A Novel Calculable Loop Antenna for Antenna Calibration Verification below 30MHz

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***Abstract*—A novel calculable loop antenna is proposed for the purpose of the antenna calibration verification below 30MHz. The calculable loop is formed by connecting a balun with a metal bending wire. For a pair of such loop antennas, the site insertion loss (SIL) is obtained by combining the measured balun scattering（S）-parameter and the calculated method of moment(MoM) S-parameter of the site two-port network. The difference of the measured SIL and the calculated SIL are within 0.62dB over 600kHz to 30MHz. As the antenna factor can be derived accurately from the SIL, the proposed calculable loop can be treated as a standard antenna as well in the calibration.**

Keywords—standard antenna; calculable loop antenna; calibration; site insertion loss (SIL)

I. INTRODUCTION

Loop antenna is widely used in the electromagnetic compatibility(EMC) field to measure the RF magnetic field strength for the frequency range below 30MHz. Its magnetic field antenna factor needs to be known.

To get the antenna factor, accurate calibration for Loop antenna is required. Several techniques have been developed for measuring the magnetic field antenna factor. Such as standard field method employing the TEM(Transverse electro-magnetic) cell or the Helmholtz coils below 150kHz[1]. A standard field method using a standard transmitting loop, and the three antenna method is also developed[2][3]. However, for the current calibrations, it has difficulties achieving great accuracy, and the calibration verification is unavailable.

Calculable loop is a key solution to this problem. It was proposed in [4] a calculable loop antenna to act as the transmitting or the receiving antenna in the standard field method to measure the magnetic field generated accurately. A novel calculable loop with improved performance proposed in this paper is the combination of a bend metal wire and a balun transformer. The SIL between a pair of loop antennas is calculated using the S-parameters network cascading technique. If the SIL, hence the antenna factor of the loop antenna can be accurately determined, it means that the proposed calculable loop can be applied to verify the loop antenna calibration and even be a reference antenna in the calibration.

II. CALCULABLE LOOP ANTENNA DEDISGN

The calculable loop antenna is formed by connecting a balun with a metal bending wire, see Fig.1.

For a pair of loop antennas facing each other, the SIL calculation requires the S parameters from three 2-port networks, *P*, *Q* and *R*, as illustrated in Fig.1. They represent for the transmitting loop balun1, the site, and the receiving loop balun2, respectively.

Therefore based on the flow chart of the network, t_{21} for the cascade combination of *P, Q, R* can be expressed as[5]

$$t_{21}=\frac{p_{21}q_{21}r_{21}}{(1-r_{11}q_{22})(1-q_{11}p_{22})-q_{21}r_{11}q_{12}p_{22}} \tag{1}$$

Where

$$P=\begin{pmatrix}p_{11} & p_{12}\\ p_{21} & p_{22}\end{pmatrix},Q=\begin{pmatrix}q_{11} & q_{12}\\ q_{21} & q_{22}\end{pmatrix},R=\begin{pmatrix}r_{11} & r_{12}\\ r_{21} & r_{22}\end{pmatrix} \tag{2}$$

The SIL can be obtained through

$$A=20\lg\frac{1}{|t_{21}|} \tag{3}$$

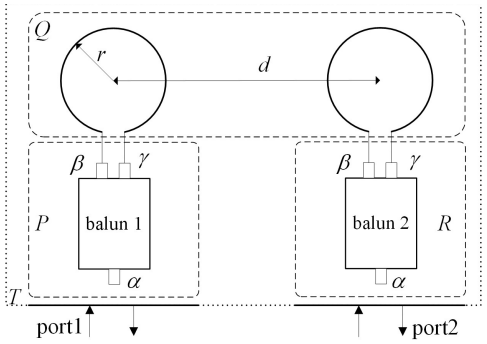

Figure 1. Proposed calculable loop antennas

It should be noted that such method has been used to make the calculable dipole antenna [5][6].

A. Calculation of P,R

After measuring nine S-parameter for the three ports of each balun, α, β, γ ,by combining port β and port γ, it yields to a two port network, whose S-parameter can be obtained by the following formula[5]

$$\begin{aligned} p_{11} &= r_{22} = s_{\alpha\alpha} \\ p_{12} &= r_{21} = (s_{\alpha\beta} - s_{\alpha\gamma})/2 \\ p_{21} &= r_{12} = s_{\beta\alpha} - s_{\gamma\alpha} \\ p_{22} &= r_{11} = (s_{\beta\beta} + s_{\gamma\gamma} - s_{\beta\gamma} - s_{\gamma\beta})/2 \end{aligned} \tag{4}$$

B. Calculation of Q

Take a pair of loop antennas (without balun) with separation d as the site 2-port network. The 2-port S-parameters Q, which are normalized to 100Ω, can be calculated numerically using MoM.

III. Experimental Verification

A pair of calculable loop antennas are formed following the above principle and measurements are performed to verified the calculation. The loop diameter $2r$ is 10cm, and the separation d is 45cm. The balun is connected to the wire in a way that the common mode current is suppressed sufficiently.

A. Measurement of the 3-port balun

The amplitude and phase differences of port β and port γ are checked to make sure that the baluns are in good behavior after the 3-port S-parameter is measured. By using (4), P and Q can be obtained.

B. Measurement of the SIL

The measured SIL and the calculated SIL for the calculable loop antennas are shown in Fig.2, and the deviation, shown in Fig.3, is well below 0.62dB, which means that the magnetic antenna factor for each loop derived from the SIL would have

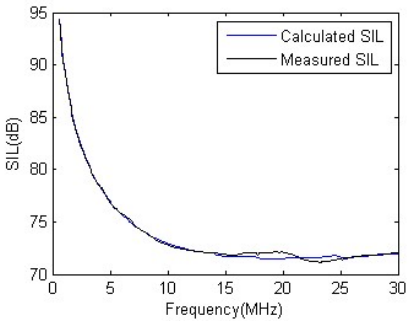

Figure 2. Measured and calculated SIL for a pair of loop antennas

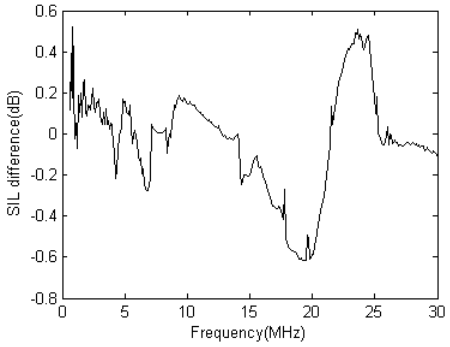

Figure 3. The deviation between the measured and calculated SIL for a pair of loop antennas

an uncertainty less than 0.3dB. It makes the calculable loop antenna good enough to be a standard antenna or a reference antenna.

IV. Conculsion

A novel calculable loop antenna is developed to verify the calibrations out of which an accurate antenna factor is expected. The method which was previously used to make the calculable dipole antenna is introduced here to calculate the SIL of a pair of loop antennas. The calculation requires accurate S-parameter measurement of the baluns and a MoM simulation of the two rings on the site. A pair of 10cm diameter calculable loop antennas are made to verify the design. The measured SIL and the calculated SIL agree well, and the deviation is within 0.62dB over 600kHz to 30MHz frequency range, hence the magnetic antenna factor derived could have even lower uncertainty which makes the calculable loop antenna not only a verification tool, but also a standard antenna with an accurate antenna factor.

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