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COMPARATIVE ANALYSIS OF SINGLE AND MULTI-TONES FOR RADIO OVER FIBER (ROF) SYSTEMS

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Abstract: In this paper a Two-tone setup for Radio over Fiber system is proposed which is used to compare a single tone and Multitone system. Different performance parameters such as Eye diagram, dynamic range, and Spurious free dynamic range (SFDR), are tested for single-tone and multi-tone RoF systems for obtaining different results. The results obtained very well suggested that Multitone system provides a comparative performance as compared to single tone system, so these can be utilized to obtain much better bandwidth and transmission distance.

Keywords: *Dynamic range,* Spurious free dynamic range*, Radio over Fiber (RoF), Single-tone, Multi-tone.*

1. INTRODUCTION

Radio over fiber (RoF) technology has emerged as a cost effective approach for reducing radio system costs because it simplifies the remote antenna sites and enhances the sharing of expensive radio equipment located at appropriately sited switching center (SC) or otherwise known as central sites/stations (CS). To improve the wavelength-reuse multi-channel RoF system issue such as O-ACI (Optically generated adjacent channel interference), double sideband carrier amplitude-phase-control modulation is used in which the amplitude and phase of the optical carrier was controlled by tuning the dual parallel Mach–Zehnder modulator bias voltage [1]. A Multi-carrier system is a preferable system for growing high data rate and high speed demands because it can efficiently utilize the fiber bandwidth capacity. A multitone RoF system employing a central station (CS) and a remote antenna station (RAS) was tested for direct and external modulation schemes. A small power penalty was reported between the two schemes [2]. A new multi-tone test signal generation method was suggested with different frequency tones that employed OFDM (orthogonal frequency-division multiplexing) and spread spectrum (SS) techniques for allowing signal parameters to users with a great flexibility [3]. A new scheme based on orthogonal frequency-division multiplexing (OFDM) technique was developed for producing multiple frequency tones with fine resolution and low design cost [4]. For evaluating the channel performance, the effect of multi-tone jitter was evaluated by an analytical bit-error-rate method that was helpful in channel design and optimization [5]. A new approach of cyclic block filtered multi-tone modulation (CB-FMT) was proposed that uses cyclic convolution for producing different frequency pulses. The scheme is advantageous to conventional FMT that uses linear convolution for producing frequency pulses [6]. Large amplitude variations in multicarrier can produce system nonlinearities. If a separation of inverse phase element is provided in multi-carriers then OFDM signal is produced [7]. The impact of multi-path interference (MPI) is investigated in RoF network implemented using directly modulated lasers (DMLs). Carrier to noise ratio (CNR) limited by MPI is investigated in terms of signal-to-interference ratio (SIR) [7]. A low-complexity Tone injection (TI) scheme containing distortion signals was suggested to improve PAPR and reduce system complexity [9]. Signal to noise and distortion ratio (SNDR) has been investigated for radio over fiber (RoF) system based on Dual Drive Mach Zehender modulator (DD-MZM) using high performance generation 120° phase shift method and optical amplifier as erbium doped fiber amplifier (EDFA) in both noise and distortion generated conditions. Significant SNDR improvement has been observed by EDFA in noise dominant condition while no significant improvement is observed in distortion dominant condition [10]. Dual parallel Mach–Zehnder modulator (DPMZM) can also be used with RoFs, which gives good results against intermodulation distortion (IMD) errors. In order to investigate the receiver performance, positive-intrinsic-negative (PIN) and avalanche photodiode (APD) photodetectors are utilized at the receiver end. The analytical analysis of DPMZM based RoF system is analyzed, and the simulation model is implemented using OptSIM software, including PIN and APD photodetectors [11].

2. SIMULATION SETUP

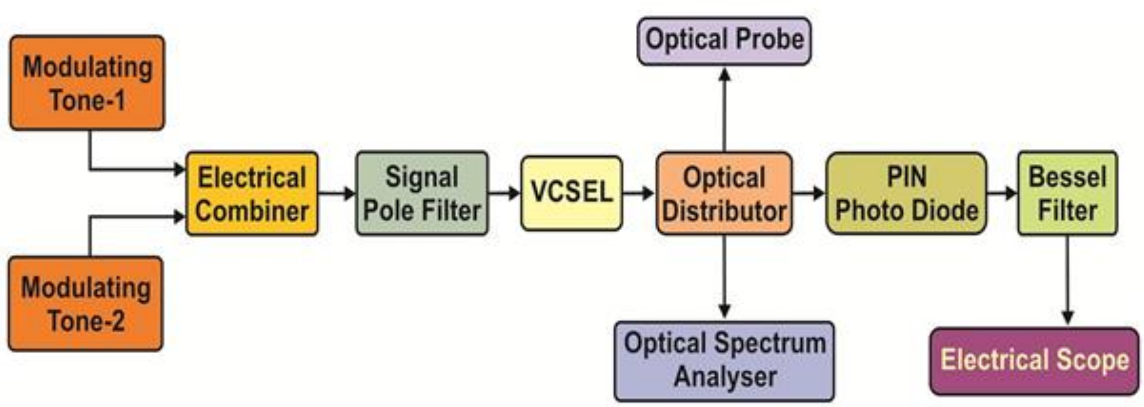

Figure 1: Conceptual diagram for system setup for Two-Tone Tester

The optical system design consists of modulating tones, VCSEL diode transmitter, single/multimode fiber, filter, PIN diode receiver etc. Optsim optical simulation tool from Rsoft Design Group is used for the design. Figure 1 shows the VCSEL optical system design. UWB RF signal is fed in to the optical system through a test data file reader block. Electrical and optical spectrum analyzers are attached to the input and output electrical and optical signals. Test data file writer collects electrical system after optical transmission for simulation in MATLAB Simulink.

3. RESULTS & DISCUSSION

In this section Single-tone & Multi-tone RoF systems are compared for obtaining different results using different parameters.

3.1 EYE DIAGRAM

Figure 2 shows the eye diagram for single-tone RoF system. Different performance matrices for single-tone RoF system are derived from this eye diagram. Similarly, Figure 3 provides eye diagram for multi-tone RoF system. Different performance matrices of multi-tone RoF system are derived from this eye diagram.

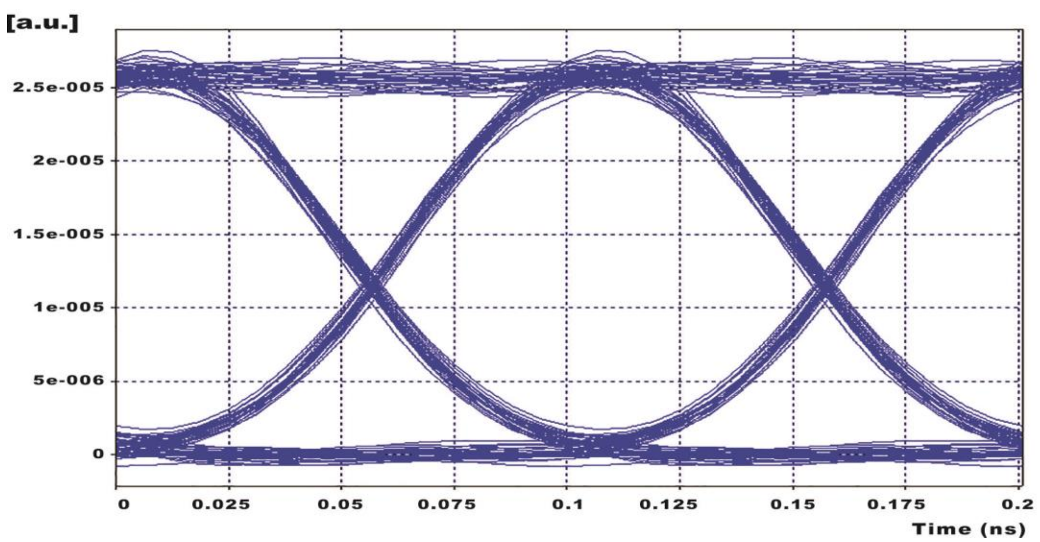

Figure 2: Eye diagram for Single-tone System

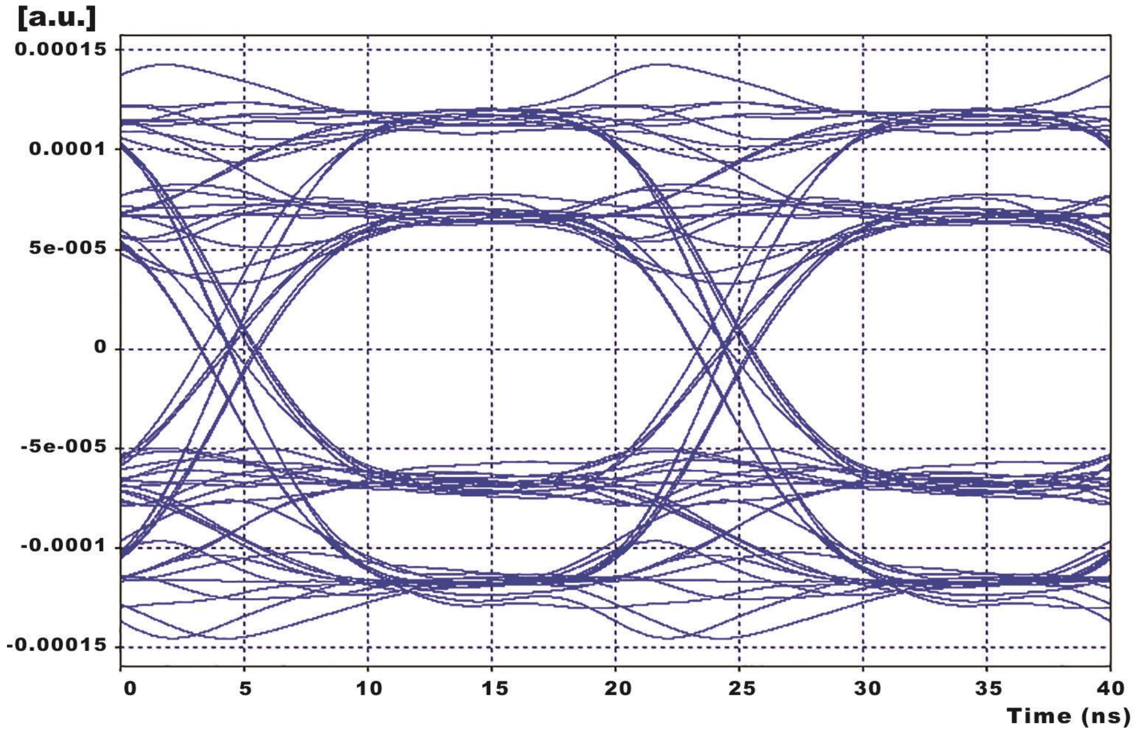

Figure 3: Eye diagram for Multi-tone System

The comparative analysis of Single-Tone and Multi-Tone RoF (as depicted from Figures 2 and 3) is summarized in table 1. By verifying this table, it is clear that single-tone and multi-tone RoF system provide similar performance and single-tone system can be replaced by multi-tone systems.

Table 1: Comparative analysis of Single-Tone and Multi-Tone RoF

Performance parameters	Single-Tone RoF	Multi-Tone RoF	
	Value 1	Value 1	Value 2
Q-value (dB)	36.1	36.2	35.7
Eye Closure (dB)	0.14	0.14	0.151
Eye Opening [a.u.]	5e-025	5e-025	5e-024

3.2 DYNAMIC RANGE

Second order harmonic distortion for single and multimode VCSEL at different bias currents are simulated.

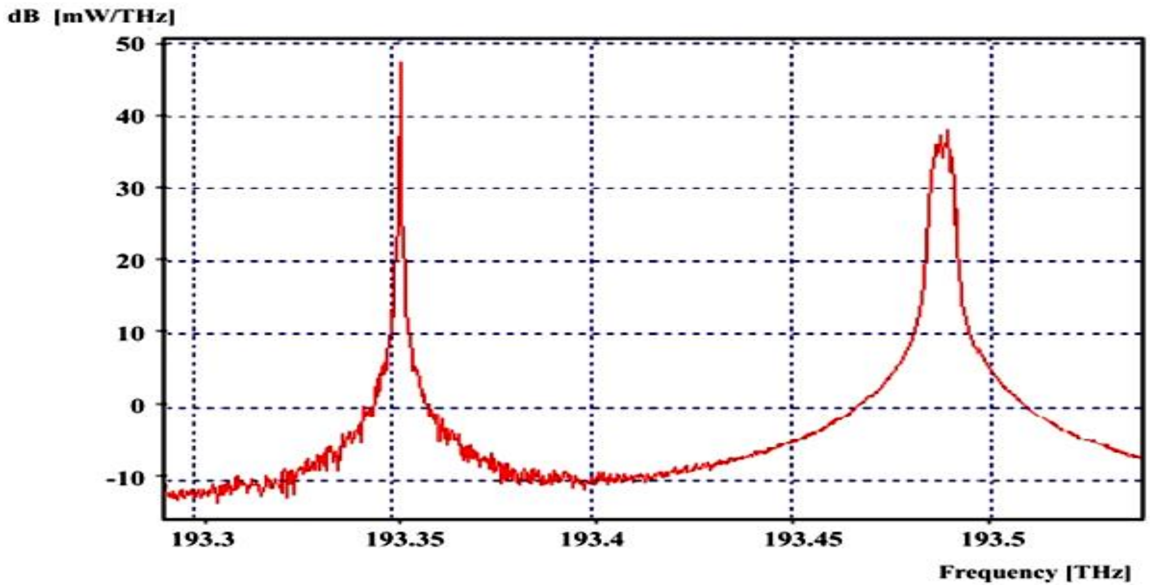

Figure 4: Single mode VCSEL second order harmonic distortion

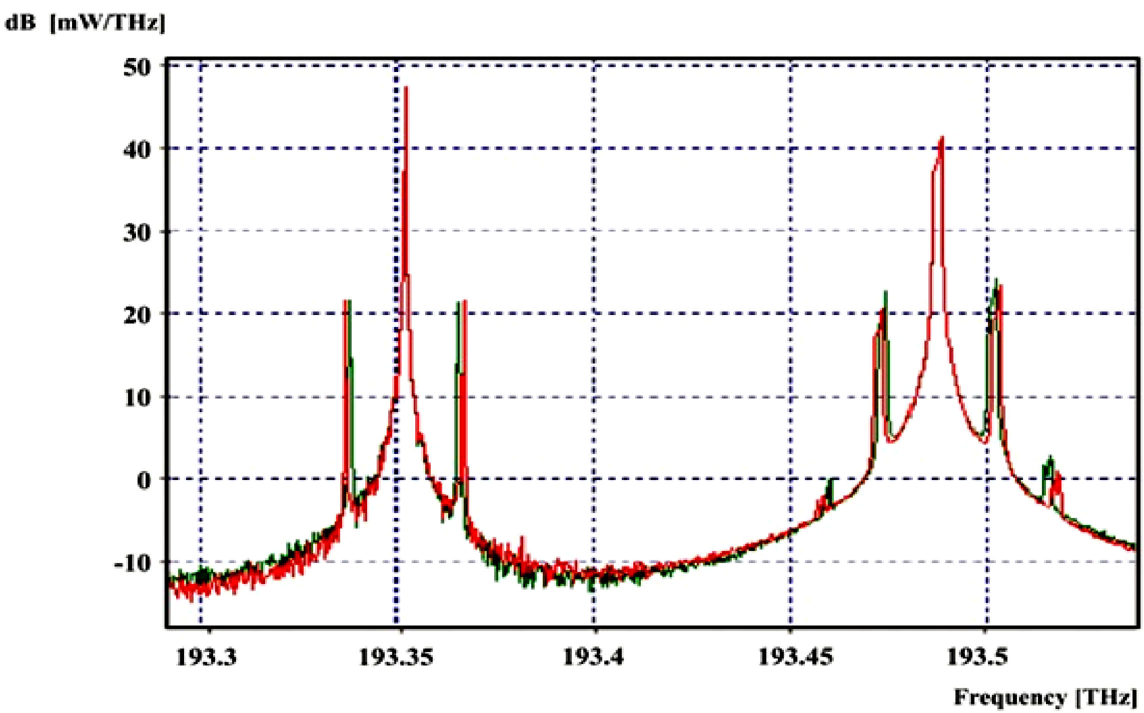

Figure 5: Multi-mode VCSEL second order harmonic distortion

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Figure 4 shows single mode VCSEL with second order harmonic distortion. Figure 5 shows multi-mode VCSEL with second order harmonic distortion. At lower frequencies (< 1.5 GHz for single mode, < 2.0 GHz for multi-mode), spatial-burning-induced distortion dominates. At intermediate frequencies, the two effects from relaxation oscillation and spatial burning cancel each other, resulting in a significantly lower distortion. Spectral hole burning effect, which is accounted for by the gain compression factor were found to have a small effect on the relative distortion levels.

3.3 SPURIOUS FREE DYNAMIC RANGE (SFDR)

SFDR is calculated from two-tone inter-modulation distortion (IMD) simulation. Two-tone signal separated in frequency by 1 MHz was fed to VCSEL with different bias currents. The simulation results are shown in Fig. 6 from single mode and Fig. 7 for multimode VCSEL. The SFDR of the multimode VCSEL at 6 mA bias current is 84–95 dB. And the SFDR of the single mode VCSEL at 2 mA bias current is 82–85 dB. The SFDR of single mode VCSEL is about 10 dB lower than multimode VCSEL. This is because of lower modulation response of the single mode VCSEL. It is analyzed that RF transfer efficiency of multimode is greater than single mode VCSEL.

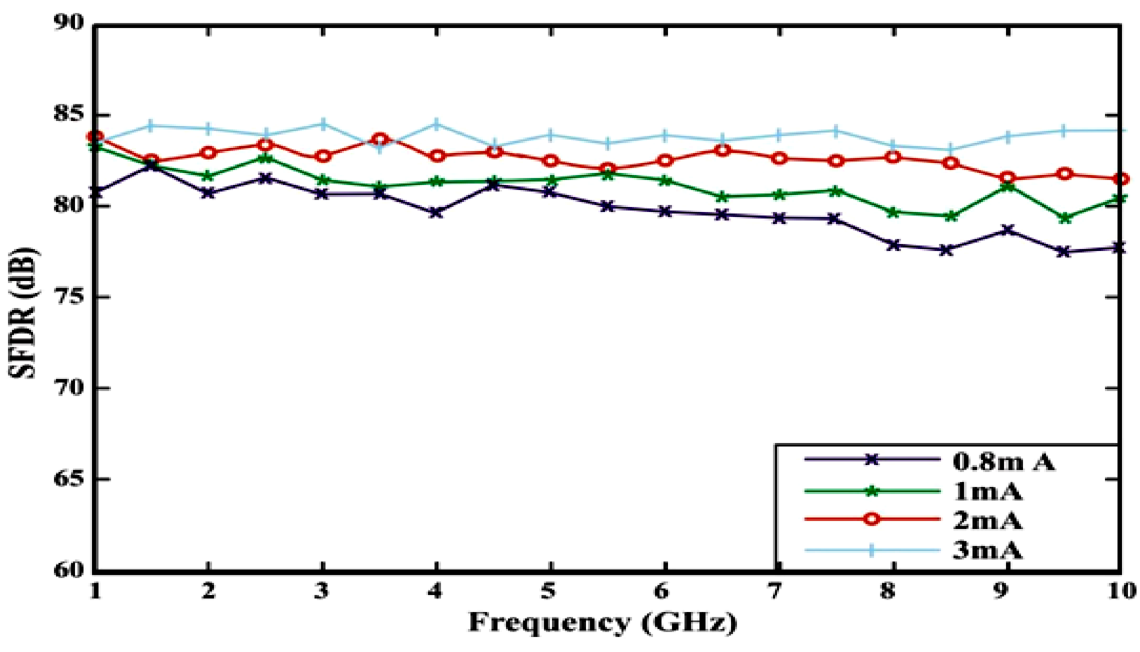

Figure 6: SFDR (dB) for 2 mm single mode VCSEL

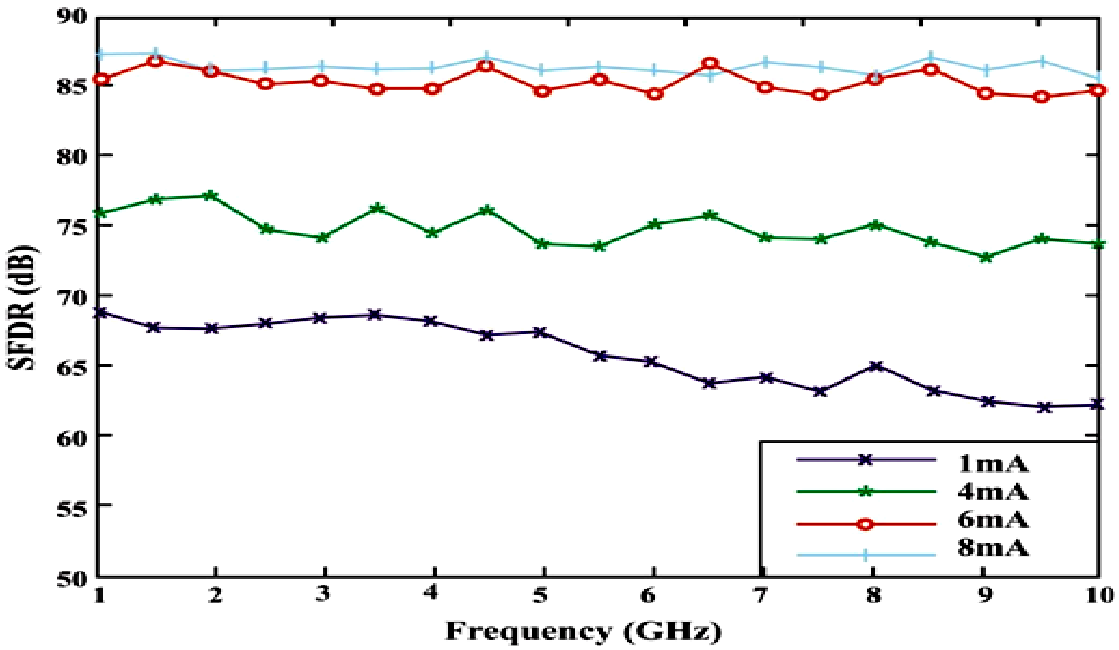

Figure 7: SFDR (dB) for 10 mm multi-mode VCSEL

4. CONCLUSIONS

A two tone setup for RoF systems is utilized to investigate the performance of single mode and multi-mode systems. Various performance parameters are investigated in order to compare the performance of two systems. Eye diagrams suggested a comparative performance of these two systems. Dynamic range of VCSEL is tested for both systems with second order harmonic distortion. Although results of single mode systems are somewhat better than multi-mode systems, yet multimode system provided good results. From simulation under different bias currents, it is found that for single mode VCSEL, the bias of 2 mA has the low SFDR. For multimode VCSEL, the bias of 6 mA has somewhat high SFDR. It is concluded that since single mode VCSEL is more favorable in analogue signal transmission, but multi-mode VCSEL can provide a good performance as these provide additional benefits like bandwidth utilization and large data transmission.

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