Demo: Experimentation with Mobile 28 GHz Phased Array Antenna Modules

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ABSTRACT

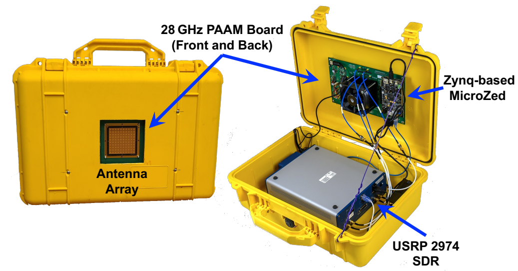
We present experiments using mobile 28 GHz Phased Array Antenna Modules (PAAMs), demonstrating their ability to perform beam steering with high granularity. The mobile node contains a 64-element IBM 28 GHz PAAM along with a USRP software defined radio, allowing for configuration of the transmit/receive (TX/RX) parameters. These parameters include beam shape, beam steering, and duty cycling. We demonstrate the capabilities of the mobile PAAMs by forming a wireless OFDM link between two mobile PAAMs. We then showcase the beam steering capabilities of the PAAM by performing beam sweeping on the RX PAAM to find the angle of arrival from the TX PAAM. A simple graphical user interface is presented for configuring the PAAMs. A tutorial is available online for users interested in experimentation with 28 GHz PAAMs*.

CCS CONCEPTS

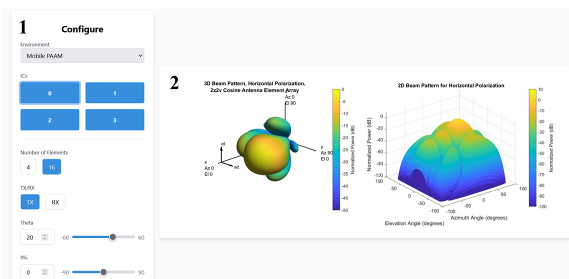
• **Networks → Wireless access networks**; • **Hardware → Wireless devices**.

KEYWORDS

Millimeter-wave communication; wireless experimentation; software defined radios; COSMOS Testbed



(a)



(b)

Figure 1: **(a) COSMOS mobile node integrating a 28 GHz PAAM board and a USRP-2974 SDR. (b) PAAM control GUI consisting of, (1) Configuration panel and (2) Rendering of current beam shape and position.**

1 INTRODUCTION

Beyond-5G and 6G wireless networks will require high data rate and low latency links at the edge to enable new applications such as V2V/V2X, AR/VR, smart cities, and more. Massive MIMO (mMIMO), which requires large-scale antenna arrays, shows promising potential to support the demands of next generation networks due to the capacity gains [1, 3, 4, 14, 16, 23]. Recent research is towards achieving massive antenna arrays at millimeter-wave (mmWave) frequencies as their compact size can enable mMIMO [11, 15, 22].

We have deployed multiple 64-element, 28 GHz phased array antenna modules (PAAMs) in the COSMOS testbed [5, 19] along with software defined radios (SDRs) to support experimentation with emerging wireless technologies, such as mMIMO. PAAMs in the indoor COSMOS sandbox were utilized to realize a 2x2 MIMO link [17] and multi-user MIMO adaptive beamforming [10]. Recent testbed development has explored the use of 28 GHz and 60 GHz phased arrays to help improve efficient beam alignment algorithms for outdoor and indoor deployment scenarios [13, 24]. Others have also incorporated RFSoC with a mmWave phased array antenna and USRP [9] for added throughput and baseband processing capability. Along with the aforementioned testbeds, the PAAM uniqely offers the user to independently control four 4x4 ICs (which can also function together as a single 64-element array) to evaluate multi-user MIMO functionalities. The combination of COSMOS FCC Innovation Zone with the use of mobile PAAMs also enables significant flexibility in real-world outdoor experimentation, fully integrated with the COSMOS testbed with easy-to-use APIs [8].

Weatherproofed mobile PAAM nodes, shown in Figure 1(a), consisting of a PAAM and SDR in a system, can be deployed in a variety of outdoor deployment scenarios representing a

*Remote 28 GHz PAAM experimentation: https://wiki.cosmos-lab.org/wiki/Tutorials/Wireless/mmwavePaamBasics.

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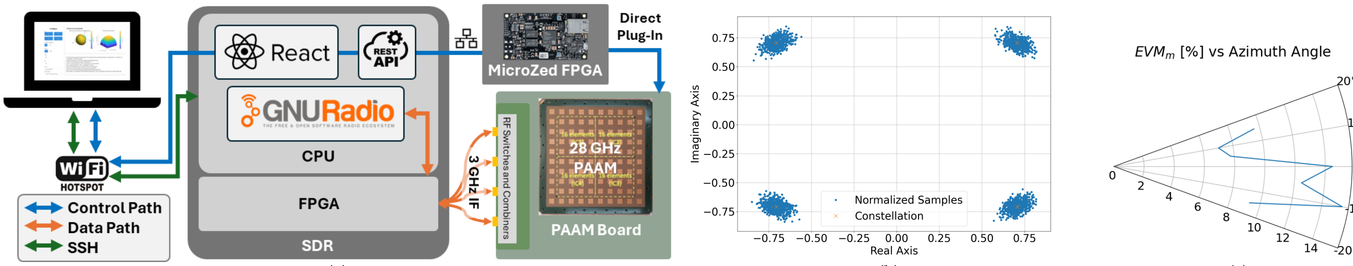

(a) (b) (c)

Figure 2: **(a) Diagram of the control and data flow of the mobile PAAM. Includes WiFi hotspot (for use outside of sandbox), USRP-2974 SDR, and PAAM board.(b) QPSK constellation of a communication link from aligned PAAMs. (c) EVM_m percentage vs the azimuth angle of RX beam when the TX beam is steered to 10°. The minimum occurs at 10° on the RX beam.**

5G NR/6G base station (BS) deployment or user equipment (UE). Additionally, the mobility of the nodes allow them to emulate realistic user equipment (UE). For example, mobile PAAMs can emulate UEs in a moving vehicle [6]. Tutorials are available online for usage of mobile PAAMs as well as PAAMs in the COSMOS sandbox [7]. A video of the demo is available at https://youtu.be/rWhODUxg9fA.

Figure 1(b) displays a graphical user interface (GUI) that has been developed to easily configure settings such as beam shape, beam steering, duty cycle, and modulation scheme on the PAAMs. This GUI works not only for sandbox deployments of the PAAMs, but also for mobile nodes.

2 THE MOBILE PAAM NODE

The mobile node consists of a PAAM board and a USRP-2974 SDR. The PAAM board contains the 64-element, dual-polarized PAAM and control circuitry. The PAAM contains 4 ICs, each controlling 16 out of the 64 elements. The board operates at 3 GHz IF.

The USRP-2974 SDR contains an on-board PC and two RF transceivers. One each is utilized for H/V polarization. When not connected directly to the COSMOS network, the user can connect to the mobile PAAM with a Wi-Fi hotspot. The user can SSH directly into the SDR's on-board PC. From there, the user can call a REST API service to configure the PAAM (TX/RX, H/V, beam steering). A central REST API service simplifies the configuration process. For transmitting and receiving RF samples, GNURadio [18] is run with the USRP Hardware Driver [21] on the USRP 2974's on-board PC.

The system architecture of the mobile nodes is shown in Figure 2(a). The PAAM's beam shape and steering are configured via calls to a REST API service running locally on the SDR. These calls trigger a corresponding command which is sent over Ethernet to an AvNet MicroZED [2] board directly plugged into the PAAM board. The MicroZed then translates commands from the service to firmware commands that are sent to the PAAM board. In the COSMOS network, a remote REST API service is running that can be called to configure a specified PAAM on the network. A GUI with a React backend was developed to simplify control of the PAAM [20]. Actions on the GUI call corresponding commands from the REST API.

3 DEMONSTRATIONS

Experiment 1: Mobile PAAM Link. This demonstration utilizes the mobile PAAMs. We demonstrate a functioning wireless communication link between two aligned mobile PAAMs using a 10 MHz bandwidth OFDM signal utilizing QPSK on the data carriers. Baseband processing is done using GNURadio. Figure 2(b) shows the received constellation from the RX PAAM demonstrating successful demodulation of the TX signal.

Experiment 2: Beamsweeping to find AoA. After physically moving the TX PAAM to a different position and electronically steer its beam to the RX PAAM. We observe the EVM of the wireless link has increased. To improve the link, we perform automated beam sweeping on the RX PAAM. The RX PAAM sweeps 8 different beam angles in real time, analogous to an SSB burst from 5G base station [12], and selects the beam with the maximum received power. After selecting this beam, the wireless link is shown to have an improved EVM.

Experiment 3: Practical GUI for Beamforming. In this demonstration, we utilize the GUI for remotely configuring the PAAMs in the COSMOS sandbox. Using the GUI, we steer the TX beam to a static position. We then program a series of angles to steer to on the RX PAAM. In Figure 2(c), the EVM is plotted for each angle on the RX PAAM. The angle of minimum EVM confirms the TX PAAM was steered to the correct angle.

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