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Research Article

Microstrip Patch Antenna Array Design for RF Energy Harvesting Applications

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Abstract

In recent years, with the rapid developments in the field of technology and the development of wireless communication systems; led to a noticeable increase in the number of portable, rechargeable and low-power devices. These electronic devices have become a necessity even in our simplest works, due to the increase in their number and variety; It is desired that the energy needs can be met continuously and quickly at a low cost. Batteries, which are non-renewable generators, provide the energy required for such low-power devices in the world. The increase in the tendency towards non-renewable energy sources leads to negative environmental and economic consequences. Therefore, it becomes important to turn to renewable energy sources and to work on it. Energy harvesting systems, which are an innovative energy source, are the best potential alternatives to collect the energy needed by the mentioned low-power devices. With the increase of different frequency bands such as GSM 900, GSM 1800, UMTS, 3G, Wi-Fi, Wi-Max and LTE, RF energy harvesting is becoming quite common. In this paper, a printed multiband microstrip patch antenna is presented. Antenna design covers numerically calculated frequencies of 1.6dBi at 2.4GHz, 3.95dBi at 5.2GHz, gain values, and frequencies often used for electronic device communication such as Wi-Fi 2.4GHz and WiMAX. The proposed antenna design has allowable gain values to be used for RF energy harvesting applications.

Keywords: RF Energy Harvesting, Antenna Design, Microstrip Patch Antenna, Array Antenna, Low Power Application

RF Enerji Hasatlama Uygulamaları için Mikroşerit Dizi Anten Tasarımı

Öz

Son yıllarda teknoloji alanındaki hızlı gelişmeler ve kablosuz iletişim sistemlerinin de geliştirilmesiyle; taşınabilir, şarj edilebilir ve düşük güçlü cihazların sayısında gözle görülebilir bir artışa neden olmuştur. Bu elektronik cihazlar en basit işlerimizde dahi ihtiyaç haline gelmiş olup, sayılarının ve çeşitlerinin artması nedeniyle; enerji ihtiyacının düşük maliyetle, sürekli ve hızlı bir şekilde karşılanabilir olması istenmektedir. Dünyada bu tarz düşük güç tüketen cihazlara gereken enerjiyi genellikle yenilenemeyen üreteç olan piller sağlamaktadır. Yenilenebilir enerji kaynaklarına yönelmek ve bunun üzerine çalışmalar yapmak önemli hale gelmektedir. Bahsedilen düşük güçlü cihazların ihtiyacı olan enerjinin toplanabilmesi için yenilikçi bir enerji kaynağı olan enerji hasatlama sistemleri en iyi potansiyel alternatiflerdir. GSM 900, GSM 1800, UMTS, 3G, Wi-Fi, Wi-Max ve LTE gibi farklı frekans bantlarının artmasıyla birlikte RF enerji hasadı oldukça yaygın hale gelmektedir. Bu yazıda, basılı birçok bantlı mikroşerit yama anteni sunulmaktadır. Anten tasarımı, sayısal olarak hesaplanan 2,4 GHz'de 1,6 dBi, 5,2 GHz'de 3,95 dBi frekansları, kazanç değerlerini ve genellikle Wi-Fi 2,4 GHz ve WiMAX gibi elektronik cihaz iletişimi için kullanılan frekansları kapsar. Önerilen anten tasarımı, RF enerji hasatlama uygulamaları için kullanılmasına izin verilen kazanç değerlerine sahiptir.

Anahtar Kelimeler: RF Enerji Hasatlama, Anten Tasarımı, Mikroşerit Yama Anten, Dizi Anten, Düşük Güç Uygulamaları

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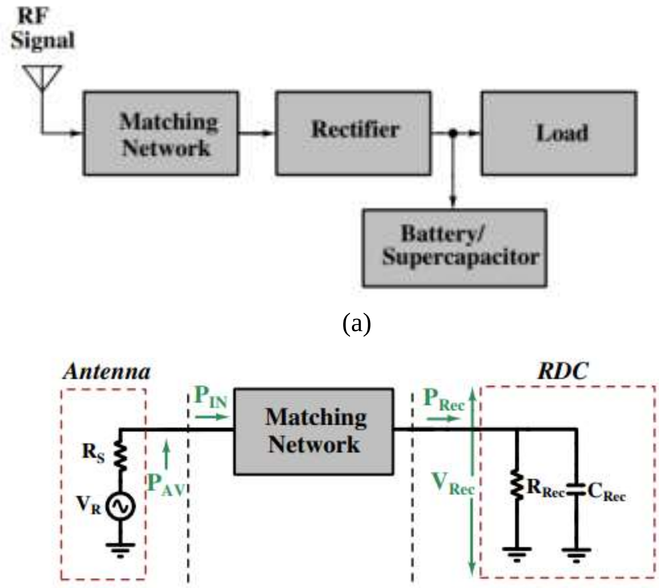
1. Introduction

With the development of wireless communication systems and their enrichment in terms of content, these technologies have been widely used and become widespread. Today, with the rapid development of technology, the problem of finding a reliable and sustainable energy source for wireless communication devices has been encountered [1]. In this paper, radio frequency energy harvesting systems have become promising solutions to power next generation wireless networks such as wireless sensors, autonomous internet of things (IoT), wireless communication devices [2]-[3]. In urban areas, there are many radio frequency energy sources such as television broadcasting, mobile phone signals and wireless networks [4]. Thus, there is a huge amount of electromagnetic energy in the environment and if this energy is collected, it can be used in low-power devices [5]. RF wireless power providers are the best potential alternatives for devices that help these devices run smoothly. Under favour of RF energy harvesting systems, some of the energy can be collected and converted into usable DC voltage.



(a)

(b)

Fig. 1 RF energy harvesting system. (a) Simplified block diagram and (b) its equivalent circuit representation [6].

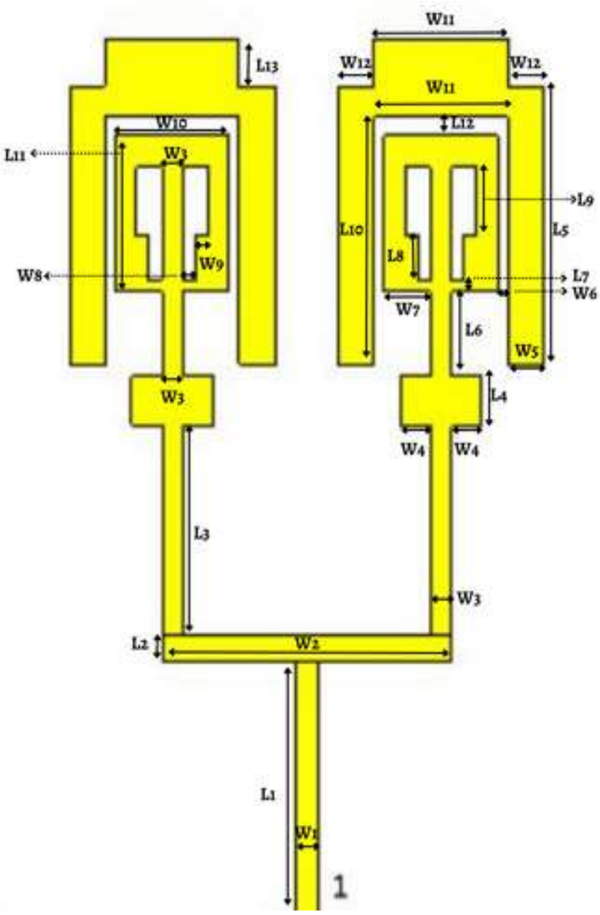
Radio frequency energy harvesting using electromagnetic waves to power such systems is becoming widespread with the increase of different frequency bands such as GSM 900 (925–960), GSM 1800 (1805–1880), UMTS (1920-1980) (2110–2170), LTE (2620–2690), Wi-Max (3400-3800) and Wi-Fi (2400-2495) (5150-5850) which used in communication [3]-[7]. Wireless energy, can be harvested using a suitable rectenna system. Rectennas consists of microstrip antenna, matching circuit, rectifier and low pass filter. The rectifier converts the RF power to a DC voltage. A resistor is usually connected as a load to the output of the rectifier to obtain the DC voltage. Proper matching with the rectifier should be made to increase the conversion efficiency.

Microstrip antenna is the most preferred antenna for energy harvesting due to its advantages such as small size, light weight and ease of manufacture [8]. To improve the demanding power requirements of the RF energy harvesting system, multiband and broadband antennas have been explored for practical options regarding efficiency. A multi-band and broadband receiving antenna is expected to efficiently collect energy from simultaneously available frequency bands in the real environment.

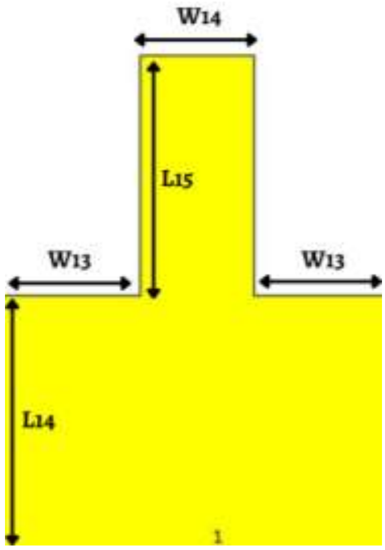
In this study, a microstrip patch antenna was designed for RF energy harvesting systems. In section II, the methods used in antenna design and antenna parameters are explained. The simulation results of the designed antenna are shown and discussed in section III. In section IV, the conclusion of the study is summarized.

2. Material and Method

The most common in wireless transmission technologies, especially in microwave systems, is the microstrip patch antenna because of its characteristics. They provide high performance and low cost in production [9]-[10]. For these reasons, microstrip patch antenna was used in antenna design for RF energy harvesting. In this study, microstrip fed antenna was used as the feeding technique. In this report, a dual-band microstrip patch antenna operating at 2.4GHz and 5.2GHz frequencies was designed and simulated for use in RF energy harvesting systems. The proposed antenna is fabricated on a low cost FR4 substrate with a thickness (h) of 1.6 mm. Annealed copper is used as ground and patch materials with 0.035 mm thickness. The designed antenna has compact dimensions of 28mm x 47mm. Antenna layout is shown in the Fig. 3 and its design was carried out with the numerical calculation program.



(a)



(b)

Fig. 2 (a) Front and (b) Back of the microstrip antenna

A dual-band microstrip antenna for RF energy harvesting is presented in [11]. Based on the proposed microstrip antenna geometry, a two-slot microstrip antenna was designed. The microstrip feed line can be thought of as a patch extension and can be easily matched by adjusting the inset feed position; however, it increases the substrate thickness and limits the bandwidth [11]-[12]. In this study, based on references, inset feeding and stub were tried and improvement was observed in S11 results. Radiated harmonics can be controlled using a stub in the feed line.

In order to improve the gain values of the additionally designed antenna, the antenna is turned into an array antenna.

Table 1. Parameters of the Proposed Antenna.

Par.	Value (mm)	Par.	Value (mm)	Par.	Value (mm)
W1	1	W11	5.9	L7	0.5
W2	12.7	W12	1.6	L8	1.9
W3	0.9	W13	10	L9	2.8
W4	1.4	W14	8	L10	10.3
W5	1.6	L1	10.8	L11	6.5
W6	1	L2	1	L12	1.5
W7	2	L3	8.8	L13	2
W8	0.6	L4	2	L14	18.5
W9	0.5	L5	11.5	L15	17
W10	5	L6	3.5		

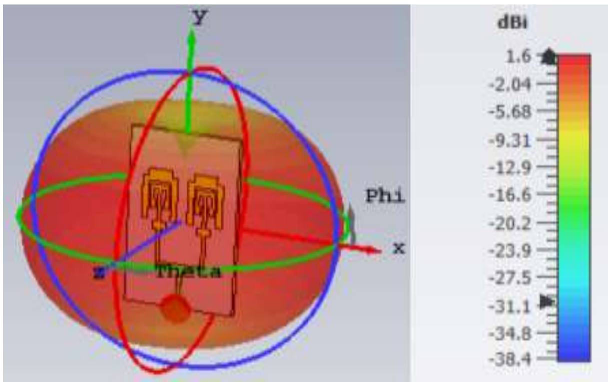
3. Results and Discussion

3.1. Results

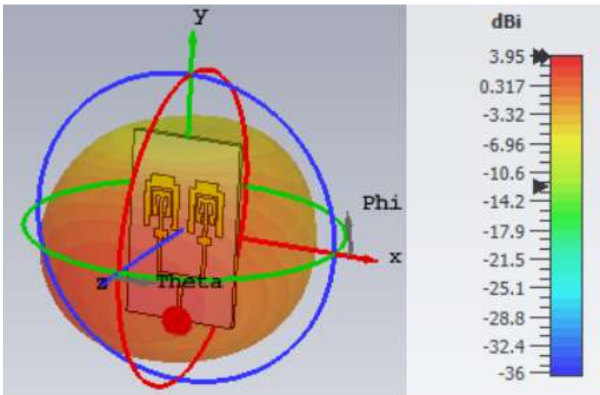
According to the simulation results, when the S1,1 properties of the antenna are examined, it is seen that it resonates at 2.4GHz and 5.2GHz frequencies. The reflection coefficient of proposed antenna are -20.6dB for 2.4GHz, -16dB for 5.2GHz. Bandwidths of the antenna are 340.5MHz (2.2961GHz-2.6366GHz), 293.4MHz (5.0606GHz-5.354GHz) respectively.

In addition, 3D radiation patterns and gains for 2.4GHz and 5.2GHz are given in Figure 4 (a, b).

Fig. 3 S11 graph of proposed antenna



(a)



(b)

Fig. 4 Simulated 3D Radiation Pattern and Gain of the Proposed Antenna (a) 2.4GHz (b) 5.2GHz

Table 2. Gain, S11 and Efficiency values of proposed antenna

Frequency	Gain (dBi)	S11 (dB)	Rad. Effic.	Tot. Effic.
2.4GHz	1.6dBi	-20.6dB	%81	%80
5.2GHz	3.95dBi	-16dB	%69	%67

3.2. Discussion

With the rapid development of technology, many wireless systems emit electromagnetic energy to the environment. A large part of this emitted energy is faded away before it reaches its target, and antenna studies aiming at the recovery of ambient energy ensure that this problem is effectively eliminated. In addition, for the design of the wireless communication network, providing the energy to replace the battery or charge the battery from the environment, that is, to be a renewable energy source, will be the most appropriate solution in terms of both cost and environment.

4. Conclusions and Recommendations

This study presents a step-by-step procedure for the design and optimization of a two-band microstrip patch antenna in Wi-Fi 2.4GHz and WiMAX bands for RF energy harvesting applications. The optimized antenna has two resonant frequencies of 2.4GHz and 5.2GHz, covering various media communication networks and systems. The simulation results show that the antenna gains 1.6dBi and 3.95dBi at the resonant frequencies, respectively. The designed antenna has satisfactory parameter values such as bandwidth, VSWR and reflection coefficient. As a result, it can be used in RF energy harvesting applications with the designed antenna combiner, rectifier and matching circuits. Thus, the antenna can be a source of energy to power low-power electronic devices

5. Acknowledge

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