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DESIGN AND OPTIMIZATION OF MICROSTRIP PATCH ANTENNA FOR 2.4 GHZ FREQUENCY BAND

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Проектування та оптимізація мікросмужкової патч-антени для частотного діапазону 2,4 ГГц

Описано підхід до проектування та оптимізації мікросмужкових прямокутних патч-антен на прикладі друкованої патч-антени з живленням мікросмужковою лінією. Проведено моделювання роботи антени методом скінченних елементів в діапазоні 2.4…2.483 ГГц. В результаті оптимізації збільшено смугу пропускання антени шляхом вибору одного з її габаритних розмірів. Наведено амплітудно-частотну характеристики та діаграму спрямованості антени.

Rapid development of mobile communication systems and growth of the number of corresponding equipment increase the demand for small-size and high-performance microwave antennas. At present, theory of antenna design is well-studied part of microwave engineering, and there are a large number of small-size antenna types and design techniques that can be used for designing and fabrication of them [1] – [3]. Nowadays, antenna design is usually an iterative procedure involving numerous simulations and optimization of its structure. Most frequently used numerical techniques for the full field simulation of antenna structures are the finite-element method (FEM) and the finite-difference time-domain method (FDTD).

In this paper, a microstrip rectangular inset-fed patch antenna for the 2.4 GHz band is designed and simulated using the finite-element method. At first, the dimensions of the antenna were calculated, then the series of FEM simulations of the antenna model was done in order to achieve the best performance. The drawback of printed microstrip antennas is narrow bandwidth, what takes place due to resonance nature of radiation of a microstrip patch. One of the approaches to overcoming bandwidth limitations is choosing the substrate and patch parameters so as to decrease the Q-factor of the patch. It was used in the present work.

The antenna to be designed should operate in the frequency range 2400…2483 MHz, which is one of Wi-Fi frequency bands. Thus, the operating frequency of the antenna was chosen to be $f_0 = 2442$ MHz, which is the central frequency of the operating band.

For the realization of the antenna, the RT/Duroid 5880 laminate was used. The parameters of the material are as follows: dielectric constant $\varepsilon_r = 2.2$; thickness $h = 1.575$ mm; thickness of the top and bottom copper layers $t = 0.018$ mm; dissipation is defined by $\tan\delta = 0.0009$.

The topology of the antenna with the dimensions of the patch is depicted in Fig. 1. The antenna was designed so as to be fed by microstrip line, which is suitable when the antenna and other parts of the circuit are mounted at the same printed circuit board. To perform the matching between the feeding microstrip line and the radiating rectangular patch, the inset feeding scheme was used, as it is shown in Fig. 1(a).

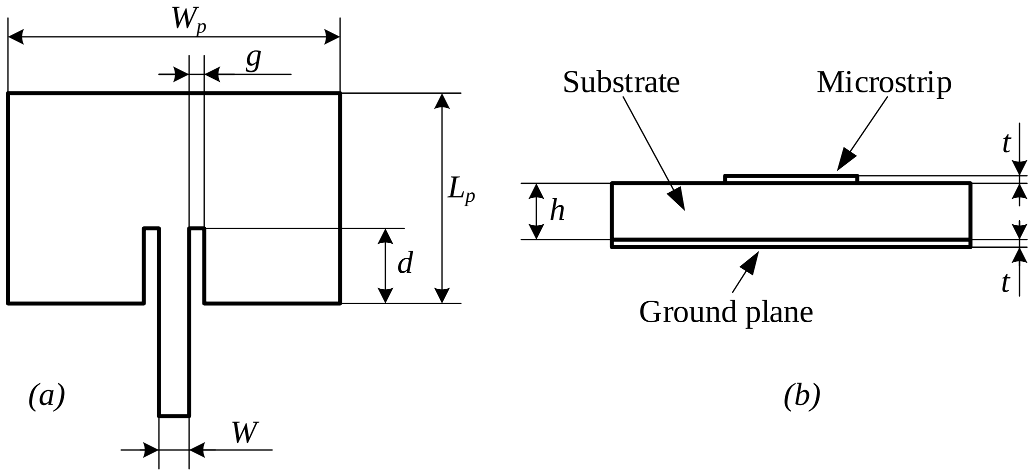


Fig.1. Dimensions of a microstrip patch antenna. (a) Dimensions of the microstrip patch.
(b) Dimensions of the substrate and copper layer.

The design procedure described in [1] and [4] was used to obtain the initial values of the dimensions of the patch, which are as follows: width of the patch $W_p = 48.56$ mm; length of the patch $L_p = 40.64$ mm; inset distance $d = 14.25$ mm; notch width $g = 0.28$ mm. The width of the feeding line strip was chosen to be $W = 4.9$ mm in order to perform the characteristic impedance of the line to be $Z_0 = 50\ \Omega$.

These values were used for preparing the 3D model of the antenna shown in Fig. 2. The HFSS software was used for preparing the model and further full field simulations using finite-element numerical method.

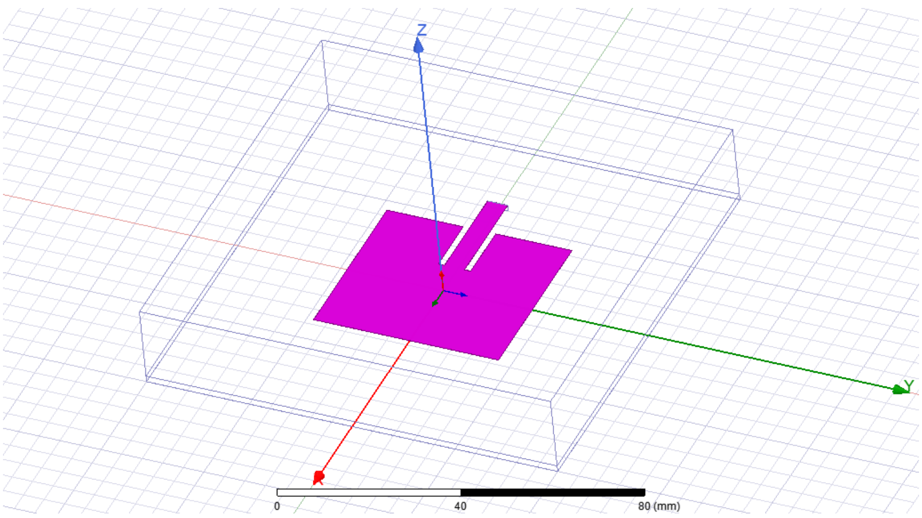
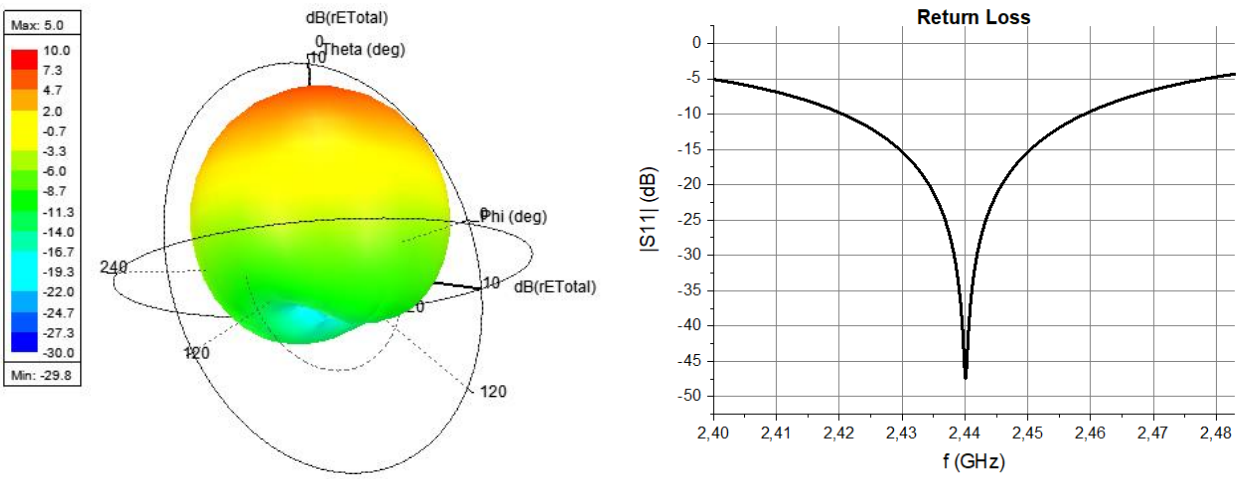


Fig.2. Model of the antenna.

During the optimization the inset distance d was firstly changed to perfectly match the 50 Ω microstrip feeding line with the patch. The length of the patch L_p was also altered to adjust the resonance frequency of the patch to the value of $f_0 = 2442$ MHz. The value of the patch width W_p impacts the Q-factor of the patch. The antenna was optimized and simulated for the three values of patch width: $W_p = 45$ mm; 48.56 mm; 55 mm. The higher is W_p, the lower is the Q-factor and, consequently, the larger is the bandwidth. Therefore, the value of $W_p = 55$ mm was chosen to achieve the higher bandwidth.

After the optimization procedure the following dimensions were chosen for the antenna: $W_p = 55$ mm; $L_p = 40.3$ mm; $d = 12.1$ mm; $g = 1.5$ mm. In Fig.3, the simulated results for the directivity diagram and the frequency responses of the antenna are shown. As it could be seen, the return loss is $RL = |S_{11}| \approx -5$ dB at the edges of the operating bandwidth, i.e. at the frequencies $f_L = 2.4$ GHz and $f_R = 2.483$ GHz, and $RL = |S_{11}| \approx -48$ dB at the centre frequency $f_0 = 2.442$ GHz. The gain of the antenna is $G = 7.24$ dB. The polarization of the antenna is linear with $\boldsymbol{E}$ vector oriented in XZ-plane, as shown in Fig. 2.



(a) (b)

Fig.3. Characteristics of the antenna. (a) Directivity. (b) Return loss.

The antenna designed in the present research is small-sized and easily fabricated. However, it has relatively high reflection at the ends of the operating frequency range. The bandwidth at the level of $RL = -5$ dB is $\Delta f = 83$ MHz, and at the level of $RL = -10$ dB is only $\Delta f \approx 40$ MHz. To enhance the bandwidth, an additional patch may be added to the antenna structure.

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