Next Generation Optical Access Based on N-OFDM with Decimation

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Abstract – The article deals with convergent solutions "radio over an optics" on the basis of N-OFDM. To comply with NG PON2 provides the possibility of rapid change in signal between OFDM, OFDMA or N-OFDM. To reduce the computational load on the segment of digital optical network proposed a distributed digital signal processing with low rates of digitization by using decimation operations.

Keywords: *Decimation, N-OFDM, Optical Access, Passive Optical Network, NGOA, WDM, DWDM, OFDM, OFDMA.*

I. INTRODUCTION

Currently, the implementation of the concept of the next generation of optical access (NGOA) [1] has several alternative routes. The most promising use should be considered convergent solutions "radio over an optics" [2] and elements of existing optical networks. Particularly relevant in this context is to improve passive optical networks (PON). Given the future prospects of upgrading network equipment to reduce investment in existing infrastructure appropriate to optimization, which corresponds to the direction of "NG PON2": new technologies that are on the existing optical distribution networks (ODN) – as an option [3]. This implies a certain level of harmonization.

However, the possibility of rapid changes in the structure and type of signal, several alternative standards or protocols may affect the profitability of these developments. As a result, one of the ways to improve converged solutions "radio over an optics" within the NG PON2 is the introduction of the hardware configuration [3] and use the circuitry that focused on low rates digitizing signals.

II. MAIN

According to [2], improvement of performance of optical access based on converged solutions "radio over an optics" can be removed by constructing hybrid PON. The simultaneous use of a few technologies of compression is assumed in them, for example, spectral (WDM) and time (TDM). Thus, as a base the orthogonal frequency discrete multiplexing (OFDM) is examined, including, with possibility of dynamic allocation of carrying sub-channels to the users (OFDMA). However, OFDM has certain disadvantages [4]. Mainly, they concern the necessary bandwidth of analog highway of reception of radio signal and use of operation of fast Fourier transformation (FFT). As a result, it follows most expedient to count application in convergent solutions instead of OFDM(A) non-orthogonal signals the example of IMT-2020 (5G) [5]. Realization of N-OFDM is offered for this purpose [2]. Unlike OFDM, diversity of carrier frequencies of sub-channels does not depend on maximums of FFT filters [6]. It follows to pay attention to circumstance that such a signal in the frequency diversity sub-channels on the width of FFT filter transforms in OFDM-signal.

On the other hand, the requirements of NG PON2 include the possibility of operative change in signal between OFDM, OFDMA or N-OFDM. It can result in the increase of cost of equipment. Especially sharply it touches the subscriber segment of the hardware. The most preferred solution to this issue is to perform the operation of decimation on a receiving side (in procedures of processing are used not ADC samples, but results of their partial summarization) [7] based digital filters [8] that thin out an information flow. This approach allows to bring down the rates of digitizing of signals, that simplifies requirements to the elements of digital segment of receiving channel of the fiber optic transmission systems FOTS on the indexes of the calculable loading, realize the distributed digital processing of signals of N-OFDM, and also to solve problem, when calculable operations cannot be executed for period of discretization of ADC, and it does not allow effectively to realize decoding real-time.

As noted in [7], the essence of decimation is to ensure that of several samples of signals with the set periodicity is formed one overall. If digitization is performed by an odd number of quarters of the oscillation period that fill signal, then the processing procedure is reduced to the separation of discrete voltage samples on the basis of parity issue receipts. Thus the separate accumulation odd and even elements of the array is performed with the inversion of sign from one frame to another. Assuming that the ADC is performed with a period sampling that is a multiple of an odd number of periods of central frequency of signal packet the analytical entry of the simplest algorithm summation samples of the ADC has the form [9]:

$$U_{df}^{c} = \sum_{s=0}^{T-1} U_s \cdot \cos\left(\frac{\pi}{2} \cdot s\right), \qquad U_{df}^{s} = -\sum_{s=0}^{T-1} U_s \cdot \sin\left(\frac{\pi}{2} \cdot s\right), \tag{1}$$

where $U_{df}^{c(s)}$ – are the quadrature components of signal on the entrance of digital filter, U_s – is the voltage of the actual ADC sample, $s = \overline{0, T-1}$ – is the current number of ADC sample, T – is the number of ADC samples that accumulates in the digital filter.

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This approach allows to coordinate the high rates of receipt of digital data from ADC with the productivity of next devices of digital processing. Decimation of flow of information is performed without the losses of energy, and formed here samples are less correlated in comparing to the entrance. Complex presentation allows to minimize the amount of parasite receiving channels, and also simplify calculable procedures. It is assumed that the noise in the quadrature components are Gaussian and uncorrelated, and during of decimators gate amplitude of signals remain constant. The feature of decimation sampling of ADC consists in possibility to accumulate of sampling for various pieces of signals – gate.

The gate is a time interval during that there is summation of the time samples of entrance signal. The number of gate must be no less than the number of frequency sub-channels [7]. At application of OFDM and similar methods of multiplexing it is necessary to use the multigate additional gating with the fixed grid of gate that follow each other continuously in time. At the fixed grid intervals of summation located without mutual overlap in time.

As a variant, demodulation of signals on a receiving side can be oriented to the previous forming of complex analog signal, for example: the quadrature components of signals are formed by multiplying of the received and supporting signals. At such method of forming of complex signal in implementing of digital filter to reduce errors of forming of quadrature components of analog signals in the wide band of reception the 90-degree phase change of heterodyne signal is recommended to carry out in accordance with the scheme of the modulator/demodulator, which is shown in [2].

The digital forming of quadrature component signals provides a 2-channel digital filter [10]:

$$U^{c}_{df_y} = \sum_{s=0}^{T-1}\left\{U^{c}_{s}\cos\left(\frac{\pi s}{2}\right)+U^{s}_{s}\sin\left(\frac{\pi s}{2}\right)\right\}, \quad (2)$$
$$U^{s}_{df_y} = \sum_{s=0}^{T-1}\left\{U^{s}_{s}\cos\left(\frac{\pi s}{2}\right)-U^{c}_{s}\sin\left(\frac{\pi s}{2}\right)\right\}$$

where $y = \overline{0,Y\text{-}1}$ – is the sequence number of gate of the digital filter, T – is the number of ADC samples accumulated in a gate of the digital filter, which is a multiple of 4 (to avoid the parasite raid of initial phase of signal between gates).

The feature of 2-channel digital filter (2) in comparing to his single-channel option (1) is to increase the frequency distance between the ground and the "parasitic" maximum AFC. Exactness of measuring of quadrature components of signal is determined by a relation signal/noise, and also diversity in frequency of carrier signal.

If it be impossible precision forming of quadrature component signals in analog form discrete transformation of Gilbert (DTG) can be used for this purpose [8]. In this case the formation of quadrature component signals in a receiver carry out by DTG in the mode of sliding window above a specified number of samples of the ADC, that depends on the order of filter of Gilbert. The operation of the additional gating is carried out on Hilbert filter formed the digital samples of voltage signals by their accumulation by the expression (2). As the DTG in the mode of sliding window accompanied the transition process, then the length of the digital signal sample that is got after the decimation of voltages over which the FFT is performed may exceed the number of samples dimension FFT on the doubled transitional interval of filter of Gilbert. As an alternative of DTG can be used I/Q- demodulation of odd order [11].

When using the FFT in the DSP should be aware that for proper decoding of signals is necessary to compensate the parasitic phase distortion of complex signal amplitudes arising from FFT. To this end, at the formation of the signal at the transmitting side is advisable to use a procedure reverse FFT.

In addition, the direct use of method of N-OFDM together with the decimation sampling ADC is related to the unoptimality of estimations of amplitudes of signals, that shows up in the shift of their estimations at demodulation. To solve this problem, it is necessary to conduct additional assessments amplitude correction signal at the output of digital filter designed by the method of maximum likelihood.

During researches the compact entry of estimations of amplitudes of quadrature components is got in a matrix form for application in calculable procedures directly of samples of digital filter, without performing FFT on them.

As a tool for realization of convergence decisions of "radio over an optics" on the basis of method of N-OFDM it is expedient to use technology of programmatic configuration of equipment. Fig. 1 shows the experimental scheme of FOTS that meet the criteria and can work with signals of N-OFDM, OFDM, QAM, NRZ. In the offered scheme the operation of decimation can be dissociated from the eventual stages of DSP.

It is set during researches, that from the point of view of receipt of a maximum of the productivity the best are modifications of DSP without realization of operation of FFT. If there is a need to use existing methods of compensation interference, unification DSP, for example, for the operation to optical carrier with linear polarization (PDM), or the introduction of converged solutions based on the methods of space-time coding the example of MIMO, it is reasonable to use a grid filters FFT.

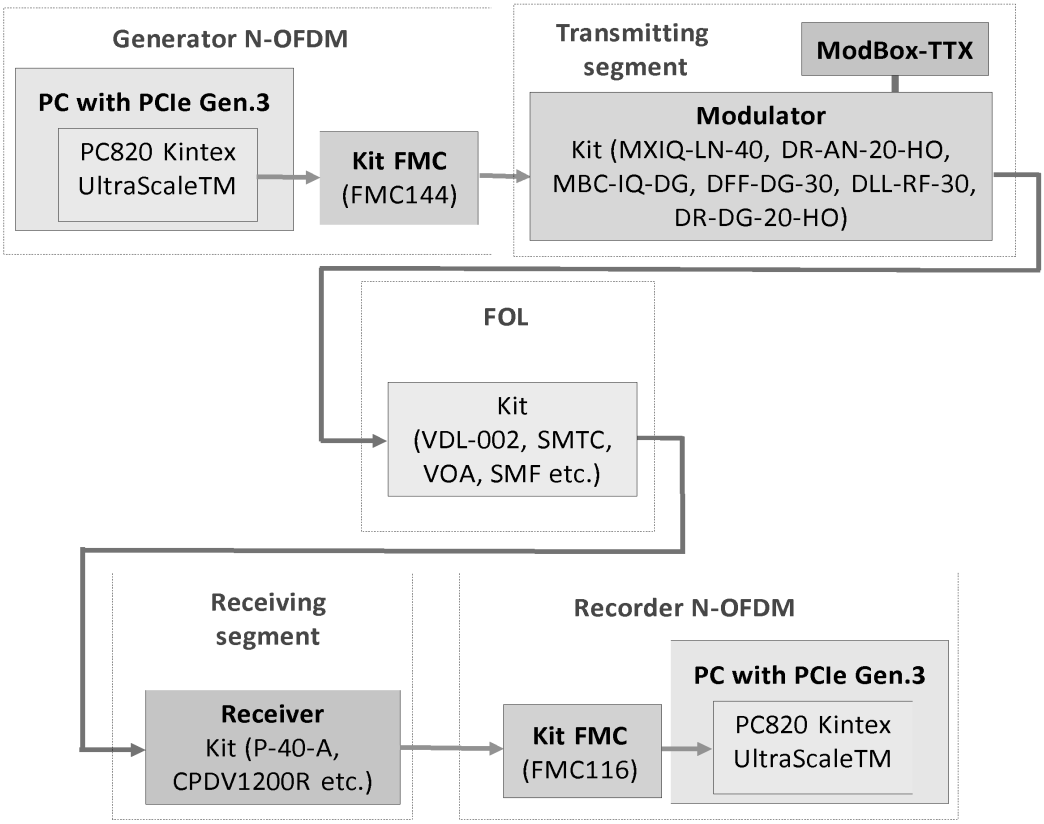

Fig. 1. Fragment FOTS structure with N-OFDM

III. CONCLUSIONS

Thus, realization of NGOA on the basis of hybrid N-OFDM-X-PON removes the lacks of optical networks with OFDM. Application on the receiving side of programmatic configuration of equipment and operation of decimation allows to bring down requirements to the elements of FOTS in relation to the volumes of the calculable loading, to realize up-diffused DSP, and also settle situations, when calculable operations cannot be executed for period of discretization of ADC. The offered experimental scheme of FOTS provides operative change between OFDM, OFDMA or N-OFDM.

Further long-range researches are sent to determination of technical aspects of practical realization of procedures of indemnification of parasite distortions that arise up during FFT and decimation.

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