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Acoustic Impedance Characteristics of Artificial Ears For Telephonometric Use

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Overview

- Artificial ears for telephonometry
- Measurement campaign
- Acoustic impedance testing
- Impedance measurement results:
  - Human ears
  - Artificial ears
- Human vs. artificial ears
- Conclusions

Paper available on the ITU-T workshop page (www.itu.int/ITU-T/worksem/speechaudio)

Artificial Ears for Telephonometry

- Analog of human ear for objective acoustic measurement
- Efficient and repeatable way of predicting acoustic performance of a handset in final usage case

- Standardization within industry:
  - ITU-T Rec. P.57: Artificial Ears
  - Ears should provide"*[...] an overall <u>acoustic impedance</u> similar to that of the average human ear over a given frequency band"*

Artificial Ears for Telephonometry

- ITU-T Rec. P.57 Type 3.3 and 3.4 become industry *de facto*
- Primarily for use with a HATS
  - ITU-T Rec. P.58 "Head and torso simulator for telephonometry"
- Type 3 - IEC 60711 occluded ear simulator with canal extension terminated in a:
  - Type 3.3 pinna simulator (anatomically shaped)
  - Type 3.4 pinna simulator (simplified)

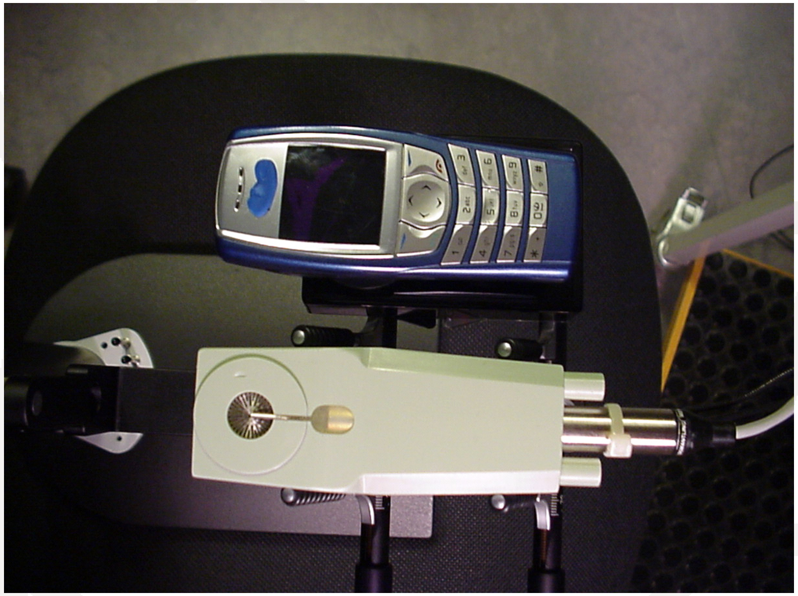
Measurement Campaign

- ITU-T SG12 responsible for development of Rec. P.57
- Recent effort to benchmark Type 3 ears against the "average" acoustic impedance of human ears

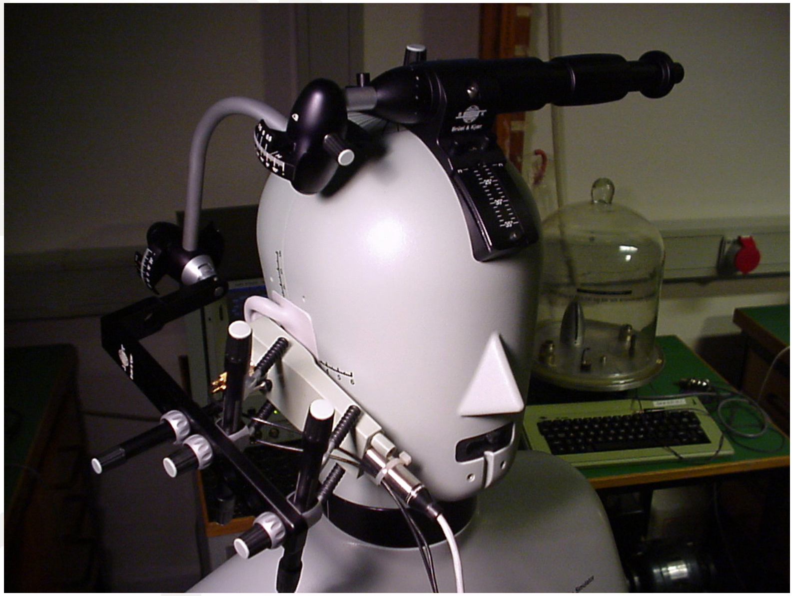
- Specific focus on:
  - Mobile phone in 'hand-portable' mode
  - Measurement for a large number and range of human users
  - Wide-band frequency range
  - Round-robin campaign (multiple industry participants)

Acoustic Impedance Testing

- Mobile phone-like impedance probe provided by Brüel & Kjær



- Frequency-dependent impedance measure close to the ECRP



Acoustic Impedance Testing

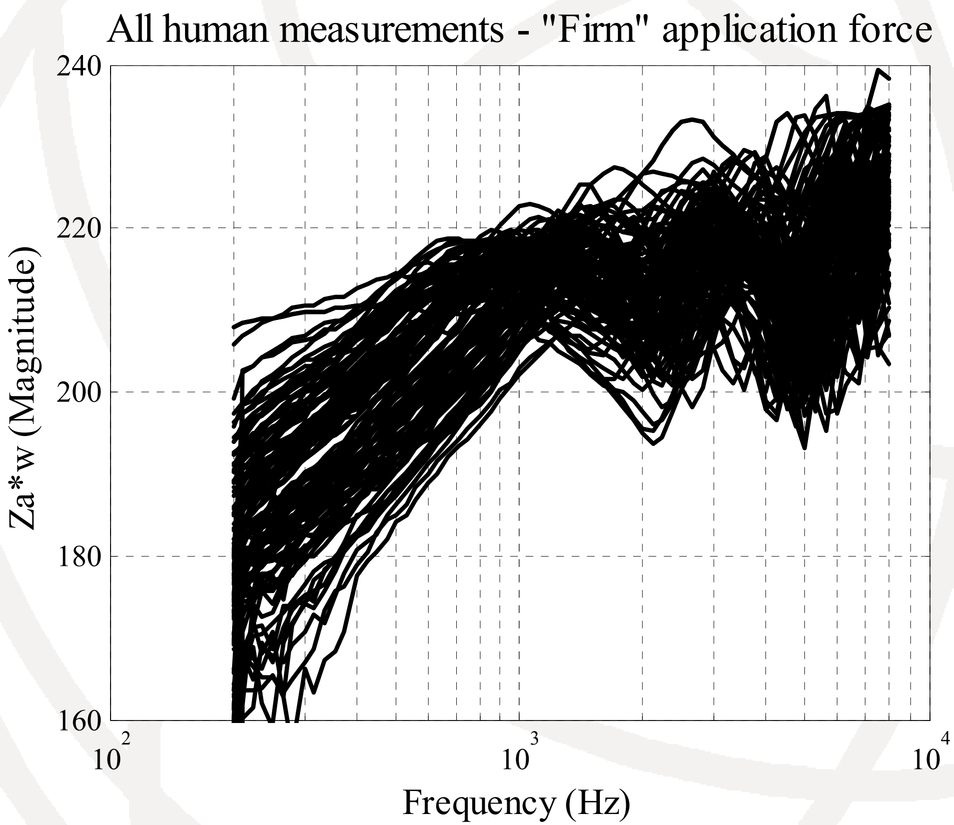
- Human measures:
  - 5 contributing (independent) laboratories
  - Subject gender and age demographic considered
  - 106 subjects total measured
  - 2 separate handset application force measures made per subject
    - 'Normal' application force (inferred from placement in silent condition)
    - 'Firm' application force (inferred from placement in lab. simulated noise field)
  - Impedance measure at each ISO R40 1/12th oct. between 0.2-8kHz for each test case

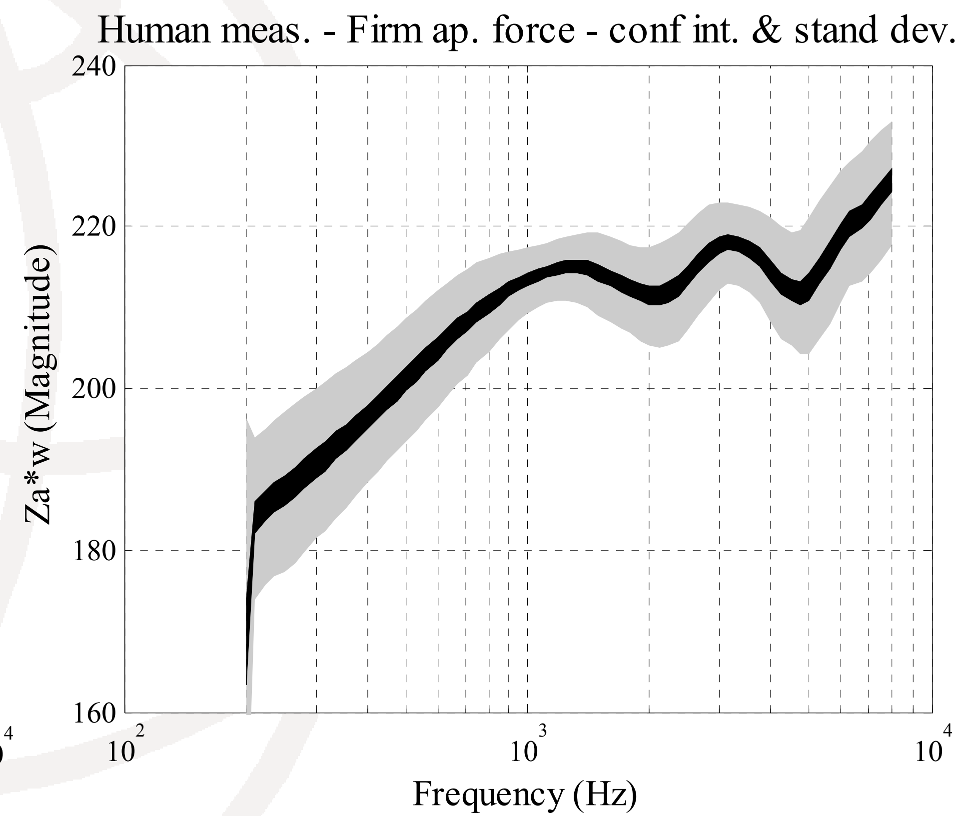
Acoustic Impedance Testing

- Artificial ear measures:
  - Commercially available artificial ears tested with same probe by each manufacturer
    - Brüel & Kjær Type 3.3 ear
    - HEAD acoustics Type 3.4 ear
  - Measurement on HATS at 'standard' position
  - Application forces between 2 and 18N increasing by 2N steps
  - Impedance measure at each ISO R40 1/12th oct. between 0.2-8kHz for each test case

Testing Results: Human Ears

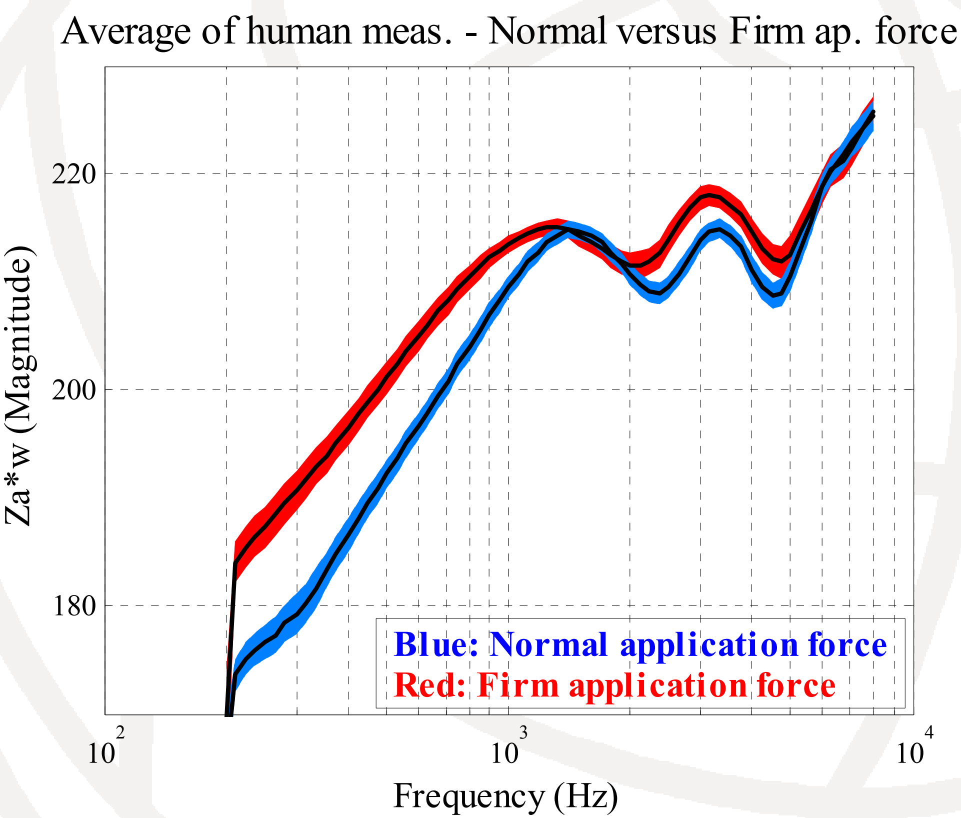
- Statistical analysis for each individual 1/12th octave band

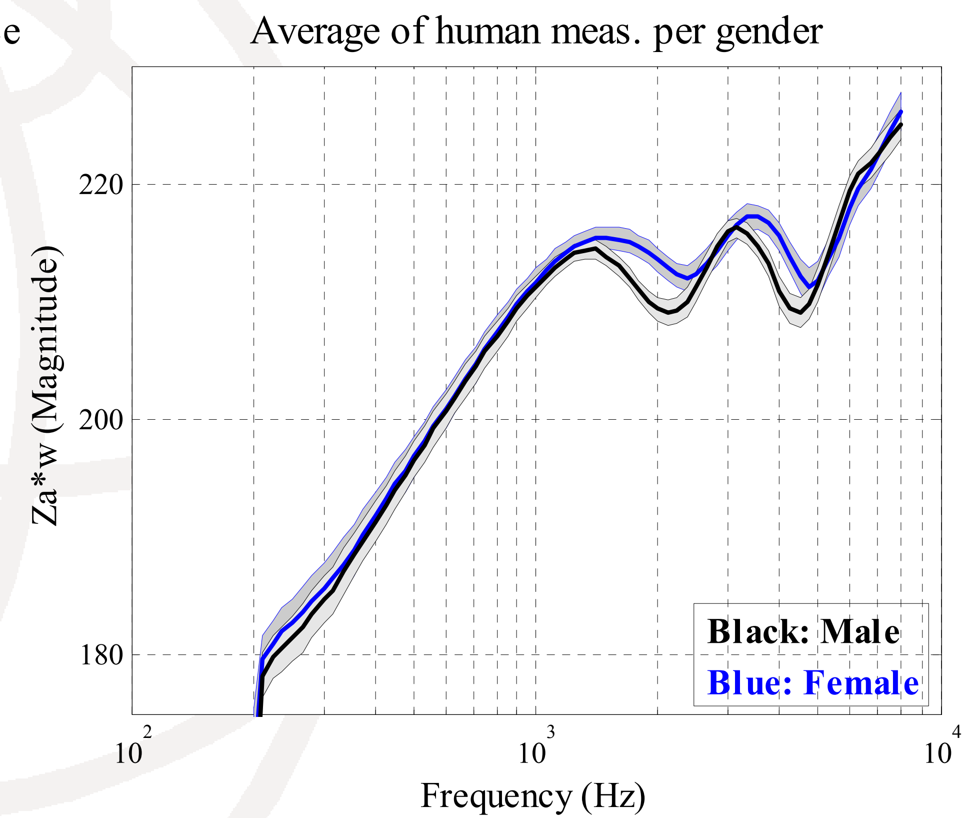




Testing Results: Human Ears

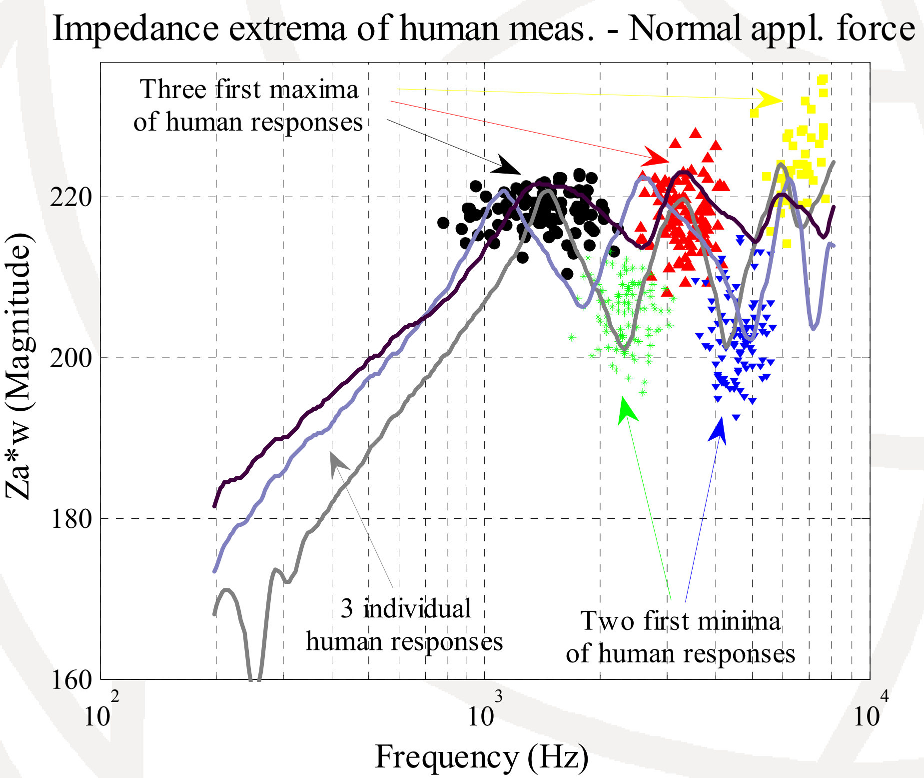
- Illustration of the two most important factors: *Application force* and *Gender*

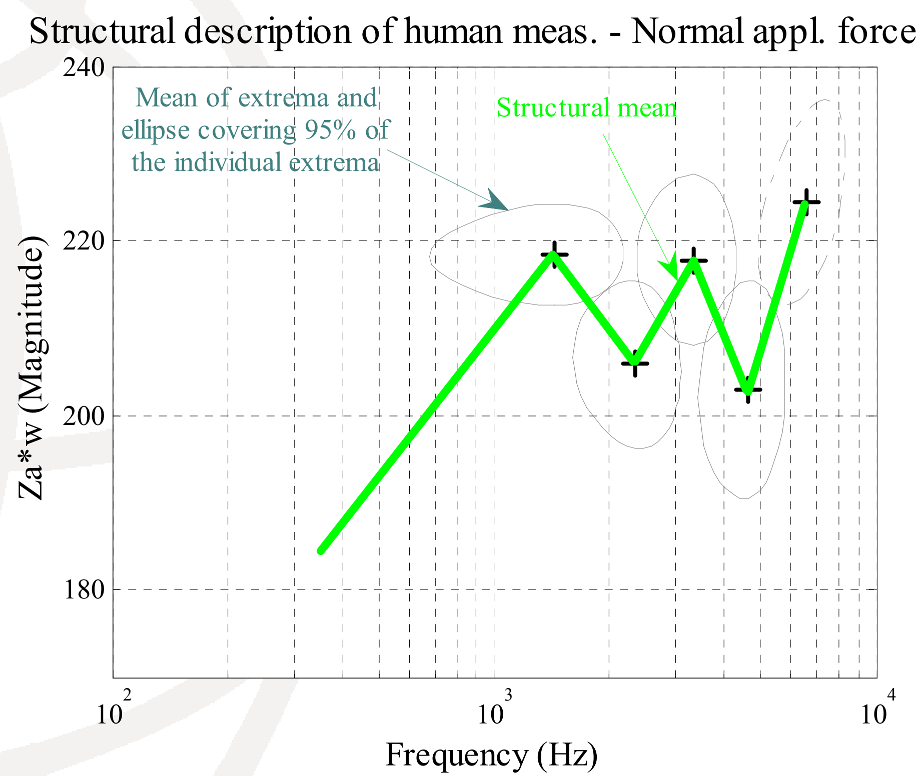




Testing Results: Human Ears

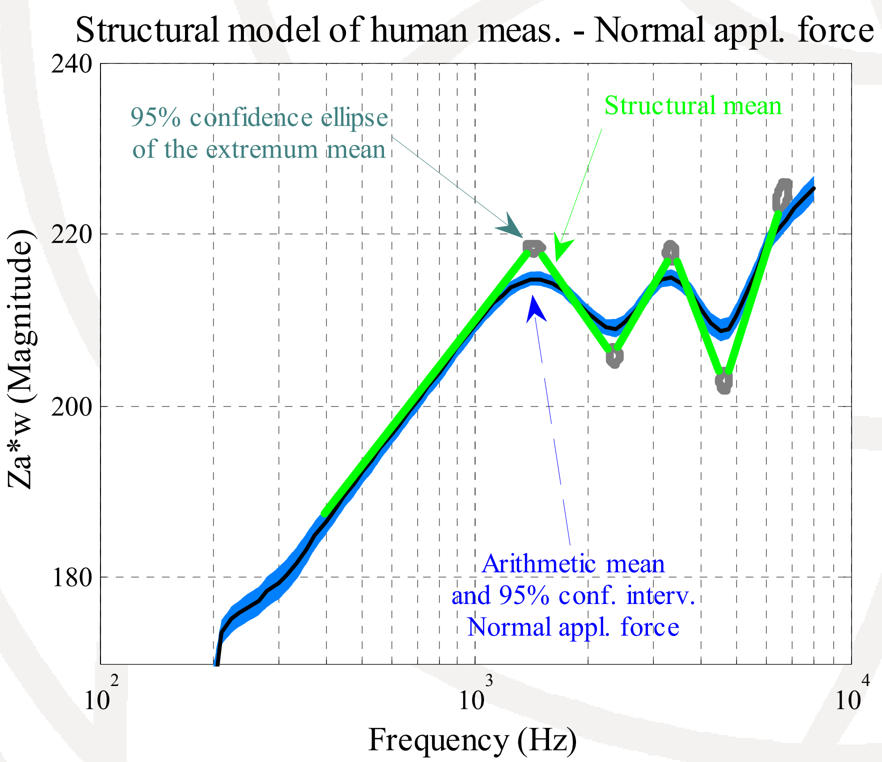
- Detection of impedance response extrema
- "Structural modeling" of measures

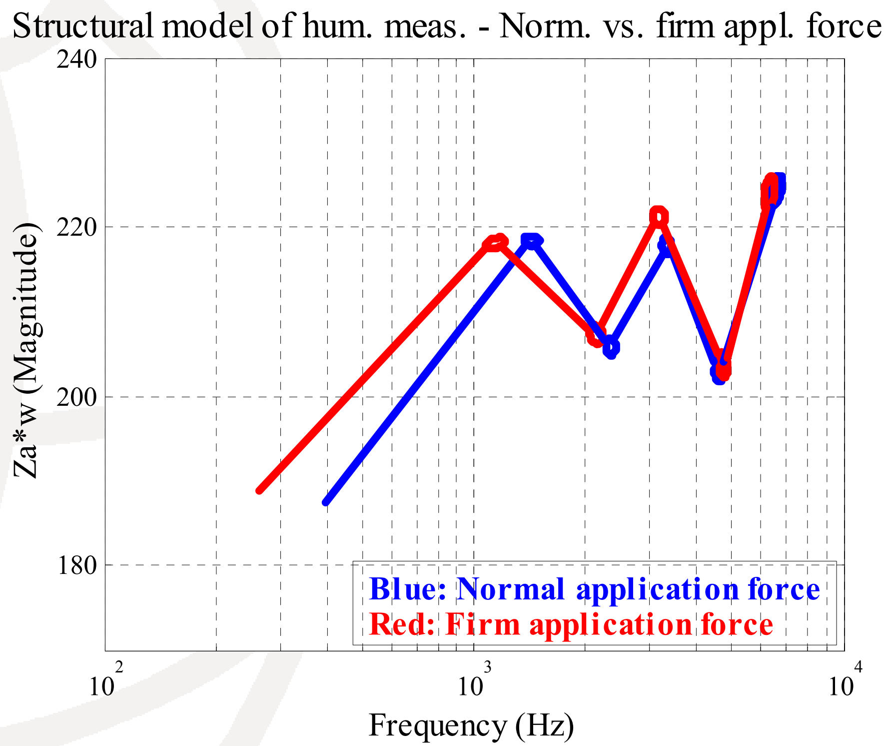




Testing Results: Human Ears

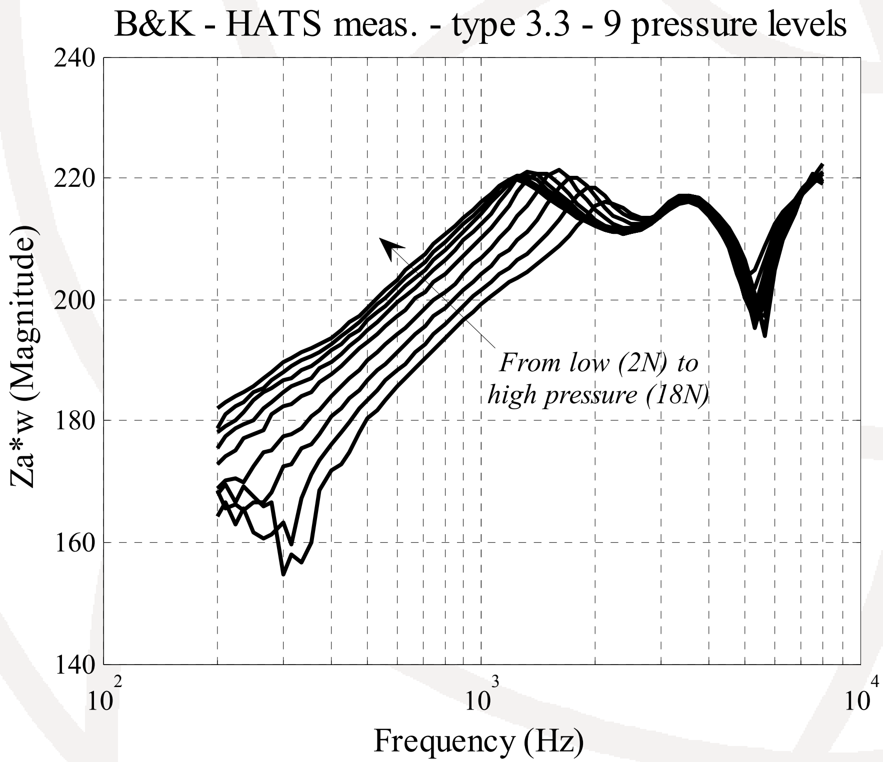
- Comparative analysis of structural means

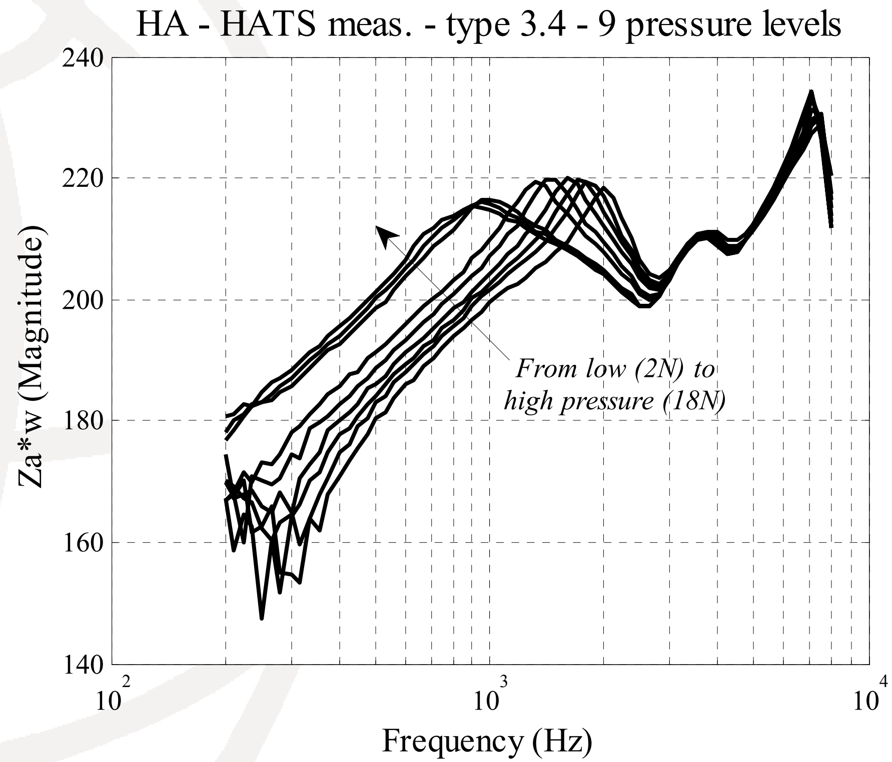




Testing Results: Artificial Ears

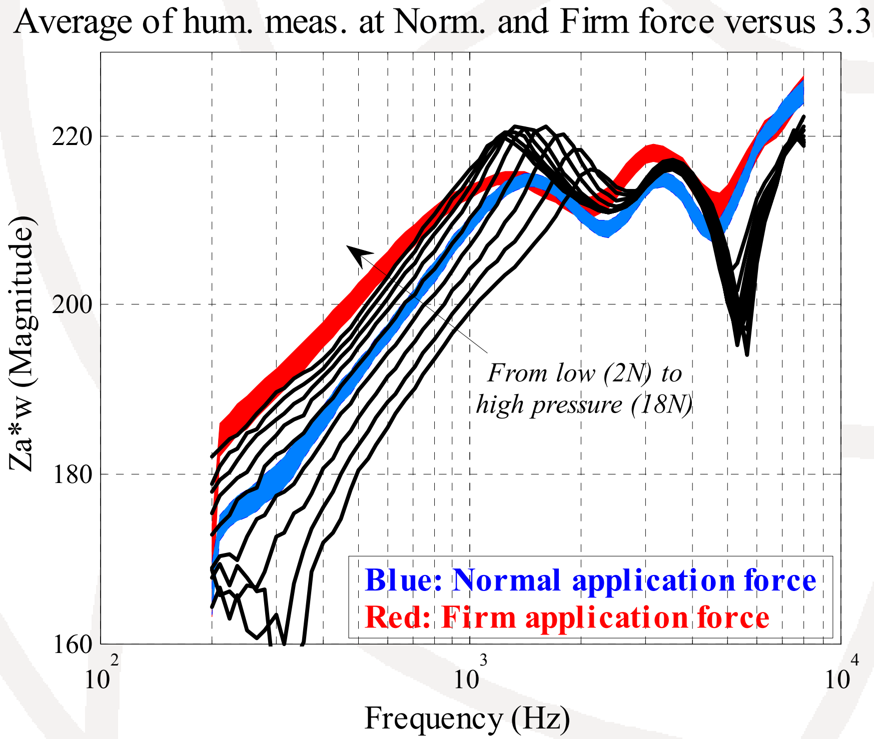
- Individual 1/12th oct. response for each artificial ear type per application force

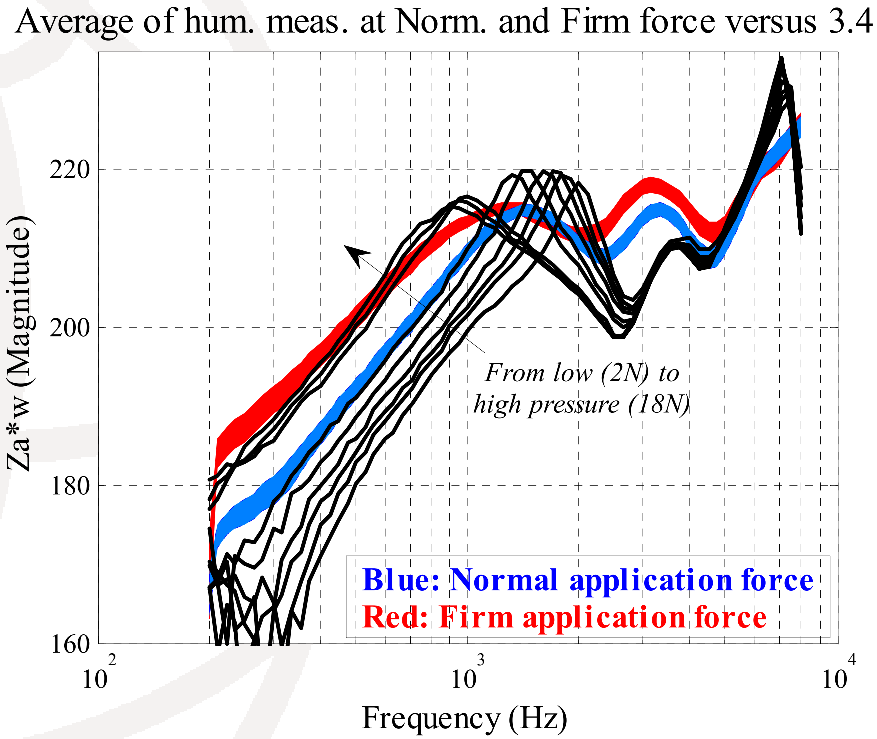




Human vs. artificial ears

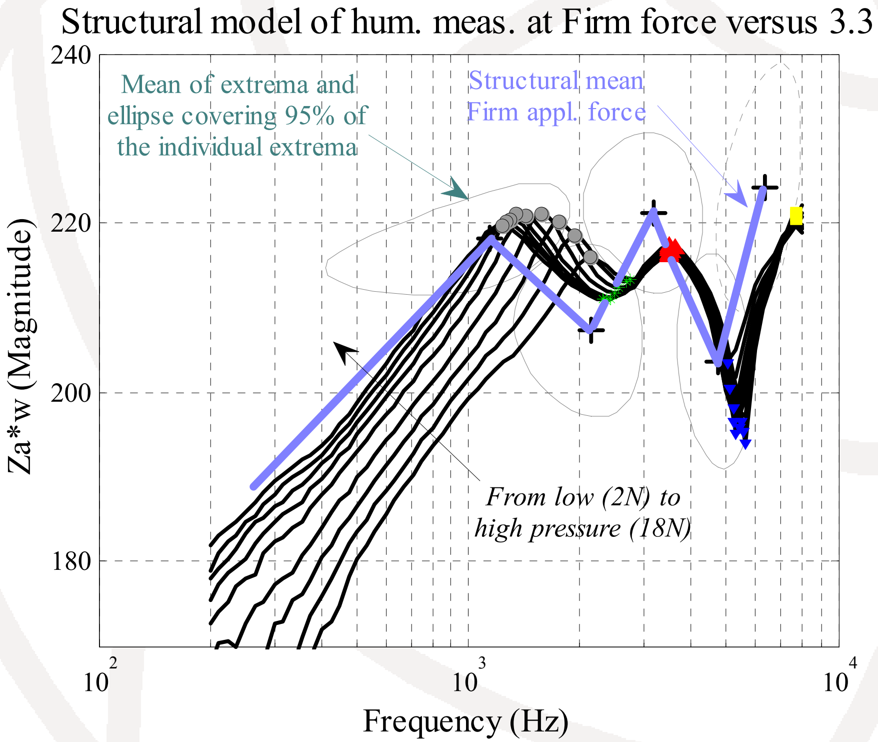
- Human individual 1/12th octave band CI95% vs. artificial ears types

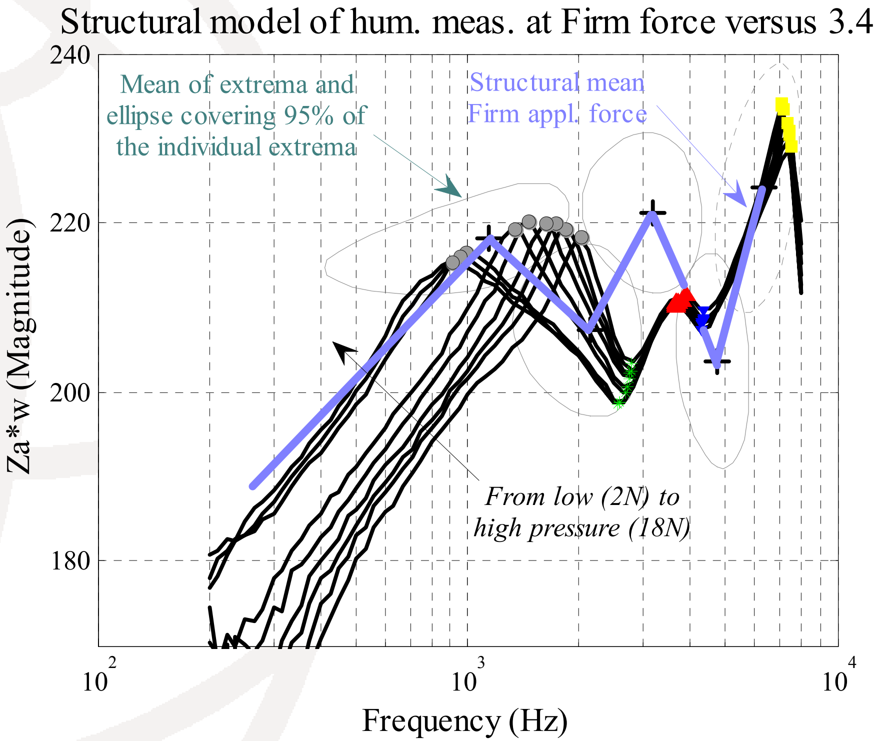




Human vs. artificial ears

- Human structural mean vs. artificial ears types





Conclusions

- The work highlighted the challenges of developing, using and interpreting artificial ears to predict the acoustic performance of mobile phones in the 'hand-held' position
- Even more apparent when extending measurement beyond the typical narrow-band frequencies
- The multiple statistical analysis methods described here give more perspectives on what the "average" human impedance response target is
- Discussion ongoing within ITU-T SG12 to make use of these results for current and future recommendations

Thank You

Acknowledgements

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