On the Resonant Behavior Analysis of Small-Size Slot Antenna with Different Substrates

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ABSTRACT
An analysis of resonant behavior of small-size slot antenna with substrates of different electrical permittivity has been presented in this paper. It has been observed that with increase in electrical permittivity of the substrate, the gain of the antenna increases, while there is decrease in bandwidth and input impedance of the antenna. Also there is shift of resonant frequency toward lower side with this increase in substrate's dielectric constant. Results shows that the proposed antenna may be used as small, compact antenna for X-band applications

General Terms
Substrates, Resonant behavior.

Keywords
Slot antenna, electrical permittivity, input impedance.

1. INTRODUCTION
The increasing progress in wireless communication system and an increasing demand to integrate different technologies in to small user equipment has remarkably increase the fashion of introducing compact antennas [1]. Microstrip patch antenna, because of its small size, low profile, low manufacturing cost and ease of integeration with feed networks, is find extensive applications in wireless communication system [2-3]. Because of extremely thin profile (0.01 to 0.05 wavelength), printed microstrip antennas have found heavy applications in military aircraft, missiles, rockets and satellites [4-5]. One of the most applicable frequency bands is X-band, ranges from 8-12 GHz. The X-band frequencies are used in satellite communications, radar applications and terrestrial communications. The accurate determination of antenna impedance is important because of the fact that most microwave sources and lines are manufactured with 50Ω characteristic impedance [6-9]. In this paper a small-size slot antenna has been designed to analyze the relationship between the resonant performances of the antenna with the change in the electrical permittivity of the substrate. The radiation properties have also been examined and it has been observe that they are nearly similar in nature.

2. ANTENNA DESIGN & STRUCTURE
Fig. 1 shows the basic geometry of proposed antenna. The antenna is a small-size slot antenna having length, L = 20 mm and width, W = 20 mm. The presented antenna structure has similar slots in its design which is responsible for the small size and its low cost. The dimensions of the slots are L_s = 12 mm and W_s = 12 mm. Because the dimensions of the patch are finite along the length and width, the fields at the edges of the patch undergo fringing.

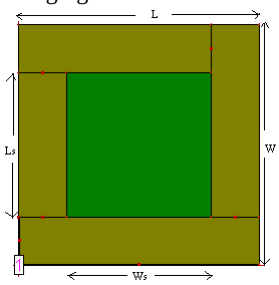


Fig. 1 Geometrical Construction of Proposed Antenna

The amount of fringing is a function of the dimension of the patch, the height of the substrate and dielectric constant ϵ_r of the substrate. Because of the fringing effects, electrically the patch of the microstrip antenna looks greater than its physical size [1]. For better resonance performance parameters, good impedance matching is required and it can be calculated using equation (2) and (3).

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12\frac{h}{w}}}\right) \quad (2)$$

$$Z_0 = \frac{120\Pi}{\sqrt{\varepsilon_{eff}}\left[\frac{w}{h} + 1.393 + 0.667\ln\left(\frac{w}{h} + 1.444\right)\right]} \quad for \quad \frac{w}{h} \geq 1 \quad (3)$$

3. RESULTS & DISCUSSSIONS
3.1 Comparison of Resonant performance with different Electrical Permittivity.
The simulation tool adopted for evaluating the performance of the proposed antennas is IE3D software, which exploits the method of moments to solve the electric field integral equation. Table.1 has shown the resonant performance characteristics of the small-size slot antenna with different electrical permittivity substrates. In this analysis we have taken three substrates Roger RT 5880, Duriod ($\epsilon_{r=}$ 2.2), Roger 5870 ($\epsilon_{r=}$ 2.33) and Benzocyclobuten ($\epsilon_{r=}$ 2.6). It has been observed that with increase in the electrical permittivity the bandwidth and input impedance decrease, but the gain of the antenna increases. And also it is illustrated that resonant frequency shift towards lower side with increase in the dielectric value of substrate.

Table.1 Comparison of resonant performance characteristics.

Electrical Permittivity	Resonant Frequency (GHz)	Bandwidth	Input Impedance (Ohms)	Gain (dBi)
2.2	9.778	4.5%	56.45	3.44
2.33	9.576	4.17%	47.61	3.49
2.6	9.172	3.36%	47.35	3.61

Fig. 2 shows the s-parameters of proposed small-size slot antenna and from the figure it is clear that the antenna resonate at 9.778 GHz, 9.576 GHz and 9.172 GHz for substrates having dielectric values 2.2, 2.33 and 2.6 respectively. It is also shown that with benzocyclobuten substrate antenna resonates at two frequencies that are 9.172 and 11.75 GHz. But for analysis we have taken the primary frequency only. With these resonant properties the proposed antenna is feasible for X-band applications.

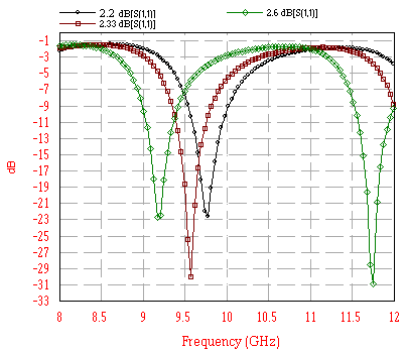


Fig. 2 S-parameters of the Proposed Antenna with different substrates.

3.2 Input Impedance

The main objective to design an antenna is to maximize the power transfer in and out of the device on the projected object. This objective can be achieved by making high impedance matching of the designed antenna. A typical input characteristics $Z_{in} = Re_{in} + jIm_{in}$ of the proposed antenna is shown in Fig. 3. The real part of input impedance at 9.778 GHz for $\epsilon_{r=}$ 2.2, 9.576 GHz for $\epsilon_{r=}$ 2.33 and 9.172 GHz for $\epsilon_{r=}$ 2.6 is 56.45 Ω, 47.61 Ω and 47.35 Ω respectively and it is illustrated that impedance matching is good at all the three frequencies.

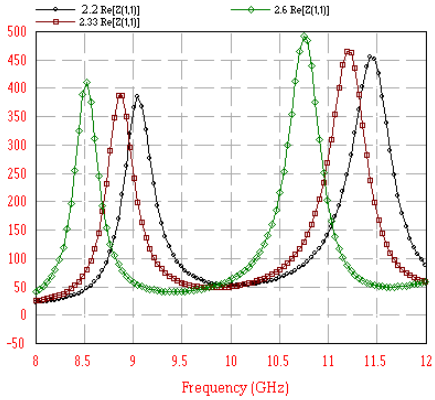
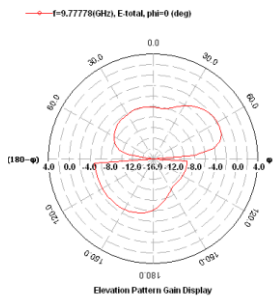


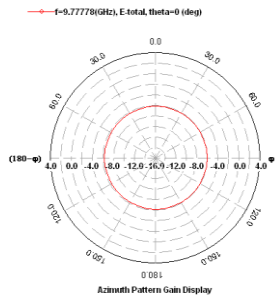
Fig. 3 Input Impedance of the Proposed Antenna

3.3 Radiation Pattern and Gain

The radiation characteristics of proposed slot antenna for different substrates are shown from Fig. 6 to Fig.8 and it has been observed that they are nearly similar in nature. The radiation pattern is symmetrical to antenna axis in E-plane and nearly omnidirectional pattern in H-plane.

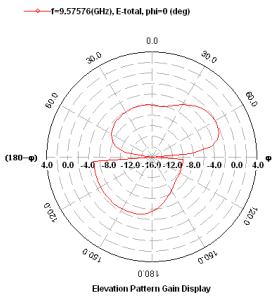


(a)

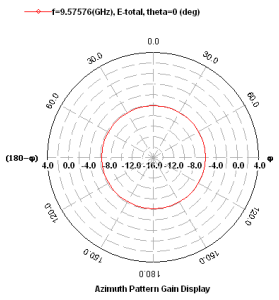


(b)

Fig. 6 Radiation Pattern at 9.778 GHz (a) E-plane (b) H-plane.

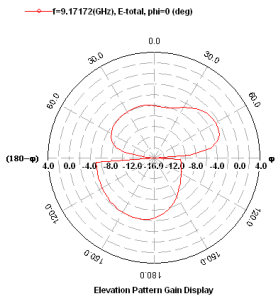


(a)



(b)

Fig. 7 Radiation Pattern at 9.576 GHz (a) E-plane (b) H-plane.



(a)

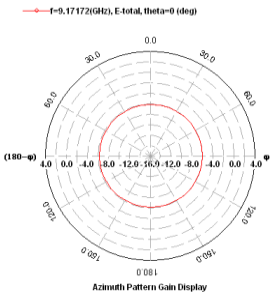


Fig. 7 Radiation Pattern at 9.172 GHz (a) E-plane (b) H-plane

4. CONCLUSION

The resonant performance of small-size slot antenna with different substrate configuration has been presented. As expected it is demonstrated that by keeping the antenna dimensions (including height of the substrate) constant and with increase in electrical permittivity of the substrate, gain of the antenna increase while there is considerable decrease in the bandwidth and input impedance of the antenna. Also the resonant frequency of the antenna shift towards the lower frequency side with the increase in substrate dielectric constant. The proposed antenna is feasible for use as small size, low profile and low cost antenna for X-band applications.

5. ACKNOWLEDGMENT

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