X-band Slotted Waveguide Antenna

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***Abstract*—A planar slot array antenna of 12x16 elements is designed at X-band with uniform aperture distribution to get maximum aperture efficiency. The antenna is centre fed from iris coupling slot with alternate slot inclinations to feed the radiating waveguides in phase. A feeding network of non-standard waveguides is formed to couple the power from feeding network to radiating aperture. A radiating aperture also of non-standard size is selected to give the low profile antenna at 9.65GHz. The longitudinal shunt slots are used with alternate offsets directions to radiate in phase at boresight.**

***Index Terms*—Longitudinal shunt slot,series inclined slot, uniform aperture illumination,aperture efficiency.**

I. Introduction

A resonant slotted waveguide antenna is presented with a feeding network. An extensive study on slot antennas has been given in [1], [2] for slot array design antennas. A number of slot types can be used as radiators like longitudinal offset slots in broad wall(shunt), inclined slots in broad wall(series) and inclined slots on narrow wall (shunt). The slots in the waveguide disturb the current along the waveguide and as a result radiate.The slot array has a feeding network structure under the radiating layer in case of a centre fed case. In end fed case the slots are fed from the start of the waveguide. A longitudinal slot is a shunt slot and for shunt elements the admittance is matched to the characteristic admittance of the waveguide. We have a 12 waveguide slot array with 16 elements in each waveguide. The structure is shown in Fig 1.

II. Feeding Network

The feeding network is a series feeding network and the coupling coefficient of each slot is different. The coupling of waveguide (6,7) is minimum as it is the first in line and as the power in feeding line decreases the coupling increases to keep the effective power in radiating apertures equal. The coupling coefficient is calculated as

$$\eta = \frac{1/N}{1-(\frac{n-1}{N})} \tag{1}$$

where n=1..N and N=6. The coupling in dB of slots 6-1 is given in TableI. The coupling of slots 7-12 is same as 6-1. Last slot of power feeding network has minimum power available and it couples 100% power. As the coupling slots are series slots the distance between the centre of last slot and the waveguide short is $\lambda_g/2$. For uniform aperture distribution the amplitude and phase of the slots has to be similar. The amplitude and phase matching of the feeding network is shown in the Fig 2 and Fig 3 which show that the amplitude is almost equal at 9.65GHz and phase is also matched at 9.65GHz. The feeding network can perform at frequency band of 9.5-9.8GHz with amplitude mismatch of $\pm$ 0.7 dB and phase mismatch of $\pm 15^o$. The coupling of slot#5 is shown in Fig 4. The slot also has an iris which helps in maintaining equal phase at output of waveguide. Fig 4 also shows the power coupled at slot#5 is 6.9dB same as required from TableI. Similarly all slots are designed for coupling mentioned in TableI. The e-fields in feeding network are shown in Fig 5

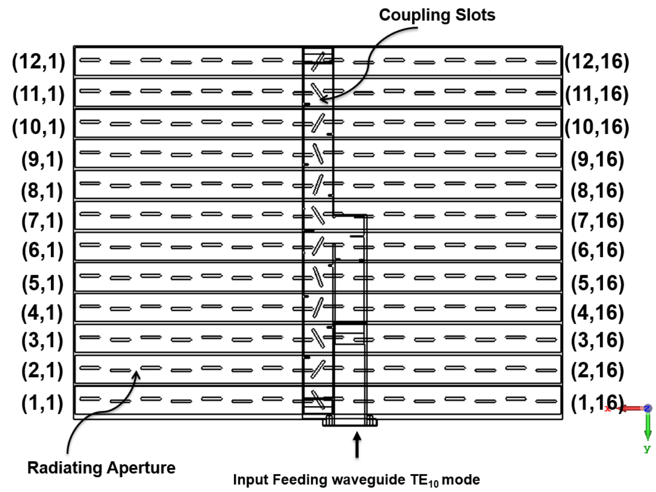

Fig. 1. Antenna Array and feeding network

TABLE I
Coupling Power divider

Slot No	Coupling	Coupling dB
Slot#6	16.667%	-7.7806dB
Slot#5	20%	-6.9897dB
Slot#4	25%	-6.0206dB
Slot#3	33.33%	-4.07712dB
Slot#2	50%	-3.0103dB
Slot#1	100%	0dB

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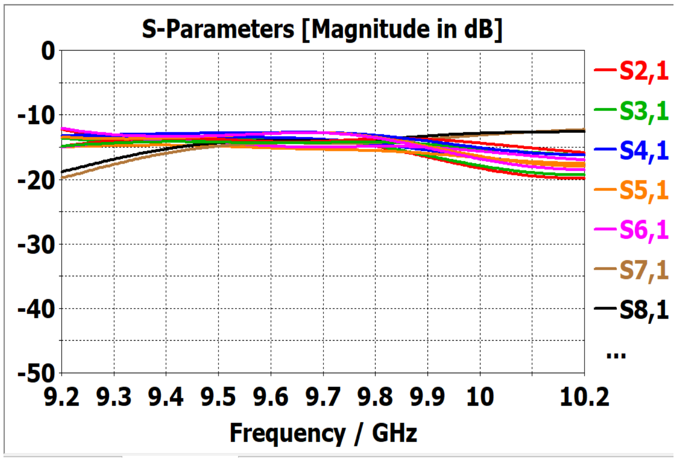

Fig. 2. Equal amplitude power divider @ 9.65GHz.

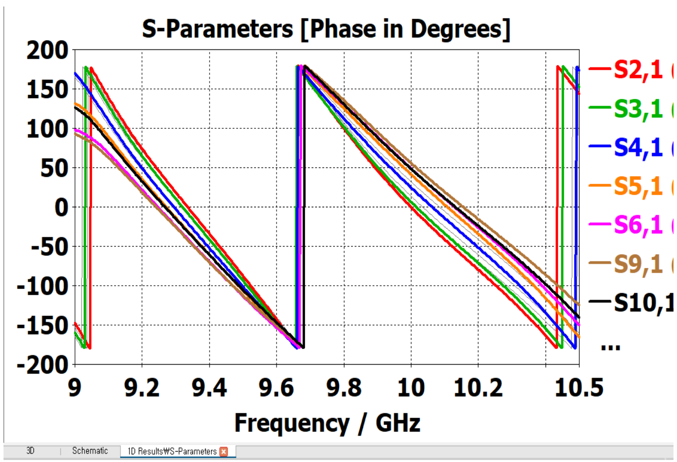

Fig. 3. Equal phase power divider @ 9.65GHz.

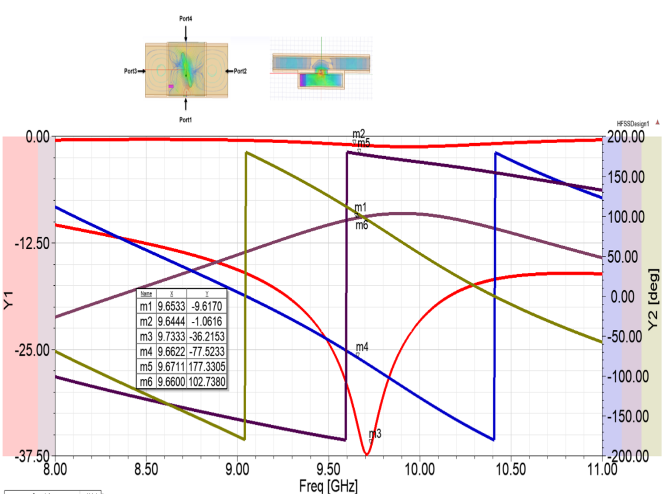

Fig. 4. Coupling response of slot# 5.

III. Radiating Aperture

The total slots in a radiating waveguide is 16. Each slot is separated by a distance of $\lambda_g/2$ and the spacing between

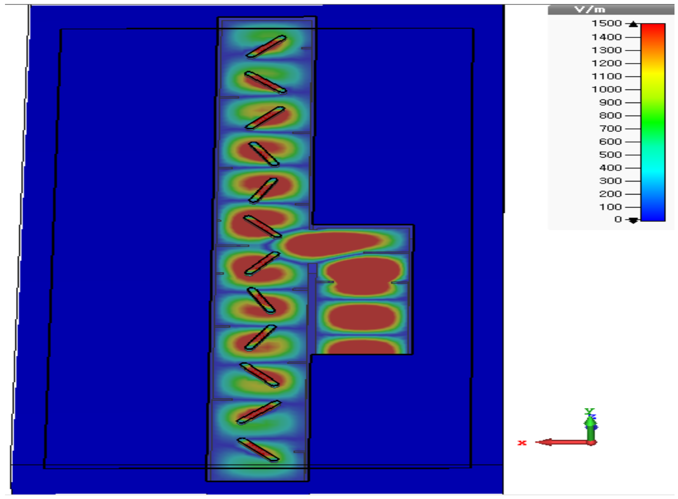

Fig. 5. Absolute Electric field plot in power divider.

last slot and wavegiude short is $\lambda_g/4$. The feeding waveguide couples the power to radiating waveguide and the length of radiating waveguide is made to produce standing waves in them. In small arrays design procedure given by Elliot in [1] is helpful as it measures the mutual coupling of each slot and then iteratively the offsets of each slot are determined for a given normalised conductance.In a large array it is cumbersome to use formulation in [1] however an infinite array approach given in [3] and [4] is used to find longitudinal slot resonant lengths and offsets. A pair of slots is used in boundary conditions and active S-parameters of a slot is used to find its admittance and eventually conductance and susceptance by

$$y = \frac{-2\Gamma}{1+\Gamma} \tag{2}$$

The real part of admittance gives the conductance and imaginary part gives susceptance of a longitudinal shunt slot. The resonant lengths are calculated at each offset. This data set gives the mutual coupling adjusted admittance and it can be directly used in the design of an array. For 9.65GHz and a=21mm and b=5 mm the slot curves for conductance vs resonant length are given in Fig 6 while curve for susceptance vs resonant length is given in Fig 7. From Fig 6 and Fig 7 it can be seen that the conductance increases as the slot offset increases and at maximum conductance the slot susceptance is 0 indicating a resonant condition. Similarly the resonant conductance vs the slot offset are shown in Fig 8.

$$end \quad fed \quad case \qquad \sum_{n=1}^{N} g_n = 1 \tag{3}$$

$$centre \quad fed \quad case \qquad \sum_{n=1}^{N} g_n = 2 \tag{4}$$

The conductance sum for end fed and centre fed case are given in (3) and (4). We will use (4) as we have centre fed feeding network. The conductance of each slot comes out to

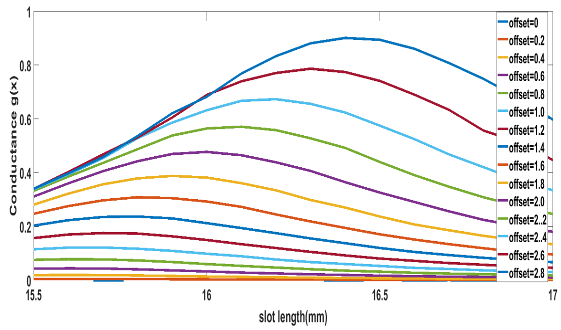

Fig. 6. Conductance of slot with PBC.

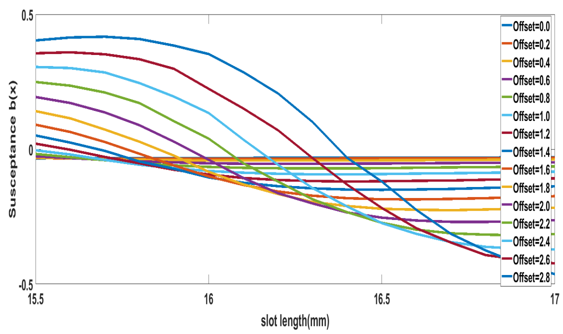

Fig. 7. Susceptance of slot with PBC.

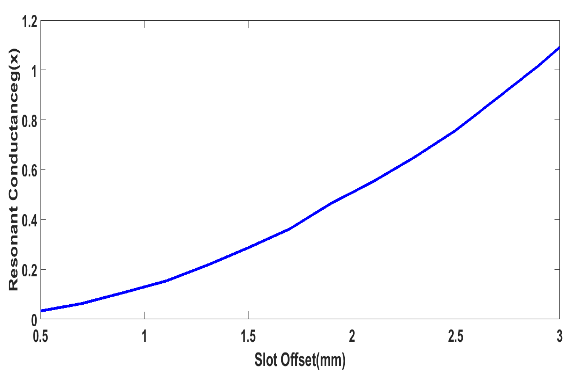

Fig. 8. Normalised admittance of slot vs offset.

be 2/16=0.125. The slot offset that gives 0.125 conductance is 0.95mm. Resonant slot of offset 0.95 is taken from the slot characterisations. The measured slot offsets and lengths are used in radiating aperture. The slot voltages are observed and the fields on each slot is shown in Fig 9a where it can be seen that they are excited in phase and with equal amplitude. Fig 9b shows the return loss S_{11} of the antenna system while Fig 9c &Fig 9d show the E-plane and H-plane radiation pattern of the antenna. The side lobe level can be observed as 13dB indicating a uniform aperture distribution and maximum aperture efficiency.

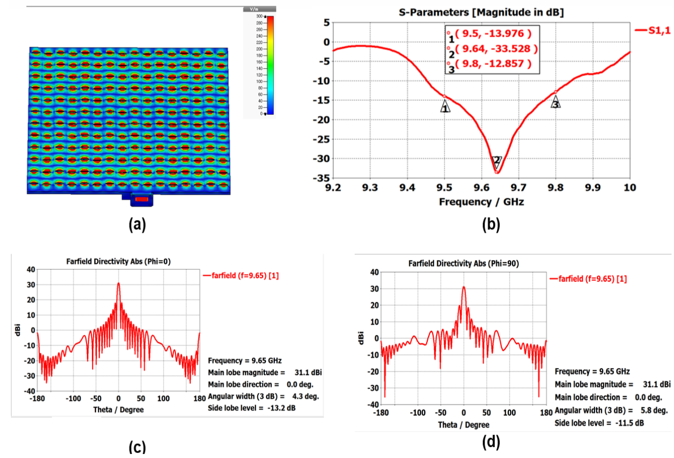

Fig. 9. Complete antenna with feeding network

IV. Conclusion

Fig 9 shows the simulated results of complete antenna system with feeding network. An infinite antenna array approach has been used to design the planar array with an equal power feeding network. A slot pair was characterised with periodic boundaries and the results were used to design the uniform aperture antenna with maximum gain and narrow beamwidth. The interface of the feeding network is standard WR-90 however the internal dimensions are changed to match the radiating waveguide dimension for slot spacing in feeding network. Commercial EM software HFSS and CST were used in simulation of the array design.

References

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