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Design of Multi-Band Microstrip Patch Antenna For Wireless Communication

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Abstract: This paper presents a new approach for the design of a multi-wideband microstrip-patch antenna. The radiating elements in this antenna are composed of rectangular slots following a chebyshev distribution of order 10 around a rectangular centre slot, and an additional triangular slot. These slots are engraved in the rectangular and triangular patch, joined together in one structure, and fed by one probe feed. A sample antenna can be used for several applications, especially in the GSM domain, and for Wi-Fi, Bluetooth, and several other applications.

Keywords: Microstrip patch antennas, WLAN, GSM, Bluetooth, wideband antennas.

Introduction: Several methods for obtaining multi-band and/or wideband antenna characteristics have been developed. In [1], a dual wideband folded micro strip-patch antenna was introduced for possible wireless local-area network (WLAN) applications in the 3.5-4 GHz frequency range. The proposed antenna operated in a wide frequency band by utilizing a unique coupling mechanism between the radiating elements and the ground plane. In [2], a novel reconfigurable patch antenna with switchable slots (PASS) was proposed to realize various functionalities, such as dual-frequency operation, dual-band circularly polarized (CP) performance, and polarization diversity with only one patch and a single feed. A cavity-modelbased simulation tool, along with a genetic optimization algorithm, was presented in [3] for the design of dual-band microstrip antennas. This used multiple slots in the patch, or multiple shorting strips between the patch and the ground plane. The optimization of the positions of the slots and shorting strips was then performed via a genetic optimization algorithm to achieve acceptable antenna operation over the desired frequency bands. A similar approach was presented in [4], where a single low-profile printed antenna, which provided dual-band operation by having loading from two-step slots embedded close to the radiating edge. In [4], it was also shown that the ratio of the two frequencies can be well controlled by the aspect ratio of the step-loading dimension.

This paper presents a multi-band antenna-design approach based on inserting rectangular slots, following a Chebyshev distribution, in addition to a triangular slot into the patch, which represents a combination of a rectangular and an isosceles-triangular has the same area as the part formed by the rectangle. The part, and the rectangular slots is inserted into the rectangular part of the patch. The whole system is fed by a coaxial probe into the substrate, with an input impedance of 50 Ω. A sample antenna was analyzed, simulated, tested. The agreement between the computed and experimental was very good.

The proposed antenna has many applications, and can be used to cover GSM, GPS, Wi-Fi, Wimax, video wireless communication, and Bluetooth applications. The concept of inserting slot array following a known antenna-array distribution has proven to give remarkable functionality to an antenna. It causes it to radiate significantly at different ranges of frequencies, using only one single feed point.

Geometry and Formulation of the Problem: The proposed antenna geometry is based on joining a rectangular patch and a triangular patch, in order to increase the radiation area, as shown in figure 1. The structure is fed by a 50Ω coaxial probe. The radiation pattern of the proposed structure with this feeding techniques is determined by adding fields radiated by the rectangular patch to those radiated by the triangular patch. The substrate used in the formulation process was of thickness h = 0.32 cm. The far electric fields of the rectangular fields of the rectangular patch are given as

$$E_\theta = \frac{K_e^{-jk_{\theta r}}}{r}\cos(k_o h\sqrt{\varepsilon_r} \quad \cos\theta)$$

$$\frac{\sin\left(\frac{\pi W}{\lambda_o}\sin\theta\sin\varphi\right)\cos\left(\frac{\pi L}{\lambda_o}\sin\theta\cos\phi\right)\cos\theta}{\sin\theta\sin\phi}, \qquad (1)$$

$$e_\theta = \frac{-K_{e^{jk_o r}}}{r}\cos(k_o h\sqrt{\varepsilon_r}\cos\theta)$$

$$\frac{\sin\left(\frac{\pi W}{\lambda_o}\sin\theta\sin\phi\right)\cos\left(\frac{\pi L}{\lambda_o}\sin\theta\cos\phi\right)\cos\phi}{\sin\theta\sin\phi}, \qquad (2)$$

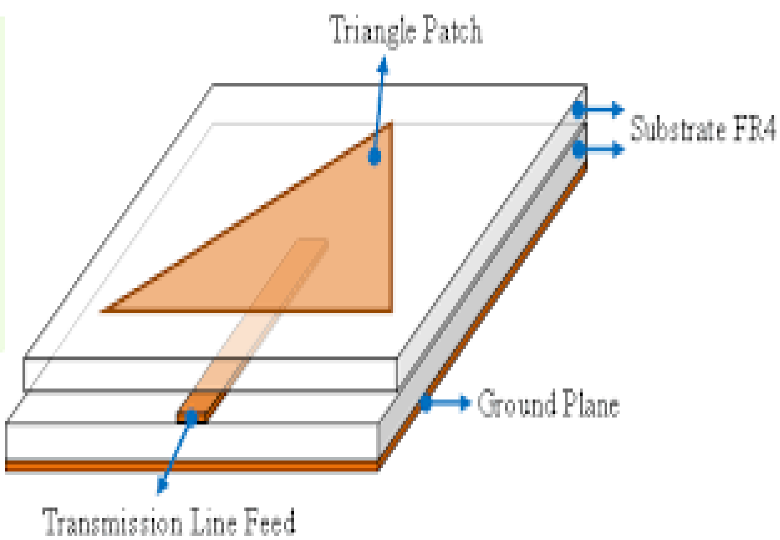

Figure 1. A rectangle added to an equilateral triangle patch, fed by a probe.

In equations (1) and (2), k_0 is the wave number, λ_o is the wavelength, ε_r is the dielectric permittivity, and W and L are the width and the length dimensions of the rectangular patch, respectively. Moreover, the far electric fields radiated from an equilateral triangle were given in [5] as

$$E_{\theta = -j\varpi\eta_o}(F_x\cos\theta\cos\phi + F_y\cos\theta\cos\phi), \qquad (3)$$

$$E_{\theta = -j\varpi\eta_o}(-F_x\sin\theta + F_y\cos\phi), \qquad (4)$$

In equations (3) and (4) $\eta_o = 120\pi\Omega$, and the terms F_x and F_y are the electric potential components. These were given in detail [4], and will not be repeated here, for convenience. By specifying the lowest-order mode, TM_{010}, for approximating the rectangular dimensions to a length, L, of 4 cm and width, W, of 3 cm, and for an equilateral triangle 3 cm on a side, for an operating frequency, F_o, of 3.24 Ghz, Equations (1) and (2) become

$$e_\theta = \frac{K_{e^{-jk_or}}}{r}\cos(0.322\cos\theta)$$
$$\frac{\sin(0.9448\sin\theta\sin\phi)\cos(0.7086\sin\theta\cos\phi)}{\sin\theta\sin\phi}\cos\theta \qquad (5)$$

$$e_\theta = \frac{K_{e^{-jk_or}}}{r}\cos(0.322\cos\theta)$$
$$\frac{\sin(0.9448\sin\theta\cos\phi)\cos(0.707\sin\theta\cos\phi)}{\sin\theta}\cos\theta \qquad (6)$$

It is clear from Equation (5) that for θ = 0° ø = 90°, both components of the electric field vanish, due to the terms sin ø and cos ø, respectively. Moreover, for ø = 90°, Equation (6) becomes

$$e_\theta = \frac{K_{e^{-jk_or}}}{r}\cos(0.322\cos\theta)$$
$$\frac{\sin(0.9448\sin\theta)}{\sin\theta}\cos\theta \qquad (7)$$

For an equilateral triangular patch the θ components of the electric field are given by the product of the terms A and C, given by

$$A = \frac{2j(139.6258 + j39.1789\sin\theta[\sin(1.01789\sin\theta)]}{6498.455 - 1534.986\sin^2\theta}$$

$$+\frac{2j\cos(1.01789\sin\theta 8-2j}{39.1789\sin\theta}\} \qquad (8)$$

$$C=-ij\varpi\eta_o[4\pi r)^{-1}\varepsilon_0 h e^{-jk_o r}]e^{-j39.1789\sin\theta_{2\,j\varpi\cos\theta_{2\,jw\mu C_{01}}}} \qquad (9)$$

C_{01} is a constant defined in [5].

The total electric field of the new structure is obtained by adding the electric field radiated from the rectangular patch, defined in Equation (7), to that of the triangular patch, derived in equation (8) and (9). The simulated result is shown in figure 2.

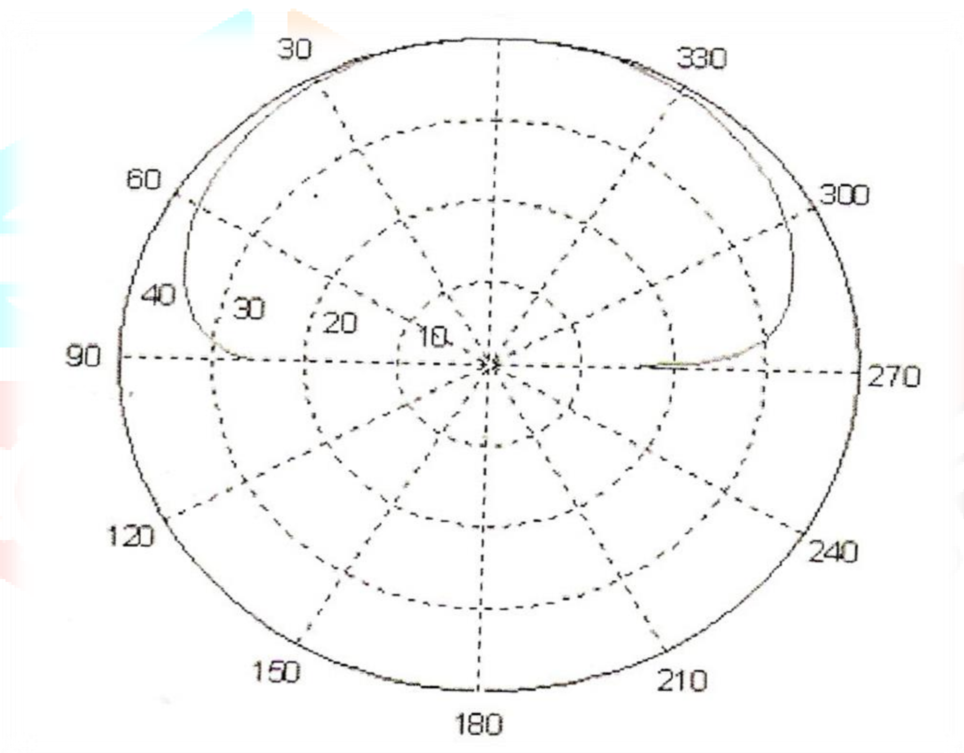

Figure 2. The simulated E-plane electric field for phi = 90 degree

Antenna application: Various applications can be the subject for this newly designed antenna, since it is multi-functional and multi-resonant antenna, according to simulation and fabrication results. Each resonant frequency can be the subject of various applications in today's modern wireless communication world. The S_{11} parameter going under – 10dB also indicated the presence of three resonant frequencies [5]. This new wideband operation of the antenna shares the presences of resonance at the wireless CCTV application at 2.8 GHz, [6] and two other completely new applications:

1. 900 MHz : GSM, ISM, WLAN, RFID applications

2. 2.8 GHz : wireless CCTV and wireless video links, WLAN applications

3. 3.5 GHz: WLAN, WiMax, wireless WiMax, 802.16 a applications

Conclusion: A new multi-band antenna design has been presented. The design consists of joining a rectangular and a triangular patch together in one patch, and inserting several forms of slots. The new idea behind this design also includes the insertion of rectangular slots following a Chebyshev distribution around a central rectangular slot, in addition to a triangular slot inserted into the triangle, which has the same area as the rectangular patch. The concept of inserting slot arrays following a known antenna-array distribution has proven to give remarkable functionality to an antenna. It causes it to be highly radiating in different, frequency ranges, using only one single feed, represented by a 50 Ω SMA connector, where the position has been optimized.

The antenna has many applications, such as GSM, GPS, Wi-Fi, WiMax, video wireless communication, and Bluetooth applications, in one single instrument, using this type of antenna.

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