

On the Potential for Artificial Bandwidth Extension of Bone and Tissue Conducted Speech: A Mutual Information Study

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Objectives

- Understanding the relationship between bone-conducted speech and free-air speech for different frequency bands.
- Using that knowledge to enhance the quality of the narrowband bone-conducted speech.
- Improving the experience of communication in noisy environments while wearing communication headsets.

Introduction

New communication headset facilitates communication in noise.

Advantages:

- Custom mold \Rightarrow good passive attenuation
- Equipped with:
 - Outer-Ear Microphone (OEM)
 - In-Ear Microphone (IEM)
 - Digital Signal Processor (DSP)
- IEM signal less sensitive to environmental noise

Disadvantages:

- IEM signal bandlimited to ~ 2 kHz

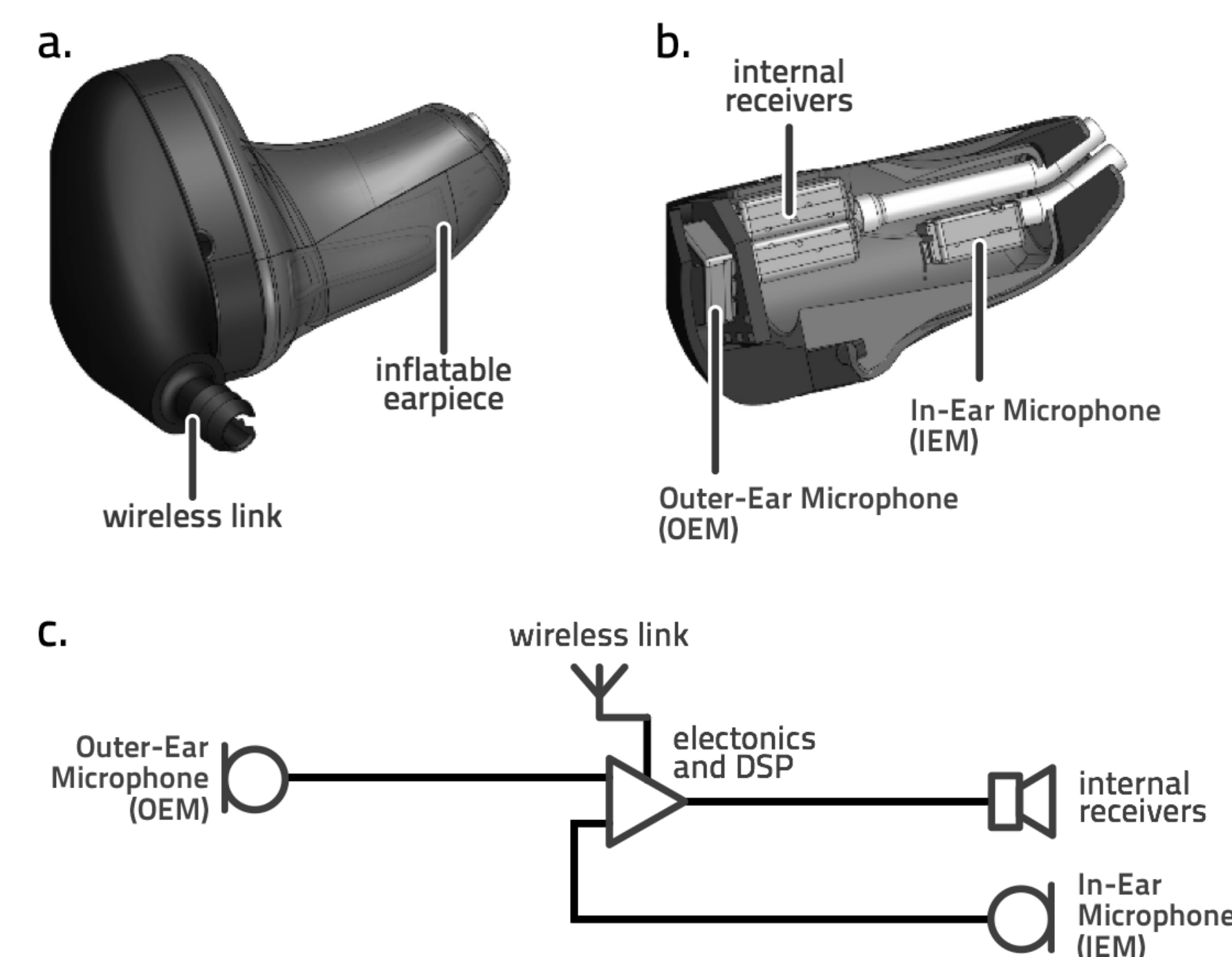


Figure 1: Overview of communication headset (a), its electro-acoustical components (b), and equivalent schematic (c).

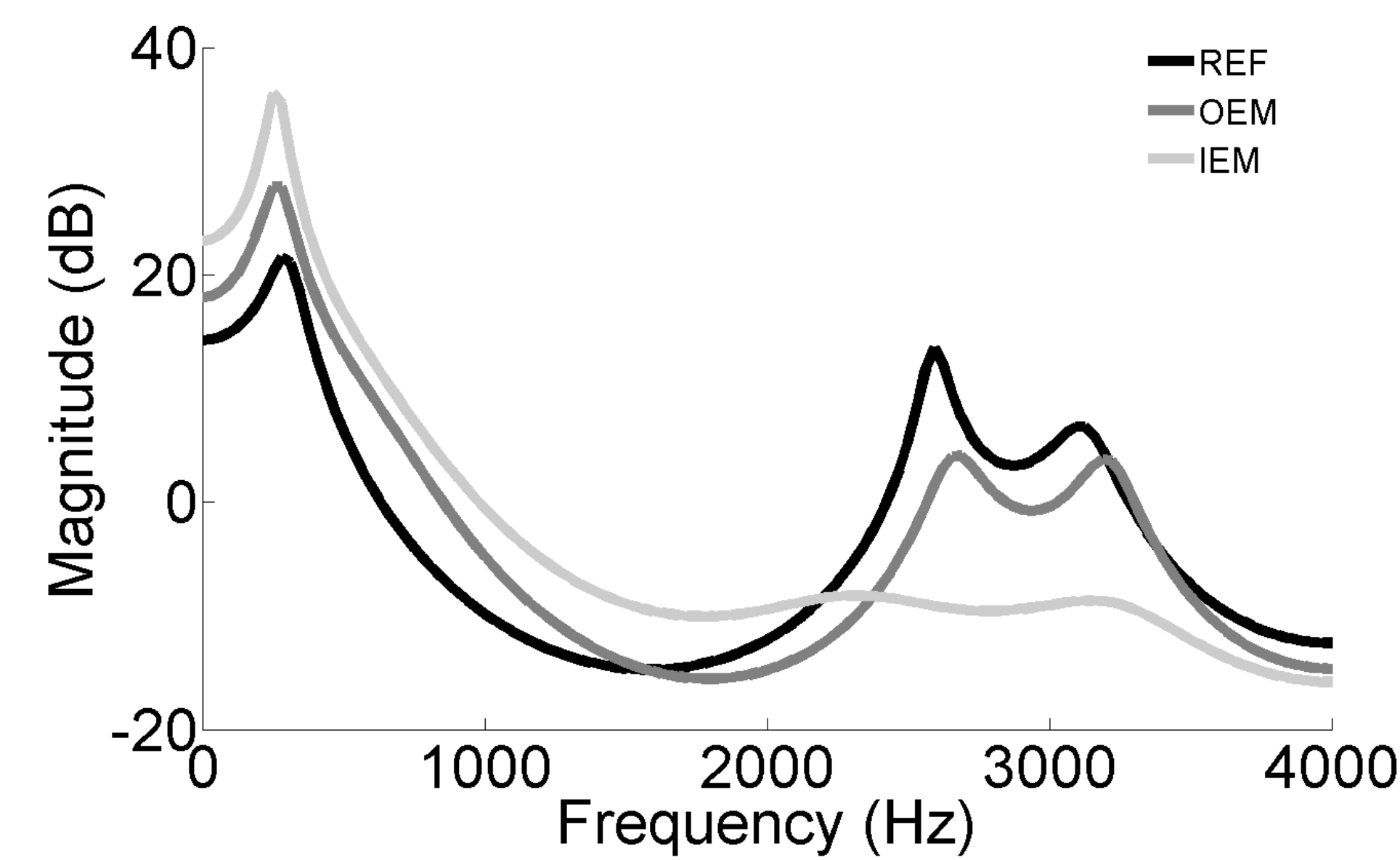


Figure 2: The LPC spectral envelope of the phoneme /i/ recorded with the REF, the OEM and the IEM simultaneously.

Methods

We are interested in the mutual information of the 0-2 kHz and 2-4 kHz sub-bands of the different microphone signals.

Gaussian mixture model PDF:

$$f_{GMM}(x, y) = \sum_{m=1}^M \alpha_m f_G(x, y | \theta_m)$$

Mutual Information:

$$I(\widehat{X}; \widehat{Y}) = \frac{1}{N} \sum_{n=1}^N \left(\log_2 \left(\frac{f_{GMM}(x_n, y_n)}{f_{GMM}(x_n) f_{GMM}(y_n)} \right) \right)$$

Experimental Setup

- Speech Corpus: first 10 lists of Harvard sentences, female speaker, recorded with OEM, IEM and REF (placed in front of the mouth).
- Measure the transfer function of the earpiece
- Compute Mutual Information

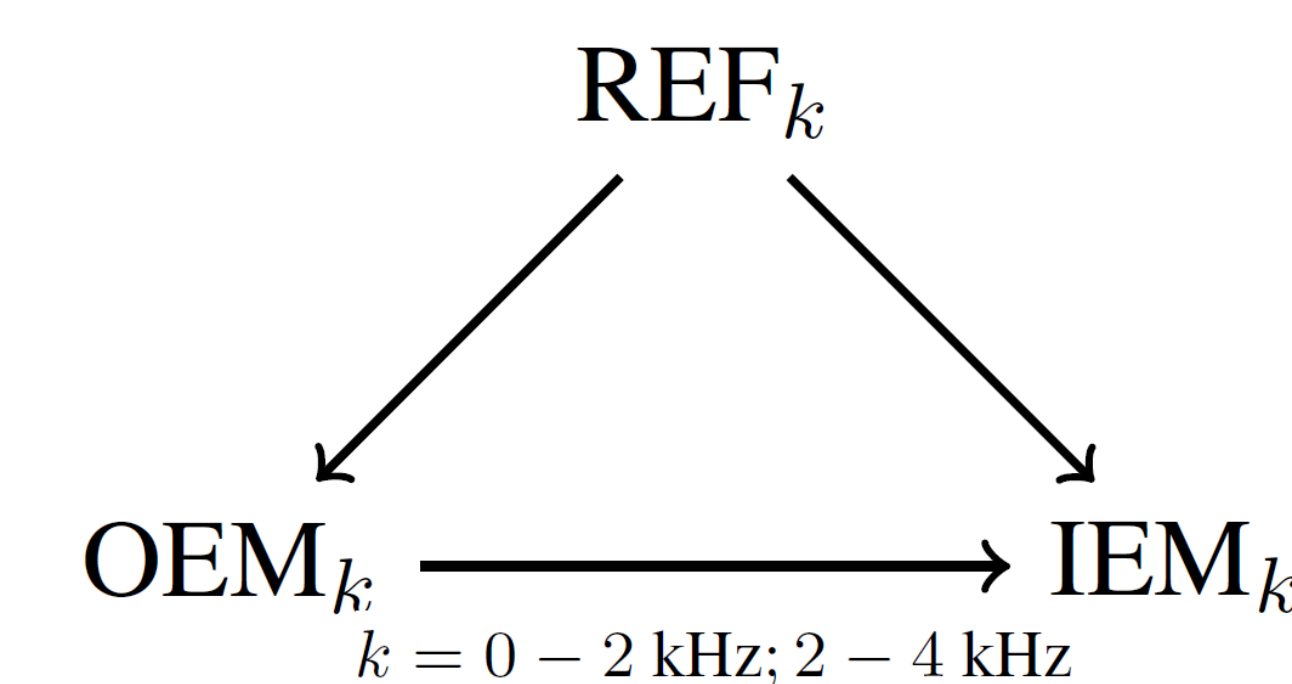


Figure 3: Mutual Information between corresponding frequency bands.

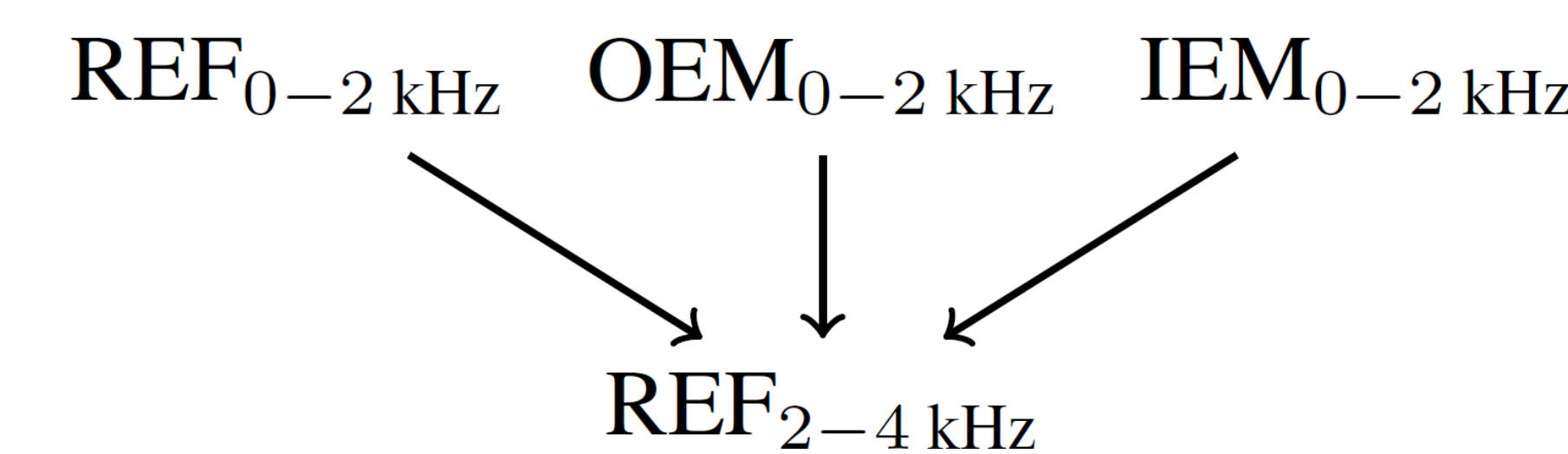


Figure 4: Mutual Information between high band of the REF and low bands.

Conclusions

- In quiet:** OEM and REF signals share mutual information in the 2-4 kHz
- All SNRs:** IEM and REF signals share information in the 0-2 kHz
- High-band of the OEM signal or the low-band of the IEM can be used to artificially extend the bandwidth of the IEM signal
- Creating a better quality/intelligibility signal that is less prone to environmental factors

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Results

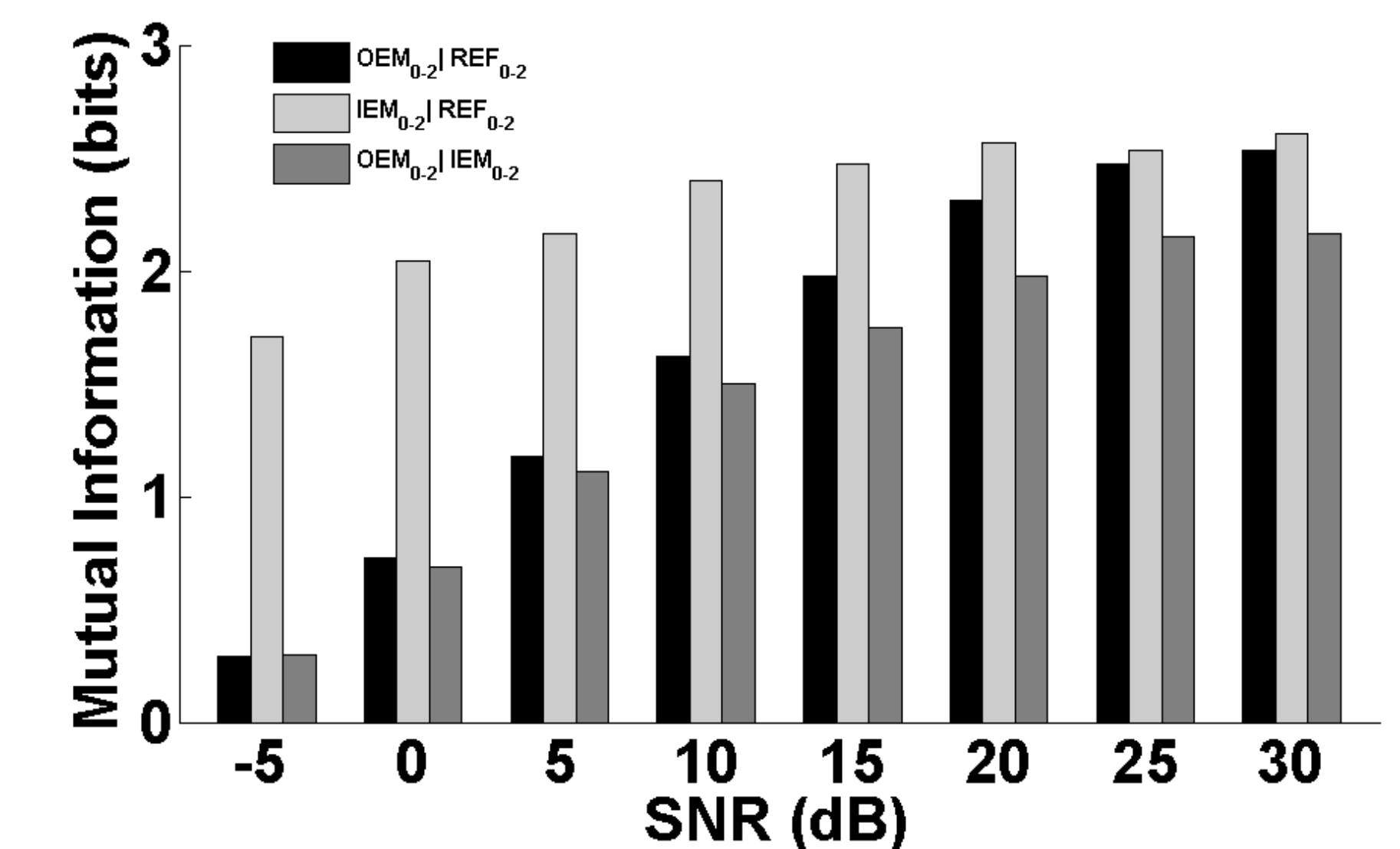


Figure 5: Mutual information of the low-band between the REF, OEM and IEM signals.

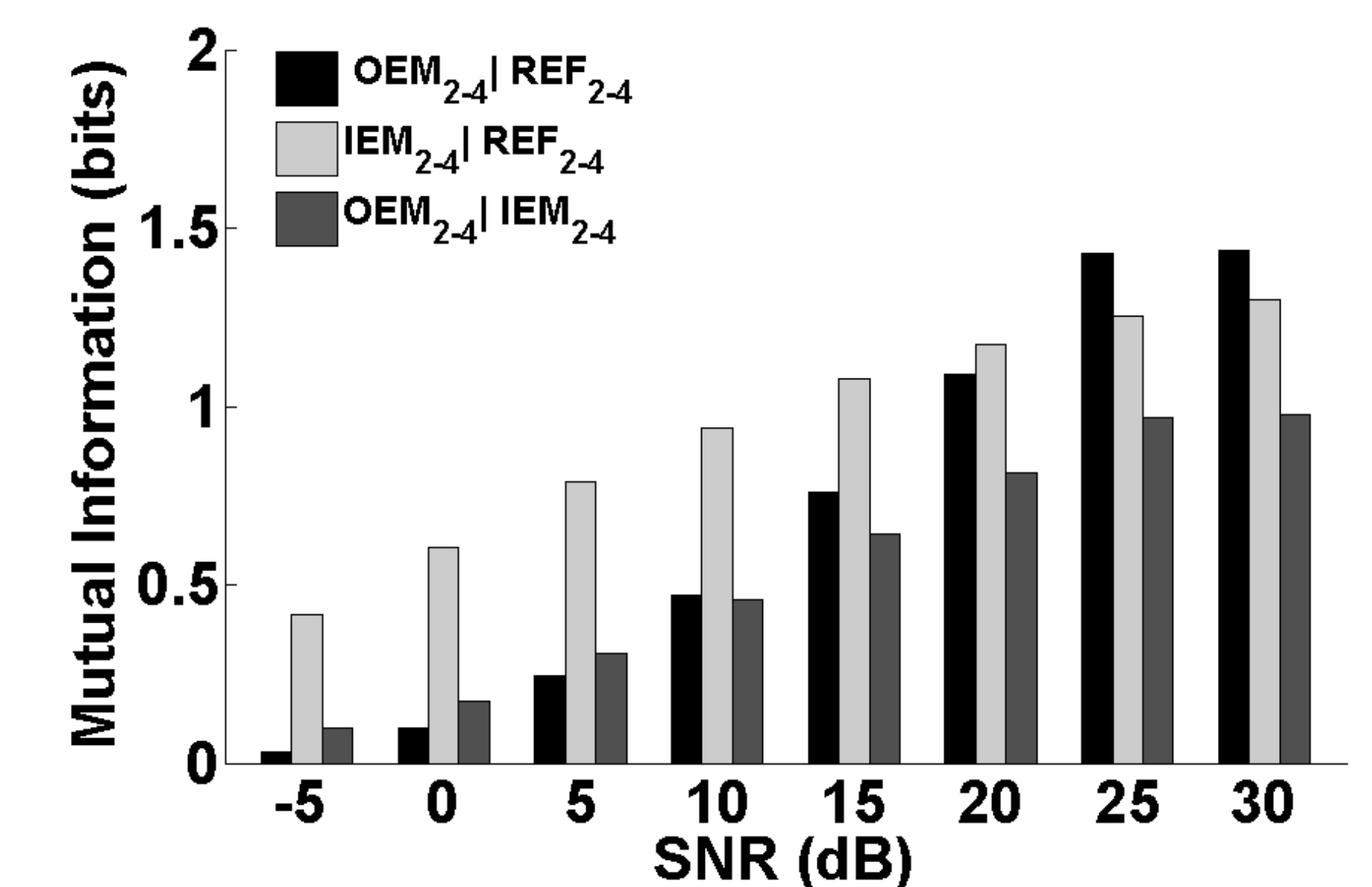


Figure 6: Mutual information of the high-band between the REF, OEM and IEM signals.

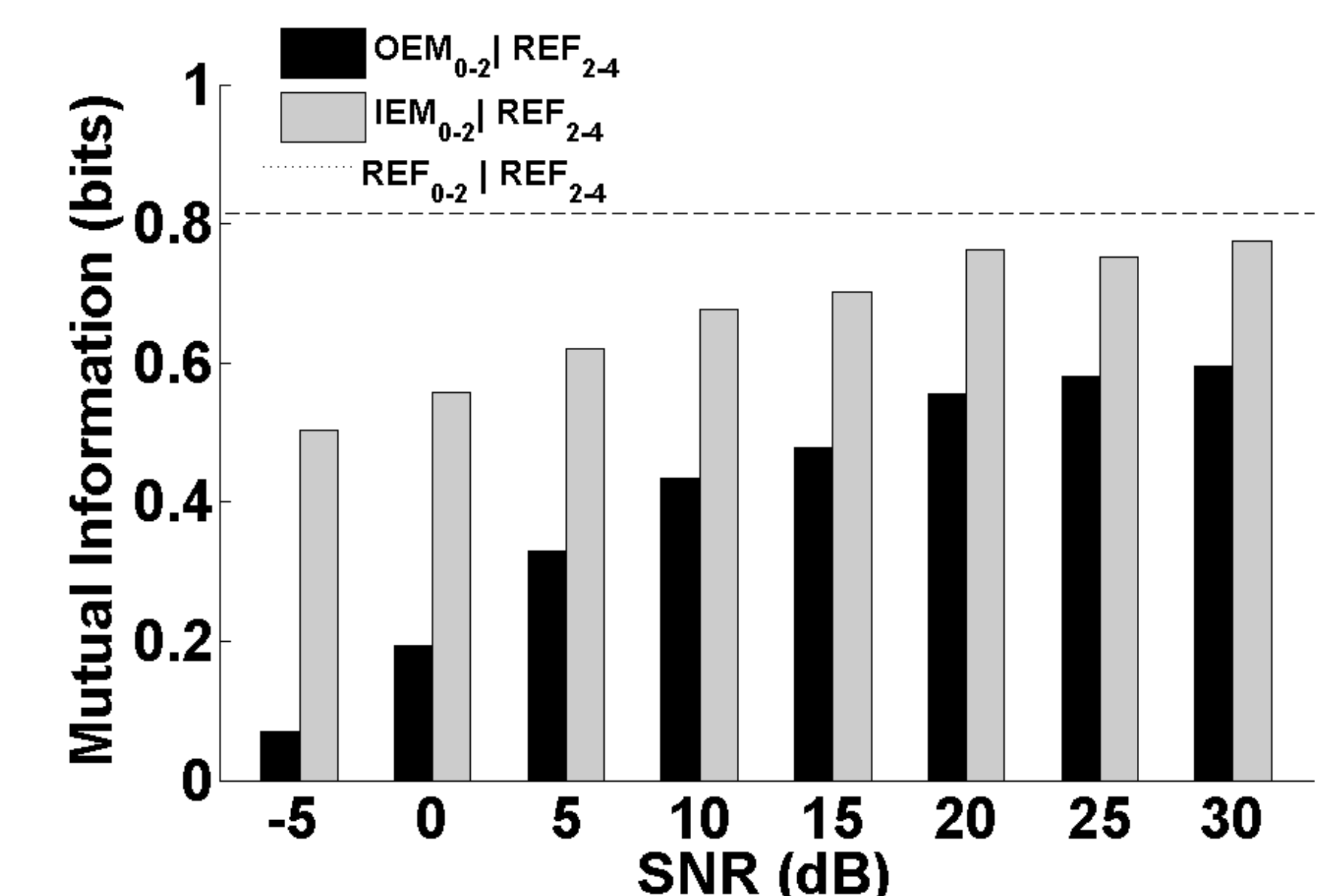


Figure 7: Cross-band mutual information between the OEM, IEM and REF signals compared with the average cross-band mutual information within the REF signal.

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