Design and Simulation of Multi Band Compact Microstrip Patch Antenna

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Abstract— **Microstrip antennas have been one of very attractive field of research in the recent years. They have become an essential component in many emerging wireless communication applications. Requirements of wide band / multiband operation have resulted in many advanced research in the field of antennas. The paper describes a design and simulation of tri band microstrip patch antenna. The antenna geometry has been loaded with three slots in the radiating element to obtain tri-band operation. The proposed antenna has been designed on 30mils Roggers RT Duroid 5880 substrate having dielectric constant 2.2 and loss tangent 0.0009. The antenna has been simulated using ANSYS HFSS full wave solver using proper boundary conditions. The antenna is resonant at three frequencies 11.65GHz with band of 800MHz, 13.95GHz with band of 1.8GHz and 17.00GHz with band of 600MHz for return loss better than -10dB. The antenna can replace three antennas being used on UAV platform. The designed antenna can be used for Ku band satellite communications in which Rx and Tx operating frequencies are 11.3GHz and 14GHz respectively. The third frequency band can be used for line of sight communications between airborne and ground terminal.**

Keywords— ***Microstrip Antenna, Dielectric substrate, HFSS, Multiband, Return loss, Satellite application, Slot loaded patch, Wireless communication***

I. Introduction

Microstrip antenna has become very popular now a days due to its several advantages over other configuration of antenna. Some of the inherent advantages of the microstrip antenna includes the low profile, light weight, ease of fabrication, ease of different polarization generation and its cost[1-3]. Due to its simpler geometry and ease of fabrication these antennas have now been used in number of applications. They are being used in radar system, satellite communications, line of sight communication system, airborne applications etc.

Some of the disadvantages of microstrip antennas are narrowband operation (bandwidth up to 1-2% of centre frequency), poor polarization purity and limited power handling etc.. Numerous techniques have been evolved to enhance the frequency band of operation of microstrip antennas[4-6].

Recent advancement in wireless communications have expanded the interest for multiband antenna operating at multiple frequencies. Some of the applications demand the antenna operation on two or more frequencies being far apart from each other and the separation between two bands are so large that it is not possible to design a antenna with that large bandwidth. Further if somehow we get the desired bandwidth we would be radiating power at unwanted frequency band and the system may be prone to jamming. To mitigate this we can either use separate narrowband antenna for each application or we can have a single antenna which can operate as multi band antenna. The techniques to obtain multi band antenna have been proposed in number of research papers. They have proposed different configuration of multi band microstrip antenna based on particular applications[7-12].

There have been large demand of multi band antenna to reduce the quantity of antennas on a system and to meet the required applications using single antenna. While designing a multi band antenna we need to consider not only the impedance matching of antenna over the desired frequency band but we have to make sure that the radiation characteristics of antenna should also remain intact.

An attempt has been made in the present paper to design a multi band rectangular microstrip patch antenna using simple single layer geometry. The multi band operation in the antenna has been obtained by introducing slits in the radiating patch. The different band of operation has been generated by slits position and its size. The designed antenna has three band of operation with centre frequency as 11.65GHz, 13.95GHz and 17.00GHz.

The rest of the paper has been organized as follows. Section II provides the Design of the tri band antenna. Simulation and optimization of the developed antenna has been discussed in section III. Results and future scope on the antenna has been explained in section IV and section V provides the conclusion of the work.

II. Design of Antenna

Selection of substrate material (its dielectric constant and loss tangent) and substrate thickness plays very important role in deciding the size of microstrip antenna. Further thick substrate results in generation of surface wave and hence affecting the radiation characteristics of the antenna. Higher dielectric constant can be used to miniaturize the antenna system but here also radiation efficiency decreases. A rectangular microstrip antenna has been designed, simulated using 30 mils Roggers RT duroid 5880 dielectric substrate material (ε_r =2.2 and tan δ =.0009).

Effective length of the radiating patch can be changed by cutting slots in the radiating patch and hence changing the electric field distribution. To obtain multiple resonance in the radiating element, the number of slots may be increased. In the initial calculation the size of slots are taken as $\lambda/4$ where λ is calculated based on the resonance frequency. The parametric optimization was carried out to optimized the size of slots. The advantages of these slots are that they increase the effective length of the microstrip patch by actually increasing the electrical length of the patch antenna which decides the resonance frequencies. However these slots also

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contributes some inductances and capacitance to the antenna impedance which needs to be nullified for impedance matching.

Coaxial feeding has been adapted in the present design. The location of feeding point is shown in the CAD model of the antenna system. As discussed earlier the cutting of slots introduces impedance mismatch at the feeding point, it is necessary to use opposite reactance in the radiating patch to neutralize its effect. A slot in the left side of radiating patch has been cut which neutralizes the effect of mismatch due to three slots cut on the right side.

The CAD model as well as optimized dimensions of upper patch, lower patch and inter element spacing of the antenna array are given in fig. 1 and Table 1 respectively.

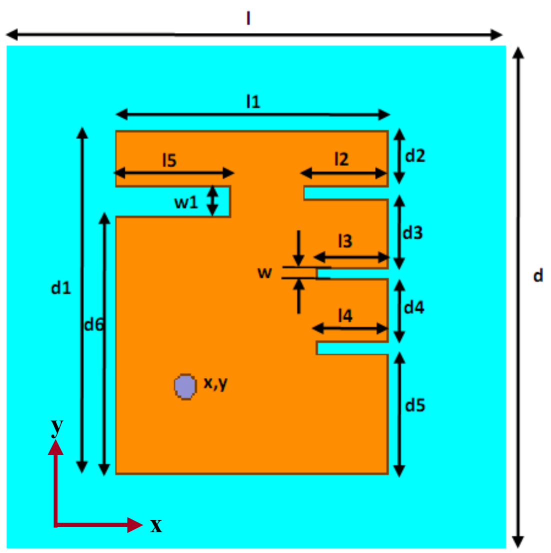

Figure 1. CAD model with dimensional details of Antenna

TABLE I. OPTIMIZED DIMENSIONS OF THE ANTENNA ARRAY

notations	*Values (mm)*
l	20
d	20
l1	6.2
l2	1.9
l3	1.6
l4	1.2
l5	2.6
d1	6.7
d2	1.1
d3	1.33
d4	1.2
d5	2.32
d6	5
w	0.25
w1	0.6
feeding location	(1.6,1.7)

III. Simulation and Optimization

After estimating all of the dimensions of the microstrip element, it has been modelled on ANSYS HFSS full wave EM simulation software. The simulation of antenna element has been carried out using proper boundary conditions. The length of each slots were optimized to get the required frequency band in the microstrip antenna. Further the feeding position of the antenna was also optimized and final coordinates of the feeding point is 1.6mm, 1.7mm considering lower left edge of the patch as origin.

Simulated return loss of the designed antenna is plotted in fig. 2. From the simulation results it is clear that antenna resonates at three frequency band (11.25GHz to 12.05GHz), (13.05GHz to 14.85GHz) and (16.7GHz to 17.3GHz). First frequency band can be used for receive operation of Ku band SATCOM, the second frequency band may be used for transmit operation of Ku band SATCOM while the third frequency band may be used for airborne LOS communication system with ground terminal. The current distribution on the antenna element is shown in fig. 3.

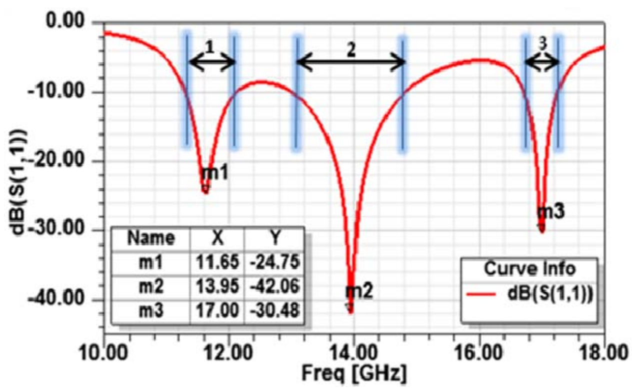

Figure 2. Simulated return loss of the designed antenna

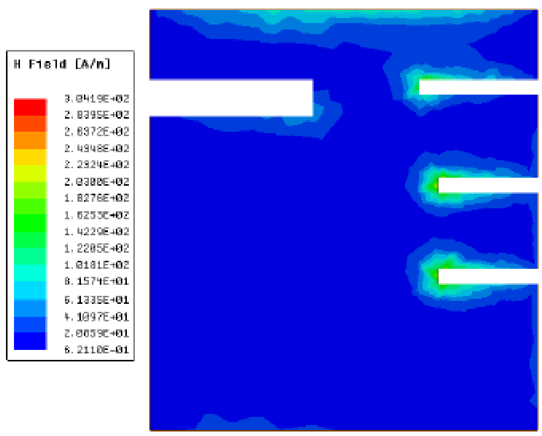

Figure 3. Current distribution on the radiating patch

From the current distribution it can be seen that amplitude of current varies at three slots which results in three different resonances.

IV. RESULTS & DISCUSSION

The radiation patterns of the designed antenna have been shown in fig. 4(a-c). The graph includes the radiation pattern plot at centre frequency of each band of operation i.e. at 11.65GHz, 13.95GHz and 17.00GHz.

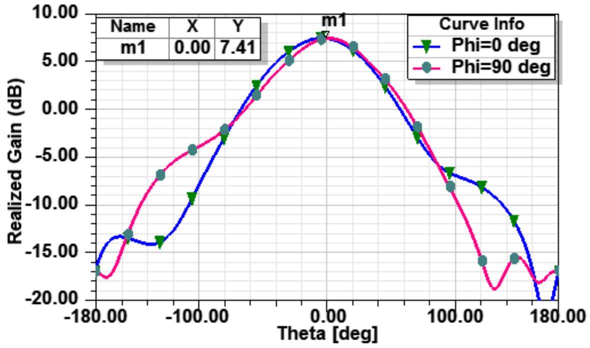

Figure 4(a). Simulated radiation pattern @ 11.65GHz

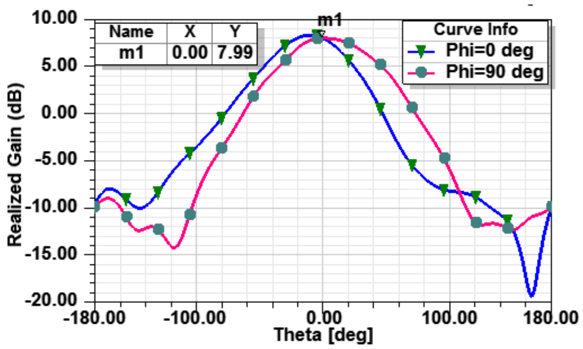

Figure 4(b). Simulated radiation pattern @ 13.95GHz

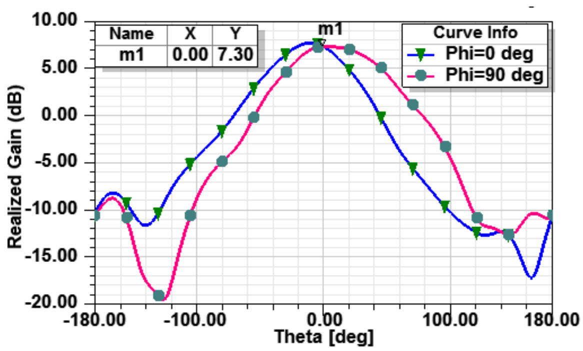

Figure 4(c). Simulated radiation pattern @ 17.00GHz

From the simulation of the antenna it can be seen that three bands having wide bandwidth have been obtained using three slots. The obtained bandwidth at each frequency is more than 600MHz which is sufficient enough for long distance high data rate communication system.

V. CONCLUSION

A tri-band with large bandwidth microstrip antenna has been designed, simulated and optimized. The antenna uses three slots to obtain three resonances. The centre frequency of each resonances are 11.65GHz, 13.95GHz and 17.00GHz. The first two frequencies can be used in Ku band satellite communication as Rx and Tx band while the third frequency can be used for airborne line of sight communication system with ground terminal. Each resonant frequency has more than 600MHz bandwidth.The designed antenna has great potential to replace three antennas being used in airborne system .

ACKNOWLEDGMENT

The authors express their sincere gratitude and thank to Director DEAL for giving permission to publish this paper.

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Raj Kumar obtained his M. E. degree in Microwave & Radar from the University of Roorkee (presently IIT Roorkee). He has published more than thirty papers in International journals and IEEE conferences. His areas of interest include microwave and mm-wave antennas design including omni directional antenna, fan beam antenna, slotted array antenna, antenna for radiometry, microstrip antennas, design of waveguide filters, reflector antennas, horn antennas, conformal antennas, phased array antenna etc. He has been awarded DRDO Technology Award, Group Technology award, & Laboratory Scientist of the Year award. He is fellow of ATMS Society.

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