Assessing radio frequency electromagnetic field exposure with a wearable network of dosimeters

Lecoutere J[1], De Clercq H[1], Thielens A[2], Agneessens S[3], Rogier H[3], Joseph W[2], Puers R[1]
[1] ESAT-MICAS, KU Leuven, Leuven, Belgium
[2] Wireless & Cable Group, INTEC, Ghent University, Ghent, Belgium
[3] Electromagnetics Group, INTEC, Ghent University, Ghent, Belgium

Abstract

In contrast to the tremendous increase of wireless applications, the knowledge about daily life radio frequency electromagnetic field (RF-EMF) exposure remains low. Some research has already been conducted using large commercial single-antenna on-body dosimeters to assess daily RF-EMF exposure in different environments. To increase measurement quality and decrease variability however, a distributed, wearable body sensor network spread over the body for the assessment of RF-EMF exposure is desired. As a better alternative to the common single node assessment technique, this work therefore presents a wearable sensor network consisting of five nodes for the assessment of exposure in the 389 to 464, 779 to 950 and 2400 to 2483.5MHz bands using only two transceivers per node. A single node supports an antenna connection for the first band, two for the second and two for the third band. This makes antenna diversity possible and hence increases sensitivity for specific frequencies, depending on the choice of antenna design. Every node is powered by two AAA batteries, which define the size of the system (53x25x15mm), making it smaller than any other commercially available dosimeter. Furthermore, the device supports an inertial sensor for the assessment of body posture and/or activity during the measurement.

***Keywords**: exposure, wearable, sensor network, RF, dosimeter, inertial, on-body*

Introduction

Controversy exists concerning the health effects of radiofrequency electromagnetic field (RF-EMF) exposure due to the widespread use of wireless RF technology in current daily life environments. The World Health Organisation's (WHO) Research Agenda for Radiofrequency Fields has stipulated that dosimetric evaluations are indispensable in the development and validation of radio frequency electromagnetic field (RF-EMF) exposure assessment methods in epidemiological research. Also, RF-EMF multisource exposure measurements are preferred over exposure from single sources [1].

The state of the art exposimeters have been shown to introduce very large uncertainties due to shadowing of the body and varying body positioning [2-6]. The human body reflects and absorbs RF-EMFs, causing the measurements of the exposimeter to show the resulting electric fields (i.e. after body effects) instead of the incident fields, which truly represent exposure levels. Previous work has shown that a distributed measurement approach using a body area network (BAN) can significantly reduce these uncertainties [7].

This work presents a novel wearable personal distributed exposimeter (PDE) that registers body exposure using a wireless body area network (BAN) of sensing units for multiple RF bands. The system consists of five identical nodes that record received power in the 779 to 950 and 2400 to 2483.5MHz bands using only two transceivers per node by using an antenna diversified architecture.

Material and Methods

Frequencies of interest

The goal of this research is to assess commonly used frequencies. Therefore, we chose to measure the GSM-900 up- and downlink bands and the 2.4Ghz band, which contains Wi-Fi, Bluetooth, ANT and other common IEEE 802.15 standards. Moreover, the system is able to assess the 2.4GHz band in two perpendicular polarizations in order to achieve more exposure information in this band. The 433MHz ISM-band is currently being used as the information carrier for the transmission of information over the wireless BAN, which connects the different measurement nodes and centralizes the data at a personal computing device.

433MHz & GSM-900

To assess GSM-900 exposure and to cover the BAN communication, a CC430F5135 [Texas

Instruments] microcontroller (MCU) with integrated transceiver is used. The transceiver can be tuned to the frequencies 300MHz to 348MHz, 389MHz to 464MHz and 779MHz to 950MHz. To increase frequency specific sensitivity, antenna diversity is used by switching between a 433MHz, 900MHz (GSM-900 uplink) and 950MHz (GSM-900 downlink) Hirose U.FL antenna connection. Antenna switching is controlled by the MCU, which sets the AS179-92LF RF switches [Skyworks Solutions] to the desired RF in- or output. To convert the balanced RF output impedance of the MCU to an unbalanced output, a single component balun [Johanson Technology] is used for every chosen frequency band. This reduces the bill of materials (BOM) and printed circuit board (PCB) surface area.

Dual polarised 2.4GHz

The system's measurement range was extended to the 2.4GHz band by adding a CC2500 transceiver. This transceiver is accessible through the MCU's serial peripheral interface (SPI). In order to be able to measure two perpendicular polarisations of the incoming RF-EMF field, antenna diversity analogous to the earlier described GSM-900 band is used in combination with two perpendicularly polarized antennas. Fig. 1 shows a schematic overview of the PDE's architecture.

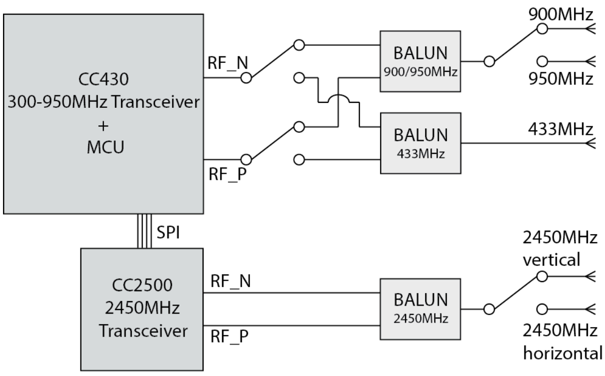

Fig. 1: A schematic overview of the system's architecture

The two transceivers in the PDE provide a continuously updated received signal strength indicator (RSSI) value, which is used to quantify the incoming RF-EMF. The RSSI is a measure of RF input power and is based on the gain setting of the transceivers [8].

Results

The resulting PCB layout of a single system node was fitted to a double AAA battery holder, giving it a small size of 53x25x15mm compared to existing dosimeters such as the EME Spy 140 (168.5x79x49.7mm). For user convenience a micro Secure Digital (SD) cardholder was added to the system in order to be able to store the data offline. Furthermore, the system supports an on-board and off-board inertial measurement unit (IMU) to measure body posture in future experiments. The MPU-6000 was chosen, as it combines a 3D accelerometer and 3D gyroscope into a single 4x4mm package. Fig. 2 shows an image of the PCB top layer of a single PDE node.

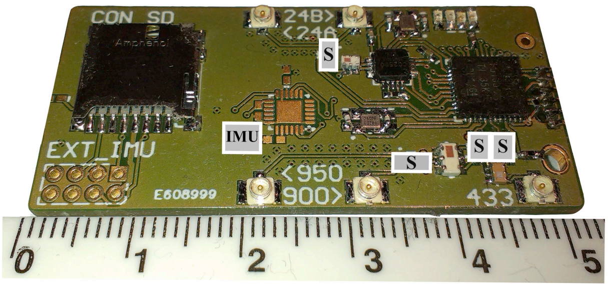

Fig. 2: A single node's PCB with the switches indicated with "S"

Discussion

Future work should provide reliable information about the value of IMU measurements combined with the assessment of RF-EMF exposure. IMU information may provide essential information about effects of the human body on the resulting electric fields, creating the opportunity to take body posture into account during the experiments.

Conclusions

This paper has presented a novel approach for PDE design in a wireless BAN. It reduces the BOM for the assessment of multi-source RF-EMF exposure assessment by the use of antenna diversity. The resulting system is an important step in the development and validation of radio frequency electromagnetic field (RF-EMF) exposure assessment methods in epidemiological research. Furthermore, the small size of the PDE increases the wearability of the system compared to existing exposimeters.

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Author's Address

Jeroen Lecoutere
KU Leuven – ESAT-MICAS
Kasteelpark Arenberg 10
B-3001 Leuven
jeroen.lecoutere@esat.kuleuven.be