Circularly Polarized Microstrip Antenna with Reactive Load Design for Wireless Local Area Network Application

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Abstract

This paper presents a design of microstrip antenna for IEEE 802.11b and for IEEE 802.11g using a nearly square patch antenna, excited by a standard miniature adapter probe feed line. The patch and ground plain are separated by a substrate; the radiating patch is loaded by a central shorting pin and feeding probe loaded by a series capacitor. This antenna has wide bandwidth in the frequency band of (WLAN) and with a return loss $\leq -10\ dB$ from 2.4 GHz to 2.48 GHz exhibits circularly polarized far field radiation pattern.

The proposed antennas have been simulated and analyzed using method of moments (MoM) based software package Microwave Office 2008 v8.0. The results show that the bandwidth of the antenna increases by using reactive load. The simulated gain of the antenna is over 6 dB.

الخلاصة

هذا البحث قدم تصميما لهوائي شريطي لمنظومتي IEEE802.11b و IEEE802.11g باستخدام الشكل شبه المربع للبث الكهرومغناطيسي والذي تتم تغذيته بواسطة خط التغذية المعياري المصغر. الهوائي يتكون من مستوي الشريحة الشبه مربع و مستوي الأرضي و ما بينهما تكون المادة العازلة. الشكل شبة المربع حمل بدائرة قصر مع مستوي الأرضي و كذلك خط التغذية حمل بمتسعة توالي لإغراض الموائمة. هذا الهوائي يمتلك حزمة تردد تغطي ترددات الشبكة اللاسلكية المحلية ومع مفقودات راجعات اقل من -10 dB من تردد 2.4 GHz إلى تردد 2.48 GHz و ذو بث دائري الاستقطاب لشعاع الإرسال البعيد المدى.

تمت محاكاة وتحليل النموذج للهوائي المقترح باستخدام مكتب الموجات المايكروية 2008 الجيل الثامن. النتائج بينت ان حزمة الاشتغال الترددي للهوائي ازدادت باستخدام الحمل الغير فعال. نتائج المحاكاة لمحصله الهوائي هي أكثر من 6 dB.

1. Introduction:-

Microstrip antenna is a type of antennas which can be used for transmitting and receiving signals. Microstrip or printed antennas are low profile, small size, light weight and widely used in wireless and mobile communications, as well as radar applications. Microstrip antennas can be divided into two basic types by structure, namely microstrip patch antenna and microstrip slot antenna. The microstrip patch antennas can be fed by microstrip line and coaxial probe [1].

Nowadays, wireless local area network (WLAN) standardized by IEEE 802.11 is becoming common in communication system [1].

Microstrip patch antennas have received considerable attention for wireless communication applications [2]. This proposed microstrip antenna designed to utilized in 2.4-2.4835 GHz frequency range (IEEE 802.11 b/g), fed by 50Ω standard miniature adapter (SMA) at a designed frequency of 2.4425 GHz.

2. The proposed antenna:-

The antenna configuration is nearly square microstrip patch antenna shown in Fig.l. In this case the circular polarization (CP) is obtained because the two modes of resonance (corresponding to the adjacent sides of the rectangle), are spatially orthogonal. The antenna is excited at a frequency in between the resonant frequencies of these two modes in order to obtain the phase quadrature relationship between the voltages (and therefore magnetic currents) of two modes. Corner or diagonal feeding is required to allow both the modes to be excited with a single feed [3].
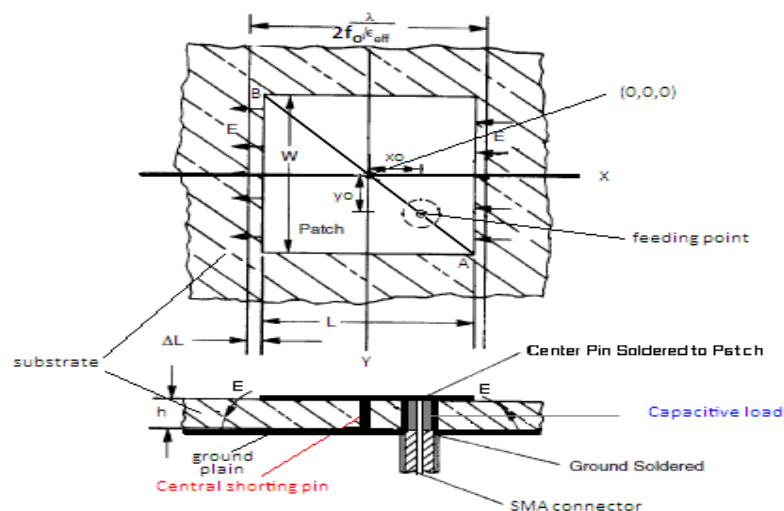

Fig.1.The nearly square patch antenna configuration.

The ratio of the two orthogonal dimensions W/L should be generally in the range of (1.01–1.10) depending upon the substrate parameters. When the patch is fed along the diagonal, then the two resonance modes corresponding to lengths L and W are spatially orthogonal.

The CP is obtained at a frequency, which lies between the resonance frequencies of these two modes, where the two orthogonal modes have equal magnitude and are in phase quadrature [4]. The feeding probe, i.e. inner conductor of SMA is connected to the patch through a small opening in the ground plane. The outer conductor of SMA is directly connected to the ground plane. A cylindrical-capacitor with larger diameter than that of the probe is inserted between the probe and patch for the impedance matching optimization [5].

By using a central pin to short the upper patch to the ground plane, one may improve the purity of the resonant mode. An addition of a shorting pin acts as an extra parameter to control the mode excitation. For a given antenna dimension, Since the introduction of the pin increases the resonance size of the patch, perhaps the most important property of the pin is to control the antenna gain by increasing the patch size. This may be a useful parameter to use in the design of higher-gain patch antennas [6]. This kind of design is the simplest form to generated circular polarization and is very suitable for the WLAN RHCP or LHCP microstrip antenna design.

3. The proposed antenna design:-

The calculation of the square Microstrip antenna length is based on transmission-line model [7]. The width W of the radiating edge, which is not critical, chosen first. The length L is slightly less than a half wavelength in the dielectric. The precise value of the dimension L of the square patch has been calculated using expression [7, 8].

$$L = \frac{c}{2f_0\sqrt{\epsilon_{reff}}} - 2\Delta L \dots\dots\dots\dots\dots\dots\dots\dots \text{(1)}$$

Where ϵ_{reff} the effective dielectric constant, and ΔL is the fringe factor [9].

For the frequency of 2.4425 GHz and using (FR-4) with a relative dielectric constant of 4.2 and loss tangent of 0.017, with substrate height of 1.575 mm, this yields nearly square patch antenna length (Fig.1) of L=28.5 mm and W=29.5 mm. The ratio of the two orthogonal dimensions W/L is 1.035, lies in the range of generating two spatially orthogonal resonance modes [4].

The feed-point of the antenna, it is defined in terms of input impedance Z_{in} of the antenna and the characteristic impedance Z_o of the feed line. The feed point position should be placed at the location where the input impedance of the antenna matches the characteristic impedance of the feed [4]. The patch can be fed by a coax line from underneath. The impedance varies from zero in the center to the edge resistance approximately as [10].

$$Ri = Re \, Sin^2 \frac{\pi x}{L} \qquad 0 \leq x \leq \frac{L}{2}\dots\dots\dots\text{(2)}$$

Where *Ri* is the input resistance, *Re* the input resistance at the edge, and x the distance from the patch center. By shifting the feed-point along the diagonal to x =-0.4875 cm and y = -0.475 cm, from the center of the patch; a perfect match with a 50Ω feed line is obtained, with cylindrical-capacitor [5].

The feeding point position is 0.323% from the diagonal long. The central shorting pin added at the center of the patch with x=0 cm, y=0 cm. A shorting pin through the center has no effect on radiation or impedance, but it allows a low-frequency grounding of the antenna [10]. The proposed antenna structure has been modeled using a full-wave numerical Method of Moment (MoM). EMSight[TM], of the Applied Wave Research (AWR), includes a full-wave electromagnetic solver that uses a modified spectral domain method of moments to accurately determine the multi-port scattering parameters for predominately planar structures [11]. In the presented design; this software package was applied to simulate the typical characteristic of the proposed antennas.

4. Simulation results:-

The proposed antenna structure had been modeled at the design frequency of 2.4425 GHz, which are the center frequency of WLAN standardized by IEEE 802.11b/g. It has been supposed that the antenna element to be located parallel to x-y plane and centered at the origin (0, 0, 0). The computed input return losses of the antenna patch is shown in Fig.2.
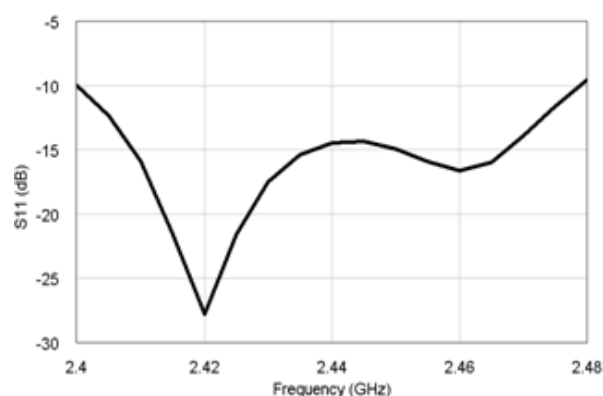

Fig.2 The calculated input returns loss for the modeled patch element.

The computed radiated electric far field intensity right handed and left handed in broadside direction with respect to frequency is shown in Fig.3. It is clear that, for this feed, this antenna supports LHCP electric field radiation pattern and if the feed is shifted to the other diagonal, then RHCP is obtained [4].
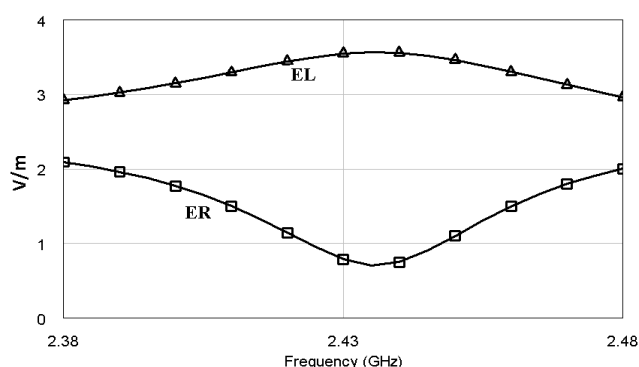

Fig.3 The computed far electric field intensity left hand and right hand circular polarization in broadside direction, of the proposed antenna.

The required axial ratio *AR* has been calculated using [12]:

$$AR(dB) = 20 log \left| \frac{|E_R| + |E_L|}{|E_R| - |E_L|} \right| \quad \dots\dots\dots\dots\dots\dots(3)$$

Where E_R and E_L are the right and left handed circularly polarized radiated electric fields. The resulting axial ratio as a function of frequency is depicted in Fig.4. It can be seen that the axial ratio in the broadside direction is below 3 dB throughout a bandwidth of about 80 MHz's.
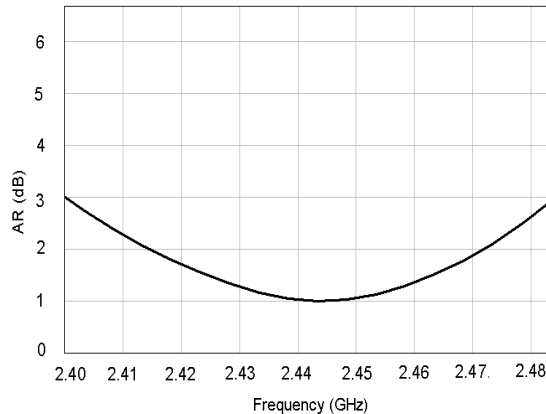

Fig.4 The computed axial ratios around the IEEE802.11b/g frequency, for the proposed antenna.

The computed gain around the IEEE802.11b/g frequency range has shown in Fig.5. As the gain response implies, the proposed antenna possesses an average gain of about more than (4.5-6) dB throughout the required bandwidth of IEEE802.11b/g antenna.
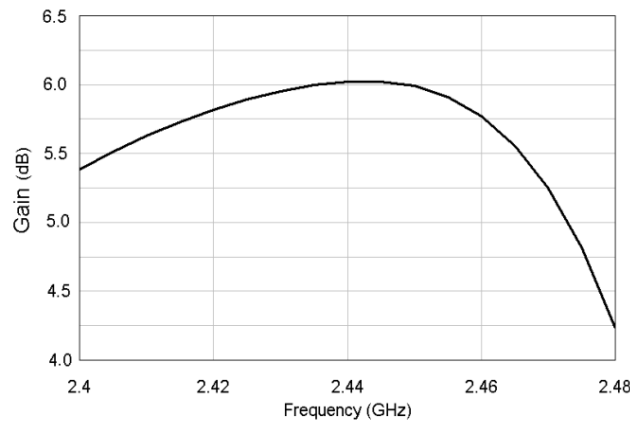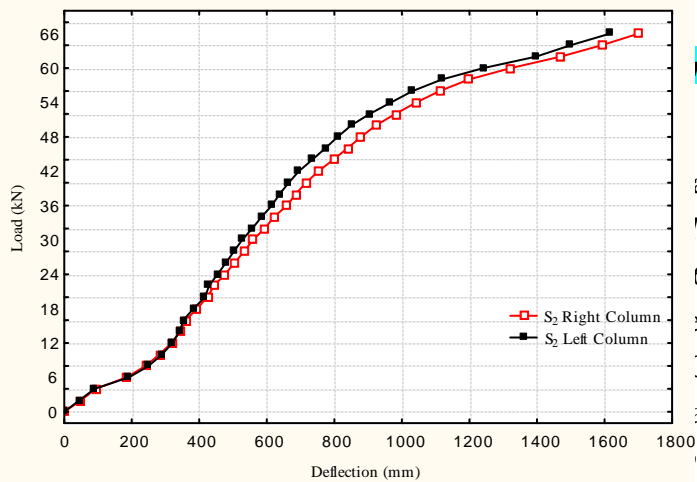

Fig.5 The computed antenna gain around the IEEE802.11b/g frequency, for the proposed antenna.

5. Conclusions:-

A nearly square wideband single probe-fed microstrip patch antenna with inserted central shorting pin and input feed matching capacitor has been investigated. The realized impedance bandwidths (return loss ≤ −10 dB) and the circular polarization bandwidth (axial ratio ≤ 3 dB) satisfy the bandwidth requirements for the IEEE802.11b/g operation.

Line Plot (Abeer1 18v*118)

Load (kN) vs Deflection (mm)

S₂ Right Column
S₂ Left Column

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