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The Novel Monopole Antenna for Sub-6 GHz 5G Applications

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Anahtar Kelimeler

5G anten
Tek kutuplu anten
6 GHz altı 5G
Haberleşme

Graphical/Tabular Abstract (Grafik Özet)

This paper explains the novel monopole antenna's design and analysis for the sub-6 GHz 5G applications. / Bu makalede, 6 GHz altı 5G uygulamaları için yeni bir tek kutuplu antenin tasarımı ve analizi sunulmaktadır.

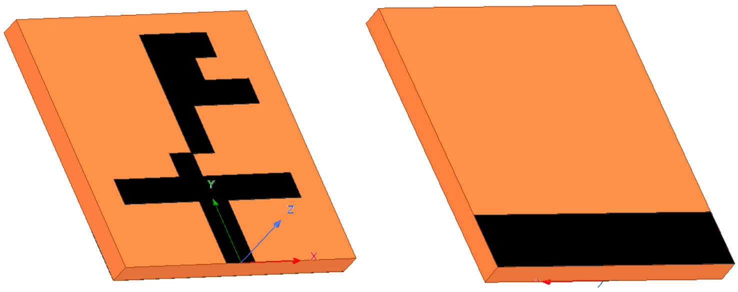

***Figure A**: Proposed antenna / **Şekil A:** Önerilen anten*

Highlights (Önemli noktalar)

- *The presented antenna has a unique geometry. / Sunulan anten özgün bir geometriye sahiptir.*
- *The proposed antenna is designed for 5G applications. / Sunulan anten 5G uygulamaları için tasarlanmıştır.*
- *The antenna operates in the 3.4-3.8 GHz 5G band. / Anten 3.4-3.8 GHz 5G bandında çalışmaktadır.*

Aim (Amaç): *Obtaining a unique antenna that operates in the 3.4-3.8 GHz range, which is the sub-6 GHz 5G band. / 6 GHz altı 5G bandı olan 3.4-3.8 GHz aralığında çalışan özgün bir anten elde etmek.*

Originality (Özgünlük): *Antenna is obtained from the reversed-cross-shaped radiator. It is modified with the help of the stubs and slots to resonate in the 3.4-3.8 GHz band. / Anten ters-çapraz şekilli ışıyıcıdan elde edilmiştir. Saplamalar ve yuvalar yardımıyla 3.4-3.8 GHz bandında rezonansa girecek şekilde modifiye edilmiştir.*

Results (Bulgular): *The antenna has a highest gain of 2.2 dBi and an efficiency of 98% in the operating bandwidth. / Çalışma bant aralığında antenin en yüksek kazancı 2.2 dBi ve verimi %98'dir.*

Conclusion (Sonuç): *The suggested antenna can be utilized for 5G applications at frequencies below 6 GHz. / Önerilen anten 6 GHz'in altındaki frekanslarda 5G uygulamaları için kullanılabilir.*

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Abstract

This paper explains the novel monopole antenna's design and analysis for the sub-6 GHz 5G applications. The proposed antenna has a volume of 20 x 20 x 1.6 mm^3. In the antenna design, the most commonly used classical insulating material, FR4, with a thickness of 1.6 mm, is used, and the antenna is obtained from the reversed-cross-shaped radiator. It is modified with the help of the stubs and slots to resonate in the 3.4-3.8 GHz band. The antenna has a highest gain of 2.2 dBi and an efficiency of 98%. The suggested antenna can be utilized for 5G applications at frequencies below 6 GHz.

6 GHz Altı 5G Uygulamaları için Özgün Tek Kutuplu Anten

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Öz

Bu makalede, 6 GHz altı 5G uygulamaları için yeni bir tek kutuplu antenin tasarımı ve analizi sunulmaktadır. Önerilen antenin hacmi 20 x 20 x 1.6 mm^3'tür. Anten tasarımında en yaygın kullanılan, klasik yalıtkan malzeme olan 1.6 mm kalınlığındaki FR4 kullanılmış ve anten ters-çapraz şekilli ışıyıcıdan elde edilmiştir. Saplamalar ve yuvalar yardımıyla 3.4-3.8 GHz bandında rezonansa girecek şekilde modifiye edilmiştir. Antenin en yüksek kazancı 2.2 dBi ve verimliliği %98'dir. Önerilen anten 6 GHz'in altındaki frekanslarda 5G uygulamaları için kullanılabilir.

1. INTRODUCTION (GİRİŞ)

Depending on the development of technology, the number of wireless devices such as tablets, smartphones, watches, and other wearable electronic devices is increasing day by day. This causes existing communication systems to fail to meet the required demand. At this point, 5G technology appears as a solution for this increasing data demand. Fifth generation (5G) is an emerging mobile broadband service that is being used today and is planned to be widely used in the near future. Increasing needs for big data speeds, low connection latency, cheap cost, minimal consumption of energy, and support for numerous users prepared the path for the birth of 5G service. It means that it is expected to address the limitations of 4.5G and substitute it in a short time.

There are two potential bands for the transmission and reception of data using the 5G wireless connectivity, which are named sub-6 GHz, and mm-wave spectrums[1-4]. The sub-6 GHz is now available in worldwide wireless communication networks, and it can be used for 5G without demanding major hardware modifications.

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The antennas designed and found in the literature for 5G applications at frequencies below 6 GHz are examined below. Yerlikaya et al. presented a monopole antenna that has a log-periodic structure with an impedance bandwidth of 3.1-3.9 GHz [5]. Saxena et al. presented a novel quad-port MIMO antenna with a circular-shaped ground and stub-shaped radiator with a bandwidth from 3.4 to 3.8 GHz [6]. Agrawal et al. presented a double-element MIMO antenna with an octagon-shaped radiator and T-shaped isolator to improve antenna effectiveness [7]. Alieldin et al. offered a triple-band dual-dipole antenna pair with compact size and stable radiation patterns [8]. Noor et al. designed a novel patch antenna with a dual-band property with the help of slots and strips [9]. Tütüncü and Kösem presented a performance analysis of four different dielectric materials on a wide-band antenna [10]. Chowdhury et al. presented a novel and complex antenna with strips, slots, and stubs and has a gain of 4.2 dB [11]. Gençoğlan and Çolak presented an origami-inspired novel monopole antenna with a fractional bandwidth of 132% [12]. Askari et al. proposed a novel artificial magnetic conductor-based antenna which one covers the n77/n78/n79 bands of 5G [13]. Kapoor et al. proposed a novel wideband rectangular antenna which one has a circular slot, and it can operate in n77/n78 bands [14]. Yixin et al. proposed a novel 12-port antenna array which one consists of π-shaped and L-shaped antennas [15]. Jaglan et al. [16] proposed a novel 18-element MIMO antenna for use in 5G smartphones.

The novel monopole antenna is exhibited for 5G applications with frequencies lower than 6 GHz in this communication. In the next part, the concept of the antenna is explained in detail, and results are given. The paper is finished with the conclusion.

2. CONCEPT OF THE DESIGNED ANTENNA
(TASARLANAN ANTEN FİKRİ)

In the present part of the paper, the novel monopole antenna designed for the sub-6 GHz 5G applications is explained in detail. The design steps of the antenna are given in Fig. 1. The S(1,1) metrics of the design stages are also given in Fig. 2. The proposed antenna has a dimension of 20 x 20 x 1.6 mm^3. In the antenna design, the most commonly used classical insulating material, FR4, with a thickness of 1.6 mm, is used. In the first step, the Ant-1 in Fig 1(a) is designed. At the back side of the dielectric material, the antenna has a ground plane with 20 mm x 4 mm. At the front side of the dielectric material; it has a reversed-cross-shaped radiator.

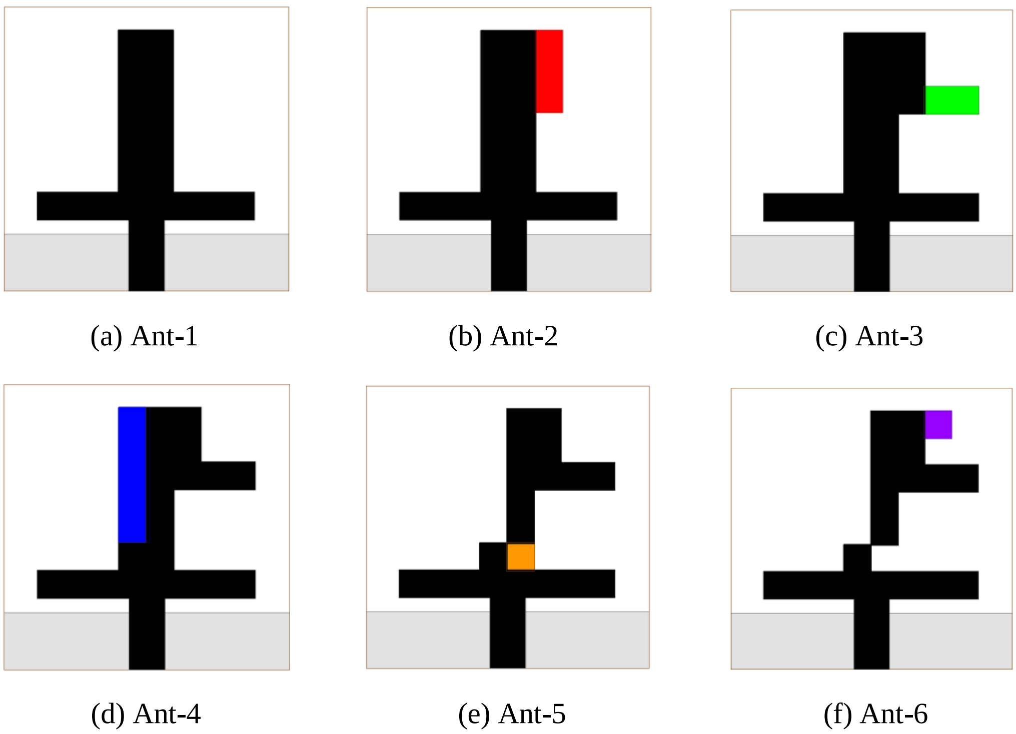


Figure 1. Design stages of the novel structure (Özgün yapının tasarım aşamaları)

The reversed-cross-shaped radiator constitutes 3-parts. The first one is feeding, which has a dimension of 2.5 mm x 5 mm. The second one is the horizontal stub which has a dimension of 15 mm x 2 mm. And lastly, it has a vertical stub with a dimension of 4 mm x 11.4 mm. Ant-1 is placed symmetrically with respect to the y-axis.

Ant-1 has an impedance bandwidth from 4.44 to 4.86, which is lower than -10 dB. In the second step, the vertical stub with the red color in Fig.1(b) is added to the Ant-1 to constitute Ant-2 with the size of 2 mm x 5.8 mm. This antenna has a bandwidth from 4.18 to 4.71 GHz, which says that the vertical stub reduces the minimum operation range of Ant-1 by nearly 0.26 GHz. In the next step, the horizontal stub with the size of 2mm x 4 mm given in Fig. 1(c) with the green color, is added to Ant-2. The Ant-3 has an operating range from 3.88 to 4.48 GHz. The added red and green stubs reduced the lower operating frequency of the Ant-1 by 0.56 GHz in total. In step 4, the blue stub with the size of 2 mm x 9.5 mm in Fig. 1(d) is subtracted from the Ant-3 to boost the overall efficiency of the antenna. The Ant-4 has a bandwidth from 3.77 GHz to 4.25 GHz. In Step 5, the orange stub with the size of 2mm x 2mm in Fig.1(e) is subtracted from the Ant-4, and Ant-5 is obtained. The operating frequency range of the Ant-5 is between 3.5 and 3.9 GHz. Lastly, the purple stub in Fig. 1(f) is added to Ant-5 for obtaining Ant-6. The operating frequency range of the Ant-6 is between 3.4 and 3.8 GHz, which spans the sub-6 GHz 5G spectrum [7, 17, 18].

The proposed antenna is given in Fig 3 separately for better visualization which covers the 5G spectrum in the frequency range of 3.4 – 3.8 GHz.

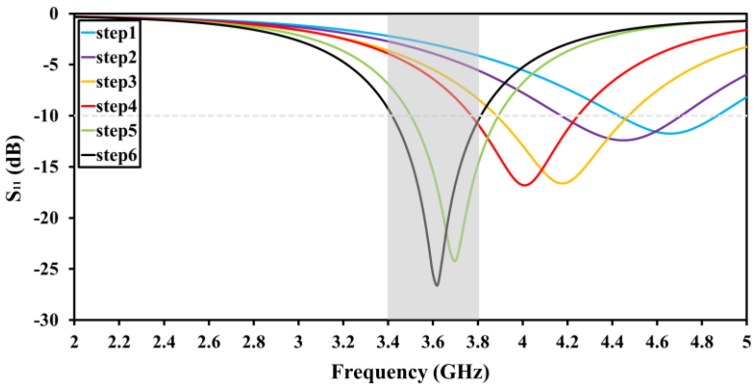
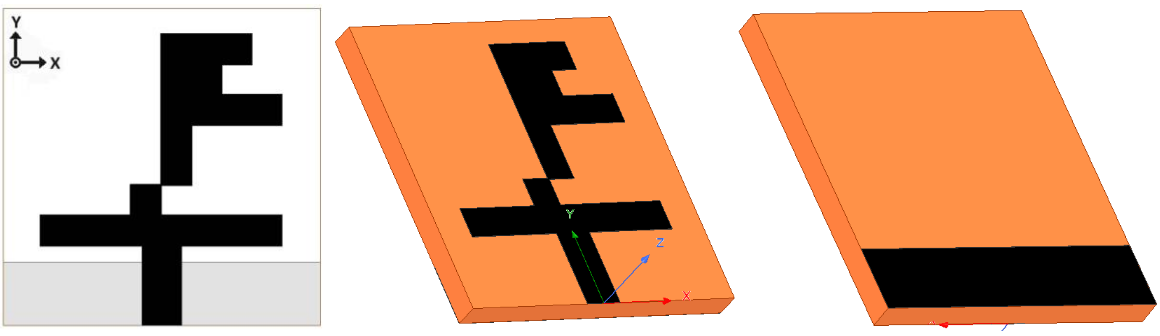
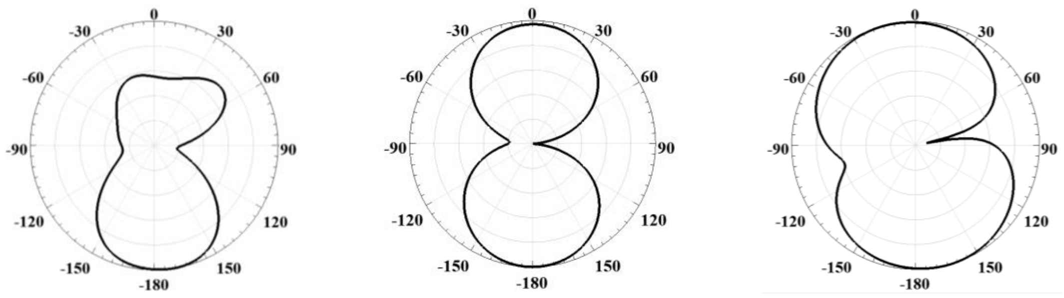


Figure 2. S(1,1) values of the design phases (Tasarım aşamalarının S(1,1) değerleri)



(a) 2D-view (b) 3D-front view (c) 3D-back view

Figure 3. The proposed novel antenna (Önerilen özgün anten)



(a) X-Z (b) Y-Z (c) X-Y

Figure 4. The normalized radiation patterns of the antenna (Antenin normalize edilmiş ışıma örüntüleri)

The normalized radiation patterns of the antenna are depicted in Fig. 4. As the intended antenna is a modified monopole, the radiation patterns appear to be slightly different from those of the monopole patch antenna. In addition to this, 3D gain graph of the antenna is given in Figure 5. he gain and efficiency of the intended novel structure are depicted in Fig. 6. In the operating bandwidth, it has nearly stable gain and efficiency values, which are between 1.5 - 2.2 dBi and 96-98%, respectively.

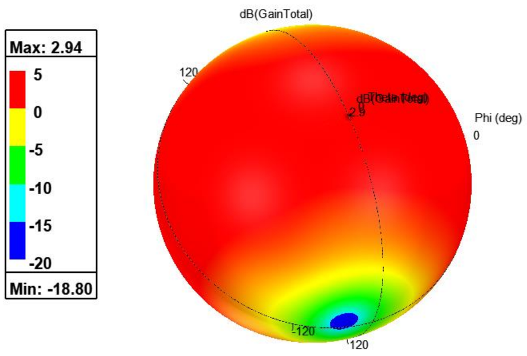


Figure 5. The 3D gain graph of the designed antenna (Tasarlanan antenin 3B kazanç grafiği)

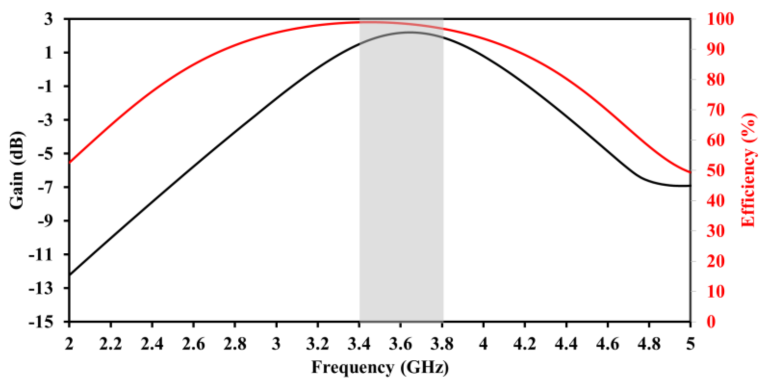


Figure 6. The gain and efficiency graph of the novel antenna (Özgün antenin kazanç ve verimlilik grafikleri)

The current distribution of the antenna at 3.4 GHz is given in Fig. 7. According to the figure, current flows upward from the feed and concentrates at the junction of the two parts. The minimum resonating frequency of the antenna can be calculated using the *Equ 1*. In this equation, L represents the maximum current path, which one equals nearly 13.4 mm for 3.4 GHz, c is the speed of the light, $\mathcal{E}_{eff}$ is the effective permittivity of a dielectric material and explained in Equ. 2 and f_{min} is the lowest operating frequency of the antenna. In Equ. 2, W is the width of the antenna and h is the thickness of the dielectric material.

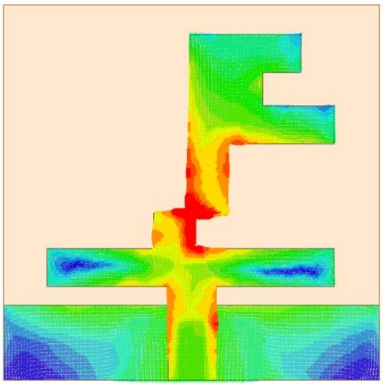


Figure 7. The current distribution of the antenna at 3.4 GHz (Antenin 3.4 GHz'deki akım dağılımı)

$$L = \frac{c}{4\, f_{min}\sqrt{\varepsilon_{eff}}} \tag{1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[1 + 12\frac{h}{W}]^{-\frac{1}{2}} \tag{2}$$

3. CONCLUSIONS (SONUÇLAR)

In this paper, the development and evaluation stages of the novel monopole antenna are explained for the 5G spectrum with a frequency lower than 6 GHz. The stated antenna has a compact dimension, which is equal to 20 x 20 x 1.6 mm^3. In the antenna design, the most commonly used classical insulating material, FR4, is used. The antenna is obtained from the reversed-cross-shaped radiator and modified with the help of the stubs and slots to resonate in the 3.4-3.8 GHz band. The design steps of the antenna are explained in detail, and the effect of the steps on the S(1,1) are explained, respectively. The antenna has a maximum gain of 2.2 dBi and an efficiency of 98% in the bandwidth. As a result, the suggested new structure may be used at frequencies below 6 GHz, such as 5G smartphones and Internet of Things applications.

DECLARATION OF ETHICAL STANDARDS (ETİK STANDARTLARIN BEYANI)

The author of this article declares that the materials and methods they use in their work do not require ethical committee approval and/or legal-specific permission.

Bu makalenin yazarı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

***Kayhan ÇELİK*:** He conducted the simulations, analyzed the results, and performed the writing process.

Benzetimleri yapmış, sonuçlarını analiz etmiş ve makalenin yazım işlemini gerçekleştirmiştir.

CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study.

Bu çalışmada herhangi bir çıkar çatışması yoktur.

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