Ultra-wideband localization of pulmonary nodules during thoracoscopic surgery

Alberto Battistel, Knut Möller

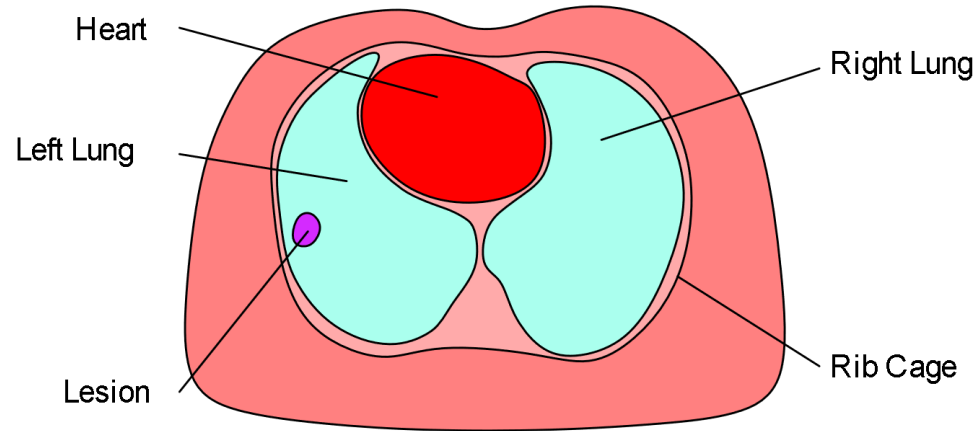Institute of Technical Medicine (ITeM), Furtwangen University, Germany

I3S 2021

- 12% of total tumor cases worldwide[1]

- 5-year survival rate less than 20%[2]

- Leading cause of tumor death[3]

[1]F. Bray, J. Ferlay, I. Soerjomataram, R. L. Siegel, L. A. Torre, and A. Jemal, CA Cancer J Clin, 2018
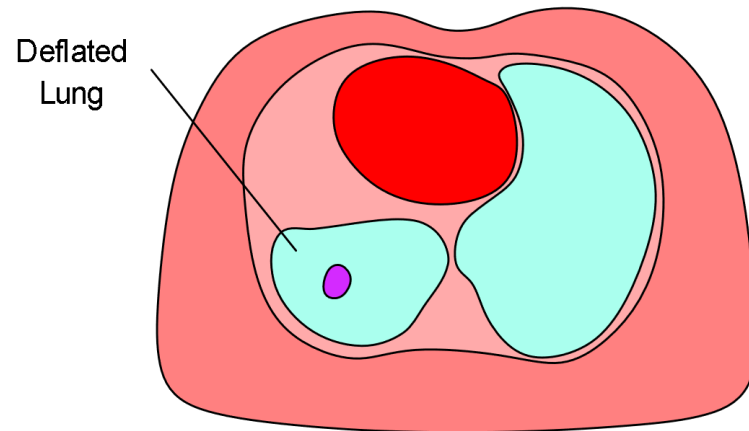[2]R. L. Siegel, K. D. Miller, and A. Jemal, CA: A Cancer Journal for Clinicians, 2016
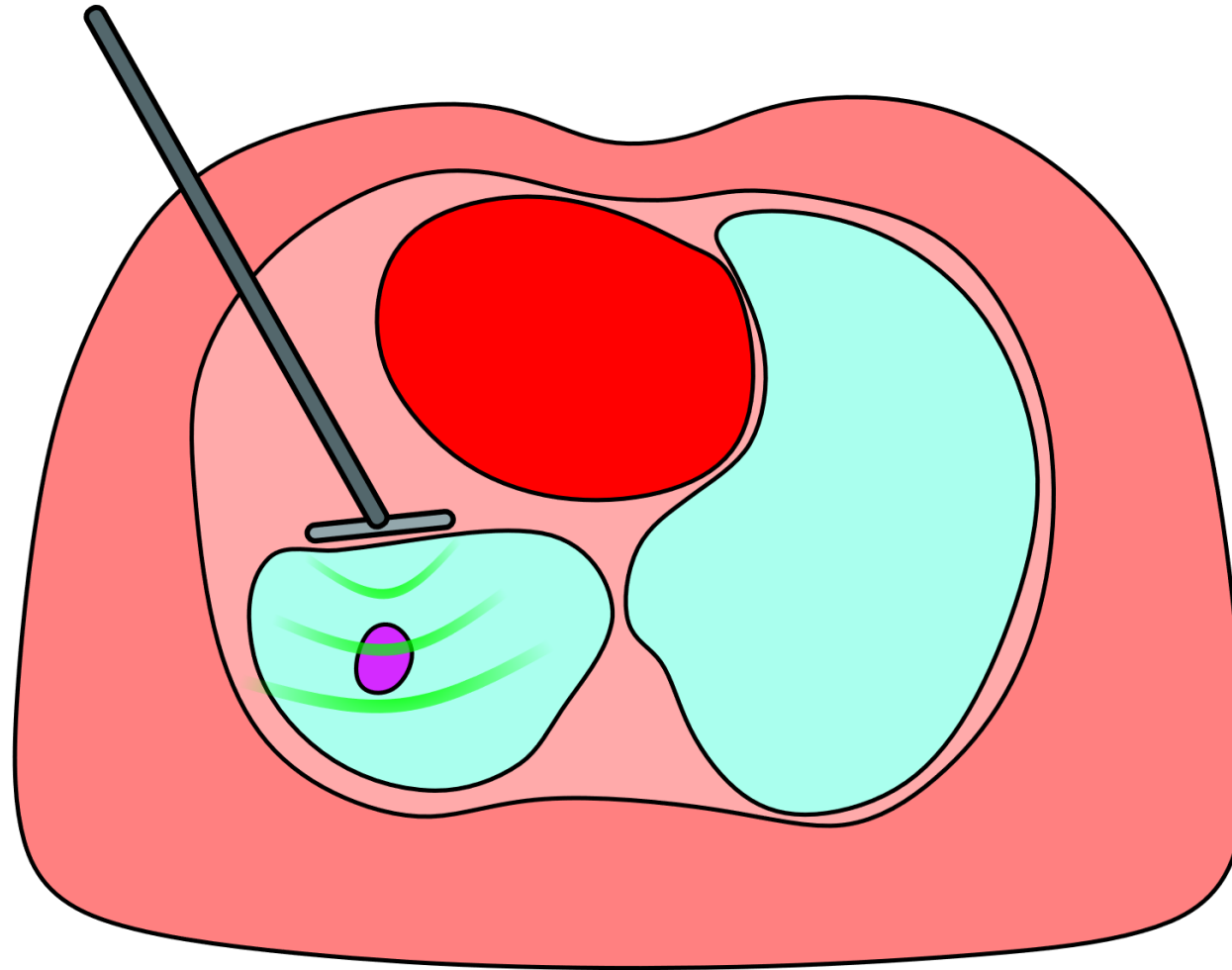[3]"Worldwide cancer data," World Cancer Research Fund, 2018. (accessed Jun. 23, 2020).
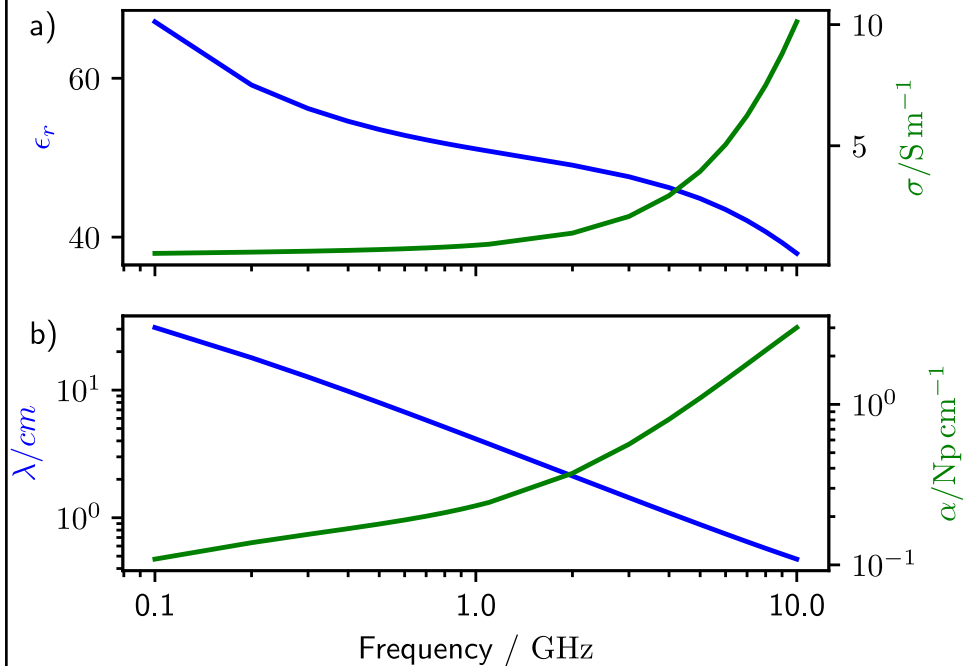
During a thoracoscopic surgery

Before Surgery

- **Pre-operation:**
  - marked by CT guide
- **Intraoperative imaging:**
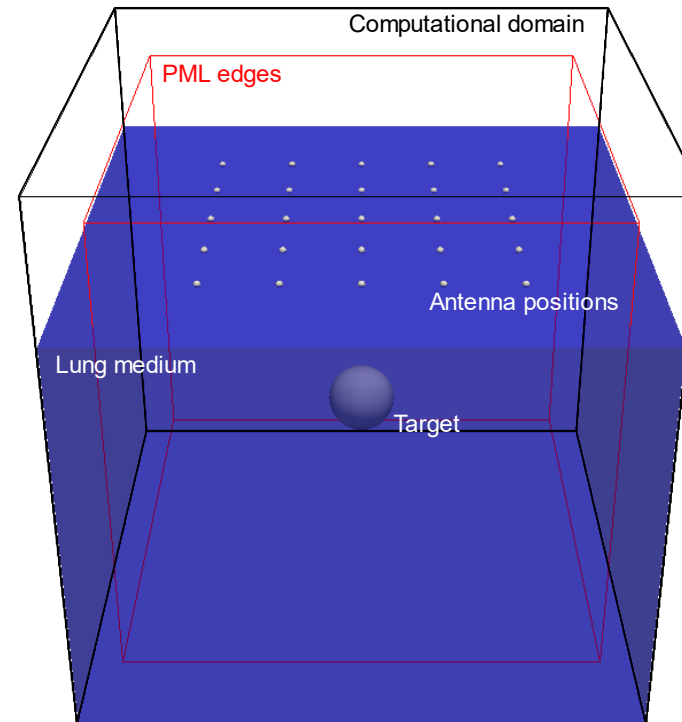 - ultrasonography,
  - fluoroscopy,
  - molecular imaging

During Surgery

Microwave imaging:
- Used for breast cancer
- Miniaturized electronics
- No ionizing radiation

Simulations details

Dielectric properties of lung tissue[1]

a)

b)

Computational domain[2]

Finite Difference Time Domain (FDTD):
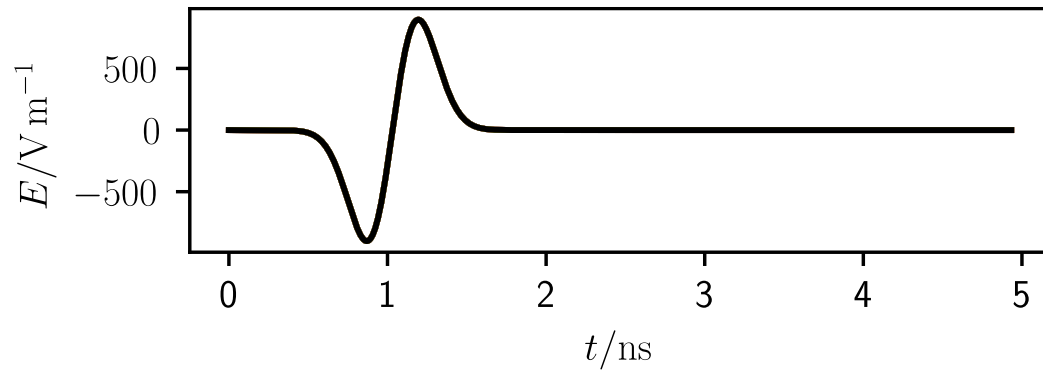GPRMax
10 frequencies (500 MHz – 5 GHz)
Target:
- 1 cm in diameter
- 6 target depths (1 – 6 cm)
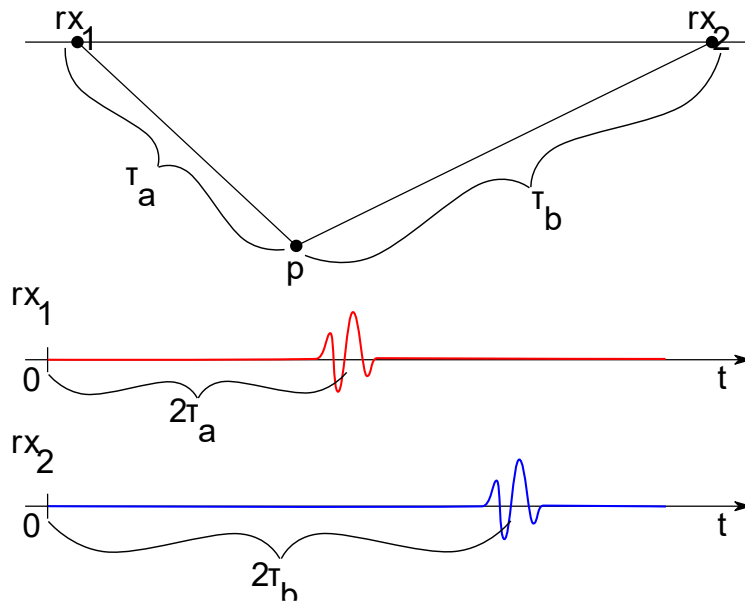- $\epsilon_r = 3 \cdot \epsilon_{r\,Lung}$
- $\sigma = 2 \cdot \sigma_{Lung}$

[1]IT'IS Foundation, "Tissue Properties Database V4.0." 2018
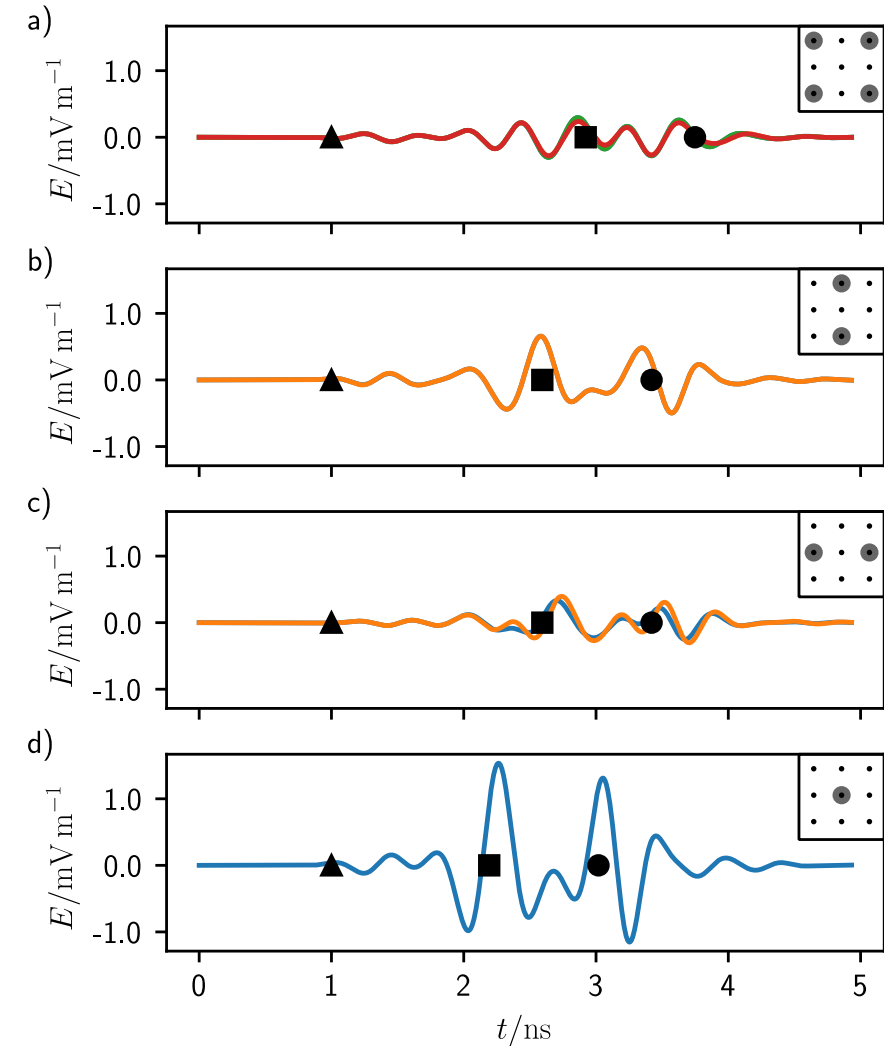[2]A. Battistel, P. P. Pott, and K. Möller, *Applied Sciences*, 2021
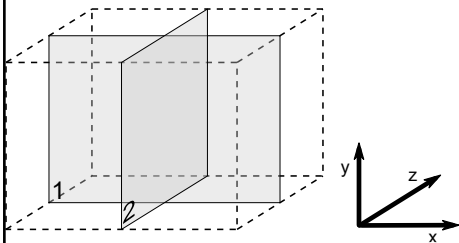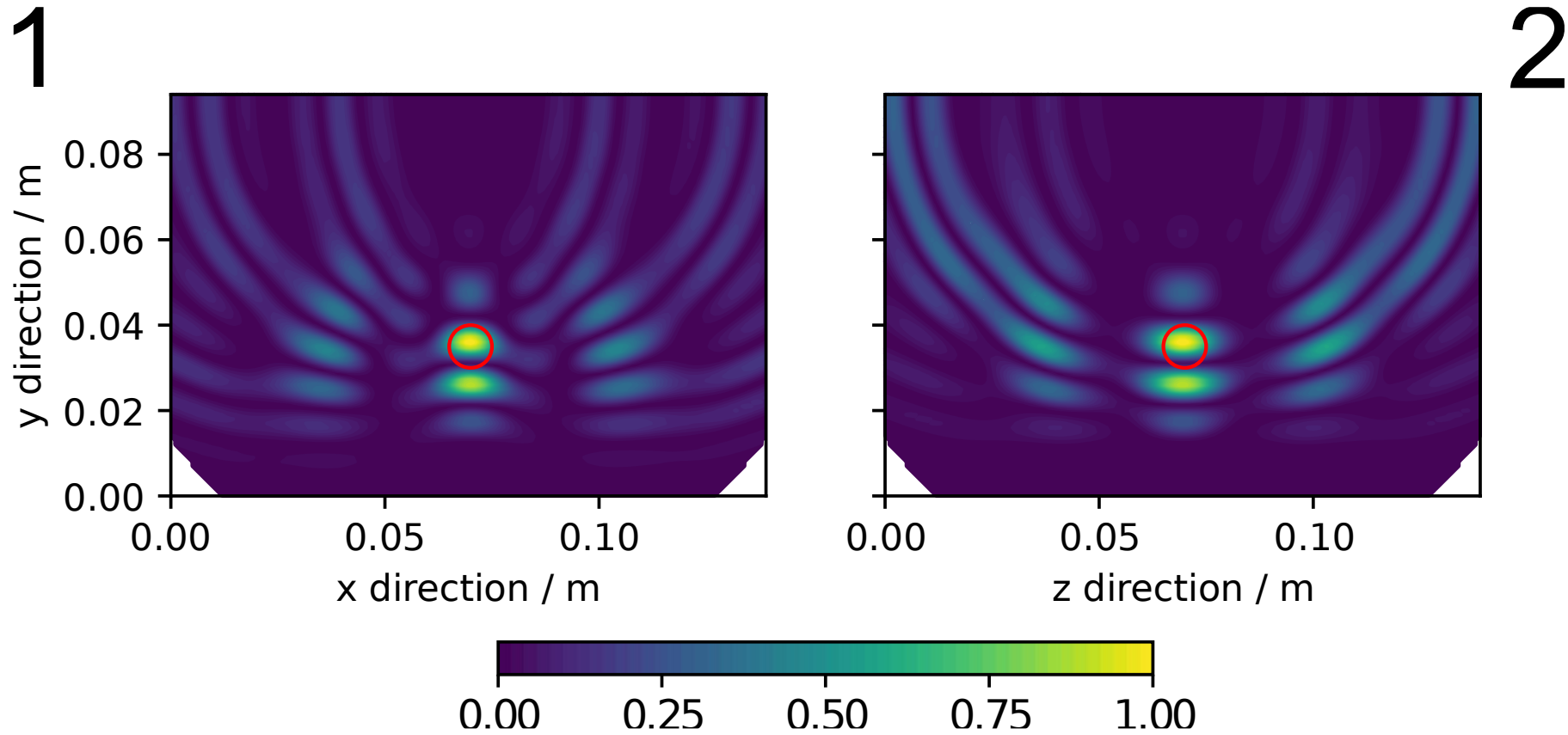
Waveform[1]
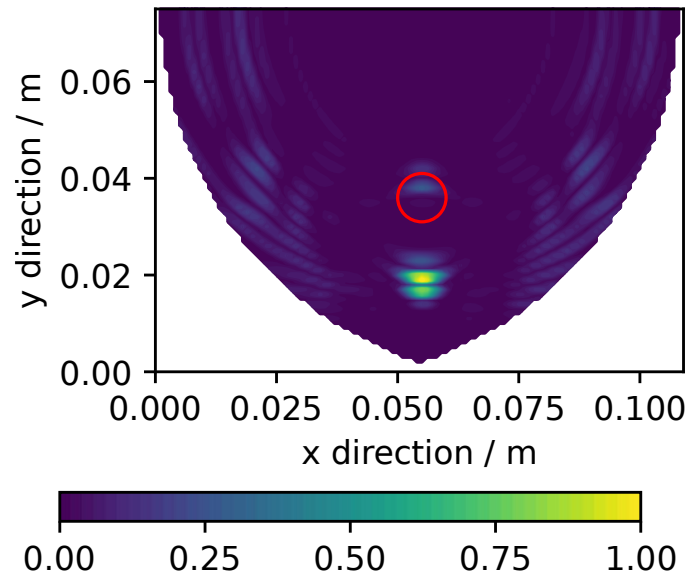
Confocal image[2]

Calibrated waveforms[1]

[1]A. Battistel, P. P. Pott, and K. Möller, Applied Sciences, 2021
[2]A. Battistel and K. Möller, in 8th European Medical and Biological Engineering Conference, Cham, 2021
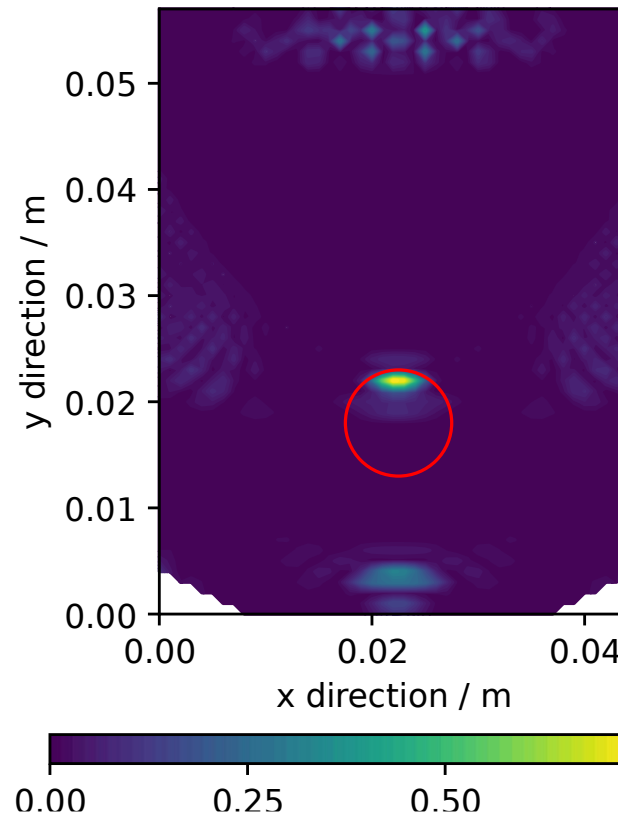
1

2

[1]A. Battistel, P. P. Pott, and K. Möller, Applied Sciences, 2021

Ghost artifact

Tumor depth 4.0 cm at 2.0 GHz

Smaller target

Tumor depth 4.0 cm at 5.0 GHz

No target

Tumor depth 5.0 cm at 5.0 GHz

[1]A. Battistel, P. P. Pott, and K. Möller, Applied Sciences, 2021

Artifacts distribution

[1]A. Battistel, P. P. Pott, and K. Möller, Applied Sciences, 2021

$$R = \frac{avg.\,pixel\,intensity\,at\,target}{avg.\,pixel\,intensity\,outside\,target}$$

$R \gg 10$ **good** localization
$R \approx 1$ **bad** localization

[1]A. Battistel, P. P. Pott, and K. Möller, Applied Sciences, 2021
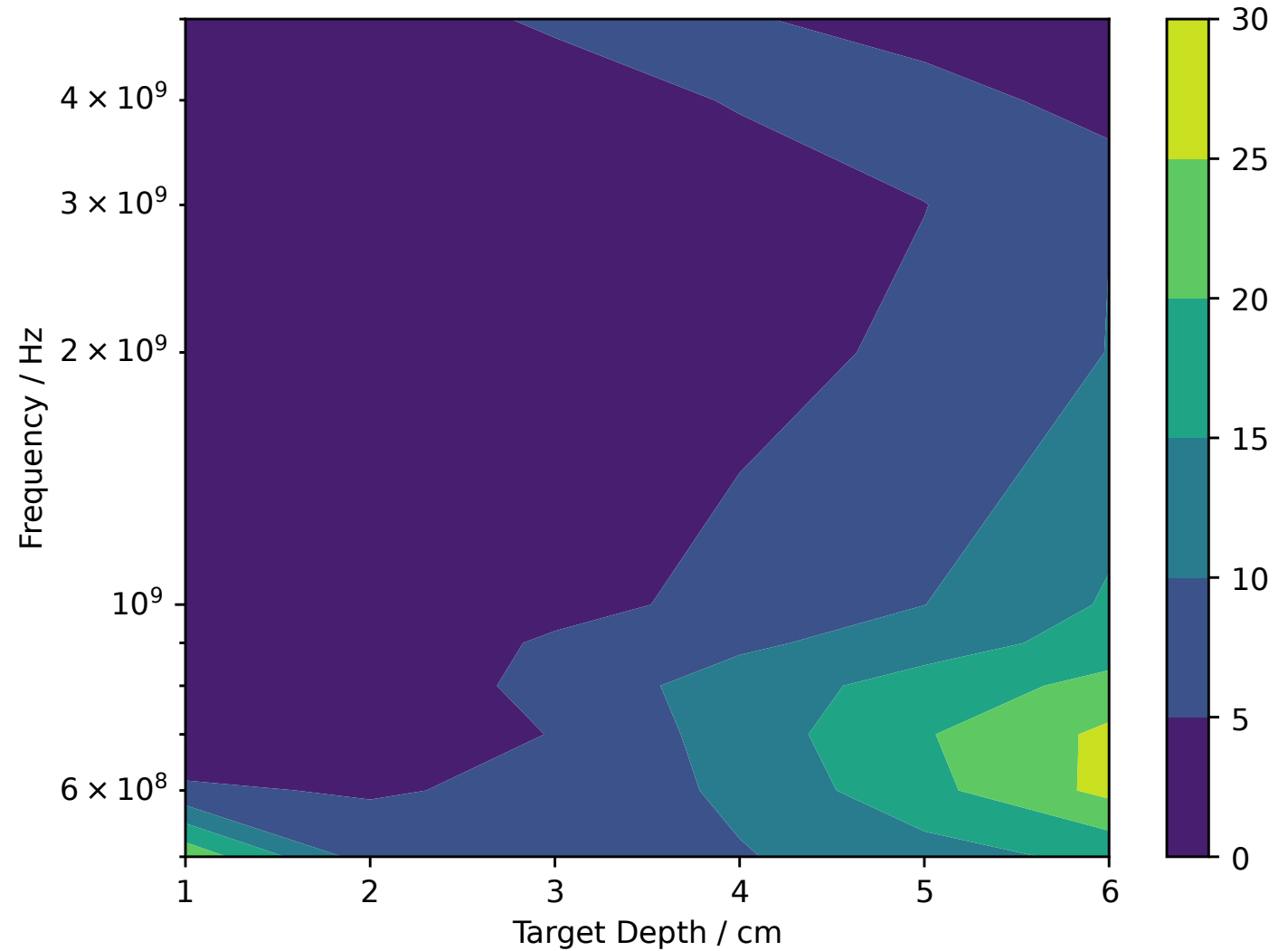
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Technical Medicine

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[1]A. Battistel, P. P. Pott, and K. Möller, Applied Sciences, 2021

- Artifacts are present

- Low frequencies (< 1 GHz) are better

- Shallow targets are a problem

- At low frequency a target is "visible" up to 10 cm of depth

Acknowledgements

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