Ph.D. Thesis: Estimation of wideband time varying channels

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**Abstract**—In this thesis, we face the problem of estimating correctly the channel in a communication link. In general, the channel communication is time varying and frequency selective, which produces distortions in the data transmitted, reducing the transmission speed. For correcting these distortions it is necessary to have an accurate estimation of the channel and then to apply corrective procedures based on this estimation. We make use of a superimposed training (ST) sequence which is added to the information data, besides, we represent the channel communication as the weighted sum of a set of functions, which conform a basis. This basis is dependent of channel characteristics known a priori such as maximum Doppler frequency, shape of the transmitter and receiver filters, etc. Following this line, the channel estimated has less discrepancy with the real channel, besides the mathematical operations due to this estimation is reduced considerably respect to other ways of thought.

**Index Terms**—Superimposed training, time-varying channel estimation, orthogonal basis expansion, universal basis, discrete prolate spheroidal.

I. INTRODUCTION

Due to the actual requirements of high speed transmissions in mobile communications, it is necessary to establish algorithms that help to make easier and faster the estimation in the receiver side of the time-varying channel communication, in order to cancel their effects over the transmitted data. For achieving this goal, in this thesis we research about techniques for modeling the time-variant channels using basis, with the aid of a superimposed training sequence which is added to the data in the receiver side and we use it for estimating the changes in the channel.

II. PROBLEM DEFINITION

A. Superimposed Training

The channel estimation could be achieved, transmitting a training pilot signal, it is known as pilot assisted transmission (PAT). Exist different manners for transmitting the aforementioned pilot signal, the first one consist in transmit the pilot signal multiplexed in the time together with the information data [18], this procedure reduce the effective bandwidth due to the pilot signal wastes valuable bandwidth for its transmission, this method is implemented in the GSM standard [18]. A second way to transmit the pilot signal is adding it (superimposing) to the information data. This method is known as superimposed training (ST), and it has been studied extensively in [2]–[4] for time-invariant channels and, in [11], [16], [17] for time-varying channels. This manner offers the advantage of a better use of the bandwidth because, we transmit all the time information data, but presents the disadvantage that we need to distribute the transmission power between the information data and the training sequence. That methods for transmitting pilot signals are showed in Fig. 1.

![Different ways for transmitting pilots.](image)

In Fig. 1, \( s(k) \) is the sum of the data signal \( b(k) \), and the training signal \( c(k) \). Allow, \( b(k) \) to be the data to be transmitted. The training signal \( c(k) \) is constructed as mentioned in [2]. The aforementioned signal \( s(k) \) is propagated through \( h(k, l) \), which is the discrete representation of the overall impulse response of the system with a maximum delay spread \( \tau_{\text{max}} \) sec as showed in Fig. 2. The discrete version of the system could be visualized as a finite impulse response (FIR) filter, with \( L \) coefficients changing in the time. \( h(k, l) \) is composed by the sampled version of the transmitter pulse shaping filter \( g_t(k) \), \( f(t, \tau) \) which posses a maximum Doppler spread of \( f_d \) Hz; and the sampled version receiver matched filter \( g_r(k) \). The resulting signal is contaminated with additive noise \( n(k) \) which is due to the electronic components in the receiver, to produce the received signal \( x(k) \). Our goal is to find an estimate of the data transmitted using the received sequence, taking account that the training sequence is known, that is:

\[
\hat{x}(k) = \phi(x(k), c(k)). \tag{1}
\]

Where \( \hat{x}(k) \) is the data estimated, \( \phi(\cdot) \) is any function dependent of \( x(k) \) and \( c(k) \) such that \( c(k) = \hat{x}(k) - x(k) \) is minimum.
C. Basis Expansion

In the case of this thesis, we use ST together basis projection. The idea of basis expansion, like a method for modeling the channel communication has been widely issued by many authors. In [11], [13], [16] the authors use discrete prolate spheroidal (DPS) or Slepian basis for approximate the time-varying characteristics of each one of the taps of the channel. In [17] the elements of the basis used for representing the taps are complex exponentials. Other approximations use polynomials [12]. It is relevant to mention that in the latter articles, the projection of the channel is only in the time dimension, and this techniques must be applied for any one of the taps in the delay dimension. The projection of the delay dimension into basis has been developed in [1], [9], where the authors propose the universal basis (UB), which is dependent of the time impulse response of both the pulse shaping and matched filters. UB has been used joint ST/DDST in [8] for estimating time-invariant channels and there is proved that projection in UB produce an improvement in the channel estimation. In [14], [19] is consider the projection in both dimension using DPS. The authors in [14] propose the use of two-dimensional DPS sequences for approximating the channel communication, but they do not take into account the impulse response of both the pulse shaping and matched filter in the delay domain. In [19], authors use two-dimensional DPS sequences for projecting the channel in an OFDM system.

Our goal is to construct a basis, capable to expand the channel in both the time and delay domain. This can be done, if we departure from the results obtained in [11], [13], [16], where the authors use DPS for modeling the time variant characteristics of each tap of the channel, and [1], [8] where the authors use UB for expand the delay dimension of the channel communication. The last idea can be expressed mathematically as (2).

\[
b(k, l) = \sum_{r=0}^{R-1} \rho_r b_r(k, l)
\]

where \(N\) is the amount of data to be estimated, \(L\) is the length of channel, \(k = 1, 2, \ldots, N - 1, l = 1, 2, \ldots, L - 1\), \(b_r(k, l)\) are the elements of the basis, depending of both the time and delay variables, \(\rho_r\) are the weights to be estimated. We can see that with this procedure, instead of estimating \(N \times L\) elements, we only need to estimate \(R \leq N \times L\) parameters, which reduce the estimation error.

III. Thesis status

The activities realized from the beginning of the thesis to this moment have consisted in the research about orthogonal basis for projecting the channel and the estimation of this with the aid of superimposed training, besides we have developed an implementation in hardware based on the 6713 DSP of Texas Instruments, for testing the performance of the algorithms developed. In Fig. 4, we present the hardware designed.

IV. Conclusions

New methods for estimating communication channels have been developed during this thesis. These methods are based on superimposed training and variants of this, because they make a better use of the available bandwidth. On the other hand, our researches have departure from the concept of modeling the channel using projections onto basis. This procedure present a less errors compared with the actual methods, this improvement is due to we include to our estimator information about the shape of both the transmitter and receiver filters.

Together with the theoretical work done, we developed a new hardware based on the Texas Instruments DSP, with the objective of testing the new algorithms designed and having a prototype for future tests.

REFERENCES


