Adaptive Beamforming for Conformal Antenna Arrays using Software Defined Radio

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***Abstract*— Adaptive beamforming for patch antenna arrays on conformal surfaces is discussed. Different from the traditional cases where the surface is flat, beamforming algorithms must be adjusted when considering arrays on curved surfaces. Here, several adaptive beamforming algorithms are applied to a microstrip antenna array with four patches which is conformed to a cylindrical surface. The array is measured using software defined radio (SDR) system NI USRP-2955. Good agreement between simulation results and measurements is observed. The developed techniques can be applied to satellite and remote sensing systems as well as radar systems.**

Keywords*—antenna array, adaptive beamforming, software defined radio

I. Introduction

Phased array antennas are widely used in many areas such as radar detection, communication and direction of arrival estimation [1]. Many research questions for phased arrays are of interest for research and development and one of them is to find out the performance of beamforming when the array is conformed to a non-flat surface. To test the beamforming performance, instead of using traditional beamforming with phase shifters or vector modulators, digital beamforming is applied to enhance the performance and functionality of conformal antenna arrays. The digital beamforming result can be captured using Software Defined Radio (SDR). Here, the receive case for beamforming is considered, the transmit cases can be developed similarly. For adaptive beamforming algorithms, minimum the variance distortionless response (MVDR) beamformer and the linearly constrained minimum variance (LCMV) beamformer provide an array response for sources and interferences signals from certain directions [2]. When the angle of arrival (AOA) of the desired source is only known within a certain angular range instead of an exactly known angle, the gain of antenna array may vary rapidly within the angular range. Robust beamforming (RB) algorithms are provided, but they are designed for isotropic arrays on flat surfaces [3]. Here, adaptive beamforming algorithms using MVDR, LCMV and RB are presented for an array on a non-flat surface with directional antenna elements. The four patches are connected to the four ports of the NI USRP-2955 SDR platform and the received data is processed using NI LABVIEW. The measurement set up and results are presented in the next sections.

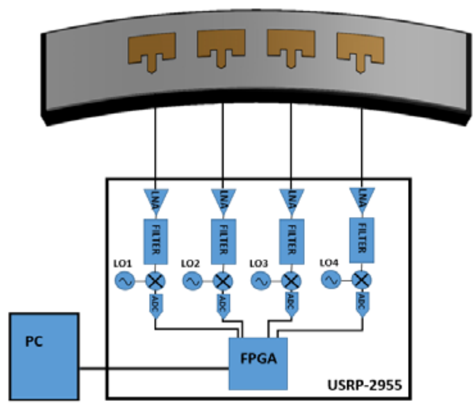


Fig. 1. Conformal antenna array with SDR beamforming.

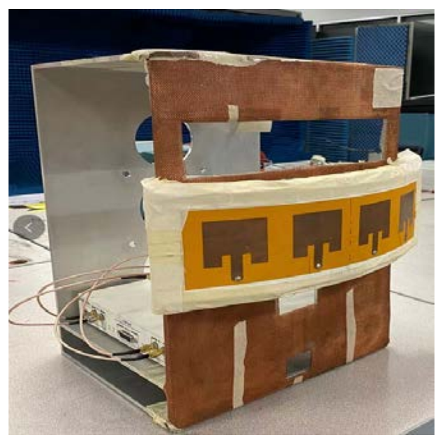


Fig. 2. Set-up of the array on a cylindrical surface with r = 733 mm.

II. Design and Measurement Setup

To demonstrate the approach, a conformal array with four patches, operating at 2.4 GHz, is used. The patches, with spacing d = 79.63 mm, are realized in copper on a 60 μm polyimide film. This polyimide film is laminated, using pressure sensitive adhesive, onto a commercial off-the-shelf silicone sponge rubber (SSR) of 3 mm thickness. For the ground plane a copper wire mesh is laminated onto the back side of the SSR.

Fig. 1 shows the internal structure of the SDR beamforming setup and Fig. 2 shows the photo of the patch array conformed to a cylinder with radius r = 733 mm and connected to the NI USRP 2955 using SMA cables.

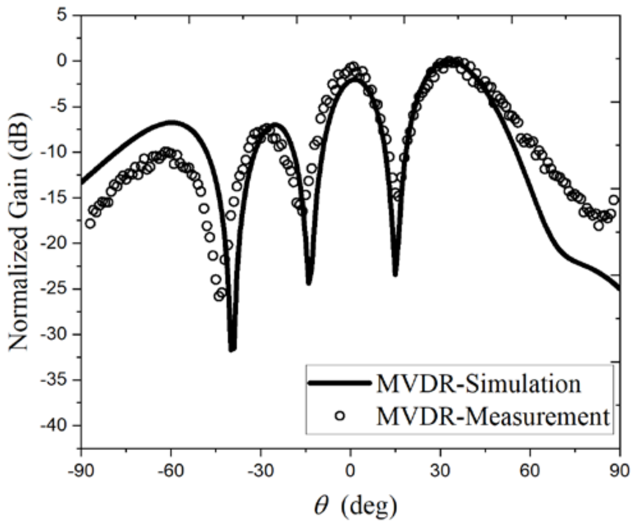


Fig. 3. MVDR normalized radiation pattern with the nulling angle at 15° for desired angle = 30°.

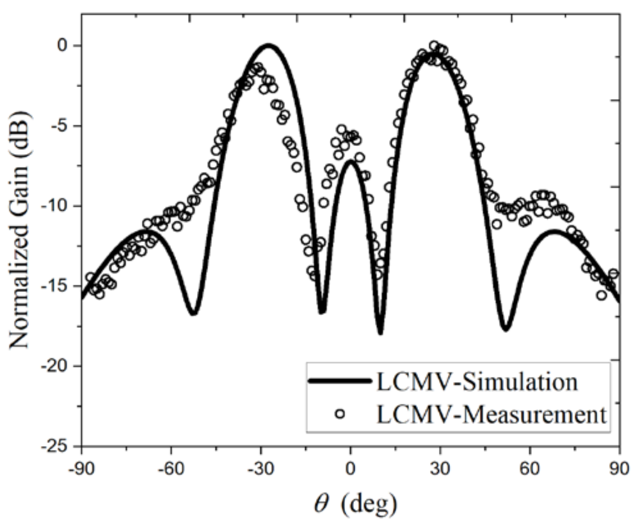
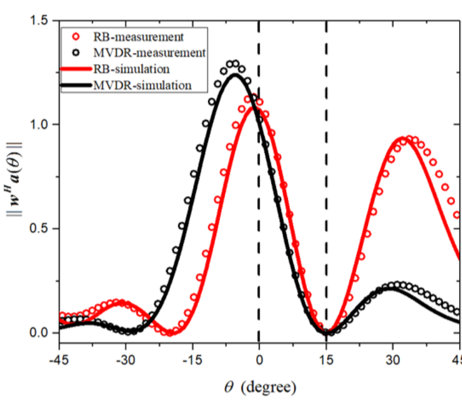


Fig. 4. LCMV normalized radiation pattern with two desired angles at ± 30°.



Angle (°)	$\|\|\boldsymbol{w}^H\boldsymbol{a}(\theta)\|\|$	
	MVDR	RB
-3	1.19	1.05
-2	1.14	1.08
-1	1.07	1.08
0	1.00	1.07
1	0.92	1.04
2	0.82	0.99
3	0.73	0.92

Fig. 5. Simulated and measured array response with a beam at 0° and a null at 15°. The table (right) shows the measured response around 0°.

III. Results

MVDR, LCMV and RB are applied to the conformal array and the beamformer performances is simulated and measured. For the MVDR algorithm the desired angle is set to 30° and an interfering signal is set at 15°. For LCMV a case with two beams with desired angles at ±30° is demonstrated. The simulation and measurement normalized radiation patterns are shown in Fig. 3 and Fig. 4. For comparing robust beamforming and MVDR beamforming, the desired angle of arrival is set to 0° with an uncertainty of ±3°. An interfering signal is set at 15°. The simulated and measured array responses are shown in Fig. 5. The antenna array is measured inside an anechoic chamber. It is observed that the simulation and measurement result of MVDR, LCMV and RB agree well. When comparing the MVDR and RB algorithms, the MVDR response is asymmetric around 0° and the gain within the uncertainty range varies severely, which is undesirable. Compared to MVDR, RB constrains the response around 0° and within the uncertainty range while suppressing the interference, which shows that RB is more robust to uncertainty in the desired angle. This robustness is achieved, however, at a trade-off cost of an increased side lobe around 35°.

IV. Conclusion

Adaptive beamforming algorithms are demonstrated for a patch antenna array conformed to a cylindrical surface. The MVDR, LCMV and RB algorithms are applied to the case of an antenna array on a conformal surface. Software defined radio is used to apply the beamforming and to do the measurements. The simulations and measurements prove the effectiveness of the conformal array beamformer. The measurement approach is easy to set up and can also easily be extended to larger arrays and different conformal surfaces.

V. References

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