Influence of Relative Permittivity of Jig Made of Microstrip Line for S-parameter Method

Taiga Yanagibashi, Takayuki Sasamori, Teruo Tobana, and Yoji Isota
Akita Prefectural University, 84-4 Tsuchiya-Ebinokuchi, Yurihonjo, Akita 015-0055, Japan

***Abstract* - Recently, S-parameter method that is the measuring method of the input impedance of the balanced antenna with a vector network analyzer is proposed. The method requires a jig composed of two unbalanced feed lines such as microstrip lines. The jig must be calibrated to achieve accurate results especially at high frequencies. To remove the influence of the jig, we have proposed the open correction and the modified open correction. In this report, we examine the influence of the relative permittivity of the jig on the S-parameter method using the FDTD method.**

***Index Terms* — S-parameter method, modified open correction, microstrip line, dipole antenna, input impedance.**

I. Introduction

In recent years, many wireless telecommunication services have spread over the world. It is known that the characteristics of conventional antennas, such as monopole antennas, change considerably when the body of the handset is touched by the hand. To decrease the influence of the hand, a balanced fed antenna is suggested [1]. Recently, the S-parameter method is proposed to measure the balanced impedance of the antenna using a jig instead of a balun, and two ports of a vector network analyzer (VNA) [2],[3]. Because the balun is not used, it is possible to measure impedance over a wide bandwidth. However, when measured frequency rises, it is known that measurement accuracy decreases because the influence of the jig cannot be disregarded for the measurement. To remove the influence of the jig from measurements of S-parameter method, we have examined the open correction, short correction etc. that use the ABCD-matrix [4].

In this report, to improve the measurement accuracy further, we examined the influence of the relative permittivity of jig made of microstrip line. We compare a calculated result of the wide-band input impedance of a dipole antenna using the S-parameter method compensated by the modified open correction with the delta gap fed dipole antenna using the FDTD method.

II. S-parameter Method

The S-parameter method is a method to obtain input impedance of a balanced-fed antenna by calculating measured S-parameters. Fig. 1 shows the dipole antenna, which is one of the balanced fed antennas. Using the impedance matrix of the two-port network, the equation for the dipole antenna is given by

$$\left.\begin{aligned} V_1 &= Z_{11}I_1 + Z_{12}I_2 \\ V_2 &= Z_{21}I_1 + Z_{22}I_2 \end{aligned}\right\}. \tag{1}$$

When the dipole antenna is fed by a balanced source, the currents that flow on the two radiation elements are $I = I_1 = -I_2$. Because the differential voltage is $V_d = V_1 - V_2$, the input impedance Z_{in} is expressed as follows using Z-parameter, in addition, it can be converted into ABCD-parameter.

$$\begin{aligned} Z_{in} &= V_d/I = Z_{11} - Z_{12} - Z_{21} + Z_{22} \\ &= \frac{1}{C}(A - D + AD + BC - 1) \end{aligned} \tag{2}$$

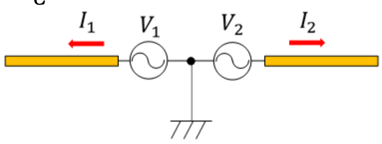


Fig. 1. Dipole antenna.

Fig. 2 shows the circuit diagram with an antenna connected to the jig for measurement in a two-port network configuration. The ABCD-matrix K' that is between the calibration planes can be determined by substituting the S-parameter in (3).

$$\mathrm{K'} = \begin{bmatrix} \frac{(1+S_{11})(1-S_{22})+S_{12}S_{21}}{2S_{21}} & \frac{(1+S_{11})(1+S_{22})-S_{12}S_{21}}{2S_{21}} \\ \frac{(1-S_{11})(1-S_{22})-S_{12}S_{21}}{2S_{21}} & \frac{(1-S_{11})(1+S_{22})+S_{12}S_{21}}{2S_{21}} \end{bmatrix} \tag{3}$$

As shown in Fig. 2, the characteristic of jigs are included in the ABCD-matrix K of the antenna can be obtained by removing the ABCD-matrices of jig $\mathrm{K_{J1}}$ and jig $\mathrm{K_{J2}}$, as given by

$$\mathrm{K} = \mathrm{K_{J1}^{-1}}\,\mathrm{K'}\,\mathrm{K_{J2}^{-1}}\,. \tag{4}$$

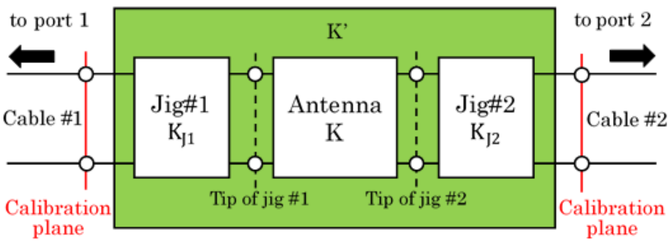


Fig. 2. Equivalent circuit diagram of antenna with jig.

III. Compensating Method for Jig

Open correction is the methods for determining the ABCD-parameter of the jig $\mathrm{K_J}$ using the characteristic impedance and the input impedance at the calibration plane when the jig is terminated in an open circuit [4]. In the conventional open correction, impedance of an open end is assumed Z=∞. Thus, the ABCD-matrix of the jig can be written as

$$K_J = \frac{1}{\sqrt{Z_O{}^2 - Z_0{}^2}} \begin{bmatrix} Z_O & -Z_0{}^2 \\ -1 & Z_O \end{bmatrix}. \quad (5)$$

Where Z_0 is the characteristic impedance of the jig and Z_O is the input impedance at calibration plane.

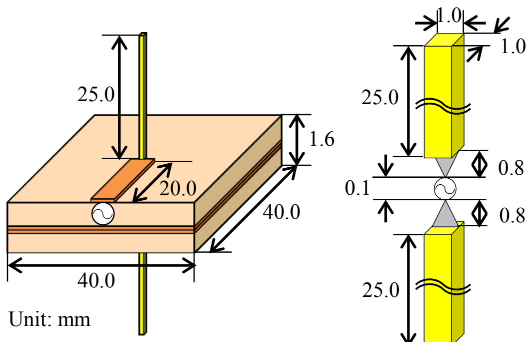
Actually, the impedance of the open end is not $Z = \infty$. Modified open correction is the methods for determining the ABCD-parameter of jig K_J using an impedance at the open end of the transmission line. The ABCD matrix of the modified open correction is given by

$$K_J = \frac{1}{\sqrt{(Z^2 - Z_0{}^2) - (Z_O{}^2 - Z_0{}^2)}} \begin{bmatrix} Z_O Z - Z_0{}^2 & -Z_0{}^2(Z - Z_O) \\ -(Z - Z_O) & Z_O Z - Z_0{}^2 \end{bmatrix}. \quad (6)$$

Where Z is the open end impedance of microstrip line, Z_0 is the characteristic impedance of the line, and Z_O is the input impedance at calibration plane when the line is terminated in an open circuit.

IV. Analysis Model for FDTD Method

Fig. 3 shows the analysis model of the dipole antenna. Fig. 3(a) is a dipole antenna with a measurement jig for the S-parameter method. The jig is made of two microstrip lines. The dimensions of the dielectric substrate are 40 × 40 × 0.8 mm^3. We examine the result of the S-parameter method, when ε_r = 2.15 and 5. The characteristic impedance of the microstrip line is 50 Ω. The dimensions of the radiation element of the dipole antenna is 1 × 1 × 25 mm^3. The open end impedance of the microstrip line is also calculated using the FDTD method. Fig. 3(b) shows a conventional dipole antenna fed by a delta gap. The dimensions of the radiation element is same as Fig. 3(a). There is a triangular metal plate between the delta gap feed and radiation element.

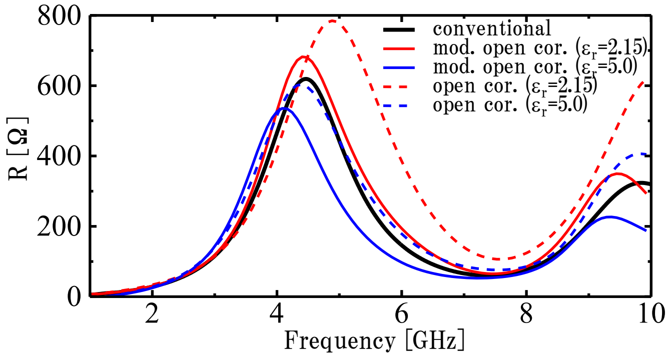


(a) Dipole antenna with jig. (b) Conventional model.

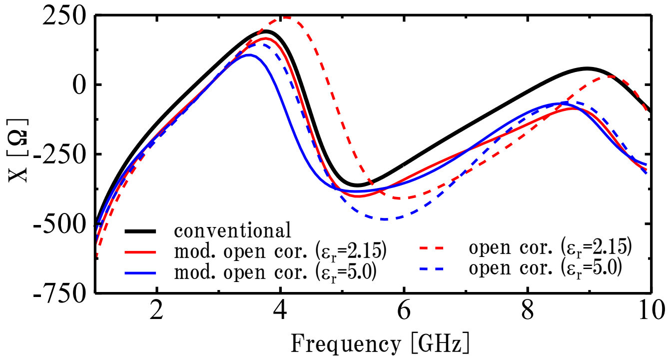
Fig. 3. Analysis model of dipole antenna.

V. Results and Discussion

Fig. 4 shows the calculated input impedance of the dipole antenna. The results of the S-parameter method are compared with the conventional model fed by a delta gap. When ε_r = 2.15, the results of the modified open correction is more agree with the conventional model than the open correction. On the other hand, when ε_r = 5, the results of the modified open correction is deviated away from the conventional model. It is considered that there is a problem in the calculated result of the end impedance.



(a) Resistance.



(b) Reactance.

Fig. 4. Input impedance of dipole antenna.

VI. Conclusion

In this report, to improve the measurement accuracy further, we examine the influence of the relative permittivity of the jig on the result of the S-parameter method. The input impedance of the dipole antenna is analyzed using FDTD method. To remove the influence of the jig from measurements of S-parameter method, the open correction and the modified open correction are performed. Consequently, it is considered that there is a problem in the calculated result of the end impedance.

References

[1] H. Morishita, Y. Kim, and K. Fujimoto, “Design concept of antenna for small mobile terminals and the future perspective,” IEEE Antennas Prepag. Mag., vol. 44, no. 5, pp. 30-42, Oct. 2002.

[2] R. Meys and F. Janssens, “Measuring the impedance of balanced antennas by an S-parameter method,” IEEE Antennas Propag. Mag., vol. 40, no. 6, pp. 62-65, Dec. 1998.

[3] K. D. Palmer and M. W. van Rooyen, “Simple broadband measurements of balanced loads using a network analyzer,” IEEE Trans. Instrum. Meas., vol. 55, no. 1, pp. 266-272, Feb. 2006.

[4] T. Sasamori, T. Tobana, and Y. Isota, “Broadband measurement of input impedance using S-parameter method,” IEICE Trans. Common. (Japanese Edition), vol.J96-B, no. 9, pp. 1067-1075, Sept. 2013.