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Electrode-based implanted HBC channel characterization and SAR analysis

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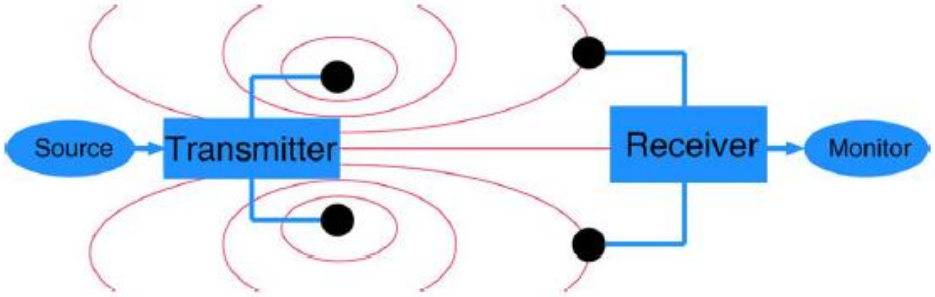
URSI GASS 2020

HBC (Human Body Communications):

- a novel rising transmission technique
- using the conductive properties of the body for electrical signal transfer
- small power requirement and absence of antenna
- potential alternative scheme of wireless RF communication

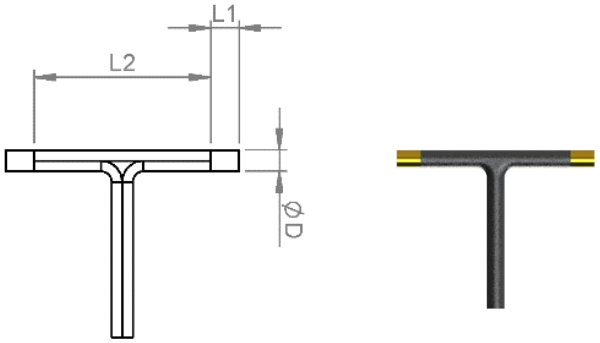
Electrode-based implanted HBC:

- pair of electrodes used
- electric field propagating through the body via the galvanic coupling
- to explore the transmission channel gain and the SAR analysis
- frequency range of interest of 5MHz-50MHz
- quasi-electrostatic approximation



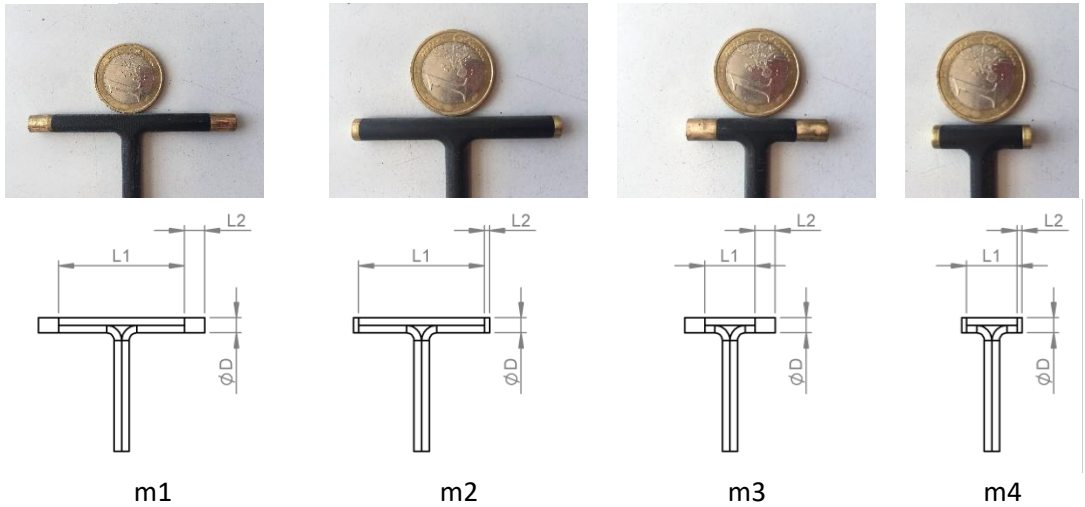
Concept of transmission using the human body as electrical transmission channel

Electrode-based implanted HBC

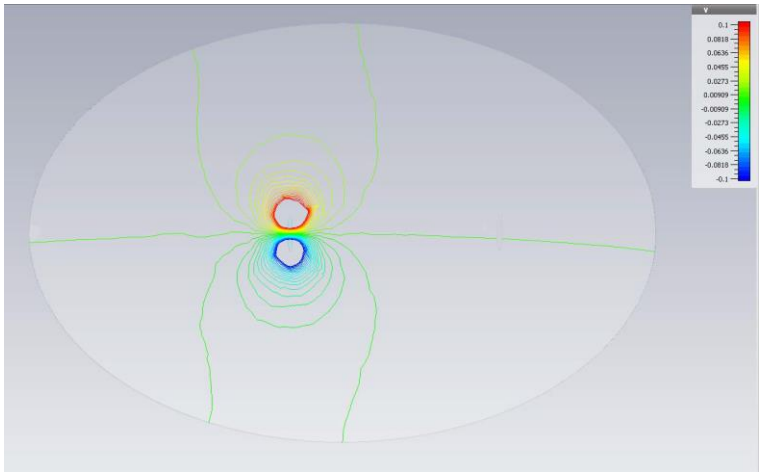


Electrode pill models

- **m1: D=0.6cm, L1=5cm (big pill), L2=0.8cm (long electrode)**
- **m2: D=0.6cm, L1=5cm (big pill), L2=0.2cm (short electrode)**
- **m3: D=0.6cm, L1=2cm (small pill), L2=0.8cm (long electrode)**
- **m4: D=0.6cm, L1=2cm (small pill), L2=0.2cm (short electrode)**



Four fabricated electrode prototypes



Electric potential distribution for the implanted electrode with low frequency time domain Electro-Quasi-Static solver in CST

Phantom measurement with balanced Balun PI100

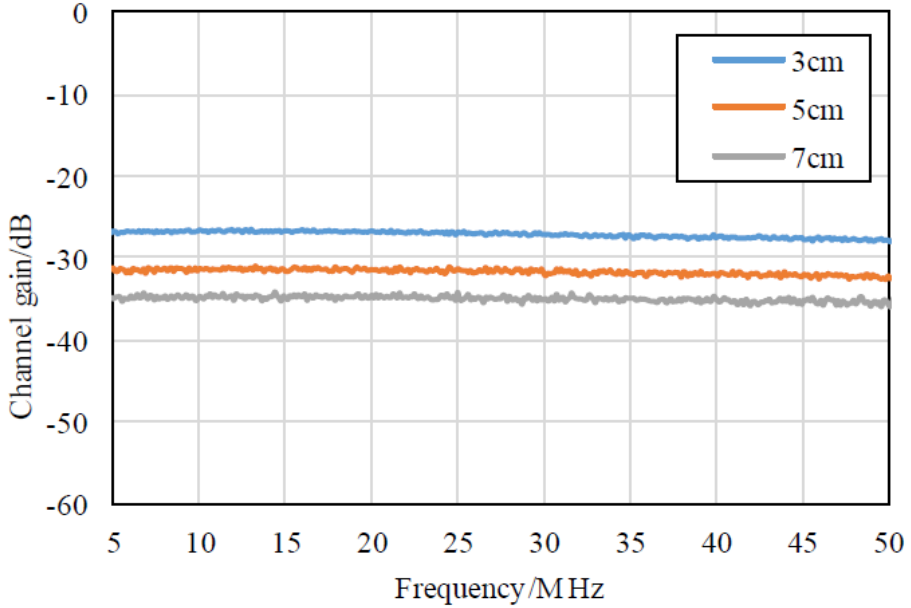
Water	52.4%
NaCl	1.4%
Sugar	45%
Sodium benzoate	1.1%

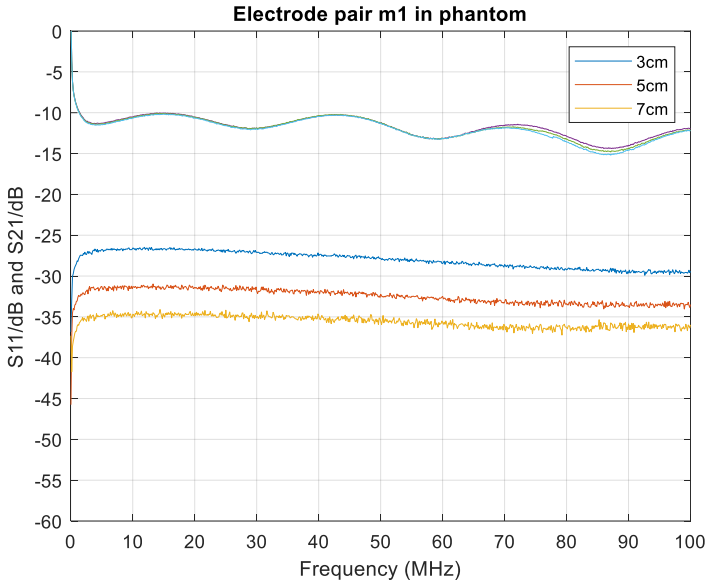
phantom recipe in HBC band

$$Gain[dB] = 20 * \log_{10} \frac{|U_{RX1} - U_{RX2}|}{|U_{TX1} - U_{TX2}|}$$

Channel gain characterization

Measured channel gain in phantom for electrode pair m1

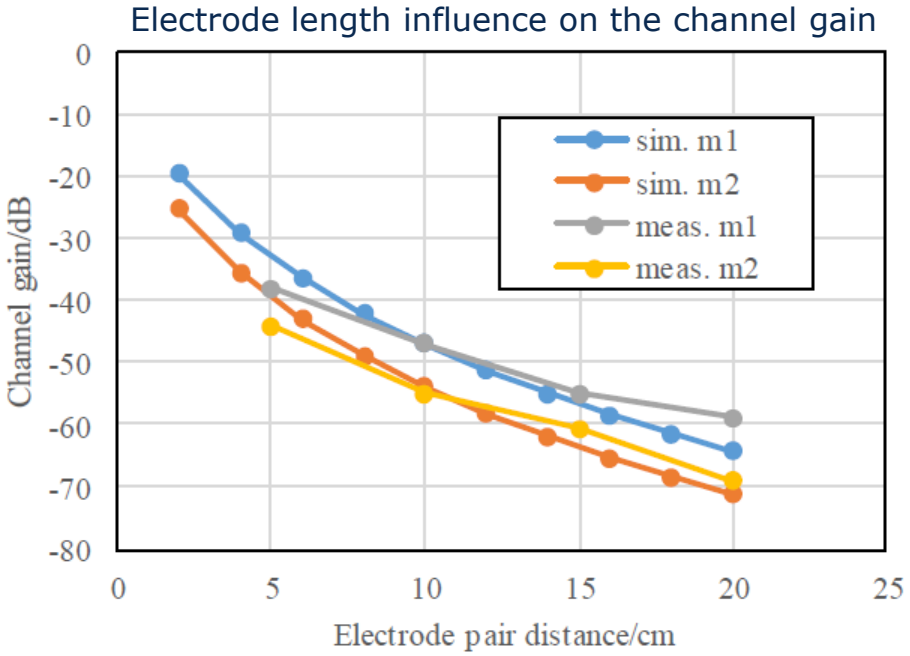




Relative good matching impedance characteristics inside the phantom S11 are below -10dB

- Frequency independent gain characteristics.
- Same conclusion drawn as well for m2, m3 and m4.
- Decreasing gain with increasing transmission distance.

Implanted channel gain characterization

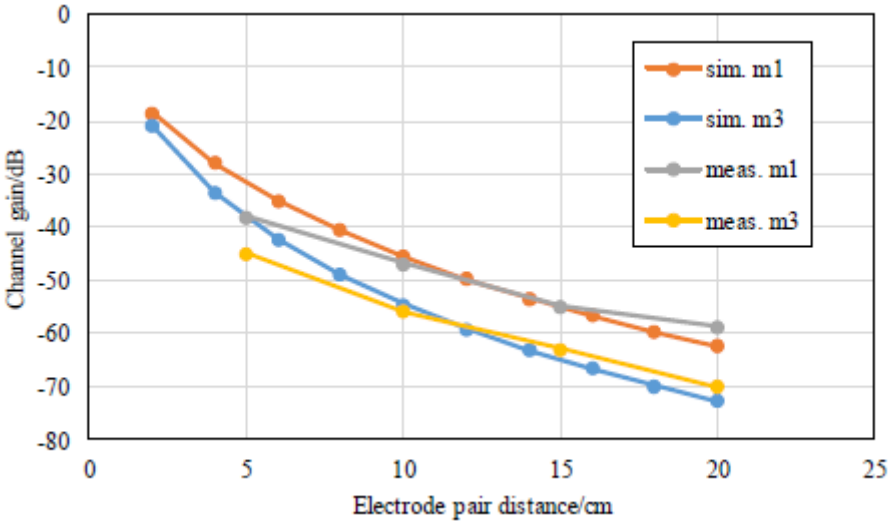


m1 (long rod and long electrode)
m2 (long rod and short electrode)

- Increasing the electrode length by 0.6cm (electrode length difference of m1 and m2) brings a channel gain enhancement of approximately 10dB.

Implanted channel gain characterization

Inter-electrode distance influence on the channel gain

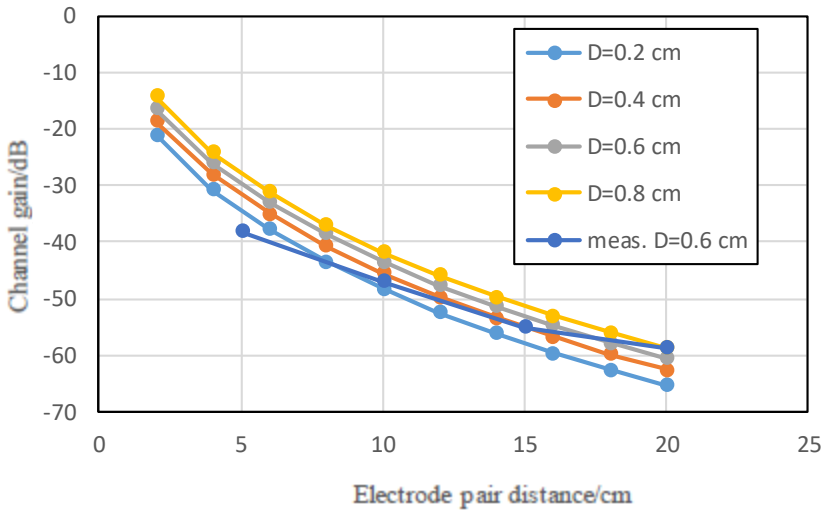


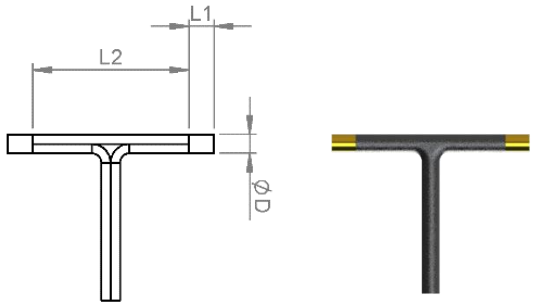
m1 (long rod and long electrode)
m3 (short rod and long electrode)

- Increasing the inter-electrode distance by 3cm (difference of m1 and m3) brings a channel gain enhancement of approximately 10dB.

Implanted channel gain characterization

Influence of the electrode diameter variation

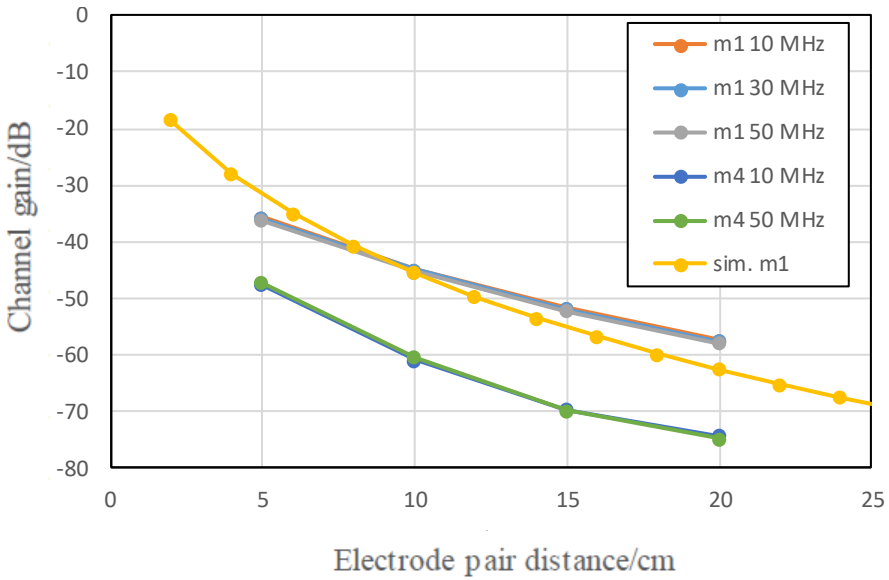




m1

- Increasing the electrode diameter by 0.6cm brings a channel gain enhancement of approximately 8dB.

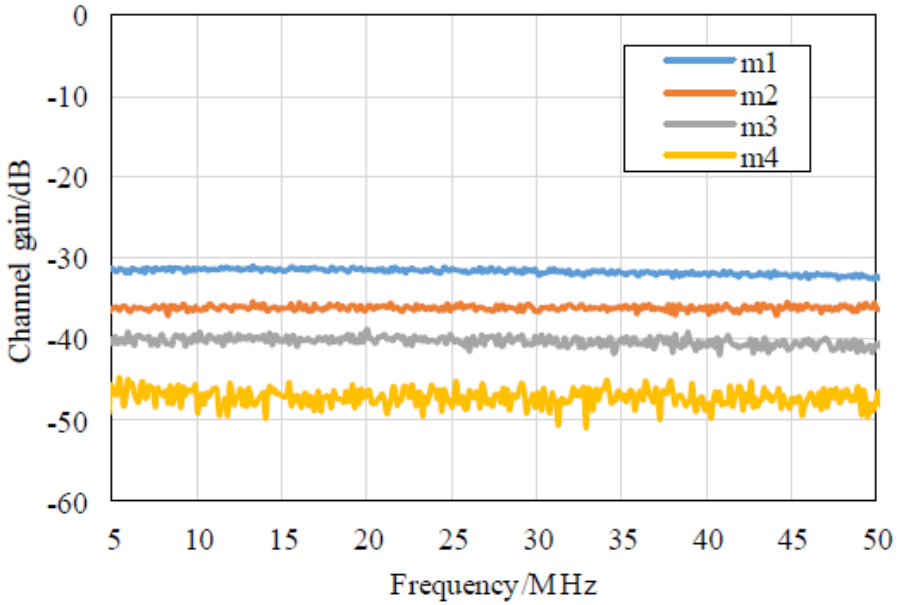
Comparison of big and small electrodes



m1 (long rod and long electrode)
m4 (short rod and short electrode)

- Measured channel gain shows frequency independence (10MHz-50MHz).
- At 10cm, 15dB PL difference can be observed of big and small electrons.
- For m1 electrode, at 10cm, the PL is around 45dB.
- For m4 electrode, at 10cm, the PL is around 60dB.

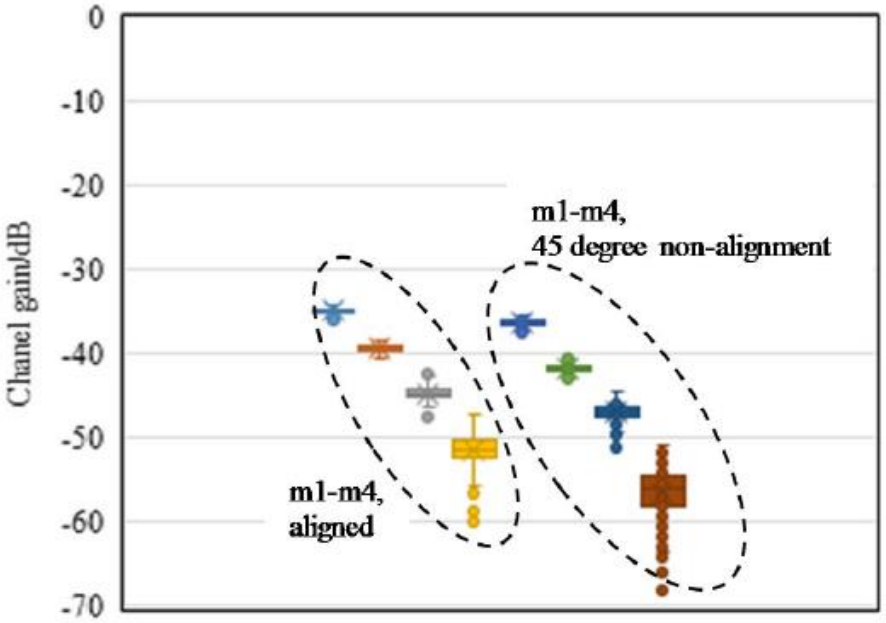
Measured channel gains in phantom with electrode pair distance 5cm



- The larger electrode m1 demonstrate the relative best channel gain characteristics.

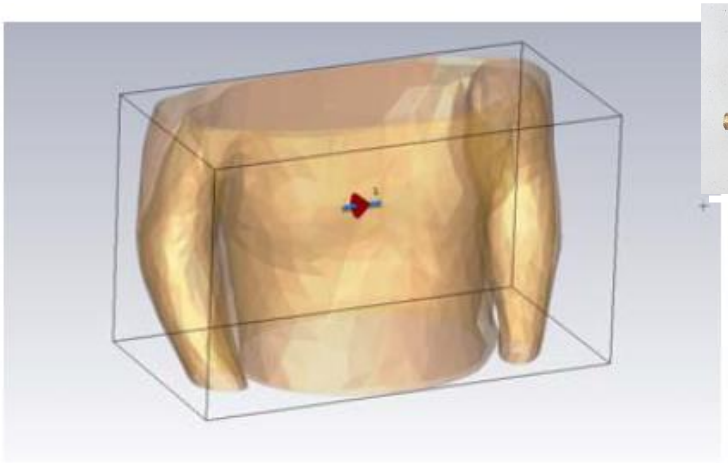
Implanted channel gain characterization

Comparison of alignment and 45 degree non-alignment, with 7 cm electrode pair distance

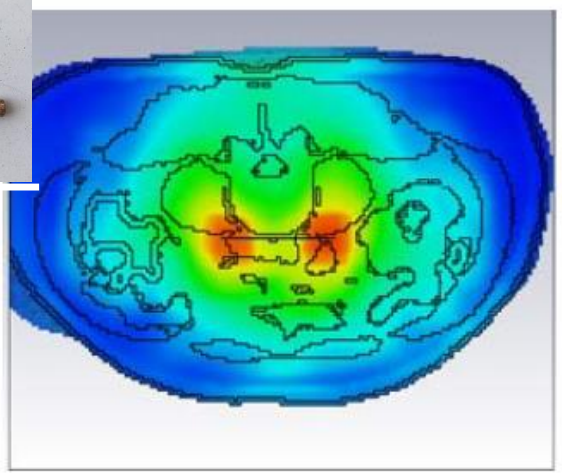


- Compared with alignment, 45 degree displacement corresponds to approximately 1.5dB@m1, 2.5dB@m2, 2.5dB@m3 additional loss.
- The smaller the pill, the larger the additional loss variation. (m3 and m4)
- The larger the metal electrode, the smaller the additional loss. (m1 vs. m2)
- Electrode vertical displacement lose the transmission connection.

m1 (long rod and long electrode)



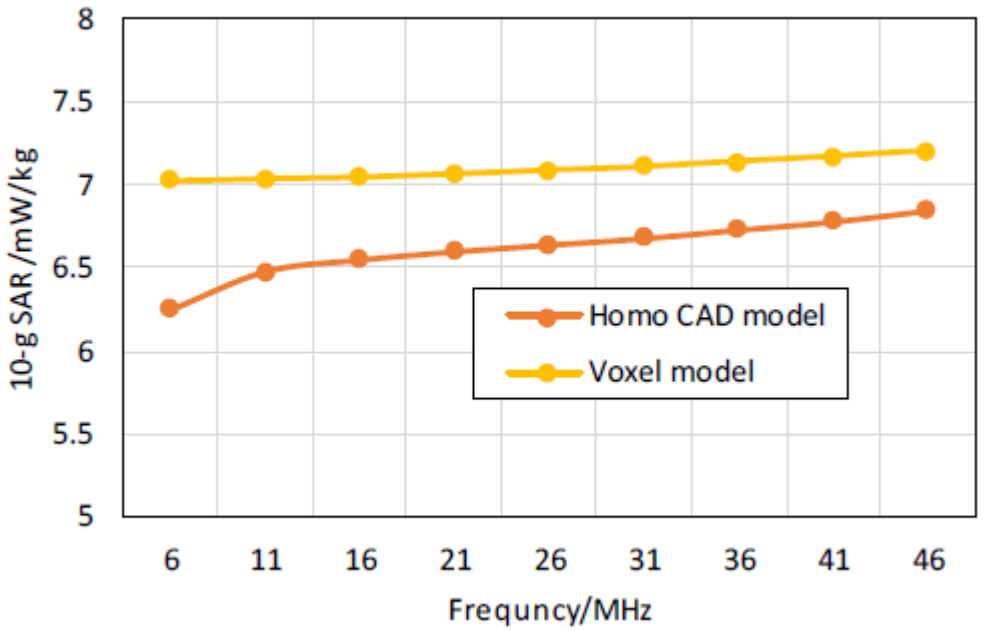
Homogeneous CAD torso model
(with 2/3 muscle dielectric properties)



10-g SAR distribution on cross-section
cut plane of the voxel torso model

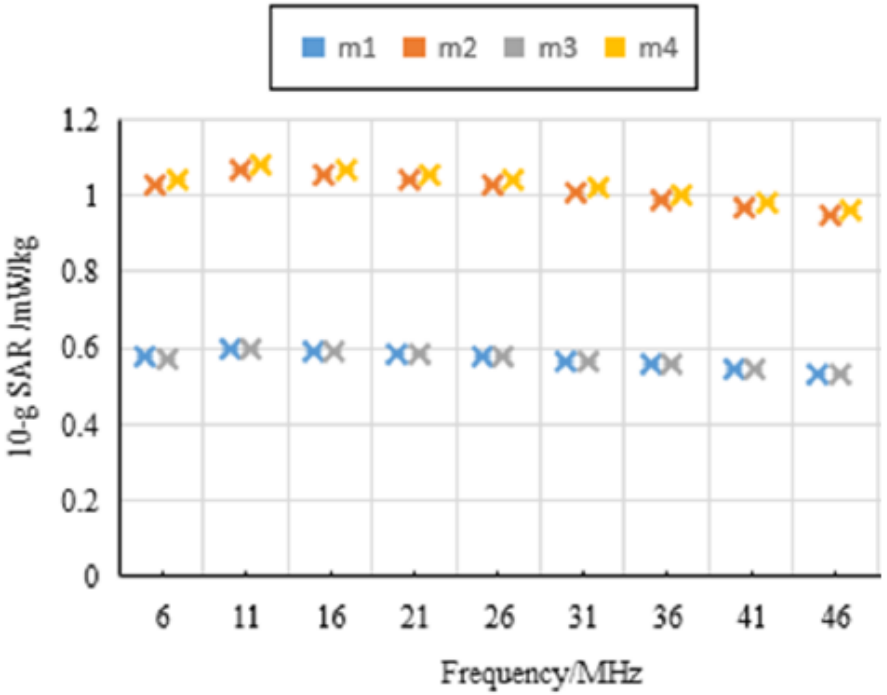
- 0.2V potential excitation at 21MHz
- Electrode pairs locating in muscle tissue region

10-g averaged SAR peak comparison of homogeneous CAD model and heterogeneous Voxel model (with 0.2V potential excitation)



- SAR with homogeneous model (2/3 muscle dielectric properties) and heterogeneous model show similar results.
- SAR in mW/kg, much smaller than the safety guideline 2 W/kg.

10-g averaged SAR peak comparison of four electrode prototypes with 1 mA current excitation



- Smaller metal electrode (m2 and m4) demonstrates higher SAR, since the resulting E-field is higher around the electrode.
- SAR highly localized, rod length make less influence on the SAR (m1 vs. m3 and m2 vs. m4).
- Larger implanted electrode demonstrates the relative better channel gain as well as lower localized SAR peak.