Effect of Curvature on the Performance of Cylindrical Microstrip Printed Antenna for TM_{01} mode

Ali Elrashidi, Khaled Elleithy, and Hassan Bajwa
Department of Computer Science and Engineering
University of Bridgeport, Bridgeport, CT

Abstract

Curvature has a great effect on fringing field of a microstrip antenna and consequently fringing field affects effective dielectric constant and then all antenna parameters.
A new mathematical model for input impedance, return loss, voltage standing wave ratio and electric and magnetic fields is introduced in this paper. These parameters are given for TM_{01} mode and using two different substrate materials RT/duroid-5880 PTFE. Experimental results are also introduced to validate the new model.

Introduction

Due to the unprinted growth in wireless applications and increasing demand of low cost solutions for RF and microwave communication systems, the microstrip flat antenna, has undergone tremendous growth recently. Though the models used in analyzing microstrip structures have been widely accepted, the effect of curvature on dielectric constant and antenna performance has not been studied in detail. Low profile, low weight, low cost and its ability of conforming to curve surfaces, conformal microstrip structures have also witnessed enormous growth in the last few years. Applications of microstrip structures include Unmanned Aerial Vehicle (UAV), planes, rocket, radars and communication industry.

General Expressions for Electric and Magnetic Fields Intensities

Starting from Maxwell's Equations E_φ and E_ρ are getting as shown:

$$\nabla \times E = -\frac{\partial B}{\partial t} \qquad (1)$$

$$E_z = \frac{e^{-jkr}}{j\omega\varepsilon\pi r}k^2 \sum_{n=-\infty}^{\infty} e^{jn\theta} j^{n+1} f_n(-k\cos\theta) \qquad (2)$$

$$H_r = \frac{e^{-jkr}(1+jkr)}{r^2} \sum_{n=-\infty}^{\infty} e^{jn\theta} j^{n+1} f_n(\ \ k\cos\theta) \qquad (3)$$

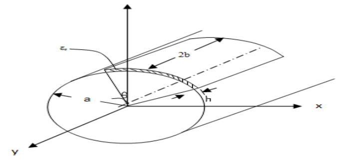

Fig1: Geometry of cylindrical-rectangular patch antenna

Input Impedance

we can obtain the input impedance for a rectangular microstrip antenna conformal in a cylindrical body as in the following Equation:

$$Z_{in} = j\omega\mu h \sum_n \sum_m \frac{1}{k^2 - k_{nm}^2} \frac{\varepsilon_m \varepsilon_n}{2a\theta_1 L} \cos^2\left(\frac{m\pi}{2\theta_1}\phi_0\right) \cos^2\left(\frac{n\pi}{L} z_0\right) \times sinc\left(\frac{n\pi}{2L} z_0\right) sinc\left(\frac{m\pi}{2a\theta_1}\phi_0\right) \qquad (4)$$

Voltage Standing Wave Ration and Return Loss

Voltage Standing Wave Ration VSWR is defined as the ration of the maximum to minimum voltage of the antenna.

$$VSWR - \frac{|\Gamma| + 1}{|\Gamma| - 1} \qquad (5)$$

where Γ is the reflection coefficient .
The return loss s11 is related through the following Equation:

$$s_{11} = -20 \log\left[\frac{V_r}{V_i}\right] = -20 \log\left[\frac{VSWR - 1}{VSWR + 1}\right] \qquad (6)$$

Results

For the range of GHz, the dominant mode is TM_{01} for $h \ll W$ which is the case. Also, for the antenna operates at the ranges 2.15 GHz we can use the following dimensions; the original length is 41.5 cm, the width is 50 cm and for different lossy substrate we can get the effect of curvature on the effective dielectric constant and the resonance frequency.
Substrate material RT/duroid-5880 PTFE is used for verifying the new model. The dielectric constants for the used material is 2.2 with a tangent loss 0.0015.
The mathematical and experimental results for input impedance, real and imaginary parts for a different radius of curvatures are shown in Figures 2 and 3. VSWR is given in Figure 4. Return loss (S11) is illustrated in Figure 5. Normalized electric and magnetic fields for different radius of curvatures are illustrated in Figures 6 and 7 consequently.

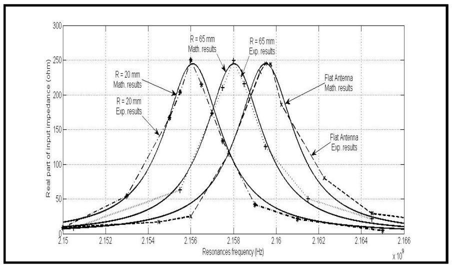

Figure 2. Mathematical and experimental real part of the input impedance as a function of frequency for different radius of curvatures.

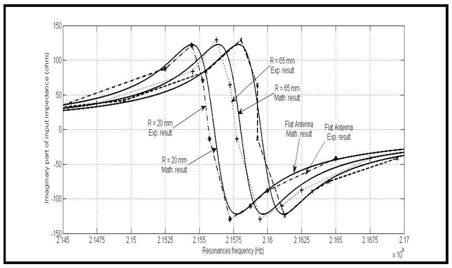

Figure 3. Mathematical and experimental imaginary part of the input impedance as a function of frequency for different radius of curvatures.

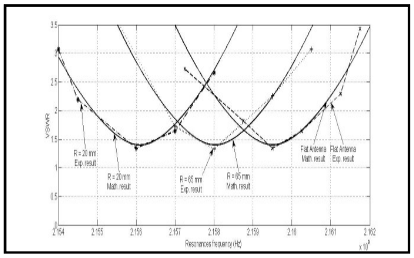

Figure 4. Mathematical and experimental VSWR versus frequency for different radius of curvatures.

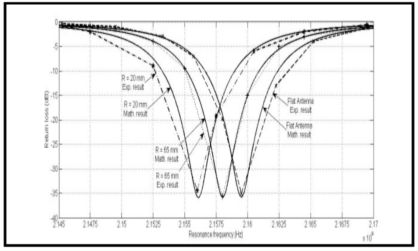

Figure 5. Mathematical and experimental return loss (S11) as a function of frequency for different radius of curvatures.

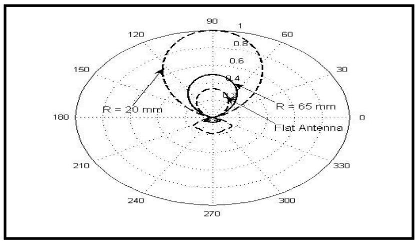

Figure 6. Normalized electric field for radius of curvatures 20, 65 mm and a flat antenna at θ=0:2π and $\varphi=0^0$.

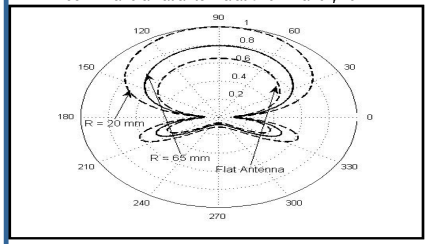

Figure 7. Normalized magnetic field for radius of curvatures 20, 65 mm and a flat antenna at θ=0:2π and $\varphi=0^0$.

CONCLUSION

The Equations for input impedance, return loss, VSWR and electric and magnetic fields as a functions of curvature and effective dielectric constant are derived. The decreasing in frequency due to increasing in the curvature is the trend and increasing the radiation pattern for electric and magnetic fields due to increasing in curvature is easily noticed.
We conclude that, increasing the curvature leads to increasing the effective dielectric constant, hence, resonance frequency is increased. So, all parameters are shifted toward increasing the frequency with increasing curvature.