A Probe-fed U-slot Patch Antenna With Suspended Microstrip Configuration

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Abstract. In this paper, a probe-fed u-slot patch antenna in a suspended microstrip configuration is presented. The effects of parameters of suspended structure on the antenna response have been investigated. It is shown that the use of suspended configuration in this antenna improves its response. Also the suspended configuration has made the fabrication of the antenna easier than the case in which the complete Foam material is used for substrate.

1 Introduction

In recent years, the demand for broad-band antennas has increased for use in highfrequency and high-speed data communication. Printed antennas are economical and easily hidden inside packages, making them well suited for consumer applications. Unfortunately, a "classical" microstrip patch antenna has a very narrow frequency bandwidth that precludes its use in typical communication systems. However, if the frequency bandwidth could be widened, a broad-band microstrip antenna would prove very useful in commercial applications such as 2.5 G and 3 G wireless systems, wireless local area networks (WLAN), and Bluetooth personal networks. Researchers have devised several methods to increase the bandwidth of microstrip antennas in addition to the common techniques of increasing patch height and decreasing substrate permittivity. These include using a multilayer structure consisting of several parasitic radiating elements with slightly different sizes above the driven element (a stacked patch antenna) [1] or a planar patch antenna surrounded by closely spaced parasitic patches (a coplanar parasitic subarray) [2]. The stacked patch antenna increases the thickness of the antenna while the coplanar geometry increases the lateral size of the antenna. Incorporation of a dissipative load in a single-layer single-patch antenna through addition of high loss material or resistors also increases bandwidth but compromises the antenna's efficiency and gain [3], [4]. The bandwidths of single patch antennas can also be increased by implementing internal structures such as shorting pins [5], [6] or slots [7]. In 1995, Huynh and Lee [7] presented an experimental study of a new kind of broad-band antenna with an impedance bandwidth of 47%. The new antenna was a probe-fed rectangular microstrip patch antenna on a unity permittivity substrate with an internal U-shaped slot as shown in Fig. 1 [7]. The antenna presented in [7] is used together with an external DIN adaptor in order to excite the second order modes with x-directed current path of the patch, as mentioned in [8]. The substrate of the u-slot patch antenna in [7] is a single-layer Foam substrate.

In this paper we show that a two-layer substrate combining a pcb for fabrication of the patch and u-slot and a Foam layer under the Fr4 substrate that is called 'A Suspended Microstrip Configuration' [9] can be used to improve the characteristics of the probe-fed u-slot patch antennas. The use of this substrate causes the fabrication of the antenna become easy. Moreover, it causes that there would be no need to the adaptor that is used in [7].

2 The antenna structure

Here the structure of a probe fed u-slot patch antenna which has a suspended microstrip configuration [9] is presented. The antenna structure is consist of a patch in which a u-shaped slot is cut with the dimensions presented in the Figure 1-a. Some dimensions that are not mentioned in this Figure can be found by the patch and u-slot symmetry.

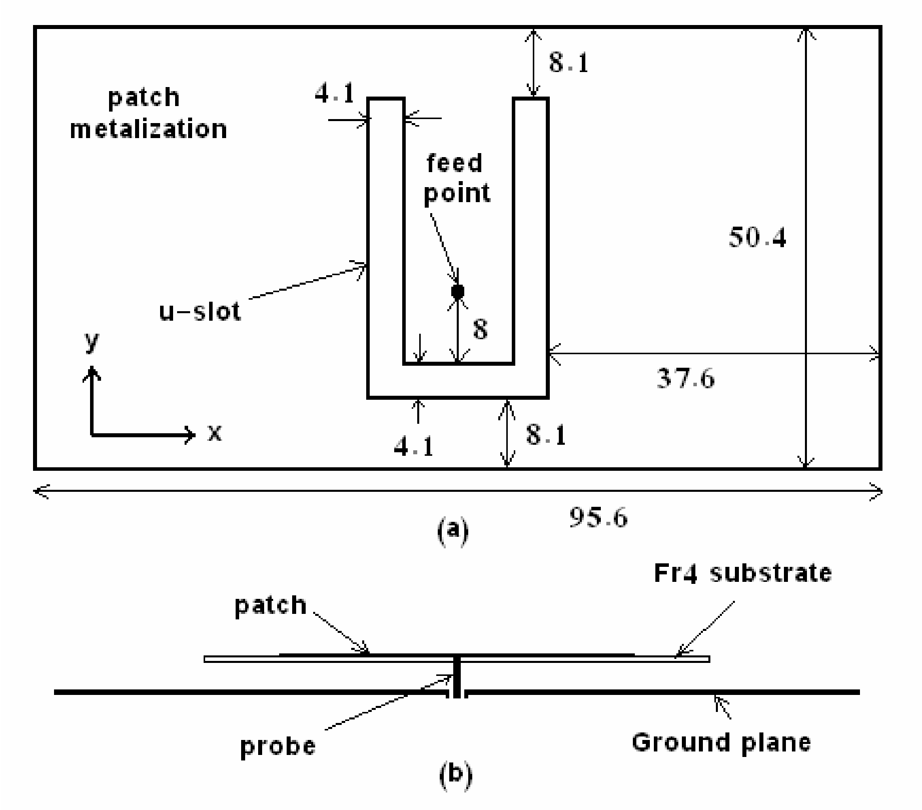

Fig.1. Structure of the probe-fed u-slot patch antenna: dimensions of the patch and u-slot in millimeters (a), the antenna substrate layers and feeding (b).

The patch and u-slot are placed on top surface of an Fr4 epoxy substrate with the thickness of 1.6mm and relative permittivity of 4.4. Under the Fr4 substrate there is a space that is filled by Foam with relative permittivity of about 1 and the thickness of 7.7mm. Under the spacing a finite ground plane with dimensions of 100mm×200mm is placed. The diameter of the probe used to feed the antenna is 1.27mm.

3 The response of the u-slot patch antenna with suspended microstrip configuration

The explained antenna structure has been fabricated (Figure 7) and tested. The antenna return loss plots of simulation and measurements are shown in the Figure 2. The presented structure has 3 resonant frequencies in its return loss plot. Nevertheless, the u-slot patch antenna in [10] has 2 resonant frequencies in its return loss plot. As mentioned in [8], a third resonant frequency can be created in this antenna by using a DIN adaptor. But the use of the suspended microstrip configuration in this paper, has caused that there would be no need to the adaptor.

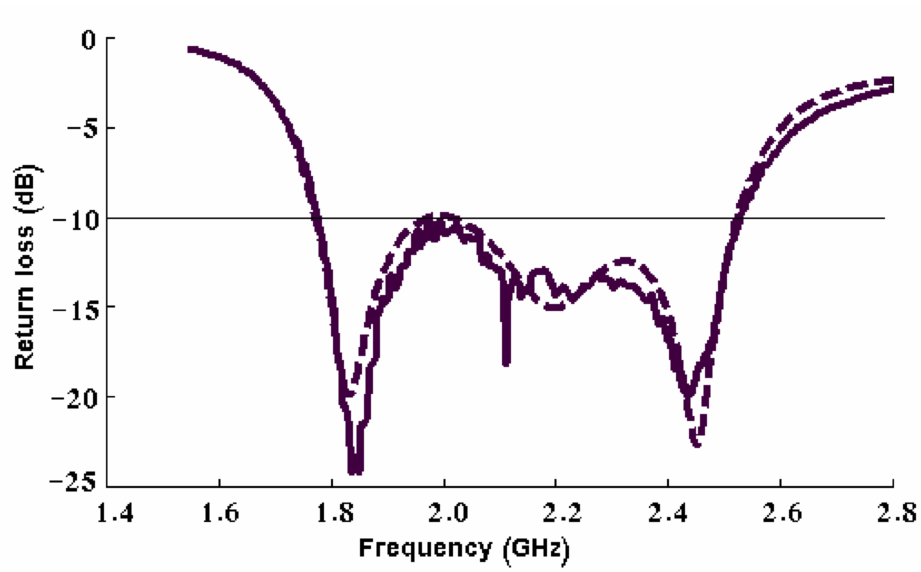

Fig. 2. Return loss plots of the proposed antenna of simulation (dashed), and measurement (solid).

The Figure 3 shows the maximum gains of x and y polarizations of the antenna versus frequency. In this Figure, at the frequencies around the third resonant frequency the gain of x polarization increases. Pattern of the antenna at 2.3GHz in the Figure 4, shows a null for the radiation pattern of x polarization. This means that the resonating mode that plays role in the radiation in x polarization is the second mode of the patch with x-directed current path, or TM_{20} mode of the patch.

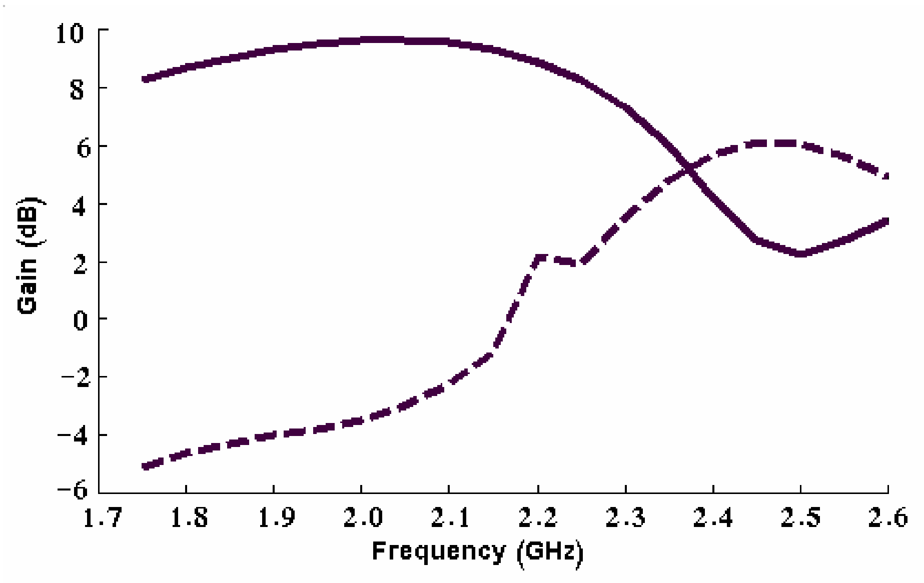

Fig. 3. The simulated maximum gain plots of x-polarization (dashed), and y-polarization (solid).

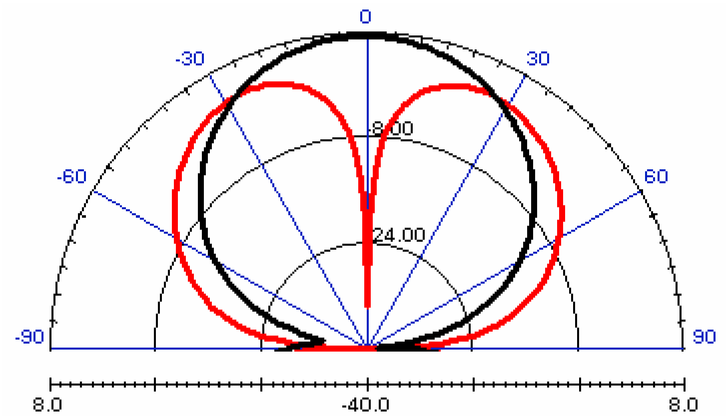

Fig. 4. The simulated radiation pattern of the proposed antenna at 2.3GHz, H-plane (xoz), y-polarization (black line), and x-polarization (red line), in decibels of the Gain.

In order to better study of the effect of using the suspended configuration of the resonant frequencies, we have changed the ε_r of the pcb or Fr4 substrate and have shown its results in the Figure 5.

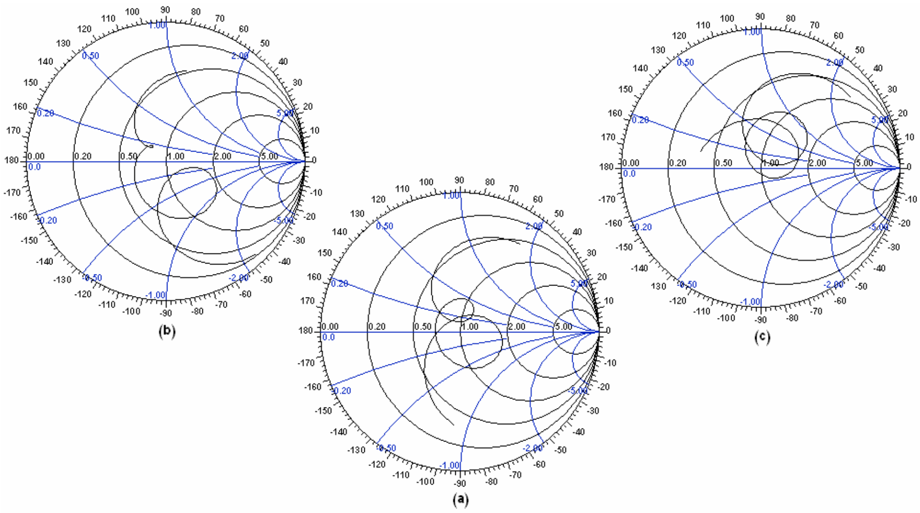

Fig.5. The simulated smith chart of input impedance of the proposed antenna structure using Fr4 pcb substrate with ε_r of 4.4 (a), and with changing the ε_r of pcb substrate to 3 (b) and 6 (c).

In the Figure 5, increasing the ε_r of the pcb substrate causes in creation of a second loop in the smith plot of the antenna input impedance. The second loop causes in creation of the third resonant frequency in the antenna return loss plots.

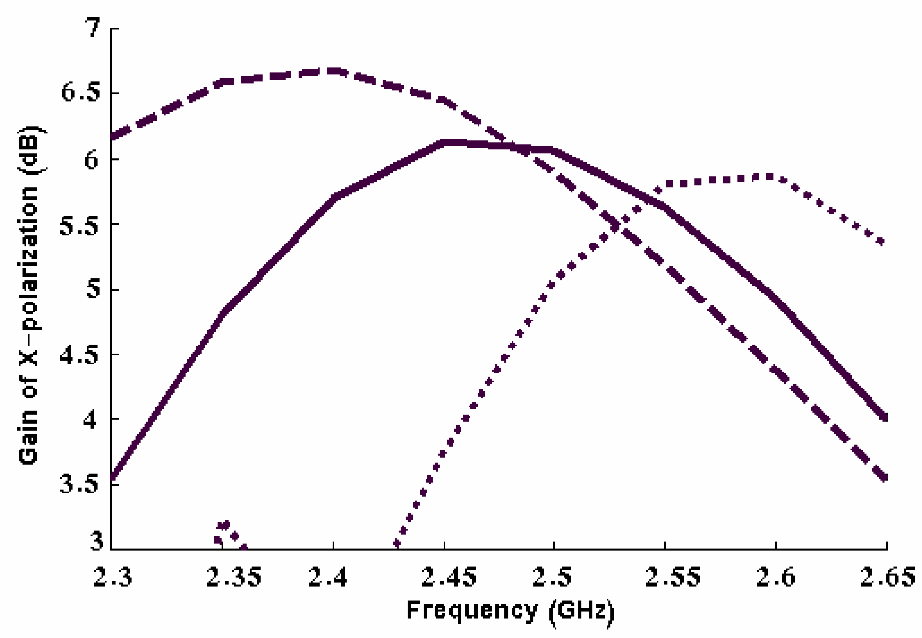

Fig. 6. The gain plot of x-polarization versus frequency for the proposed antenna with ε_r of pcb equal to 3 (dotted), and 4.4 (solid), and 6 (dashed).

The antenna maximum gain of the x polarization with changing the ε_r of pcb is shown in the Figure 6. Also in this Figure it can be seen that increasing the ε_r of pcb causes in increasing in the gain of x polarization. Therefore, the use of suspended microstrip configuration with a substrate with a high ε_r on top of the Foam substrate in the u-slot patch antennas has caused in excitation of the TM_{20} mode.

Fig.7. The fabricated antenna top view

4 Conclusion

A u-slot patch antenna with suspended microstrip configuration was presented. The antenna return loss plots were shown. As mentioned, the presented antenna using a suspended microstrip configuration does not need an adaptor to excite the patch TM_{20} mode. The relationship between the suspended configuration and the excitation of TM_{20} mode studied. However, the exact mechanism responsible for the excitation of the TM_{20} mode by using the suspended configuration is not well understood at the present time. Study about this mechanism is still in progress.

References

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