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Optimization Technique of OFDM Used in SCADA System

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Abstract— ***SCADA is designed to automate various systems like process industry, power grid etc. SCADA consist of master station (MS) and a number of remote terminal units (RTU). RTUs are connected to Master Station via communication channels. Communication channel limits the speed of data acquisition and control. To send many data from RTUs to Master Station multiplexing technique like Orthogonal Frequency Division Multiplexing (OFDM) can be used. OFDM has been focused on high-data-rate wireless communication. But high Peak-to-average power is one of the main obstacles to limit wide applications. Here a technique of reducing PAPR is presented. This technique is Selective Mapping (SLM) using standard array.***

Keywords: SCADA, RTU, MS, OFDM, SLM.

I. INTRODUCTION

SCADA system is developed to control the process at a distance. Different parameters can be controlled by the same master station. Control parameters are sent to the master station by remote terminal units. Communication channel work as a bridge between master station and remote terminal units. Total parameter sending capacity depends on the communication channel type. SCADA is a concept that is used to refer to the management and procurement of data that can be used in developing process management criteria. As in a SCADA system many RTUs are connected to the same MS through channel. Hence using an efficient communication channel is of much importance. For the purpose wireless channel with multiplexing technique can be used to use the channel more efficiently. OFDM is a very suitable technique to use the wireless channel more efficiently. OFDM is an attractive multicarrier technique for high-bit-rate transmission. In OFDM system data is transmitted simultaneously through multiple frequency bands. Even OFDM technique is proved to be very effective for sending data from many RTUs to MS, this technique has a drawback of its high peak-to-average power ratio (PAPR). In order to reduce PAPR of OFDM system many techniques have proposed. Here in a technique of scrambling type called Selective Mapping (SLM) is used to reduce PAPR

II. COMPONENTS OF SCADA SYSTEM

SCADA systems are primarily control systems. A typical control system consists of one or more remote terminal units (RTU) connected to a variety of sensors and actuators, and relaying information to a master station.

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For the most part, the brains of a SCADA system are performed by the Remote Terminal Units (sometimes referred to as the RTU). The Remote Terminal Units consists of a programmable logic converter. The RTU are usually set to specific requirements, however, most RTU allow human intervention, for instance, in a factory setting, the RTU might control the setting of a conveyer belt, and the speed can be changed or overridden at any time by human intervention. In addition, any changes or errors are usually automatically logged for and/or displayed. Most often, a SCADA system will monitor and make slight changes to function optimally, SCADA systems are considered closed loop systems and run with relatively little human intervention. One of key processes of SCADA is the ability to monitor an entire system in real time. This is facilitated by data acquisitions including meter reading, checking statuses of sensors, etc that are communicated at regular intervals depending on the system.

A. Master Station

This Component of the SCADA system is heart of the system and is located under operators control. All the control decisions are made in this system. This subpart is connected to the RTU through communication channel.

B. Remote Terminal Unit

Remote unit is installed near the process. This unit collects the information of process and send it to master unit. Remote Unit is connected to the Master Unit by communication channel.

C. Communication Mode

This unit transmit data between master unit and remote unit. Communication mode can be a cable, wireless media, satellite etc. This unit is a bridge between MS and RTU.

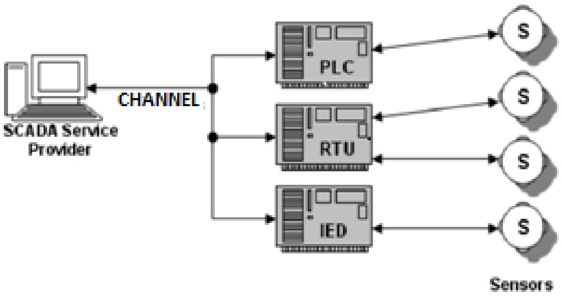

Figure 1 Basic SCADA Diagram

SCADA systems have traditionally used combinations of radio and direct serial or modem connections to meet communication requirements, although Ethernet and IP over SONET / SDH is also frequently used at large sites such as railways and power stations.

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The remote management or monitoring function of a SCADA system is often referred to as telemetry. In SACADA system communication can be using OFDM. Which is much more efficient and effective method of communication. Using OFDM the available channel can be made more utilized as this is the technique in which the bandwidth is used more efficiently. In OFDM the same bandwidth can be used to send the more data through the channel.

III. OFDM AS MULTIPLEXING TECHNIQUE

OFDM is a block modulation scheme where a block of information symbols is transmitted in parallel on subcarriers. An OFDM Modulator can be implemented as an inverse discrete fourier transform (IDFT) on a block of information symbols followed by an analog-to-digital convertor.

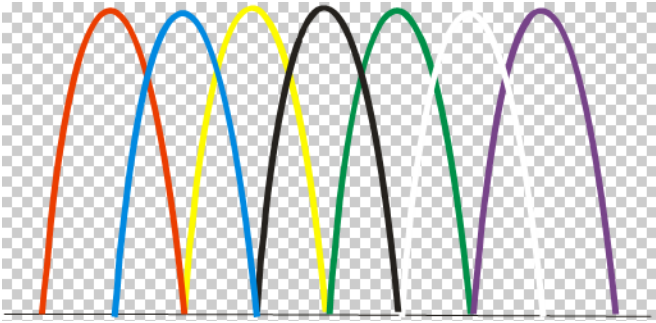

Figure 2 Multiplexing in OFDM

A. Vulnerable of OFDM (PAPR)

The big drawback of OFDM technique is its high Peak-to-Average Power Ratio (PAPR). When N signals are added with same phase they produce a peak power which is N times the average power. Which brings high value of peak to average power ratio? The big disadvantage of high PAPR is that it brings complexity in A/D and D/A convertors. The complex baseband OFDM signal x in one symbol period can be represented by [2]

$$X_i = \text{IFFT (X)} = \frac{1}{N}\sum_{K=0}^{N-1} X_k\ e^{j2} x_i\ \ k/n$$

The PAPR of the transmitted OFDM signal can be defined in [3]. The peak to average power ratio for a signal x is defined a

$$PAPR = \frac{\max(|x_i|)^2}{E(|x_i|)^2} \qquad (2.2)$$

Expressing in decibels,

Where E[lxil] is the average power of signal and it can be computed in the frequency domain because Inverse Fast Fourier Transform (IFFT) is a (scaled) unitary transformation. The PAPR of the discrete time sequences typically determines the complexity of the digital circuitry in terms of the number of bits necessary to achieve a desired signal to quantization noise for both the digital operation and the DAC. However, we are often more concerned with reducing the PAPR of the continuous-time signals in practice, since the cost and power dissipation of the analog components often dominate. To better approximate the PAPR of continuous-time OFDM signals, the OFDM signals Samples are obtained by L times oversampling. L-times oversampled time-domain samples are LN-point IFFT of the data block with zero-padding.

$$x_i = \frac{1}{N}\sum_{k=0}^{N-1} X_k e^{j2\pi nk/LN}, 0 \le n \le LN-1 \qquad (2.3)$$

Therefore, the over-sampled IFFT output can be expressed. However, the PAPR does not increase significantly after L=4. It has shown that L>=4 is sufficient to get accurate PAPR results [4]. PAPR is a random variable because it is a function of the input data, and the input data are random variable. Therefore PAPR can be calculated by using level crossing rate theorem that calculates the average number of times that the envelope of a signal crosses a given level. Knowing the amplitude distribution of the OFDM output signals, it is easy to compute the probability that the instantaneous amplitude will be above a given threshold and the same goes for power.

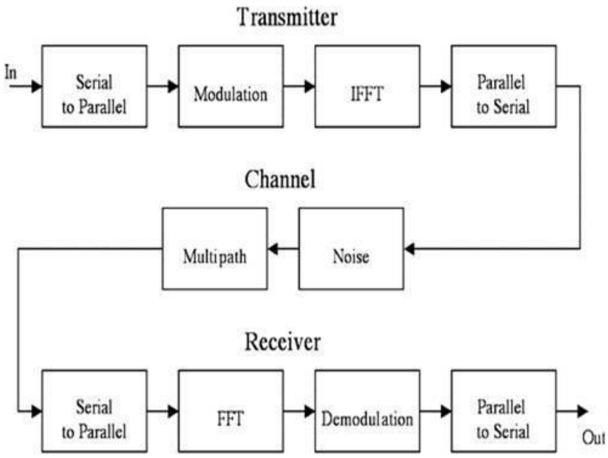

Figure 3 Block Diagram of OFDM Transmitter

This is performed by calculating the complementary cumulative distribution function (CCDF) for different PAPR values as follows:

CCDF = Pr (PAPR > PAPR0)

$$P(PAPR > z) = 1-(1-e^{-z})^N \qquad (2.4)$$

B. PAPR REDUCTION

In a typical OFDM system with SLM approach to reduce the PAPR, the input data block in X is partitioned into M disjoint subblocks, which are represented by the vectors $\{X^{(m)}\ m=0,1,2,\ldots M-1\}$.

In general, for SLM scheme, the known subblock partitioning methods can be classified into three categories [6]: adjacent partition, interleaved partition and random partition. Then, the subblocks are transformed into time-domain partial transmit sequences

These partial sequences are independently rotated by standard phase factors b. The objective is to optimally combine the sub blocks to obtain the time domain OFDM signals with the lowest PAPR.

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As a PAPR reduction technique, Selective Mapping (SLM), each sub-block is calculated by IFFT of size N (not N/M), while treating all other subcarriers as zero. The input data sequences are multipled by each of the phase sequences to generate alternative input symbol sequence. Each of these alternative input data sequence is made the IFFT operations, and then the one with the lowest PAPR is selected for transmission. A block diagram is depicted in Figure 4 below.

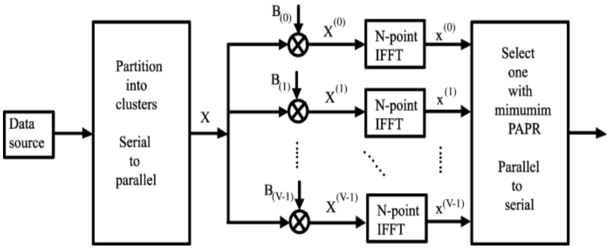

Figure 4: Block Diagram of SLM

The selection of a best PAPR is performed after M parallel IFFTs, by weighting M Sequences with M phase factors and adding them together. Parallel calculation of IFFTs means there is no sacrifice of system speed. The optimization of the phase factors is performed after all IFFT operations. So there is no need to repeat IFFT calculations, as required by many other PAPR reduction techniques. Each carrier in the sub blocks X (v) is multiplied with the same rotation factor Rd. Finally, the time domain vector with the lowest PAPR is transmitted. In the figure, Rd is chosen {±1}. With increasing the number of subblocks V, the probability of high PAPR decreases obviously, compared to the original OFDM signal.

IV. PERFORMANCE ANALYSIS

The complementary cumulative distribution function (ccdf) is defined as the probability that the PAPR value is larger than a specific value PAPR0, is generally used to evaluate the PAPR reduction performance for different schemes.

Table 1: Parameters of simulation

Number of subcarrier	64
Modulation type	QPSK
Number of simulated Bits	Over 1MBits

To evaluate and compare the performance of the Selective Mapping with the original PAPR reduction technique, computer simulation has been performed in which SLM are explained for which standard arrays are used for phase shifting in both the techniques.

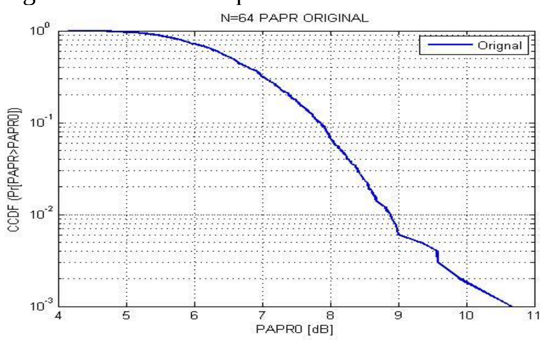

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Figure 5: Complementary cumulative distribution functions for theoretical PAPR

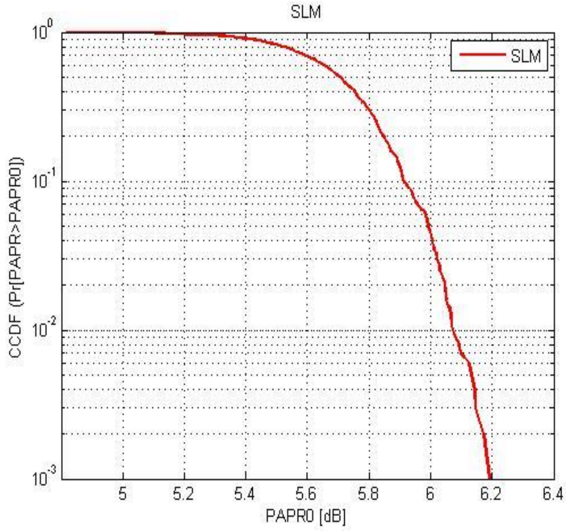

Figure 6: Complementary cumulative distribution function of SLM

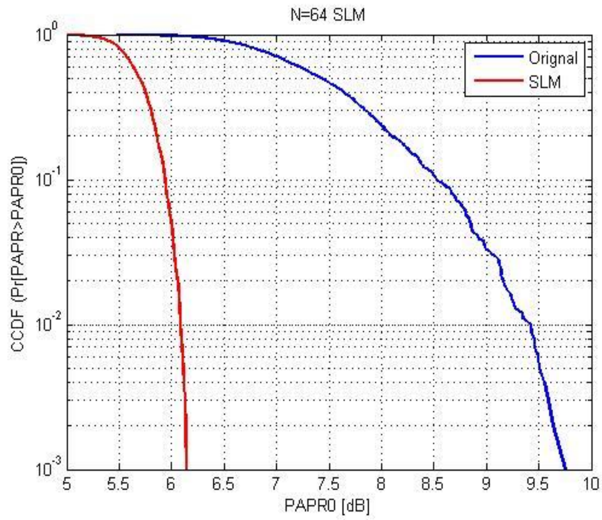

Figure 7 Comparison of ccdf Function of symbols PAPR

A few input symbols are selected by using standard array for phase rotation. This scheme has the advantage of not increasing the input power. These related schemes are effective and flexible to reduce the PAPR without nonlinear distortionFigure 5 and 6 shows the ccdf of the PAPR for theoretical and SLM scheme respectively. A combined comparison is also shown in Figure 7.

V. CONCLUSION

In this paper, we propose the use of OFDM as multiplexing technique in SCADA communication and to make the OFDM more effective and to minimize its vulnerable i.e. PAPR selective mapping technique is proposed. A few input symbols are selected by using standard array for phase rotation. This scheme has the advantage of not increasing the input power. Simulation results show that the Selective Mapping has peak power reduction capability than ordinary OFDM system. SLM scheme have shown the PAPR= 6.2 dB at the probability of 10^{-2}

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