EXTENDING THE IMPULSE RESPONSE IN ORDER TO REDUCE ERRORS DUE TO IMPULSE NOISE AND SIGNAL FADING

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ABSTRACT

A FINITE IMPULSE RESPONSE (FIR) DIGITAL SMEARING FILTER WAS DESIGNED TO PRODUCE MAXIMUM INTERSYMBOL INTERFERENCE AND MAXIMUM EXTENSION OF THE IMPULSE RESPONSE OF THE SIGNAL IN A NOISELESS BINARY CHANNEL. A MATCHED FIR DESMEARING FILTER AT THE RECEIVER THEN REDUCED THE INTERSYMBOL INTERFERENCE TO ZERO. SIGNAL FADES WERE SIMULATED BY MEANS OF 100% SIGNAL BLOCKAGE IN THE CHANNEL. SMEARING AND DESMEARING FILTERS OF LENGTH 256, 512, AND 1024 WERE USED FOR THESE SIMULATIONS. RESULTS INDICATE THAT IMPULSE RESPONSE EXTENSION BY MEANS OF BIT SMEARING APPEARS TO BE A USEFUL TECHNIQUE FOR CORRECTING ERRORS DUE TO IMPULSE NOISE OR SIGNAL FADING IN A BINARY CHANNEL.

DISCUSSION:

Smearing and desmearing filters have not received much attention in the literature. Whether this is due to simple oversight is not at all clear, but our own analysis of these filters indicates that their advantages are such that they deserve further investigation. They appear to have characteristics which are ideally suited to counter both impulse noise and sudden signal fades.

The earliest paper which we found on smearing and desmearing filters was that by Wainwright in 1961 [1]. This paper and that of subsequent authors such as Engel [2], Richter et al [3], and Beenker et al [4], discuss using smearing filters to reduce the effects of impulse noise in a data transmission system. Filter lengths were relatively short, and except for Beenker, matched filters were used at the transmit and receive terminals. Beenker showed acceptable results without precisely matched filters.

In our work, we found it difficult to define a simple model for impulse noise which was generally accepted as an objective model. Instead, we decided to demonstrate the effects of smearing filters on sudden signal fades. Although complex models of signal fading

are available, for purposes of simplicity, we decided to assume a 100% fade, knowing that lesser fades would always show improvements over our very simple model.

Figure 1 is a block diagram of our model of a smearing filter in operation. Figure 2 is the frequency response curve for our model, a baseband data transmission system with frequency response from dc to 4 khz. Sampling rate for all of the data given in this paper is 10 khz.

The zero phase impulse response for the filter shown in Figure 2 is given in Figure 3, with inset showing greater detail of the center region of the response. This impulse response is for a filter of length 1024.

The smearing filter phase response, based on the same filter of length 1024, is shown in Figure 4. This phase response is the integral of a linear time delay from dc to midband, followed by a linear return to zero delay. Although this is a different phase response from that used by previous authors, we found that it produced very good results in terms of low passband ripple and low stopband sidelobe levels. The impulse response for this smearing filter is shown in Figure 5.

To simulate a 100% signal fade, the time signal in the channel was simply made zero at somewhere near midpoint in the data stream, for a variable period.

To provide a plot of bit errors, the output of the smearing filter was detected, then correlated with the original data stream. The result, which we call a "scatter diagram", shows a line at 1.0 for all normal noiseless data. Detected data bits which fall below zero in this scatter diagram are detected as errors.

Figure 6 is a typical scatter diagram for a zero phase filter of length 1024. The 100% signal fade in this case is 112 bits in length. Total errors are 49, from an expected 56 for a binary signalling system. (We found less than expected errors for the zero phase filter in all of our measurements).

Figure 7 is a typical scatter diagram for the comparable smearing filter, for a 100% signal fade of 112 bits in length. Total errors in this case was 7. Filter length again was 1024.

Figure 8 is a plot of fade duration versus average number of errors, for 100% signal fade of various lengths, for filters of length 256, 512, and 1024. The zero phase filter characteristic is also plotted, showing an improvement over expected errors in all cases.

Figure 9 shows the same data plotted in terms of percentage improvement ratio (probability of correcting an error), versus duration of fade, for the same filters, including the zero phase filter (length 1024).

In conclusion, although we have not yet tried these smearing filters on a complex model of a data signalling system, the simulations to date indicate good reason for optimistic expectations of the smearing filter as a counter to signal fades.

Because of the similarities, as far as the filter is concerned, between disruption due to sudden signal fades and disruption due to impulse noise, it seems reasonable to conclude that this filter may also have application as a counter to impulse noise.

REFERENCES

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Engel, J.S. Digital Transmission in the Presence of Impulse Noise, Bell System Technical Journal, pp 1699-1743, October 1965.

Richter, W.J., and Smits, T.I. Signal Design and Error Rate of an Impulse Noise Channel, IEEE Transactions on Communications Technology, Vol. COM-19, No. 4, pp 446-458, August 1971.

Beenker, G.F., Claasen, T.A. and Gerwen, P.J. Design of Smearing Filters for Data Transmission Systems, IEEE Transactions on Communications, Vol. COM-33, No. 9, pp 955-963, September 1985.
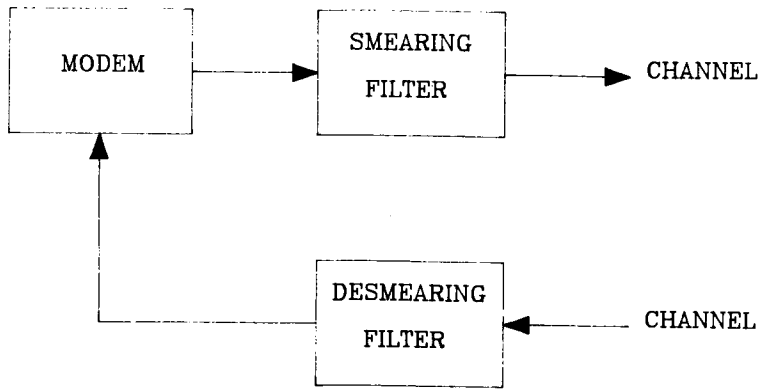
Figure 1. Block diagram showing smearing and desmearing filters in relation to a data modem.
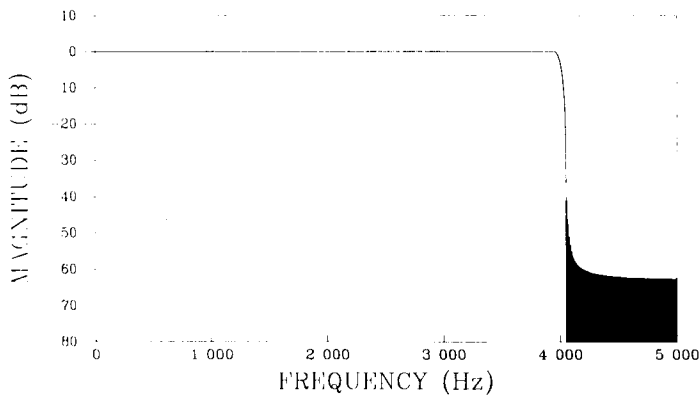

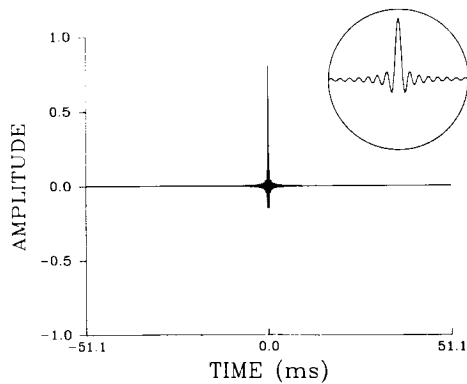Figure 2. Frequency response of the smearing and desmearing filters.

Figure 3. Zero phase impulse response of a filter of length 1024 with the frequency response of Figure 2.
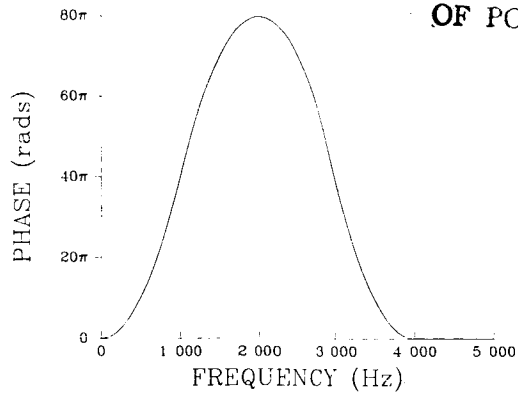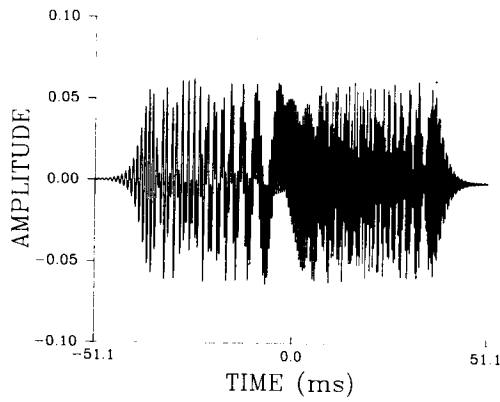
Figure 4. Comulative phase delay of the smearing filter of length 1024.

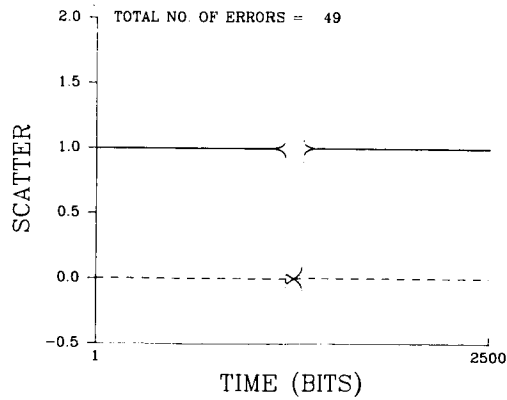Figure 5. Impulse response of the smearing filter with phase delay as in Figure 4.

Figure 6. Scatter diagram for a zero phase filter with a 100% signal fade of length 112 bits.
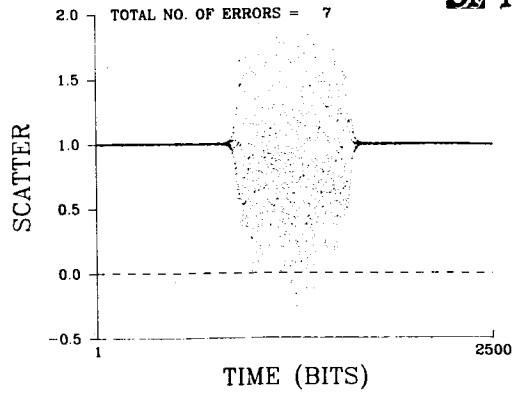
Figure 7.   Scatter diagram for a 1024 length smearing filter with a
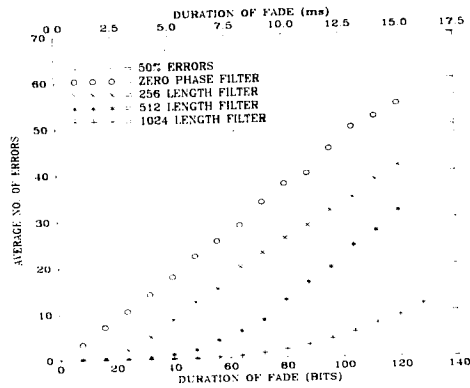100% signal fade of length 112 bits.

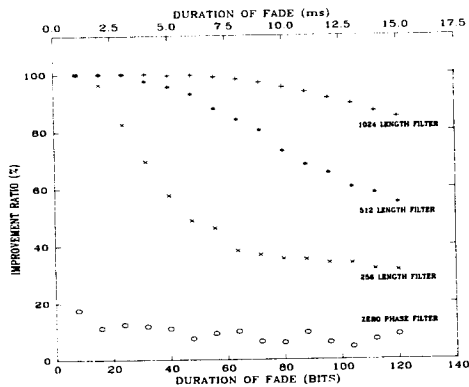Figure 8.   Average errors versus 100% fade length.

Figure 9.   Average improvement ratio versus fade length.