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Review paper on flexible rectennas for wireless transfer to wearable applications

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Abstract

The demand for flexible and efficient energy harvesting solutions has surged with the widespread adoption of wearable devices. This review paper provides a comprehensive overview of the current state of research on flexible rectennas, focusing on their application in wireless power transfer to wearable devices. Rectennas, a combination of rectifiers and antennas, play a crucial role in converting radio frequency (RF) energy into usable electrical power. The flexibility of these rectennas is paramount or seamless integration into wearable electronics.

Keywords: Flexible rectenna, wearable applications , wireless power transfer.

Introduction

Most energy resources, such as gas, oil, and nuclear businesses, do not persist indefinitely and their prices fluctuate from time to time. Furthermore, they are not environmentally friendly. To prevent the drawbacks of present energy supplies, alternative ones will be required. There is now a lot of research being done on greener, cleaner, and safer energy resources [1]-[3].

Electronic gadgets have become an integral part of our daily lives in today's globe. However, because to their power consumption, they must be recharged on a regular basis. Furthermore, we must transport the chargers everywhere, which is problematic. An optimised approach is to employ wireless energy harvesting devices, which exploit ambient energy signals in the environment to generate useable electricity. RF radiations are employed for this since they are non-harmful to people and can even reach the ionosphere. As a rlt, this technology is more secure and environmentally friendly. This research examines recent advances in flexible rectennas and their prospective uses in wireless power transmission to wearable devices.

1. Rectenna

A device called "Rectenna" is used to harvest RF energy, which is a combination of a rectifier and an antenna. It essentially transforms electromagnetic energy to direct current (DC). A radiator, an impedance-matching circuit, a rectifier, a DC filter, and a load are all part of it. Rectenna detects electromagnetic (EM) impulses in the environment. Then it transforms them to direct current voltage, which may power low-power devices such as wireless sensors [4]. Rectenna is made up of a radiator, a rectifier, a filter, and a load. Figure 1 shows one example of this. The EM impulses are received by the radiator. There are many different types of antennas, including bipolar, microstrip, helical, dipole, array, planar, and parabolic antennas. Because they have varied design structures and features, they may be used for a variety of purposes.

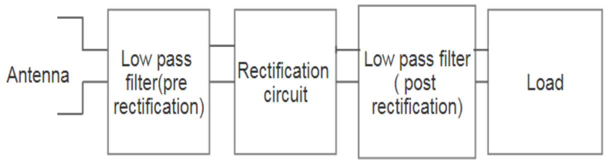

Fig.1 General Rectenna structure

The RF signals recorded by the antenna contain harmonics, which cause signal loss and interference. A low pass filter aids in the reduction of harmonics. It suppresses harmonics to eliminate signal power losses. Rectification is essential for the smooth ac signals received. A rectifier is a device that uses rectifying diodes to correct signals. There are three basic rectifier configurations: 1. single diode, 2. voltage multiplier, and 3. bridge of diodes.

2.Flexible Antenna

One of the issues with an RF energy harvesting system is the size of the embedded devices. They must be compact in order to be installed in low-power devices. As previously stated, an energy harvester requires a radiator to gather RF energy, as well as an impedance matching network and a rectifier. The measurements of the antenna have an effect on the output of the energy harvester. To get high voltage levels, very high impedance loads (e.g., 5M) are required.

Organic, flexible, or printed electronics are powerful research topics [1].Flexible electronics may be designed on flexible and environmentally friendly substrates. This has a wide range of applications. When compared to the cost of silicon industry fabrication techniques, printed electronics is less expensive. Another intriguing development is the growth of IoT. The use of sensors has risen in various fields (domestic, space, military, medical, etc.), most notably in regions with limited access or danger. Normal battery power demands cyclic replacement and is also expensive to reprocess. A way of harvesting RF energy is wireless transfer energy. Heinrich Hertz pioneered wireless energy transmission in 1888 [2], and Nicola Tesla followed suit in the following year.

With reference to the rectenna design, research has been carried out on the following choices of flexiblesubstrate to name a few:

a. Textile-based substrate
b. Polymer-based substrate
c. Paper-based substrate

The above can be used depending on the type of application. These substrates are becoming increasingly important in research for flexibility.

a. **TEXTILE BASED SUBSTRATE**: Textile antennas are the product of combining common textile materials with cutting-edge technology. These are now playing an active role in wireless communication systems [1, 2], aimed at applications such as mobile computing, tracking and navigation [3, 4]. Furthermore, for mass manufacturing and development, wearable antennas must be small in weight, thin, strong, readily maintenance, and inexpensive in cost [5]. To that end, microstrip patch type and planar antennas for garment applications have been proposed, and these antennas have all of the above-mentioned features and are adaptable to any type of surface [6].

b. **POLYMER BASED SUBSTRATE:** The author of [7] created a low-cost energy harvester by combining a rectenna with a solar cell.The design can capture EM energy. The antenna and solar cell shared the same space after using EM analysis to analyse and optimise the specified circuits. As a result, the construction has compact dimensions. A non-linear harmonic balancing optimisation was employed in this study to improve the efficiency of the device rectenna as well as the solar cell. Furthermore, a low-cost and flexible polyethylene terephthalate, also known as PET substrate, and a flexible amorphous silicon solar cell were selected. They provide inexpensive prices as well as a steady structure. A prototype generated a maximum power of 56mW after being lit by solar light. The rectenna with twin bands showed an efficiency of 15% around 850 & 1850 MHz when powered with a microwave beam was presented.

c. **PAPER BASED SUBSTRATE:** Paper is now the cheapest material accessible on Earth [8]. When compared to an equivalently sized FR4 substrate, paper substrate is less expensive. In [9], an optimised design of a circularly polarised 2.45GHz rectenna to be inkjet printed on a paper substrate was demonstrated. This suggested antenna was a shorted ring slot with a mesh ground plane optimised to reduce the size of the region that required inkjet printing. As a result, the amount of silver nano particle ink that had to be applied was reduced. Inkjet printing is an additive method that deposits conductive micro particles on a variety of substrates such as paper. To produce an optimal inkjet printed structure, the quantity of ink must be reduced conductive nanoparticles. A mesh rectenna design was designed to diminish surface that to be inkjet printed. The proposed rectenna is a circularly polarized shorted ring slot structure together with a rectifier element [6]. The presented design results presented that it is feasible to bring down the amount of conductive material and still maintain a good performance. At 2.45GHz frequency, the conversion efficiency was is 39- 45 % when the rectifier is receiving -15 dBm

The flexible substrates are weightless & can be easily bent when compared to that of microwave substrates. This makes them a good substrate choice for using them in wearable antennas where measurements & conformity to the body are basic factors. Organic & polymeric substrates having values of low permittivity [10] can increase the antenna's size. But it also helps in bandwidth enhancement and decreasing the surface wave propagation. This in turn increases the antenna's radiation capability [11].

3.Intergration with Wearable Devices

In [12] we discuss the design and implementation of flexible rectennas (antenna + rectifier) for wireless power transmission to wearable IoT sensor nodes at 24 GHz. Two distinct rectifier setups, shunt and voltage doubler, have been investigated, as illustrated in gig 2 and fig 3. The rectifier circuit is coupled with the antenna array in this design to build a full rectenna for WPT to wearable IoT devices at 24 GHz. This flexible rectifier is made using the traditional PCB fabrication process. At 24 GHz, an RF-DC conversion efficiency of 31% and DC voltage of up to 2.4 V was measured for 20 dBm input power over an ideal load resistance of 300. The proposed flexible rectennas might have a wide range of applications in the field of wearable IoT devices.

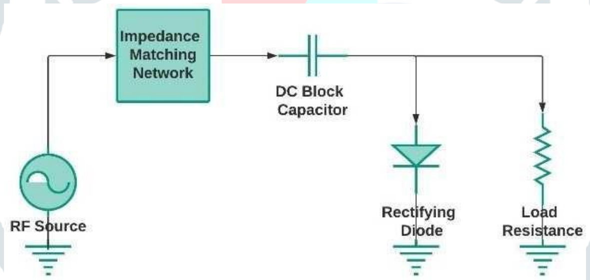

Fig 2. Rectifier circuit in Shunt configuration.

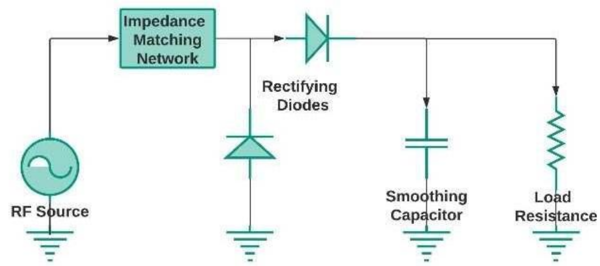

Fig 3. Rectifier circuit in Voltage Doubler configuration.

Dual-polarization antennas are required for both communications and energy harvesting because to the mobility of a wearable antenna and the unpredictable body-centric communications environment. [13] discusses a four-port dual-polarized textile antenna/rectenna for wearable simultaneous wireless information and power transfer (SWIPT) applications. The antenna has two ports for off-body communication as well as gathering energy from horizontal and vertical polarisations. In the presence and absence of the human body, the antenna maintains a 100 MHz bandwidth with an S11 of less than 10 dB about 2.4 GHz, and at least 10 dB small-signal and large-signal isolation across all ports. For varied on-phantom positions across both communication ports, the antenna maintains a measured overall efficiency of 70-88% and a gain of 8.4-9.6 dBi. The measured mutual coupling is less than 10 dB between co-polarized rectenna/antenna ports, and under 16 dB between orthogonally-polarized ports. A broadside harvesting pattern achieves a high RF to DC peak power conversion efficiency of more than 70% (5%). SWIPT microstrip antennas may be used for both full-duplex and multi in multi out (MIMO) applications based on their performance, considerably decreasing the complexity of future battery-free networks for both wearable and non-wearable applications. The antenna compares well with published dual-polarization wearable antennas for off-body communications, demonstrating that the addition of the rectifier ports does not compromise the antenna's performance in terms of port isolation, off-body gain, efficiency, and polarization-purity.

Technological advancements have significantly improved mobile phones. One of the most fundamental restrictions of a mobile phone is its power capacity. As a result, efficient energy management is crucial in such gadgets everywhere. Researchers in [14] are working on a method to wirelessly charge electrical gadgets using radio frequency (RF) electromagnetic (EM) waves (Rectenna employing energy detection-based spectrum sensing). Mechanical deformations result in frequency detuning, which reduces the efficiency of antennas and rectennas, which would otherwise enable wireless communication and RF energy harvesting in the distant field. A self-powered rectenna based on a stretchy multiband antenna is designed to work reliably and integrate RF power received across its multiband despite mechanical deformations. Depending on the demands of the battery, the multiband antenna may operate as an RF transducer and an RF energy harvester at 900 MHz, 1800 MHz, 2100 MHz, and 2.45 GHz. When the battery's current voltage is less than 20% (referred to as "low voltage"), the incoming RF wave will be used for both communication and RF energy harvesting (RF-EH) depending on the received RF power density (high). If not, the received RF wave will only be used for RF-EH. In terms of efficiency and bandwidth, the installed multiband rectifiers perform well. Depending on the position of the mobile phone or receiver of ambient EM waves, this strategy might lessen the charge issue by 60-90%.

In [15] we discuss a unique miniaturised, flexible wearable rectangular patch antenna with Defected Ground Structure (DGS) for wireless body area network application. This antenna's resonance frequency and bandwidth are 2.45 GHz and 0.379 GHz, respectively, and it works in the ISM (Industrial, Scientific, and Medical) frequency range. Denim jeans, one of the most often used textiles for wearable antennas, is employed as the substrate, while copper tape is used to fabricate the patch, feed, and ground for the intended antenna. The patch antenna is made up of rectangular and circular slots, as well as a deflected ground structure (DGS) with a split ring resonator. A 50 microstrip line supplies power to the antenna. The antenna is 31 42 0.6 mm3 (0.25_o mm x 0.34_o mm x 0.005_o mm) in size totally. The antenna is intended to function at the appropriate frequency while retaining high levels of directivity, gain, and Reflection Coefficient (S11), with values of 2.93 dBi, 2.627 dBi, and - 41.723 dB, respectively. The radiation efficiency of the antenna is 90.86%.To see if the antenna was suitable for wearable usage, its performance was tested under various bending situations and curvature radii. The final antenna's Specific Absorption Rate (SAR) was determined to be 0.0548w/kg for 1g of tissue. The antenna was constructed, simulated, and tested with Computer Simulation Technology software and a vector network analyzer.

4. Conclusion

This RF energy harvesting technique will play a significant part in battery replacement in the future. Because of its features of being safe, plentiful in free space, and good capacity to permeate soft tissues, RF waves are a viable alternative source of energy to replace batteries in many applications. Electronic devices are utilised everywhere, thanks to recent advancements in IoT technology. As a consequence, next-generation sensors will be integrated into the products (modules).This will be an obstacle and make it harder to reach. As a result, battery replacement will be difficult, if not impossible. The rectenna is the ideal answer for this. A small antenna with strong gain and a broad bandwidth is desirable for IoT sensors. Flexible rectennas are a potential technology for wireless power transmission to wearable devices. The present level of research in antenna design, rectifier technologies, substrate materials, integration with wearables, and performance optimisation is summarised in this review article. This work seeks to contribute to the ongoing development of flexible rectennas for efficient and seamless energy harvesting in wearable applications by addressing the issues and recommending future possibilities.

5. References

[1] C. Hertleer, H. Rogier, S. Member, L. Vallozzi, and L. Van Langenhove, "A Textile Antenna for Off- Body Communication Integrated Into Protective Clothing for Firefighters," IEEE Trans.AntennasPropag., vol. 57, no. 4, pp. 919–925, 2009.

[2] A. Dierck, F. Declercq, and H. Rogier, "A Wearable Active Antenna for Global Positioning System andSatellite Phone," IEEETrans. Antennas Propag., vol. 61, no. 2, pp. 532–538, 2013.

[3] B. Grupta, S. Sankaralingam, and S. Dhar, "Development of Wearable and Implantable Antennas in theLast Decade: A Review," IEEE Conf. Publ., pp. 251–267, 2010.

[4] Caroline Loss, Ricardo Gonçalves , Catarina Lopes, Rita Salvado , Pedro Pinho," Textile Antenna for RF Energy Harvesting Fully Embedded in Clothing"10th European Conference on Antennas andPropagation (EuCAP),2016.

[5] C. Hertleer, H. Rogier, L. Vallozzi, and F. Declercq, "A textile antennas based on high-performance fabrics," in 2nd European Conference on Antennas and Propagation, 2007.

[6] C. A. Balanis, Antenna Theory: Analysis and Design, 3rd ed. Wiley Interscience, 2005.

[7] A.Collado, A. Georgiadis, "Conformal Hybrid Solar and Electromagnetic (EM) Energy Harvesting Rectenna," IEEE Transactions on Circuitsand Systems, vol. 60, no.8, August 2013.

[8] A. H. Rida, "Conductive Inkjet Printed Antennas On Flexible Low-Cost Paper-Based Substrates For Rfid And Wsn Applications," Masters of Science, EE, Georgia Institute of Technology, Atlanta, 2009.

[9] R. Martinez, 1. Kimionis, A. Georgiadis, A. Collado, M. Tentzeris, G.Goussetis, and J. L. Tornero, "Circularly Polarized Shorted Ring Siot Rectenna with a Mesh Design for Optimized Inkjet Printing on Paper Substrate," 9th European Conference on Antennas and Propagation(EuCAP), Lisbon, 13-17 April2015.

[10] A. H. Rida, "Conductive Inkjet Printed Antennas On Flexible Low-Cost Paper-Based Substrates For Rfid And Wsn Applications," Masters of Science, EE, Georgia Institute of Technology, Atlanta, 2009.

[11] A. Rashidian, D. M. Klymyshyn, M. T. Aligodarz, M. Boerner, and J. Mohr, "Development Of Polymer-Based Dielectric Resonator Antennas For Millimeter-Wave Applications," Progress in ElectromagneticsResearch C, vol. 13, pp. 203-216, 2010.

[12] Bilal Tariq Malik, Viktor Doychinov, Syed Ali Raza Zaidi, Ian D. Robertson, Nutapong Somjit, and Robert Richardson, "Flexible Rectennas for Wireless Power Transfer to Wearable Sensors at 24 GHz" conference paper,October 2019, https://www.researchgate.net/publication/336564198

[13] Mahmoud Wagih, Geoffrey s. Hilton, Alex S. weddell, Steve beeby, "Dual-Polarized Wearable Antenna/Rectenna forFull-Duplex and MIMO Simultaneous Wireless Information and Power Transfer (SWIPT)" ournal of Antennas and Propagation, Vol2, pp.844-857,2021

[14] Pankaj Chandra Kar, Md. Ariful Islam, " Design and performance analysis of a rectenna system for charging a mobile phone from ambient EM waves", Heliyon 9 (2023) e13964

[15] Avish Fakirde, Saikumar Mulkallal, Parul Sahare,Paritosh Peshwe, " Wearable Flexible Jeans Textile Microstrip PatchAntenna for ISM band Application" Research square, https://orcid.org/0000-0003-4077-7984