Design & Development of a Ku-Band Microstrip Array Antenna

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Abstract:

A Ku-Band array antenna with 4x4 rectangular microstrip elements has been designed and developed for a distant point-to-point data communication purpose. A stepwise approach of the design with different array configurations have been studied and the performances of single element, 1x2, 2x2, 2x4 and 4x4 have been compared and reported. The design has been optimised using IE3D electromagnetic simulation code and developed to meet the required specifications. A unique dc shorting technique has been proposed to enhance the antenna performance and reported.

Keywords – Ku-band microstrip array, dc short

I. INTRODUCTION

A wireless communication system requires an antenna designed to resonate at the pre-determined frequency of operation which is system specific and decided by its application. The operation in Ku Band is generally used for satellite data communication systems. Present work aims at designing an antenna array in Ku Band for its use as a test antenna to evaluate the performance of a ósatcomô based data communication system.

The requirement demands for a compact planar antenna with moderate gain to operate in Ku-Band. Initially, we attempted to design the array with coplanar feed network scheme and found it to be difficult to route the feed lines along with the printed radiators. In addition, the design resulted in an antenna whose bandwidth was too narrow to meet the requirement. To overcome these limitations, multilayer microstrip arrays with proximity coupled feed network has been designed and developed. Different array configurations with increasing number of elements have been worked out and simulated. Finally, a sixteen element array antenna has been designed, optimised through simulation and fabricated for the intended application. A study to incorporate dc grounding scheme has been carried out and reported.

II. PROXIMITY COUPLED ANTENNA

The radiation from a microstrip patch antenna is primarily because of the fringing fields between the patch edge and the ground plane. In proximity coupled antenna, the microstrip feed is of non-contact type and is placed on a different layer of substrate than the patch radiators. The microstrip antenna and the microstrip feed line shares a common ground plane. The RF energy from the feed network is coupled to the radiating patch electromagnetically, as opposed to a direct contact type in which they are co-planar and energy transfer takes place directly.

In the present assignment, the thickness of each of the dielectric substrate is 0.8 mm and its dielectric constant (Ů) is 2.5. The top layer of the substrate consists of patch array, the feed in the middle layer and ground plane at the bottom layer as shown in Fig 1.

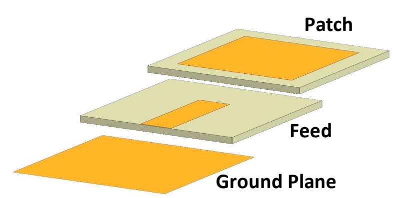

Fig 1: Schematic of Proximity Coupled Antenna

The dimension of a Ku Band rectangular patch is very small due to its frequency of operation. However, the widths of the microstrip lines for various impedances in the feed network do not change much for higher frequency of operations. A microstrip line with 50 Ω impedance is very close to the resonant length of the radiating patch in Ku Band, which may degrade the antenna performance. Therefore, appropriate routing of the feed lines and its optimisation is important to maintain its array performance.

Another important aspect of a microstrip array is the spacing between the radiating elements. Closely spaced elements suffer from mutual coupling, on the contrary if the separation is too far it causes grating lobes. In the present design, separation between the two elements has been optimized to 0.7λ in both the directions. After designing the single element proximity coupled antenna at the intended frequency in Ku Band, it is duplicated and placed at the optimised separation to configure the smallest array configuration of 1x2 elements. This is further extended to make 2x2, 2x4 and 4x4 arrays with appropriate routing of feed network for the respective array.

The corporate feed network is chosen for designing the array. Quarter-wave transformers are used in the printed feed network to match impedances at various junctions appropriately. In this work, equal power distribution has been used to feed each of the microstrip patch. The feed lines of the network terminate open ended underneath each of the radiating patch elements which are energized through proximity coupled technique.

The schematic of 2x2 array of rectangular patches, their spacing and feed network on the bottom substrate have been optimized and is as shown in Fig 2. The VSWR plot obtained after simulation through IE3D is presented in Fig 3(a). The 2D directional radiation patterns in two orthogonal planes are shown in Fig 3(b).

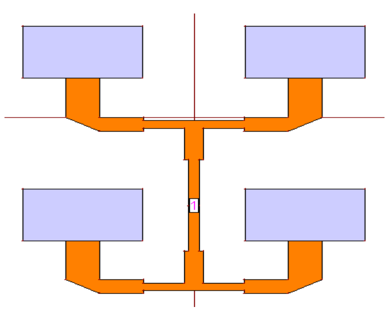

Fig 2: 2x2 Array scheme with feed network

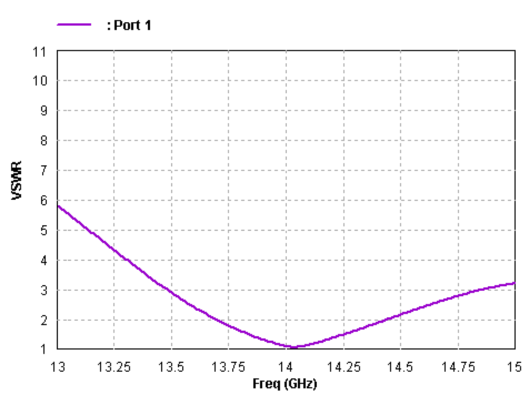

Fig 3(a): VSWR plot of the 2x2 array

II. Incorporation of DC Short

In general, antennas are open-circuited and there is an isolation between the signal and ground terminals. In any antenna system, there is a possibility of the accumulation of static charges in the vicinity of the antenna radiating element. This accumulation of charges leads to the generation of spurious fields which may likely degrade the antenna performance. Even though there is isolation between the radiator and the ground, it is possible to ground the static charges. This can be done by introducing a low impedance path or a dc short appropriately between the two terminals. The dc short is generally used to bypass the spurious field and radiations to the ground.

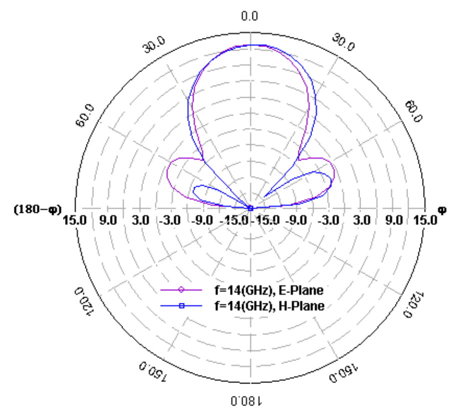

Fig 3(b): Radiation pattern in E & H planes for 2x2 array

In the present design of Ku Band microstrip array antenna, a unique scheme for dc grounding is proposed. A microstrip patch antenna can be modelled as an open circuited transmission line with two slots. The understanding of the physical behaviour of the patch antenna reveals that the slots are equivalent to terminations with very high impedances when viewed from both sides of the transmission line. With this assumption, the current is minimum at edges of the patch which is near half-wave length long and the value is maximum at the centre. Since the high value of current represents a short circuit, and with this interpretation a conductive path has been provided in the form of a vertical thin wire between the radiating element at its central location and the ground plane.

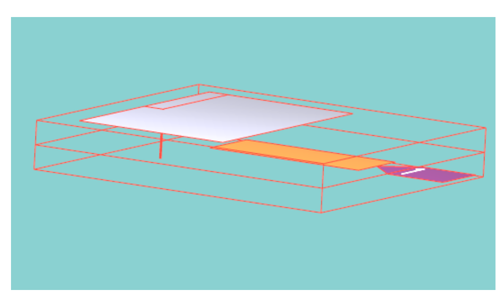

Fig 4. Schematic of Proximity coupled patch with DC short

The conceptual design has optimized through a process of simulation by varying the location of shorting pin and analyzing its effect on various antenna parameters. The schematic of single element patch antenna with shorted pin is shown in Fig. 4. A similar approach is followed for array configurations.

We moved the location of the shorted pin along the axis of the microstrip feed line, from the central location towards the outward open circuit edge and found that its resonating frequency increases gradually. In addition, a noticeable change in the VSWR is also observed. The results are given in Fig 5 & 6 respectively.

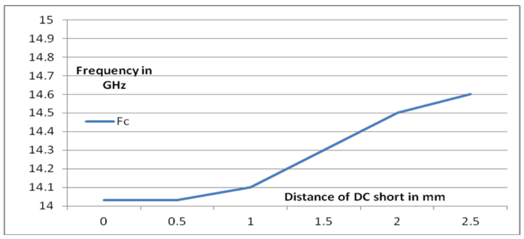

Fig 5. Resonating frequency changes on deviation of DC short from the center

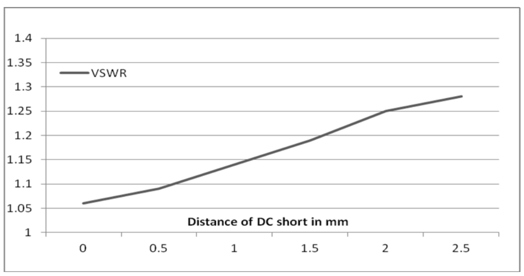

Fig 6. VSWR dependance on deviation of DC short from the center

III. Design Optimization & Hardware Development

The Ku Band operation restricts the design flexibility of the array antenna particularly for 2x4 and 4x4 configuration. However, through a process of simulation using IE3D, these arrays have been optimised. The 4x4 array antenna has been fabricated and the hardware of printed array and feed network are shown in Fig 5.

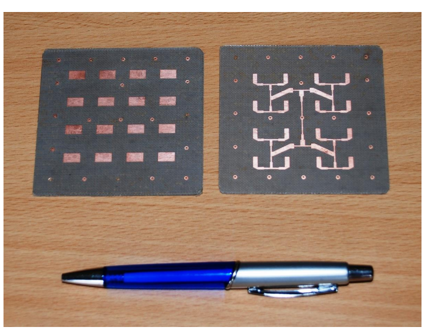

Fig 7. Hardware of 4x4 Array Antenna and Feed Network

The integrated array in its multilayer form has been evaluated and its VSWR and radiation pattern are shown in Fig 6 & 7 respectively. The comparative results of all the antennas that have been simulated along with the measured results of the 4x4 array are summarised in Table I.

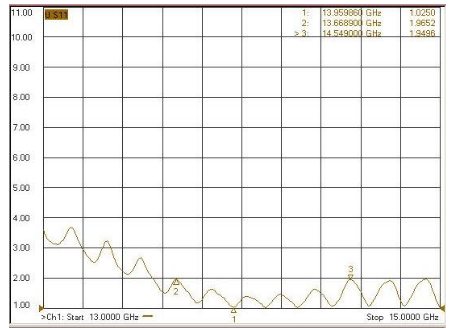

Fig 8. VSWR result of 4x4 Array Antenna

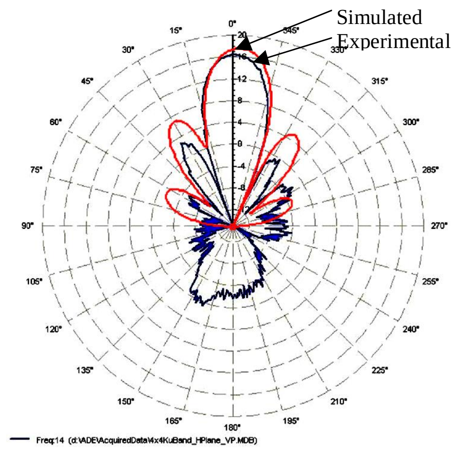

Fig 9. Comparison of Simulation & Experimental Patterns of 4x4 Array

Table 1: Comparision table for simulated results

Antenna Array configuration	Bandwidth (VSWR <2) in MHz	Gain in dBi	$HPBW_\theta$ in degrees	$HPBW_\varphi$ in degrees
Single	1510	6.7	77.4	91.0
1x2	3000	9.6	38.9	78.0
2x2	743	12.5	37.1	41.4
2x4	852	14.6	18.0	40.9
4x4	536	17.0	18.4	19.3
4x4 (Exp)	880	16.2	17.8	20.2

Conclusion

The design and development of a compact and planar 4x4 antenna array in Ku-band for its application as a test antenna for evalution of ósatcomô datalink system has been presented. A scheme for DC short for microstrip array in Ku Band and its effect has been discussed.

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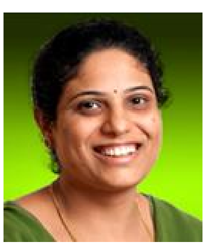

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