Bandwidth Extension of Telephone-Speech Aided by Data Embedding

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Abstract

In this paper a system for bandwidth extension of telephone-speech, aided by data embedding, is presented. The proposed system uses the transmitted analog narrowband speech signal as a carrier of the side information needed to carry out the bandwidth extension. The upper-band of the wideband speech is reconstructed at the receiving end from two components: a synthetic wideband excitation signal, generated from the narrowband telephone-speech and a wideband spectral envelope, parametrically represented and transmitted as embedded-data in the telephone-speech. We propose a novel data embedding scheme, in which the scalar Costa scheme is combined with an auditory masking model allowing high rate transparent embedding, while maintaining a low bit error rate. The signal is transformed to the frequency domain via the discrete Hartley transform (DHT) and is partitioned into subbands. Data is embedded in an adaptively chosen subset of subbands by modifying the DHT coefficients. In our simulations, high quality wideband speech was obtained from speech transmitted over a telephone line (characterized by spectral magnitude distortion, dispersion, and noise), in which side information data is transparently embedded at the rate of 600 information bits/second and with a bit error rate of approximately $3 \cdot 10^{-4}$. In a listening test, the reconstructed wideband speech was preferred (at different degrees) over conventional telephone speech in 92.5% of the test utterances.

Keywords and phrases: speech bandwidth extension, auditory masking, data embedding, digital watermarking, scalar Costa scheme.

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