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Research Article

ISM 2.4 GHz Band Antenna Model for RF Energy Harvesting Systems

Cem Gocen[1], Ismail Akdag[2], Mehmet Ali Belen[3], Peyman Mahouti[4], Adnan Kaya[5], Merih Palandoken[6*]

[1] Izmir Katip Çelebi University, Department of Electrical and Electronics Engineering, Smart Factory Systems Application and Research Center, İzmir, Turkey, (ORCID: 0000-0002-8086-5690), cem.gocen@ikcu.edu.tr

[2] Izmir Katip Çelebi University, Department of Electrical and Electronics Engineering, Smart Factory Systems Application and Research Center, İzmir, Turkey, (ORCID: 0000-0001-6470-5892), ismail.akdag@ikcu.edu.tr

[3] İskenderun Technical University, Department of Electrical and Electronics Engineering, Hatay, Turkey, (ORCID: 0000-0001-5588-9407), mali.belen@iste.edu.tr

[4] Yıldız Technical University, Department of Avionics Electronic, İstanbul, Turkey, (ORCID: 0000-0002-3351-4433), pmahouti@yildiz.edu.tr

[5] Izmir Katip Çelebi University, Department of Electrical and Electronics Engineering, Smart Factory Systems Application and Research Center, İzmir, Turkey, (ORCID: 0000-0002-9943-6925), adnan.kaya@ikcu.edu.tr

[6*] Izmir Katip Çelebi University, Department of Electrical and Electronics Engineering, Smart Factory Systems Application and Research Center, İzmir, Turkey, (ORCID: 0000-0003-3487-2467), merih.palandoken@ikcu.edu.tr

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Abstract

In today's world many technological devices can operate with very low power levels. Despite this situation, these devices need to be fed with a sustainable energy source and constantly charged. This low level power need can be attained from ambient electromagnetic waves from any radio frequency sources. Radio frequency energy harvesting systems can be offered to feed these type of devices and these systems have been used in many areas in recent years. In this study, an antenna designment that can be used in RF energy harvesting systems is emphasized. Within the scope of this study, an RF energy harvesting antenna operating at 2.4 GHz frequency has been modeled. The electromagnetic performance and antenna fundamental parameters of the RF energy harvesting antenna are numerically calculated using a commercial 3D based on a transmission line matrix (TLM) and the finite integration technique (FIT). The physical extents of the antenna are 35 x 28 x 1.6 mm. The proposed RF energy harvesting antenna has 2.1 dBi directivty and %98.1 radiation efficiency performance parameters. The antenna proposed here can be have usage areas such as an RF energy harvesting antenna for low-power medical devices, self sustainable wireless devices in Internet of Things (IoT), Wireless Body Sensor Network (WBSN) devices.

Keywords: RF Energy Harvesting, ISM Band, Microstrip Antenna, 2.4 GHz, Rectifying Antenna.

RF Enerji Hasatlama Sistemleri için ISM 2.4 GHz Bandı Anten Modeli

Öz

Günümüz dünyasında birçok teknolojik cihaz çok düşük güç seviyelerinde çalışabilmektedir. Bu duruma rağmen bu cihazların sürdürülebilir bir enerji kaynağı ile beslenmesi ve sürekli şarj edilmesi gerekmektedir. Bu düşük seviyeli güç ihtiyacı, herhangi bir radyo frekansı kaynağından gelen elektromanyetik dalgalarından elde edilebilir. Bu tür cihazları beslemek için radyo frekans enerji hasatlama sistemleri sunulabilir ve bu sistemler son yıllarda birçok alanda kullanılmaktadır. Bu çalışmada, RF enerji hasatlama sistemlerinde kullanılabilecek bir anten tasarımı üzerinde durulmuştur, 2.4 GHz frekansında çalışan bir RF enerji hasatlama anteni modellenmiştir. RF enerji toplama anteninin elektromanyetik performansı ve anten temel parametreleri, iletim hattı matrisine (TLM) ve sonlu entegrasyon tekniğine (FIT) dayalı ticari 3D tabanlı simulator kullanılarak sayısal olarak hesaplanmıştır. Antenin fiziksel boyutları 35 x 28 x 1.6 mm'dir. Önerilen RF enerji hasat anteni, 2.1 dBi yönlülüğe ve %98.1 radyasyon verimliliği performans parametrelerine

* Corresponding Author: merih.palandoken@ikcu.edu.tr

sahiptir. Burada önerilen anten, düşük güçlü tıbbi cihazlar için RF enerji toplama anteni, Nesnelerin İnterneti (IoT) içinde kendi kendini sürdürebilen kablosuz cihazlar, Kablosuz Vücut Sensör Ağı (WBSN) cihazları gibi kullanım alanlarına sahip olabilir.

Anahtar Kelimeler: RF Enerji Hasatlama, ISM Bandı, Mikroşerit Anten, 2.4 GHz, Doğrultucu Anten.

1. Introduction

Wireless energy harvesting is nearly a century old term (Tran et al., 2017). The achievements as a result of research conducted to date have made energy harvesting (EH) that can provide alternative energy sources a reality. One definement for a wireless power transmission (WPT) system describes a unit that sends electrical power from one place to another without the use of cables or a supporting medium (Brown, 1996). Radio frequency energy harvesting (RF EH) is an energy conversion technique used to convert energy from electromagnetic (RF) signals to DC electric signal (Serdijn et al., 2014). Fundamentally, the system has two antennas to send and receive electromagnetic waves, and a DC power converter unit to convert the electromagnetic wave received by the receiving mode antenna into direct current. With the developing technology, smart devices that encountered in all areas of our lives, IoT devices with internet connectivity, small medical equipment constantly need low power. However, it is impractical to constantly charge devices with very low power consumption. By using RF EH systems, it is possible to operate some devices with low power consumption with electromagnetic waves floating freely in the air. Many of the mobile phones, modems, bluetooth devices, TV and radio systems operate with RF waves. As a concept, energy can be obtained by harvesting RF energy waves on the devices with a system designment at the operating frequency of these devices.

There are many publications on RF energy harvesting in the literature, especially on antenna with rectifier and system design (Kaur et al., 2019; M Palandoken et al., 2018; Merih Palandoken & Gocen, 2019; Zeng et al., 2017). In (Sun et al., 2012), offered rectenna with simple structure and 8.6 dBi gain operates at 2.45 GHz. Also in (Sun et al., 2012), have been modeled a rectenna for near field wireless power transmission system on high power level also operates at 2.45 GHz. Physically transparent rectifier (Sun et al., 2012), and RF EH antenna and RF to DC rectifying circuit for urban applications studies (Jiang et al., 2014) also be found in literature. (Zhang et al., 2009) has been used compact folded dipole architecture for rectenna designment.

In this paper, an antenna designment is proposed for use in RF EH applications operating at 2.4 GHz frequency. Electromagnetic numerical calculation tools have been used in antenna modeling and antenna performance has been verified with these programs. Antenna modeling has been made on FR-4 base material with a 1.6 mm thick. Section 2 presents the designment parameters of proposed RF EH antenna, Chapter 3 presents the performance parameters and numerical calculation results of the proposed antenna, and Chapter 4 presents the conclusion and recommendations.

2. Material and Method

The designment of the proposed radio frequency energy harvesting (RF EH) antenna with geometrical model parameters in mm is shown in Figure 1. The antenna substrate is FR-4 the material thickness of the substrate is 1.6 mm with a ε_r of 4.3 and a tan δ of 0.02. The RF EH antenna is modeled and optimized to retrieve the energy from the ambient at the electromagnetic spectrum in microwave range of ISM band 2.4 GHz. The physical extents of the antenna are 35 x 28 mm.

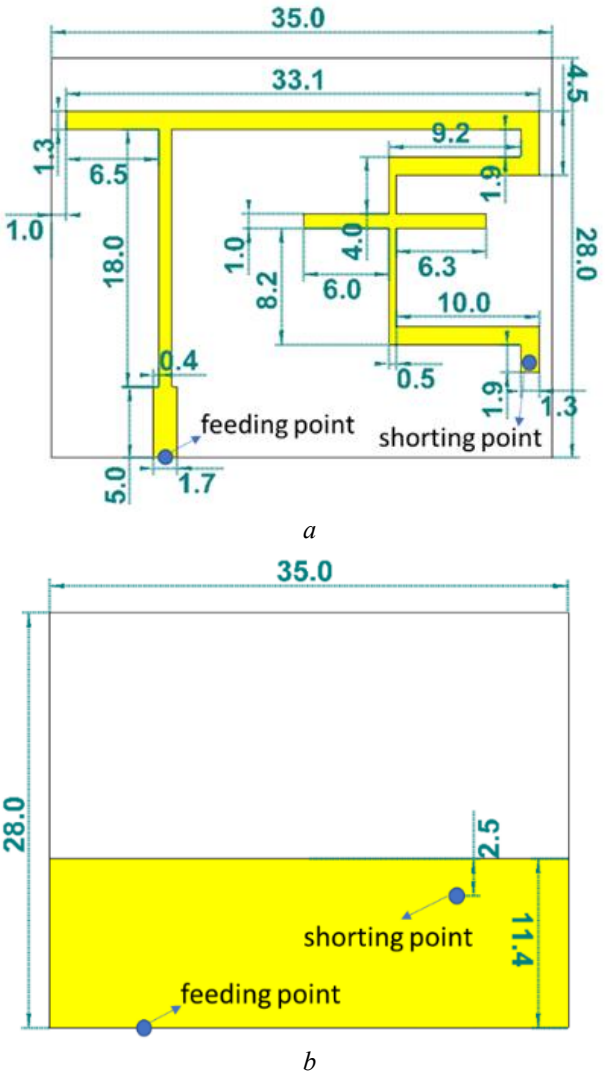

Figure 1. Proposed RF EH antenna designment: (a) top and (b) ground layers.

There is a long feed line on the top layer of the RF EH antenna, which is subsequently narrowing in the middle, this line is divided into two asymmetrical transmission lines at the top. An E-shaped conductor is formed at the end of the right one of these asymmetrical transmission lines. The E-shaped conductor, created to adjust the 2.4 GHz resonance frequency, the antenna has been short-circuited to the ground layer according to a pin to improve the return loss parameter. On the ground layer of the RF EH antenna, there is a short and wide ground conductor extending from the bottom to the middle.

3. Results and Discussion

The RF performance parameters of the RF EH antenna is numerically computed using a commercial 3D based on a TLM

and the FIT, CST Studio Suite. The operating performance of the proposed RF EH antenna has been examined in the 1.8 - 3 GHz range, and the S_{11} value has been obtained as 23.29 dB at the 2.4 GHz centre operating frequency, and the operational bandwidth has been obtained as 170 MHz in the 2.33 - 2.50 GHz range. The S_{11} graph is presented in Figure 2.

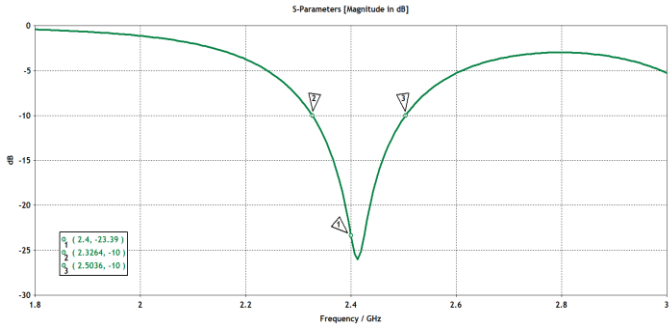

Figure 2. The S_{11} graph of the proposed RF EH antenna.

The 3D radiation pattern of the proposed RF EH antenna is shown in Figure 3. The peak level of realized gain is 2.0 dBi at 2.4 GHz. The antenna radiation performance can be concluded as 98.1% radiation efficiency with a directivity of 2.1 dBi.

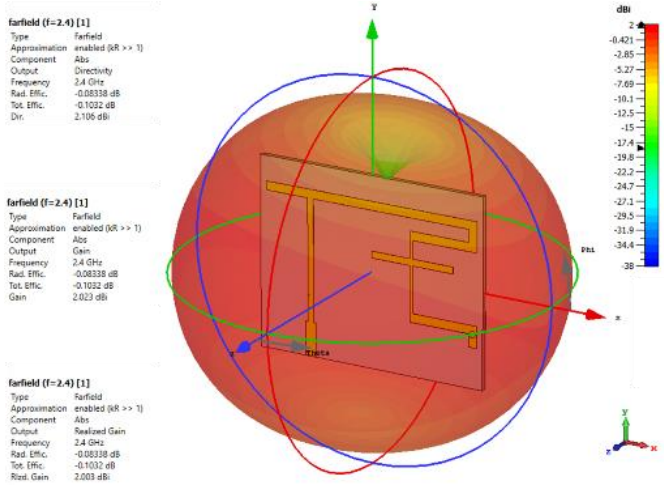

Figure 3. The 3D radiation pattern of the proposed RF EH antenna at the resonance frequency of 2.4 GHz.

The polar radiation pattern of the proposed RF EH antenna is shown in Figure 4. The HPBW of the radiated field is 92.1 degrees in the phi = 90 plane.

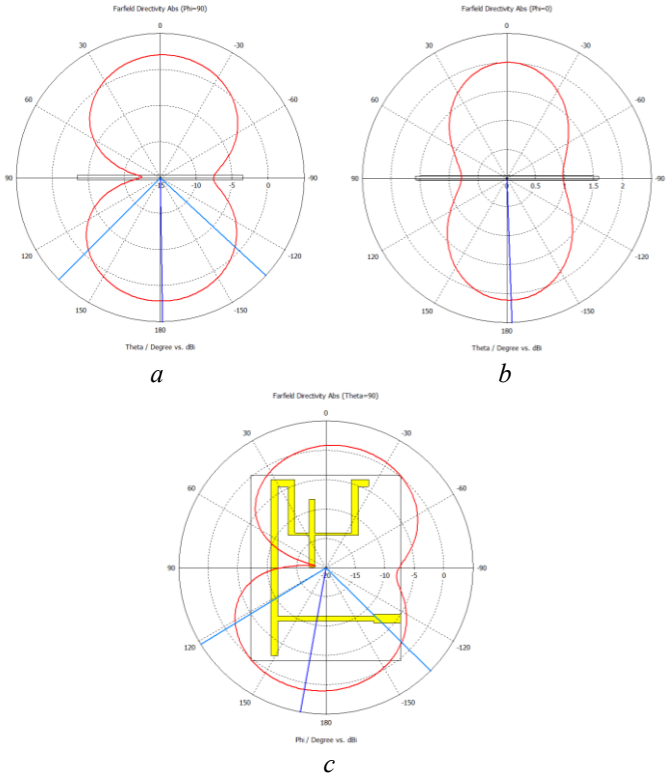

Figure 4. The 3D radiation pattern of the proposed RF EH antenna at the resonance frequency of 2.4 GHz.

4. Conclusions and Recommendations

In this study, an RF EH antenna which operates in the ISM 2.4 GHz band has been modeled. The realized antenna has 2.0 dBi gain and 98.1% radiation efficiency. Due to the small size and compact structure of the antenna, it is thought that it is possible to use it with a rectifier unit in small medical devices with low energy consumption. The performance of the proposed antenna can be improved by developing surrogate based models.

5. Acknowledge

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