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CHARACTERIZATION OF BROADBAND MULTILAYER ARRAY ANTENNA

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ABSTRACT: Multilayered printed arrays are being designed to reduce the size of the antenna to a reasonable extent as well as to enhance radiation pattern. In this paper a simple multilayer aperture coupled configuration [1] has been used as a building block of a large array where the other antenna parameters have been optimized to suit a particular requirement of a side lobe level and gain.

INTRODUCTION

Microstrip patch antennas get more and more important in these days. This is mostly due to their versatility in terms of possible geometries that makes them applicable for many different situations. The light weight construction and the suitability for integration with microwave integrated circuits are two more of their numerous advantages. Additionally the simplicity of the structures makes this type of antennas suitable for low-cost manufacturing.

Researchers have been successful in achieving impedance bandwidth of up to 90% and gain bandwidth up to 70% in separate antennas [2] .But most of these innovations involves more than one mode, give rise to increase in size, height or volume and are accompanied by degradation of the other characteristics of the antenna. Alternatively increase in bandwidth can also be achieved by a suitable choice of feeding technique and impedance matching network.

In this design of the array antenna aperture coupled feed configuration is chosen which uses two substrates, separated by a common ground plane. Here the microstrip feed line on the lower substrate is electromagnetically coupled to the patch through a slot aperture in the common ground plane. The slot can be any shape or size and these parameters can be used to improve the bandwidth. The substrate parameters for the two layers are chosen in a manner to optimize the feed radiation function independently. Polarization purity also improves, as radiation from the open end of the feed line does not interfere with the radiation pattern of the patch because of the shielding effect of the ground plane. In the Aperture coupled feeding network, all the power dividers are absolutely identical and the parasitic impact of the network on the radiating elements in both decreased and symmetric.

UTILITY

Arrays are useful for a particular application of narrow beamwidth, high gain or low sidelobes .But use of parasitically coupled antenna element leads to increase in overall size of the antenna which makes it unsuitable as an array element. The radiation pattern of an antenna varies over the frequency bandwidth in many cases. Also fabrication tolerance may affect each element separately and cumulative performance may detoriate. In a large array, coupling between the network and the radiating elements can result in a number of undesired effects such as shift in the resonance frequency of the entire array and a significant increase in the cross polar level. In the aperture coupled feeding network, all the power dividers are absolutely identical and the parasitic impact of the network on the radiating elements in both decreased and symmetric.

Here the design and implemention of a microstrip patch antenna array that meets the requirements of a broadband communication antenna in Ku-K band. The array consists of linearly arranged single rectangular patch elements with an element spacing of half a free-space wavelength.

The antenna was designed to operate in Ku band at 17.5-19.5 GHz, where the required bandwidth is 2.0GHz. Since microstrip patch antennas have a low bandwidth, the aperture-coupling feeding technique was implemented. This technique makes it possible to use a low-permittivity patch substrate with a large thickness. With this configuration a broadband microstrip patch antenna has been realized.

For the design of the antenna a commercial simulation tool based on the Method of Moments (IE3D) was used. After optimizing and implementing a single patch antenna that achieved satisfactory measurement results, the antenna array with the matched T junction power divider has been designed, simulated and optimized for best performance over the frequency band. The excellent measured results for the antenna array a bandwidth of 2.0GHz. a front-to-back ratio larger than 17dB, and a maximum mutual coupling below -14.5dB has been observed.

THEORY

Aperture coupled feeds are difficult to analyze using the approximate model of microstrip antenna.[3] .Transmission model or multiple network models uses single mode analysis and made of a number of simplifying assumptions. Hence they suffer from a number of limitations, which can be overcome in full wave moment method technique that maintains rigor and accuracy at the expense of numerical simplicity. The formulation of the solution is based on rigorously enforcing the boundary condition at the air dielectric interface and at patch metallization leading to an integral equation. This is done by using the exact Green`s function for the composite dielectric which include the effect of dielectric loss, conductor loss, loss due to surface modes and space wave radiation. In this analysis numerical computation has been done using commercially available software (IE3D) where full wave technique has been used to predict near field and far field characteristics of the array antenna. In practice a frequency domain full-wave simulation approach is followed for the analysis of aperture coupled antenna array. The time-domain

Excitation signals are decomposed into Fourier series, thus obtaining the excitation distributions at the central operating frequency and the sideband frequencies. Traditional frequency domain full-wave simulation approaches are then adopted to simulate the corresponding antenna array at the central frequency and the sideband frequencies, using the corresponding excitation distributions at each frequency. The frequency domain radiation patterns are then combined to form the far field pattern of the array antenna.

DESIGN

A single aperture coupled patch was designed at Ku &K band (Fig 1) and simulated result is found to give 10.0 % impedance bandwidth (1.5:1) over center frequency.Array design using corporate feeding network is implemented with uniform amplitude distribution for 2x2 array, 4x4 array, 16x16 array, 32x32 array, and 32X64 array using aperture coupled rectangular patch element .

The design parameters chosen are
Substrate thickness: 20 mil for feed circuit & ground plane.
Substrate thickness: 31 mil for patch antenna.
Substrate dielectric constant 2.2(for both the layers).
Patch dimension: 4.36 mm.x 7.0mm.
Slot dimension: 3.2mm.x 0.5 mm.
Element spacing is 0.8λ0.

One 16x16 APCP array was designed with tapered amplitude distribution and fabricated where top and bottom layers (Fig 2) were aligned properly. Measured impedance bandwidth of the 16x16 array antenna (Figure 3) shows a 10% bandwidth around center frequency. Beamwidth obtained from the measured radiation pattern is 5.0 x 5.7 degrees (Figure 4a-b). The measured gain of 16 X 16 APCP array is –22.4 dB at center frequency compared to the gain of the order of 18.0 dB a for a 4 X 4 APCP array antenna over the full frequency band of 2.0 GHz.

MEASUREMENT

Measured result of 16 X16 array antenna and 32x32 array antenna(dx=0.6λ,dy=0.6λ) is shown in Table 1 & 2 respectively. Measured return loss of a 32x 32 array is more than 10% as shown in Figure 5

Measured Side lobe levels [Figure 6a-b] are –31.96 dB,-26.25 dB in H plane and that of E plane is -23.12 & -25.38 dB at 18.5 GHz. The radiation pattern has been measured in frequencies other than centre frequency and is shown in Fig 6(a-b). Measured gain of this 32X 32 APCP array antenna is –23.8 dB at center frequency. It was observed that unlike the case of aperture antennas gain of a large printed circuit array antenna does not increase linearly with array size. The excellent measured results for the antenna array having a bandwidth of 2.0GHz, a front-to-back ratio larger than 17dB and a maximum mutual coupling below -14.5dB proves the suitability of the configuration for practical application.

CONCLUSION

In this work microstrip configuration is chosen which is inherently narrowband and its bandwidth is increased by multi-layer coupling technique while keeping its gain constant. In order to achieve ultra low side lobe level effort was made to minimize unwanted feed radiation and thus maximum achievable power gain imposes a limitation for the designer. However the configuration chosen for this purpose is easily reproducible and has a vast application in radar, missiles, tracking antenna system and many more.