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Research Article

Γ-Shaped Asymmetrical Monopole Antenna on Truncated DGS For Multiband RF Energy Harvesting Applications

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Abstract

In today's world, through the advancement of technology, wireless communication has become an integral part of our lives with the utilization of versatile electronic devices such as cell phones, tablets, and computers that contain wireless communication modules. The idea of utilizing different frequencies and power of RF signals in the environment has led to the concept of harvesting RF signals to produce DC output voltage. In this paper, a printed multiband monopole antenna is presented. The proposed antenna is composed of two Γ-shaped asymmetrically positioned feeding lines which are located on slotted truncated ground plane with three stubs loaded on both ground plane sides. The antenna design covers the frequently used frequencies for electronic device communication, such as GSM 1800, UMTS 2100, WLAN 2450 and LTE 2600 With the numerically computed gain values of 3.89dBi at 1.8GHz, 4.51dBi at 2.1GHz, 5.02dBi at 2.45GHz, and 5.03dBi at 2.6GHz, respectively. The proposed antenna design has permissible gain values to be used for RF energy harvesting applications.

Keywords: RF Energy Harvesting, Antenna Design, Monopole Antenna.

Γ-Shaped Asymmetrical Monopole Antenna on Truncated DGS For Multiband RF Energy Harvesting Applications

Öz

Günümüz dünyasında teknolojinin gelişimi ile birlikte cep telefonları, tabletler ve birgisayarlar gibi kablosuz iletişim modülü içeren cihazlar hayatımızın ayrılmaz bir parçası haline gelmiştir. Bu cihazlardan çevreye yayılan radyo frekans sinyallerinden DC çıkış voltajı üretme fikri RF enerji hasatlama fikrini ortaya çıkarmıştır. Bu bildiride baskılı multi-band monopol anten tasarımı sunulmaktadır. Antenin tasarımı asimetrik besleme hattına sahip, her iki yanı Γ şeklinde ve iç kısmında 3 yarıktan oluşmaktadır. Tasarlanan anten elektronik haberleşmede sıklıkla kullanılan GSM1800, UMTS 2100, WLAN 2450 ve LTE 2600 frekanslarını kapsar ve kazanç değerleri sırasıyla 1.8GHz'de 3.89dBi, 2.1GHz'de 4.51dBi, 2.45GHz'de 5.02dBi, 2.6GHz'de 5.03dBi değerlerinde sayısal olarak hesaplanmıştır.

Anahtar Kelimeler: RF Enerji Hasatlama, Anten Dizayn, Monopol Anten.

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1. Introduction

Communication technology is developing with an exponential growth in today's world. Wireless electronic devices have become an undetachable part of our lives with development IoT technology. Especially daily used electronic devices are those that almost everyone has operated with the amount in billions today and they emit a certain amount of radio frequency energy[1]. Since radio frequency energy is transmitted to the receiver in omni-directions, most of the energy is wasted. For this reason, the idea of RF energy harvesting is introduced for the scavenging of wasted RF energy. The first RF power transmission system has been designed by Brown et. all. at NASA[2]. RF signals can carry energy with the power densities between 0.1μW/cm^2 and 0.01μW/cm^2[3].

Table 1. Performance of harvestable ambient energy sources with power density[3].

Energy Source	Types	Energy-Harvesting Method	Power Density
Radiant	Solar	Solar cells (indoors)	< 10μW/cm^2
		Solar cells (outdoors, sunny days)	15mW/cm^2
	Radio Frequency	Electromagnetic conversion	0.1μW/cm^2 (GSM)
		Electromagnetic conversion	0.01μW/cm^2 (WiFi)
Mechanical	Wind Flow and Hydro	Electromechanical conversion	16.2μW/cm^3
	Acoustic Noise	Piezoelectric	960nW/cm^3
	Motion	Piezoelectric	330μW/cm^3
Thermal	Body heat	Thermoelectric	40μW/cm^2

Compared to other energy sources, the energy content is very low. Therefore there is a requirement for an efficient system to harvest RF signals.

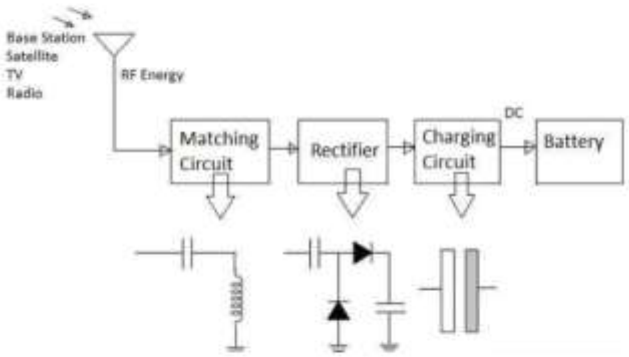

Fig. 1 RF energy harvesting system block diagram[4].

The typical block diagram of RF energy harvesting circuit is shown in Fig. 1 [4]. It consists of a receiving antenna, impedance matching circuit, rectifying circuit. The antenna receives radio frequency (RF) signals from the surrounding environment. To enable efficient and matched transmission of power between the antenna and rectifier circuit, a matching network is employed. The rectifier circuit converts the RF signal to direct current (DC) form. By utilizing a DC-DC converter, the desired voltage value can be achieved.

Recently, much progress has been made in RF energy harvesting technology[5]. Jeroen A.C. Theeuwes et.al are able to work the wall clock with the RF energy harvesting system which has been designed without cell battery[6]. Also, RF energy harvesting system has a very important place in the biomedical science. Wireless sensors implanted in the body are desired to be as small as possible and to be long-lasting.

Wireless sensors use batteries as an energy source for instance in the case of pacemakers. When these devices are implanted in the body, battery usage is undesirable because of it is bulky. In addition, the battery limits the operating times of the wireless sensors. Therefore, implanted sensors need to be replaced regularly, and this process requires surgical operation in the patient's body. Therefore, the patient may become infected[7]. If the wireless sensors used in the biomedical science work with the RF energy harvesting system, battery usage can be eliminated. In this way, patients are going to be able to live with this sensors for a lifetime without the need for surgical operation.

In this paper, multiband monopole antenna design used for RF energy harvesting system is presented. In Section II, the materials and methods used in antenna design are explained. In section III, the results of the designed antenna are shown. In Section IV, the discussion is conducted. In Section V, the study result is summarized.

2. Material and Method

In this study, a multiband monopole antenna is designed. Two Γ-shaped asymmetrically positioned feeding lines are located on slotted truncated ground plane with three stubs loaded on both sides of ground plane. The proposed antenna size is 60x90x0.87 mm^3 and has been optimized using parametric sweep. This antenna is printed on a RO4003C substrate with a dielectric constant of 3.55, loss tangent of 0.0027 and thickness of 0.87 mm. Annealed copper is used as ground and patch materials with 0.035 mm thickness.

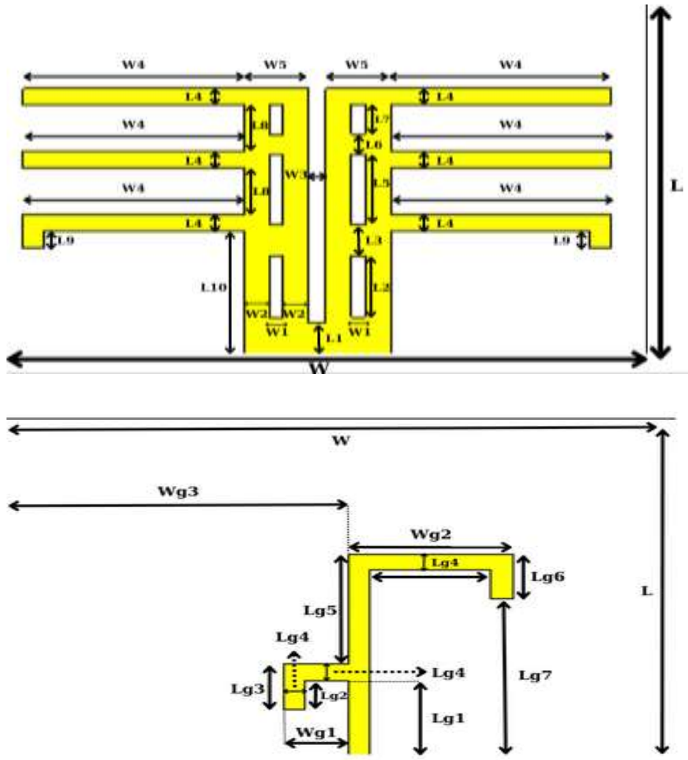

Fig. 2 Proposed antenna design.

Table 2. Parameters of the Proposed Antenna.

Par.	Value (mm)	Par.	Value (mm)	Par.	Value (mm)
W1	2	**L1**	5.5	**L6**	3.5
W2	3.425	**L2**	11.5	**L7**	5
W3	2.3	**L3**	5.5	**L8**	8.05
W4	30	**L4**	2.9	**L9**	3
W5	8.85	**L5**	12.4	**L10**	21.5
Wg1	8.65	**Wg2**	21.70	**Wg3**	43.85
Lg1	13.48	**Lg2**	5.15	**Lg3**	8
Lg4	2.85	**Lg5**	19.67	**Lg6**	8
Lg7	28	**W**	90	**L**	60

The designed antenna model is numerically computed.

3. Results and Discussion

3.1. Results

According to the simulation results, the bandwidths of antenna are 99.8 MHz (1496.5 MHz – 1596.3 MHz), 108.1 MHz (1701.4 MHz – 1809.5 MHz), 787.3 MHz (1828.8 MHz – 2616.1 MHz) respectively. The resonance frequencies are numerically computed as 1554 MHz (1496.5 MHz – 1596.3 MHz), 1803.4 MHz (1701.4 MHz – 1809.5 MHz), 1998.4 MHz and 2532 MHz (1828.8 MHz – 2616.1 MHz) respectively. Farfield parameters at 1.8 GHz, 2.1 GHz, 2.45 GHz and 2.6 GHz are summarized in Table 3. Also, 3D radiation patterns for 1.8 GHz, 2.1 GHz, 2.45 GHz, 2.6 GHz are given in Figure 4 and Figure 5, Figure 6, Figure 7.

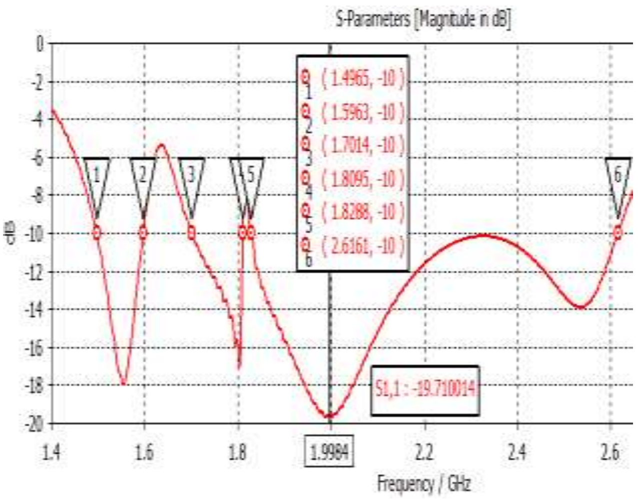

Fig. 3 S11 graph of proposed antenna.

The input reflection coefficients, S11 values of proposed antenna are -18 dB for 1554MHz, -16.995dB for 1803.4MHz, -19.7dB 1998.4 MHz, -13.9 dB for 2532 MHz.

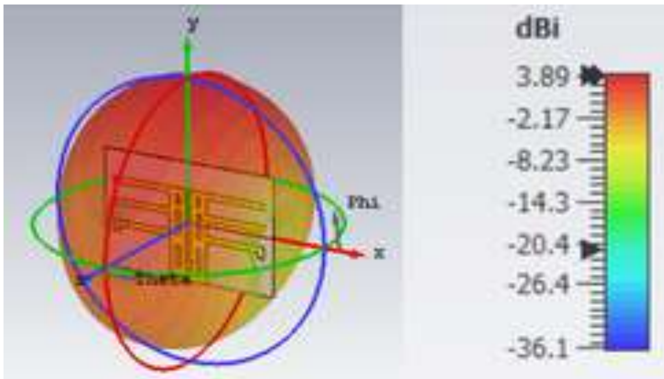

Fig. 4 Simulated 3D radiation pattern at 1.8 GHz for the proposed antenna.

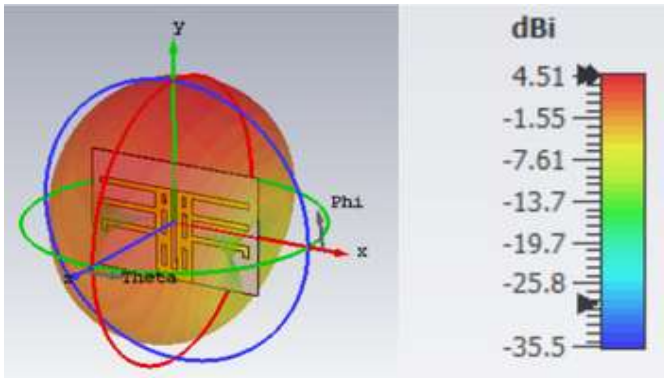

Fig. 5 Simulated 3D radiation pattern at 2.1 GHz for the proposed antenna.

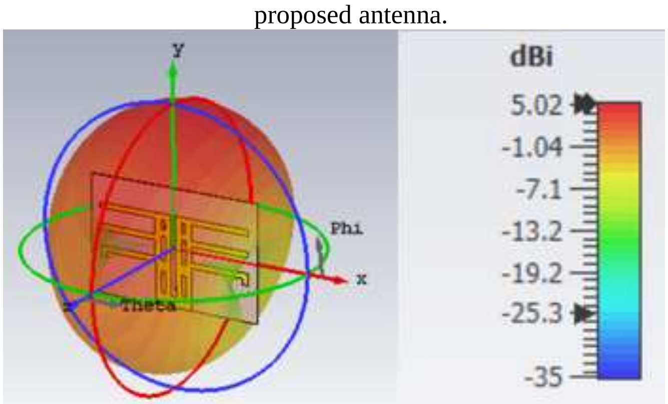

Fig. 6 Simulated 3D radiation pattern at 2.45 GHz for the proposed antenna.

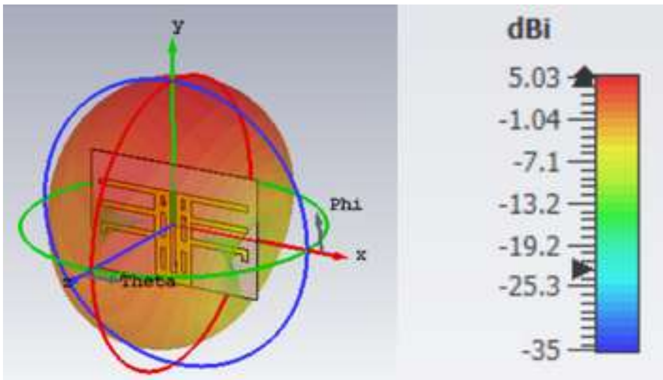

Fig. 7 Simulated 3D radiation pattern at 2.6 GHz for the proposed antenna.

Table 3. Gain, S11 and Efficiency values.

Frequency (GHz)	Gain (dBi)	S11 (dB)	Radiation Efficiency	Total Efficiency
1.8 GHz	3.89 dBi	-15.784 dB	%95	%92
2.1 GHz	4.51 dBi	-15.218 dB	%97	%94
2.45 GHz	5.02 dBi	-11.791 dB	%97	%90
2.6 GHz	5.03 dBi	-11.151 dB	%95	%88

3.2. Discussion

Many electronic devices operate where battery replacement is very costly, inconvenient or impossible. Therefore, there is a high demand for wireless energy transfer to these devices. There are two main advantages of using the RF energy harvesting system. First of all, unlike batteries, RF energy harvesting systems have an almost unlimited lifetime. Secondly, it is an environmental friendly as it does not create waste that pollute the environment. In consequence, the RF energy harvesting system is a very good alternative power supply for devices operating in extreme conditions.

4. Conclusions and Recommendations

In this paper, an antenna design that can harvest radio frequency energy at low power and high efficiency has been designed. The antenna can harvest the widely used in communication GSM 1800, UMTS 2100, WLAN 2450 and LTE 2600 frequencies. The gain values are 3.89dBi at 1.8GHz, 4.51dBi at 2.1GHz, 5.02dBi at 2.45GHz, and 5.03dBi at 2.6GHz, respectively. Based on these results, the antenna designed is proper for RF energy harvesting.

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References

[1] Özkaya, U., & Seyfi, L. (2018). Dimension Forecast in Microstrip Antenna for C/X/Ku Band by Artificial Neural Network. *In 2nd International Symposium on Innovative Approaches in Scientific Studies* (Vol. 3, pp. 518-522).

[2] Brown, W. C. (1984). The history of power transmission by radio waves. *IEEE Transactions on microwave theory and techniques*, *32*(9), 1230-1242.

[3] Adu-Manu, K. S., Adam, N., Tapparello, C., Ayatollahi, H., & Heinzelman, W. (2018). Energy-harvesting wireless sensor networks (EH-WSNs) A review. *ACM Transactions on Sensor Networks (TOSN)*, *14*(2), 1-50.

[4] Shahabuddin, A. A., Shalu, P. D., & Akter, N. (2018). Optimized process design of rf energy harvesting circuit for low power devices. *International Journal of Applied Engineering Research*, *13*(2), 849-854.

[5] Takacs, A., Okba, A., Aubert, H., Charlot, S., & Calmon, P. F. (2017, May). Recent advances in electromagnetic energy harvesting and Wireless Power Transfer for IoT and SHM applications. In *2017 IEEE International Workshop of Electronics, Control, Measurement, Signals and their Application to Mechatronics (ECMSM)* (pp. 1-4). IEEE.

[6] Theeuwes, J. A., Visser, H. J., Van Beurden, M. C., & Doodeman, G. J. (2007, October). Efficient, compact, wireless battery design. In *2007 European Conference on Wireless Technologies* (pp. 233-236). IEEE.

[7] Kim, Y. J., Bhamra, H. S., Joseph, J., & Irazoqui, P. P. (2015). An ultra-low-power RF energy-harvesting transceiver for multiple-node sensor application. *IEEE Transactions on Circuits and Systems II: Express Briefs*, *62*(11), 1028-1032.