RADAR IMAGING WITH PARTIALLY COHERENT ARRAY

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INTRODUCTION

For high resolution array radar imaging, large coherent antenna array imposes the problems of very high data rate and cost for the use of a large number of coherent receiving channels on the imaging system. A possible way to reduce the number of array elements is to use random thinned array[1] in which elements exist at some randomly selected positions only. This approach can achieve high angular resolution, but the array has high sidelobes. To reduce the sidelobe inteference, sidelobe reduction process like CLEAN[2] must be applied.

In this paper a partially coherent array (PCA) is proposed for achieving high angular resolution. This array is considered to have non-coherent channels mostly and only a few coherent channels. With a limitation on the field of view (FOV) of the imaging array, the missing phases of the non-coherent channels can be reconstructed through an iterative Fourier transformation process. After this process a PCA can do imaging like a totally coherent array.

THE USE OF PCA

A PCA is a linear periodic array. It consists of two sub-arrays. One is a coherent thinned sub-array whose elements are placed randomly within a PCA. The other is a non-coherent sub-array which fills up the coherent thinned sub-array to make a filled periodic array. The coherent sub-array works like a random array which can sample the envelope and phase of the E-field signal coherently. The non-coherent sub-array can sample the envelope (or power) of the E-field signal only. For far-field imaging, the E-field signal is the Fourier Transform of a scene function (target field).

A PCA can not use a simple Discrete Fourier Transform (DFT) for imaging like a periodic array or random array does. There is no problem in performing DFT on the coherent sub-array data. However the non-coherent sub-array can not join the DFT due to the lack of phase. Performing DFT on the PCA data will mix the data to be something meaningless, especially when the number of coherent elements is much less than the non-coherent ones. An algorithm which combines the coherent and non-coherent sub-array to do imaging is given in the following section. This is an iterative algorithm which has four steps of operations in each iteration. These steps are image-formation, bandlimitation, inverse DFT and data-correction.

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The algorithm starts with image-formation which performs DFT on the coherent sub-array data. An initial image FO is formed. This is an image produced by a random array. Therefore high sidelobe inteference is expected in FO.

In an active array imaging system, a transmitter which serves as an illumination source is required. The illuminated region of the target field can be designed to cover several angular resolution cells (beamwidth) of the receiving array. And the transmitter can be controlled to illuminate any portion of the FOV of the receiving array. According to the knowledge of the illumination condition, the high sidelobes outside the illuminated region in FO are set to be zeros. This is an operation of bandlimitation.

After bandlimitation the image left within the illuminated region is an estimation of the target field. This image is transformed back to be the E-field data by an inverse DFT. This operation makes the complex data at every elements of the whole array available. The complex data are the reconstruction of the E-field signals.

The reconstructed data are definitely in error, since they are generated from FO which is an image formed by a random array. Two kinds of data-correction operations are applied to reduce this error. One is replacing the data over the coherent sub-array with the true data that were received by this sub-array. The other is scaling the data over the non-coherent sub-array to have the true envelope values that were received by this sub-array.

After data-correction the PCA becomes a totally coherent array and only the reconstructed phases over the non-coherent sub-array are in error. Then the corrected complex data are treated as if they were the data received by a coherent array which has the same number of elements as the PCA has, and the algorithm returns to the image-formation step. This is the first iteration of the algorithm. In further iterations the image-formation operation will use a filled perodic array, but not the coherent sub-array, to do imaging.

COMPUTER SIMULATION

A linear periodic array of 256 elements was simulated with ten of them being coherent elements. These ten elements were spreaded randomly across the whole array. The illuminated region has a size of fifteen resolution cells of the receiving array and is centered at θ_T , the pointing direction of transmitter, where $u_T = \sin(\theta_T) = 0.5$. Two kinds of scenes were used to generate the array data.

The first scene consists of two point sources with equal power and opposite phases, and they are 4 resolution-cell apart. The initial image is shown in Fig 1.a. The illuminated region is marked with two vertical lines. This image is totally smeared. It is questionable that any detection scheme may detect these two point sources. Even with the knowledge of the illumination region, it is still hard to say that there are really two targets. The image after five iterations of the phase reconstruction algorithm is shown in Fig 1.b. These two point sources are seperated clearly.

The second scene has an extended target with constant RCS and phase over a width of 4 resolution cells of the receiving array. The initial image is shown in Fig 2.a with the same format of Fig 1.a. The image after fifteen iterations of the phase reconstruction process is shown in Fig 2.b.

REFERENCES:

[1] B.D.Steinberg, Microwave Imaging With Large Antenna Arrays, Wiley, New York, 1983.
[2] J.Tsao and B.D.Steingberg, "Application of the CLEAN Technique to Microwave Imaging", 1984 IEEE AP-S Symposium & URSI Radio Science Meeting, Boston, MA., June 25, 1984.

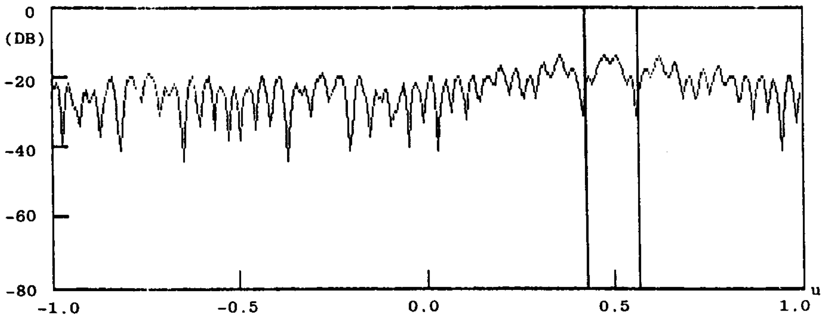

FIG1.a THE INITIAL IMAGE OF A TWO-TARGET SCENE.

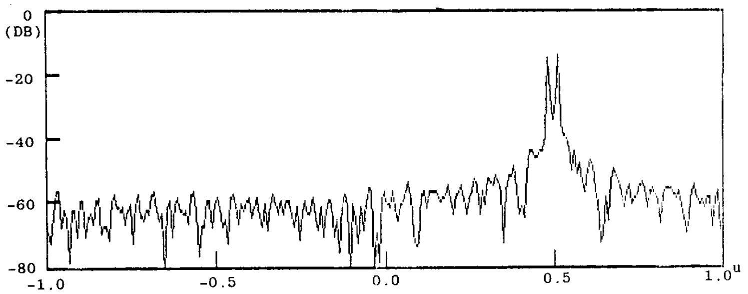

FIG 1.b THE IMAGE OF THE TWO-TARGET SCENE AFTER FIVE ITERATIONS OF THE PHASE RECONSTRUCTION ALGORITHM.

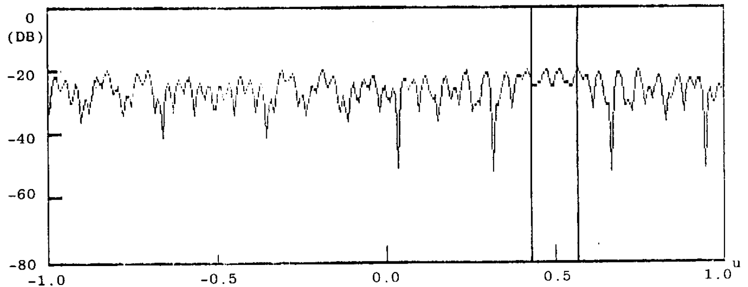

FIG 2.a THE INITIAL IMAGE OF AN EXTENDED TARGET.

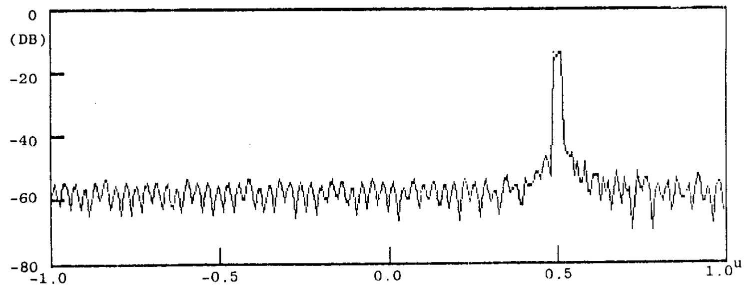

FIG 2.b THE IMAGE OF AN EXTENDED TARGET AFTER FIFTEEN ITETRATIONS OF THE PHASE RECONSTRUCTION ALGORITHM.