Elliptical Disk Monopole Antenna with Built-in Diode for PIM-Measurement Facility Assessment

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1. Introduction

To assess small anechoic chambers in terms of passive intermodulation (PIM), antennas generating stable PIM of which level can be controlled would be useful. As a method to generate the stable PIM, the incorporation of a diode into the parasitic element of a patch antenna was proposed [1]. Its maximum PIM level can be determined by rotating the parasitic element because the rotation of the parasitic element does not degrade both of the input characteristics and radiation pattern. On the other hand, omnidirectional antenna is another object to be tested in anechoic chambers. However, it will be difficult to introduce such a PIM source as a part of rotatable parasitic element without degrading the original antenna characteristics.

In this paper, an elliptical disk monopole antenna is chosen as omnidirectional antenna because of its broad band characteristics [2]. Several methods to incorporate a PIM source into the antenna are evaluated by experiment. As PIM source, electrically small dipole and small loop with diodes are used. The targets of this study is the mechanical controllable arrangement of PIM source with no electrical contact, and realization of controlling the maximum PIM around -80dBm for 43dBm/tone excitation which can be reducible down to the self-PIM of antenna itself. It is also important to have linearity in log scale against excitation power. As a result, we confirm the validity of the small dipole with diode and the effectiveness of its slanting arrangement for controlling PIM generation.

2. Antenna Configuration

In this paper, the two-tone test using f_1=2.05GHz and f_2=2.20GHz is carried out to evaluate the 3rd-order reverse PIM characteristics of the antenna at f_{PIM3}=1.90GHz. The antenna under test (AUT) should be designed to cover all the frequencies with small reflection. Figure 1 shows the antenna configuration. The antenna element is made of brass and mounted on a circular aluminium ground-plane. It is fed by a thick silver-plated cylinder with the diameter of 7mm. The antenna is connected to the PIM tester using DIN-7/16 coaxial connector.

As Figure 2 shows, to obtain stable PIM level we load the Schottky barrier diode (1SS108) as PIM source near the antenna element. There is air-gap h_d between the antenna element and the diode. Diodes are prepared in two forms; small dipole with diode and diode-loop. The small dipole with diode is used as it is, and the diode-loop is soldered edges of bended lead line of the small dipole. We propose two methods to control the PIM generation. First one is to control the PIM by diode position z_d, where the PIM generated from diode is dominated by the current distribution of the antenna element. Another one is the use of diode alignment angle ϕ_{d1} or ϕ_{d2}. In the small dipole method, the current on the diode is determined by ϕ_{d1} because the current on the antenna element is excited in the z-direction. In the diode-loop, the current on the diode is determined by ϕ_{d2} because the magnetic flux is excited parallel to the antenna element.

2. Effect of Loaded PIM Source on the Antenna Basic Performance

Figure 3 shows the measured S-parameter characteristics of the each antenna to evaluate the effect of loaded diode on the antenna basic characteristics, where the characteristics of the antenna with no diode are also presented for comparison purpose. The antenna without diode obtains the small reflection characteristics at the transmitting frequencies f_1 and f_2, which are less than -20dB. At the receiving frequency f_{PIM3}, S_{11} is about -15dB. These basic characteristics are maintained at the operating frequencies when the diode is loaded.

The effect of loaded-diode on the radiation pattern is estimated using FDTD method as shown in Figure 4, where only the result at 1.9GHz. In the *zx*-plane, the beam is launched to θ=45° because the antenna height is approximately 3λ/4. In the conical plane at θ=45°, uniform radiation pattern is obtained. Similar results are obtained at the transmitting frequencies f_1=2.05GHz and f_2=2.20GHz. Therefore, it is concluded that the effect of diode is negligible in the radiation pattern as well as the input characteristics.

3. PIM Characteristics

Figure 5 shows the measured PIM of proposed antenna as a function of diode position z_d. We evaluate two diode-dipoles with different length l_d and a diode-loop of that circumference l_c is 30mm. Excitation power $P_{\rm in}$ is 43dBm/tone, where the self-PIM of no-diode antenna is -106dBm. The PIM of diode-dipoles decrease linearly as z_d increases until 30mm. In the range from z_d =30 to 80mm, the PIM of l_d = 30mm increase gradually. The PIM of l_d = 15mm is constant around -106dBm in that range, which is not caused by the diode but the self-PIM of the antenna. The rapid increase of the PIM in the z_d > 80mm is caused by the electrical coupling of the diode-edge to the antenna edge. The optimum parameter satisfying the maximum PIM requirement is l_d = 15mm and z_d = 5mm, which exhibits -75dBm. On the other hand, the diode-loop produces quite high PIM such as the maximum level of -30dBm, although it has similar tendency with PIM of diode-dipole in the range from z_d = 5 to 80mm. When z_d is greater than 80mm, it maintains the constant PIM around -60dBm. It indicates that the coupling using magnetic flux is too strong for PIM source. As a consequence, the diode-dipole of which maximum PIM can be controlled from -106dBm to -80dBm is considered as better PIM source.

Although we obtained required maximum and minimum level, it is difficult to control PIM generation because PIM varies sharply by diode position. Accordingly, we propose another method for tuning the PIM generation. Figure 6 shows PIM response of the antenna with diode-dipole as a function of the diode alignment angle ϕ_{d1} (z_d=5mm). The maximum PIM level is measured when ϕ_{d1} = 0° and minimum level of -108dBm is measured when ϕ_{d1} = 90°. From 0° to 90°, PIM level decreases as ϕ_{d1} increases. This method using the angle ϕ_{d1} is more convenient than z_d because of its slow variation of PIM for the diode angle. Figure 7 shows PIM characteristics of the antenna with diode-loop as a function of the diode alignment angle ϕ_{d2} (z_d=35mm). Although it has similar tendency with the diode-dipole, the controllable range is limited to about 20dB. Therefore, diode-loop is attractive when high PIM generation is required.

Next, in Figure 8, we show the PIM characteristics of the antenna with diode as a function of input power $P_{\rm in}$. For comparison purpose, PIM response of the antenna without diode is also showed. Although the no-diode antenna has 3dB-slope even when the antenna is excited in 43dBm/tone, the antenna loading diode-dipole has decreased 2dB-slope, and saturation occurs when $P_{\rm in}$ is greater than 25dBm/tone. On the other hand, the antenna loading diode-loop has 3dB-slope when $P_{\rm in}$ is less than 31dBm/tone although saturation is observed under the high power condition.

As a result, the diode-dipole is better choice as built-in PIM source in terms of controlling the PIM production. The diode-loop can be another choice if quite strong PIM is required.

4. Conclusion

In this paper, a diode-loaded omnidirectional antenna was proposed for PIM-measurement facility assessment, and the effectiveness of the small dipole with a diode besides the elliptical disk monopole was confirmed. Fine tuning capability was obtained by the mechanical control of the diode-arrangement angle, and the achieved control range was from -75dBm down to -106dBm (self-

PIM level of antenna) for 43dBm/tone excitation. Approximate linear characteristics in log scale against excitation power were also confirmed for the diode-dipole loaded antenna.

References

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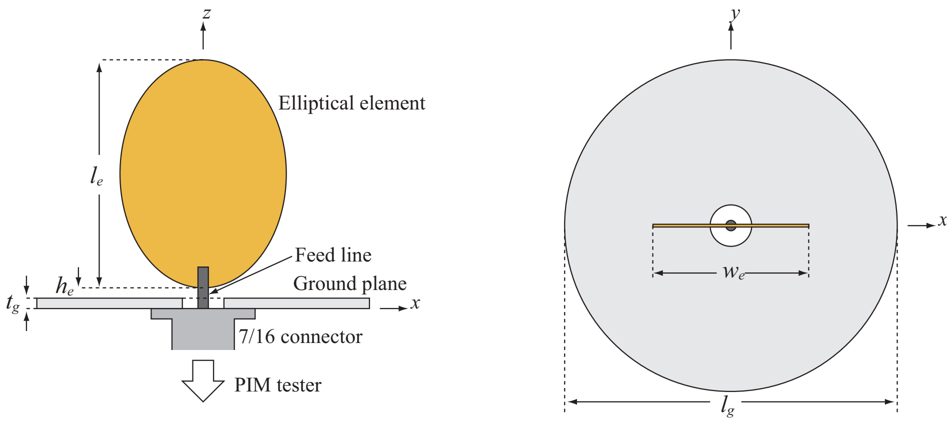
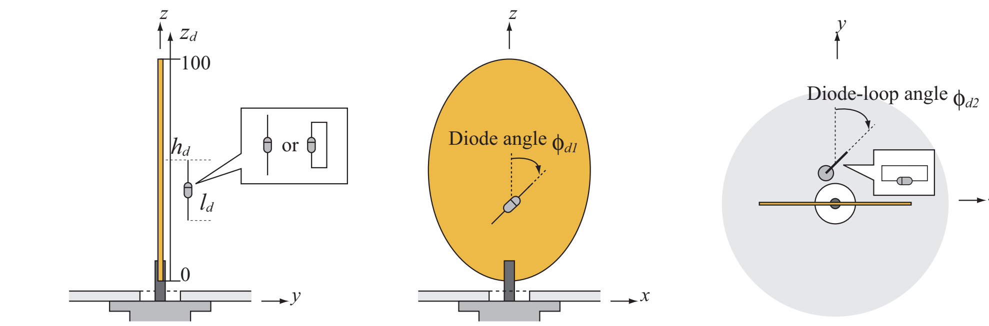
[2]N.P. Agrawall, G. Kumar, et.al., "Wide-Band Planar Monopole Antennas," IEEE Trans. on AP, Vol.46, No.2, pp.294-295, Feb. 1998



(a) Front View (b) Top View

$l_e = 100$, $h_e = 2$, $t_g = 10$, $w_e = 70$, $l_g = 300$ [mm]

Figure 1: Elliptical Disk Monopole Antenna



(a) Position of Diode(h_d=5mm) (b) Diode-Dipole (c) Diode-Loop

Figure 2: Antenna with PIM source

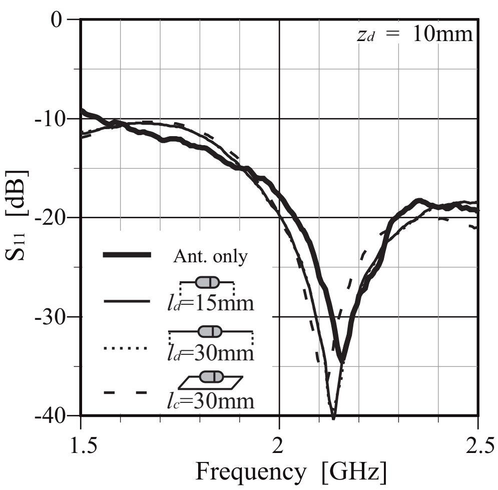


Figure 3: S_{11} Characteristics of the Diode-Loaded Antenna

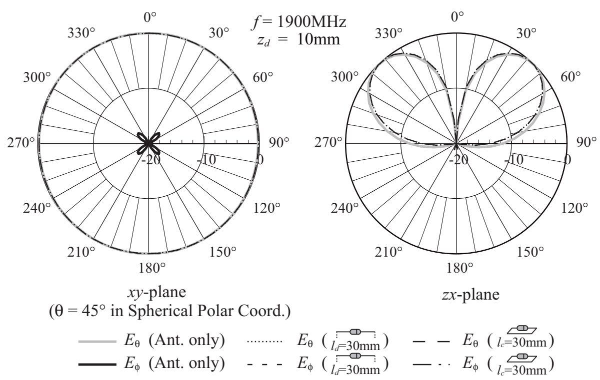


Figure 4: Radiation Pattern of the Diode-Loaded Antenna at 1.90GHz

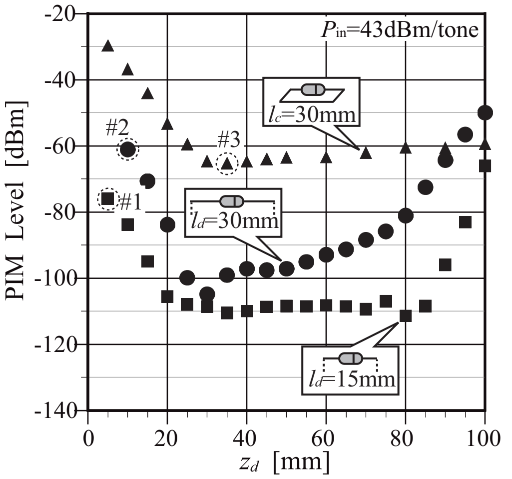


Figure 5: PIM Characteristics of the Diode-Loaded Antenna as a Function of Diode Alignment Position z_d

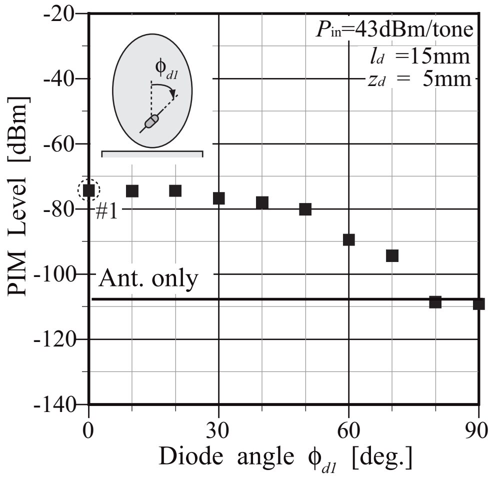


Figure 6: PIM Characteristics of the Diode-Loaded Antenna (l_d=15mm) as a Function of Diode-Dipole Angle ϕ_{d1}

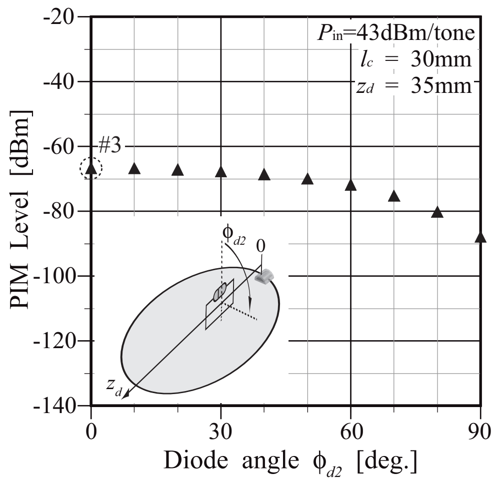


Figure 7: PIM Characteristics of the Diode-Loaded Antenna as a Function of Diode-Loop Angle ϕ_{d2}

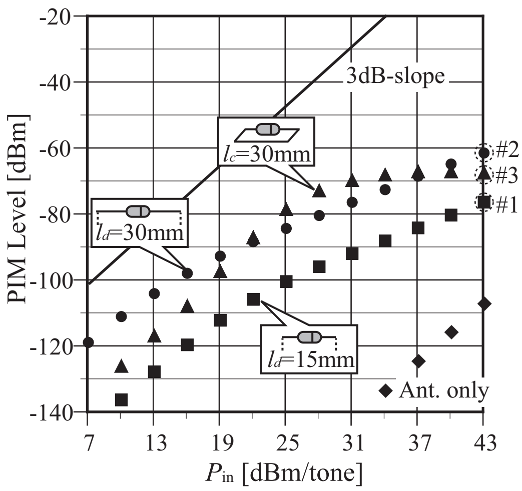


Figure 8: PIM Characteristics of the Diode-Loaded Antenna as a Function of Excitation Power P_{in}

Note

#1: l_d=15mm, z_d= 5mm, ϕ_{d1}=0°, P_{in}=43dBm/tone

#2: l_d=30mm, z_d=10mm, ϕ_{d1}=0°, P_{in}=43dBm/tone

#3: l_c=30mm, z_d=35mm, ϕ_{d2}=0°, P_{in}=43dBm/tone

(Figure 5 - Figure 8)