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Research Article

UWB Microstrip Patch Antenna Design for Energy Harvesting Applications

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Abstract – RF energy harvesting systems, which are the receiver part of Wireless Power Transfer (WPT), have gained significant development in recent years. For maximum energy acquisition over a wide frequency range, such as to provide power to small handheld devices like cell phones, tablets, smart watches, and other smart devices, wideband and compact antennas are desired. RF systems are expected to cover different frequency bands, such as 2.4 GHz, 5.1 GHz, 5.8 GHz (Bluetooth/Wi-Fi), 2.3 GHz, 2.5 GHz, 3.5 GHz, 5 GHz (WiMAX), for energy harvesting. For such an RF harvesting system, the antenna is desired to have a wide bandwidth, good gain, and an omnidirectional radiation pattern. Energy harvesting devices refer to designs that integrate production and storage. For instance, radio frequency energy sources contain a large amount of electromagnetic energy in the environment, and with RF energy harvesting systems, a portion of this electromagnetic energy can be collected and converted into usable DC voltage. Microstrip patch antennas are very good alternatives for energy harvesting applications because they are cost-effective, compact in size and weight, flat in structure, and highly repeatable. This paper presents a microstrip patch antenna with a bandwidth of 3.9 GHz in the 3.4 to 7.3 GHz range for UWB applications. The antenna design has a gain value of 3.28dBi at the numerically calculated resonance frequency of 4.9 GHz and generally covers frequencies used for electronic device communication such as Wi-Fi 5 GHz and WiMAX. The proposed antenna design has gain values that are allowed to be used for RF energy harvesting applications.

Keywords – Microstrip Patch Antenna, UWB, Energy Harvesting, Antenna Design, WPT

I. Introduction

The need for self-sufficient energy harvesting devices has been steadily increasing in recent years, driven by the difficulties associated with charging or replacing battery, as well as the maintenance demands of battery-powered systems. Significant amount of energy is consumed during the charging of electronic devices. Harvesting ambient energy from sources such as radio frequencies ($1\mu W/cm^2$), solar ($100mW/cm^2$), thermal ($60\mu W/cm^2$) and vibration ($200\mu W/cm^2$) can provide a solution to the energy demand [1]. Most of the other sources, except for RF energy, are reliant on the surrounding environment, which makes RF energy harvesting technology more useful in important application areas such as environmental monitoring, health, and defense [2-3]. While Nicola Tesla [3] had previously introduced the idea of transforming electromagnetic energy into electrical energy, it was early 1990s that the notion of RF energy harvesting was introduced.

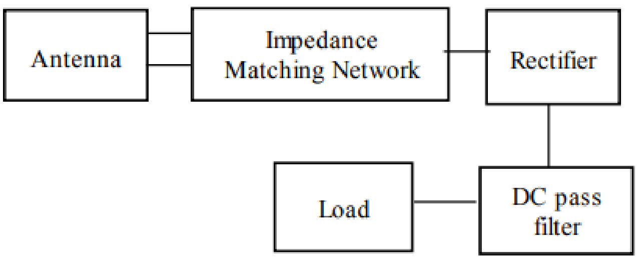


Fig. 1 RF energy harvesting block diagram [4].

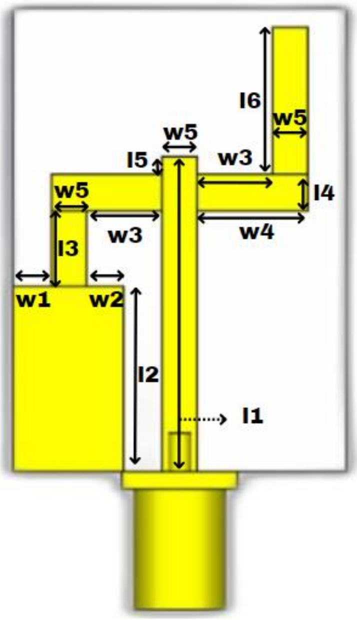
The Ultra-Wideband (UWB) system has been used frequently in addition to the artificial materials [5-6] based planar antenna designs dedicated to be used in energy harvesting systems [7]. Applications for UWB include radar, medical imaging, and military communications [8]. Devices with a bandwidth greater than or equal to 500 MHz, but with a fractional bandwidth that is at least 20% higher than the center frequency, are classified as UWB devices [9]. The advantages of UWB technology are; high data rate, security, low cost and low interference as encountered in high frequency operating integrated photonic transmitter modules [10].

Coplanar waveguide powered antenna designs in addition to modified Hilbert fractal shaped microstrip antennas for RF energy harvesting are presented in [8] and [11-12]. In this study, an asymmetric coplanar line fed antenna was designed. The aim of the design is to realize an antenna that meets properties such as wide bandwidth and good radiation characteristics, which can be employed in RF energy harvesting applications alongside combiner, rectifier, and matching circuits. In this paper, describes the design of a compact asymmetric coplanar line-fed antenna for wideband applications.

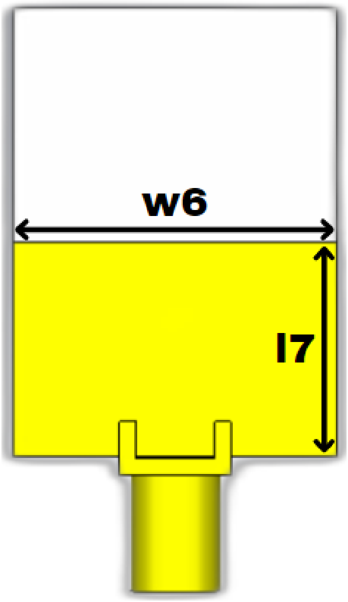
Section II elaborates on the antenna design methodology and the various antenna parameters utilized in the study, while section III shows and discusses the simulation results of the designed antenna. Section V summarizes the conclusion of the study, which focused on designing a UWB microstrip patch antenna for RF energy harvesting systems.

II. Materials and Method

On a low-cost FR4 substrate with a relative permittivity (εr) of 4.3, loss tangent of 0.025, and thickness (h) of 1.6 mm, the proposed antenna is fabricated using annealed copper with a thickness of 0.035 mm for the ground and patch materials. The antenna design was performed using a numerical calculation program, and its compact dimensions of 18mm x 27mm are shown in Fig. 2.



(a)



(b)

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

Table 1. Dimensions of the Antenna

Par.	Value (mm)	Par.	Value (mm)
w1	2.1mm	l2	10mm
w2	2mm	l3	4mm
w3	4.1mm	l4	2mm
w4	6mm	l5	1mm
w5	1.9mm	l6	8mm
w6	18mm	l7	12mm
l1	17mm		

III. RESULTS

The simulation results indicate that the antenna resonates at a frequency of 4.9 GHz when examining its S11 properties. The antenna being proposed has a reflection coefficient of -35.2dB at 4.9 GHz, with a bandwidth ranging from 3.4128 GHz to 7.3302 GHz, which amounts to a total bandwidth of 3.9174 GHz. This work has satisfactory results for the 3.9 GHz bandwidth and the central frequency shown in Fig. 3 is 4.9 GHz. In addition, 3D radiation pattern and gain for 4.9 GHz are given in Fig. 4

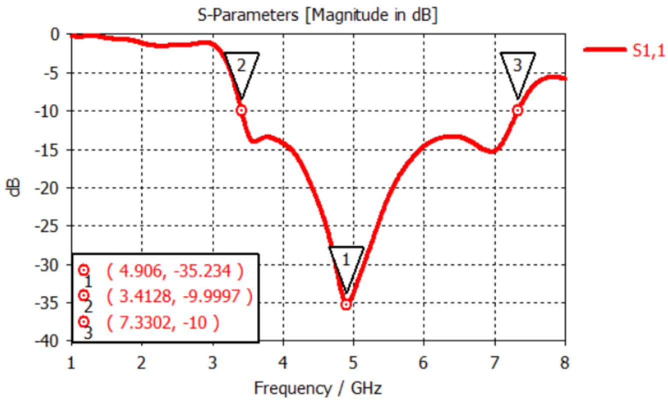


Fig. 3 S11 Parameters

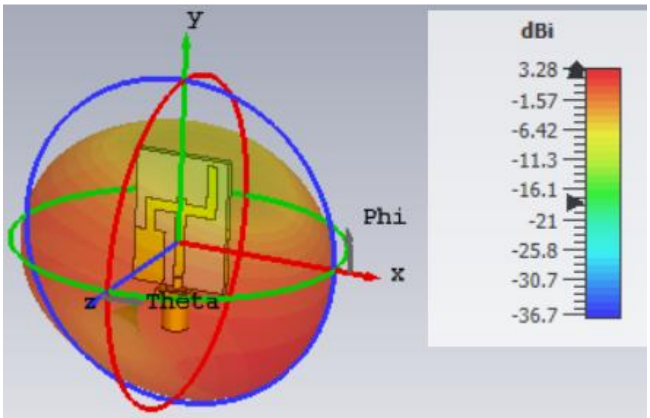


Fig. 4 Gain of antenna for 4.9 GHz

Table 2. Gain, S11, Radiation Efficiency and Total Efficiency values for 4.9 GHz

Frequency	Gain (dBi)	S11 (dB)	Rad. Effic.	Tot. Effic.
4.9GHz	3.3dBi	-35.2dB	89%	89%

IV. DISCUSSION

Increasing reliance on non-renewable batteries to provide energy for low-power devices worldwide has resulted in negative environmental and economic consequences, highlighting the importance of turning towards renewable energy sources. The utilization of energy harvesting systems has emerged as a promising alternative for gathering energy required by low-power devices, serving as a novel and eco-friendly energy source that can effectively tackle these concerns.

V. CONCLUSION

In this study, procedure is presented for the design of a microstrip patch antenna that can cover the Wi-Fi 5GHz and WiMAX bands for RF energy harvesting applications. The designed antenna has a wide bandwidth that covers different media communication networks and systems, with simulation results showing a resonant frequency gain of 3.28dBi. Using CPW technology, a tiny wideband antenna was designed. With a total size of 18x27x1.6 mm^3, the antenna was simulated to operate within the frequency range of 3.41-7.33 GHz. Satisfactory results were obtained in the bandwidth, VSWR and reflection coefficient values of the designed antenna. This antenna has the potential to be integrated with energy harvesting and matching circuits, allowing for the conversion of AC energy into DC energy. As a result, the designed antenna can be an energy source to power low-power electronic devices.

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