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# IMPEDANCE STABILIZATION NETWORKS FOR MEASURING DISTURBANCES AT BALANCED MULTIPLE-PAIR TELECOMMUNICATION SIGNAL PORTS

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## ABSTRUCT

A dedign method of Impedance Stabilization Networks (ISNs) for measuring disturbances at balanced multiple-pair telecommunications signal ports is proposed. This paper describes that newly developed ISN designed by the proposed method meets the draft requirements proposed by IEC/CISPR Sub-Committee G and can measure disturbances at telecommunication signal ports of both analog and digital telecommunications equipment without a current probe.

## INTRODUCTION

Wide introduction of digital, high-speed and broad band equipment in the field of advanced information systems has resulted in a serious increase in electromagnetic noise and the resulting interference among systems. For telecommunications systems, this interference has also aroused an interest in the problems of electromagnetic compatibility (EMC). To restrict electromagnetic noise and to achieve EMC, the International Special Committee on Radio Interference (CISPR) has been investigating the additional requirements for emission from information technology equipment connected to public network or local area networks.

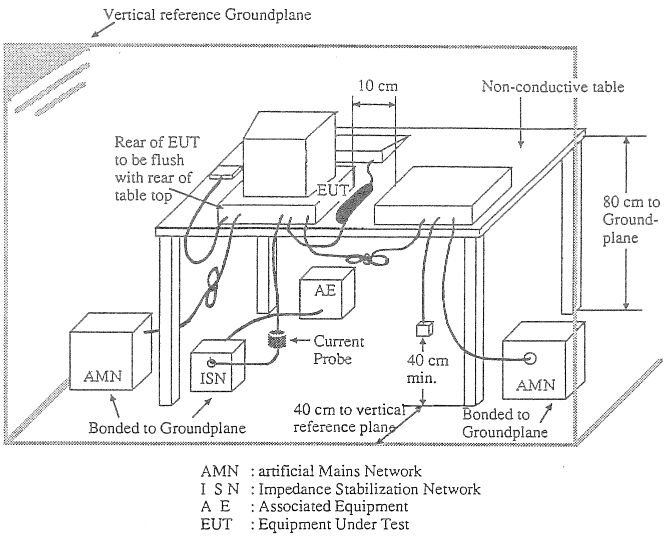
CISPR Sub-Committee G (CISPR/SCG) has been studying the limits and measurement method of disturbances at telecommunication signal ports [1]. In CISPR/SCG, when measuring the disturbances at telecommunication signal ports, the use of an Impedance Stabilization Network (ISN) is agreed in order to get measurement reproducibility. When measuring the disturbance level, common mode voltage is measured by an ISN or common mode current is measured by a current probe in combination with an ISN. Recently developed telecommunications systems use high-speed digital signals, and more than 4-wire (balanced 2-pair) to communicate between terminals. Therefore, ISNs should be designed for use with both conventional analog signals and digital signals, and with telecommunications line using more than 4-wires.

An ISN for 2-wire (a balanced pair) telecommuncation signal ports is already available [2]. Two types of 4-wire ISNs have been proposed in CISPR/SCG [1],[3], but one cannot be used to measure the disturbances at analog telecommunication signal ports due to large insertion loss, and the other needs a current probe to measure the disturbances.

In this paper, a design method of ISN for balanced multiple-pair telecommunication signal ports is described. Then we show prototype 4-wire ISN produced on the basis of the design method and show that the 4-wire ISN can be used for emission measurement both analog and digital telecommunications equipment with balanced 2-pair telecommunication signal ports. Finally, Measurement results show that the developed ISN meets the draft requirements proposed by CISPR/SCG and can measure disturbances at both analog and digital telecommunication signal ports without a current probe.

## DESIGN METHOD OF ISN FOR BALANCED MULTIPLE-PAIR TELECOMMUNICATION SIGNAL PORTS

The conducted emission measurement layout at telecommunications signal ports for table top equipment is illustrated in Fig. 1 [4]. In CISPR/SCG, when measuring the disturbance level at telecommunication signal ports, the use of an ISN or




AMN : artificial Mains Network
I S N : Impedance Stabilization Network
A E : Associated Equipment
EUT : Equipment Under Test

Fig.1 Conducted emission measurement layout for table top equipment a current probe in combination with an ISN is agreed in order to get measurement reproducibility. To measure the disturbance level at telecommunication signal ports from 150 kHz to 30 MHz, CISPR/SCG proposes the draft requirements for ISN shown in Table 1 [1]. It is necessary for ISNs to satisfy the requirements shown in Table 1.

Table 1 Requirements for ISN

| Item | Requirements |
|---|---|
| Common mode impedance | Amplitude: 150 ±20 ohm (0.15-30MHz)<br>Phase angle: ±20 deg (0.15-30MHz) |
| Isolation | - The measured level from AE at the measuring receiver input shall be at least 10 dB below the relevant emission limit. |
| Longitudinal conversion loss (LCL) | - The specific system unbalance with reference to ground shall be satisfied in the presence of the ISN.<br>- The common mode component of the wanted signal due to insufficient LCL of the ISN shall not influence the measurement. |
| Insertion loss for signal | - The presence of ISN shall not affect the normal operation of the EUT. |

The basic configuration of the ISN for a balanced pair (2-wire) telecommunication signal ports is shown in Fig. 2 [2]. To stabilize the common mode impedance between wires and the ground, impedance Za terminates each wire to the ground through Zb. A common mode choke Ta is employed to suppress the common mode noise traveling from the

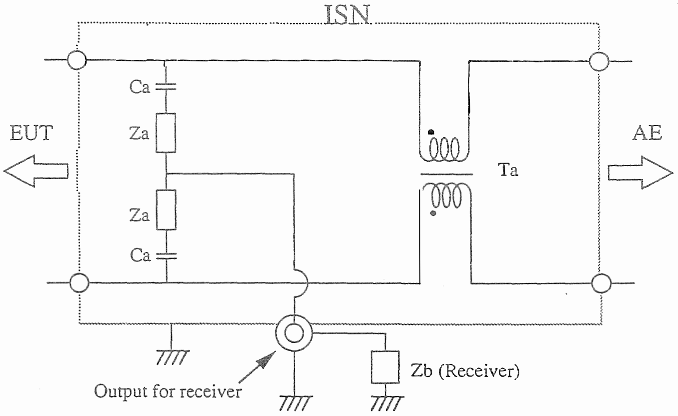



Fig.2 Basic configuration of the ISN for a balanced pair (2-wire) telecommunication signal port

associated equipment (AE) and to suppress the influence to the common mode impedance due to the terminating conditions at AE terminal of the ISN. Capacitance Ca inserted between each wire and Za blocks DC current in order to avoide the influence to normal operation of equipment under test (EUT). The disturbance level is obtained by measuring the voltage at the end of Zb or current by a current probe as shown in Fig. 1.

ISNs for balanced multiple-pair telecommunication signal ports should also satisfy the requirements shown in Table 1. Next we show a design method of ISN for balanced 2-pair telecommunication signal ports (4-wire ISN) by way of example for designing ISNs for balanced multiple-pair telecommunication signal ports.

The configuration of newly developed 4-wire ISN is shown in Fig. 3. To stabilize the common mode impedance between all wires and the ground, impedance Ra terminates each wire to the ground through Rb. A common mode choke Ta and capacitance Ca play the same role as those of 2-wire ISN. Rb and Rd form the circuit to measure disturbance voltage at telecommunication signal ports. It is therefore unnecessary to use a current probe for measuring the disturbance level.

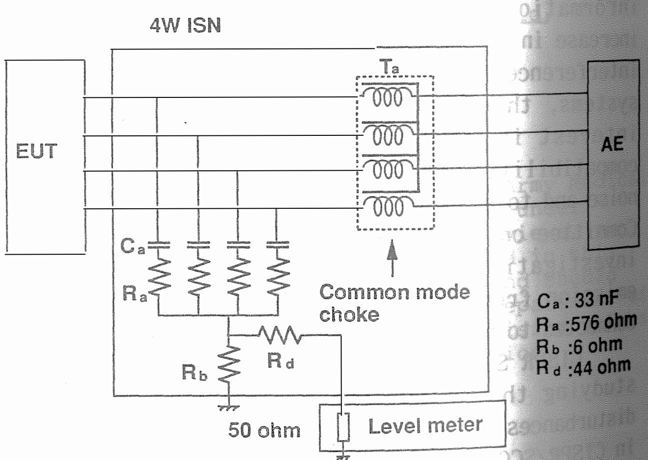



Fig. 3 Configuration of 4-wire ISN

The disturbance level is obtained by measuring the voltage at the end of Rb, where Rb is selected to be much lower than the impedance between the wires and the ground. Rd is used to match the impedance to the input impedance of the level meter.

From the conditions mentioned above, the relationship between Rb and the common mode impedance Zc is given by

$$|Zc| >> Rb \quad (1)$$

Rb of 6 ohm is selected because it is far less than |Zc| shown in Table 1. The relationship between Rb and Rd is also given by

$$Zr = Rb + Rd \qquad (2)$$

where Zr is the input impedance of a level meter (measurement receiver). As Zr is usually 50 ohm, Rd of 44 ohm is obtained.

Ra is determined to satisfy the requirement of common mode impedance. The relationship between the common mode impedance Zc and Ra is then given by

$$Zc = Ra/N + Rb//(Rd + Zr) \qquad (3)$$

here,

$$Ca >> 1/\omega Ra \qquad (4)$$

where, N is a number of wires and $\omega$ is angular frequency. When N is 4 (2-pair), Ra of 576 ohm is obtained from Eq. (3). Ca is determined from Eq. (4) and the requirement for insertion loss. The equivalent circuit of an ISN for normal mode signal is represented as shown in Fig. 4.

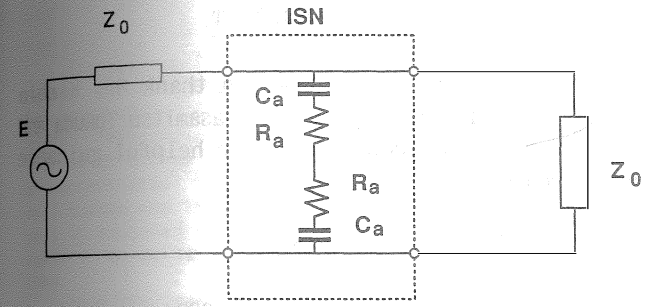



Fig. 4 Equivalent circuit for a normal mode signal

In Fig. 4, Zo is the characteristic impedance of the transmission line. The influence of the common mode choke Ta is neglected because the insertion loss of Ta for normal mode signal is very low. The insertion loss L is therefore given by

$$L = 20\log\{1 + Zo/(4(Ra + 1/j\omega Ca))\} \qquad (5)$$

From Eqs. (4) and (5), the optimum value of 33 nF is obtained.

The common mode choke Ta is designed to have sufficient insertion loss for common mode signals. It is also necessary for Ta to have large impedance for common mode signal enough to avoide the influence to common mode impedance Zc. The condition is given by

$$Zc << |Zt| \qquad (6)$$

where $|Zt|$ is absolute value of the impedance of Ta for common mode signal.

The parameters of the ISN are determined to meet the requirements by the method mentioned above and are shown in Fig. 3.

The design method mentioned above is also applicable to ISNs for more than 4-wire telecommunication signal ports.

## CHARACTERISTICS OF THE ISN

To confirm the validity of the design method, a 4-wire ISN was produced and the characteristics of the ISN were measured. Items measured are common mode impedance, common mode noise isolation, longitudinal conversion loss (LCL), insertion loss for normal mode signal and conversion factor. The conversion factor is the difference between the voltage appearing across the 150 ohms common mode impedance and the resulting voltage appearing across a 50 ohms measurement receiver input attached to the measuring port of the ISN. Measurement results are shown in Tables 2.

Table 2 Caracteristics of 4-wire ISN

| Item | Caracteristics |
|---|---|
| Common mode impedance | Amplitude: 150(-8/+0) ohm (0.15-30MHz)<br>Phase angle: 0(-7/+0) deg (0.15-30MHz) |
| Isolation | > 44 dB (0.15-30MHz) |
| Longitudinal conversion loss (LCL) | > 76 dB (0.15MHz)<br>> 60 dB (1MHz)<br>> 55 dB (10MHz) |
| Insertion loss for signal | 600 ohm: < 2 dB (300Hz-10kHz)<br>100 ohm: < 2 dB (100Hz-10MHz) |
| Conversion factor | 34(-0/+1) dB (0.15-30MHz) |

Table 2 shows that the developed 4-wire ISN meets the requirements for ISNs and it has almost the same performance as that of available 2-wire ISN [2]. In particular, the insertion loss of less than 2 dB is achieved. This means that the ISN can be used to measure the disturbance at both analog and digital telecommunication signal ports.

## COMPARISON WITH THE MEASUREMENT USING CURRENT PROBE

It is convenient to remove a current probe when measuring the disturbances at telecommunications signal ports from the measurement simplicity point of view. The disturbance level at 4-wire telecommunications signal ports was measured by a current probe in combination with the ISN and by the ISN alone, and those results were compaired. The test setup is shown in Fig. 5.

A digital telephone with ISDN basic access interface port is selected for equipment under test

(EUT). An artificial mains network (AMN) is inserted in the power line to suppress the common mode disturbances traveling from AC line. A current probe is inserted in the telecommunications line at a distance 10 cm from the ISN. An ISDN simulator is connected to the AE port of the ISN for EUT's normal operation.

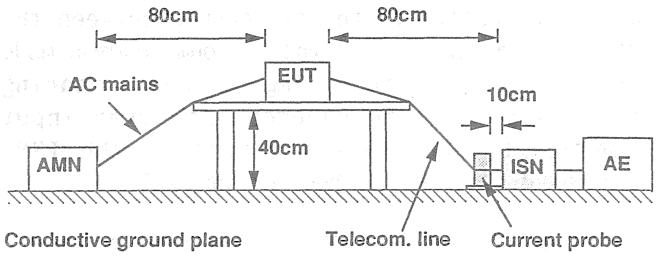



Fig. 5 Measurement layout for disturbances at telecommunication signal ports

Two types of current probe are used in the measurement. One is R&S ESH2-Z1 and the other is EATON 93686. The measured value by the current probe is converted to voltage value by adding 44 dB [=20log150(ohms)], and they are compared with the measured value by ISN alone. The result is shown in Fig. 6.

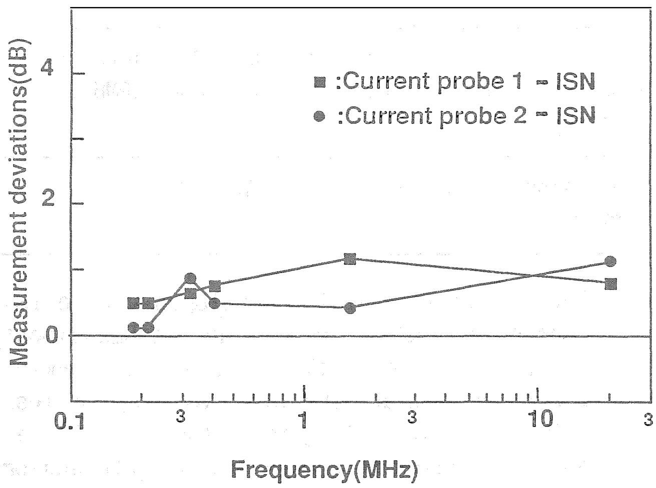



Fig. 6 Deviation of measurement results using current probes and ISN

From Fig. 6, the measurement deviation is less than 1.5 dB. This means that the newly developed ISN designed on the basis of the proposed design method can measure the disturbances at 4-wire telecommunication signal ports without a current probe.

## CONCLUSION

A design method of ISNs for measuring the disturbances at balanced multiple pair telecommunications signal ports is developed. In case of ISN for balanced 2-pair (4-wire) telecommunication signal ports, the method for determining the parameters of ISN is presented on the basis of the equivalent circuit of ISN and the requirements for ISN. The performance of the ISN meets the draft requirements for ISN proposed by CISPR/SCG, and also satisfies the transmission conditions of both analog and digital telecommunications. The experimental results show that the disturbance level measured by the ISN is almost the same to that measured by a current probe in combination with an ISN.

The design method described in this paper can be applied to ISNs for more than 4-wire telecommunication signal ports.

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