distribution

Table 3: -30dB Taylor coefficients and displacements

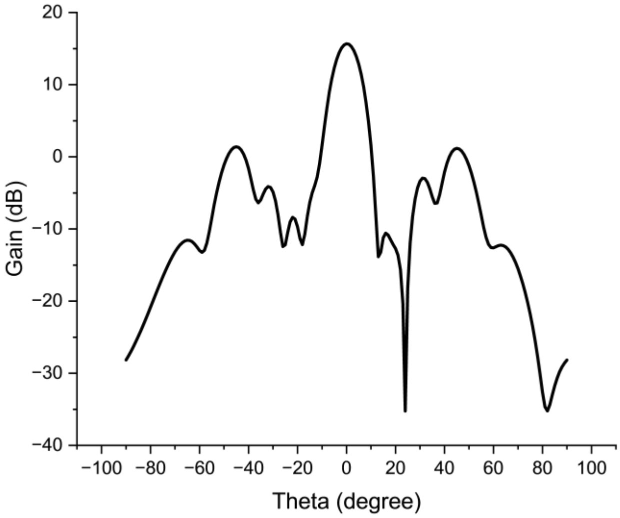
Slot number	Coefficients	Displacements
1	1	1.658
2	6.611	4.284
3	16.828	6.898
4	24.573	9.090
5	36.519	10.357
6	36.519	10.357
7	28.573	9.090
8	16.828	6.898
9	6.611	4.284
10	1	1.658

Figure 6**:** Reflection coefficient of -30dB Taylor distribution



For the values generated in table 3. Rectangular waveguide is designed and it is resonated at 3Ghz with -34.01dB. The Figure 6 gives the graph between reflection coefficient vs Frequency.

Figure 7 : -30dB taylor distribution gain



Peak gain attained at 15.669dB with side lobe level of -24.064dB.But the expected SLL is -30dB.

5.CONCLUSIONS

In this paper, python program is written to find displacements from the center line of slotted antenna array waveguide. With the generated values rectangular waveguide is designed in HFSS. All the distributions are resonated at 3Ghz. It is observed that Binomial distribution SLL is not controllable. Taylor ditributions diplacements are designed for 2 SLLs. Uniform Slot displacements achieve results of reflection coefficient of -13 dB. In this nonuniform cases, the reflection coefficients obtained are -24 dB, -17dB and -24dB.

REFERENCES

1. R. S. Elliott and L. A. Kurtz, "The design of small slot arrays", IEEE Trans. Antennas Propagation., vol. AP-26, pp. 214-219, Mar. 1978
2. R. Elliott, "An improved design procedure for small arrays of shunt slots", IEEE Trans. Antennas Propagate., Vol 31, 48-53, January 1983
3. Hilal M. El Misilmani, Mohammed Al- Husseini and Karim Y Kabalan, “Design of slotted waveguide antennas with low side lobes for high power microwave applications, Progress in Electromagnetics Research C, Vol 56, 15-28, 2015
4. Kabalan, K. Y., A. El-Hajj, and M. Al-Husseini, “The bessel planar arrays,” Radio Science, Vol. 39, No. 1, RS1005, January 2004
5. Jacob C. Coetzee, Johan Joubert, Derek A. McNamara, “Off-Center-Frequency Analysis of a Complete Planar Slotted-Waveguide Array Consisting of Subarrays”, IEEE Transactions on antennas and propagation, Vol. 48, NO. 11, November 2000