37 Adaptive Receivers Based on Self-Organizing Maps

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In this research project, new receiver structures based on the Self-Organizing Map (SOM) algorithm [2] have been developed. The SOM is used both as an adaptive decision device and to follow up error signals.

The SOM is a competitive neural network algorithm that produces localized responses to input signals and represents the topology of the input signal space over the network. Due to the active topology preserving property of the learning scheme, the SOM is able to adapt to time-varying situations. In communication systems, the signals are corrupted with various distortions caused by the transmission channel, interfering signal and noise (Fig. 66). These distortions can be adaptively compensated using the capability of on-line adaptation of the SOM [3, 5].

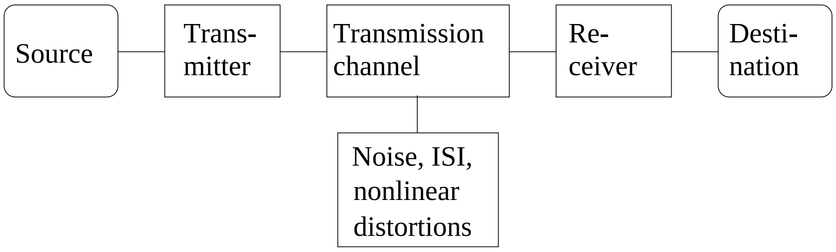


Figure 66: Communication system

When the SOM is used as an adaptive decision device, comparisons with conventional equalizers such as the linear equalizer and the decision feedback equalizer (DFE) [4] have been performed. The new structures were also compared with other neural methods like radial basis function (RBF) networks and multi-layer perceptrons (MLP) [1]. The performances of the neural equalizers and especially the SOM have been found to be better in nonlinear multipath channels and about equal in linear channels.

When the SOM has been used to follow up error signals, the actual idea has been to cancel interference. This task has been divided between following up the error distribution and finding out the error estimate. The error is approximately the same as the interference. Other sources of error are noise, intersymbol interference, wrong error estimates and detection errors due to the reasons mentioned before. The error distribution can be followed up, but the problem is how to predict the error. Some solutions have been found, but they do not provide satisfactory results. The performance has been compared with a pure detector without any kind of interference cancellation and with a receiver based on the RBF network.

In our research, the wanted signal has been of QAM (Quadrature-Amplitude Modulation) type as well as the interfering signal if it is present. The aim of the research has been to use the SOM as a building block of new adaptive receivers, which are able to compensate the nonlinear distortions or cancel the interfering signals.

37.1 Compensation of Nonlinear Distortions

Neural networks are an obvious choice for the compensation of nonlinearities, because the task is often such that either analytic solutions do not exist or they cannot be found. The networks can be trained to follow up distortions.
The Self-Organizing Map algorithm is used as an adaptive detector preceeded by the DFE (Fig. 67). In the conventional SOM the samples are classified one after each other, but the algorithm can also be made to accept input data as batches.

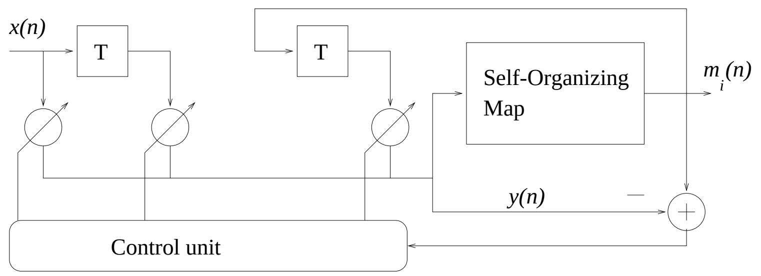
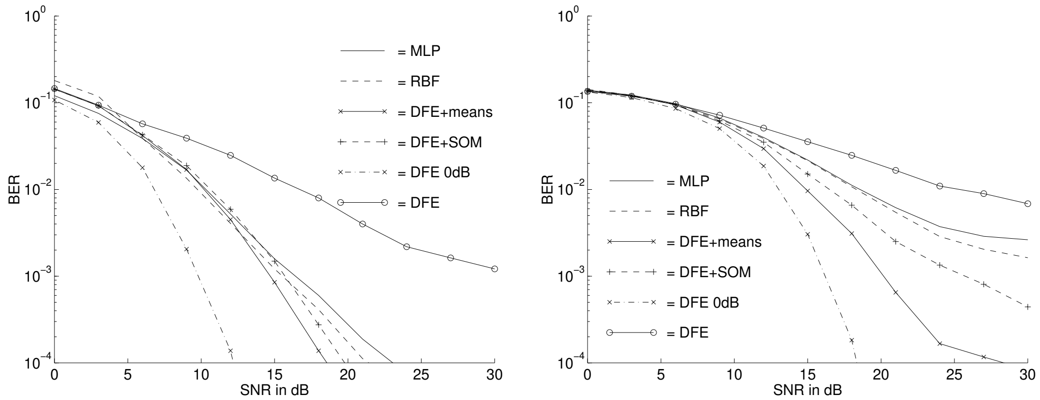


Figure 67: DFE and SOM in cascade

Usually, the nonlinear distortion is introduced by transmitter or receiver amplifiers, but other sources are also possible. More often the distortions are unwanted, but sometimes the signal is distorted on purpose. It is possible, that the distortion has been created in the receiver amplifier in order to cut off the amplitude peak values. When such a distortion is compensated, the signal to interference ratio (SIR) vs. bit-error-ratio (BER) of the equalizers in a two-path channel are as shown in Figure 68.



(a) 16-QAM signal and 6 dB decay (b) 64-QAM signal and 3 dB decay

Figure 68: Compensation of nonlinear amplifier which decays the signal.

37.2 Interference Cancellation

The SOM has been used to interference cancellation by feeding detection errors into the map. The idea is to form an estimate of the error on the basis of previous error and signal values. A signal sequence is fed into the SOM. The error estimates are listed in a separate table, the output of the SOM is used to decide which one of

the error estimates is the best. The interference estimate is subtracted from the incoming signal before the classification. This kind of an interference cancellation can be combined with various equalizer structures. The cancellation can also be preceded by a DFE.
One possible architecture of the SOM based receiver is shown in Figure 69. In this structure, the DFE is used only for cancellation of intersymbol interference and multipath propagation. Other distortions are cancelled by the feedback loop, in which the error signal corresponding to the distortion, i.e. the interference and noise, is calculated and used in estimating the next value of the error for compensation.

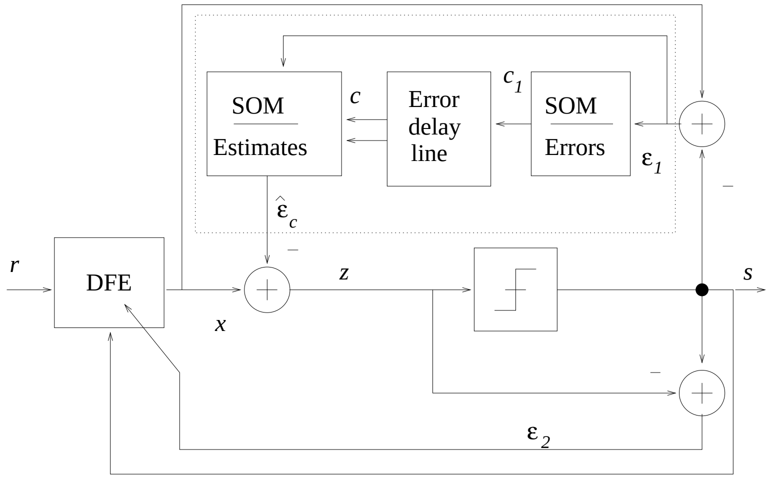
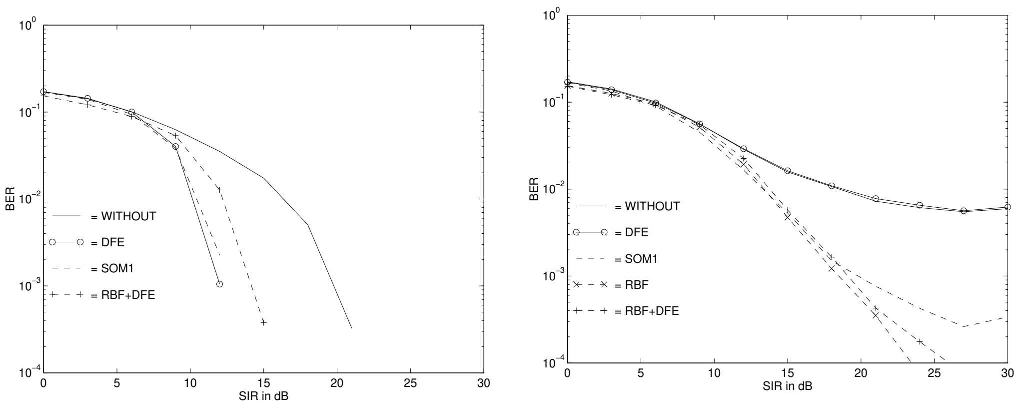


Figure 69: The sep-SOM receiver structure.

In computer simulations interference cancellation with various receiver structures utilizing the SOM algorithm have been investigated. We have concentrated on interference effects by using QAM modulation (16-QAM). Interference has been both from a Gaussian noise source and from a similar signal source as the desired signal. The latter with equally modulated signals is called co-channel interference (CCI). Some results of cancellation of the CCI are shown in Figure 70.



(a) Linear two-path channel (b) Nonlinear one-path channel

Figure 70: CCI cancellation

The BER vs. the signal to interference ratio (SIR) of the receivers have been studied. The SOM is compared to the DFE, the RBF network, and to the situation where no interference cancellation is performed. With no cancellation the samples are only classified to predefined states.

37.3 Conclusion

In this research, the Self-Organizing Map has been used in compensating nonlinear distortions and cancellation the Gaussian and co-channel interference. The simulation results have been derived using the QAM-modulation. The SOM based receivers are able to compensate nonlinear distortions, but their performance in interference cancellation is not so satisfactory.

References

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