Simulation of Direct Measurement Method for Balanced and Unbalanced Mode of a Small Antenna

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Abstract – **A simple measurement method for the balanced and unbalanced modal power ratios of a small antenna is proposed. Because the conductance corresponding to each mode can be calculated by applying the S-parameter method to the power dissipated at the antenna, the modal power ratio can be obtained by measuring only the 2-port S-parameters. In this paper, we demonstrate a simulation for the analysis of the modal power ratios of the folded dipole antenna using the proposed method. The results are in good agreement with the results calculated using the radiation pattern. The proposed method is useful for quantitative analysis of the unbalanced mode of an antenna mounted on a wireless device.**

Index Terms — **modal power ratio, S-parameter, balanced mode, unbalanced mode.**

1. Introduction

Because the performance of a small antenna will be changed by surrounding structures, it is important to reduce the influence of an unbalanced current. For example, in the case of measurements when connecting a coaxial cable to a small antenna, the impedance and radiation characteristics may be measured in different forms from its natural characteristics due to influence of the unbalanced current on the outer conductor of the coaxial cable. The S-parameter method is a measurement method that eliminates the influence of the unbalanced current [1]. In this method, the impedance of the antenna is obtained by synthesizing the full 2-port S-parameters under the condition that the unbalanced currents on the outer conductor of the coaxial cable are canceled at the feed point. The full 2-port S-parameters are measured by connecting two coaxial cables to the antenna element and the ground plane.

On the other hand, it is effective to use balanced antennas for antennas mounted on small wireless devices so as to reduce the influence of the surrounding environment. However, unbalanced current is also induced in the real-world case because of the asymmetric structures around the antenna. Thus, it is important to quantitatively evaluate the ratio of unbalanced modal power to total power. Some methods have been proposed in the past. One is a method that calculates the modal power ratio from the radiation pattern [2]. The other method uses a hybrid coupler [3].

In this paper, a simple measurement method for calculating the balanced and unbalanced modal power ratios of a small antenna is proposed. The modal power ratio can be directly obtained from full 2-port S-parameters. The formulation of the proposed method and the simulation results are shown below.

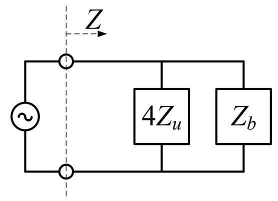
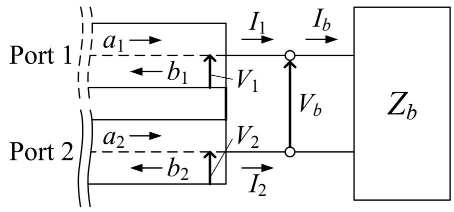
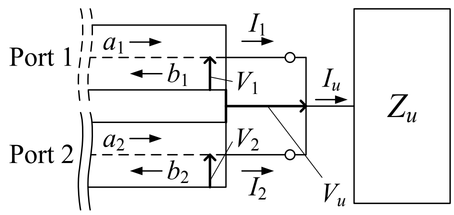


Fig. 1. Equivalent circuit model for input impedance of an antenna.



(a) Balanced mode



(b) Unbalanced mode

Fig. 2. 2-port network expression for each mode.

2. Formulation of modal power ratio using 2-port S-parameters

The impedance of the antenna at the feed point is represented as a parallel circuit with a balanced-mode impedance, Z_b, and an unbalanced-mode impedance, Z_u, as shown Fig. 1 [2]. Therefore, the dissipated powers of the balanced mode and unbalanced mode are expressed as follows:

$$R_b = \frac{G_b}{G_b + (G_u/4)}, \quad R_u = \frac{G_u/4}{G_b + (G_u/4)} \qquad (1)$$

where G_b and G_u are the conductances of the balanced mode and unbalanced mode, respectively. If the impedances corresponding to each mode are measured using the S-parameter method, the modal power ratio can be calculated from (1).

The antenna can be represented as a 2-port network; the impedances are calculated based on the relationship between the port voltage and the port current in each mode. Fig. 2 shows the 2-port network expression for each mode. The port voltages are defined as V_1 and V_2. The port currents are defined as I_1 and I_2. The balanced-mode impedance can be obtained under the condition of $I_1 = -I_2$, as expressed below.

$$Z_b = 2R_0 \frac{1 - S_{12} - S_{21} - S_{11}S_{22} + S_{12}S_{21}}{1 - S_{11} - S_{22} + S_{11}S_{22} - S_{12}S_{21}} \quad (2)$$

Similarly, the unbalanced-mode impedance can be obtained under the condition of $I_1 = -I_2$, as expressed below.

$$Z_u = \frac{R_0}{2} \frac{1 + S_{12} + S_{21} - S_{11}S_{22} + S_{12}S_{21}}{1 - S_{11} - S_{22} + S_{11}S_{22} - S_{12}S_{21}} \quad (3)$$

Substituting (2) and (3) into (1), the modal power ratio can be directly calculated from the S-parameters.

3. Simulation results

Fig. 3 shows the configuration of the simulated antenna. A folded dipole antenna is formed on a dielectric substrate. The length, width, and thickness of the substrate are 100 mm, 15 mm, and 1 mm, respectively. The length of the folded dipole is 96 mm, and the antenna resonates at 1.2 GHz. A conductor block that corresponds to the outer conductor of a coaxial cable is located at a right angle to the substrate. The conductor block extends into the absorption boundary to simulate a sufficiently long cable. Port 1 and Port 2 are used between the conductor block and each end of the folded dipole. A standard FDTD method is used. The cell size in the x and y directions is 1 mm and in the z direction is 0.5 mm.

Fig. 4 shows the frequency characteristics of the balanced and unbalanced modal conductance of the folded dipole antenna shown in Fig. 3. The frequency range is 0.4–2.0 GHz. The balanced-mode conductance is at its maximum in the vicinity of the resonant frequency. On the other hand, the unbalanced-mode conductance is nearly equal to zero at 1.2 GHz. This result shows the characteristics of a half-wavelength folded dipole antenna acting as a self-balanced antenna. The unbalanced current on the conductive block is suppressed at the frequency for which the length of the antenna is equal to one half of the wavelength. Thus, the effectiveness of the unbalanced current suppression can be quantitatively confirmed using the proposed method.

Fig. 5 shows the frequency characteristics of the unbalanced modal power ratio. The broken line indicates the result obtained using the proposed method. The dots indicate the result calculated from the radiation pattern using the method shown in the literature [2]. These results are in complete agreement. Therefore, the modal power ratio obtained using the proposed method is the same as the ratio of the actually-radiated unbalanced power to the total radiated power.

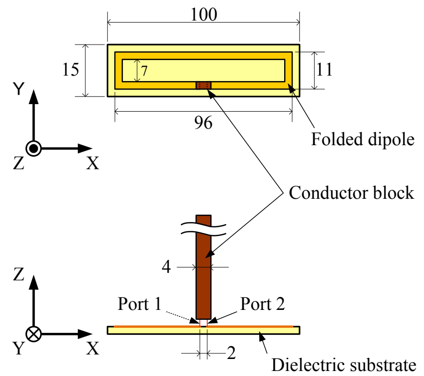


Fig. 3. Simulation model.

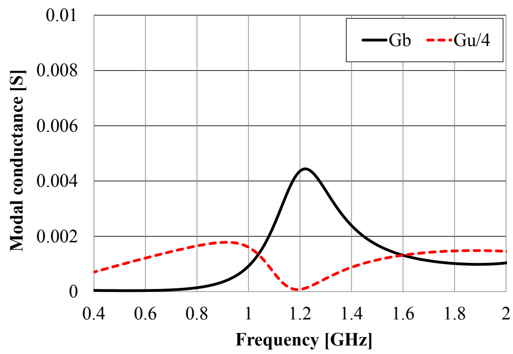


Fig. 4. Simulation result of balanced- and unbalanced-mode conductance of the folded dipole antenna.

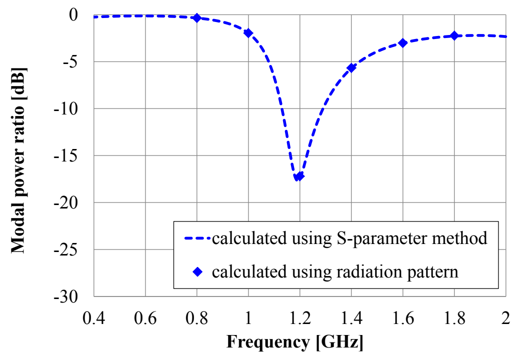


Fig. 5. Simulation result of unbalanced modal power ratio.

4. Conclusion

We have proposed a simple method for obtaining the modal power ratio of an antenna. We have confirmed the validity and effectiveness of the proposed method using a simulation of a folded dipole antenna.

References

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