Development of a low cost sensor network for measurement of 5G signals in the Netherlands

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[BioEM2022, Nagoya, Japan, Jun 19 - 24, 2022 (/node/41106)](/node/41106)

We aim to set up a continuous low cost monitoring system for electromagnetic fields in the Netherlands, so that a trend in exposure to 5G signals can be observed. A number of options will be explored for this, such as software-defined radio and measurement nodes for specific 5G frequencies. We developed and tested low cost dedicated measurement nodes for four 5G bands: the 800, 1400, 2100 and 3500 MHz bands. Generally, the error is less than 1 dB and close to dynamic range limits (-65 to 5 dBm) the error increases to 3 dB.

Introduction

Due to the increasing use of wireless communication, for example for mobile telephony and Internet-of-Things, the possible influence of electromagnetic fields (EMF) on health is attracting attention. Until now, the scientifically proven health effects have been based on short-term effects such as warming of tissue and electric fieldin the body (ICNIRP, 2020). In addition, there is evidence of long-term effects such as certain cancers that have led IARC to classify it as category 2B - possible carcinogen. There are also health complaints and non-specific physical symptoms mentioned by self-proclaimed electrosensitives such as headache, fatigue and loss of concentration. Although a number of studies have found a statistical relationship between these complaints and EMF, the causal relationship is not yet understood (Baliatsas et al, 2015; Bogers et al., 2018).

Especially with the introduction of the 5G network, intended to provide faster and more broadband mobile communications and enable new applications such as autonomous driving vehicles and IoT, there have been more alarmed voices from protest groups and lawsuits from concerned citizens against the state and the local government.The ruling in the lawsuit against the government of the Netherlands of 25 May 2020 was that the 5G network may be rolled out. Although the 5G network is designed to communicate more data in a more targeted way and with less energy than with the 4G network, with increasing data traffic, the total exposure will likely increase. Also, due to other types of data traffic, such as with autonomous vehicles and IoT networks, both the modulation of the signals and the locations from which transmission and reception are made will change and will in any case be more intricate with picocells at a short distance.

RIVM published a report on exposure to 5G in 2020 that states that it is important to keep a close watch(Stam et al., 2020). The Health Council of the Netherlands published a report in September 2020 indicating that the arrival of 5G networks in society raises concerns about the possible impact of 5G on health. She also advises monitoring the exposures of individuals and groups before, during and after the roll-out of 5G systems (Health Council of the Netherlands, 2020).

We focus on setting up a Smart City measurement network on the universitycampus in Delft with datanodes that communicate with a central server via a fixed, WiFi or LoRa network, and display it on a website. Initially, we focus on measuring the local field strength of electromagnetic fields. At the moment there are no local measurement networks on a dense grid in the Netherlands.In Belgium, Ghent University has developed such a network in Flandres (https://www.imeccityofthings.be; Aerts et al., 2022). A similar project is the SmartSantander study in Spain (Diez et al, 2017; Aerts et al., 2018). In the Netherlands, the first methods of measurement have been designed by the Telecom Agency and the RIVM, but there is not yet a dense grid measurement network to observe the trend in urban areas (Colussi et al., 2020) and combined with methods developed by Ghent (Deprez et al., 2022). The upcoming years we aim to roll out a low cost monitoring network of low cost nodes.

The aim of this project is to set up a continuous monitoring system for electromagnetic fields, so that a trend in exposure can be observed, and to keep a close watch whether a correlation with health effects may occur. A number of options will be explored for this, such as software-defined radio and measurement nodes for specific 5G frequencies. On the basis of this, the footprint of economic activities on our living environment and health can be monitored. The data from the measuring instruments will be collected wirelessly and made public via a server to which students and later members of the general public will have access during the pilot.

Method of sensor development

The aim of this project is to set up a continuous monitoring system for electromagnetic fields, so that a trend in exposure can be observed, and to keep a close watch whether a correlation with health effects may occur. A number of options will be explored for this, such as software-defined radio and measurement nodes for specific 5G frequencies. On the basis of this, the footprint of economic activities on our living environment and health can be monitored. The data from the measuring instruments will be collected wirelessly and made public via a server to which students and later members of the general public will have access during the pilot.

The aim was to develop a low-cost RF EMF sensor, hence off the shelf components are used. The sensor node can measure four frequency bands in 5G for Netherlands. In Table 1 the frequency bands in the Netherlands for downlink are listed. However, the frequency band 3500-3700 MHz is not active yet in the Netherlands.

The EMF sensor consist of two PCB's, the first part (Figure 1.a) is the analog part to measure the received EMF power levels and the second part (Figure 1.b) is the digital part to process and save the data. Each frequency band (channel) receives the signals from the antenna through an SMA connector, followed by filters to block the out of interest signals. The output of the filters is fed to LNA's (QPL9057TR7) to amplify the signals between 20-23 dB to be able to measure the lower signal levels. Then the output of LNA's is connected logarithmic RF power detectors (LT5538) with up to 75 dB dynamic range to measure the RF power levels. The digital part consists of a microcontroller (ESP32-S2) which receives the voltage levels from each channel to process the data. The signals are sampled internally by 1 ms and averaged over 1000 ms to store the results. The sensor node is equipped with a battery to be able to operate for mobile measurement purposes, have a WIFI connection to read the real-time measurements on a mobile device (e.g. laptop, tablet, phone) and also to upload the measurement results to a server. Furthermore, it also has an SD card to save the measured data. The total cost of the sensor node is less than€200.

The RF power detectors yields voltage levels which are linearly related to power levels (dBm). This first order linear relationship is frequency dependent. That is why within each frequency band limits those linear function variables are calibrated by means of a reference signal generator and spectrum analyzer.

Table 1: Frequency bands of the RF power meter sensor	
Channel 1	758-788 MHz
Channel 2	1452-1492 MHz
Channel 3	2110-2170 MHz
Channel 4	3500-3700 MHz – not yet into service

Results

The EMF node is firstly tested with a reference signal generator and compared the results with spectrum analyzers. Generally, the error is less than 1 dB and close to dynamic range limits (-65 to 5 dBm) the error increases to 3 dB. For the initial measurements we used a wideband antenna (CM.02.03F21.02806) which covers all the frequency bands. However, the aim is to develop and use dedicated narrow band antennas. The sensor is tested inside the university building, located close to windows, to observe the present 5G signals. The aim in the near future is to conduct systematic measurements of 5G signals which will be presented at the symposium.The electric field values are depicted in Figure 2 for three frequency bands. The frequency band 3500-3700 MHz is not depicted since it is not active yet in Netherlands. Interestingly close to building the signal levels for 2100 MHz band are very low.

Conclusions

Low-cost 5G EMF sensors were designed for four frequency bands in the Netherlands. The sensors are validated in-situ and initial results are presented. The sensor node has a wide dynamic range able to use for mobile measurement purposes to evaluate the real time exposure of EMF from 5G technologies

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Figures

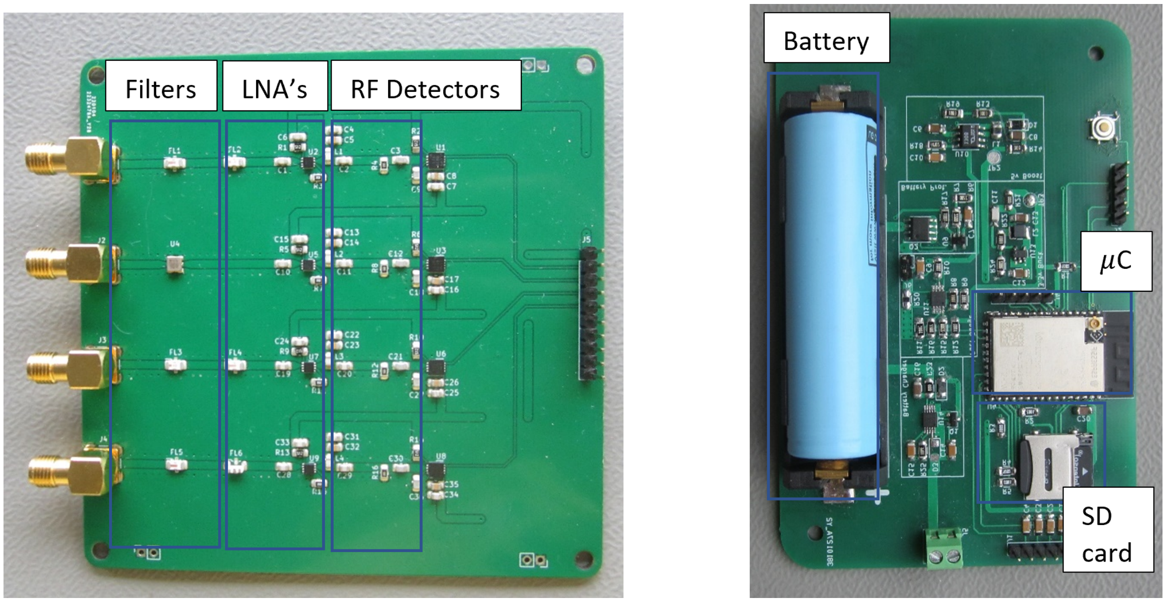

Figure 1. Radiofrequency power meter sensor

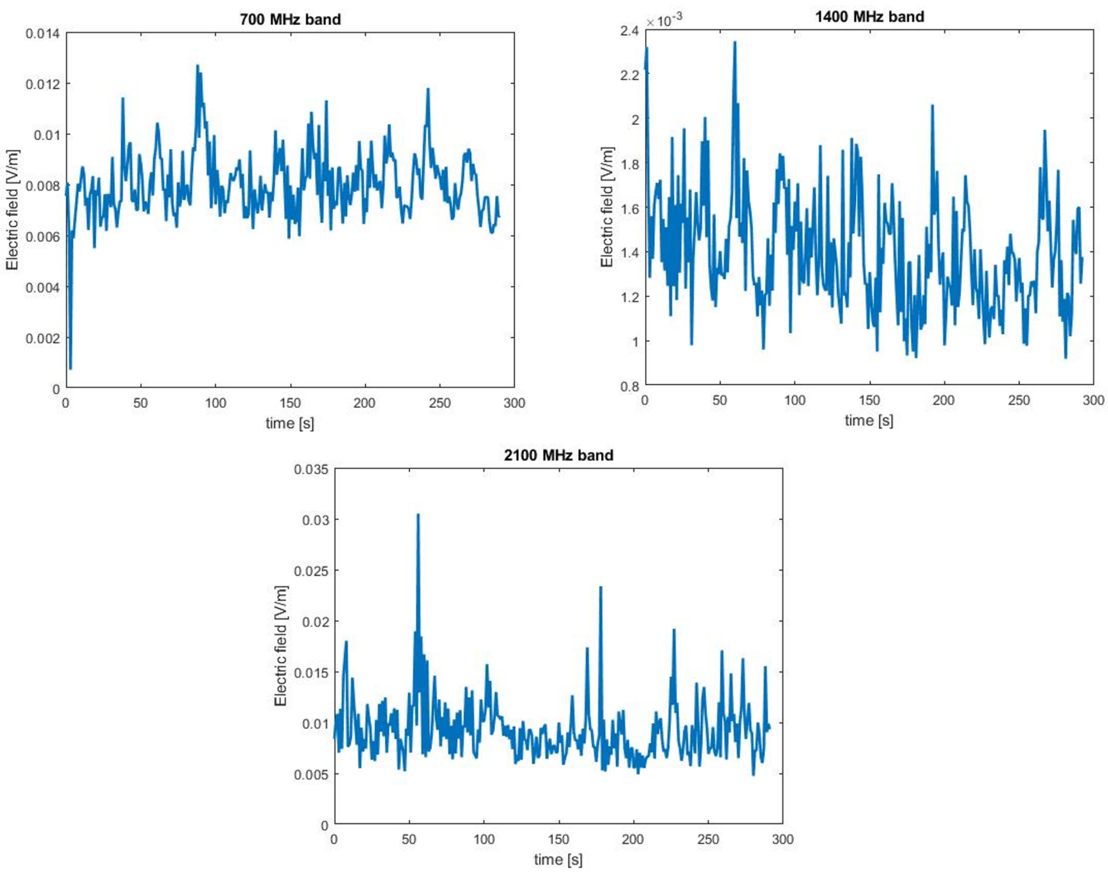

Figure 2. Measured E-field values for three frequency bands