SWIFT-SAT:

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

RUTGERS THE STATE UNIVERSITY OF NEW JERSEY

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Investigators: Narayan Mandayam, Ivan Seskar, and Chung-Tse Michael Wu

Students: Emir Accilien, Sreeram Mandava, and Shaghayegh Vosoughitabar

Summary

The radio frequency band spanning from 7.125 GHz to 24 GHz, referred to as Frequency Range 3 (FR3), holds significant promise for the evolution of next-generation cellular systems. This project aims to extend the current COSMOS testbed at WINLAB to facilitate experimental studies of coexistence between terrestrial and satellite systems using software-defined radios (SDR) to emulate dense 5G cellular networks and satellite equipment. Specifically, 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, operating 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.

The project unfolds in three key thrusts:

(1) Designing, validating, and deploying FR3 SDR-based heterodyne devices, emulating 5G New Radio (NR) and SAT waveforms, and developing coexistence emulation methods.

(2) Employing emulation experiments to craft centralized Machine Learning algorithms for integrated radio resource management in sharing between terrestrial 5G and active commercial satellites.

(3) Leveraging emulation experiments to evaluate radiometer sensitivity to terrestrial 5G interference and develop Machine Learning algorithms for interference identification and mitigation by passive scientific satellites.

One outcome from thrusts 2 and 3 is the measurement of the fraction of spectrum allocated to terrestrial 5G cellular systems that is lost due to the strategies used to mitigate interference to satellites.

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
- Emulation of spectrum coexistence and sharing amongst FR1, FR2, and FR3 systems.
- 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)

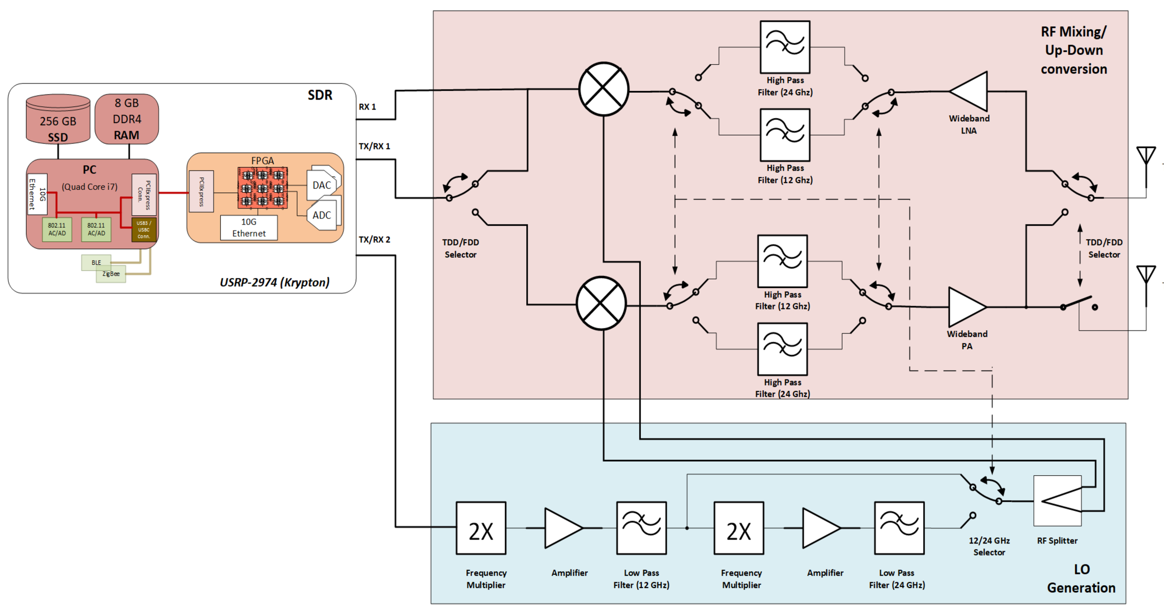

Figure 1: Proposed SDR-Based Heterodyne Transceiver for FR3 Testbed for full-band operation up to 24 GHz

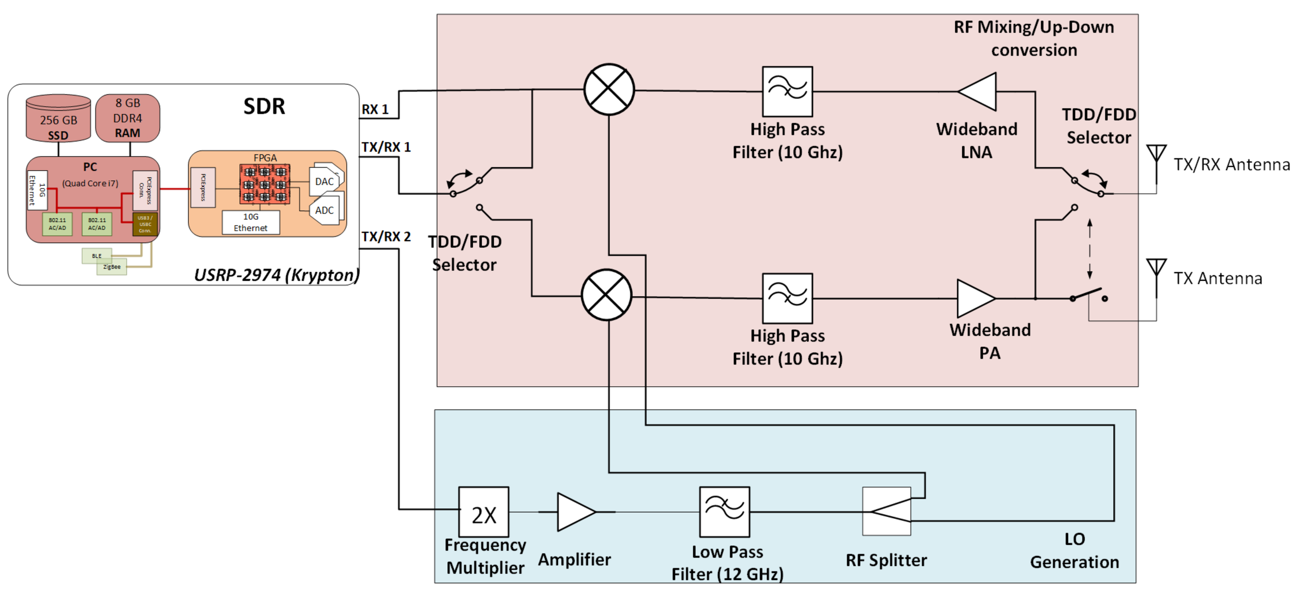

Figure 2: Proposed SDR-Based Heterodyne Transceiver for FR3 Testbed for lower-band operation up to 18 GHz

Emulation of 5G NR Protocol Stack and DBS SAT downlink signals in 12 GHz

- ❑ 3GPP 5G NR Software Stack
  - Open-Source 5G Network: OpenAirInterface (OAI)
  - User Equipment: Amarisoft
- ❑ Digital Broadcasting Satellite (DBS) Downlink Emulation
  - Digital Video Broadcasting Satellite Generation 2 (DVB-S2) receiver through GNU Radio w/ SDR N310
  - TSduck generates 8PSK, 6 Mbps Transport Stream (TS), Occupied Bandwidth: 4.725 MHz, Total: 5.225 MHz
- ❑ Next Steps:
  - Develop DVB-S2 Transmitter w/ GNU Radio & SDR
  - Investigate and develop Dynamic Exclusion Zone model for DVB-S2 & 5G systems coexistence in 12.2-12.7 GHz

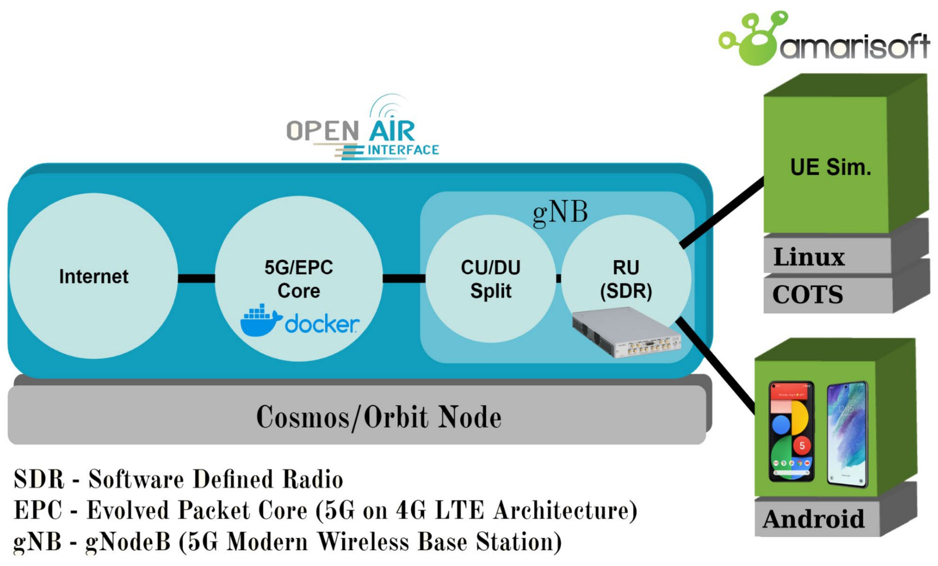

Figure 3: 5G NR Protocol Stack through OAI/Amarisoft Architecture

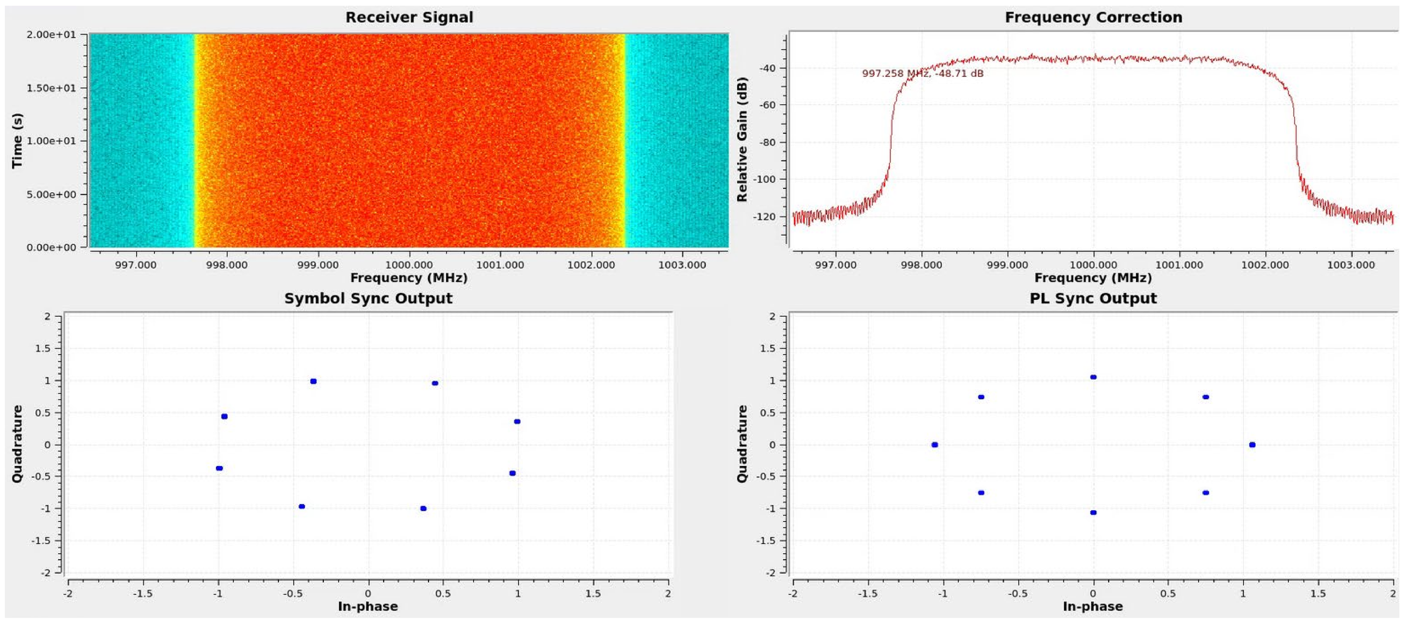

Figure 4: DVB-S2 Receiver Output from demodulating TSDUCK 8PSK MPEG TS generation wo/ SDR

Radio Frequency Interference (RFI) impact on Radiometry

- ❑ Estimation of the RFI from a 5G base station (BS) into adjacent bands through sending a 5G signal with a center frequency of 2.58942 GHz and 10MHz bandwidth using a SDR and observing the received signal with a spectrum analyzer
- ❑ Increasing the gain of the BS to emulate the effect of aggregate interference from multiple BSs through using an amplifier
- ❑ Next Steps:
  - Investigating the interference of 5G BSs, operating at 10-10.5 GHz with a SDR-based radiometer working in the 10.6-10.7 GHz band
  - Microwave radiometry with SDR
  - Fast Fourier Transform (FFT) spectrometer in GNU Radio
  - Calibration: Hot-Cold method

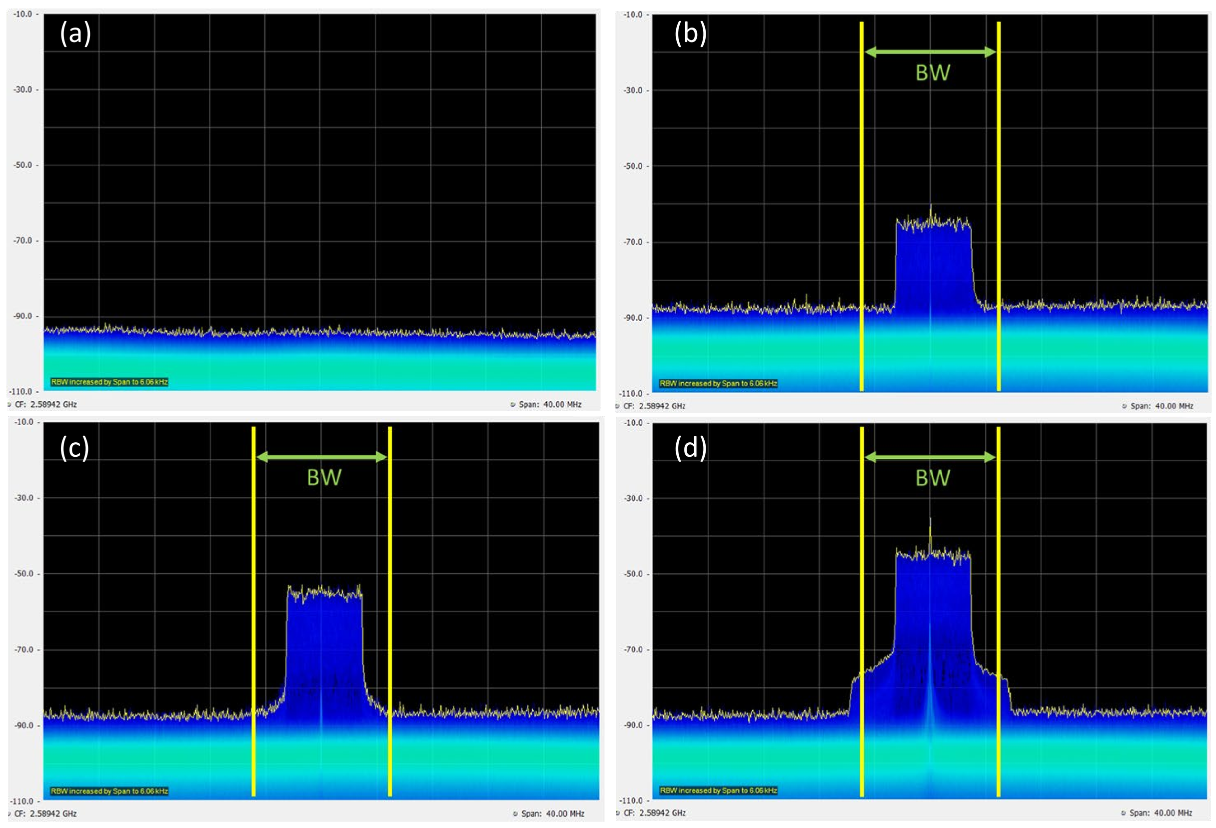

Figure 5: (a) BS is turned off. (b) BS sends a 5G signal with a center frequency of 2.58942 GHz and 10MHz bandwidth with a specific gain. The gain of the BS increased by (c) 10 dB. (d) 20 dB. We can see the impact of RFI as aggregate interference level increases in (c) and (d).

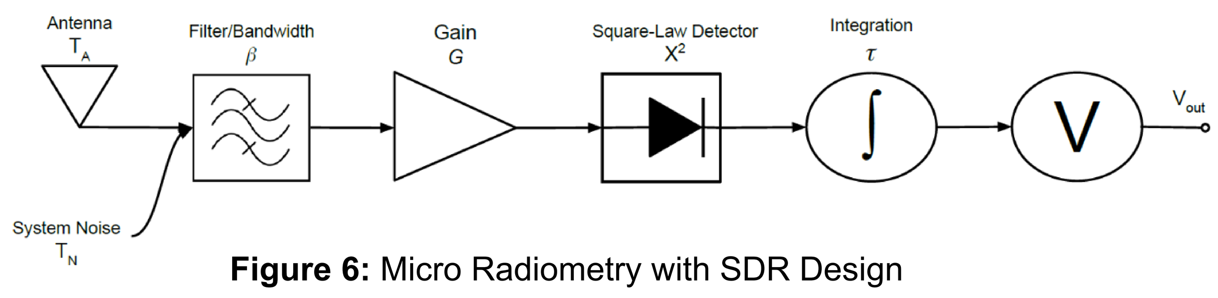

Figure 6: Micro Radiometry with SDR Design

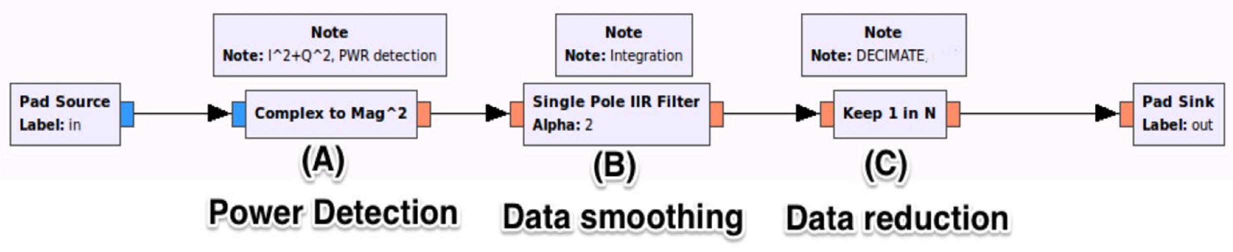

Figure 7: FFT Spectrometer Architecture

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

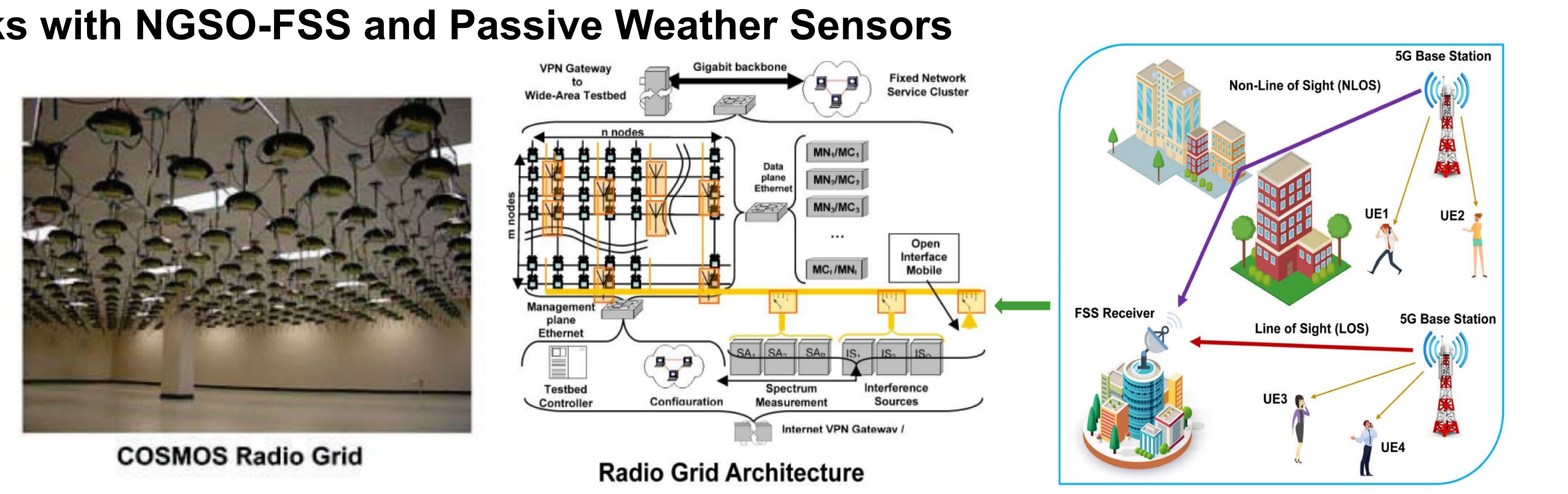

Figure 8: COSMOS GRID@WINLAB with Control Plane, Measurement Infrastructure and Radio Mapping

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]. 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