Significance of Dielectric Constant on the Performance of Micro-Strip Antennas

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Abstract— The performance and advantages of microstrip patch antennas such as low weight, low profile, and low cost made them the perfect choice for communication systems engineers. They have the capability to integrate with microwave circuits and therefore they are very well suited for applications such as cell devices, WLAN applications, navigation systems and many others This report presents the construction, working, analysis, applications, advantages and drawbacks of themicrostrip antenna. In this paper a rectangular patch antenna has been designed for licensed free band 2.4GHz and the effect of dielectric constant has been analyzed. The resonate frequency and bandwidth of microstrip antenna depends on the dielectric constant. As the dielectric constant is changed the effect can be observed in the simulated result. Resonate frequency of theantenna is directly proportional to the resonate frequency.

Key words: Terms–micro-strip antenna, apatch antenna, dielectric constant

I. INTRODUCTION

The Microstrip Patch Antenna is a single-layer design which consists generally of four parts (patch, ground plane, substrate, and the feeding part). Patch antenna can be classified as single – element resonant antenna. Once the frequency is given, everything (such as radiation pattern input impedance, etc.) is fixed. The patch is a very thin ($t<<\lambda_0$, where λ_0 is the free space wavelength) radiating metal strip (or array of strips) located on one side of a thin no conducting substrate, the ground plane is the same metal located on the other side of the substrate. The metallic patch is normally made of thin copper foil plated with a corrosion resistive metal, such as gold, tin, or nickel. Many shapes of patches are designed some are shown in figure-15 and the most popular shape is the rectangular and circular patch. The substrate layer thickness is 0.01–0.05 of free-space wavelength (λ_0). It is used primarily to provide proper spacing and mechanical support between the patch and its ground plane. It is also often used with high-dielectric-constant material to load the patch and reduce its size. The substrate material should be low in insertion loss with a loss tangent of less than 0.005.

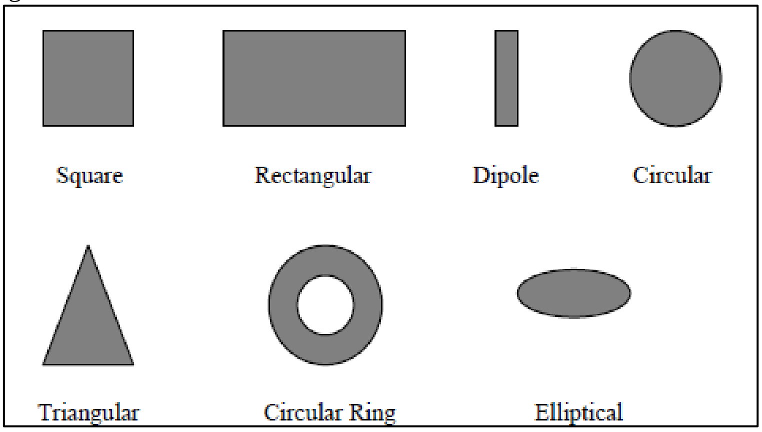

Fig. 1: Different shapes of patch

In its most basic form, a Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 3.1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structure. Therefore they are extremely compatible with embedded antennas in handheld wireless devices such as cellular phones, pagers etc... The telemetry and communication antennas on missiles need to be thin and conformal and are often Microstrip patch antennas. Another area where they have been used successfully is in Satellite communication.

II. RESONANT FREQUENCY

The resonance frequency is controlled by the patch length *L* and the substrate permittivity.a higher substrate permittivity allows for a smaller antenna (miniaturization) – but lower bandwidth. The calculation can be improved by adding a "fringing length extension" ΔL to each edge of the patch to get an "effective length.

$$L_e = L + 2\Delta L$$

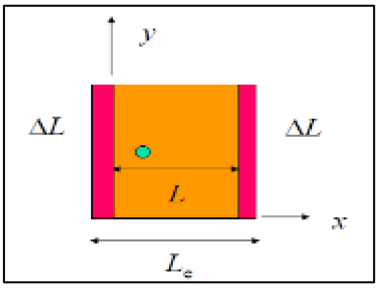

Fig. 2: Effective length

Approximately:

$$W = \frac{c}{2fr}\sqrt{\frac{2}{\epsilon r+1}}$$

$$\epsilon reff = \frac{\epsilon r+1}{2} + \frac{\epsilon r-1}{2}[1+12\frac{h}{w}]^{-1/2}$$

$$\Delta L = hx0.412\frac{(\epsilon reff+0.3)(\frac{w}{h}+0.264)}{(\epsilon reff-0.258)(\frac{w}{h}+0.264)}$$

$$L = \frac{c}{2fr\sqrt{\epsilon reff}} - 2\,\Delta L$$

$$L_e = L + 2\Delta L$$

III. BANDWIDTH

The bandwidth is directly proportional to substrate thickness *h*. However, if *h* is greater than about 0.05 λ0, the probe inductance becomes large enough so that matching is difficult. The bandwidth is inversely proportional to **ε***r*(a foamsubstrate gives a high bandwidth). The bandwidth is directly proportional to the width *W*. Normally $W < 2L$ because of geometry constraints:

$$W = 1.5\,L$$

For a typical substrate thickness (h / λ0 = 0.02), and a typical substrate permittivity (εr = 2.2) the bandwidth is about 3%. By using a thick foam substrate, thebandwidth of about 10% can be achieved. By using special feeding techniques (aperture coupling) and stacked patches, thebandwidth of over 50% has been achieved.

IV. ANTENNA CONFIGURATION

The dimensions of proposed antenna are illustrated in Fig. 3. It composed of 50Ω transition, 50Ω probe feeds. The width of the antenna is 40mm, length 30mm, and height 3.2mm. The patch is etched on a different dielectric material with dielectric constant 2.2, 2.5 and 2.6 respectively for thickness 3.2mm. To achieve the impedance matching the feed point is placed at (5, 0, 0) mm from the center of the patch. The above feeding point gives the best impedance matching. Two rectangular slots have been incorporated to enhance the bandwidth and to achieve desired frequency response.

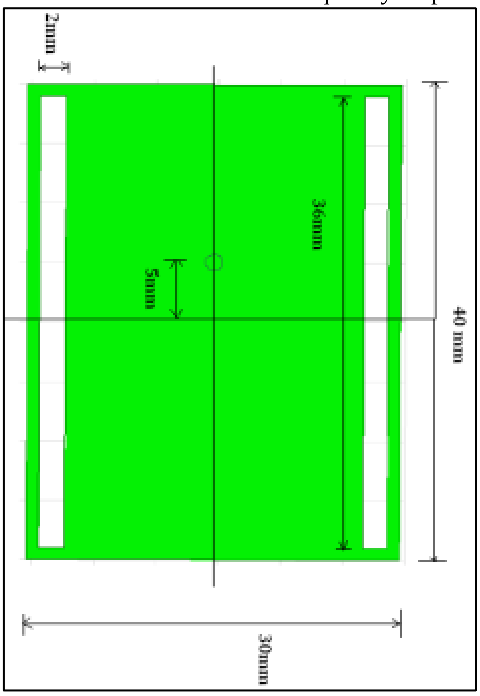

Fig. 3: Antenna geometry

V. RESULTS

The proposed antenna is simulated using AnsoftCorporation HFSS-13 and results are displayed in Fig.4. The antenna is simulated for three different dielectric constant and results has been compared in the plot.

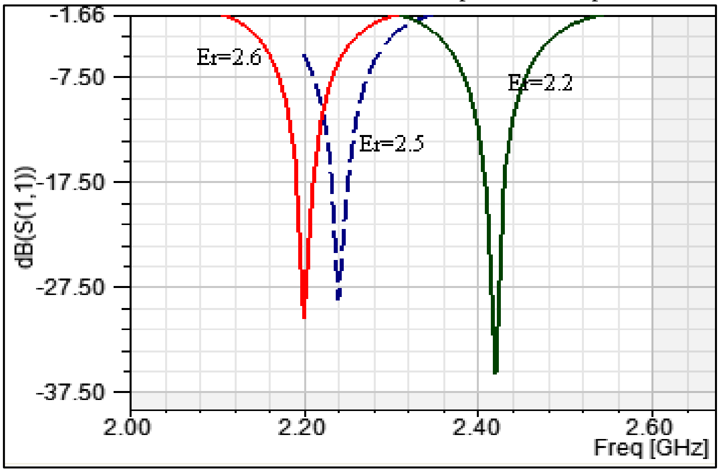

Fig. 4: a Return loss of the antenna as a function of dielectric constant

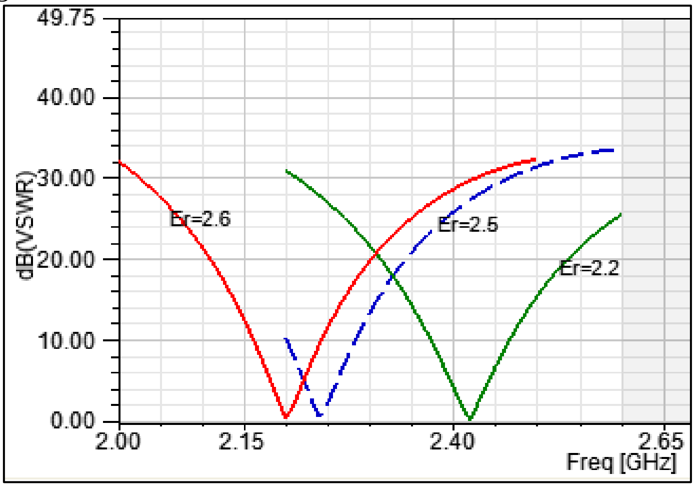

Fig.4: b VSWR of the antenna as a function of dielectric constant

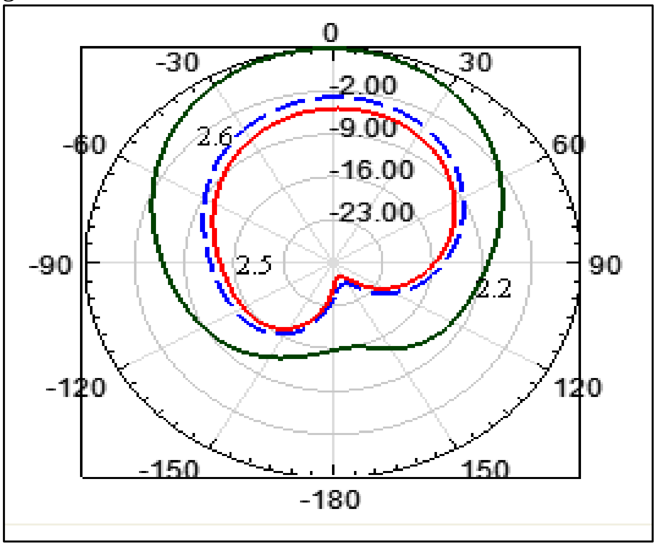

Fig. 4: c Radiation pattern of the antenna as a function of dielectric constant

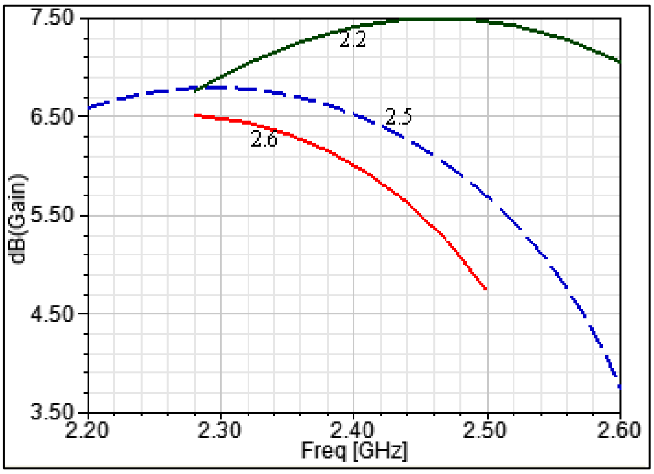

Fig. 4: d Gain of the antenna as a function of dielectric constant

VI. CONCLUSION

From the simulation result we can clearly see that the dielectric constant is inversely proportional to the resonating frequency. Also the dielectric constant of the antenna is directly related to antenna bandwidth. Higher dielectric constant materials exhibit higher bandwidth but poor radiation performance. As the dielectric constant increases frequency decreases also higher dielectric constant gives less radiation efficiency.

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