A Compact Beam Steering Planar Array with Broadband and High Gain

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Abstract—**A broadband beam steering continuous transverse stub planar array fed by the parabolic reflector of substrate integrated waveguide (SIW) is proposed in this paper. The beam steering function could be realized by mechanically moving the H-plane SIW horn straightly along the direction of the stub. A 16-element array is simulated to validate the design. The simulation results show that the relative bandwidth of the reflection coefficient less than -10dB is 16.6% (12.18GHz-14.34GHz) with the center frequency of 13.0GHz. The gain at the broadside is 27.94dB with the first sidelobe level of -22.8dB and the 3dB beam width of 7.2°. Within the scanning angle of ±33° range, the gain decrease less than 3dB. This beam steering array has the good feature of broadband, high gain, simple and compact structure, and low cost. It could be applied in Ku band and millimeter wave bands.**

Keywords—beam steering; substrate integrated waveguide (SIW); broadband; gain

I. INTRODUCTION

With the rapid development of the satellite communication technology, the strong demand for the real time communication on the moving vehicles, names as satcom on the move, has grown rapidly. Beam steering antenna arrays are the key component of the satcom on the move systems. At present, most beam steering arrays are the reflector antenna because of the good performances of broadband and high gain. However, the reflector antenna has bulky size and high cost. Waveguide slot array is another choice for the compact sizes of the radiator elements and the feed network. CTS (Continuous Transverse Stub) arrays was firstly proposed in early 1990s [1]. The CTS are periodically arrayed on the plane waveguide and act as the radiation elements, which are fed by a linear source. The CTS arrays have the good features of compact format, low loss, broadband, and easiness to realize the beam steering [1-3]. Generally, CTS arrays are fed by plate waveguides after transfers from rectangular horns and the feed network are complicated.

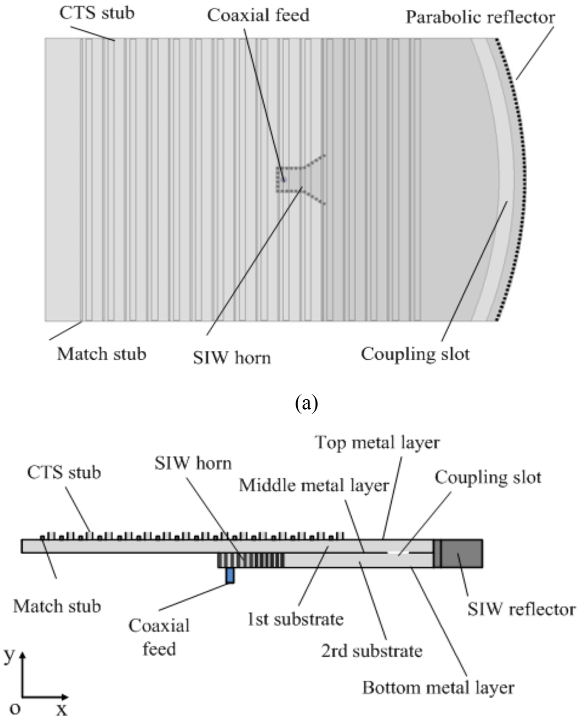
Meanwhile, the SIW (Substrate Integrated Waveguide) suggested in early 2000's is a new planar transmission line, which has the good characteristics of the regular waveguide's low loss and broadband. Ref. [4] design a millimeter wave SIW multibeam antenna based on the parabolic reflector. The scanning range was -30°~23° and the bandwidth with the reflection coefficient less than -10dB was 8%. The antenna aperture was huge because the feed network and the radiation slots were on the same layer. Ref. [5] suggested a SIW slotted waveguide array fed by a SIW parabolic reflector with compact structure by using three substrate layers. The scanning range is ±33° and the relative bandwidth of the reflection coefficient less than -10dB was 5%. In Ref. [6], a CPW-CTS antenna array with metamaterial-based phase shifters was proposed. A scan-angle range from 58° to 124° was achieved and the bandwidth with the reflection coefficient less than -10dB was 16%. The gain of the antenna is 9.7dBi. Ref. [7] design a novel partially reflective surface (PRS) antenna with the capability of beam steering. It achieves a consistent beam steering from – 15° to 15°. From the above discussion, it may be seen that the design of beam steering antenna array with broadband, high gain and wider scan-angle range continues to be a challenge.

In this paper, a broadband beam steering array, CTS array fed by parabolic reflector of SIW, is proposed by combing the preferable features of the CTS array and the SIW feed structure. This broadband beam steering array has the simple and compact structure and low cost. It could be applied in the satcom on the move systems and other communication systems with beam steering.

II. CTS ARRAY DESIGN

The top and the side views of the array configuration are shown in Fig.1.The SIW feed structure includes two substrate layers. The SIW parabolic reflector is formed by a series of vias, which are from the top metal layer to the bottom one. The series of vias shape a parabolic line form the top view. The H-plane horn fed by a coaxial feedline at the bottom layer

is located at the focus of the parabolic plane with the radiation aperture on the second substrate. The EM wave fed by the coaxial line is coupled by the slot on the middle metal layer before the parabolic plane and transferred to the SIW parabolic reflector. The EM wave reflected by the SIW reflector propagates as the plate waveguide mode in the first layer substrate and is radiated by the CTS in series manner. The mini stub beside every CST is used to match the impedance to obtain low reflection coefficient.



(a)

(b)

Fig.1 Configuration of the CTS array. (a) top view, (b) side view

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The beam steering function could be achieved by mechanically moving the SIW horn along the straight line at the direction of the CTS stub. The operation frequency of the CTS array is mainly determined by the sizes of CTS. The sizes of the SIW H-plane horn and the parabolic reflector should be designed by the operation frequency and the substrate characteristics. The impedance match stubs beside the CTS and the coupling slot on the middle metal layer influence the reflection coefficient deeply.

III. SIMULATION RESULTS

A 16 element CTS array at Ku band has been simulated by HFSS software [6]. The normal substrate with the relative dielectric constant of 2.65 and the depth of 3.0mm has been used. The center frequency is 13.0GHz. The main sizes in Fig. 1 are obtained as follows. The length L, width W and height H of the CTS stub are 200mm, 4.0mm and 2.5mm, respectively. The element space between every CTS stub is 14.5mm. The match stub has the width W' of 1.0mm and the height H' of 1.0mm. The rectangular waveguide length a of the horn is 16mm and the width is the size of the substrate's depth. The horn aperture a' is 35mm. the coupling slot has the width s of 10mm. The focal distance f and the curvature radius R of the parabolic reflector are design as 135mm and 100mm, respectively.

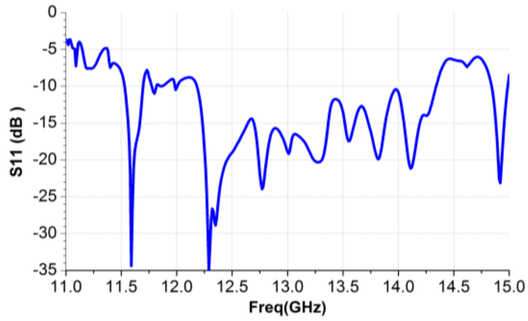

Fig. 4 Simulated reflection coefficient

The simulated reflection coefficient versus frequency is shown in Fig. 4. A broad relative bandwidth of 16.6% (12.18GHz-14.34GHz) with |S11| less than -10dB is achieved. Fig. 5 plots the H-plane beam steering patterns at the center frequency of 13.0GHz. The gain at the broadside is 27.94dB with the sidelobe level of -22.8dB and the 3dB beam width of 7.7°. The gain decrease is less than 3dB within ±33° range, which is the scanning angle. Table I lists the beam steering characteristics from 0° to 33°. At 33° steering angle, the gain is 25.33dB and the beam bandwidth is 9.8°. The front-to-back ratios are high than 30dB within the steering range.

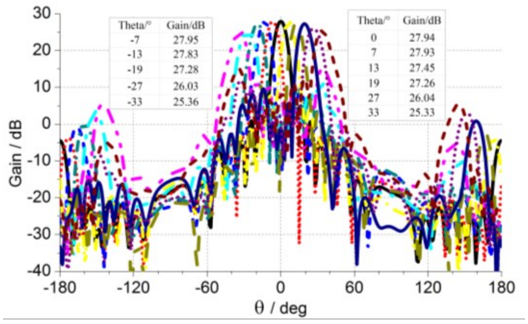

Fig.5 Simulated patterns of beam steering (13GHz)

TABLE I. BEAM STEERING PERFORMANCES (13.0GHZ)

Horn location (mm)	**Beam steering (°)**	**Gain (dB)**	**1st sidelobe level (dB)**	**FBR (dB)**	**Beam width (°)**
0	0	27.94	-22.8	31.5	7.2
10	7	27.93	-19.8	49.4	7.8
20	13	27.45	-29.4	43.6	7.6
30	19	27.26	-21.3	48.3	8.9
40	27	26.04	-20.8	52.1	10
50	33	25.33	-13.1	50.4	9.8

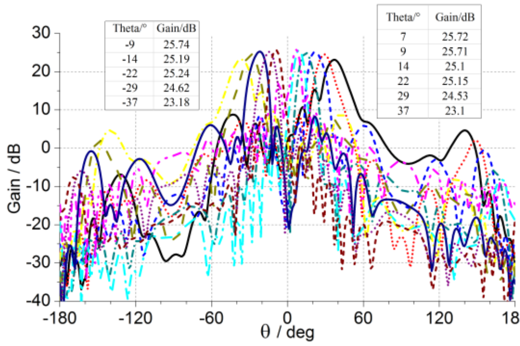

Fig.6 Simulated patterns of beam steering (12.2GHz)

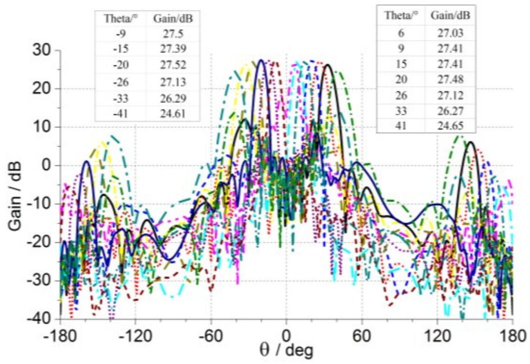

Fig.7 Simulated patterns of beam steering (13.8GHz)

Figs. 6 and 7 plot the beam steering patterns at 12.2GHz and 13.8GHz, respectively. It could be found that the directivity remain nearly the same as those at the center frequency of 13.0GHz and the broadside is at -9° when the frequency is 13.8GHz. The gain decrease to 25.7dB at the broadside of 7° when the frequency is 12.2GHz. However, the front-to-back ratio remain good and the scanning range increase a little.

This broadband beam steering array has the simple and compact structure and low cost. The gain could be improved by enlarging the CTS size and element number to meet further applications. Furthermore, it is suitable for millimeter wave application.

IV. CONCLUSION

A beam steering CTS array with broadband and compact structure is suggested. A 16.6% bandwidth of the reflection coefficient less than -10dB is achieved. The scanning angle is ±33° and The gain at the broadside is 27.94dB with the first sidelobe level of -22.86dB and the 3dB beam width of 7.2°.,This kind of antenna array could be designed at microwave and millimeter wave bands and. The gain could be improved by enlarge the array aperture. This CTS array could be applied on the sitcom on move systems due to the good feature of broadband, compact size and low cost.

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