Mechanical Rotating Arrays for Sidelobe Suppression

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***Abstract*—A novel approach by utilizing the fast mechanical rotation of arrays has been proposed for low sidelobe levels by integrating the rotational time-varying radiation pattern in a short time. From the experimental measured radiation pattern for a 4-element circular polarized array antenna with 0.87λ element spacing, the mainlobe of the radiation pattern for the rotation array is almost the same as the non-rotation array, while the sidelobe level is decreased by 14.2 dB from the non-rotation array. This technique could be potentially applied for sensing and radar systems that require high SNR and frequency resolution by integrating the received signals within the rotation period.**

***Index Terms*—sidelobe level, beamwidth, spatial filter, rotation antennas, interference mitigation, time-varying, sparse arrays.**

I. Introduction

For many applications such as radar detection and sensing, a large spatial resolution and low sidelobe levels are required for an array system [1][2]. To avoid the grating lobe issue, the element spacing for an array antenna should be less than 0.5λ, leading to a large number of array element required for a large antenna aperture. It is interesting to find a way to reduce the array element number while maintain a large spatial resolution and low sidelobe levels.

A mechanical rotation array based on a large aperture with a small number of elements is proposed for low sidelobe level and narrow beamwidth designs. This concept is a fusion of the aperiodic arrays by averaging the element radiated field vectors outside the mainlobe direction and the time-modulated arrays by fast sampling the antenna aperture with time-varying array elements. For the mechanical rotation arrays, the antenna aperture is continuously sampled by the rotated time-varying array elements. The mainlobe of array radiation pattern keeps stable by adjusting the phase of each array element periodically and the sidelobes are fluctuated as a function of time. After averaging the array radiation pattern, the mainlobe of the array radiation pattern keeps the same as that for the non-rotation array, while the sidelobes can be largely reduced due to the time-average effect. Since the array aperture is continuously sampled by rotation elements, the mechanical rotation array is equivalent to a dense circular array, whearas the number of array element can be largely decreased.

Compared to the aperiodic arrays [2], the mechanical rotation array could be more efficient to reduce the number of array element while maintaining narrow beamwidth and low sidelobe levels. Different from the time-modulated arrays based on lossy switches[3], the system noise temperature for a rotation receiving array can be largely decreased due to the low loss and less mutual couplings [5][5]. Less electronics help to reduce the complexity and cost of the system. The required averaging time for a mechanical rotation array equals to the rotation period of the driving motor divided by the number of element in the circular array. The mechanical rotation array system with short averaging time, large spatial resolution and high signal interference ratio (SIR) could be potentially used for radar detection, remote sensing and direction of arrival (DOA) estimations.

II. Analytical Analysis

Fig. 1 shows a comparison of radiation pattern for non-rotation and rotation arrays. The array antenna consists of two circular rings with four equally spaced elements in each ring. The diameter of the inner ring is 2.5 λ and that for the outer ring is 5 λ. The directivity of the rotation array is calculated by averaging the time-varying radiation pattern.

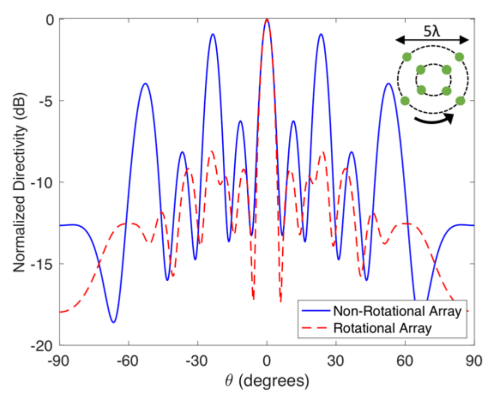


Fig. 1 Comparison of normalized directivity for non-rotation and rotation arrays. The array diameter is 5λ and the element number is 8.

Since the array element spacing is larger than 0.5 λ, large grating lobes with -0.92 dB appears at $\pm 23.5^{\circ}$. When the antenna is rotated along the center of the array, the peak sidelobe can be largely decreased by 8 dB, while the directivity and beamwidth of the main lobe maintain the same as the non-rotation antenna.

The physics of grating lobes mitigation for the rotation array can be understood by that the space of each circular ring in the array are continuously sampled by the rotated elements. The time-average effect for the rotation array with finite elements behaves as a circular array with continuous element distribution. Thus, the time integral of the rotation array with sparse element distribution is equivalent to a circular two-ring array with closely spaced elements. The time-average peak sidelobe levels for the rotation array can be largely decreased due to the equivalent continuous distributed array elements.

III. Measurements

Fig. 2 shows the geometrical dimensions for a 4-element circular polarized array. The feed point of the array antenna is overlap with the geometrical center and the rotation center of the array antenna. The circular polarized array antenna includes four circular polarized square patch antenna elements connected by a feed network with equal excitations. The advantage for a circular polarized array is that the received signal from the boresight direction maintains the same response during the rotation. The array center frequency is 10 GHz and the element spacing is 0.87λ.

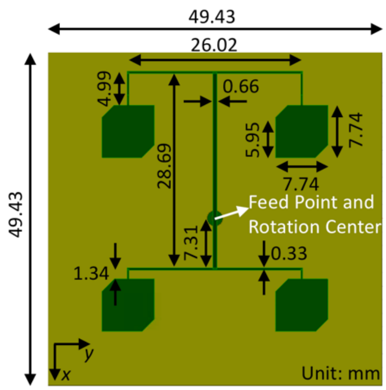


Fig. 2 Geometrical parameters for a circular polarized patch array antenna. A coaxial feed point locates at the rotation center of the array antenna. The thickness of the PCB board is 1.524mm and the relative permittivity of the substrate is 3.

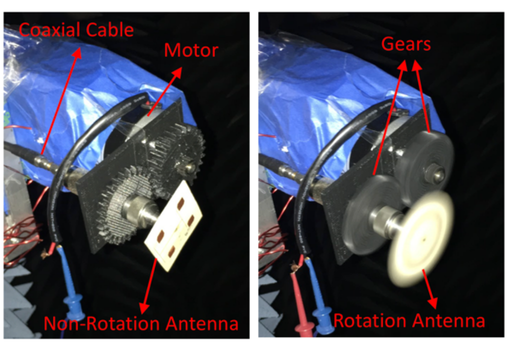
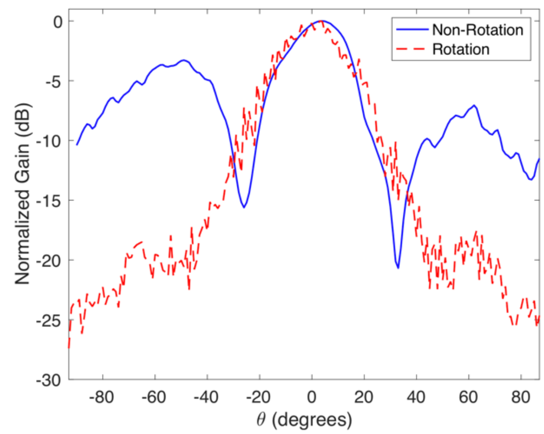


Fig. 3 Test pictures for non-rotation and rotation array antennas in the anechoic chamber.

For the rotation array, the radiation pattern is measured by the same standard horn antenna in the *y-z* cut plane at 10 GHz. The antenna gain is measured by averaging the received signal over time. Compared to the non-rotation array, the measured peak sidelobe level of the rotation array is decreased from -3.3 dB to -17.5 dB, while the beamwidth maintains almost the same as the non-rotation array. Compared to the measured pattern of the non-rotation array, the reason for the increased beamwidth for the rotation array is because of the vibration of antenna platform during the rotation, leading the shakes of the array radiation pattern. The vibration of the array antenna can be improved by building a more robust rotation platform using metal material rather than the polylactic acid material used in this design.



(b) Test results

Fig. 4 Comparison of radiation pattern for non-rotation and rotation 4-element circular polarized array antennas.

IV. Conclusion

A novel concept of time-varying array is proposed in this paper. The array sidelobe levels can be largely decreased by the time-averaging of the array radiation pattern. A 4-element circular array antenna with 0.87λ element spacing is designed and fabricated. By maintaining almost the same mainlobe, the peak sidelobe level for the rotation array is decreased by 14.2 dB from the non-rotation array. The mechanical rotation array provides a new way to the design of a low cost and ultra-low loss phased array, which could be potentially used for radar detection, remote sensing and direction of arrival (DOA) estimation.

References

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