Low-cost System for Electromagnetic SAR Evaluation in a Human Phantom

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***Abstract*—We developed a low-cost system to evaluate electromagnetic Specific Absorption Rate (SAR) in a human phantom. Our system is based on the manual sweep of a near field isotropic probe, with optical tracking of the position that allows 3-D polarimetric reconstruction of the electric field, hence Specific Absorption Rate (SAR). We describe and compare the performance of our in-house developed tracking system based in two web cameras, and a commercial infrared motion capture system. Furthermore, we describe the process to manufacture a human phantom container and the preparation of tissue-emulating fluid, and compare the performance to industry-standard products. Detailed results of the validation campaign of our system will be presented during the conference.**

***Index Terms*—Motion tracking system, Software Defined Radio (SDR), Specific Absorption Rate (SAR), 5G, Human phantom.**

I. Introduction

The forthcoming deployments of the 5G infrastructure in Colombia have raised interest on the impact of that technology in human health and its overall perception, echoing concerns from around the world. In this context, the Agencia Nacional del Espectro (ANE) has funded the project entitled ”5G Radio signals and human health: qualitative and quantitative analysis in the colombian context” where one of the main contributions is the measurement of the electromagnetic Specific Absorption Rate (SAR) in a human phantom [1].

SAR is defined as the absorption rate of radio frequency energy in the human body per unit mass, as in Eq. 2 [2]:

$$SAR = \frac{\sigma E^2}{\rho} \tag{1}$$

$$SAR = C_h \left.\frac{\partial T}{\partial t}\right|_{t=0} \tag{2}$$

where:

- E is the RMS value of the electric field intensity in V/m
- σ is the electrical conductivity of the tissue in S/m
- ρ is the mass density of the tissue in $\mathrm{kg/m^3}$
- C_h is the specific heat capacity of the tissue in $\mathrm{J/kg/^\circ K}$
- t is time in s
- T is the temperature in $^\circ K$

When a 3-D representation of the SAR in several positions of the human body is required, then the measurement probe has to move inside a human tissue-emulating fluid. For this reason, a complete measurement system includes a human phantom, tissue emulating liquids, signal generator and antenna, isotropic field probe, and positioning and tracking systems. As these techniques are extremely time-consuming and require considerable budget, we propose a procedure in which the sweep is made manually and the position is tracked with a camera-based motion capture similar to that proposed in [3], with an in-home designed human phantom based on well-known recipes [4]. The whole procedure is carried out inside a shielded chamber.

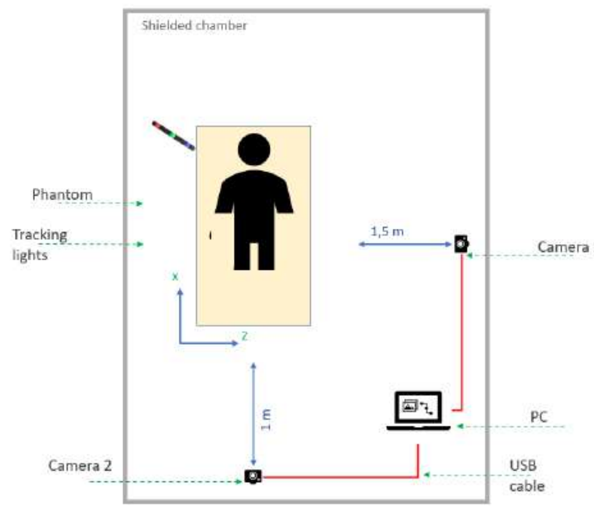

Fig. 1. Web camera setup for electromagnetic SAR evaluation in a phantom.

II. System description

First, two web cameras were used with a three-LED probe support in order to track its position and orientation. The system is displayed in Fig. 1, and a sample capture is shown in Fig. 4 for a manual sweep used to cover a planar surface in a near field scan, which was acquired with the speed and accuracy required for SAR evaluation (20 data points per second with millimeter resolution, including position and orientation). In addition to this approach, the commercial motion capture system, Optitrack [5], has also been tested for this purpose with the layout in Figs. 2 and 3.

III. Component comparison

In Table I, the characteristics of the suggested experimental structure and the commercial setup are compared [6], [7]. There is a significant improvement in the samples per second rate, the spatial resolution and operation range in meters. Also, the commercial system cost is substantially higher (over ten times).

TABLE I
RESOLUTION, COST AND ACCURACY COMPARISON OF THE PROPOSED SYSTEM AND SPEAG'S DASY8 COMMERCIAL SAR MEASUREMENT SETUP.

Setup		Samples/ s	Spatial resolution and measurement range	Software	Cost (USD) (Approx.)
Proposed system	Optitrack Flex13 tracking and positioning	120	0.1mm in 6m setup area volume	Motive 2.x	9000
	2 USRP B210	20	N/A	Matlab	3.870
	EASY6-EX3DV4	>20	<1 mm and 5uW/g	Speag	21.000
	2 PCs	>20	N/A	Matlab	1.500
	Phantom				400
	Tissue emulating liquid				400
					36.170
DASY8-EX3DV4 with robot arm		16	<1 mm with a 920 mm reach and 5uW/g	Speag	400.000

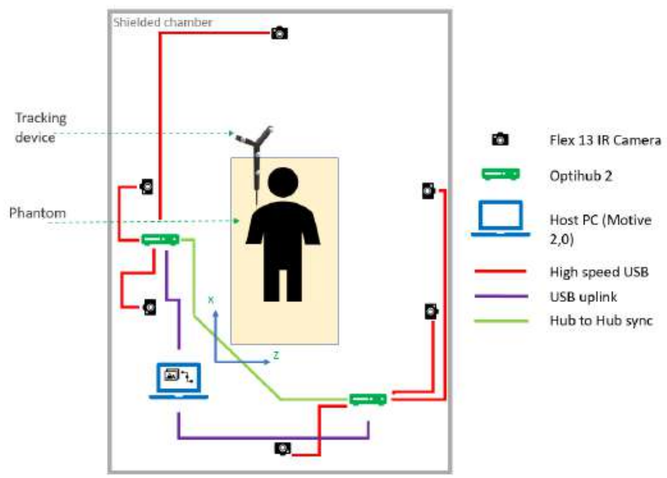

Fig. 2. Infrared Optitrack setup electromagnetic SAR evaluation in a phantom.

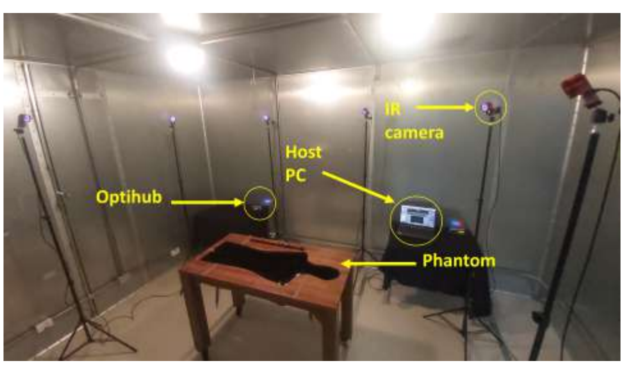

Fig. 3. Experimental setup with the IR Tracking system and the human phantom for SAR measurement inside a shielded chamber.

IV. CONCLUSIONS AND OUTLOOK

A low-cost experimental SAR measurement setup has been presented that is based on in-house developed position tracking system and human phantom. During the conference we will present detailed results on the validation of our system in the context of 5G communications for the first frequency range (FR1).

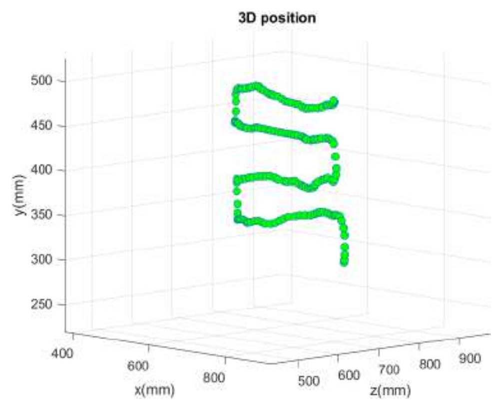

Fig. 4. Data captured by our LED-support web camera tracking system during a manual planar sweep.

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