# Study of ICI in PRS - OFDM systems

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*Abstract* – **In this work the inter carrier interference (ICI) in PRS-OFDM system with different polynomials is investigated. Carrier to interference ratio (CIR) is studied depending on the frequency offset (ε) for OFDM systems with any Correlative Coding (PRS) and without PRS.**

*Keywords* – **ICI, PRS, OFDM, CIR, Correlative coding**

## I.INTRODUCTION

It is known that OFDM is widely used in digital communications in recent years. OFDM is successfully applied in mobile communications [4], such as: Wireless LAN (WLan) with very high speed transmission, ADSL, digital broadcasting (DAB and DVB) [3], data transmission in power line (PL) systems and in Satellite TV. In these systems arise some problems: ICI is caused by an error in synchronization of subcarriers, channel parameters that change over time and phase noise. OFDM is also sensitive to the frequency error between transmitter and receiver [2]. Carrier frequency shift causes many problems: Amplitude attenuation and phase shift of each subcarriers and interference between subcarriers (ICI) [1]. Impacts of frequency offset of the mobile communication systems performance are stronger. As a result of the relative displacement Doppler shift of carrier frequency occurs [5]. This causes synchronization errors between the bearing carriers in the receiver and transmitter, damage to orthogonality between the subcarriers, which causes rise to interference and ICI .

## II. THEORETICAL BACKGROUND

In the presented paper basic relations are shown. These equations are used by the synthesis of the simulation model of the OFDM system, shown on fig.1. The main aim of the article is to obtain a global relation for the CIR estimation.

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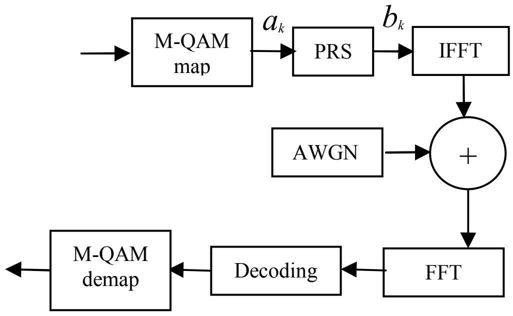


*Fig.1 Block Diagram of PRS OFDM system*

Here the following abbreviations have been used:
M-QAM mapping and demapping. Modulation in base band;
PRS: partial response signalling;
IFFT: inverse fast Fourier transformation;
FFT: fast Fourier transformation;
AWGN: additive white Gauss noise channel.

CIR is a key parameter in OFDM communication systems and it shows the effect of ICI, which is a random process. Several studies of the CIR value have been made. These values have been obtained by the investigation of OFDM system with and without PRS. A comparison has been made in [3]. The $k$-th subcarrier of the received signal in OFDM system with $N$ subcarriers has the form [3]**:**

$$r_k = \frac{1}{N}\sum_{n=0}^{N-1}\sum_{l=0}^{N-1} b_l \exp(j\frac{2\pi}{N}nl)\exp(j\frac{2\pi}{N}n\varepsilon)\exp(j\frac{2\pi}{N}nk) = \sum_{l=0}^{N-1} b_l S(l-k) \quad (1),$$

where:

$$S(l-k) = \frac{\sin(\pi\varepsilon + l)}{N\sin(\frac{\pi}{N}(\varepsilon + l - k))\exp(j\frac{\pi}{N}((N-1)\varepsilon - (l-k)))} \quad (2).$$

The parameter ε is the normalized frequency offset. The symbol, obtained at the output of the correlative coding block, is denoted by $b_l$. The received signal: $r_k$ can be written as:

$r_k = C_k + I_k$,

where $C_k$ is the information signal, and $I_k$ is the interference in the $k$-th subcarrier. Basic relation for CIR estimation for M-ary modulation and any PRS polynomials is proposed:

$$CIR = \frac{E(|C_k|^2)}{E(|I_k|^2)} \quad (3).$$

$$E(|C_k|^2) = E(|b_k|^2).\left(\frac{\sin \pi.\varepsilon}{\pi.\varepsilon}\right)^2 = Eq.C.C^T.\left(\frac{\sin \pi.\varepsilon}{\pi.\varepsilon}\right)^2 \quad (4)$$

where:

$$Eq = \begin{cases} 1 & M = 2 \\ \dfrac{2(M\text{-}1)}{3}, & M = 4,16... \end{cases} \quad (5)$$

$M$ -ary modulation,

$Eq$- the mean of the energy of the sequence $a_k$.,

$C$ - vector, which elements are the coefficients of the PRS polynomial.

The signal interference between the subcarriers is:

$$E[|I_k|^2] =$$

$$Eq.C.C^T.\sum_{l=1}^{N-1}|S(l)|^2 - \left[\sum_{l=2}^{N-1} S(l)S^*(l-1)\mathrm{E}[\mathrm{b}_l,\mathrm{b}_{l+i}] + S(l-1)S^*(l)\mathrm{E}[\mathrm{b}_l,\mathrm{b}_{l-i}]\right] \quad (6)$$

Where: $i$ =1,2..$K$-1, a $K$ is the PRS polynomial elements number and $E[b_l,b_p]$ is the cross correlation function between $b_l$ and $b_p$.

This expression is used to develop a simulation model, designed to measure CIR. The results of the experiments are given bellow.

## III. EXPERIMENTAL RESULTS

The Diagram obtained as a result of simulations of PRS - OFDM systems using polynomial encoding of different classes is shown on fig.2.

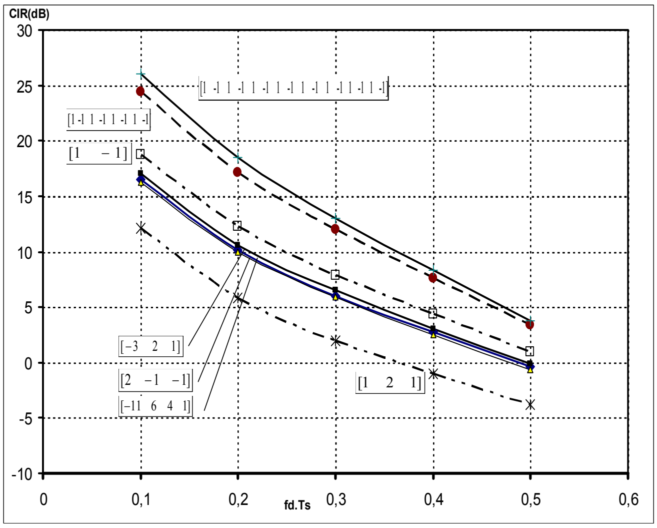


*Fig.2. CIR in PRS - OFDM systems using polynomials with coefficients* [-1 1 6 4 1], [-3 2 1], [2 -1 -1], [1 -1], [1 2 1] [1-1 1 -1 1 -1 1 -1].

On the x axis is ε - the normalized frequency offset and y-axis is the CIR in [dB]. The simulation environment is Matlab .

The simulation results are obtained under the following conditions:

the parameter ε has been changed

CIR has been measured.

The comparison between the obtained and the well known in the scientific literature results allows general estimation to be made and can be used as methodology for choice of appropriate coefficients for PRS polynomials, where the ICI has been minimized without decreasing the BER.

After number of experiments, selection of polynomials set, used in OFDM systems with PRS, in whom a significant improvement in CIR compared to conventional systems, has been carried out. The results of simulation studies have shown that PRS-OFDM system, using polynomials with coefficients (4, -3, -1) (-3, 2, 1) (2, -1, -1) , (1 -1 1 -1 1 -1 1 -1 1 -1 1 -1) in the PRS simulation model, give an improvement of CIR compared with the OFDM system without PRS.

## IV.CONCLUSION

The given relations for CIR estimation for M-ary modulation and any PRS polynomials and simulations describe a possible methodology for the study of ICI in OFDM systems with PRS coding. It can be selected such polynomials that minimize ICI and keep the BER performance. This is particularly important for communications with fast moving mobile objects, where the Doppler shift is relatively large compared with the distances between the subcarriers .

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