The Effect of Input Limiting on Linear and Nonlinear Filters for the Removal of Impulsive Noise

S. M. W. Masra#1, M. S. Muhammad#2, R. Sapawi#3

Department of Electronics Engineering, Universiti Malaysia Sarawak
Faculty of Engineering, Sarawak, Malaysia
[1]wmmasnia@feng.unimas.my
[2]msaufee@feng.unimas.my
[3]srohana@feng.unimas.my

***Abstract*— This paper investigates the effects of input limiting on the performance of linear and nonlinear filters when the input signal is contaminated by impulsive noise modeled as an alpha-stable (α-stable) random process. The nonlinear filters chosen are from the median family filters: median and recursive median filter, and Wiener filter from the linear filter group. The hypothesis being tested in this paper is that front-end limiting will increased the performance of median filter when the noise was extremely impulsive. Each image has been analyzed for four impulsive noise parameter values, α = 2, 1.5, 1, and 0.5 which cover a range of noise behaviors from Gaussian, through Cauchy, to impulsive. One method of handling very large impulses is to incorporate in the receiver over-voltage protection in the form of an analog limiter which clips the received signal before the filtering process. The simulation results obtained suggest that the front-end limiting enhances the performance of median filters in dealing with images, where it eliminates the highly impulsive noise while preserving useful detail in the image.**

***Keywords*— impulsive noise, α-stable random process, median family filters, input limiting, analog limiter**

I. Introduction

It is well known that a large number of filtering algorithm used in signal processing rely on the fundamental assumption that the underlying signal and noise obey a Gaussian distribution [1]. However, their performance is degraded in the presence of impulsive noise. Therefore, there is a need to study the case of impulsive noise more closely: and one way to do this is to model the noise as an α-stable random process. The complete class of symmetric α-stable distributions is usually characterized by their characteristic functions as (1) [2]:

$$c(\alpha,\gamma;\xi) = \exp(-\gamma|\xi|^{\alpha}) \tag{1}$$

where

- α is the characteristic exponent satisfying $0 < \alpha \leq 2$ and it controls the heaviness of the tails of the distribution; a smaller α signifies heavier tails, and thus the noise more impulsive.
- γ is the dispersion parameter which measures the spread of the probability density function (pdf) around its location parameter, similar to variance of a Gaussian pdf [2].

Two well known classes of α-stable pdfs are the Gaussian distribution, arising from (1) when α = 2, and Cauchy distribution when α = 1, as shown in Fig. 1.

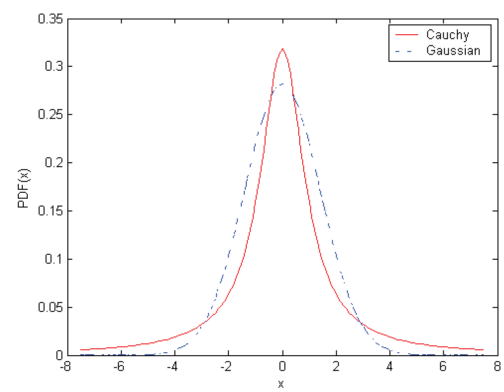

Fig. 1 Pdfs of Gaussian and Cauchy distributions

II. Limiting the Impulsively Noisy Input

Signals are often corrupted by impulsive noise due to errors generated in communication channels. It is possible to eliminate or suppress noise in the signals before the filtering operation. One method of handling very large impulses is to incorporate in the receiver over-voltage protection in the form of an analog limiter which clips the received signal before filtering. Fig. 2 depicts the proposed method.

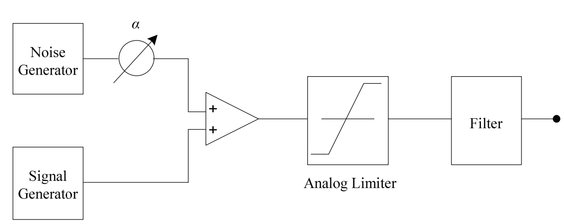

Fig. 2 The proposed limiter-filter combination

An analog limiter is added at the front-end of the receiver in order to clamp the impulsive peak noise to the threshold values, $\pm V$. The limiting operation can be represented by (2), and depicted pictorially as in Fig. 3.