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Synthesis of Array of H-plane Tee Junctions with L-band Wave guides

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ABSTRACT:-*Shaped or narrow beam patterns are useful in microwave and radar applications. Such radiation patterns can be designed by an array of slot coupled waveguide junctions by using the concept of cosine distribution method. No literature is available on slot coupled H-plane Tee junctions of L band wave guide array and no data on such array radiation patterns are reported.*

In the present work, an array of H plane Tee junctions of L band wave guide with inclined slots in the narrow wall of primary wave guide are considered and excited with a suitable amplitude distribution. Using recursive formulation of transmission matrix and normalized power balance relation the resonant conductance for a given amplitude distribution are evaluated. The synthesis is carried out by considering a primary guide with matched termination and the amount of incident power absorbed in the terminating matched load. The results are presented in tabular form.

Keywords:-*H plane Tee junctions, amplitude distribution, resonant conductance, incident power absorbed.*

I. INTRODUCTION

In guided missiles, supersonic aircrafts and atmospheric entry space vehicles the array of wave guide junctions are very useful, as they desire low profile or flush mounted antennas. L band permits very good long range search performance. The size of the associate antennas is moderate. At the same time EM waves in that range have excellent weather penetration, with well-behaved ground clutter environment. In the array design the primary guide feeds cascaded H plane junctions. The radiation pattern obtained from an array of wave guide junctions depends on various parameters like inter element spacing between the elements, number of elements present in the array, the excitation given to elements and slot parameters (position and inclination of each element, offset displacement from the axis), which provide additional parameters for the array designer.

In the present work, an array of cascaded H-plane Tee junctions as shown fig.1. are considered and are excited with a suitable amplitude distribution .when the primary guide is matched terminated, the resulting resonant conductance is evaluated for different amounts of incident power delivered to the terminating load, for the number of array elements. An inclined slot in the wave guide radiate cross polarized component, which can be suppressed by slot coupled junctions [4].

Cascaded section of Junctions can be represented by load line shown in fig 1.The impedance due to successive junctions appear in the planes of symmetry of individual sections shown in fig 2. At a particular frequency, the sections of lines between the consecutive planes are equal to their electrical lines and given by θ_s. The amplitude distribution is obtained by Taylor's method [1]. The incident and reflected wave at input and output at nth load section are related by transmission matrix [2]. Das [3]presents an analysis of the cascaded sections of a number of slot-coupled Tee junctions between rectangular and circular waveguides taking into account the mutual interactions of all possible modes generated by the discontinuities, as well as the effect of wall thickness. The formulation is based on solving a set of coupled integral equations resulting from the boundary conditions at the two interfaces of the waveguide sections representing the coupling slots. Raju et al [4] reported that in estimating the performance of cascaded section of identical junctions, the side lobe levels are found to be high and the radiation pattern cannot be controlled in accordance with the given specification. The realization of desired radiation pattern is possible with junctions which are not identical. The primary guide will be loaded with impedance by each junction in the cascade/ array. Elliot et al [5] 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. The theory of Stevenson's method, and usesa modified form of Booker's relation based onBabinet's principle to treat non resonant longitudinal shunt slotsin the broad wall of a rectangular waveguide. John [6] analyzed a one-dimensional array comprising tilted edge slots cut in the narrow wall of a rectangular waveguide is presented. The fields in the slots are calculated from a hybrid finite element-boundary integral (FE-BI) equation method.Elliot et al [8] design procedure for arrays of longitudinal slots in one broad wall of each rectangular waveguide is extended to the case that the waveguides have ridges in the opposite broad walls. External mutual coupling has been taken into account. Zhang et al. [9] designed and fabricated a two dimensional slot array waveguide. The design is made to obtain side lobe level at -35dB. Waveguide slot arrays with low loss characteristics at microwave and mill metric wave bands are widely used in communication and radar applications.

II. FORMULATION

2.1 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. 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

$$A(x) = (1 + 0.48 \cos\pi x)\ ,\ -L \leq x \leq L \text{ --------------------------- } (1)$$

The second derivative of equation (1) 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

$$E(u) = \int_{-L}^{+L} A(x) e^{\frac{j2\pi L}{\lambda} xu} dx \text{ --------------------------- } (2)$$

The raised cosine on pedestal aperture is presented in fig. (3). It is then applied to discrete arrays containing the number of elements equal to N= 10 and 30. This is done by considering individual weights of each radiating element. Fig.3. Amplitude distribution of raised cosine on pedestal distribution the continuous distribution, A(x) is discretized and the resultant excitation levels are shown in figs. (4 & 5) for N = 10 and 30. The ordinate indicates the element locations.

These locations are found out using Ishimaru spacing [8]. Radiation patterns are numerically computed for raised cosine on pedestal distribution for discrete arrays containing the number of elements equal to 10 and 30. The realized patterns in u - domain are presented in figs. (6&7).
The incident and reflected waves at the input and outputof the nth loaded sectionare relate by the following transmission matrix

$$\begin{bmatrix} I_{n-1} \\ R_{n-1} \end{bmatrix} = \begin{bmatrix} A_{11}^n & A_{12}^n \\ A_{21}^n & A_{22}^n \end{bmatrix} \begin{bmatrix} I_n \\ R_n \end{bmatrix} \text{ ---------------------- } (3)$$

Where$\theta_d = (2\pi/\lambda)\ d + \pi$, d being the inter element spacing. If P_x is the normalized power delivered to the xth junction and is the fraction of power delivered to the load, it is found

$$\sum_{n=1}^{N} P_x + \Delta = 1 \text{ ------------------ } (4)$$

For inter element spacing equal to $\lambda_g / 2$,the voltage, V appearing across all the elements of Fig. 3is identical and hence it can be shownthat the conductance of x^{th} element is obtained fromthe formula

$$g_x = \frac{P_x}{\Delta} \text{ ------------------- } (5)$$

If a_x is the sampled values of the square ofthe amplitude distribution curve which is represented as curve of Fig.3 in the locations

$p_x = \frac{1-\Delta}{\sum_{n=2}^{N} a_x}$------------------- (6)

The normalized powers p_x is appearing in equation (4)are obtained as of the radiating elements,
For matched termination of the array,

R_x= *0 and* I_N^2 .1=Δ

where N is the total number of junctions, The conductance of the last coupling slot is, hence given by

$g_N = P_N/I_N^2$--------------------------- (7)

Substituting the values of $I_N$and g_N in equation (1) and solving the set of simultaneous equations f or P=N, I_{x-1} and R $_{x-1}$ are found. Conductance of (N-1)th junction is given by

$g_{N-1} = \frac{P_{N-1}}{|I_{N-1}+R_{N-1}|^2}$------------------------------------- (8)

Generating a recursive function in this way the remaining slot conductance satisfying the amplitude distribution of curveof Fig.1 are evaluated for d = 0.5λ.,N=10,30 and Δ =0.05,0.1, 0.15 .Slot parameter resonant length are determined from thedata and presented in tabular form.
The method of synthesis described above is quite general and can be applied for therealization of any , desired radiation pattern using either an array of waveguide radiators excited through slot coupled junction or an array of slots radiating into free space.

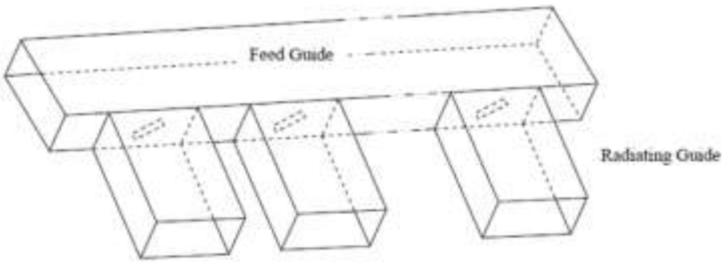

Fig.1 H plane Tee junction array

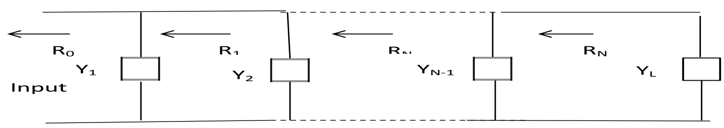

Fig.2.Equivalent circuit of array of slots with matched termination

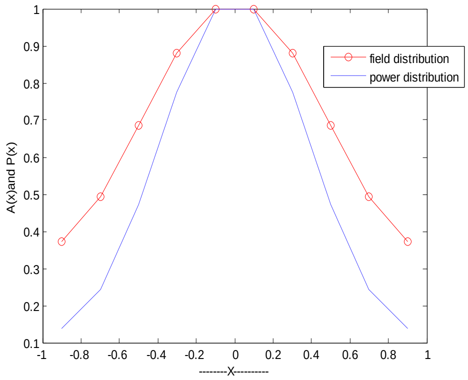

Fig.3. Amplitude and Power distribution for A(x) = 1+0.48 cosπx

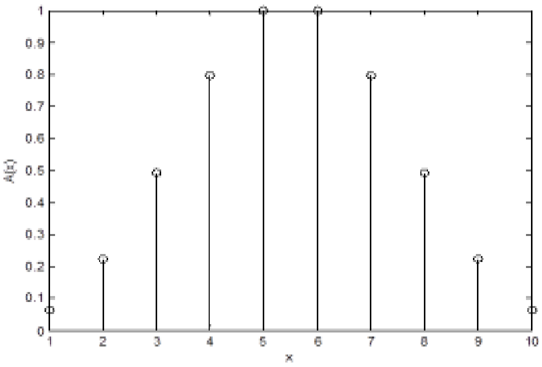

Fig 4 Excitation levels for number of elements = 10

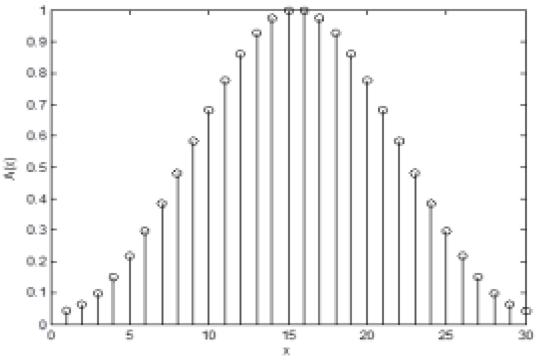

Fig.5 Excitation levels for number of elements = 30

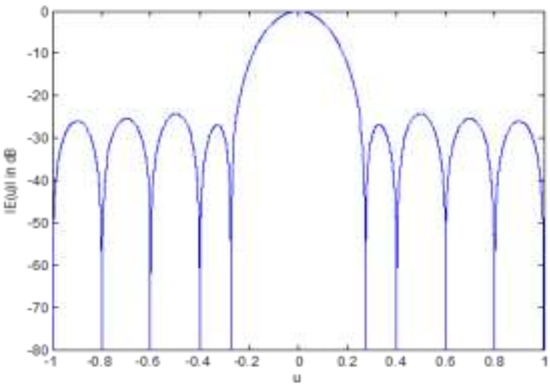

Fig. 6 Pattern for discrete array of 10 elements

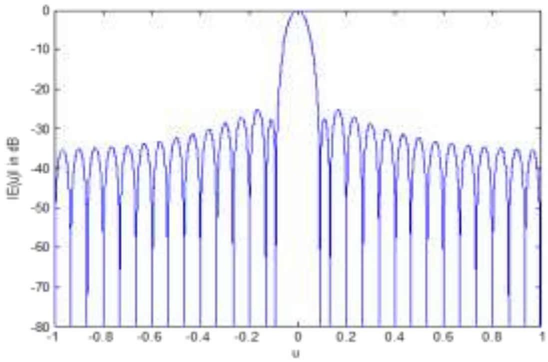

Fig.7.Pattern for discrete array of 30 elements

III. RESULTS

From the expressions of self-reaction and discontinuity in modal current, the admittance parameters are numerically computed for L-band H plane Tee junction array. The realized patterns in u-domain using raised cosine on pedestal are presented in figs. (6-7) and the proposed element weights are presented in figs.(5-6). The required conductance of slots to produce the desired radiation patterns are obtained from the expressions. The realized conductance are obtained from the admittance parameter. The required conductance and realized conductance are presented in the tables (1, 2, 3 ,4,5 and 6). The tabulated results correspond to arrays of 10 and 30 elements. All these results are presented for 0.05, 0.1 and 0.15 of fractional power dissipated in load.

No. of elements	Amplitude level	Required Conductance	realized conductance	Resonant slot length in cm	Slot inclination in degrees
1	0.3731	0.0252	0.0241	11.64	30
2	0.4929	0.0450	0.0441	11.78	30
3	0.6866	0.0915	0.0915	11.93	45
4	0.8803	0.1656	0.1659	12.39	45
5	1.0000	0.2561	0.2589	12.41	45
6	1.0000	0.3442	0.3552	12.45	50
7	0.8803	0.4067	0.4008	12.46	50
8	0.6866	0.4171	0.4185	12.53	50
9	0.4929	0.3687	0.3599	12.48	50
10	0.3731	0.3348	0.3304	12.43	50

Table.1 .L band wave guide H plane Tee junction array with number of elements N=10, Δ=0.05 and A(x)= 1+0.48 cosπx

No. of elements	Amplitude level	Required Conductance	realized conductance	Resonant slot length in cm	Slot inclination in degrees
1	0.3731	0.0238	0.0241	11.64	35
2	0.4929	0.0426	0.0429	11.67	35
3	0.6866	0.0864	0.0862	11.91	45
4	0.8803	0.1554	0.1552	12.26	45
5	1.0000	0.2374	0.2375	12.34	40
6	1.0000	0.3113	0.3241	12.42	50
7	0.8803	0.3502	0.3552	12.45	50
8	0.6866	0.3279	0.3241	12.42	50
9	0.4929	0.2514	0.2589	12.41	45
10	0.3731	0.1925	0.1955	12.39	35

Table.2 .L band wave guide H plane Tee junction array with number of elements N=10, Δ=0.1 and A(x)= 1+0.48 cosπx

No. of elements	Amplitude level	Required Conductance	realized conductance	Resonant slot length in cm	Slot inclination in degrees

1	0.3731	0.0225	0.0218	11.63	45
2	0.4929	0.0402	0.0400	11.58	45
3	0.6866	0.0812	0.0812	11.89	40
4	0.8803	0.1454	0.1441	12.22	40
5	1.0000	0.2195	0.2176	12.32	40
6	1.0000	0.2812	0.2861	12.38	50
7	0.8803	0.3032	0.3057	12.42	50
8	0.6866	0.2646	0.2589	12.41	45
9	0.4929	0.1855	0.1819	12.35	30
10	0.3731	0.1305	0.1306	12.13	50

Table.3 .L band wave guide H plane Tee junction array with number of elements N=10, Δ=0.15 and A(x)= 1+0.48 cosπx

No. of elements	Amplitude level	Required Conductance	realized conductance	Resonant slot length in cm	Slot inclination in degrees
1	0.3538	0.0078	0.0075	10.85	45
2	0.3679	0.0085	0.0084	10.96	45
3	0.3955	0.0099	0.0094	10.96	30
4	0.4354	0.0121	0.0133	11.45	30
5	0.4859	0.0152	0.0149	11.45	30
6	0.5447	0.0194	0.0189	11.54	30
7	0.6093	0.0248	0.0241	11.66	40
8	0.6769	0.0313	0.0309	11.71	50
9	0.7444	0.0391	0.0397	11.77	50
10	0.8090	0.0481	0.0513	11.80	30
11	0.8679	0.0581	0.0583	11.82	45
12	0.9183	0.0691	0.0679	11.88	40
13	0.9583	0.0808	0.0803	11.91	30
14	0.9859	0.0931	0.0936	11.95	40
15	1.0000	0.1056	0.1023	11.98	40
16	1.0000	0.1181	0.1194	12.13	35
17	0.9859	0.1301	0.1306	12.21	50
18	0.9583	0.1413	0.1410	12.23	45
19	0.9183	0.1511	0.1512	12.26	30
20	0.8679	0.1590	0.1552	12.32	45
21	0.8090	0.1643	0.1642	12.39	40
22	0.7444	0.1664	0.1659	12.45	45
23	0.6769	0.1651	0.1642	12.39	40
24	0.6093	0.1602	0.1602	12.35	35
25	0.5447	0.1525	0.1512	12.26	35
26	0.4859	0.1431	0.1441	11.24	40
27	0.4354	0.1342	0.1349	11.22	30
28	0.3955	0.1278	0.1292	11.17	50
29	0.3679	0.1268	0.1241	11.16	50
30	0.3538	0.1343	0.1349	11.58	30

Table.4 .L band wave guide H plane Tee junction array with number of elements N=30, Δ=0.05 and A(x)= 1+0.48 cosπx

No. of elements	Amplitude level	Required Conductance	realized conductance	Resonant slot length in cm	Slot inclination in degrees

1	0.3538	0.0073	0.0071	10.85	45
2	0.3679	0.0080	0.0084	10.96	45
3	0.3955	0.0093	0.0094	10.96	50
4	0.4354	0.0114	0.0115	11.31	30
5	0.4859	0.0144	0.0144	11.46	30
6	0.5447	0.0183	0.0181	11.52	30
7	0.6093	0.0234	0.0241	11.64	30
8	0.6769	0.0295	0.0273	11.68	40
9	0.7444	0.0368	0.0359	11.74	30
10	0.8090	0.0451	0.0441	11.78	35
11	0.8679	0.0544	0.0549	11.80	35
12	0.9183	0.0644	0.0679	11.88	35
13	0.9583	0.0749	0.0768	11.84	50
14	0.9859	0.0857	0.0848	11.93	50
15	1.0000	0.0965	0.0960	11.95	45
16	1.0000	0.1068	0.1075	11.97	35
17	0.9859	0.1162	0.1151	12.01	30
18	0.9583	0.1242	0.1243	12.03	50
19	0.9183	0.1302	0.1306	12.13	50
20	0.8679	0.1337	0.1349	12.15	30
21	0.8090	0.1341	0.1349	12.15	30
22	0.7444	0.1311	0.1306	12.13	50
23	0.6769	0.1248	0.1243	12.03	50
24	0.6093	0.1155	0.1111	12.01	30
25	0.5447	0.1044	0.1023	11.95	40
26	0.4859	0.0927	0.0936	11.91	40
27	0.4354	0.0821	0.0823	11.89	40
28	0.3955	0.0738	0.0768	11.84	50
29	0.3679	0.0689	0.0679	11.88	40
30	0.3538	0.0684	0.0679	11.88	40

Table.5 .L band wave guide H plane Tee junction array with number of elements N=30, Δ=0.1 and A(x)= 1+0.48 cosπx

No. of elements	Amplitude level	Required Conductance	realized conductance	Resonant slot length in cm	Slot inclination in degrees
1	0.3538	0.0069	0.0067	10.80	30
2	0.3679	0.0076	0.0071	10.85	45
3	0.3955	0.0088	0.0096	10.96	30
4	0.4354	0.0108	0.0105	11.34	50
5	0.4859	0.0135	0.0133	11.45	30
6	0.5447	0.0173	0.0179	11.53	30
7	0.6093	0.0220	0.0218	11.58	30
8	0.6769	0.0277	0.0278	11.63	50
9	0.7444	0.0345	0.0352	11.73	30
10	0.8090	0.0422	0.0441	11.78	30
11	0.8679	0.0507	0.0513	11.79	30
12	0.9183	0.0598	0.0583	11.82	45
13	0.9583	0.0693	0.0664	11.83	40
14	0.9859	0.0788	0.0787	11.89	45
15	1.0000	0.0880	0.0879	11.91	30
16	1.0000	0.0964	0.0960	11.93	45
17	0.9859	0.1037	0.1058	11.95	30
18	0.9583	0.1094	0.1058	11.95	30
19	0.9183	0.1128	0.1151	12.04	30
20	0.8679	0.1135	0.1151	12.04	30
21	0.8090	0.1113	0.1117	12.03	30
22	0.7444	0.1060	0.1058	11.95	30
23	0.6769	0.0980	0.0985	11.94	35
24	0.6093	0.0881	0.0896	11.89	40
25	0.5447	0.0772	0.0773	11.84	35
26	0.4859	0.0666	0.0679	11.82	40
27	0.4354	0.0573	0.0583	11.83	30
28	0.3955	0.0501	0.0050	12.04	30
29	0.3679	0.0456	0.0441	11.78	30
30	0.3538	0.0442	0.0441	11.78	30

Table.6 .L band wave guide H plane Tee junction array with number of elements N=30, Δ=0.15 and A(x)= 1+0.48 cosπx

IV. CONCLUSION

It is evident from the results that the proposed amplitude distribution resulted in a radiation pattern with first side lobe level at -30dB. The distribution is symmetrically tapered and the centered two elements have equal levels. The continuous distribution is discretized and the levels are evaluated at the sampled locations of elements.

In order to generate such a data an array of H-plane Tee junctions with L-band wave guides is designed by evaluating the data on normalized conductance for each junction. Recursive formulation has been applied to obtain required conductance. This method takes into account the internal reflections of each element. It can be applied to generate any desired shape of radiation pattern.

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