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SWIFT-SAT:
Software Defined Radio based Emulation of SAT-Terrestrial Network Coexistence in FR3 Bands

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Summary

- The radio frequency band between 7.125 GHz and 24 GHz, known as Frequency Range 3 (FR3), is promising for next generation cellular systems.
- This project will extend the existing COSMOS testbed at WINLAB for experimental studies of coexistence between terrestrial and satellite systems using software-defined radios (SDR) to emulate dense 5G cellular networks and satellite equipment.
- The project focuses on spectrum sharing between terrestrial 5G and active commercial satellites in the 12.2-12.7 GHz band, and adjacent band coexistence between terrestrial 5G at 10-10.5 GHz and passive scientific satellites in the 10.6-10.7 GHz band.
- Metamaterial software-defined beamforming is used to emulate coexistence with satellites like non-geostationary orbit fixed satellite service (NGSO-FSS), and hot-cold calibration and comparison to datasets from on-orbit AMSR-E and AMSR2 sensors is used to enhance the reliability and realism of radiometer interference experiments.
- There are three thrusts:
  1. Design, validate and deploy FR3 SDR-based heterodyne devices, emulation of 5G New Radio (NR) and SAT waveforms, and coexistence emulation methods
  2. Use emulation experiments to develop centralized Machine Learning algorithms for integrated radio resource management in sharing between terrestrial 5G and active commercial satellites
  3. Use emulation experiments to assess radiometer sensitivity to terrestrial 5G interference and to develop Machine Learning algorithms for interference identification and mitigation by passive scientific satellites
- One outcome of the work in thrust 2 and thrust 3 is a measurement of the fraction of spectrum assigned to the terrestrial 5G cellular system that is lost due to the strategies used to mitigate interference to satellites
- This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

Research Progress

SDR-based Heterodyne Design for FR3 spectrum using COSMOS Sandbox

- SDR-based Heterodyne circuit for FR-3 spectrum
  - Hardware capable of handling FR-3 frequencies is not available
  - FR-3 testbed extension will:
    - up convert 6.0 – 12.7 GHz to 18 – 30 GHz
    - down convert 18 – 30 GHz to 6 – 12.7 GHz
  - Thus, ensuring the possibility to emulate spectrum coexistence and sharing amongst FR1, FR2, and FR3 systems.
  - And enabling emulation of 5G NR waveforms (in 12.2-12.7 GHz and 10-10.5 GHz) and DBS/NGSOFSS downlink waveforms (in 12.2-12.7 GHz)

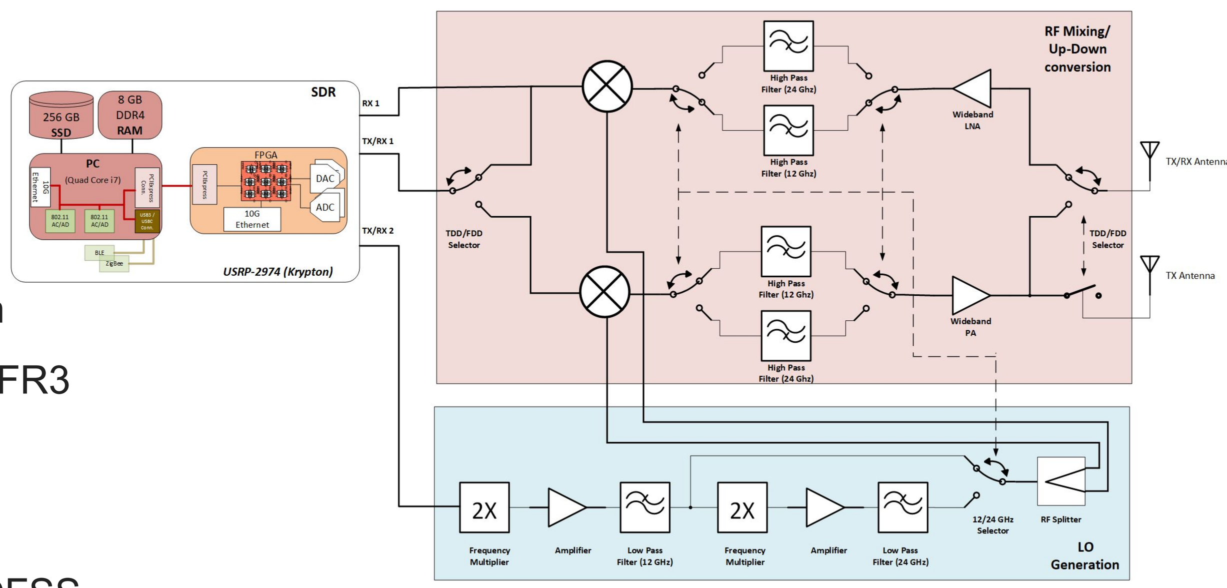

Figure 1: Proposed SDR-Based Heterodyne Transceiver for FR3 Testbed for full-band operation up to 24 GHz

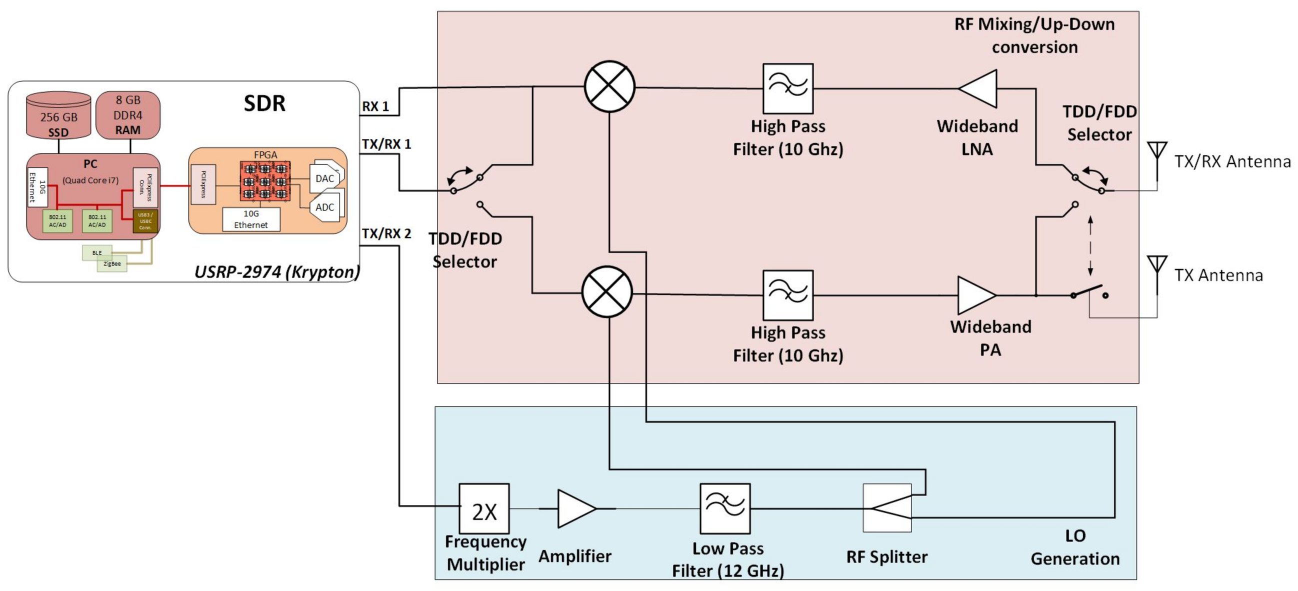

Figure 2: Proposed SDR-Based Heterodyne Transceiver for FR3 Testbed for lower-band operation up to 18 GHz

Emulation of 5G NR Protocol Stack and DBS/NGSO-FSS SAT downlink signals in 12 GHz

- 3GPP 5G NR Software Stack
  - 5G Network implementation: Open-Sourced OpenAirInterface (OAI)
  - User Equipment implementation: Amarisoft
- Emulation of DBS Sat downlink Signal
  - Digital Video Broadcasting Satellite Generation 2 (DVB-S2) through GNURadio
- Coexistence between 5G SAT systems and DBS/NGSO-FSS bands
  - Identify 5G propagation effects in 12.2 – 12.7 GHZ, while studying interference between 5G emission and DBS/NGSO-FSS signals

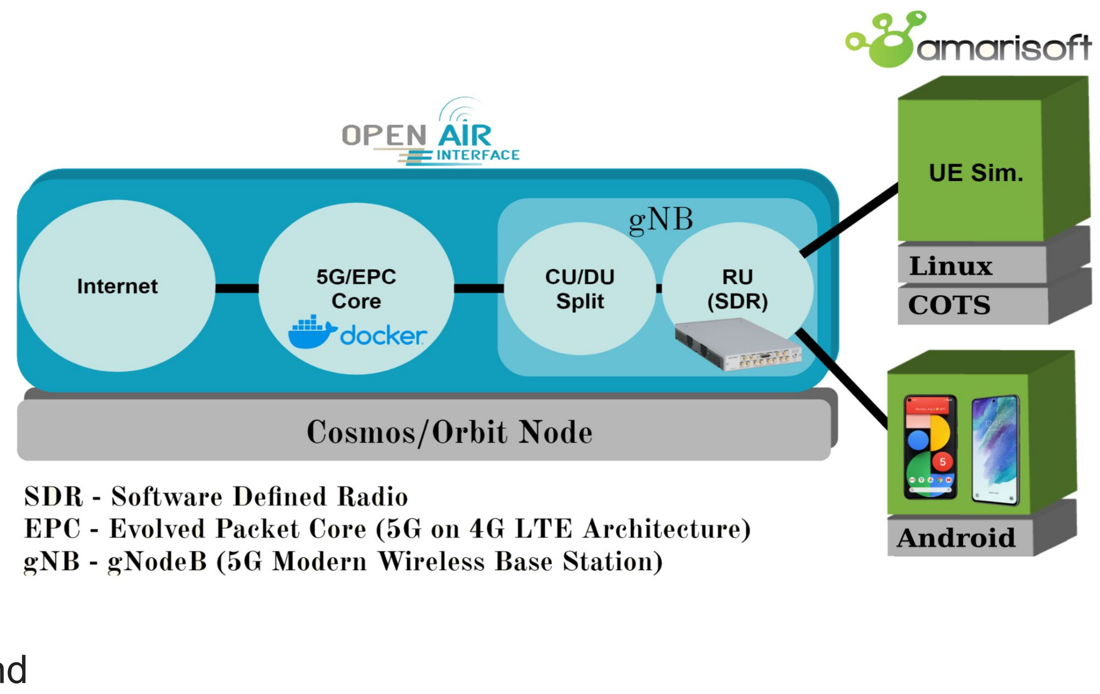

Figure 3: 5G NR Protocol Stack through OAI/Amarisoft Architecture

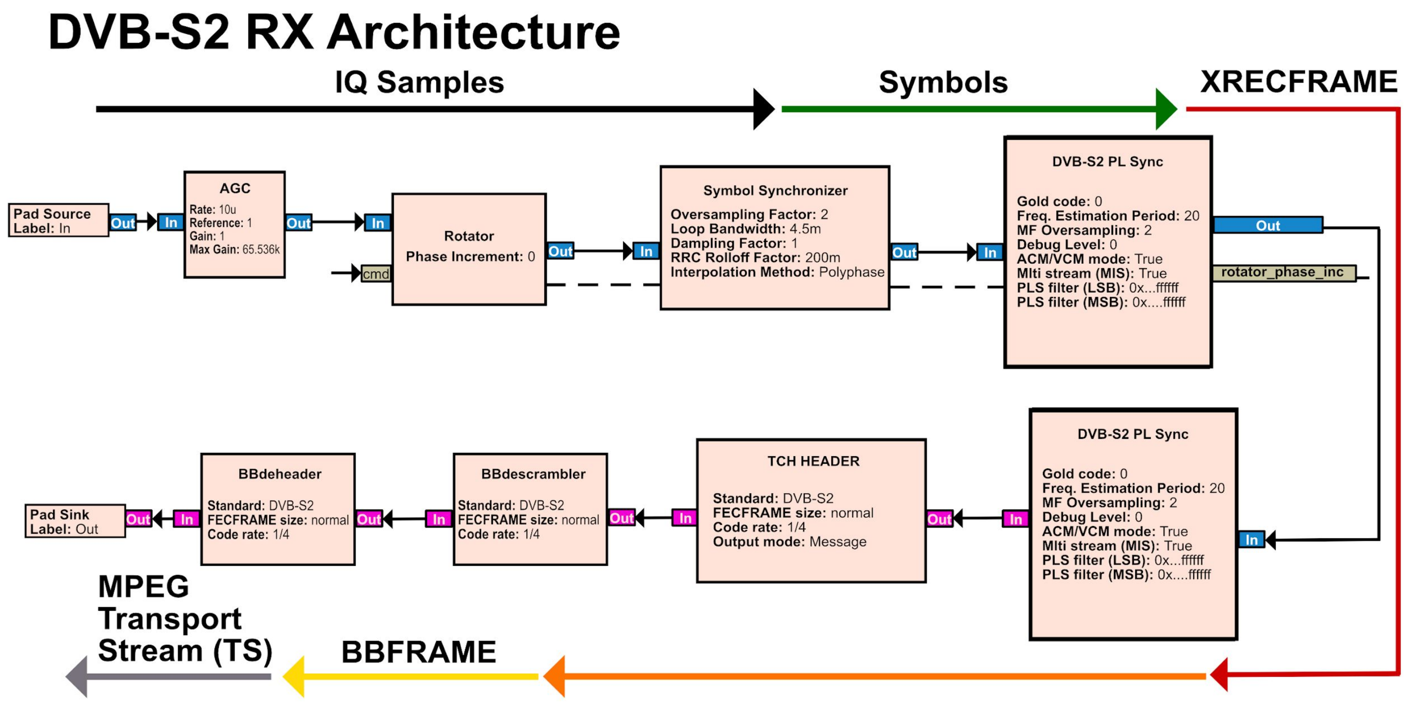

Figure 4: DVB-S2 Receiver Architecture

10.6-10.7 GHz SAT Radiometry

- Microwave radiometry with Software Defined Radio (SDR)
- Fast Fourier Transform (FFT) spectrometer in GNU Radio
- Calibration
  - Hot-Cold method

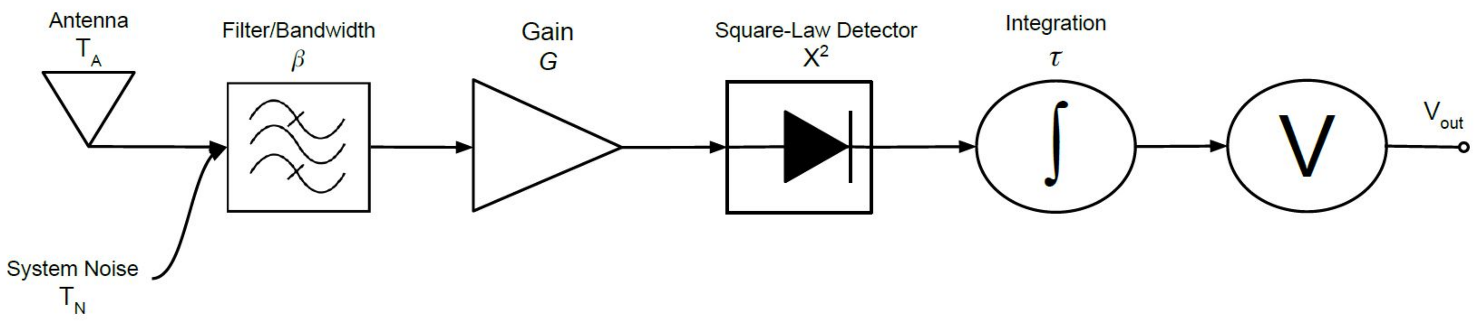

Figure 5: Micro Radiometry w/ SDR Design

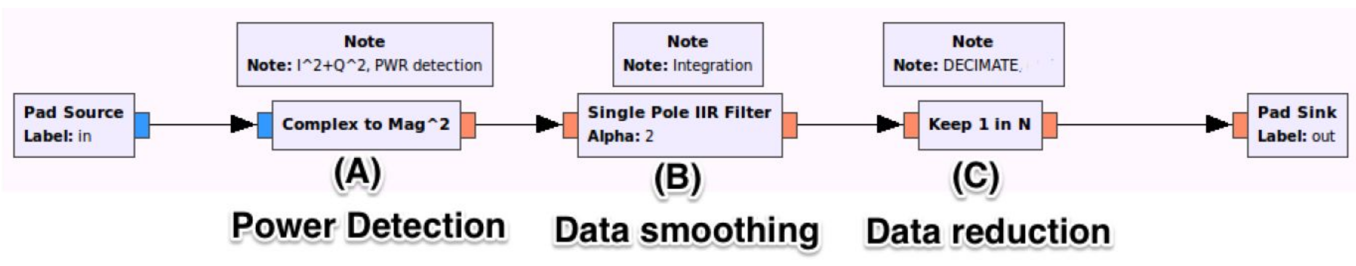

Figure 6: FFT Spectrometer Architecture

Spectrum Coexistence of 5G Terrestrial Networks with NGSO-FSS and Passive Weather Sensors

- Emulation on COSMOS Sandbox to study:
- Spectrum Coexistence between 5G Terrestrial Networks and Passive Sensors on Earth Observation Satellites in 10.6-10.7 GHz
  - Data-driven Modeling of Sensitivity to RFI and Identification
  - Data-driven Radio Resource Management for RFI Mitigation
- Spectrum Coexistence between 5G Terrestrial Networks and 12.2-12.7 GHz DBS/NGSOFSS
  - Integrated 5G Radio Resource Management and Dynamic Exclusion Zones
  - Dynamic Scheduling with Noncontiguous Orthogonal Frequency Division Multiplexing

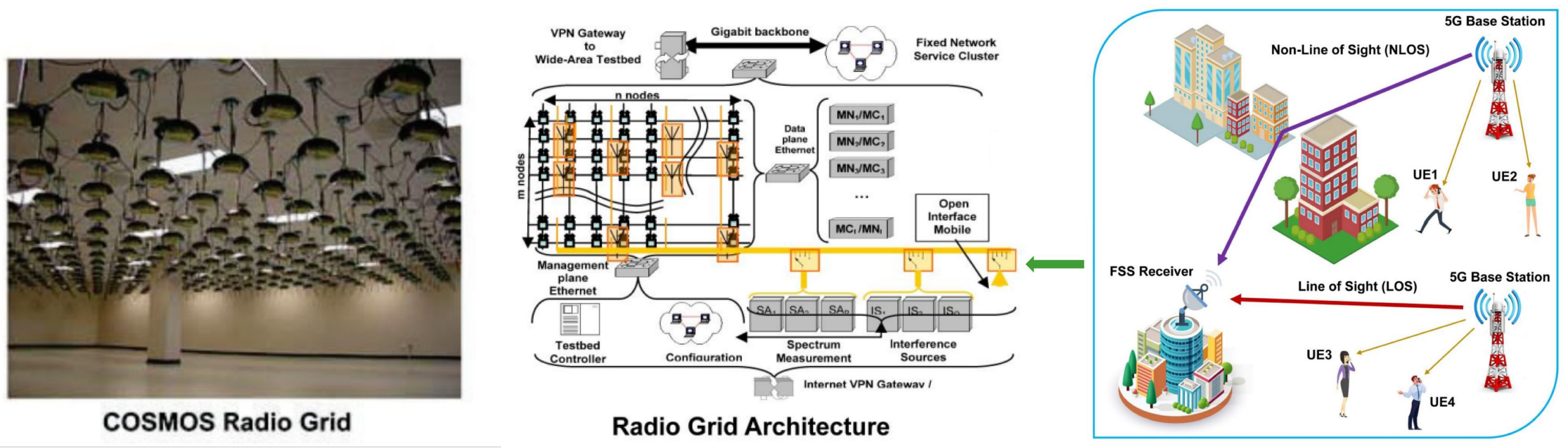

Figure 7: COSMOS GRID@WINLAB with Control Plane, Measurement Infrastructure and Radio Mapping

References

[1]. A. Singh, V. Petrov, H. Guerboukha, I. V. A. K. Reddy, E. W. Knightly, D. M. Mittleman, and J. M. Jornet, "Wavefront engineering: Realizing efficient terahertz band communications in 6g and beyond," 2023. [Online]. Available: https://arxiv.org/abs/2305.12636

[2]. OpenAirInterface Software Alliance. (2020). About OpenAirInterface. Retrieved from https://openairinterface.org/

[3]. Freire, I. (2022, October 26). GRCon22 - gr-dvbs2rx An Overview of the Project State and Path Forward [Video]. GNURadio. https://www.youtube.com/watch?v=qcqvfElQUVk

[3]. Nelson, Matthew Erik. *Implementation and evaluation of a software defined radio based radiometer*. Diss. Iowa State University, 2016.

[4]. J. Lei, R. Yates, L. Greenstein, and H. Liu, "Wireless link SNR mapping onto an indoor testbed," in Proceedings of the First International Conference on Testbeds and Research Infrastructures for the DEvelopment of NeTworks and COMmunities, ser. TRIDENTCOM '05. USA: IEEE Computer Society, 2005, p. 130–135. [Online]. Available: https://doi.org/10.1109/TRIDNT.2005.39

[5]. L. RKF Engineering Solutions, "Assessment of feasibility of coexistence between NGSO FSS earth stations and 5G operations in the 12.2 – 12.7 GHz band," May 2021. [Online]. Available: https://5gfor12ghz.com/wp-content/uploads/2021/05/ AS-FILED-Comments-of-RS-Access-Apx.-A-RKF-Engineering-Technical-Study-5.7.21.pdf

[6]. Z. Hassan, E. Heeren-Moon, J. Sabzehali, V. K. Shah, C. Dietrich, J. H. Reed, and E. W. Burger, "Spectrum sharing of the 12 ghz band with two-way terrestrial 5g mobile services: Motivations, challenges, and research road map," IEEE Communications Magazine, pp. 1–7, 2023.