UDC 621.391.3

DESIGN AND OPTIMIZATION OF COAXIAL-FED RECTANGULAR TWO-RESONATOR PATCH ANTENNA FOR 2.4 GHZ FREQUENCY BAND

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ПРОЕКТУВАННЯ ТА ОПТИМІЗАЦІЯ ДВОРЕЗОНАТОРНОЇ ПРЯМОКУТНОЇ ПАТЧ-АНТЕНИ З КОАКСІАЛЬНИМ ЖИВЛЕННЯМ ДЛЯ ЧАСТОТНОГО ДІАПАЗОНУ 2,4 ГГЦ

Здійснено проектування та оптимізацію дворезонаторної прямокутної 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 антени збільшено смугу її пропускання за рахунок електромагнітного зв’язку між активним та пасивним резонаторами антени. В межах робочої смуги частот КСХ розрахованої антени перебуває в діапазоні 1…1.4.

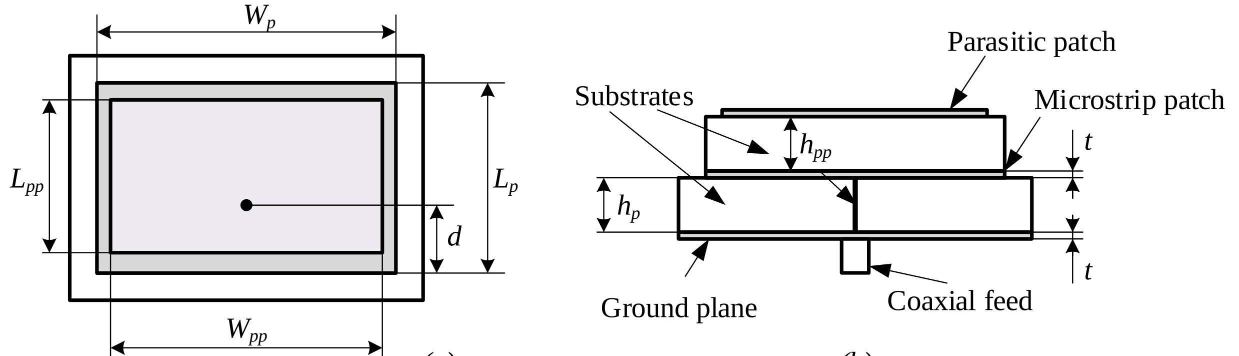
Development of mobile communication systems and IoT-devices increases the demand for small-size and high-performance microwave antennas. At present, theory of antenna design is well-studied part of microwave engineering covering a large number of small-size antenna types and design techniques that can be used for their design [1] – [3]. Antenna design is typically an iterative procedure involving numerous simulations to optimize its parameters. 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 the analytical model and the FEM simulation was done in [4] for a 2.4 GHz patch antenna.

In this paper, a microstrip rectangular coaxial-fed patch antenna for 2.4 GHz band is designed and simulated using the finite-element method.

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 center 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_p = 2 mm; thickness of the top and bottom aluminium layers t = 0.5 mm.

The topology of the antenna with the dimensions of the patches 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 rectangular 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.

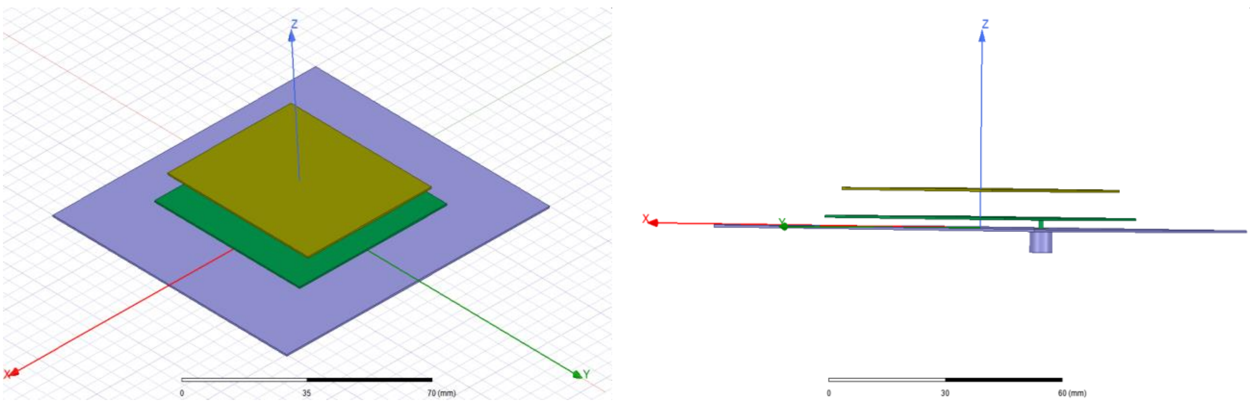


(a) (b)

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

The design procedure described in [1] – [3] was used to obtain the initial values of the dimensions of the patch, which are as follows: width of the patch W_p = 62 mm; length of the patch L_p = 56 mm; inset distance d = 18 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 Ω.

These values were used for preparing the 3D model of the antenna shown in Fig. 2. A parasitic resonator was added to antenna, and the whole structure was simulated using finite-element numerical method. Single-resonator patch antennas were considered in [5], [6]. However, they have a resonance-like frequency response. Adding of additional resonator allows to increase antenna bandwidth.



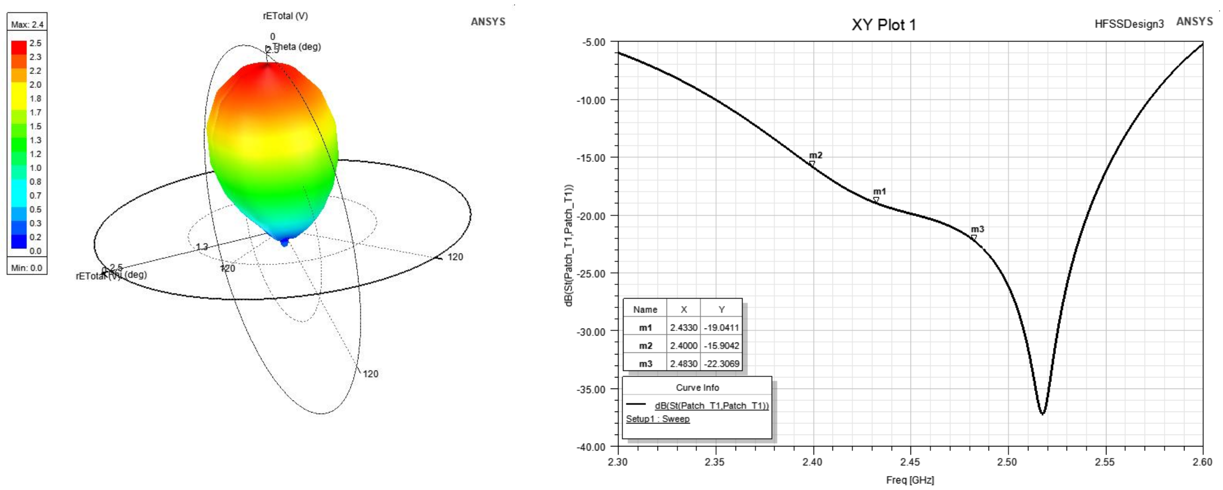
(a) (b)

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: W_p = 62 mm; W_{pp} = 60 mm; L_p = 56 mm; L_{pp} = 47 mm; d = 9 mm. In

Fig.3, the simulated results for the directivity diagram and the frequency response of the antenna are shown. As it could be seen, the return loss is $RL = |S_{11}| \approx$ -16 dB at the left band edge (f_L = 2.4 GHz), and $RL = |S_{11}| \approx$ -22.3 dB at the right band edge f_R = 2.483 GHz, and $RL = |S_{11}| \approx$ -19 dB at the center frequency f_0 = 2.442 GHz. The gain of the antenna is G = 9.3 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. Adding a parasitic resonator as small value of dielectric constant $\varepsilon = 1$ lead to the relatively high bandwidth of the antenna comparing with the one studied in [5]. VSWR value within the operating bandwidth 2.4…2.483 GHz is in the range 1…1.4.

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