Fully integrated multipurpose microwave frequency identification system on a single chip

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Abstract: We demonstrate a multipurpose microwave frequency identification system on silicon-on-insulator platform. The chip is able to identify different types of microwave signals, as well as discriminates instantaneous frequency variation thanks to its multipurpose features. © 2022 The Author(s)

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1. Introduction

Photonic-based microwave measurement techniques have attracted great attention because of its advantages including large operation bandwidth, low loss and anti-electromagnetic interference [1, 2]. Some integrated photonic chips have been reported based on frequency to power mapping (FTPM) scheme to implement instantaneous frequency measurement (IFM), which provide agile measurements but is unable to identify multiple frequencies simultaneously. Frequency to time mapping (FTTM) has the ability to achieve multiple-frequency measurement. However, it is still a challenge to develop a multipurpose frequency identification system that can both identify different types of microwave signals and identify the frequency instantaneously. Besides, previous approaches are only partially integrated with the key component such as microring resonator (MRR), Mach-Zehnder interferometer (MZI), Bragg gratings [3-5]. None has monolithically integrated all the main active and passive optoelectronic components. Here, we propose and experimentally demonstrate a fully-integrated multipurpose microwave frequency identification system. The system has an operation bandwidth of 10-20 GHz and the measurement error is 483.8 MHz. This monolithic integrated microwave frequency identification system, featuring low size, weight and power consumption, is potential in future integrated microwave systems.

2. Principle and device fabrication

![Schematic diagram](image)

Fig. 1. (a)Schematic of the multipurpose microwave frequency identification chip. (b)Microscope image of the fabricated chip.

Figure 1a shows the schematic structure of our microwave frequency identification system that consists of four main building blocks. Optical carrier generated by a tunable laser source is injected to an on-chip dual-parallel Mach-Zehnder modulator (DPMZM), where the unknown RF signals are modulated with carrier-suppressed single-sideband modulation. This signal is split and then sent to a thermally tunable microring for microwave frequency classification through FTTM technique. The MRR is driven by a periodic sawtooth voltage and exhibits as a scanning filter. It has a large free spectral range (FSR) of 80 GHz with a Q-factor of ~22000. When the scanning filter is aligned with the sidebands, a temporal pulse will be observed at the oscilloscope. Therefore, the unknown frequencies will be mapped to the time domain. The band-selection block can filter the unwanted jamming signals, which is constituted by three cascaded MRRs. An IFM block is subsequently employed to identify the frequency varying signals in a dynamic manner. A monotonic relationship between the frequency and the ratio of two output.
powers of an asymmetric MZI, i.e. amplitude comparison function (ACF), is established. The MZI has an FSR of 144 GHz and the extinction ratio is 18 dB. The chip is fabricated on a silicon-on-insulator wafer using CMOS-compatible process. Figure 1b shows the micrograph of the fabricated chip including four MRRs, an MZI as well as active optoelectronic components.

3. Results

In experiment, a periodic sawtooth voltage is loaded onto the MRR. The spectral drift of the MRR is proportional to the electric power, thus a quadratic function is determined between the frequency and the pulse delay as shown in Fig. 2a. We scan a given microwave frequency from 10 to 20 GHz to fit the curve. This FTTM function is used afterwards to estimate the unknown frequency. The measurement bandwidth is mainly limited by the on-chip DPMZM, which has a 3 dB-bandwidth of 22 GHz. The FTTM scheme is capable of identifying multiple-frequency signals. Fig. 2b-d show the measured waveform of different types of microwave signals. In Fig. 2b, a two-tone signal set as 10 and 15 GHz is loaded onto the DPMZM. Fig. 2c-d exhibit frequency-hopping sequence with components of 10, 12, 14, 16 GHz and chirped signals spanning 12.5-17.5 GHz respectively. IFM is implemented by an MZI, whose transmission responses are employed to define the ACF. Figure 3a-b show the corresponding transmission response of the MZI and the power ratio of the two output ports. Figure 3c shows the estimated frequencies compared to the input frequency for each of the test tones with a root mean square error of ~483.8 MHz.

![Fig. 2. (a) Measured frequency-time mapping function of the system. (b) Measured results of two-tone signals. (c) Measured results of frequency hopping signals. (d) Measured results of chirped frequency signals.](image)

![Fig. 3. (a) Optical transmission spectrum of the two ports of the MZI. (b) ACF curve. (c) Estimated frequency (blue dots) and corresponding error (red dots) measured by frequency-power mapping.](image)

Acknowledgments

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4. References

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