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Design and Development of Microstrip Array Antenna with Broader Bandwidth and Beam

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Abstract: *The design and development of an X-band linearly polarized microstrip array antenna is presented. The array elements are fed by corporate feed network, which improves the impedance bandwidth of the four element rectangular microstrip array antenna (4RMSAA) by 18.65 %. By increasing the array elements from four to eight, impedance bandwidth is improved to 38.47 % which is 2.06 times more. Experimental results for the array antennas in term of return loss, -3dB beam width and gain are presented.*

Keywords: *Microstrip Array, Antenna, Corporate Feed, Broader Bandwidth, Broader Beam, X-band, Gain.*

1. INTRODUCTION

In many wireless-communication systems, there is a requirement for light, low-profile antennas. These antennas are less obtrusive than traditionally used parabolic reflectors. In addition, snow, rain or wind has less affect on their performance. A planar antenna, incorporating an array of microstrip patches, is one example of a low-weight, low-profile antenna. In order to make this array an effective radiator, each individual patch has to be suitably fed [1, 2]. Different methods can be used to achieve this goal.

The conventional approach to the design of feed network aims at a division of power from the input port to the patch element with ideal match at any level within the network up to the patch element. The patch element impedance bandwidth is dependent on the substrate thickness. Conventional impedance bandwidth enhancement approaches aim at broadening the bandwidth by employing multilayer construction, using parasitic elements and electromagnetic coupling or by employing a matching filter network attached to each element. The latter approach requires additional circuit area for every patch element, which often is in conflict with the required circuit area for the feed network [3]. One very popular choice is a corporate-feed network, in which two-way power divider or T-junctions are arranged in a rectangular matrix [4].

This presentation provides a new approach of feed network design in which the network is used for the power division and, at the same time, for broad banding of the impedance match of the array antenna. The designed feed network works at dominant mode and gives broader beams.

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2. ANTENNA CONFIGURATIONS

The proposed antennas are designed using low cost glass epoxy material having dielectric constant $\epsilon_r = 4.2$ and thickness $h = 0.166$ cm. The geometry of 2RMSAA is shown in Figure 1.

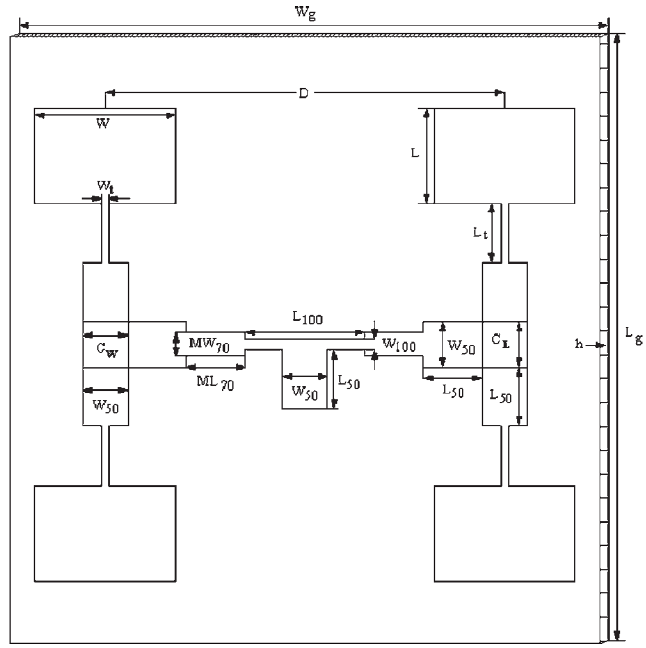

Figure 1: Geometry of 4RMSAA

The elements of array are designed for 9.4 GHz frequency with dimensions (L = 0.66) cm and (W = 0.99) cm. The length (L_g = 4.82) cm and width (W_g = 5.05) cm of the ground plane of antenna is calculated using $Lg = 6h + L$ and $Wg = 6h + W$ [5]. The elements of this array antenna are excited through simple corporate feed arrangement. This feed arrangement consist of matching transformer, quarter wave transformer, coupler and power divider for better impedance matching between feed and radiating elements [6]. A two-way power divider made up of 70 Ω matching transformer of dimension (ML_{70} = 0.41, MW_{70} = 0.16) cm is used between 100 Ω microstrip line of dimension (L_{100} = 0.83, W_{100} = 0.07) cm and 50 Ω microstrip line of dimension (L_{50} = 0.41, W_{50} = 0.31) cm. A coupler of dimension (C_L = C_W = 0.31) cm is used between 50 Ω microstrip lines to couple the power [7, 8]. The 50 Ω microstrip line is connected at the center of the driven element through a quarter wave transformer of dimension (L_t = 0.41, W_t = 0.04) cm for better impedance matching. At the tip of microstrip line feed of 50 Ω, a coaxial SMA connector is used for feeding the microwave power. The array elements are kept at a distance of D = 2.79 cm from their center point. This optimized distance is selected in order to achieve minimum side lobes in the radiation pattern and to add the radiated power in free space [9]. Further the study is carried out for eight element rectangular microstrip array antenna (8RMSAA) which is as shown in Figure 2.

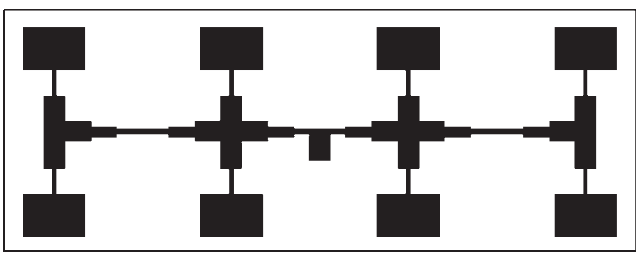

Figure 2: Geometry of 8RMSAA

3. EXPERIMENTAL RESULTS

The impedance bandwidths for the proposed antennas are measured at X-band frequencies. The measurements are taken on Vector Network Analyzer (Rohde & Schwarz, German make ZVK Model No. 1127.8651). The variation of return loss versus frequency of 4RMSAA and 8RMSAA are shown in Figure 3.

Figure 3, presents the experimental impedance bandwidth of 4RMSAA (BW_1) which is found to be 2240 MHz i.e. 18.65 %, which is 6.54 times more when compared to single radiating element (2.85%). The combined resonance of each element results in improvement of impedance bandwidth [10]. The minimum return loss measured in this antenna is –14.33 dB at 12.64 GHz.

Further, from the graph it is clear that the impedance bandwidth of 8RMSAA (BW_2) is found to be 4340 MHz i.e. 38.47%, which is 2.06 and 13.5 times more when compared to 4RMSAA and single radiating element respectively. This improvement in impedance bandwidth is also due to combined resonance of all the eight elements fed by corporate feed network. The minimum return loss measured in this antenna is –36.40 dB at 12.08 GHz.

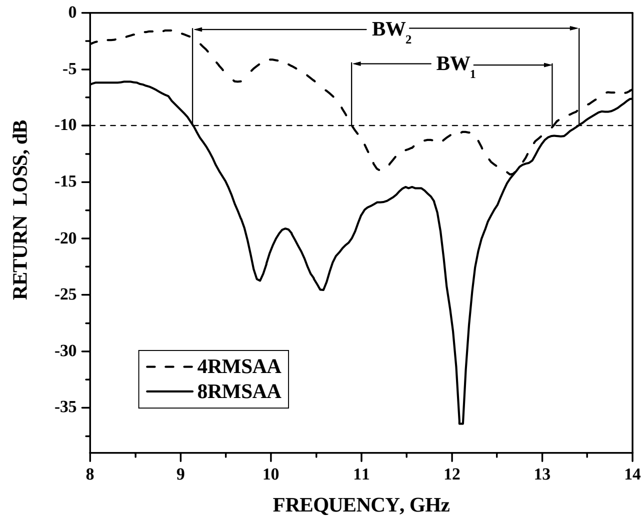

Figure 3: Variation of Return Loss versus Frequency of 4RMSAA and 8RMSAA

The far-field H-plane co-polar and cross-polar radiation patterns of 4RMSAA and 8RMSAA are measured at their resonating frequencies and are shown in Figures 4 and 5. From these figures, it is clear that both the antennas are showing broad side radiation characteristics with lower cross polarization level less than -15 dB and -23 dB for 4RMSAA and 8RMSAA respectively.

The -3 dB beam width (HPBW) of 4RMSAA and 8RMSAA is calculated for their resonating frequencies and is found to be 70^0 for 4RMSAA and 60^0 for 8RMSAA. Microstrip antennas working at dominant modes, such as the TM10/TM01 modes for rectangular microstrip antennas and TM11 mode for circular and ring microstrip antennas are typical broadside antennas. Although, higher modes of microstrip antennas, such as TM21 and TM 31 modes and etc. can realize radiation at lower angles, it is rather difficult

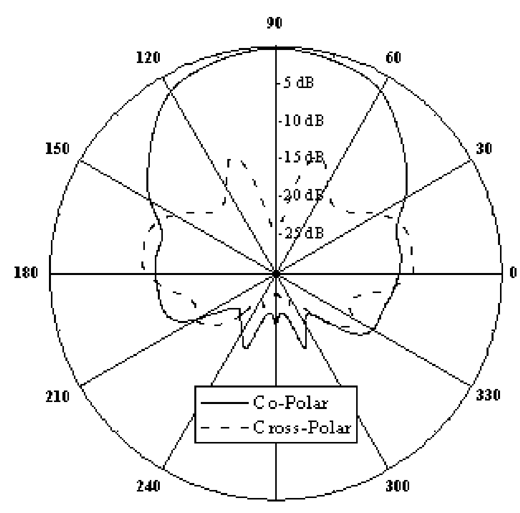

Figure 4: Variation of Relative Power versus Azimuth Angle of 4RMSAA at 12.64 GHz

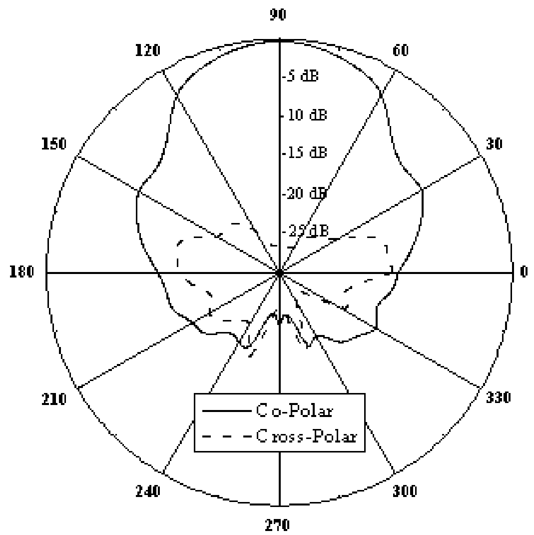

Figure 5: Variation of Relative Power versus Azimuth Angle of 8RMSAA at 12.08 GHz

to obtain broad radiation with dominant mode and higher modes at one radiator. But it is difficult to realize broader beams for microstrip array consisting of radiators working at dominant modes only. Here, a microstrip array antenna designed working at TM10 mode will give broader beams then traditional microstrip array antenna, which can be used to trace targets exactly as soon as finding them and for anti-jamming [11].

In order to calculate the gain, the power received (P_s) by the pyramidal horn antenna and the power received (P_t) by 4RMSAA and 8RMSAA are measured independently. With the help of experimental data, the gain of antenna under test (G_T) in dB is calculated using the formula,

$$(G_T)_{dB} = (G_s)_{dB} + 10 \log (P_t/P_s)$$

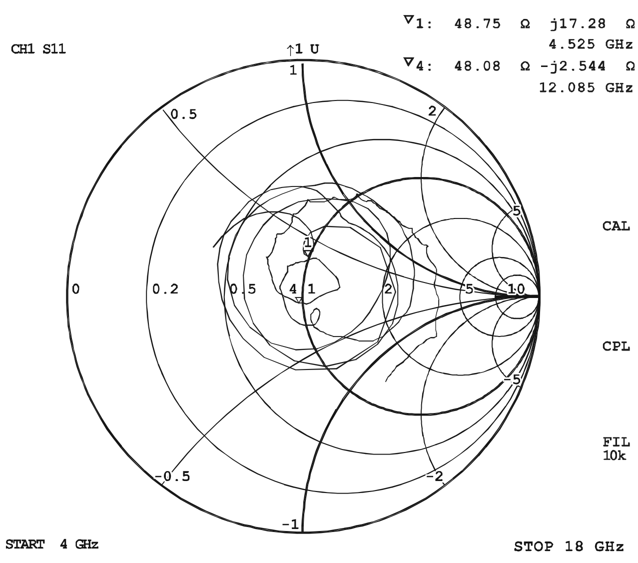

Figure 6: Input Impedance Profile of 8RMSAA

where, G_s is the gain of pyramidal horn antenna. It is seen that the gains of 4RMSAA and 8RMSAA are 5.29 dB and 5.36 dB respectively. When compared with 4RMSAA, the gain of 8RMSAA is also improved by 1:1.01 ratio. This shows the use of array configuration also improves the antenna gain considerably [12].

As 8RMSAA gives improved impedance bandwidth, the variation of input impedance is shown in Figure 6. It is seen that the input impedance has multiple loops at the center of Smith chart that validates its broad band operation.

4. CONCLUSION

From the detailed experimental study it is clear that, the proposed antennas are quite simple in design and fabrication and quite good in enhancing the impedance bandwidth and give better gain with broadside radiation pattern at X-band frequencies. These antennas are also superior as they use low cost substrate material. These antennas may find application in modern communication system and in microwave wireless communication system.

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