Modeling of the Test Fixtures to Improve the HBC Channel Interpretation

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Presentation Outline

- **Human Body Communication - HBC**
- **HBC Channel modeling**
  - Primary channel model
- **HBC Channel measurements**
  - Measurement system and results
- **Test Fixture modeling**
  - Extended Model
- **Final Considerations**

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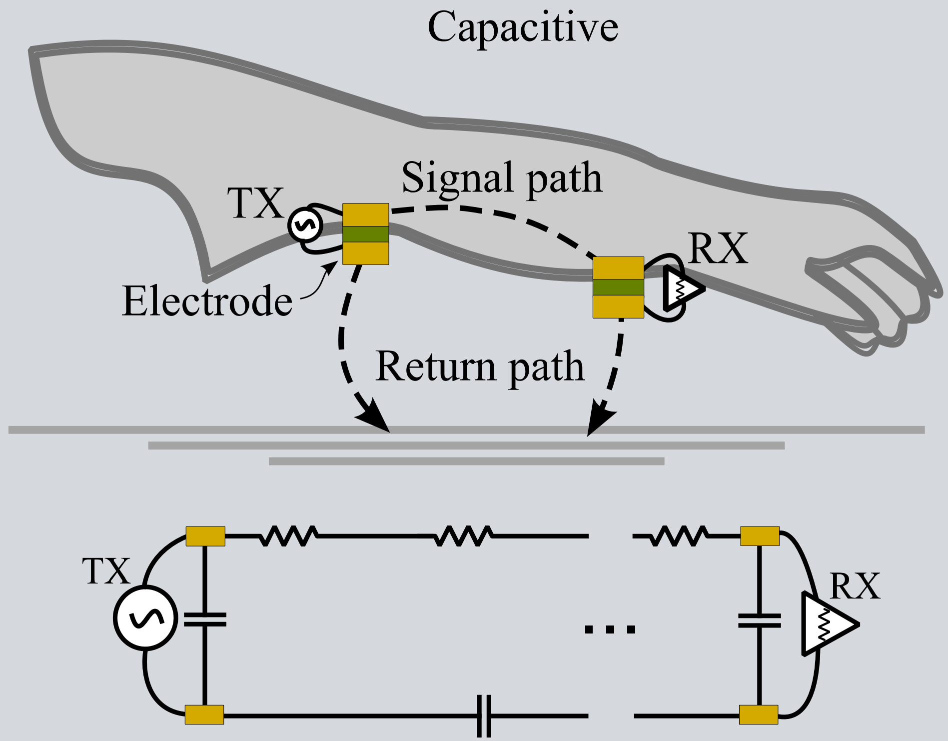
HBC – Human body communication

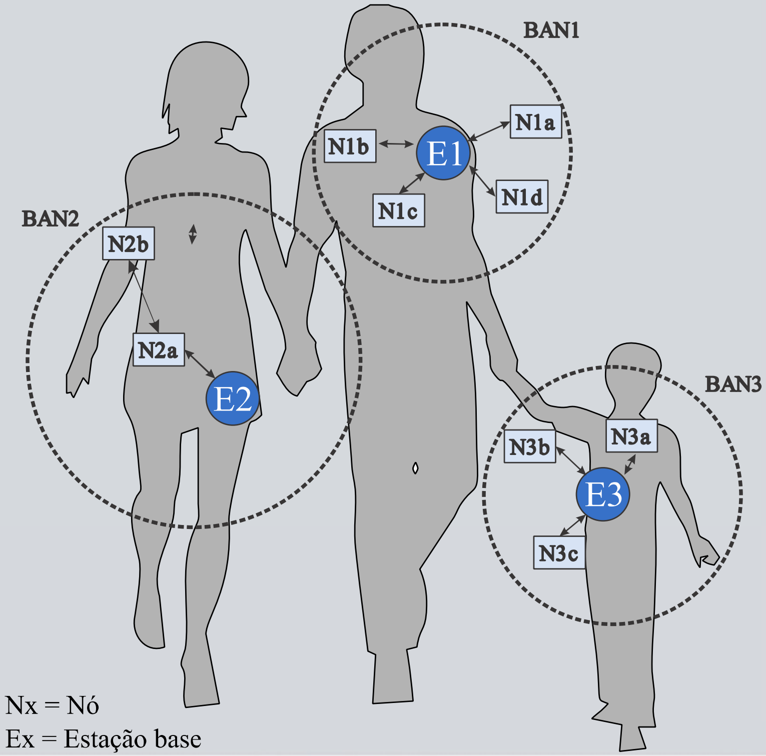
- PAN/HBC/IBC/BCC - Thomas G. Zimmerman [Zimmerman, 1995].
- Electrostatic coupling to the body using electrodes (galvanic e capacitive).



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

HBC – Human body communication

- PAN/HBC/IBC/BCC - Thomas G. Zimmerman [Zimmerman, 1995].
- Electrostatic coupling to the body using electrodes (galvanic e capacitive).
- Low frequency operation (<100 MHz).
- Advantages over other BAN options:
  - Higher data security.
  - Higher coexistence.
  - Lower channel attenuation.
  - Lower power consumption.



Nx = Nó
Ex = Estação base

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

Capacitive HBC characterization and modeling

- Required for link budget analysis (Tx output power, Rx sensitivity, operating frequency).
- Literature review:
  - Different author find different attenuation levels and frequency profile.
  - Most models cannot fully reproduce the measured channel frequency profiled.
  - Obtained models are not complete or where not validate correctly.
  - Correct channel path is not preserved.
  - Neglecting of the influence of test fixture.

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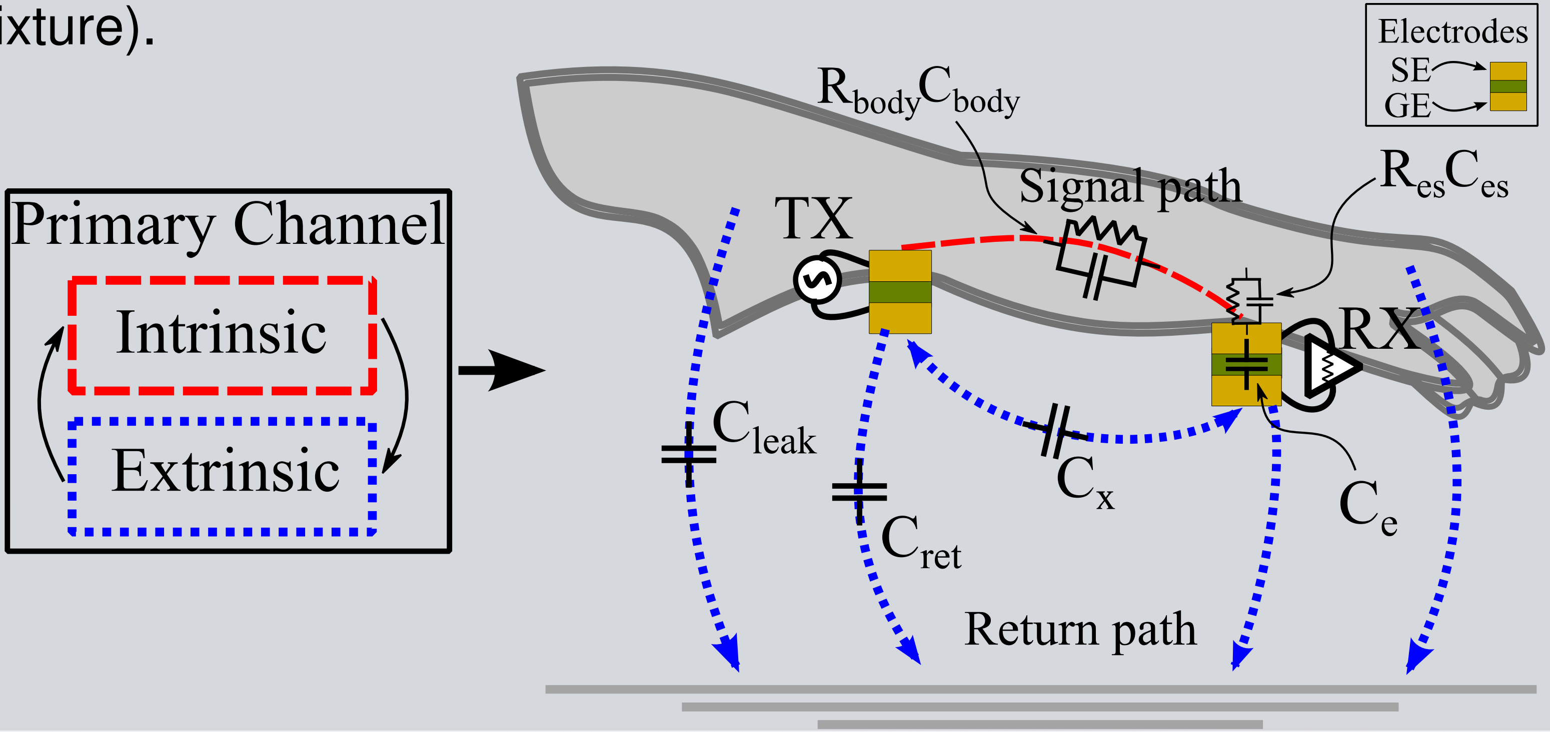
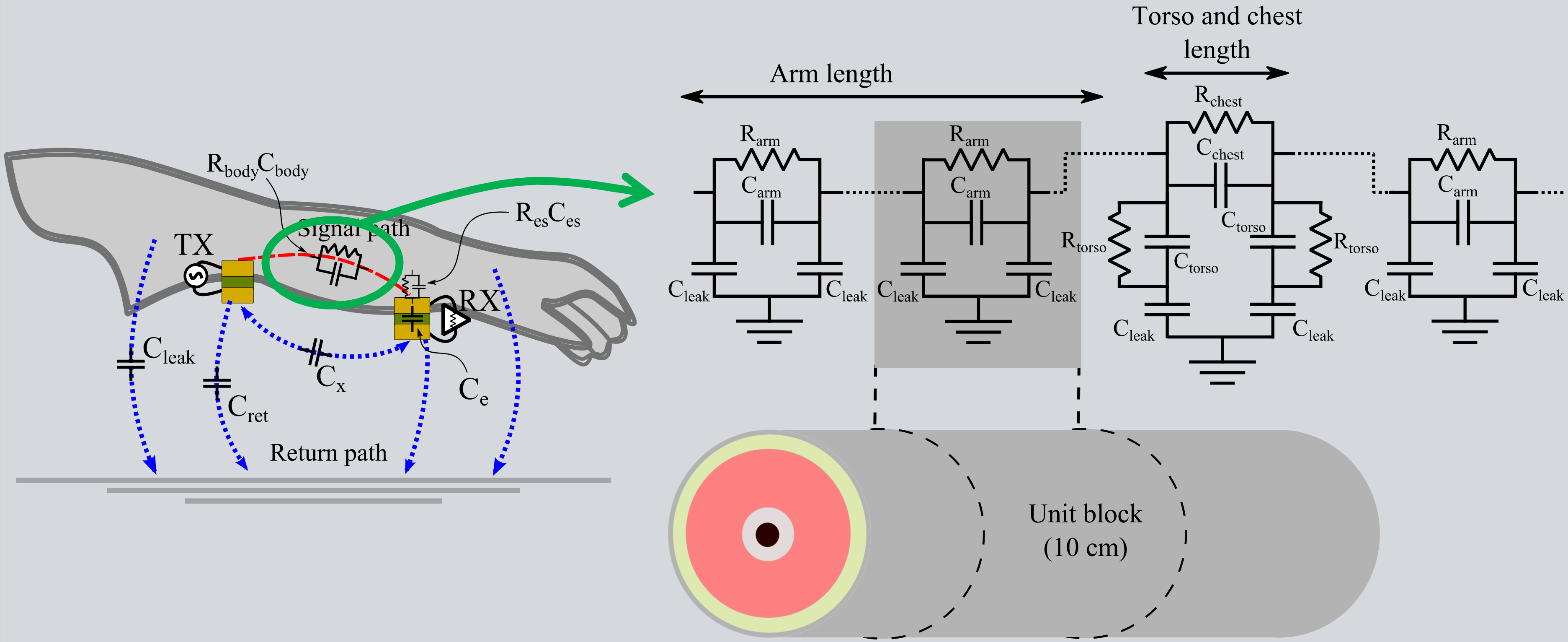
Primary channel

- Primary channel partitioning:
  - Intrinsic channel.
  - Extrinsic channel.
- Secondary channel: external structures (environment and test fixture).



Intrinsic channel

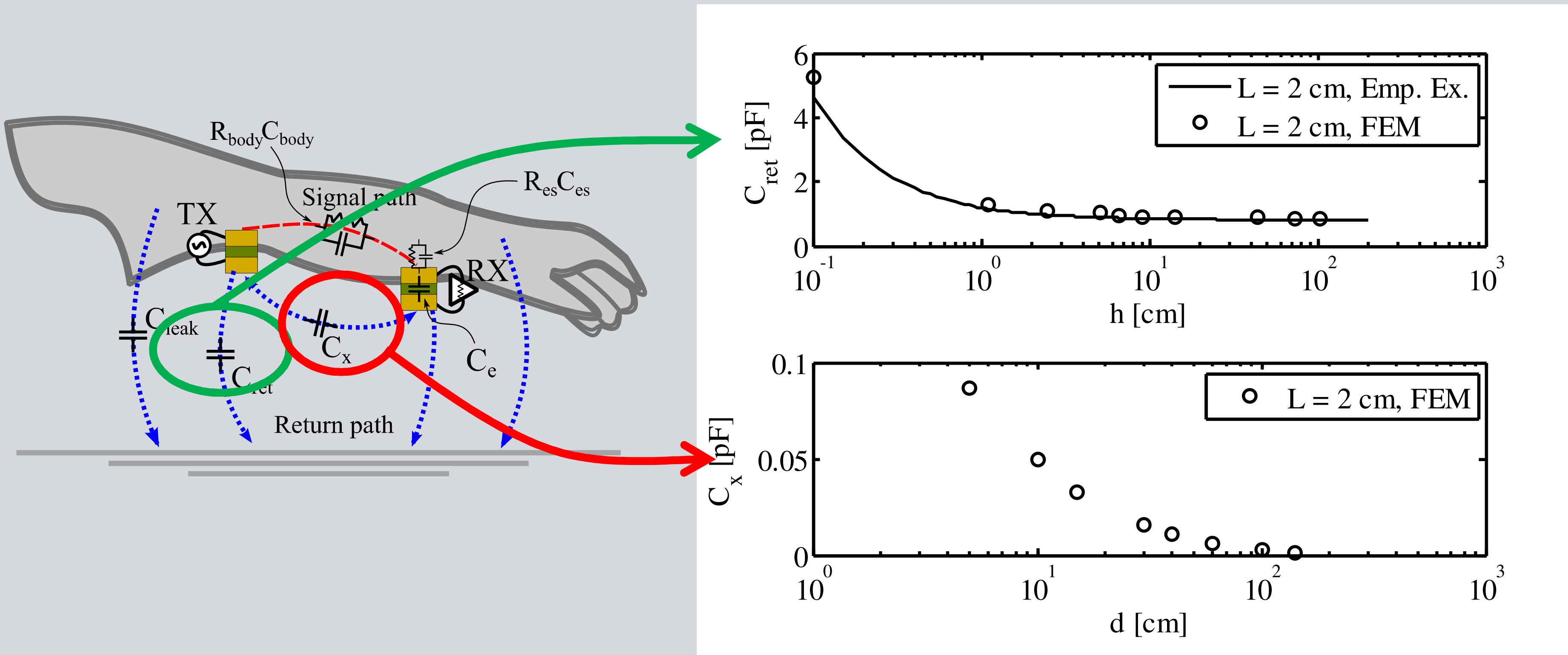
- Network based on unit blocks equivalent circuit offers good compact alternative [Xu *et al, 2011*].



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

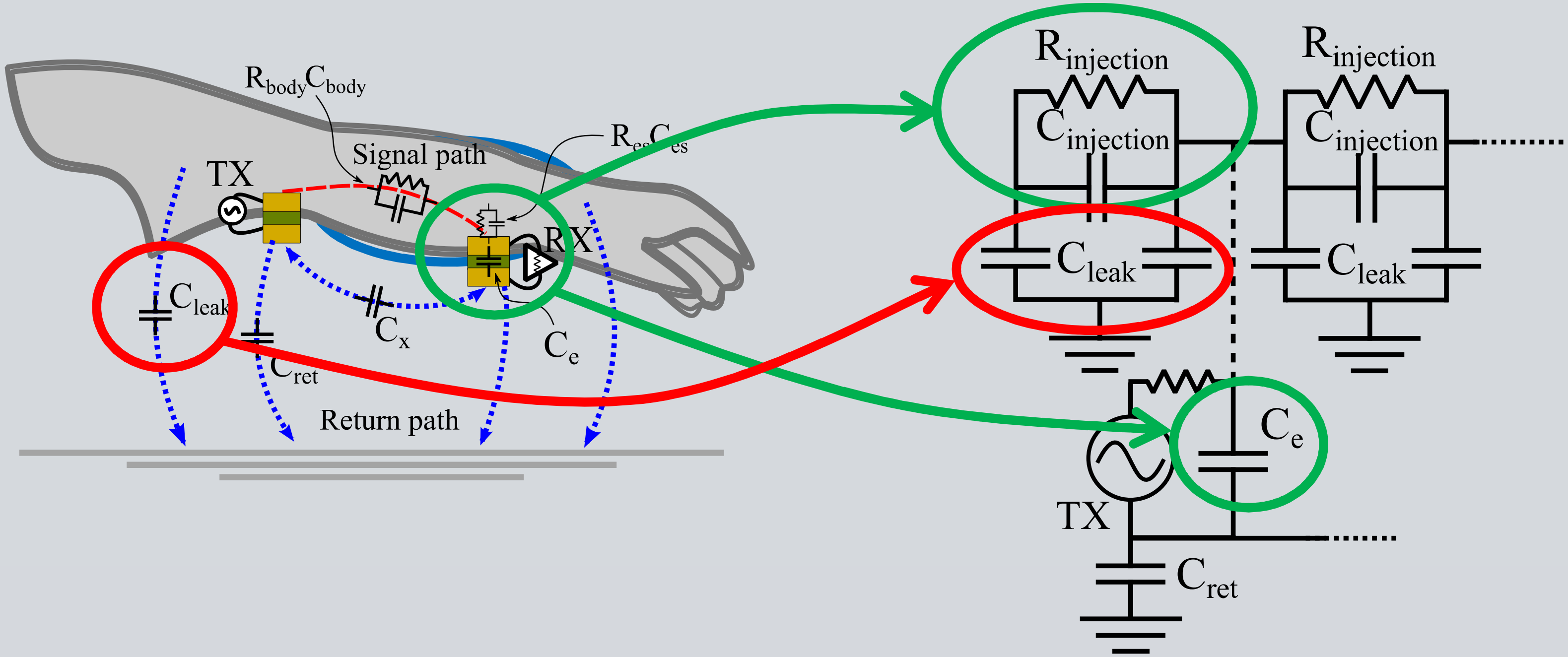
Extrinsic channel

- Return capacitances: empirical exp. and 3D EM simulations EM 3D.



Extrinsic channel

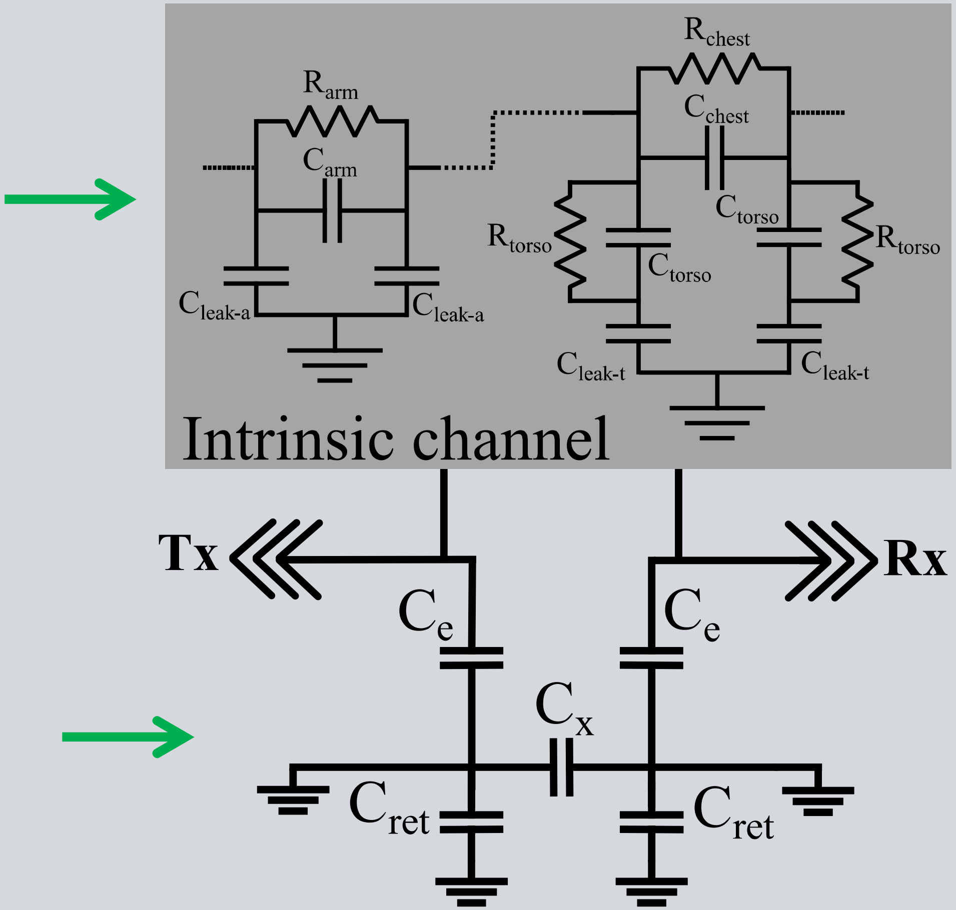
- Body leakage capacitances.
- Inter-electrode and electrode skin impedances.



Primary channel

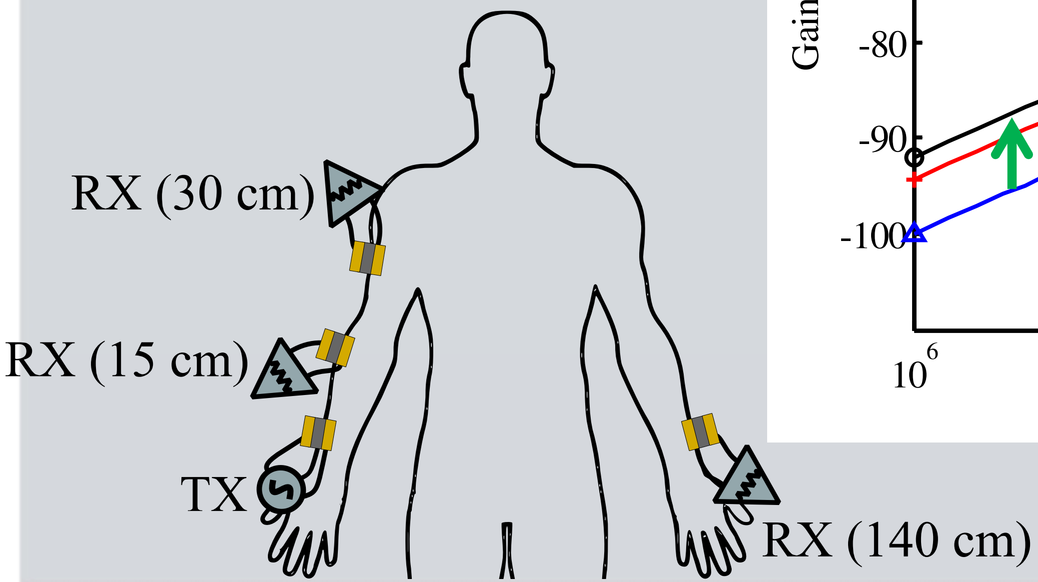
R_{arm}	65 Ω	R_{chest}	500 Ω
C_{arm}	25 pF	C_{chest}	3.5 pF
$C_{leak\text{-}a}$	0.7 pF	R_{torso}	600 Ω
$C_{leak\text{-}t}$	15 pF	C_{torso}	4 pF
C_{injec}	5.5 pF	R_{injec}	250 Ω

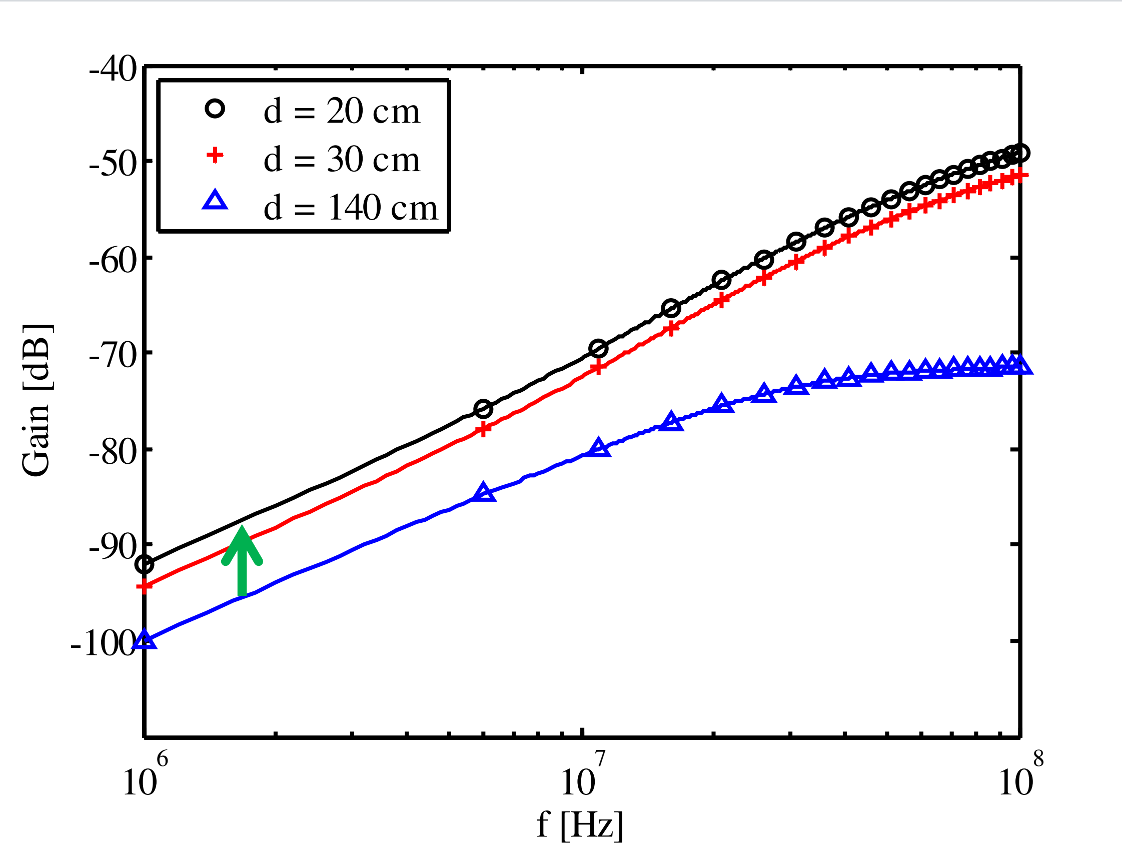
C_{ret}	870 fF	C_e	11.3 pF
$C_{x\text{-}20}$	25 fF	$C_{x\text{-}30}$	16 fF
$C_{x\text{-}140}$	1.25 fF	-	-



Primary channel model

- High pass profile.
- Low frequency dependence on distance.
- Attenuation levels between 50-100 dB.





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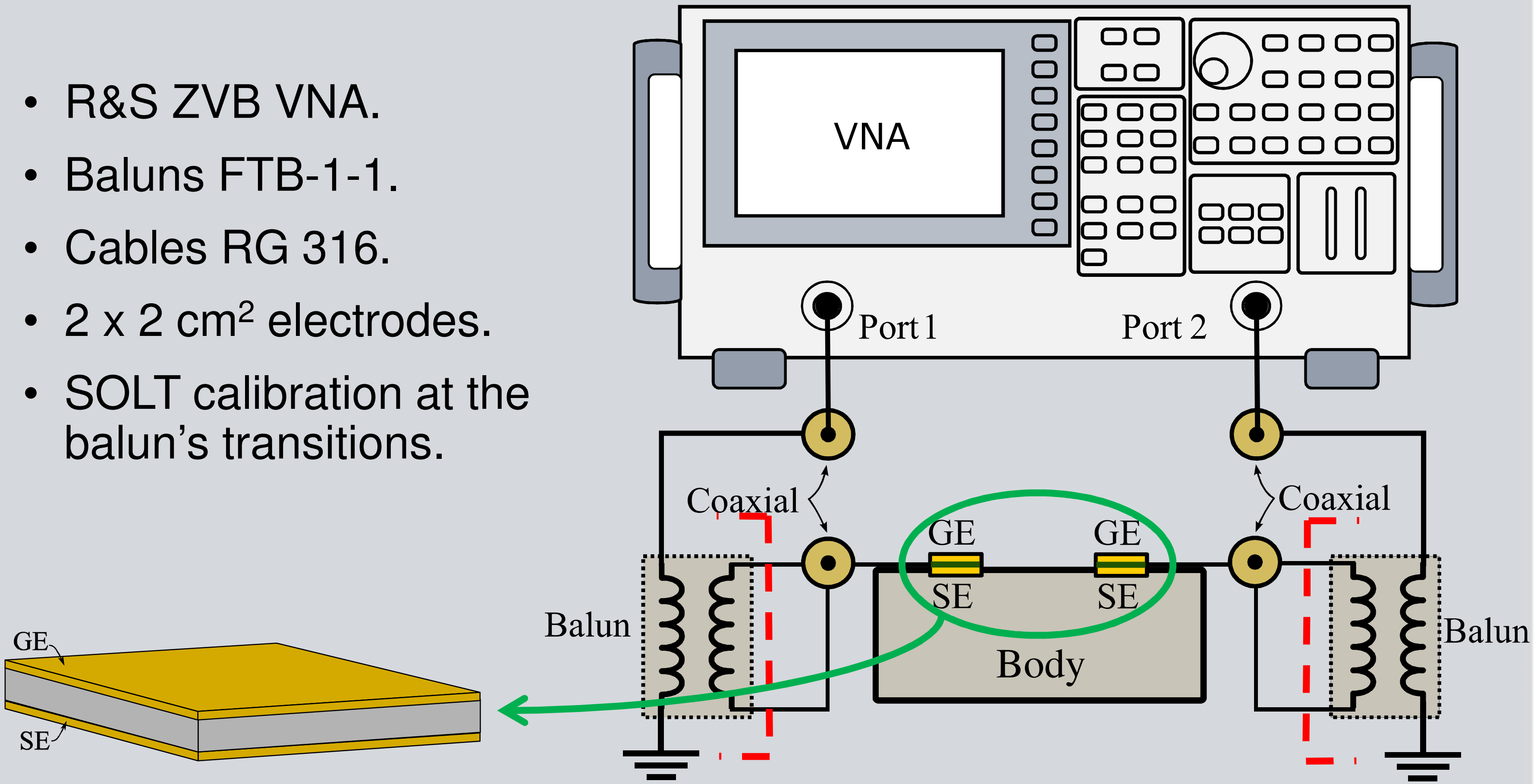
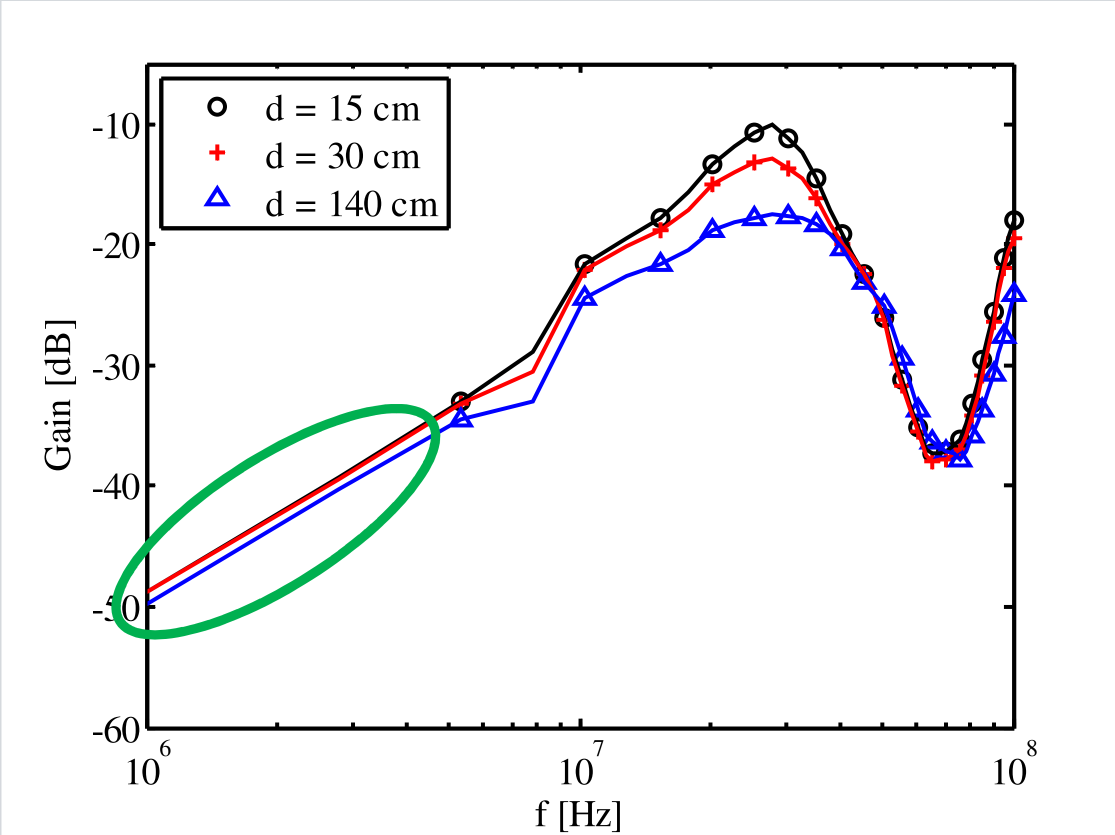
Measurement system

- R&S ZVB VNA.
- Baluns FTB-1-1.
- Cables RG 316.
- 2 x 2 cm² electrodes.
- SOLT calibration at the balun's transitions.



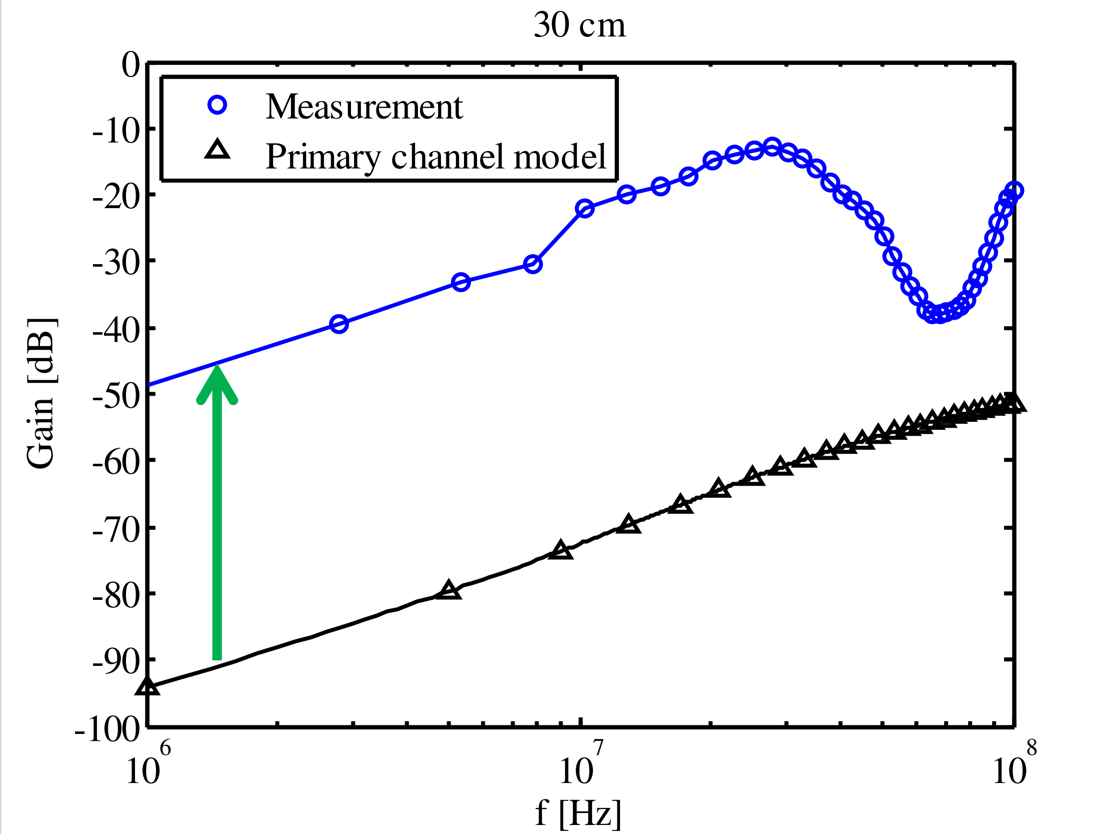
Channel measurements

- Pass band profille.
- Independence of *d* in lower frequencies.
- Attenuation levels between 10-50 dB.



Measurements and model comparison

- 30 cm propagation distance.
- Differences on freq. profile.
- Over 45 dB higher attenuation.
- Balun's effect [Sakai et al, 2013].



Sakai, J.; Lin-Sheng Wu; Hu-Cheng Sun; Yong-Xin Guo, "Balun's effect on the measurement of transmission characteristics for intrabody communication channel," Microwave Workshop Series on RF and Wireless Technologies for Biomedical and Healthcare Applications (IMWS-BIO), 2013 IEEE MTT-S International , vol., no., pp.1,3, 9-11 Dec. 2013.

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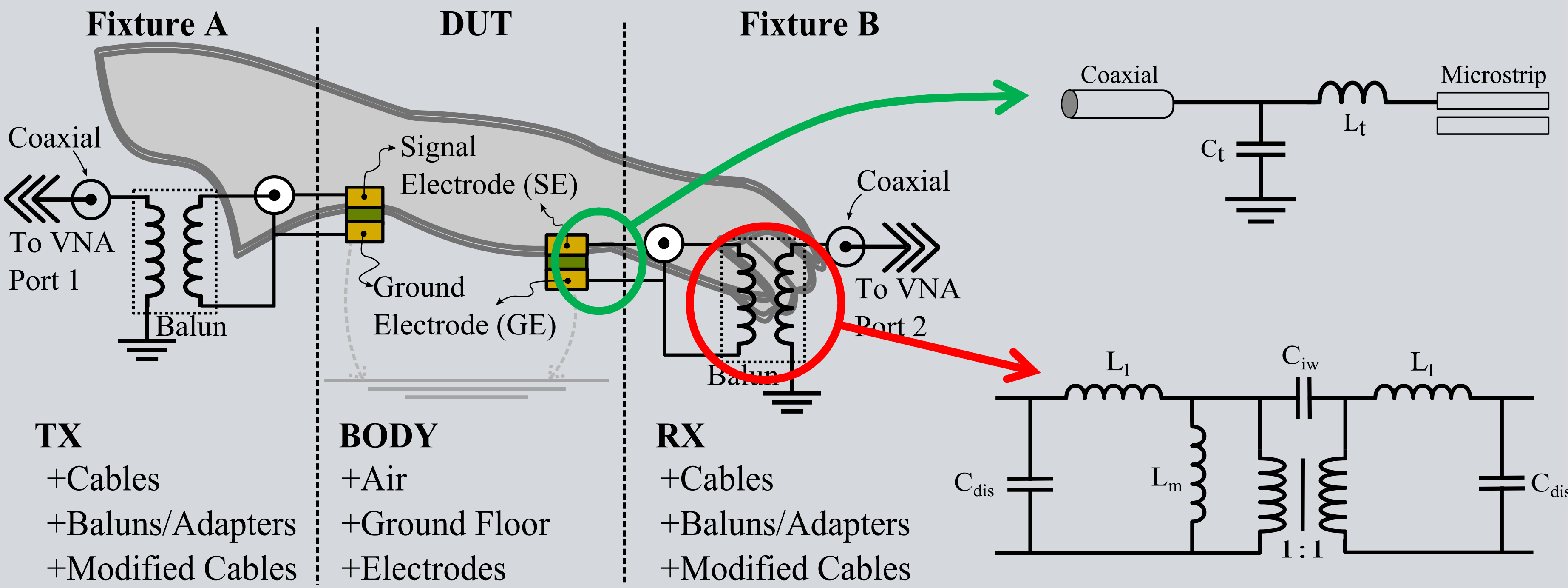
Test fixture modeling

- DUT and test fixture transitions.
  - Modifified cables transitions model.
  - Baluns: model extraction.



Extended model

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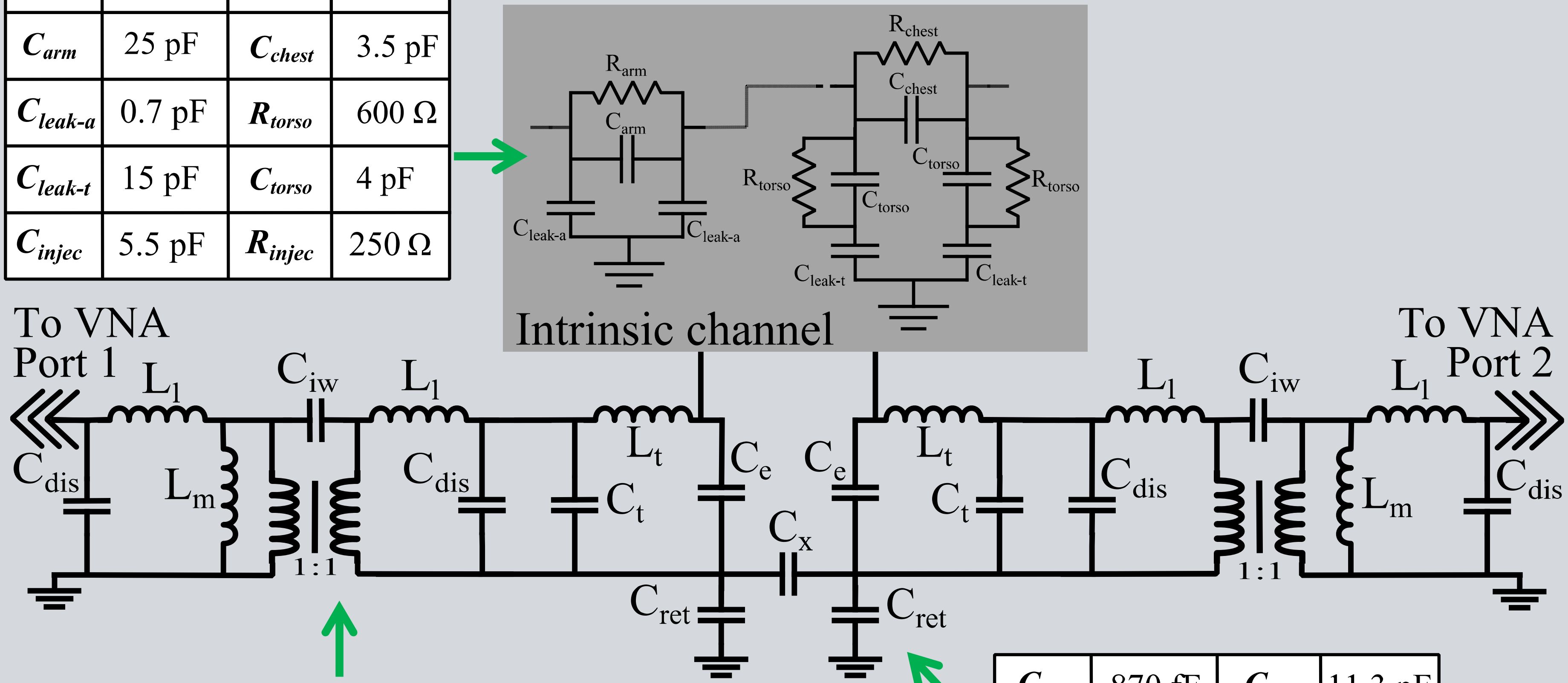
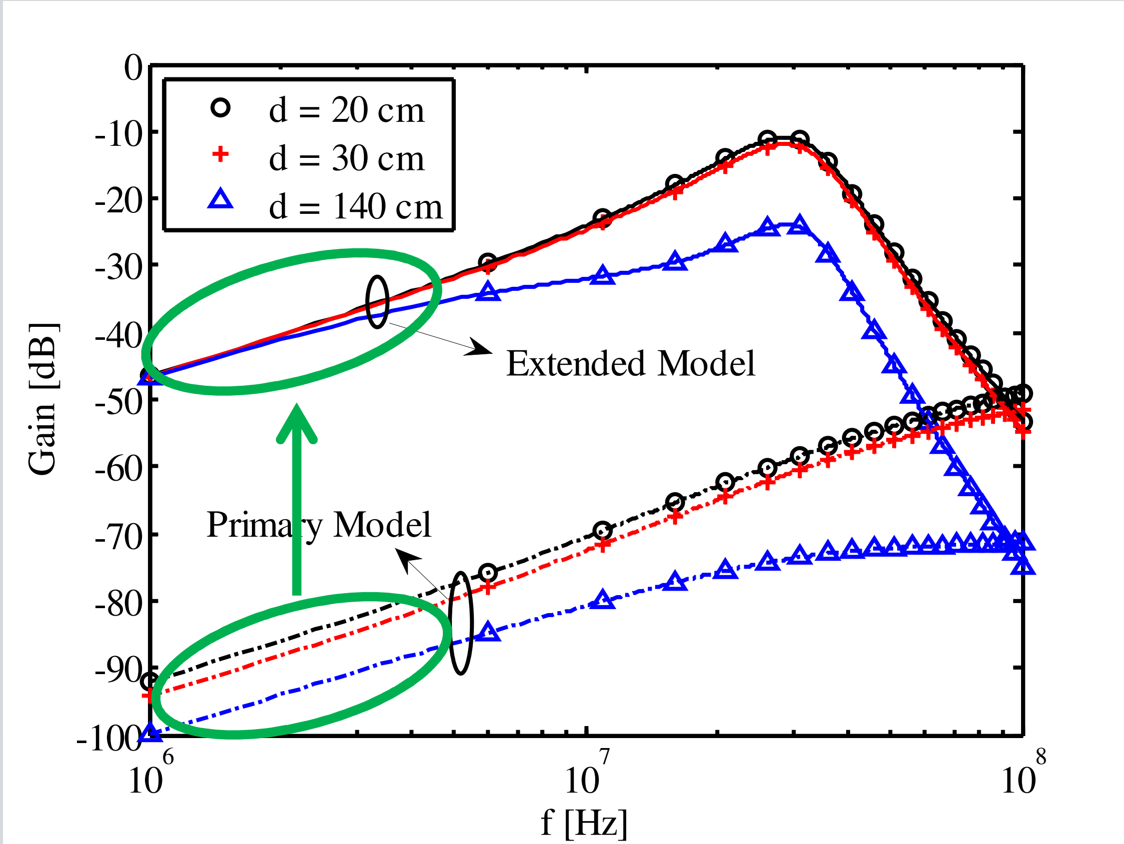


C_{iw}	27.2 pF	L_l	420 nH	L_t	6 nH
C_{dis}	12.3 pF	L_m	200 uH	C_t	-

C_{ret}	870 fF	C_e	11.3 pF
$C_{x\text{-}20}$	25 fF	$C_{x\text{-}30}$	16 fF
$C_{x\text{-}140}$	1.25 fF	-	-

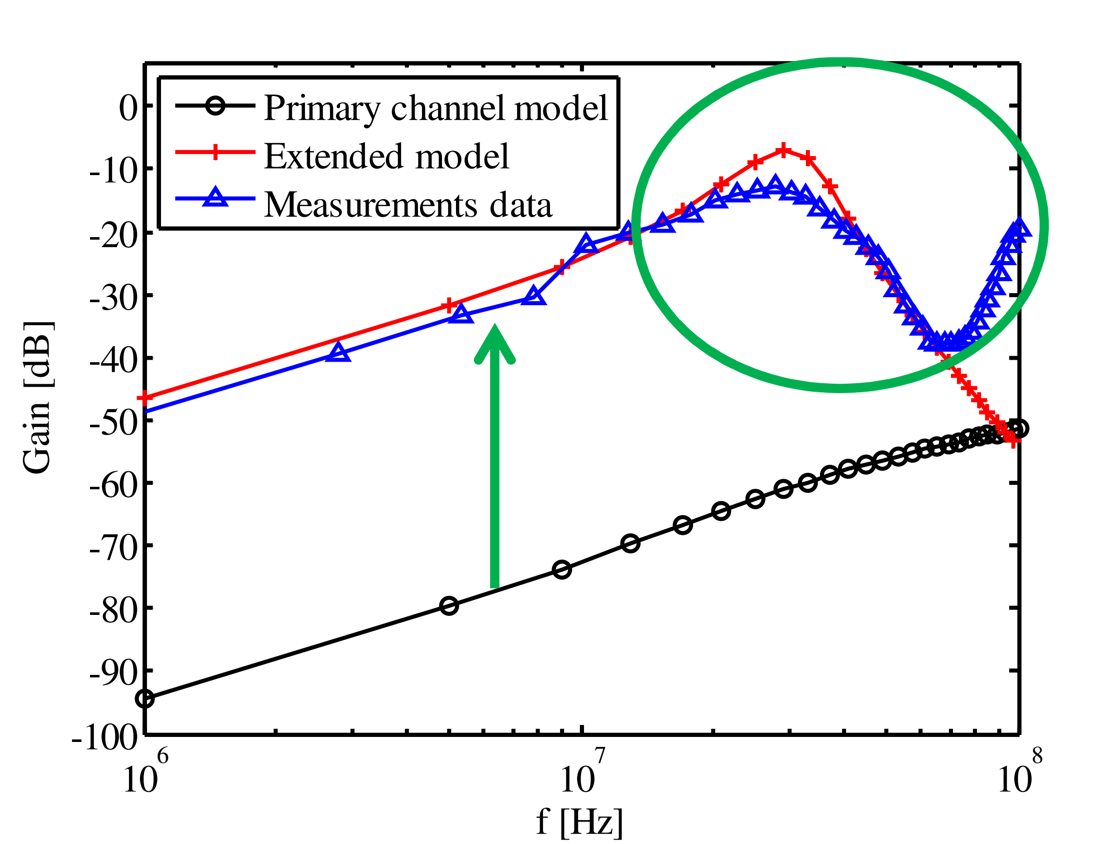
Extended model

- Reproduces the band pass profile.
- Low frequency independence of d.
- Around 45 dB lower attenuation.



Measurements and Extended model comparison

- Good extended model fit below 70 MHz
- Differences < 5.5 dB.



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Final Considerations

- Contributions:
  - Proposal of a systematic primary channel partitioning that facilitates HBC understanding and modeling.
  - Proposal of extended model that includes the test fixture.
  - Verification of test fixture influences.
  - Validation of primary channel model and identification of challenges for transceiver design.
- Ongoing studies:
  - Methodology to de-embed the test fixture from measurements.

Thank You

RF

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