EEE 452 - Individual Project - Report 1

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Introduction

Slotted waveguide antennas are antennas manufactured by cutting slots on the surface of the waveguide. In this report, we will focus solely on longitudinal slots on the broad wall of the waveguide. When the waveguide is operating in TE_{10} mode, the individual radiation of each slot can be controlled by adjusting its offset from the center of the broadwall. This principle allows for flexibility in each slot's radiation, resulting in a flexible, non-uniform array-like antenna. Therefore, using slotted waveguide antennas, one can achieve low SLL levels.

For this project, our objective was to design an antenna with an SLL of less than 30dB, featuring 8 slots, at X-band (10 GHz was chosen).

Design Principles

Firstly, we need to decide on the excitations of each slot. To determine this, we need to compare different distributions and their performances in terms of directivity and SLL. In Table 1, we can observe various distributions and their corresponding properties.

Distribution	Mainlobe Width	SLL as $N \to \infty$
Rectangular	7	-13.4
Taylor	9	-30.34
Chebyshev (-100)	15	-100
Blackman	13	-58.23
Hamming	11	-44.75
Kaiser(4)	9	-30.11
Taylor(4,-35)	9	-35.22

The Taylor distribution satisfies the SLL requirement while also featuring a small mainlobe width. Therefore, we will implement a Taylor distribution. Taylor distributions can be modified with two parameters, which determine SLL and the taper of the sidelobes. For N = 8, we may not reach the limit; hence, we will use a Taylor distribution with SLL << -30. Then we need to calculate the offset of each slot from the middle of the broadwall to get the desired excitations for each slot. To do so, we will use the following formulas from Top[1]:

$$\bar{H} = -A_{10}\frac{\beta_{10}a}{\pi}\sin\left(\frac{\pi x}{a}\right)e^{j\beta_{10}z}\hat{a}_x + jA_{10}\cos\left(\frac{\pi x}{a}\right)e^{-j\beta_{10}z}\hat{a}_y$$

$$\bar{J}_s = \hat{a}_n \times \bar{H} \text{ where } \hat{a}_n = \hat{a}_y \Rightarrow \bar{J}_s = -A_{10}\frac{\beta_{10}a}{\pi}\sin\left(\frac{\pi x}{a}\right)e^{j\beta_{10}z}\hat{a}_z$$

We can infer that the excitation of each slot is proportional to $\sin(\pi x/a)$. Calculating the offsets as a normalised ratio is sufficient, as the absolute values will be calculated later.

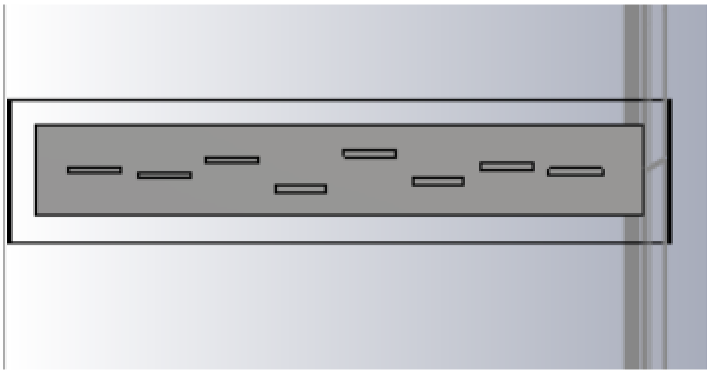

Figure 1: Non-Uniform Offset Slots on the Waveguide

Finally, taking the standardized values for slot lengths and widths, the distance between slots, and the waveguide ports from Top[1], and using a WR-90 waveguide with dimensions $a = 22.86$mm, $b = 10.16$mm, we can implement the antenna in CST.

Design of the Antenna in CST

We haven't calculated the impedance at all in this discussion. We will tune the values using CST's optimiser. The pattern and related values are related to the ratio of the excitations of the slots, not their absolute values. The impedance is therefore related to the absolute values. We can optimize the excitations while keeping the ratio fixed to match the antenna at 10 GHz. This process gives us the offsets.

Results of the Antenna

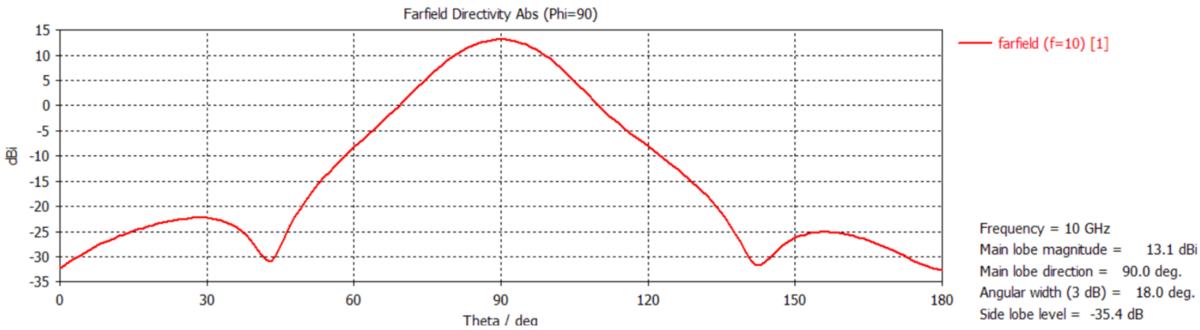

Figure 2: xy Plane Pattern

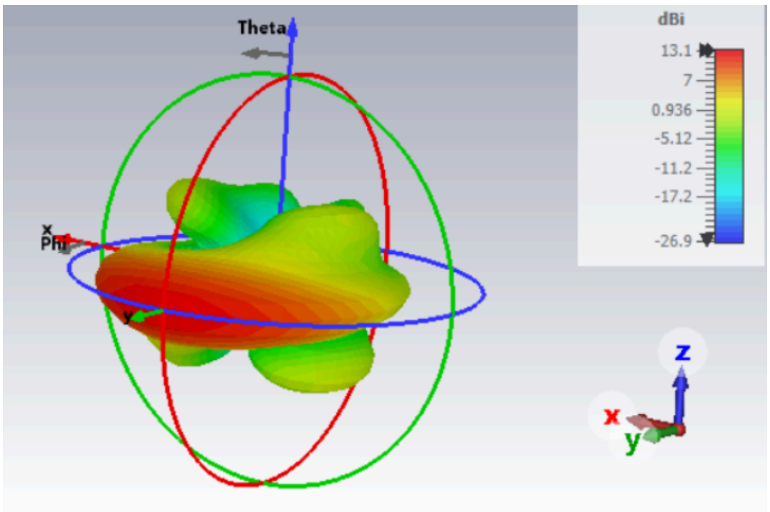

Figure 3: 3-D Pattern

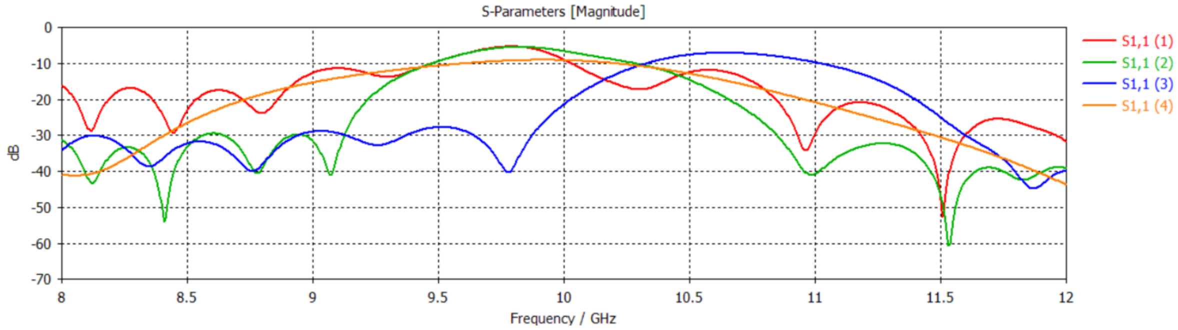

Figure 4: S_{11} Results (Blue is Final)

Antenna Dimensions

a	= 22.86+2*h	25.86	broadwall dimension
b	= 10.16+2*h	13.16	narrow wall dimension
d_1	= 0.26	0.26	d_of_slot1
d_2	= -1.23	-1.23	d of slot2
d_3	= 3.13	3.13	d_of_slot3
d_4	= -5.03	-5.03	d_of_slot_4
d_5	= 5.03	5.03	d_of_slot5
d_6	= -3.13	-3.13	d_of_slot6
d_7	= 1.23	1.23	d_of_slot7
d_8	= -0.26	-0.26	d_of_slot8
g_wavelength	= 1.323*lambda	39.69	guided wavelength inside waveguide
h	= 1.5	1.5	waveguide thickness
input_port_margin	= 0.5*g_wavelength	19.845	margin between first slot and input port
lambda	= 30	30	lambda at 10GHz
length_wg	= input_port_margin+g_wavelength*seperation*7+output_port_margin+(ls8/2)	176.3175	waveguide length
ls	= 0.495*lambda	14.85	length of slots
ls5	= 0.491*lambda	14.73	length of 5&4th slots
ls6	= 0.496*lambda	14.88	length of 6&3th slots
ls7	= 0.502*lambda	15.06	length of 7&2th slots
ls8	= 0.509*lambda	15.27	length of 8&1th slots
output_port_margin	= 0.25*g_wavelength	9.9225	margin between last slot and matched port
position_1	= input_port_margin	19.845	position of 1st slot along z
position_2	= input_port_margin+g_wavelength*seperation	39.69	position of 2nd slot along z
position_3	= input_port_margin+g_wavelength*seperation*2	59.535	position of 3rd slot along z
position_4	= input_port_margin+g_wavelength*seperation*3	79.38	position of 4th slot along z
position_5	= input_port_margin+g_wavelength*seperation*4	99.225	position of 5th slot along z
position_6	= input_port_margin+g_wavelength*seperation*5	119.07	position of 6th slot along z
position_7	= input_port_margin+g_wavelength*seperation*6	138.915	position of 7th slot along z
position_8	= input_port_margin+g_wavelength*seperation*7	158.76	position of 8th slot along z
seperation	= 0.50	0.50	seperation of slots in terms of g_wavelength
ws	= g_wavelength*0.05	1.9845	width of slots

Figure 5: CST Parameters

References

[1] C. B. Top, “Design of a slotted waveguide array antenna and its feed system,” M.S. thesis, Dept. Electr. Electron. Eng., Middle East Technical Univ., Ankara, Turkey, Sep. 2006.