# Development of a drone-based measurement system for 3D radiofrequency exposure assessment

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## SUMMARY

A significant drawback for current measurement-based modelling of exposure to radiofrequency (RF) electromagnetic fields (EMF) is its inherent two-dimensional-only application. Therefore, we developed a measurement system, composed of a hexacopter carrying RF measurement nodes, that will enable researchers to accurately measure 3D exposure patterns in outdoor or large indoor environments. Here, we introduce the measurement system as well as an application consisting of outdoor measurements as a function of height (up to 60 m) of RF radiation from mobile phone base stations in the 900 MHz band used by Global System for Mobile Communications technology (GSM900).

## INTRODUCTION

As most people spend considerable time at higher elevations (e.g., multi-level residences, office buildings, and/or apartment buildings), current measurement-based RF-EMF models [1], which only offer two-dimensional exposure information, suffer a significant drawback compared to 3D computer modelling techniques [2].

To overcome this problem, we developed a simple but effective measurement system made up of a hexacopter carrying lightweight electronics and three RF measurement nodes. This system has two substantial advantages over other spatial measurement systems (e.g., spectrum analysers, exposimeters, car-based systems): (1) it is truly isotropic, as if offers unshielded and uninfluenced free-space measurements, and (2) it offers fast sampling in three dimensions. Considering these benefits, our measurement system allows not only extension of existing 2D measurement methods to 3D (assessment of exposure as a function of height), but also unmanned measurements in close proximity of (base station) antennas (occupational exposure assessment), as well as measurements at other locations difficult to reach by the operator executing the measurements.

We present here the first drone-based RF measurement system, the proposed measurement [illegible] as a function [illegible]



## MEASUREMENT SYSTEM

Our measurement system consists of a mid-sized drone, a lightweight and compact RF exposure acquisition system, and a battery (**Error! Reference source not found.**). For this study, we constructed a hexacopter from the DJI F550 flamewheel kit (DJI, Shenzhen, China). The drone contains a GPS (Global Positioning System) module, a barometric pressure altimeter and a compass for positioning and autonomous flight mode, and it is piloted with a controller (type NAZA V2), which transmits at 2.4 GHz (no interference with our measurements). The RF measurement system consists of three identical RF measurement nodes composed of a linearly polarized patch antenna (bandwidth 60 MHz, gain 3 dBi) [3] connected with lightweight electronics (containing a log detector, a tuned GSM downlink 942.5 MHz SAW filter, an analogue digital convertor, controlled via I2C by a microcontroller, and an SD card to store the data). The sampling rate of the measurement nodes is 1 Hz. A lithium-polymer (LiPo) battery (PK Racing, Dordrecht, The Netherlands) feeds the whole system. The combined measurement uncertainty of the system is 2.3 dB (Table 1). As the drone measurement system operates in free space, uncertainty terms related to the anisotropy of the antenna caused by the body of an operator or mounting on a carrier (e.g., a vehicle) are avoided.

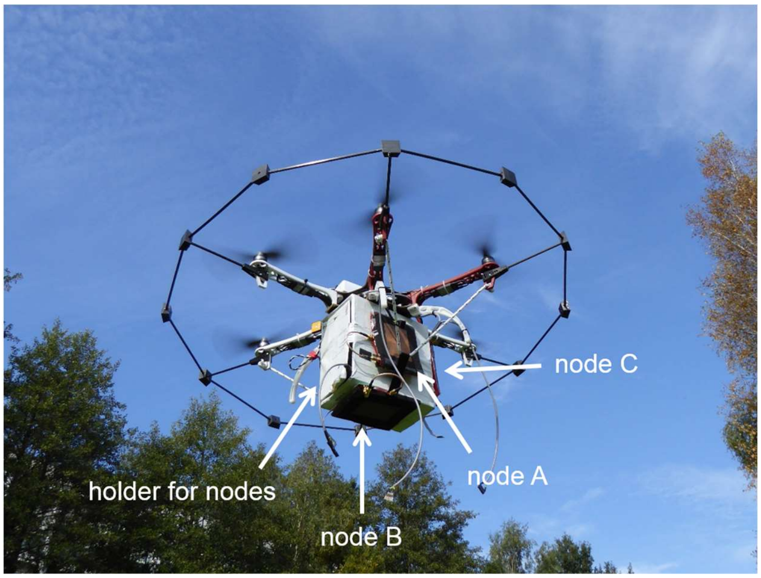


Figure 1: Drone measurement system with indication of the three nodes (consisting of lightweight electronics and patch antennas [3]).

| cause of uncertainty | u (dB) |
| --- | --- |
| received power | 0.19 |
| out-of-band signals | 0 |
| incident power density $S_{inc}$ | 0.17 |
| measurement equipment | 1.1 |
| processing | 0.1 |
| small-scale fading | 1.9 |
| combined standard uncertainty | 2.3 |
| expanded uncertainty (k=2) | 4.6 |

Table 1: Uncertainty assessment of the drone-based measurement system in the GSM900 downlink band.

For flight stability reasons, the centre of mass of the complete measurement system is required. After input of an educated guess, short test flights are done to accurately determine the centre of mass.

## APPLICATION

In a suburban office environment, measurements of GSM900 downlink (signals radiated by base stations) were performed at steps of 3 to 5 (at higher elevations) m between 6 and 60 m above ground level. At each step the drone was held stationary for at least 30 seconds. The rootmean-square (RMS) electric-field strength was calculated from the collected samples. Because of the limited battery life (< 15 min), three flights were needed. The variation in height is +/- 1.5 m (altimeter uncertainty) and in the xy-plane +/- 1 m (GPS uncertainty).

The results are shown in **Error! Reference source not found.**. Below a height of 30 m, the electric-field strength increases almost monotonically from 0.18 V/m at 6 m to 0.50 V/m between 24 and 30 m (maximum of 0.52 V/m); above 30 m, the field strength decreases again, down to 0.25 V/m at 60 m. The elevation at which the maximum field strength occurs (24 m) is not a coincidence, as mobile phone base stations are typically installed at heights of about 30 m. With directive antennas with a tilt of 0 - 6°, at a distance of 100 m from the base station the main beam, and thus the highest exposure, is situated at a height between 20 and 30 m. Measurements above 30 m were performed above the main beam. Furthermore, below 20 m, additional factors such as shadowing by buildings and foliage increasingly influence the electric-field strength.

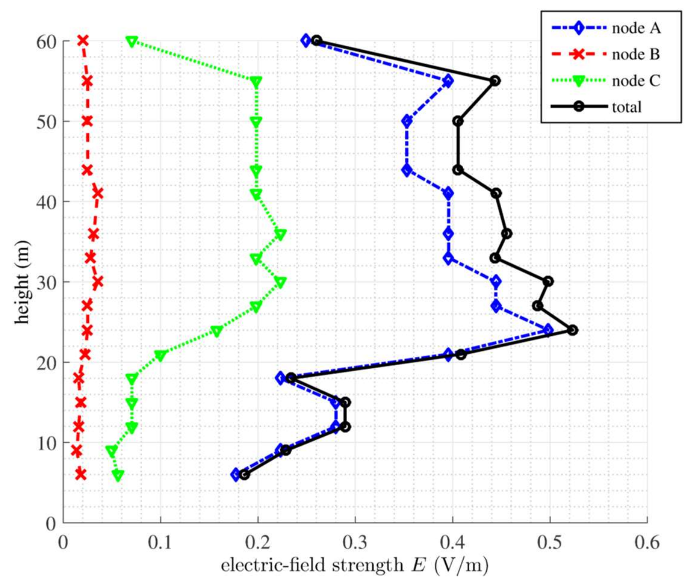


Figure 2: Electric-field strength (V/m) in the GSM900 downlink band measured by the three nodes (A,B, and C) as a function of height up to 60 m.

## CONCLUSIONS

We developed a drone-based RF measurement system with which unshielded, continuous measurements can be performed over any stretch of space, thus enabling us to assess experimentally three-dimensional RF-EMF exposure. Besides being a welcome and necessary addition to measurement-based RF-EMF exposure modelling, it can also be used for occupational exposure assessment in the vicinity of mobile phone base stations and at any location difficult to reach with conventional measurement equipment.

## REFERENCES

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