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ANALYSIS OF ENERGY HARVESTIG IN HEALTHCARE APPLICATIONS

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ABSTRACT

It is widely believed that the next-generation wearable system will consist of self-powered skin electronics that are also capable of energy harvesting and health monitoring. This type of system will have a wide range of applications, including academic research on artificial intelligence as well as the clinical practise of healthcare medicine. Examples of self-powered skin electronics have been demonstrated using a variety of different types of devices, such as those associated with piezoelectricity, triboelectricity, biofuel cells, photovoltaics, and thermoelectricity, which convert various forms of energy into an electrical power source. The transformation of the biomechanical energy carried by limbs and joints into electrical energy has the potential to address a significant number of the existing constraints. Traditional vibratory energy harvesters call for one set of design and construction strategies, whereas wearable energy harvesters for wearable applications call for an entirely new set of strategies. A case study based on system integration and miniaturisation is also described in this chapter for applications in the field of human-machine interfacing. This chapter focuses on transduction materials, modelling strategies, experimental setups, and data analysis for the design of biomechanical energy harvesters. A rundown of the many techniques now in use to derive electricity for self-powered devices from the bodies of live organisms is shown here. The concept of using the human body as a source of energy spans a wide range of subtopics, including thermoelectric generators, power harvesting via kinetic energy, energy harvesting from the cardiovascular system, and blood pressure.

Keywords: sophisticated electronics, wearable applications, cardiovascular system, kinetic energy.

INTRODUCTION

Because of its significant usage in care management, disease preventive applications, treatment, and diagnosis the most recent advancements in implanted and wearable devices have attracted substantial academic and corporate attention. The vast majority of applications are still powered by batteries, despite the fact that inadequate battery capacity and excessively high battery sizes provide challenges. This study especially focuses on power energy harvesting from the human body as a result of the many methods that may be used to collect energy from live subject electronics. Such methods include: Thermoelectric generators, energy harvesting via the use of kinetic energy, and energy harvesting through the use of the cardiovascular system and blood pressure are a few examples of how the human body may be used as a source of energy.

It is essential to the functioning of the device to produce a sufficient and consistent quantum of energy supply for skin electronics if the gadget is to function dependably and continuously. Primary cells and rechargeable batteries are the most compelling options when it comes to the portability of their platforms. This gives birth to the hysteretic behaviour that is distinctive of ferroelectrics (strain-electric field and polarization-electric field). As a consequence of this, any materials that are classified as ferroelectric may also be classified as pyroelectric and piezoelectric due to the fact that the polarisation of these materials changes depending on temperature and stress, respectively. The inherent multifunctionality of ferroelectric materials allows them to sense and harvest energy from mechanical vibrations (piezoelectric performance) as well as thermal fluctuations (pyroelectric performance).

Additionally, ferroelectric materials can be used in polymer or composite form, which offers unique advantages that enable greater mechanical flexibility and functionalization of wearable devices. To be more precise, one of the developing technologies in the wearable device industry is comprised of flexible multifunctional sensing devices (Xie et al., 2019). The market for wearable medical devices is expanding at a fast rate. By 2021, it is anticipated that these devices will help save 1.3 million lives yearly and will have reached a size of $72.7 billion. Materials that belong to the subcategory of piezoelectric known as pyroelectrics have a spontaneous polarisation that changes as a function of temperature. When subjected to a change in temperature, these substances display a shift in the amount of bound charge that they possess. Certain pyroelectric materials also show ferroelectric properties, which means they have a spontaneous electric polarisation that may be switched by an electric field or mechanical stress. In addition, it is not ideal to have a battery with a greater capacity since the relationship between battery capacity and battery volume is often linear. Emerging technologies have been developed to extract energy from natural environments via the use of energy harvesters, which are then used for the production of electrical power. Energy harvesters may increase the battery life of implantable and wearable devices by acting as a single power source or as a supplement to the lifetime of the device's batteries. Intelligent medical devices may now diagnose, monitor, or cure illnesses, allowing patients with physical limitations to live lives that are more independent. These gadgets also allow for more mobility for patients.

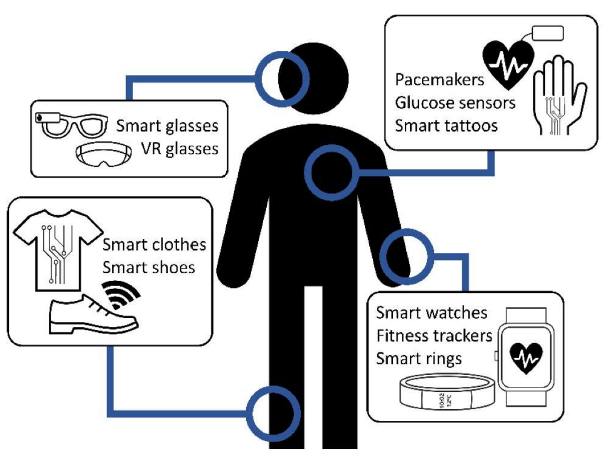

Figure 1 Solar Energy Harvesting to Improve Capabilities of Wearable Devices

Despite this, using these batteries in skin electronics continues to be difficult for a number of reasons, including the following: If the battery becomes overheated, a small explosion may take place, which will result in harm to the human body. Any possible risks associated with them must rule out their usage in technologies that interact with humans. When the material is subjected to mechanical deformation such as stretching and twisting, the bigger volume and more rigid structure are a fundamental mismatch to the pliable and curved surfaces of the skin. In this context, the electronic devices need to be flexible, stretchable, and lightweight. These devices make use of piezoelectricity, triboelectricity, biofuel cells, photovoltaics, and thermoelectricity. Examples that are representative of the whole illuminate the major scientific questions that were investigated in these studies, with a particular emphasis on the connection between electrical performance and mechanical flexibility performance. The assessment came to a close with a discussion of the most significant obstacles that lie ahead, as well as a rundown of the potential that lie ahead for self-powered skin electronics. In this piece, the science of metamaterials is used to develop high-efficiency sensors and antennas that include a harvesting energy unit for usage in healthcare, 5G, and Internet of Things devices. As compared to traditional printed antennas, dual-polarized metamaterial antennas provide a number of major benefits. For example, a high degree of efficiency and profit. The bandwidth of the antenna is around 40%, and its VSWR is more than 3:1. The efficiency of the sensors is more than 90%, and the gain of the antennas that use CSRRs is around 7 dB. The self-powered, efficient, and space-saving sensors are provided by the energy harvesting devices that are attached to the sensors. The history and development of self-powered skin electronics is covered in the first section of the article.

In a wireless wearable device that has a protocol that is aware of temperature is addressed. Wearable sensors and antennas for medical applications are given in the references listed. Wearable medical sensors allow for continuous monitoring and assessment of a patient's health. The paper presents a dual polarisation dipole wearable antenna that is intended for use in medical applications. Because of their smaller size and less weight, portable sensor nodes often have shorter battery lives than their stationary counterparts. The biomechanical energy harvester (EH) allows the nodes to be energetically self-sufficient under normal circumstances, and also reduces the rate at which the battery discharges in stressful conditions when movement is severely restricted. This paper presents a healthcare remote monitoring system for use in hospitals. There is the possibility that the design and construction of sensing nodes that are characterised by high integration and reliability, self-powering, cheap cost, and wearability have the potential to detect vast amounts of biological parameters of humans for the sectors that were described.

In addition, they will make it possible to reduce the size and weight of gadgets, as well as eliminate the need to recharge, replace, or dispose of batteries. They also need to be in ultrathin film forms that are comparable to the epidermis and capable of coupling seamlessly with skin. Finally, their electrical performance characteristics need to be comparable to those of conventional wafer-based devices. Wearable technology is defined by several design restrictions, the most prominent of which are often the devices' diminutive size, low power consumption, and manageable weight. This final specification, in particular, advises employing energy harvesting from the motion of the human body to provide the necessary power to feed the electronic devices that are worn on the body.

LITERATURE REVIEW

M. V. Byrdina (2022): An ever-increasing need has led to the development of flexible wearable electronics for usage in fields as diverse as robotics, manufacturing, agriculture, apparel, medicine, and so on. Several different sensors and devices for reading and transmitting information based on environmentally friendly, flexible, and long-lasting materials can be safely mounted in the shell structure of the robot or attached to the surface of human skin, which will allow for the extraction and examination of a number of significant technical and medical indicators. Crucial characteristics include temperature, pressure, load levels, air composition, environmental parameters, medical signs, etc. In this paper, an approach to describing the different types of wearable electronics for monitoring information about the state of robotic objects involved in production, or a person, about his health, environmental monitoring, pressure sensors, various types of deformation, force sensors that can be combined with temperature sensors, physiological and biochemical sensors, as well as sensors that can be included in multifunctional sensors, is proposed. It is required to have a network of sensors in order to identify the characteristics of the shell structure while it is operating, as well as in order to monitor the status of a human or a robot. The local values of the distributed load on the multilayer protective shell, pressure, tensile or bending deformation, etc. are all examples of technical characteristics that may be used to characterise the shell. We look at the fundamentals of how sensors and transmitter's function when they are encased in a flexible, layered protective shell structure, and we also provide some suggestions for improvements to the structure itself. The study discusses potential functional modules that, when implemented, would make wearable electronics more suitable both for people and for actual technological objects. The development of wearable electronics and its use for modelling flexible intelligent shell structures has given birth to a variety of challenges, which are explained in this article.

G. You, L. Zhu and J (2019): People's expectations of the degree of care they should get from medical professionals continue to rise in tandem with the progression of medical technology. Individuals' day-to-day personal health information is of utmost importance for the real-time monitoring of their vital signs and health issues, which, in turn, may assist individuals in better comprehending their physical states and in recognising symptoms at an earlier stage. A wearable mobile user health information-aware system was built by reviewing a plethora of relevant literature in the disciplines of WIT120, sensing, and communication. After this, the application possibilities and future development prospects of the system were rigorously assessed.

A. Sowmya and A. S (2021): The continuous monitoring of people's physical activities and behaviours throughout their everyday lives is one way in which wearable technology might be improved in healthcare systems. One of the technologies that make up a wearable system is based on sensors, while the other is based on cameras. The implementation of machine learning (ML) in health care applications, such as the detection of human falls, has emerged as an important topic of study in recent years. Since most individuals take their privacy concerns rather seriously, the researchers working on this project came up with the idea of a sensor-based human fall detection system. This system would detect a fall by using sensor-based technology as opposed to vision-based technology in order to do so. Four different machine learning algorithms—namely, Support Vector Machine (SVM), k-nearest neighbour's (KNNs), Decision Tree (DT), and Random Forest—were used in order to evaluate the overall performance of the suggested system (RF). By using an ensemble approach as its RF classifier, the suggested methodology is able to attain the highest level of accuracy possible for human fall detection, which is 98%.

S. Mohsen (2020): A self-powered Internet of Things (IoT) wearable sensor node is presented here for the purpose of monitoring heath. Because of this node, medical professionals are able to measure things like the body temperature, blood oxygen saturation (SpO 2), and heart rate. The NodeMCU board, which has a microcontroller and a Wi-Fi chip, serves as the foundation for this node. In order to give a solution for the problem of extending the lifespan of the node, a solar energy harvester is being created as a power source. A charging controller, a lithium-ion battery, and two flexible photovoltaic (PV) panels make up this harvester's architecture. The harvester is put through its paces in real-world situations, including exposure to bright sunshine and partially overcast skies. In laboratory tests, the IoT wearable sensor node used an average of 20.23 milliwatts of power over the course of one hour, and its lifespan was determined to be 28 hours while operating in a wake-up-sleep mode. The findings of the experiments demonstrate, as a last point of interest, that the observed physiological data of the node are saved onto a cloud server run by Ubidots.

T. H. Hafsiya and B. Rose (2021): The Corona virus, also known as COVID 19, is now the most significant threat that the world is facing. The majority of the population in the Indian country consists of individuals from more mundane backgrounds. There are a lot of different testing for Covid19, and most of them are quite costly and out of reach for most people. Because of the newly discovered Corona Virus, the health care system in every nation has received a lot of attention recently. As a result, the IoT-cloud based health monitoring system is now the most effective treatment for infectious illnesses at this time. The use of the Internet for research is relatively recent, particularly in the realm of medicine and related fields. This kind of remote health care monitoring has grown at such a rapid speed as a direct result of the expansion of suitable sensors and, therefore, cell phones. Internet of Things (IoT) health monitoring helps to stop the spread of illness and enables a precise diagnosis of a patient's state even when the attending physician is located a significant distance away. The portable physiological checking framework will be presented in this paper. This framework will be able to continuously check the patient's heart rate, temperature, blood oxygen level, and blood pressure. The most prominent symptoms of coronavirus are a high fever, extreme fatigue, and difficulty breathing. Wi-Fi is used to make the direct connection between sensors and the Internet of Things cloud. Any HTTP and MQTT protocols that are utilised in the IoT cloud to offer users with visible and timed sensor data are considered to be included in this definition. Almost every intelligent terminal that has a web browser gives users quick and simple access to this data. The camera also has the capability of observing the patient's physical state from a distance. In this article, we propose a gadget that can monitor and regulate the patient's health round-the-clock, as well as save the patient's information in the cloud server and allow for remote communication via a Wi-Fi module. Patients may get remote diagnoses via the use of a mobile or laptop application from a remote health monitoring system that makes use of IoT. These diagnoses are based on values collected by authorised personnel who have access to data stored on any IoT platform.

W. Tesema (2019): There are a significant number of individuals throughout the globe who are coping with chronic conditions, which need ongoing monitoring, diagnosis, and treatment.

Since continuous physiological monitoring is essential to the delivery of preventative healthcare and the precise detection of illness, there is an increasing need for autonomous wearable technology. In order to function in a mode that allows for continuous data collection, wearable devices that collect physiological data from the patient need a high level of power efficiency. While methods for conserving power are used in wearable devices for a variety of purposes, relatively few of these methods are explored for biomedical applications. In this study, we investigate several methods that already exist for reducing the amount of power used by wearable medical equipment. The power consumption of wearable medical devices is one of the topics that our research investigates, as well as the devices' applicability for various medical signal processing applications. In addition, we provide a classification system for various methods of conserving electricity.

METHODOLOGY

Wireless Body Area Networks, WBANs, can measure and record several healthcare parameters such as body temperature, blood pressure, heartbeat rate, electrocardiograms, arterial blood pressure, sweat rate, and electro-dermal activity. Wearable devices will be in the next decade an important part of individuals' daily lives. Wearable sensors may provide scanning and sensing features that are not offered by mobile phones and laptop computers. Wearable devices usually have communication links and users may have access to online information. Wireless technologies are used to process and analyse the data collected by the medical system. The collected data may be stored or transmitted to a medical centre to analyse the collected data. Wearable sensors gather data which is analysed by medical software. Depending upon the type of catalyst. In addition to emerging energy conversion technologies mentioned above, other self-powered devices like photovoltaic and thermoelectric ones, which harvest energy from photic and heat also have been further studied for application to skin electronics.

Compared with mechanical energy and other energies, solar energy is one of the most abundant and renewable green energy in the world. In this section, representative examples of photovoltaic cell will be discussed, including advances in functional. In this part, we will give a brief introduction for the energy conversion mechanism and review the latest progress in the functional materials such as flexible electrodes and friction. Fuel cells are green and environmentally friendly batteries that have attracted much attention in recent years. Fuel cells convert the chemical energy released from chemical reactions into electrical energy where hydrogen, natural gas, methanol, etc. acting as fuel and oxygen (O2) acting as oxidant. The biofuel cell is a special kind of fuel cell, which uses natural microorganisms or enzymes as catalysts to complete the energy conversion process.

The system is equipped with two different types of energy harvesters; the first one was attached to the sensing-capable backscattering RFID tags for the harvesting of the 464.5 MHz signal energy that will power the tags; the second type of energy harvester was attached to the hands of the wearer for the harvesting of the same 464.5 MHz signal to provide both the carrier signal and the DC power. The efficiency of this second energy harvester is higher than that of standard ambient energy harvesters. Triboelectric nanogenerators (TENGs), converting mechanical energy from frication into electrical energy based on triboelectricity effect, are another attractive example for self-powered skin electronics due to the advantages of low-cost, ease of fabrication, diverse range of material selection. Their work fabricated circuit prototypes through a combination of conductive traces developed with conductive inkjet printing and masking technologies with lumped circuit components. Furthermore, the S-parameters were used to estimate the input power for the RF to DC conversion circuit; the circuit produced a peak output power of 0.146 W with a H-field harvester and 0.0432 W with an E-field harvester. The harvesters (E-and H-field) were subjected to several operation tests using a microcontroller communication module and an LED in both on-bottle and on-body bent/flex conditions to validate the functionality based on the energy from a two-way talk radio. The outcome of these tests ensures the compatibility of the developed inkjet-printed flexible energy harvesters to be adopted in wearable biosensors.

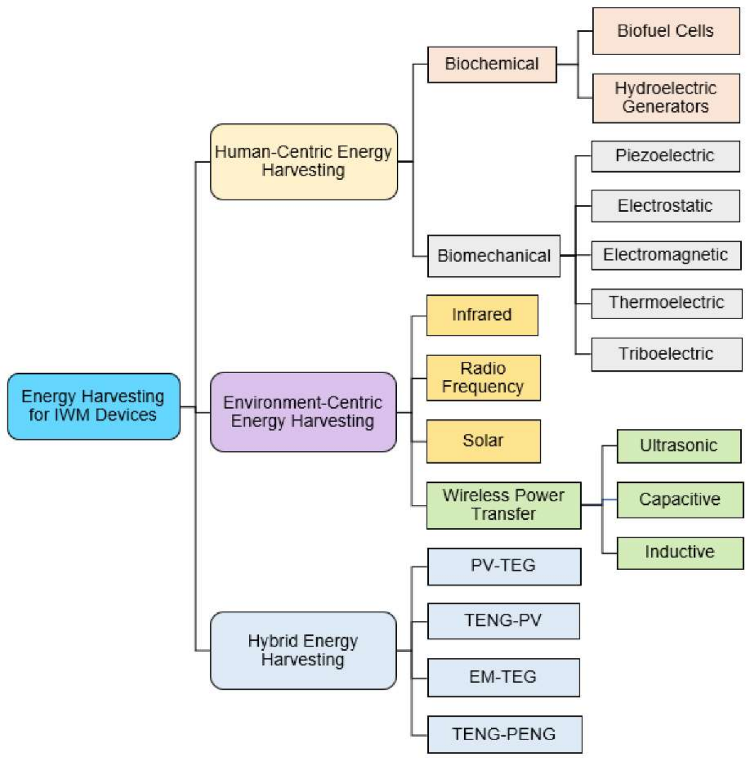

Figure 2 Energy Harvesting in Implantable and Wearable Medical Devices

Besides that, the work presented a flexible and wearable energy-autonomous on-body sensor network with complete RFEH operability using a handheld 464.5 MHz UHF band two-way talk radio, which was created using 3D printing and inkjet processes. The environmental friendliness and low-cost fabrication processes of additive manufacturing, such as 3D printing and inkjet printing, have increased its industrial relevance, as these emerging fabrication techniques are designed to significantly reduce the required number of manufacturing steps, such as the elimination of the etching processes, thereby improving the fabrication efficiency. Most of the time, wearable sensor devices are preferable in areas where disposable or single-time use is hygienically sorted, such as in hospital settings. This application type requires the creation of numerous circuit components within the device, using additive manufacturing to reduce the device cost. The improvements recorded recently in fabrication and performance have endeared inkjet printing technology to sensor and RF applications. In this regard, a design of enabling near-field RFEH for wearable sensors with an additional fabrication process was proposed. Therefore, particular attention will be given to the interaction between each different component and how these affect the performance of the final device needs particular attention.

In addition to synthetic substrates, natural materials are also of interest for wearable, flexible systems. This category of materials includes fibres and textiles derived from silk or cotton.
These environmentally friendly substrates are promising since they are inexpensive, exhibit desirable characteristics such as biodegradability, good biocompatibility, sustainability and versatility, and satisfy most of the mechanical requirements of irregular deformation. Physiological monitoring devices using paper substrates have also been developed (Chen et al., 2018; Yao et al., 2017), which are of significant interest due to their recyclability, abundance (derived from renewable resources) and mechanical flexibility. A seamless, non-invasive, durable interface must be ensured before the device can be placed on human skin. The main components of multifunctional, flexible, and stretchable sensing devices have already been presented in the introduction. In this section, materials for flexible piezoelectric devices will be overviewed, including flexible substrates, the use of piezoelectric materials as an active sensing material, and conductive flexible electrodes. In addition, the strategies for battery-free, human motion energy harvesting wearable devices will be discussed.
The authors investigated the bi-stable hybrid device's frequency sensitivity by examining the relationship between the optimal design's power output and the heart rate. They found that the output power of the bi-stable energy harvester was more than 3 μW.A previous study applied the electromagnetic induction principle to harvest energy by using copper coils connected in a series to a permanent magnet stack suspended between two flexures. A mathematical model to simulate three heart motions was developed in this work. Two in vivo experiments on domestic pigs harvested a mean output power of 0.78 μW and 1.7 μW at a heart rates of 84 bpm and 160 bpm. Reference developed a low-frequency vibration energy harvester used to run implantable pacemakers and cardioverter defibrillators (AICDs).

EXPERIMENT RESULT

The wearer's heart wall motion was utilised to generate kinetic energy, which was then converted into electrical power by an energy-harvesting device in the form of a clock. In addition to this, the scientists devised a mathematical model to help improve the setup of the device. They performed in vitro and in vivo investigations. In the in vitro experiment, a robotic arm reproduced the action of the heart, which sped up the clock; in the in vivo experiment, the gadget was linked to the heart of a sheep for an hour. The produced power for the in vitro was 30 μW, and in vivo, it was 16.7 μW. For the purpose of harvesting heart rate fluctuation, reference presented linear low-frequency and nonlinear mono-stable as well as robust bi-stable harvesters. They were built according to the distinctive characteristic of heart vibrations. Parkinson's disease is characterised by motor impairments, such as gait difficulty, slowness of movement and limb stiffness. Gait analysis has been validated as one of the most accurate diagnostic markers of this condition.

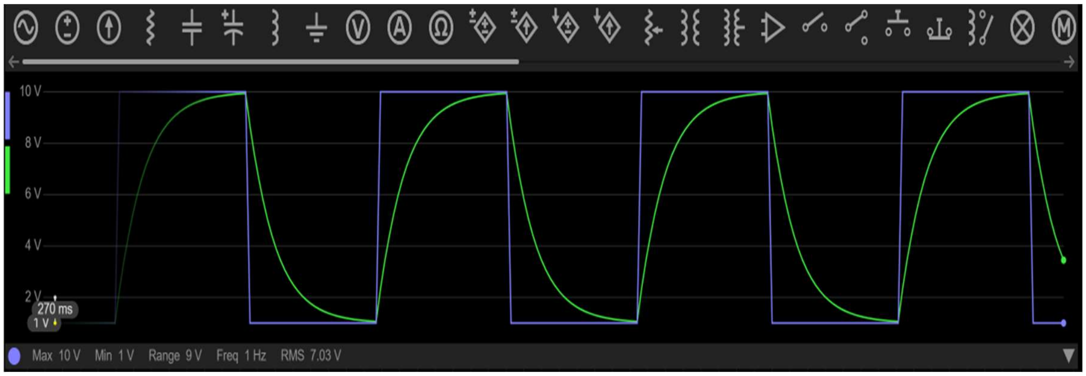

Figure 3 Low-frequency and nonlinear mono-stable

For patients with neurological issues, such as Parkinson's disease and stroke, the ambulatory gait analysis is a crucial tool in their recovery process and may offer low-cost and simple rehabilitation monitoring. A dual polarisation metamaterial antenna with CSRR, metallic strips, and an energy collecting unit is depicted. The antenna comprises of two layers with thickness of 0.16cm. The dipole matching network and the metallic strips are printed on the first layer. The radiating dipole with CSRR is carved on the second layer. The wearable antenna, with the matching network and the energy collecting device, dimensions are 21x4cm. The dipole with CSRR is horizontal polarised. The slot antenna is vertical polarised. This analysis may send signal to the physician to call a patient who requires urgent healthcare treatment. Human gaits are the numerous ways in which a person may move. Walking, jogging, skipping and sprinting are normal human gait. Variations in limb movement patterns, overall velocity, kinetic and potential energy cycles, forces, and variations in the contact with the ground are some of the distinguishing features that differentiate the various gait patterns. In order to define human movement, gait measurements and analysis are an essential research tool. Prediction precision, attained at shorter slots, is traded off against the corresponding memory cost imposed by the huge number of slots when employing statistical techniques to create energy projections based on historical time-series data. From EWMA to IPro-Energy, research have refined statistical methodologies in response to uncertain weather and quick seasonal swings. Forecasts in the near, middle, and distant future are all achievable utilising these strategies. The aforementioned solar panel is folded in half to cover the flexible PCB and make it more compact.

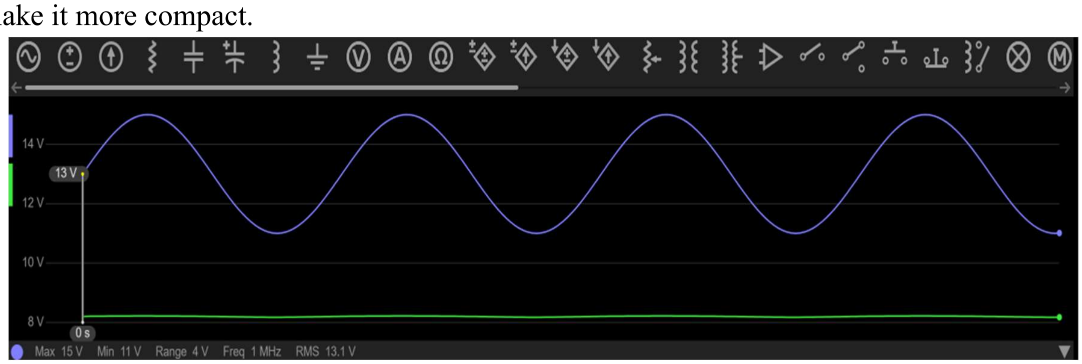

Figure 4 Energy harvesting

The whole device is shielded by a transparent silicone rubber shell constructed from Smooth-On R's Ecoflex 00-10. As can be observed, the cured rubber housing is not only malleable but also robust and elastic. The software for viewing data from implanted sensors, which may be operated on a mobile device equipped with Bluetooth 4.0, is depicted in. Both a microprocessor (ARM Cortex M0) for processing data before it is sent and an on-chip antenna are included in the RFD77101 BLE module. RFD77101 has a peak transmission current of 8 mA and a sleep current (with the clock running) of less than 4 A. Both of these currents are lower than 4 A. As part of this initiative, we are developing a web application for the Evo things R platform that will display sensor values on a mobile device. A representation of the small flexible PCB that measures 33 mm by 27 mm and is installed with all of the electrical components. The modulator's sensitivity declined with increasing separation distances, but its signal-to-noise ratio (SNR) remained higher than that of the amplifier throughout, indicating the usefulness of FM encoding of MRI signals in overcoming larger transmission attenuation. In order to permit communication in both directions between the inside and the outside of the body, an implanted sensor system places a significant amount of reliance on its wireless transmission. Yet, the relatively large amount of power that it consumes presents a new challenge for the power system of an implant. The data collected by the implanted sensors are sent to a mobile device by means of a high-quality BLE module that is included into the suggested prototype (a smartphone or tablet). We would be able to systematically modify the transmission attenuation between the modulator and the volume coil even if the physical size of the circuit remained the same. The transmission attenuation for each position shift was estimated using a passive inductive coupling method with regard to a wire-connected surface coil. The amount of excitation power applied to the volume coil has to be scaled proportionately by the amount of attenuation experienced during transmission in order to maintain the same effective flip angle. The signal-to-noise ratio (SNR) of the amplifier and the modulator was almost equivalent when the attenuation was lower than 21 dB. The modulator, however, maintained its consistent sensitivity for attenuation up to 34 dB even when it was put beyond the edge of the volume coil. The sideband pattern provided conclusive evidence that, contrary to what was expected by Equation, the modulator did not need the use of any specialised down-converters in order to encode the input signal at the offset frequency.

CONCLUSION

Work that has been done on energy harvesters over the course of the last several years has brought about the high-performance, lightweight, mechanically durable self-powered skin electronics that were promised in the sectors of energy harvest and healthcare monitoring. To allow these energy harvesters to satisfy the requirements of the skin electronic microsystems better and give full play to their functions, both electrical output that needs to offer continuous and reliable energy supply and mechanical robustness that is built-in when connected. Nevertheless, the most difficult task will be to optimise the suggested models in terms of the amount of memory that will be needed and the amount of time that will be needed to run them. On the other hand, statistical approaches are the way that is best suitable for short-term forecasts since they give effective short-term performance while using the least amount of memory and execution time. This makes them the most acceptable method. The EH-WSN prediction methods, which make use of the same energy sources as present-day wearable devices, such as PV and RF sources, served as an inspiration for these different approaches. By conducting an in-depth analysis, we have come to the conclusion that the combination of linear and non-linear machine learning approaches may produce a hybrid model that has the potential to achieve respectable prediction error when applied to long-term predictions.

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