Bandwidth Characteristics of Waveguide-Fed Planar Slot Arrays

***Sembiam R. Rengarajan*[1], *Sayan Chatterjee*[2]**

[1]Department of Electrical and Computer Engineering, California State University, Northridge, CA 91330 USA
srengarajan@csun.edu

[2]Sameer-Kolkata Centre, Salt Lake Electronics Complex, Plot-L2, Block-GP, Sec V, Kolkata-700091, India
sayan1234@gmail.com

Abstract

In this work we investigated the bandwidth characteristics of waveguide-fed planar slot arrays. Elliott's technique was used to design a number of end-fed and center-fed planar arrays with different aperture distributions and different amounts overloading in terms of conductances of radiating slots and resistances of coupling slots. Subsequently these arrays were analyzed by employing a full wave method of moments to solve for the coupled integral equations for the slot aperture electric field. Results of a study of radiation pattern and return loss as a function of frequency for different amounts of overloading are presented.

1. Introduction

Waveguide-fed planar slot arrays are increasingly used in many spacecraft applications because of their high efficiency and ease of manufacture and deployment. Accurate design techniques [1, 2] incorporating external and internal mutual coupling have been employed. The development of full wave analysis techniques based on method of moments solutions of the coupled integral equations for the slot aperture electric field have been helpful in validating, improving and optimization of the design process [3]. Since slot arrays generally have limited bandwidth because of the use of resonant elements and the standing wave type design, knowledge of the effect of overloading on impedance and pattern bandwidth is important. Derneryd and Petersson presented results of their analysis on bandwidth characteristics of slot arrays [4]. They used a simplified transmission line model with constant loads. In this paper we study the bandwidth characteristics of planar slot arrays using full wave analysis models.

Figures 1 and 2 show end-fed and center-fed configurations of slot arrays considered in this paper respectively. The end-fed case consists of two layers. In the top layer radiating longitudinal slots are cut in the broad walls of radiating rectangular waveguides. In the lower layer, there are centered-inclined coupling slots cut in the common broad walls of the radiating waveguides and the orthogonal feed waveguide. The feed port is at one end of the feed waveguide while the other end is shorted. The center-fed configuration has three layers, the lowest one containing an input shunt series coupling slot cut in the common broad wall of the input waveguide that is orthogonal to the feed waveguide. The feed port is at one end of the input waveguide whereas the other end is shorted.

2. Methodology

In order to design the 6x6 slot arrays shown in Figs. 1 and 2 we first generated slot data for coupling and radiating slots using the moment method solutions to the pertinent integral equations for the slot aperture electric field. Scattering data thus generated are used in the design procedure [1, 2] to obtain the slot lengths, offset or tilt to yield the specified aperture distribution and an input match. The total slot conductance in each radiating waveguide was varied in different designs. In the center-fed case the total resistance in the feed guide was also varied as a parameter. The full wave analysis technique [3] was used to study the bandwidth performance of the return loss and pattern characteristics, especially the sidelobe level. The analysis computer program is based on the method of moments solution to the coupled integral equations for the slot aperture electric field. There are two apertures for each thick slot and therefore the total number of coupled integral equations is twice the number of slots, radiating, coupling and input (for the center-fed) slots. Once the slot aperture electric field distribution is known, the radiation pattern and the return loss data are easily obtained. The return loss bandwidth is assumed to be the frequency range where the return loss is better than 10 dB.

3. Numerical Results and Discussion

Tables 1 and 2 show the analysis results for two end-fed designs with different aperture distributions. In case 1 the sidelobe level is in the order of 20 dB whereas in the second case it is in the high thirties. The center frequency of design is 9.3 GHz. Half height rectangular waveguides were used for the design. At the lower and upper end of the frequencies the return loss is 10 dB. The computed values of the directivity and the largest sidelobe level in the elevation and azimuth planes are also displayed in dB scale. Larger conductance values provide greater amounts of return loss bandwidth with greater sidelobe level degradation. A conductance value of 2.0 is found to be a good compromise for optimum values of return loss bandwidth as well as pattern bandwidth.

Table 1 End-fed array characteristics (case 1)

Total Conductance	Lower end of the band				Center				Upper end of the band			
	F	Dir	SLL (Az)	SLL (EL)	F	Dir	SLL (Az)	SLL (EL)	F	Dir	SLL (Az)	SLL (EL)
1.0	9.14	22.89	20.16	20.86	9.3	23.06	20.61	20.03	9.43	23.13	20.18	19.47
1.5	9.1	22.87	20.16	20.62	9.3	23.08	20.69	20.09	9.46	23.15	20.34	19.15
2.0	9.09	22.88	20.4	20.34	9.3	23.09	20.79	20.18	9.46	23.15	20.73	19.34
2.5	9.1	22.89	20.78	20.19	9.3	23.08	20.96	20.33	9.45	23.14	21.14	19.62
3.0	9.1	22.87	21.1	20.39	9.3	23.08	21.02	20.58	9.44	23.11	21.45	20.21
3.5	9.1	22.87	21.39	20.6	9.3	23.07	21.11	20.85	9.41	23.08	21.61	20.39

Table 2 End-fed array characteristics (case 2)

Total Conductance	Lower end of the band				Center				Upper end of the band			
	F	Dir	SLL (Az)	SLL (EL)	F	Dir	SLL (Az)	SLL (EL)	F	Dir	SLL (Az)	SLL (EL)
1.0	9.14	21.54	36.04	40.74	9.3	21.79	37.93	39.23	9.43	21.94	34.53	37.19
1.5	9.11	21.55	36.02	37.23	9.3	21.80	37.36	39.98	9.46	21.96	34.22	37.09
2.0	9.09	21.59	36.17	35.04	9.3	21.81	37.54	40.71	9.47	21.97	36.49	37.71
2.5	9.1	21.64	37.14	31.87	9.3	21.81	37.81	41.97	9.45	21.93	37.00	39.35
3.0	9.1	21.67	37.39	30.99	9.3	21.81	38.36	42.07	9.44	21.90	36.38	41.34

Tables 3 and 4 present results for the center-fed array geometry for the two cases corresponding to those in Tables 1 and 2. The total radiating slot conductance value is chosen to be 2.0 in this case. The sum of the normalized resistances of the coupling slots is varied between 1.0 and 3.5. Larger values of resistance provide greater amounts of return loss bandwidth. However the sidelobe level degradation in the elevation plane is greater, especially for case 2 (lower sidelobe level design) for increased values of resistance.

Table 3 Center-fed array characteristics (case1)

Total resistance	Lower end of the band				Center				Upper end of the band			
	F	Dir	SLL (Az)	SLL (EL)	F	Dir	SLL (Az)	SLL (EL)	F	Dir	SLL (Az)	SLL (EL)
1.0	9.18	23.07	20.7	19.02	9.3	23.14	20.76	20	9.41	23.21	20.9	19.66
1.5	9.14	23.07	20.63	18.22	9.3	23.14	20.76	19.98	9.45	23.25	20.75	19.4
2.0	9.12	23.07	20.58	17.8	9.3	23.14	20.77	19.93	9.48	23.29	20.55	19.08
2.5	9.11	23.06	20.52	17.61	9.3	23.13	20.78	19.89	9.5	23.31	20.26	18.81
3.0	9.11	23.06	20.52	17.61	9.3	23.14	20.78	19.81	9.53	23.35	20.03	18.3
3.5	9.11	23.07	20.51	17.6	9.3	23.14	20.78	19.72	9.56	23.39	19.61	17.63

Table 4 Center-fed array characteristics (case2)

Total resistance	Lower end of the band				Center				Upper end of the band			
	F	Dir	SLL (Az)	SLL (EL)	F	Dir	SLL (Az)	SLL (EL)	F	Dir	SLL (Az)	SLL (EL)
1.0	9.19	21.80	40.92	36.16	9.3	21.87	38.81	37.26	9.41	22.02	36.21	35.09
1.5	9.15	21.79	38.89	34.25	9.3	21.86	39.19	36.74	9.44	22.04	37.3	33.94
2.0	9.12	21.82	38.03	32.9	9.3	21.86	39.58	36.25	9.47	22.10	35.94	32.79
2.5	9.11	21.83	37.68	32.0	9.3	21.87	40.01	35.62	9.49	22.14	35.68	31.75
3.0	9.11	21.83	37.65	32.08	9.3	21.89	40.42	34.85	9.52	22.22	34.98	30.19
3.5	9.10	21.85	37.26	31.42	9.3	21.90	40.78	33.89	9.54	22.28	34.43	28.98

4. Conclusion

This paper has presented results of a full wave analysis of slot arrays. Return loss bandwidth increases with overloading of radiating slot conductances and coupling slot resistances. Radiation pattern performance degrades with increasing amounts of overloading. Based on the results of this study we recommend radiating slot conductance value of 2.0 and coupling slot conductance values in the range of 2.0 to 3.0.

5. References

1. R. S. Elliott, “An Improved Design Procedure for Small Arrays of Shunt Slots,” *IEEE Transactions on Antennas and Propagation,* 31, 1, 1983, pp. 48-53

2. R. S. Elliott, “The Design of Waveguide-Fed Slot Arrays,” in Y. T. Lo and S. W. lee (eds.), *Antenna Handbook*, New York, Van Nostrand Rheinhold, 1988.

3. S. R. Rengarajan, “Coupling Between Slot Arrays,” *URSI Electromagnetic Theory Symposium Proceedings*, Ottawa, Canada, July 2007.

4. A. Derneryd and R. Petersson, “On Bandwidth Characteristics of Monopulse Slotted Waveguide Antennas,” *Fourth International Conference on Antennas and Propagation Proceedings,* April 1985.

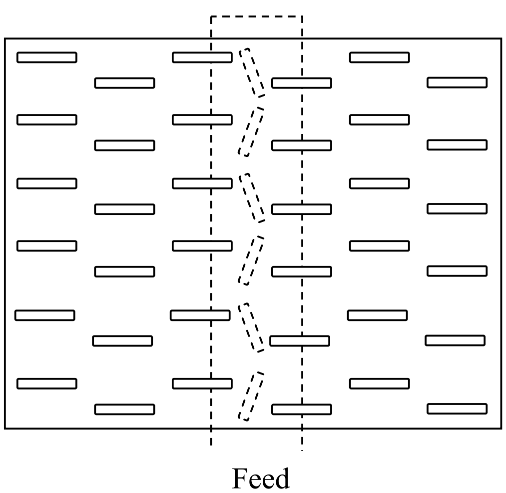

Fig. 1 End-fed array geometry

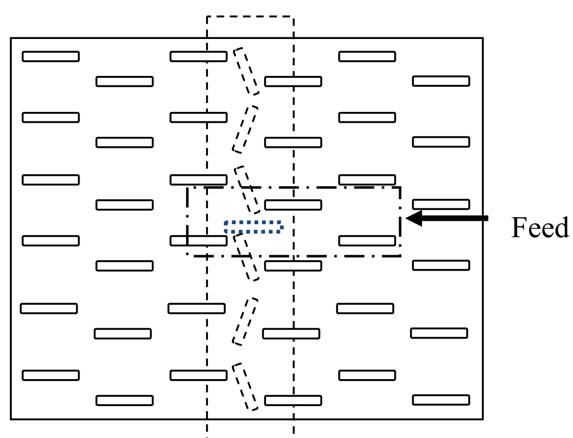

Fig. 2 Center-fed array geometry