2017

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Conference Paper · October 2017

DOI: 10.1109/ISANP.2017.8228737

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Compact Antenna for Digital Beamforming with Software Defined Radios

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***Abstract*—An adaptive radio system combining compact switchless reconfigurable antenna with Software Defined Radio is proposed. The system allows control of the direction of the transmitted signal solely by adjusting the baseband I and Q components of the modulated signal, while maintaining small antenna size through the use of compact multiport antenna. The system is demonstrated in a line-of-sight configuration with QPSK modulation. Experimental results demonstrate good received power and low error vector magnitude of the demodulated signals.**

Keywords—smart antenna; radiation pattern; reconfigurable antenna; digital beamforming; software defined radio

I. Introduction

Pattern reconfiguration is an important feature of modern wireless systems, as – among others - it allows to increase communication capacity through spatial multiplexing. Many reconfigurable antennas advocate the use of switching components, such as pin diodes or MEMS [1-4] to reconfigure between different radiation patterns. Such solutions however exhibit multiple disadvantages, as the switching mechanism is relatively slow, limited to discreet number of patterns and cannot flexibly operate for multiple frequency channels. Those problems can be overcome by digital beamforming [5], which allows synthesizing desired radiation patterns by means of digital signal processing. The approach is common with antenna arrays, where each radiating element is separated from other elements by a certain distance. Nevertheless, the persistent need for miniaturization limits the use of antenna arrays in compact wireless nodes.

Recently, a compact multiport antenna was proposed [6], able to introduce phase variation without the need for spacing between arrays elements. This property makes the antenna a good candidate for digital beamforming. The proposed paper demonstrates convenient technique to control the radiation pattern of such compact antenna solely by controlling the baseband signals I and Q, used for modulation at both antenna ports. The setup relies on two synchronized Software Defined Radio (SDR) units, programmed to transmit QPSK signal.

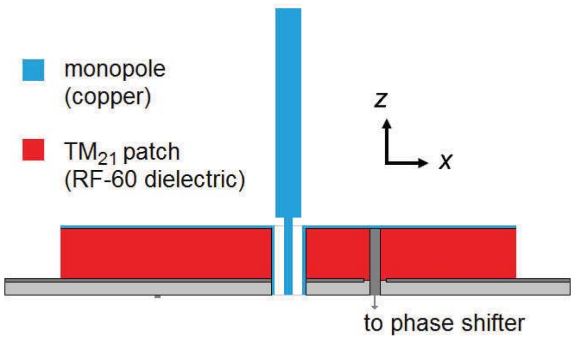

Fig. 1: Simplified scheme of the multiport antenna used.

II. Experimental setup

A. Antenna

The study uses compact antenna proposed in [6], which consists of two radiators: the top monopole provides omnidirectional coverage with constant phase shift within 360° beam (blue parts in Fig. 1). The lower is a microstrip patch antenna designed to operate with two orthogonal TM_{21} modes (red parts in Fig. 1). The two orthogonal modes are excited with 90° phase shift, which produces the radiation pattern with omnidirectional amplitude, while the phase of the signal changes linearly with angle. The phase difference between signals produced by the two radiators in given direction facilitates control of the radiation pattern, eliminating the need for λ/2 spacing. Each radiator is fitted with separate SMA port allowing direct connection to SDR unit. For more details on antenna structure please see [6].

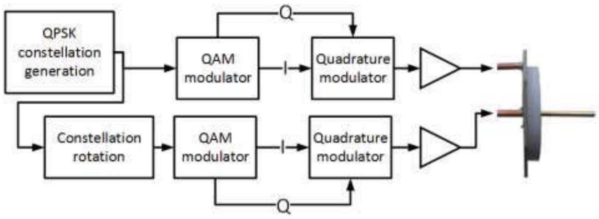

Fig. 2: Block diagram describing signal processing in two SDR units and connections to the antenna.

B. Signal processing

Each antenna port was connected to NI USRP-2922 SDR unit from National Instruments, as seen in Fig. 2. Both units are programmed to generate QPSK modulation and transmit the same message, as seen in Fig. 2. Synchronization is provided through MIMO expansion cable, which allows two SDR devices to share common reference clocks, time synchronization and the Ethernet interface. The phase shift Δ_{ph} required to control the beam is executed by rotating the modulation constellation ("Constellation rotation" block in Fig. 2) in one SDR. To compensate for the difference in realized gains of the two radiators an additional amplification of 6 dB was applied to the TM_{21} patch signal.

III. RESULTS

The full setup was positioned on a rotating platform within anechoic chamber of the Gdansk University of Technology. The receiver was a NI USRP-2922 device connected to vertically polarized horn antenna with gain of 5.42 dBi located at 8 m distance from the proposed transmitter. Three configurations were tested, with Δ_{ph} = 0°, 45° and 180°. Measured results are shown in Fig. 3, demonstrating received power (Fig. 3a) and Error Vector Magnitude (EVM) of the demodulated signal (Fig. 3b). The EVM was averaged over 20 symbols.

A bidirectional, angular dependency is visible with the maximum values of EVM corresponding with the minimum power angles. Some additional shouldering and irregularities are visible in the characteristics, which are not visible in the beamsteering realized by standard RF phase shifter shown in [6]. This is most likely due to the proximity of SDR units, which were placed directly below the antenna and may have caused minor reflections. For the directions of intended communication, the EVM is 5%, which is low enough to establish wireless communication in 802.11n standard, with QPSK modulation [7]. The residual EVM (i.e. with two SDRs connected directly via cable) is 2.5 %, thus antenna contribution towards EVM is estimated at 4.3 %.

IV. CONCLUSION

The paper provided experimental validation for the use of the compact switchless reconfigurable antennas controlled by baseband I and Q modulation signals generated with software defined radios. A bidirectional performance, similar to radiation patterns generated with RF phase shifters is observed. The antenna contributes 4.3% EVM for the demodulated QPSK signal.

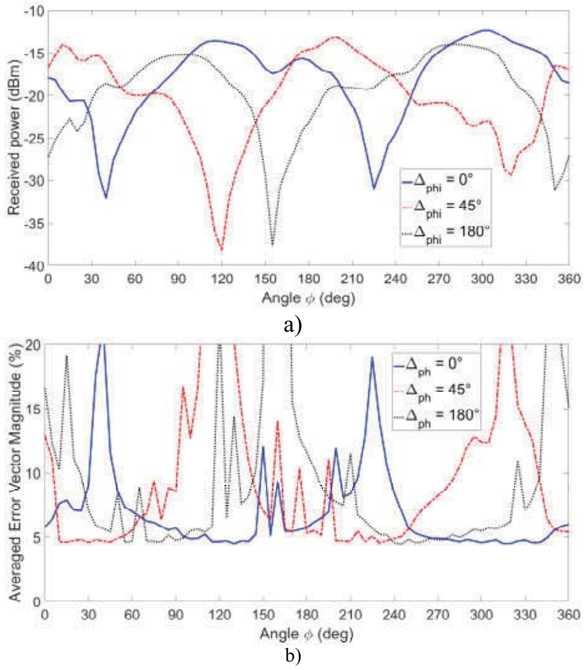

Fig. 3: Measured results for the proposed system: a) received power; b) averaged EVM after demodulation.

ACKNOWLEDGMENT

This project received funding from Irish Research Council ELEVATE fellowship No. ELEVATEPD/2017/79, European Union's Horizon 2020 programe under the Marie Skłodowska-Curie grant No. 713567, Science Foundation Ireland grant No. 13/RC/2077 and also the ENABLE-S3 project funded from the ECSEL Joint Undertaking under grant No. 692455. This Joint Undertaking is supported by the European Union's HORIZON 2020 programe and Austria, Denmark, Germany, Finland, Czech Republic, Italy, Spain, Portugal, Poland, Ireland, Belgium, France, Netherlands, United Kingdom, Slovakia, Norway.

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