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A 24×24 Microstrip Array Antenna at K-band

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Abstract: A 24×24 microstrip array antenna for Doppler radar is presented. For the low side lobe, the feeding network of microstrip array antenna is used for Taylor series amplitude weighting. The side lobe of microstrip array antenna is less than -18.5 dB at 24.15GHz. The proposal design is confirmed by both simulation and measured results.

Keywords: Feeding network, low side lobe, microstrip array antenna, Taylor series.

1. INTRODUCTION

Planar antenna attracts increasing interest in high- performance wireless communication commercial and government defense applications due to its flat profile, low weight, case of easy fabrication and low cost [1-4]. And microstrip antennas are used not only as single elements, but are also very popular in arrays [5-7]. Microstrip arrays are very versatile and are used to synthesize a required pattern that cannot be achieved with a single element. In addition, they are used to scan the beam of antenna system, increase the directivity, and perform various other functions which would be difficult with any one single element sketch.

For applications of Doppler radar and intelligent transportation network system, a 24×24 microstrip rectangular array antenna with low side lobe is proposed as shown in Fig. (**1**), which consists of 576 rectangular microstrip elements. The microstrip array is designed on a 20mil thick RT-Duroid 4350 substrate material.

2. MICROSTRIP ARRAY SIMULATION

In general, radiation characteristics of an antenna array can be determined once the feeding-network distribution is known. Existing methods that have been employed to feed microstrip arrays can be categorized into parallel and series feeds [8-11], which refer to geometries rather than to actual equivalent circuits. The amplitude and phase distribution at each element is usually determined from the intended application, for example, low side lobe and beam direction. The means of excitation of the radiation elements are thus an essential and important factor which must be carefully considered.

The microstrip array antenna as shown in Fig. (**1**), is designed at 24.15GHz on 20 mil thick RT-Duroid 4350 substrate material, which the 3dB beam-widths are both less than 5° in the H-plane and E-plane. And the side lobe of the array antenna is less than -18.5dB in Doppler radar and intelligent transportation network system. In order to reduce the side lobe, the excitation coefficients of the feeding network are related to Taylor series distribution.

In order to obtain a beam pattern that meets the specifications, both the element factor and the array factor are under control of the designer. Usually however, the design of the element is dominated by other factors, like bandwidth requirements. Therefore, the requirements of the beam can not be fulfilled by a single element, in general. So in order to obtain a certain beam pattern, the array factor has to be designed accordingly.

First step, the rectangular microstrip resonator element of the array is shown in Fig. (**2**). And the size of resonator is 4.0 mm×3.12mm on 20mil thick RT-Duroid 4350. The insert gap of feed line is 0.28mm and the insert distance of feed line is 1.0mm.

Based on the EM simulation, the VSWR diagram of single patch element is shown in Fig. (**3**). The resonator frequency of single patch is at 24.15 GHz. And the radiation pattern of rectangular element is shown in Fig. (**4**).

Second, the feeding network of microstrip array is calculated as shown in Fig. (**1**). To obtain the 3dB beam-widths less than 5° in the H-plane and E-plane, the elements in the linear array are 24 in both directions. Furthermore, the Taylor series distribution factors and the impedances of the feeding transmission lines are calculated and element numbers in the E-plane and H-plane [12, 13].

For example, the current amplitude distributions of linear array elements n=24 are shown in Fig. (**5**). with -20dB side lobe in the left side are I1 : I2 : I3 : I4 : I5 : I6 : I7 : I8 : I9 : I10 : I11 : I12 = 0.5194 : 0.5358 : 0.5674 : 0.6121 : 0.6669 : 0.7281: 0.7914: 0.8525:0.9072:0.9521:0.9836:1.

The equivalent circuit of the left feeding network is shown in Fig. (**6**). Y_A is the input admittance of single microstrip patch element, Y_{in} is the input admittance of the left or right side microstrip linear array. Y_{c1} and Y_{c2} are characteristic admittance of transformation microstrip line.

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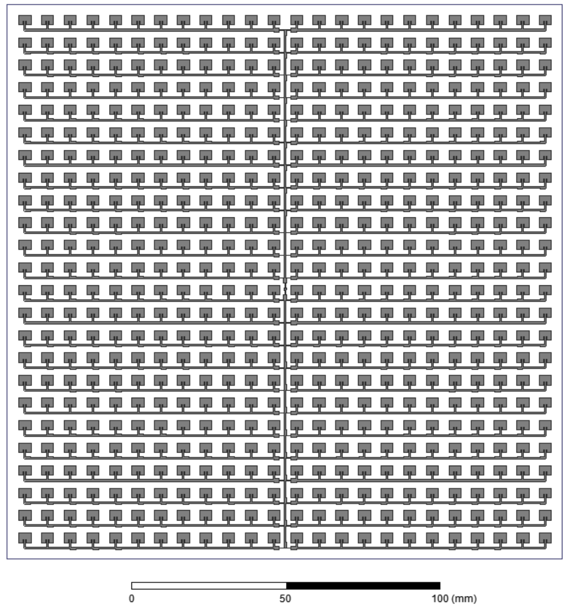

Fig. (1). Layout of 24×24 microstrip array.

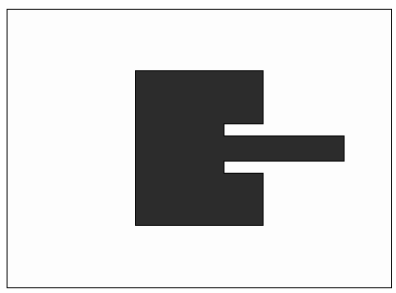

Fig. (2). Structure of microstrip resonator unit.

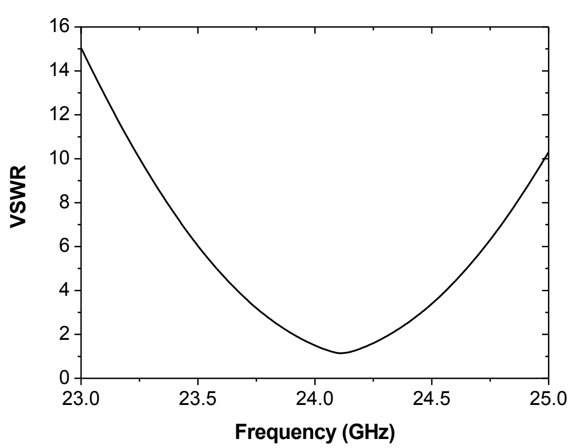

Fig. (3). VSWR diagram of microstrip unit.

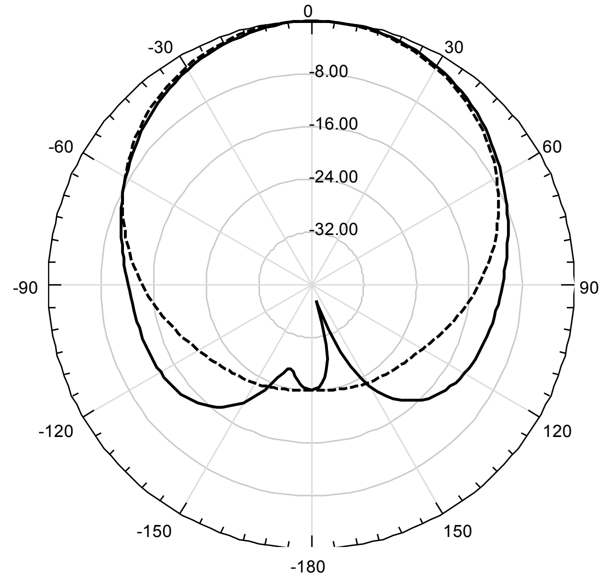

Fig. (4). Radiation pattern of unit (dashed is H-plane and solid is E-pane).

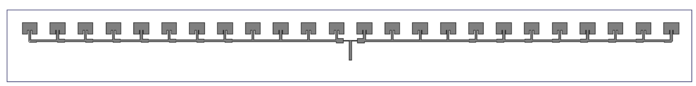

Fig. (5). Feeding network of microstrip linear array.

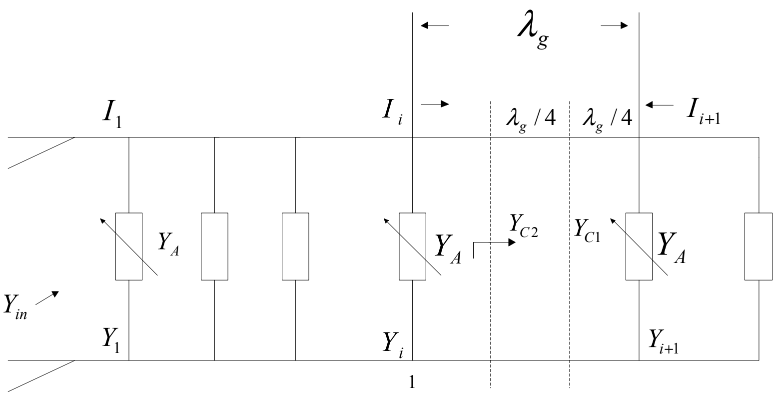

Fig. (6). Equivalent circuit model of feeding network.

$$Y_i = Y_A + Y_i^{'} \tag{1}$$

$$Y_i^{'} = \left(\frac{Y_{c2}}{Y_{c1}}\right)^2 Y_{i+1} = n_i^2 Y_{i+1} \tag{2}$$

$$n_i = \frac{Y_{c2}}{Y_{c1}} \tag{3}$$

$$\begin{aligned} Y_{in} &= Y_1 = Y_A + n_1^2 Y_2 = Y_A + n_1^2(Y_A + n_2^2 Y_3) = ... \\ &= Y_A\left(1 + n_1^2 + n_1^2 n_2^2 + ... + n_1^2 n_2^2 ... n_{n-1}^2\right) \end{aligned} \tag{4}$$

where,

$$I_1 : I_2 : ... : I_n = 1 : n_1 : ... : n_{n-1} \tag{5}$$

At last, the microstrip array antennas as shown in Fig. (**1**), was simulated by EM soft. The H-plane radiation pattern of the microstrip arrays is shown in Fig. (**7**). The 3dB beam-width in the H-plane is less than 5° and the side lobe is less than -18 dB. And the E-plane radiation pattern of the microstrip arrays is shown in Fig. (**8**), the 3dB beam-width in the E-plane is less than 5° and the side lobe is less than -18.5 dB. The simulation results are satisfied with the specification of Doppler radar.

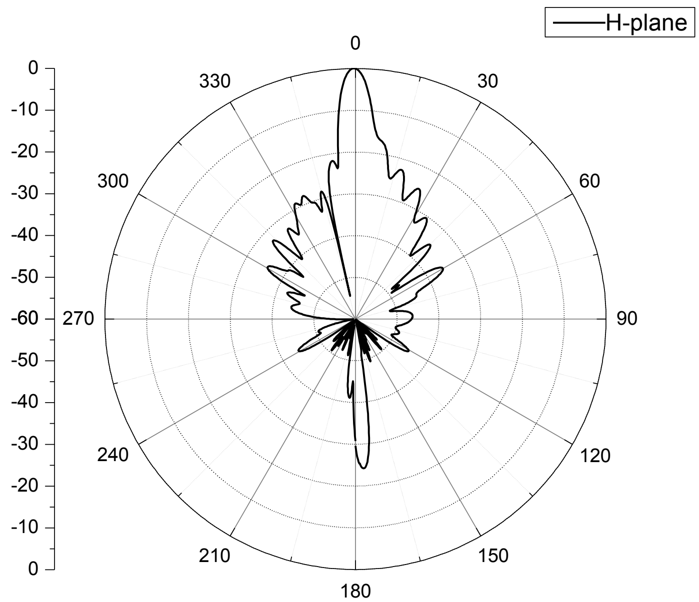

Fig. (7). H-plane simulation radiation pattern of microstrip array.

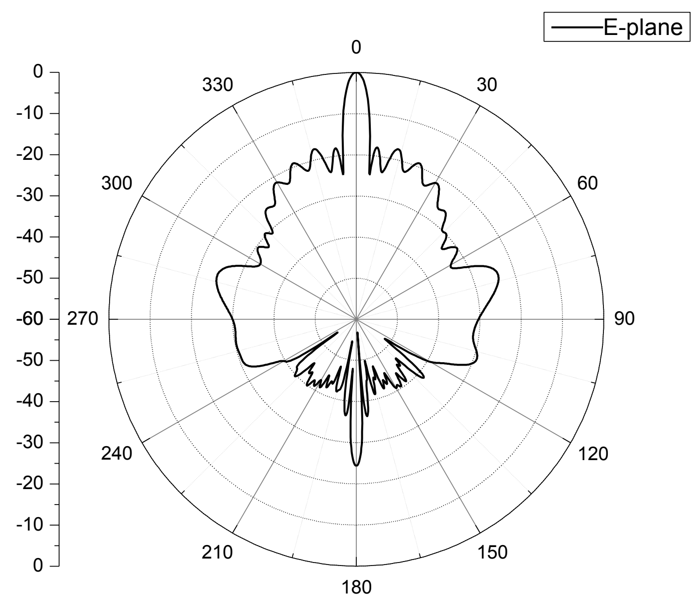

Fig. (8). E-plane simulation radiation pattern of microstrip array.

3. MICROSTRIP ARRAY REALIZATION

The microstrip array antenna shown in Fig. (**1**) with 576 rectangular resonators is fabricated on 20mil thick RT-Duroid 4350 substrate. The photo of the array is shown in Fig. (**9**). And the coaxial feed-line and SMA connector to the array is on the rear of microstrip array. The whole size of the array is about 180mm ×180mm.

Fig. (**10**) and Fig. (**11**) give the measured H-plane and E-plane radiation patterns. The 3dB beam widths of H-plane and E-plane are 5.05° and 4.85°. The side lobes of H-plane and E-plane are less than -19dB and -18.5dB. Considering the tolerance of machining and the error of measurement, the measured results are well consistent with the simulated results.

CONCLUSION

A 24.15GHz microstrip array antenna with Taylor series feeding network is proposed, which has low side lobe less than -18.5dB. Measured radiation patterns verify the design of the microstrip array antenna.

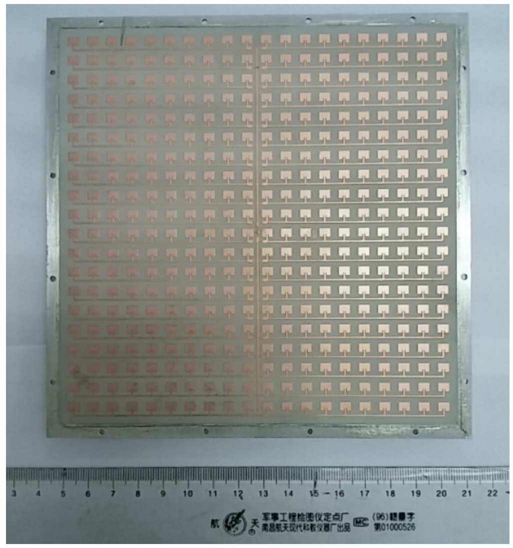

Fig. (9). Photo of microstrip array antenna.

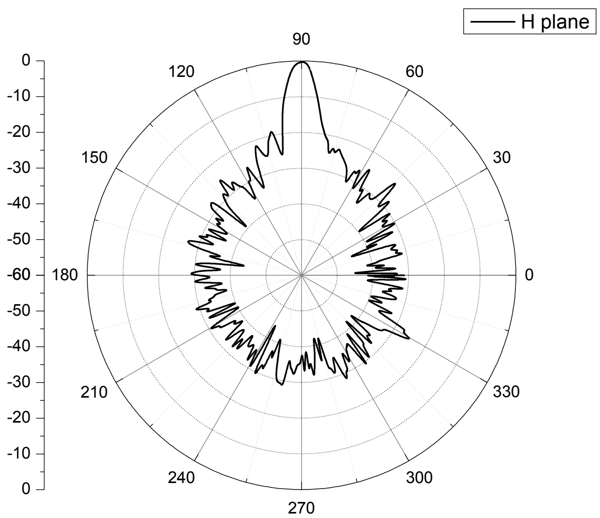

Fig. (10). H-plane radiation pattern of measure.

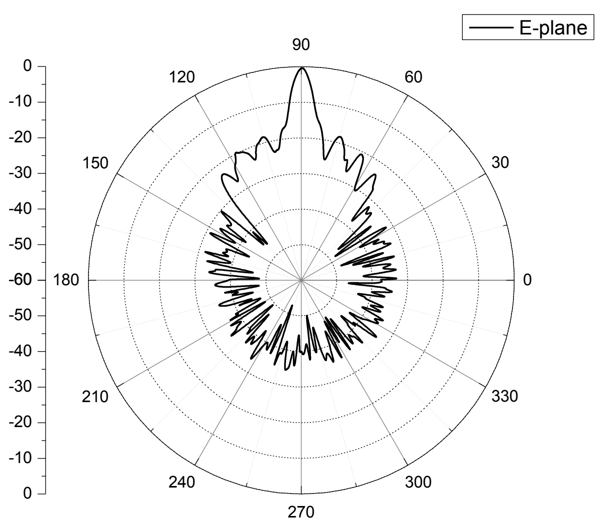

Fig. (11). E-plane radiation pattern of measure.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

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