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Scattering and Radiation Performance of Ninja Array Antennas

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***Abstract*—Phased array antennas whose backscattering level is lower than conventional phased arrays are presented. The array antennas are composed of non-identical elements and plane wave of normal incidence to the array antennas is scattered to non-specular direction. As a result, backscattering level which implies existence of the array antennas is difficult to be detected and secure wireless system is available. The array antennas are named as "Ninja array antennas" because of their secure and invisible performance, where Ninja is Japanese traditional undercover who works stealthily. Beam scanning of the non-identical array antennas is realized by an excitation making use of array element patterns. Numerical simulation is performed and scattering/radiation performance of the Ninja array antenna using log-periodic dipole array element is demonstrated.**

***Index Terms*—Phased array antennas, Backscattering, Radar cross section, Log-periodic dipole array**

I. Introduction

Owing to their beam scanning capability and high gain performance, phased array antennas are applicable to wireless communication system, radar system, and imaging system [1]-[2]. In general, phased array antennas are periodic structure and are composed of identical array elements. As a result, backscattering signal level of the phased array antennas can be high. High level of backscattering signal may result in serious problems, such as interference to the other electronic devices and leakage of antenna performance to eavesdropper.

In order to reduce the backscattering signal level of the phased array antennas, various remedies have been proposed. Radar absorbing materials (RAM) can reduce the backscattering signal level of the phased array antennas [4]-[6]. The RAM is capable of absorbing incident wave to the phased array antennas and resultant backscattering signal level is expected to be low. One of the disadvantage of the RAM is to absorb radiation wave from the phased array antennas. A bandpass radome is another promising technique for reducing backscattering signal level of the phased array antennas [7]-[8]. The bandpass radome is transparent over a specific frequency band while is opaque out of the frequency band. Therefore, the bandpass radome can be designed to absorb incident wave out of the operating frequency band of the phased array antennas without interrupting their in-band performance. Resultant backscattering level of the phased array antennas is small but their in-band backscattering signal level is still high.

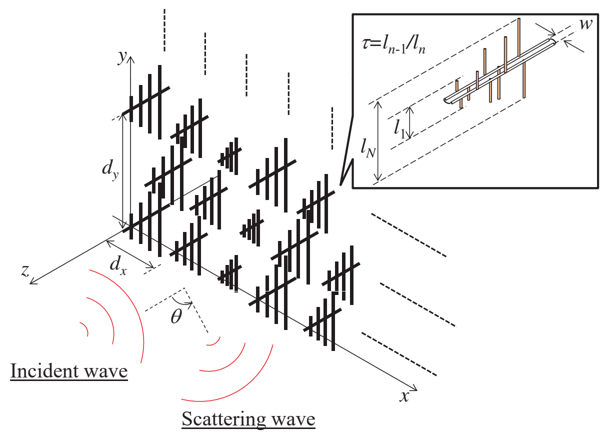

Fig. 1. Ninja array antennas with non-identical log-periodic dipole array elements.

In this paper, a phased array antenna whose in-band backscattering signal level is low is presented. The phased array antenna is composed of non-identical array elements and its geometry is similar to reflectarrays [12]-[14]. Owing to non-identical array elements, the phased array antenna is capable of scattering plane wave of normal incidence to non-specular direction. As a result, backscattering of the phased array antenna is relatively low rather than conventional one. The phased array antenna is named as "Ninja array antenna" due to its invisible performance. Excitation of the Ninja array antenna is obtained via an array element pattern. Results of numerical simulation demonstrate that the Ninja array antenna shows low backscattering performance without degrading its radiation performance. This paper is enhancement of [15].

II. Ninja Array Antenna

A Ninja array antenna using log-periodic dipole array (LPDA) element is designed. Geometry of the Ninja array antenna is shown in Fig. 1. The Ninja array antenna is composed of non-identical LPDA elements. Reflection coefficient of the LPDA element for plane wave of normal incidence is obtained using method of moments (MoM). According to the phase of reflection coefficient, size of each LPDA element is given so that main beam of scattering field is directed to desired direction.

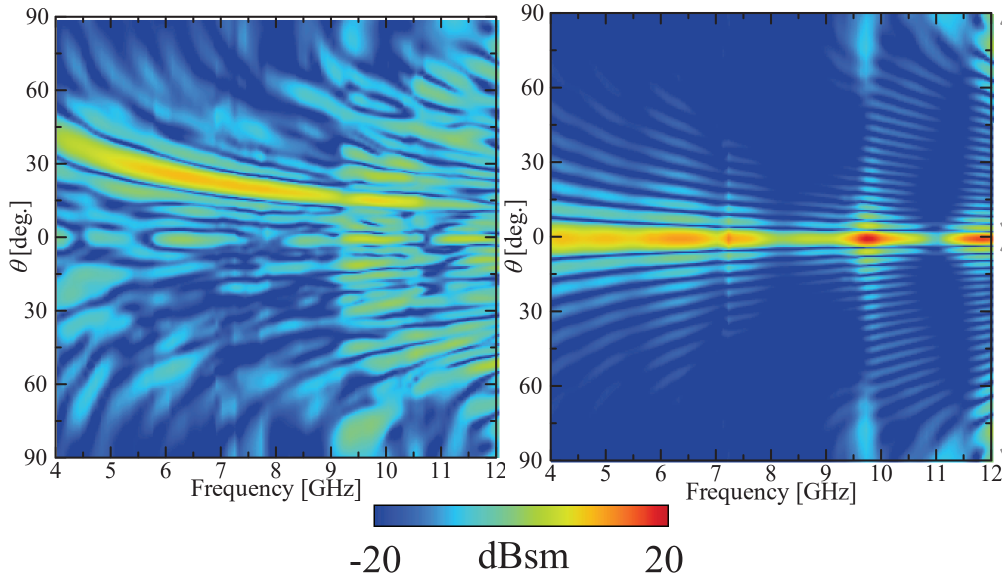

Fig. 2. Bistatic radar cross section of 10×10 arrays (Left: Ninja array antenna, Right: Uniform array antenna ($l_1 = 12.55$ mm)).

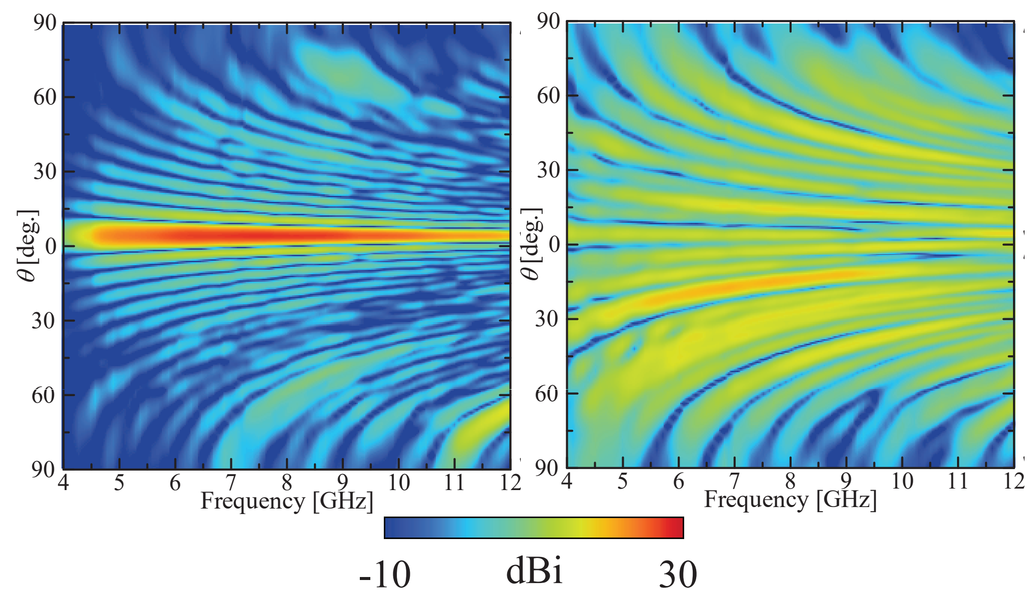

Fig. 3. Actual gain of 10×10 Ninja array antenna (Left: Array element pattern based excitation, Right: Array factor based excitation).

On the other hand, beam scanning capability is indispensable for the Ninja array antenna. The Ninja array antenna is composed of non-identical elements and excitation using array factor is incomplete for beam scanning. Instead of array factor, an array element pattern is used to obtain excitation of the Ninja array antenna.

Due to the limitation of space, detail process of design of the Ninja array antenna is omitted here. Interest readers can refer our previous publication [15].

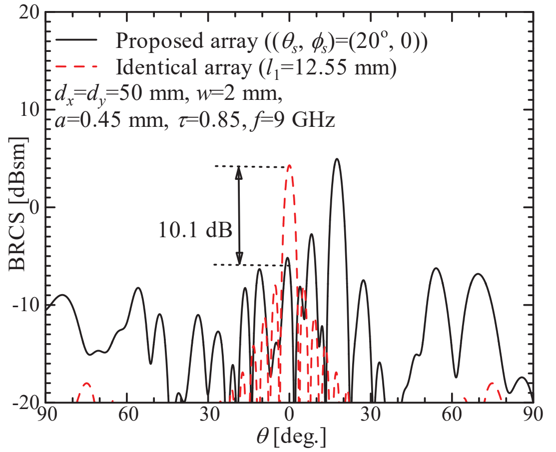

Fig. 4. BRCS pattern of 10 × 10 Ninja array antenna @ 9 GHz.

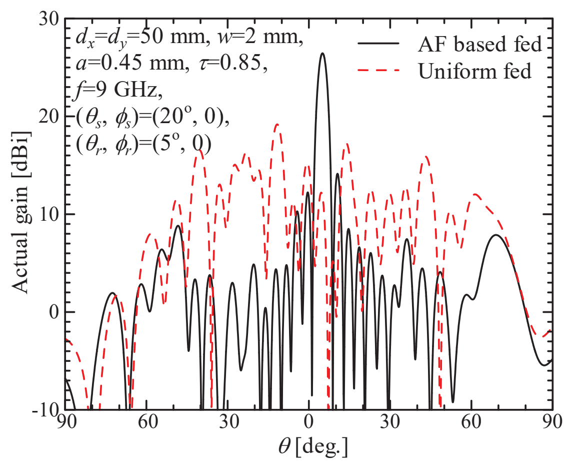

Fig. 5. Actual gain of 10 × 10 Ninja array antenna @ 9 GHz.

III. Numerical simulation

A Ninja array antenna using LPDA elements was designed and its scattering/radiation performance is clarified numerically. Operating frequency of the LPDA element is ranging from 4 to 12 GHz. Array spacing is $d_x = d_y = 50$ mm, $l_1 = 6.25 \sim 13.25$ mm, $\tau = 0.85$, w=2 mm, and radius of each element is 0.45 mm. The Ninja array antenna was designed so that main beam of scattering field is directed to $(\theta, \phi) = (20^\circ, 0)$@8 GHz.

Bistatic radar cross section (BRCS) of the designed Ninja array antenna and uniform array antenna is shown in Fig. 2. It is found that BRCS of the Ninja array antenna is directed to non-specular direction over its operating frequency band while that of the uniform one is directed to specular direction. Backscattering of the Ninja array antenna is 17.1 dB lower than that of uniform one at 8 GHz and low backscattering phased array antenna is available.

Actual gain of the designed Ninja array antenna is shown in Fig. 3. Beam scanning direction is $(\theta, \phi) = (5^\circ, 0)$. It can be seen that array element pattern based excitation is capable of beam scanning while array factor based excitation is not. As mentioned earlier, excitation with array factor is incomplete for beam scanning of the Ninja array antenna because it neglects the effect of non-identical geometry of the array elements, i.e. difference of both current distribution and far-field pattern. On the other hand, excitation with array element pattern works well because it includes the effect of non-identical geometry of the array elements.

Fig.4 and Fig. 5 show BRCS pattern and actual gain pattern of the designed Ninja array antenna at 9 GHz, respectively. Low backscattering performance and beam scanning capabillity of the Ninja array antenna with array factor based excitation are clearly demonstrated at different frequency band.

IV. Conclusion

In this paper, low backscattering phased array antennas, called as Ninja array antennas, have been presented. Radiation and scattering performance of the Ninja array antennas have been demonstrated numerically.

Acknowledgment

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