Recording Speech
During Magnetic Resonance Imaging

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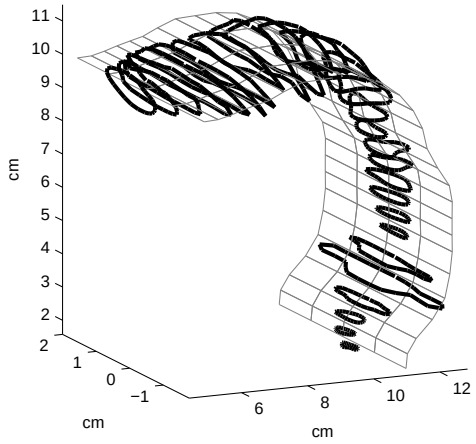
Background

$$\begin{cases} \Phi_{tt} = c^2 \Delta \Phi & \text{for } (\mathbf{r}, t) \in \Omega \times \mathbb{R}, \\ \Phi = 0 & \text{for } (\mathbf{r}, t) \in \Gamma_1 \times \mathbb{R}, \\ \frac{\partial \Phi}{\partial \nu} = 0 & \text{for } (\mathbf{r}, t) \in \Gamma_2 \times \mathbb{R}, \text{ and} \\ \Phi_t + c \frac{\partial \Phi}{\partial \nu} = 2 \sqrt{\frac{c}{\rho_0}} u & \text{for } (\mathbf{r}, t) \in \Gamma_3 \times \mathbb{R}, \end{cases}$$

(a)



(b)

Figure 1: (a) The wave equation model and (b) a sample vowel geometry

- The main goal is to simulate vowels based on a wave equation model.
- We need accurate anatomic data and simultaneously recorded sound to validate the simulation results.

Sound measurements: What would we like to get?

- The fundamental frequency F0, . . .
- F1, F2, F3 and, if possible, F4 . . .
- . . . and their bandwidths . . .
- . . . before, after and during the MR imaging sequence.
- Access to clean speech signal in real time.

Sound measurements: What’s the problem then?

- No metal allowed inside the MRI main coil.
- No ferromagnetic material allowed inside the MRI room.
- All electronics in the MRI room have to be RF-shielded.
- Strong acoustic noise (over 90 dB SPL) present during the imaging sequence.

What did we decide to do?

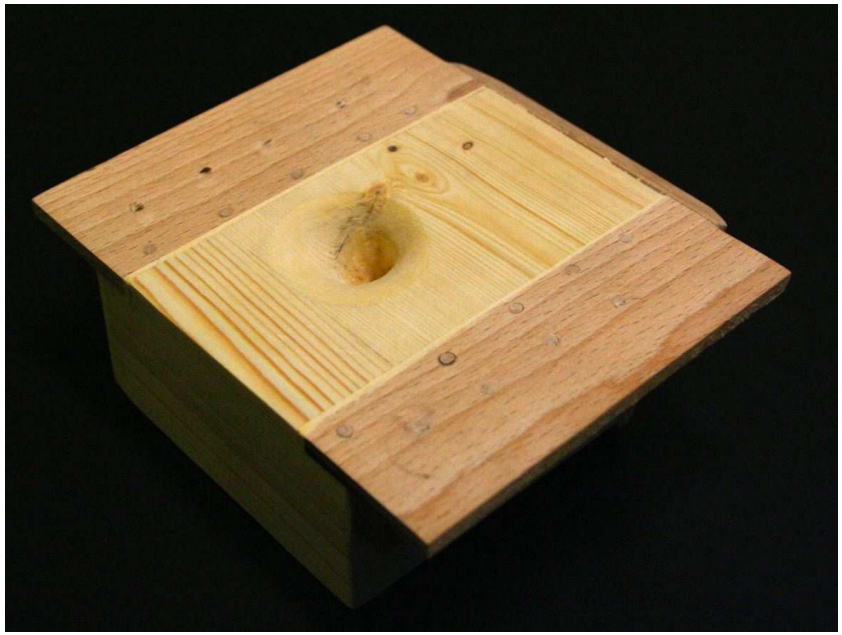
The recording system is based on three main design principles:

1. using air as signal medium when electronics can not be used,
2. using real-time analog electronics for first stages of signal processing, and
3. using DSP for post-processing.

Sound collector

There is a two channel sound collector in our system. One channel is for noise and the other for the contaminated speech.

(a)



(b)

Figure 2: The sound collector seen from (a) above and (b) below

Acoustic wave guides

A two channel acoustic wave guide leads to a shielded microphone array in the MRI room.

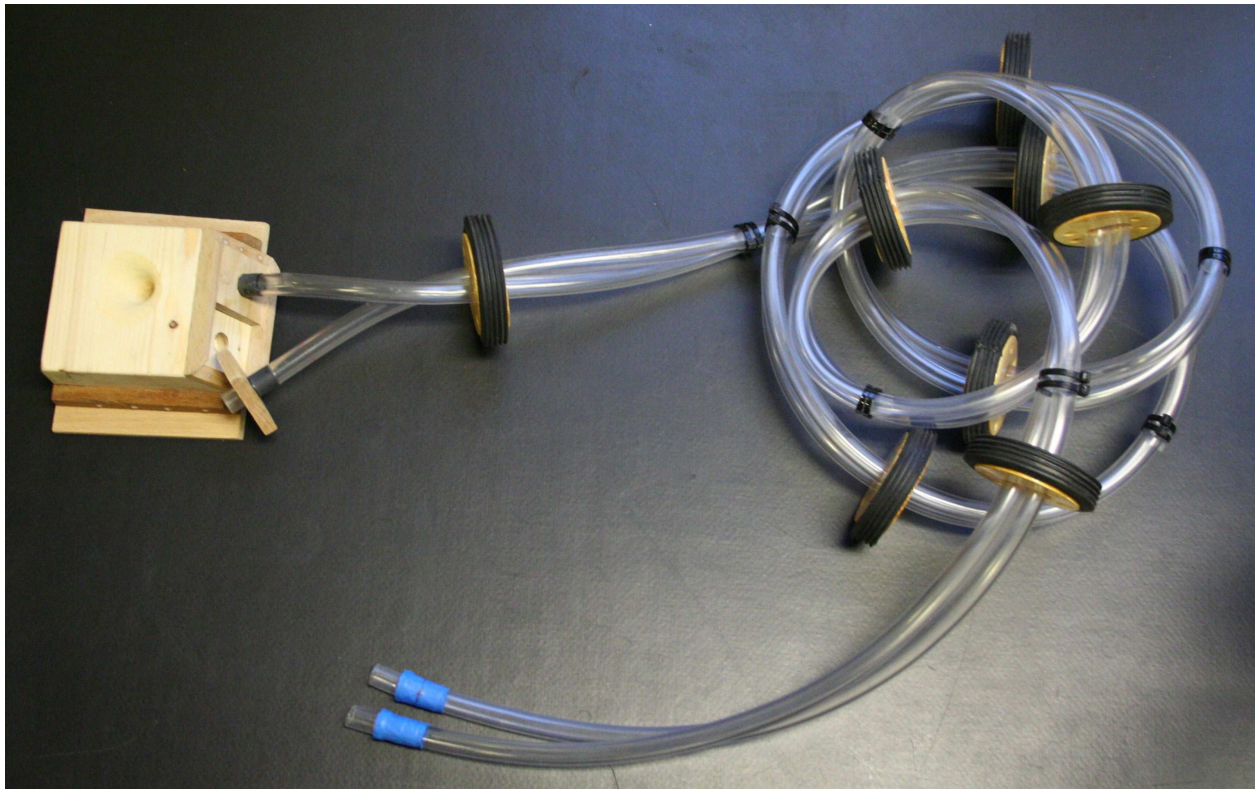


Figure 3: Acoustic wave guides connected to the sound collector

Microphone array

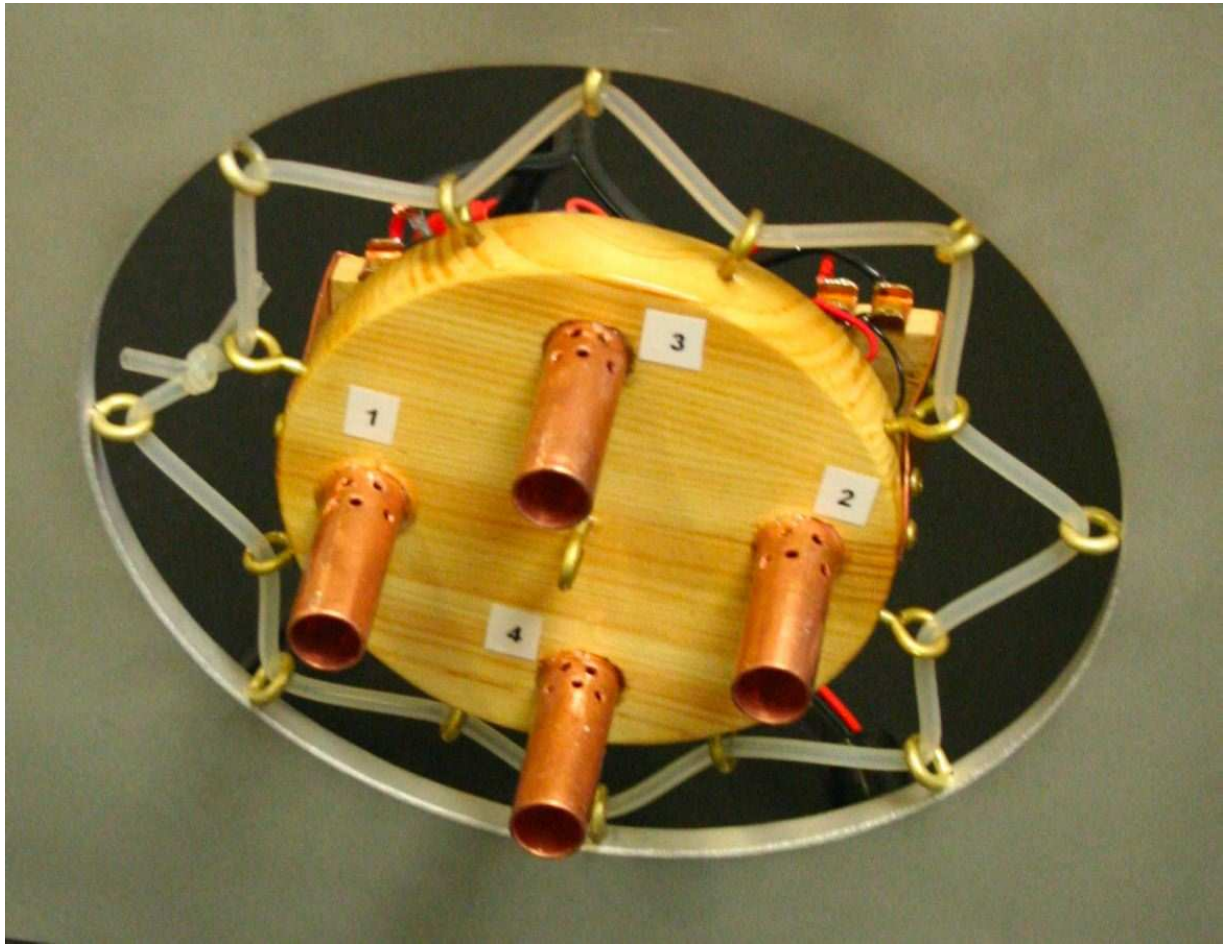


Figure 4: The microphone array consists of four microphones.

Faraday cage

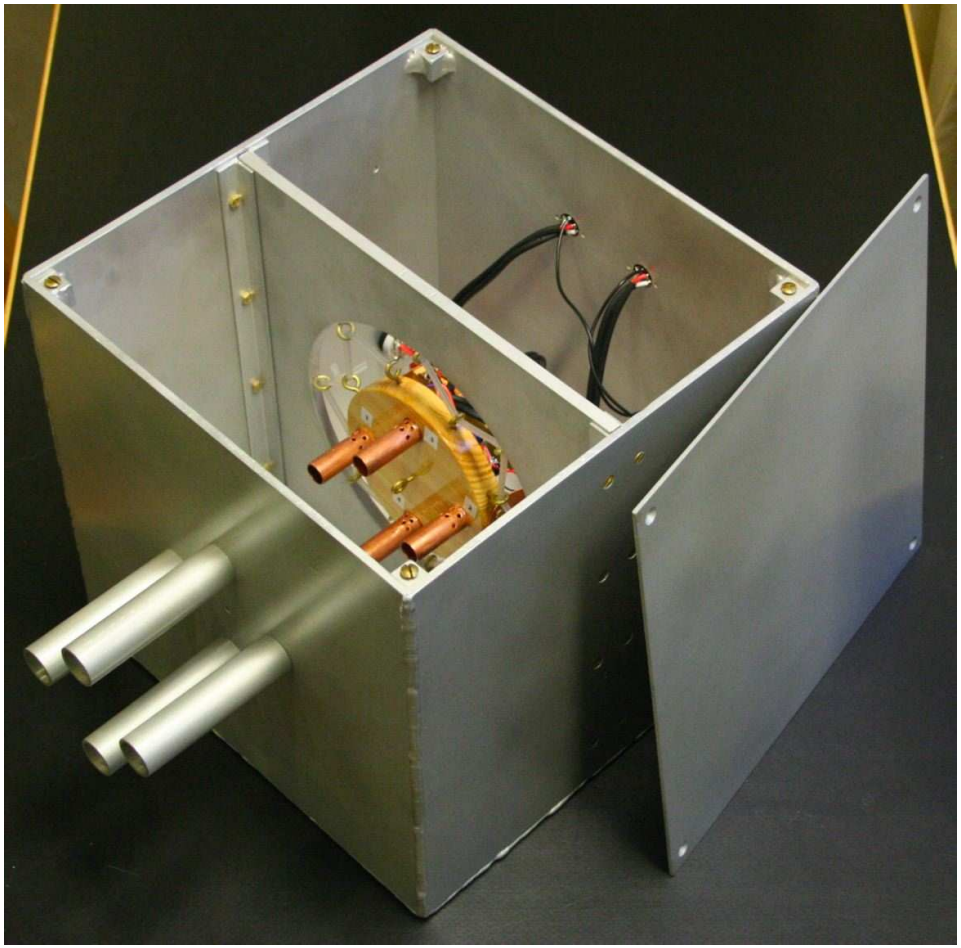
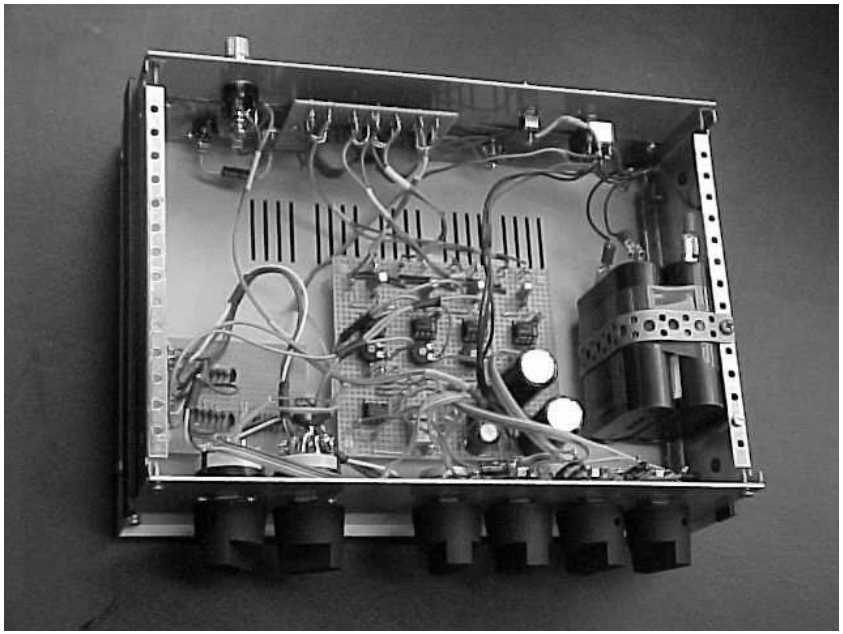


Figure 5: The microphone array inside the Faraday cage.

De-noising amplifier

- Analog electronics provide real time response.
- Overvoltage and RF shielded inputs
- One speech input channel
- Up to three noise input channels
- Optional low-pass filtering and independent amplifications



Tests: Acoustic wave guides

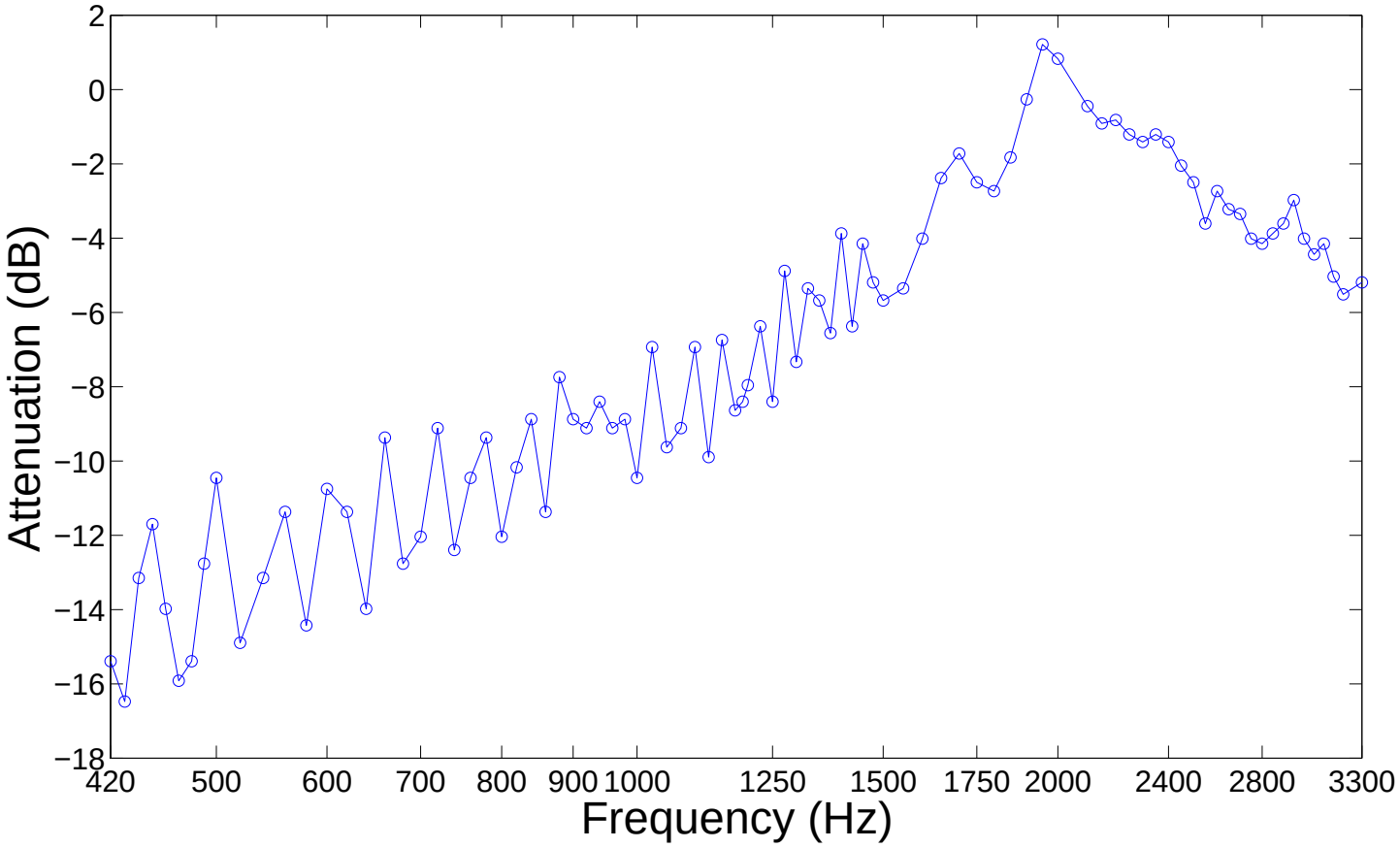


Figure 6: Frequency response of the acoustic wave guides

Tests: Does the noise cancellation work with acoustic components?

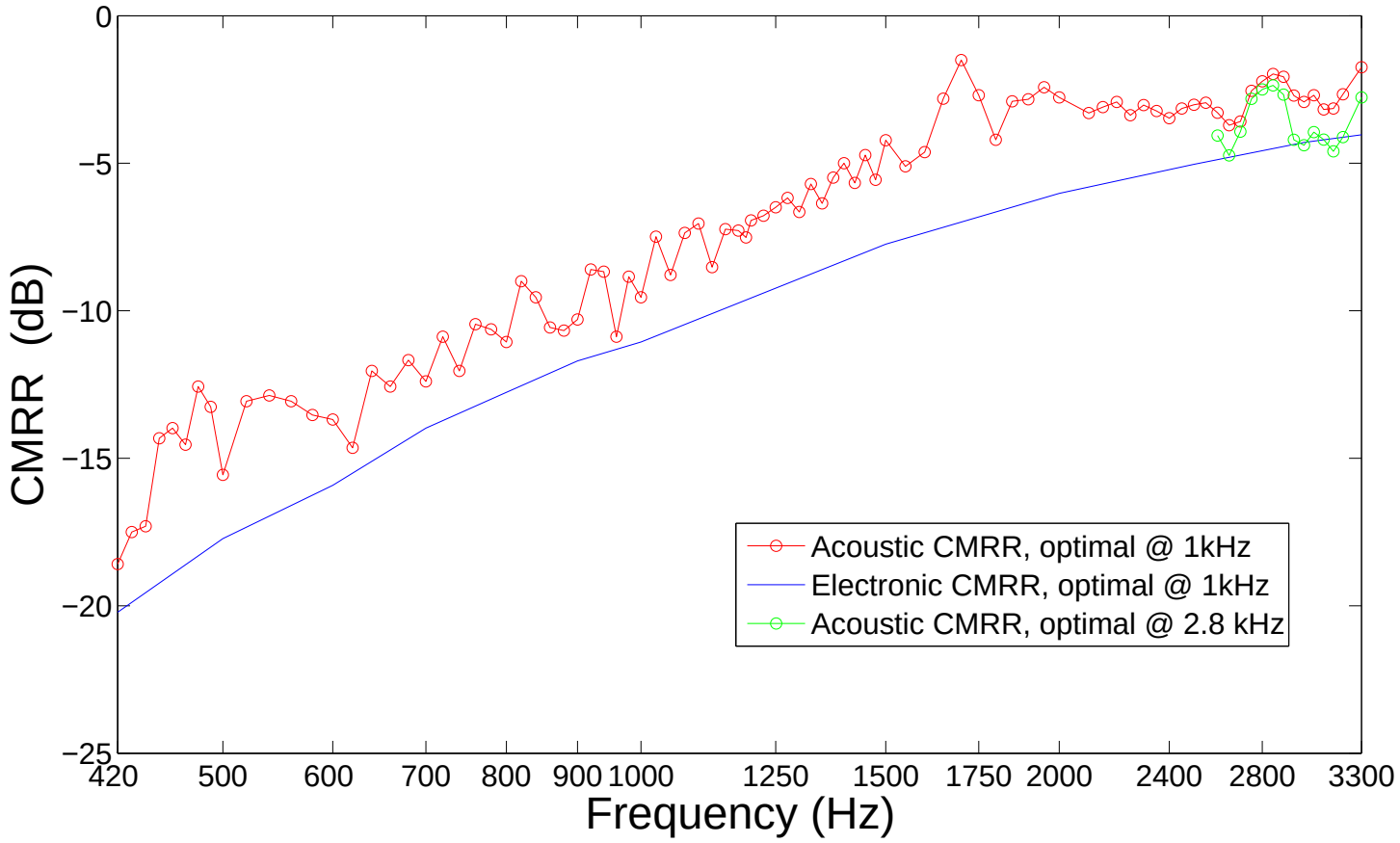
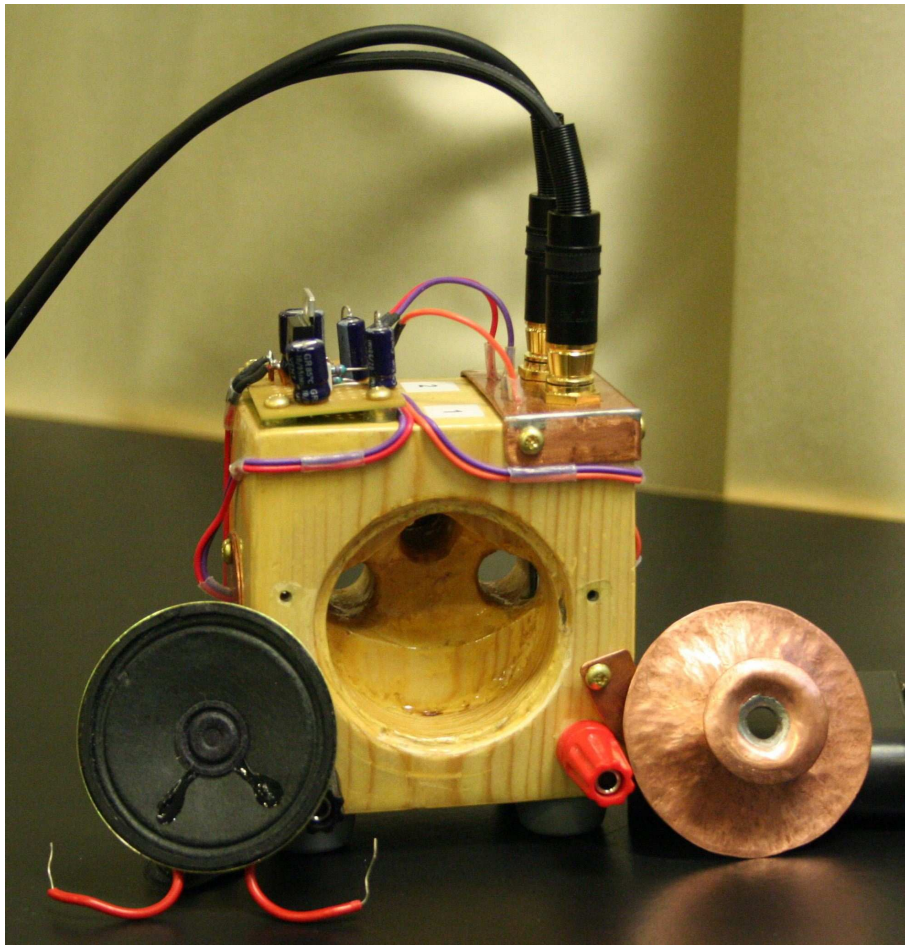


Figure 7: CMRR of the whole system excluding the sound collector

Tests: Two channel signal source



We used a custom built acoustic signal source to obtain the previous data.

Full circle

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Thank you.

Questions, please?