Numerically and experimentally assessed skin temperature elevations for localized RF exposure at frequencies above 6 GHz

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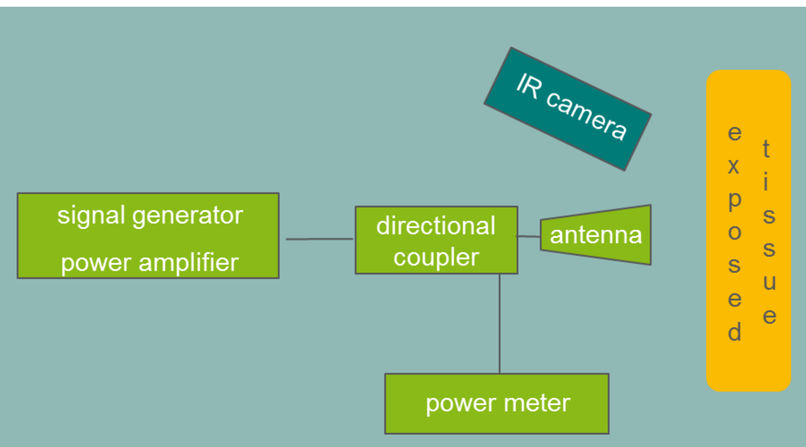
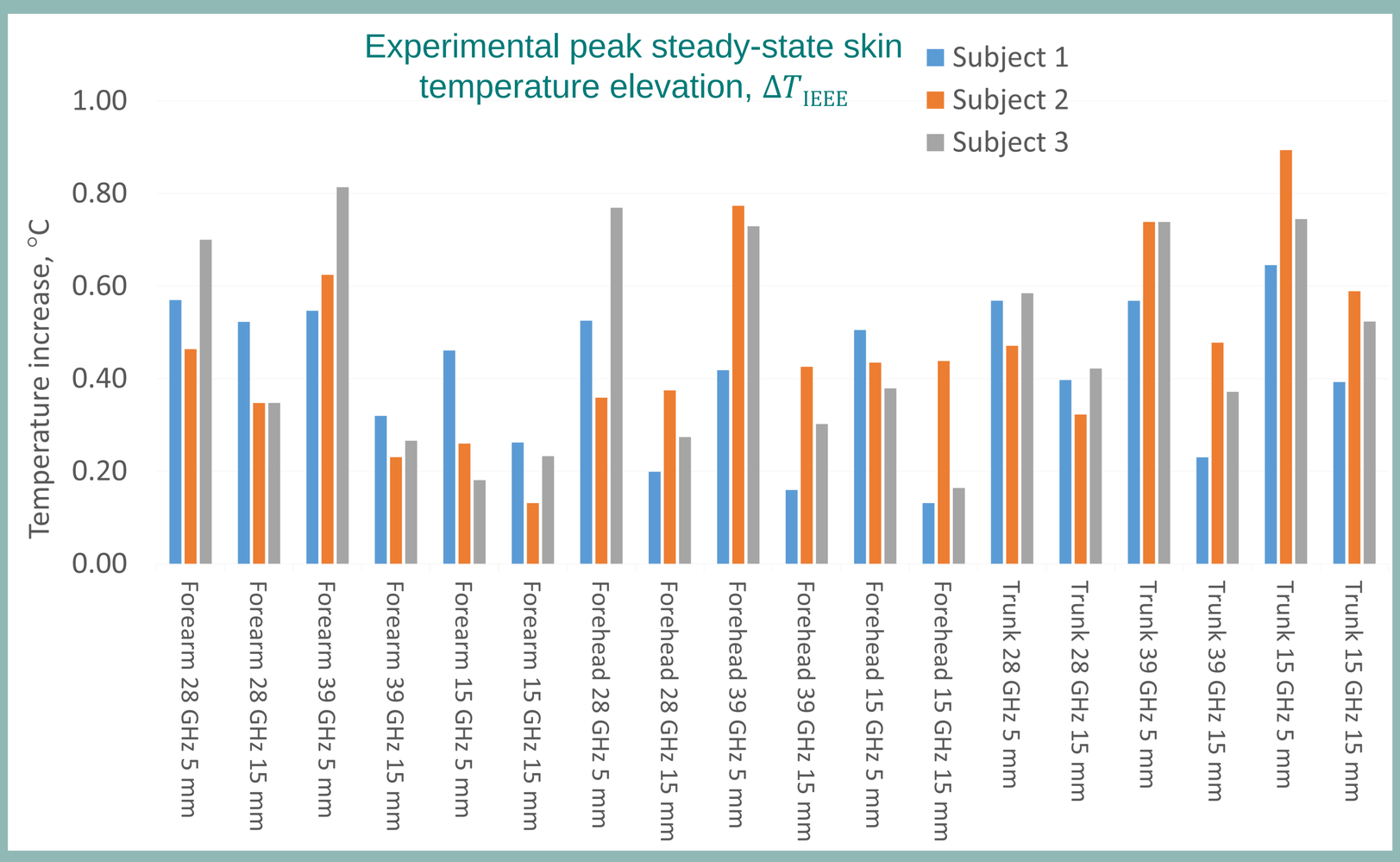
Objective: **Collect experimental data for skin temperature elevation due to RF exposure at frequencies above 6 GHz and compare with numerical results obtained by means of thermal modelling**

Results: (1) **State of the art thermal models can be used to conservatively predict skin temperature elevation due to RF energy absorption.** (2) **For the assessed configurations, the localized peak skin temperature elevation, corresponding to the exposure reference levels (ERL) recently proposed in the draft revision of IEEE C95.1, is less than 1 °C.**

Measurements

- Thermographic measurements based on IR recordings of the skin in close proximity to RF sources
- Frequencies investigated: 15 GHz, 28 GHz and 39 GHz (CW)
- Standard waveguide horn antennas (WR-62 and WR-28)
- FLIR A6750sc, cryo-cooled camera (sensitivity: < 20 mK)





$$\Delta T_{\mathrm{IEEE}} = \Delta T_{\mathrm{RAW}} \frac{P_{\mathrm{IEEE}}}{100\ \mathrm{mW}}$$

P_{IEEE} = Max forward power to comply with IEEE/ICES draft general public ERLs ($55f^{0.177}$ W/m^2 averaged over 4 cm^2, 6 GHz ≤ f ≤ 100 GHz)

100 mW = Forward power to the horn antenna

ΔT_{RAW} = Measured temperature increase for a forward power of 100 mW

ΔT_{IEEE} = Temperature increase for a forward power of P_{IEEE}

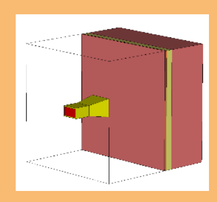
P_{IEEE} (based on power density measurements)

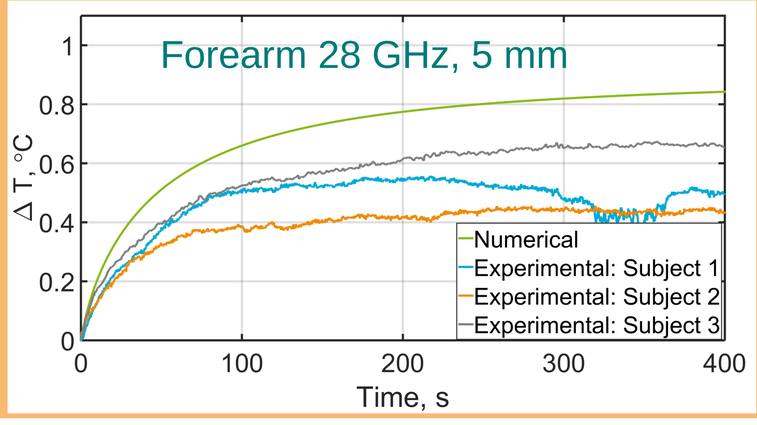
	15 GHz	28 GHz	39 GHz
5 mm	25 mW	16 mW	14 mW
15 mm	33 mW	24 mW	18 mW

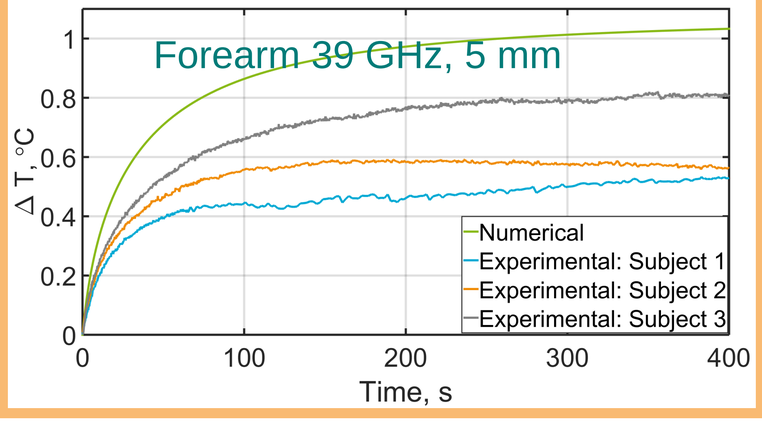
Comparison with simulations

4-layer tissue model as described in:

Sasaki, et al. "Monte Carlo simulations of skin exposure to electromagnetic field from 10 GHz to 1 THz." Physics in Medicine & Biology 62.17 (2017): 6993.







	Thickn.	Thermal Properties			
		Thermal cond.	Heat cap.	Blood perf.	Meta. rate
	mm	W/K/m	kJ/K/kg	W/K/m^3	W/m^3
epidermis	0.102	0.42	3.5	0	1620
dermis	1.08	0.42	3.5	9100	1620
subcutaneous tissue	3.89	0.25	2.5	1700	300
muscle	23.3	0.5	3.6	2700	480

Additional results and future work

- IR measurements of a mockup device (characterized by a notch array at 28 GHz, see IEC TR 63170) were also conducted; the measured peak skin temperature increase at touch position with the forearm was less than 1°C for a forward power of 75 mW
- Thermographic measurement samples with clothing (wool jumper) showed similar or lower skin temperature increase compared with bare skin
- The skin temperature increase due to a lightbulb (20 W, halogen) placed at 20 cm from the forearm was 4.5° C after 7 minutes
- The surface skin temperature variation for the forearm when not exposed to any RF source, was found to be within 4 °C to 5 °C
- Additional numerical evaluations are needed in order to quantify the impact of the layering structure of skin tissue and the uncertainty of the thermal tissue parameters