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PRINTED MICROSTRIP LINE-FED PATCH ANTENNA ON A HIGH-DIELECTRIC MATERIAL FOR C-BAND APPLICATIONS

TISKANA MIKROTRAKASTA LINIJSKO NAPAJANA KRPASTA ANTENA NA VISOKO DIELEKTRIČNEM MATERIALU ZA UPORABO V C-PASU

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A printed microstrip line-fed patch antenna for C-band applications is presented, using a high-dielectric material. The proposed antenna dimensions are 0.53 λ × 0.53 λ × 0.02 λ and it is fed by a microstrip line. The antenna outline and electromagnetic analysis were done with the help of a commercially available computer-aided EM simulator. This antenna initiates three resonances at 4.64 GHz, 5.52 GHz, and 6.34 GHz with the average gains of 2.68 dBi, 6.02 dBi and 4.83 dBi, respectively, covering the entire frequency bands. The overall performance analysis and a nearly omnidirectional radiation pattern prove that the proposed antenna is promising for C-band applications.

Keywords: C-band, dielectric material, microstrip line feeding

Predstavljena je tiskana mikrotrakasta, linijsko napajana, krpasta antena za uporabo v C-pasu, z uporabo visoko dielektričnega materiala. Predlagana dimenzija antene je 0,53 λ × 0,53 λ × 0,02 λ, ki je napajana z linijo mikrotraku. Oris antene in elektromagnetska analiza sta bili izvršeni s pomočjo komercialno razpoložljivega in računalniško podprtega EM simulatorja. Ta antena sproži tri resonance pri 4,64 GHz, 5,52 GHz in 6,34 GHz, s povprečno sposobnostjo 2,68 dBi, 6,02 dBi in 4,83 dBi pri pokrivanju vseh frekvenčnih pasov. Analiza zmogljivosti in skoraj vsesmerna slika sevanja kažeta, da predlagana antena obeta dobro uporabo v C-pasu.

Ključne besede: C-pas, dielektrični material, linijsko napajanje z mikrotrakom

1 INTRODUCTION

Currently, the microstrip patch antenna is a milestone in the wireless communication system and it continues to fulfill the changing requirements of the new-generation antenna technology. Microstrip patch antennas are widely utilized in the present wireless communication system because of their low profile, light weight, conformal design, low cost, and because they are easy to fabricate and integrate. Advances in wireless communications have initiated remarkable demands. Antennas are used for a wide range of cellular mobile phones in the current society, causing concerns about their harmful radiation.[1–5] Many researches were done, covering the entire C-band and many techniques and methods are stated in the reference literature.

A hexagonal scrimp-horn antenna with different aperture sizes was proposed for operating in C-band applications.[6] A modified dual-band CPW-fed antenna was proposed for a WLAN-band application on a thin substrate.[7] A broadband planar monopulse antenna was presented to increase the impedance bandwidth for C-band applications, where a monopulse comparator was used as the sum-difference feed network.[8] A rectangular slot antenna with a U-shaped strip was proposed for a dual broadband operation in WLAN applications.[9] A compact broadband slot antenna with a circular polarization was proposed for C-band applications, where two rectangular stubs are embedded to excite two orthogonal *E* vectors in the feedline structure.[10]

In this paper, a printed microstrip line-fed patch antenna with a high-dielectric material that attains a compact triple-resonant profile due to a nearly omnidirectional radiation, high gain and a reasonable current distribution is proposed. This line-fed antenna is made of circular radiating patches with a partial ground plane generating three resonances for C-band applications. The antenna is smooth, with a simple design and comfortable fabrication. The proposed line-fed antenna generates three resonances to cover C-band applications. The results are impedance bandwidth values of (160, 100 and 160) MHz at three resonances on the C-band. Due to a double Ω-shaped radiating patch with a partial ground, nearly omnidirectional radiation properties are realized over the entire operating bands with a reasonable gain.

This line-fed antenna with a high-dielectric material is very effective for C-band applications.

2 ANTENNA STRUCTURES

The design of the proposed antenna is indicated in **Figure 1**. The antenna comprises of a double Ω-shaped patch and a partial ground. The design procedure begins with a radiating patch with a substrate, a ground plane and a feed line. It is printed on a ceramic-filled bio-plastic substrate with a relative permittivity of 15 and a relative permeability of 1. The overall antenna dimensions are 40 mm × 40 mm × 1.2 mm. An SMA (Sub-Miniature version A) connector is used for providing a 50 Ω impedance and it is attached at the end of the antenna feeding.

Figure 2 exhibits the structure of the substrate material. This sandwich-structured substrate material was generated using ceramic powder and bioplastic. The selected ceramic powder was sintered with a polymeric binder using the polymeric sponge method. A 9.8 ml (0.25) bioplastic sheet was included. This bioplastic sheet was obtained from organic biomass sources, such as cornstarch, vegetable oil and palm oil, and used as the ceramic cover. The three-layer bioplastic-ceramic-bioplastic sandwich structure was laminated using 35 μm of copper foil. The characteristics of this substrate material are low cost, ease of fabrication, design flexibility and availability. For this reason, a high-dielectric material is preferred for the antenna design.

Two Ω-shaped circular slots were cut from the copper patch with a partial ground. In this way, the proposed line-fed patch antenna was achieved. Three resonant frequencies of (4.64, 5.52 and 6.34) GHz were obtained, continuously adjusting the length, the width and the slots of the proposed antenna. Here, the microstrip line is used to provide the feeding to the proposed antenna. The length and width of the patch antenna can be calculated from Equations (1) and (2).[11] L and W are the length and width of the patch, c is the velocity of light, ε_r is the dielectric constant of the substrate, f_0 is the target center frequency, and ε_e is the effective dielectric constant:

$$W = \frac{c}{2f_0}\sqrt{\frac{\varepsilon_r + 1}{2}} \tag{1}$$

$$L = \frac{c}{2f_0\sqrt{\varepsilon_r}} - 2\Delta l \tag{2}$$

Finally, the optimum dimensions were determined as follows: L = 40 mm, W = 40 mm, P = 20 mm, M_w = 2.5 mm, W_s = 8 mm, and L_g = 19 mm.

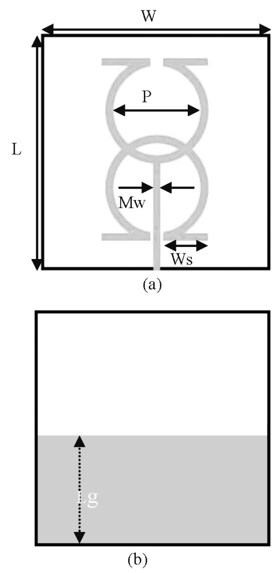

Figure 1: Proposed C-band antenna: a) front view, b) back view
Slika 1: Predlagana antena za C-pas: a) pogled spredaj, b) pogled zadaj

3 RESULTS AND DISCUSSION

The simulated return loss of the proposed antenna is illustrated in **Figure 3**. Return losses of –20.21 dB, –19.58 dB and –16.70 dB were acquired at three resonant frequencies of (4.64, 5.52 and 6.34) GHz, respectively.

We obtained the 160 MHz bandwidth with the 1st resonant frequency, 100 GHz with the 2nd and 1.60 MHz with the 3rd frequency. The mutual coupling effect was increased with the lower frequency; as a result, the bandwidth was small with the 1st and 2nd resonances. On the other hand, the bandwidth was broadened due to the suppressed mutual coupling effect. These bandwidths

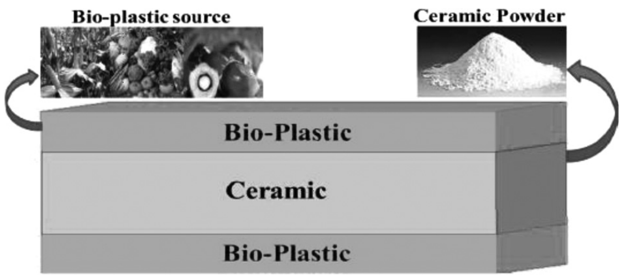

Figure 2: Structure of the substrate material[12]
Slika 2: Struktura materiala podlage[12]

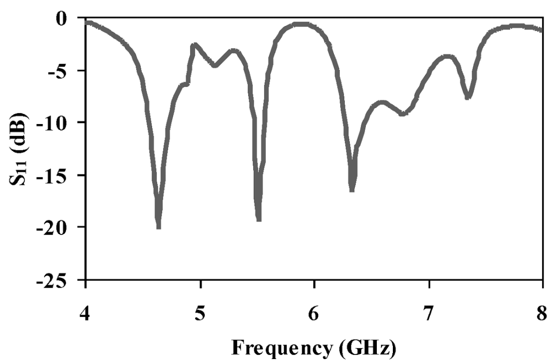

Figure 3: Proposed C-band antenna return loss
Slika 3: Povratne izgube, predlagane antene za C-pas

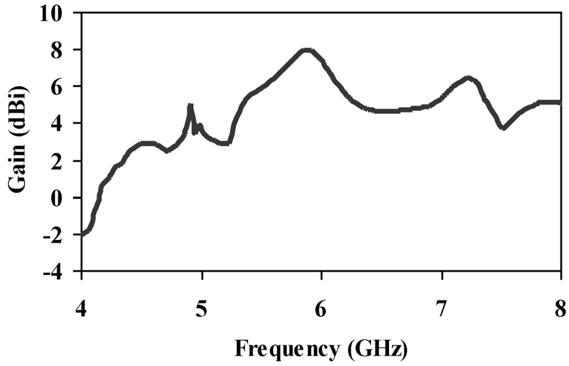

Figure 4: Proposed C-band antenna gain
Slika 4: Sposobnost predlagane antene za C-pas

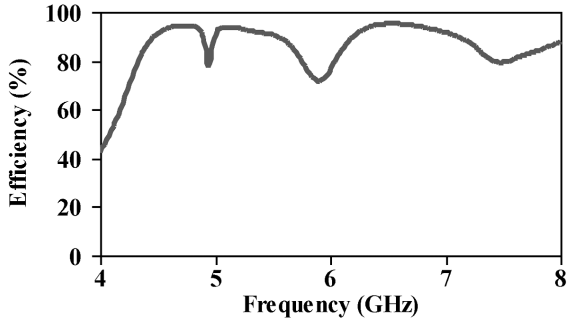

Figure 6: Proposed C-band antenna efficiency
Slika 6: Učinkovitost predlagane antene za C-pas

were generated at the operating frequencies throughout the entire C-band application.

The average gain of the proposed antenna is shown in **Figure 4**. The average gains of (2.68, 6.02 and 4.83) dBi are achieved in the operating frequency bands of (4.64, 5.52 and 6.34) GHz, respectively. The used dielectric substrate material controls the mutual coupling effect and, as a result, the antenna gain is widened. It can be observed that the antenna gain was considerably increased with the incorporation of this high-dielectric material in the lower and upper bands, compared to the existing antennas.

The voltage standing wave ratio (*VSWR*) of the proposed antenna is plotted in **Figure 5**. The value of the *VSWR* is less than 2, as clearly seen on the graph. It is the desired value.

Figure 6 exhibits the result of the radiation efficiency of the proposed patch antenna. The radiation efficiency is 94 % with the 1st resonance, 90.06 % with the 2nd resonance and 94.08% with the 3rd resonance. This efficiency is broadly appropriate for C-band applications. It is considerable in comparison with the existing ones. It is obtained using a high-dielectric material for the proposed antenna and this antenna is perfect for C-band applications.

The surface-current distribution of the proposed patch antenna is demonstrated in **Figure 7**. The arrow sign is applied to denote the flow of the current distribution. From the graph, it can be easily observed that the current flow is maximum at the microstrip line and the lower Ω-shaped slot, at 4.64 GHz. At 5.52 GHz, the upper Ω-shaped slot and the microstrip line show the maximum current. At 6.34 GHz, the parts of the intersection between double Ω-shaped slots control the maximum current flow. Due to the high-dielectric substrate material, the overall surface-current distribution is smooth and sharp. As a result, the mutual coupling effect is under consideration and it is controlled in the case of the proposed patch antenna.

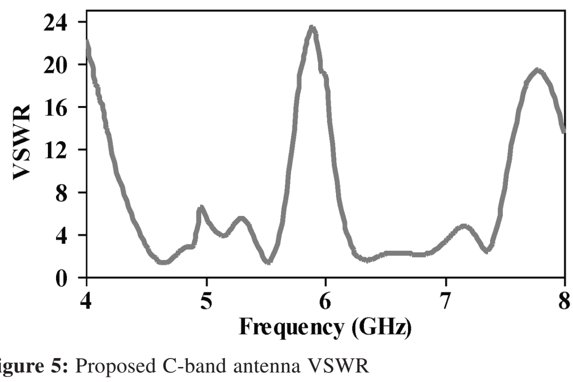

Figure 5: Proposed C-band antenna VSWR
Slika 5: VSWR predlagane antene za C-pas

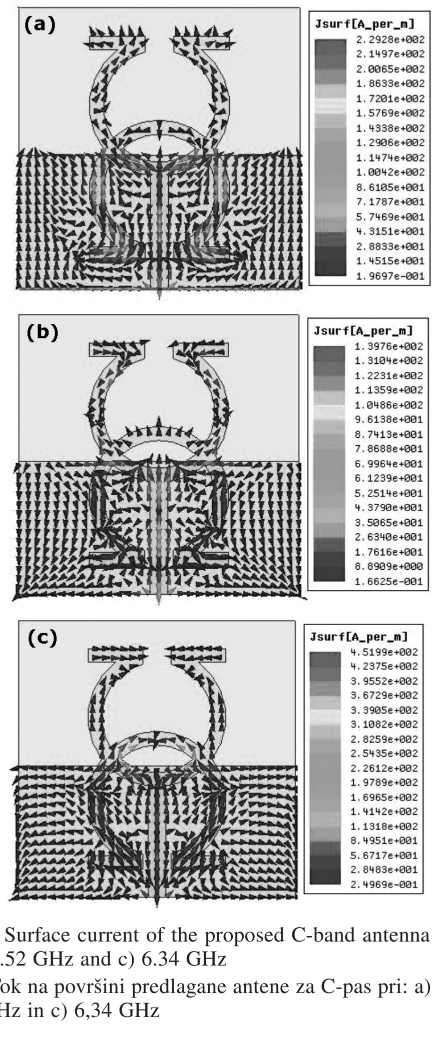

Figure 7: Surface current of the proposed C-band antenna at: a) 4.64 GHz, b) 5.52 GHz and c) 6.34 GHz
Slika 7: Tok na površini predlagane antene za C-pas pri: a) 4,64 GHz, b) 5,52 GHz in c) 6,34 GHz

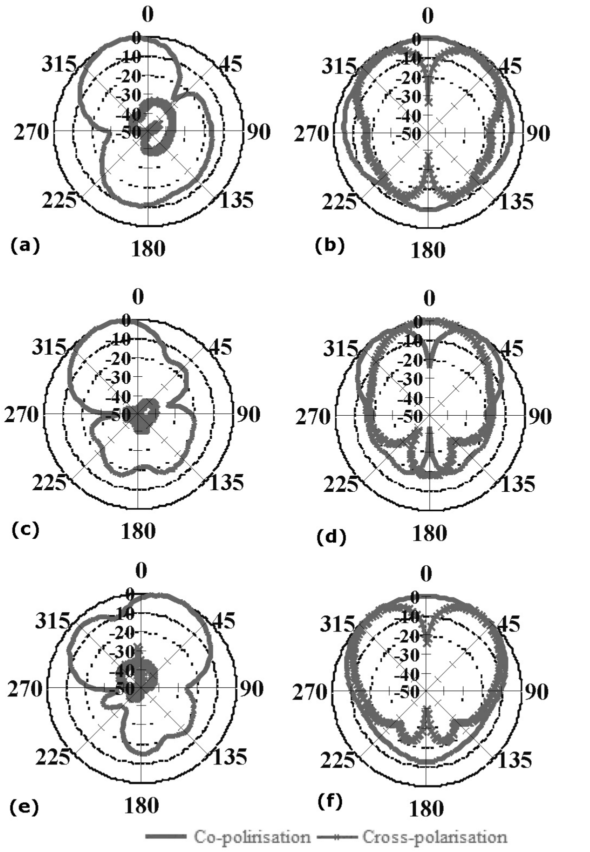

Figure 8: Radiation patterns: a) E-plane at 4.64 GHz, b) H-plane at 4.64 GHz, c) E-plane at 5.52 GHz, d) H-plane at 5.52 GHz, e) E-plane at 6.34 GHz and f) H-plane at 6.34 GHz

Slika 8: Sevalni diagrami: a) E-ravnina pri 4,64 GHz, b) H-ravnina pri 4,64 GHz, c) E-ravnina pri 5,52 GHz, d) H-ravnina pri 5,52 GHz, e) E-ravnina pri 6,34 GHz in f) H-ravnina pri 6,34 GHz

The radiation patterns of the proposed antenna on the E-plane and H-plane, at resonant frequencies of (4.64, 5.52 and 6.34) GHz are shown in **Figure 8**. It is shown from the results that significant, nearly omnidirectional radiation patterns are acquired along the H-plane and E-plane, respectively. The cross-polarization is low on the E-plane at all the resonances; on the other hand, the cross-polarization is high on the H-plane. The cross-polarization is lower than the co-polarization at all the resonances, leading to omnidirectional or nearly omnidirectional radiation characteristics. As a result, the radiation pattern of the proposed patch antenna is almost durable for C-band applications.

4 CONCLUSION

The article presents a printed line-fed patch antenna with a high-dielectric material appropriate for C-band applications. It uses a double Ω-shaped patch instead of a conventional patch with a view to obtaining a triple band operation. The microstrip line-fed antenna with a high-dielectric material was designed and simulated using the HFSS software, while the current-distribution plots were made to verify the proposed track. The simulation results indicate good characteristics. Consequently, the proposed microstrip line-fed antenna with a high-dielectric material can be appropriate for C-band applications.

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