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# Filterless optical millimeter-wave generation using cascaded-parallel Mach–Zehnder modulators with tunable frequency multiplication factor

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**Abstract**
A filterless optical millimeter-wave generator using two cascaded-parallel Mach–Zehnder modulators (MZMs) with tunable frequency multiplication factor is theoretically analyzed and verified by computer simulation. Frequency multiplication factor of 4, 8, 12, 16 and 24 can be achieved by proper adjustment of modulation index. From a 5 GHz radio frequency driving signal, generation of 20 GHz, 40 GHz, 60 GHz, 80 GHz and 120 GHz signals with radio frequency spurious-sideband suppression ratio greater than 25 dB is demonstrated. All MZMs are operated at maximum transmission point, which reduces the burden of DC bias voltage sources. For the system, modulation index (m) range in which optical sideband suppression ratio (OSSR) is greater or equal 10 dB is evaluated. It has been found that system works as frequency quadrupler, octupler, 12-tupler, 16-tupler and 24-tupler for 'm' in the range of 1–3, 1–3.5, $5.135 \pm 2.5\%$, $4 \pm 3\%$ and $5.1313 \pm 1.2\%$ respectively. Similarly, effect of offset in phase shifters from ideal value on OSSR has been also evaluated.

**Keywords** Optical mm-wave · Radio-over-fiber · Microwave photonics · Mach–Zehnder modulator

## 1 Introduction

With tremendous proliferation of portable devices, there is strong wireless bandwidth quest. To cater such ultra-high wireless bandwidth demand, network operators need to evolve. Due to spectral congestion at lower microwave frequencies, radio-over-fiber (ROF) systems based on millimeter-wave technology have been considered as promising solution of last mile link for the future wireless communication systems (Fernando 2014;

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