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Design of Narrowband Frequency-Tunable Antenna

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Abstract

In this paper, a narrowband frequency-tunable antenna is proposed. The tuning operation is achieved by integrating a variable capacitor in a narrowband antenna. Both simulated and measured results of the designed antenna are presented and discussed. The experimental results show that very narrowband resonant frequency can be accurately tuned in a large frequency range. Hence, the proposed design can be a good candidate for modern wireless communication systems.

1 Introduction

Nowadays, microstrip antenna with the capability of tunable frequency become more and more attractive, due to the development of wireless industry and the increasing demand in the modern wireless communication [1].
Frequency-tunable antenna can be used for multi-functional operations that operate at different frequencies. Although, this kind of antenna cannot cover all the frequency bands at the same time but it can be configured/tuned to different frequencies according the need [2].
According to the various advantages of frequency-tunable antenna they are currently part of modern wireless communication systems such as (GSM, WCDMA, Bluetooth, WLAN), navigation systems like GPS and MIMO systems [3].
Several studies have been carried out to demonstrate electronic tunability for different antennas structure. It has been shown that the operating frequency of an antenna can be varied when a tuning mechanism is introduced [4], [5].
In the present paper, a narrowband frequency-tunable antenna is designed. The approach presented herein consists of a narrowband microstrip antenna to which a variable capacitor is integrated. The narrowband operating frequency of the designed antenna can be adjusted over a large frequency band. This allows its use in various wireless communication standards.
This work is organized as follows: section 2 presents the design and simulation of the narrowband antenna, in section 3 we illustrate the frequency-tunable antenna design and configuration, section 4 is devoted to present and comment the simulation and measurement results. Finally, conclusions are then provided in section 5.

2 Narrowband antenna design

In this section, a narrowband microstrip antenna operating at nearly 2.4 GHz is designed. The layout of the microstrip antenna is shown in figure 1. It consists of a simple rectangular patch with dimension L_p x W_p, determined by using the transmission line model [6]. The patch is designed on a Rogers RT5880 substrate with dielectric constant of $\varepsilon = 2.2$ and $tan\delta = 0.0009$. The thickness of the substrate is $h = 0.79$ mm.

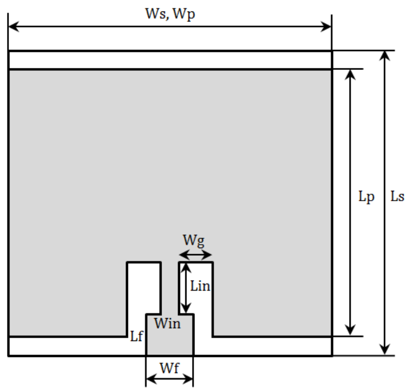

Figure 1. Layout of the designed microstrip antenna based on transmission-line model.

As shown in figure 1, the patch has the following parameters shown in table 1. The units of all parameters are given in millimeter (mm).

Table 1. Parameters of the patch.

W_s	W_p	W_g	W_f	W_{in}
49.4	49.4	2.4	2	2

L_s	L_p	L_f	L_{in}
42.6	41.8	5.5	8.86

L_p and W_p are the length and the width of the patch, respectively . L_f and W_f are the length and the width of the microstrip line feed, respectively. An inset feed with the dimensions L_{in} x W_{in} between the transmission feed line and the patch has been created in order to get a narrowband antenna and improve the impedance match.

The simulated result of the narrowband antenna is illustrated in figure 2

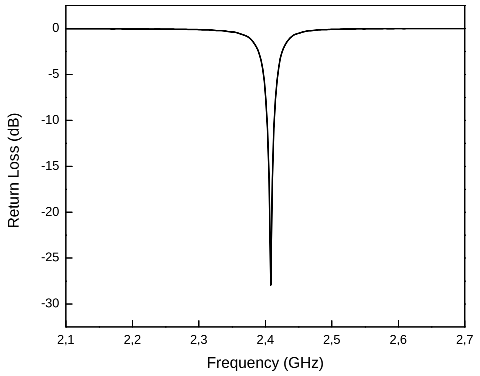

Figure 2. Simulated S_{11} parameter of the designed narrowband antenna.

The antenna provides at 10 dB return loss, a bandwidth of 10.9 MHz with a fractional bandwidth less than 1%. The realized gain of the antenna is 6.5 dB.

3 Frequency - tunable antenna design and configuration

In this section, a narrowband frequency-tunable antenna is proposed and implemented. It consists of the antenna configuration proposed on section 2 with a rectangular shaped slot with dimension L_{slot} x W_{slot}. Furthermore, an RF variable capacitor C has been introduced on the slot, as depicted in figure 3.

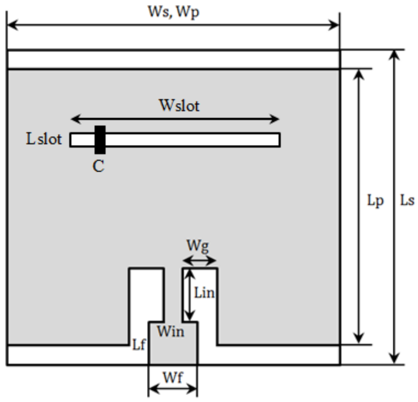

Figure 3. Configuration of the proposed tunable antenna.

The parameters of the designed tunable-antenna are shown in table 2.

Table 2. Parameters of the proposed tunable antenna.

W_s	W_p	W_g	W_f	W_{in}	W_{slot}
49.4	49.4	2.4	2	2	20

L_s	L_p	L_f	L_{in}	L_{slot}
42.63	35	5.5	8.85	1

4 Simulation and measurement results

Figure 4 shows the behavior of the antenna when the capacitor C changes.

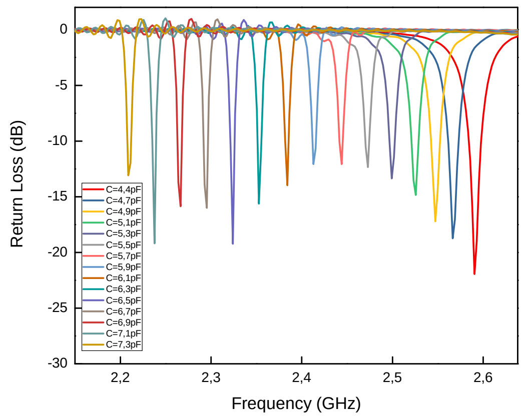

Figure 4. Simulated return loss (S_{11}) for different value of capacitor C.

From figure 4, we can see that the increase of the capacitance C will cause a shift to the left of the narrowband resonant frequency of the antenna. This behavior is illustrated in figure 5 that presents the resonant frequency of the antenna as a function of the capacitance C.

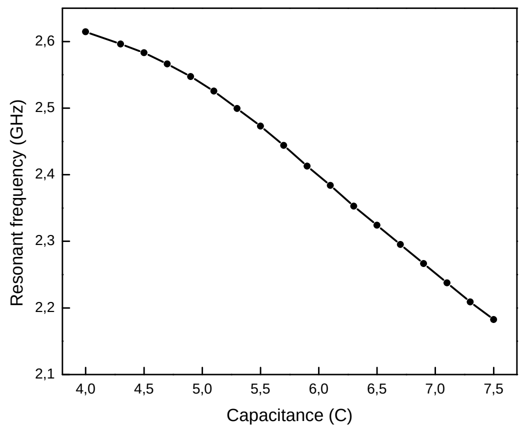

Figure 5. Capacitor C effect on the resonant frequency.

As shown in figure 5, every monotonous change in the value of capacitor C, will imply a monotonous change on resonant frequency of the antenna. This last can be conveniently controlled over the frequency range of $2.2-2.6$ GHz. The tuning is accurately achieved, thanks to the narrowband characteristic. The bandwidth is approximately less than 1% at each operating frequency.

In order to justify that those narrowband resonances are radiating, the simulated radiation efficiency as a function of the frequency is presented in figure 6.

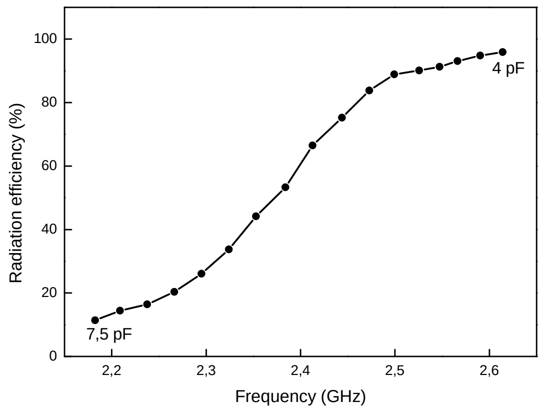

Figure 6. Simulated radiation efficiency of the designed antenna.

As depicted in figure 6, the radiation efficiency of the antenna rises from 10% up to 95% over the frequency range of $2.2 - 2.6$ GHz according to the change of the capacitor value C from 7.5 pF to 4 pF, respectively.

A prototype of the frequency-tunable antenna has been fabricated and measured. The photograph of the fabricated antenna is given in figure 7.

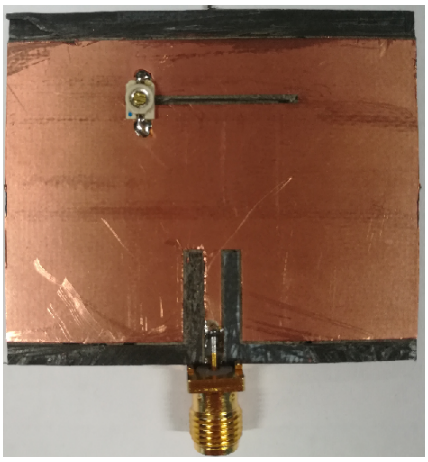

Figure 7. Photograph of the fabricated frequency-tunable antenna.

In order to perform measurements and to check easily the behavior of the antenna, an SMD variable capacitor C (ref: JZ060) is used. it can be tuned from 2 pF to 6 pF with $+0.50\%$ of maximum capacitance tolerance (figure 7).

The measured return loss coefficient S_{11} is illustrated in figure 8. By adjusting the cursor position of capacitor C, we can change the capacitance value from 2 pF to 6 pF. It can be observed from figure 8, that the measurement results have almost the same behavior as the simulation results which validate the proposed concept.

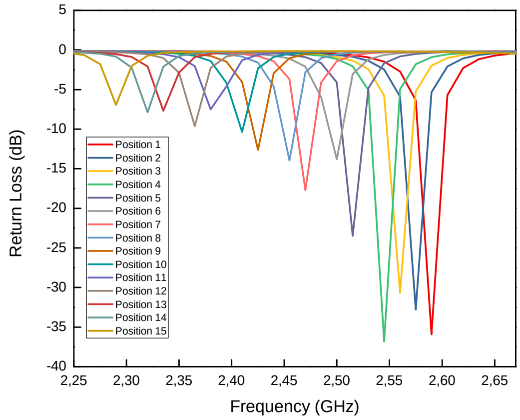

Figure 8. Measured return loss (S_{11}) for different cursor positions of capacitor C.

5 Conclusion

A narrowband frequency-tunable antenna is presented. The narrowband operating frequency can be shifted over a large frequency range. The simulated and measurement results show a reasonable agreement which validate the proposed concept. Finally, The proposed antenna is suitable for applications in modern wireless communications.

References

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