IIT MADRAS
Indian Institute of Technology Madras

Technology Transfer Office
TTO – IPM Cell

Industrial Consultancy & Sponsored Research (IC&SR)

Method and Opto-electronic apparatus for determining frequency of intercepted signal using sub-Nyquist sampling

IITM Technology Available for Licensing

PROBLEM STATEMENT

- In general, **instantaneous frequency measurement (IFM)** always has been a **critical** technology for **efficient broadband spectrum sensing**.
- **IFM** initially **Started** as **analog** and **later** it transforms to **digital** instantaneous frequency measurement **(DIFM)** systems.
- DIFM further **develops** to **high-speed** sample-and-hold circuits, analog-to-digital converters (ADCs), and FFT processors and **aided to start** the **compressed sensing** technologies called as **sub-Nyquist sampling** based **frequency discriminators.**
- Compressive sensing methods (such as sub-Nyquist sampling) **require low frequency** and **low complex hardware**, enabling miniaturization.
- **Photonic-assisted** microwave measurement techniques offer **distinct advantages** such as **wide spectrum coverage, low frequency dependent loss, and immunity to electromagnetic interference**.
- Optical sub-Nyquist sampling **using mode locked lasers (MLLs)** offer **very low jitter performance** and **ability to process the signal** at baseband frequencies.
- Thus there is a **need for alternative technology** for better results.

TECHNOLOGY CATEGORY/ MARKET

Category: Information & Communication Technologies (ICT) / Photonics
Industry: Semiconductor & Electronics Manufacturing, Integrated devices.
Applications: Wireless Communication Devices, Telecommunication Infrastructure,
Market: The global Opto electronic apparatus market size is **estimated at USD 1.64 trillion in 2024**, and is **expected to reach USD 2.25 trillion by 2029**, growing at a **CAGR of 6.5%** during the forecast period **(2024-2029).**

INTELLECTUAL PROPERTY

IITM IDF Ref. 2204; Patent No: IN 531779;

TRL (Technology Readiness Level)

TRL-4, Experimentally validated in Lab;

Research Lab

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TECHNOLOGY

- An **Opto-electronic apparatus** for **determining a frequency** of an **intercepted signal** using **sub-Nyquist sampling**, the Opto-electronic apparatus comprises

1. An **Optical sampler** for **providing an Optical signal**;
2. A **Optical delay lines** for **interleaving the Optical signal** in each Optical delay line.
3. A **electro-Optic modulators** for **obtaining a Optically sampled versions** of the **intercepted signal** using a corresponding interleaved Optical signal from each Optical delay lines **based on the sub-Nyquist sampling**, wherein the **intercepted signal is a radio frequency (RF) signal.**
4. A **Opto-electric converters** for converting each **Optically sampled versions** of the **intercepted signal into electrical domain**
5. A **frequency estimator** for **determining a frequency** of the **intercepted signal** using each Optically sampled versions of the intercepted signal in **the electrical domain** based on a **location in the left window or the right window**.

- A **single optical sampler** is used and **parallel** optical delay lines are provided **to multiply the repetition rate** of a pulsed optical signal which is then modulated with an intercepted signal **to determine a center frequency** of the **intercepted signal**.

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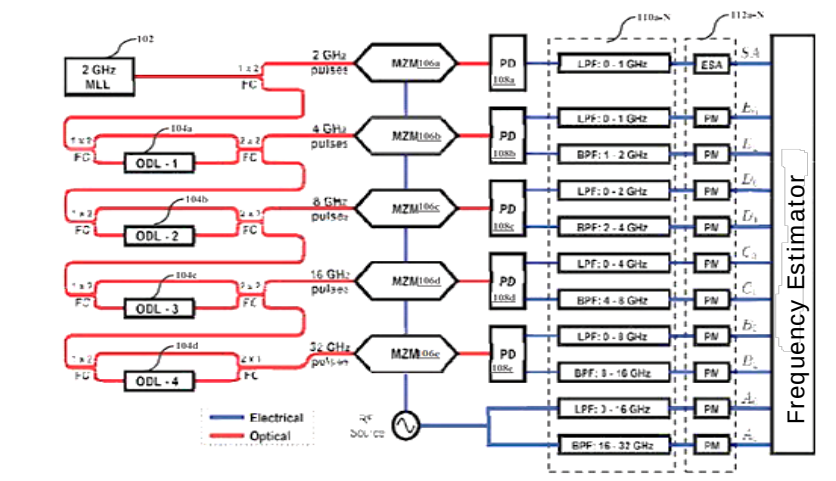

Figure 1 illustrates an **opto-electronic apparatus** for determining a frequency of an intercepted signal using sub-Nyquist sampling.

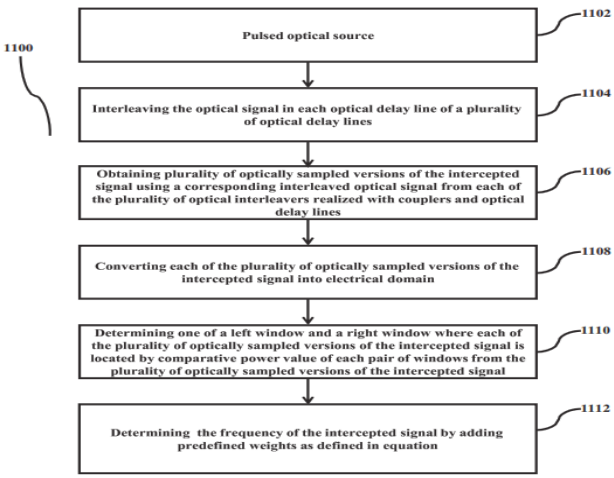

Figure 2 illustrates a **method for determining a frequency** of an intercepted signal **using sub-Nyquist sampling** by the **Opto electronic apparatus.**

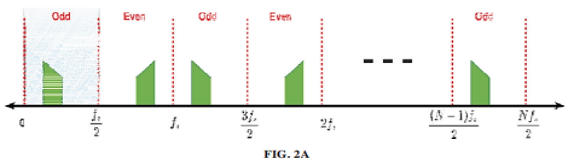

FIG. 2A

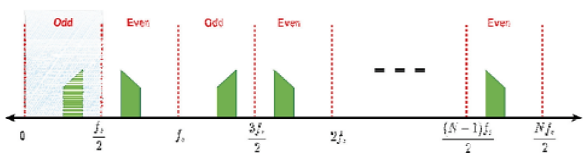

FIG. 2B

Figure 3 illustrates **spectrum folding** when a **passband signal** is at **odd fold** and at **even fold**,

Key Features / Value Proposition

- ✓ A novel **frequency measurement device** based on **optical sub-sampling**.
- ✓ A novel **sub-Nyquist** based **photonic instantaneous frequency measurement .**
- ✓ The **intercepted signal** is **a radio frequency (RF)** signal.
- ✓ The optical sampler is a **Mode Locked Laser (MLL)** of **2 GHz repetition rate**.
- ✓ Electro-optic modulators is **Mach Zehnder Modulator (MZM).**
- ✓ The **optical signal** of the intercepted signal is **direct copy** for **odd fold** and **mirrored copy** for even fold.
- ✓ Interleaving of the optical signal **doubles a frequency of the optical signal** at each of the optical delay line and Incorporation of the **parallel channels** was made in a **single integrated optic chip**.
- ✓ **Highly stable** and **cost effective** .

Applications:

➢ **ESM systems, Radar, surveillance, telecommunications, vehicular communication.**

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