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Array of Slot Coupled H-Plane Tee Junctions in Non-Standard Rectangular Waveguide

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***Abstract:-* In the design of an array antenna, the desired array pattern characteristics are essentially specified. In the case of linear array design the radiation pattern is a function of θ alone and is independent of ϕ. This means the patterns are always computed as a function of θ. In fact, the specifications of complete radiation pattern through analytical expression are complex and involved. As a result, these specifications are usually centered around the specification of first side lobe level and the null to null main beam width. Arrays are used to produce specified directional characteristics, high antenna gain and to steer the beam. They are also used to obtain low side lobes with narrow beam width for point to point communications. Waveguide slotted arrays are designed for the generation of low side-lobe far-field patterns and are preferred in several strategic applications. Element weights are determined at junction by sampling. In the present work, array of H-plane Tee junctions of non-standard waveguides are designed using tapered amplitude distribution.**

Key Words : Arrays, Non Standard Waveguides, H-Plane Tee, Array Pattern, Beam width

I. INTRODUCTION

The theoretical analysis and design tools are well developed and readily available in the open literature for broad-wall slot arrays. Elliot and Kurtz [1] developed a design procedure that would permit determination of the length and offset of each slot in a linear/planar, array of longitudinal broad-wall slots once the desired pattern and input admittance were specified. They presented an expression for the active admittance of the slot in terms of slot voltages and self and mutual admittances. Following a similar approach, they developed a design approach for non-resonantly spaced broad-wall longitudinal slots [2] and waveguide-fed series slot array [3].

Inclined slots in a narrow wall are usually attractive for using in linear slot arrays, as the machining of these slots is relatively easy. However, when the resonant slot arrays are required to be designed where in each individual slot should be at resonant, it is not possible to accommodate the resonant length of each slot entirely in the narrow wall because of the limited wall dimension. As a result they are protruded into the broad wall exhibiting a depth of cut in the broad wall. This additional length of the slot in the broad wall disturbs the desired polarization. Moreover, the inclination of the slot also creates cross-polarized fields when horizontally polarized fields are desired.

There is no literature on the design of arrays of H-plane Tee junctions. But these are useful for polarization control. Therefore, it is of interest to design such arrays in the present work. Considering equivalent circuit of array of junctions containing shunt admittance parameters, required conductance values of each junction are evaluated. The amplitude weights, required and realized conductance, slot length and width, slot inclinations are numerically evaluated for desired radiation pattern.

II. AMPLITUDE DISTRIBUTIONS

Different amplitude distributions are used for the reduction of side lobe levels. The common amplitude distributions are uniform, circular, triangular, cosine and raised cosine on pedestal etc. Uniform amplitude distribution is the simplest of all and in this, all elements are excited equally. The radiation pattern of two element uniform array is given by

$$E(u) = \cos(KLu) \tag{1}$$

Here, u = sinq ; K = 2p/ λ ; 2L = array length ;
λ = operating wavelength ;
E(u) = radiation field

Similarly, the patterns for circular taper is represented by

$$E(u) = J_1(KLu) / KLu \tag{2}$$

Here, $J_1(KLu)$ is Bessel function of order one.

For isotropic sources radiating in phase with different amplitudes given by $a(x_1)$, $a(x_2)$ $a(x_3)$ - - - - - - - - - $a(x_m)$ etc, the total field intensity is given by

$$E(u) = a(x_1)\, e^{ju} + a(x_2)\, e^{2ju} + a(x_3)\, e^{3ju} + \ldots\ldots a(x_m)\, e^{ju\,m/2}$$

$$+ a(x_1)\, e^{-ju} + a(x_2)\, e^{-2ju} + a(x_3)\, e^{-3ju} + \ldots\ldots a(x_m)\, e^{-jum/2}$$

$$= 2[a(x_1)\, \mathrm{Cos}u + a(x_2)\mathrm{Cos}2u + a(x_3)\mathrm{Cos}3u + \ldots a(x_m)\mathrm{Cos}\, mu] \tag{3}$$

Above expression is readily recognized as a finite Fourier series. If the spacing between the radiating elements is smaller and smaller, more terms are considered and the series in the limit can be replaced by a finite Fourier transform. Under these conditions, the antenna array is considered as a continuous line source. The first side lobe levels are found to be – 13.5 dB, - 17.5 dB, - 22.0 dB, - 23.5 dB and – 26.5 dB for uniform, circular, parabolic, cosine and for certain triangular tapers respectively [4]. It is evident that these side lobe levels are considered to be high for certain applications. With an objective to reduce the side lobe levels further, another standard distribution represented by raised cosine on pedestal is considered in the present chapter.

The raised cosine on pedestal aperture distribution is represented by

$$a(x) = \left(1 + \cos\frac{\pi x}{2}\right), -L \le x \le L \tag{4}$$

The second derivative of this expression (4) indicates that the raised cosine on pedestal type of distribution does not contain impulses until the third derivative. It is a gently terminated aperture distribution and it does not exhibit a jump in amplitude at the edges.

The far-field complex radiation pattern due to line source is given by the equation

$$E(u) = \int_{-L}^{L} A(x)\, e^{j\frac{2\pi L}{\lambda}xu}\, dx \tag{5}$$

The raised cosine on pedestal aperture is presented in fig. (1). It is then applied to discrete arrays containing the number of elements equal to N= 20 and 50. This is done by considering individual weights of each radiating element.

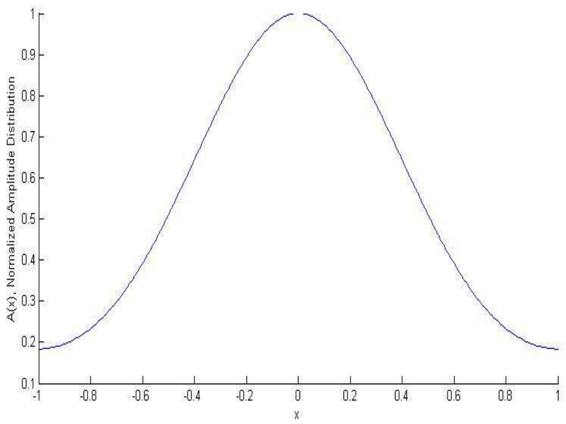

Fig. 1 Amplitude distribution of raised cosine on pedestal distribution

The continuous distribution, a(x) is discretized and the resultant excitation levels are shown in figs. (2 & 3) for N = 20 and 50. The ordinate indicates the element locations. These locations are found out using Ishimaru spacing [5]

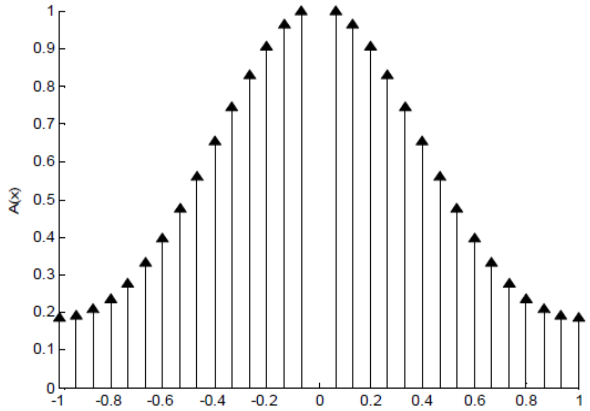

Fig. 2 Excitation levels for number of elements = 20

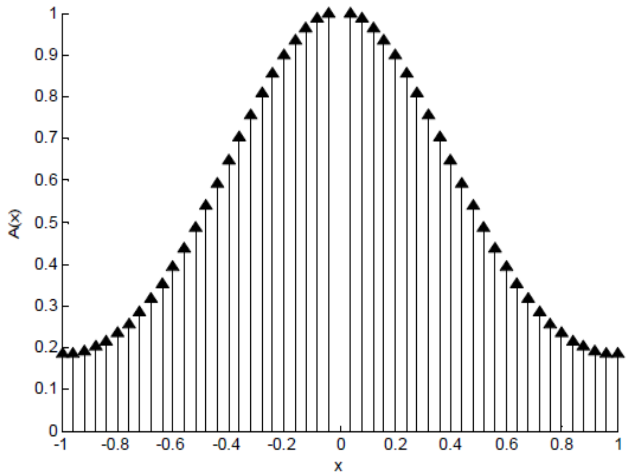

Fig. 3 Excitation levels for number of elements = 50

Radiation patterns are numerically computed for raised cosine on pedestal distribution for discrete arrays containing the number of elements equal to 10, 20, 30,40 and 50. The realized patterns in u - domain are presented in figs. (4 & 5).

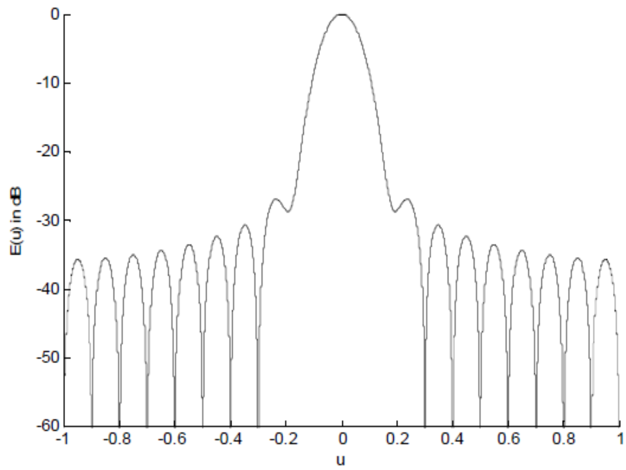

Fig. 4 Pattern for discrete array of 20 elements

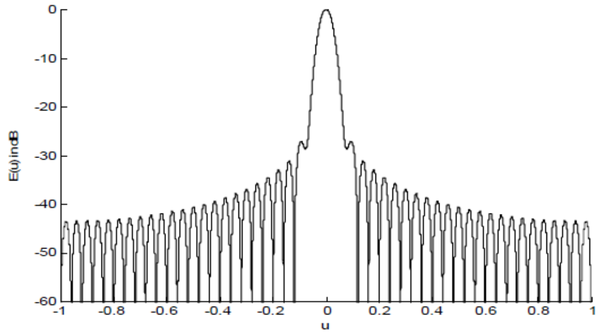

Fig. 5 Pattern for discrete array of 50 elements

The design of an array of H-plane Tee junctions shown in the fig 6 for the generation of specified directional characteristics is also presented. The electrical length between the junctions is equal and it Feed Guide Radiating Guide is given by Θ_d. The formulation is based on transmission matrix approach.

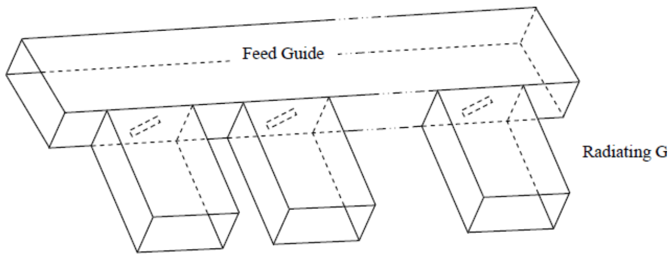

Fig. 6 Array of inclined slot coupled H-plane Tee junctions

In case of non-resonant arrays, slots radiate very little power and hence represent a small discontinuity in the waveguide. When the slots are not spaced at lg/2, the reflections from different slots do not add up in phase and total reflection at the input to the array will be small. However, when the spacing is lg/2, the reflections will add in phase at the input. Infact, this is a resonant condition and the array produces a main beam in the direction of boresight.

III RESULTS

From the expressions of self-reaction and discontinuity in modal current, the admittance parameter is numerically computed. The realized patterns in u-domain using raised cosine on pedestal are presented in figs. (4-5) and the proposed element weights are presented in figs. (2-3). The required conductances of slots to produce the desired radiation patterns are obtained from the expressions and the realized conductances are obtained from the admittance parameter and are presented in the tables (1 and 2). The tabulated results correspond to arrays of 20 and 50 elements. All these results are presented for 0.10 of fractional power dissipated in load.

Table 1 Number of elements = 20, p_d = 0.10

No of Elements	Amplitude Level	Required Conductance	Realized Conductance	Slot Length L(cm)	Slot Width W(cm)	Slot Inclination θ(Deg)
1	0.1880	0.0040	0.0040	1.00	0.08	45
2	0.2128	0.0052	0.0052	1.00	0.10	60
3	0.2643	0.0081	0.0081	1.10	0.12	30
4	0.3441	0.0138	0.0138	1.12	0.12	45
5	0.4515	0.0241	0.0242	1.24	0.14	30
6	0.5801	0.0407	0.0407	1.32	0.14	30
7	0.7174	0.0649	0.0647	1.28	0.20	45
8	0.8456	0.0964	0.0965	1.34	0.14	75
9	0.9453	0.1384	0.1384	1.54	0.16	30
10	1.0000	0.1722	0.1728	1.52	0.10	45
11	1.0000	0.2081	0.2076	1.40	0.20	75
12	0.9453	0.2348	0.2347	1.54	0.20	45
13	0.8456	0.2455	0.2454	1.58	0.12	45
14	0.7174	0.2341	0.2340	1.56	0.14	45
15	0.5801	0.1999	0.1997	1.48	0.08	75
16	0.4515	0.1514	0.1513	1.40	0.18	60
17	0.3441	0.1086	0.1086	1.34	0.18	60
18	0.2643	0.0682	0.0681	1.40	0.08	45
19	0.2128	0.0475	0.0475	1.36	0.12	30
20	0.1880	0.0389	0.0385	1.22	0.14	75

Table 2 Number of elements = 50, p_d = 0.10

No of Elements	Amplitude Level	Required Conductance	Realized Conductance	Slot Length L(cm)	Slot Width W(cm)	Slot Inclination θ(Deg)
1	0.1844	0.0016	0.0016	0.84	0.10	45
2	0.1883	0.0016	0.0016	0.88	0.08	75
3	0.1961	0.0018	0.0018	0.86	0.10	75
4	0.2080	0.0020	0.0020	0.90	0.08	60
5	0.2240	0.0023	0.0023	0.92	0.08	60
6	0.2445	0.0023	0.0023	0.86	0.14	75
7	0.2694	0.0034	0.0034	0.98	0.08	75
8	0.2988	0.0042	0.0042	0.96	0.16	30
9	0.3329	0.0052	0.0052	0.94	0.14	60
10	0.3714	0.0066	0.0066	0.94	0.18	45
11	0.4142	0.0082	0.0082	1.04	0.18	30
12	0.4609	0.0102	0.0103	1.04	0.14	60
13	0.5108	0.0127	0.0127	1.06	0.16	45
14	0.5633	0.0157	0.0156	1.10	0.14	60
15	0.6175	0.0191	0.0191	1.10	0.16	75
16	0.6723	0.0231	0.0231	1.24	0.08	60
17	0.7266	0.0276	0.0276	1.26	0.14	30
18	0.7792	0.0327	0.0326	1.24	0.20	30
19	0.8288	0.0382	0.0383	1.32	0.08	45
20	0.8742	0.0442	0.0442	1.34	0.08	45
21	0.9141	0.0505	0.0505	1.34	0.16	30
22	0.9474	0.0572	0.0575	1.26	0.20	45
23	0.9733	0.0640	0.0644	1.36	0.20	30
24	0.9910	0.0709	0.0708	1.30	0.16	60
25	1.0000	0.0777	0.0780	1.40	0.08	60
26	1.0000	0.0842	0.0841	1.48	0.08	30

27	0.9910	0.0903	0.0906	1.40	0.12	45
28	0.9783	0.0958	0.0951	1.32	0.16	75
29	0.9474	0.1003	0.1001	1.46	0.18	30
30	0.9141	0.1038	0.1036	1.34	0.18	60
31	0.8742	0.1060	0.1059	1.36	0.16	60
32	0.8288	0.1065	0.1063	1.38	0.18	45
33	0.7792	0.1054	0.1058	1.48	0.16	30
34	0.7266	0.1024	0.1024	1.36	0.20	45
35	0.6728	0.0977	0.0979	1.38	0.16	45
36	0.6175	0.0918	0.0914	1.48	0.10	30
37	0.5633	0.0887	0.0888	1.44	0.14	30
38	0.5108	0.0751	0.0752	1.40	0.18	30
39	0.4609	0.0661	0.0665	1.30	0.18	45
40	0.4142	0.0571	0.0570	1.36	0.08	60
41	0.3714	0.0487	0.0488	1.40	0.08	30
42	0.3329	0.0412	0.0412	1.18	0.20	60
43	0.2988	0.0346	0.0346	1.24	0.12	60
44	0.2694	0.0291	0.0298	1.16	0.16	75
45	0.2445	0.0247	0.0247	1.16	0.14	75
46	0.2240	0.0218	0.0218	1.10	0.18	60
47	0.2080	0.0187	0.0188	1.22	0.08	45
48	0.1961	0.0170	0.0171	1.04	0.20	75
49	0.1883	0.0159	0.0160	1.10	0.14	75
50	0.1844	0.0155	0.0155	1.12	0.20	30

CONCLUSIONS

It is evident from the results shown in figs. (2-5), the proposed tapered distribution is found to yield radiation patterns with sidelobe level of about -28dB. The beamwidth is decreasing as the number of elements in the array is increasing. The designed conductance values of slot coupled H-plane Tee junction radiators to realize specified patterns shown in tables (1 – 2) are found to be small for large arrays and high for small arrays.

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