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DESIGN AND ANALYSIS OF MICRO STRIP ANTENNA USING HFSS SOFTWARE

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ABSTRACT

A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate. This concept was undeveloped until the revolution in electronic circuit miniaturization and large-scale integration in 1970. After that many authors have described the radiation from the ground plane by a dielectric substrate for different configurations. |In this work, a probe fed microstrip antenna design for the implementation of two dimensional arrays with individually fed radiating elements is presented. The performance of the antenna element, both isolated and in a 4 £ 4 fixed array topology, is analyzed HFSS simulation software. Prototypes of the antenna element and of the array are manufactured and measured for the experimental validation of the design We obtained radiation patterns, return loss, input impedance, E-field, H-field and current distributions that are simulated for this proposed antenna with Ansoft-HFSSsoftware.

Keywords: microstrip antenna, HFSS software, two dimensional antenna arrays

1. INTRODUCTION

In recent years demand of microstrip antennas are increased due to its use in high frequency, high speed data communication applications. Printed antennas are economical and can be accommodated in the device package. Microstrip antennas are best form of antennas because they are light weight, low profile, low cost, ease to analyze, fabricate and are compatible with the integrated circuits [1].

Antenna arrays have been widely employed in a great variety of applications, taking advantage of their beamforming [1], conformation [2] and pattern nulling [3] possibilities. Additionally, the behavior of the array can be modified in real time by separately tuning the feeding signals of the different individual radiators, providing adaptive solutions [4, 5]. Microstrip technology has become a widespread option for the implementation of antenna arrays, owing to its well-known advantages, conformability, ease of fabrication and low cost, especially after the development of different enhancement techniques, aimed at counteracting the traditional drawbacks of this technology(limited bandwidth, spurious radiation of the feeding lines,). In reconfigurable implementations of antenna arrays, the feeding signals of the radiating elements must be separately controlled, which requires these signals to be individually conducted from each of the tuning circuits to its corresponding radiating element. Although this is straightforward in linear arrays, by simply extending the feeding lines of the antenna elements to the edge of the circuit board [6], the transmission line layout process might become a challenging task for two dimensional arrays, especially for applications where a large number of elements is required [7]. This is overcome in [8], with a topology based on quasi Yagi antennas, in which the tuning circuits for each row of the array are placed in a perpendicular plane. Similarly, in microstrip technology, probe feeding techniques are more appropriate.

Than others based on microstrip transmission lines for these cases, as the connectors associated to the individual patches can be installed in the ground plane, where the necessary circuitry is connected (Figure 1). Although probe fed microstrip antennas present inherently reduced operating bandwidths in the order of 1{2% at low frequencies [9], multiple works can be found in the literature, focused on improving the impedance bandwidth of these structures. Bandwidths around 4% can be obtained by introducing short circuited parasitic elements [9] or with an H-shaped radiating patch [10], providing circular polarization. Further improvements can be achieved using thick air substrates with L-shaped probes [11] (26.5%), T-shaped probes [12, 13] (33{40%) or with stacked patches on thick dielectric layers [14] (up to 60%). However, besides the usually reduced mechanical stability of designs with air substrate layers, thick substrates generally give rise to high coupling levels between patches, which make them inappropriate for array designs.

The proposed antenna is designed for the Bluetooth/ WLAN-2.4 applications at 2.4 GHz. Liquid crystals are having some unique combination of properties that make them ideally suited for high density electronic substrate applications [2] include.

1. They are having excellent electrical properties up to millimeter wave frequencies.
2. Virtually impermeable to moisture, oxygen and other gases and liquids.
3. Low coefficient of thermal expansion (CTE) 8 or 17 ppm/0C.
4. Very low moisture absorption, < 0.04% by weight.
5. Excellent dimensional stability (< 0.1%) [3].

Since most of the probe fed topologies available in the literature operate at somewhat lower frequencies, the design process, as explained in Section 2, relies on simulations carried out using Agilent Advanced Design System (ADS) and Ansoft HFSS (which provides a more complete 3D model of the structure that might lead to more accurate.

Results at this frequency). In Section 3, the performance of this design in dimensional array topology is studied, assessing its properties in terms of mutual coupling and radiation pattern. Finally, in Section 4, the simulation and optimization are commented, and remainder of paper contains results and conclusion in order both to evaluate and compare the simulation methods and to validate the design.

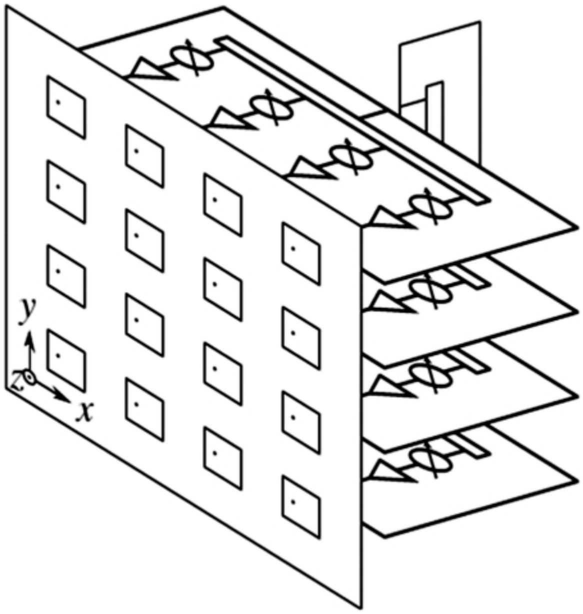

Figure 1: Topology of the Two Dimensional Antenna Array with Individually Fed Radiating Elements

Microstrip antennas are attractive due to their light weight, conformability and low cost. These antennas can be integrated with printed strip-line feed networks and active devices. This is a relatively new area of antenna engineering. The radiation properties of micro strip structures have been known since the mid 1950's. The application of this type of antennas started in early 1970's when conformal antennas were required for missiles. Rectangular and circular micro strip resonant patches have been used extensively in a variety of array configurations. A major contributing factor for recent advances of microstrip antennas is the current revolution in electronic circuit miniaturization brought about by developments in large scale integration. As conventional antennas are often bulky and costly part of an electronic system, micro strip antennas based on photolithographic technology are seen as an engineering breakthrough. A micro strip antenna in its simplest form consists of a sandwich of two parallel conducting layers separated by a single thin dielectric substrate [1]. The lower conductor functions as a ground plane and the upper conductor functions as radiator. Among different shapes of micro strip patch elements such as rectangular, square, dipole, triangular, circular and elliptical for better radiation characteristics we use rectangular micro strip patch antenna [2].

To analyze micro strip patch antenna we have, (1) Transmission model; (2) Cavity model and (3) Full wave model. Transmission line model is simplest but less accurate. Cavity model is more accurate but complex in nature. Full wave model is very accurate, versatile, and can treat single element, finite and infinite arrays, but are most complex. Among this transmission line model is used which provides better physical insight and provide approximate relationships to calculate dimension of patch. Feed line and matching networks are fabricated along with antenna structure. If the substrate is flexible, conformal antennas are possible. Etching is done with the standard photolithographic processes [3]. The accuracy of etching process also ensures uniformity of different parts over a production run. The main reason for using micro strip patches is the ability to construct array antennas with the feed network and the radiating elements on a single surface. This arrangement means that the antennas are fed by a micro strip connected directly to the patch [4].

2. MICROSTRIP ANTENNA DESIGN

The design also checks for maximum power transfer by matching the feed line impedance to the impedance of the patch antenna. The different feeding techniques used for impedance matching are micro strip line, coaxial probe, Proximity coupling and aperture coupling. Micro strip line: In this Impedance matching is easier. And feed can be fabricated on some substrate as single layer to provide planner structure [9].But disadvantage is we must use transformer to match impedance and it excites cross polarization. Coaxial probe: Probe location is used for impedance matching. Ease of insetting and low radiations is advantages of probe feeding. Proximity coupling: Proximity coupling offers some opportunity to reduce feed line radiation while maintaining a relatively thick substrate for the radiating patch. The input impedance of antenna is affected by the overlap of the patch and the feed line, and by the substrates. However due to multilayer fabrication the antenna thickness increases [8]. Aperture coupling: No spurious radiation escapes to corrupt the side lobes or polarization of the antenna. However due to multilayer fabrication antenna, thickness increases. Among this coaxial probe is used for impedance matching, as it is ease of insetting and low radiation and also used with plated for multi layer circuits[10]. Micro strip antennas are versatile in the sense that they can be designed to produce a wide variety of patterns and polarizations, depending on the mode excited and the particular shape of the patch used. The impedance bandwidth of microstrip antennas is known to be larger for higher values of the substrate thickness and for lower permittivity. However, apart from its impact on the mutual coupling, when the substrate thickness is increased in simple probe fed topologies, the length of the probe is extended accordingly, leading to high inductance values that must be subsequently compensated. The proposed topology, shown in Figure 2, uses a relatively thin substrate layer through which the probe is connected to the first patch, while the layer between the first and the second can be moderately thickened to improve the bandwidth. The coaxial connector is soldered to the bottom layer of a 0.762mm thick ARLON 25N substrate (²*r* = 3:38 and tan ± = 0:0025 at 10 GHz) and the probe is connected to the specified point in the first patch, edged on the top layer or this substrate. The second patch is placed on top of a double layer of ARLON 25N (1.524 mm).

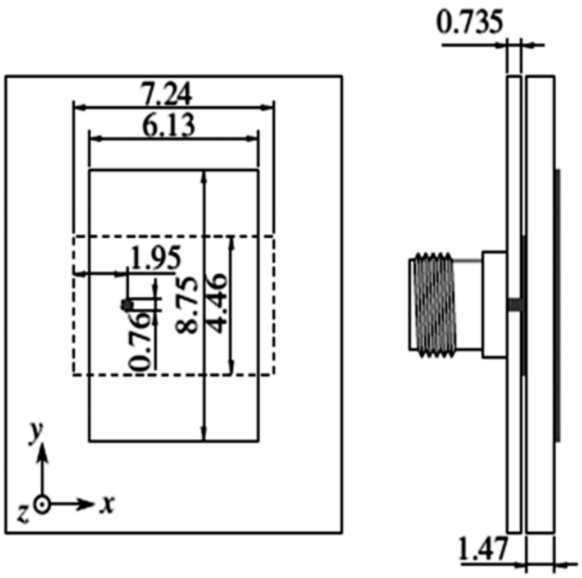

Figure 2: Proposed Microstrip Antenna Dimensions in Millimeters

3. ANSOFT-HFSS

HFSS is an interactive software package for calculating the electromagnetic behavior of a structure. The software includes post-processing commands for analyzing this behavior in detail.

Using HFSS, we can compute:

- Basic electromagnetic field quantities and, for open boundary problems, radiated near and far fields.
- Characteristic port impedances and propagation constants.
- Generalized S-parameters and S-parameters renormalized to specific port impedances.
- The eigenmodes, or resonances, of a structure. To draw the structure, specify material characteristics for each object, and identify ports and special surface characteristics. HFSS generates the necessary field solutions and associated port characteristics and S-parameters [8].

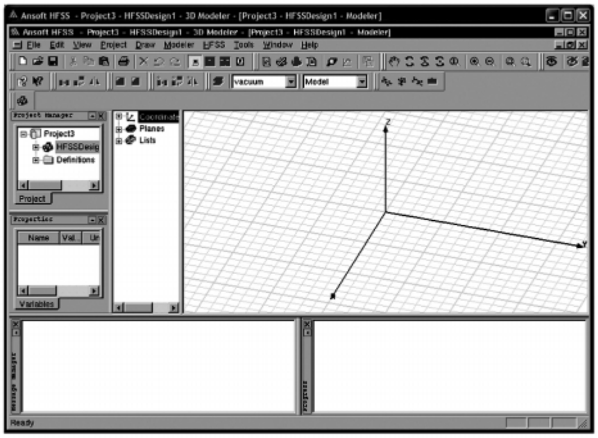

Figure 3: New Window with HFSS Interface

4. SIMULATION

4.1 Simulation and Optimization

The performance of the proposed design has been studied using the Agilent Advanced Design System Method of Moments (Momentum) electromagnetic simulator. This analysis software, in which the substrate layers are considered infinite, does not support coaxial feeding and, therefore, the simulations have been carried out using an Internal Port, directly placed on the feeding point of the first patch. At the same time, the complete design structure, including the coaxial feeding and the finite substrate layers, has been analyzed using the Ansoft HFSS finite element simulator. Using the results of these two methods, the dimensions of the design have been optimized to increase its impedance bandwidth. The results obtained with both simulation methods for the final design are compared in Figure 4. The antenna presents a bandwidth (*jS*11*j* < ¡10 dB) of approximately 1.15 GHz centered at 10 GHz (11.5%). Despite the fact that the probe feeding is not modeled in the ADS simulations, the results obtained with both methods are reasonably similar, yielding analogous values for the frequency of operation and for the impedance bandwidth. The radiation patterns, evaluated at 10 GHz in the *E*-plane (*XZ* plane in Figure 2) and in the *H*-plane (*YZ* plane in Figure 2), have been calculated using *ADS* and HFSS obtaining gain values of 5.17 and 6.5 dB respectively. The normalized values of the co-polar (CP) and cross-polar (*XP*) components are compared in Figure 4, as a function of the spherical coordinate µ. For the co-polar components, similar results are obtained with both simulation methods, whereas, for the cross-polar ones, noticeably higher values are observed in the HFSS simulations. A very pure linear polarization is found in the *E*-plane, with cross-polar levels under ¡30 dB (under ¡50 according to the ADS simulation). However, in the *H*-plane the cross-polar levels are low in the boresight direction and increase with *j*µ*j* (although, in the ADS simulation, the ¡30 dB level is never reached).

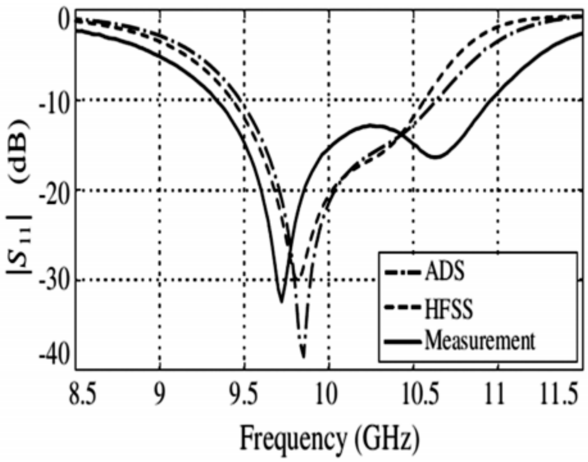

Figure 4: Simulation of the Antenna using HFSS (Finite Element Method) and ADS Method

5. SIMULATION RESULTS

The major limitation in micro strip antenna is the narrow bandwidth, which can be stated in terms of antenna's quality factor, *Q*. Micro strip antennas are high-*Q* devices with Qs sometimes exceeding 100 for the thinner elements. High-*Q* elements have small bandwidths. Also the higher the *Q* of an element the lower is its efficiency. From Figure 5 and Figure 6 the return loss of –14.5 dB, –18.5 dB and minimum VSWR value 1.36 and 1.45 is

Obtained at the two frequencies. And the rms value and bandwidth obtained from Fig. 7 input impedance plot is 0.7064 and 6.8789 GHz respectively.

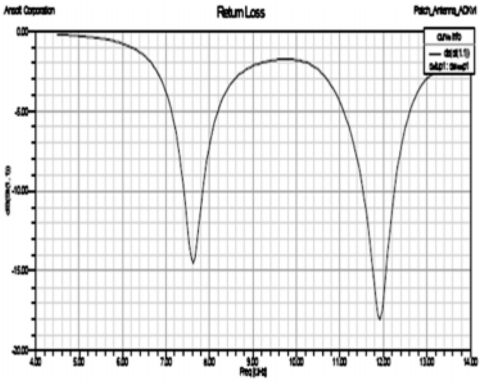

Figure 5: Return Loss

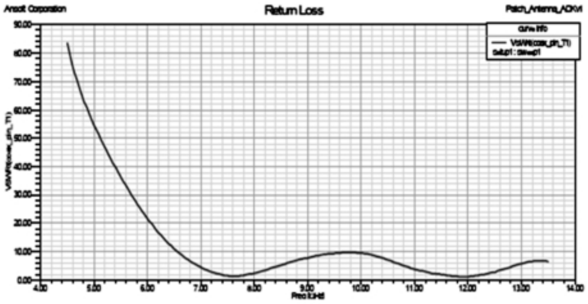

Figure 6: VSWR Reading

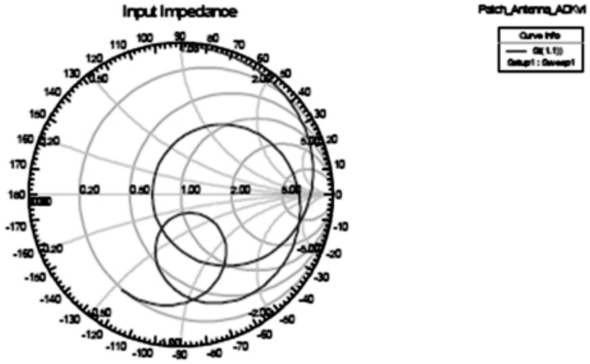

Figure 7: Input-impedance Plot

Several prototypes have been manufactured for the evaluation of the accuracy of the different simulation methods that have been used in this work. In this section, the measurements of the prototypes are compared to the simulated results.

5.1 Microstrip Antenna Design

A prototype of the microstrip antenna design analyzed In Section 2 has been manufactured for the experimental validation of the simulated results. Plastic screws have been used for the alignment of the complete multi-layer structure. The S11 parameter of the prototype, measured with a vector network analyzer, has been represented in Figure 3, together with the simulated results. The isolated antenna is matched to 50- in the band from 9.33 to 10.66 GHz (16%), which represents a significant improvement with respect to the simulated results. The radiation patterns of the antenna have been measured in the anechoic chamber at 10 GHz. The co-polar and cross-polar components evaluated in the *E*- and *H*-planes are compared to the simulations in Fig. 4. The simulated co-polar components are in good agreement with the corresponding measurements, although the HFSS simulation is slightly different when approaching the endfire directions (µ = §90±) in the *E*-plane. For the cross-polar component, on the other hand, while neither of the simulation methods provides an accurate estimation, the levels of the HFSS results are somewhat closer to the measured values. The polarization purity of the antenna is higher in the *E*-plane, in which the cross-polar component is under the ¡30 dB level in almost any direction, whereas, in the *H*-plane, several oblique lobes of about ¡25 dB can be found.

5.2 Antenna Array

The array topology with individually fed elements designed and analyzed in Section 3 has been manufactured and measured, obtaining approximately the same 16% impedance bandwidth of the isolated element. In agreement with the simulations, the isolation levels between elements with the same kind of alignment are similar and, thus, only one parameter for either alignment is represented in Figure 5. Similar isolation levels, over 20 dB, have been found for both Arrangements. In order to measure the radiation pattern of the array, a simple fixed feeding network based on 4£1 dividers (Figure 1), has been designed and manufactured for the phase distribution studied in Section 3. The radiation pattern measured in the anechoic chamber along the plane ’ = 45± is shown in Figure 6. The main beam is pointing at μ = 21±, 4 degrees under the value predicted by the simulations, with the *SLL* < ¡10 dB, except when approaching the endfire directions.

5.3 Antenna Parameters and Maximum Field Data Values

From antenna parameters the values of Peak Directivity, Peak Gain, Peak Realized Gain, Radiated Power, Accepted power, Incident power, Radiation Efficiency, Front to back ratio, Power and Radiation Efficiency, Max U values are obtained and tabulated in Table 1.

Table 1
Antenna Parameters

Antenna Parameters

Quantity	*Value*	*Units*
Max U	2.2717	w/st
Peak Directivity	344.51	
Peak Gain	343.9	
Peak realized gain	97.338	
Radiated Power	0.082864	w
Accepted Power	0.08301	w
Incident Power	0.29328	w
Radiation Efficiency	0.99824	w
Front to Back Ratio	1338.7	

The infinite sphere radiation setup for antenna parameters are computed and tabulated in the Table-1

6. CONCLUSION

A probe fed microstrip antenna design for the implementation of two dimensional reconfigurable arrays has been presented. The performance of the antenna element both isolated and in a 4£4 array topology has been analyzed using ADS Momentum and HFSS. Despite the fact that coaxial feeding is not supported in ADS Momentum and that it considers infinite dielectric layers, the results obtained with both methods are not substantially different in general. Prototypes of the antenna element and the array with a fixed feeding network have been manufactured and measured, obtaining a 16% impedance bandwidth centered at 10 GHz. The isolation between the elements of the array was found to be higher than 20 dB.

Finally, the optimum dimension of dual frequency rectangular patch antenna has been investigated. The performance properties are analyzed for the optimized dimensions. In future, the same procedure could be applied to design other planar antennas operating at other frequency levels. The designed patch element could be part of an array.

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