DELAYED-ACTION RADAR REFLECTOR USING A HORN ANTENNA

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Introduction: Calibration of radar is important for the interpretation of radar images of terrain. A reflector using an antenna and its functions of reception and radiation is useful for the external calibration, because it can be applied to any kind of polarization configurations and bistatic configuration, and because its radar cross-section(RCS) is variable by an amplifier or an attenuator.

The re-radiation from an antenna comprises the radiation and structural mode components.[1] The former is based on the antenna operation in its normal antenna mode and the latter is due to the parasitic scattering from the antenna structure. The RCS of the reflector will be easily determined by the antenna gain without measuring the scattering itself, if the latter can be ignored. But the power of the latter is generally larger than that of the former for a large class of antennas.[2] Though the detailed treatment of the scattering properties of antennas is found in [3] and [4], it is not easy to estimate definitely the properties such as the RCS and the directivity of the structural mode scattering which are different from those of the radiation mode. Then, the structural mode scattering has much and inestimable effect on the resultant response of an antenna as a reflector.

A method for eliminating the effect of the structural mode scattering is shown by the Active Radar Calibrator which makes the radiation mode to be dominant by using an amplifier of 35 dB.[5] In this paper, we propose another method of the Delayed-Action Radar Calibrator(DARC). It can separate two modes of scattering by the range resolution of the radar under calibration through a time-delay inserted between reception and transmission of the radar signal. Then, we show the results of the experiments for a FM-CW radar about the DARC using an X-band standard gain horn.

DARC and FM-CW radar: All measurements are made on the antenna gain measuring system in an anechoic chamber of our laboratory as shown in Fig.1. Two horn antennas are faced each other on the holders and the alignment is adjusted with the reference of a laser beam. Antenna 1 which can be rotated in the horizontal plane, is used for the DARC with a wave-guide delay and a short-circuit. A basic FM-CW radar used for the scattering measurement comprises antenna 2 and a homodyne circuit, from which the detected signal is measured and processed by a digital spectrum analyzer synchronized with the sweep oscillator. The back-scatter distribution in the range is observed directly on the display of the analyzer with the range resolution corresponding to the sweep bandwidth.

The measuring radar is calibrated at the center frequency of 10GHz and with the bandwidth of 500MHz by a calibration target of a metal sphere of 4 inches diameter, whose RCS can be theoretically estimated.[6] The scattered signal from a metal sphere consists of two components, which are the optical and creeping wave terms. The value calculated by the optical term is adopted for the calibration, because the path difference between these terms is comparable to the range resolution and these scattered signal components are separately measured in some degree. The RCS of the sphere is 19.1 dBscm(square centimeter) by calculation. A metal plate which has the same size (20cmx15cm) as the aperture of the horn antenna is used for the calibration of the frequency dependence, where the RCS of the plate is assumed to be $4\pi A^2/\lambda^2$. The measured RCS of the plate is

49.92dBscm at 10GHz. The theoretical estimation is 50.09 dBscm after the compensation of the short range effect, for which the compensation value(0.45 dB) to the horn antenna[7] having the same aperture is adopted. Then, the dynamic range of 30 dB is expected from 20 to 50 dBscm of RCS.

Measurements: The re-radiation from the DARC using a horn antenna comprises the radiation mode reflection by the short-circuit and two structural mode scatterings by the edges of the aperture and the throat connecting to the wave-guide. The frequency dependence of the RCS is shown in Fig.2. In the case of no delay (d=0cm), sharp fluctuations appear over the range of 20 dB, because the inseparable three return signals interfere to each other. The RCS's separated into two modes by the delay(d=140cm) are also shown for two directions of the broadside and 2.4 degree off in the horizontal plane. The return signal of the radiation mode is observed on the range axis separately from the radar returns of the structural mode and the multiple reflection between the short-circuit and the antenna structure by about more than five range resolutions. The constant difference of the RCS's of the radiation mode between two cases of different directions corresponds to the gain reduction in the normal antenna directivity by the angular shift from the broadside. The RCS σ of the radiation mode should be estimated by the gain G as follows,

$$\sigma = G^2 \lambda^2 / 4\pi \qquad (1)$$

The gain of the horn used for the DARC has been measured with the accuracy of $\pm$ 0.1dB for three frequencies of 8, 10 and 12 GHz by the three antenna method, then the RCS's are calculated and shown in Fig.2. Besides, they are numerically compared with the measured RCS's strictly compensated for the short range effect at these frequencies in Table-1. Though these two set of RCS's are based on the measurements of the different bandwidth, the good agreement shows that the RCS of the DARC can be accurately determined by the antenna gain. The structural mode scattering left shows inestimable dependence on the frequency and direction. The directivity patterns of the RCS of the DARC are also shown in Fig.3. The inseparable RCS (d=0cm) has the level and shape greatly different from those of the normal antenna operating mode, while the RCS directivity of the radiation mode (d=70cm) shows a good agreement with the 2-way antenna pattern.

As the mode separation of the scattering from the DARC is attained by the delay and the range(time) resolution of the radar, the measured RCS of the DARC may be reduced by the dispersion property of the delay particularly for a high resolution radar of large bandwidth. The bandwidth dependence of the DARC is shown in Fig. 4. It is shown that the RCS of the delayed return is much reduced in the large sweep bandwidth region, because a long waveguide which is dispersive is used as a delay in the DARC. The small reduction shown in the RCS's of the throat and edge of the horn is owing to the waveguide(70 cm) used in the FM-CW radar, since the same drooping is shown in the measured curve of the metal plate.

Discussion: The radar cross-section based on the delayed return from the DARC is easily and accurately estimated by the antenna gain which can be measured by the ordinary antenna method without measuring the scattering directly. Besides, good stability is also expected because the DARC can consist of only passive components. Though the dispersion property of the delay used in the DARC may cause the reduction of the RCS for high resolution radars, the compensation is possible to maintain the accuracy of the calibration.

In addition to separating parasitic scatterings from the antenna structure, the external radar calibration after the image relocation by the DARC can improve the measurement uncertainty due to the scattering from the background or the support of the calibration reflector.

References:
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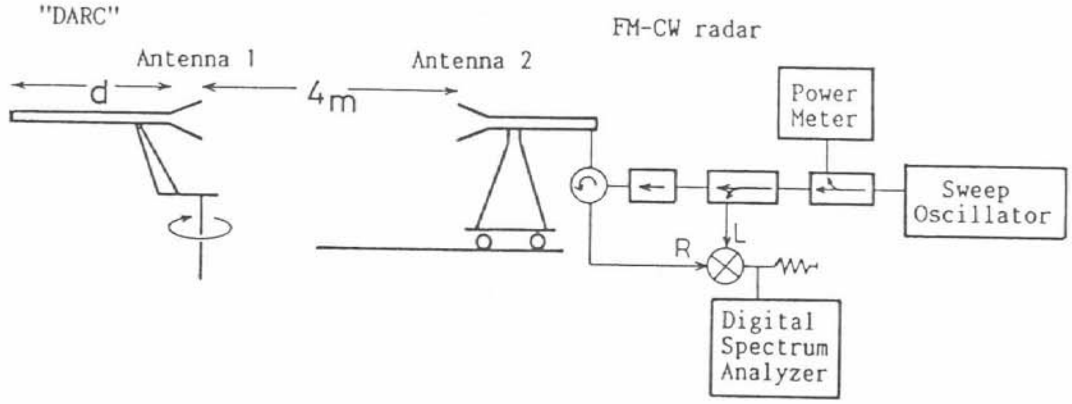

Fig.1 Measurement system of antenna and scattering

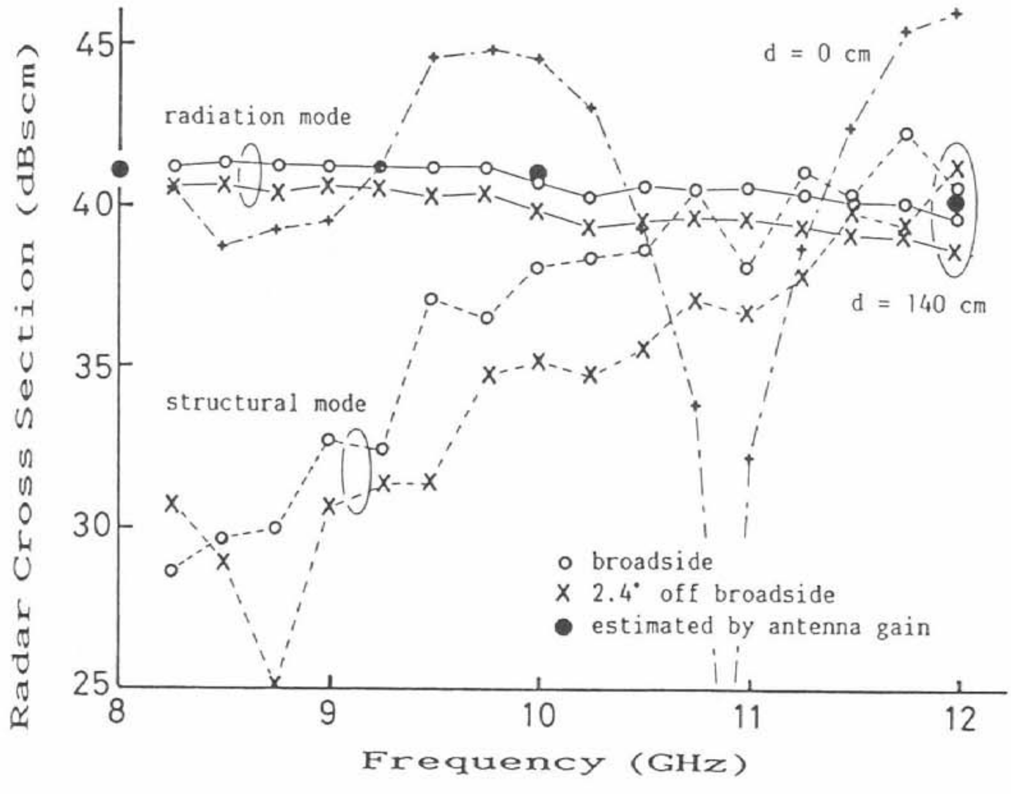

Fig.2 Frequency dependence of the scatterings from the "DARC" of a horn antenna

Table 1
Radar cross sections of the "DARC" calculated by the antenna gain and measured with FM-CW radar
f_0=10GHz, Broadside.

Frequency	8	8.25	10	12	GHz
Ant. gain	21.27		22.19	22.68	dBi
RCS by gain	41.19		40.99	40.17	dBscm
Measurement		41.03	40.78	40.07	dBscm
Difference	0.16		0.21	0.10	dB

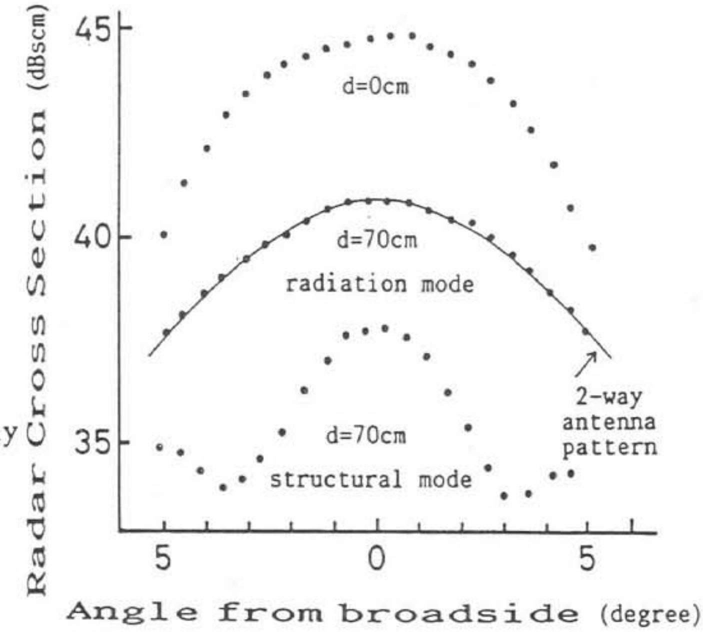

Fig.3
Radar cross section directivity of the "DARC"
f_0=10GHz, Bandwidth:500MHz

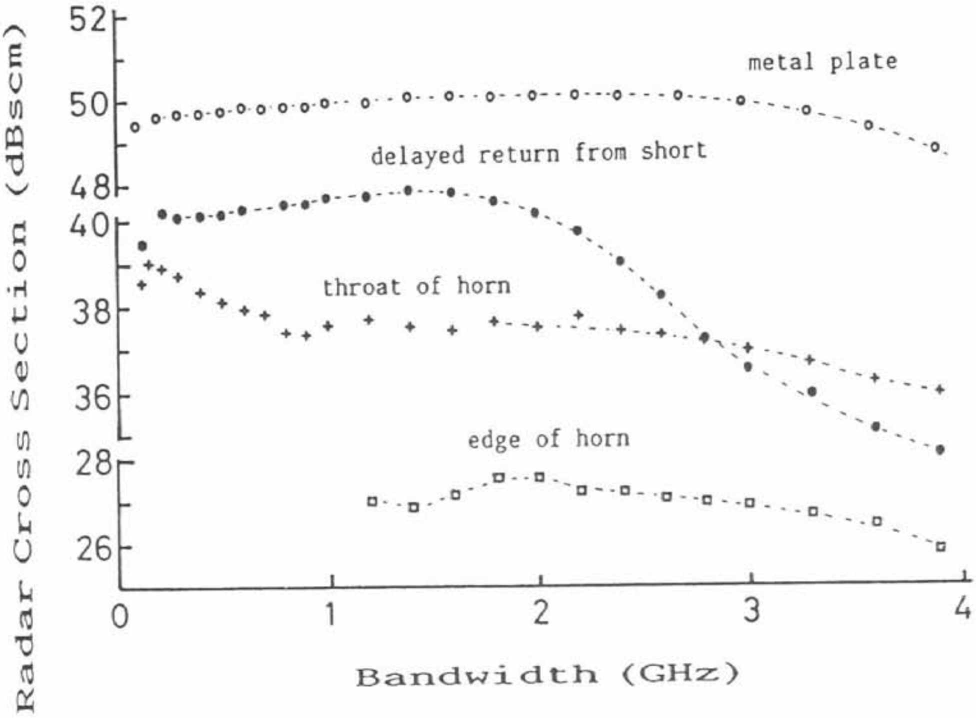

Fig.4 Bandwidth dependence of the scatterings from the "DARC" and a metal plate.