UDC 621.391.3

DESIGN AND OPTIMIZATION OF COAXIAL-FED CIRCULAR PATCH ANTENNA FOR 2.4 GHZ FREQUENCY BAND

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Проектування та оптимізація круглої патч-антени з коаксіальним живленням для частотного діапазону 2,4 ГГц

Здійснено проектування та оптимізацію круглої патч-антени з коаксіальним живленням діапазону 2.4 ГГц. Проведено моделювання роботи антени методом скінченних елементів в діапазоні робочих частот 2.4…2.483 ГГц. В результаті оптимізації, відкореговано резонансну частоту випромінювача так, щоб вона відповідала центральній частоті робочого діапазону, а також покращено узгодження на даній частоті, чим було досягнуто збільшення робочої смуги частот антени. КСВ розрахованої антени знаходиться в діапазоні 1…1.5 у робочій смузі частот.

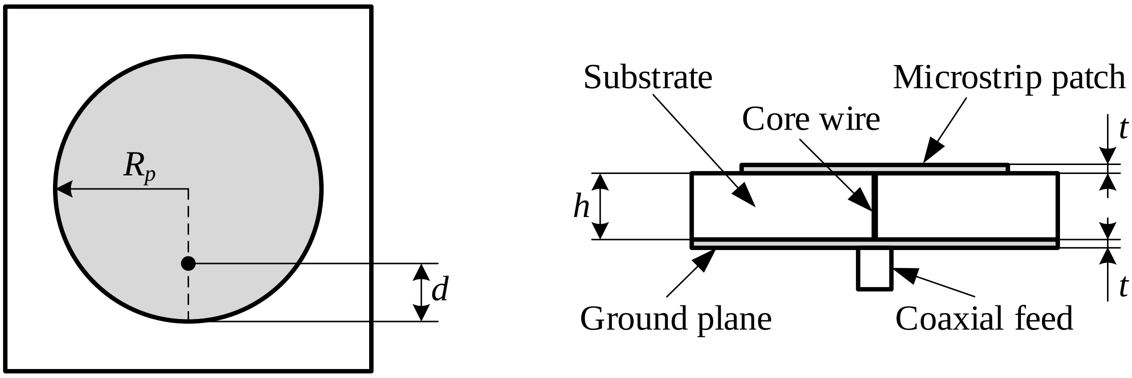
Fast development of mobile communication systems and IoT-devices, as well as growth of the number of corresponding equipment increase the demand for small-size and high-performance microwave antennas. At present, theory of antenna design is well-studied part of microwave engineering, and there are a 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). The comparison of microstrip filter design using different numerical techniques was previously done in [4]. The comparison of the analytical model and the FEM simulation was done in [5] for the example of the 2.4 GHz patch antenna.

In this paper, a circular coaxial-fed patch antenna for the 2.4 GHz band is designed and simulated using the finite-element method. In order to achieve the best performance, the dimensions of the antenna were calculated, and then the series of FEM simulations of the antenna model was done.

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.

To enhance the antenna bandwidth, the air was used as a dielectric between the ground plane and the patch. Aluminium was chosen as a material of which conducting parts of the antenna are made. Thus, the parameters of the layers are as follows: dielectric constant $\varepsilon_r = 1$; thickness h = 6 mm; thickness of the top and bottom aluminium layers t = 0.5 mm.

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 coaxial line. To perform the matching between the coaxial feeder and the radiating circular patch, the end of the coaxial probe should connect to the patch at the point at which its input impedance is equal to the characteristic impedance of the coaxial feeder.

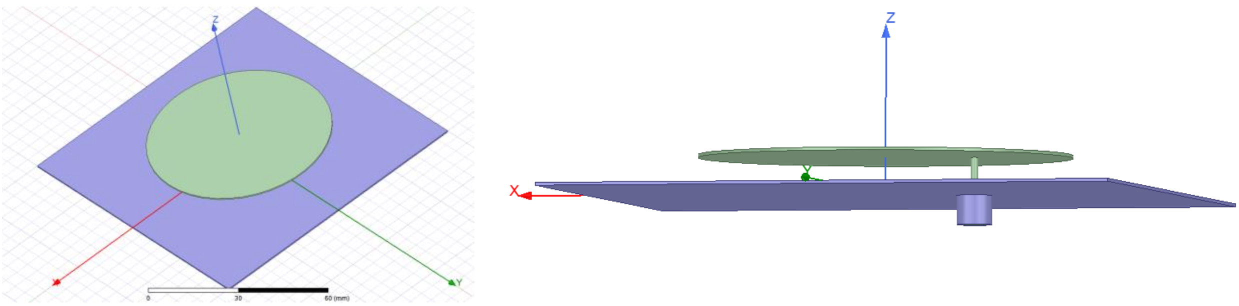


(a) (b)

Fig.1. Dimensions of a microstrip patch antenna. (a) Dimensions of the microstrip patch. (b) Dimensions of the substrate and aluminium layers.

The patch geometry is characterized by only one parameter: radius of the patch. The design procedure described in [1] was used to obtain its initial value that turned out to be $R_p = 30.14$ mm. As a coaxial feed, the model of SMA connector was used. Thus, the inset distance should correspond to the point at which the input impedance of the patch is equal to $Z_0 = 50\ \Omega$.

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.

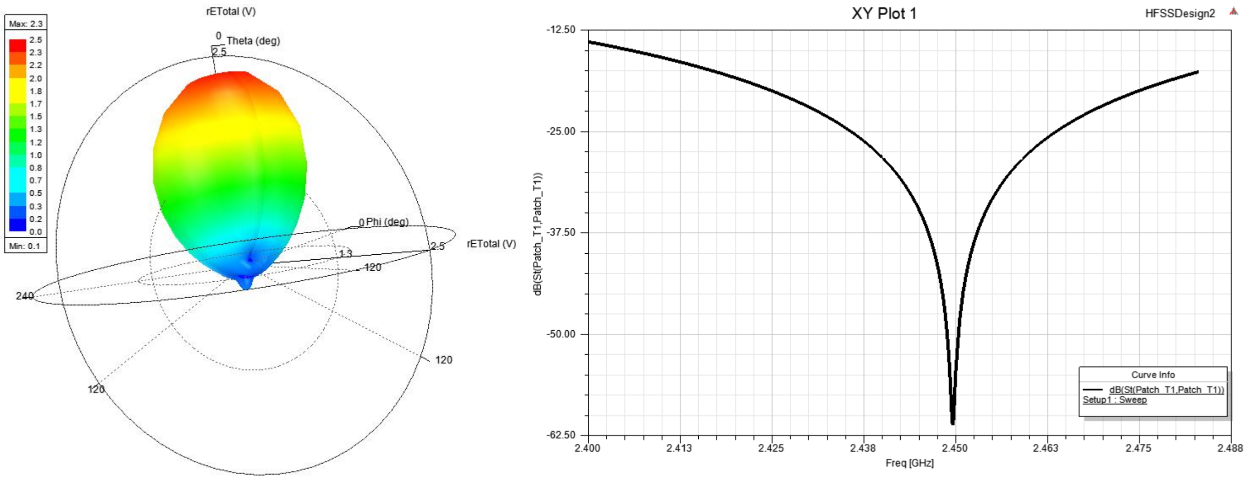


(a) (b)

Fig.2. Model of the antenna. (a) Upper view. (b) Side view

During the optimization the inset distance *d* was firstly changed to perfectly match the 50 Ω coaxial 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.

After the optimization procedure the following dimensions were chosen for the antenna: $R_p = 32$ mm; $d = 16.5$ 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 $RL = |S_{11}| \approx$ -14 dB at the lower frequency f_L = 2.4 GHz of the operating frequency band and $RL = |S_{11}| \approx$ -17 dB at the higher frequency f_R = 2.483 GHz, and $RL = |S_{11}| \approx$ -61 dB at the resonance frequency f_0 = 2.449 GHz which is slightly different from the centre frequency of the band f_c = 2.442 GHz. The gain of the antenna is $G \approx$ 8.9 dB. The polarization of the antenna is linear with ***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 key parameters of the designed antenna, namely bandwidth, gain and directivity pattern are close to those of the rectangular patch antenna with the same initial conditions. The relatively high dielectric substrate height h = 6 mm as well as small value of dielectric constant ε = 1 lead to the relatively high bandwidth of the antenna comparing with the one studied in [5]. The designed antenna provides the matching of VSWR = 1…1.5 within the operating frequency band 2.4…2.483 GHz.

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