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Estimation and Equalization of Fiber Wireless Uplink for Multiuser CDMA 4g Networks

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Abstract: ***Recently, wireless last mile has received considerable attention since it requires much less infrastructure compared to wire line alternatives such as x DSL and cable modem networks. FiWi networks become rapidly mature and give rise to new powerful access network solutions and paradigms. Fiber-wireless (Fi-Wi) access fronts can support 100s of Mb/s envisioned by 4G networks. However, a major issue associated with Fi-Wi links is the nonlinear distortion of the radio-over-fiber (ROF) link coupled with the multipath dispersion of the wireless channel. Estimation and subsequent equalization of the concatenated fiber-wireless channel needs to be done, especially at high bit rates. The uplink is severely affected due to large fluctuations in the radio signal. This paper proposes an estimation and subsequent equalization algorithm for the Fi-Wi CDMA uplink. The estimation employs the properties of pseudo noise (PN) sequences and the equalization uses a novel Hammerstein type decision feedback equalizer (HDFE). The estimation and equalization are performed in the presence of multiple access interference (MAI) and wireless and optical channel noise. Furthermore, we propose a unique algorithm to mitigate MAI. Numerical evaluations show a good estimation and equalization of both the linear and nonlinear channels.***

Keywords: Fiber-wireless systems, radio over fiber, code division multiple access, parameter estimation, identification, pseudo noise process, multiple access interference, channel estimation and equalization

I. INTRODUCTION

With the evolution of internet & computer technology, people are using various mobile technologies. The high data rate and broadband demands of wireless & wired line networks have rapidly increased in recent years. New wireless subscribers are signing up at an increasing rate demanding more capacity whereas the radio spectrum is limited. One scheme that has become increasingly popular to alleviate this demand is radio-over-fiber (ROF).

ROF, where an optical signal is modulated at radio frequencies & transmitted via an optical fiber, provides for an excellent link allowing for high band-width communication of several channels.There is an intermediate stage between the central base station and the mobile units. The intermediate stage is the optical fiber & the radio access point (RAP). The RAPs provide wireless access instead of the conventional base station and are connected to the central base station via the ROF links.Optical fiber based wireless access schemes have become very popular recently because of their potential to increase system capacity. A Fiber – Wireless uplink consists of a wireless channel followed by ROF link. Optical fiber has some advantageous properties such as low attenuation, longevity, and low maintenance costs which will eventually render fiber the medium of choice in wired first / last mile access networks.

Within the more advanced solutions focus will be on active networks including programmable networks evolution to 4G wireless networks, programmable 4G mobile network architecture, cognitive packet networks and the random neutral networks based algorithms. The major expectation from the fourth generation of wireless communication networks is to be able to handle much higher data rates. These technologies are based on OFDMA and space time coding.

Another advantage of Fi-Wi networks is that radio resources can be allocated when and where it is most needed. The possibility of using existing fiber for Fi-Wi networks makes it even more attractive. In this paper, we investigate and suggest performance improvements for a radio-over-fiber (ROF) based Fi-Wi solution that will support broadband access envisioned in 4G networks. Direct sequence code division multiple access (DS-CDMA) with proper equalization has been investigated for 4G uplink for a number of good reasons. Direct sequence CDMA does not require synchronization among users and enables low power transmission. Therefore, in this paper we assume a pseudo noise (PN) sequence based DS-CDMA uplink.

II. BACKGROUND

FIBER WIRELESS ACCESS

Optical fiber based wireless access schemes have become very popular recently because of their potential to increase system capacity, enable wideband access and to cover special areas such as tunnels and supermarkets. These schemes are especially useful for indoor applications with micro and pico cellular architecture.

When the fiber is short and the radio frequency is only a few GHz, effects of fiber dispersion and the laser chrip are negligible. This is especially true at 1310nm.Therfore, the ROF link has adequate bandwidth to support wireless multimedia services. In this case, however nonlinear distortion of the electrical to optical conversion process becomes the major limitation. The impairment is severe in the uplink where, the received signal largely fluctuates due to multipath fading of the wireless channel. Both direct modulation and external modulation schemes suffer from limited dynamic range because of this nonlinear distortion .

III. EXISTING METHOD

RADIO-OVER-FIBERFOR 4G

Radio-over-fiber, where an optical signal is modulated at radio frequencies and transmitted over an optical fiber, provides the broadband link needed to bring the radio-access-point (RAP) closer to the user. The RAP provides wireless access to the user instead of conventional base stations. The RAP is connected to the central base station via the ROF link. Typically, the complexity, cost, and power consumption of the RAP is kept at a minimum in order to allow large scale deployment.

This architecture significantly shortens the air interface and supports broadband services. The RAP performs RF-to-optical (uplink) and optical-to- RF (downlink) conversions only. The baseband to RF modulation/ demodulation is done at the central base station or at the user handsets only. The optical fiber and the RAP handle RF/optical signals and not baseband. Hence, the baseband analysis and signal processing has to be done for the concatenated fiber-wireless system together. This is done at the central base station for the uplink. This concatenation makes the Fi-Wi CDMA link special and different than regular CDMA links. There are many studies around multiuser and iterative detection algorithms in CDMA system.

BASIC DECISION FEEDBACK EQUALIZER

The decision feedback equalizer (DFE) has been very successful in wireless communications. The basic DFE itself is nonlinear because of the decision device and the feedback loop. However it is important to note that, although the basic DFE is nonlinear, it is effective in equalizing only linear channels .

IV. PROPOSED METHOD

WIRELESS CHANNEL ESTIMATION THEORY

A model of the fiber-wireless uplink is shown in Fig. This class of system consists of a wireless channel (linear system with impulse response h(n)) in cascade with an optical fiber link (nonlinear system with a function F(.)). The first step in estimating the wireless channel of the fiber-wireless uplink is to define the output of the system. According to the theorem of Weiner strass , any function which is continuous within an interval may be approximated to any required degree of accuracy by polynomials in this interval. Therefore the output of the nonlinear system plus the noise can be represented by a polynomial of the form where v(n) is the total noise of both the optical and wireless channels. The system output r(n) can then be expressed by the functional series

$$
\begin{aligned}
r(n) &= A_1 \sum_{m_1=-\infty}^{\infty} h(m_1)u(n-m_1) \\
&+ A_2 \sum_{m_1=-\infty}^{\infty} \sum_{m_2=-\infty}^{\infty} h(m_1)h(m_2)u(n-m_1)u(n-m_2) \\
&+ A_l \sum_{m_1=-\infty}^{\infty} \cdots \sum_{m_l=-\infty}^{\infty} \prod_{i=1}^{l} h(m_i)u(n-m_i) + \cdots + v(n)
\end{aligned}
$$

where u(n) is a compound input that can be written as

$$u(n) = x_1(n) + x_2(n) + \cdots + x_N(n)$$

where N is the number of PN sequences (or equivalently the number of users). It is at this point where we are considering multiple users. In , u(n) was simply taken as a single PN sequence but u(n) is taken as a summation of multiple independent PN sequences x(n) of period Nc where

$$N_c = 2^n - 1 \qquad n \equiv \text{degree of the PN polynomial}$$

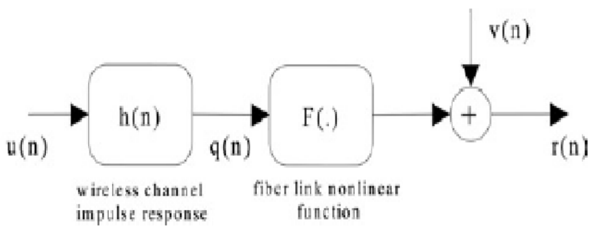

Fig-Fiber-wireless uplink modeled as a wiener system.

The output can also be written as a summation of the isolated the order kernel as sequences are used to aid the discussion.

$$r(n) = w_1(n) + w_2(n) + w_3(n) + \cdots + w_l(n) + v(n)$$

where

$$w_l(n) = A_l \sum_{m_1=-\infty}^{\infty} \cdots \sum_{m_l=-\infty}^{\infty} \prod_{i=1}^{l} h(m_i)u(n-m_i)$$

Therefore the output r(n) consists of a compound input u(n) that has been dispersed in time because of the impulse response and then raised to higher order powers because of the nonlinearity.

OPTICAL CHANNEL ESTIMATION THEORY

The optical channel is estimated by performing a least squares polynomial fit between the input and output of the nonlinear system. In the Fi-Wi channel there is no access to the internal signal (n) (the input to the nonlinear system) at the RAP and therefore it must be estimated. the internal signal can be estimated by: 1) convolving the final CIR estimates ˜$h(p)$ 1 (n)...˜$h(p)$ N (n) (after p iterations) with their respective PN inputs $x1(n)$...$xN(n)$, and 2) summing the result over all user convolutions, giving the signal ˜$q(n)$. The least squares polynomial fit is then applied to the estimated signal ˜(n) and the measured output $r(n)$. Estimates of the polynomial coefficients can be made by using the aforementioned signals and an appropriate curve fitting algorithm.

Let the estimated polynomial coefficients be given as

$$\hat{\mathbf{A}} = [\hat{A}_0 \quad \hat{A}_1 \quad \hat{A}_2 \quad . \quad . \quad . \quad \hat{A}_l]^T.$$

V. SIMULATION RESULTS AND ITS PERFORMANCE

1. CIR and polynomial channel :all CIR'S used in the simulations satisfied the property of unit energy , *i.e.*, Σ n |$h(n)$|2 = 1, to ensure no amplification from the wireless channel. The gain of each path was selected using the Rayleigh fading model. The optical channel was modeled using a third order memoryless nonlinearity

$$y = c_1 x^3 + c_2 x.$$

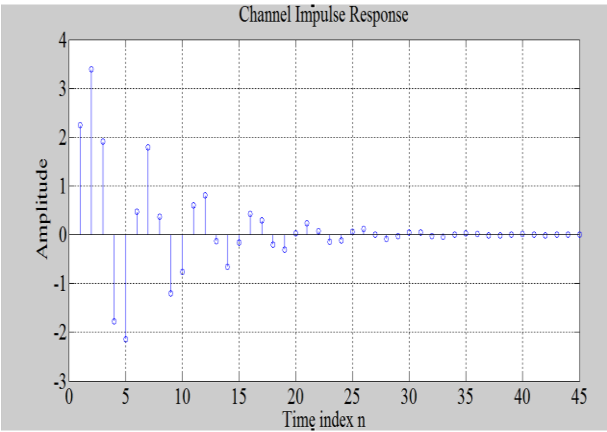

Fig 1.Channel impulse response

2. Number of users and PN sequence length: The effect of including additional users will also be shown. Simulations were performed with a PN sequence length of 4095 based on several trials. Compared to the single user case identification in a multiuser environment requires a longer sequence length because there is MAI in addition to ISI.

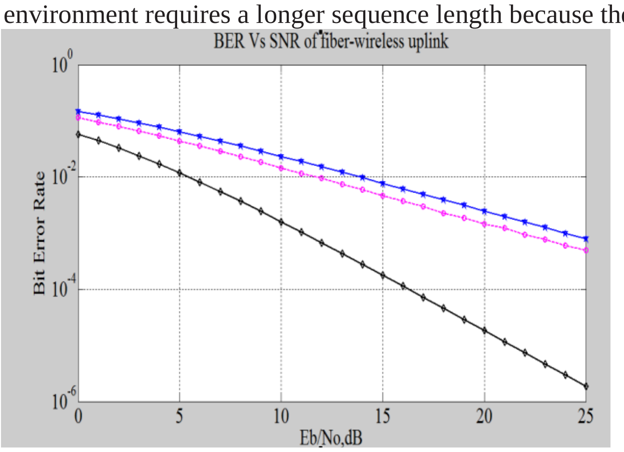

Fig 2.BER Vs SNR

3. Each of the multiple PN sequences was generated from a separate maximal-length linear feedback shift register (LFSR) polynomial. This is in contrast to the common technique (used in current CDMA systems) of using delayed versions of a single PN sequence to represent different users. The 'delay' technique requires a priori knowledge of the channel memory and is therefore undesirable. If the PN sequence offset is not longer than the memory, there will be multiple identifications.

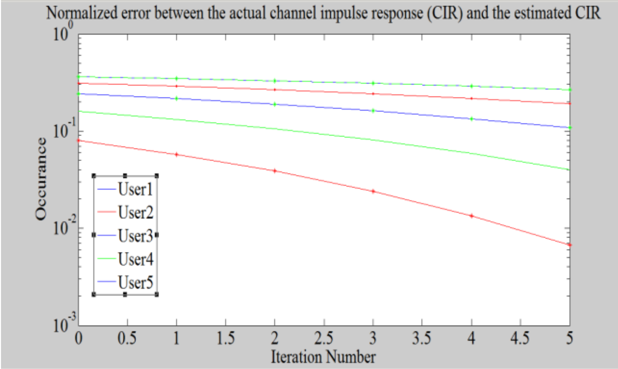

Fig 3.normalized error between actual CIR and estimated CIR

VI. CONCLUSION

In this paper we have proposed a Hammerstein type decision feedback equalizer, for compensating wiener type nonlinear channels. Although the motivation is triggered by the fiber-wireless uplink, the equalizer is effective against any general Wiener type nonlinear channel that consists of a time dispersive linear system followed by a memory less static nonlinear system. These type of channels are frequently encountered in communication systems. The HDFE architecture has the advantage that when the linear dynamic system is a fast changing wireless channel, it enables updating only the linear filter coefficients, leaving the nonlinearity compensation unchanged. Furthermore, this architecture is especially useful when multiple users share a single nonlinear link such as the fiber channel. This paper also presented an efficient algorithm for the identification and equalization of the uplink in a multiuser CDMA Fi- Wi network. Estimation was performed using the correlation properties of PN sequences and equalization was performed using a unique equalizer that has separate linear and nonlinear modules. The algorithm also mitigates MAI with few iterations. This technique works in an asynchronous CDMA environment, which is ideal for a 4G uplink. A key advantage of this approach is the separate estimation and equalization of the linear and nonlinear portions.

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