# New Time-Frequency Code Scheme for Bidirectional Ultra-wideband WDM Access Networks

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**Abstract-** *A novel time-frequency code scheme for bidirectional multiband OFDM ultra-wideband WDM access networks is proposed. Experiment results demonstrate that the scheme can provide simple structure, reducing wavelength and low-cost usage for high-speed wireless access networks.*

## Introduction

Ultra-wideband (UWB) radio-over-fiber (RoF) is an attractive solution for broadband services[1,2]. The major multiple access technologies for multi-user UWB systems have been reported in the literatures[3,4] such as time hopping (TH) scheme, direct sequence (DS) scheme and multiband scheme. The multiband scheme method for UWB systems can employ the multiband pulsed (MBP) approach and the multiband orthogonal frequency-division multiplexing (MB-OFDM) approach[5]. MB-OFDM system is more efficient at capturing multipath energy than an equivalent single-carrier system using the same total bandwidth. MB-OFDM modulations also provide the high spectral efficiency and inherent resilience to narrow-band RF interference.

MB-OFDM is divided the whole band into the smaller 14 sub-bands. Each sub-band has 528MHz and contains 128 subcarriers. The MB-OFDM standard defines both an UWB physical layer (PHY) and medium access control (MAC) and supports data rates from 53.3 to 480 Mb/s[6-7]. In this study, we propose a new time frequency code (TFC) scheme for a bidirectional MB-OFDM wireless access network. We measure the actual transmission package error rate (PER) and various wireless transmission distances on an ONU cascade ring under up/downstream transmission simultaneously using only one wavelength.

## Architecture

A bidirectional TFC-based MB-OFDM ring access network architecture is shown in Fig.1. In the optical line terminal (OLT), the Wisair DV9110 development kit (DVK) controlled by a laptop computer is used to generate MB-OFDM signals. The MB-OFDM signals directly modulated in DFB laser, and then the up/downstream optical modulation signal is divided by the optical circulator. Arrayed-waveguide grating (AWG) is used as a routing device to multiplex and de-multiplex the optical channels transmitted along the fiber to ONU rings. Moreover, the downstram signals send to the ONU rings through the optical circulators. The optical signal is demodulated by PIN photo diode (PIN-PD) to electric MB-OFDM signal. The signal was separated into two parts by a power splitter. One emits by UWB antennas over the indoor wireless channel environment and received signal by another received UWB antenna of end user. Another and end user's upstream data are combined to new signals with

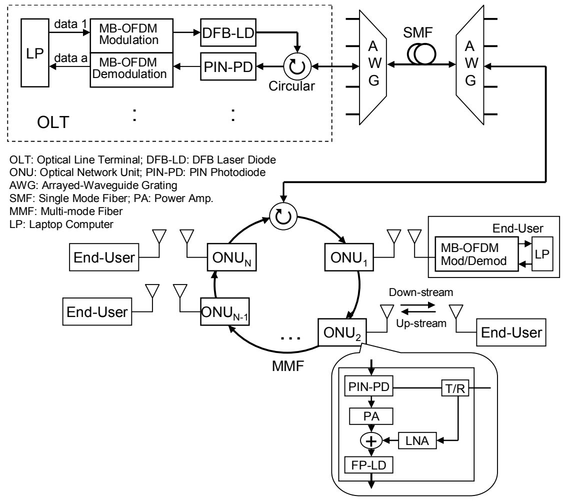


Fig.1 Bidirectional MB-OFDM UWB WDM access network architecture.

up/downstream data, which was transmitted by a FP-LD over multimode fiber (MMF) to next ONU. The DFB-LD have to use in the last OUN and then transmitted total signals to OLT.

The operation band of the DVK is band group 1 from 3.168 to 4.752 GHz. The hopping sequence is used a regular sequence as $f_1$, $f_1$, $f_1$,…(TFC 5) and $f_3$, $f_3$, $f_3$,….(TFC 7). The offered data rate is from 53.3 to 480 Mbps. In the proposed architecture, one ONU take care one end-user. Moreover, each end-user is allotted different TFC to up/downstream transmission. Here, two different TFCs are applied for three cases of up/downstream. Case 1 is the downstream transmitted TFC 5 and TFC 7 simultaneously, and we surveyed the downstream PER of $ONU_2$'s end-user in TFC 5. Case 2 is the upstream transmitted from $ONU_1$'s end-user by using TFC 7 and ONU2's end-user by using TFC 5 simultaneously and then the upstream PER of TFC 5 from ONU2's end-user is measured. Case 3 is two end-users operation on $ONU_2$ simultaneously. TFC 5 is on downstream, and TFC 7 is transmitted by $ONU_2$'s end-user 2. The downstream PER is surveyed at ONU2's end-user 1.

## Experimental Results and Discussion

To generate MB-OFDM signals, we used a Wisair DV9110 DVK which support the band group 1. Fig. 1 shows the experimental setup to demonstrate our proposed system. The band group has three sub-bands. Each sub-band has 528 MHz and contains 128 subcarriers. Each sub-band center frequency $f_1$, $f_2$, $f_3$ is 3432, 3960 and 4488 MHz, respectively. The band group provided seven kinds of TFCs. Agilent E4446A spectrum analyzer is operated to observe the spectrum of TFC 5 and TFC 7 in Fig. 2.

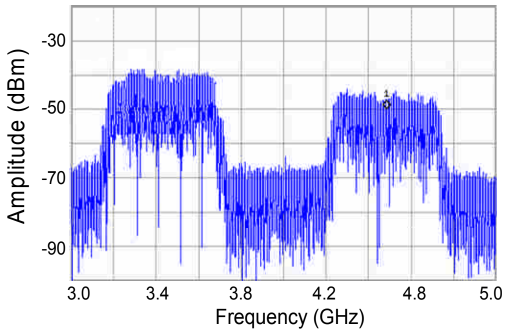


Fig.2 The spectrum of TFC 5 and TFC 7.

In case 1 the downstream PER of $ONU_2$'s end-user in TFC was measured when the downstream transmitted TFC 5 and TFC 7 simultaneously. In other words, TFC 7 signal be the noise of TFC 5 and measured PER of the downstream for $ONU_2$'s end-user. The fixed data rate was 200 Mbps for TFC 7 from OLT. Besides, four various data rates (53, 106, 200 and 480 Mbps) can be set for TFC 7. In general indoor environment, the end-user of $ONU_2$ be set to different wireless transmission distances of from 1 to 3 m. Figure 3 shows the measured results of case 1. When the downstream data rate was 480 Mbps, the wireless transmission could arrive 2 m. The PER can tallied with IEEE TG3a technical requirement that is PER < 8%. Moreover, when the data rates were set for 106 Mbps and 53 Mbps, the wireless distance could get beyond 3 m. So we obtained that TFC 5 and TFC 7 can transmit in fiber and radiate in free space with low interference. The SMF and MMF were set a short length.

In case 2 the upstream transmitted from $ONU_2$'s end-user by using TFC 5 and $ONU_1$'s end-user by using TFC 7 simultaneously. The upstream PER of TFC 5 from $ONU_2$'s end user is surveyed. That is to say, the TFC 7 was to be noise of TFC5. The TFC 7 of upstream data rate was set to 200 Mbps and wireless distance of 1 m between $ONU_1$ and end-user of $ONU_1$. In Fig. 4, we observe that change the wireless distance of 0-1 m and data rates of 200-480 Mbps. The PER increases very rapid. However, the low speed as 53 Mbps and 106 Mbps is still kept stable. About PER increasing very rapid the reason could be that MB-OFDM signal was distorted by interference and attenuation in the wireless channel.

In case 3 $ONU_2$ has two end-users. TFC 5 was for downstream and TFC7 was transmitted by $ONU_2$'s end-user 2. The downstream PER is measured at ONU2's end-user 1. The data rate of 200 Mbps was set for TFC 7 and fixed the distance between $OUN_2$ and each end-user. Moreover observe PER varying with the wireless distance 1 m between end-user1 and end-user 2. Experimental results can be seen that the link quality would be impacted by TFC 7 when the wireless distance between end-user 1 and end-user 2 was to be shorter than 5 cm at 53 Mbps.

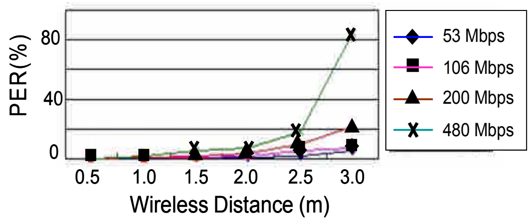


Fig.3 PER versus wireless transmission distance of $ONU_2$'s end user from $OUN_2$ in case 1.

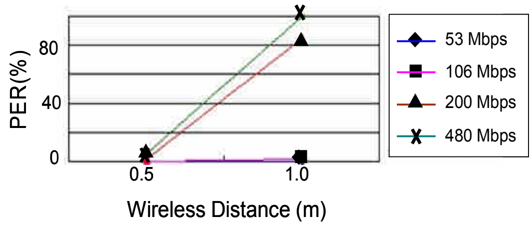


Fig. 4 PER versus wireless transmission distance of $ONU_2$'s end user from $OUN_2$ in case 2.

## Conclusions

The proposed MB-OFDM WDM access network can avoid the interference by using different TFCs under bidirectional transmission in the same wavelength. Moreover, FP laser diodes and multi-mode fibers are adopted in the access ring due to cost down and increase number of ONUs. Finally, the experimental results demonstrated that the proposed scheme can indeed provide many advantages of very low-cost, simple structure and reducing wavelength usage for practically bidirectional high-speed wireless networks.

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