Gazi Üniversitesi
Fen Bilimleri Dergisi
PART C: TASARIM VE TEKNOLOJİ

Gazi University
Journal of Science
PART C: DESIGN AND TECHNOLOGY

GU J Sci, Part C, 11(4): 1035-1045 (2023)

A Novel Broadband Filtenna with using SRR and DGS for Wireless Communication Applications

Galip Orkun ARICAN[1*], Mert KARAHAN[2]

[1]*ASELSAN Inc., Communication and Information Technologies Division, Ankara, Türkiye*

[2]*National Defence University, Turkish Military Academy, Department of Electronics and Communication Engineering, Ankara, Türkiye*

Article Info

Research article
Received: 20/12/2022
Revision: 28/05/2023
Accepted: 08/08/2023

Keywords

Filtenna
Broadband Antenna
5G
Microstrip Antenna
DGS

Makale Bilgisi

Araştırma makalesi
Başvuru: 20/12/2022
Düzeltme: 28/05/2023
Kabul: 08/08/2023

Anahtar Kelimeler

Filtenna
Genişbant Anten
5G
Mikroşerit Anten
KZY

Graphical/Tabular Abstract (Grafik Özet)

In this study, a broadband and high-gain filtenna is developed and the effects of the different substrates on the design examined. / Bu çalışmada geniş bantlı ve yüksek kazançlı bir filtenna geliştirilerek farklı alt tabakaların tasarım üzerindeki etkileri incelenmiştir.

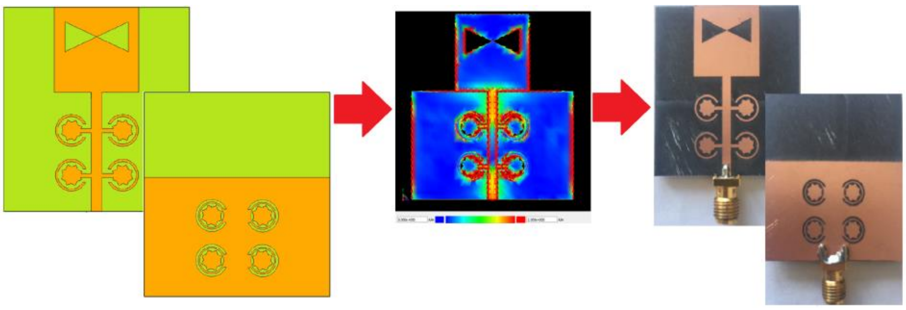

***Figure A**: Design and prototype of a novel filtenna /**Şekil A:** Yenilikçi bir filtenna tasarımı ve üretimi*

Highlights (Önemli noktalar)

- *The effects of split ring resonator (SRR) on the filtering performance of the proposed design have been investigated. / Ayrık halka rezonatörünün (AHR) önerilen tasarımın filtreleme performansına etkileri incelenmiştir.*
- *The effects of defected ground structures (DGS) on the operating frequency bandwidth of the proposed design have been investigated. / Kusurlu zemin yapısının (KZY) önerilen tasarımının çalışma frekans bantgenişliği üzerindeki etkileri incelenmiştir*
- *The effects of the four different dielectric substrates (Rogers RT5880, RO3003, RO4003, and RT6006) on the electrical performance of the design have been investigated. / Dört farklı dielektrik alt tabakanın (Rogers RT5880, RO3003, RO4003, and RT6006) önerilen tasarımının elektriksel performansı üzerindeki etkileri incelenmiştir.*

Aim (Amaç): *In this study, it is aimed to enhance the bandwidth amd antenna gain with utilizing SRR and DGS methods by introducing a novel filtenna design. In addition, the effects of the different substrates on the same design are examined. / Bu çalışmada, yenilikçi bir filtenna tasarımı ortaya konarak AHR ve KZY yöntemleri kullanılarak bant genişliği ve anten kazancının iyileştirilmesi hedeflenmiştir. Ek olarak, aynı tasarımın farklı alt tabakalardaki etkileri incelenmiştir.*

Originality (Özgünlük): *A novel filtenna desing has been investaged with utilizing a bow-tie slot-loaded patch antenna with a four-pole lowpass filter structure on the feedline for the first time. / Besleme hattında ilk kez dört kutuplu alçak geçiren filtre yapısına sahip, papyonlu ve yuva-yüklemeli bir yama anten tasarımı incelenmiştir.*

Results (Bulgular*): The prototyped filtenna has a center frequency of 3.9 GHz and an operating frequency bandwidth of 2.86 to 4.89 GHz, which yields a fractional bandwidth of 52%. In addition, the filtenna has a reflection coefficient better than -10 dB and the measured maximum antenna gain was 3.26 dBi. / Prototiplenen filtenna 3,9 GHz'lik bir merkez frekansına ve 2,86 ila 4,89 GHz'lik bir kesir bant genişliği sağlamaktadır. Ek olarak, filtennanın yansıma katsayısı -10 dB'den iyidir ve ölçülen en yüksek anten kazancı 3,26 dBi'dir.*

Conclusion (Sonuç): *This study shows that a compact size, low-cost, and high performance filtenna can be developed with utilizimg SRR and DGS methods for 5G applications. / Bu çalışma, 5G uygulamaları için AHR ve KZY methodları kullanılarak kompakt boyutlu, düşük maliyetli ve yüksek performanslı bir filtenna geliştirilebileceğini göstermektedir.*

*Corresponding author, e-mail: goarican@aselsan.com.tr
DOI: 10.29109/gujsc.1221805

GU J Sci, Part C, 11(4): 1035-1045 (2023)

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Abstract

This paper presents a novel broadband filtering antenna (filtenna) design for 5G applications. The filtenna structure consist of a bow-tie slot-loaded patch antenna with a four-pole lowpass filter structure on the feedline. In addition, the defected ground structure method was applied to miniaturize the size and widen the operating frequency bandwidth. The proposed filtenna was designed and optimized with using Keysight's PathWave EM Design (EMPro) software. In addition, the filtenna design was analyzed with utilizing four different substrates, which are Rogers RT5880, RO3003, RO4003, and RT6006, and the electromagnetic simulation results were presented. Moreover, the design was manufactured with using Rogers RT5880 and the design was validated with measurements. The developed filtenna operates at a center frequency of 3.9 GHz and an operating frequency bandwidth of 2.86 to 4.89 GHz, which yields a fractional bandwidth of 52%. Furthermore, the filtenna has a reflection coefficient better than -10 dB and the measured maximum antenna gain was 3.26 dBi. The filtenna has a compact size of $0.463\lambda_0 \times 0.506\lambda_0$ where λ_0 is the wavelength at the center frequency. With its compact size, low-cost, and high-performance characteristics, the proposed filtenna can be used for 5G applications.

Kablosuz İletişim Uygulamları için AHR and KZY Kullanan Yenilikçi bir Geniş bant Filtenna

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Öz

Bu makalede, 5G uygulamaları için yeni bir geniş bant filtre anten (filtenna) tasarımı incelenmiştir. Filtenna yapısı, besleme hattında dört kutuplu alçak geçişli filtre yapısına sahip, papyonlu, yuva-yüklü bir yama antenden oluşur. Ayrıca tasarımın boyutunu küçültmek ve çalışma frekansı bant genişliğini genişletmek için kusurlu zemin yapısı yöntemi uygulanmıştır. Önerilen filtre anteni, Keysight'ın PathWave EM Design (EMPro) yazılımı kullanılarak tasarlanmış ve optimizasyonları yapılmıştır. Ek olarak, filtenna tasarımı Rogers RT5880, RO3003, RO4003 ve RT6006 olmak üzere dört farklı alt tabaka için simülasyonları yapılmış ve elde edilen elektromanyetik simülasyon sonuçları sunulmuştur. Önerilen filtenna tasarımı Rogers RT5880 kullanılarak üretilmiş ve tasarlanan filtenna yapısı ölçüm sonuçlarıyla doğrulanmıştır. Geliştirilen filtennanın 3,9 GHz merkez frekansında çalıştığı ve 2,86 ila 4,89 GHz çalışma frekansı bant aralığında çalışarak %52'lik kesirli bant genişliği sağladığı görülmüştür. Ayrıca, filtre anteni -10 dB'den daha iyi bir yansıma katsayısına sahiptir ve ölçülen maksimum anten kazancı 3,26 dBi'dir. Filtenna kompakt bir boyuta $0{,}463\lambda_0 \times 0{,}506\lambda_0$ sahiptir; burada λ_0, merkez frekanstaki dalga boyudur. Önerilen filtenna, kompakt boyutu, düşük maliyeti ve yüksek performans özellikleriyle 5G uygulamalarında kullanılabilecektir.

1. INTRODUCTION (GİRİŞ)

The pursuing growth in the utilization of communication systems sets a great demand on the utilization of compact and multifunctional systems [1, 2]. With the increasing reliance on wireless communication applications, there is a need for innovative solutions that can provide both efficient filtering and radiation characteristics while maintaining a compact form factor and cost-effectiveness [3-6]. The RF front-end systems,

*Corresponding author, e-mail: goarican@aselsan.com.tr
DOI: 10.29109/gujsc.1221805

which are crucial components in receivers and transmitters, typically consist of an antenna, filter, and amplifier. Traditionally, these components have been implemented separately, leading to larger physical sizes and increased costs. However, the emergence of multifunctional modules has attracted significant attention in recent years due to their ability to integrate multiple functionalities within a compact design.

In this context, the combination of the antenna and filter, known as a filtenna, provides an alternative solution to conventional microwave solutions by offering both filtering and radiating characteristics in a single module. The filtenna stands apart from traditional methods where the antenna and filter are implemented separately. By integrating these components into a single unit, the filtenna eliminates the need for multiple parts and complicated connections. This integration not only reduces the physical size of the system but also simplifies the manufacturing process. As a result, the filtenna offers enhanced overall system performance, making it an attractive solution for wireless communication applications [7].

Over the past few decades, various filtenna design topologies and techniques have been investigated. Each of the filtenna design topologies and techniques has advantages and disadvantages over the others. The electrical performance of the filtenna can be categorized in terms of bandwidth, selectivity, gain, efficiency, polarization, etc. [8]. So as to enhance the radiation and electrical performance of the filtenna, a variety of filtenna design topologies such as multilayer printed circuit board (PCB), split ring resonator (SRR), slot-loaded, diode-loaded, probe-fed and defected ground structures (DGS) have been proposed in the literature [9-15]. The selection of the dielectric substrate material and its properties, like the thicknesses of the dielectric and conductive material, have a significant effect on the performance of the design. On the other hand, the selection of the dielectric material and its properties is a crucial challenge since there is a trade-off between high performance and low-cost in the design process. In the literature, a variety of microstrip filtenna designs on different dielectric substrates with different design methods have been proposed [16-28]. In light of these facts, it is a charming topic for the designers to develop a compact filtenna with high performance to integrate into wireless communication systems.

In this article, a novel broadband filtenna design, which is comprised of a bow tie slot loaded path antenna with a four-pole lowpass filter structure on the feedline, is proposed for 5G applications. The proposed filtenna utilizes four resonators and each resonator has an eight-edge star-shaped open stub that is surrounded by a circular open loop split ring resonator (SRR) to achieve the filtering characteristic. In addition, DGS was utilized to accomplish wider bandwidth, enhanced selectivity, and compact size. Moreover, the proposed study examines four different dielectric substrates for the same layout to analyze the effects of the dielectric substrates on the performance of the filtenna. Furthermore, the proposed filtenna accomplishes a fractional bandwidth (FBW) of 58.9% (2.67-4.89 GHz) with a reflection coefficient of -10 dB and a maximum antenna gain of 3.26 dBi. The developed filtenna is evitable for the 5G applications with its compact-size, low-cost, and high-performance characteristics.

2.MATERIALS AND METHODS (MATERYAL VE METOD)

2.1. Filtenna Design (Filtenna Tasarımı)

The filtenna structure is designed to feature a patch antenna with enhanced electrical performance, accompanied by an antenna feed line that incorporates a low-pass filter configuration. In the first step of the design process, the patch antenna design was taken into consideration. To design the patch antenna, the initial dimensions were calculated based on Equations 1-3 [29],

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \quad \text{(Eq.1)}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{W}\right)}}\right] \quad \text{(Eq.2)}$$

$$L = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} - 0.824h\left[\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right] \quad \text{(Eq.3)}$$

where W and L are the width and length of the patch antenna, f_0 is the resonant frequency, ε_r is the relative permittivity of the dielectric substrate, h is the thickness of the dielectric substrate, ε_{eff} is the effective dielectric constant and c is the speed of light ($3\text{x}10^8$ m/s).

In the patch antenna design, the width and length of the patch were calculated as 30.8 mm and 25.08 mm, respectively, for a resonant frequency of 3.9 GHz. However, conventional patch antennas typically exhibit a narrow frequency bandwidth. To eliminate this limitation by increasing the bandwidth, a bow-tie slot was etched into the patch antenna, and the location and dimensions of the bow-tie were optimized. In addition, a Rogers RT5880 dielectric substrate with a relative permittivity of 2.2 was used in the design so as to enhance the efficiency and bandwidth performance of the patch antenna. Moreover, a microstrip feed line was designed with a four-pole low-pass filter (LPF) to suppress the unwanted harmonics at the upper frequency spectrum. The proposed LPF consisted of four resonators, each featuring an eight-edge star-shaped open stub surrounded by a circular open-loop split ring resonator (SRR). The inclusion of these SRR units in the proposed design enhanced the out-of-band harmonic suppression level. Furthermore, the defected ground structure (DGS) method was employed on the ground plane to introduce parallel RLC circuit into the antenna feed network. This method ensures a slow-wave impact on the design which enables miniaturizing the circuit size and increasing the frequency bandwidth. Meanwhile, it was revealed that the DGS unit provides a sharp roll at the higher cut-off frequency. The filtenna design comprised a monopole bow-tie slot loaded patch antenna and a feed line with a four-pole LPF. By incorporating DGS units with SRR structures, the size of the patch antenna was reduced to 16.2x16.2 mm^2, which is 66.03% smaller than the conventional patch size. Additionally, the filtenna has a compact size of 0.463λ_0 x 0.506λ_0 where λ_0 represents the wavelength at the center frequency. Figure 1 illustrates the proposed filtenna layout design, and Table 1 depicts the dimensions of the proposed filtenna layout design.

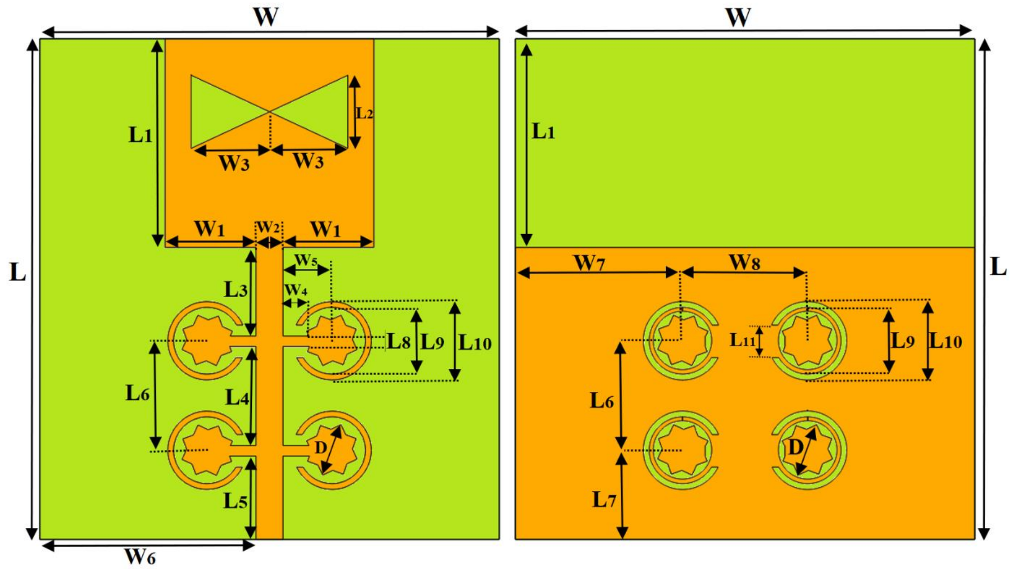

Figure 1. Layout of the proposed Filtenna (a) Top, (b) Bottom (Önerilen Filtennanın serimi (a) Üst, (b) Alt)

Table 1. Dimensions of the proposed filtenna (Önerilen Filtennanın boyutları)

Parameter	L	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}
Value	38880	16200	5670	6885	7695	6480	8505	6885	810	5186	6088
Parameter	L_{11}	W	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	D
Value	2529	35640	7050	2100	6075	1998	3816	16770	12954	9732	4175

In the layout design process, a variety of DGS structures have been tried in the design and the proposed filtenna design has been applied on the layout because of both having a novel structure and enhanced electrical characteristics. In addition, the proposed layout design was simulated with different dielectric substrates to analyze the effects of the dielectric substrates on the performance of the filtenna. During the EM simulations, the dimensions of the proposed filter remained constant, and the simulations were conducted using commercially available dielectric substrates; Rogers RT5880 (ε_r=2.2), RO3003 (ε_r=3.0), RO4003 (ε_r=3.55) and RT6006 (ε_r=6.15), respectively. In addition, the chosen thicknesses of the dielectric substrates were similar to one another. The 3D EM simulations were performed with Keysight's PathWave EM Design (EMPro) software.

According to the simulation results, the proposed filter design on the RT5880 has a reflection coefficient better than 10 dB in the frequency bandwidth of 2.67-4.89 GHz, which yields a fractional bandwidth (FBW) of 58.9%. In addition, the reflection coefficient of the proposed filtenna achieves -20 dB at the center resonant frequency of 3.9 GHz. Notably, in the simulation results, it was observed that the reflection coefficient deteriorates with increasing dielectric permittivity and center frequency. Furthermore, as the dielectric permittivity increases, the center frequency of the filtenna shifts to the lower frequencies, and the bandwidth becomes narrower. Figure 2 illustrates the reflection coefficient of the proposed filtenna with different dielectric substrates.

Figure 3 illustrates the simulated antenna gain of the proposed filtenna using different dielectric substrates. The simulation results revealed that the operating frequency bandwidth of the filtenna becomes narrower as the dielectric permittivity increases. Additionally, it was observed that the filtenna achieves better suppression levels as the dielectric permittivity decreases. Notably, the simulated maximum antenna gain of 3.37 dBi was achieved when utilizing the RT5880 dielectric substrate.

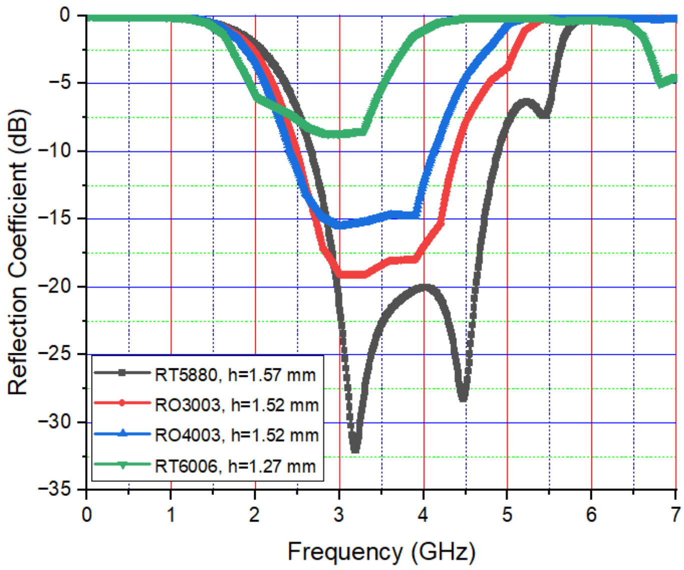

Figure 2. Simulated reflection coefficients with respect to the different substrates

(Farklı alt tabakalara göre simüle edilen yansıma katsayıları)

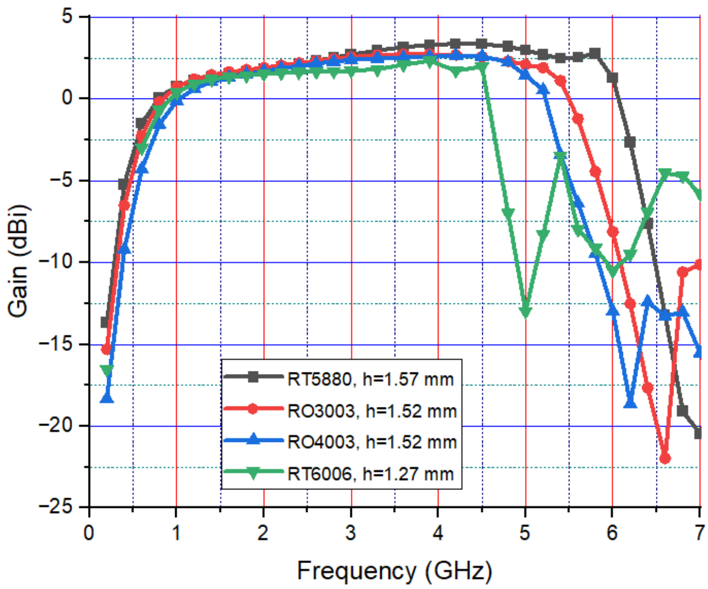

Figure 3. Simulated Antenna Gains with respect to the different substrates
(Farklı alt tabakalara göre simüle edilen anten kazançları)

Table 2 presents the comparison of properties of the dielectric substrates and the simulation results of the proposed filtenna for different dielectric substrate types. As shown in Table 2, the upper cut-off frequency of the filtenna shifts through the lower frequencies, and the simulated maximum antenna gain decreases as the dielectric permittivity increases. The simulated reflection coefficient achieves -10 dB within the bandwidths of 2.67-4.89 GHz, 2.49-4.38 GHz, and 2.42-4.11 GHz for RT5880, RO3003, and RO4003, respectively. However, for the RT6006 substrate, the reflection coefficient of the filtenna reaches -5 dB within the bandwidth of 1.93-3.54 GHz. Furthermore, the simulated maximum antenna gain of the filtenna is measured 3.37 dBi, 2.74 dBi, 2.64 dBi and 2.33 dBi for RT5880, RO3003, RO4003, and RT6006 substrates, respectively. Figure 5 depicts the 3D radiation pattern of the proposed filtenna using the RT5880 substrate at the center frequency of 3.9 GHz.

Table 2. Comparison of the Filtenna Design Simulation Results with respect to the different substrates
(Farklı alt tabakalara göre simüle edilmiş Filtenna tasarımı simülasyon sonuçlarının karşılaştırması)

Parameters	Dielectric Substrate Type			
	RT5880	RO3003	RO4003	RT6006
ε_r	2.20	3.0	3.55	6.15
Substrate Thickness (mm)	1.57	1.52	1.52	1.27
Center Frequency (GHz)	3.78	3.44	3.26	2.74
Bandwidth (GHz)	2.67 - 4.89	2.49 - 4.38	2.42 - 4.11	1.93 - 3.54
FBW (%)	58.9%	55.0 %	51.8%	-
Reflection Coefficient (dB)	-10	-10	-10	-5
Reflection Coefficient (dB) @f_0	-20.05	-18.59	-15.15	-8.52
Max. Gain (dBi)	3.37	2.74	2.64	2.33

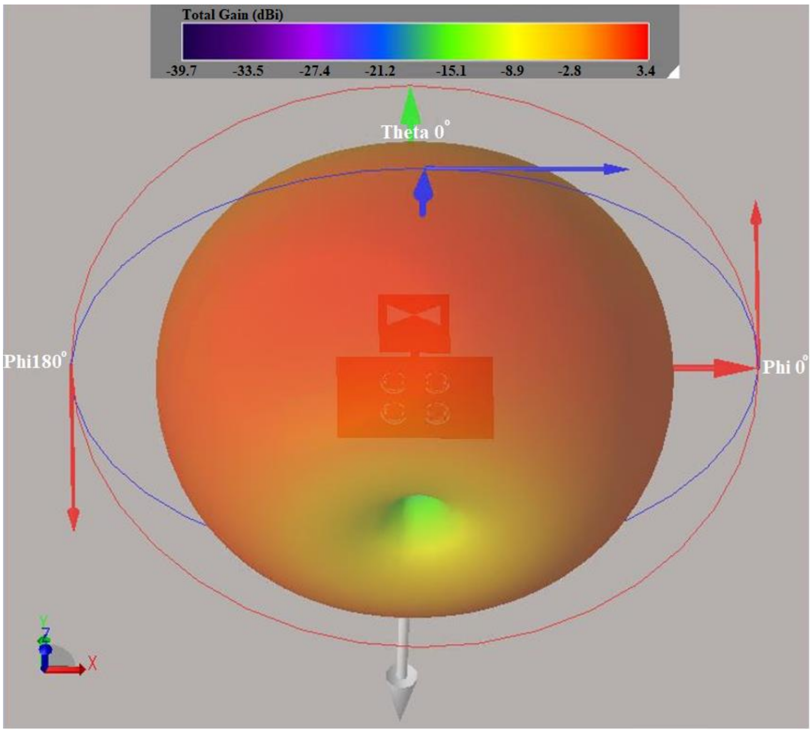

Figure 4. The 3D radiation pattern at the center frequency (3.9 GHz)
(Merkez frekanstaki (3,9 GHz) 3B ışıma örüntüsü)

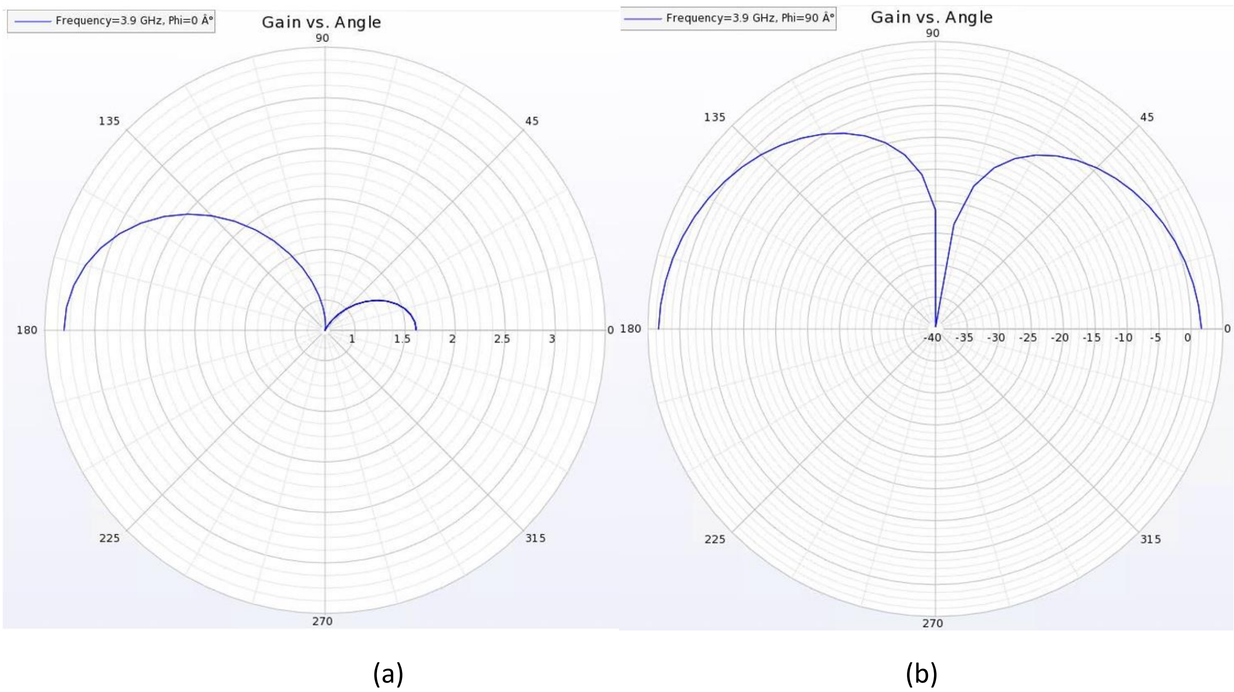

Figure 5. Far field radiation patterns when a) φ=0° b) φ=90° (Uzak alan ışıma örüntüsü a) φ=0° b) φ=90°)

Figure 5 shows the far-field radiation patterns of the proposed filtenna at the center frequency of 3.9 GHz, specifically for azimuthal angles *φ=0°* and *φ=90°*. The simulation results reveal that the radiation exhibits an omnidirectional characteristic, indicating a consistent radiation pattern in all directions around the filtenna.

Figure 6 illustrates the surface current distribution at the center frequency of 3.9 GHz and Figure 7 depicts the surface current distribution at the lower cut-off frequencies of 400 MHz and upper cut-off frequencies of 7000 MHz, respectively. The results from the simulations indicate that the surface currents are predominantly concentrated along the edges of the bow-tie slot and antenna feed line within the passband. On the other hand, the current is faded on the low-pass filter of the feed line and does not flow through the patch antenna at the lower and upper cut-off frequencies.

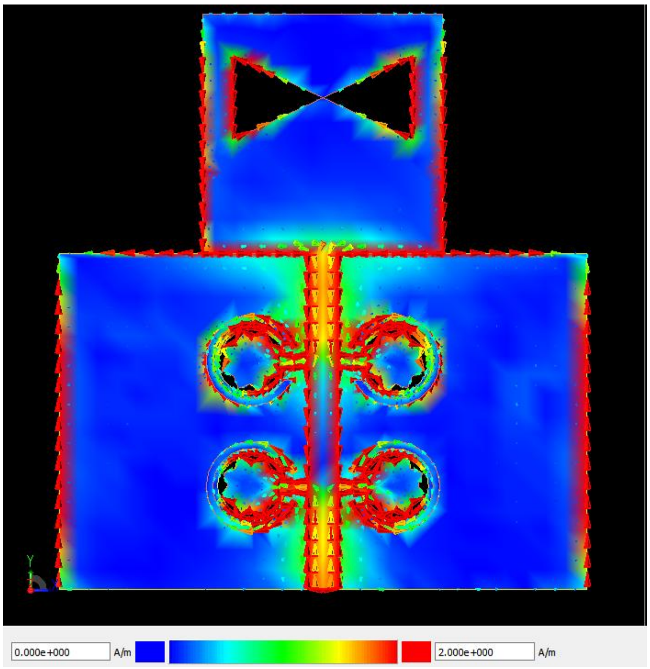

Figure 6. Current distribution at the center frequency (@3.9 GHz) (Merkez frekanstaki (3,9 GHz) akım dağılımı)

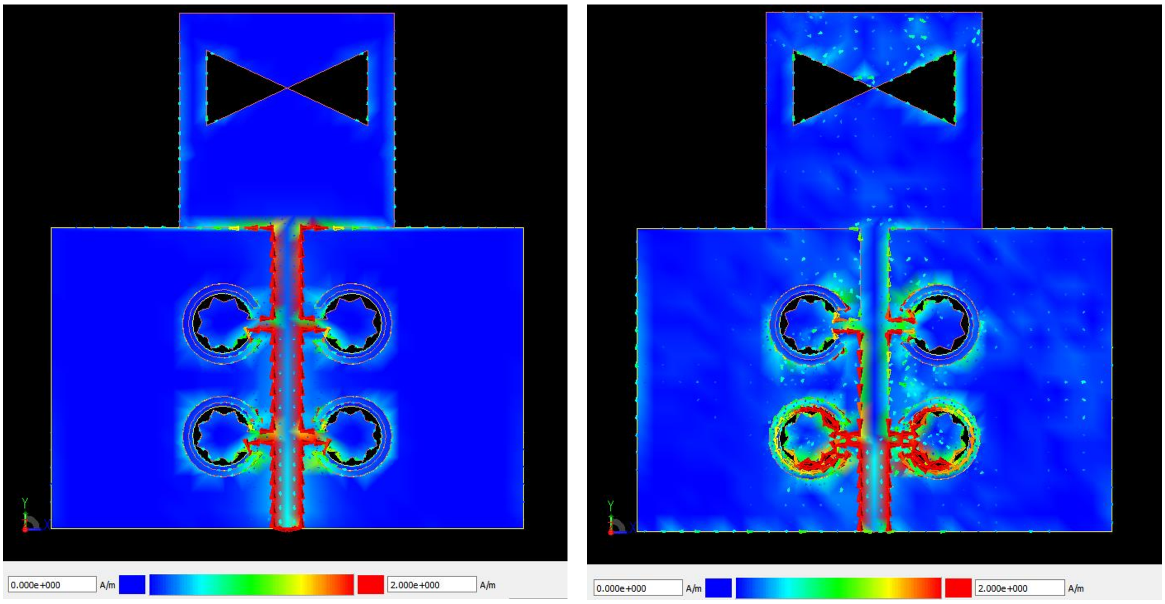

Figure 7. Current distribution at a) Lower Stop band (@400 MHz) and b) Upper Stop band (@7.0 GHz)
(a) Aşağı Bastırma bandındaki (@400 MHz) ve b) Yukarı Bastırma bandındaki (@7.0 GHz) akım dağılımı)

3.RESULTS (BULGULAR)

The proposed filtenna design was fabricated on a Rogers RT5880 dielectric substrate (ε_r=2.2) with a thickness of 1.57 mm using an LPKF laser prototyping machine. Furthermore, a subminiature version A (SMA) connector was soldered to the antenna feed to perform the electrical tests. The S-parameter measurements were carried out using a Keysight N5222B power network analyzer in the laboratory environment at ambient temperature. Figure 8 depicts the prototyped filtenna and test setup.

Figure 9 illustrates the comparison between the simulated and measured reflection coefficients (S_{11}) of the fabricated filtenna on RT5880 substrate. It was observed that the filtenna exhibits two resonances, contributing to a smooth passband response. Consequently, the simulated FBW with $S_{11}\leq$ -10 dB was calculated as 58.9% (2.67-4.89 GHz), while the measured FBW with $S_{11}\leq$ -10 dB was determined as 52.4% (2.86-4.89 GHz). Furthermore, the measured FBW with $S_{11}\leq$ -12 dB was calculated as 48.1% (2.94-4.8 GHz). Notably, the measured reflection coefficients of the fabricated filtenna showed good agreement with the simulation results. However, it is worth mentioning that the simulated (S_{11}) exhibited approximately an 8-dB improvement compared to the measurement result.

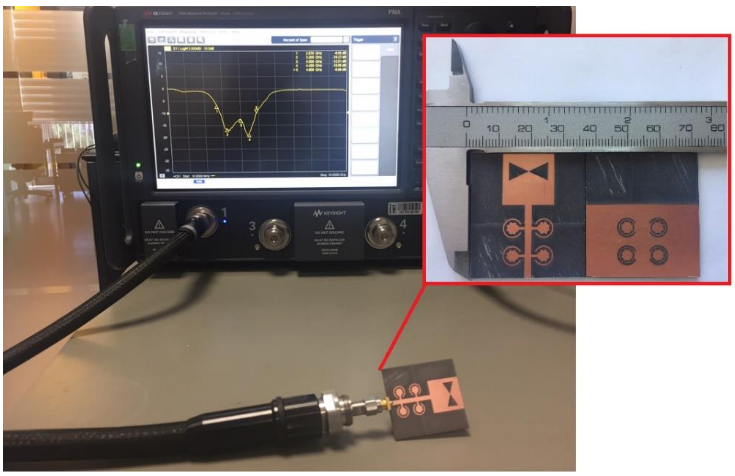

Figure 8. Test Setup (Ölçüm Düzeneği)

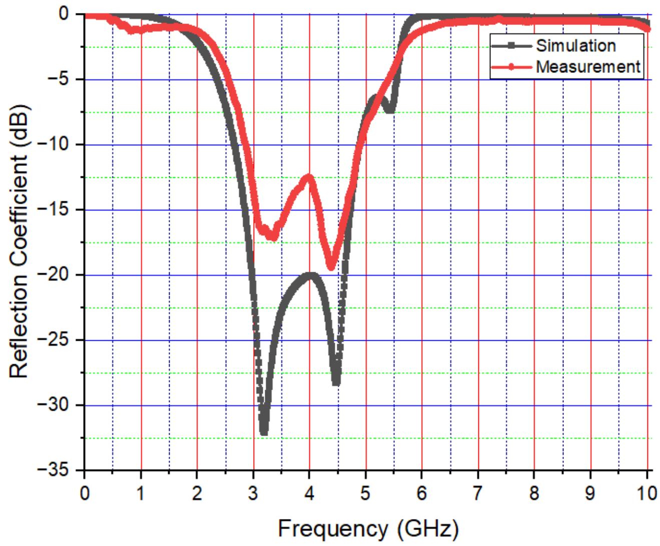

Figure 9. Simulated and Measured Reflection Coefficient (Simüle edilen ve ölçülen yansıma katsayısı)

Figure 10 illustrates the comparison between the simulated and measured antenna gain of the proposed filtenna on the RT5880 substrate. The measured and simulated antenna gains were determined as 3.26 dBi and 3.37 dBi, respectively. Furthermore, the measured harmonic suppression level exhibited better performance compared to the simulation results. However, a noticeable shift of approximately 350 MHz shift was observed between the simulation and measurement results at the lower cut-off frequency. This difference between the simulation and measurement results of the antenna gain may be attributed to factors such as the feeding with the SMA connector and the manufacturing tolerances. Additionally, it is believed that conducting the measurements in an anechoic chamber would provide more accurate and closer alignment with the simulation results in terms of the measured gain performance.

The relation between the quality factor (Q_c) of the filter can be calculated with the equation 4,

$$Q_c = \frac{f_0(VSWR-1)}{FBW\sqrt{VSWR}} \quad (4)$$

where *FBW* represents the fractional bandwidth and f_0 denotes the center frequency. By applying equation 4, the Q_c can be calculated as 4.96, when the maximum *VSWR* is 1.925:1 within the operating frequency bandwidth.

Table 3 presents a comparison of the state-of-the-art filtennas found in the literature. The proposed filtenna demonstrates several advantages, including a wide FBW, excellent reflection coefficient, and a compact size.

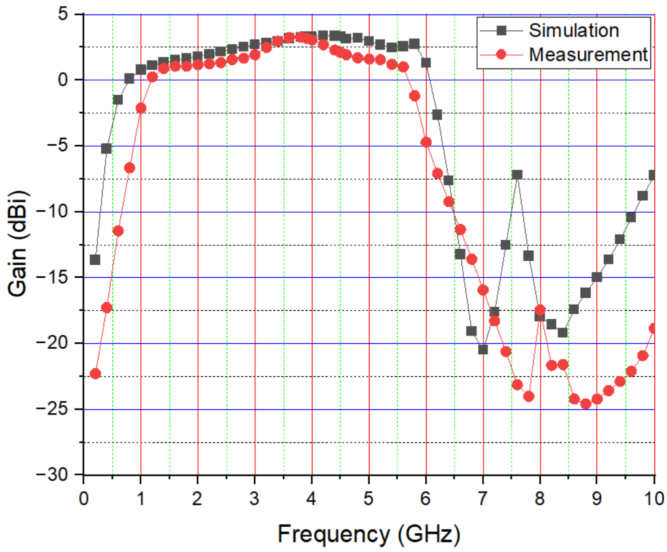

Figure 10. Simulated and Measured Antenna Gain (Simüle edilen ve ölçülen anten kazancı)

Table 3. Comparison of the state of art filtennas (Son teknoloji ürünü filtennnaların karşılaştırılması)

Ref	f_0 (GHz)	FBW (%)	Size (λ_0 x λ_0)	Min.$|S_{11}|$ (dB)	Gain (dB)	Technology
[16]	2.6	2.6	0.31 × 0.27	13	2.2	Multilayer
[17]	3.6	15	0.92 x 0.86	14	10	Metasurface
[18]	2.5	22.8	1.70 x 1.30	20	5	Multilayer
[19]	2.45	12.2	0.65 × 0.33	28	3.5	FR4
[20]	2.4	3	0.37 × 0.36	10	2.61	FR4
[21]	1.9	19	0.35 × 0.24	12	5.6	4003C
[22]	2.45	12	0.49 × 0.49	10	5.26	FR4
[23]	2.45	10	0.49 × 0.49	10	0.65	4003C
[24]	2.4	3	0.36 × 0.39	-	2.6	FR4
[25]	2.45	6.7	0.34 × 0.18	10	1.3	F4B
[26]	2.4	19	0.38 × 0.28	10	2.3	FR4
[27]	2.45	-	0.41 × 0.41	15	1.2	4003C
[28]	2.4	7.5	0.28 × 0.24	-	0.74	FR4
This work	3.9	52.4	0.46 × 0.51	10	3.26	RT5880
	3.9	48.1	0.46 × 0.51	12	3.26	RT5880

less pits and less crater formations increased the accuracy of measurement.

4.CONCLUSIONS (SONUÇLAR)

This study focuses on the design, simulation, and experimental validation of a bow-tie slot-loaded monopole patch antenna featuring a single feed and a four-pole low pass filter. The fabricated filtenna achieves a reflection coefficient of -10 dB within the frequency bandwidth of 2.86 to 4.89 GHz, resulting in a fractional bandwidth of 52%. The maximum realized antenna gain reaches 3.26 dBi, and the radiation pattern exhibits an omnidirectional characteristic. In addition, the filtering characteristic is achieved by incorporating split ring resonators on the antenna feed lines, and the defected ground structure is utilized to enhance the bandwidth. It is considered that the prototyped filtenna can be utilized for 5G applications with its compact size, low cost, and high-performance characteristics.

ACKNOWLEDGMENTS (TEŞEKKÜR)

The authors would like to thank ASELSAN Inc. for allowing them to utilize the manufacturing and testing infrastructure.

Yazarlar ASELSAN AŞ'ye üretim ve test alt yapılarının kullanımına imkân tanıdığı için teşekkür ederler.

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)

***Galip Orkun ARICAN*:** He conducted the design, simulations, electrical tests, analyzed the results and performed the writing process.

Tasarımı, simülasyonları, elektriksel testleri, sonuçlarını analiz etmiş ve maklenin yazım işlemini gerçekleştirmiştir.

***Mert KARAHAN*:** He conducted the electrical tests, analyzed the results and performed the writing process.

Elektriksel testleri 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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