Out-of-band and adjacent-channel interference reduction by analog nonlinear filters

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Abstract

In a perfect-world communication technology we would have "brick wall" filters, no-distortion amplifiers and mixers, and well-coordinated spectrum operations. The real world, however, is prone to various types of unintentional and intentional interference of technogenic (man-made) origin that can disrupt critical defense communication systems, with the impacts ranging from slight reduction in the channel capacity to the channel failure. In this paper, we introduce a methodology for mitigation of technogenic interference in communication channels by analog nonlinear filters, with a particular emphasis on the mitigation of the out-of-band and the adjacent-channel interference.

Interference induced in a communications receiver by external transmitters can be viewed as a wide-band non-Gaussian noise affecting a narrower-band baseband signal of interest. In many cases this noise may contain a strong component within the passband of the receiver, which may dominate over the thermal noise. While the total wide-band interference seen by the receiver may or may not be impulsive (e.g. characterized by a high degree of peakedness), we demonstrate that the interfering component due to power emitted by the transmitter into the receiver channel is likely to appear impulsive under a wide range of conditions, especially if observed at a sufficiently wide bandwidth. When a linear filter is used to suppress the interference outside of the passband of interest, the resulting signal quality is invariant to the type of the amplitude distribution of the interfering signal, as long as the total power and the spectral composition of the interference remain unchanged. However, the spectral density of a non-Gaussian interference in the signal passband can be reduced, without significantly affecting the signal of interest, by introducing an appropriately chosen feedback-based nonlinearity into the response of the linear filter.

In particular, impulsive interference characterized by frequent occurrence of outliers can be effectively mitigated by the Nonlinear Differential Limiter (NDL) described in this paper. An NDL can be configured to behave linearly when the input signal does not contain outliers, but when the outliers are encountered, the nonlinear response of the NDL limits the magnitude of the respective outliers in the output signal. As a result, the signal quality is improved in excess of that achievable by the respective linear filter, increasing the capacity of a communications channel. The behavior of an NDL and its degree of non-linearity is controlled by a single parameter in a manner that enables significantly better overall suppression of the noise containing impulsive components compared to the respective linear filter. Adaptive configurations of NDLs are similarly controlled by a single parameter, and are suitable for improving quality of non-stationary signals under time-varying noise conditions. NDLs are designed to be fully compatible with existing linear devices and systems, and to be used as an enhancement, or as a low-cost alternative, to the state-of-art interference mitigation methods.

We demonstrate that the most effective way to suppress out-of-band and adjacent-channel interference is to deploy an appropriately chosen linear filter in the signal chain of the receiver preceding an NDL. This filter can selectively suppress the non-impulsive component of the total interference without affecting the baseband signal of interest, while increasing the peakedness of the remaining interference affecting the baseband signal, thus increasing the effectiveness of interference mitigation by a subsequently deployed NDL.