Simple Channel Capacity Evaluation of MIMO Antenna Using Small Reverberation Chamber

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Abstract **– For multiple-input multiple-output (MIMO) antenna evaluation, over-the-air (OTA) performance testing is commonly conducted using fading emulator and reverberation chamber. However, such conventional approaches require huge and expensive measurement setups, and therefore, the simplification of the evaluating system configuration is a key challenge. In this paper, we propose a novel channel capacity evaluation method using a small reverberation chamber and only one-side MIMO antenna. In the proposed method, first, S-parameters of an evaluated MIMO antenna are measured in both free-space and a reverberation chamber. Then, scattering wave components are equivalently extracted by subtracting the former S-parameter from the latter. Finally, channel capacity is evaluated regarding the extracted scattering components as pseudo multipath-rich propagation channels. From experimental results, it is confirmed that the channel capacity characteristics obtained by the proposed method has a good agreement with that of 3D-uniform ring model.**

Keywords—MIMO antenna, Reverbera chamber.

I. Introduction

In recent years, for the purpose of speed-up in radio communications, multiple-input multiple-output (MIMO) technology has been widely introduced. MIMO channel capacity strongly depends on the antenna characteristics. In particular, a compact MIMO antenna has a problem that mutual coupling deteriorates transmission capacity. Therefore, the impact of the antenna characteristics on MIMO channel capacity needs to be evaluated.

Conventionally, over-the-air (OTA) testing is commonly conducted using fading emulator [1] and reverberation chamber [2] for MIMO antenna evaluation. However, such measurement setups could be large-scale and costly, and therefore, a simpler evaluation method is being required.

In this paper, we propose a novel channel capacity evaluation method using a small reverberation chamber and only one-side MIMO antenna. In the proposed method, first, S-parameters of an MIMO antenna are measured in both free-space and a reverberation chamber; the former S-parameter represents only reflection and mutual coupling of the antenna, while the latter contains not only the antenna characteristics but also scattering wave effect by the chamber. Then, regarding this scattering effect as a virtual multipath propagation process between the two identical MIMO antennas, pseudo multipath-rich propagation channels can be extracted by subtracting the former S-parameter from the latter.

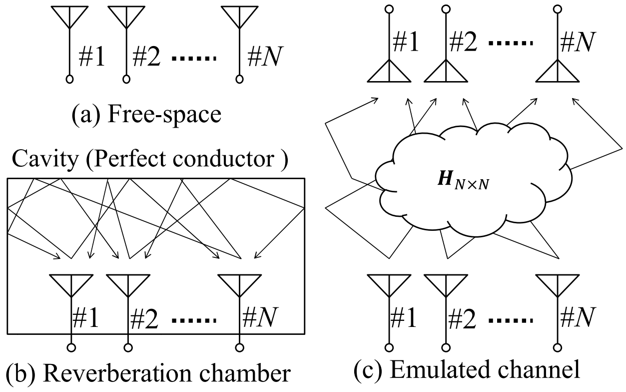

Fig.1 Proposed concept

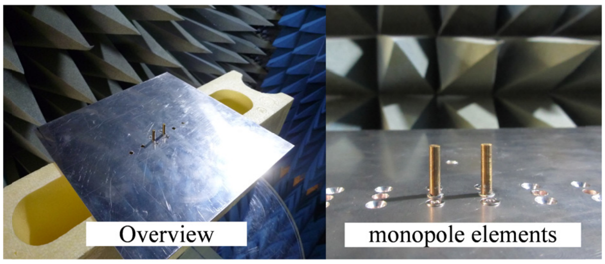

Fig.2 Fabricated antenna

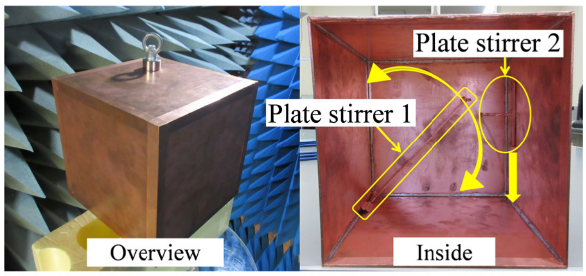

Fig.3 Reverberation chamber

In the rest of the paper, the theory of the proposed evaluation method is explained, and some experimental results are presented to demonstrate its validity.

II. Theory of Proposed Method

This section describes the theory of the proposed channel capacity evaluation method. Figure 1 shows the conceptual sketch of the propos ed method. First, two types of S-parameters of an evaluated MIMO antenna are measured in free-space and in a reverberation chamber, and defined as $\boldsymbol{S}_{\mathrm{rad}}$ and $\boldsymbol{S}_{\mathrm{cap}}$, respectively. Note that both $\boldsymbol{S}_{\mathrm{rad}}$ and $\boldsymbol{S}_{\mathrm{cap}}$ are the N-th order complex matrices where N is the element number of the MIMO antenna. Ideally, $\boldsymbol{S}_{\mathrm{rad}}$ represents only reflection and mutual coupling characteristics of the MIMO antenna, where measurement in free-space is considered to be ideal, i.e. there is no influence of other objects such as cables. On the other hand, $\boldsymbol{S}_{\text{cap}}$ includes scattering wave components by the chamber besides the antenna characteristics. If the chamber is perfect electric conductor (PEC) and completely sealed, all radiated power is received and consumed at the MIMO antenna itself. Thus, by subtracting $\boldsymbol{S}_{\text{rad}}$ from $\boldsymbol{S}_{\text{cap}}$, only the scattering components can be extracted in theory. Then, this scattering effect is regarded as a virtual multipath propagation process between the two identical MIMO antennas, and a pseudo multipath-rich channel matrix is equivalently obtained as

$$\boldsymbol{H}_{N\times N} \simeq \boldsymbol{S}_{\text{cap}} - \boldsymbol{S}_{\text{rad}}.$$

Finally, using the above channel matrix, a MIMO channel capacity can be simply evaluated.

III. Measurement Setup

Figure 2 shows an evaluated two-element monopole array. Its antenna spacing was set to 14.12 mm, equivalent to a quarter-wavelength in the center frequency of 5.2 GHz. Figure 3 shows a copper reverberation chamber and it has a 20-centimeter cuboidal configuration. In the chamber, there are two stirring copper plates to emulate fading behaviors. Plates 1 and 2 in Fig. 3 are rotated clock-wise and moved parallel along the vertical side of the chamber, respectively. During the agitation, 100 channel matrix samples are measured at the center frequency.

IV. Measurement Result

Figure 4 shows the cumulative distribution function (CDF) of channel capacity. In the figure, "Proposed (solid line)" represents the channel capacity obtained by the proposed method. For comparison, the channel capacity calculated using 3D-uniform ring model is also shown as "Exact (dash line)." In the 3D-uniform ring model, 3D-uniform scatterers are assumed and measured 3D complex patterns of the MIMO antennas are factored into a calculation to consider antenna correlation. Here, the number of the scatterers was 100, and the number of trials was 1000. The channel capacities are calculated based on Shannon's theorem, and signal to noise ratio (SNR) was set to 20 dB. This figure shows that, 50 % values of proposed and exact distributions are almost same, although proposed CDF has steeper slope than exact CDF does. This reason is considered as due to insufficient agitation.

Figure 5 shows the channel capacity characteristics versus SNR. In the figure, 50 % capacities of CDF are shown. This figure, reveals the capacity of proposed result is in good agreement with that of exact over the analysis range of SNR. Consequently, these two results clarify that the proposed method offers high-accuracy channel capacity evaluation with a quite simple measurement configuration.

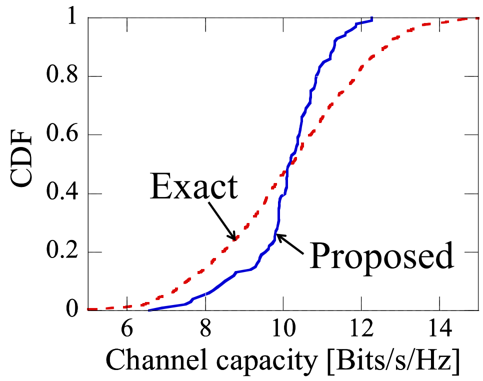

Fig.4 CDF of channel capacity

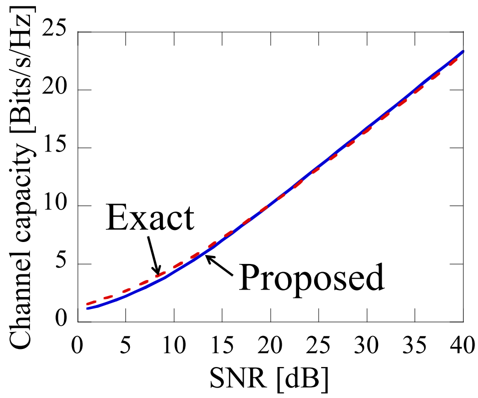

Fig.5 Channel capacity versus SNR

V. Conclusion

In this paper, a novel channel capacity evaluation method using a reverberation chamber and only one-side MIMO antenna has been proposed. Experimental results demonstrated that the channel capacity characteristics obtained by the proposed method were well accorded with those of 3D-uniform ring model. Thus, the experimental results support the proposed method offers simple and small-scale evaluation of MIMO antennas.

Acknowledgment

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References

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