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Analysis of the carrier suppressed single sideband modulation for long distance optical communication systems

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ABSTRACT

In this research paper, we report on a simulation study of the Radio over Fibre (RoF) Carrier Suppressed Single Sideband (CS-SSB) modulation scheme. This scheme is based on a Dual Parallel Dual Drive Mach-Zehnder modulator (DP-DDMZM), for a long-distance transmission. The proposed system consists of the combination of a carrier and a message signal at two parallel modulators, where the laser and link power is varied for the two different dispersion compensation techniques. We found that by suppressing the optical carrier and cancelling one sideband, we can limit the nonlinear effects that are caused by power fading and interference. We demonstrate that by varying the launched laser and link power up to optimised threshold levels, the signal to noise ratio (SNR) increases and the Q-Factor improves significantly. Our proposed RoF optic communication architecture can support an extended reach transmission of up to 200 km without dispersion compensation. Moreover, for the bitrate of 10 Gbit/s and span length of 25 km, we achieved a span ratio of 520, alternatively viewed as the system link signal transmission distance of 13,000 km. Therefore, this method is cost-effective and less complex.

1. Introduction

Radio-over-fibre (RoF) signal transmission has experienced tremendous growth and has had great interest for the research community in the last decades. This increased interest is due to the high capacity that the fibre optic system offers and the transparency of the system to the modulation and transmission. This transparency is beneficial for future system upgrades. Despite the significant advantages that RoF offers, there are still issues that the fibre optic system faces. These issues are consequence of the modulation, nonlinear effects, fibre chromatic dispersion, and other associated transmission losses [1]. It is known that losses can be improved by increasing the quality of the optical signal at the modulation [2]. However, for long distance transmission, dispersion is a major limiting factor that causes degradation of the signal transmission, and diminishes the data rate.

One of the key tasks when designing RoF systems is finding the method to modulate the signal into an optical carrier while achieving the least possible losses. Overall, there are three main factors limiting signal transmission at the fibre optic communication; nonlinear effects, attenuation, and dispersion. Many techniques have been proposed to compensate these losses. These techniques are divided in to; pre-distortion compensation at the transmitter, inline compensation at the

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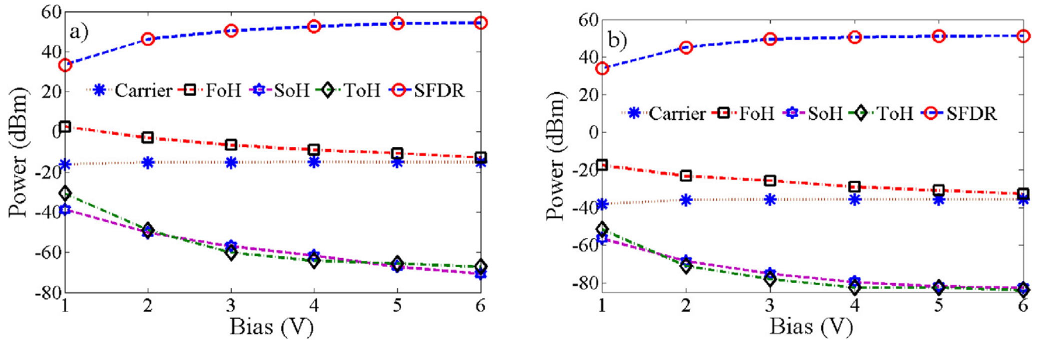

Fig. 1. Behaviour of harmonics and the analysis on Dynamic Range (DR), variation of the bias as a function of the output power at the coherent detection (a). Optical output power, and (b) Electrical output power.

Table 1
Optical and RF Spectrum Analysis at the Coherent Detection.

	Optical Spectrum	RF Spectrum
Carrier	J_0 = −15.18 dBm	J_0 = −35.68 dBm
Fundamental	J_1 = −6.54 dBm	J_1 = −25.67 dBm
SOH	J_2 = −60.14 dBm	J_2 = −75.25 dBm
TOH	J_3 = −57.02 dBm	J_3 = −78.11 dBm
SFDR	J_1- J_3 = 50.48 dBm	J_1- J_2 = 49.58 dBm

channel, and post-spotted at the receiver [3,4]. The transmission of the RF signal over the fibre optic link can be improved by the optical carrier suppression [4], given that the optical carrier takes most of the optical power and does not carry any information. Several methods have been utilised to generate linearized signal modulation by deploying two or more electro-optic modulators [5]. To improve the overall system performance, several inline compensation techniques have been proposed, specifically Dispersion Compensation Fibre (DCF) [6] and Fibre Bragg Grating (FBG) [7]. FBG is one of the most used techniques due to its low insertion losses, low-cost, and most importantly, its compatibility within the existing optical communication structure configuration. In our transmission system, to observe the performance of the RoF, we have used a coherent detection with bias values from 1 (V) to 6 (V) as a function of output power. Based on Ref. [4], to reduce the RF power fading and interference between two bits, the minimum transmission point (mTP) is applied to both modulators at the push-pull configuration. This resulted in maximum optical carrier suppression and the complete cancelation of one of the sidebands. This occurred by increasing the gain of the useful signal on the optical sideband and improving the efficiency of the message signal transmission. Taking in to account system deteriorations due to the nonlinear effects at the channel link, we have investigated two compensation techniques for 10 Gbit/s and 40 Gbit/s at three different stages of launched laser power and link power.

2. Methodology

We have developed a thorough analytical model and compared various modulation formats using CS-SSB optical modulation schemes. We have also deployed VPI simulation software packages [8] to implement the analytical model, and to scrutinise the proposed system performance. Initially, we studied a few action points, investigating the behaviour of the harmonics as a function of biased voltage in the CS-SSB configuration spectrum, as illustrated in Fig. 1a and b. As demonstrated by these figures, the bias voltage significantly affects the system's performance, particularly impacting the harmonic distortion [9]. Both modulators are biased at various RF and DC switching voltages from $V\pi = 1(V)$ up to 6 (V) as a function of output power, operating at mTP point for $V_{Bias} = V_{\pi}$, by changing $V_{bias1} = 1(V)$ up to 6(V) and $V_{bias2} = 0(V)$. The 90° phase shifter is applied to the input of the first child modulator and the output of the second child modulator, which makes the parent modulator biased at a quadrature point [10].

By increasing the bias voltages, the carrier for any input power is practically constant, as compared to the sidebands which are gradually decreasing. The existence of Second Order Harmonic (SOH) and Third Order Harmonics (TOH) depends on bias voltage. The higher the bias level, the smaller the harmonics and the higher the Dynamic Range (DR) [11].

By keeping the bias at 3 (V) in the transfer function, where the halfway switching voltage is $V\pi = 3$ (V), we managed to suppress the even order distortion, while leaving the third order as the dominant distortion product. The analytical calculations and simulation testing taken at the optical and RF side, are illustrated in Table 1.

The difference between the fundamental and highest harmonic (spur) gives us the spurious free dynamic range at the optical spectrum SFDR = $f_1 - f_3$ = 50.48 dBm, and at the RF spectrum SFDR = $f_1 - f_2$ = 49.58 dBm. The optical and RF spectrum, illustrated in Table 1, demonstrates the consistency between both sides of the transmission link.