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K15 Liquid Crystal Substrate Based 4X4 Array Elliptical Patch Antenna Operating At 36 GHz Band

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ABSTRACT

The selection of array patch antennas is mainly due to the enhancement of gain and the radiation. In the present paper we deals with the 4x4 elliptical array patch antenna designed on a special K15 nematic liquid crystal substrate material. The operating frequency is chosen at 36GHz for the desired operation and whole simulation is carried out by Ansoft HFSS. The radiation patterns, gain, filed distributions VSWR and return loss are computed and generated with the simulation results. This antenna is showing superior performance over other traditional array\antennas as per the output parameters are concerned. The selected liquid crystal substrate K15 material is having dielectric constant of 2.88 and loss tangent of 0.01.

KEYWORDS: *K15 liquid crystal substrate, Elliptical patch antenna, VSWR (Voltage Standing Wave Ratio)*

I. Introduction

Microstrip patch antennas are a class of planar antennas which have been researched and developed extensively in the last three decades. The idea of microstrip patch antennas arises from utilizing printed circuit technology not only for the circuit components and transmission lines but also for the radiating elements of an electronic system [1-4].

The basic structure of microstrip patch antenna consisting of an area of metallization supported above a ground plane by a thin dielectric substrate and fed against the ground at an appropriate position. The patch shape can be of rectangular, circular, elliptical, triangular etc. In this present work we selected elliptical shape for the patch [5-7].

The advantages of selecting microstrip antenna are due to its low profile, low radar cross section, rugged against different surface components and can be used in printed circuit technology. It is much more suitable for aircrafts, space crafts and missiles than conventional antennas as they do not interfere with the aero dynamics of these moving vehicles. The disadvantages are very less in compared with the advantages [8-9]. They are having narrow impedance bandwidth typically less than 5%, low handling capability of RF power are some of the disadvantages that we can consider in the design.

By using single patch element we cannot get the gain of higher values so, to achieve high antenna gain we have to go for array of elements .The microstrip antenna arrays are attractive for various high gain applications as they can be fabricated by low cost photolithographic technique. The main problem that arises from the array design is by the mutual coupling. If the mutual coupling between the neighboring elements in an antenna array is small and can be ignored, the input impedance of each element is the same as the individual radiating element [10-12]. The electrical performance such as radiation patterns, gain, and bandwidth can be obtained easily with some enhancement over single patch elements antennas.

II. Substrate material selection

K15 nematic phase liquid crystal material is used in this model as a substrate. Nematic phase state liquid crystal is a non linear dielectric material in which the dielectric constant can be changed between two extreme states that are described by the orientation of the LC molecules, either parallel or perpendicular to the excited RF field. The permittivity of the tunable layer and hence the electrical size of the patches can therefore be controlled by varying the voltage that is applied between each patch element and the ground plane. This commercial available K15 LC is well investigated and its microwave properties are also known at the targeted operation frequencies [13-14].

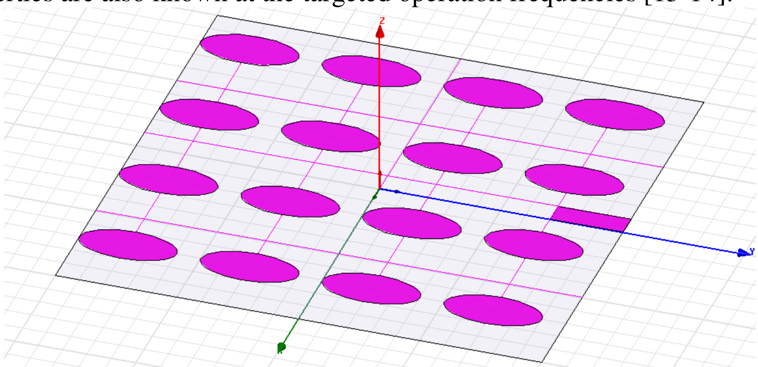


Figure (1) 4X4 Elliptical patch antenna

The antenna dimensions are as follows. The substrate height is 0.14mm, substrate length is 28mm and substrate width is 24mm, patch dimensions of 2.6mm along y and 2.2mm along x-axis. Feed length is of 6mm along y-axis. Total dimension of antenna is 34x32mm.

III. Simulation Results

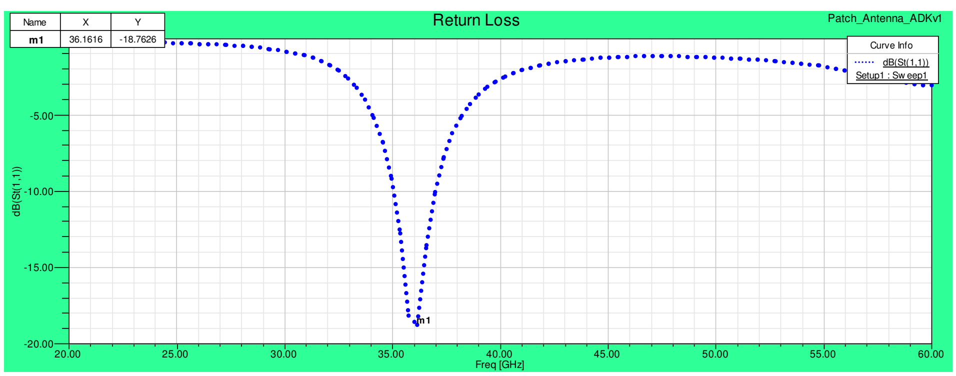


Figure (2) Return loss Vs Frequency

Figure (2) shows the return loss curve for the proposed antenna. A good antenna might have a value of -10dB as 90% of the signal is absorbed and 10% is reflected back. The current antenna model is giving the return loss of -18.78dB at the desired frequency 36GHz.

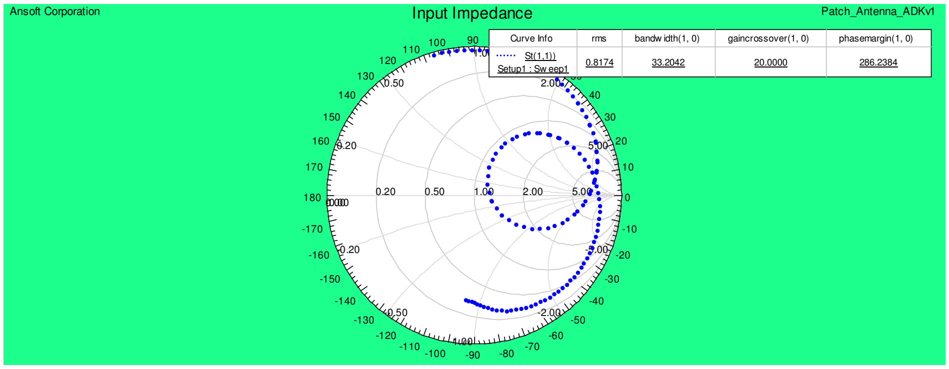
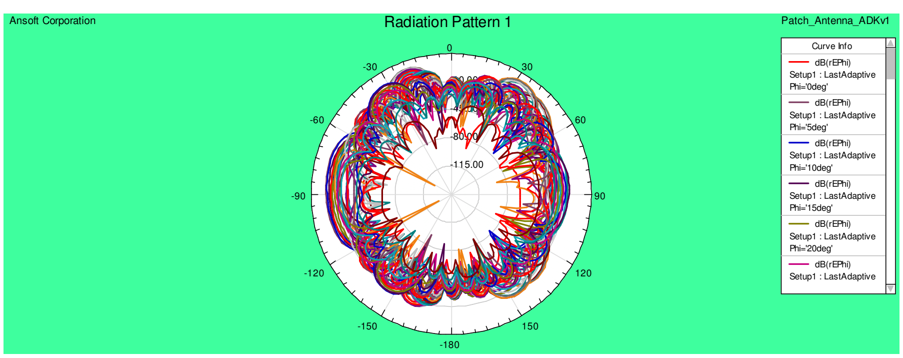


Figure (3) Input impedance smith chart

Figure (3) showing the input impedance smith chart for the antenna. Impedance matching should be perfect to transfer maximum amount of energy from one to another device. From the simulation results we got rms of 0.8174 and bandwidth of 0.91% enhancement and gain crossover of 20dB and phase margin of 286.23 is obtained.

Figure (4) 3D-gain

In many wireless systems an antenna is designed to enhance radiation in one direction while minimizing radiation in other directions. This is achieved by increasing the directivity of the antenna which leads to gain in a particular direction. The gain is thus the ratio of the radiation intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically (that is, equally in all directions). In the case of a receiving antenna, an increase in gain produces increased sensitivity to signals coming from one direction with the corollary of a degree of rejection to signals coming from other directions. Antenna gain is often related to the gain of an isotropic radiator, resulting in units dBi. Figure (40 showing the 3D-view of the gain of the antenna. A gain of 22dBi is obtained from the current model.



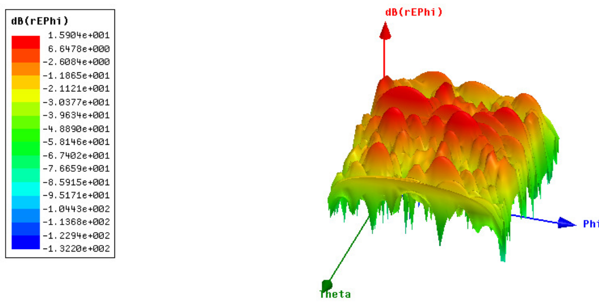
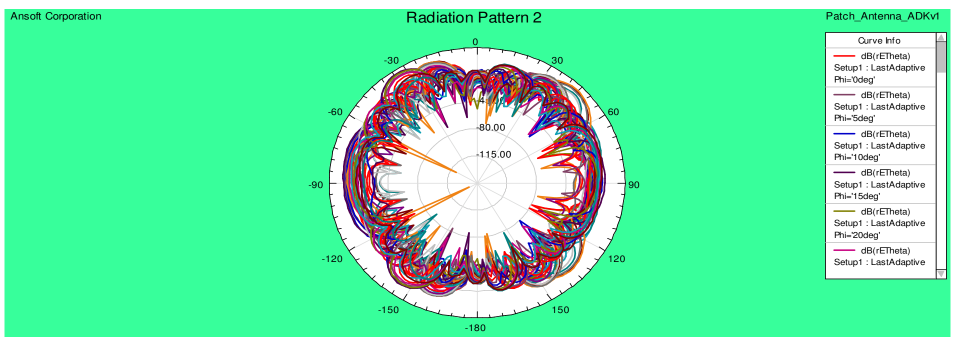


Figure (5) & (6) Radiation pattern (phi direction) in polar coordinates and 3-Dimension

The radiation pattern represents the energy radiated from the antenna in each direction, often pictorially. The IEEE Definition states that it is “the spatial distribution of a quantity that characterizes the electromagnetic field generated by an antenna”. Most often this is the radiation intensity or power radiated in a given direction. Figure (5) and (6) shows the radiation pattern of the antenna in phi direction with respect to polar coordinates and 3-Dimensional view.



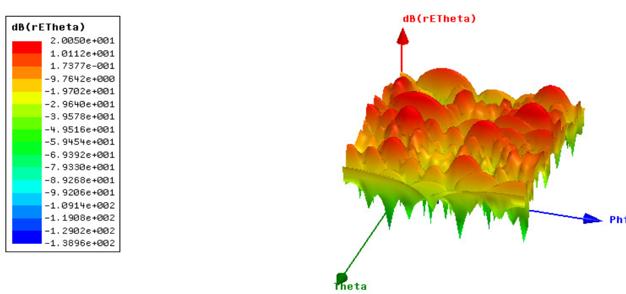


Figure (7) & (8) Radiation pattern (Theta direction) in polar coordinates and 3-Dimension

Figure (7) and (8) shows the radiation pattern of the antenna in theta direction with polar coordinates and 3-dimensional view.

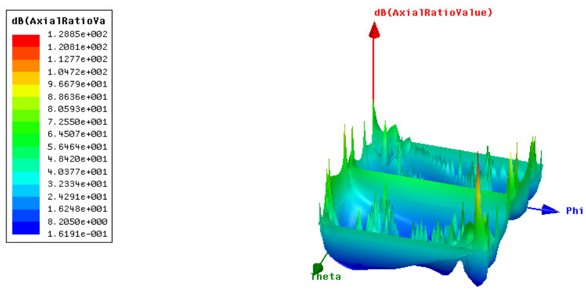


Figure (9) Axial ratio

The axial ratio is a parameter which measures the purity of the circularly polarized wave. The axial ratio will be larger than unity when the frequency deviates from f_0. Figure (9) shows the axial ratio for the current model in 3-Dimensional view.

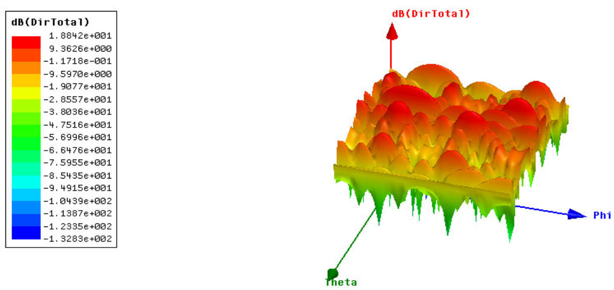


Figure (10) Directivity

Directivity is how much an antenna concentrates energy in one direction in present to radiation in other directions. It is equal to the power gain when antenna radiates equally in all directions. Figure (10) shows the directivity of the present antenna in 3-Dimensional view. Polarization of the wave radiated from an antenna describes the behavior of the electric and magnetic field vectors as they propagate through free space. Polarization is typically approximately linear. When linear the polarization may be further described as either vertical or horizontal based on the orientation of the electric field with respect to earth. This type of pattern can boost the signal strength due to its higher gain if aimed in the required direction. This comes at the expense of reduced effectiveness in other directions which may be desirable in certain applications. Highly directional antennas are desirable for point-to-point links and have application in automotive radar systems where a narrow beam may be scanned to detect nearby targets.

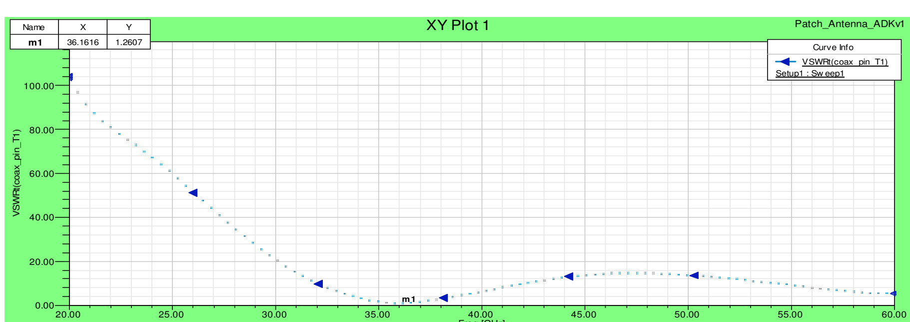


Figure (11) VSWR Vs Frequency

Impedance mismatch between the transmission line and its load can be measured using VSWR curve. If the VSWR is high then the mismatch will be greater, the minimum VSWR corresponds to a perfect impedance match is unity. Figure (11) shows the VSWR curve with good agreement value of 1.26 at 36GHz.

IV. Conclusion

4X4 array patch antenna was designed on liquid crystal substrate material and simulated using HFSS. This antenna is producing gain around 22dBi and bandwidth enhancement of 0.91%. The radiation pattern and other output parameters are showing superior performance over other traditional antennas and VSWR of less than 2 is obtained from the current model. This proposed antenna is flexible and compact in design to fit in the application specific environment. The gain crossover of 20dB and phase margin of 286.23 is obtained from the design. The results are giving encouragement for fabrication and testing this by using network analyzer.

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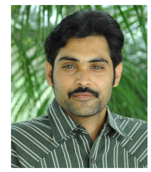

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