LOW PERTURBATION ANTENNA IMPEDANCE MEASUREMENT TECHNIQUES

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ABSTRACT

The indirect two-port reflection method for measuring antenna impedances is reviewed using scattering parameter techniques and developed into a more accurate low perturbation optically coupled transmission measurement. This transmission measurement infers the antenna impedance by measuring the voltage induced in a number of loads connected to the antenna port with reference to the antenna used for illumination. Both these techniques have proved to be very versatile: applications to a typically electromagnetic compatibility problem, consisting of a box and wire above a ground plane, and to the design of a challenging multi-band Digital Audio Broadcast antenna are presented.

INTRODUCTION

In this paper we propose to present our latest results to illustrate the flexibility of the technique. The first application is a classical box-wire-box system, where the radiation impedance is solved by measuring the reflection coefficient from the probe antenna. The second application is an antenna measurement case, where a helical type antenna is measured by the low perturbation two-port measurement technique.

In the first case the radiation impedance is solved numerically in the way where the change of the impedance of the known antenna is measured when the wire connection to the box is loaded by three different loads of varying complex impedance. In this method the unknown radiating structure is measured through a two-port network [1]. The network describes the mutual coupling between the probe antenna and the radiation impedance of the measured system. The probe antenna is presented as port one and the transfer impedance as port two. The input impedance of port one is measured by a network analyser. After making reference measurements, the impedance of port two is calculated.

In the second case the antenna impedance is solved by measuring the voltage from the antenna port that is loaded by the set of varying loadings. In this case the two-port presentation is also used to present the coupling from the reference antenna through the loaded antenna into the network analyser. An electro optical (EO) system is used to minimise the effect of the the measuring cable that is used in conventional measurement.

INDIRECT ONE-PORT MEASUREMENT

The unknown antenna can be measured either by indirect [2] one-port measurement or by two-port measurement. The one-port measurement is presented in [3] and [4]. In the indirect method the impedance of an unknown antenna is solved by measuring reflections from the probe antenna for number of loads. The unknown antenna is loaded by three known loadings. Then the impedance is solved from 1-4.

$$\mathsf{A}\mathsf{y} = \mathsf{B}, \tag{1}$$

where

$$\mathsf{A} = \begin{bmatrix} Z_L(2) - Z_L(1) & Z_{in}(1) - Z_{in}(2) \\ Z_L(3) - Z_L(1) & Z_{in}(1) - Z_{in}(3) \end{bmatrix} \tag{2}$$

$$\mathsf{B} = \begin{bmatrix} Z_L(2)Z_{in}(2) - Z_L(1)Z_{in}(1) \\ Z_L(3)Z_{in}(3) - Z_L(1)Z_{in}(1) \end{bmatrix} \tag{3}$$

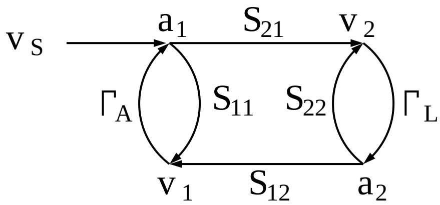

Figure 1: S-parameter presentation for 2-port

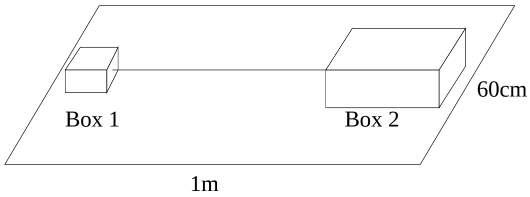

Figure 2: Set-up for box-wire-box system

and

$$\mathbf{y} = \begin{bmatrix} Z_{11} \\ Z_{22} \end{bmatrix}. \tag{4}$$

LOW PERTURBATION OPTICALLY COUPLED TRANSMISSION MEASUREMENT

Due to the sensitivity of the indirect method (as a one-port measurement) to small changes in the proximity of the known probe antenna and antenna under test as well as uncertainties in the proximity effects on the antenna impedance, a second non-contact measurement method was developed. Again the system was designed to remove the need for large cables to be attached to the antenna/system under test. This transmission measurement infers the antenna impedance by measuring the voltage induced in a number of loads connected to the antenna port with reference to the antenna used for illumination. The technique is based on the same two-port presentation as the indirect method is. In this case, $S21$ parameters are measured to predict the unknown antenna impedance. The impedance of the unknown antenna is solved from 5 and 6.

$$S22 = \frac{S21(1)\,T(2) - S21(2)\,T(1)}{S21(1)\,\Gamma(1)\,T(2) - S21(2)\,\Gamma(2)\,T(1)} \tag{5}$$

$$Z_{ant} = \frac{1+S22}{1-S22}\,50 \tag{6}$$

Where $\Gamma(n)$ are reflection parameters from EO system to the antenna, $T(n)$ are transfer parameters through the EO system from load to network analyser and Z_{ant} is the wanted antenna impedance.

BOX-WIRE-BOX BY ONE-PORT TECHNIQUE

In the first case, two metal boxes were placed above metal surface and they were connected together by a conductive wire, Figure 2. Box 1 has dimensions 190mm x 120mm x 80mm and Box 2 is 300mm x 300mm x 120mm in size. The boxes were connected by a wire which has 3mm diameter. The setup was illuminated by an logperiodic reference antenna and change of reflection parameters were measured by network analyser for three known loadings. Then the radiating impedance was calculated from recorded data. The radiation impedance was also measured directly from the loading point. Measured complex impedances are in good agreement as shown in Figure 3.

ANTENNA MEASUREMENT BY ELECTRO OPTICAL SYSTEM

The measurement system consisted of a drive antenna (bilog) driven from the network analyser. The antenna under test was positioned 3m from the source antenna (in an anechoic chamber or on an open field test site) and was again connected to a switched load. The output from the load was amplified and routed to the network analyser measurement system via an optical system consisting of a modulator, optical fibre and de-modulator. The switched load was controlled via another

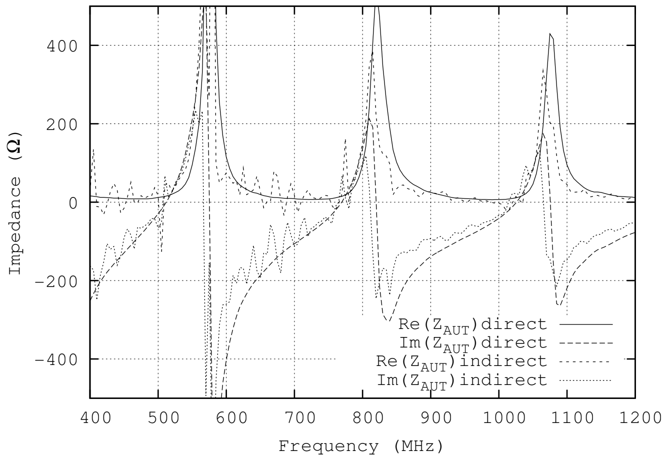

Figure 3: Measured impedance by direct and indirect method

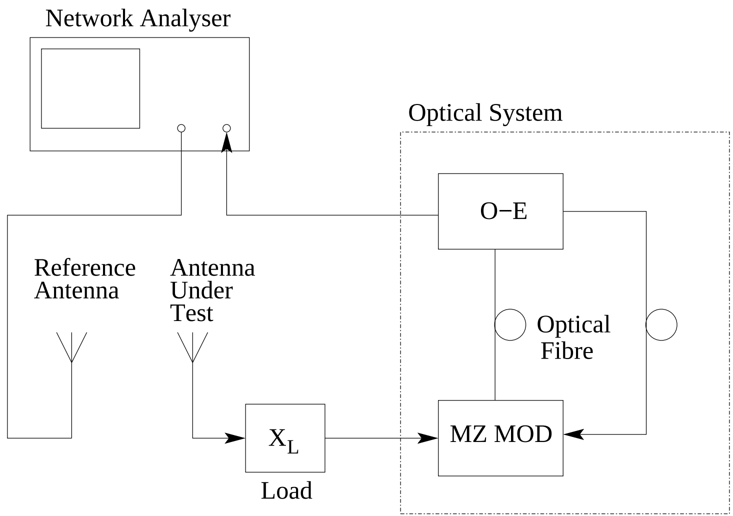

Figure 4: Setup for Electro Optical antenna measurement

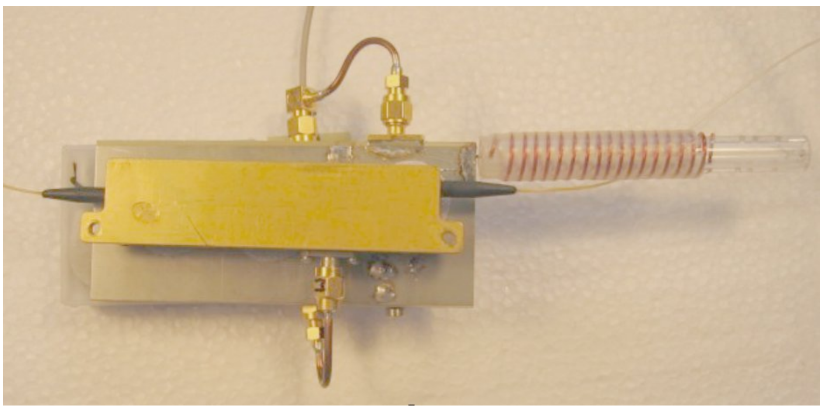

Figure 5: Measured device with EO system

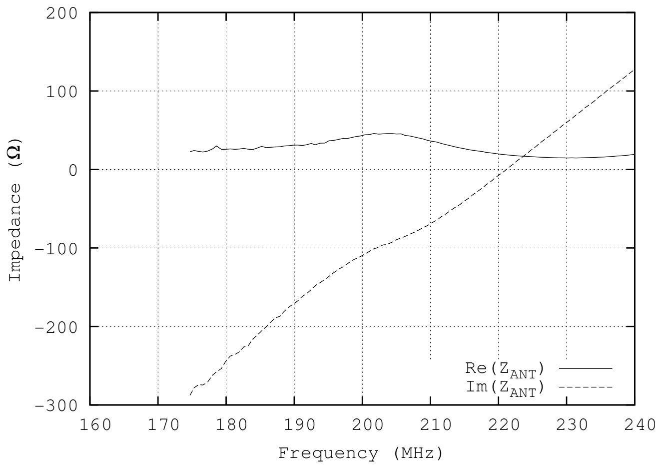

Figure 6: Antenna impedance measured by EO system

optical fibre to avoid the need to touch or move anything during the measurement, Figure 4. The measured device with EO system can be seen in Figure 5.

The switched loads consisted of four reactive loads were equally spaced around the complex plane. The calculations were made using two opposing loads to obtain two sets of results. The measured impedances for both load sets were equal. This gave some degree of confidence in the results obtained. The complex impedance of the measured antenna can be seen in Figure 6.

The whole system was designed to operate under computer control with the results being calculated by the controller at run time so that problems could be investigated while the system was set up. The advantage of this system is that it could also be used to measure the field pattern of the antenna/system due to the lack of cables which in standard measurement environments can cause problems due to coupling to the cables and reflections from them.

DISCUSSION

In previous studies it was found that the stability of the physical placement is very critical factor to achieve reliable results, [3] and [4]. In this study, spacing accuracy was solved by the usage of remotely controlled loadings. When there is no need to interfere the physical placement of the measuring system the mutual coupling remains stabile during the measurement. That gives more reliable results even that the mutual coupling is week. The limiting factor in that case is the numerical accuracy of the measured parameters. Amplification of the measurand will increase the confidence of the used methods as we can see from the resent results from the new low perturbation EO method.

CONCLUSIONS

In cases where the two-port technique can be compared with conventional techniques, the measurement results are in good agreement with the conventional measurements. In other cases where conventional measurements cannot be made the two-port technique gives an usable method to predict the radiating impedance of an unknown antenna structure.

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