Measurement Results and Analysis on a HBC Channel

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June 11, 2014

IEEE INTERNATIONAL SYMPOSIUM ON MeMeA Medical Measurements and Applications
JUNE 11-12, 2014 - ISCTE - UNIVERSITY INSTITUTE of LISBON - LISBON, PORTUGAL

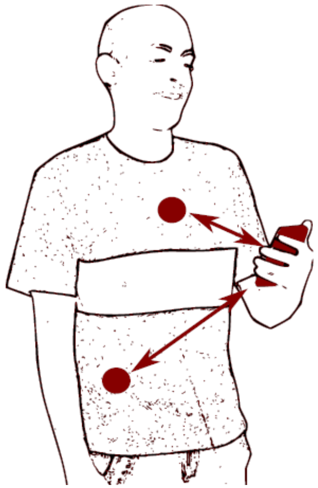
IEEE

Presentation Outline

- What is HBC
- Channel characterization
- HBC measurement setup
- Measurement results
- Final remarks

Human Body Communication - HBC

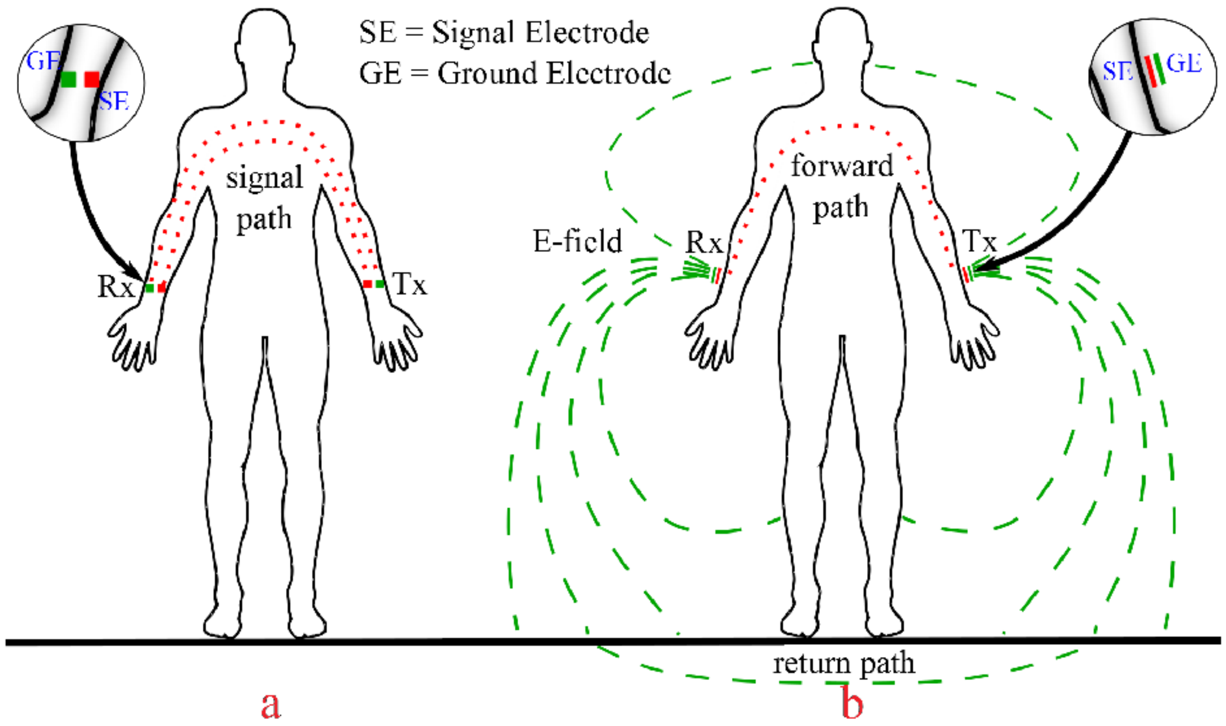
- 1995: Zimmerman proposes HBC concept [1].
- Electrostatic coupling of signals to the body using electrodes.
- Suitable in the 0.1 -100MHz range.
- Low interference, high security, low power and better spectral efficiency.
- Application in wearables and implantable circuits for BANs related to health-care, entertainment, identification, etc.



[1] Zimmerman, T. G., “Personal Area Networks: Near-field intra-body communication,” M.S. Thesis, MIT Media Laboratory, Cambridge, MA, Sept. 1995

HBC – Coupling methods

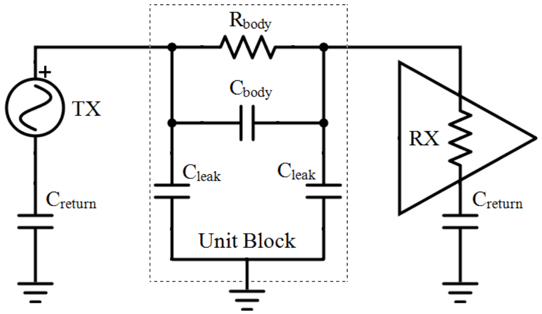
- Electric field coupling: galvanic (a) and capacitive (b).
- Focus on capacitive HBC



Channel characterization

- Diverse literature results due to dependence of the characterization on the <u>measurement setup</u> and the operation conditions.
- Analytical analysis, EM simulations, or circuits based models still can not properly reproduce measurements.
- Main aspects: verify relevant channel variables, keep the correct return path, evaluate influences of test fixture, correctly explain the frequency response.

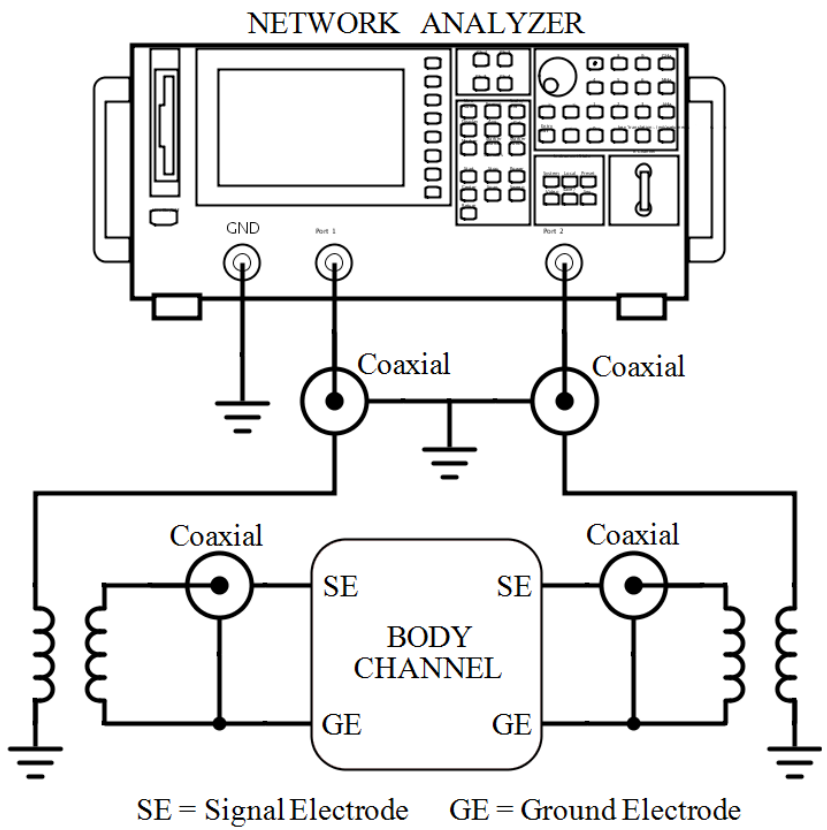
Channel path compact model.



[2] R. Xu; H. Zhu; J. Yuan, "Electric-Field Intrabody Communication Channel Modeling With Finite-Element Method," Biomedical Engineering, IEEE Transactions on, March 2011.

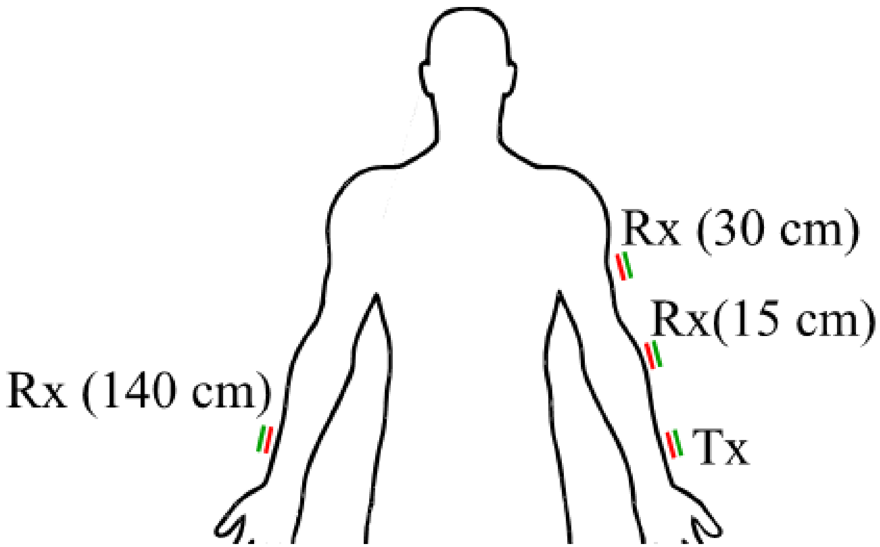
Channel measurement setup

- H&S VNA as TX and RX.
- 0 dBm signal, 1-100 MHz range.
- FTB1-6 baluns to isolate internal ground.
- Calibration at the balun's transitions.
- RG316 coaxial cables with adapted electrodes.



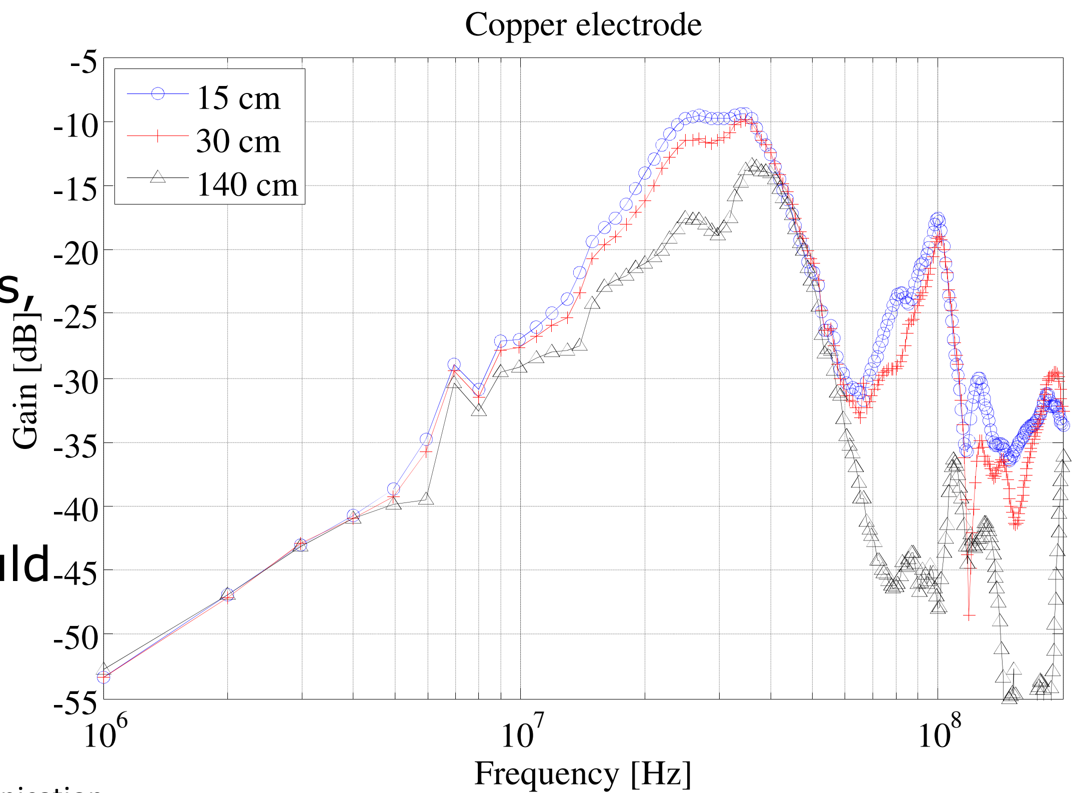
Channel measurement setup

- Subjects sitting and signal injected in the wrist.
- Arms extended to the front, at 75 cm from the floor, and resting over a table.
- Electrodes in a vertical arrangement (ground over signal).
- Characteristics verified:
  - distance of propagation over the body,
  - material of the signal electrodes,
  - differences between subjects,
  - test fixture/coaxial cables length,
  - return path investigation.



HBC – On body distance

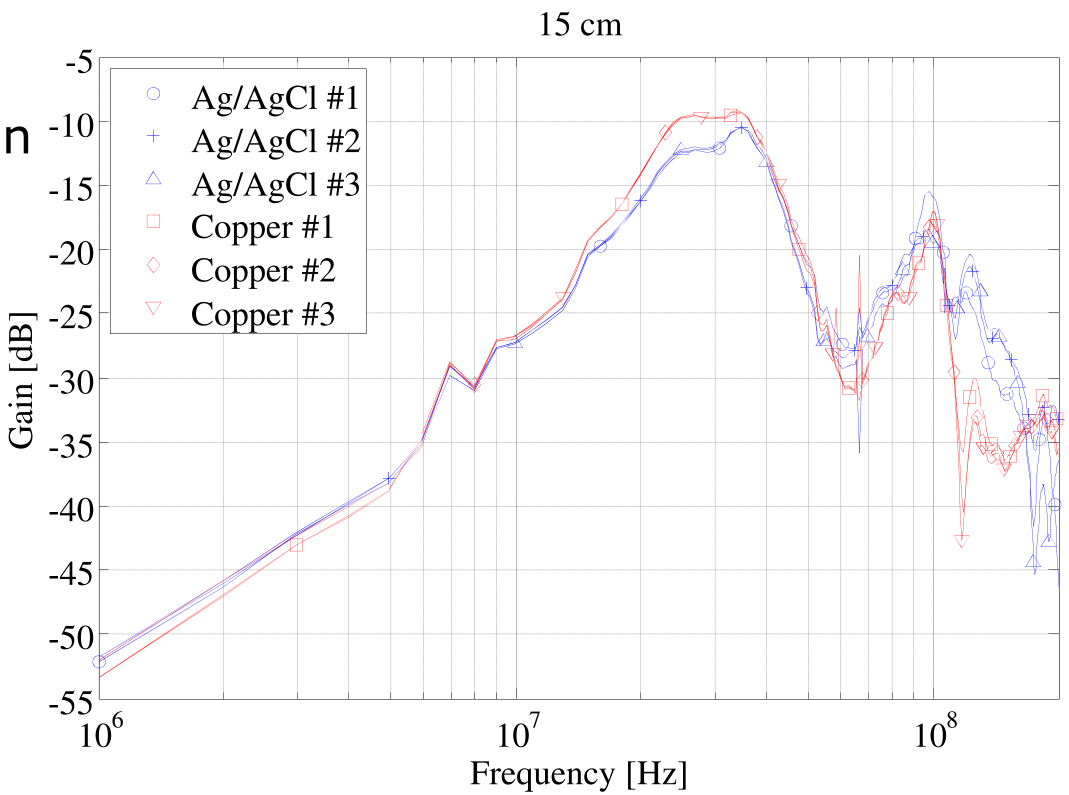
- At low frequency the capacitive return path dominates.
- For intermediate frequencies, as distance over body increases also does attenuation.
- Valley in high frequency could be due to coaxial cable discontinuities[3].



[3]R. Xu; H. Zhu; J. Yuan, "Electric-Field Intrabody Communication Channel Modeling With Finite-Element Method," Biomedical Engineering, IEEE Transactions on, March 2011.

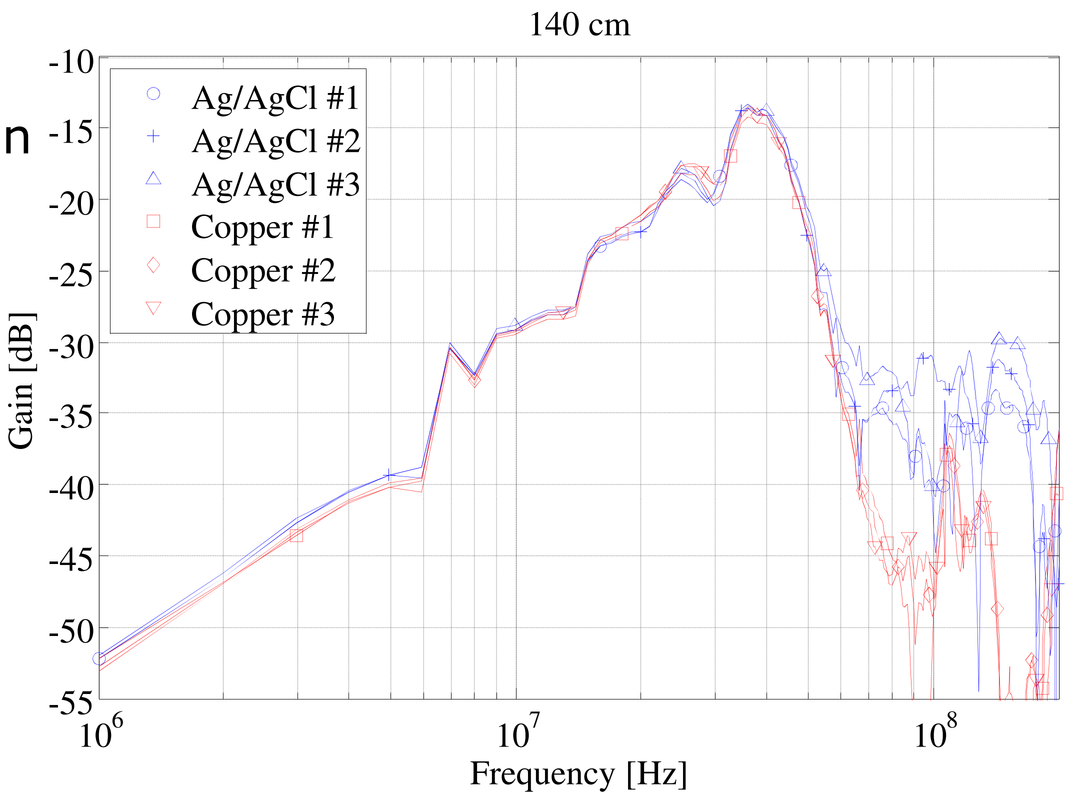
HBC – Electrode Material - 1

- Negligible variability between multiple measurements.
- Differences between electrodes is always lower than 3dB for all distances.
- Identical attenuation at 140 cm, likely due to signal radiation.



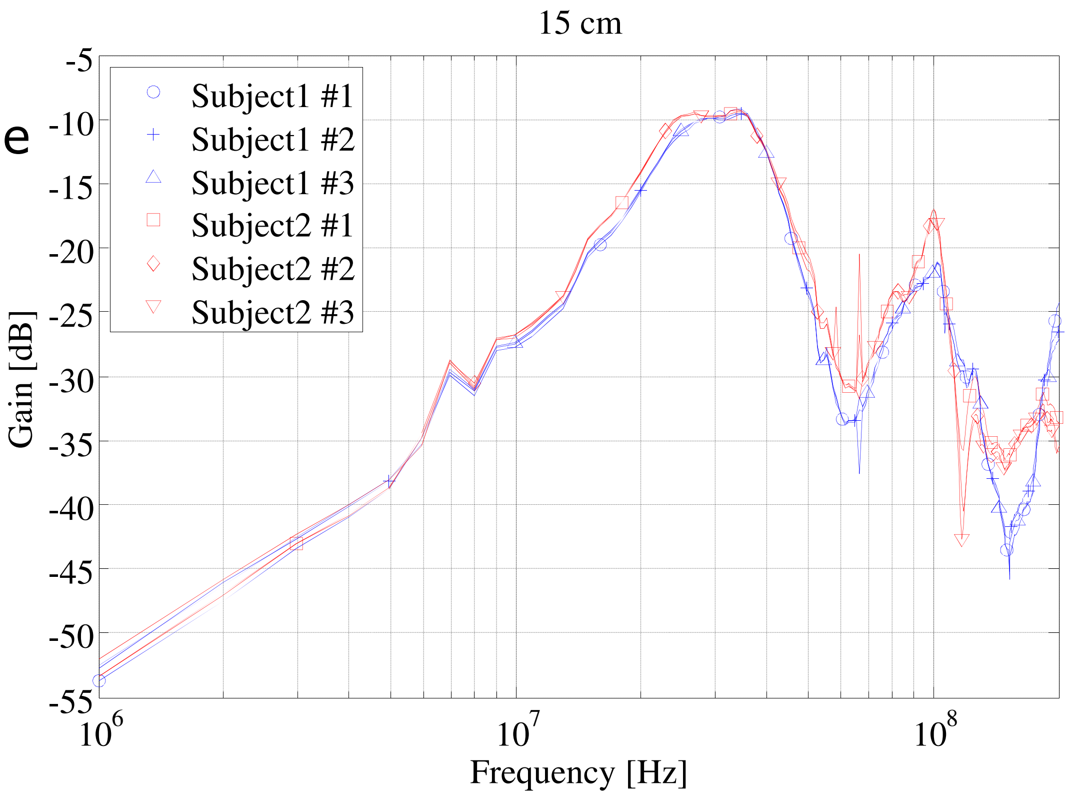
HBC – Electrode Material - 2

- Negligible variability between multiple measurements.
- Differences between electrodes is always lower than 3dB for all distances.
- Identical attenuation at 140 cm, likely due to signal radiation.



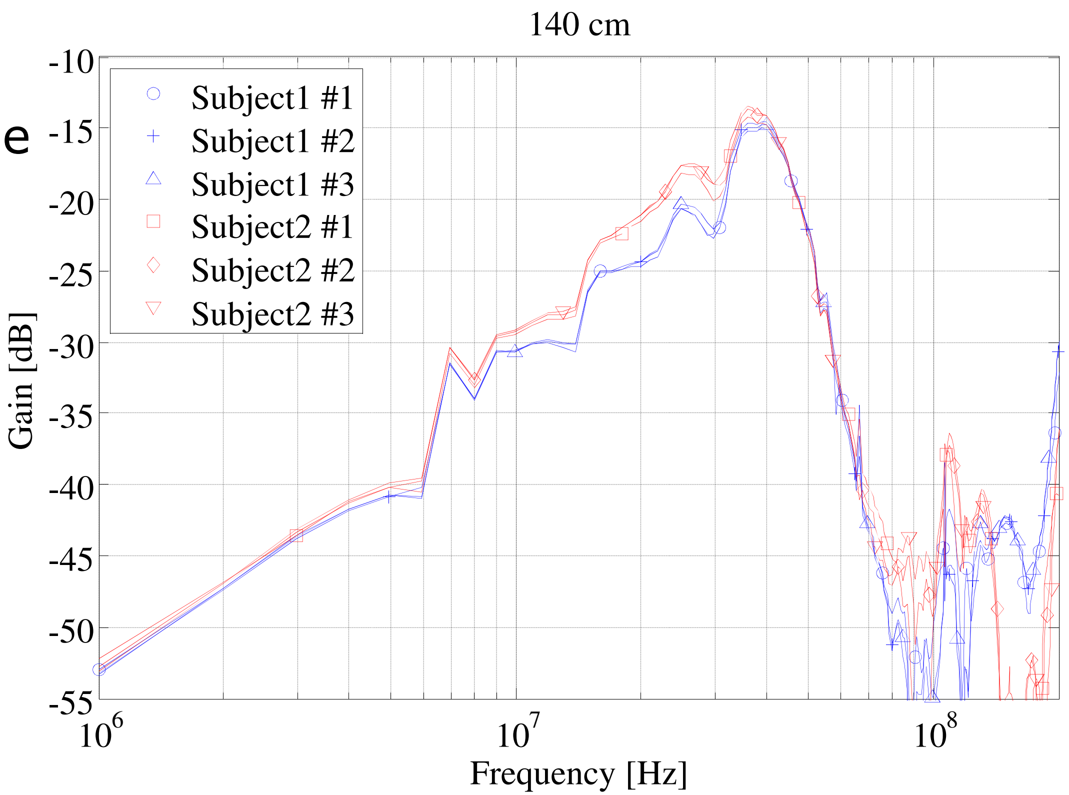
HBC – Different subjects - 1

- Subjects had about the same height, but different weight and body composition.
- For larger propagation distance the differences between subjects is more noticeable, but still small.



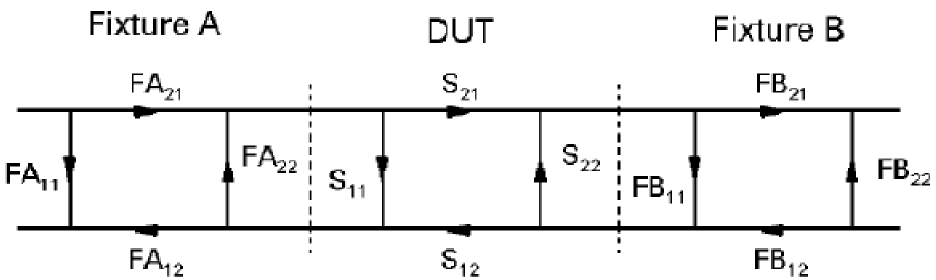
HBC – Different subjects - 2

- Subjects had about the same height, but different weight and body composition.
- For larger propagation distance the difference between subjects is more noticeable, but still small.



HBC – Full de-embedding

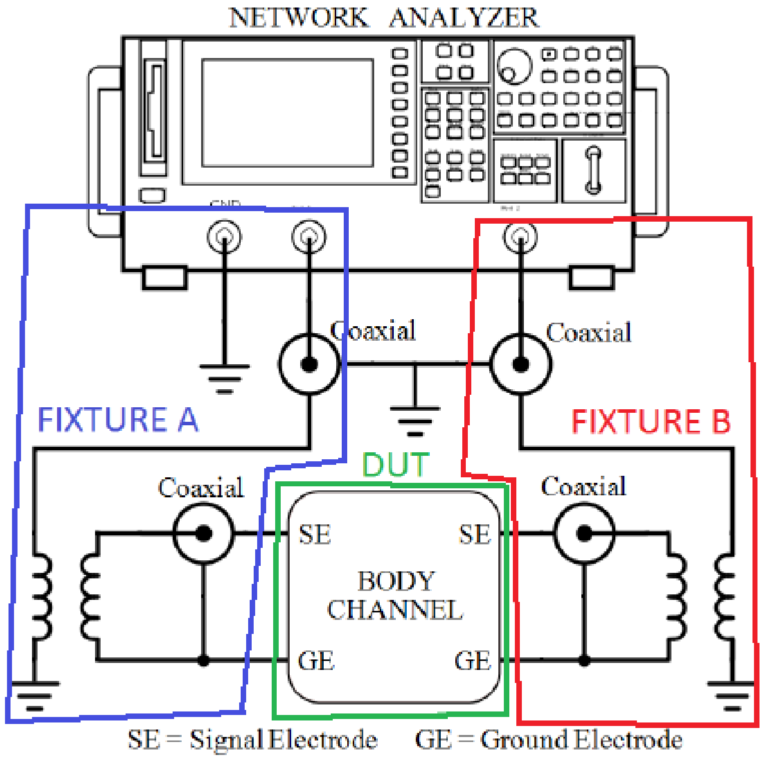
- SOLT calibration at baluns transition.
- Custom cables modeled in ADS for fixture de-embedding.
- Full S-parameters extraction.



TX(VNA)
+cables
+baluns/adapters
+modified cables

Body
+Air
+ground floor
+electrodes

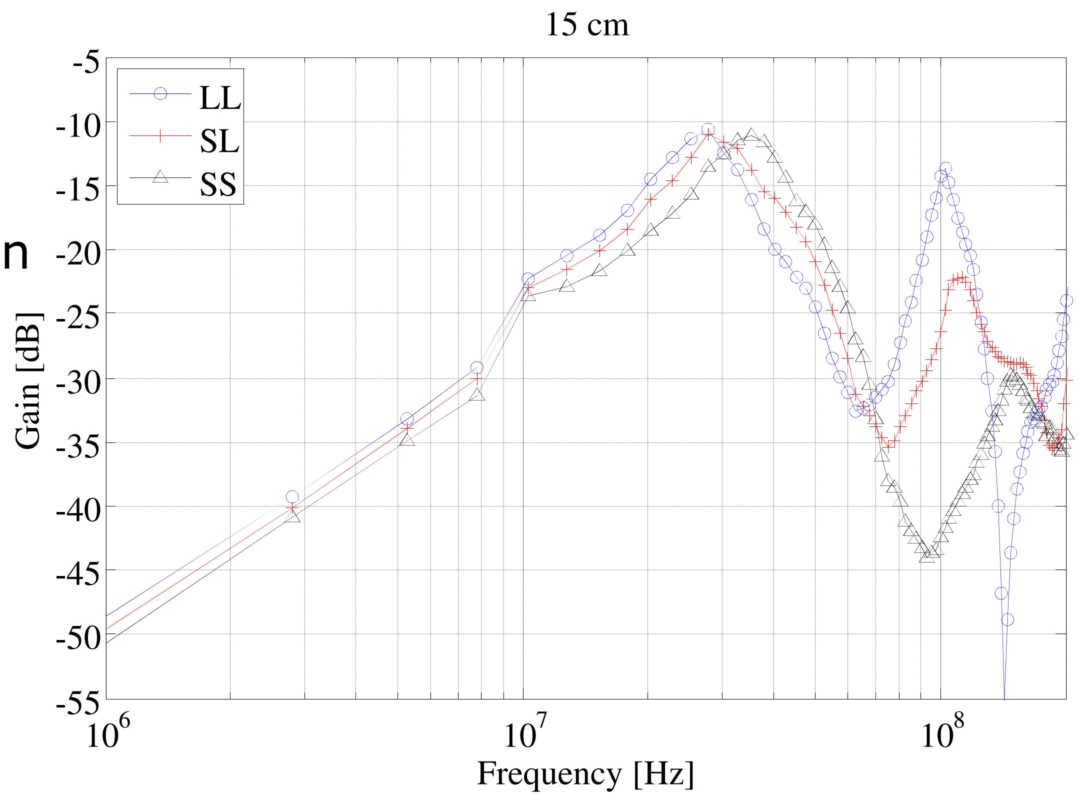
RX(VNA)
+cables
+baluns/adapters
+modified cables



"Agilent De-embedding and Embedding S-Parameter Networks Using a Vector Network Analyzer", Application Note 1364-1.

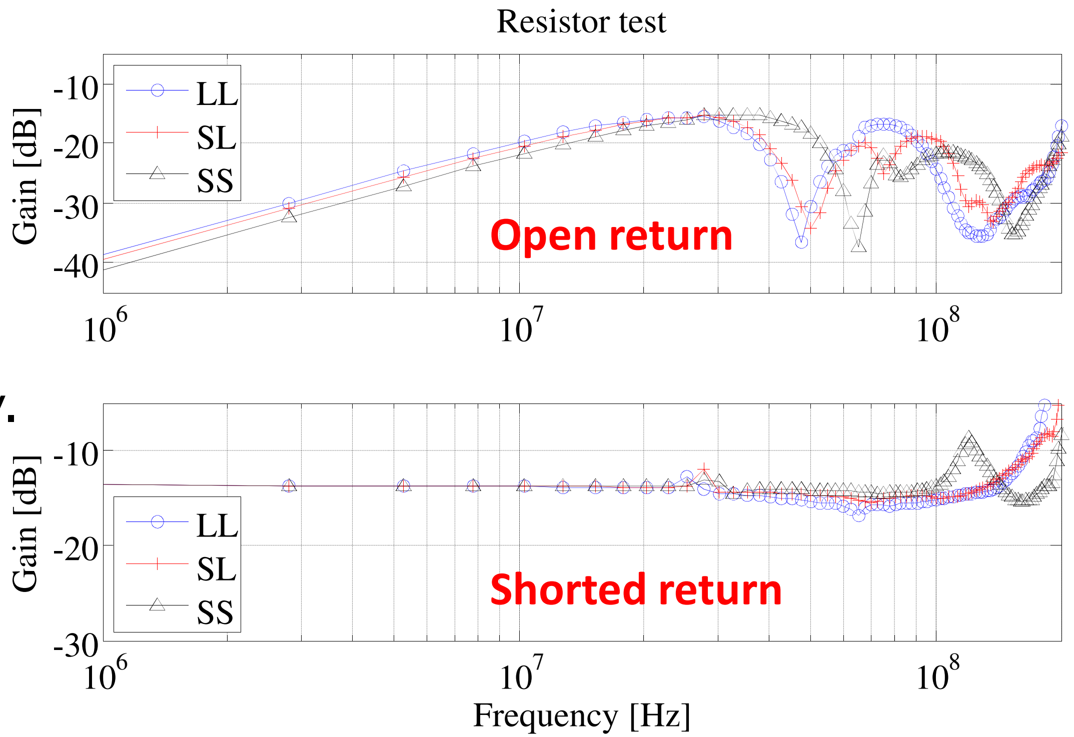
HBC – Cable length

- Two cables of 70 cm each (LL), two cables of 20 cm each (SS) and a combination of both (SL).
- Cable length changes peak and valley position over frequency.



'Resistive' channel

- 330 Ω resistor (electrode-body contact impedance).
- Most of the frequency response was preserved despite absence of the body.
- Lower graph for shorted ground electrodes.



Final Remarks

- Channel characterization:
  - Band-pass profile,
  - high dependence on frequency,
  - moderate dependence on distance,
  - different electrode types or subjects had minor effect,
  - identified influence of the test fixture through cables,
  - return path is responsible by important characteristics of the channel profile.
- Overall results: channel responses compatible with literature, identified fixtures influences, and return path dominance.
- Future work: modified model with improved representation of the channel response, including cables, baluns, electrodes.

Thank You

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