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A Practical Implementation of a Wavelet Based Filtered Multitone Modulation

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Abstract: - In this paper we describe hardware implementation of a communication transceiver based on novel WFMT modulation. The attractive feature of WFMT is its low implementation complexity compared to known filtered multitone modulation architectures that are based on polyphase synthesis and analysis filter banks. The developed FPGA prototype of WFMT Transceiver was oriented on application in VDSL system, but may be successfully used in different wireless applications.

Key-Words: - Filtered multitone modulation (FMT), multicarrier, OFDM, hardware prototype, wavelet, FPGA.

1 Introduction

The Filtered Multitone Modulation was proposed by group of researches from IBM as alternative technology for xDSL [1]. This technology is based on Wavelet theory and uses complex filter-banks for synthesis and analysis of multi-channel signal.

The theoretical aspects of FMT for Wireless Application were developed by Cambridge University [2] and Udine University [3]. It was shown that in many cases FMT modulation might guarantee better performance than OFDM.

A most significant advantage of FMT is absence of out of band side lobes and high rejection of narrowband RF noise. The FMT receiver is working as high order bandpass filter and minimizes requirements to analogy components of the System. A second advantage of FMT before OFDM is absence of guard time interval (cyclic prefix) that is necessary for OFDM. The cyclic prefix in OFDM Systems takes up to 25% of OFDM symbol that means: the FMT may have up to 25% better performance.

The FMT advantages are not realized up today because of high complexity of synthesis and analysis filter-banks, which were proposed for theoretical study of FMT.

A novel Wavelet based Filtered Multitone Modulation was developed by Data-JCE Electronics Ltd in 2002 –2003 years [4]. A new processing algorithm lets realize a low complexly WFMT core that can be implemented in a small silicone chip.

The new algorithm was publicized in [5], [6].

2. Hardware Prototype

For experimental proving of theoretical results a hardware prototype of WFMT Transceiver was realized. The functional block diagram of WFMT transmitter is shown on Figure 1.

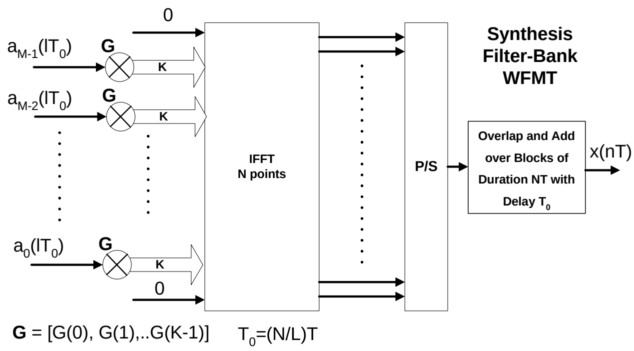

Figure 1. WFMT Transmitter Block Diagram

The WFMT transmitter uses an *N*-point core IFFT and transmits *M* data streams a_i each at rate $1/T_0 = L/(NT)$. The data streams modulate wavelet frequency components *K*. some of the outermost frequencies can be set to zero for spectral containment reasons. The frequency components are passed through the IFFT, P/S converted and finally an overlap and add operation takes place to obtain the synthesized multicarrier signal. D/A conversion and analog filtering is then implemented. The transmitter prototype was realized in FPGA VERTEX2 (3000) using Nallatech DSP BENADDA board.

In design were used standard Xilinx cores for 1024-point IFFT, RAMs, and multipliers. A 1024-point core IFFT was used to obtain 44 sub-channels in the frequency band 200 kHz – 3 MHz. The bandwidth of each WFMT channel is about 59 kHz. Constellations from 2 to 12 were used. The system clock of transmitter is 88 MHz. The transmitter test has shown a close coincidence with the simulation results. The power spectrum density of a realized WFMT transmitter is shown on Figure 2.

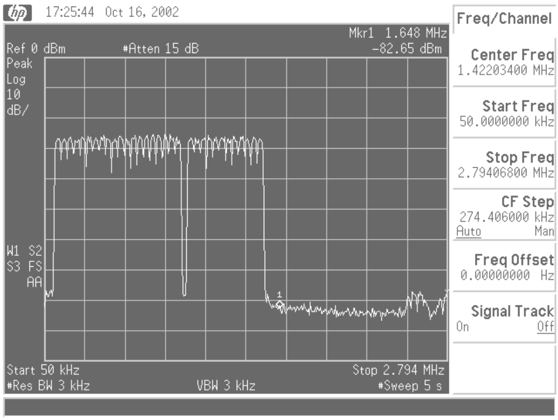

Figure 2. PSD of the WFMT Transmitter

As may see from figure 2. The WFMT spectrum practically not comprises side lobe components. One of 33 sub-channels was disabled for demonstration of possible rejection of RF narrowband noise. Others 32 sub-channels were modulated by QAM-64 random symbols. One of significant advantages of WFMT modulation is a very precision equalization algorithm that gives possibility to compensate a distortion of communication channel. This algorithm includes an independent correction for each frequency component of a transmitted wavelet. Figure 3 illustrates functional block diagram of WFMT receiver.

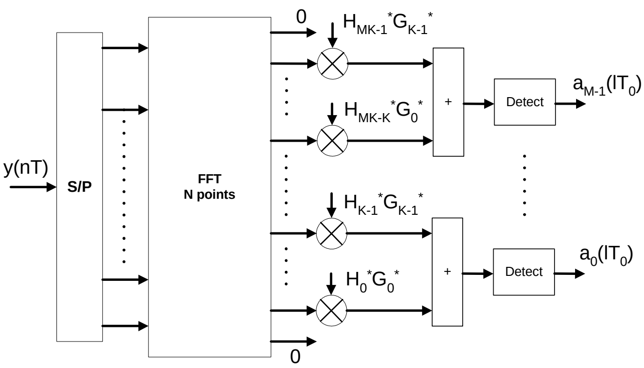

Figure 3. WFMT Receiver Block-Diagram

The WFMT receiver consists of a matched filter bank. Filters are matched to the equivalent sub-channel response [7]. Instead of wide known polyphase filter-bank, WFMT receiver includes 1024 point FFT core that provides analysis of frequency components of received wavelets. Each received wavelet component on output of FFT is multiplied on an equalizer coefficient H_j for compensation of distortion in communication channel. The information data a_i is calculates for each sub-channel by summing of weighted (G_i) wavelet components. The WFMT receiver is realized in FPGA XILINX VERTEX2 (3000) and uses about 1.5 million gates. A constellation diagram shown on figure 4 illustrates the WFMT receiver performance.

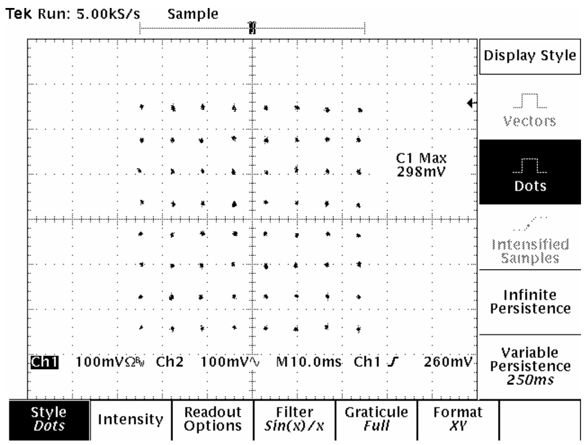

Figure 4. Constellation diagram of the WFMT receiver

3. Conclusion

We have presented results of practical realization of novel WFMT modulation. The FPGA based hardware implementation of a WFMT transceiver was developed and tested.

The experimental results are very close to the simulations and show good spectral characteristic of a new technology. For example we can see the MATLAB Simulation results shown on Figure 5. There is demonstrated a theoretical PSD graph of WFMT Transmitter calculated for the same number of sub-channels and the same prototype wavelet those were used in FPGA Design. We can see that FPGA system shows the same resultants that the MATLAB simulation. The bigger level of noise in real transmitter is explained by non-ideality of Digital to Analog Converter (14 bit).

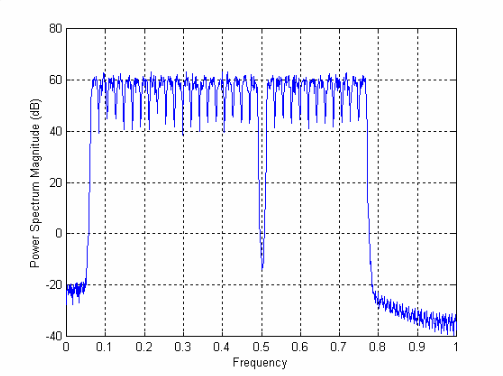

Figure 5. WFMT Transmitter PSD -MATLAB Simulation

A practical realization of a novel WFMT modulation shows that WFMT modulation may be a real candidate for a new line code for future DSL and Wireless System.

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