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Low Power RFID Photoplethysmography (PPG) Monitoring

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***Abstract*— This paper introduces a Battery-Assisted Passive (BAP), ring-shaped Radiofrequency Identification (RFID) tag that streams photoplethysmography (PPG) signals from an on-tag PPG sensor to a remote reader via UHF. Unlike Bluetooth or Wi-Fi based real-time systems, this wearable tag consumes sub 10 mW and requires no connection or pairing protocol, beginning to stream automatically when a reader is detected. The ring tag also transmits tri-axial accelerometer data (ADXL363) that used to compute a Motion Quality Index (MQI) at the reader-PC, which preserves signal integrity and identifies user activity states (for example, walking or stationary) and to mitigate motion artifacts (MA). Experimental validation with a ThingMagic M7E reader demonstrates reliable heart-rate calculation up to 300 bps with high data integrity at a 5 m read range in low noise laboratory environments.**

Keywords*— *photoplethysmography, wearable sensors, heart rate, Radiofrequency identification, Accelerometers, Small Loop Antenna.

I. Introduction

Photoplethysmography (PPG) is a method of measuring heart pulse rate that is well suited to long term wearable monitoring systems as the sensors are non-invasive, electrode-free and -unlike ECG- precise referencing or measuring nodes are not required [1], [2]. Some recent studies concentrate on improving algorithms and hardware to derive accurate Heart Rate (HR) and oxygen saturation (SpO_2) from PPG, typically by measuring both infrared and red reflectance from the skin which is proportional to the variation in capacity of the blood vessels. PPG accuracy depends directly on the amount of reflected light, which varies with skin tone, sensor position, and the skin hydration. Motion artifacts (MA) further degrade signal quality, so secure physical mounting and careful device geometry are essential design considerations [1],[3],[4].

Body-worn systems commonly integrate four main subsystems: power, processing, sensors, and communication. System weight, communication range, ease of use, and data integrity are key considerations for wearables, especially for application-specific devices such as PPG sensors [4].

Wi-Fi and Bluetooth (both Classic and Low-Energy technologies) are widely used in vital-sign monitoring because they offer robust data integrity and long-range coverage [5], [6]. Their main drawback for wearables is the need for a stable, high-capacity power source. Power instability can break the link and require time to reconnect, which in turn forces the use of batteries to maintain performance and can lead to nonuniform relatively bulky form factors, increased mass, and safety concerns [4], [6].

The authors in [7] have explored battery-free, Near Field Communication (NFC)-powered PPG systems to avoid batteries. NFC can enable very small form factors, but its limited energy transfer range (typically 2–5 cm) constrains usability for continuous monitoring. A few studies propose on-nail, NFC-energized, battery-less PPG devices, but these solutions remain impractical for long-duration monitoring and require the user to remain very close to the energy source [8].

UHF Radio-frequency identification (RFID) offers a promising alternative for ultra-low power systems where the backscatter communication from the tag can only require a few hundred microwatts. On tag electronics can be powered by energy harvesting or by a small battery in Battery-Assisted Passive (BAP) tags which are suitable for low power wearable monitoring [9], [10], [11].

This paper proposes a BAP UHF RFID ring tag that streams PPG and accelerometer data to a remote reader while operating with ultra-low power. The tag begins streaming automatically when a reader is detected, using the same mechanism described in [6]. The reader-PC side uses accelerometer measurements to compute a Motion Quality Index (MQI) that preserves signal integrity and identifies user activity states (for example, walking or stationary). Compared with Bluetooth/Wi-Fi solutions, the proposed approach reduces power and battery size, and it extends practical read range over NFC wearable monitoring.

The paper is organised as follows: Section II describes the system design; Section III provides Validation and Results; and Section IV presents Conclusions.

II. System Design

The system comprises two parts, the tag and the reader -PC.

A. The PPG ring tag

The introduced wearable PPG ring-shaped RFID tag was fabricated and implemented as shown in Fig. 1. It uses a

small-loop antenna (SLA) design from [12] to achieve a compact form factor that fits human fingers. The placement and distribution of the EM4325 UHF IC, the MAX86150 biosensor, the ADXL363 accelerometer, and passive components with 0402 footprint on the flexible polyimide Kapton PCB were critical to a successful layout. The EM4325 is placed closest to the SLA feeding point for optimal matching; the MAX86150 and ADXL363 are positioned to avoid any risk of short-circuiting when the tag is wrapped into its ring shape; and the MSP430FR2433 microcontroller is placed in the region of low SLA radiation to minimize noise and interference.

B. The RFID reader

The UHF Jadak ThingMagic M7E RFID [13] reader was used to capture the tag backscattered signal. A C# application using the Mercury API configured the reader according to the settings in Table I, in order to start the reader then forward the collected data for post-processing.

Fig. 2 shows the microcontroller functional flowchart to acquire, package, and deliver PPG and accelerometer data to the RFID chip, which are further explained as follows:

1. Initialize modules: The MSP430FR2433 microcontroller initialises and configures the MAX86150 (IR/RED PPG), ADXL363 (accelerometer), and EM4325.
2. Acquire sensor samples: If reader signal exists, the controller will read synchronized samples from the PPG channels (IR and RED) and the accelerometer (X, Y, Z) at the configured sampling rates.
3. Assign frame number: Increment and attach a frame number to each PPG packet and each accelerometer packet to preserve ordering and enable packet integrity checks.
4. Encapsulate into one frame: Combine the PPG packet, accelerometer packet, and frame number into a single frame structure in microcontroller memory.
5. Write frame to EM4325: Write the frame directly to the EM4325 RAM/register file to minimise latency and maximise read/write throughput precisely as in [6]. The frame is mapped in the register file (pages 65 and 66) as listed in Table II.
6. Trigger tag response: The EM4325 exposes the frame to the reader via backscatter; the tag responds when interrogated by the ThingMagic M7E reader.

TABLE I. JADAK THINGMAGIC M7E RFID READER PARAMETER SETTINGS.

Reader parameter	Value
Reader protocol	EPC gen2
Antenna port	1
Region	EU3 (865-868 MHz)
Tari	25 us
Tag encoding	M4
BLF	250 KHz
Slots count (2^Q)	1 (i.e. Q=0)
Baud rate	115200 b/s

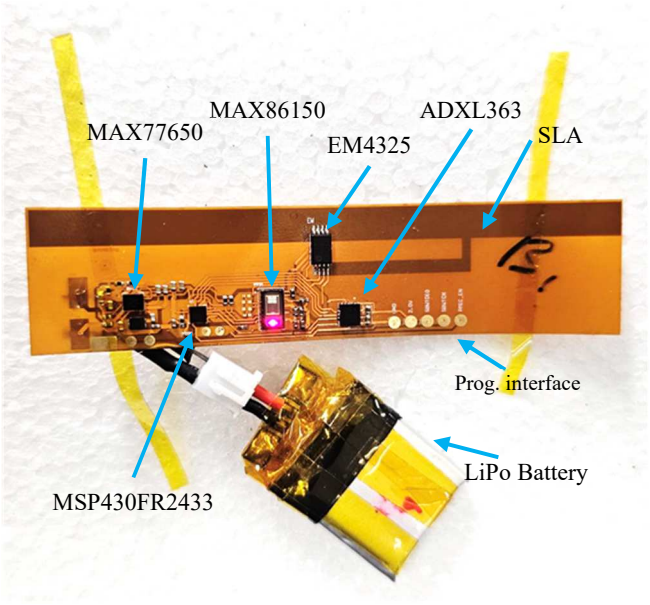


Fig. 1. Unwrapped ring tag.

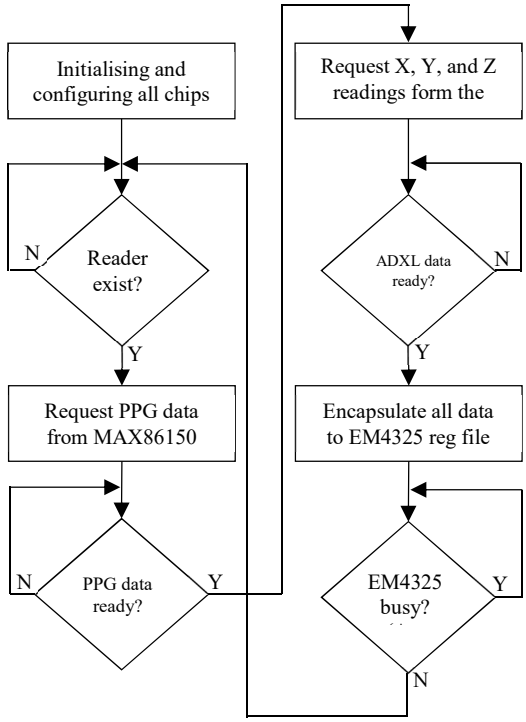


Fig. 2. Flowchart of microcontroller processes for a single PPG sample.

TABLE II. DATA PACKET ENCAPSULATED IN THE EM4325 REGISTER FILE (RAM PAGES 65 AND 66).

Page 65

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Packet Number		IR			RED		

Page 66

Byte 8	Byte 9	Byte 10	Byte 11	Byte 12	Byte 13	Byte 14	Byte 15
Packet Number		ACC_X		ACC_Y		ACC_Z	

III. Validation and Results

A. Ring antenna performance

To validate the work of ring's SLA in both EU3 and the new EU4 bands, An SMA connector is placed after the antenna matching network at the feeding points as shown in Fig. 3, then connected to a VNA. The measured S_{11} for four cases is illustrated in Fig. 4 showing that the finger worn ring-shaped tag is matched below -4.2 and - 4.9 dB in the EU3 and EU4 bands respectively.

B. Overall system function and integrity

While awaiting ethics approval, recorded data from DaLiA [14] was used to provide a mock PPG signal and corresponding ECG data. These datasets were streamed with a frame rate of 50 per second through the ring tag to the reader for validation purposes and to verify the overall system operation. As depicted in Fig. 5, the PPG ring functioned at 1.2 m away from the Jadak ThingMagic M7E RFID reader antenna. A high-performance computer (Intel i9 12950HX with 64 GB RAM) was used to capture the reader data to exclude any latency.

Ten runs (120 s each) were used to compare received PPG frames with the transmitted PPG and the corresponding ECG data from [14] to investigate the latency and integrity of the system. The received PPG data at the reader matches well the original waveforms without significant errors. Fig. 6 shows 40 s cutout from the 1200 s of transmission. For comparison with the PPG waveforms, the weak ECG amplitude was amplified tenfold to ensure both signals were visible on the same scale.



Fig. 3. Wrapped ring tag compared to a £1 coin for scale.

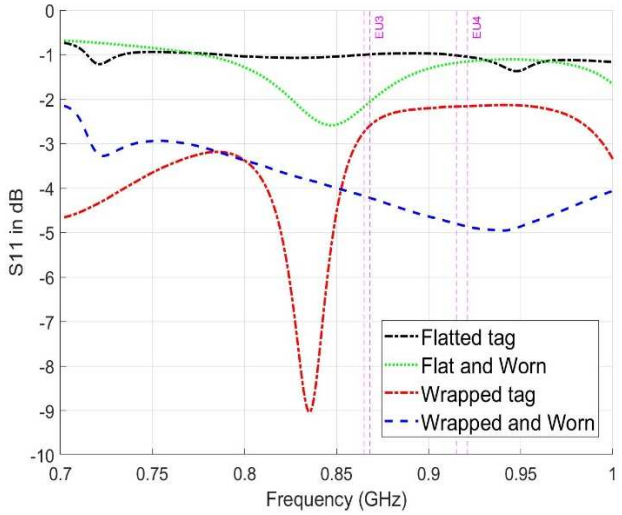


Fig. 4. Measured RFID ring tag antenna S_{11} when on and off skin and wrapped and unwrapped.

Both the transmitted and received PPG waveforms are correlated to the corresponding ECG. The data integrity level (percentage successful frame transmission) exceeded 99.99%, indicating virtually no frame loss and very high signal fidelity.



Fig. 5. PPG ring tag 1.2m away from a Jadak ThingMagic M7E RFID reader's antenna.

C. Read range testing

To evaluate read range, the system test in B was repeated with horizontal transmission for increasing reader-tag separation with signals successfully received at up to 5 m. As the tests were conducted in an open lab environment, fading effects were observed as expected.

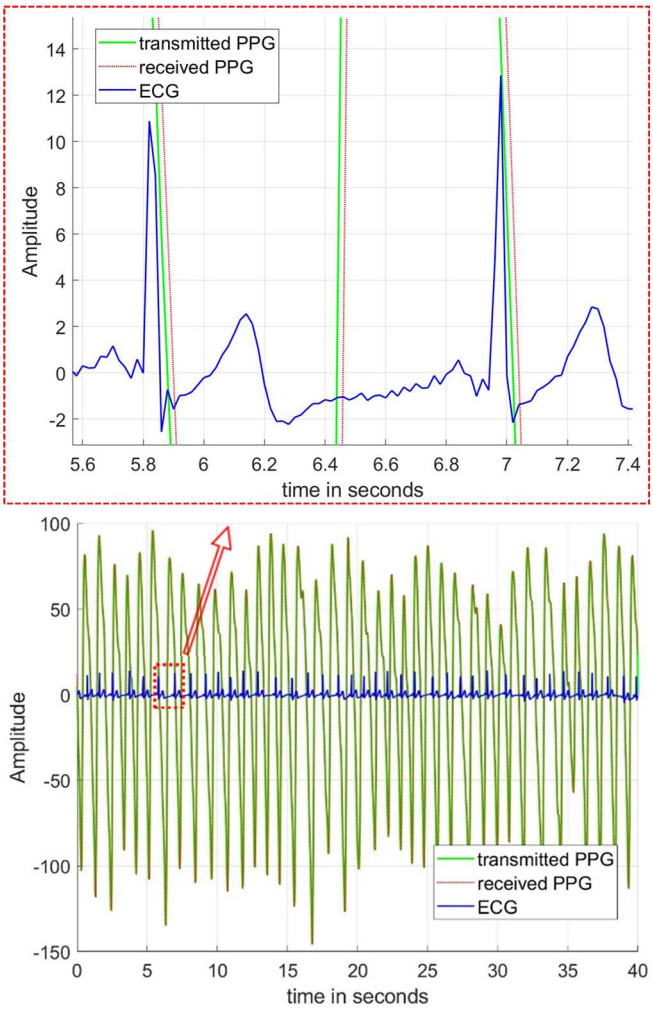


Fig. 6. Transmitted and received PPG waveforms correlated to coressponding ECG.

IV. Conclusions

This paper presented a system for real-time photoplethysmography (PPG) transmission using an RFID ring shaped tag. By alternating the microcontroller between ultra-low-power modes and adjusting the PPG sensor sampling rate, the proposed tag achieves reliable data transmission with low overall power consumption. Employing phase modulation of the reflected RFID signal further enhances immunity to noise and external disturbances.

The results showed that the ring tag maintained its performance at a distance 5m from the M7E reader in an open lab environment.

References

[1] P. Armañac-Julián, S. Kontaxis, J. Lázaro, A. Rapalis, M. Brazaitis, V. Marozas, P. Laguna, R. Bailón, E. Gil, "Vascular reactivity characterized by PPG-derived pulse wave velocity," Biomedical Signal Processing and Control, Volume 105, 2025, 107641, ISSN 1746-8094, https://doi.org/10.1016/j.bspc.2025.107641.

[2] L. Peter, N. Noury, M. Cerny, "A review of methods for non-invasive and continuous blood pressure monitoring: Pulse transit time method is promising?, " IRBM, Volume 35, Issue 5, 2014, Pages 271-282,ISSN 1959-0318, https://doi.org/10.1016/j.irbm.2014.07.002.

[3] D. Castaneda, A. Esparza, M. Ghamari, C. Soltanpur, H. Nazeran. "A review on wearable photoplethysmography sensors and their potential future applications in health care," Int J Biosens Bioelectron. 2018;4(4):195-202. doi:10.15406/ijbsbe.2018.04.00125

[4] Y. -H. Kao, P. C. . -P. Chao and C. -L. Wey, "Design and validation of a new ppg module to acquire high-quality physiological signals for high-accuracy biomedical sensing," in IEEE Journal of Selected Topics in Quantum Electronics, vol. 25, no. 1, pp. 1-10, Jan.-Feb. 2019, Art no. 69000210, doi: 10.1109/JSTQE.2018.2871604.

[5] *Bluetooth Radio Standards 2025*. Accessed: Feb. 14, 2026. [Online]. https://www.bluetooth.com/learn-about-bluetooth/key-attributes/

[6] R. Horne and J. C. Batchelor, "A framework for a low power on body real-time sensor system using UHF RFID," IEEE Journal of Radio Frequency Identification, vol. 4, no. 4, pp. 391-397, Dec. 2020, doi: 10.1109/JRFID.2020.3018405.

[7] J. Kim, P. Gutruf, A.M. Chiarelli, S.Y. Heo, K. Cho, Z. Xie, A. Banks, S. Han, K. Jang, J.W. Lee, K. Lee, X. Feng, Y. Huang, M. Fabiani, G. Gratton, U. Paik, J.A. Rogers, "Miniaturized battery-free wireless systems for wearable pulse oximetry," Adv Funct Mater. 2017 Jan 5;27(1):1604373. doi: 10.1002/adfm.201604373.

[8] N. A. A. B. H. Mohtadzar et al., "Heart rate estimation using on-nail wearable photoplethysmography," 2024 46th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Orlando, FL, USA, 2024, pp. 1-4, doi: 10.1109/EMBC53108.2024.10782437.

[9] S. Vora, K. Dandekar and T. Kurzweg, "Passive RFID tag based heart rate monitoring from an ECG signal," 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Milan, Italy, 2015, pp. 4403-4406, doi: 10.1109/EMBC.2015.7319371.

[10] M. Barati, H. Khoshniyat and R. Mirzavand, "Real-time heart rate monitoring via batteryless RFID tags," 2024 IEEE MTT-S International Microwave Biomedical Conference (IMBioC), Montreal, QC, Canada, 2024, pp. 21-23, doi: 10.1109/IMBioC60287.2024.10590283.

[11] (2026). *GS1.org,* "*Gen2 Release 3.0, Ratified Jan 2024*". Accessed: Feb. 14, 2026. [Online]. Available: https://www.gs1.org/standards/rfid/uhf-air-interface-protocol.

[12] P. S. Taylor and J. C. Batchelor, "Finger-Worn UHF Far-Field RFID Tag Antenna," in IEEE Antennas and Wireless Propagation Letters, vol. 18, no. 12, pp. 2513-2517, Dec. 2019, doi: 10.1109/LAWP.2019.2941731.

[13] (2026). jadaktech.com. Accessed: Feb. 14, 2026. [Online]. Available: https://www.jadaktech.com/product/thingmagicm7e-uhf-rain-rfid-module-series-2/.

[14] A. Reiss, I. Indlekofer, and P. Schmidt. "PPG-DaLiA," UCI Machine Learning Repository, 2019," Accessed: Feb. 14, 2026. [Online]. Available: https://doi.org/10.24432/C53890.