EMC Mini Symposium - Audio Break Through

Ji Hoon Jang, Sandeep Chandra, Ketan Shringarpure
EMC Team, Google Hardware
Oct 03 2019

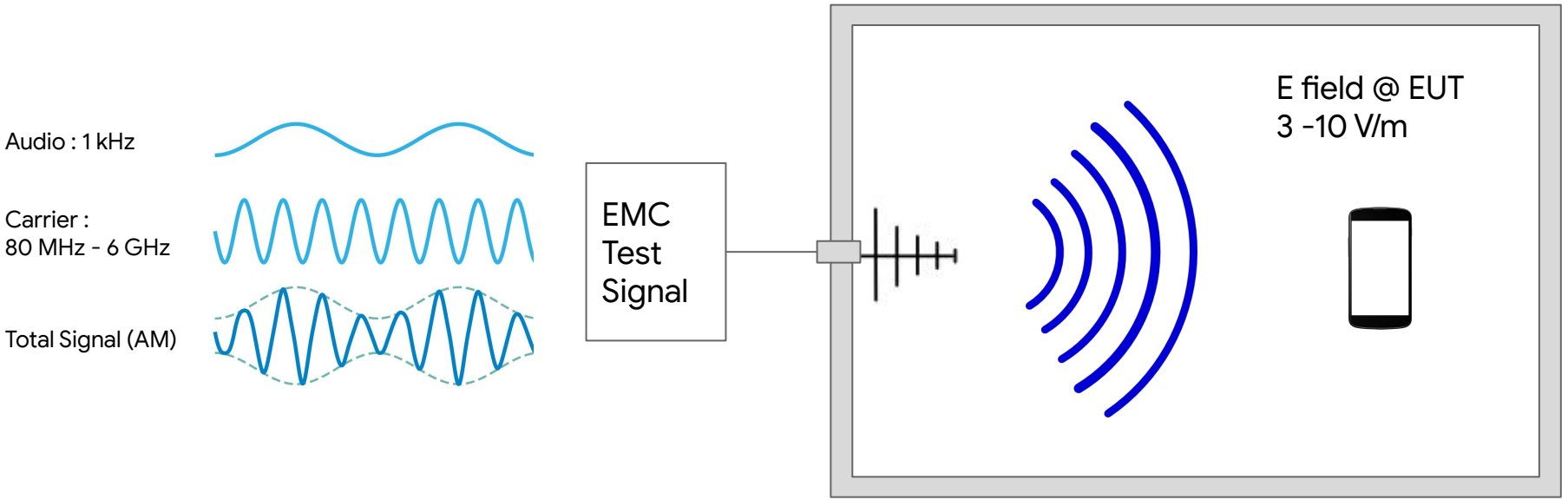
Overview

- Basics of audio breakthrough (ABT) testing
- Calibration and process of testing
- Things that can go wrong (variations) in the lab ABT testing
- Explaining the variations
- Methods to do bench level ABT testing, enabling easy debugging

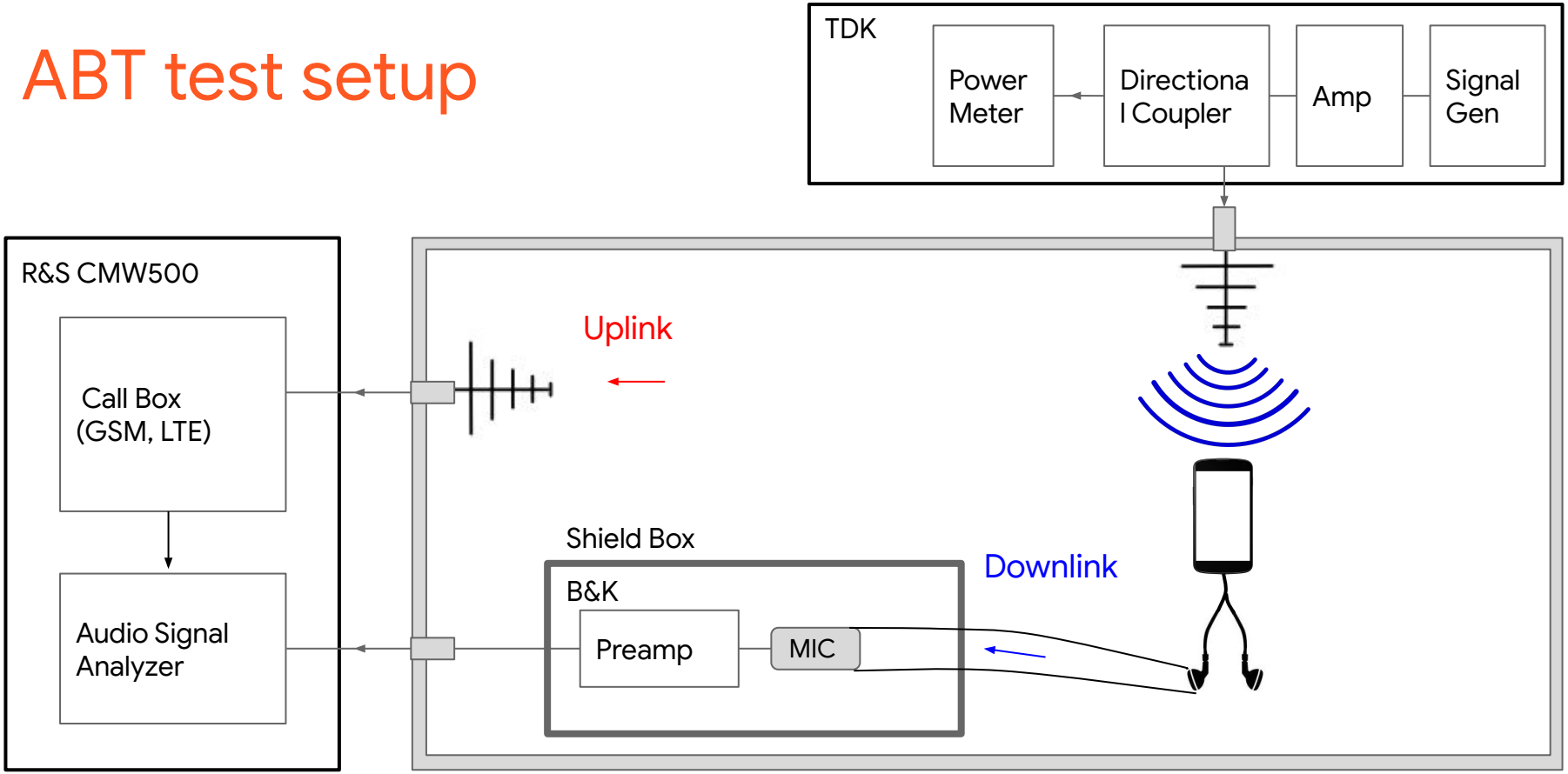
Basics

Audio Breakthrough (ABT) - Immunity Test

EMC Test Signal & Interference Calibration - Standard

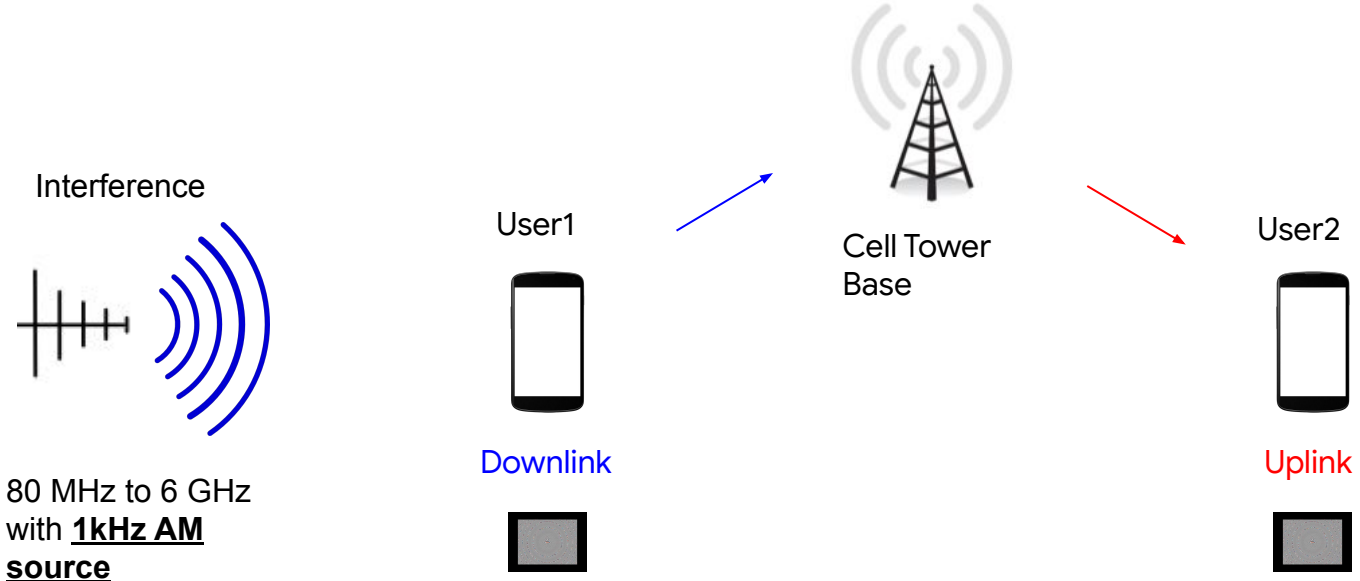


ABT test setup



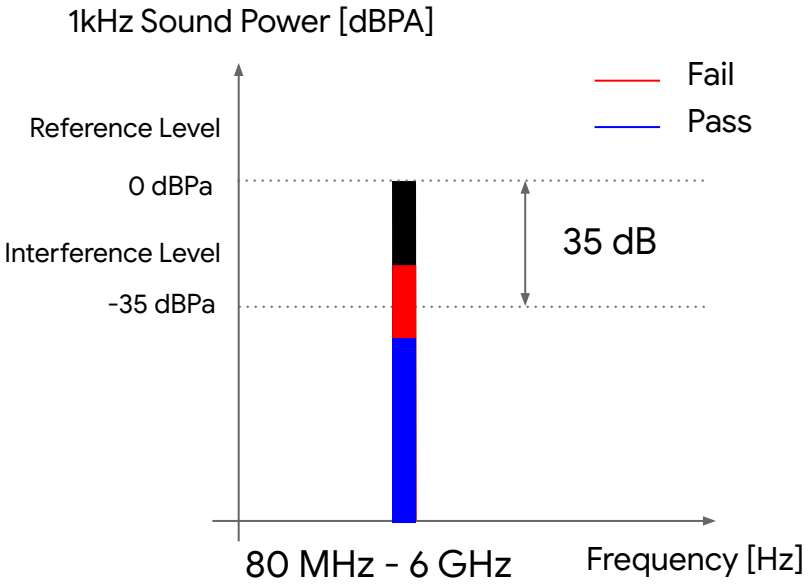
Audio Breakthrough (ABT) - Definition

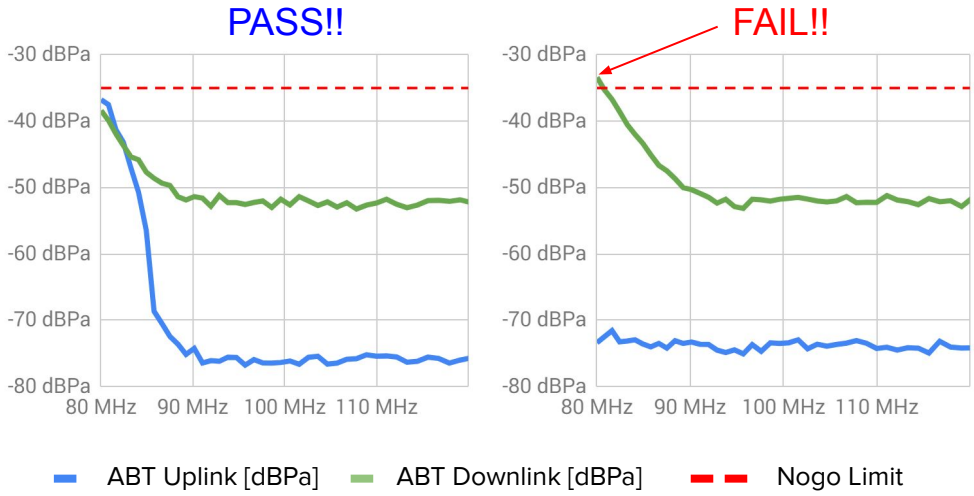
ABT Uplink / Downlink



Audio Breakthrough (ABT) - Standard

Performance Criteria (Pass/Fail)





? How to measure reference level
How to measure interference level

Audio Breakthrough (ABT) - Standard

Sound Pressure Level (dB SPL) vs dB Pa.

dB SPL is the level with the reference level 20 µPa

1 Pa is 20 $\log_{10}$ (1 Pa/20 µPa) = 94 dB SPL

dB Pa is the level with the reference level 1 Pa

1 Pa is 20 $\log_{10}$ (1 Pa/1 Pa) = 0 dB Pa

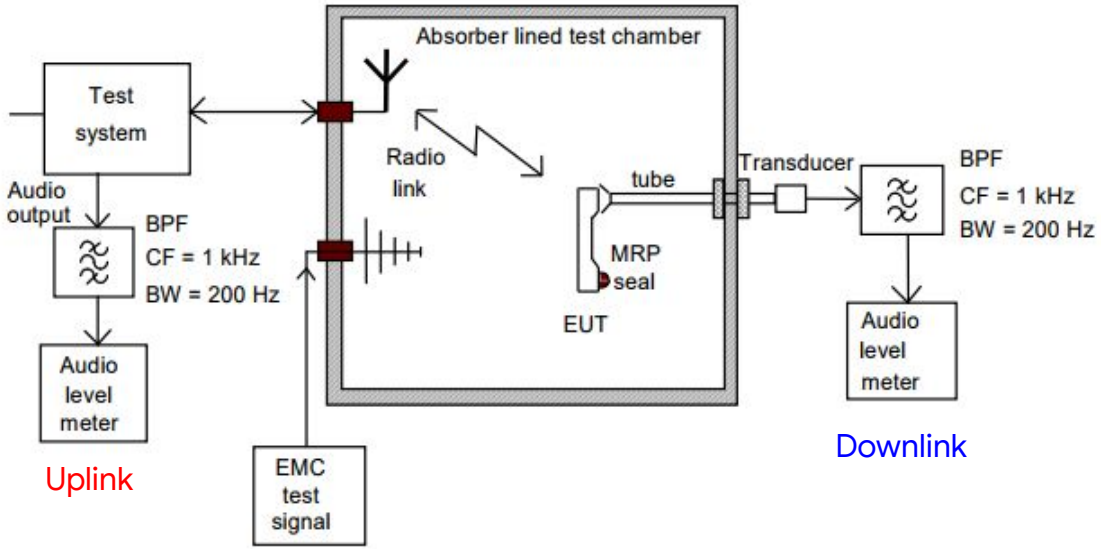
-35dB Pa = 60 dB SPL = Average conversation level

Sound source	dB SPL
Colt 45 pistol - 8 meters	140
Threshold of pain	130
Rock Concert	120
Night club music	110
Chainsaw / Jet ski	100
Lawnmower	90
Cabin of jet aircraft cruising	80
Car - 10 meters	70
Average conversation - 1 meter	60
Average suburban home (night)	50
Quiet auditorium	40
Quiet whisper - 1.5 meters	30
Extremely quiet recording studio	20
Anechoic Chamber	10
Threshold of hearing	0

Calibration Process and Standards

Audio Breakthrough (ABT) - Standard

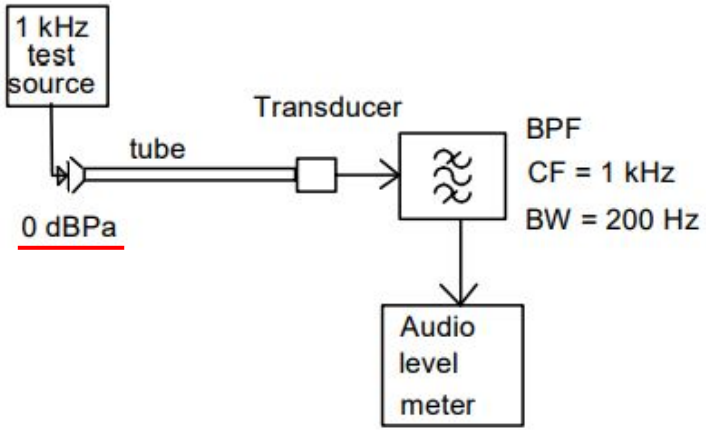
Interference Level Measurement **(ETSI EN 301 489-52)**



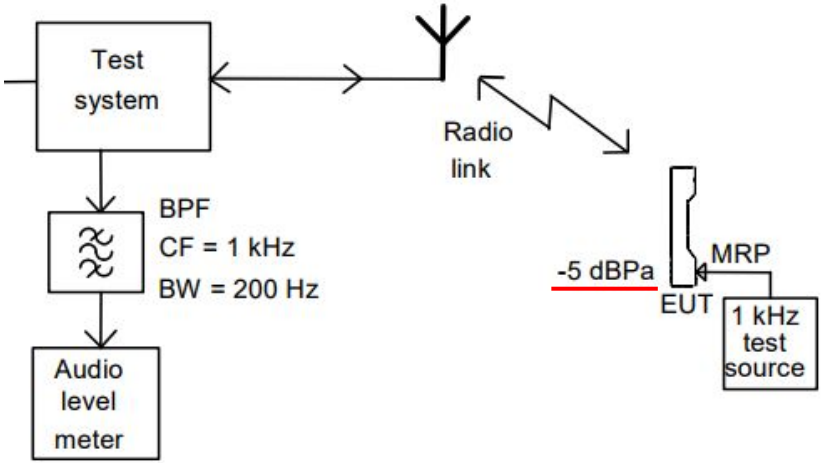
Audio Breakthrough (ABT) - Standard

Reference Level Measurement **(ETSI EN 301 489-52)**

Downlink



Uplink



Audio Breakthrough (ABT) - Standard

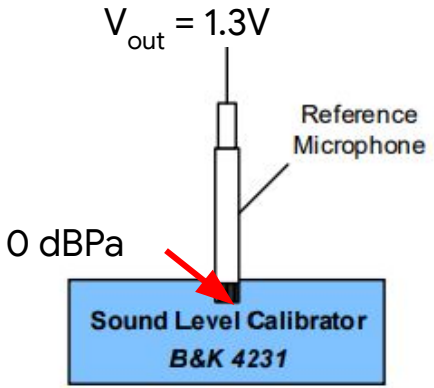
Acoustic Calibration **(R&S TS9982 Application Note)**

Sound Level Calibrator (B&K 4227)

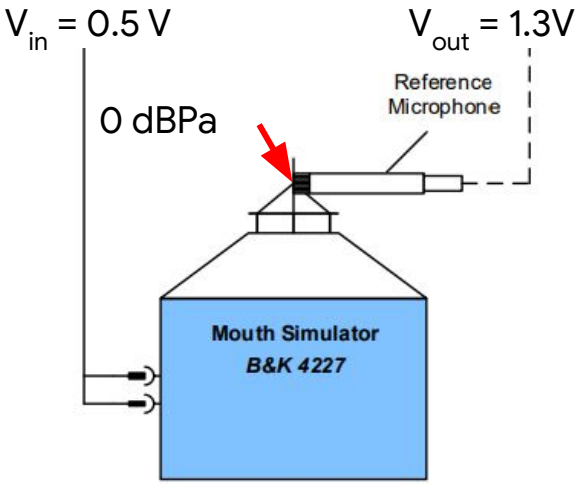
Mouth Simulator (B&K 4227)

Pressure Microphone (B&K 4192)

Step1
: calibrate ref mic



Step2
: calibrate mouth sim



Calibrate mic -> use that to calibrate sound pressure from mouth simulator

-5 dB Pa = 0.56 Pa => 0.5V x 0.56 = 0.28 V

Audio Breakthrough (ABT) - Standard

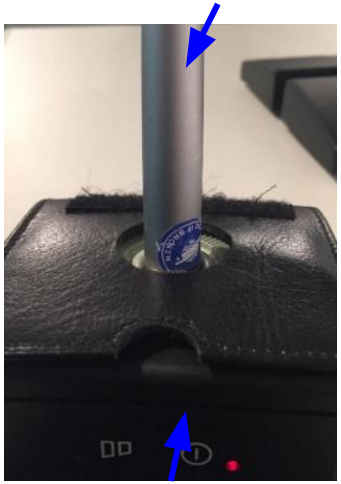
Acoustic Calibration **(R&S TS9982 Application Note)**

Sound Level Calibrator (B&K 4227)

Mouth Simulator (B&K 4227)

Pressure Microphone (B&K 4192)

Pressure Microphone

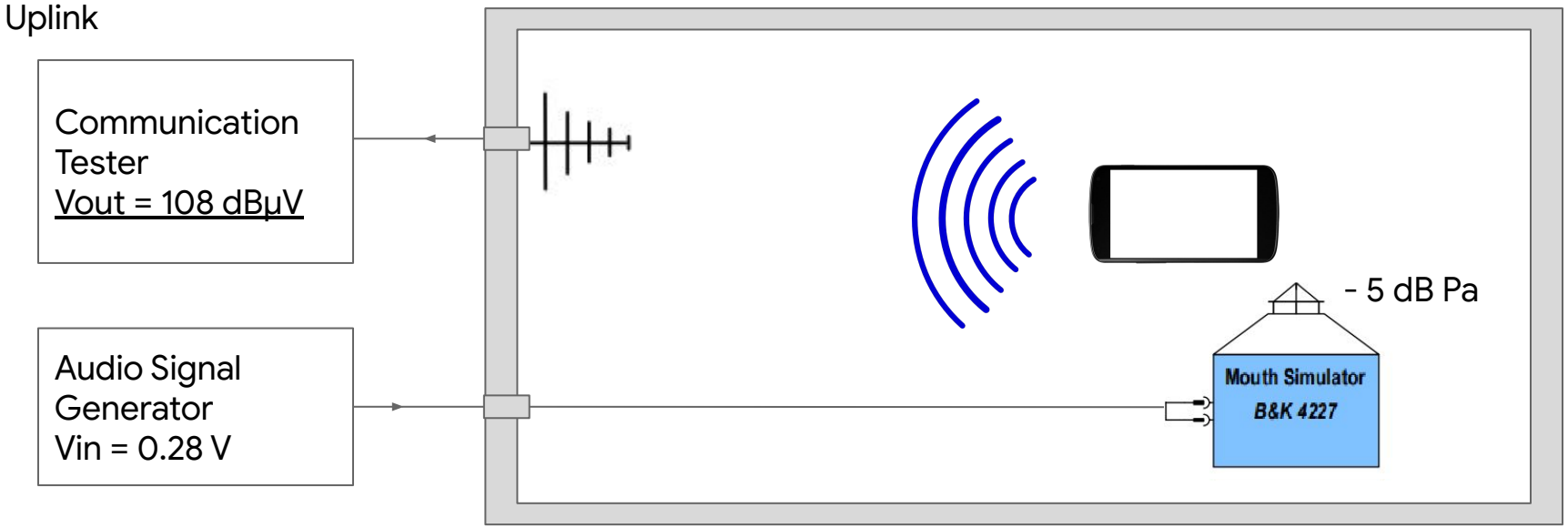


Sound Level Calibrator

Mouth Simulator

Audio Breakthrough (ABT) - Standard

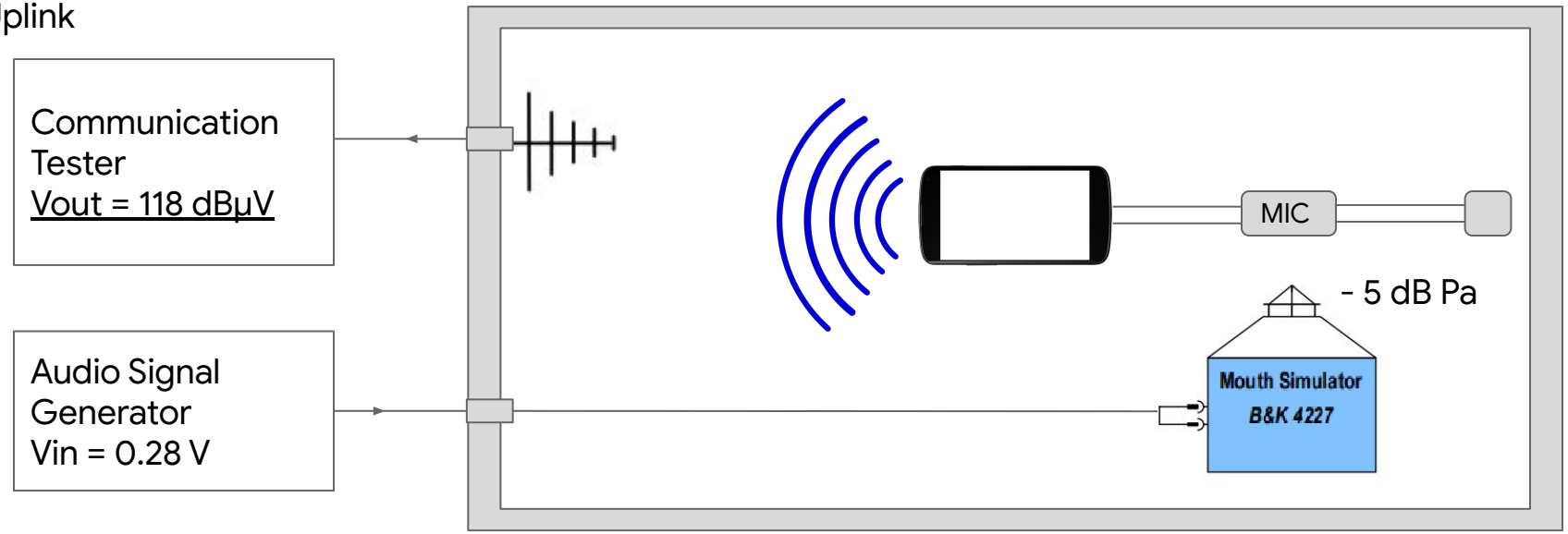
Reference Level Measurement **(R&S TS9982 Application Note)**



Audio Breakthrough (ABT) - Standard

Reference Level Measurement **(R&S TS9982 Application Note)**

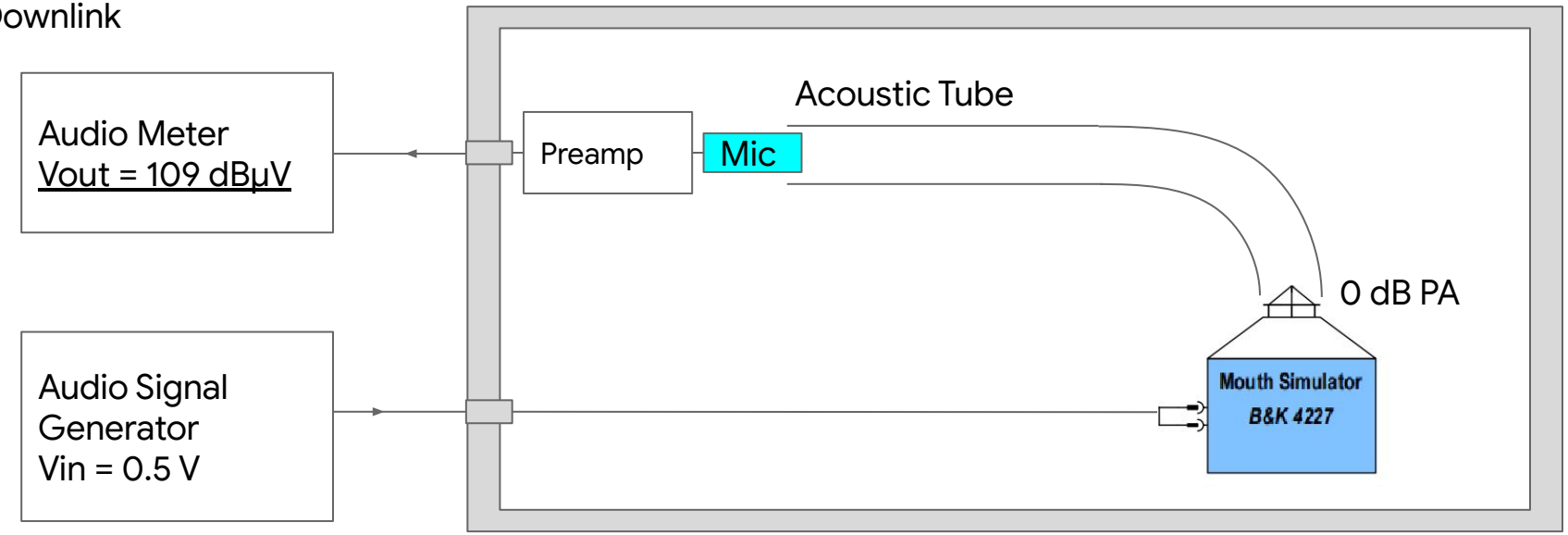
Uplink



Audio Breakthrough (ABT) - Standard

Reference Level Measurement **(R&S TS9982 Application Note)**

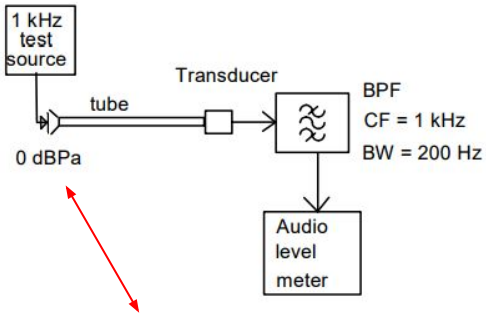
Downlink



Audio Breakthrough (ABT) - Standard

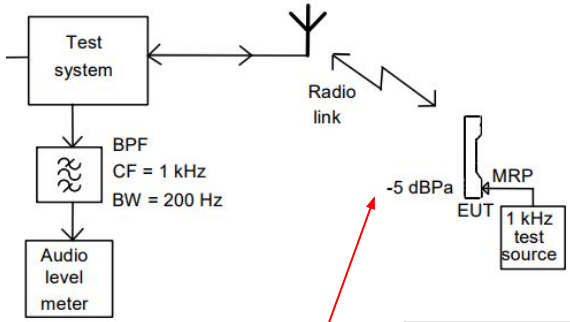
Review of Reference Value in Standard (ETSI EN 301 489-52)

Downlink

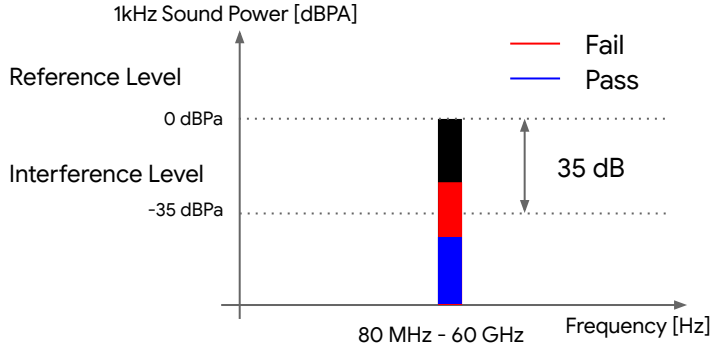


** Downlink Reference Value = 99.913 dBµV

Uplink



** Uplink Reference Value = 109.542 dBµV



** Values are from previous slides.

	Downlink Reference	Uplink Reference
Audio Level Meter @ 0 dB Pa = **1 Pa**	99.913 dBµV / 1 Pa	109.542 dBµV / 1 Pa
Audio Level Meter @ -35 dB Pa = **18 mPa**	64.913 dBµV / 18 mPa	74.542 dBµV / 18 mPa

Variations Observed and Explanations

Variations Observed in Third party labs

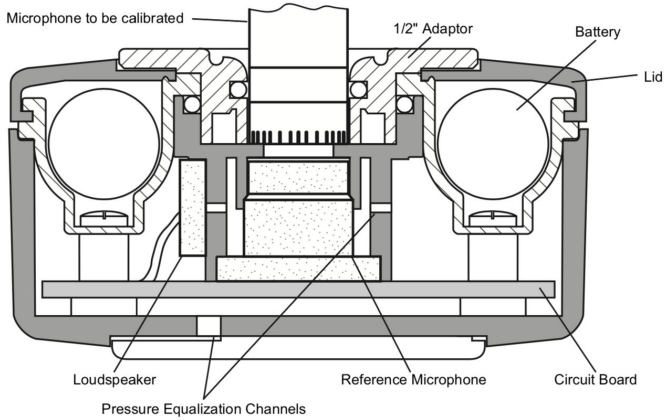
- Wrong calibration with sound level calibrator
- Wrong calibration procedure with mouth simulator and sound level calibrator
- Non-uniform field calibration and Field variations caused due to setup variations
- Placing audio pre-amp in a leaky (fields) shielded box inside the chamber.
- Sine-wave cancellation on mobile devices
- Second and third harmonics (sometimes higher than fundamental) ignored
- Frequency steps missing high Q resonances
- Variation due to phone orientation, different earphone lengths used by different labs and how they position the ear phones in the field

Next

ABT - CMW500 Audio and Shield Box Test

The calibrator is controlled by closed loop in the speaker and reference microphone. If the calibrator is not sealed properly with the audio tube, it can increase the output pressure.

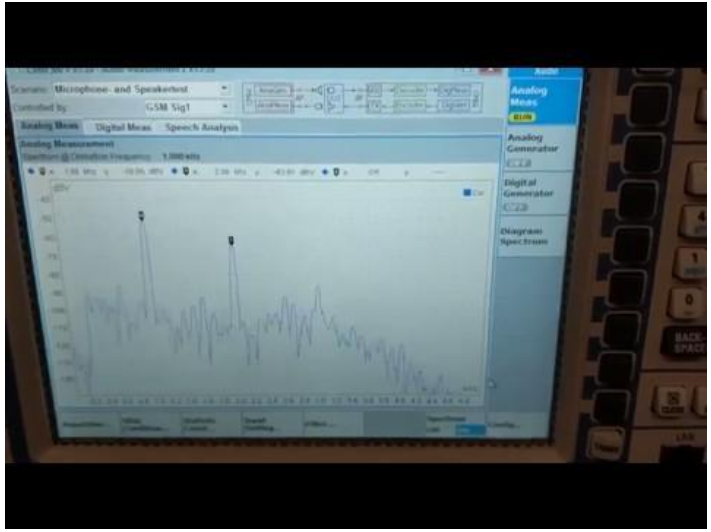
This is why a mouth simulator is used for calibration.



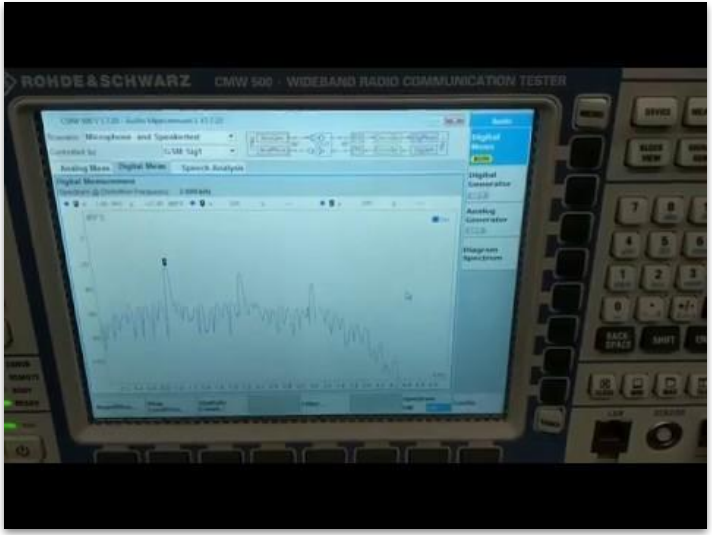
Back

Test - CMW500 - Downlink/Uplink

Downlink Measurement

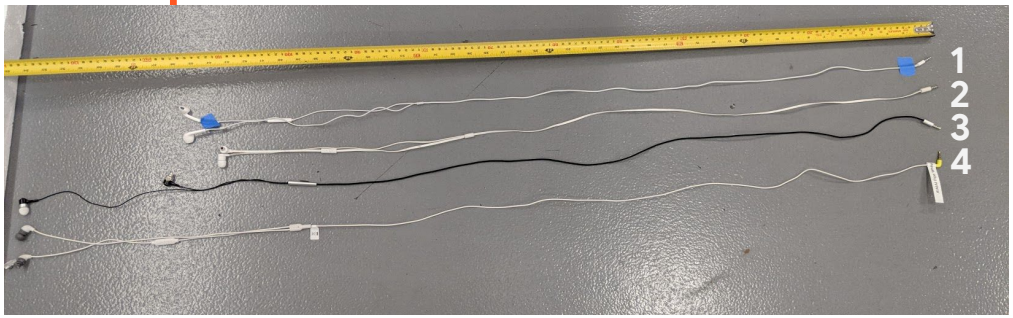


Uplink Measurement

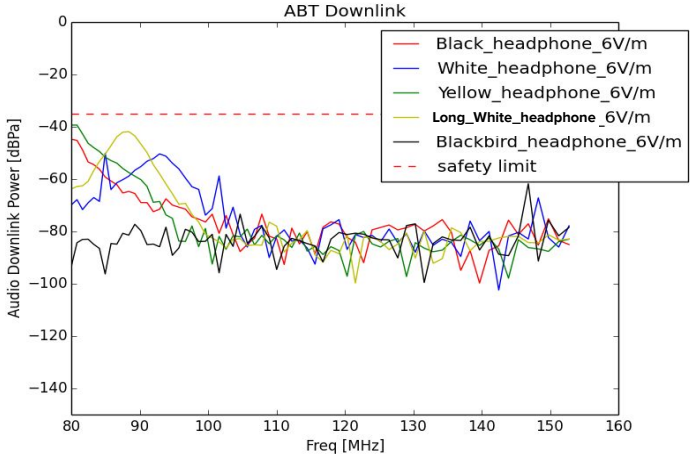


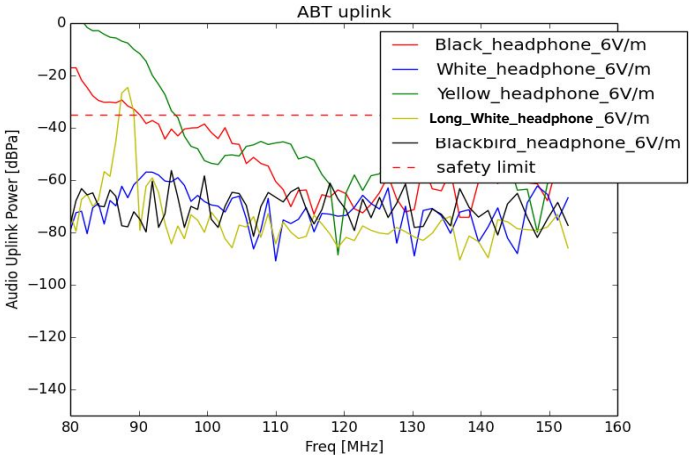
Back

Test - Different Headphone



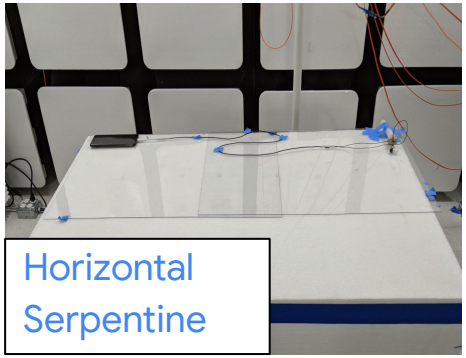
	Name	Length
1	Long White	118 cm
2	White	110 cm
3	Black	140 cm (Right) 120 cm (Left)
4	Yellow	140cm

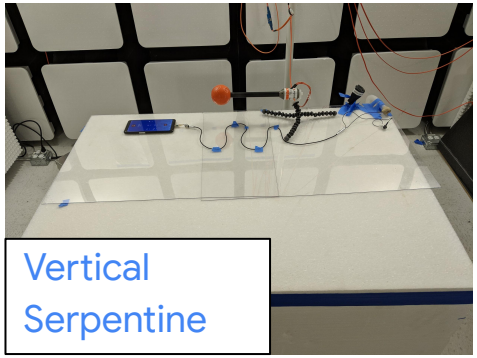


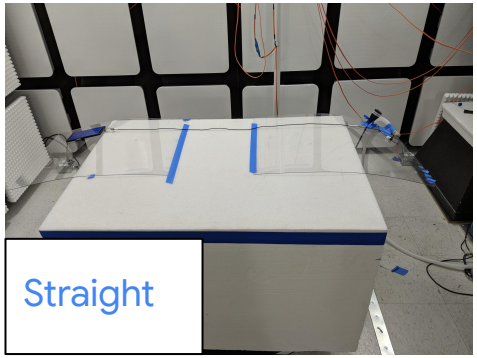


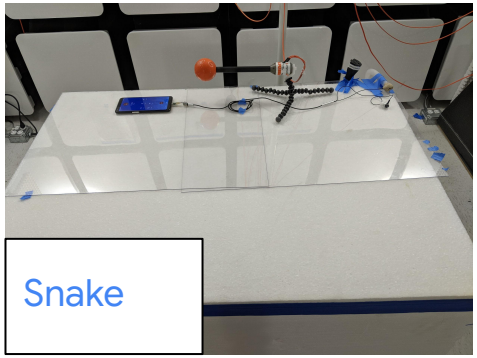
Back

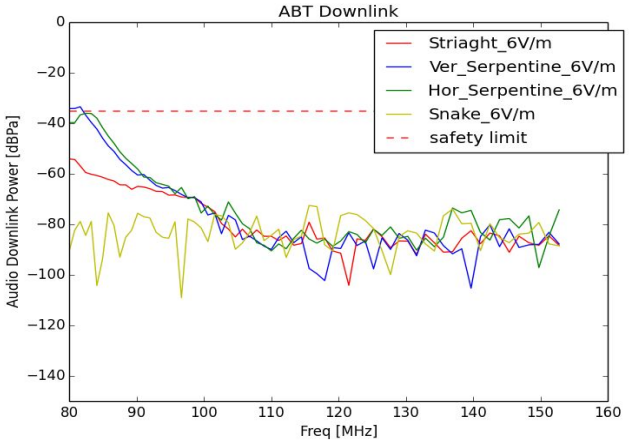
Test - Headphone Placement

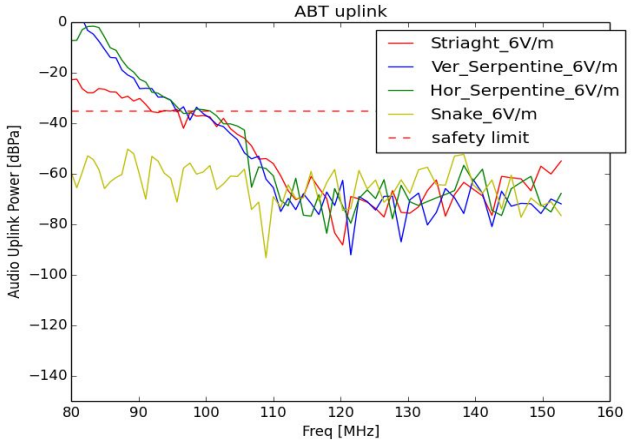






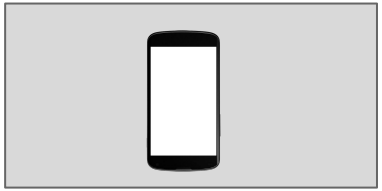
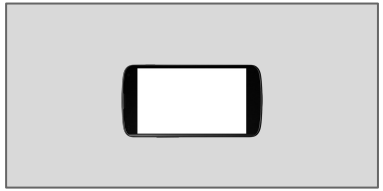
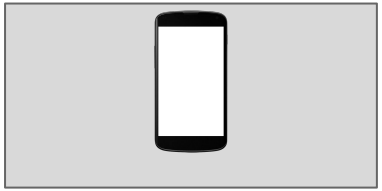
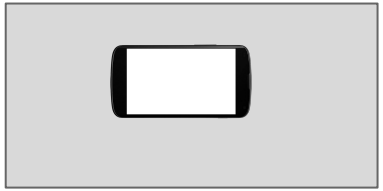




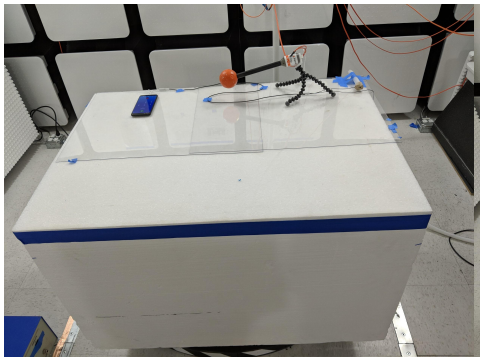
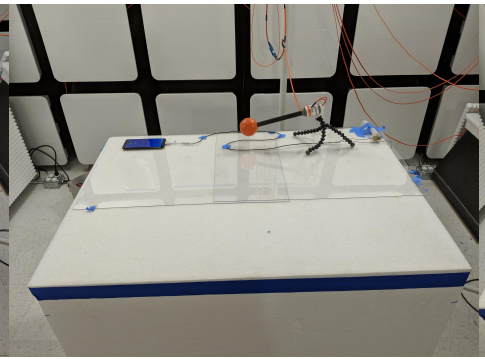
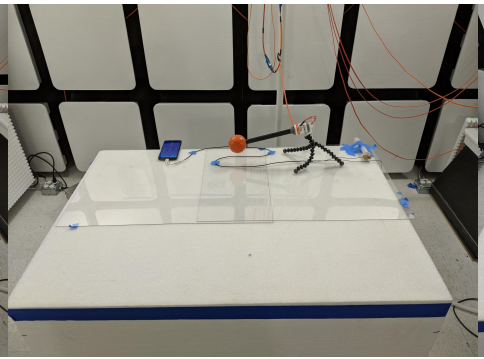
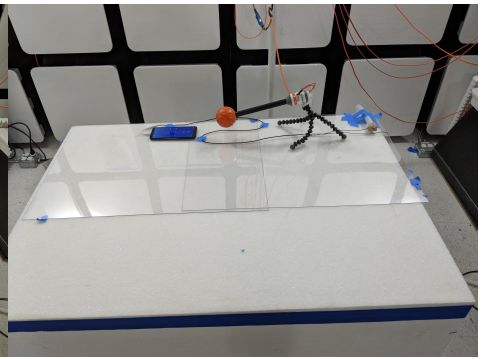


Back

Test - Horizontal

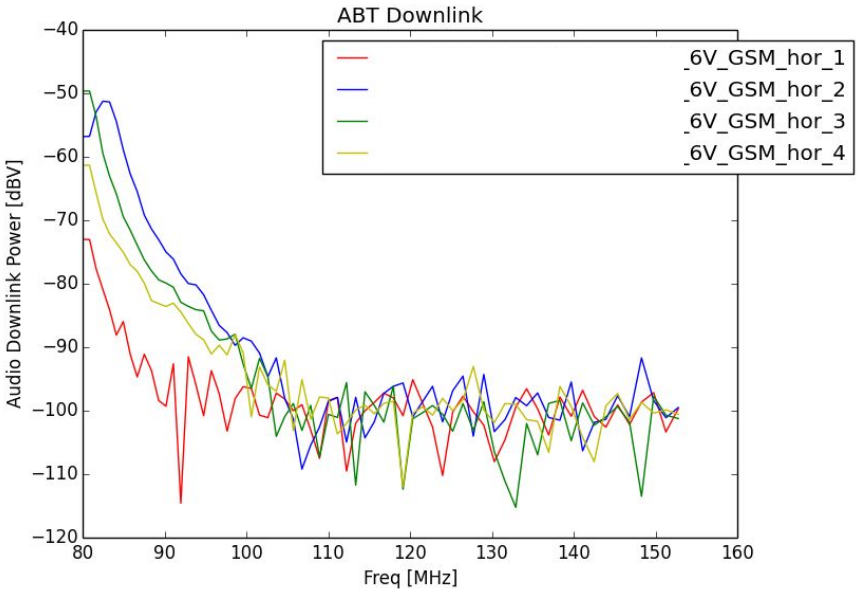







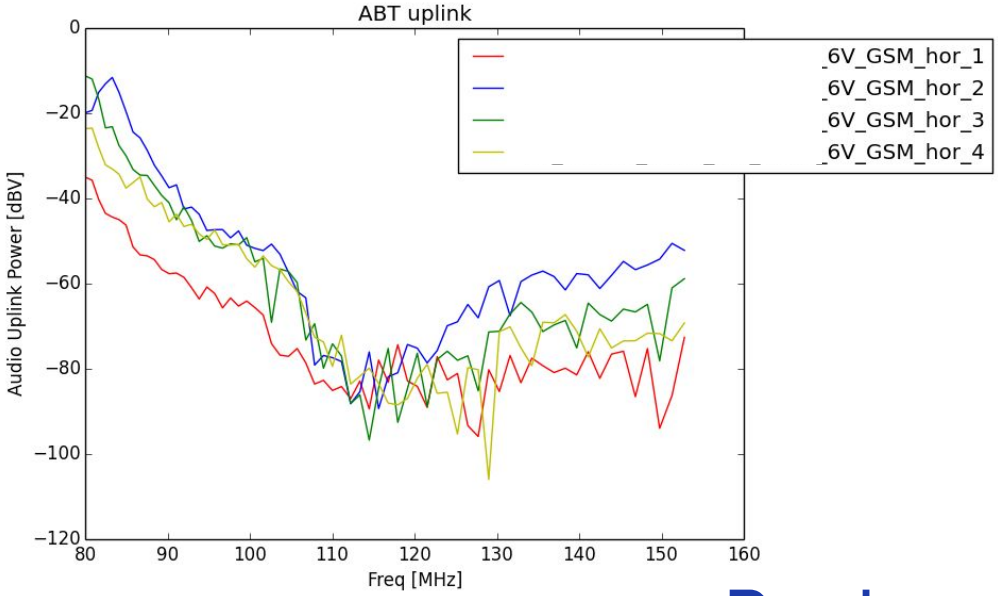






Test - Horizontal - 6 V/m Field Strength

Downlink

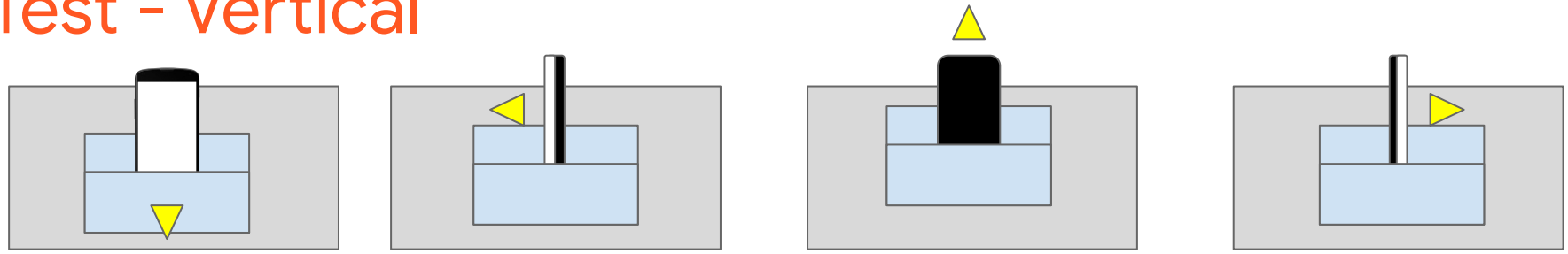


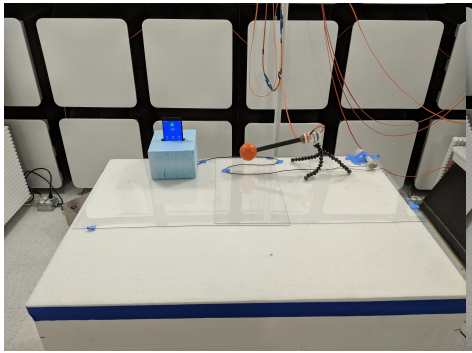
Uplink

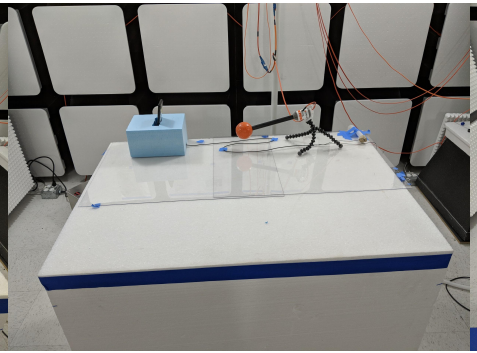


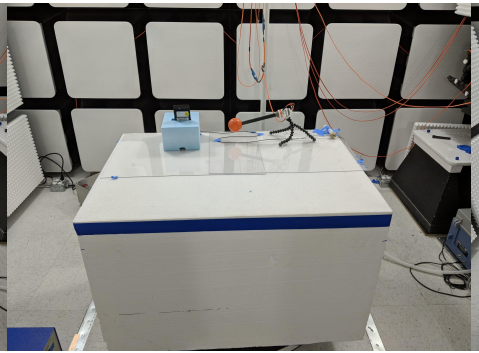
Back

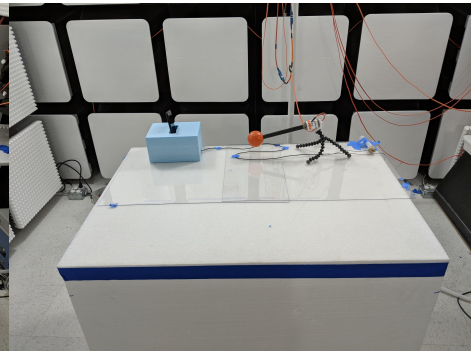
Test - Vertical





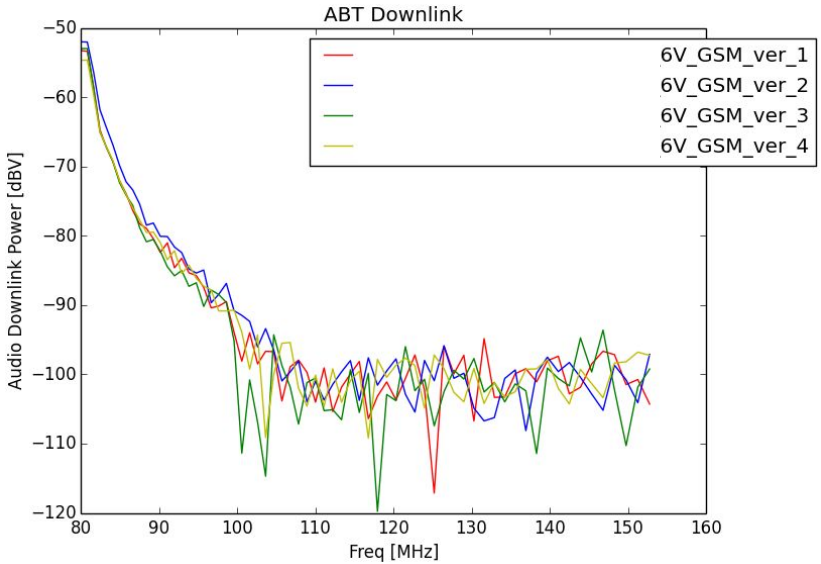




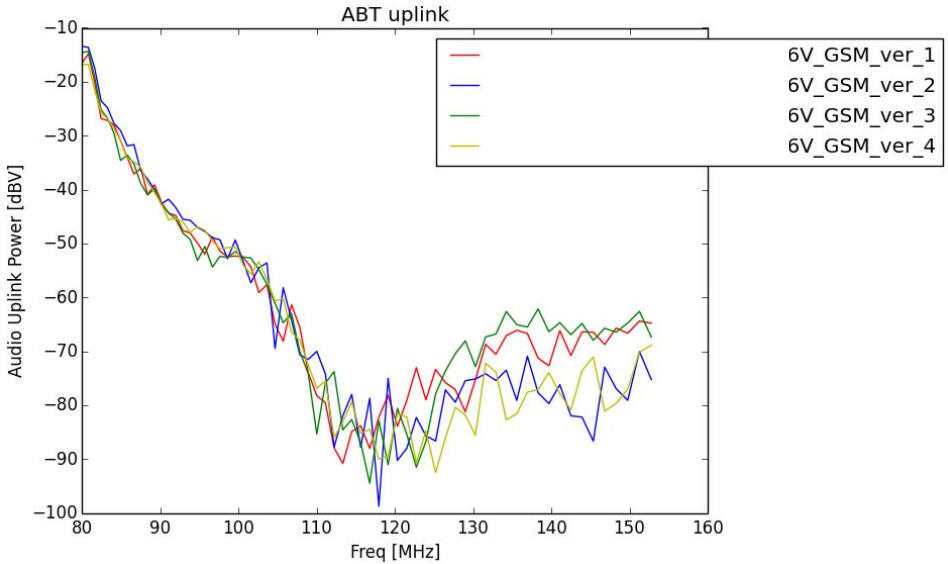


Test - Vertical - 6 V/m Field Strength

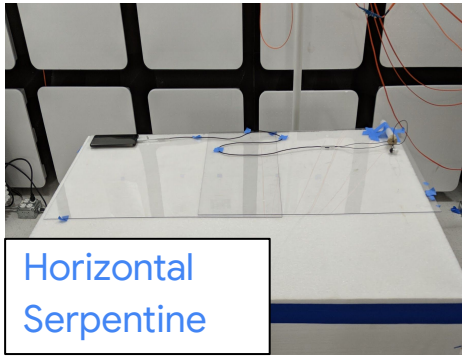
Downlink

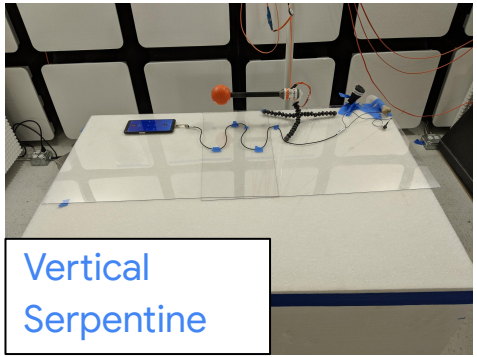


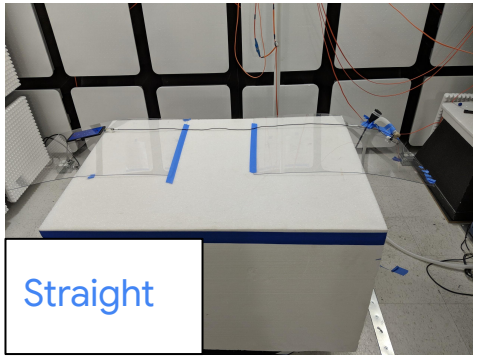
Uplink

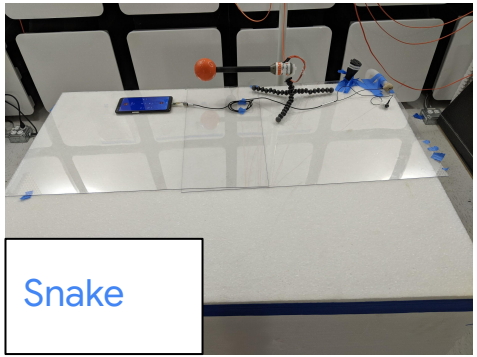


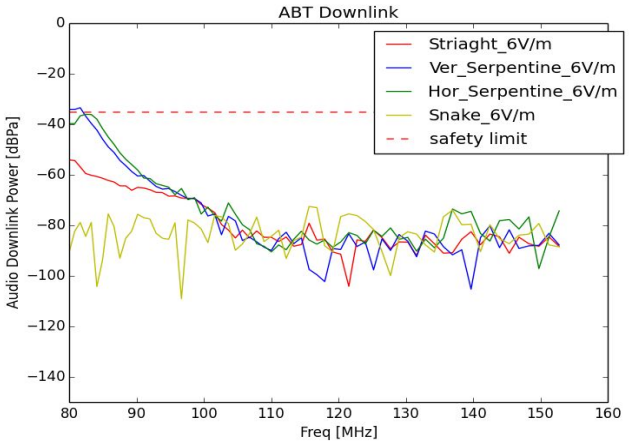
Test - Headphone Placement

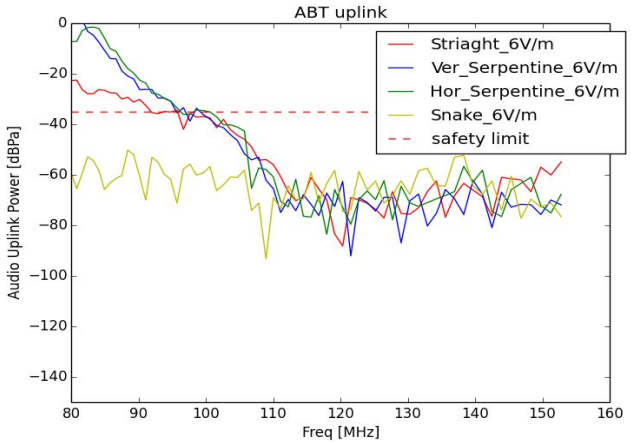












Methods for Bench Level ABT

ABT - EMC Lab Test

Goal : Minimize these variations to have consistent results

Method : Provide the guideline to the outside lab.

Procedures : By setting up Audio Breakthrough (ABT) test in lab, we can test how each variations will affect the measurement results

Debug ability : Ability to debug the failure while not working in active field

Bulk Current Injection -ABT Test

No Full-size Chamber

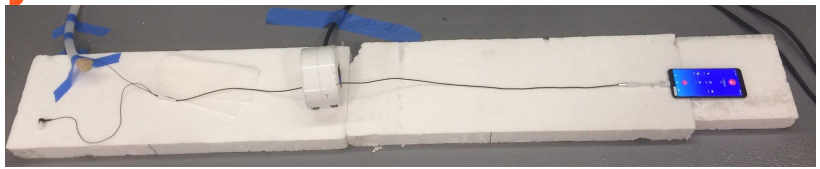
No Field Calibration

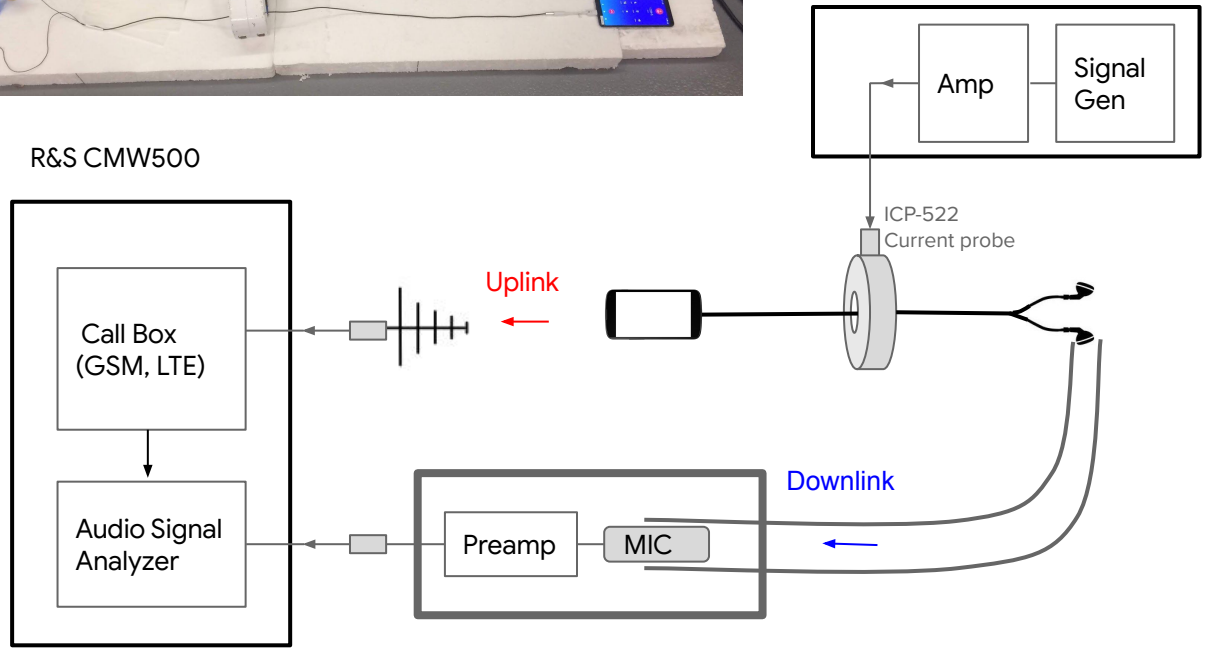
No Interference Antenna

No Cable or antenna placement variation

Fast and can use more frequency points

Easy to Debug





ABT - CMW500 Audio Generator / Analyzer

2 Inputs / 2 Outputs

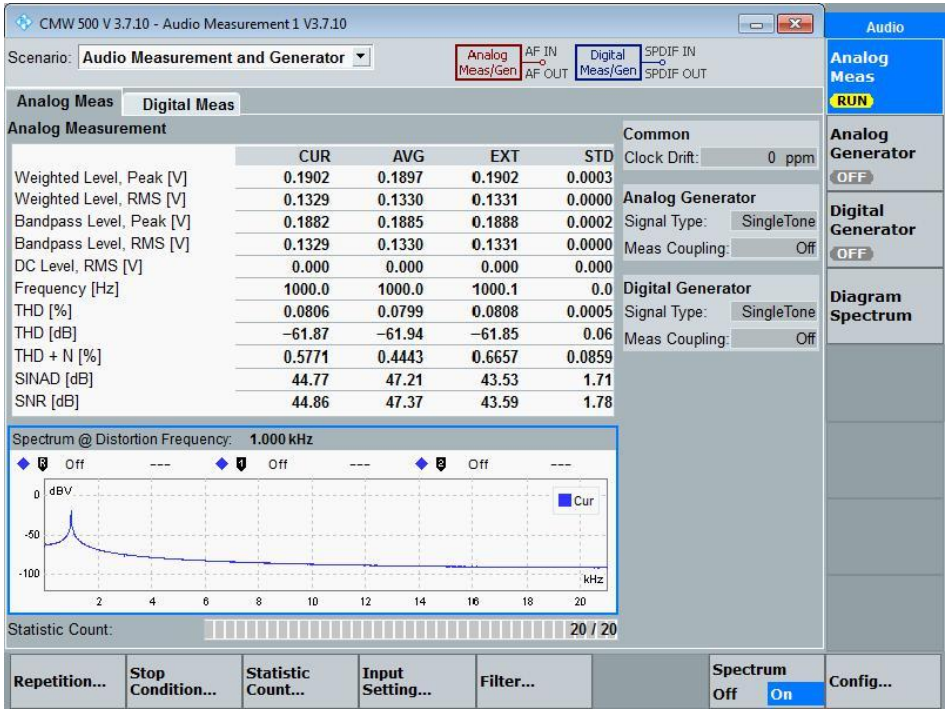
Analog / Digital

Frequency Spectrum

Single / Multi Tone Measurement

Current/Average/Extreme

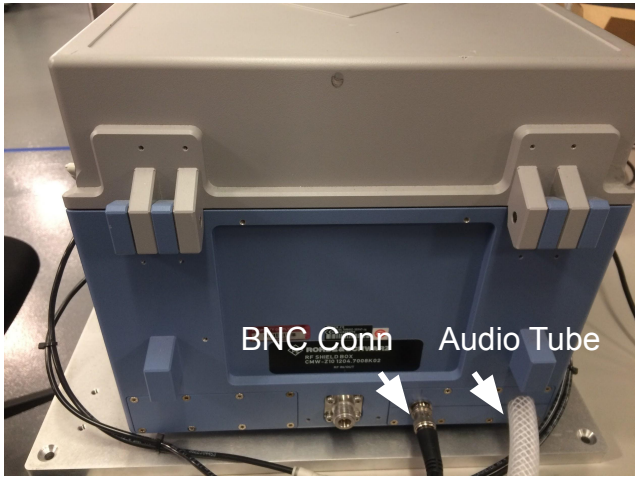
Sampling Frequency = 48 kHz

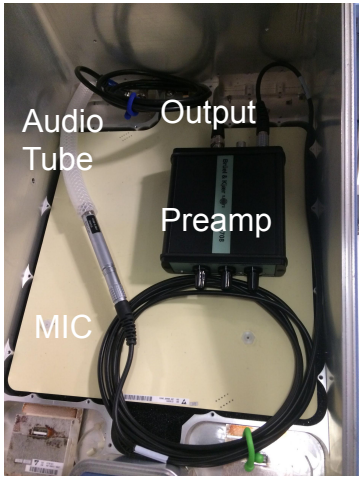


ABT - R&S Z10 RF Shield Box

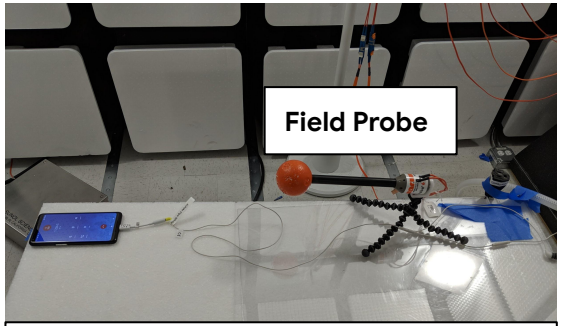
Frequency range up to 6 GHz

Shielding characteristics (< 80 dB)

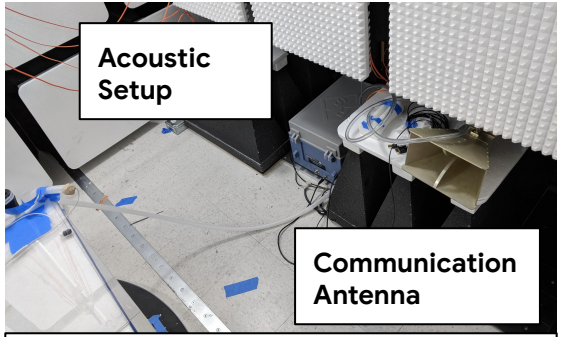




Chamber ABT Test

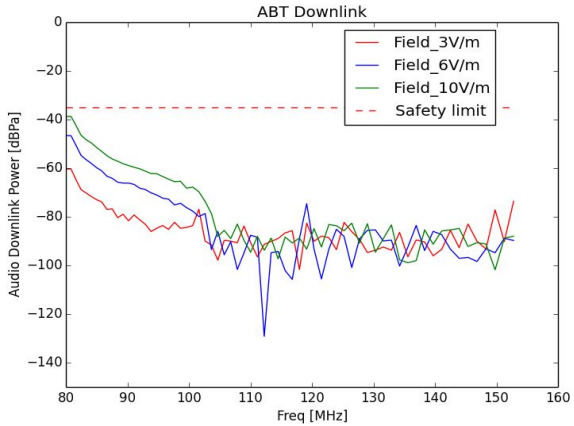


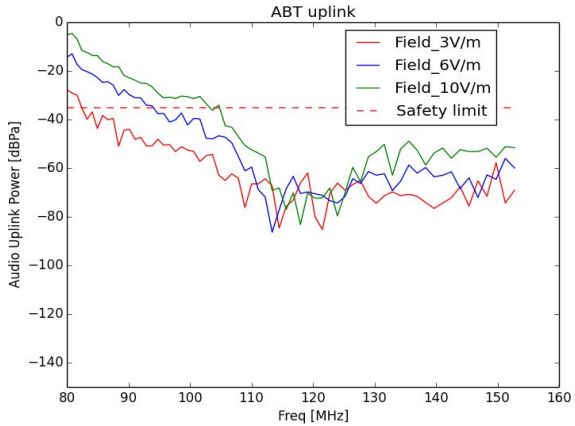
Field calibration



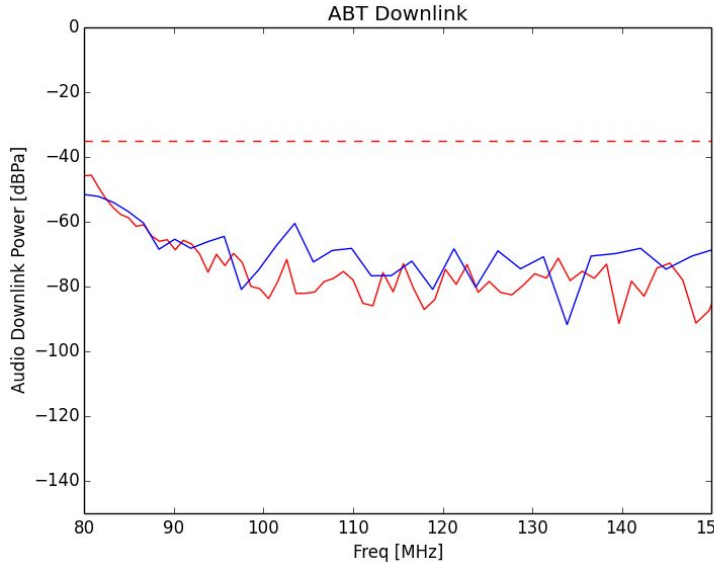
Shield box with acoustic setup

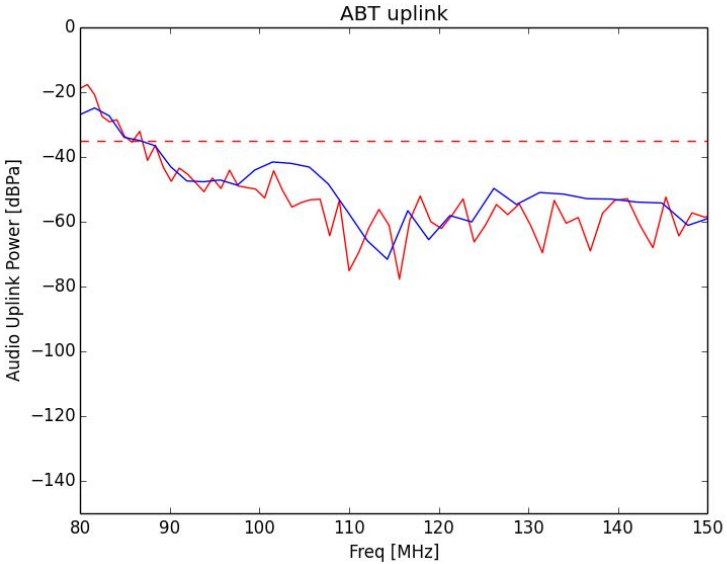
Call box setup





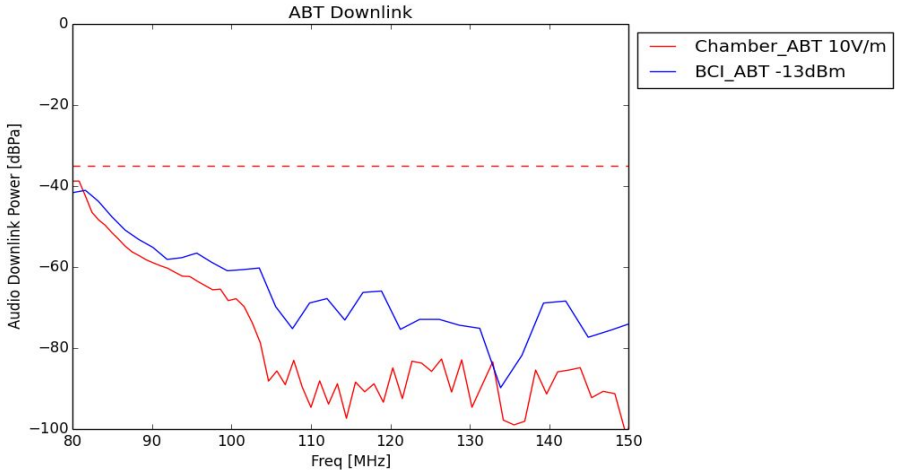
Comparison between Chamber ABT and BCI ABT

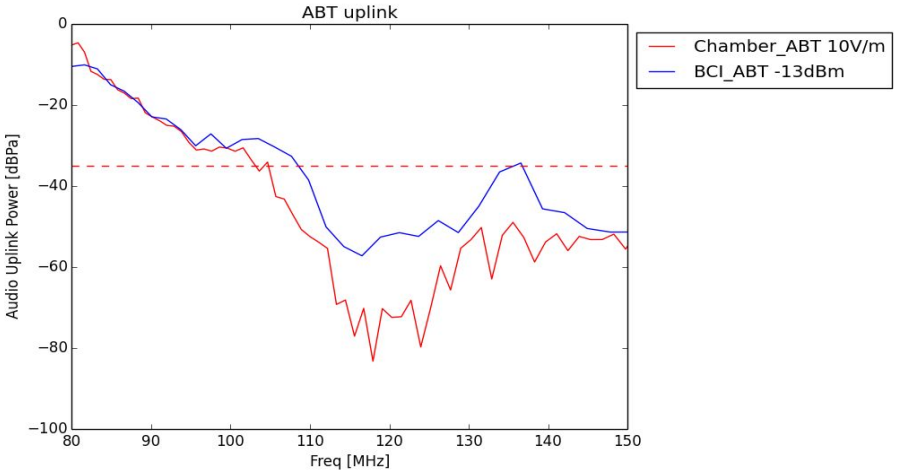




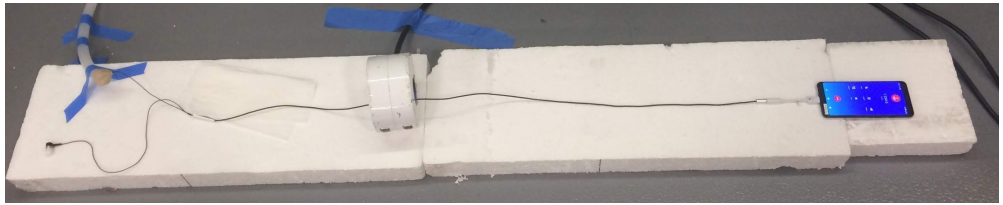
Red - Chamber ABT 6V/m
Blue - BCI ABT - 15dBm

Comparison between Chamber ABT and BCI ABT

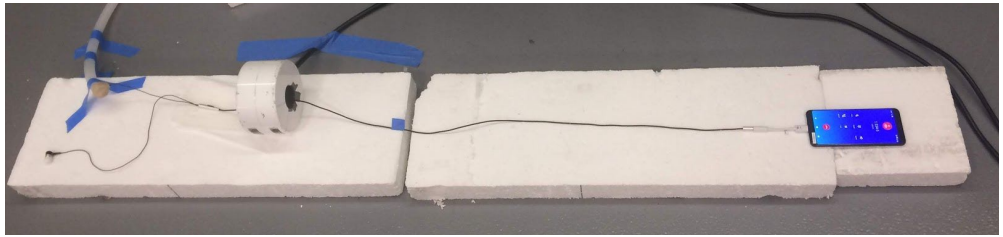




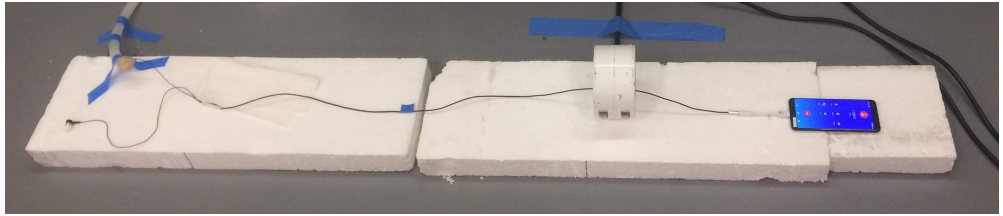
BCI Placement



Center

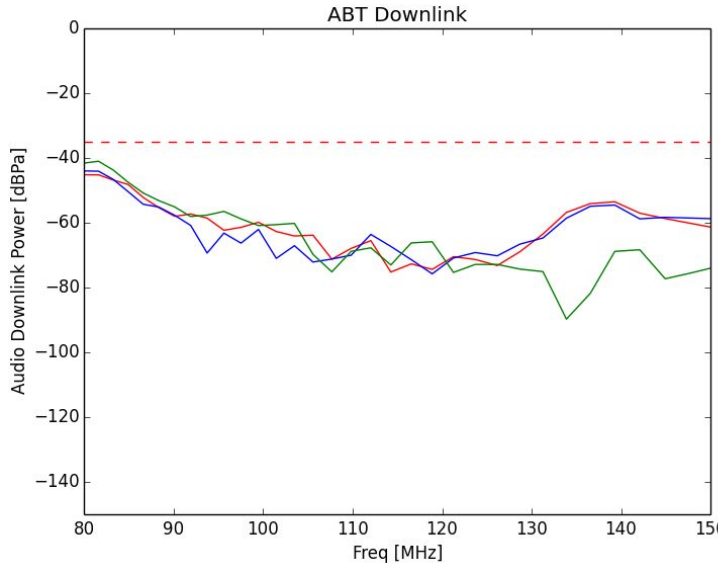


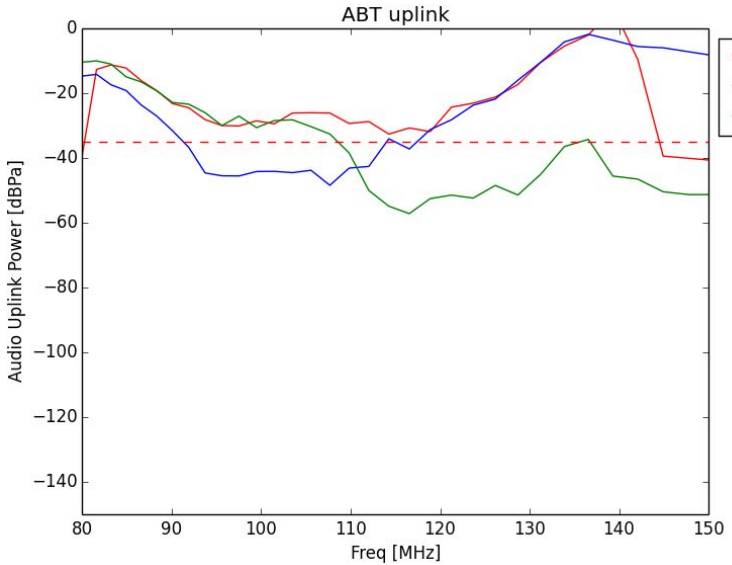
Far from the phone



Close to the phone

Comparison between Chamber ABT and BCI ABT



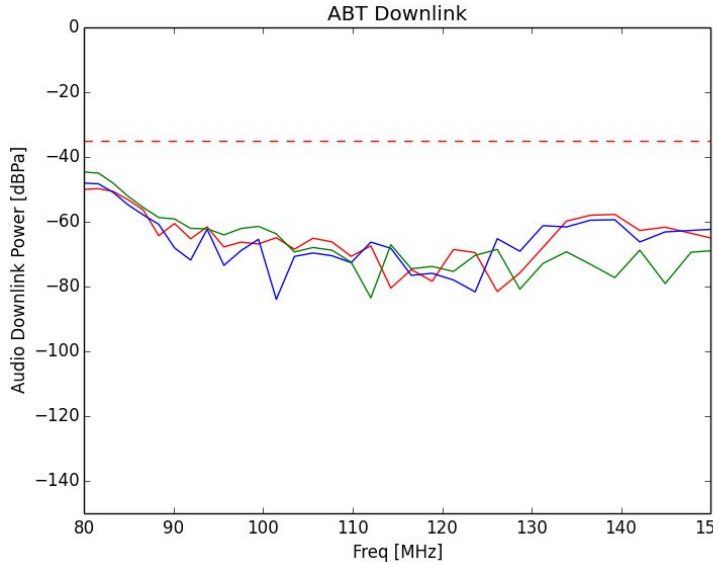


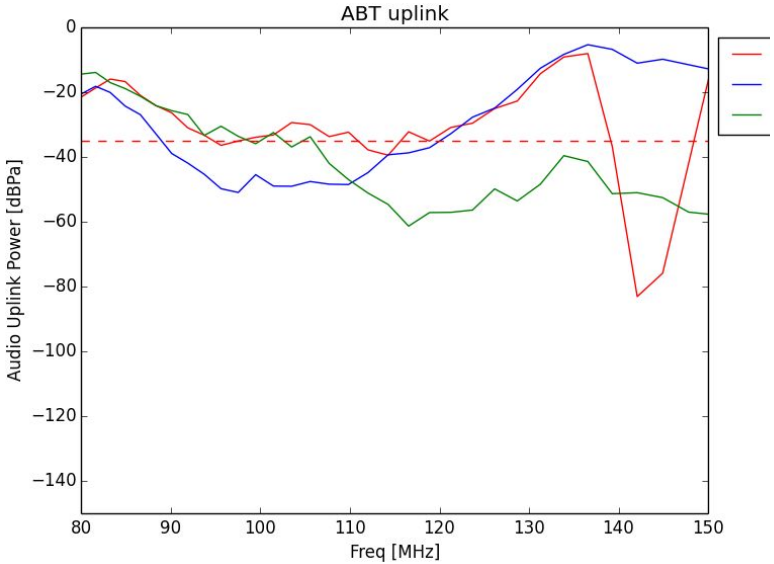
Conclusions

- Variations are expected for ABT when tested in third party labs
- Setup and process should be carefully examined to ensure correct test process
- BCI ABT method takes out lot of variation. Gives ability to reproduce and debug on bench level without the need for full-size chamber.

Appendix - Audio Breakthrough (ABT)

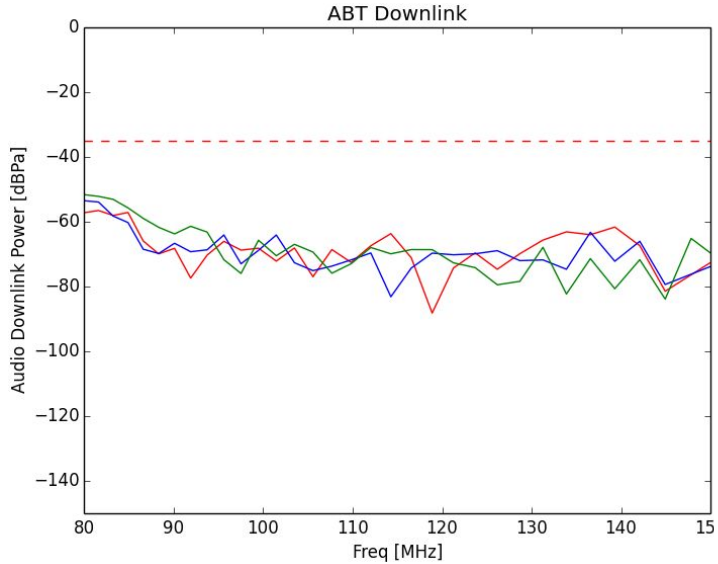
Comparison between Chamber ABT and BCI ABT

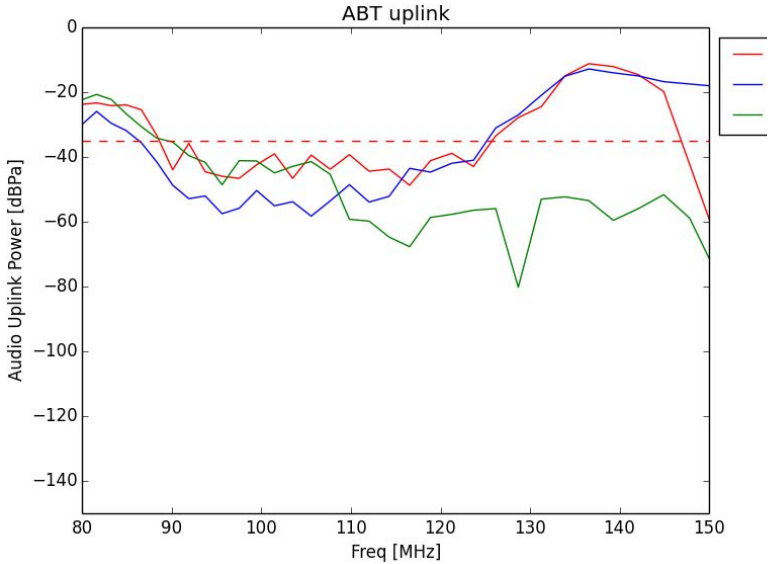




power_15_clo
power_15_far
power_15_wi

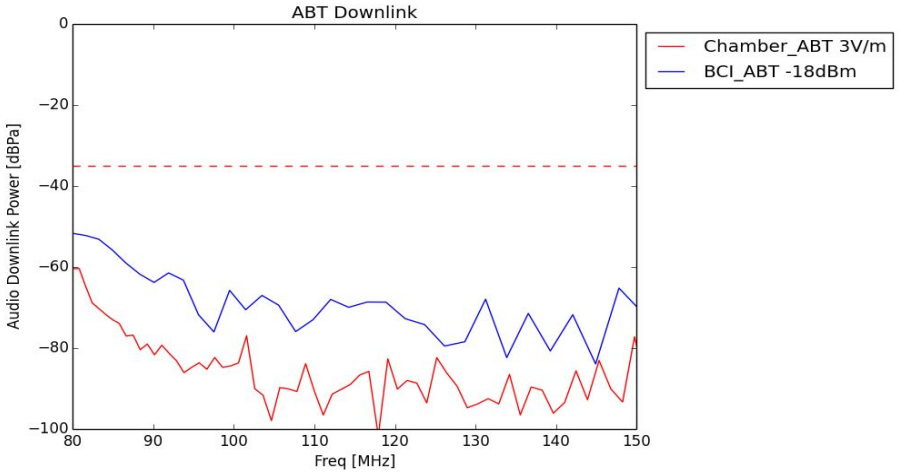
Comparison between Chamber ABT and BCI ABT

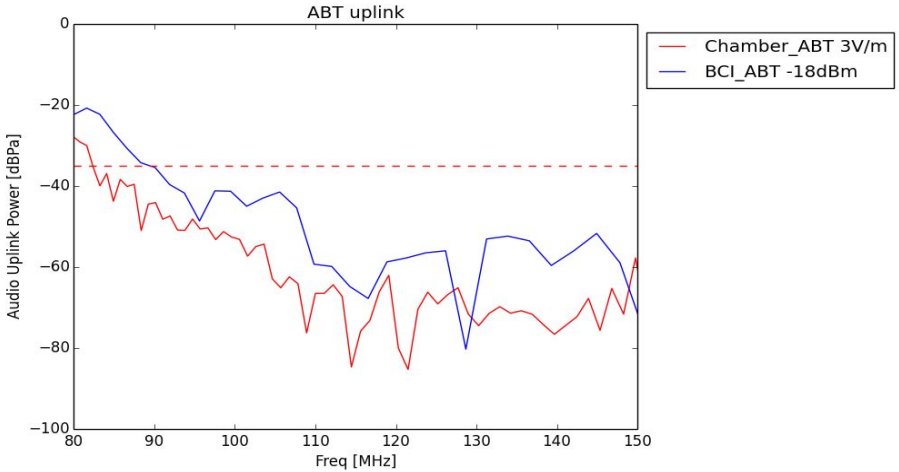




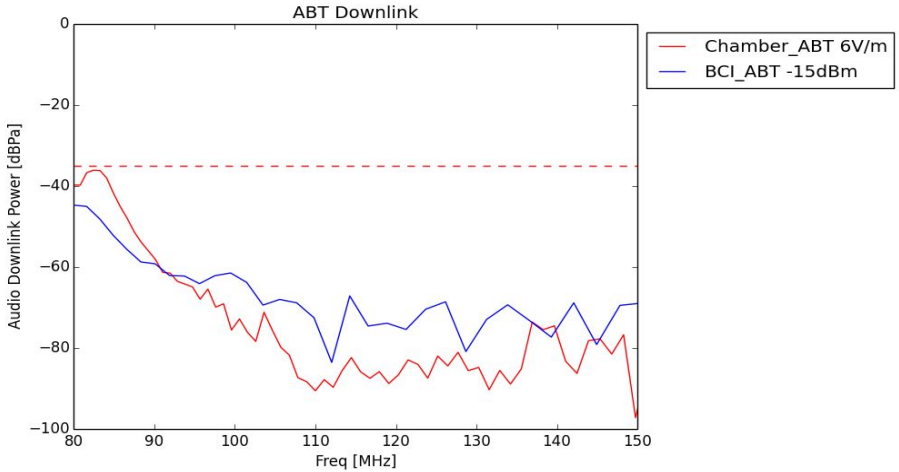
power_18_clo
power_18_far
power_18_wi

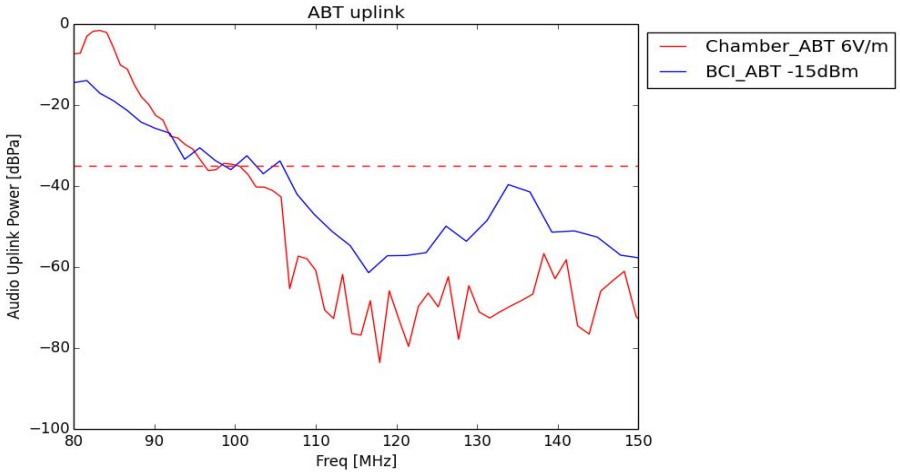
Comparison between Chamber ABT and BCI ABT





Comparison between Chamber ABT and BCI ABT





Audio Breakthrough (ABT) - Standard

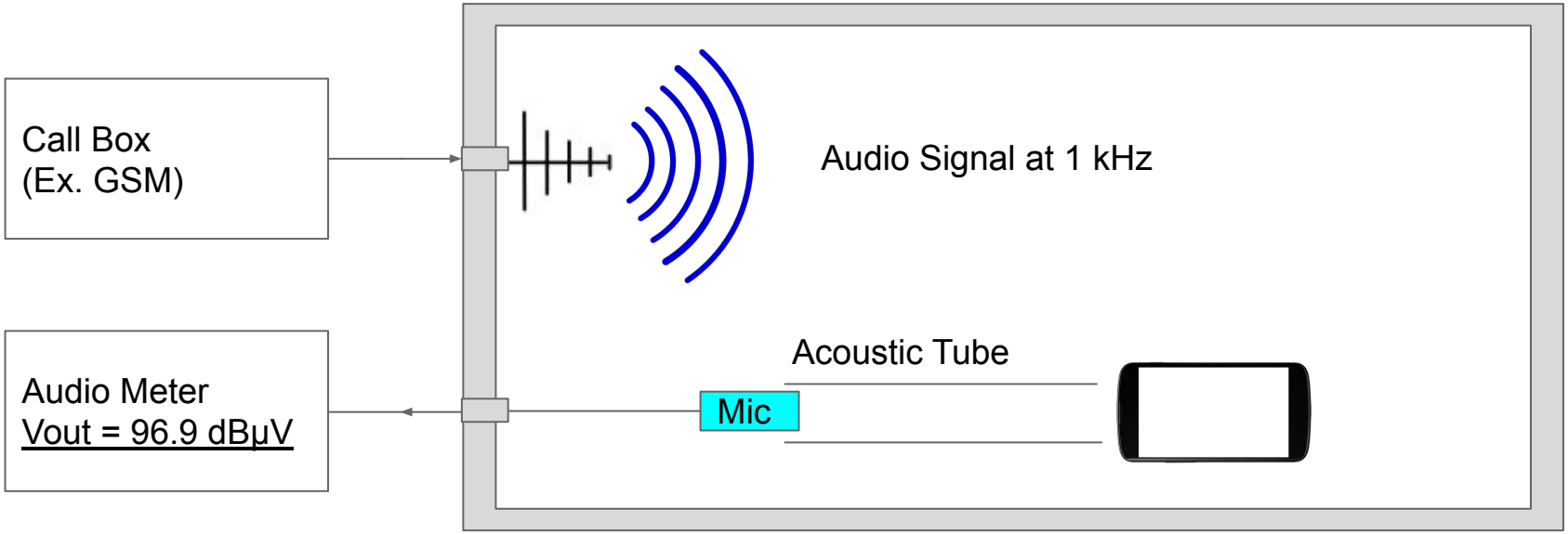
Handsfree Application

In ETSI EN 301 489-52,

> When an external loudspeaker is used, **the SPL from the external loudspeaker is higher** than that from the earpiece of the portable by a certain amount in order overcome a high ambient noise level. Two methods can be used to achieve the required SPL:
> - **the downlink reference level shall be increased** by the same amount in order to compensate for the
> difference in SPL; or
> - the distance between the loudspeaker and the measuring microphone shall be adjusted during the measurement procedure resulting in the required SPL.

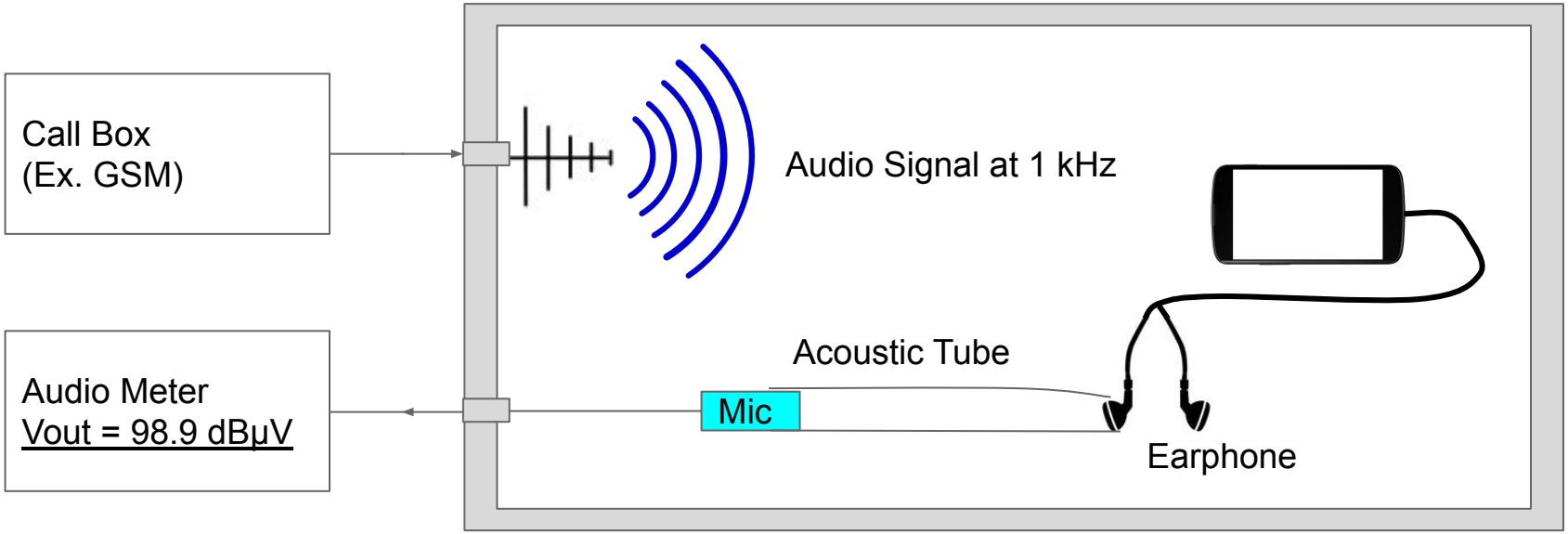
Audio Breakthrough (ABT) - Standard

Reference Level Measurement **with earphone - Step 1**



Audio Breakthrough (ABT) - Standard

Reference Level Measurement **with earphone - Step 2**



Audio Breakthrough (ABT) - Standard

Reference Level Measurement **with earphone (R&S TS9982 App Note)**

Mobile Speaker Audio Level = 96.902 dBµV

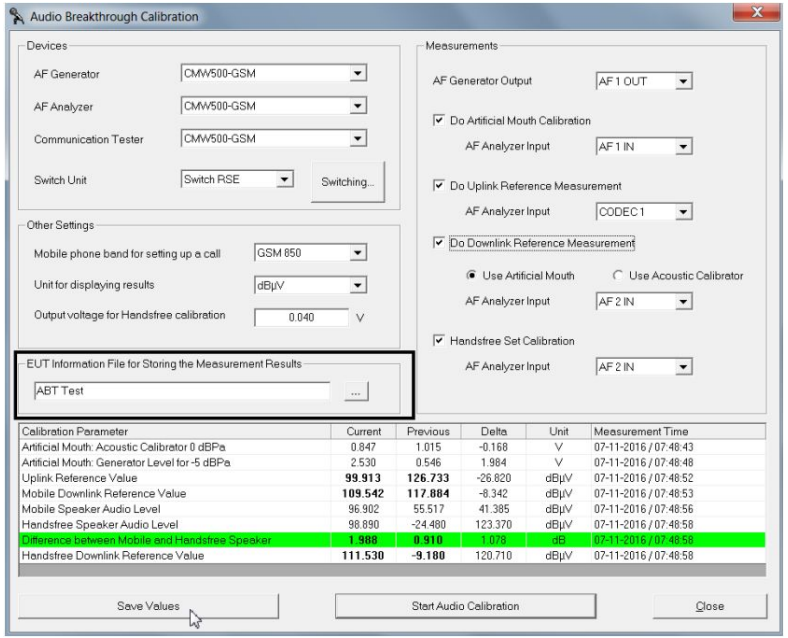
Handsfree Speaker Audio Level = 98.890 dBµV

Difference between Mobile and Handsfree Speaker = 1.988 dB

Handsfree Downlink Reference Value

= Mobile Downlink Reference Value + Difference

= 111.53 dBµV



Audio Breakthrough (ABT) - Standard

Field Calibration - Number of points, amplifier thermostability, metallic box under the table

Freq Step = 1%

Distortion to 2kHz, 3kHz, and so on.

Acoustic Calibration

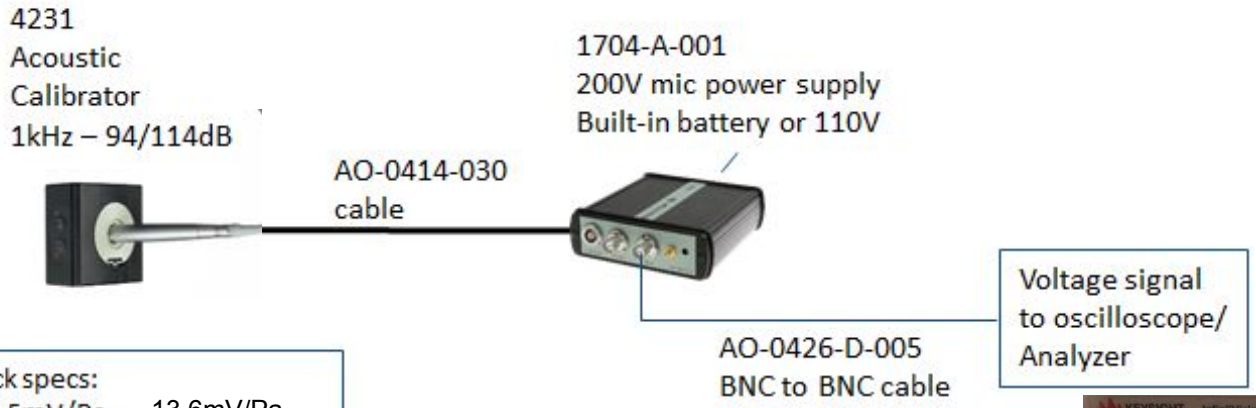
Mic Sensitivity, Different calibration steps, headphone positioning with artificial mouth

Audio Measurement/Susceptibility of Audio Box

Position Phone/Cables

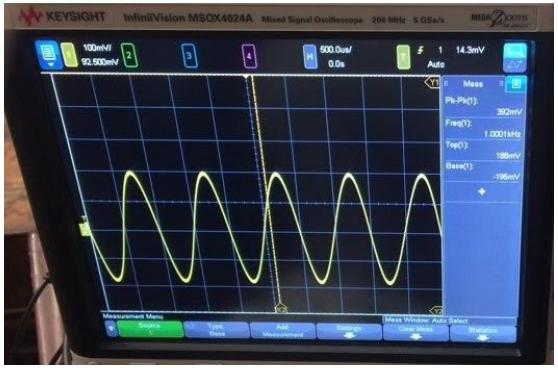
Echo Cancellation - Max Hold, Turn on/off between Freq Steps, Clear the data measure it again, Dwell Time

ABT - B&K Microphone

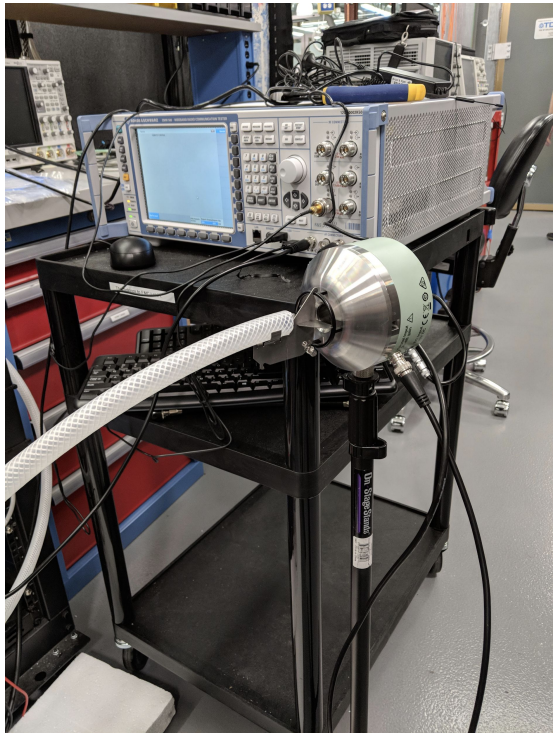


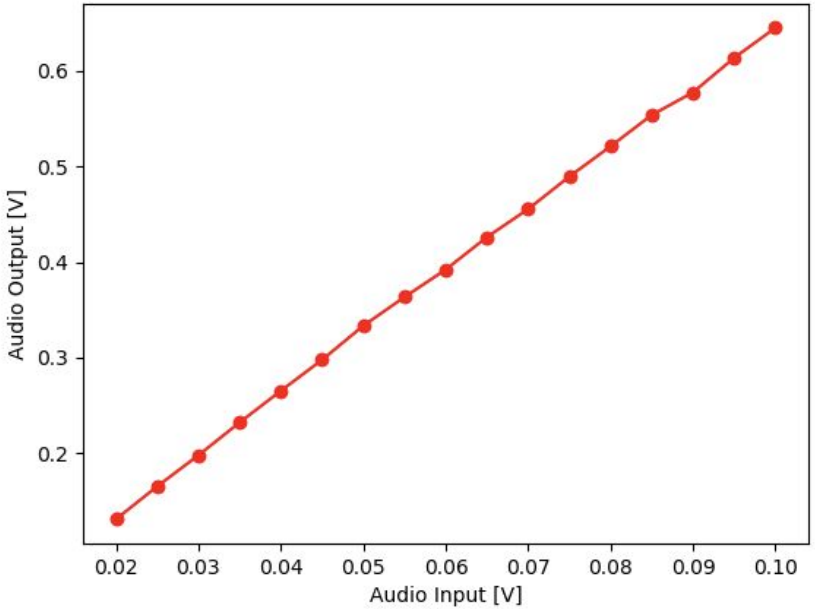
4192 Mic quick specs:
Sensitivity: ~~12.5mV/Pa~~ → 13.6mV/Pa
Frequency Range: 3.15-20kHz
Dynamic Range: 19-162 dB
Operation temperature: -30 to 300deg C
Polarization: 200V

Preamp = x10 gain
Measurement Results = 392mV ptp
Sensitivity : 13.6mV$_{RMS}$/Pa = 19.23mVpeak/Pa
Expected Results = 385mV ptp



Mouth Simulator/Acoustic Tube/Microphone Test





ABT - CMW500 Remote Control Comm

Serial Communication of Single Tone Measurement Using **Matlab/Python and USB port**

Code

```
55  # Start the audio measurement.
56  # Query the average and extreme measurement results from the result table.
57  \
58  cmw.write('FETCh:AUDio:MEAS:ANALog:SINGletone:Average?');
59  current_temp = cmw.read()
60  current = current_temp.strip().split(',');
61
62  print('READ VALUE')
63
64  print "Reliability:", current[0]
65  print("THD Percent[%]: {:04.2f}" .format(float(current[1])))
66  print("THD dB: {:.5}" .format(float(current[2])))
67  print("THD + N: {:.5}" .format(float(current[3])))
68  print("SINAD: {:.5}" .format(float(current[4])))
69  print("SNR: {:.5}" .format(float(current[5])))
70  print("DC Level: {:.5}" .format(float(current[6])))
71  print("Frequency: {:.5}" .format(float(current[7])))
72  print("Weight Level RMS: {:.5}" .format(float(current[8])))
73  print("Band Level RMS: {:.5}" .format(float(current[9])))
74  print("Weight Level Peak: {:.5}" .format(float(current[10])))
75  print("Band Level Peak: {:.5}" .format(float(current[11])))
76
77  cmw.write('FETCh:AUDio:MEAS:ANALog:STATe?');
78
79  state = cmw.read()
80  print('State:', state)
```

Output

```
jhjang-macbookpro:python_cmw500 jhjang$ python cmw_audio_v0
('Connected to:', u'Rohde&Schwarz,CMW,1201.0002k50/164807,3.7.10\n')
('Count :', u'5\n')
('Dfreq :', u'1000\n')
('Generator:', u'ON\n')
READ VALUE
Reliability: 0
THD Percent[%]: 0.03
THD dB: -84.135
THD + N: 0.536
SINAD: 75.908
SNR: 77.533
DC Level: 0.00012449
Frequency: 1012.9
Weight Level RMS: 0.99786
Band Level RMS: 0.99818
Weight Level Peak: 1.4234
Band Level Peak: 1.4094
('State:', u'RUN\n')
```

CMW500 - Uplink/Downlink

Setup Uplink and Downlink successfully

GSM - FRV1 - speech instead of echo

Select Audio Measurement - Microphone and Speaker Test

Uplink - Digital Measurement [Unit - Full Scale]
Downlink - Analog Measurement [Unit - V]

Next Step - Audio Calibration with the setup, remove the earphone and do the better sealings (Max : -15), R&S how to set the spectrum (data points)

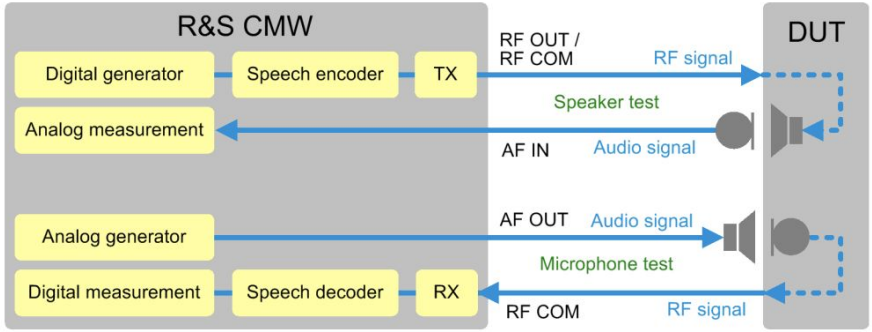


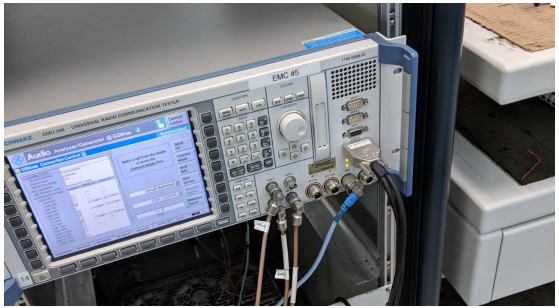
Figure 3-3: Test setup for microphone and speaker test

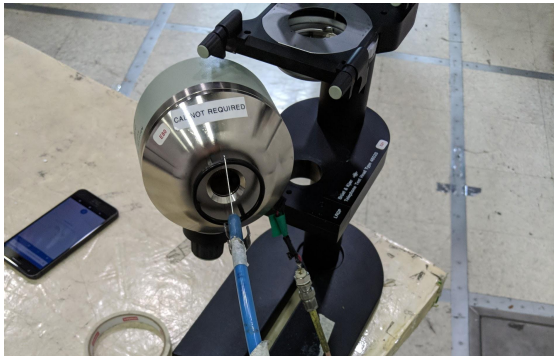
Third party Labs

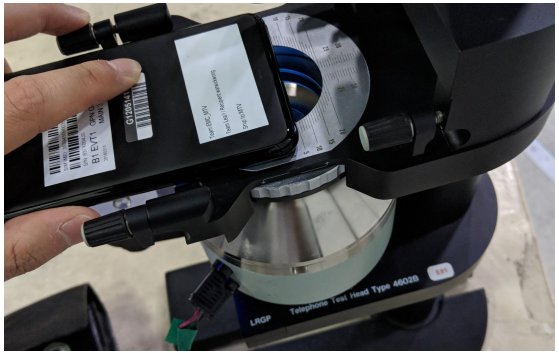
Some labs use CMW200 and separate codec cable for speech analysis.

They use artificial mouth for downlink calibration, but not the calibrator.

They use artificial mouth for uplink calibration (Many variations between the phone).

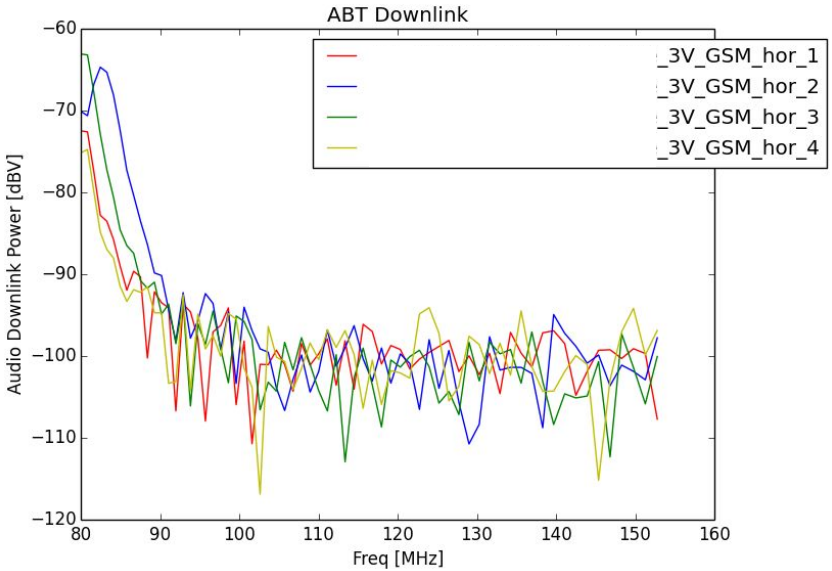




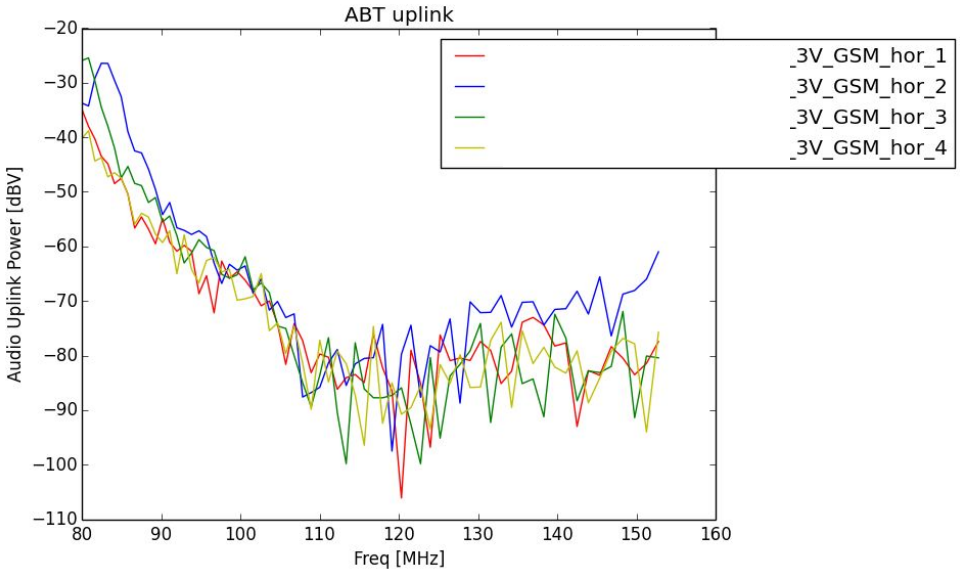


3 V/m Field Strength

Downlink

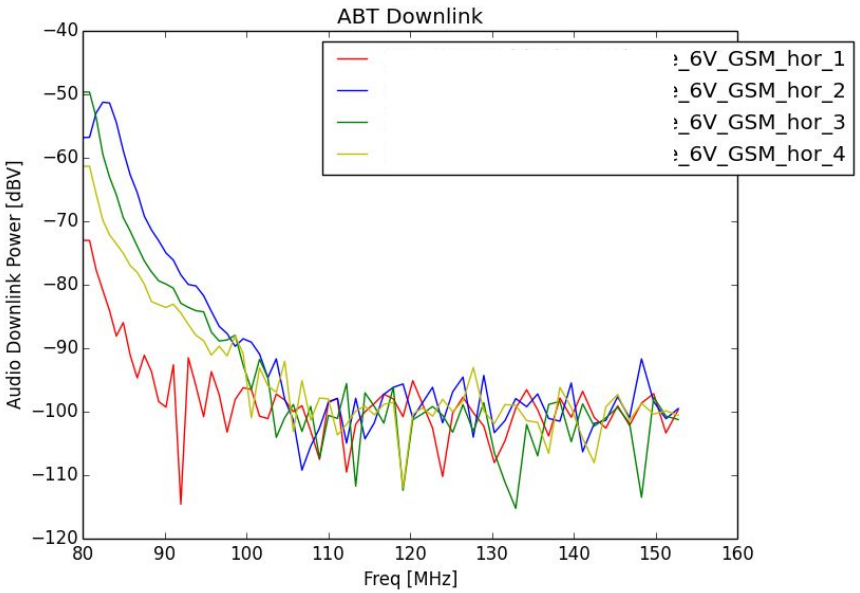


Uplink

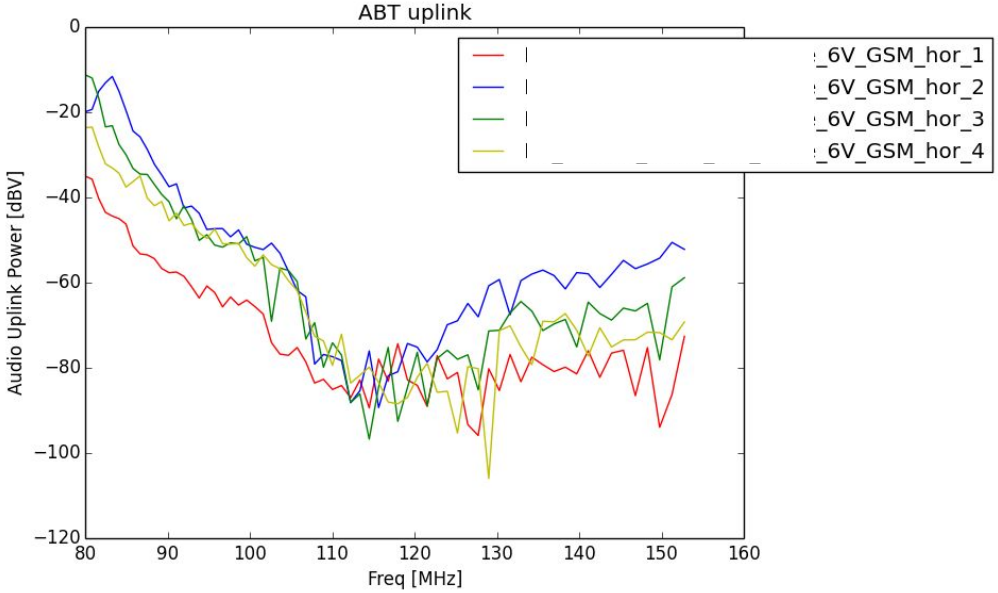


6 V/m Field Strength

Downlink

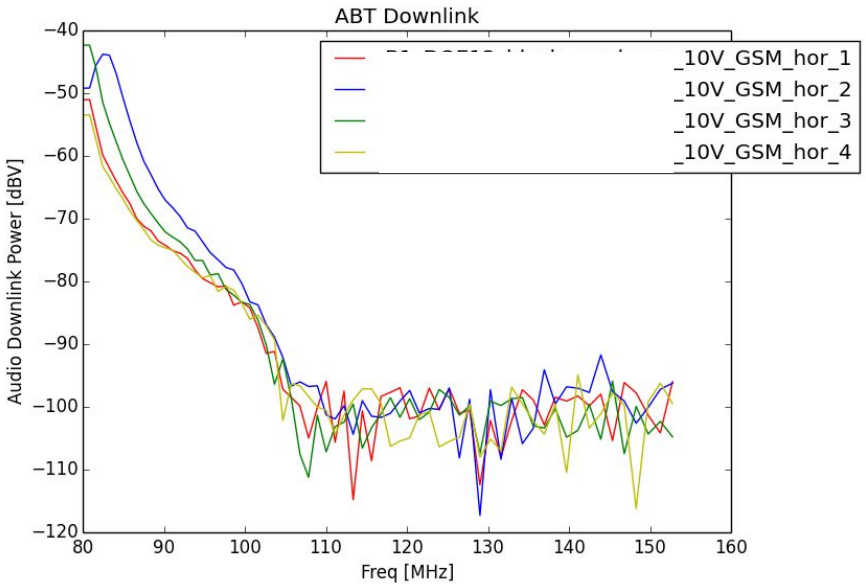


Uplink

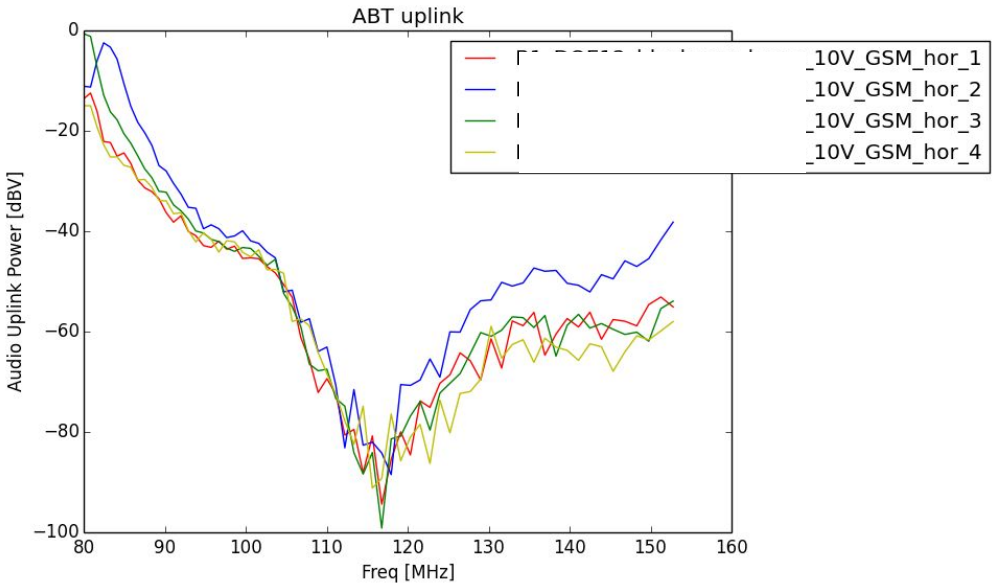


10 V/m Field Strength

Downlink

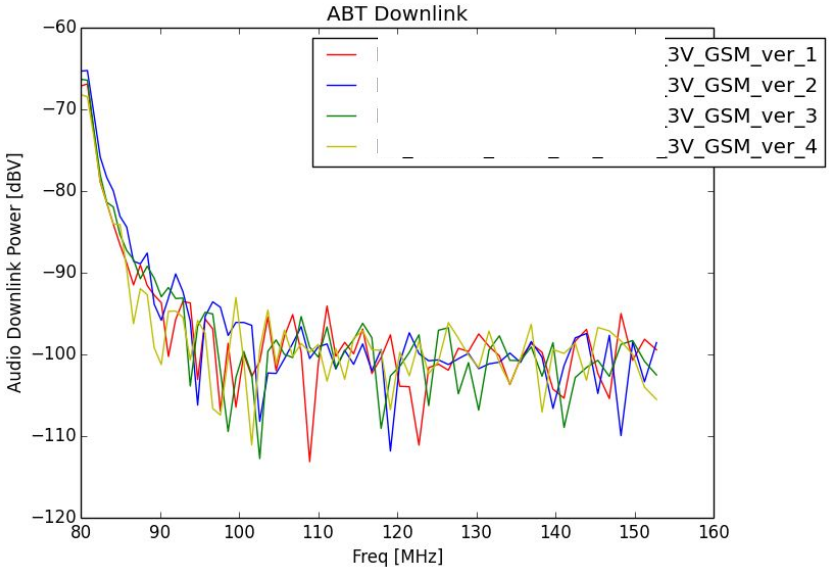


Uplink

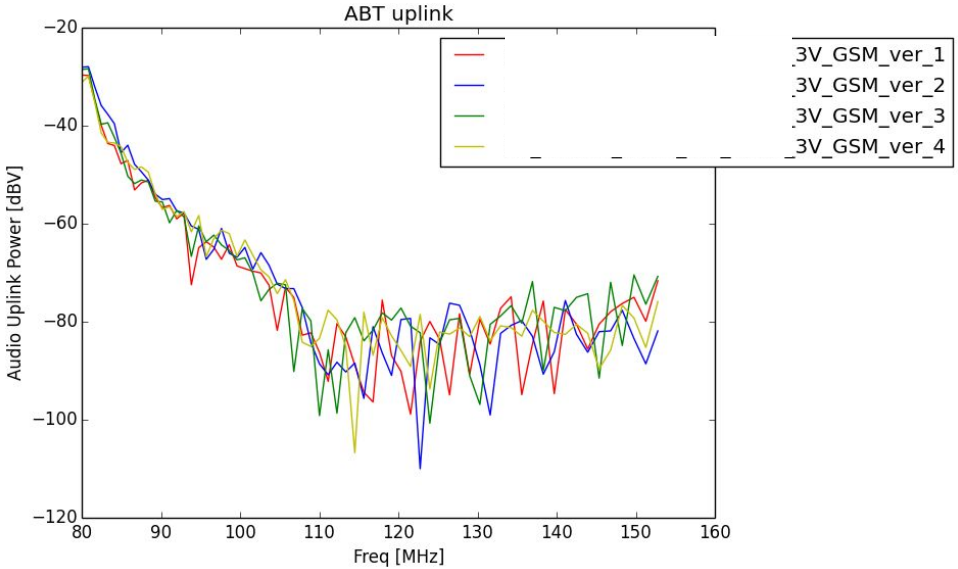


3 V/m Field Strength

Downlink

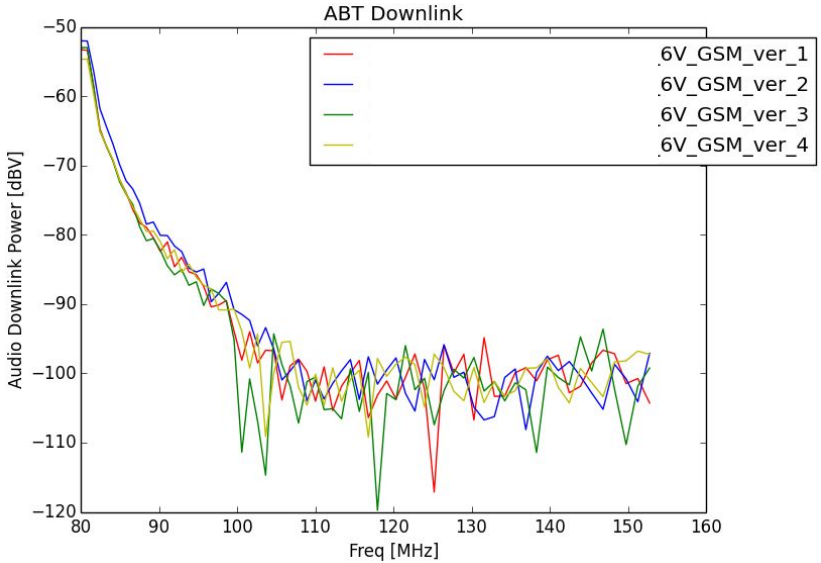


Uplink

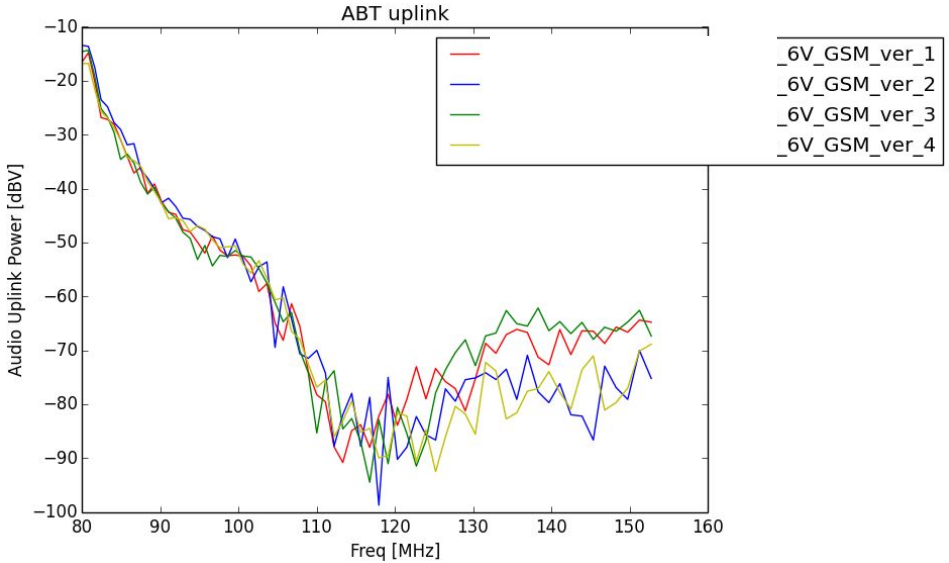


6 V/m Field Strength

Downlink

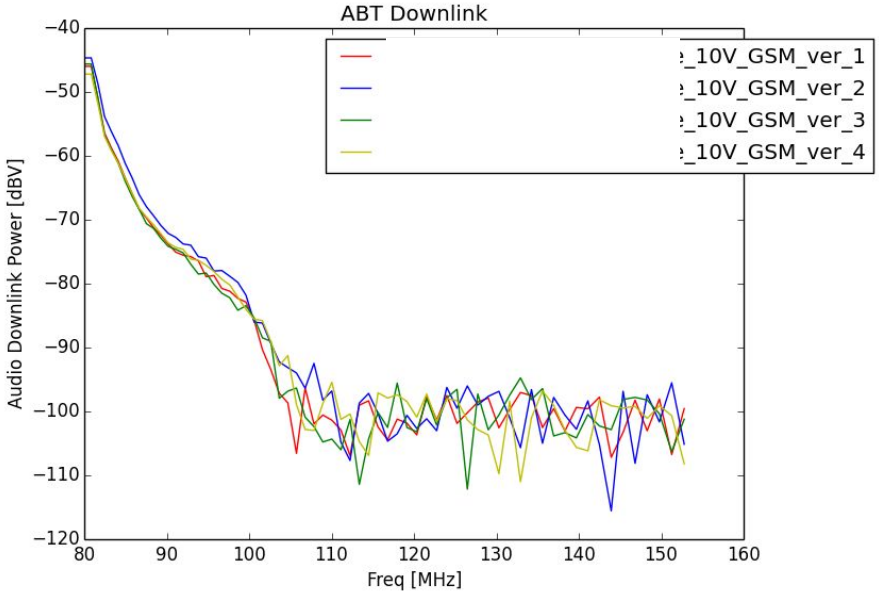


Uplink

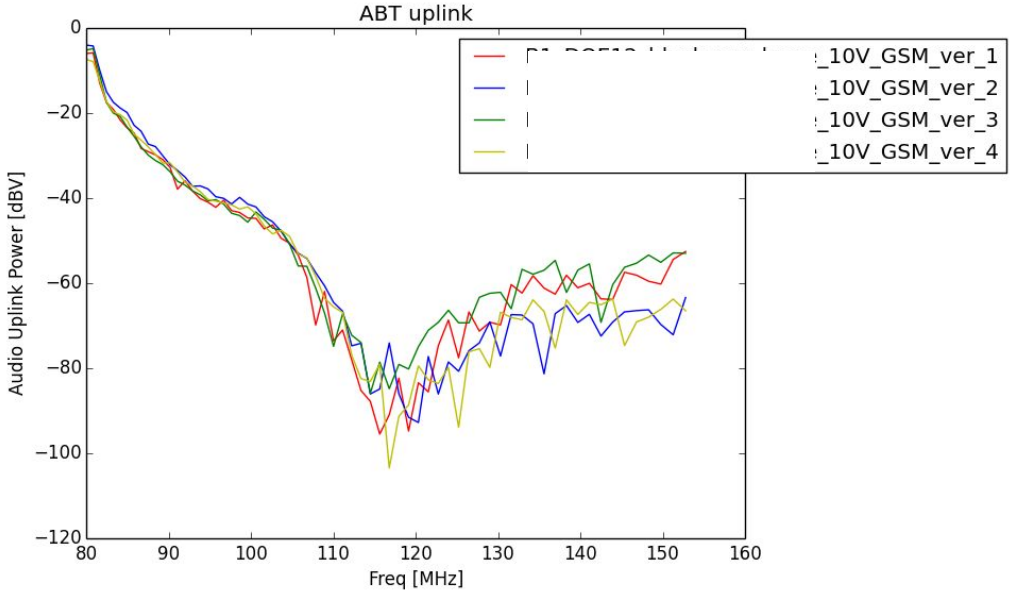


10 V/m Field Strength

Downlink

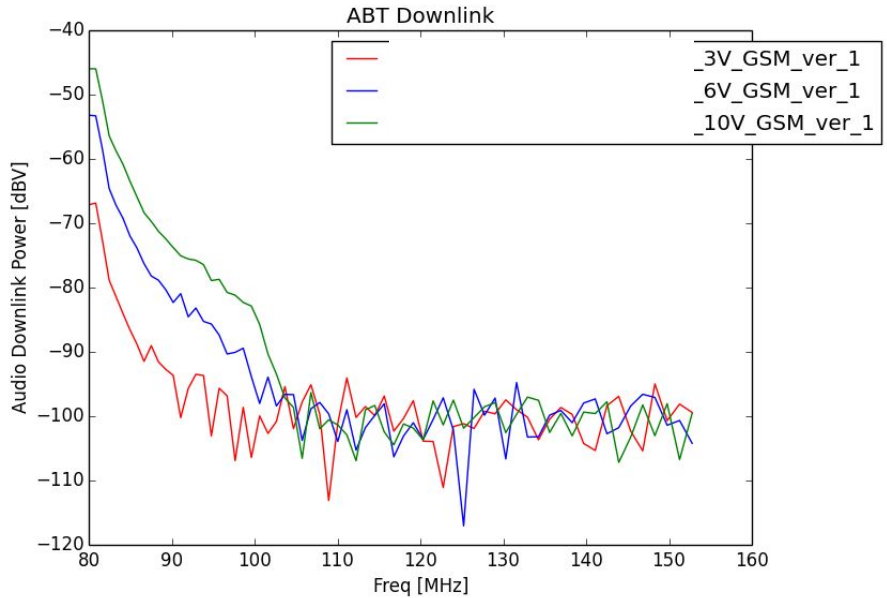


Uplink

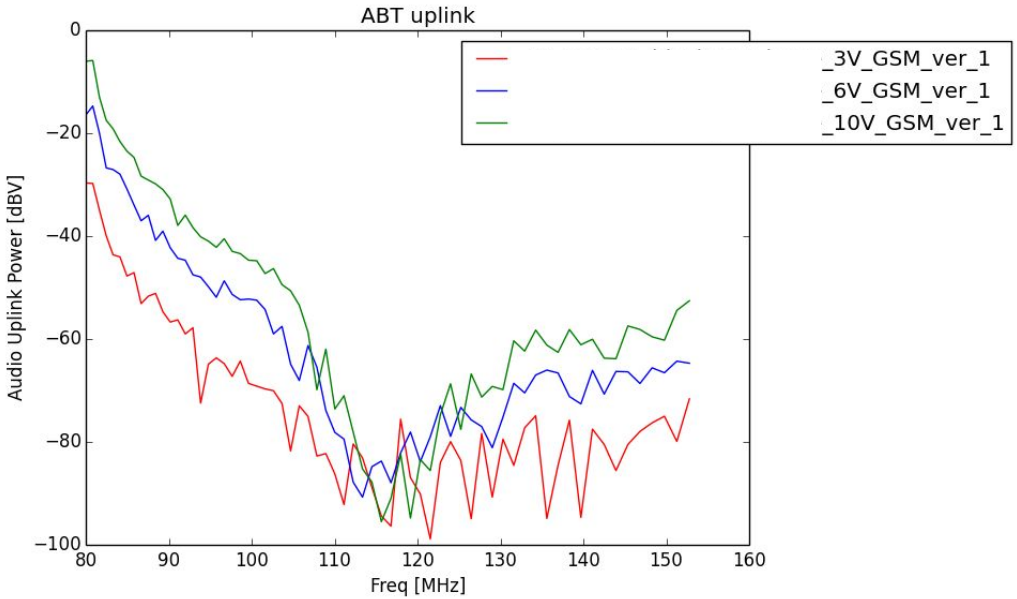


Vertical Comparison

Downlink

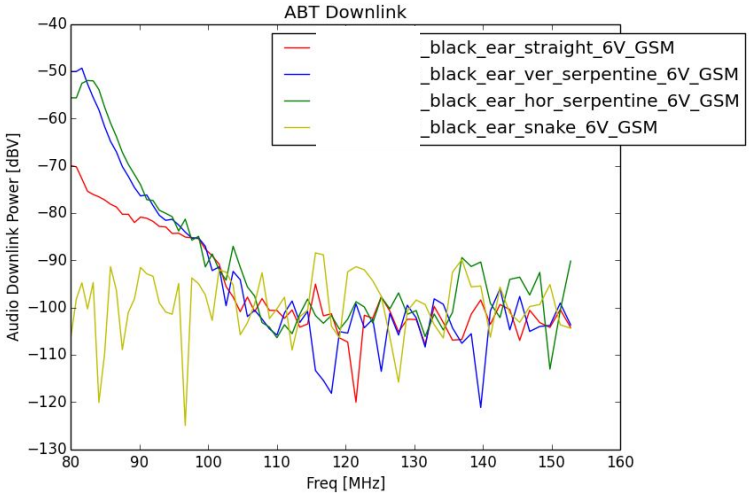


Uplink

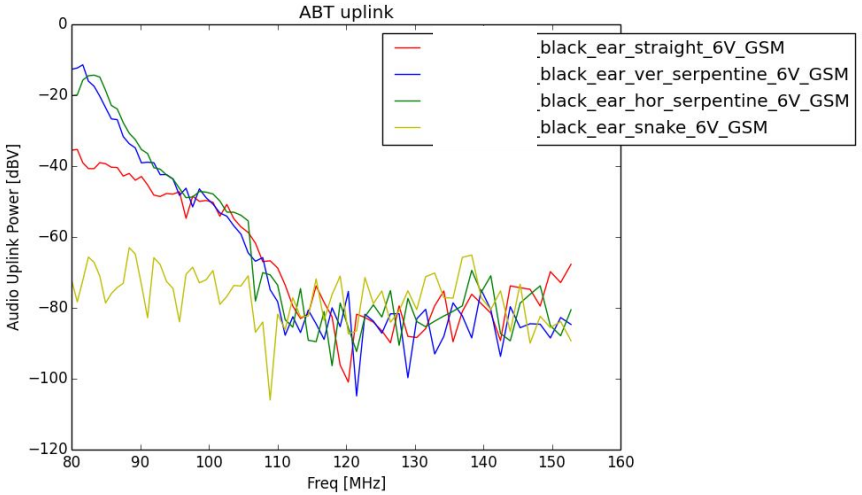


6 V/m Field Strength

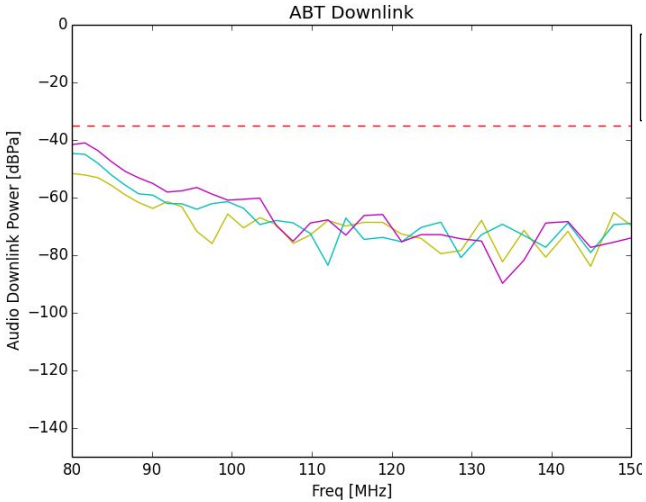
Downlink

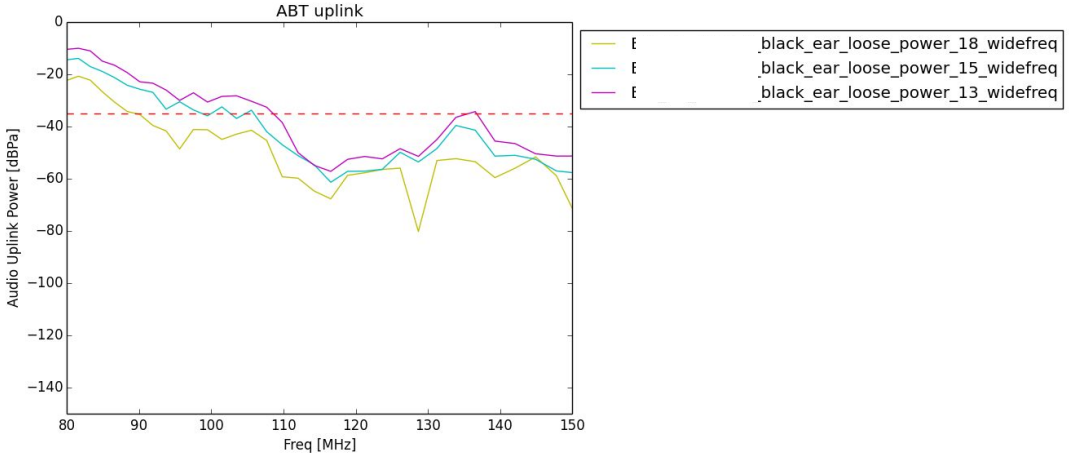


Uplink

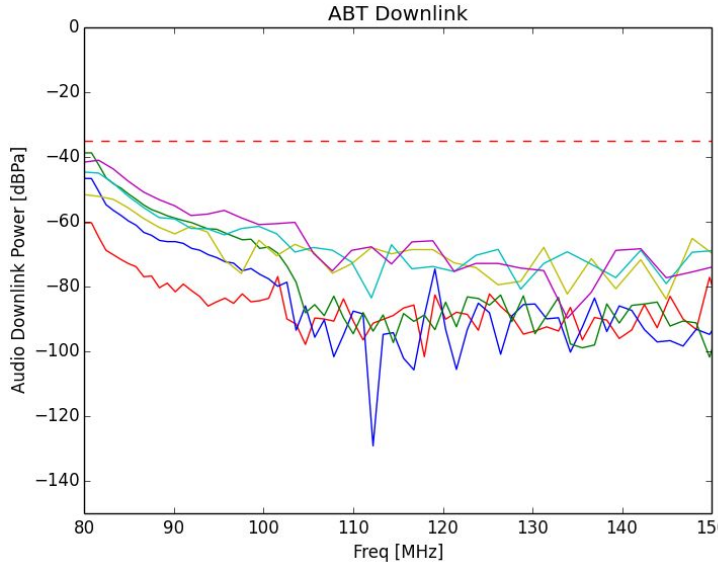


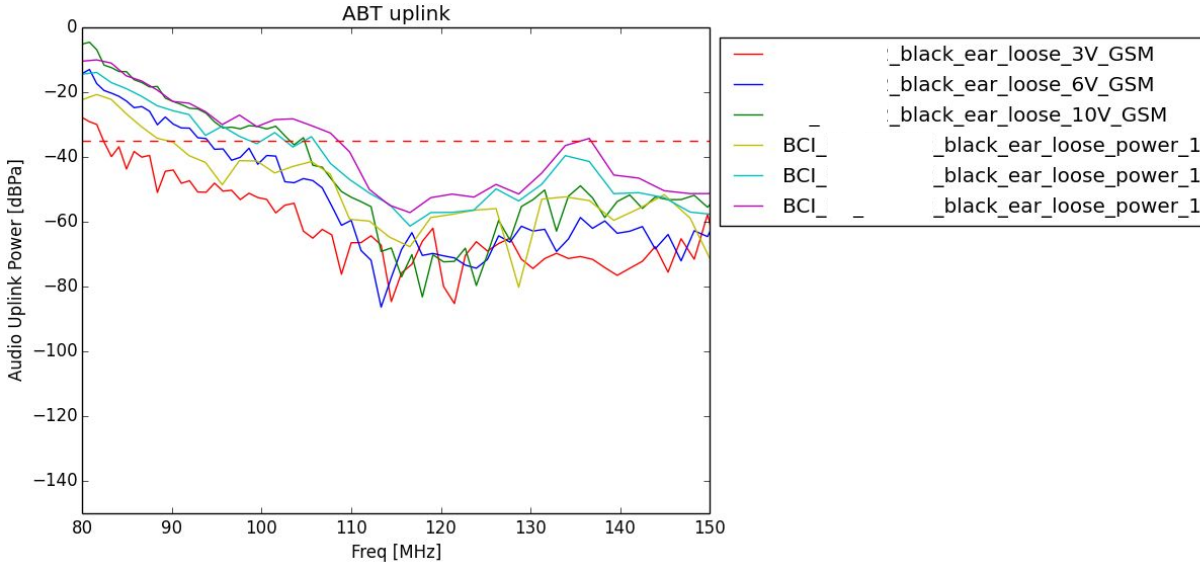
Comparison between Chamber ABT and RCI ABT



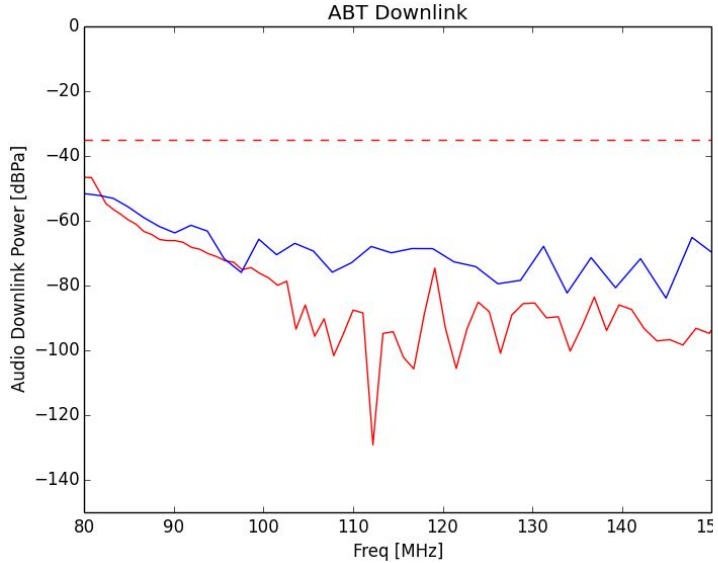


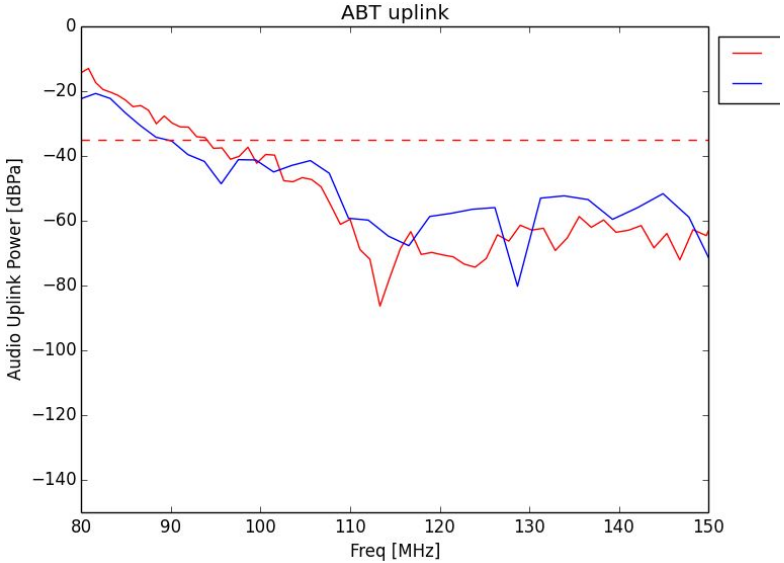
Comparison between Chamber ABT and BCI ABT

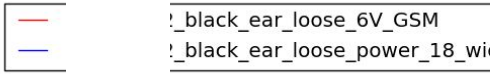




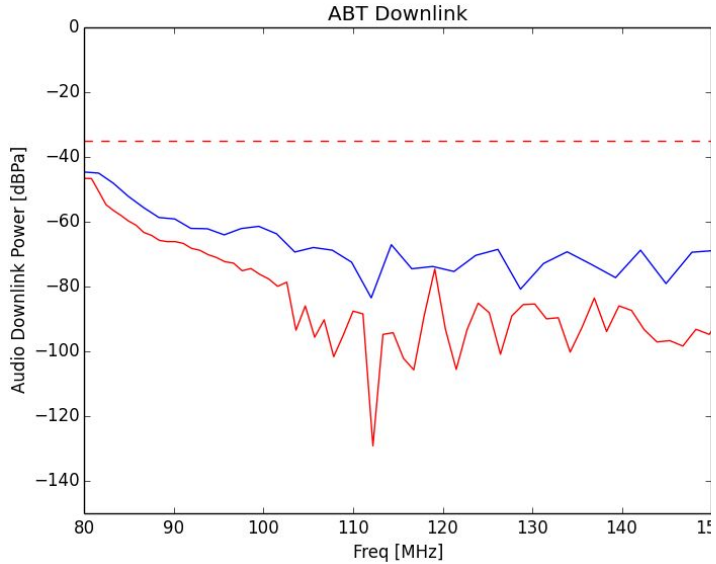
Comparison between Chamber ABT and BCI ABT

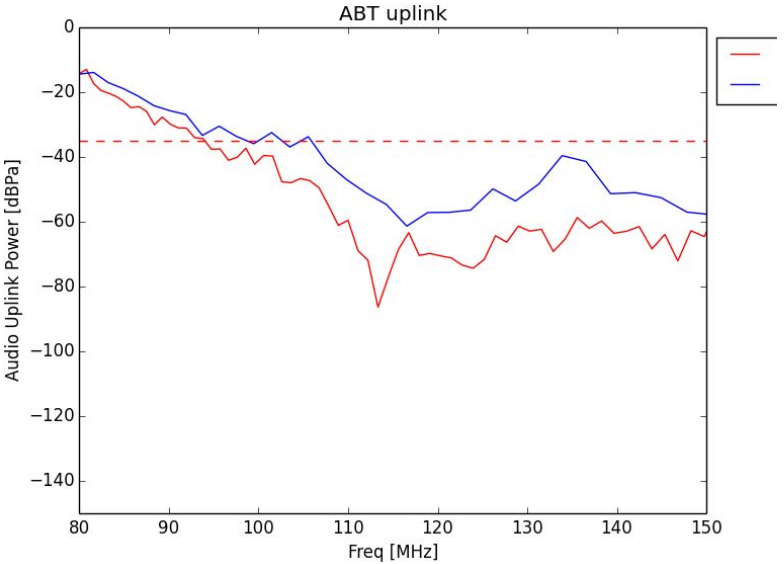


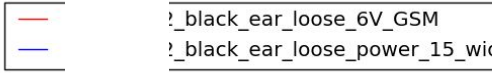




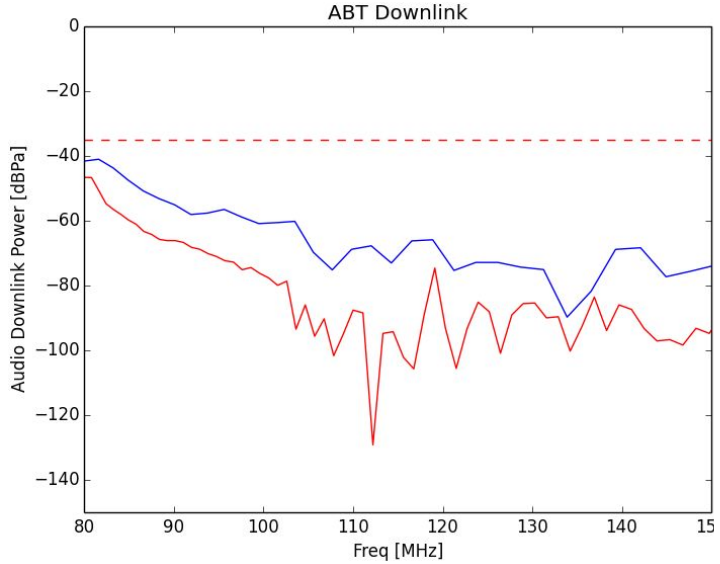
Comparison between Chamber ABT and BCI ABT

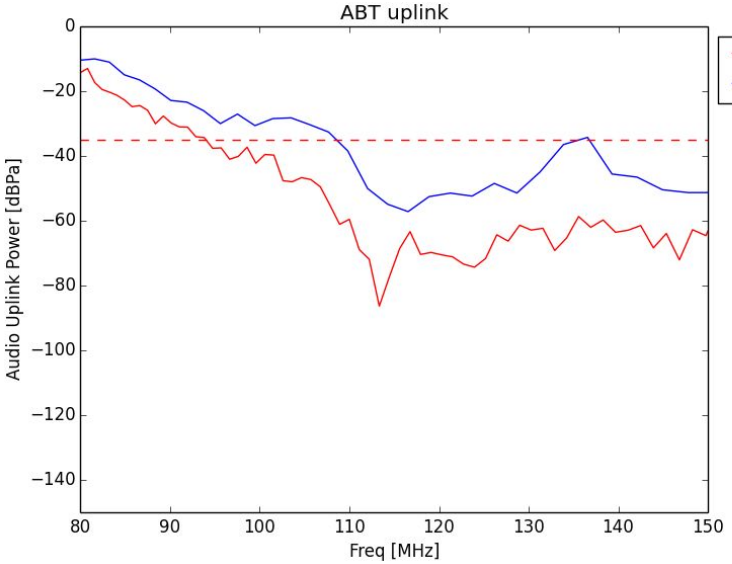


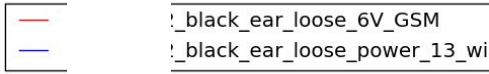




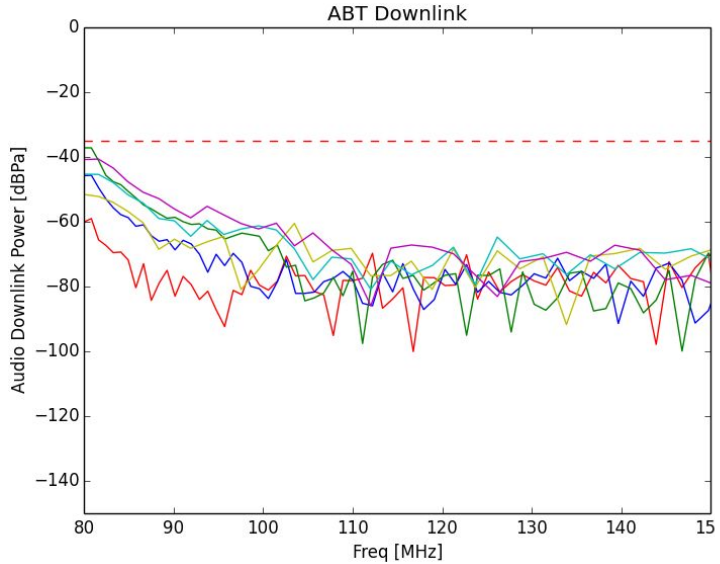
Comparison between Chamber ABT and BCI ABT

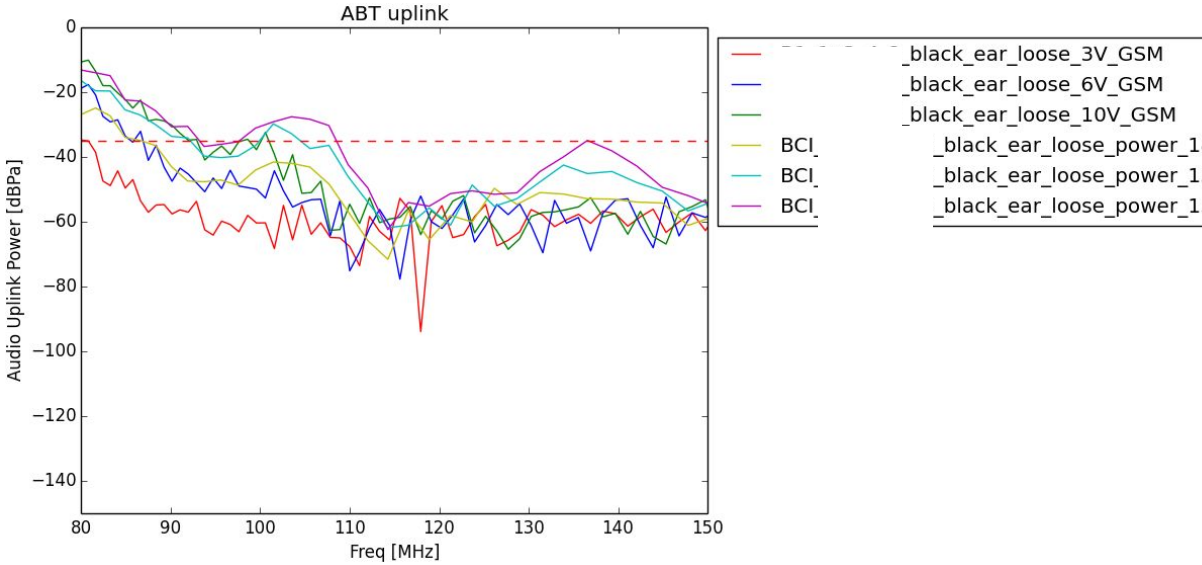




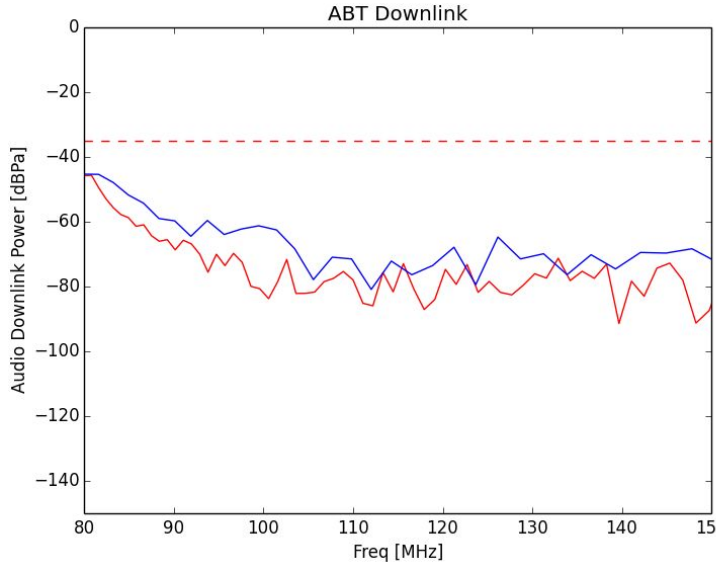


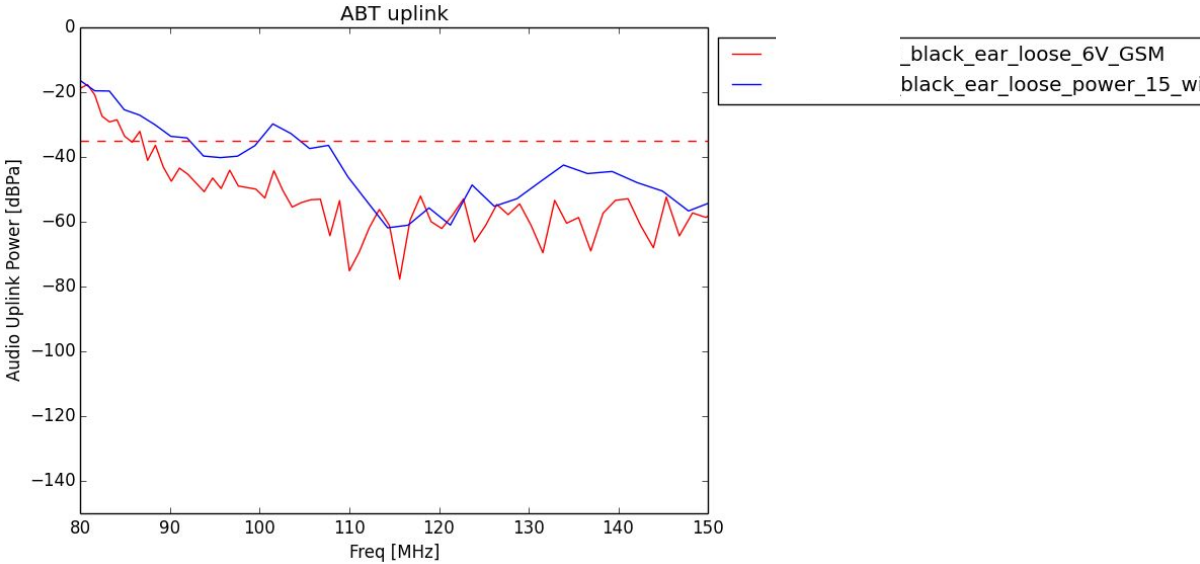
Comparison between Chamber ABT and BCI ABT



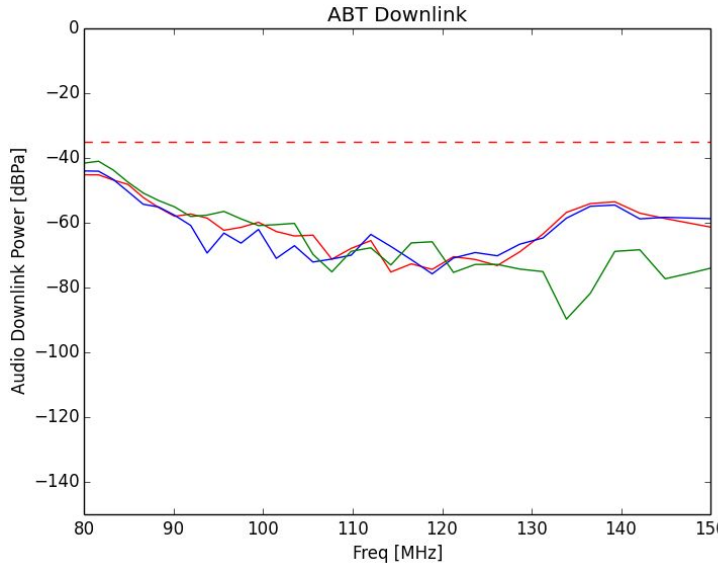


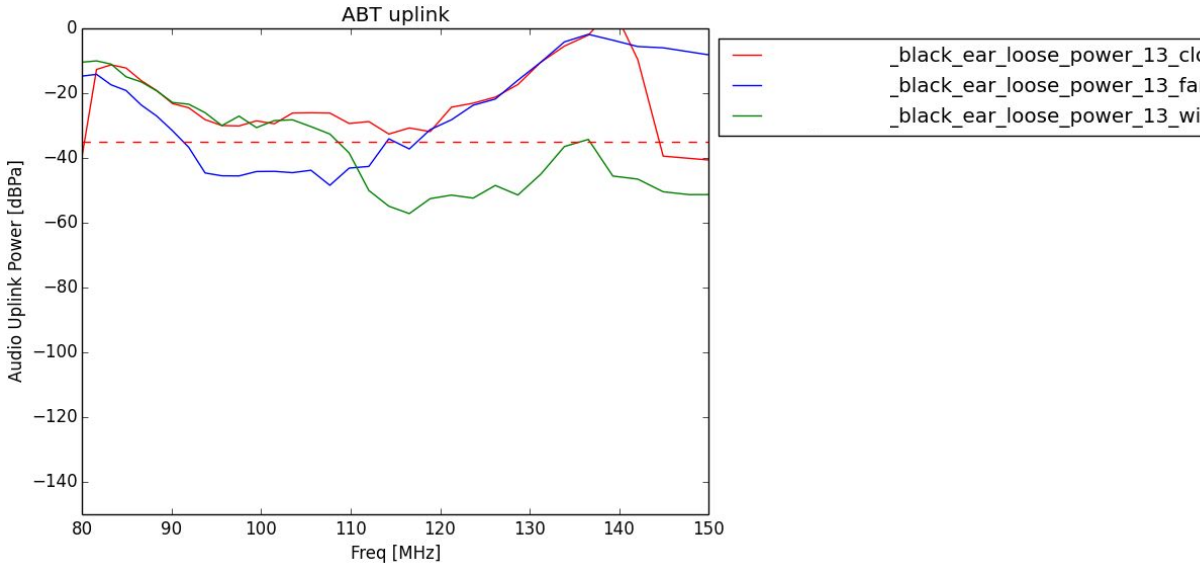
Comparison between Chamber ABT and BCI ABT



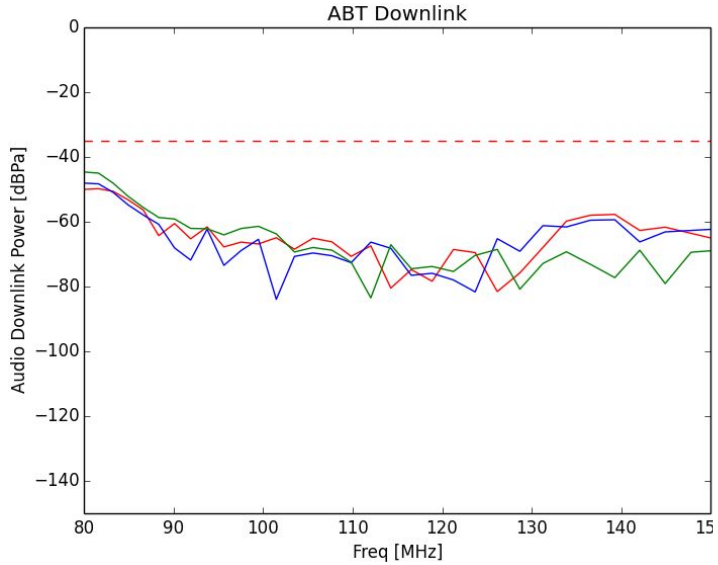


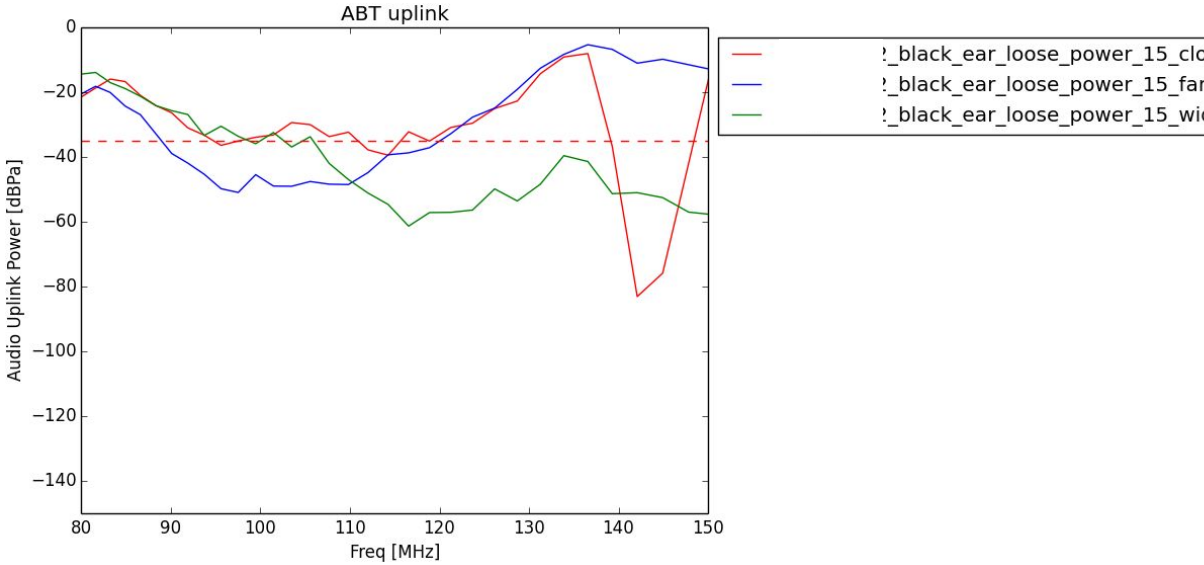
Comparison between Chamber ABT and BCI ABT





Comparison between Chamber ABT and BCI ABT





Comparison between Chamber ABT and BCI ABT