Equalizer Optimization under a precoded transmission

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Abstract-This paper deals with the reduction in complexity of equalizers when the receiver is working under the precoded transmissions. Precoded transmissions are generally used in the systems where the channel is known to have spectral nulls or responses that are very unpredictable /varying at some bands in comparison to other general bands of a given spectrum. Recently the technique has even been used for pilot insertion. In this paper, a novel scheme of seeding the equalizer has been proposed that leads to the overall reduction in the Equalizer complexity without sacrificing the performance (measured in steady state error variance)

I. INTRODUCTION

Precoding and spectral shaping is a technique widely used in modern communication systems to make spectrum more amiable for a good receiver performance. The main purpose of the spectral shaping is to store as much information in the normal bands of the channel leaving out the abnormal bands. This helps in the noise reduction and a better performance of the receiver as discussed in Cavers et al [1], Tomlinson [6], Harashima [7], Laroia [8]. It is also being used for pilot insertion [5]. Some of the practical examples of spectral shaping are seen in the voice band modems [4], wireless networks [5], digital subscriber loops etc. The occurrence of abnormal characteristics in the channels may happen due to the types of codecs (as in telephony), A/D and D/A converters, AC coupling, power line interference, band pass filter characteristic of the channel etc.

II. GENERAL STRUCTURE AND IMPLEMENTATION

In the receiver, there is an equalizer implementation that offsets the symbol interference and is generally implemented as an adaptive equalizer as the channel characteristics are non-stationary and unknown to the receiver. There may be a training sequence that is used by the equalizer algorithm (LMS, RLS) [2-3] to learn the channel characteristics. The complexity of such an equalizer can be broadly classified into these categories:

Timing Convergence: The normal equalizer may require a training sequence for getting converged to a nominal mean square error (MSE) and thus rendering itself useful for the subsequent decisions. The training time taken to converge is one of the most important complexities involved with a receiver implementation [2].

Computational Units: The number of taps and states required to get a good performance of the equalizer is directly proportional to the number of addition and multiplication units required to perform various operations (convolution, error calculation, tap updation) required in the equalizer filter structure [2-3].

Structural Complexity: The performance of the equalizer depends on its structure. For instance, a decision feedback equalizer performs better than its linear equalizer equivalent if the channel has varying characteristics or in other words, signal passed through the channel has a larger eigen span [2-3].

A. EQUALIZER SEEDING TO REDUCE COMPLEXITY:

In a general precoded system, the receiver *a priori* knows the structure of spectral shaper/precoder to be used in the transmitter. The specification of the spectral shaper can be given as shown in Fig1 [1]. The transmitter can use this specification of the spectral shaper to shape the transmitted signals. Let's this is represented as T (f).

$$T(f)=A(f)/B(f) \quad (1)$$

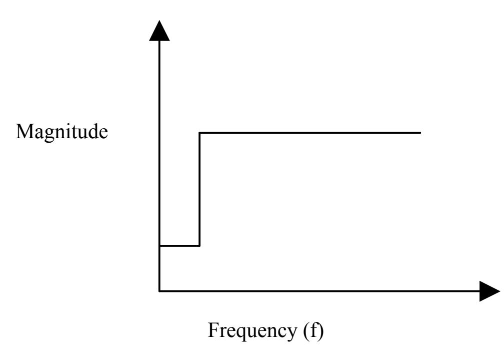

Fig1: T (f)

When allowed to equalize the Channel having spectral nulls, the equalizer would introduce a very high gain wherever there were spectral nulls. To learn these spectral nulls the equalizer is taxed in time, computation and structure.

In simulation, a T/2 fractionally spaced equalizer has been implemented in DFE with 200 taps in the feed forward path and 20 taps in the feedback path. The frequency response of the learnt equalizer is shown in the figure3 and as can be seen there is a high response at the band of the channel null. The Channel is simulated in 450 taps FIR using IFFT of the shown response in Fig.2. In the simulation a LABI (look ahead block inversion) [1] based precoding has been used with one flag bit “1” inserted with every Nb=5 data bits at boundary. The T (f) is a 7nth order IIR filter with the inverse (T (f)) being a stable filter.

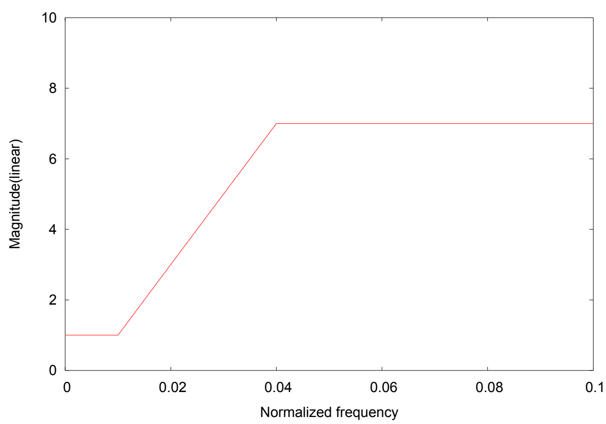

Fig2: Channel response

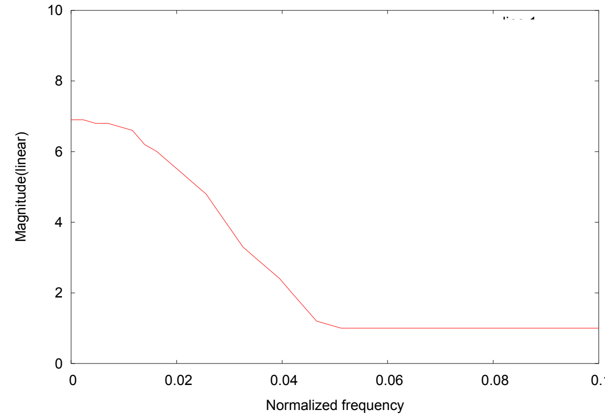

Fig3: Equalizer response

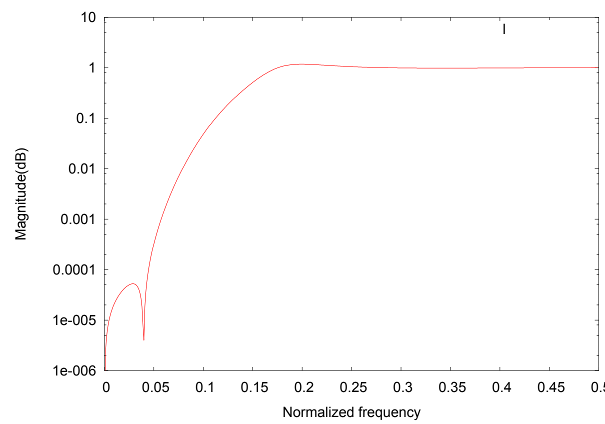

Fig4: T (f)

The metric trellis for precoding has two states with allowed transition as follows:

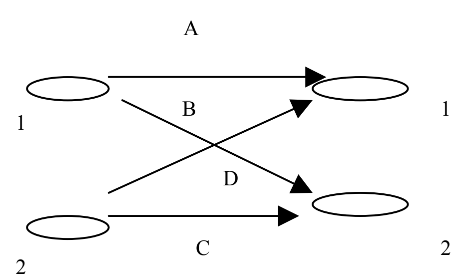

Fig5: Trellis diagram

A: Don't invert any bit in a frame.
B: Invert all the bits in the frame.
C: Invert Odd bits in frame.
D: Invert even bits in a frame.

A frame is defined as consisting of Nb bits and a flag bit. A look ahead L=5 frames has been used to get the required spectral shaping minimization of filter 1/T (f) in the transmitter.

In this paper, a novel way of seeding the equalizer has been proposed, so that the convergence time of the equalizer is faster. The idea is to use the inverse of the precoder filter before the equalizer. This, here onwards, will be called a complementary filter R (f) that takes care of the spectral nulls that were pre-empted by the precoder. This leads to the reduction of the spread of eigen values of signal autocorrelation matrix or covariance matrix [2]. Thus,

$$R(f) = 1/T(f) \quad (2)$$

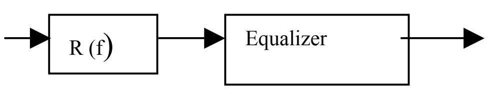

Figure6: Proposed structure of equalizer

This way the equalizer is not needed to equalize the abrupt channel conditions and the ensuing gain is manifested in the following ways:
1) Convergence time is reduced (Fig6 and Fig7).
2) The computational requirements can be reduced by reducing the number of taps of feedforward and feed backward (Fig8) paths.
3) The structure can be simplified from a complex DFE to a simpler FFE (Fig9).

The simulation has been done using 200taps in feed forward path and 20 taps in feed backward path. With the proposed structure a 60 percent save in the convergence time is seen (please see conclusion). The computational requirements are reduced by decreasing the number of taps (200 taps FFE to 150 taps FFE and 20 taps DFE to 15 taps DFE) but paying in convergence time (total save in time 30 percent). The structure is also modified from DFE to FFE (200 taps) and the effectiveness of the equalizer, more or less, has remained the same (mostly because the pole effects of the channel is already taken care by the new structure).

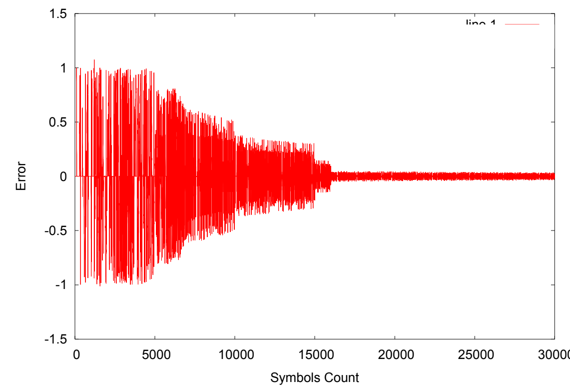

Fig7: Normal Equalization

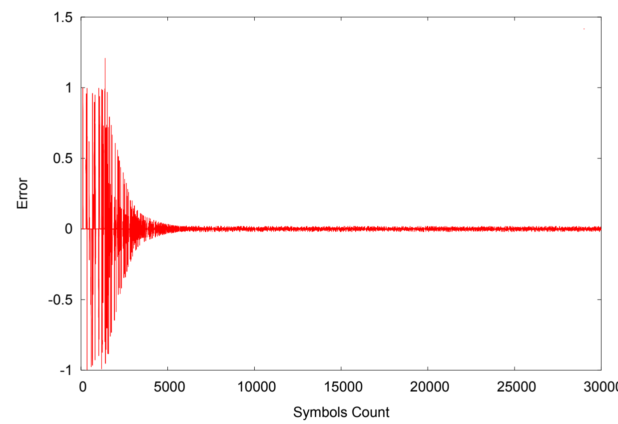

Fig8: Equalization with proposed structure

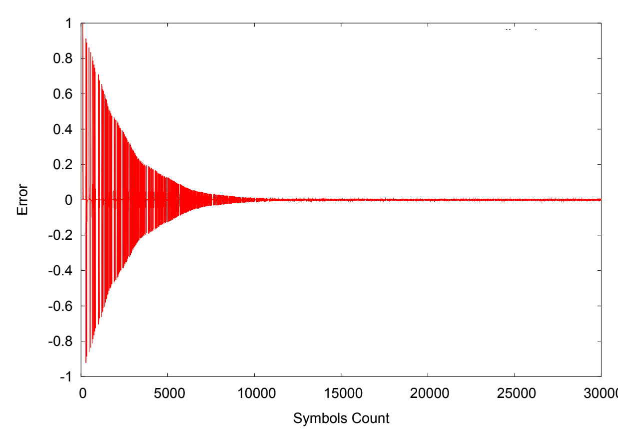

Fig9: Equalization with reduced no. Of taps

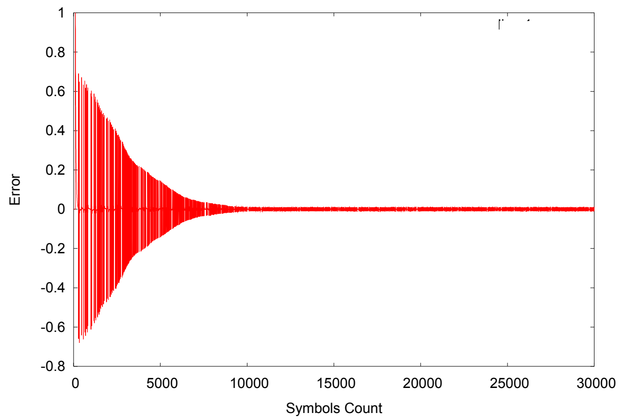

Fig10: Equaliztion with only feedforward structure

III. CONCLUSION

In deriving the above results it has been assumed that the precoding is working ideally which may not be the case in practical situations where efficiency of the precoded signals is also important. This scheme then can be pragmatically evaluated for the specific cases in terms of convergence time, reduced computation and simpler structures. This scheme also assumes that the precoding filter and the complimentary filter are stable. This may also not be the general case where the complimentary filter may be unstable. But if the receiver is to use this kind of scheme discussed, the stability of complimentary filter has to be ensured. *It can be shown that the effectiveness of using a stable complimentary filter is same as an unstable complimentary filter when working under infinite precision arithmetic*. The optimization scheme discussed here pre-empts the equalizer and hence is able to reduce the general complexity of the system. There is no improvement in steady state error performance of the equalizer.

IV. ACKNOWLEDGEMENT

The author gratefully acknowledges the stimulating and useful discussions with Sheela Prabhakar, Shantanu Jha and Narashima Pai at Ittiam Systems Pvt Ltd.

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