Investigating the semi-rigid cable of a jig to improve the S-parameter method

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Abstract: Recently, the S-parameter method using a vector network analyzer was proposed whereby the differential input impedance of a balanced-fed antenna was obtained. To improve its measurement accuracy, the dependence on diameter of the semi-rigid cable used for the measurement jig is obtained from results of calculations using the FDTD method. Three jigs made from semi-rigid cables of differing diameter are fabricated; when coupled to a dipole antenna, the input impedances are measured as well as calculated using the S-parameter method. The impedances are also compared with those obtained from theories of King. Results from the S-parameter method indicate that using thinner-diameter coaxial cable produced very accurate measurements.

Keywords: S-parameter method, balanced fed antenna, modified open correction, measurement jig, semi-rigid cable

Classification: Antennas and Propagation

References

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1 Introduction

The antenna characteristics of a portable radio terminal are known to change greatly when the body of the terminal is held in the hand [1]. This is due to leakage current flowing on the body of the terminal. The effect of a balanced-fed antenna with symmetrical structure such as a dipole antenna and loop antenna was reported to diminish the effects on hand-held terminals.

Recently, the S-parameter method was proposed to measure the balanced impedance of the antenna using a jig instead of the balun and two ports of a vector network analyzer (VNA) [2]. Measurements using a balun can be made in a narrow band, but the S-parameter method permits measurements over a wide band. However, if the measured frequency rises, measurement accuracy decreases because during measurements the influence of the jig cannot be disregarded. To account for this jig influence, we propose a modified open correction using the ABCD-matrix [3]. Results of the S-parameter method using three semi-rigid cables of different diameter are compared [4]. However, the open-end impedance of three cables for the modified open correction were not shown.

In this report, to improve the measurement accuracy of the S-parameter method, the influence of the diameter of the semi-rigid cable used for the measurement jig is assessed using calculations developed within the FDTD method. First, three jigs are fabricated from semi-rigid cables of different diameters. Next, the open-end impedance of the three cables for the modified open correction are shown. Finally, the input impedance of a dipole antenna is calculated and measured using the S-parameter method, and the input impedances obtained are compared with those from available theories developed by King [5].

2 S-parameter method and open-end impedance

A diagram is given by the measurement system for the input impedance of a balanced antenna using the S-parameter method (Fig. 1(a)). The measurement procedure involves connecting the coaxial cables to each of the two input/output ports of the VNA. A full two-port SOLT (Short-Open-Load-Through) calibration is employed at the tip of the coaxial cables. Next, a measurement jig is soldered the radiation element of the balanced-fed antenna is connected the coaxial cable, from the measured S-parameter the input impedance is determined by calculation.

From Fig. 1(b), the characteristics of the jigs are included in the ABCD-matrix $K'$ of the antenna, which can be obtained by removing the ABCD-matrices of the jigs $K_{J1}$ and $K_{J2}$, as given by

$$K = K_{J1}^{-1}K'K_{J2}^{-1}. \quad (1)$$

The modified open correction method is used to determine the ABCD-parameter of the jig $K_J$ from the characteristic impedance of the transmission line $Z_0$, the measured input impedance at the calibration plane when the line is terminated in an open circuit $Z_{\text{Open}}$, and the calculated impedance at the open-end of the line $Z_L$. The ABCD-matrix of the modified open correction is then
Fig. 1(c) depicts the FDTD model of a semi-rigid coaxial cable used in calculating the open-end impedance. To connect the antenna element, the inner
conductor was 2 mm longer than the outer conductor. The open-end impedance $Z_L$ was calculated from the electric and magnetic fields at the end of the outer conductor. Given the specifications of the semi-rigid cable (Table I), we fabricated three jigs from semi-rigid cables of different diameters. The semi-rigid cables were designed with a characteristic impedance of 50 $\Omega$.

| Table I. Specifications of the three semi-rigid coaxial cables. |
|---------------------------------------------------------------|
| Diameter of outer conductor: $d_O$ | 1.2 mm | 2.2 mm | 3.6 mm |
| Diameter of insulation: $d_I$ | 0.9 mm | 1.7 mm | 3.0 mm |
| Diameter of inner conductor: $d_i$ | 0.3 mm | 0.5 mm | 0.9 mm |
| Relative permittivity | 2.1 | | |
| $\tan \delta$ | | | 0.0002 |

Fig. 1(d) and (e) shows the compensated results of the open-end impedance (resistance, reactance) for the three semi-rigid cables. The resistance values are almost constant with respect to frequency. Theoretically, the resistance value at the open-end is 0, but this calculation is not 0 because the open-end radiates what is radiated from the open end. The reactance values are inversely proportional to the waveform, indicating that the three semi-rigid cables are characterized by electric capacity. Therefore, the results for the open-end impedances are reasonable.

3 Results and discussion

Fig. 2(a) shows the calculation model of the dipole elements with a measurement jig for the S-parameter method. To obtain the analysis results of the input impedance, an FDTD model of a dipole antenna is employed. The dipole element has a roughly circular cross-section of diameter 0.8 mm and a total length of about 57.0 mm. Fig. 2(b) presents a photo of the dipole element with measurement jig used for the S-parameter method. Coupling each of the fabricated jigs in turn, the input impedance of the dipole antenna was calculated and measured using the S-parameter method. The space of the antenna device was changed by inserting a jig because the total length needed to remain constant.

Fig. 2(c) and (d) shows the calculated input impedance of the dipole antenna. Using the three fabricated jigs, the input impedance of the dipole antenna was calculated using the S-parameter method, and compared with the available theories by King. The results of the S-parameter method were adjusted using the modified open corrections. At roughly 3 GHz and below, all three results from the S-parameter method and those from the theory of King were in good agreement. Moreover, results from the jig fabricated from thinner cable is preferred as frequency rises.

Fig. 2(e) and (f) shows the measured input impedance of the dipole antenna as well as similar results. The peak of the waveform is seen at 2.6 GHz agreeing with the maximum value of the measured input impedance at the open end of the semi-rigid coaxial cable at 2.6 GHz. This represents a numerical error of the modified open correction. The resonant frequency was confirmed to be lower because the
spacing in the antenna device is spread open as the cable diameter increases. Therefore, more accurate measurements are believed to be obtained when the spacing of the antenna device is small.

4 Conclusion
To improve the measurement accuracy of the S-parameter method, we investigated the influence of diameter of the semi-rigid cable used for the measurement jig. The influence of diameter were assessed by comparing the input impedance of the dipole antenna obtained using three jigs fabricated from semi-rigid cables of different diameters. 

Fig. 2. S-parameter method setup and input impedance of the dipole antenna obtained using the S-parameter method
diameters and results from theories developed by King. We formulated the S-parameter method based on a two-port network and analyzed a practical setup where we eliminated the influence of the measurement jig in the measurement of the input impedance. Furthermore, to verify the validity of the proposed approach for this measurement, the results were given of the input impedance using the three fabricated jigs. The results of the S-parameter method showed that using thinner-diameter coaxial cable yields more accurate measurements.