Spectrum Sharing and Spatial Isolation for 5G Cellular Networks and Military Radars in the FR1 Frequency Bands

C. Nicolas Barati*, Aditya Dhananjay†, Michael Zappe†, Paulo Marques‡, Luis Pereira‡ Roberto Magueta‡, Sundeep Rangan§, Kimberly Gold¶, Scot A. Hawkins¶, and Sachin Shetty*

* Old Dominion University, Norfolk, VA. Email: {cbaratin, sshetty}@odu.edu

†Pi-Radio, Brooklyn, NY. Email: {aditya.dhananjay, michael.zappe}@pi-rad.io

‡ Allbesmart, Castelo Branco, Portugal. Email: {pmarques, lpereira, rmagueta}@allbesmart.pt

§ New York University, Brooklyn, NY. Email: srangan@nyu.edu

¶ NAVSEA Crane Division, Crane, IN. Email: {kimberly.d.gold2, scot.a.hawkins}.civ@us.navy.mil

***Abstract*—One of the most persistent challenges wireless systems, especially cellular licensed bands, face is the scarcity of bandwidth as demand grows. Spectrum sharing, i.e., mix use of frequency resources shared between an incumbent and secondary users has emerged as a remedy to this problem. In this work, we present a modular, open-source and versatile approach to spectrum sharing between a 5G cellular network, as a secondary user, and incumbent military radar systems. We present the architecture of the overall configuration and demonstrate the parallel coexistence of these fundamentally different systems by spatially suppressing interference emanating from the 5G network to the radar transmitter. Leveraging multi-element beamformers and through a step-by-step approach, we first detect the presence of a radar transmission, then estimate the angle of arrival and finally project nulls towards the radar transmitter while serving 5G users on the remaining spatial degrees of freedom (beams). This entire system will be part of a spectrum sharing testbed at Old Dominion University and all components, software and hardware, will be open-sourced and available to the research community for verification and extension.**

***Index Terms*—Spectrum sharing, 5G, testbed, beamforming, MIMO.**

I. Introduction

The architecture of our modular and open-RAN-based system is presented in Fig 1. The hardware is comprised of

- **Radio Unit (RU)**: A pair USRP X410s, one dedicated to 5G users and the other used for radar detection and null-forming.
- **Pi-Radio Beamformers**: Custom-designed boards to implement beamforming and null-forming.
- **Open Central Unit & Open Distributed unit**: These are the main processing nodes to perform operations for and mange the 5G network and reaction to radar presence as well as a near-real-time RIC. The CU and DU implement a 2 split while the DU-RU connection will be split 8.
- **USRP B210**: Used as a radar emulator to transmit radar pulses in fixed intervals. **UEs**: Two iPhone 13 and Quectel nodes. Either stand-alone or attached to a host computer and a Pi-Radio frequency translator. This way, the iPhone modem can "see" the entire 3.1 – 3.45 GHz band instead of only those bands it is restricted to by design.

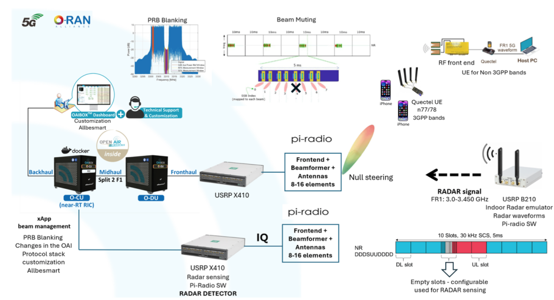

Fig. 1. 5G-Radar spectrum sharing architecture.

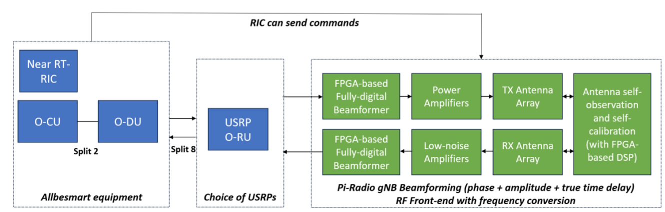

Fig. 2. Interconnection of O-CU & O-DU with the RU and the beamforming board, all controlled by near-real-time RIC.

The 5G network itself, designed and architected by ODU and Allbesmart, will run on the Open Air Interface open-RAN software stack while Pi-Radio boards can be controlled through either the 5G network or in a standalone mode through a MATLAB interface. In Figure 2, we showcase the interfacing and configuration of the RU, beamformers and the near-real-time RIC along with the flow of commands.

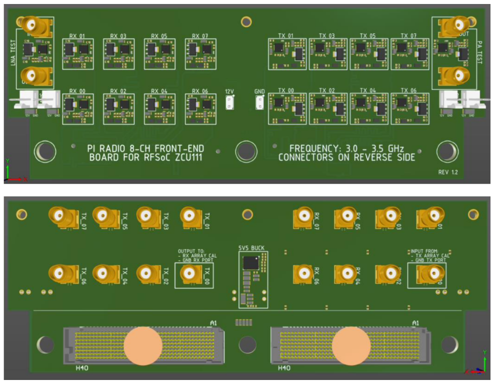

Fig. 3. Pi-Radio SDR boards. Designed for the 3.1 to 3.45 GHz range capable of supporting fully digital beamforming.

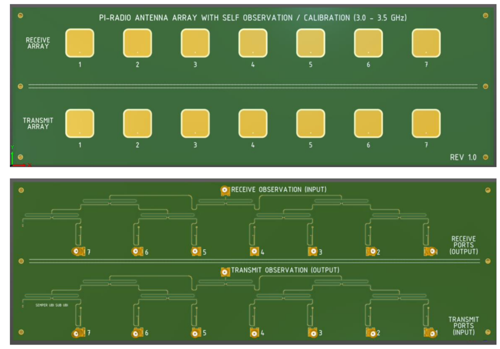

Fig. 4. Pi-Radio antenna array with self-calibration.

II. Beamformers and Wideband Nullforming

The beamforming board presented here, see Figure 3, is specifically designed and manufactured to support the 3.1–3.45 GHz radar bands, providing a fully digital front-end that mates with the Xilinx RFSoC ZCU111. Its architecture and feature set are tailored to enable squint-free beam steering, null projections towards undesired angles (i.e., where the radar signal is coming from), and precise per-channel calibration. The key characteristics of the board are summarized below:

*a) **Versatile Deployment Modes**:* : *Mode 1: Stand-Alone SDR.* In this configuration, the board itself functions as a complete software-defined radio with no dependency on the 5G network infrastructure. *Mode 2: Add-On Beamformer for an Existing RU* Here, the board serves as a beamforming and calibration mechanism, while external RF hardware (e.g., RU front-ends) handles the initial frequency conversion. The board receives intermediate-frequency (IF) and applies amplitude/phase/true-time-delay adjustments.

*b) **Fully Digital Beamforming and Null-Forming**: True Time-Delay (TTD)*: To eliminate beam squint over the full 3.1–3.45 GHz band, each channel incorporates a tapped delay-line network within the FPGA that provides digital time-shift (in sub-nanosecond increments). This TTD block ensures that the main lobe and nulls maintain their angular positions across the entire target bandwidth, making it suitable for wideband coexistence scenarios in the radar bands. *Squint-Free Steering*: By combining per-channel TTD with fine phase adjustments, the board achieves beam steering over the angular domain without frequency-dependent pointing errors. Furthermore, users can specify undesired angles and project nulls towards those whereby suppressing interference towards the incumbent radar system. *Self-calibration*: The multi-antenna board, as depicted in Figure 4, is capable of self-calibration. It corrects and adjusts **per-channel** amplitude, phase and timing offsets through a fairly simple auto-calibration loop at both the transmitter and the receiver. These corrections are an order of magnitude finer and more precise compared to existing systems with similar functionalities.

III. Demonstration

We will be demonstrating the coexistence of 5G network and radar systems through the following scenario. A USRP B210 node will periodically send radar pulses while the RU + beamformers sense the channel expecting a radar signal. Once the radar signal is detected, the receiver will estimate the direction the signal came from through angle-of-arrival energy detection methods, namely, MUSIC and ESPIRIT [2] and [3]. Once the direction is determined, the beamformers will create a collection of beams such that the energy towards intended users, 2 UEs, is maximized while null-projecting in the direction of the radar signal. We will show through live measurements the effect of beamforming and null projection with and without nulling. Thus we will illustrate the interference suppression capabilities of our system enabling spatial isolation of these two systems whereby allowing seamless spectral sharing and co-existence.

IV. Conclusion

With this demonstration we showcase spatial isolation between an incumbent radar transmitter and the 5G cell by wideband nullforming towards the radar and beamforming in the direction of intended cellular users. This way, we offer a long-awaited solution for spectrum sharing in the FR1 bands.

References

[1] OpenAirInterface Software Alliance, "OpenAirInterface O-RAN Implementation," GitLab repository, 2025. [Online]. Available: https://gitlab.eurecom.fr/oai/openairinterface5g.

[2] R. O. Schmidt, "Multiple Emitter Location and Signal Parameter Estimation," IEEE Transactions on Antennas and Propagation, vol. 34, no. 3, pp. 276–280, 1986. DOI: 10.1109/TAP.1986.1143830.

[3] R. Roy and T. Kailath, "Esprit—Estimation of Signal Parameters via Rotational Invariance Techniques," IEEE Transactions on Acoustics, Speech, and Signal Processing, vol. 37, no. 7, pp. 984–995, 1989. DOI: 10.1109/29.32276.