

An EVM Evaluation for RF OFDM signal transmission over Radio on Optical OOK Fiber Link

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Abstract Analog radio over fiber (ARoF) is an candidate to construct mobile optical backhaul and fronthaul network that connects between wireless radio transceiver and remote antenna unit (RAU) because of its centralized signal processing capability and heterogeneous property of the optical fiber communication technologies. Its broad bandwidth for transmitting heterogeneous radio signal enables us to share single optical fiber infrastructure even if the light source has single wavelength resource. There were some reports on the method for sharing the 10Gbps optical Ethernet infrastructure to transmit radio frequency (RF) signal without introducing extra light source. Previous paper has reported on the probability density function (pdf) of RF signal amplitude that modulates an optical OOK signal, and derived the bit error rate (BER) performance for the OOK signal. However, only the continuous wave (CW) was assumed as an RF signal in the last work. This paper proposes an application of frequency shift for transmitting the RF orthogonal frequency division multiplexing (OFDM) signal over fiber with optical On-Off Keying (OOK) in order to avoid serious interference. In this paper, the error vector magnitude (EVM) performance is evaluated by using computer simulation.

Keywords radio over fiber, radio over optical OOK, orthogonal frequency division multiplexing (OFDM), error vector magnitude (EVM)

1. Introduction

Radio over Fiber (RoF) is a technology to transmit radio frequency (RF) signal over an optical fiber using optical carrier. In the typical RoF link, RF signal is transported with analog format. Analog radio over fiber (ARoF) is an candidate to construct mobile optical backhaul and fronthaul network that connects between wireless radio transceiver and remote antenna unit (RAU) because of its centralized signal processing capability and heterogeneous property of the optical fiber communication technologies. Its broad bandwidth for transmitting heterogeneous radio signal enables multiple mobile operators to share single optical fiber infrastructure even if the light source has single wavelength resource[1,2]. Lots of schemes for simultaneous transmission of BB and RF signals have been proposed. Actually, [2] proposed simultaneous transmission for broadband BB signal, microwave signal and millimeter signal. The other report [3] describes that critical interference can be avoided by shaping a frequency spectrum of BB signal relating its coding scheme even though the radio frequency is at the main lobe of BB signal in frequency domain.

A novel configuration of RoF link using optical 10Gbps Ethernet has been proposed [4]. The

proposed scheme uses optical OOK signal not only for BB transmission but also as an optical carrier for RF transmission. The optical OOK signal is intensity modulated again by the electrical RF signal, and directly detected at the receiving side after through the optical fiber link. The proposed system is called Radio over Optical OOK (RoOOOK). In this system, single light source can be shared by both of the 10Gbps optical Ethernet signal and RF signal, then extra light source that is required in isolated RoF link for RF transmission is not required.

However, only the continuous wave (CW) was assumed as an RF signal in the recent work[4] even though orthogonal frequency division multiplexing (OFDM) is becoming common air interface in wireless communication. It is also reported that since OOK signal seriously interferes to the RF signal, interference suppression and avoiding methods are required. This paper contributes two new aspects. First, the OFDM signal transmission with optical OOK is considered for the first time. Second, this paper proposes an application of frequency shift for transmitting the OFDM signal to avoid serious interference with OOK spectrum.

This paper is organized as follows. In section 2, proposed system configuration is explained. Section 3 describes performance evaluation and its parameters. Conclusions are drawn in Section 4.

2. Proposed System

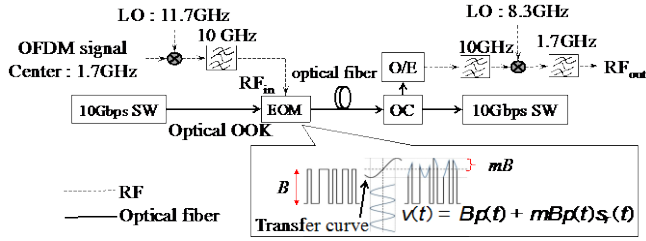


Fig.1 Configuration of OFDM transmission over radio over optical OOK link using frequency shift, SW: Ethernet switch, EOM: external optical modulator, LO : local oscillator, OC : optical coupler, O/E : optic to electric converter

Fig.1 shows system configuration. A pair of 10Gbps optical Ethernet switch is connected by a fiber. The OOK is employed as standard modulation scheme in their PHY layer. The RF OFDM signal with center frequency of 1.7GHz modulates an optical OOK signal using external optical modulator (EOM). In the proposal, center frequency is shifted to 10 GHz before the external modulation. The re-modulated OOK signal can be expressed as [4],

$$v(t) = Bp(t) + mBp(t)s_r(t) \quad (1)$$

where m ($0 \leq m \leq 1$), $p(t)$, and B are modulation index, probability of ‘mark’ symbol, and pulse amplitude, respectively. The 1st term represents OOK signal and the 2nd term represents modulated RF signal. In another viewpoint, it can be considered as a natural sampling of RF signal amplitude with its sampling function of non-periodic pulse train. Their power spectrum can be theoretically derived, and if center frequency is located within the main lobe of OOK spectrum, the dominant component of interference is not aliasing, but OOK spectrum [4]. After the transmission through the optical fiber link, receiving signal is divided into two branches using optical coupler. One is led to Ethernet switch, another is led to the O/E converter. At the O/E converter, optical intensity is directly converted to photo current. At the output of O/E, since RF signal is still sampled, the signal can be regenerated by using bandpass filter. Finally, RF signal is down converted to the original center frequency in the proposal.

In the proposal, center frequency is shifted from 1.7GHz to 10GHz. Target frequency is null point of OOK signal spectrum at frequency domain. Proposal can avoid serious frequency interference.

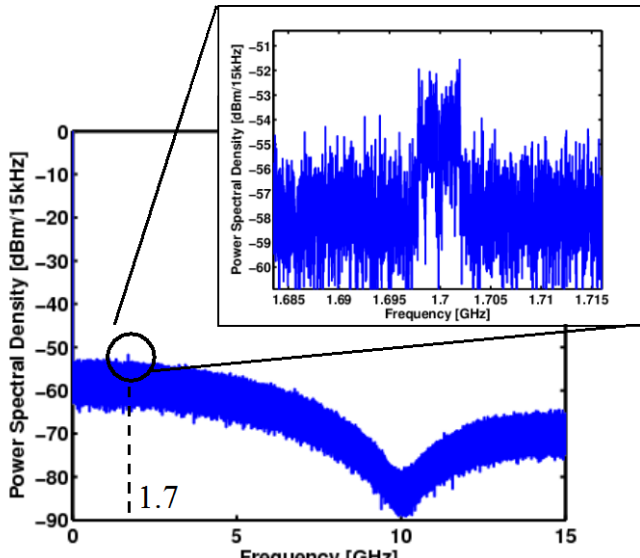
3. Computer simulation

Table.1 Simulation parameters

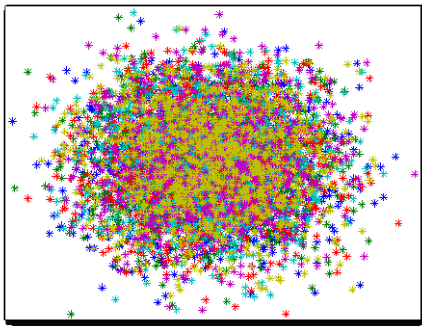
Elements	Value
RF spec.	
Carrier Frequency	1.7GHz (w/o frequency shift)
	10GHz (w/ frequency shift)
Number of sub-carrier	128
Sub-carrier Interval	15kHz
Modulation Index m	0.9
Sub-carrier modulation	64QAM
Optical system spec.	
Baseband Bit Rate	10Gbps
Pulse Scheme	NRZ
FEC	N/A
Mark / Space Probability	0.5 / 0.5
SNR for OOK with no RF	17dB
Noise type	AWGN
Optical fiber	Single Mode Fiber

Table 1 shows the parameters for both RF signal and optical signal used in the computer simulation. In RF system, we assume the OFDM signal with the number of subcarrier and its interval of 128 and 15kHz, respectively. Occupied bandwidth is about 1.92MHz. The optical system is based on current standard of 10Gbps Ethernet as 10GBASE-ER. The PRBS with 15-stage shift register is used to generate information bits for OOK signal. After the O/E converter, additive white Gaussian noise is assumed as an electrical noise with its relative power to receiving RF signal power of -17dB. Optical power loss of fiber transmission is assumed to be negligible small. In this simulation, output signal labeled as RF_{out} is analyzed its spectrum. In addition to the spectral analysis, signal constellation of receiving OFDM 64QAM signal is evaluated. This measurement is required to evaluate the error vector magnitude (EVM) performance for the RoF repeater.

Fig.2 and Fig.3 show power spectrum and its constellation. Fig. 2 shows them without frequency shift, fig. 3 shows them with using frequency shift. You can see that proposal can avoid the interference between RF and BB signals. The RF spectrum is clearly observed as shown in Fig. 3(a). In this simulation, to obtain the constellation of OFDM signal, 128–points Fast Fourier Transform (FFT) was carried out to the receiving waveform after the loss less down conversion and perfect symbol synchronization. As for the constellation of OFDM signal, signal bits are highly deteriorated in case of without using frequency shift as shown in Fig. 2 (b). The 64QAM symbols are clearly observed when frequency shift is applied. Observed EVM was 7% as shown in Fig.3 (b).



(a) Power spectrum, RF_{out}

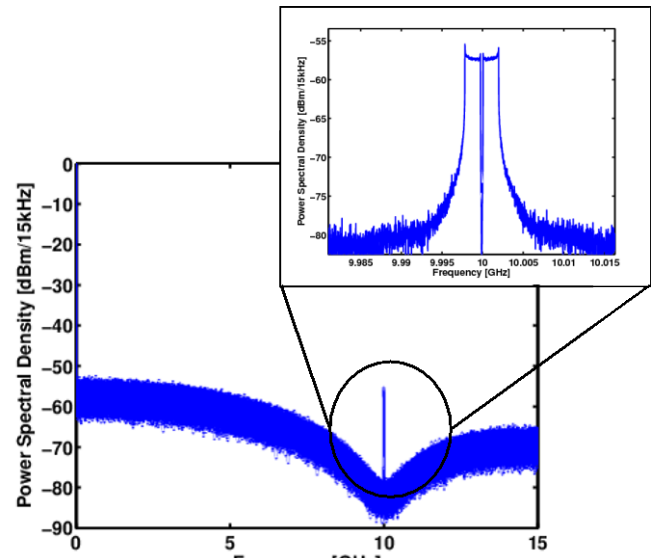


(b) Constellation

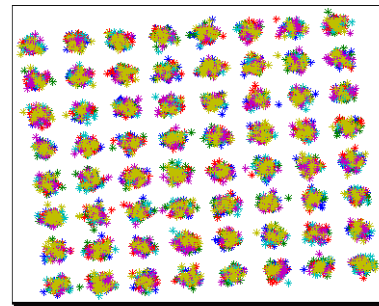
Fig.2 (a) Power spectrum and (b) constellation without frequency shift

4. Conclusion

Broadband RF signals can be transmitted over an optical fiber link whose bandwidth is much larger than coaxial cables. This paper has demonstrated the RF signal transportation over optical fiber utilizing the computer simulation. In other word, electro-magnetic fields are able to be remotely measured by connecting between remote sensing devices including antenna and measurement equipment. This paper has proposed an application of frequency shift for transmitting the RF OFDM signal over fiber with broadband optical OOK signal in order to avoid serious interference. The spectrum analysis revealed RF signal can be transferred to the remote site, and proposal outperforms the method without using frequency shift in terms of the EVM. A clear constellation of 7% EVM was observed at the system output. Unfortunately, all evaluations have done by the computer simulations. Experimental investigation is left for further study.



(a) Power spectrum, RF_{out}



$EVM \cong 7\%$

(b) Constellation

Fig.3 (a) Power spectrum and (b) constellation with frequency shift

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