

Design and Dosimetric Characterization of a Broadband Exposure Facility for In Vitro Experiments in the Frequency Range 18–40.5 GHz

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Background

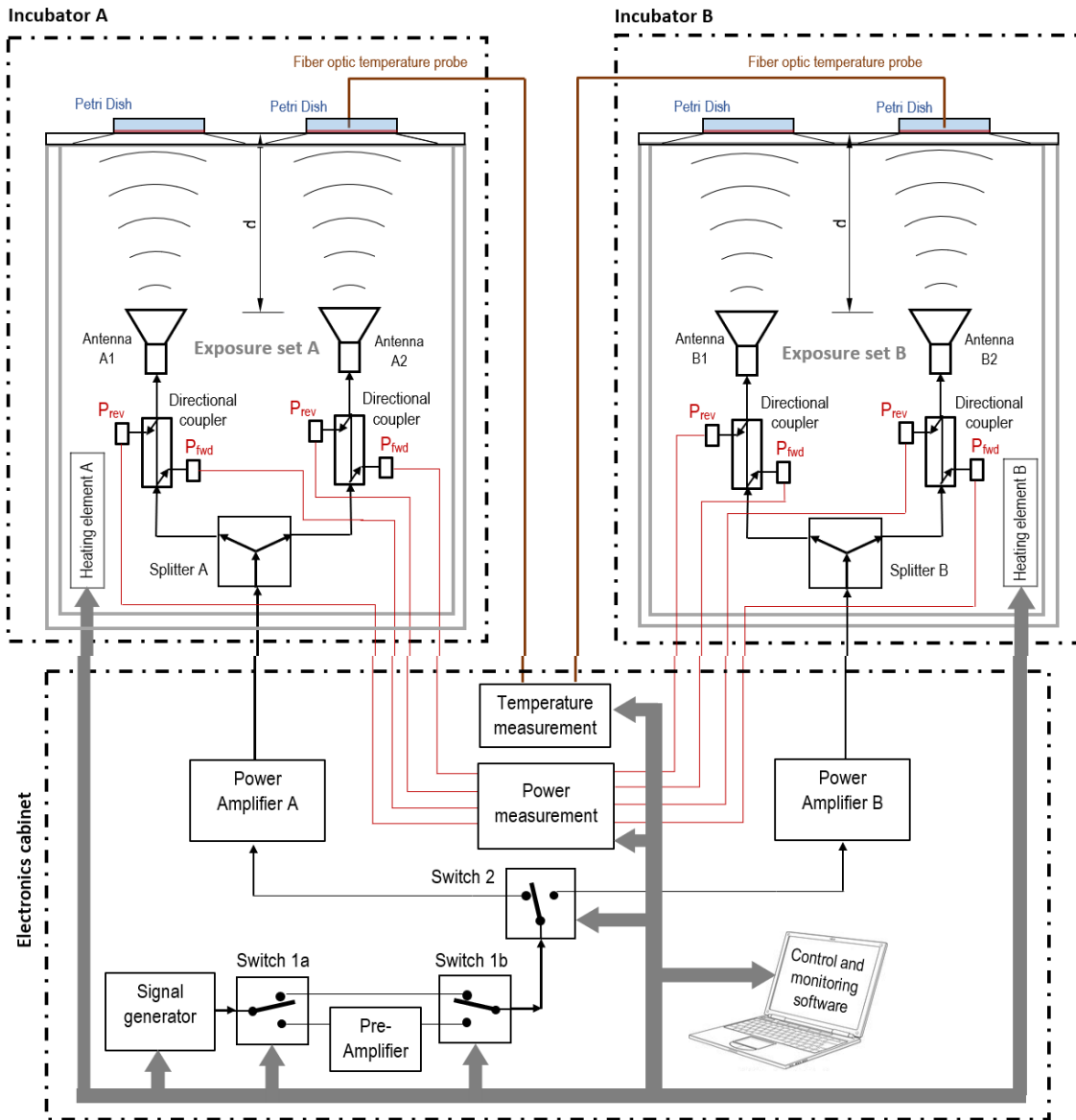
- Future cellular mobile communication networks will use millimeter wave (mmW) frequencies in addition to traditional frequency bands (< 6 GHz)
- **5G NR FR2:** ~ 24.3 – 27.5 GHz; ~ 39.5 – 43.3 GHz
- Reliable data about potential non-thermal effects caused by mmW exposure is scarce (Simkó & Mattsson 2019*)
- German Federal Office for Radiation Protection (BfS) is funding an in vitro study to investigate potential effects of future 5G-FR2 frequencies on human dermal fibroblasts and keratinocytes
- Presently carried out by Jacobs University Bremen (Lerchl-Group)
- Exposure facility developed by Seibersdorf Laboratories

* Simkó M, Mattsson MO. 2019. 5G Wireless Communication and Health Effects - A Pragmatic Review Based on Available Studies Regarding 6 to 100 GHz. Int J Environ Res Public Health 2019; 16 (18): E3406

Exposure Facility - Requirements

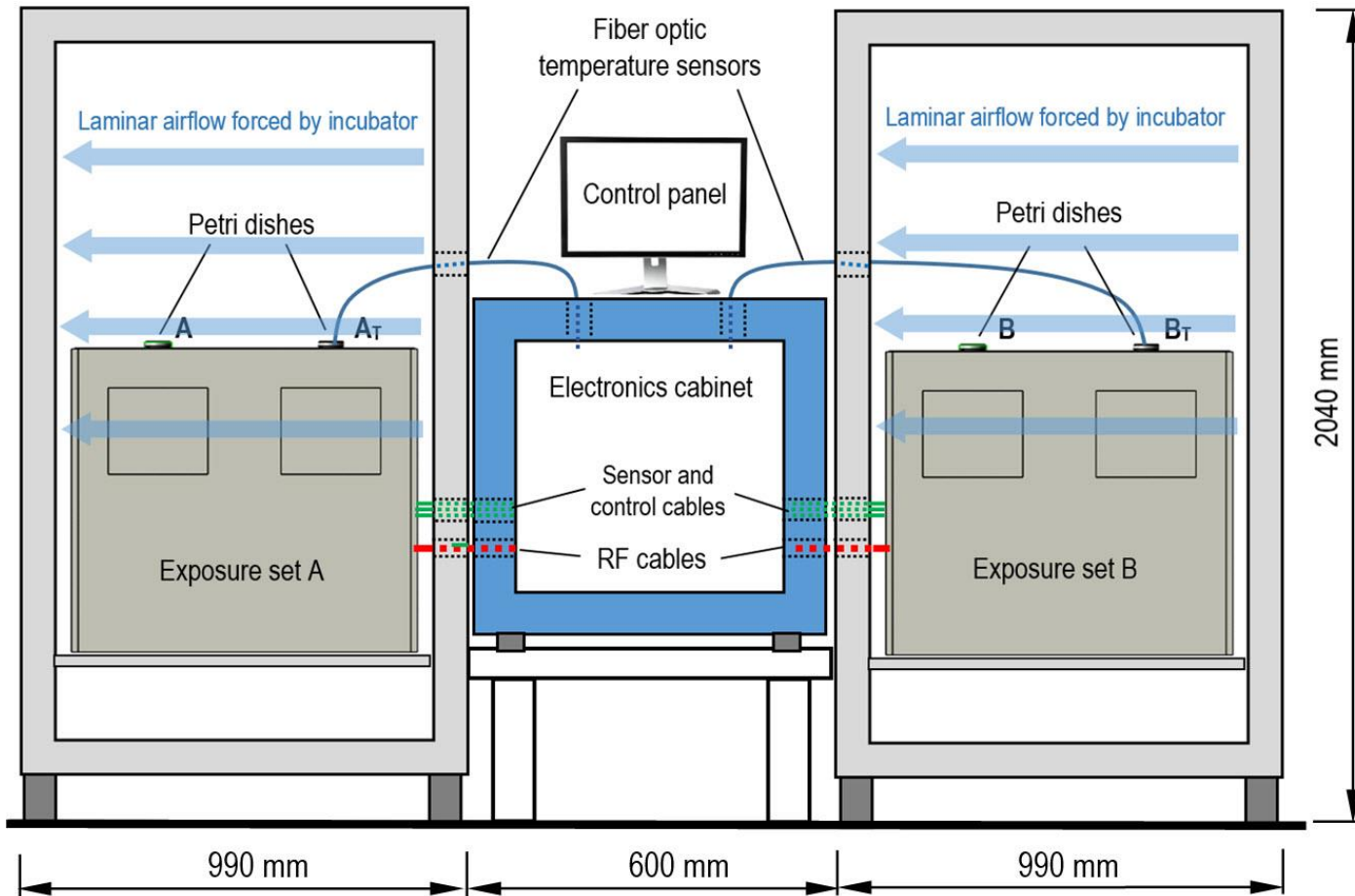
- Cell monolayer at the bottom of 5 ml culture medium inside a polystyrene (PS) petri dish (inner diameter 50 mm)
- Inside incubator(s) with constant environmental conditions (37 °C, saturated humidity, 5% CO₂)
- Selectable frequencies (27 or 40.5 GHz) and exposure duration
- Adjustable incident power flux density up to 100 W/m²
- Sham exposure shall be executed simultaneously to real exposure
- Continuous temperature monitoring of exposed and sham exposed samples during the experiments
- Minimum deviation from routine workflow of cell experimental procedures (e.g., avoiding laborious or poorly reproducible positioning of petri dishes inside the exposure apparatus)
- Blinded exposure control via easy-to-understand software interface

Exposure Facility - Concept





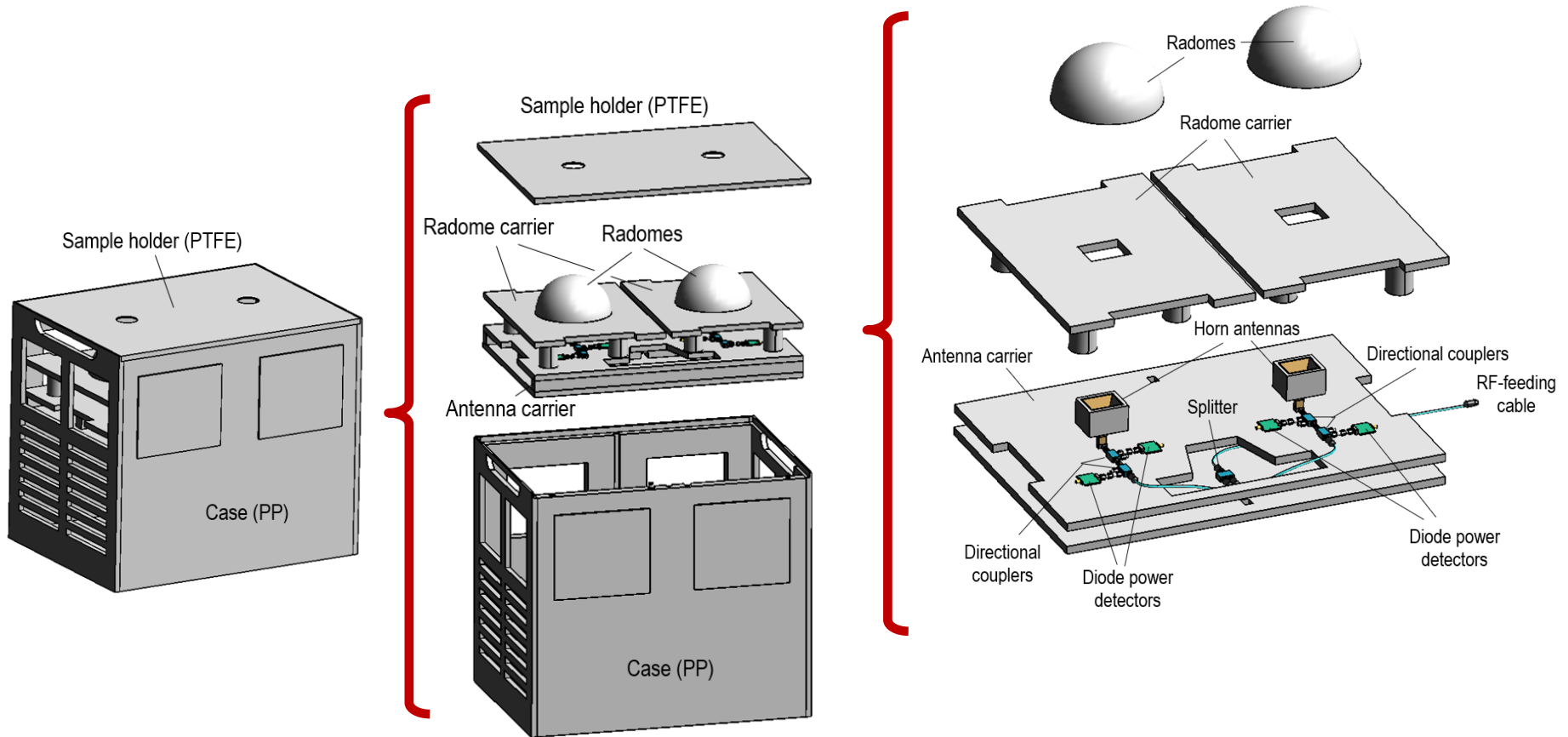
Exposure Facility – Outline overview



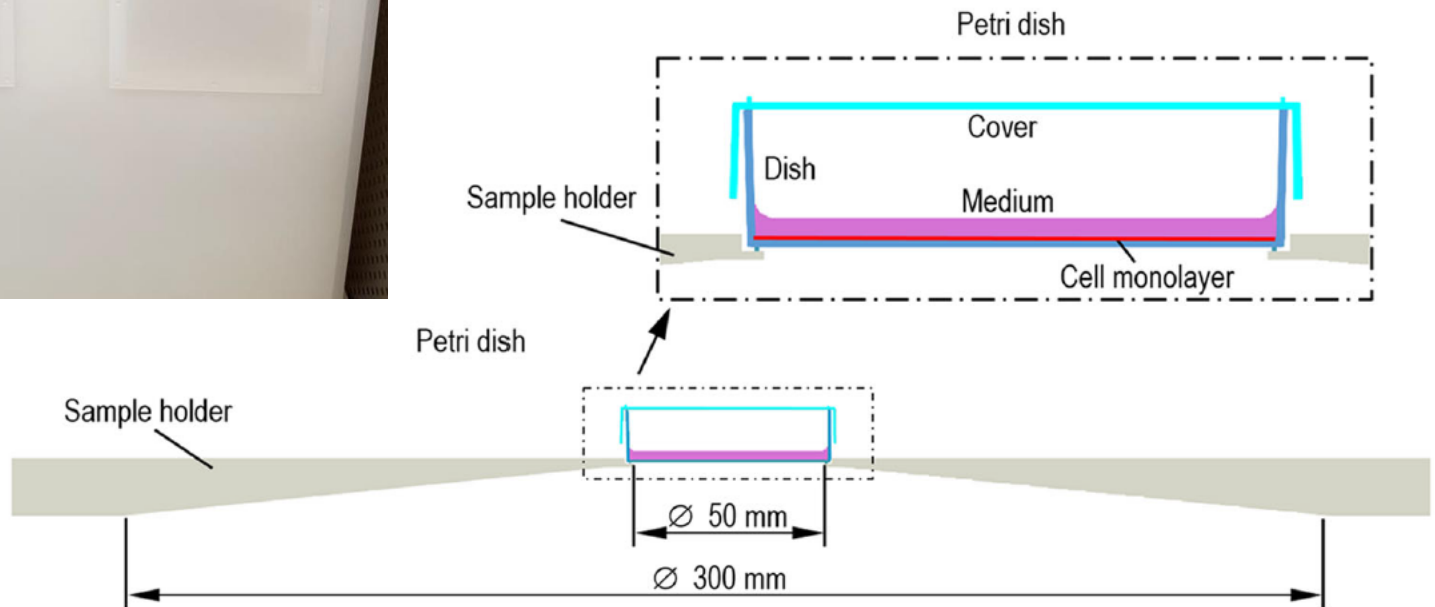
Exposure Facility – Outline overview



Exposure Facility – Outline details



Exposure Facility – Outline details



Exposure Facility – Outline details

Top view, sample holder removed (view on radoms)



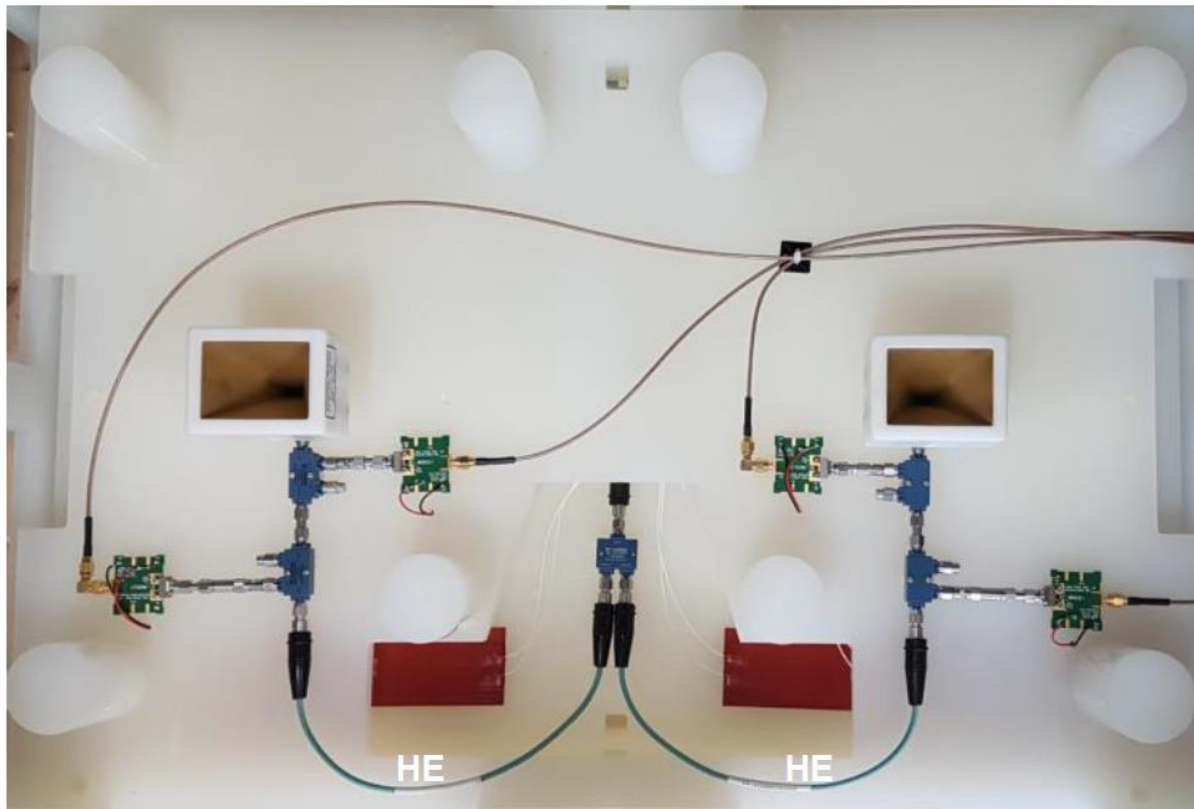
Exposure Facility – Outline details

Top view, radoms removed (view on antennas)



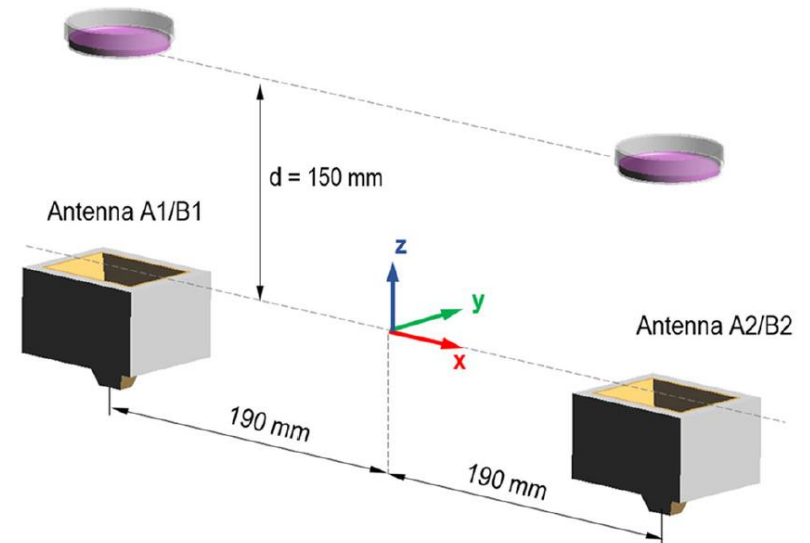
Exposure Facility – Outline details

Top view, radom carrier removed



Dosimetric characterization

- Full wave (FDTD) computations
Sim4Life (Zurich Med Tech)



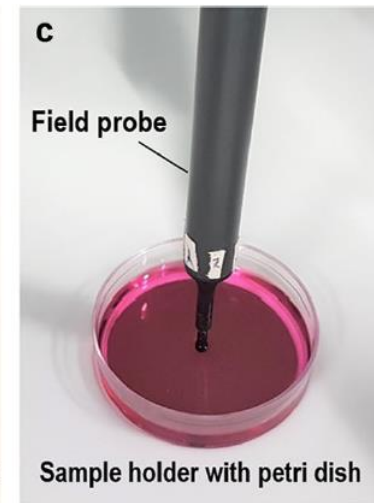
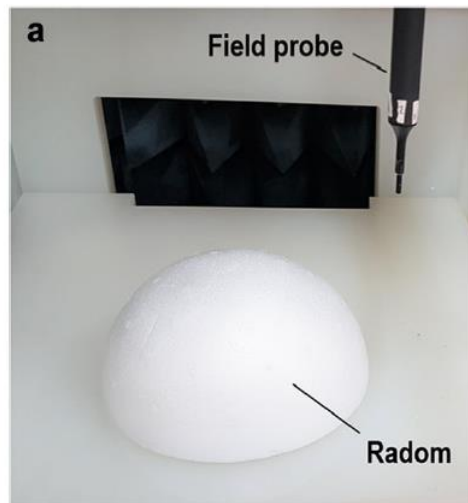
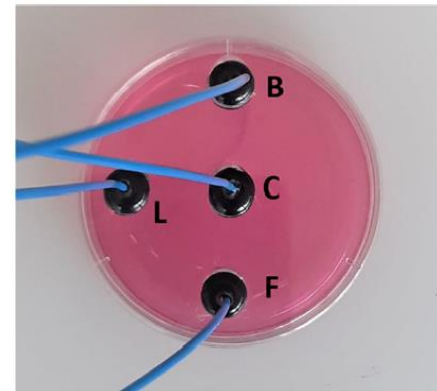
Dosimetric characterization

- Full wave (FDTD) computations
Sim4Life (Zurich Med Tech)
- Detailed CAD Model including all
components / materials

	f [GHz]	Rel. permittivity ϵ_r	Conductivity σ [S/m]
Sample	27.0	2.05	0.05
holder (PTFE)	40.5	2.05	0.08
Petri dish (PS)	27.0	2.54	0.25
	40.5	2.54	0.25
Setup case (PP)	27.0	2.25	0.25
	40.5	2.25	0.35
Radomes	27.0	1.50	0.001
(styrofoam)	40.5	1.50	0.001
Culture medium	27.0	35.2	55.5
	40.5	20.6	72.2
Cell monolayer	27.0	24	32
	40.5	16	42

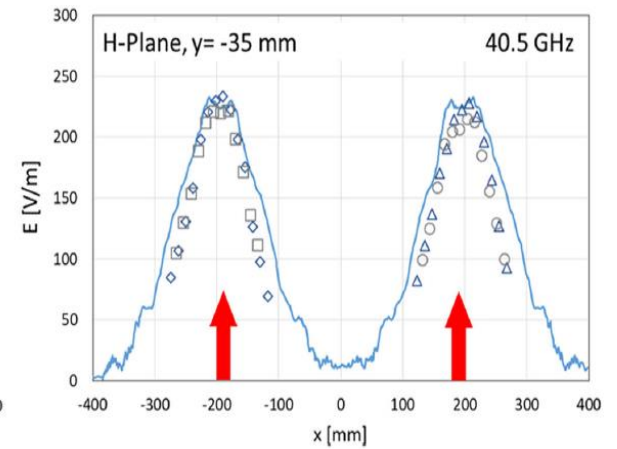
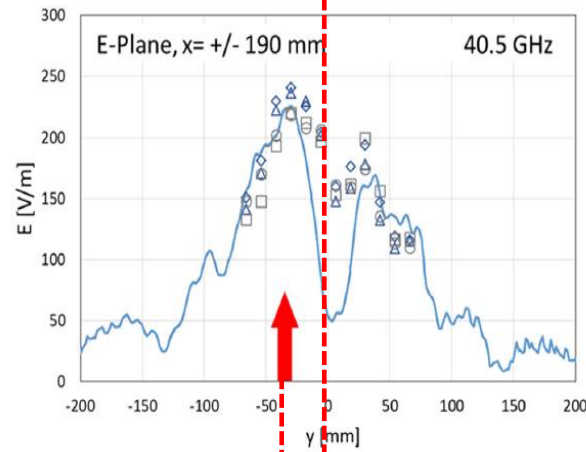
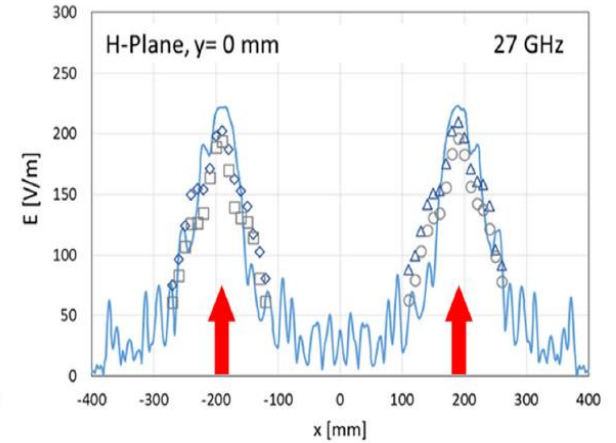
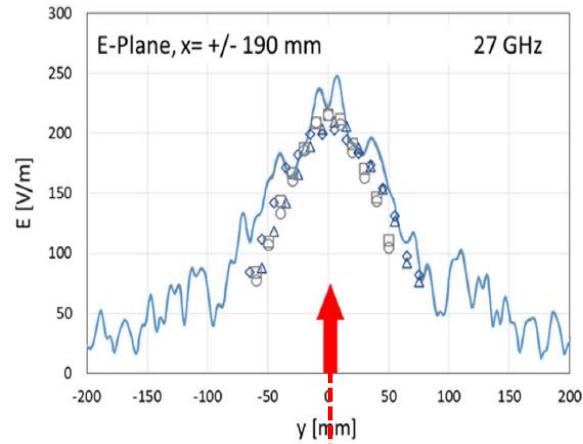
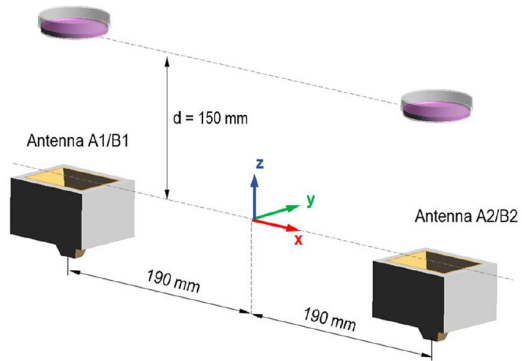
Dosimetric characterization

- Full wave (FDTD) computations
Sim4Life (Zurich Med Tech)
- Detailed CAD Model including all
components/materials
- Experimental validation





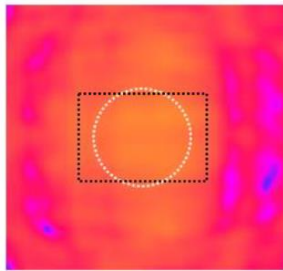
Dosimetric characterization



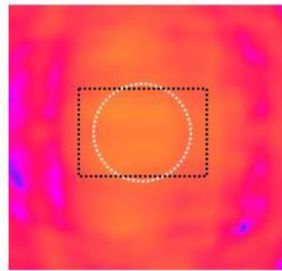
Dosimetric characterization

27 GHz

Simulation
Antenne A1/B1
(linke Seite)

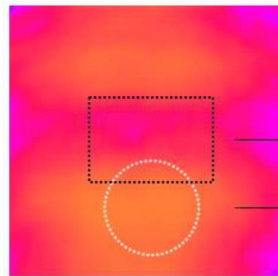


Simulation
Antenne A2/B2
(rechte Seite)

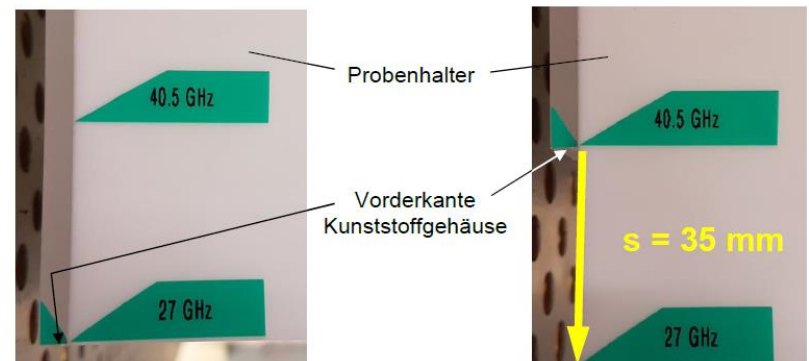
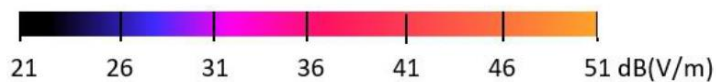
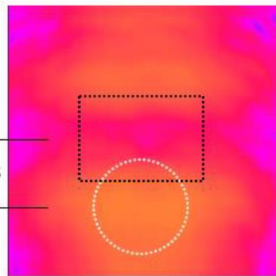


40,5 GHz

Simulation
Antenne A1/B1
(linke Seite)



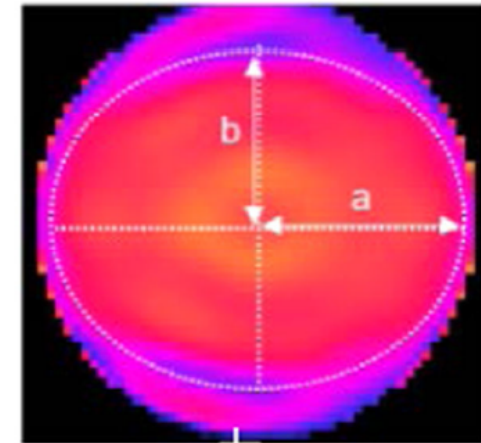
Simulation
Antenne A2/B2
(rechte Seite)



Dosimetric characterization

SAR statistics in cell monolayer @ 27 GHz, 1 W

		Elliptical harvesting area (centered in petri dish, semi-axis $a = 24$ mm)							
		Semi-axis b [mm]							
		24	23	22	21	20	19	18	17
Cell yield ^a [%]		92	88	84	81	77	73	69	65
Maximum SAR [W/kg]		162	162	162	162	162	162	162	162
Mean SAR [W/kg]		111	112	114	115	117	119	121	123
Minimum SAR [W/kg]		68.8	69.6	69.6	69.6	72.3	72.6	78	86.7
Fraction of cells exposed to [%]	>90% v. Max	8.3	8.6	9.1	9.5	10	10.5	11	12
	>80% v. Max	20	21	22	23	25	26	27	29
	>70% v. Max	52	54	57	60	63	66	70	74
	>60% v. Max	68	71	75	78	83	86	91	96
	>50% v. Max	87	89	90	93	96	99	100	100
	Max/Min [dB]	3.71	3.66	3.66	3.66	3.49	3.47	3.14	2.70
	Max/Mean [dB]	1.64	1.58	1.52	1.46	1.39	1.32	1.25	1.18



SAR = specific absorption rate.

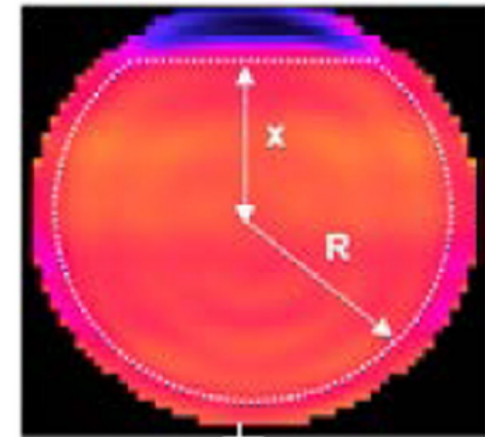
^aRelative of entire circular inner petri dish bottom area with radius 25 mm.

Dosimetric characterization

SAR statistics in cell monolayer @ 40.5 GHz, 1 W

Harvesting area in the shape of circle segment (R,x)

	R/x [mm]							
	24/24	24/20	24/19	24/18	23/23	23/20	23/19	23/18
Cell yield ^a [%]	92	88	87	86	85	84	81	80
Maximum SAR [W/kg]	211	211	211	211	211	211	211	211
Mean SAR [W/kg]	159	161	162	163	162	163	164	165
Minimum SAR [W/kg]	66.7	85.4	97.7	108	67.1	85	99	112
Fraction of cells exposed to [%]								
>90%	6.8	7.1	7.2	7.3	7.5	7.6	7.7	7.9
v. Max								
>80%	36	37	38	38	39	40	41	41
v. Max								
>70%	76	78	80	81	82	84	85	87
v. Max								
>60%	91	94	95	97	94	96	97	99
v. Max								
>50%	95	98	100	100	96	98	100	100
v. Max								
Max/Min [dB]	5.00	3.94	3.35	2.92	4.98	3.94	3.29	2.76
Max/Mean [dB]	1.25	1.17	1.14	1.12	1.16	1.11	1.08	1.06



^aRelative of entire circular inner petri dish bottom area with radius 25 mm.

Software

In vitro Studie Exposition von Hautzellen bei 27 GHz und 40,5 GHz
Steuer und Monitoring Software V1.0 - November 2020

Session ID festlegen

Expositionsparameter

27 GHz
 40,5 GHz

Expositionsstärke

Expositionszeit

Start Exposition

Software

In vitro Studie Exposition von Hautzellen bei 27 GHz und 40,5 GHz
Steuer und Monitoring Software V1.0 - November 2020

Session ID festlegen

Expositionsparameter

Frequenz

Expositionsstärke
✓

10 mW/cm2
anderer Wert:

Start Exposition

Software

In vitro Studie Exposition von Hautzellen bei 27 GHz und 40,5 GHz
Steuer und Monitoring Software V1.0 - November 2020

Session ID festlegen

Expositionsparameter

Frequenz

Expositionsstärke

Expositionszeit Stunden Minuten

Exposition aktiv
verbleibende Zeit [min]:

Stop

Start Exposition

Summary and conclusions

- Novel exposure facility for in vitro studies on cell monolayers investigating possible effects of radiofrequency exposure in the frequency range 18 – 40.5 GHz has been developed
- Presently executed at frequencies of 27 and 40.5 GHz for a study on human dermal fibroblasts and keratinocytes
- Mean SAR values inside cell monolayer of 115 W/kg (27 GHz) and 160 W/kg (40.5 GHz) per watt antenna input power
- For reasonable amounts of harvested cells (80% of petri dish bottom area), variation (max/min) of SAR over the cell monolayer remains below 3.7 dB (27 GHz) and 3.0 dB (40.5 GHz), respectively

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Thank you!