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An experimental consideration on the effect of antenna gain on the observed PIMs for an external PIM-source

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1. Introduction

Passive Intermodulation (PIM) is caused by non-linearity in passive circuits such as base station antennas in mobile communication systems [1]. When measuring PIM performances of a microwave device, standard PIM generators are very useful to assess the performance of a measurement system [2].

From such a background, PIM-source loaded on antennas have been studied by the authors [3] [4] [5]. The proposed antennas were based on the concept that a diode as PIM source is loaded in the proximity of the feeding element with no physical contact, and the produced PIM level can be determined by the placement angle of the diode. The patch antenna and the monopole antenna proposed respectively in [3] [4] and [5] had been developed as a simplified model of sector-beam array antennas and omni-directional pattern array antennas in cellular base-stations.

The final objective of our research is to asses a small measurement environment for large array antennas by using a small array antenna or a single element antenna. To realize that, we should discuss the effect of antenna gain on PIM measurements in a small space.

In this paper, an PIM-source loaded on printed dipole antenna which is an modification of [6] is proposed, and a simplified model of external PIM source [7] is also proposed. After presenting their basic performance in terms of PIM characteristics, the effect of antenna gain on PIM measurements will be discussed using the proposed antenna and the patch antenna in [3] [4].

2. PIM-source loaded on printed dipole antenna and external PIM-source

Figure 1 shows the configuration of a printed dipole antenna loading a diode as PIM-source. As shown in Figure 1(a), the conductive pattern of antenna is fabricated on the bottom side of a printed circuit board (PCB), and semi-rigid cable is used as feeding line instead of microstrip lines. In this paper, a 1. 6mm-thick PCB with ε_r=2. 6 is used, where the thickness of the copper foil is 35μm. In the semi-rigid cable, the outer conductor overlapping with the slit line on the PCB is partially removed to excite the antenna. A L_{os}-long open stub and a L_{ss}-long short stub is connected to the excitation point, which contributes to bandwidth enhancement for the antenna. An PIM-source (diode1) is loaded on the top side of the antenna as shown in Figure 1(b) and (c), where the diode is placed above the slit with a small air gap H_d. A loop-shaped PIM sources which made of an axial Schottky diode (RB721Q-40) is employed, and its perimeter is chosen as 30mm in this paper. The proposed antenna produces the maximum PIM when ϕ_{d1}=0°, and the minimum PIM when ϕ_{d1}=90°. Thus, PIM-level is determined by the angle of diode ϕ_{d1}. It does not affect the basic characteristics of the antenna except for produced PIM level.

Two types of external PIM sources are also prepared in this paper, and their configuration are shown in Figure 2. As shown later, the short-model and dipole-model are used for high-PIM production and

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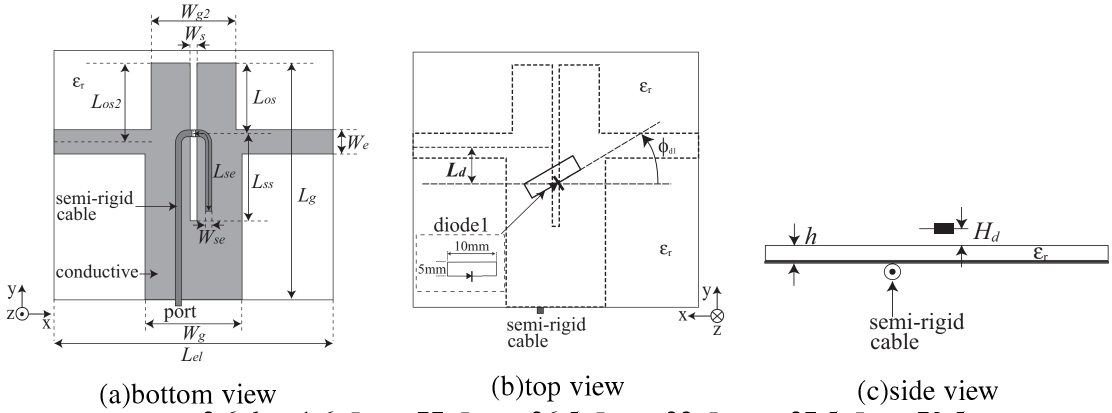


$\varepsilon_r = 2.6, h = 1.6, L_{el} = 77, L_{os} = 26.5, L_{ss} = 23, L_{os2} = 27.5, L_g = 72.5,$
$L_{se} = 24.5, W_g = 29, W_{g2} = 26, W_e = 6, W_s = 3, W_{se} = 4.3, L_d = 9, H_d = 13$[mm]

Figure 1: Configuration of a PIM-source loaded on printed dipole antenna

low-PIM production, respectively. The employed diodes are same products with the one employed in the antenna.

Figure 3 shows the measurement environment, which is an small anechoic chamber with $H \times D \times W$, where the parameters h, d_x, d_y represent the position of the antenna. A semi-rigid cable which has the same specification is used to connect the antenna to PIM-tester via a metallic wall of the chamber.

3. PIM characteristics

Figure 4 shows the observed PIM as a function of the input power when the diode angle ϕ_{d1}=0°, 50°, 90°, where the result of patch antenna presented in [3] is also shown as a reference. In this paper, the 3rd PIM at f_{IM3}=1. 9GHz is evaluated for 2-tone test with the input frequency f_1=2. 05GHz and f_2=2. 2GHz. It is confirmed that each result has almost 3dB/dB-slope which is linear in the log-scale in the measurement range to be tested. Although small saturation of the PIM-level in P_{in} >40dBm/tone is observed when ϕ_{d1}=0°, it can be negligible and can be improved by increasing the diode angle ϕ_{d1}. The saturated PIM-level ϕ_{d1}=0° is almost same with the one of the patch antenna [3]. From another viewpoint, it is confirmed that produced PIM level can be determined by the diode angle ϕ_{d1}, which is ranging from -56dBm down to -106dBm for the P_{IN}=43dBm.

Figure 5 shows the influence of the external PIM-source (diode2) on observed PIM level. The position of the external PIM source is chosen so that its influence on the input characteristics is negligibly small. Observed PIM level depends on employed external PIM sources, especially in ϕ_{d1} =90°. It is found that the short-type source produces high PIM, while the dipole-type source does not produce PIM so much.

We discuss the reason why the short-type source generates higher PIM than dipole diode. Since the short-type source has jumping wires in parallel with the diode, it can be seen as a 35mm-long conductive wire. Meanwhile in the dipole-type source, the current path on the element is intercepted by the diode, the source is considered as two conductive wires of which length is about 35/2mm. As a consequence, the current amplitude induced on the short-type source is much larger than that on the dipole-type source. It is the reason why the larger PIM is observed for the short-type source.

Next, we discuss the influence of antenna gain on observed PIM level. Figure 6(a) shows the observed PIM by the proposed printed dipole antenna in comparison with the patch antenna in [3], while the short-type source is commonly used as diode2. In this case the angle ϕ_{d2} and ϕ_{d1} are chosen as 0° and 90°, respectively. The difference of the observed PIM levels between two antennas is caused by their antenna gains. Now denoting the input powers of a patch antenna and a print dipole antenna to generate the same power density at the position of the external PIM-source respectively as P_p[dBm] and P_d[dBm], the gain difference G[dB] between the print dipole antenna and the patch antenna is given by

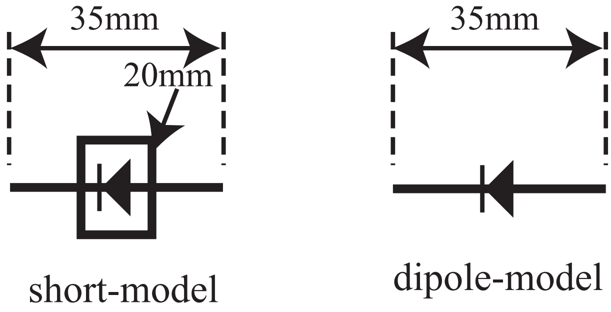
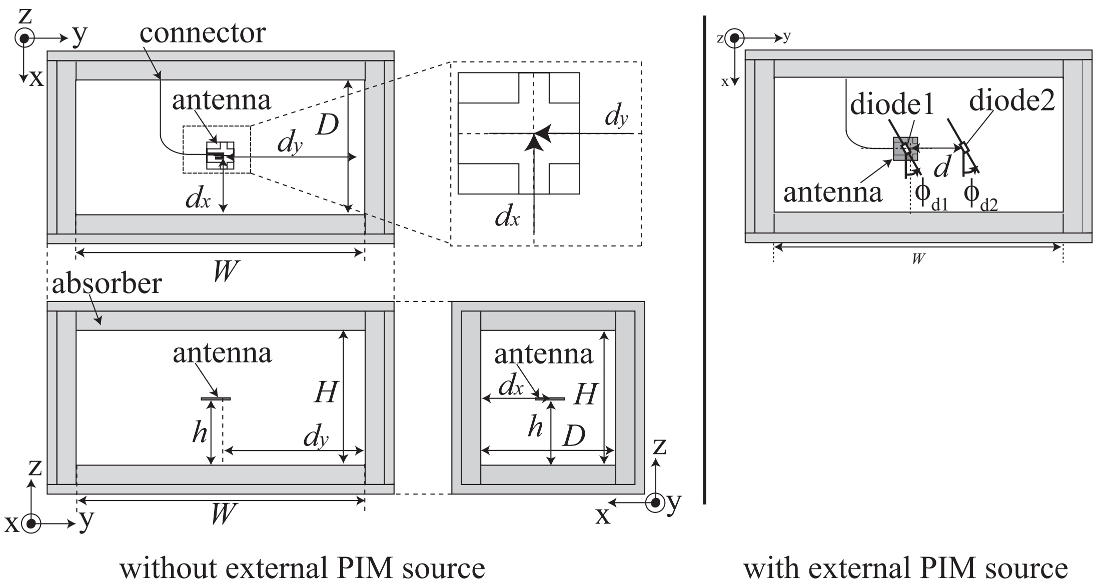


Figure 2: External PIM-source



$$h = 240, d_x = 240, d_y = 450, W = 1000, D = H = 500[mm]$$

Figure 3: PIM measurement environment using a small anechoic chamber

next equation.

$$G = P_d - P_p[\mathrm{dB}] \quad (1)$$

Denoting the received PIM-power of the patch antenna and the print dipole antenna respectively as $P_{p,IM}$[dBm] and $P_{d,IM}$[dBm], their relation is expressed by next equation.

$$P_{d,IM} = P_{p,IM} - G[\mathrm{dBm}] \quad (2)$$

Calibrating the observed PIM by the patch antenna using the above equations, resultant PIM value must be coincident to the one by the proposed patch antenna. The result is shown as Figure 6(b). In this case, the resultant gain difference G is determined as 5dB.

4. Conclusion

In this paper, a PIM-source loaded printed dipole antenna and a model of external PIM source were proposed, and their basic performances in terms of PIM characteristics were presented. The effect of antenna gain on PIM measurements was also discussed using the proposed antenna and the patch antenna in [3] [4]. As a result, it was shown that PIM levels observed by different antennas can be calibrated by considering the antenna gain.

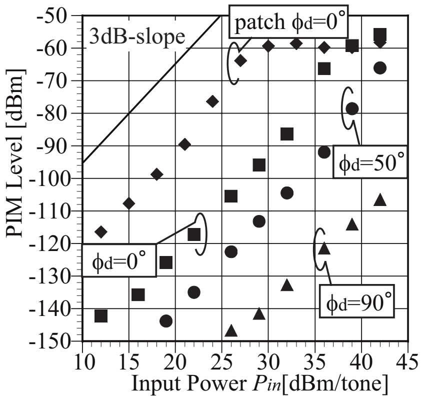


Figure 4: Observed PIM level as a function of the input power

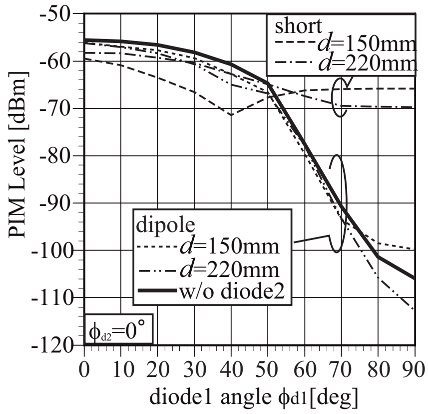
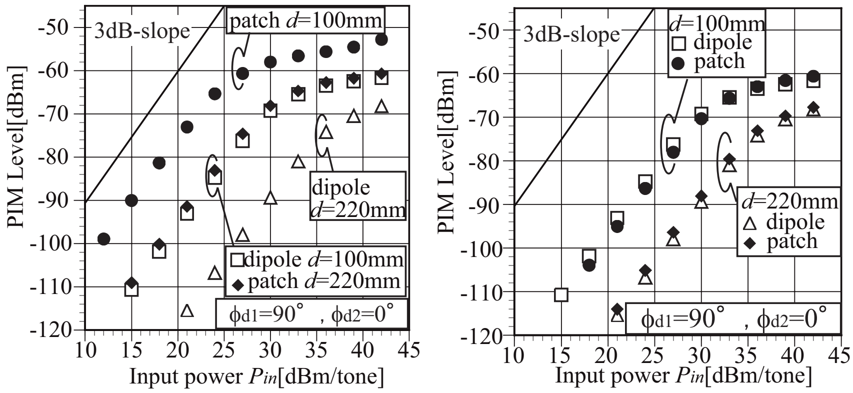


Figure 5: Effect of an external PIM-source on the observed PIM level of the antenna



(a)Experimental results@ (b)Calibrated results

Figure 6: Effects of antenna gain on observed PIM level and their calibrated results

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