Design and experiments on series fed conformal microstrip antenna array

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Abstract: In this work design and development of the conformal microstrip antenna array is demonstrated. Important system parameters and overall performance of the Array antenna is described and experimental results for reflection coefficients and far field patterns is included as well as simulated pattern and synthesis results. To improve the performance of microstrip antenna array, a modified configuration of microstrip series-fed taper array is designed. Compared to the traditional one, the novel antenna array has a better VSWR characteristic. The design procedure of the conformal antenna array is discussed and some valuable results are acquired. Numerical results are obtained and a very good agreement is observed between experimental and simulated results of such arrays.

Index Terms - Antenna array, antenna design, antenna feed, patch antenna.

INTRODUCTION

Conformal antenna arrays fitted to the surface of a non planar part of a modern aircrafts, vehicles or ships are considered an attractive alternative for certain applications where planar arrays or reflector antennas have definite drawbacks. Some of the potential advantages are improved aerodynamics, increased payload, large field of view (LFOV) and low observability (LO). However, the usage of conformal array technology in commercial applications is still comparably rare. Recent examples of antenna arrays on curved apertures are typically of circular cylindrical shape and mostly exhibit a weak degree of curvature only [1].

The most commonly used approach for reducing the side-lobe level of a uniform array involves amplitude tapering in which the excitation amplitudes of the array elements generally decrease with distance from the center of the array. In order to obtain the amplitude shading coefficients for a linear array of uniformly spaced point sources, several techniques [2], [3] have been developed and the narrowest possible beam was produced at a given degree of uniform minor lobe suppression. There exists another major disadvantage in these related designs, i.e., the narrow bandwidth. Several techniques, including impedance matching, the use of multiple resonators and the use of lossy materials has been proposed to enhance the bandwidth of microstrip antennas.
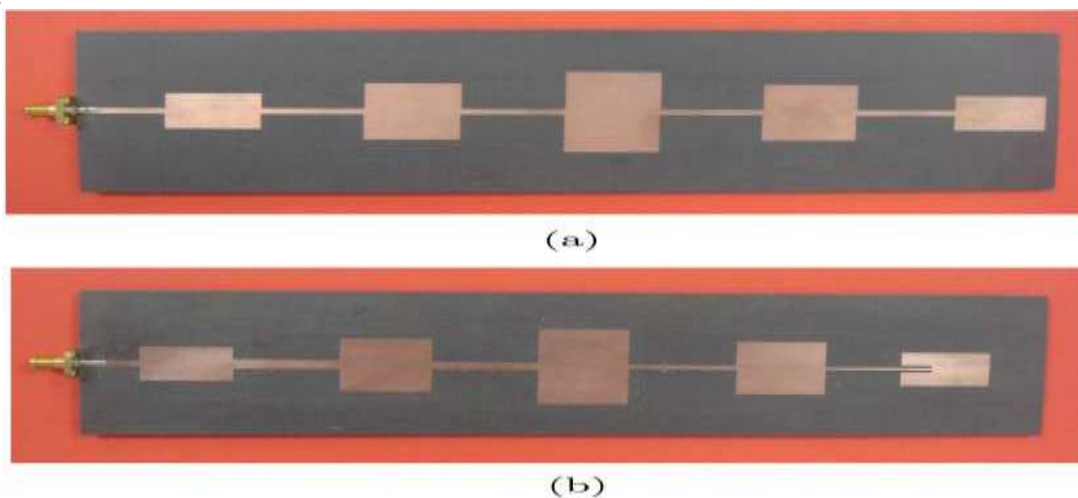

Fig.1 .a) Traditional taper antenna array. b) Modified taper antenna array
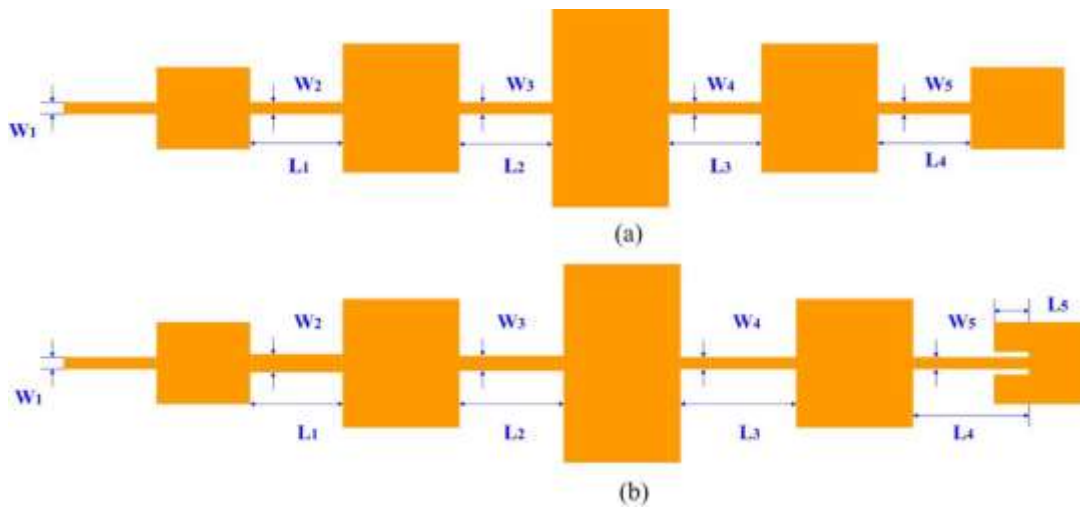
Fig 2. (a) Configuration of the traditional series-fed taper antenna array. (b) Configuration of the novel series-fed taper antenna array.

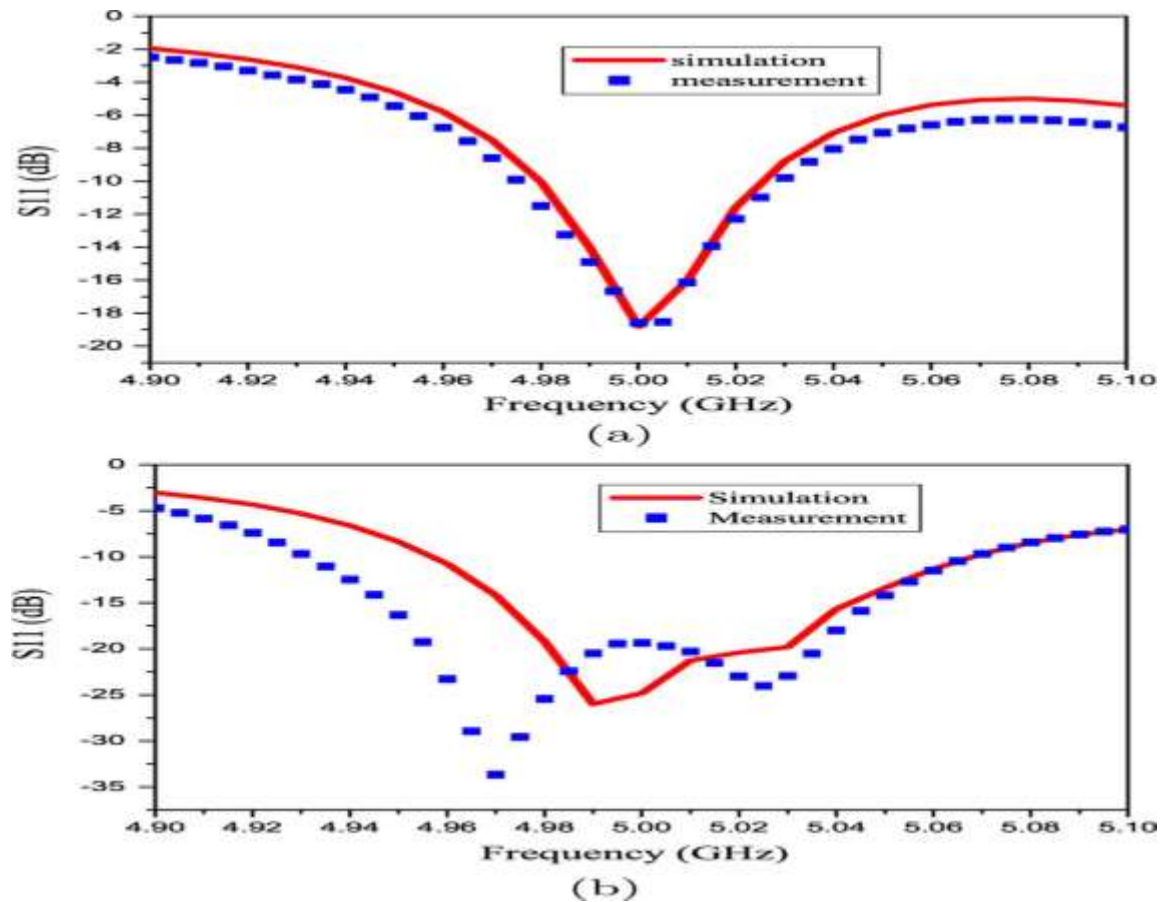

Fig3. The S-parameters of the two antenna arrays. (a) S11of traditional series-fed taper antenna array. (b) S11 of novel series-fed taper antenna array.
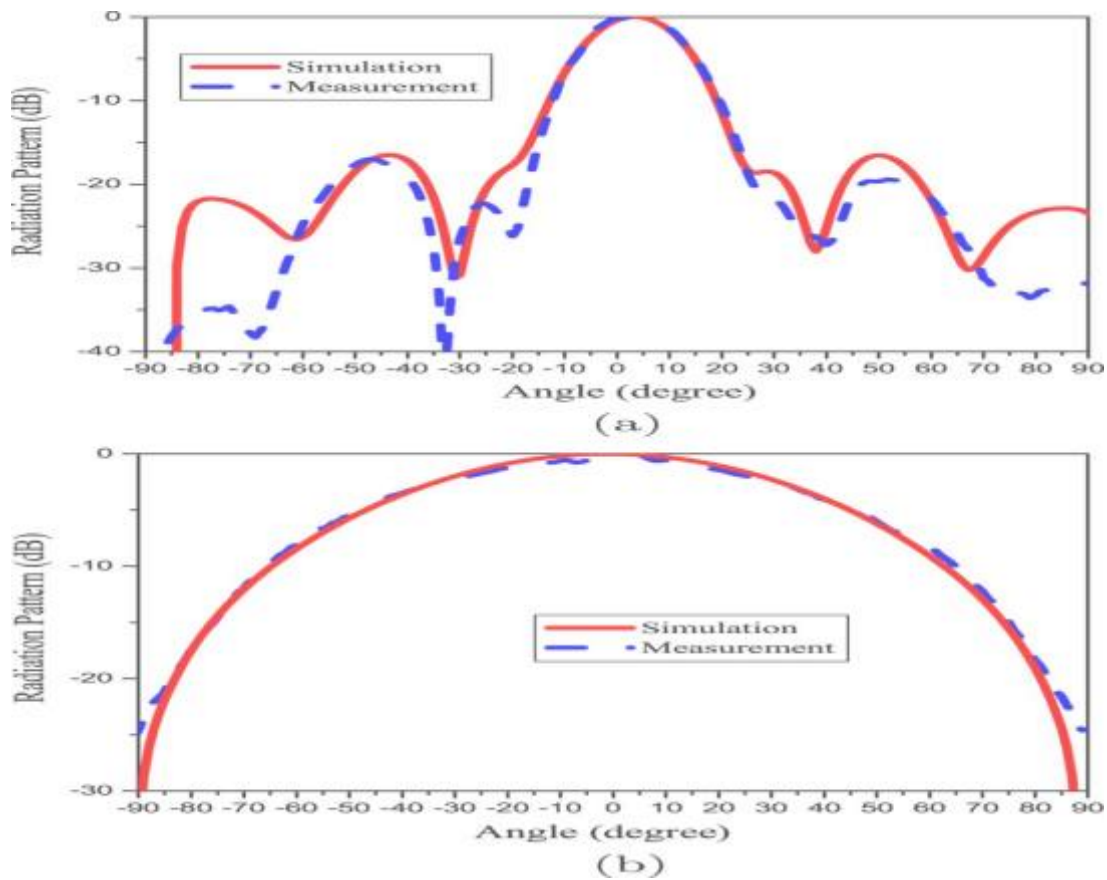
Fig 4. The E- and _H plane radiation patterns of the novel series-fed taper antenna array. (a) E-plane. (b) H-plane.

The traditional series-fed taper antenna array is shown in Fig. 1(a), which was used as the starting point of the present work. The array mounted on the top of a grounded dielectric substrate of thickness 31mil and a relative dielectric constant = 2.2. With end-fed arrays, the elements nearest the feed couple only a small amount of power and therefore must be fairly narrow. The feed line must be small compared to the narrowest patch. In this case, a 50 ohm line will be used. The line width is 2.42 mm that is considerably smaller.

A new configuration of matching feed is proposed which can improve significantly the antenna array performance. In order to improve the performance of microstrip antenna array, a new configuration of microstrip series-fed tapered array is designed. Compared with the traditional one, the novel antenna array has a better VSWR characteristic. The side-lobe level is also reduced by using the tapered structure.

Design

The rectangular array elements are spaced a wavelength apart where the patch and the connecting transmission line are both half-wavelength in length. Assuming that the line has a characteristic impedance of Z0, at the design frequency, the radiating element impedance is purely real. Compared with the traditional series-fed antenna array, the terminal element of the array is designed using recessed microstrip-line feed. The circuit consists of shunt impedance, representing the elements, connected together by transmission line segments. According to the equivalent circuit, the total input impedance is determined by the smallest one of the patch elements. At resonance, the input resistance for a patch fed at one edge is usually high, being in the order of 150 to 500. It can be reduced by moving the feed inward toward the center of the patch because input impedance varies approximately as a cosine squared function of the inset distance (which has a maximum at the edge and is zero at the center. When using the recessed feed at the end of the elements, the total input impedance of the array is determined by the terminal element because its input impedance is the smallest one. Here in the proposed array, the terminal input impedance is designed to be 80. Then the total input

impedance of the array is nearly 50 and changes slowly as compared with the traditional one. Therefore, it has better VSWR characteristics. For the geometry of the conformal antenna array an elliptical cross section with a large axial ratio (*a/b* = 4) and a strong degree of curvature at the center was chosen, such as an antenna mounted circumferentially around the wing or fin of an aircraft.

Results

The S-Parameters of the antenna array have been measured using an Agilent E8364B network analyzer. It can be seen that the 10 dB-bandwidth of the antenna elements exceeds 1 GHz ($\approx$ 10%). Compared to the isolated antenna design the resonance frequency is shifted and levels are slightly increased due to multiple imperfect transitions between different lines inside the calibration network. Calculated results of radiation patterns return loss of the microstrip antenna array is shown in Figs. 3-4 and compared with the experimental results. It shows that a reasonable agreement between the designed results and the experimental results of the modified antenna array . To be able to judge the performance of this proposed new antenna array properly, a traditional series-fed taper antenna array shown in Fig. 1(a) is first analyzed (where permittivity 2.2 and thickness of the substrate are 31mil, respectively). Compared to the traditional one, the novel series-fed taper antenna array is also designed, as shown in Fig. 1(b). Finally, E plane the H plane radiation patterns at 5 GHz of the deigned array are shown in Figs. 5 a) and 5b) Side-lobe level is apparently reduced by using the taper antenna array. Compared with the traditional series-fed taper antenna array, the novel taper antenna array also has a low side-lobe level (dB) and it also exhibits a good radiation characteristic.
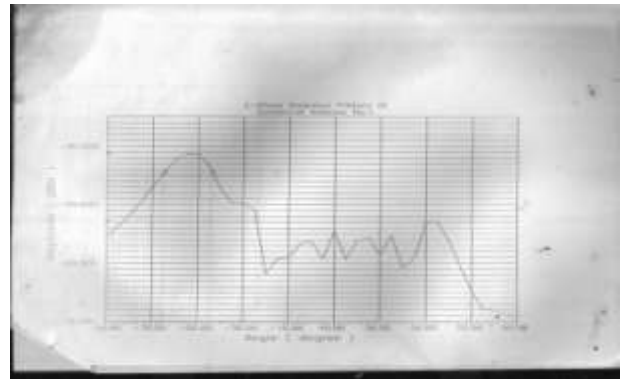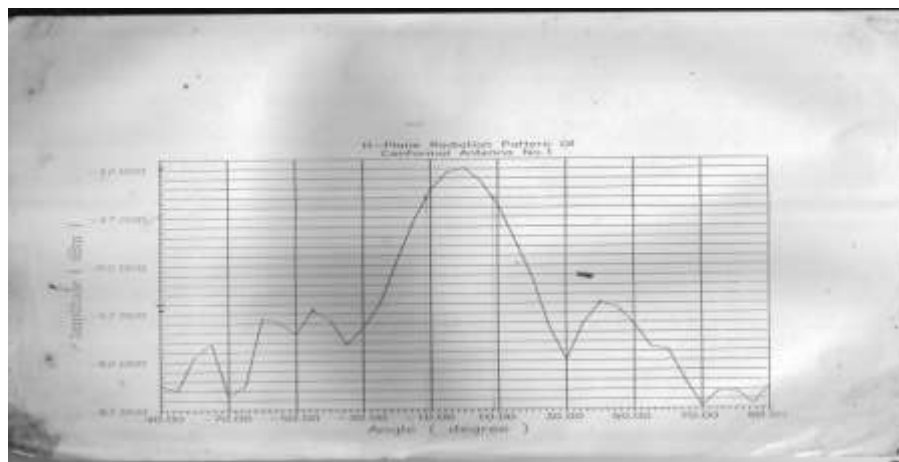

Fig 5a)

Fig 5b)

Fig 5c)

Fig. 5. The measured a) VSWR b) E plane and c) H Plane radiation pattern of conformal microstrip antenna array.

Conclusion

A new configuration of microstrip series-fed taper array is designed in order to improve the performance of microstrip antenna array. Compared with the traditional one, the novel antenna array has a better VSWR characteristic. The side-lobe level is also reduced by using the taper structure. A 5-element linear taper microstrip array is, thus, designed and it achieve a peak side-lobe level as low as -14 dB. A very good agreement has been obtained between calculated and measured results of such an array.

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