Chapter 8

Conclusion

8.1 Introduction

The research carried out for this thesis primarily examines the design and analysis of Neuro-Fuzzy Adaptive filters for ISI mitigation in mobile cellular channels. We start our discussion with a brief introduction to the principles of mobile cellular telephony. We then review the equalizer models currently available. The proposed equalizers for Non-Linear Time-Variant (NLTV) channels are discussed. The modeling of UWB channels based on the Channel Covariance Matrix (CCM) is undertaken. It is also shown that the ANFIS equalizer can be suitably adapted for UWB as well. Then, we arrive at a generic framework for the ANFIS, CNFF and FAF based adaptive equalizers. We show that all the three can be brought under variants of RBF neural networks. We propose a new modular approach for equalizers for NLTV channels.

The signal transmitted through a channel suffers from linear, nonlinear and additive distortion. The conventional method for compensation of channel distortion is based on introducing of the linear equalizer (linear inverse filter to the channel frequency response) to the output of the channel. This design methodology is appropriate when the channel model is precisely known and the characteristics of the channel are time-invariant. When the channel has time-varying characteristics the adaptive equalizers are used. Various approaches have been used for nonlinear channel equalization. Classical approaches are based on the knowledge of the parametric channel model. Next type is decision feedback equalizer that improves the performance of the equalizer. Nowadays neural networks are widely used for channel equalization. One of the classes of nonlinear adaptive equalizers is based on Multi-Layer Perceptrons (MLP) and Radial Basis Functions (RBF). The MLP equalizers require long training and are sensitive to the initial choice of network parameters. RBF equalizers are simple and require less time for training, but they usually require a large number of centers, which increase the complexity of computation.
The mobile cellular channels are generally considered as non-linear and time-variant. They also show Rayleigh fading or Ricean fading characteristics. The fading characteristics will be that of a Ricean distribution, if apart from the major ray, one more component reaches the receiver (two-ray model). It will exhibit a Rayleigh distribution, if three or more multipath components reach the receiver (three-ray model).

8.2 Achievements of the Thesis

The major achievements of this work can be summarized as follows:

- The mobile cellular channel can, in general, be modeled as a Non-Linear Time-Variant channel (NLTV) with Rayleigh or Ricean fading characteristics. However, under limiting conditions, it can also be modeled as a linear time-variant channel. It is shown that the indoor mobile cellular channel has the Rayleigh fading characteristics, using a three-ray model. It is also shown that the mobile cellular channel is either Linear Time-Variant (LTV) or Non-Linear Time-Variant (NLTV).

- The mobile channel being non-linear, the non-linear equalizers are more appropriate for them. We consider three such equalizers—the fuzzy adaptive equalizer (FAF), Adaptive Network based Fuzzy Inference System (ANFIS) and the Compensatory Neuro-Fuzzy Filter (CNFF). The performances of these are studied. Various structures of the ANFIS based equalizers are considered for channel equalization and their performances are compared. It is also shown that equalizers based on the ANFIS structure can be adapted for Ultra-Wide Band (UWB) channels as well. Consequent to the deployment of UWB in most modern communication scenario, the need for equalization at these frequencies has gained more momentum.

- A Radial Basis Function (RBF) Neural Network framework for the above three equalizer models is derived. This is especially useful for the easier comparative performance analysis of the equalizers. It is shown that the lower order ANFIS based equalizer (ANFIS–25 with 75 nodes and 25 rules) has almost identical performance of that of a RBF NN based equalizer.

- A modular approach is proposed for the design and simulation of equalizers for non-linear time-variant channels. In this model, a nonlinear prefilter precedes the equalizer block at the receiver. This approach provides considerable improvements in the equalizer performance. It is shown that the method is highly efficient in removing higher order nonlinearities introduced by the nonlinear channel.
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The prefilter is implemented using an ANFIS-37 structure and RBF NN. Both of them perform equally well in removing the nonlinearities at the channel output. It simplifies the design and simulation of channel equalizers, where there is nonlinearity due to output power amplifier performance and due to the channel itself.

The papers published based on this thesis are enlisted in appendix-A.

8.3 Confinements of the Work

The principles discussed in this thesis are equally applicable to all kinds of mobile cellular systems including GSM, and CDMA based technologies. We had considered only a few of the currently available modulation schemes in digital communication in this work. It is imperative that the principles evolved in this work need to be extended to several other modulation schemes like 256QAM or 512QAM.

The novel modular approach in the design of equalizers introduced in Chapter 6 need to be analyzed more critically. There are some recent papers in that direction by some authors.

Eventhough we have considered many techniques for channel equalization of mobile cellular channels, practical implementation of the algorithms is not considered. As it is seen from literature, most of the algorithms are suitable for implementation on DSP platforms [88].

8.4 Scope for Further Research

To conclude the thesis, the following are some pointers for further research work which can lead to interesting results:

- Possible extensions of this work can be found useful in developing equalizers for MIMO systems. Multi-Channel CDMA is one of such applications. This is a fast developing area of research.

- As we can see from current literature, wireless access is another highly investigated topic of intense research activity. Most of the principles developed can be used in wireless networking as well.

- The equalizers based on ANFIS structure can be extended for equalization of Ultra-Wide Band (UWB) channels as shown in Chapter 4. Further, it can be exploited in the deployment of Personal Area Networks (PAN) and Body Area Networks (BAN).
• Broadband wireless technology will have an important role in the future evolution of advanced global telecommunications [89, 90]. The IEEE 802.11 standard comprehensively covers data transmission in wireless LANs, which includes methods for CCI suppression and equalization [91].

• As wireless LAN is getting popular rapidly, many predict that wireless LAN can be used to build wireless Internet and compete against 3G systems in terms of providing broadband wireless data service at hot spots. This scenario can be exploited to the full extent. More study in this direction is most appropriate.
Appendix-A

Papers Published in Conference Proceedings/Journals:


