Bowers & Wilkins

Automatic Equalization of Subwoofers

Sean Thomson

3 October 2018

Presentation Overview

- Bowers & Wilkins
- Subwoofers in Rooms
- DB Series & Room EQ Demo
- Development & Deployment
- Conclusion

Who are we?

Bowers & Wilkins

Founded by John Bowers in Worthing in 1966, we are a private company led by Gideon Yu.

We focus on providing a fully complementary portfolio of high performance loudspeaker, audio, video and integration products for the discerning customer.

Bowers & Wilkins is distributed in over 60 markets.

We have our own distribution companies plus integrated manufacturing in UK and China in our own plants.

Our R&D offices are in Steyning, Worthing, Silicon Valley and Taipei.

Bowers & Wilkins

We are the singular dream of one man that became a world-famous centre of audio excellence.

We believe in collective effort. Each product is the outcome of a team vision. We challenge each other all the time.

Just being ‘good enough’ isn’t good enough for us.

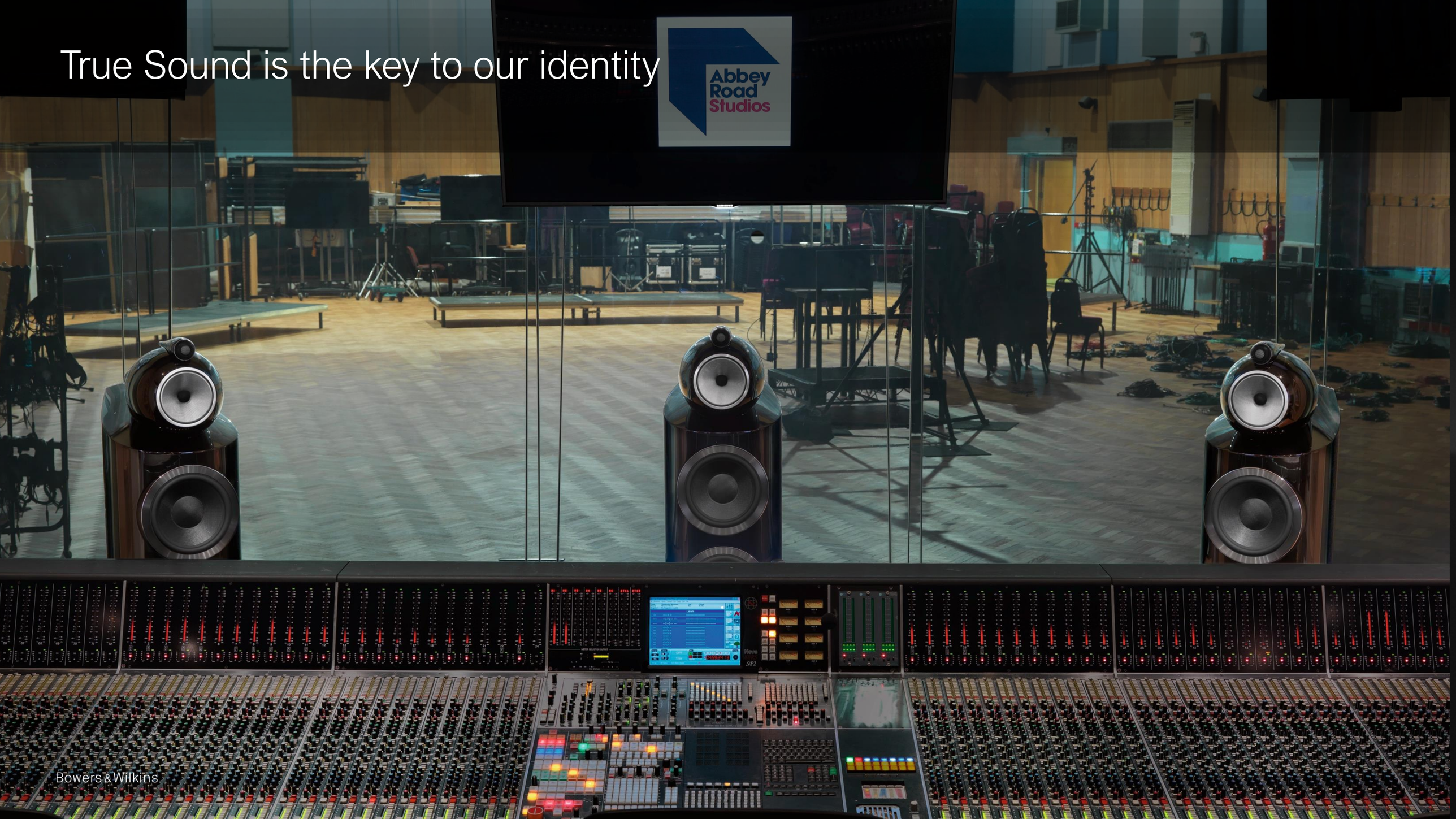
Everything we do is driven by our focus on performance, technology and leadership.

We pursue our ideal of True Sound in everything we make.

Listen and you’ll see.

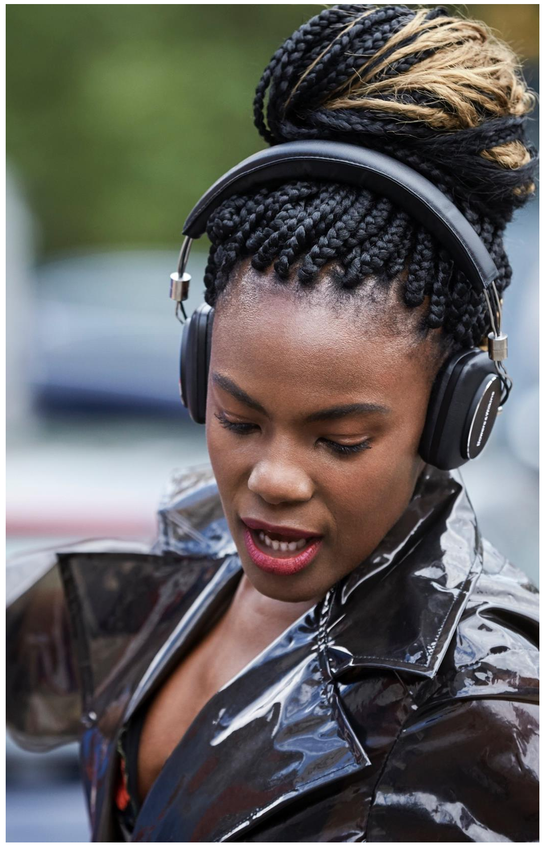
Bowers & Wilkins

True Sound is the key to our identity



Bowers & Wilkins

Our products: for the home, the car and on-the-go



How we use MATLAB

- Research electro-acoustics & signal processing

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- Research electro-acoustics & signal processing
- Audio Test & Measurement

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- Product Tuning

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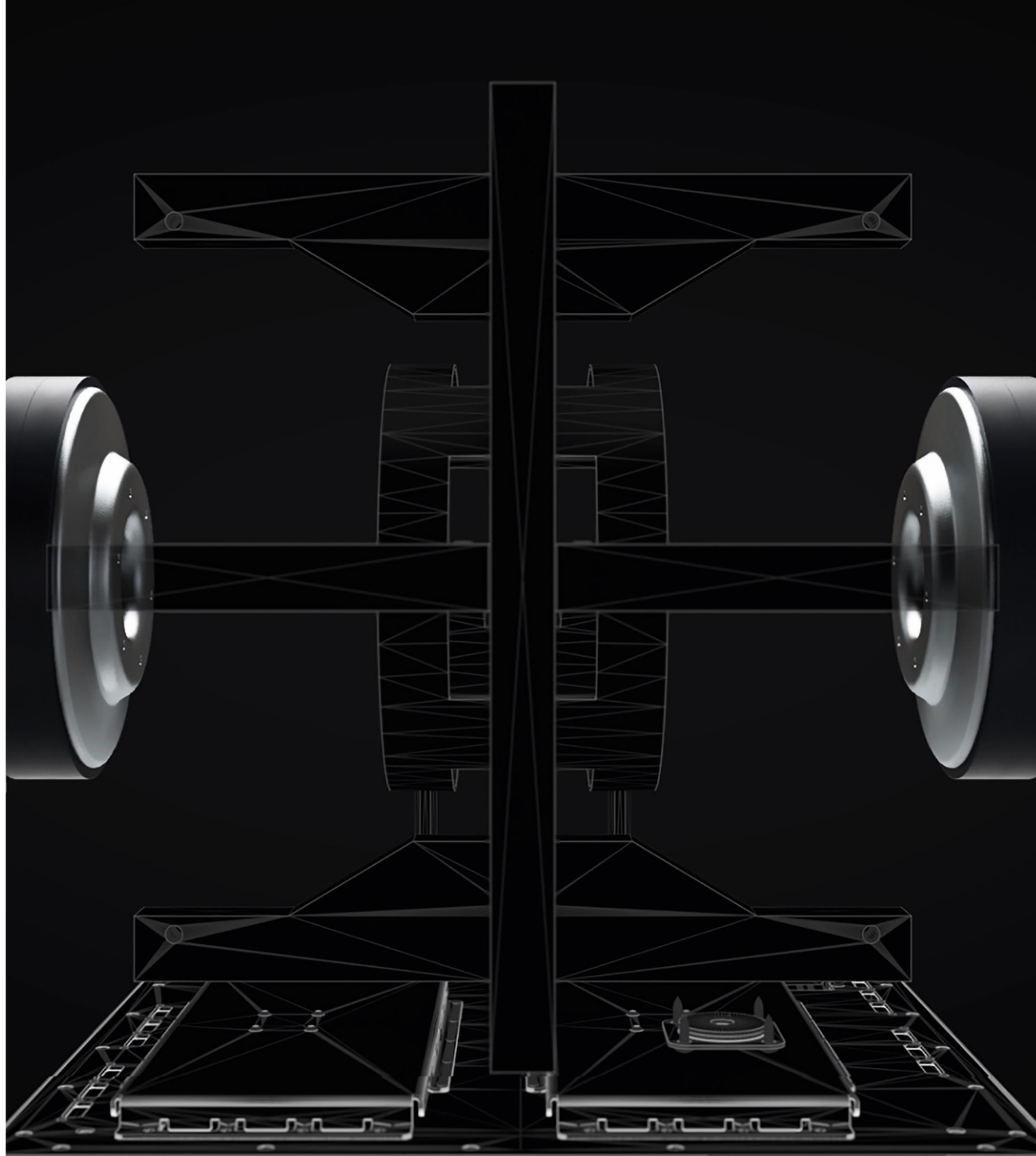
- Algorithm Development



How we use MATLAB

- Research electro-acoustics & signal processing
- Audio Test & Measurement
- Product Tuning
- Algorithm Development
- Algorithm Deployment

→ DB Series Subwoofers

→ Room EQ

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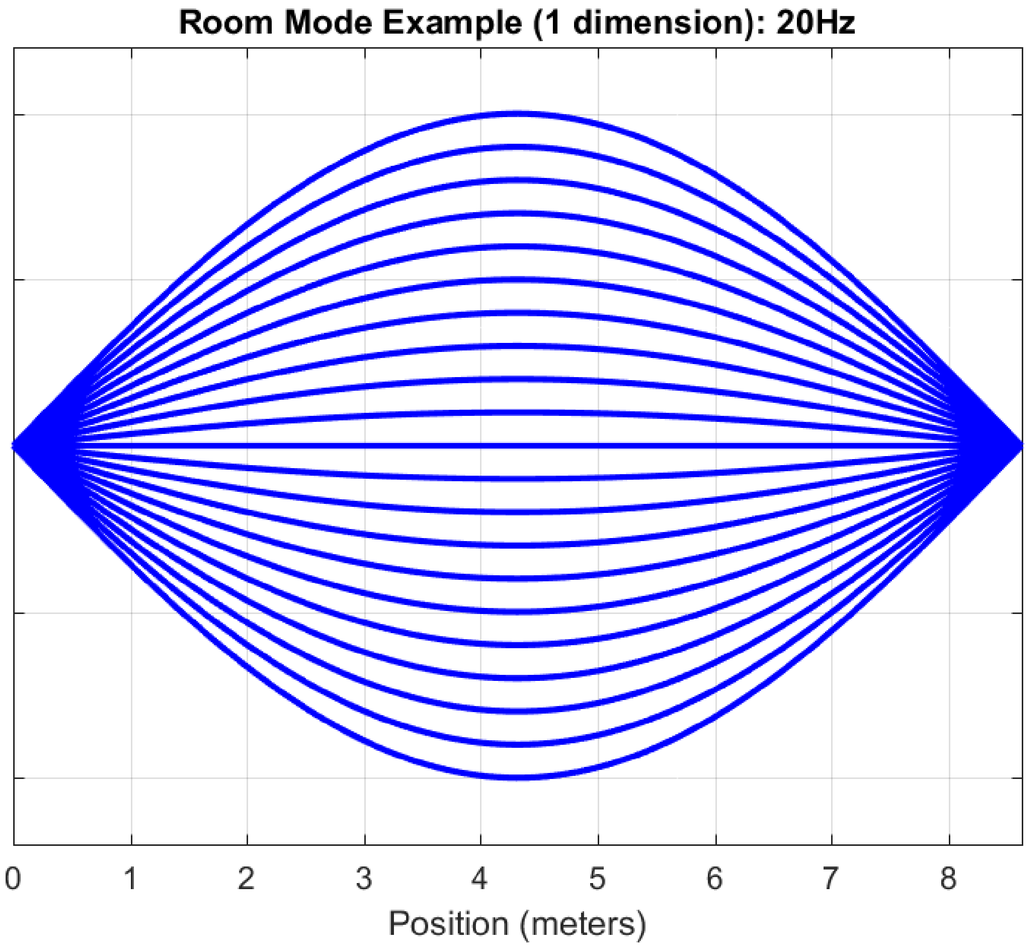
Subwoofers in Rooms

Challenges

The Low Frequency Problem in Rooms

- At low frequencies the room is modal
- Standing waves:
  - Room dimensions



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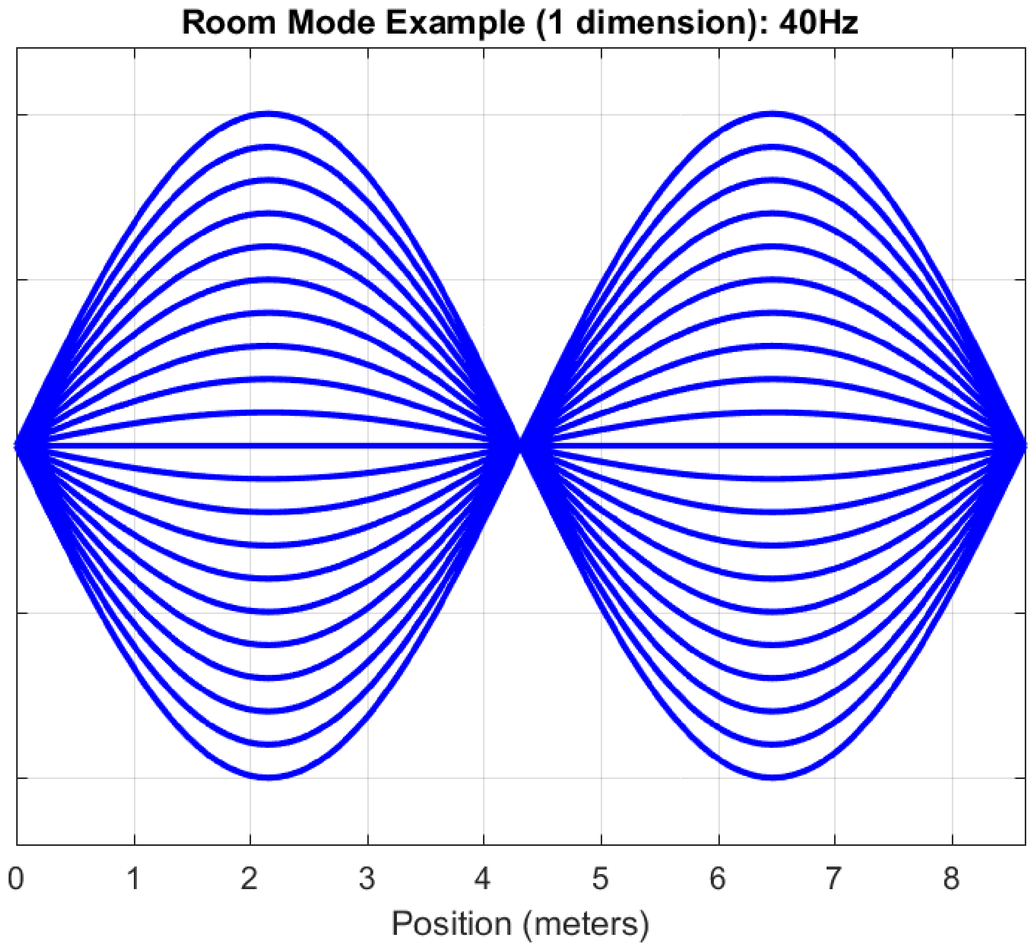

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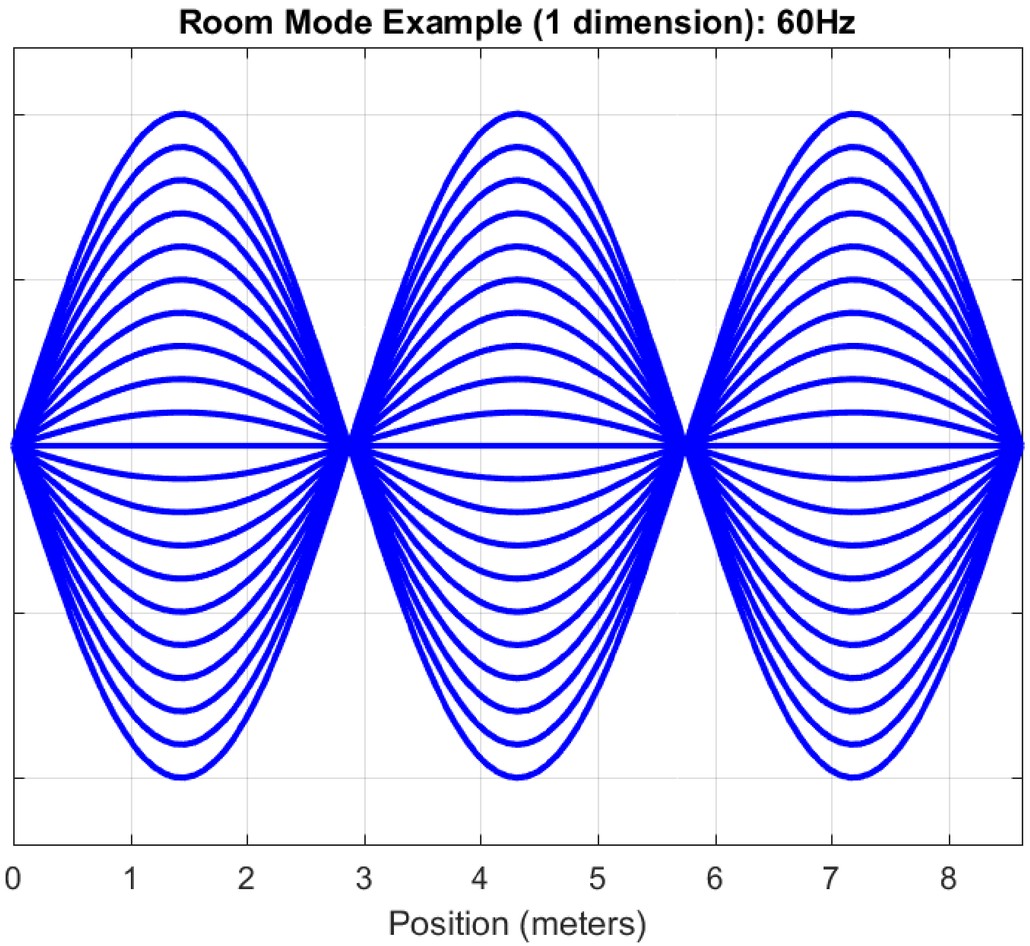
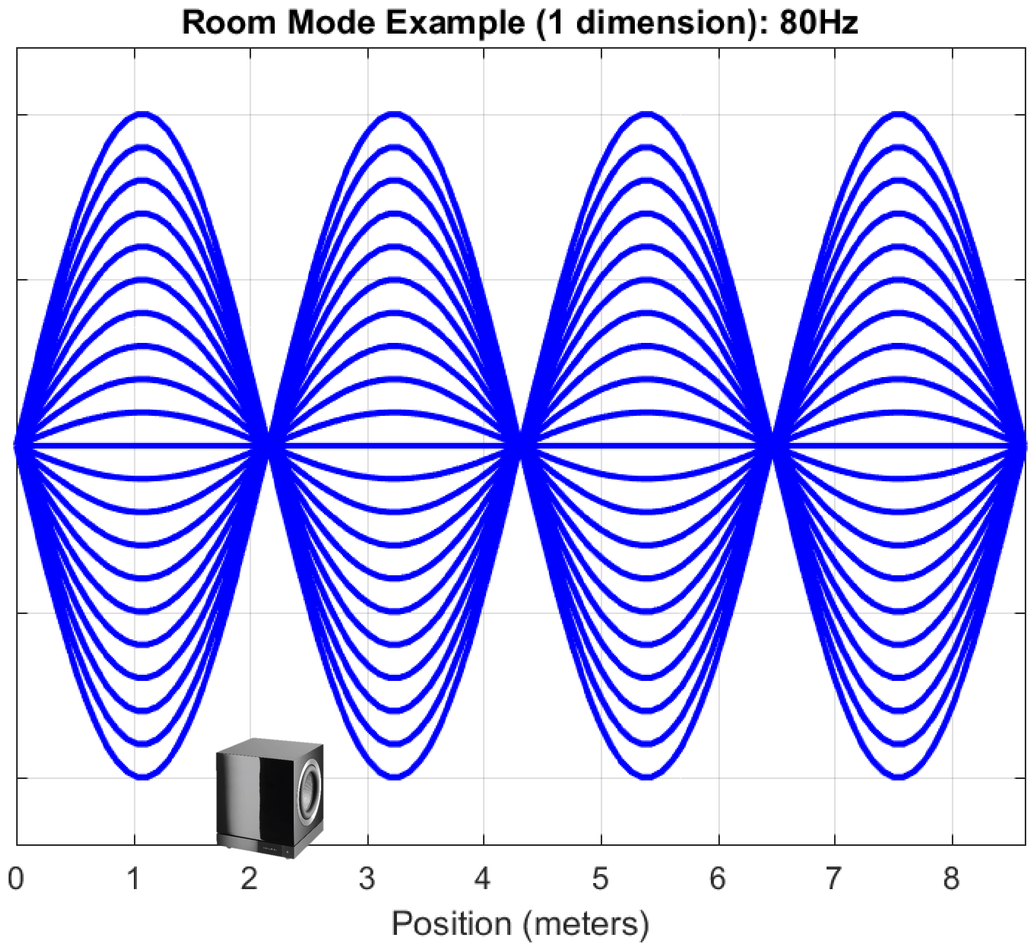


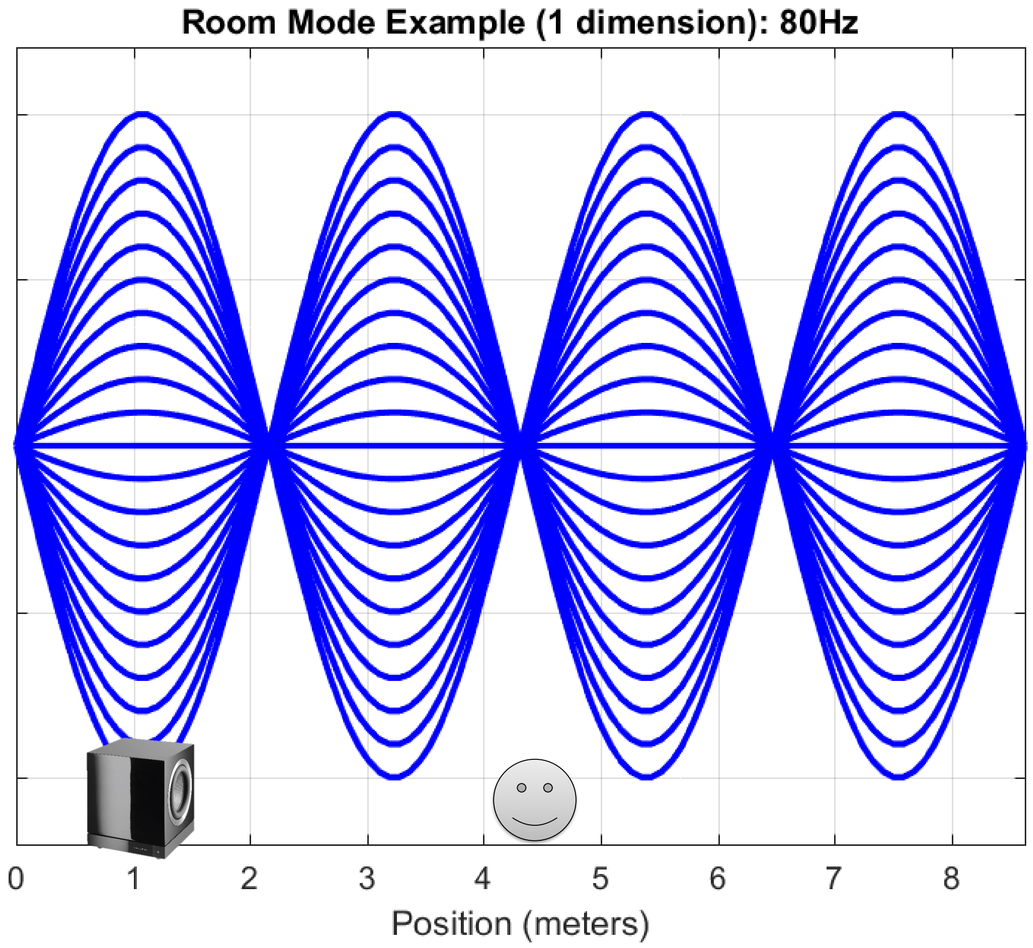
The Low Frequency Problem in Rooms

- At low frequencies the room is modal
- Standing waves:
  - Room dimensions
  - Loudspeaker Location



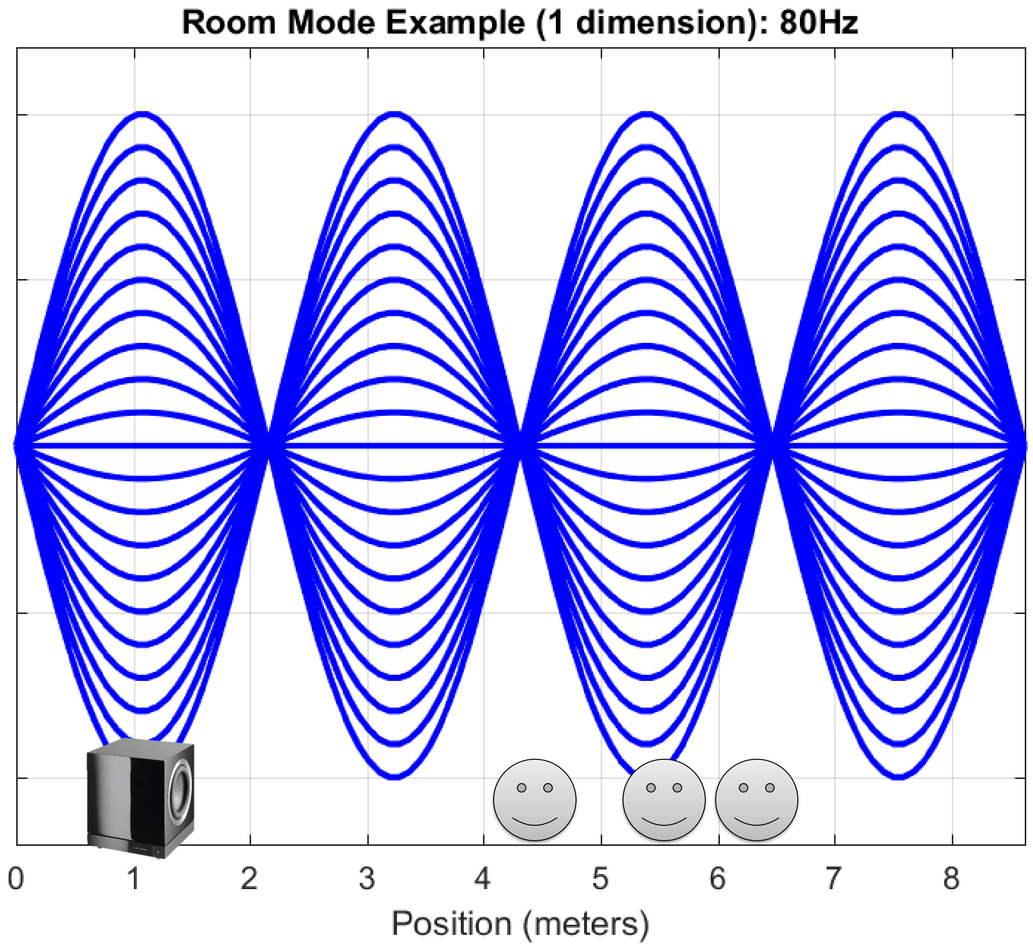
The Low Frequency Problem in Rooms

- At low frequencies the room is modal
- Standing waves:
  - Room dimensions
  - Loudspeaker Location
  - Listener Location



The Low Frequency Problem in Rooms

- At low frequencies the room is modal
- Standing waves:
  - Room dimensions
  - Loudspeaker Location
  - Listener Location + Area



The Low Frequency Problem in Rooms

- What do room modes sound like?
- Synthetic example by boosting two frequencies

  (+12dB @ 60Hz & 120Hz)

- Normal
- With boost = “unwanted modes”

Bowers & Wilkins

DB Series Subwoofers & Room EQ

Automatic room equalization for your B&W DB subwoofer

The DB1

- Flagship Subwoofer launched in 2010
- Balanced Configuration
- Setup app
  - PC / Visual Studio
  - Room EQ
  - Microphone, sound card, cables
  - MATLAB Compiler + Runtime

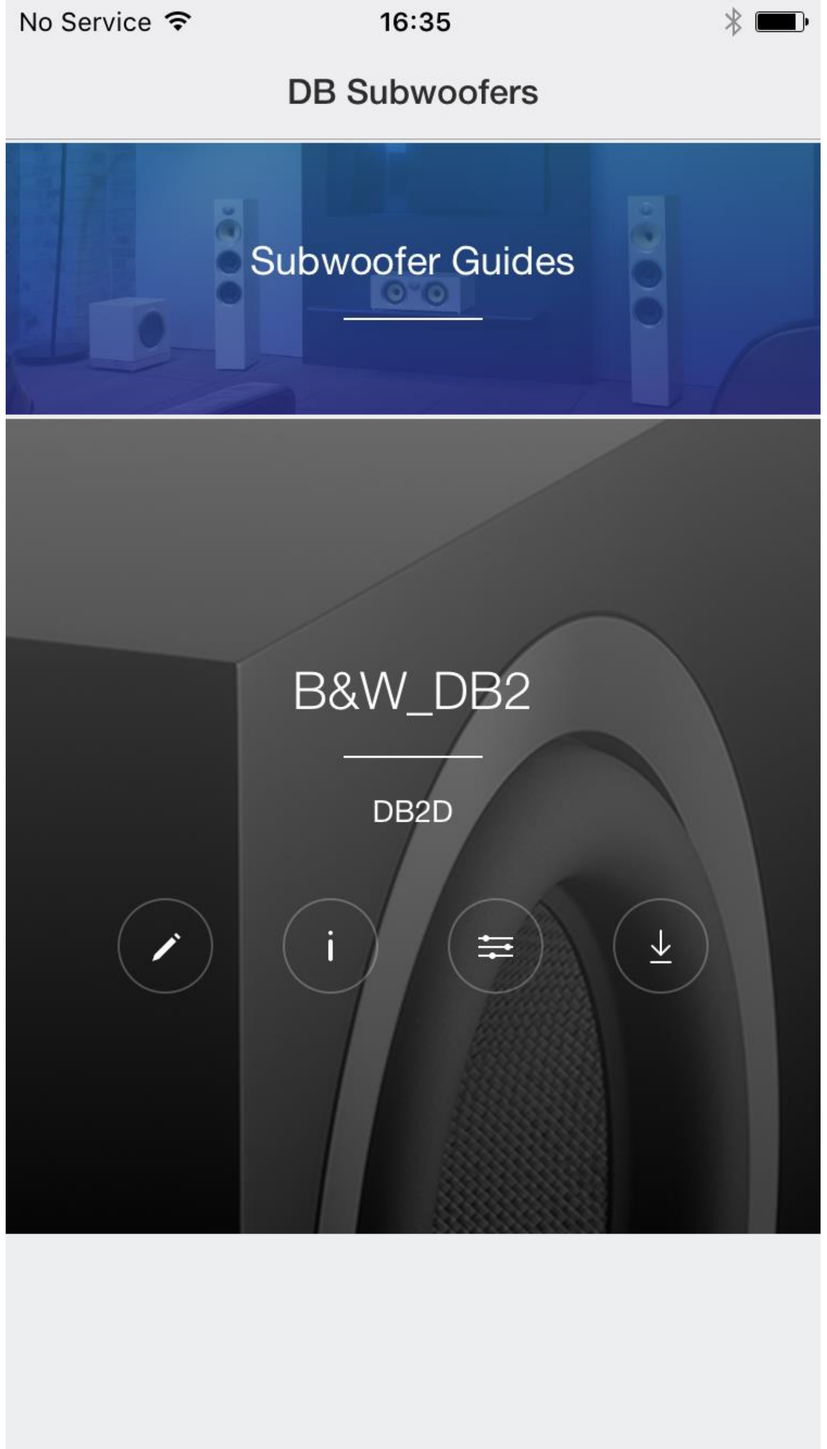
The DB Series

- DB1D, DB2D, DB3D launched in 2017
- Setup App
  - iOS, Android
  - Room EQ
  - Use phone’s microphone
  - Microphone I.D.
  - No cables or hardware
  - MATLAB & C code generation

Demo

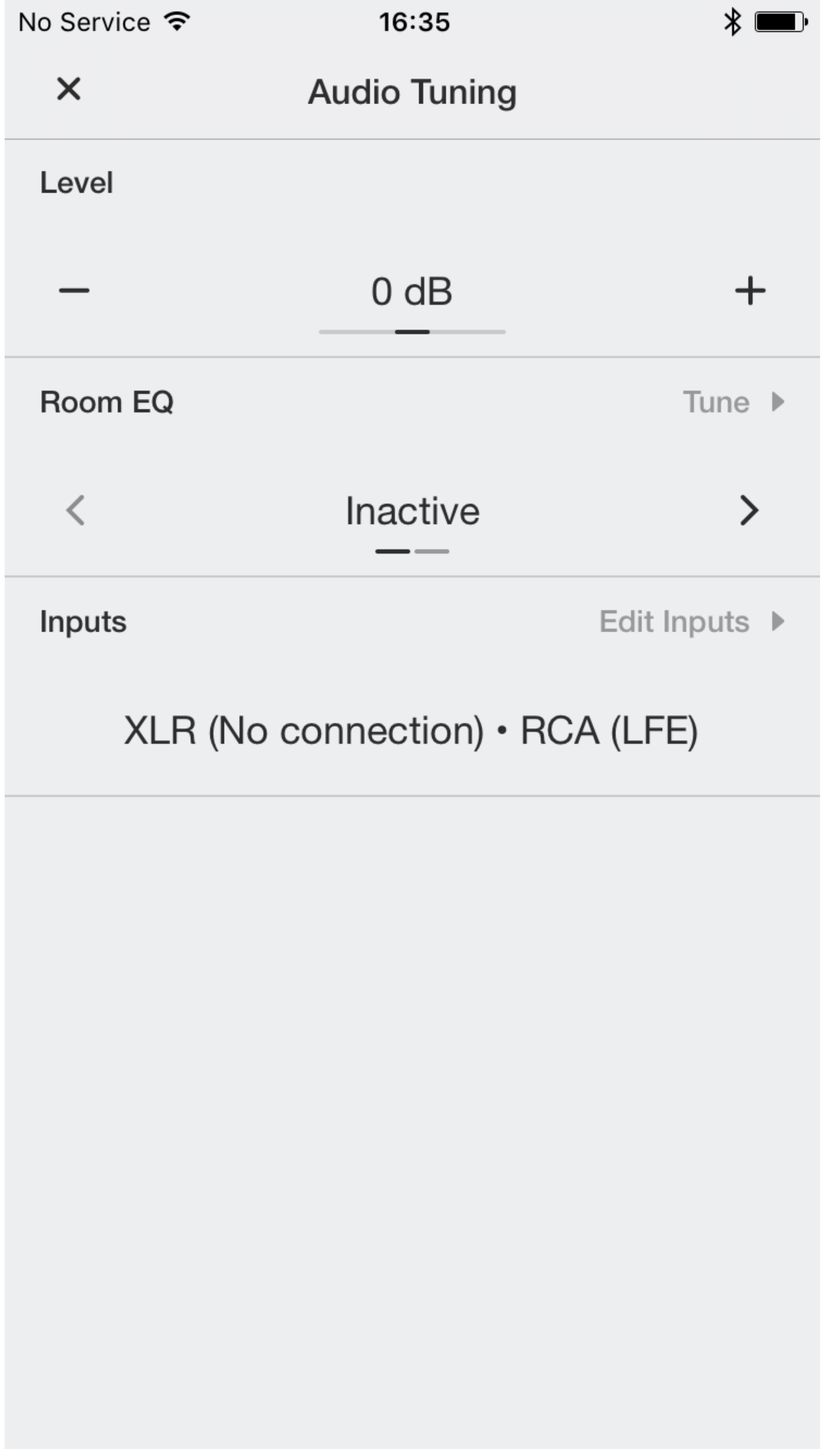
Demo

- Top Page
- Press tuning →



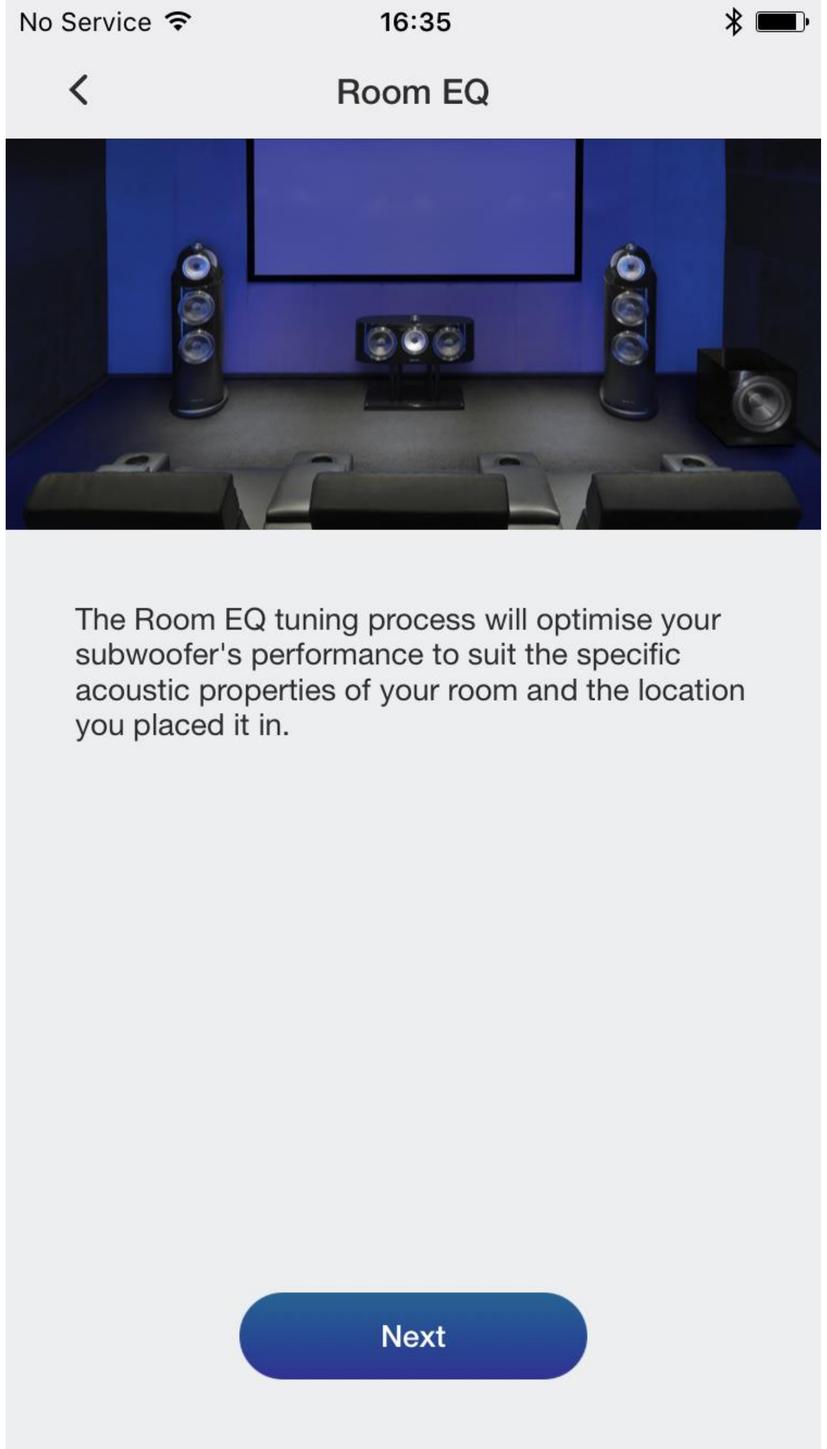
Demo

- Audio tuning Page
- Press Tune →



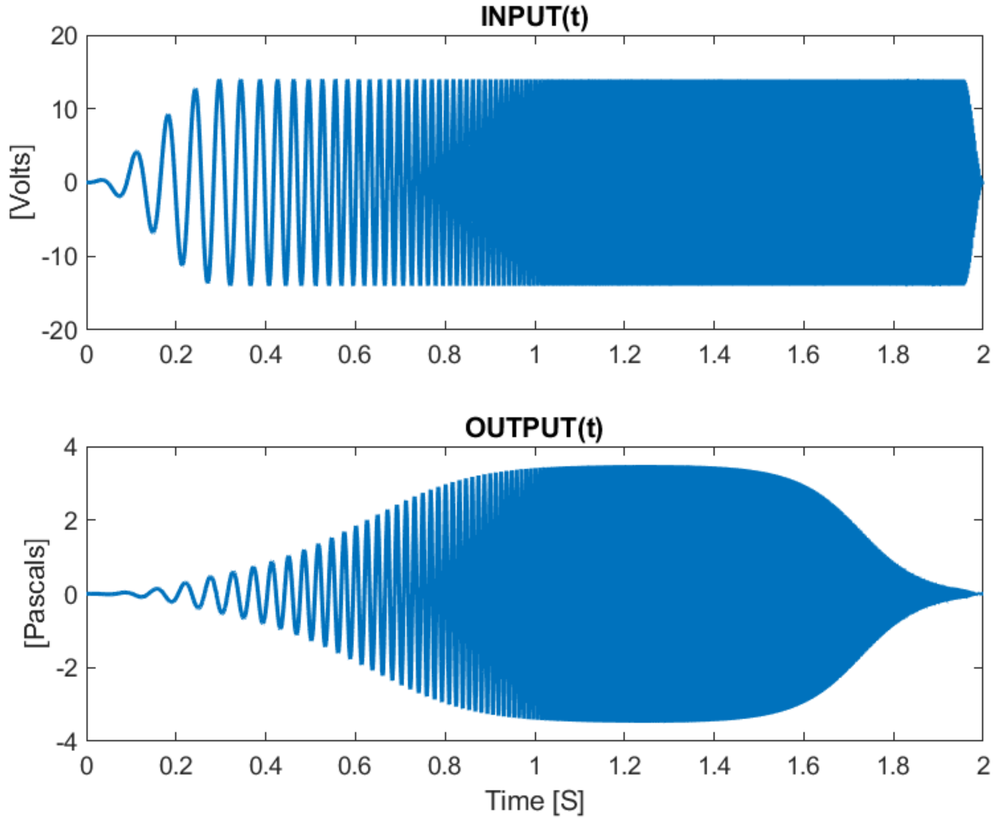
Demo

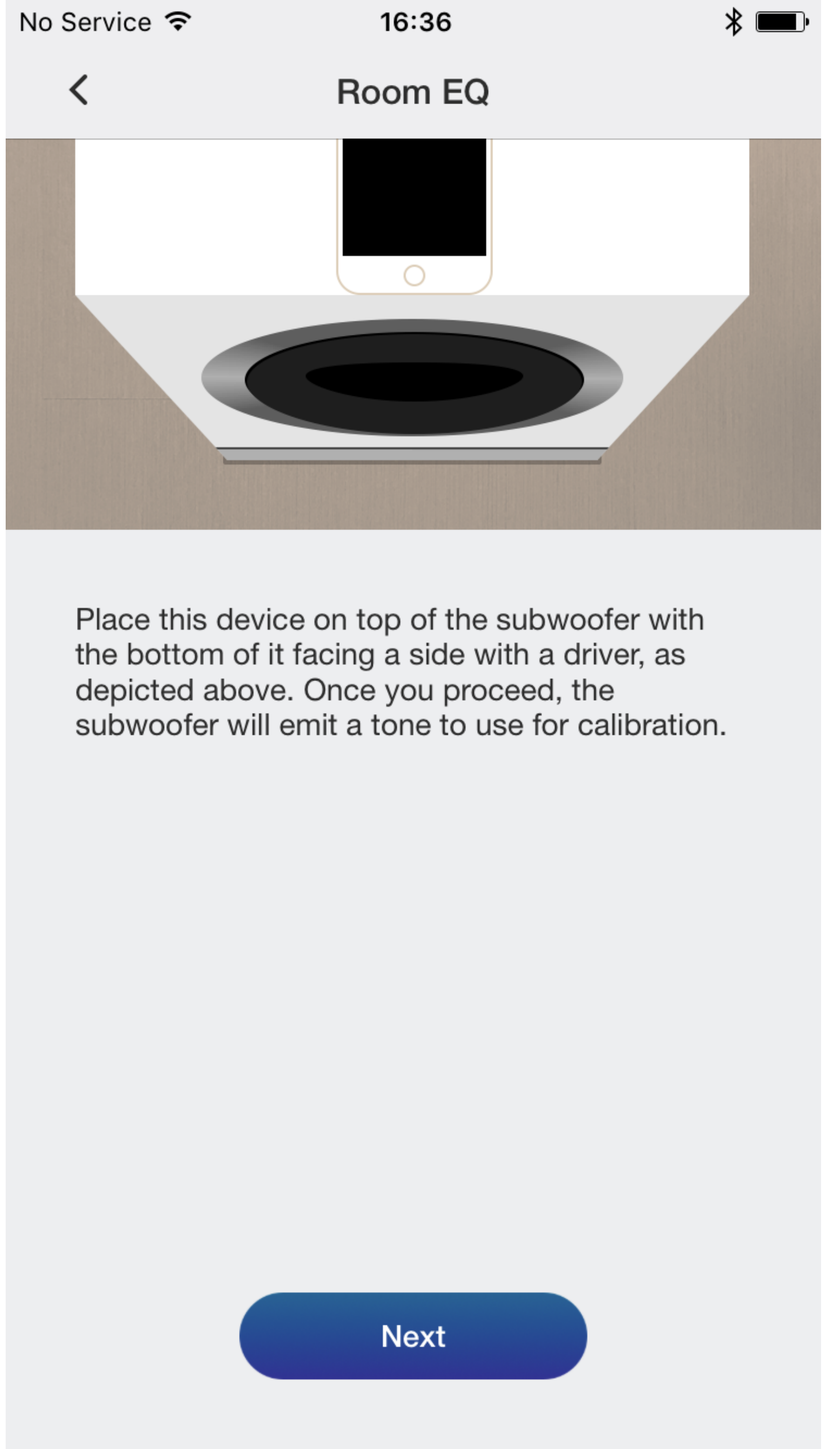
- Room EQ Intro
- Next →



Demo

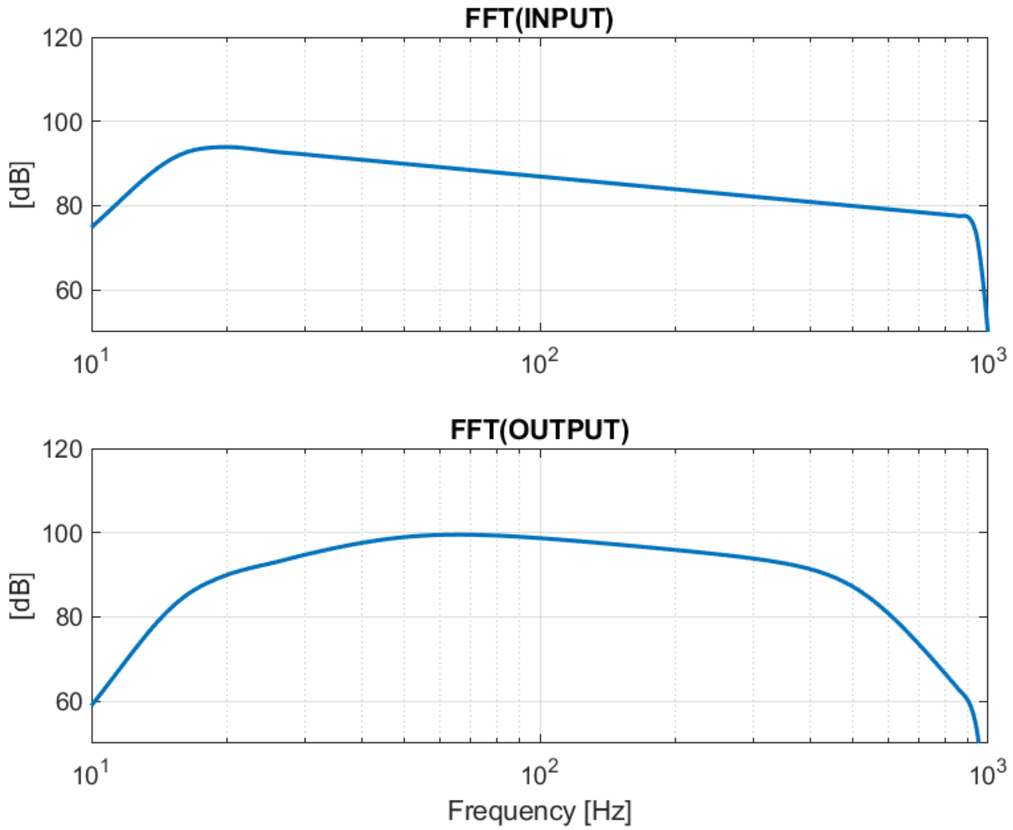
- Mic Calibration

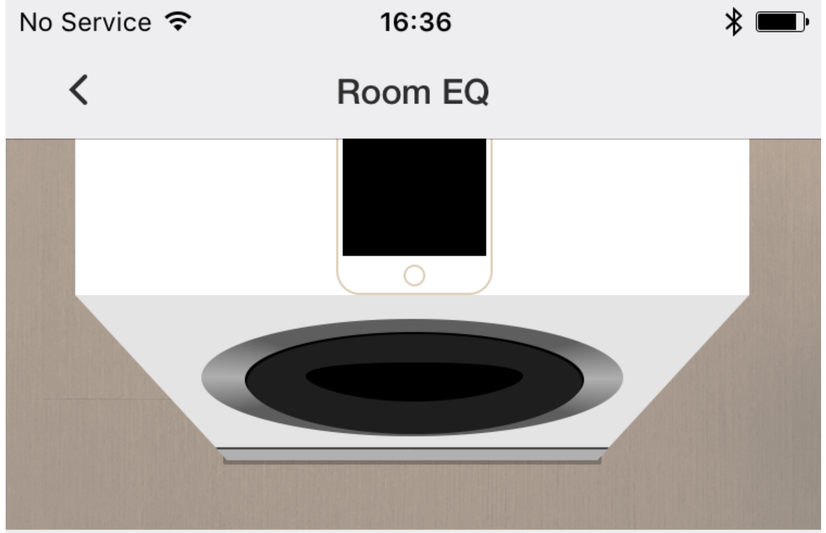




Demo

- Mic Calibration



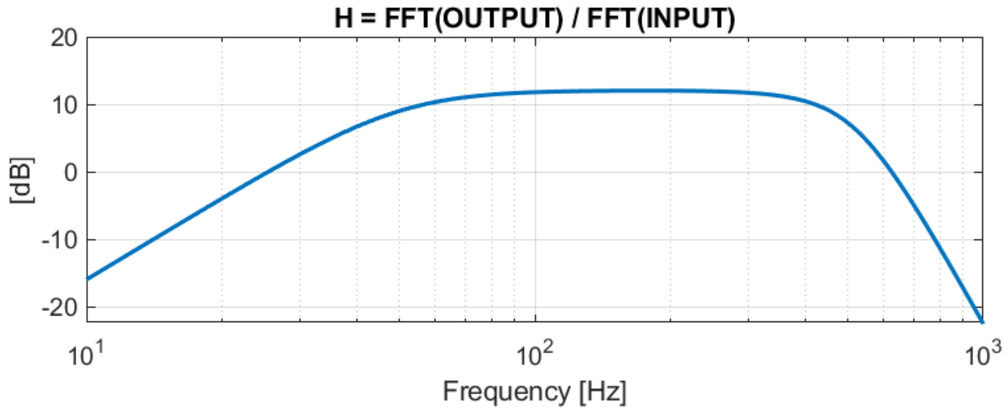


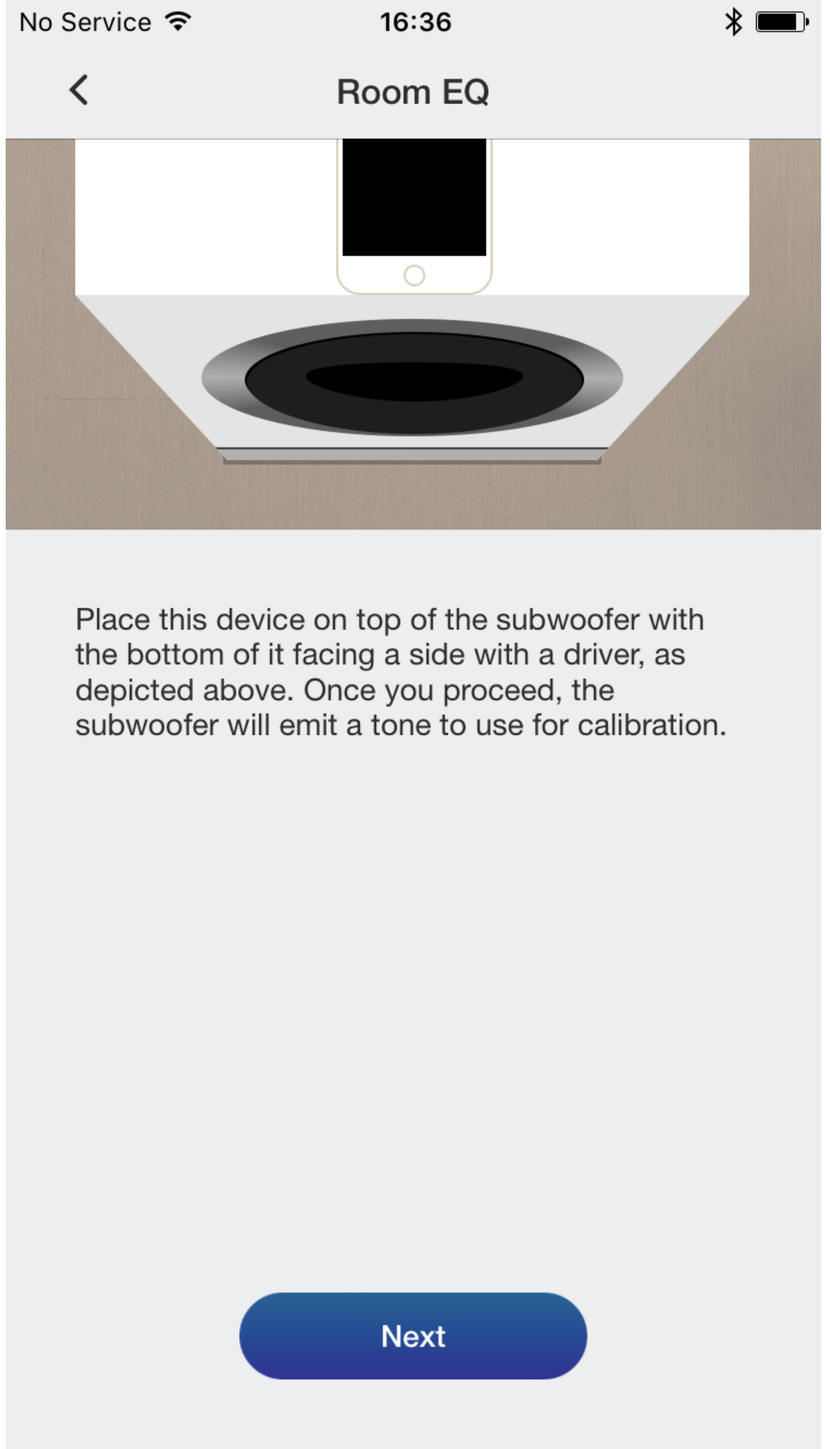
Place this device on top of the subwoofer with the bottom of it facing a side with a driver, as depicted above. Once you proceed, the subwoofer will emit a tone to use for calibration.

Next

Demo

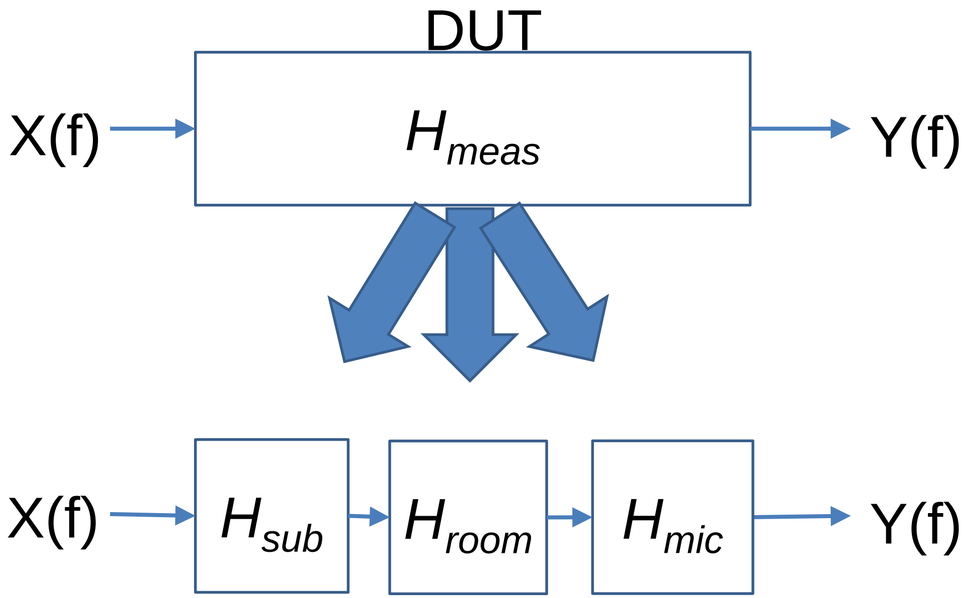
- Mic Calibration

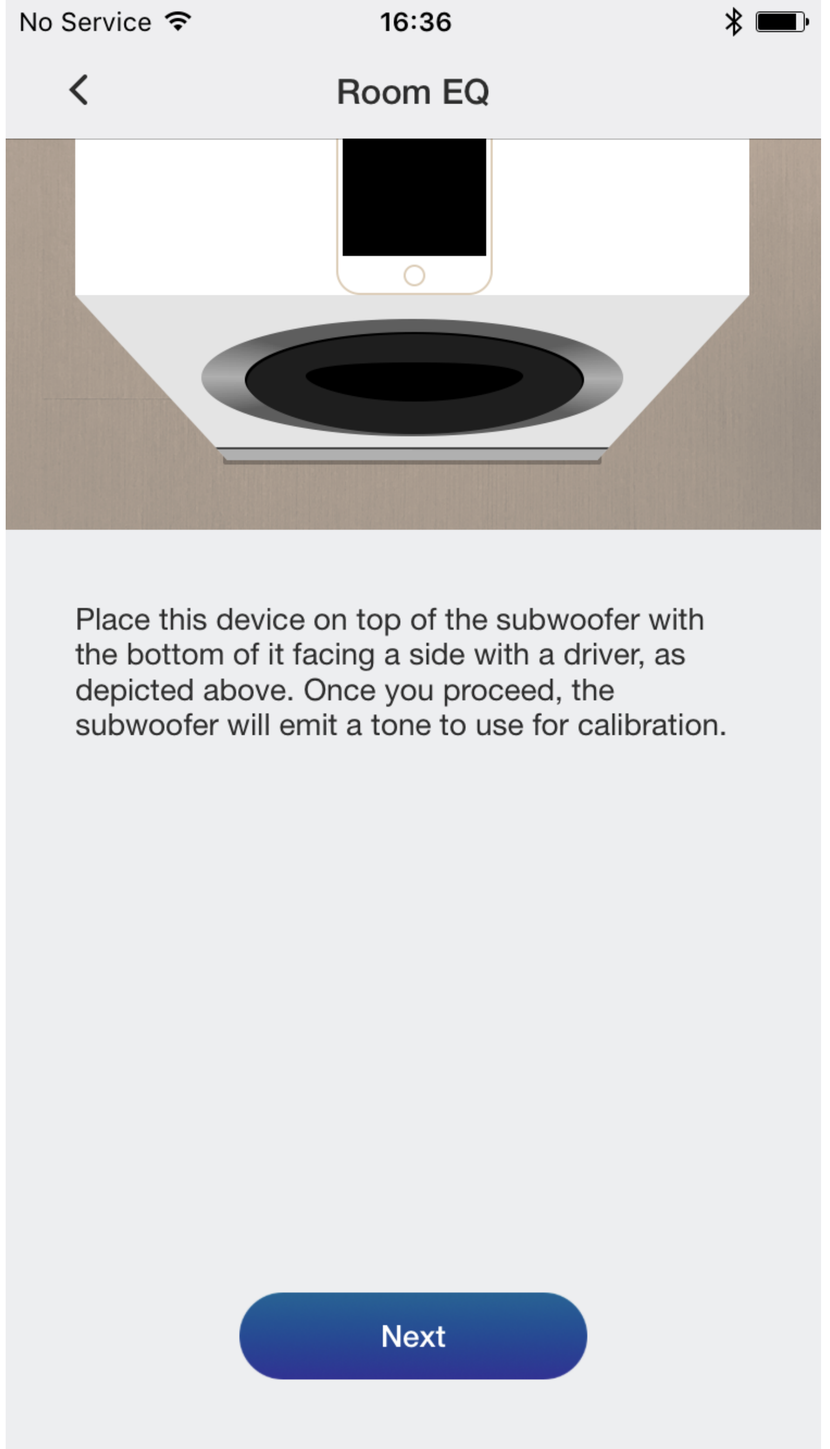




Demo

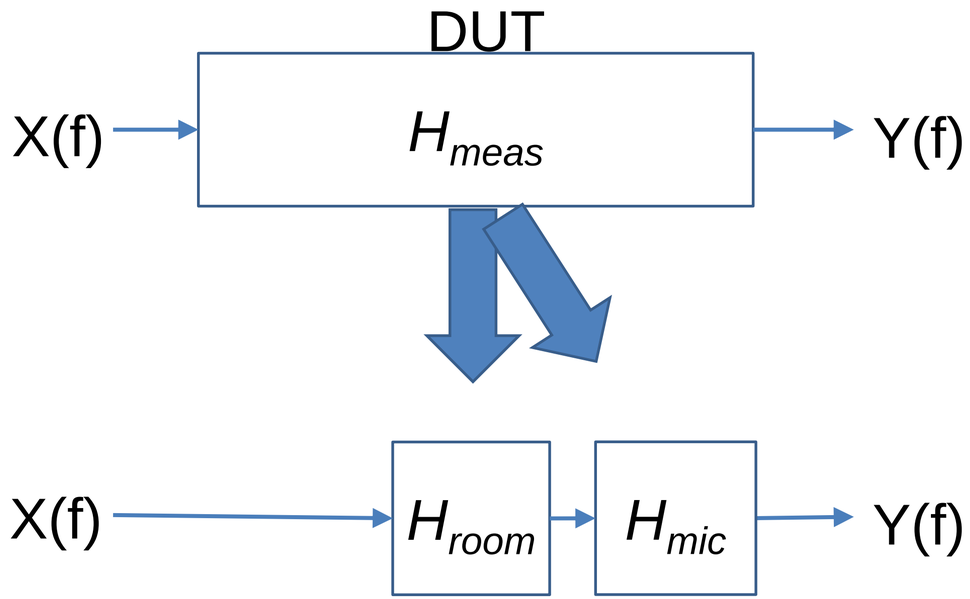
- Mic Calibration

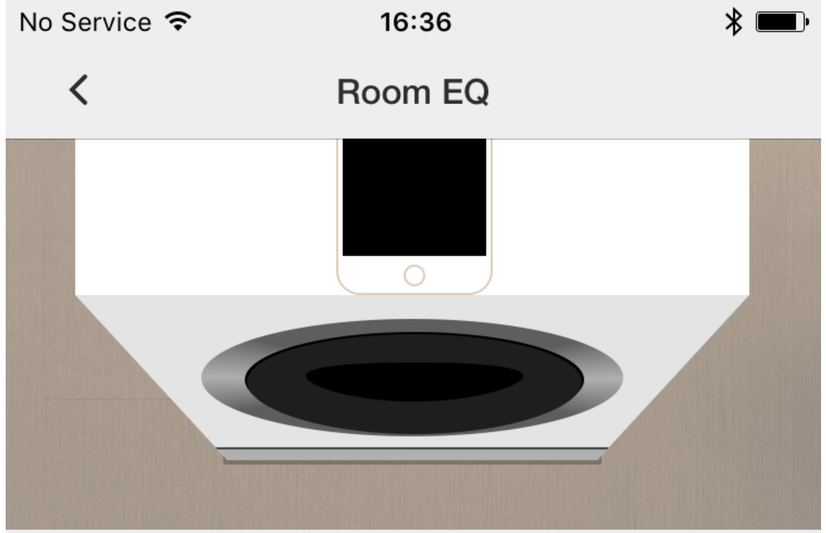




Demo

- Mic Calibration



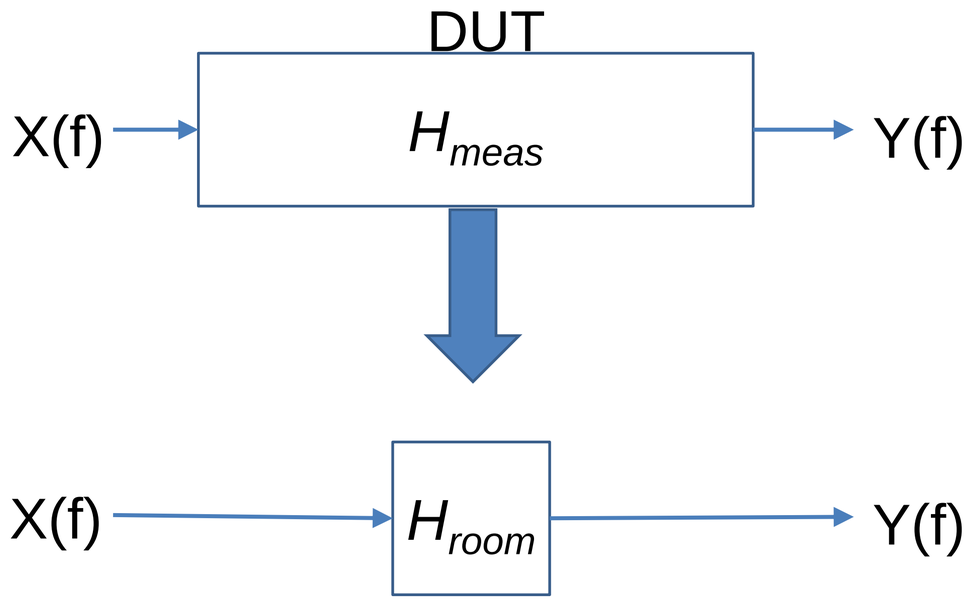


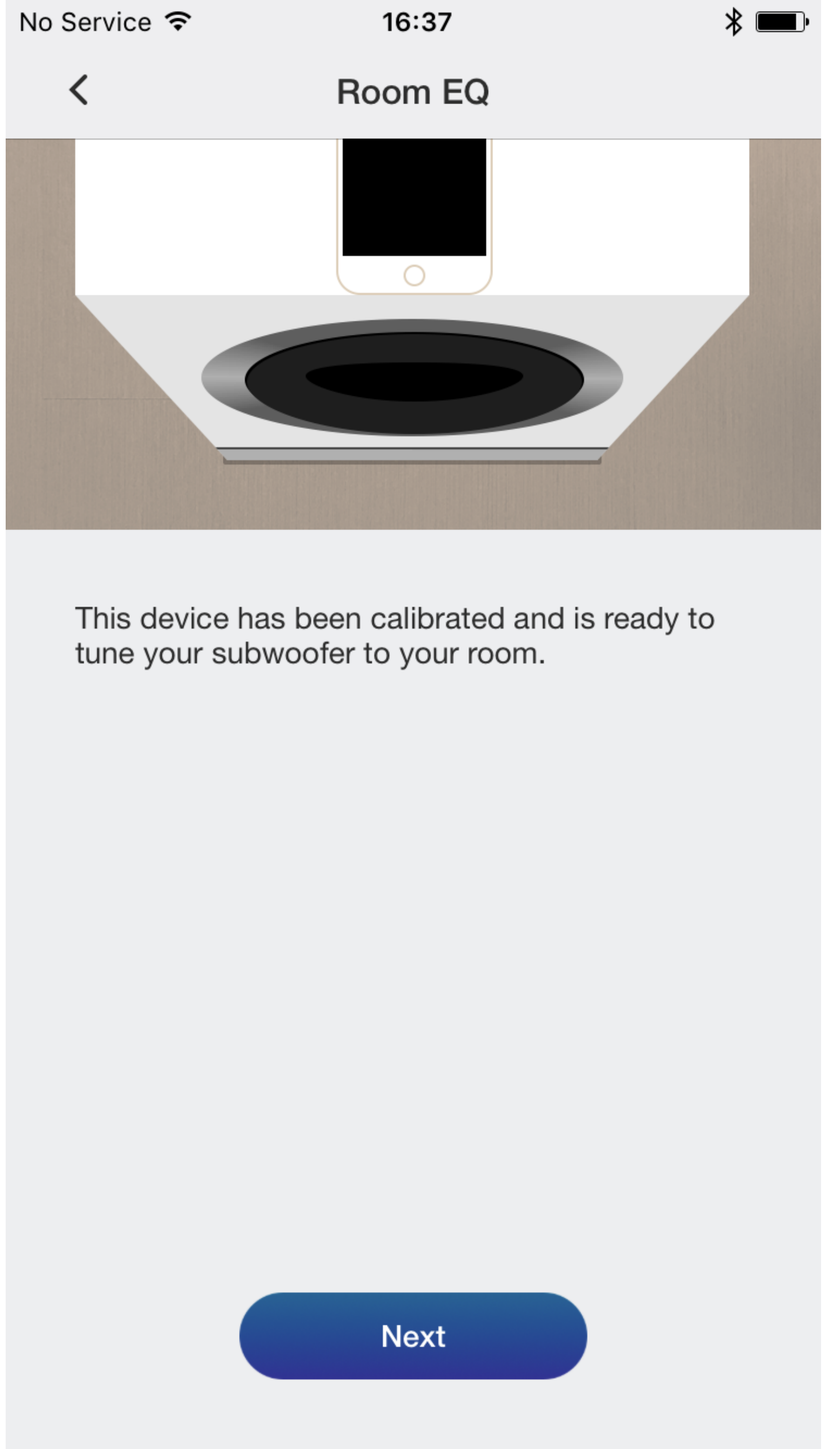
Place this device on top of the subwoofer with the bottom of it facing a side with a driver, as depicted above. Once you proceed, the subwoofer will emit a tone to use for calibration.

Next

Demo

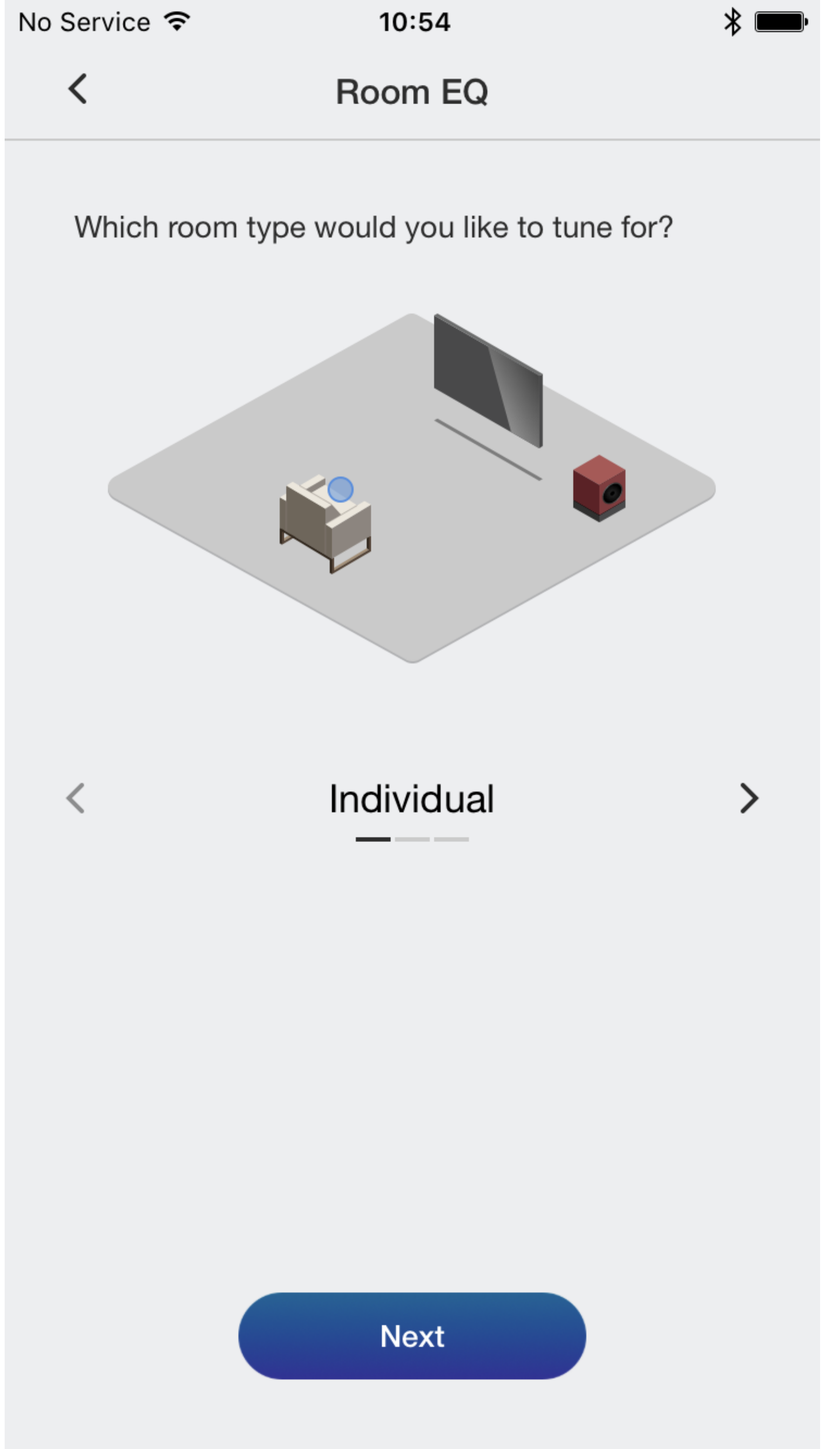
- Mic Calibration Done





Demo

- Choose Sweet Spot Size
  - Individual
  - Group
  - Room



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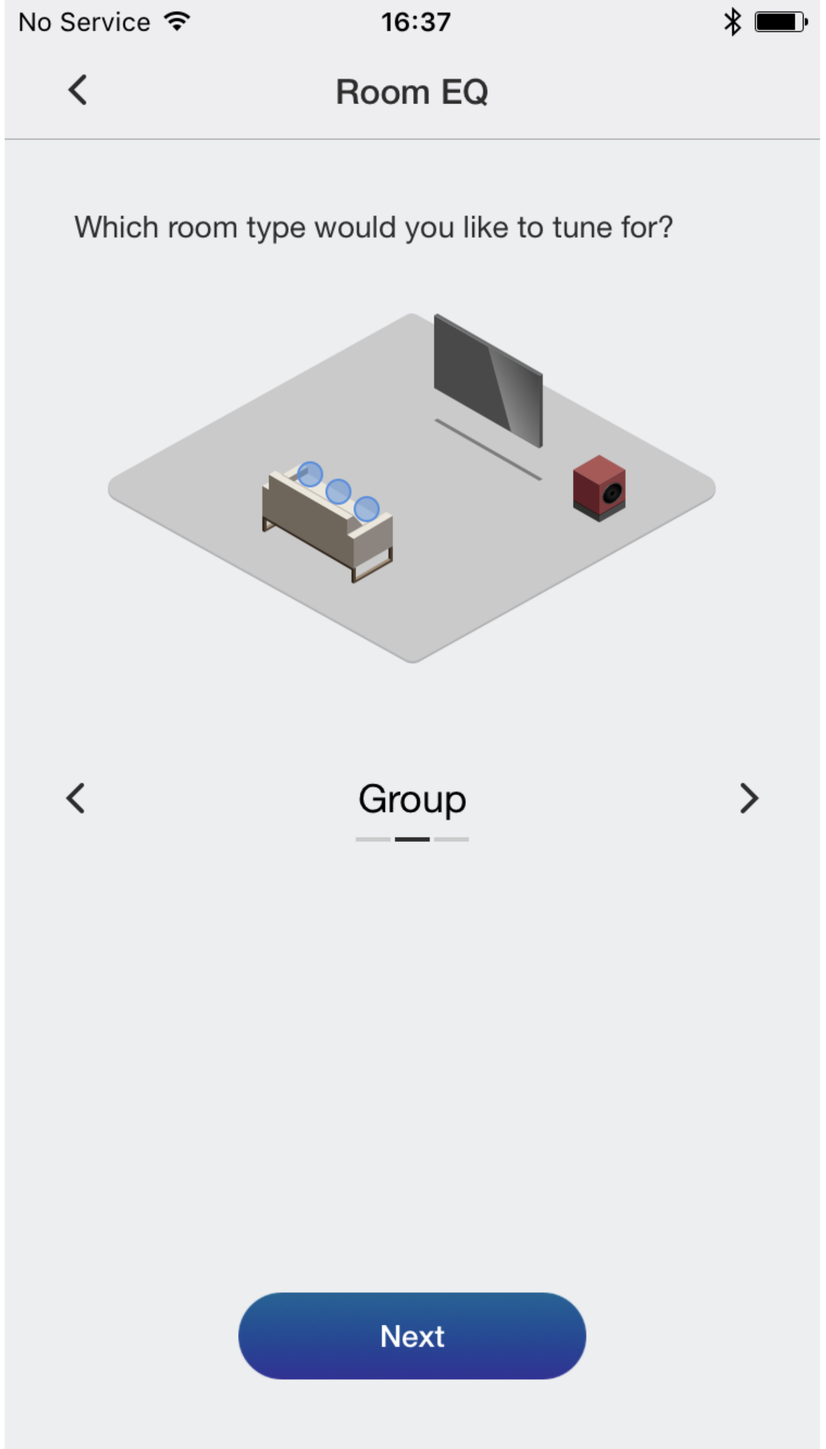

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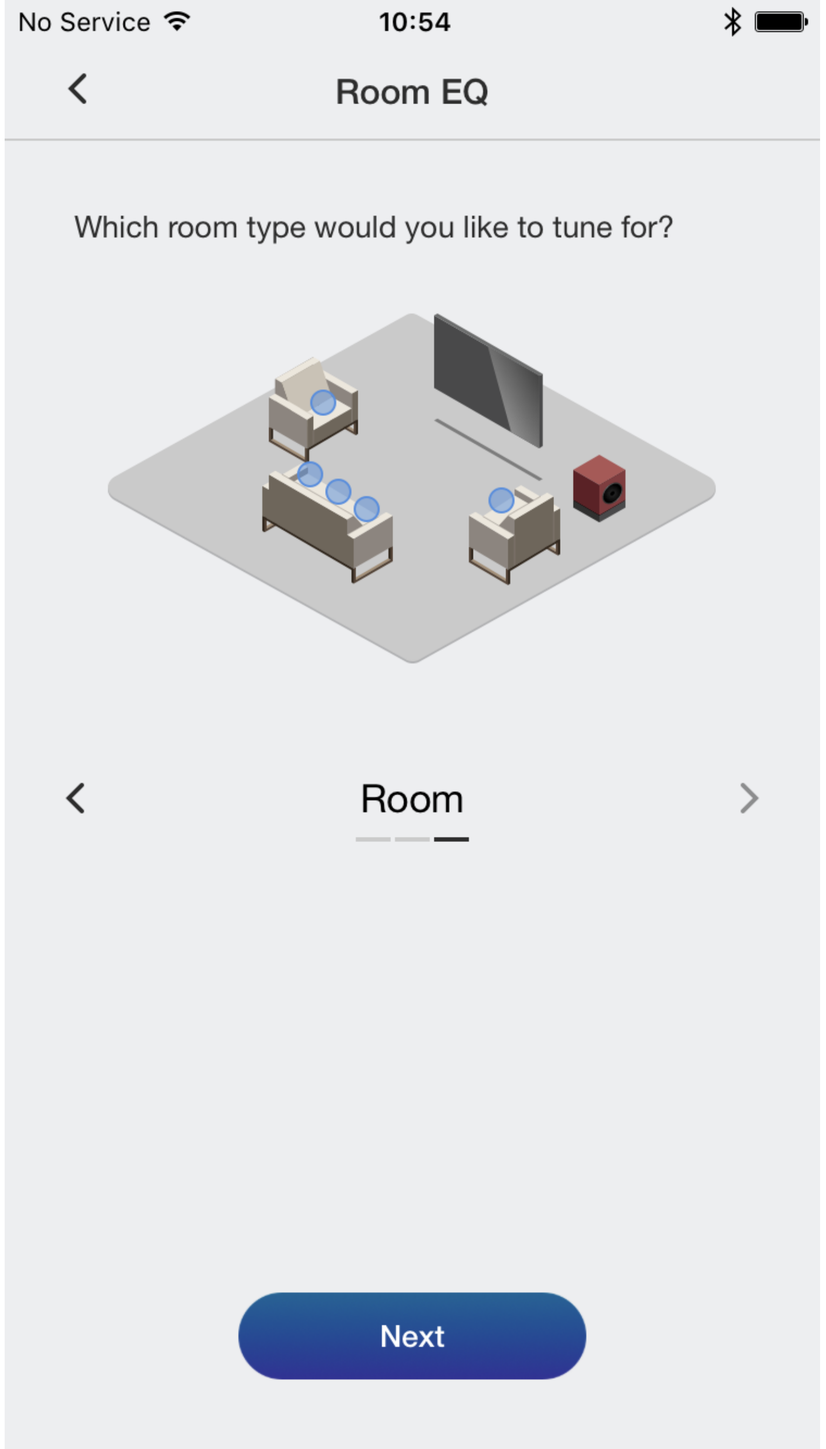
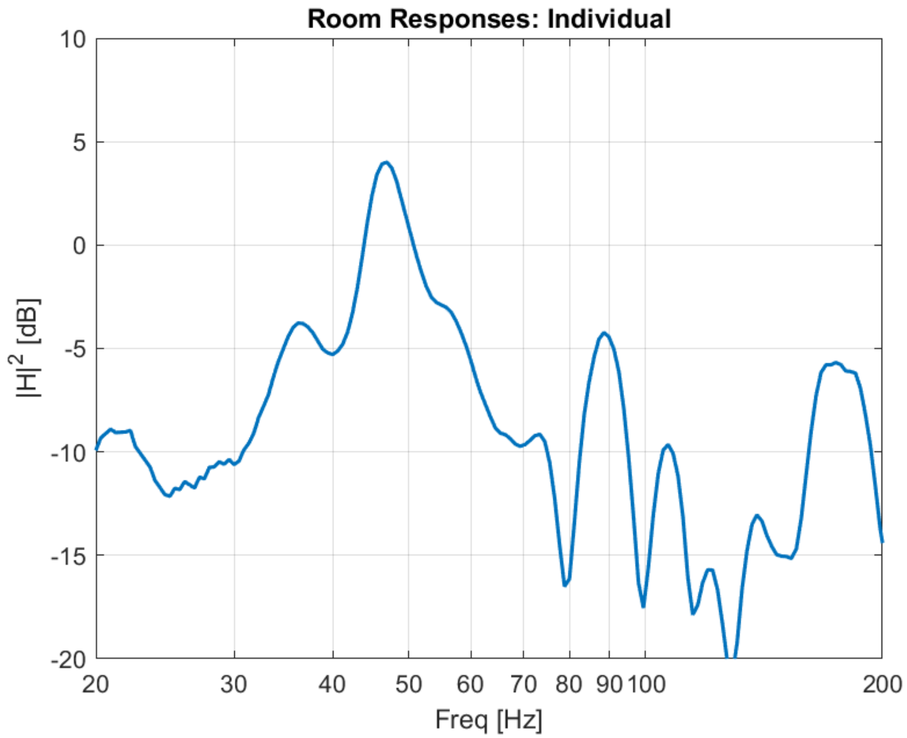
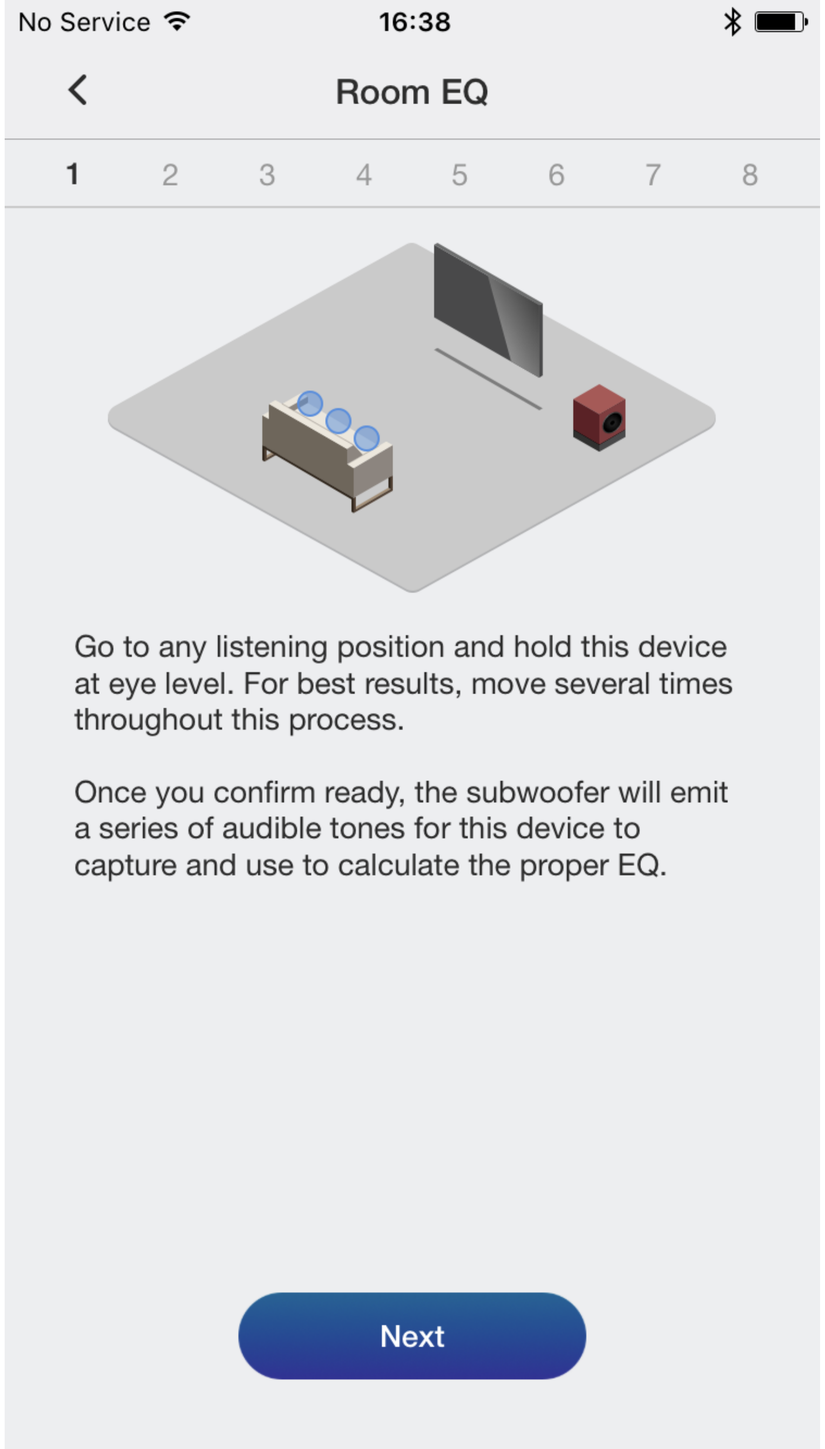


Demo

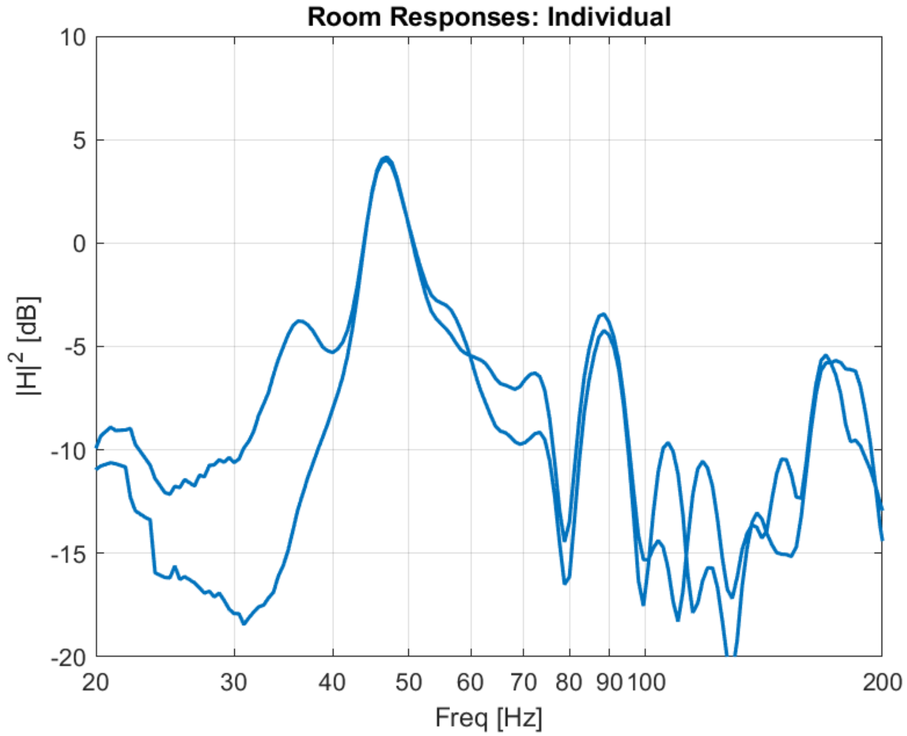
- Measurement Position
- 1 of 8

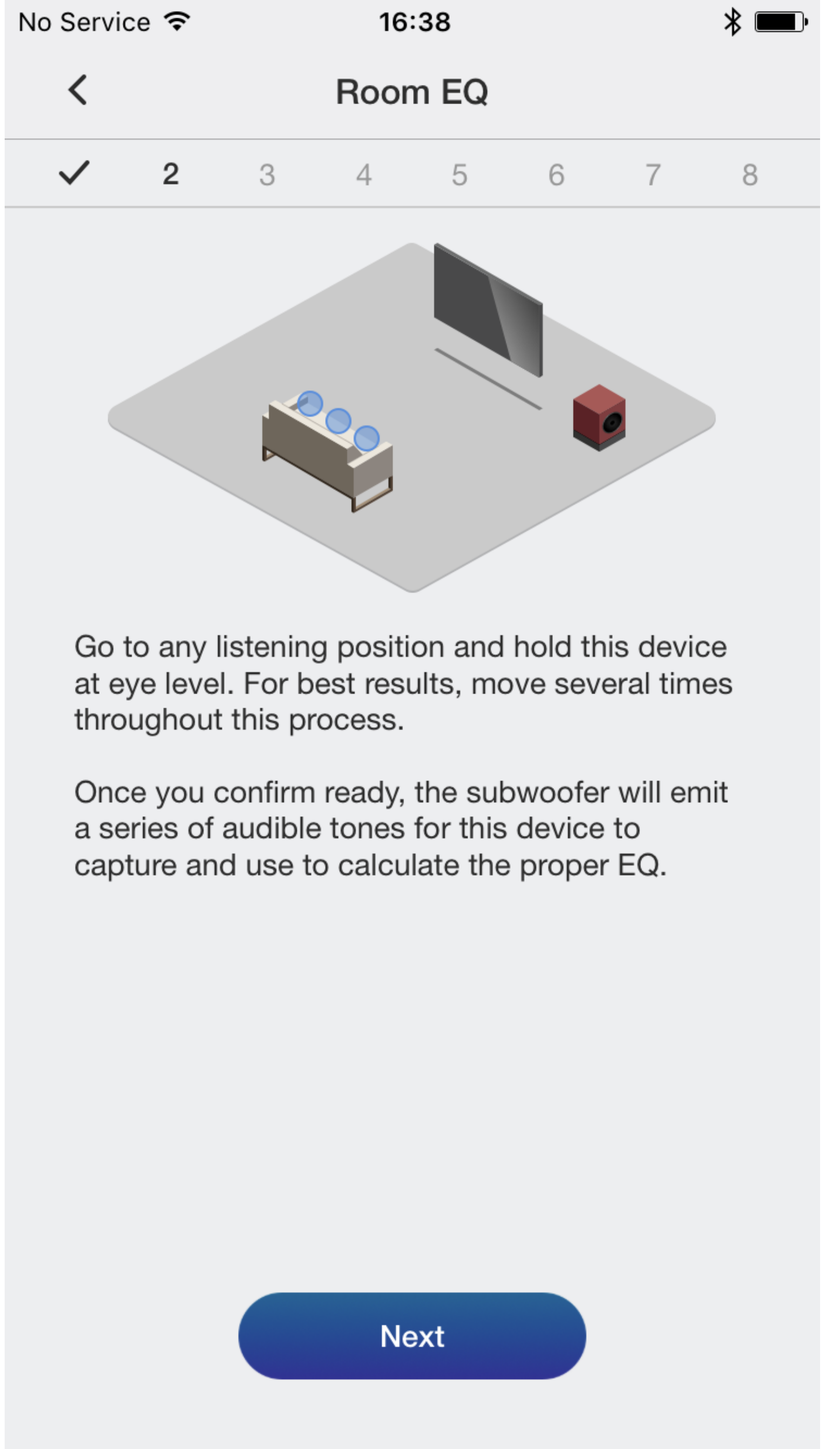




Demo

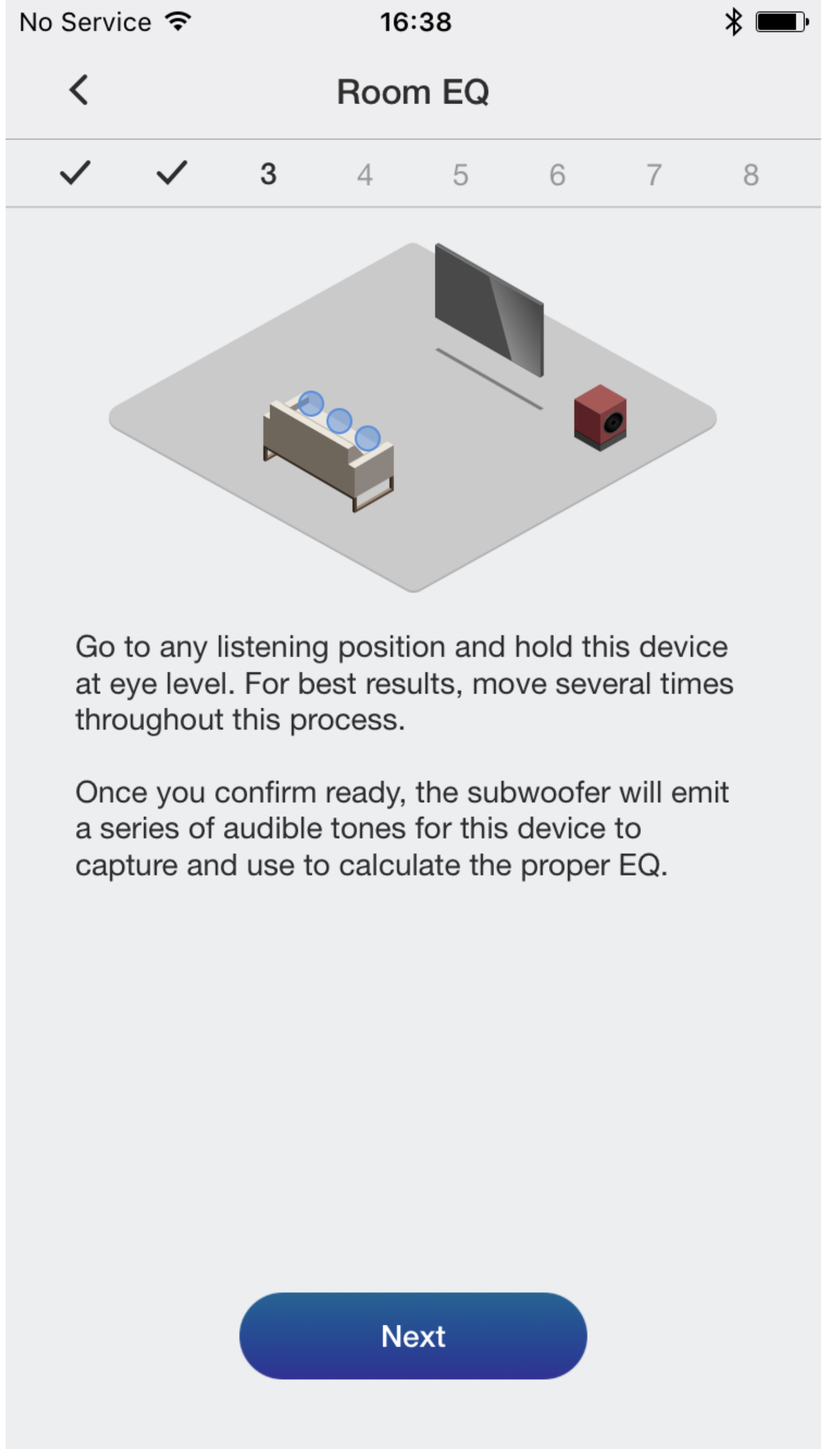
- Measurement Position
- 2 of 8





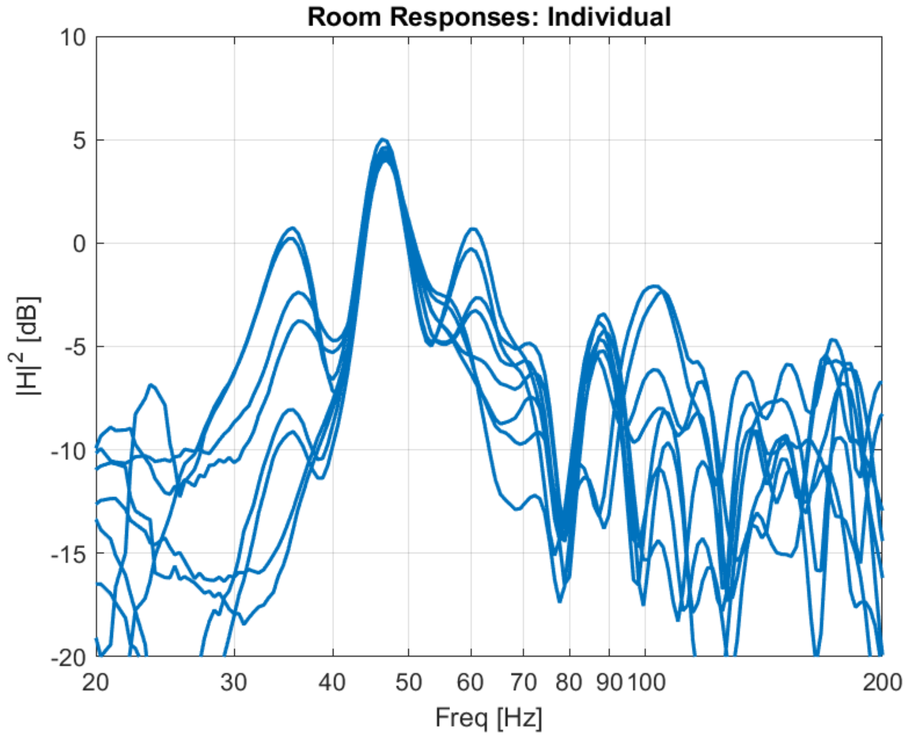
Demo

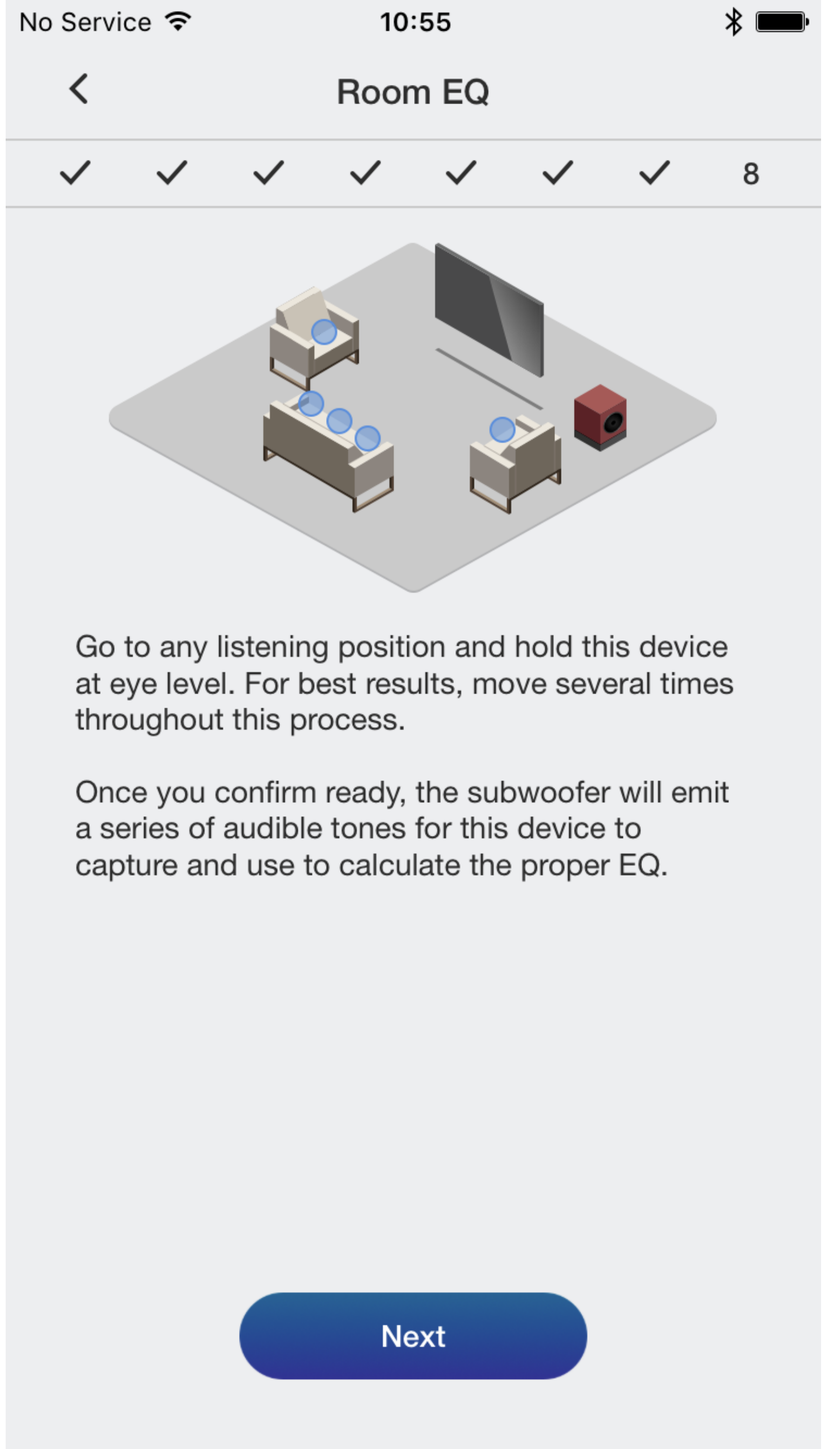
- Measurement Position
- 3 of 8 …



Demo

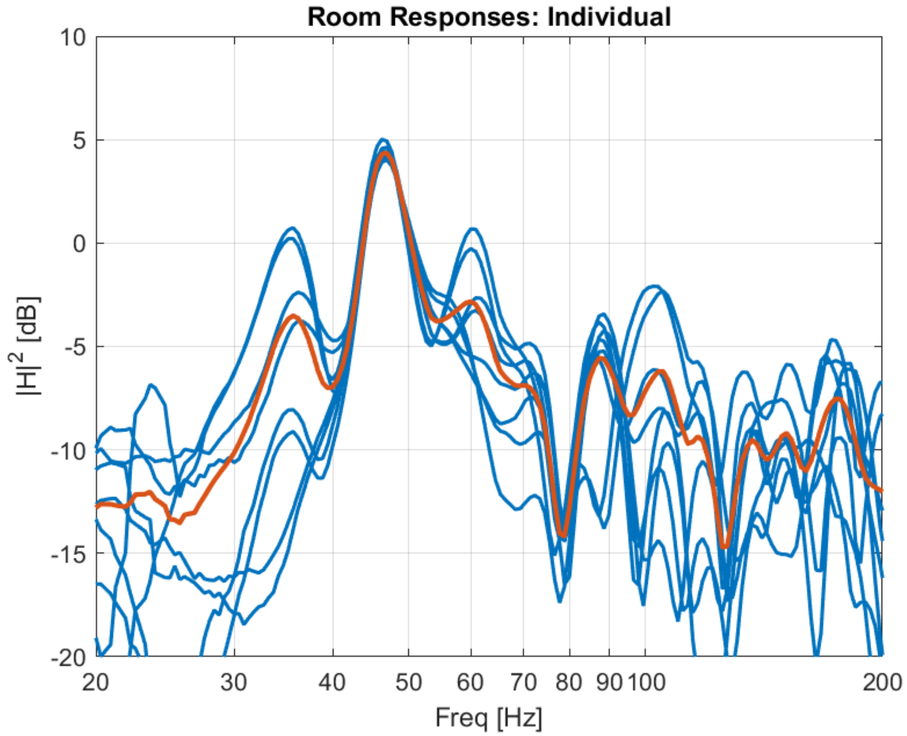
- Measurement Position
- 8 of 8 …

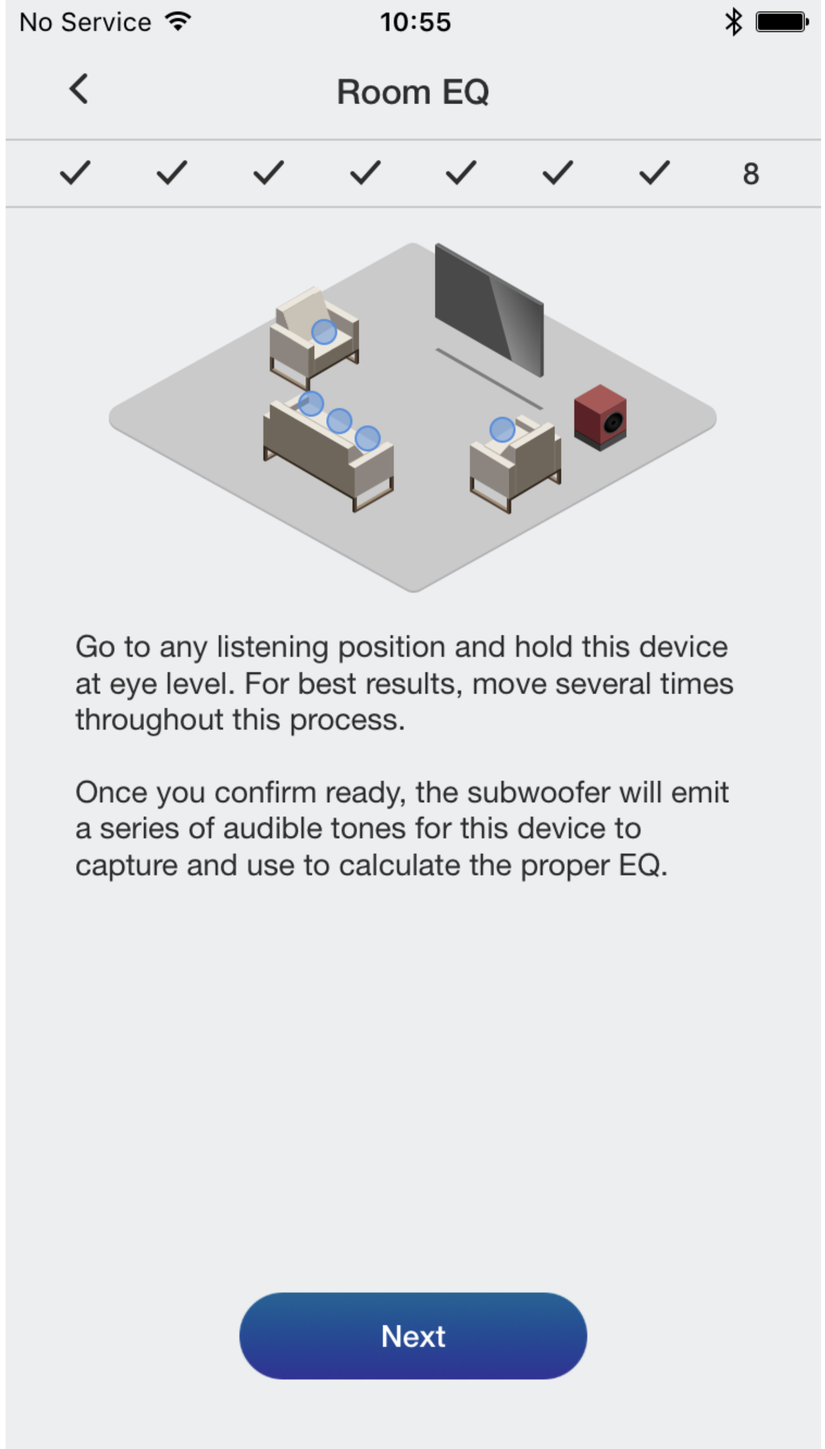




Demo

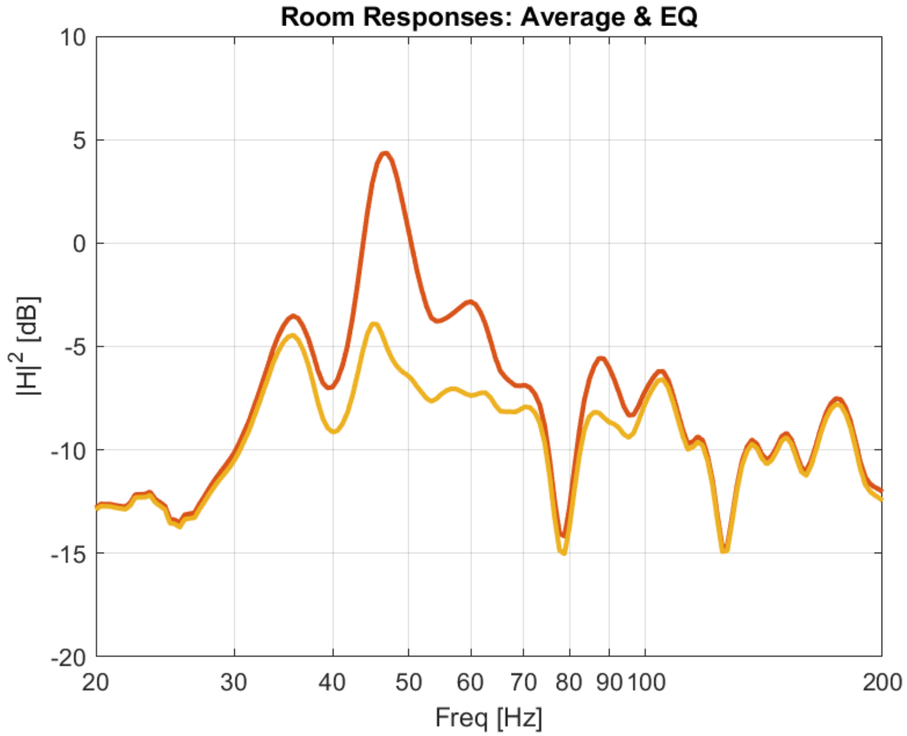
- Measurement Position
- 8 of 8 …

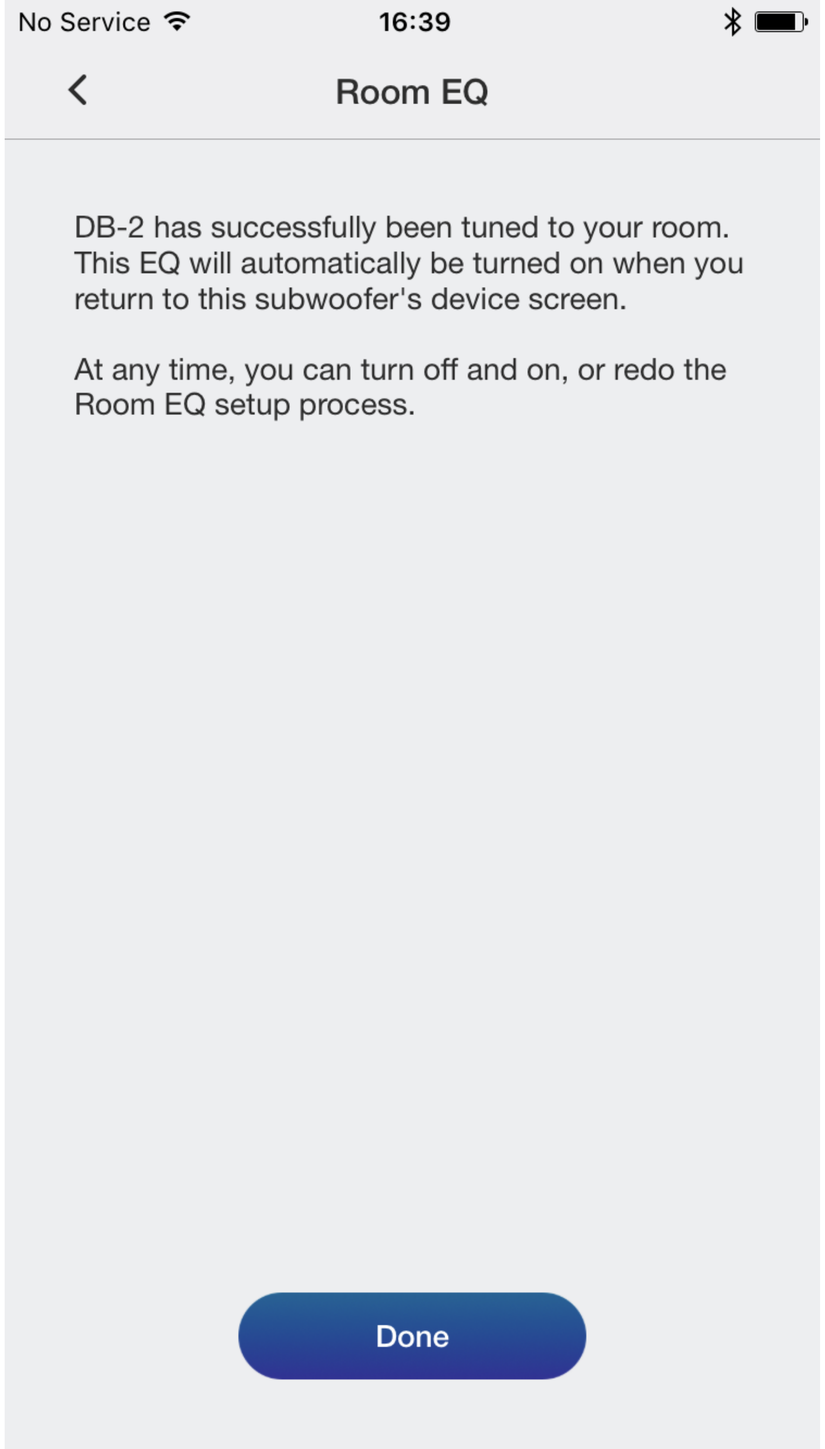




Demo

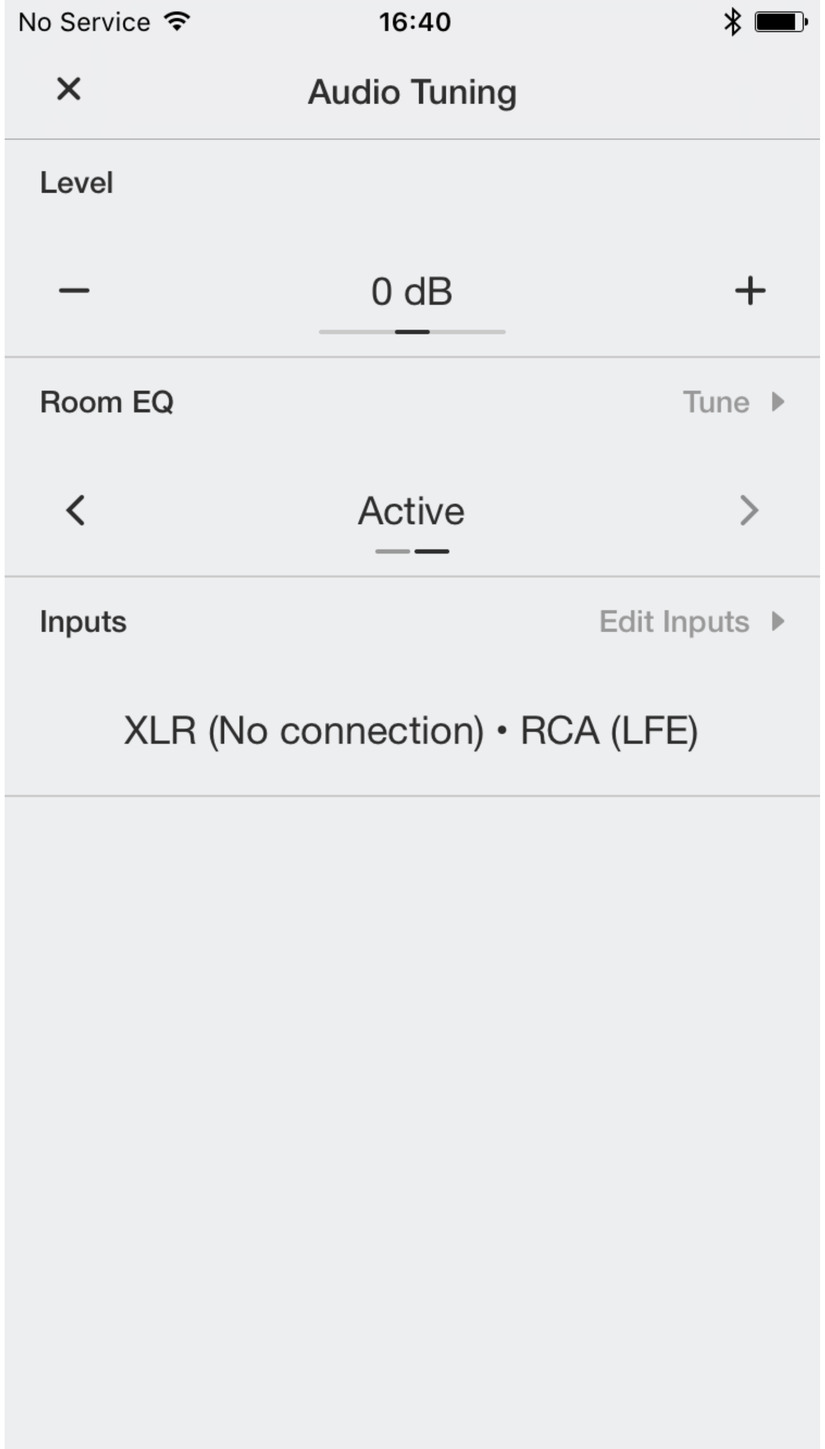
- 8 of 8
- Room EQ Calc Complete





Demo

- Complete
- Room EQ: Active
- Toggle On/Off as desired



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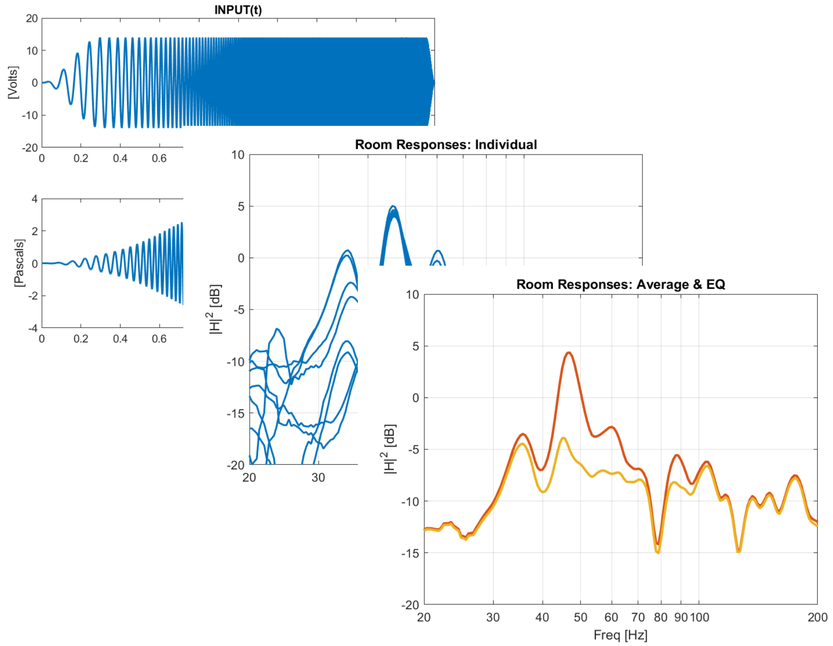
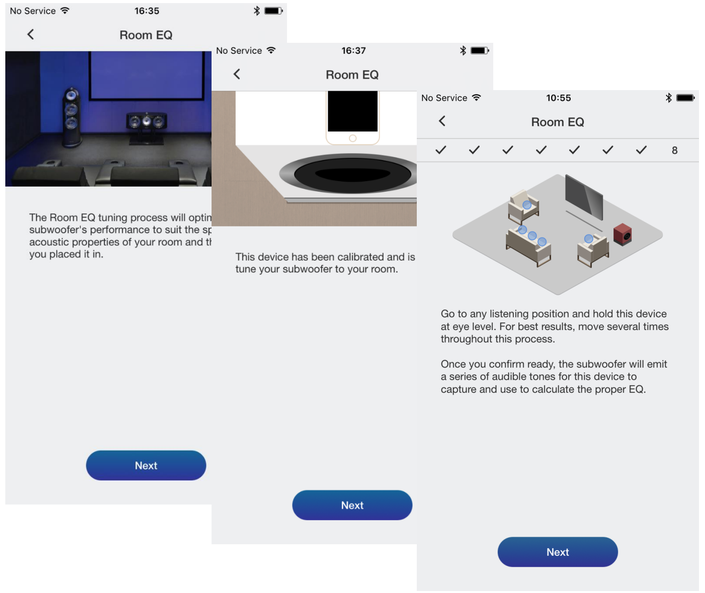
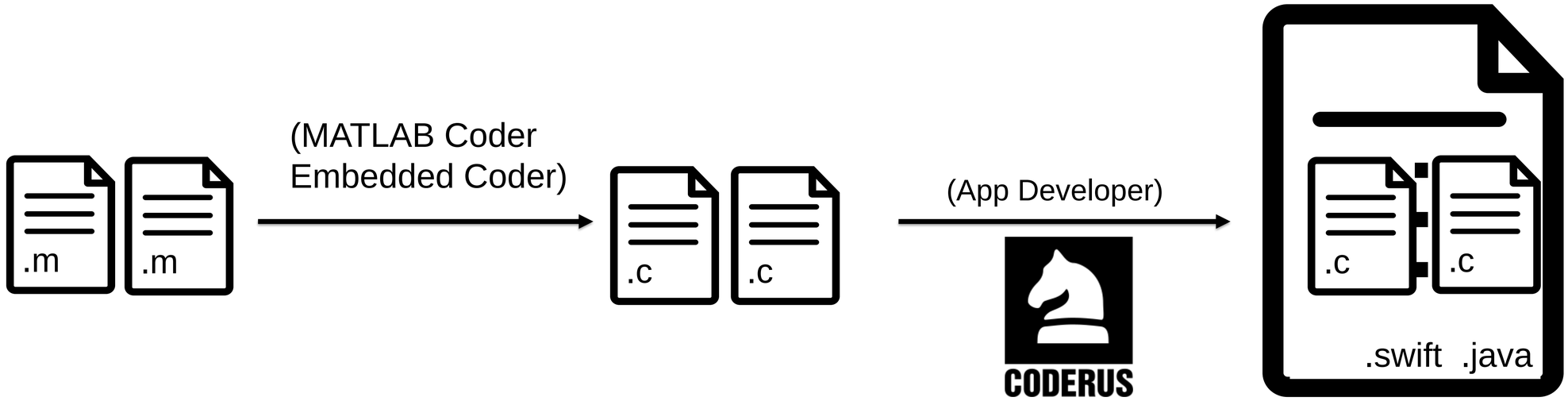
Algorithm Development and Deployment

Algorithm Development & Deployment







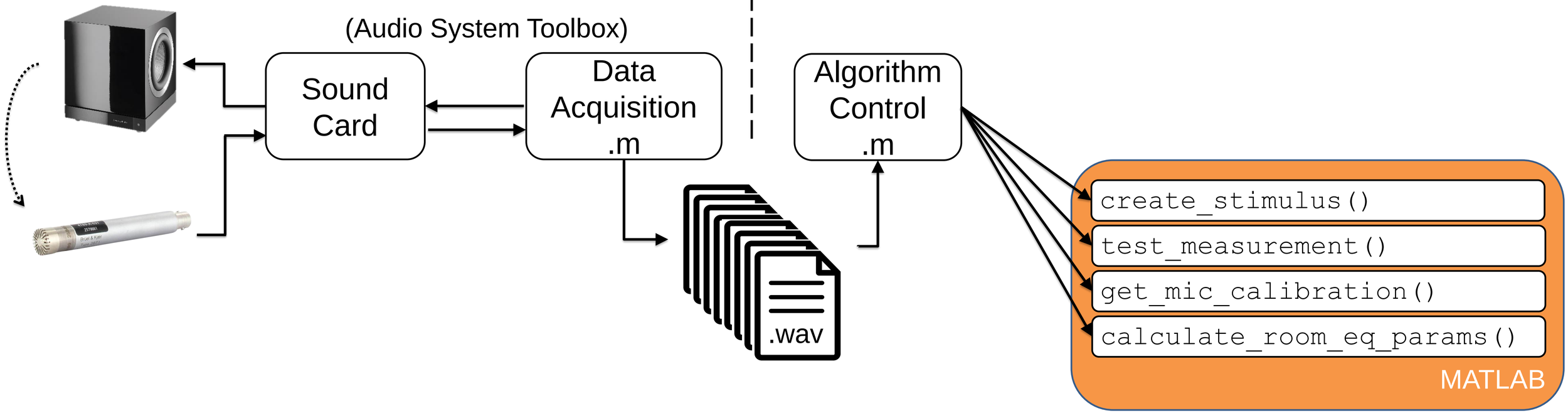
Algorithm Development Flow

- Three Development Phases

1. MATLAB only
2. Recorder App
3. Final App

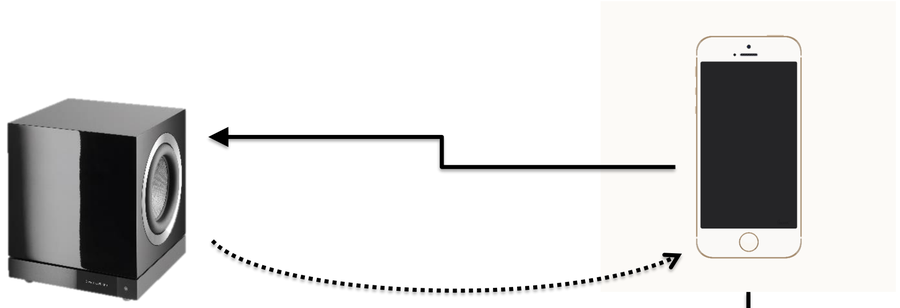
Algorithm Development Flow – Phase 1

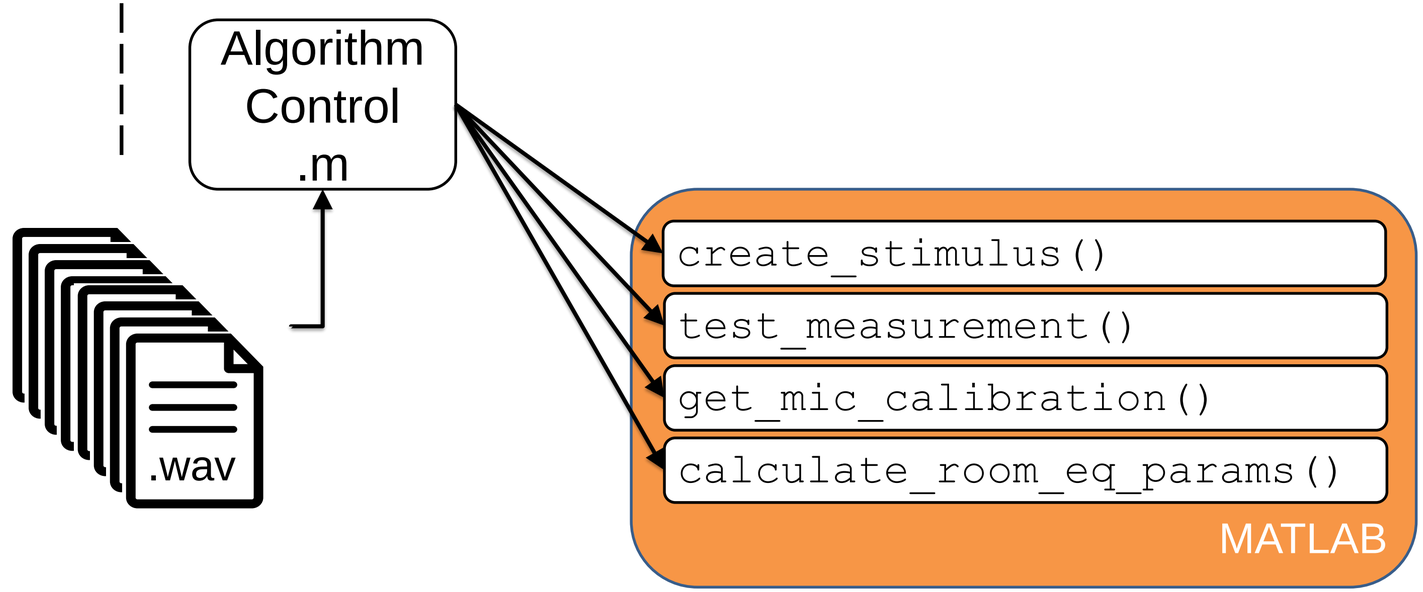
- **Data Acquisition Script**
  - Play stimulus & record audio files (directly in MATLAB)
  - Sound card & speaker
  - Laboratory mic
- **Algorithm Control Script**
  - Load audio files
  - Call the MATLAB entry functions
  - Check results



Algorithm Development Flow – Phase 2

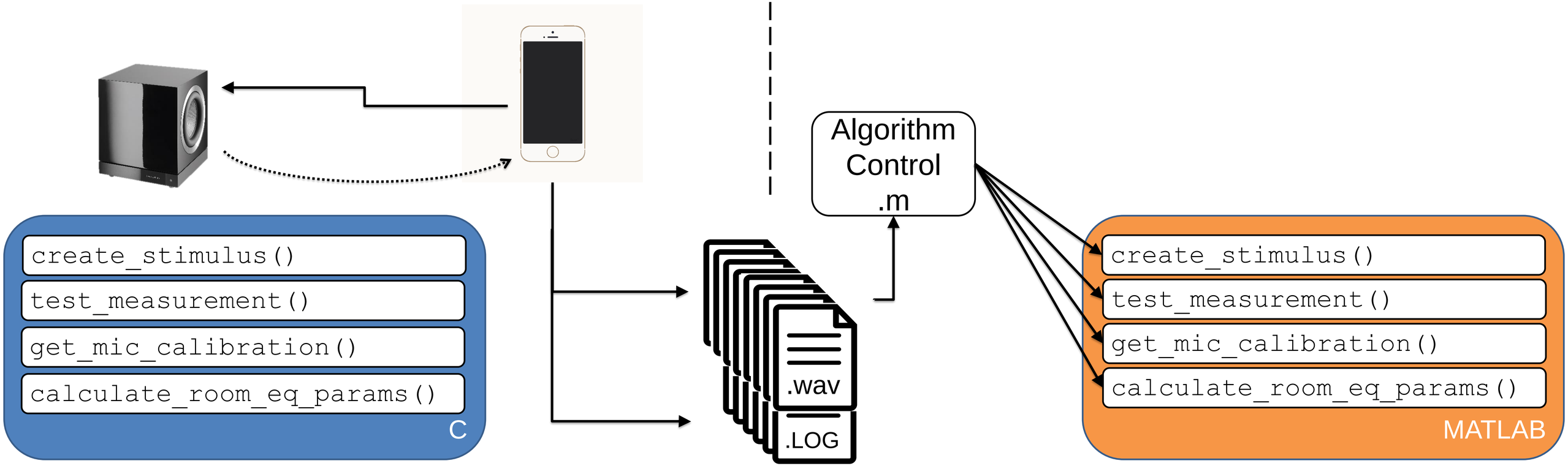
- Phone Recorder App
  - Play stimulus & record audio files
  - Using phone mic
- Algorithm Control Script
  - Load audio files
  - Call the MATLAB entry functions
  - Check results





Algorithm Development Flow – Phase 3

- Phone Room EQ App
  - Play stimulus & record audio files
  - Call the C entry functions
  - Store results
- Algorithm Control Script
  - Load audio files
  - Call the MATLAB entry functions
  - Check results



Code Generation & Deployment – Tips, Tricks & Hindsight

- Legacy MATLAB code:
  - re-write vs modify
- Unsupported functions:
  - Write custom versions
- Collaboration:
  - API Documentation
  - Independence between app team & algorithm team.
- Matrices & Arrays:
  - Static vs Dynamic memory allocation
  - Inputs, outputs, internals

Code Deployment – Code Snippets

- Mobile App wrapping C code.
- iOS
  - Objective-C: C superset, direct interface.
  - Class wrapper around entry functions.
- Android
  - NDK
  - Java wrapped with extra layers

```
% test the measurement
[flagOut, Hout] = req_test_measurement(sweep, measData, fs, gain);
```

```
//IOS
/// Runs microphone calibration, recorded at the given gain
- (void)calibrateMicrophoneWithSampleAtPath:(NSString *)path gain:(CGFloat)gain
{
//...
    // Test Measurement
    unsigned int flagOut;
    emxArray_real_T *HOut;
    emxInitArray_real_T(&HOut, 1);
    req_test_measurement(sweep, sampleData, fs, gain, &flagOut, HOut);
//...
    emxDestroyArray_real_T(HOut);
//...
```

```
//android
    JNIEXPORT void JNICALL
Java_com_RoomEQJNI_calibrateMicrophone(JNIEnv *env,
                                       jobject caller,
                                       jfloat gain,
                                       jdoubleArray *sample,
                                       jobject callback) {
//...
    // Test Measurement
    unsigned int flagOut;
    emxArray_real_T *HOut;
    emxInitArray_real_T(&HOut, 1);
    req_test_measurement(sweep, sampleData, fs, gain, &flagOut, HOut);
//...
    emxDestroyArray_real_T(HOut);
//...
```

CODERUS

Toolboxes Used

- MATLAB
- Signal Processing Toolbox
- DSP System Toolbox
- Audio System Toolbox
- MATLAB Coder
- Embedded Coder

Conclusion

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- DB Series Subwoofers
- Automatic Room Equalization

- Algorithm code in MATLAB
- Deployed to a smartphone
- Code generation

- Performance Technology Leadership

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Thank you

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