Iterative Cancellation Of Non-Linear Distortion Noise In Digital Communication Systems

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ABSTRACT:

In this paper, an iterative receiver that performs nonlinear distortion noise cancellation is presented. The performance is assessed for time division multiple access (TDMA), orthogonal frequency division multiple access (OFDMA) and single-carrier frequency division multiple access (SC-FDMA) waveforms. Even though a return link setup is considered, the receiver is equally applicable in the forward link, taking into account the differences in the data multiplexing and the channel. Analytical modeling of the received electrical signal-to-noise ratio (SNR) is carried out for OFDMA with one iteration of non-linear distortion noise cancellation.

The performance is assessed in terms of power efficiency and spectral efficiency, where the total degradation (TD) of the received SNR in a non-linear channel is minimized. The modulation formats of the DVB-RCS2 satellite return link standard and a respective non-linear channel have been used. OFDMA shows the highest power efficiency gain of 1.1–2.5 dB with 2 iterations of non-linear noise cancellation across the different modulation orders. In SC-FDMA, the gain is in the range of 0.3–1.1 dB, while gains of 0.1–0.8 dB and 0.2–1.9 dB are presented in TDMA with 20\% roll-off and 5\% roll-off, respectively.

INTRODUCTION

NOWADAYS, broadband access is considered a commodity. To provide coverage to all households on the territory of the European Union and Turkey, the project on Broad band Access via Integrated Terrestrial and Satellite Systems (BATS) develops an integrated network solution, merging the benefits of terrestrial mobile networks, digital subscriber line (DSL) networks and satellite communication systems. In particular, intelligent network and user gateways are designed which can classify the traffic of different types of applications and route it via low-latency terrestrial networks or high-
bandwidth satellite links to maximize the quality of experience. Due to the ongoing shift towards more bandwidth demanding applications and services, next generation networks need to offer higher system throughput and user data rates, flexibility to adapt to traffic demand across the coverage area, and at the same time decrease the cost per transmitted bit. For this purpose, a higher spectral efficiency without a significant increase in the computational complexity of the air interface is imperative.

The utilization of larger pieces of bandwidth in the higher frequency bands, such as Ka, Q and V radio frequency (RF) bands, imposes significant hardware implementation challenges, and imperfections cause signal distortion. Therefore, suitable signal processing techniques at the transmitter or receiverside that maximize the information rate of the link are still an open issue. For example, communication over the satellite channel suffers from linear and non-linear distortion. The linear distortion is attributed to mismatch of the signal spectrum and the spectral response of the filters along the chain, while the non-linear distortion originates from the non-linear transfer characteristic of the high-power amplifiers (HPAs) onboard the satellite and at the user terminal. These adverse effects reduce the power and spectral efficiencies of the transmission waveform. Time division multiplexing (TDM) is the waveform of choice in the latest DVB-S2X standard for the satellite forward link, while TDMA is employed in the return satellite link according to the DVB-RCS2 standard. Waveforms such as OFDMA and SC-FDMA are at the heart of terrestrial mobile long-term evolution (LTE) networks due to their high spectral efficiency and flexible traffic allocation.

**Existing Method:**

This paper presents a detailed comparative study of two single-carrier frequency-division multiple access (SC-FDMA) schemes, namely localized FDMA scheme (LFDMA) and interleaved FDMA scheme (IFDMA), versus orthogonal FDMA scheme (OFDMA), for a satellite uplink. The air-interface of the latter is based on the digital video broadcasting (DVB) family of standards. Considering two state-of-the-art high power amplifiers (HPAs), operating in the K- and S-bands, the performance of synchronous and asynchronous LFDMA, IFDMA and OFDMA is evaluated in a multi-user environment. Systematic comparison results show that although for synchronous reception IFDMA outperforms the other two schemes, for asynchronous reception it is the most sensitive to degradation caused by inter-block interference (IBI). Furthermore, due to its relatively large envelope fluctuations, OFDMA is the most sensitive scheme to non-linear distortion. Although for synchronous reception LFDMA shows only slightly inferior performance as
compared to IFDMA, it outperforms the other two schemes for the asynchronous reception considered, especially for increased IBI distortion.

**Disadvantage:**

1. Not properly applicable on non-linear distortion noise
2. Hardware complexity will increase with high power amplifiers

**Proposed Method:**

In this paper, an iterative receiver that performs non-linear distortion noise cancellation is presented. The performance is assessed for time division multiple access (TDMA), orthogonal frequency division multiple access (OFDMA) and single-carrier frequency division multiple access (SC-FDMA) waveforms. Although a return link setup is considered, the receiver is equally applicable in the forward link, taking into account the differences in the data multiplexing and the channel. Analytical modeling of the received electrical signal-to-noise ratio (SNR) is carried out for OFDMA with one iteration of non-linear distortion noise cancellation.

The performance is assessed in terms of power efficiency and spectral efficiency, where the total degradation (TD) of the received SNR in a non-linear channel is minimized. The modulation formats of the DVB-RCS2 satellite return link standard and respective non-linear channel have been used. OFDMA shows the highest power efficiency gain of 1.1–2.5 dB with 2 iterations of non-linear noise cancellation across the different modulation orders. In SC-FDMA, the gain is in the range of 0.3–1.1 dB, while gains of 0.1–0.8 dB and 0.2–1.9 dB are presented in TDMA with 20% roll-off and 5% roll-off, respectively.

**Advantages:**

1. Applicable on non-linear distortion noise
2. Low Hardware complexity with DVB-RCS2

**Disadvantage:**

1. Congestion will occur with big intervals

**Transmitter**
An OFDM carrier signal is the sum of a number of orthogonal sub-carriers, with baseband data on each sub-carrier being independently modulated commonly using some type of quadrature amplitude modulation (QAM) or phase-shift keying (PSK). This composite baseband signal is typically used to modulate a main RF carrier.

$s[n]$ is a serial stream of binary digits. By inverse multiplexing, these are first demultiplexed into $N$ parallel streams, and each one mapped to a (possibly complex) symbol stream using some modulation constellation (QAM, PSK, etc.). Note that the constellations may be different, so some streams may carry a higher bit-rate than others.

An inverse FFT is computed on each set of symbols, giving a set of complex time-domain samples. These samples are then quadrature-mixed to passband in the standard way. The real and imaginary components are first converted to the analogue domain using digital-to-analogue converters (DACs); the analogue signals are then used to modulate cosine and sine waves at the carrier frequency, $f_c$, respectively. These signals are then summed to give the transmission signal, $s(t)$.

**Receiver**

The receiver picks up the signal $r(t)$, which is then quadrature-mixed down to baseband using cosine and sine waves at the carrier frequency. This also creates signals centered on $2f_c$, so low-pass filters are used to reject these. The baseband signals are then sampled and digitised using analog-to-digital converters (ADCs), and a forward FFT is used to convert back to the frequency domain.

**Extension Method:**
The next generation of interactive satellite terminals is going to play a crucial role in the future of DVB standards. As a matter of fact in the current standard, satellite terminals are expected to be interactive thus offering apart from the possibility of logon signalling and control signalling also data transmission in the return channel with satisfying quality. Considering the nature of the traffic from terminals that is by nature bursty and with big periods of inactivity, the use of a Random Access technique could be preferred. In this paper

In DVB-RCS2 is considered with particular regard to the recently introduced Contention Resolution Diversity Slotted Aloha technique, able to boost the performance compared to Slotted Aloha. The extension analyzes the stability of such a channel with particular emphasis on the design and on limit control procedures that can be applied in order to ensure stability of the channel even in presence of possible instability due to statistical fluctuations.

Simulation Results

Random Access congestion control
Variance of non-linear distortion noise for 16-QAM with an SSPA in return link

1. Analytical model by means of BER performance evaluation, simulation (solid lines) vs theory

![Graph showing variance of non-linear distortion noise for 16-QAM with an SSPA in return link.](image)

![Graph showing analytical model by means of BER performance evaluation, simulation (solid lines) vs theory.](image)
OBO of digital transmission schemes for QPSK with an SSPE and AWGN in return link. (a) No i

OBO of digital transmission schemes for QPSK with an SSPE and AWGN in return link. (b) One
CONCLUSION

In this paper, an iterative receiver has been presented which performs cancellation of the IMI that originates from the nonlinear distortion in the channel. The performance of single-carrier transmission schemes such as TDMA and SC-FDMA is maximized by the joint application of ML detection with respect to the received constellation centroids and nonlinear noise cancellation using individual scaling factors for the detected symbols. The proposed receiver can be applied in all types of commercial digital communication systems. These include terrestrial mobile wireless communications, DSL and cable communications, satellite communications, and optical wireless communications such as infrared communications and VLC. In addition, it can be applied in both the forward and the return links.

The receiver has been tested with TDMA, SCFDMA, and OFDMA transmission formats, and it has demonstrated significant
gains in the power efficiency. An analytical model has been developed for 1 iteration of IMI cancellation in OFDMA. It has been shown that even 1 iteration is sufficient to present the majority of the gain of IMI cancellation in the tested transmission schemes. In the considered modulation setup, gains of up to 2.5 dB are expected for OFDMA, 1.1 dB for SC-FDMA, 0.8 dB for TDMA with 20% roll-off and 1.9 dB for TDMA with 5% roll-off. The receiver is particularly suitable for application with higher order modulation formats which are more vulnerable to non-linear distortion, and as a result higher gains are expected. Consequently, higher spectral efficiency can be achieved which can be translated into higher throughput and lower cost per transmitted bit.

REFERENCES


[10] J. Gazda, “Iterative receiver for nonlinearly distorted SC-FDMA transmission,” in Proc. 10th SCYR, Kosice, Slovak Republic,