A NEW BISTATIC DOPPLER MEASUREMENT SYSTEM WITH REDUCED CONTAMINATION BY SIDELOBE ECHOES

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1. INTRODUCTION

The bistatic Doppler velocity measurement, with one traditional transmitting radar associated with one or more passive radar receivers, is a useful way to retrieve the 2D or 3D wind field with low costs. On the other hand, the sidelobe contamination of the bistatic Doppler velocity measurement is the serious problem because low-gain wide beamwidth receiving antennas are usually used. Various studies have investigated the reliability of wind estimation with bistatic radar systems in terms of sidelobe contamination [1-7]. Some studies have proposed the method to identify the regions with strong contamination [8, 5-6], though the removal of these regions leads to a reduction of the area of available bistatic measurements. Recently the method to correct for the contribution of sidelobe effects to the measurements of bistatic Doppler velocity by solving the inverse problem using the transmitting and receiving antenna pattern is also proposed [9].

In this study,we propose a new measurement system by which the sidelobe itself is reduced with an array receiving antenna. The simulated results to verify this system are presented.

2. CONCEPT OF NEW SYSTEM

We use low-gain wide beamwidth receiving antennas that are supposed to be fixed in azimuth and elevation from viewpoint of costs and easy to install. These are just same as the ordinal bistatic receiving antennas. But we compose an array with these antennas as elements. An array (multiple elements) leads to the improvement of receiving gain.

Furthermore, we dare to use grating lobes. In case of usual array antenna, the spacing between elements is selected short (less than one wavelength) to form only one strong main lobe and to avoid forming grating lobes. But it is difficult to form a narrow beam enough to reduce the sidelobe contamination with limited number of elements. In this study, we dare to select long spacing (e.g. 10 wavelengths) and to form many sharp grating robes (beams) simultaneously. Sidelobe contaminations near around the strong echoes are expected to be reduced with these sharp beams. Echoes from multiple beams can be separated (identified) by receiving time difference because the path lengths of transmitter-target-receiver are different among every receiving beam.

Once the number of elements and their positions are determined, the directions of receiving beams (namely observable area) are also fixed. To extend the observable area, we introduce the digital beam forming (DBF) technique. By shifting phases of receiving signals from each element, we can change the directions of receiving beams and extend the observable area.

3. SIMULATION

We, National Institute of Information and Communications Technology (NICT), have a full polarimetric Doppler weather radar named COBRA (5.34 GHz, wavelength λ is about 5.6 cm) in Okinawa, Japan. Supposing to apply this new bsitatic system to COBRA, realistic conditions for COBRA are introduced to calculations. Figure 1 shows a one-way power pattern of a COBRA bistatic receiving antenna in azimuth direction. Now we compose an array with this kind of antennas as the elements. A power pattern of an array antenna (number of elements n is 4 and spacing is 10 λ) is shown in Figure 2. Multiple sharp receiving beams are formed.

3.1. Trans-receiving antenna pattern

Figure 3 and 4 show examples of trans-receiving power pattern. Receiving site is assumed to NICT Okinawa Center (R in figures), and distance between receiving site and COBRA site (T in figures) is about 23.9 km. In these examples, the azimuth of the receiving antenna is 10 degrees and azimuth of transmitting antenna is 315 degrees. The number of elements is one (ordinal bistatic system) in Figure 3 and four in Figure 4 (new system, element spacing is 10 λ). A part of ellipsoid with positions of transmitter and receiver as foci is drawn in both figures. Echoes reflected on this ellipsoid are received at the same time (in the same range gate). Figure 5 shows the cross section power pattern on this ellipsoid. The solid and dashed lines correspond to the cross sections in Figure 4 and 3, respectively. In case of the array receiver (new system), the sidelobe level near the illuminated area is decreased by more than 10 dB, and the reduction of sidelobe contamination effect can be expected.

3.2. Received power

Figure 6 and 7 show the simulated received power when the uniform rainfall whose reflectivity Z is assumed to be 20 dB. The number of elements is one (ordinal bistatic system) in Figure 6 and four in Figure 7 (new system, element spacing is 10 λ). Since we can scan receiving beams by DBF, this affect is considered and observable area is already extended in Figure 7. Transmitted pulse length is selected to 2 μs.

The bistatic angle β (transmitter-target-receiver angle) has a qualification from transmitting and receiving geometry. The available range of β is expressed by $40° < \beta < 150°$ [5]. So the simulated power is plotted only in this area. In case of array antenna, if the transmitted pulse (illuminated volume) strides over the plural receiving beams, we cannot resolve these areas. These areas (near the receiver) are also eliminated. Furthermore, if the receiving beamwidth is narrow and can cover only a part of the illuminated volume, received power is decreased.

This effect, which is dominant near the receiver, is also considered. Due to this effect, received power near the receiver is lower in the new system. But in the other area (almost all area) received power becomes stronger when the array receiver is used.

4. SUMMARY

We proposed a new bistatic measurement system using array receiving antenna with sharp grating lobes and the DBF technique. It can be expected in this system that the sidelobe contamination effect is reduced, and received power in almost all observational area is increased.

5. REFERENCES

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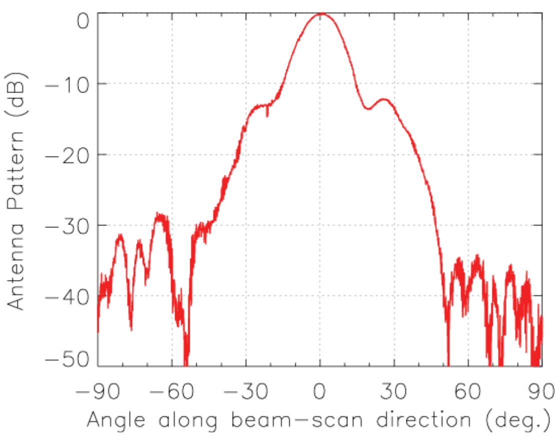

Figure 1. One-way power pattern of a COBRA bistatic receiving antenna in azimuth direction.

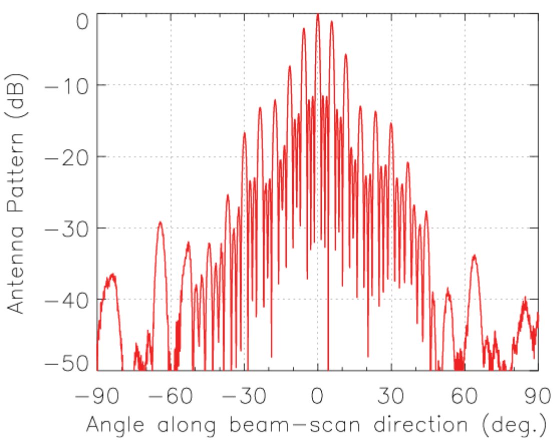

Figure 2. One-way power pattern of an array antenna (number of elements is 4 and spacing is 10 λ).

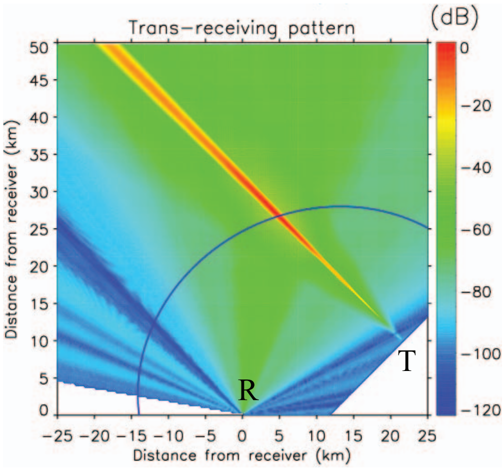

Figure 3. Trans-receiving power pattern of ordinal bistatic system (not array).

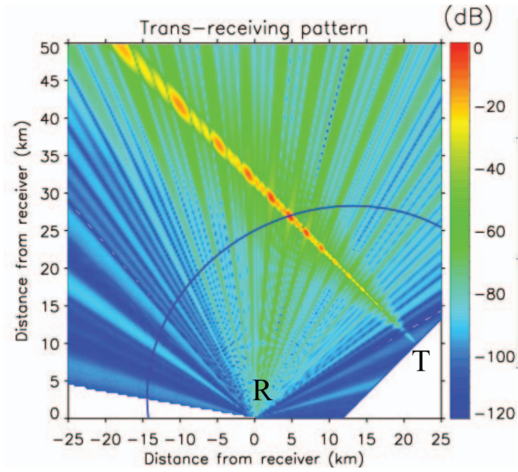

Figure 4. Trans-receiving power pattern of the new bistatic system (array, n=4, spacing equal to 10λ).

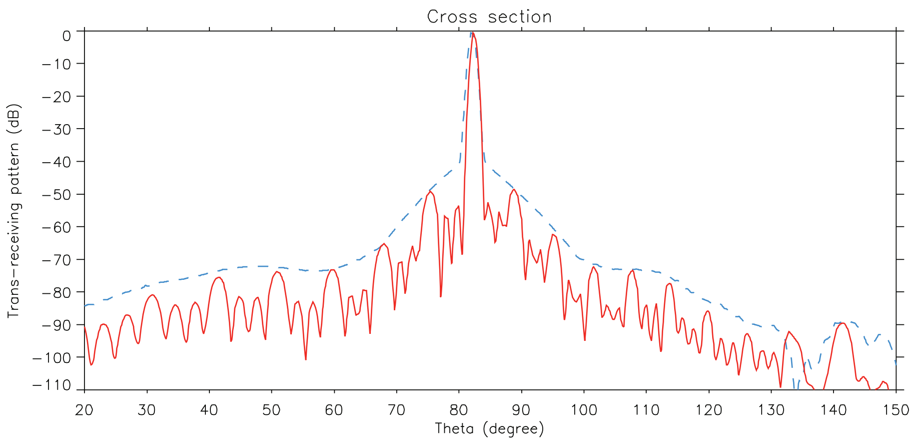

Figure 5. Cross section power patterns on the ellipsoids. The solid and dashed lines correspond to the cross sections in Figure 4 (array) and 3 (non array), respectively.

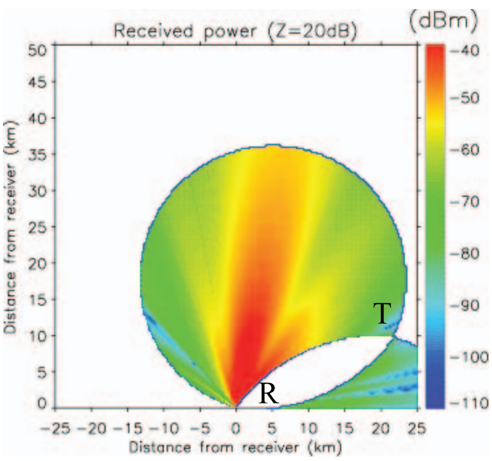

Figure 6. Simulated received power (uniform rainfall, Z = 20 dB, not array).

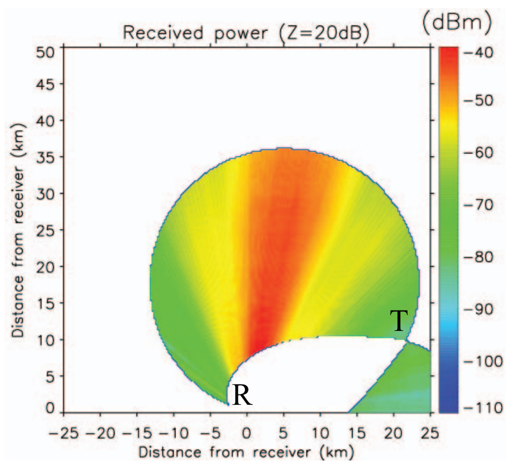

Figure 7. Simulated received power (uniform rainfall, Z = 20 dB, array, n=4, spacing equal to 10λ).