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A Beam Switched Log-Periodic Antenna for EMI Measurement

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1. Introduction

In EMI (Electromagnetic Interference) test, the electric field intensity of radiated emission from EUT (Equipment Under Test) is measured. To find the maximum radiation by EUT, a receiving antenna is moved along a vertical pole, because the electric field intensity is seriously changed by the effect of ground reflection wave. In addition to this vertical movement, the main beam tilting is required to keep stable reception level from the EUT. A mechanical tilting is the current standard, however quick and fine adjustment is expected.

This paper presents electrically beam switching antennas operating from 1 GHz to 10 GHz using pair of log-periodic antenna. We show an overview of this EMI measurement, and clarify target performance of beam switching antenna. Then we propose broadband beam switching using log-periodic antennas.

2. Overview of EMI measurement with beam switching antenna

In this section, we present an overview of EMI measurement and clarify target performance of beam switching antenna. By several standards of EMC such as CISPR 22, EMI test should be conducted at OATS (Open-Area Test Site) or SAC (Semi Anechoic Chamber) [1] to measure the position of the strongest emission level of EUT, moving a receiving antenna vertically along antenna mast as shown in Fig. 1. But the antenna receives a direct path from EUT and a reflected wave from the floor, then received electric field intensity is given as follows,

$$E_A = E_0\{1 + Re^{-jk(d_2-d_1)}\} \tag{1}$$

where E_0 is electric field intensity of direct path in free space, R is reflection coefficient, and d_1, d_2 are path length of direct and reflected path, respectively.

Fig. 2 shows height patterns of electric field intensity along the antenna mast as given in eq. (1). At each frequency, the electric field intensity shows a strong standing wave in vertical line. In EMI measurement, this standing wave causes errors of test results. As a solution to this inconvenience, we can use a high gain directive antenna and control its main beam direction to receive the EUT signal to reduce reflected wave. In Japanese standard VCCI, the mechanical control to scan the source direction of its radiated emissions is recommended [2], however it requires high accurate antenna positioning and we propose an electric beam switching of measuring antenna.

Fig. 3 shows overview of EMI measurement using beam switching antenna. When antenna is moving along the vertical mast, the main beam is tilted electrically to scan the EUT emission. Distance between the receiving antenna and EUT is the longest at the mast top, and then no tilted beam is toward to the EUT. From Fig. 3, the distance is $\sqrt{2}$ times larger than the shortest distance at the mast bottom. To keep the same reception level in antenna moving along vertical mast, the main beam is tilted upward as the antenna position being low. To scan the EUT correctly at the lowest position, maximum beam tilt angle should be 45°, and gain difference should be less than 3 dB.

3. Electrically beam switching of log-periodic antenna

As an electrically beam switching antenna, a pair of dipole antennas with half-wavelength is a simple technique. Radiation pattern of this array is controlled by a phase difference feeding. This dipole array normally operates at a single frequency, and narrowband array is not suitable for EMI measurement. Then we consider a pair of log-periodic antennas, operating over wide frequency band. The geometry of this antenna is like log-periodically positioned dipole antenna, and active elements region of antenna shifts as frequency changes as shown in Fig.4. In order to reduce grating lobes of the array, two log-periodic antennas are arrayed to keep the spacing of active elements of half wavelength.

To set the distance between two transmission lines as half-wavelength of corresponding frequency for this antenna arrangement, two types of array are considered. One is an H-plane array, and the other is an E-plane array as shown in Fig. 5. In E-plane array, two antennas are arrayed with 1 mm spacing not to touch each other. Fig. 6 shows radiation pattern of each array at 1, 4, 6, and 10 GHz, respectively, with phase difference in feeding port of 0°, 90°, and 180°. Table 1 shows maximum gain and tilt angle at each frequency. From Fig. 6 and Table 1, main beam of antenna tilts as phase difference increase for each array. For the in phase excitation, the main beam gain is toward x-axis, and the radiation is cancelled in the x-axis and main beam is split into two lobes for the out of phase case. Radiation pattern in higher frequency bands has many ripples due to harmonic resonances of element corresponding lower frequency elements, however the gain tilted beam is enough for this application. At 1 GHz, the maximum tilt angle is 46° and the gain difference is 2.11 dB for H-plane array, which satisfies target performance shown in previous section. At 4 and 6 GHz, the maximum gain differences are 3.33 and 3.25 dB, and maximum beam tilt angle are 33° and 34°, respectively. These performances are almost close to required ones. For E-plane array, maximum beam tilt angle for the out phase excitation is smaller than 45°, while the difference of maximum gain is less than 3 dB for each frequency, which is enough characteristics for EMI measurement.

4. Conclusion

In this paper, we presented an overview of electrically beam switching antenna for EMI measurement. We considered the height pattern of electric field intensity caused by the vertical movement of receiving antenna, and proposed electrically beam switching of antenna as a solution, and presented the target performance to conduct a correct EMI measurement with beam switching antenna. We presented the design of beam switching antenna using a pair of log-periodic antenna. Array of log-periodic antenna and phase difference feeding enables beam switching over wide frequency band. From the beam switching characteristics, the maximum beam tilt angle and gain difference are suitable for EMI measurement to search the position of maximum electric field intensity.

The future challenges are to design practical antenna with feeding circuit, and experimental consideration.

References

[1] H. TAGI, et. al., “An Evaluation of the Measurement Method for Fully Anechoic Room,” IEICE Technical Report, EMCJ 2007-111, pp. 31-36, Jan. 2008.

[2] VCCI council, “VCCI standards Technical Requirement,” Apr. 2012

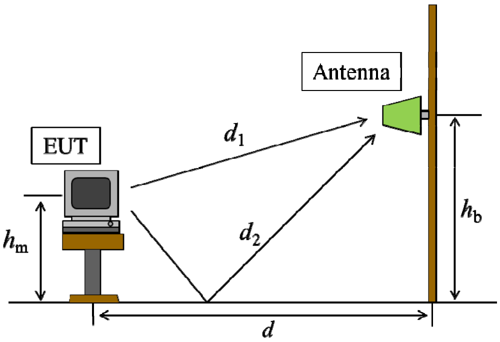


Fig. 1: Overview of EMI measurement

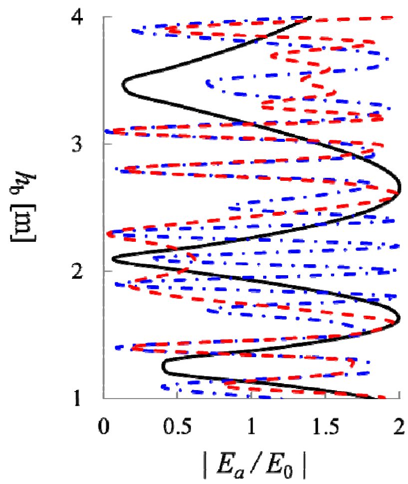
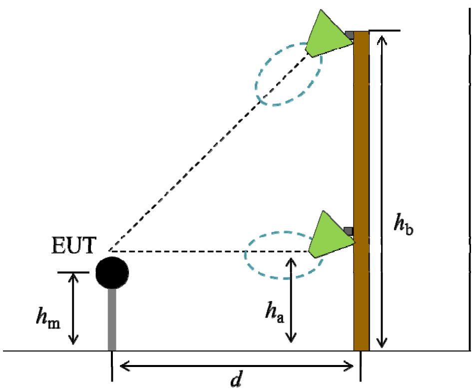


Fig 2: height pattrn of electirc field intensity in EMI measurement
solid: 1 GHz, dash: 5 GHz, short-dash: 10 GHz



$h_a = 1$, $h_b = 4$, $h_m = 0.8$, $d = 3$

Fig. 3: EMI measurement with beam switching antenna

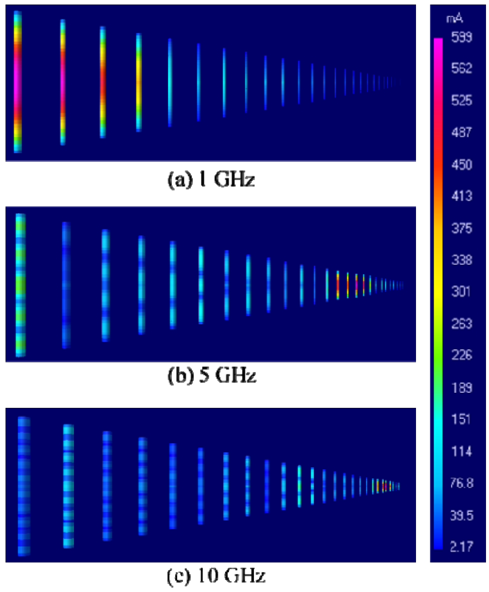


Fig. 4: Current distribution of log-periodic antenna

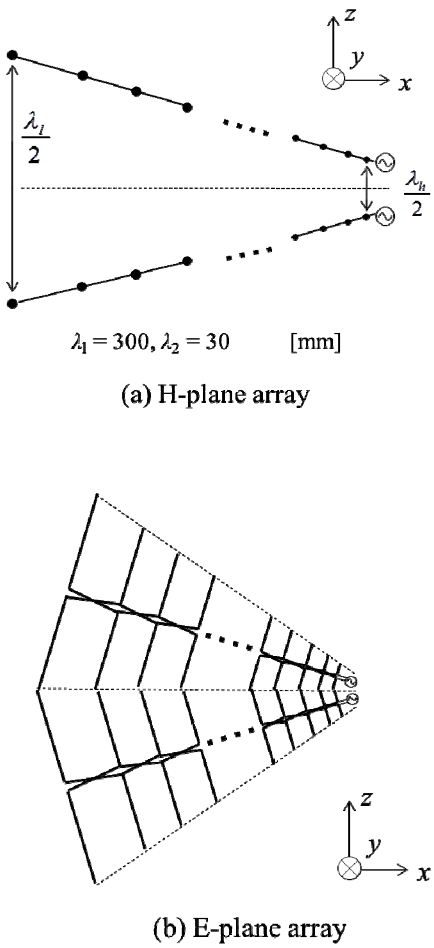


Fig. 5: Array geometry of log-periodic antenna

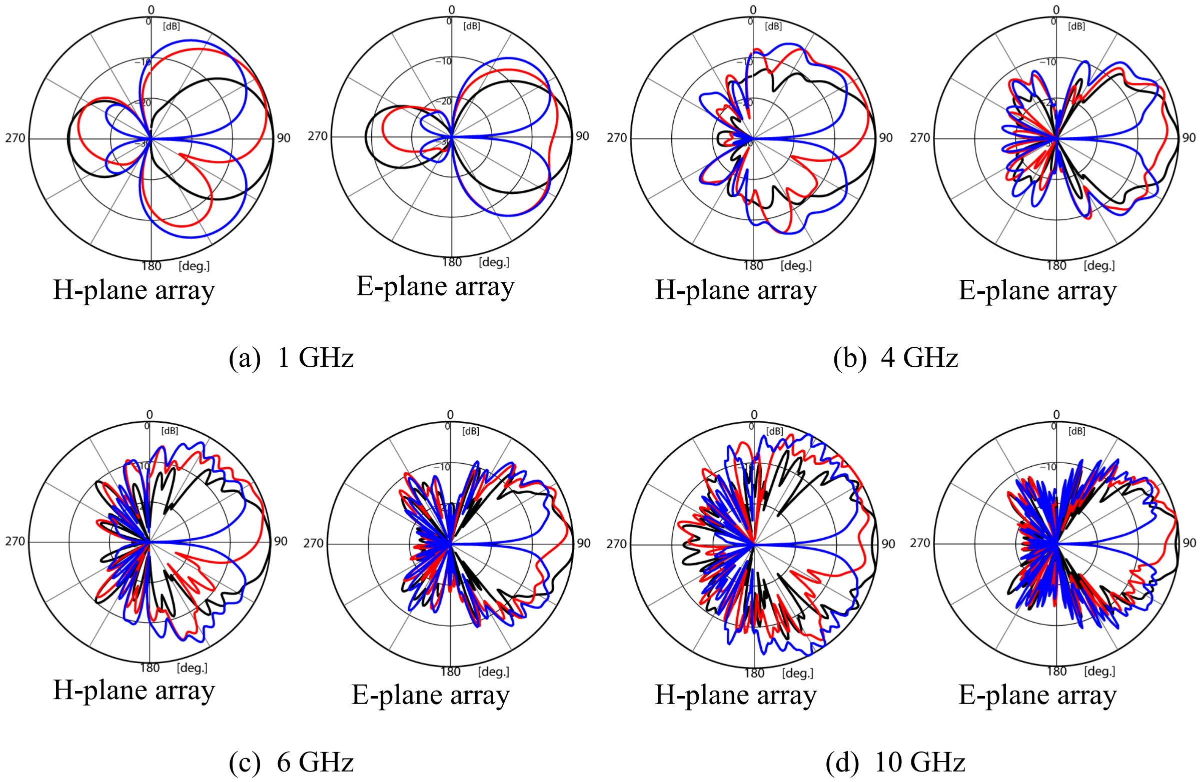


Fig. 6: Radiation pattern of each array (1 – 10 GHz, zx-plane), black: $\beta = 0°$, red: $\beta = 90°$, blue: $\beta = 180°$.

Table 1: The maximum gain and tilt angle for each frequency

(a) 1 GHz

	H-plane array		E-plane array	
Phase [deg.]	Gain [dBi]	Tilt angle [deg.]	Gain [dBi]	Tilt angle [deg.]
0	10.34	0	9.89	0
90	9.96	25	7.15	20
180	8.45	46	7.43	33

(b) 4 GHz

	H-plane array		E-plane array	
Phase [deg.]	Gain [dBi]	Tilt angle [deg.]	Gain [dBi]	Tilt angle [deg.]
0	11.52	0	10.17	0
90	10.49	25	8.92	23
180	8.19	34	8.21	28

(c) 6 GHz

	H-plane array		E-plane array	
Phase [deg.]	Gain [dBi]	Tilt angle [deg.]	Gain [dBi]	Tilt angle [deg.]
0	11.0	0	10.22	0
90	10.43	19	8.92	27
180	7.75	33	7.46	29

(d) 10 GHz

	H-plane array		E-plane array	
Phase [deg.]	Gain [dBi]	Tilt angle [deg.]	Gain [dBi]	Tilt angle [deg.]
0	8.4	20	9.64	0
90	10.13	37	10.41	13
180	9.20	53	7.73	32