Design Considerations to Improve the Performance of a Rectangular Microstrip Patch Antenna at THz Frequency

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***Abstract*—The effect of multilayer, 2-D photonic band gap substrate on the performance of rectangular microstrip patch antenna at THz frequency is simulated. The radiation efficiency, gain and directivity for the proposed antennas are 93.28%, 10.46 dB and 10.76 dBi, respectively at 875 GHz. The 10dB impedance bandwidth of the antenna is 36.67%, which is ultra-wide bandwidth. The simulation has been performed by commercially available CST Microwave Studio simulator, which is based on the finite difference time domain technique (FDTD).**

I. Introduction And Background

THE frequencies higher than the microwaves/millimeter waves offer many advantages for technology, including wider communication bandwidths, improved spatial directivity and resolution with system compactness. THz communication link is most likely secure communication for short distance, point-to-point, and demanding high information data rate. The carrier frequency of choice for future THz communication systems could be located in one of the frequency windows between 300 GHz and 1 THz. Above 1THz, atmospheric damping becomes so severe that maintaining a sufficient link budget together with ultra-broad bandwidth required by the high Gbps data rate would be very difficult. Microstrip patch antennas, because of their ease of fabrication/integration as well as compactness, are highly desirable components for wireless communication systems. The substrate of microstrip antenna plays a very important role in achieving desirable electrical and physical parameters. To increase the antenna efficiency, gain as well as bandwidth, multilayered substrate with lower layer of photonic bandgap has been considered in simulation model. Photonic bandgap crystal is a new class of periodic dielectric structures in which electromagnetic wave propagation in any direction is completely prohibited for all frequencies within a stop band [1]. Electromagnetic propagation through such a medium is affected by the scattering and diffraction properties of the periodic elements. If we use the photonic bandgap as substrate [2-4], whose forbidden gap encompasses the antenna excitation frequency, in the manner that there are no surface modes, the power previously radiated into the substrate will be reflected towards the air-side.

In this paper, we have simulated the rectangular microstrip patch antenna on the three dielectric layer substrate materials at THz frequency. The lower layer is of photonic bandgap substrate [5]. This multi-dielectric layer substrate has been used to reduce the radiation losses by surface waves and to enhance the bandwidth [6]. The selection of the dielectric permittivity and dimension of the substrates will determine the surface wave losses. The organization of the paper is as follows. The section II is concerned with antenna configuration. The section III discusses the simulated result, and finally section IV concludes the work.

II. Geometrical Configuration

Figure 1 shows the geometrical configuration of the proposed rectangular microstrip patch antenna using multilayer (three layer) dielectric substrate at THz frequency. The first layer as shown in Figure 1 is photonic bandgap crystal, which have relative $\varepsilon = 4.2$, $h = 50\mu m$ and dimensions 400 x 400μm^2. Similarly, the relative permittivity and thickness for middle and upper layer substrate materials are 1.7, 350µm and 6.15, 55µm, respectively. The high permittivity material of the upper layer substrate is used to reduce the radiation from the microstrip feed line. The width, length and thickness of the stripline are 26, 150 and 25µm, respectively. The lower layer of the substrate has 2-D photonic bandgap crystal. The lower layer has implanted with regular period of air gaps. The diameter of the air-gaps is 10µm with 50µm height.

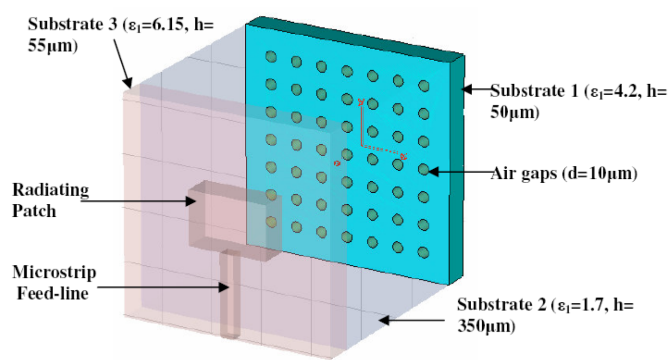

Figure 1: The geometrical configuration of the rectangular microstrip patch antenna at THz frequency.

III. Results And Discussion

Figure 2 shows the frequency versus return loss for the proposed antenna at THz frequencies (700GHz to 1050GHz). The return loss at frequency 875GHz is -28.91dB. The 10dB impedance bandwidth obtained from Figure 2 is 36.67%. This ultra-wide impedance bandwidth is due thicker middle layer. As we know that the impedance bandwidth of a patch antenna varies inversely as quality factor of the patch antenna. Therefore, substrate parameters such as dielectric permittivity and thickness can be varied to obtain different quality factor, and ultimately increase in impedance bandwidth. The impedance bandwidth increases monotonically with thickness of substrate. Also, with decrease in the dielectric permittivity, increase in the bandwidth obtained.

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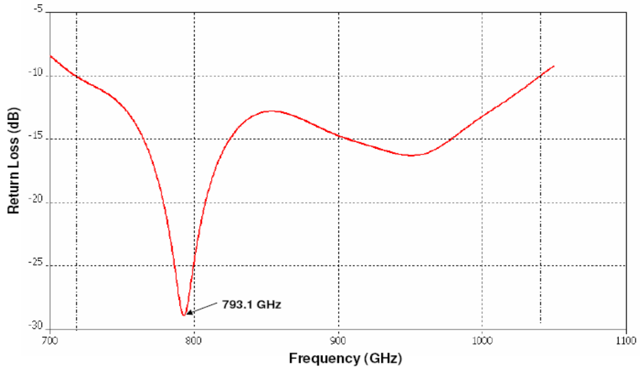

Figure 2: Frequency versus return loss of the rectangular microstrip patch antenna at THz frequency.

The efficiency, gain and directivity of the antenna are 93.28%, 10.46dB and 10.76dBi, respectively at the 875GHz. The far-zone radiation pattern for gain and directivity in H-plane and E-plane is shown in Figure 3. Main lobe magnitude and direction for the gain in H-plane are 10.5dB and 90^0, respectively and same for E-plane is -4.6dB and 70^0, respectively. In similar way, the main lobe magnitude and direction for directivity in E-plane is 0.8dBi and 90^0, respectively and same for the H-plane is -4.3dBi and 70^0, respectively.

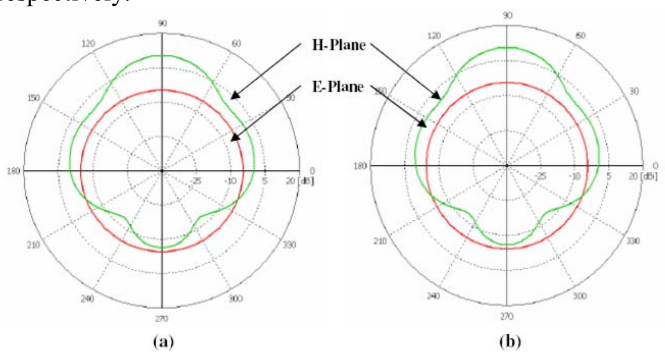

Figure 3: Far-field radiation pattern for (a) gain and (b) directivity at 875 GHz.

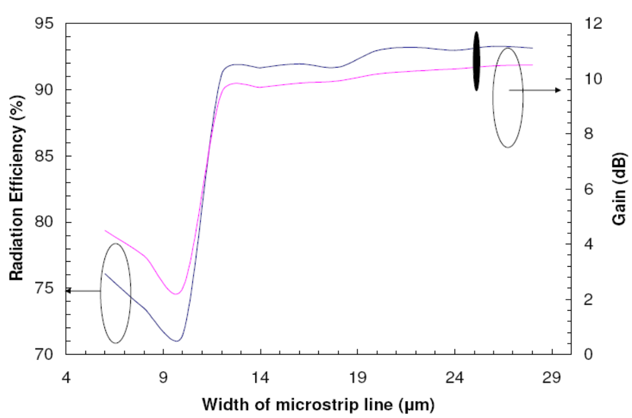

Figure 4: variation of the radiation frequency and gain with the width of the microstrip feed-line.

We have also studied the effects of variation of the width of microstrip feed-line on radiation efficiency and gain. As the width of the microstrip feed-line increases, the radiation efficiency and gain also increases and becomes almost constant after 12µm as shown in Figure 4. The effects of varying the diameter of air gaps in the lower substrate are also observed. As the diameter of the air-gaps increases the radiation efficiency and gain both decreases, but the variation is very small. The point where we have done our simulation is highlighted in the figure. At this point the radiation efficiency as well as gain is maximum as compare to other points.

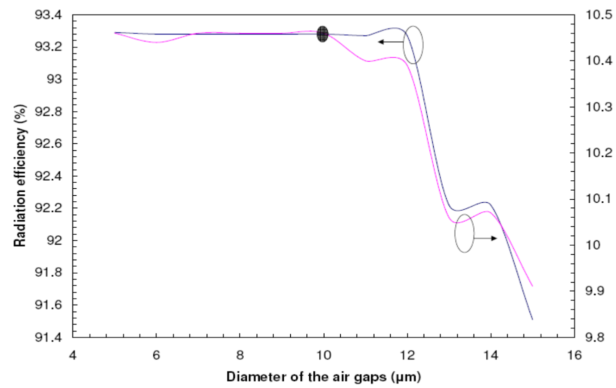

Figure 5: Variation of radiation efficiency and gain of the antenna with the diameter of the air-gaps in lower substrate.

IV. CONCLUSION

This paper explored a novel theoretical concept for the development of ultra-wide band and efficient rectangular microstrip patch antennas using photonic crystals as lower substrate in multilayer substrate structure at THz frequency. Photonic crystals were realized to reduce and, in some cases, eliminate surface waves, which leads to an increase in directivity and radiation efficiency. In future communication we will optimize the geometrical parameters of the proposed microstrip antenna to obtain the optimum electrical parameter.

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