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A Mid-Rise/Mid-Tread Quantizer Switch for Improved Idle-Channel Performance in Adaptive Coders

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A mid-rise/mid-tread switch is proposed for improving the idle channel performance of an adaptive quantizer. The method incorporates the advantages of both mid-rise and mid-tread quantizer characteristics.

In adaptive waveform coding such as ADPCM (adaptive differential PCM), ADM (adaptive delta modulation),[1,2] and sub-band coding,[3,4] the quantizer step-size in the coder varies in accordance with the short-time energy of the signal being coded in order to take advantage of its non-stationary properties. In practice, these types of coders generally have minimum and maximum limits on their step-size. Furthermore, they often use a mid-rise quantizer characteristic as depicted in Fig. 1 where x denotes the input signal level, $\hat{x}$ denotes the discrete output signal levels, and Δ denotes the quantizer step-size. This mid-rise characteristic is desirable because of its symmetry and because it uses the 2^B possible levels of a B-bit coder efficiently.

A disadvantage of this mid-rise characteristic is that it cannot represent a zero output level. During very low, or zero, input signal intervals (such as silent regions in speech), the output of the coder must be $\pm\Delta_{\min}$, where $\Delta_{\min}$ is the minimum step-size in the coder. Generally, $\Delta_{\min}$ is chosen to be small enough so that this signal is very low. Unfortunately, in many coder designs the sign of the output signal varies in a systematic pattern which can be perceived even for very low values of $\Delta_{\min}$.

For example, in ADPCM with a zero input level, the coder output level can oscillate between $\pm\Delta_{\min}$, creating (in a speech coder) a low level tone at half the sampling rate. Because of the sensitivity of our hearing mechanisms to tones, this tone can be perceived even at very low levels (i.e., very small $\Delta_{\min}$s). In sub-band coders, this problem is compounded further by the fact that sub-bands of speech are lowpass-translated to dc, encoded and decoded, and then bandpass-translated back to their

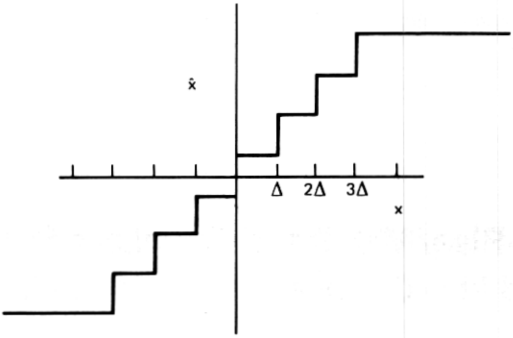

Fig. 1—Mid-rise quantizer characteristic.

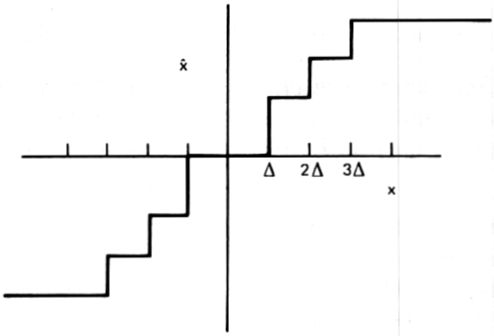

Fig. 2—Mid-tread quantizer characteristic.

respective bands. This modulation process can translate such small tones directly into the middle of the speech band where they are particularly noticeable. Even a dc level of $+\Delta_{\min}$ or $-\Delta_{\min}$ will appear as a low-level tone when modulated to the middle of the speech band. Furthermore, decaying exponentials, in which the quantizer systematically uses its lowest level as its step-size decays to $\Delta_{\min}$, will appear as decaying tones in this situation.

One way to alleviate the above situation is to use a mid-tread quantizer characteristic as shown in Fig. 2. Unfortunately, this characteristic has an odd number of levels (if it is symmetric) or it must be nonsymmetric about zero. Therefore, it does not use the 2^B possible levels of a B-bit quantizer efficiently.

For adaptive quantizers, fortunately, there is a solution to the above problem. Since the quantizer step-size Δ varies with the short-time energy of the signal being coded, it also tells us when the input signal level is near zero. We propose a mid-rise to mid-tread switch on the decoder quantizer output which occurs when the step-size Δ falls below some threshold Δ_{th}. That is, when $\Delta \le \Delta_{th}$, the two lowest levels of the quantizer in the decoder are switched to zero to give a mid-tread char-

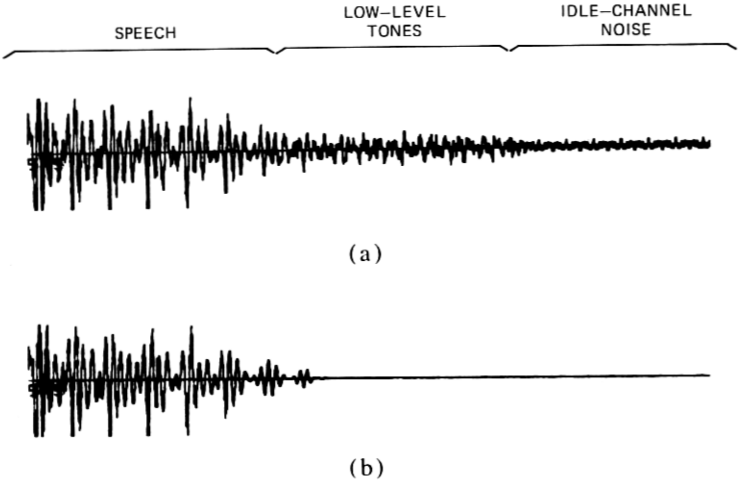

Fig. 3—(a) Output of a sub-band coder with mid-rise quantizers as the step-size is decaying. (b) The same output using the mid-rise/mid-tread switch.

acteristic as in Fig. 2. When $\Delta > \Delta_{th}$, the characteristic in Fig. 1 is used because of its more efficient use of levels. Typically, a practical choice of Δ_{th} is about 1.5 $\Delta_{\min}$ to 3 $\Delta_{\min}$.

The above mid-rise/mid-tread switch has been used successfully in a sub-band coder. It greatly improved the performance of the sub-band coder when it was driven at the low end of its dynamic range. The slight amount of center-clipping introduced by the mid-tread characteristic (at very low input levels) was found to be greatly preferred to the low-level tones and idle channel noise of the mid-rise quantizer characteristic. Figs. 3a and 3b show the results of a sub-band coder output, as the quantizer step-sizes are decaying, for coders with and without the mid-rise/mid-tread switch. As seen in the figure, the low level tones and the coder noise are completely eliminated by the mid-rise/mid-tread switch.

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