

Experimental Realization of Multi-Service RoF System using OCS-PolMux Techniques

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Abstract — Optical Carrier Suppression has been proven as an efficient way of generating high frequency optical carrier for Radio over Fiber (RoF) systems. However, previous studies show that OCS with the combination of RF and optical components can only transmit a single service in RoF system. This paper shows that two different services can be transmitted using a single wavelength through RoF system with the use of Polarization Multiplexing (PolMux) method. The combination of these two techniques enables multiservice RoF such as LTE and WiFi services to be transmitted simultaneously to the customers.

Keywords — Local Multipoint Distribution Service (LMDS), Multiservice, Optical Carrier Suppression (OCS), Polarization Multiplexing (PolMux), Radio over Fiber (RoF)

I. INTRODUCTION

Radio over Fiber (RoF) technology, is a method of combining wireless and optical techniques over an optical network where wireless transmission is at the last mile. Increase in demands for bandwidth and capacity in fiber-to-the-home (FTTH) network of wireless connectivity has been foreseen. Optical wireless technology operating in the high frequency band for higher data rate is seen as a promising technology. Hard to reach areas such as rural deployment and geographic areas where optical cable deployment is limited justifies the need for RoF as well as potential usage at home and business areas where the last mile on the customer side will be wireless.

RoF architectures are commonly design to carry a single type of signal or service. Current studies to improve RoF are such as using wavelength-division multiplexing (WDM) techniques [1], multiple-input multiple-output (MIMO) [2], exploiting two orthogonal modulation formats [3] and PolMux methods [4].

Multiservice in RoF using PolMux is one way to improve this technology. Recent works have tried to address this such as conducted using a Polarization Modulator (PolM) [5]. This method needs additional components such as Polarization Beam Splitters (PBS) and a Polarization Controllers (PC) to split the carrier frequency and double sidebands for optical carrier generation. Another method splits generated optical double sidebands, splitting and modulating each of its polarization axes and combining again for RoF transmission

[6]. The method needs components such as RF signal source and WDM. Moreover, another study uses an RF signal to generate the carrier mixed with data over PolMux [7]. This method uses high frequency RF components which lead to higher cost and more power consumption. Thus, a more effective method needs to address these issues.

This paper shows a promising way by using the combination of OCS and PolMux method to carry two services at Local Multipoint Distribution Service (LMDS) frequency at a single wavelength with optional frequency selections. LMDS is a fixed broadband wireless access system operating at the 26 GHz frequency band [8]. The OCS method is a much direct optical carrier generation. Furthermore, the outcome provides options for frequency selection to adjust to regulatory standards and licences.

II. EXPERIMENTAL SYSTEM OVERVIEW

The proposed OCS method is illustrated in Figure 1 which generates a LMDS frequency at 25.5GHz. The configuration is as following, a tunable laser which continuously emits optical power is connected to an erbium doped fiber amplifier (EDFA) 1. This EDFA is used to increase the optical power significantly and to supply sufficient power into a dual arm Mach Zehnder Modulator (MZM). RF input from a Signal Generator is divided through a power divider (PD) of which one output goes directly into the 1st arm of the MZM. The 2nd output travels into a phase shifter before going into the 2nd arm of the MZM. Each arm of the MZM is connected to a biasing circuit. EDFA 2 is added to compensate the high loss of the MZM. The output of EDFA 2 generates multiple sidebands with reference to the original laser wavelength for high frequency electrical carrier generation.

OCS generated carrier is then feed into the PolMux setup. The signals are split into 2 optical polarization axis using Polarization Beam Splitters (PBS). Each MZM is set for each polarization axis with each modulated by either signal of WiFi or LTE. After modulation, the axes are combined by using Polarization Beam Combiners (PBC). Polarization Controllers (PCs) were used to maintain polarization axis split before and after both MZMs. The carrier frequency of WiFi (IEEE 802.11a) is set at 200 MHz and LTE at 875 MHz. The WiFi frequency is a down converted signal from the 5 GHz in order

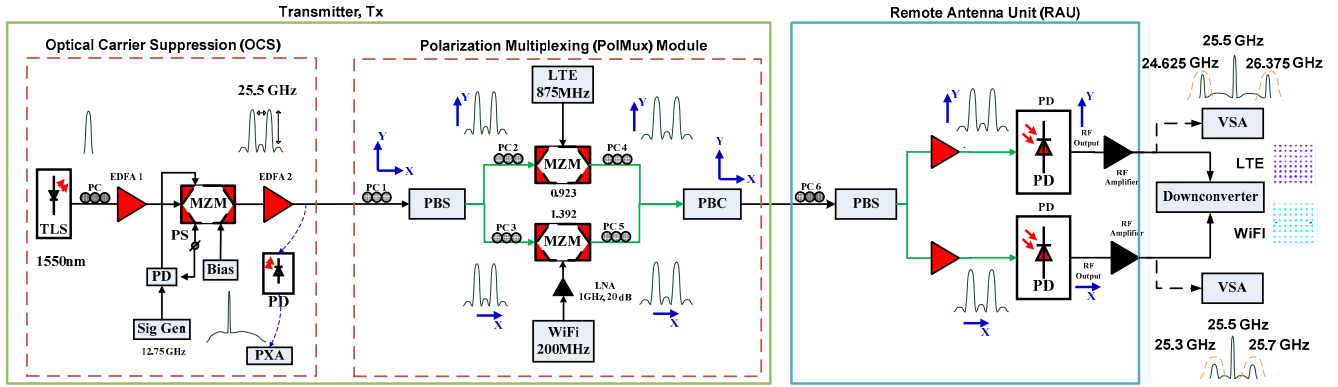


Figure 1. Illustration of OCS - PolMux transmission setup measurement

to set within the LMDS frequency range. The signal is connected to another PC and split again through another PBS where each polarization axis is amplified to reach within respective photodiodes (PDs) power sensitivity range. RF amplifiers at 25-30 GHz are added after PD before being measured into the vector signal analyzer (VSA).

III. RESULTS AND DISCUSSIONS

A. Optical Carrier Generation

Figure 2 shows the optical carrier generated at 25.5 GHz using the OCS method. The laser source fed into the dual arm MZM resulted in 2 sidebands at each sides of the laser source frequency. A combination of parameters are varied to suppress the center signal such as optimizing the polarization controller, DC biasing of each arm and setting optimum RF power for each arm at 12.75 GHz have been carried out.

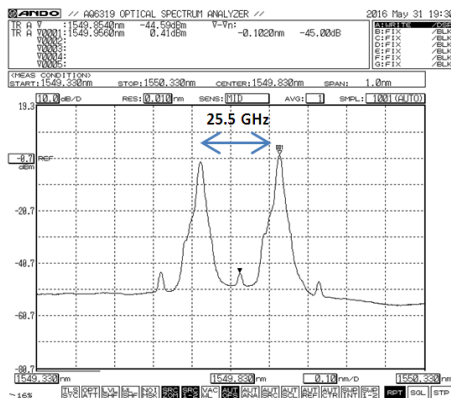


Figure 2. Optical Carrier Suppression optical sideband center suppression

The 2 sidebands with a suppressed signal, forms a difference of 25.5GHz in between them. The beating between the optical frequency component (or $\Omega - w$ and $\Omega + w$) results in a mm-wave frequency component at $2w$ (where w is RF frequency). In this case, when w is 12.75GHz, an output spectrum at 25.5 GHz was obtained [9]. The difference between the sidebands peak power and the suppressed signal achieved is 45 dB. Thus, a clean optical carrier is obtained for the PolMux process. Electrical signal in Figure 3 is measured at a power of -10dBm at 25.5 GHz.

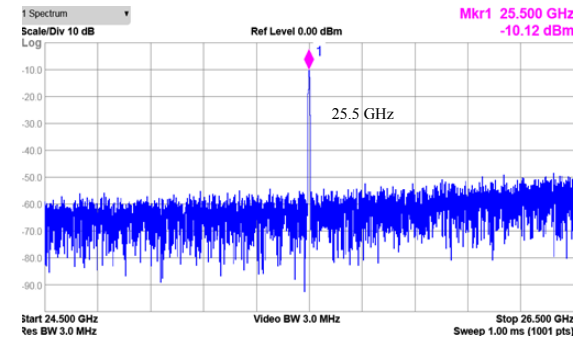


Figure 3. 25.5GHz electrical measurement at the Signal Analyze

In Figure 4, phase noise of OCS generated is compared to a directly generated signal from the VSA signal generator at 25.5 GHz as a standard reference.

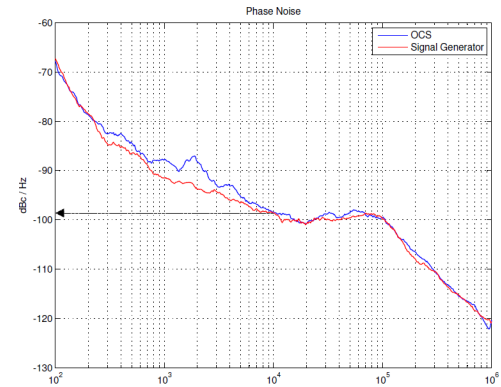


Figure 4. Phase Noise measurement of OCS vs Signal Generator

It clearly shows OCS generated carrier has similar performance when compared to the signal generator. It is shown approximately 98 dBc / Hz at the frequency of 10 kHz offset.

B. Carrier and Data modulation

External modulation method was used by using two MZM each for WiFi (200 MHz) and LTE (875MHz) signals which exhibits better performance and produces a stable and symmetric spectrum rather than direct modulation method [10]. Figure 5 illustrates the frequencies generated at each polarization axis measured at 25.7 and 25.3 GHz for WiFi.

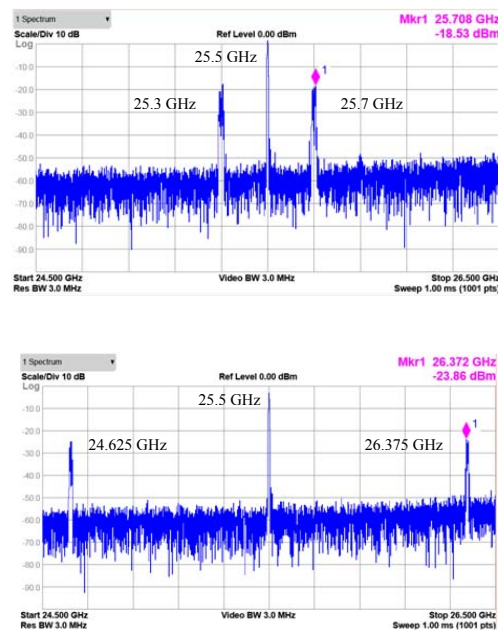


Figure 5. WiFi on the x-axis(above) and LTE on the y-axis(below)

LTE signal was measured at 26.375 and 24.625 GHz. The center signal for both is at 25.5 GHz which was the carrier generation by the OCS module. These two modulated frequencies for each polarization can be chosen and filtered out for desired usage and following standard purposes using a narrow filter. The bandwidth of WiFi and LTE were 20MHz and 10MHz, respectively. Experimental measurements were directly observed using a Vector Signal Analyzer (VSA) after the photodiode and RF amplifier. No down-converting process was yet carried out. This was to measure the signal before transmitting wirelessly for RoF setups at the RAU. WiFi is quite close to the center carrier while the LTE is much further away.

C. EVM Measurement

The down conversion was done using a local oscillator (LO) at 25.5 GHz. This was to measure the EVM percentage as a back to back (BTB) reference. Figure 6 shows the best EVM percentage with an EVM of 2.0475% for WiFi and 2.461% for LTE which are within the 8% 64 QAM limit for IEEE 802.11a code rates 2/3 and 3GPP, respectively [11, 12, 13]. The RF input power of each MZMs were set to achieve the best EVM at 2 dBm for WiFi and 5dBm for LTE with a biasing of 1.1V and 2.2V respectively.

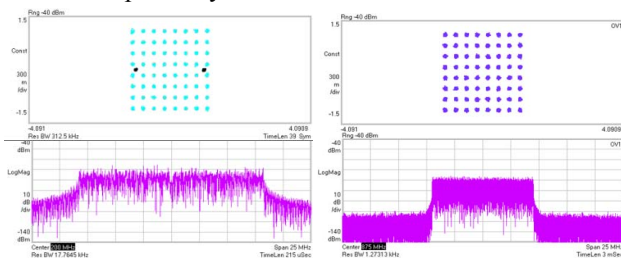


Figure 6. WiFi EVM: 2.0475% (left) and LTE EVM: 2.461% (right)

IV. CONCLUSIONS

Multiservice RoF using OCS-PolMux has been presented with results showing it is possible to carry services of WiFi and LTE signals at a single wavelength. Results show a stable carrier generation. Frequencies of services can be selected with a narrow filter. EVM of both signals are approximately at 2% which is within the 8% 64 QAM limit according to IEEE and 3GPP standards.

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