Wideband Spectrum Coexistence Enabled by Photonic Circuits: Cross-Layer Design and Implementation

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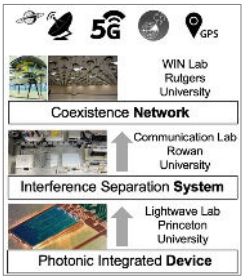
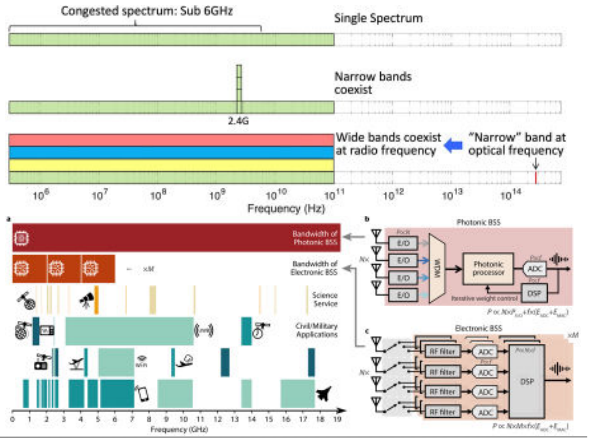
Project Summary

Passive Users: Evolving communication systems rely on using increasingly higher frequencies for larger channel bandwidths. The increased channel capacities enabled by higher carrier frequencies provide high speed communication for commercial and active users, however, these benefits do not extend to passive users, such as radio astronomy.

Wideband Interference: The dramatic growth of commercial and active users will generate increasingly more interference at both high and low frequencies, which will impair the success of both commercial and scientific use of spectrum.

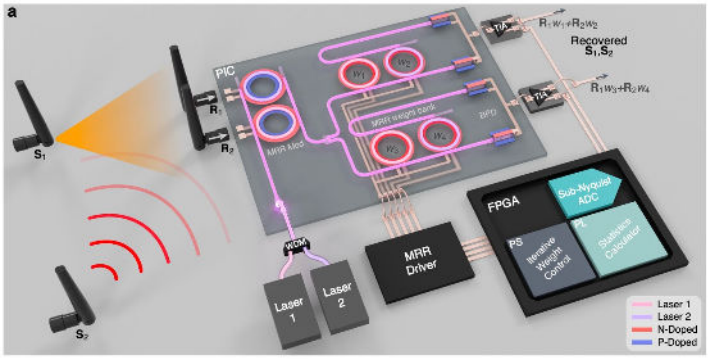


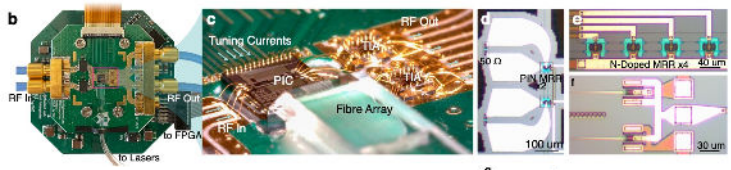
Spectrum Coexistence: The focus of the proposed effort is to create a framework that is beneficial for both active and passive users. Instead of simply switching to higher and undeveloped frequencies - which passive users cannot - our proposed research employs high frequency, optical signal carriers for interference separation, enabling the coexistence of active and passive users at the same time and in the same physical location.

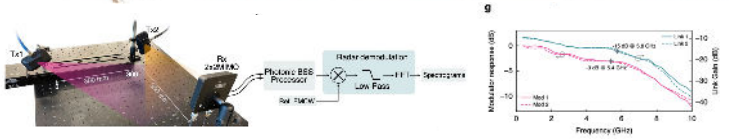


Research Progress

Experimental Setup: System on Chip Microwave Photonic Processor

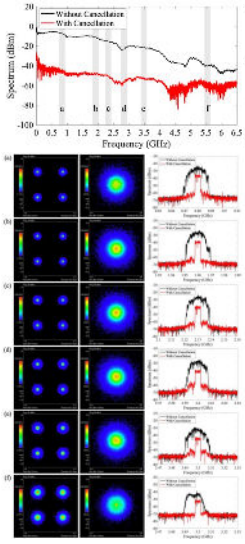




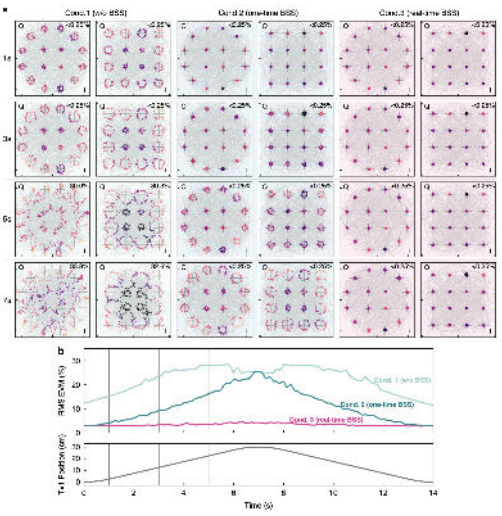


Intellectual Merit: The intellectual merit stems from the completely orthogonal approach to the challenges of radio spectrum, and the seamless integration of hardware innovation with the communication protocols. By harnessing the unique properties of optical carriers, the photonic system processes analog signals before digitization, which eliminates both the current bandwidth limit and the resolution limit. Such limits are determined by the spectrum ranges of radio frequency carriers, and digitization errors in the traditional systems.

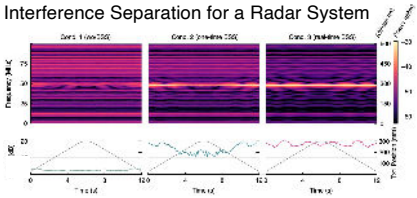
Wide Band Operation



Interference Separation for Communication Systems



Interference Separation for a Radar System



Broader Impacts: The proposed coexistence solution will enable continuous availability of wideband spectrum for passive users, an important requirement for detecting unknown signals, since the bandwidth and the time window for unknown astronomical, atmospheric and geospace signals cannot be manipulated. The PI team has diverse expertise in device, system, and network levels, and such diversity will enable interdisciplinary research and education. With the collaboration of one private and two state universities in New Jersey, the proposed research supports education in various levels.

Remaining Task and Future Directions

- Field and network test of the interference separation system.
- Adding non-linear function to the photonic processor for pattern recognition.
- Apply the signal separation system in passive receivers.

Publications

1. W. Zhang, J.C. Lederman, P. Prucnal*, et al., "A system-on-chip microwave photonic processor solves dynamic RF interference in real time with picosecond latency," ***Light: Science & Applications***, 13, 14, 2024.
2. J. Garofolo, Y. Qi, T. Shi, G. Tian and B. Wu*, "Photonic Interference Cancellation for LiDAR Sensors," ***IEEE Photonics Technology Letters***, vol. 35, no. 23, pp. 1279-1282, 2023.
3. J.C. Lederman, W. Zhang, P. Prucnal*, et al., "Real-time photonic blind interference cancellation," ***Nature Communications*** 14, 8197, 2023.
4. W. Zhang, A. Tait, B. J. Shastri, P. Prucnal*, et al "Broadband physical layer cognitive radio with an integrated photonic processor for blind source separation," ***Nature Communications***, 14, 1107, 2023.
5. T. Shi, Y. Qi, B. Wu*, et al "Sub-Nyquist optical pulse sampling for photonic blind source separation," ***Optics Express***, 30(11), 19300 -19310, 2022.
6. T. Shi, Y. Qi, and B. Wu*, "Hybrid free space optical communication and radio frequency MIMO system for photonic interference separation," ***IEEE Photonics Technology Letters***, 34(3), 149 – 152, 2022.
7. T. Shi, J. Garofolo, Y. Qi, and B. Wu*, "Photonic Blind Source Separation Based on Point cloud Analysis and Deep Learning," in ***Frontiers in Optics + Laser Science Conference***, paper FD4.3, (Optica Publishing Group, 2023).