Optoelectronic oscillator based on Class AB photonic link

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ABSTRACT

An optoelectronic oscillator topology based on a class AB analogue optical link is proposed. The motivation for this approach is based on the unique property of class AB links for mitigating both shot noise and relative intensity noise contributions. The class AB optoelectronic oscillator is compared with a conventional single loop optoelectronic oscillator.

Keywords: optoelectronic oscillators, class AB, microwave photonics, analogue optical links.

1. INTRODUCTION

Optoelectronic oscillators (OEOs) have been a topic of active research in microwave photonics since the mid-1990's [1] and are a good example of a microwave photonic system used for the generation of microwave signals with high spectral purity [2]. The key aspect of OEOs is the use of optical elements (typically optical fibres but also, in recent work, whispering gallery mode resonators [3]) in order to achieve very high Q-factors and thus to achieve phase noise better than conventional microwave oscillators, such as dielectric resonator oscillators for example.

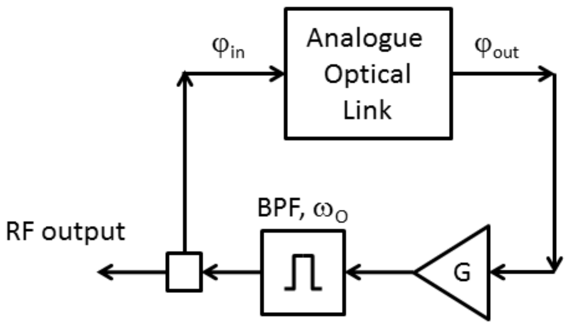

Fig.1. Generic topology of a single-loop optoelectronic oscillator.

The basic topology of an OEO consists of an analogue optical link (which in the majority of cases is an externally modulated link using Mach-Zehnder modulators) in a closed loop configuration, with a microwave amplifier of gain *G* being used to overcome loop losses and a narrowband bandpass filter at ω_0 being used to suppress side mode oscillations.

For the analogue link, we have $\phi_{out}=f\left(\phi_{in}\right)$, where ϕ is the normalised voltage (with respect to the V_π voltage of the modulator) and f is a function of the link topology and various link components and associated optical and microwave bias conditions. Assuming a steady-state single mode of oscillation at a frequency ω_m, amplitude ϕ_m and phase offset θ, the oscillation condition for the OEO may be written as:

$$f\left(\phi_{out}\right)=G\phi_m \sin\left(\omega_m t+\theta\right). \qquad (1)$$

The spacing between adjacent modes (i.e. the free spectral range – FSR) is determined largely by the optical fibre delay, and a common problem is that due to the requirement for high optical Q factors, long fibre delays are used that subsequently result in a FSR that is smaller than the filter bandwidth, resulting in multiple modes of oscillation. Various techniques have been investigated to both obviate the need for microwave amplification [4] and to achieve side mode suppression optically rather than with microwave filters [5].

Here we investigate a different aspect of OEO design that is related to the issue of the noise contributions of the analogue optical link. Specifically we propose the application of class AB techniques as originally developed for analogue optical links [6], where it has been shown that they can minimise the contributions of both RIN and shot noise to the dynamic range.

2. CLASS AB APPROACH

The conventional approach in first generation OEOs is to implement the analogue optical link in Fig.1 using the topology shown in Fig.2 (a), in which the modulator is typically biased at the quadrature point in order to maximise its contribution to the link gain (assuming a single sinusoidal input). In doing so, however, there is a significant DC component to the RF output current and also an associated shot noise component.

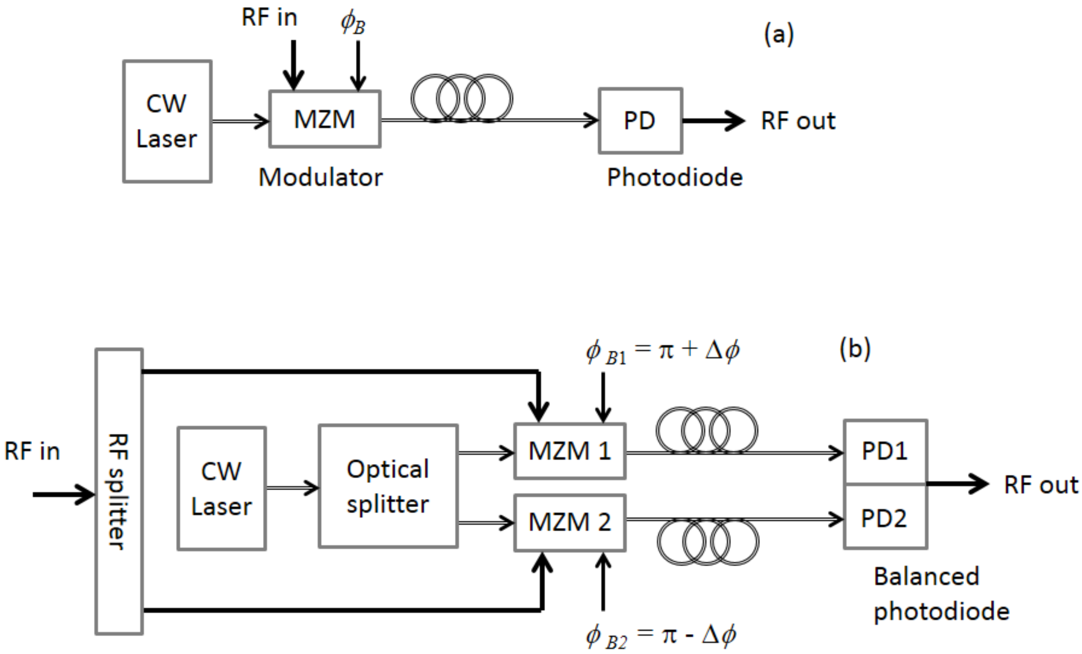

Fig.2. Analogue optical link. (a) Conventional link with quadrature bias.
(b) Class AB link with complementary biased modulators.

In the class AB link (Fig.2), a pair of identical single-drive modulators are biased at complementary points around extinction, such that $\phi_{B1}=\pi+\Delta\phi$ and $\phi_{B2}=\pi-\Delta\phi$ where $\Delta\phi$ is the offset bias. Assuming the modulators are driven by identical RF inputs and CW optical inputs, then detection through a perfectly balanced photodiode will produce an RF output with zero mean:

$$\phi_{out}(t)=\frac{R_D\Re P_O\gamma\varepsilon}{2V_\pi}\sin(\Delta\phi)\sin\left(\frac{\phi_{in}(t-\tau)}{\sqrt{2}}\right)=\phi_O\sin(\Delta\phi)\sin\left(\frac{\phi_{in}(t-\tau)}{\sqrt{2}}\right). \quad (2)$$

Here, R_D is the detector load, $\Re$ is the responsivity, P_O the optical CW power, γ the insertion loss, ε the extinction ratio and τ the fibre delay time, while ϕ_O is the RF output at 100% transmission.

We have conducted preliminary simulations using the VPI Transmission maker simulation tool. Fig.3 shows the impact of varying the bias offset for an OEO with the following parameters: $\Re$ = 0.8 A/W, τ = 314 ns, G = 10 dB, V_π = 5 V and for a filter centred at 3.5 GHz with a 12 MHz bandwidth. Oscillations were observed, with a peak power at around 0.17 to 0.20 V_π, while at 0.30 V_π the loop gain is insufficient to support oscillation due to the reduced modulator slope efficiency.

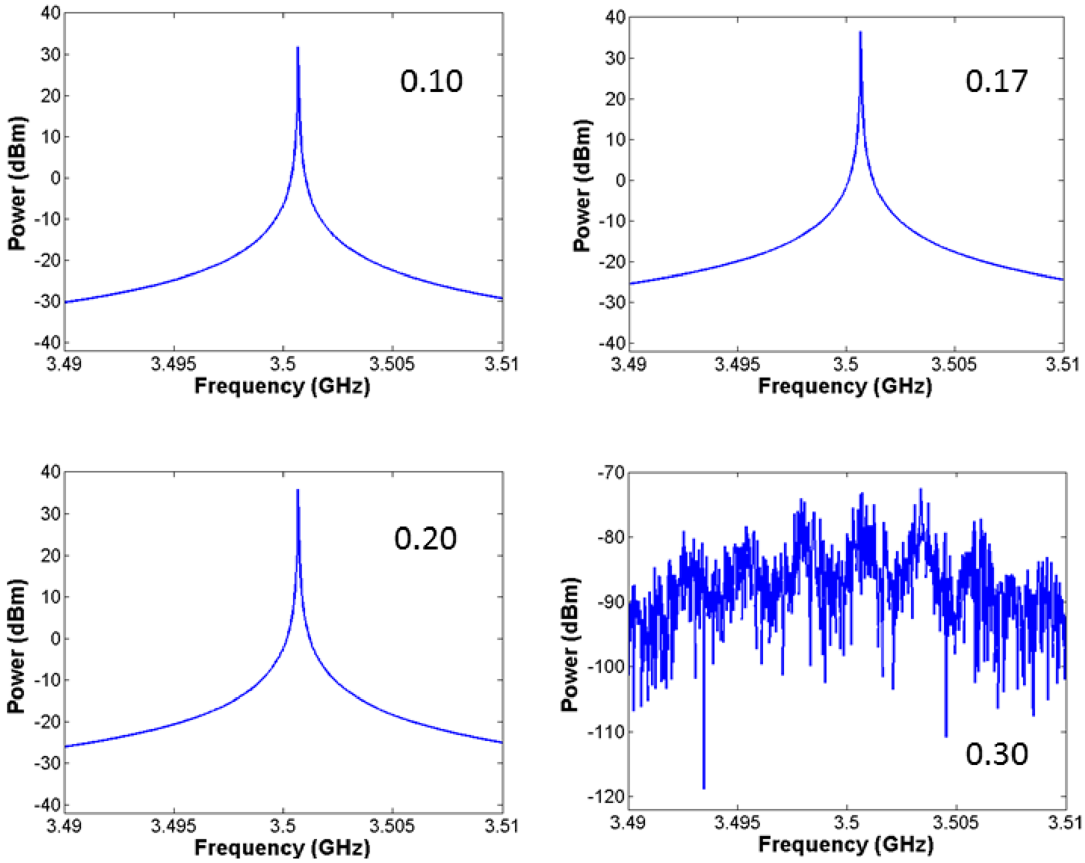

Fig.3. Simulated spectra for the class AB OEO as the bias offset is varied from $\Delta\phi = 0.10\pi$ through to $\Delta\phi = 0.30\pi$. Power axis is in arbitrary units.

3. CONCLUSIONS

The application of a class AB microwave photonic analogue link to the standard single-loop optoelectronic oscillator has been proposed. Initial simulations indicate the feasibility of the approach. We will present a more detailed analysis of the effect of bias offset on both output RF power and phase noise at the conference..

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