Experimental Studies on Reconfigurable Multi-beam Antenna Arrays using a Software Defined Radio Digital Beamformer

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In the most general form, multiple simultaneous beams can exist when an array of N elements is connected to a beamformer with M beam ports, where N and M may be different. While several different configurations of multibeam arrays such as, beamforming networks using Butler, Blass, Nolen matrices, or lens configurations such as Rotman and Bootlace have been demonstrated over the years, digital beamforming (DBF) is conceptually the simplest and at the same time the most capable configuration. The RF frontend of each element is directly connected to a A/D converter (for a receiver array). The outputs of the A/Ds are connected to a serial bus and sent to the computer which can then form any number of multiple beams, perform rapid beam scan, produce low-sidelobe beams, perform adaptive nulling, or any other digital signal processes.

DBF creates receive and/or transmit beams in software rather than forming the beams through RF or IF analog circuits. In general, forming beams in software is easy, it is the hardware that is the limiting factor. Our approach for practical implementation of DBF with a low cost uses a software defined radio (SDR) at each element of an array. Each antenna element has an SDR that converts the RF signal to an amplitude and phase representation in the computer. These signals are calibrated then sent to signal processing algorithms. Our experimental testbed uses an array of four 2922 National Instruments USRPs. When the USRP is connected to a host PC, it acts as an SDR with host-based digital signal processing capabilities. The USRP devices are interfaced to the PC via an Ethernet switch. The SDR has a tunable center frequency from 400 MHz to 4.4 GHz, and up to 20 MHz baseband I/Q bandwidth. Our experimental studies were conducted at 2.45 GHz.

The experiments conducted consist of transmitting multiple signals using Signal Hound VSG25A vector signal generators and receiving these using the four-element SDR digital beamformer. In the studies conducted, the number of signal sources as well as their location are change, which requires an antenna array with reconfigurable multiple beams for communication. It should be noted that our experimental test setup is not an anechoic chamber. These experiments are conducted in a realistic environment with multiple large conductive objects that create a high-multipath scenario. The results of this study show the feasibility of our custom DBF test best for reconfigurable multibeam operation.