A TWO-WAY POWER DIVIDER FOR A WIDE-BAND SINGLE-LAYER FEED WAVEGUIDE

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1. INTRODUCTION

A single-layer slotted waveguide array antenna is an attractive candidate of high frequency and high-gain planar antennas. It has negligibly small transmission loss and is advantageous in terms of efficiency. It has a simple single-layer structure shown in Fig.1 for the mass production with low manufacturing cost. The feed structure is a single waveguide placed on the same layer as radiating waveguides[1]. However when the number of radiating waveguides increases and a series feed circuit becomes longer for realizing higher gain, the bandwidth becomes narrower due to the long line effect. This paper proposes a partially parallel feed in a feed circuit which reduces the line length and widens the bandwidth as is shown in Fig.2[2]. The key component in it is the H-plane two-way power divider with desired power division ratio. The authors have conducted the method of moment analysis to realize desired power ratio.

2. STRUCTURE AND DESIGN

Figure 3(a) shows the configuration of a two-way power divider. It consists of two feed waveguides which couple to each other through one window. The thickness of waveguides is t. The widths of the feed waveguides are a and l. The window width is w. The distance from the window to the conducting plate is s. It has two inductive walls; one suppresses the reflection to Port1 while the other controls the ratio of divided power to Port2 and Port3. Inductive wall I with the thickness r_1 is located at $x=p_1$ and $z=q_1$. Inductive wall II with the thickness r_2 is located at $x=p_2$ and $z=q_2$. Let a TE_{10} mode of unit amplitude be incident from Port1. The structure as well as the total field is two-dimensional and has no variation along the y-direction [3][4].

Figure 3(b) shows the analysis model of this power divider. The field equivalence theorem is applied and the whole region of this model is divided into complete rectangular waveguide regions separated by several unknown magnetic currents M_1, M_2. For reducing the computation time, the inductive wall is replaced by several unknown line currents $J_{ij}(i=1\sim6,\ j=1\sim N_i)$ with only the y-component on its surface since the total field does not vary along the y-direction[3][4], where N_i denotes number of the line currents on the surface $\#i$ of the inductive wall. The continuity of tangential component of magnetic fields at the surfaces of M_1, M_2 as well as the condition for cancellation of tangential electric fields at the surface of inductive wall leads us to the integral equations for M_1, M_2, $J_{ij}(i=1\sim6,\ j=1\sim N_i)$. Key feature is that only the simple Green's functions for rectangular regions are used in the equations. A set of linear equations are derived by Galerkin's method of moment [5][6][7] and the scattering matrix is obtained for this model.

3. RESULT

The authors simulate the scattering matrices of this power divider designed at 12.45GHz which is used for satellite broadcast in USA. The number of radiating waveguides is 28. Since one "πjunction" [4] feeds two radiating waveguides through one windows, 14 π-junctions are grouped into two 7 π-junctions.

Figure 4(a) shows reflection to Port1 for fixed design of Inductive wall II (p_2=9 mm, q_2=0 mm, r_2=2.0 mm). The reflection is below -36dB at p_1 =8.1mm, q_1 =3.2mm. Figure 4(b) shows reflection to Port1 for the above fixed design of Inductive wall I. Figure 4(c) shows the ratio of divided power. By using Figure 4(b) and (c), parameter p_2 and q_2 can be determined to realize the desired divided power of Port2 and Port3. The reflection is below -30dB in Fig.4(b) for wide variety of the ratio $(|S_{31}|/|S_{21}|)^2$ between 2.52 and 0.33 in Fig.4(c). This means that one can select the ratio 3:4, 4:3, 2:5, or 5:2 depending upon the position of two-way power divider in one group of 7 π-junctions.

Figure 5 shows frequency characteristics of the gain for various ratio of divided power to Port2 and Port3. In this calculation, the authors assumed only the phase error due to the long line effect. When the ratio to Port2 and Port3 is 4:3 or 3:4, the gain in 500MHz bandwidth is higher than any other ratio. The authors determine that the ratio to Port2 and Port3 is 4:3. Then from Fig.4(b) and Fig.4(c), p_2 and q_2 are determined (p_2 =9.0 mm, q_2 =0.54 mm, $(|S_{31}|/|S_{21}|)^2$ =0.748). Table 1 shows design parameters.

Figure 6 shows frequency characteristics of the reflection to the Port1. At the design frequency, the reflection is suppressed sufficiently. In 500MHz frequency bandwidth, the reflection is suppressed below -21dB.

Figure 7 shows frequency characteristics of the ratio of divided power $(|S_{31}|/|S_{21}|)^2$ and the phase difference of divided power between Port2 and Port3 arg(S_{21})-arg(S_{31}). In 500MHz bandwidth the ratio of divided power is almost constant, and the phase difference of divided power is about 9 degree and remains unchanged. This 9 degree phase error is canceled by shifting the location of two-way power divider in feed waveguide.

4. CONCLUSION

The authors propose a wide-band single-layer feed waveguide using two-way power dividers. In this power divider, the authors can control the ratio of divided power. Henceforth by giving weight to divided power, it is also possible to synthesize the directivity. Experimental verification is left for further study.

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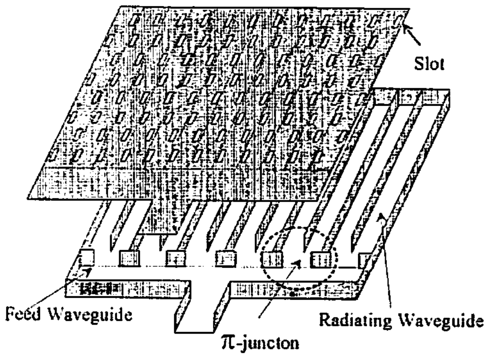

Fig.1 Single-Layer Slotted Waveguide Array Antenna with a series feed

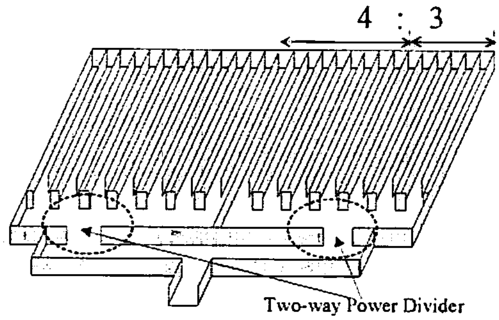

Fig.2 A Partially Parallel Feed

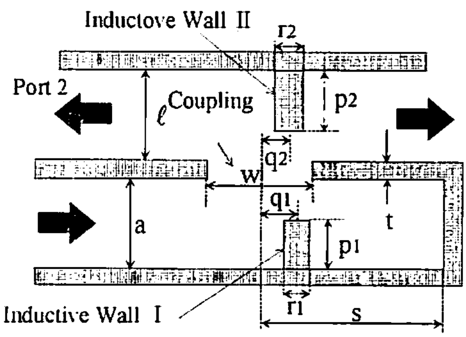

Fig.3(a) Configuration of a Two-way Power Divider

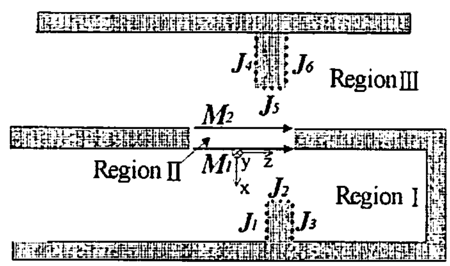

Fig.3(b) Unknown Electric and Magnetic Currents in the Analysis Model

Table 1 Design parameter of power divider

The width of waveguide a	17.3 mm
The width of waveguide l	17.3 mm
The distance from window to the conductive plate s	9.9 mm
The width of window w	13.5 mm
The thickness of waveguides t	2.0 mm
The length of inductive wall I p_1	8.1 mm
The location of inductive wall I q_1	3.2 mm
The thickness of inductive wall I r_1	2.0 mm
The length of inductive wall II p_2	9.0 mm
The location of inductive wall II q_2	0.54 mm
The thickness of inductive wall II r_2	2.0 mm
Design Frequency	12.45GHz

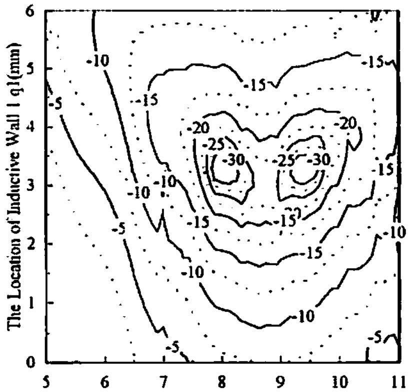

Fig.4(a) Reflection to Port1 for p_2 =9mm and q_2 =0mm

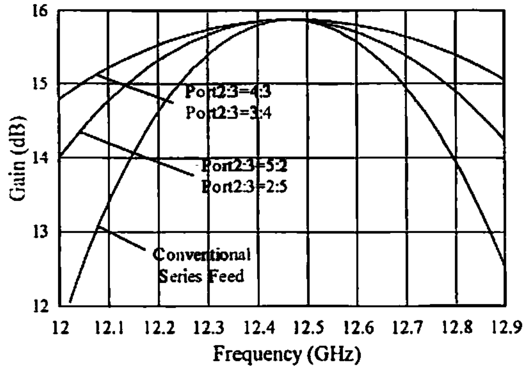

Fig.5 Frequency Characteristics of the Gain

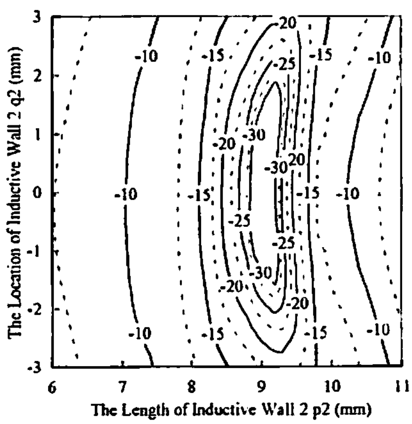

Fig.4(b) Reflection to Port1 for p_1 =8.1mm and q_1 =3.2mm.

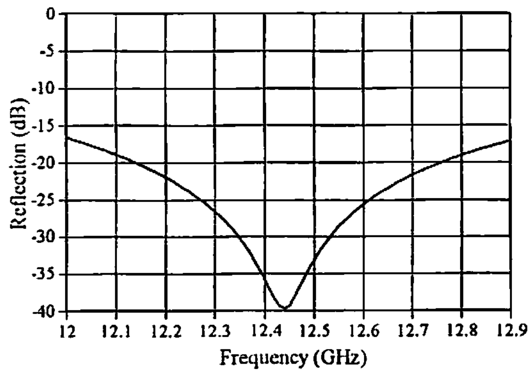

Fig.6 Frequency Characteristics of Reflection to Port1

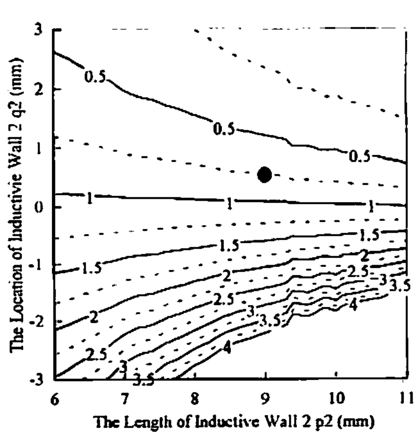

Fig.4(c) Ratio of Divided Power for fixed values of p_1 and q_1.

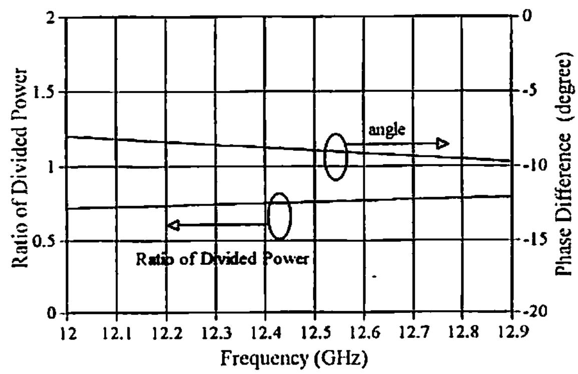

Fig.7 Frequency Characteristics of Ratio of Divided Power $(|S_{31}|/|S_{21}|)^2$ and Phase Difference of Divided Power Between Port2 and Port3 $[\arg(S_{21})-\arg(S_{31})]$