Design of Longitudinal Coupling Slots with Matching Walls for a Rectangular Parallel Plate Slot Array Antenna

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Abstract – **A waveguide feeder with longitudinal coupling slots is proposed for a rectangular parallel plate slot array antenna. Compared to conventional inclined slots, longitudinal slots are used for minimizing vibration of field distribution in the parallel plates. Coupling slots with matching walls of the feeder network are designed by HFSS. The simulated results show that a reflection less than -16dB can be achieved. An in-phase uniform excitation can be achieved in each slot.**

***Keywords* — Slot array antenna, parallel plates, waveguide feeder, coupling slots**

I. INTRODUCTION

A rectangular parallel plate slot array antenna with a traveling-wave feeder beneath was proposed [1]. The structure is attractive for millimeter-wave applications due to its lightweight and high efficiency. In [2], a waveguide feeder with center-inclined coupling slots and reflection-canceling walls was designed by the method of moments (MoM) with fast speed. However, it would cause a large vibration of both phase and amplitude field distributions in the parallel plates by using tilted slots. This is undesired because a uniform field distribution is needed for achieving high antenna efficiency. A novel feeder with longitudinal coupling slots is proposed. This paper aims to show the process of the coupling slot design by HFSS.

II. ANTENNA STRUCTURE AND PRINCIPLE

Fig.1 shows the antenna structure with the new feeder network. The antenna aims to operate at the center frequency of 9.65 GHz with 300MHz bandwidth in X band. The antenna panel is truncated by hard walls at the edges for achieving TEM wave propagation. The waveguide feeder with coupling slots is installed underneath the parallel plates. The τ-junction locates in the center of the antenna panel and functions as a power divider with 1:1 division ratio. A TE_{10} mode traveling wave from the antenna input couples with the parallel plates through the coupling slots. Instead of using inclined slots in [2], longitudinal coupling slots cut along the center of the waveguide broad wall are employed for reducing vibration of field distribution in the parallel plates. However, in this case, the presence of the slot causes no disturbance on the current distribution of the waveguide, and no coupling occurs. Hence a coupling wall for achieving the desired coupling amount and an inductive wall for reflection-canceling are introduced corresponding to each slot, which are together termed as matching walls. Adjacent coupling slots are placed spacing around half guided wavelength ($\lambda_g/2$) to feed the parallel plates in phase. The coupled waves then propagate in both $+y$ and $-y$ directions in the parallel plates and radiate through horizontal radiating slot pairs.

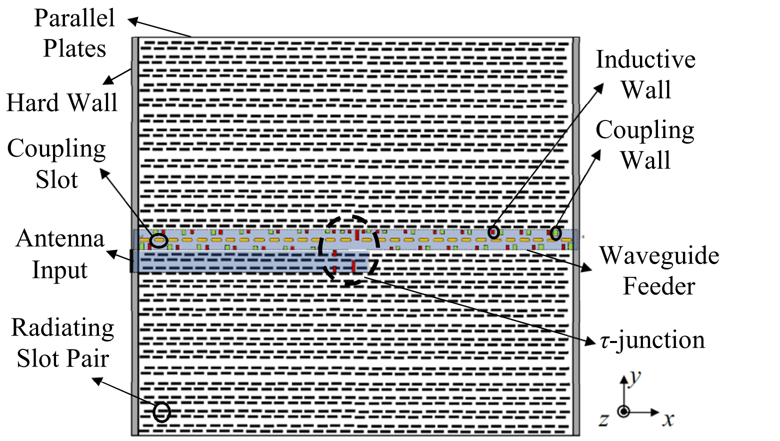


Fig. 1. Antenna Structure

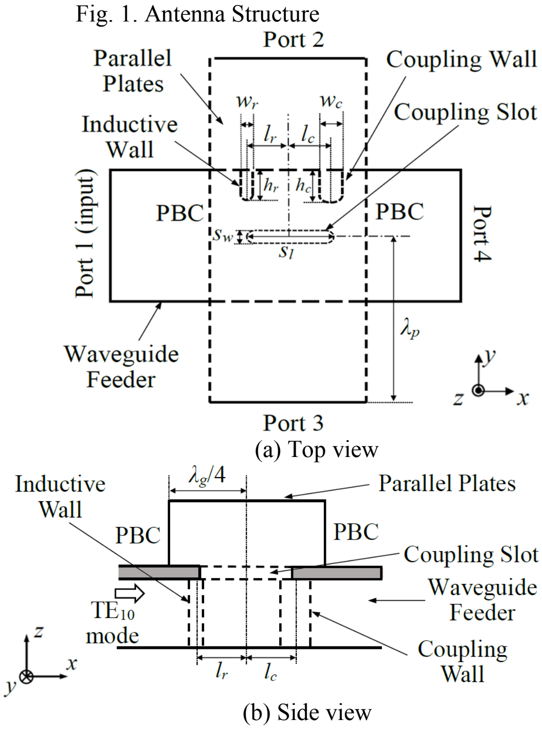


Fig. 2. HFSS design model for a single coupling slot

III. DESIGN FOR THE COUPLING SLOT

The feeder consists of $2N$ coupling slots with N slots on each side of the τ-junction, where N=15. The array from the slot number n=1 to n=N-1 is symmetric with respect to the τ-junction, where n is numbered from the shorted

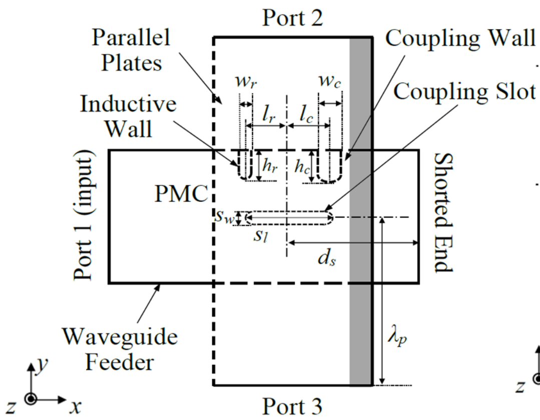


Fig. 3. HFSS design model for slot 1 with 100% coupling

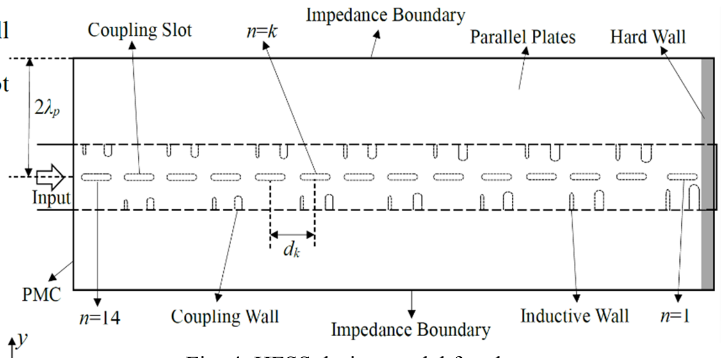


Fig. 4. HFSS design model for slot array

end of the waveguide feeder. The design aims to suppress reflection in the waveguide and achieve uniform field distribution in the parallel plate region.

A. Design of Individual Slots

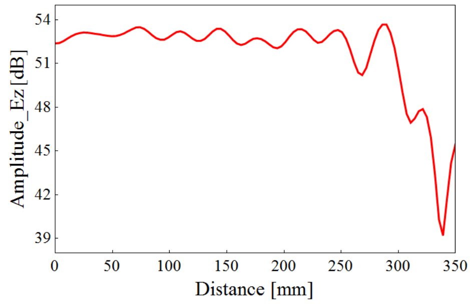
Fig. 2. shows both the top and side views of the HFSS design model for a single coupling slot with a coupling factor of less than 100%. Periodic boundary conditions (PBC) in the side walls are introduced in the parallel plate region for including external mutual coupling effect among the coupling slots. Port 1 and port 2 are the feeder input port and outport port, respectively. Port 3 and port 4 are defined as outputs of the PBC waveguide. Each slot is associated with two matching walls for achieving certain coupling and reflection canceling. The round-ended coupling slot with the width s_w=2 mm and the inductive wall with the width w_r=1mm are applied in the model. A uniform power should be transmitted throughout each coupling slot for exciting the parallel plate region uniformly. Therefore, the required coupling factor for each slot is $1/n$. The model should be used for designing such that $|S_{31}|^2 = |S_{41}|^2 = 1/(2n)$ since the coupled power travels in both directions in the parallel plates. A coupling wall with a wide width is needed for slots with large coupling. All slots are designed such that the reflection (S_{11}) less than -30dB over the operation bandwidth can be achieved. For slot 1 at the edge with 100% coupling, the design model in Fig. 3. is applied. The hard wall and the shorted end are taken into consideration and perfect magnetic boundary condition in the left side wall is introduced. The reflection is below −25dB over the bandwidth after the design.

B. Design of Slot Array

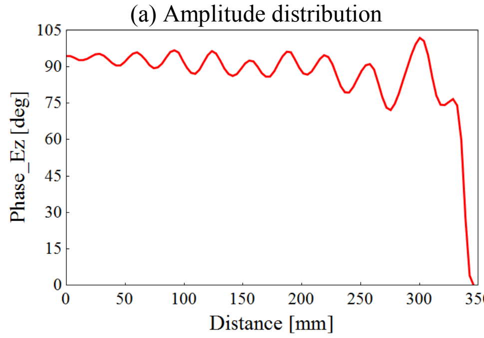
Fig. 4. shows the design model of slot array from n=1 to n= 14. Only the half part of the structure is shown due to the symmetry. The presence of the coupling slot and the matching walls lead to a phase progression $\angle S_{21}$ in the single slot model (Fig.2). To achieve in-phase excitation through all the slots, the distance d_k between the centers of the adjacent coupling slots (n=k and n=k+1) is adjusted from k=13 to k=1 by the following,

$$d_k = \frac{\lambda_g}{2} + \left(\angle S_{21,k} + \angle S_{31,k\text{-}1} - \angle S_{31,k}\right)\cdot\frac{\lambda_g}{2\pi}, \quad 1 \le k \le 13 \tag{1}$$

where phase values $\angle S_{21,k,}$ and $\angle S_{31,k}$ can be obtained from the design procedure in the last section. The procedure lasts



(a) Amplitude distribution



(b) Phase distribution

Fig. 5. Field distribution of E_z in parallel plates

for more than one iteration due to the mutual coupling effect. The reflection is below -17dB in the operation bandwidth. Fig. 5 shows the amplitude and the phase variation of E_z as a function of distance in the x direction in the center of the parallel plates. Maximum vibration of 4dB on the amplitude and 25 degrees on the phase profile are observed. However, there is a large drop near the position of the slot n=1 and n=2, which will be solved in the future work by increasing the coupling of the slot n=2 properly.

IV. CONCLUSION

The longitudinal coupling slots with matching walls for the waveguide feeder have been designed by HFSS. The simulated results have shown that the reflection below -17dB can be achieved in the target bandwidth for the slot array. There is only small vibration on the field distribution in the parallel plates after optimization.

REFERENCES

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