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PROBE FOR MEASURING INTERFERENCE VOLTAGES AT ISDN TELECOMMUNICATION LINE INTERFACES

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Abstract

Information technology equipment connected to ISDN(Integrated Service Digital Network) telecommunication lines can be a source of emission noise. A probe for measuring interference voltages at ISDN telecommunication line interfaces is designed to satisfy the ISDN system operation conditions.

The asymmetrical characteristic impedance of the probe is designed to measure the voltages appearing at the interfaces of the telecommunication lines. The measurement error due to longitudinal conversion loss of the telecommunication lines is also studied.

Investigation shows that the normal mode interference voltages should be measured to estimate the common mode voltages, which are converted from normal mode voltages by unbalance of telecommunication lines.

1.Introduction

The Integrated Service Digital Network (ISDN) will be introduced to subscriber networks in many countries[1],[2]. The equipment for ISDN telecommunication contains many digital processing circuits, so the emission noise from the equipment should be considered[3].

The equipment connected to ISDN telecommunication lines can constitute a source of three types of emissions[4]; 1)conducted to main terminal, 2)radiated from the equipment, 3)conducted and radiated though the telecommunication lines. Though the limits of 1) and 2) have already been determined[4], the limit of 3) is still under consideration. A probe measuring the interference voltages at the telecommunication line has been presented [5]. However, neither the limits nor the requirements of a probe for equipment connected to ISDN telecommunication lines have been clarified.

This report proposes a probe for measuring interference voltages at the interfaces of ISDN telecommunication lines. The asymmetrical impedance of the probe is studied based on the input impedance on telecommunication lines. The measurement error caused by Longitudinal Conversion Loss(LCL) of the line is also studied.

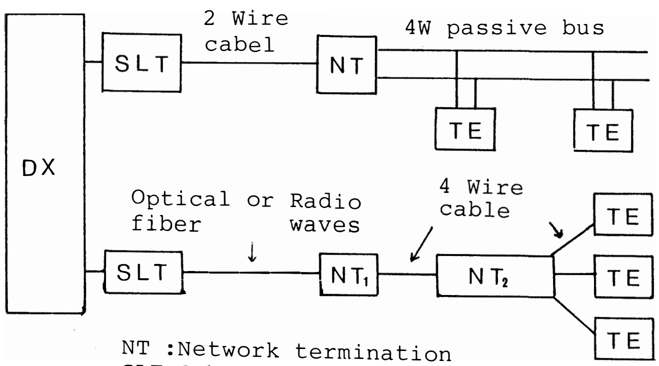
2.Outline of ISDN system

An ISDN system is outlined in Fig.1. A digital exchange is connected to the Network Termination(NT) through the Subscriber Line Termination(SLT). Two-wire paired cable is used for the low bit-rate telecommunication between SLT and NT. Optical cable or radio waves are used for the high-bit rate telecommunication between SLT and NT_1. Terminal Equipment (TE) is connected with NT by a 4-wire passive bus, and the NT_2 is connected with NT_1 by a 4-wire point-to-point network.

3.Measurement of the interference through the telecommunication line

Test methods for the interference through telecommunication line are summarized in Fig.2. Three types of limit are considered for the interference field strength E_1 from the telecommunication line. They are: (1)limit of the interference voltages V_1 at the telecommunication terminals of the equipment, (2)limit of the interference currents I_1 on the telecommunication lines. (3)limit of the radiated field strength E_1.

In above limits, measuring the interference currents I_1 is difficult because the maximum currents point should be searched and the interference field strength E_1 should be calculated. Direct measurement of



NT :Network termination
SLT:Subscriber line termination
TE :Terminal equipment
DX :Digital exchange

Fig.1 ISDN system configuration

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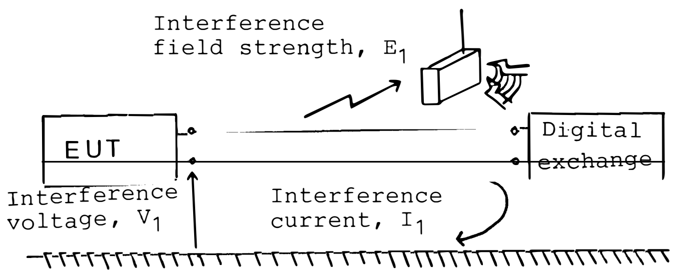
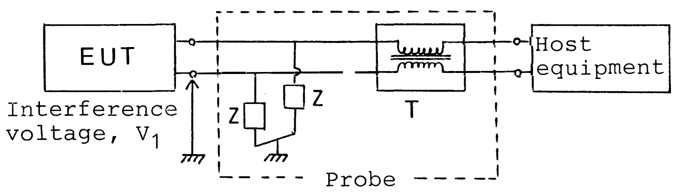


Fig.2 Measurement parameters to test the interference caused by telecommunication lines.



T:Common mode choke
Z:Asymmetrical impedance

Fig.3 Basic configurations of probe for measuring interference voltages at interfaces of telecommunication lines.

interference field strength E_1 is also difficult because this field strength varies with the surrounding conditions. Therefore, interference voltages V_1 is measured because of its simplicity, though the interference field strength E_1 should be calculated.

3.1 Probe for measuring interference voltages at interfaces of telecommunication lines

A probe for measuring interference voltages at the interfaces of telecommunication lines is outlined in Fig.3. The interference voltage should be measured under operating conditions so the equipment under test(EUT) should be connected to the telecommunication line. However, it is difficult to measure the voltages under these conditions because of the ambient noise. Therefor, the probe is constructed with a pair of asymmetrical impedances Z and a common mode choke T, where the impedance Z simulates the input impedance between the conductor of the cable and ground and the choke T suppresses the common mode noise from the host equipment. The host equipment in Fig.3 means the equipment to operate the EUT, such as the SLT and NT.

The requirements of the probe are as follows.

(1) The interference voltages should be measured under the EUT is operating, and the common mode noise from the host equipment should be sufficiently suppressed.

(2) The measuring voltages should be identical with the voltages appearing at the interfaces of telecommunication lines to calculate the interference field strength.

(3) The interference level should be given from the measured voltages.

Probes for analog telecommunication equipment satisfy some of these conditions[5]. However, there are some problems with the high bit-rate telecommunication signals: the asymmetrical impedance of the telecommunication line, and the measurement error caused by the LCL of the telecommunication lines.

A probe is designed to investigate these problems. The circuit for measuring interference voltage is shown in Fig.4.

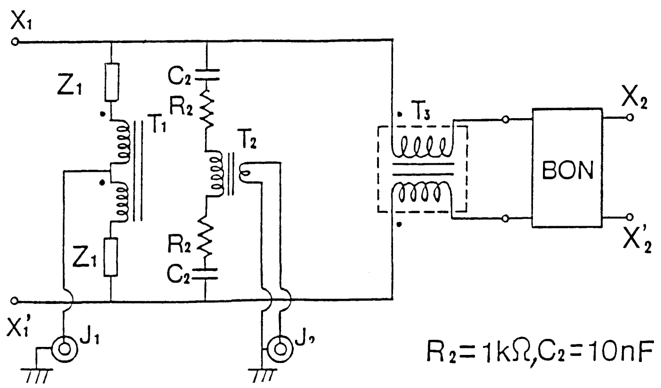
In this circuit, terminal X_1-X_1' is connected to the EUT, and terminal X_2-X_2' is connected to the host equipment. The circuit is divided into 4 parts.

The series circuit composed of Z_1, T_1, J_1 simulates the asymmetrical impedance of the lines and measures the common mode voltage. Here, Z_1 simulates the asymmetrical impedance, and the relation ship between the asymmetrical impedance Z and Z_1 is given by

$$Z = Z_1 + 2Z_r \, . \qquad (1)$$

In Eq.(1), Z_r is the input impedance of the level meter. T_1 is used to obtain the high impedance between wires of a balanced pair, and J_1 is the terminal connected to the level meter.

The series circuit composed of C_2, R_2, T_2, J_2 is used to measure the normal mode interference voltage, which corresponds with the telecommunication signal. The current through R_2 is probed by the current transformer T_2. In this circuit, C_2 is used



X_1-X_1':Terminal connected to EUT

X_2-X_2':Terminal connected to host equipment

J_1 :Terminal to measure common mode voltages

J_2 :Terminal to measure normal mode voltages

Fig.4 Probe configuration for measuring interference voltages.

to cut DC current, J_2 is the terminal connected to the level meter.

T_3 is the common mode choke to suppress common mode noise from the host equipment.

BON(building-out network) simulates the loss characteristics of the lines.

The requirements for measuring interference voltages and the characteristics of the probe are shown in Table 1. Table 1 shows that the probe in Fig.4 satisfies the requirements.

3.2 Asymmetrical impedance of the probe

The input impedance between the balanced pair of conductors and the ground is measured to determine the asymmetrical impedance of the probe. Three subscriber lines of different lengths(500m-4km) are selected and ten pairs for each lines are used in the test. The mean values obtained from the data are shown in Fig.5. Figure 5 shows that the impedances are about 100Ω in the frequency range from 10 kHz to 5MHz and they increase rapidly above 5 MHz. It seems

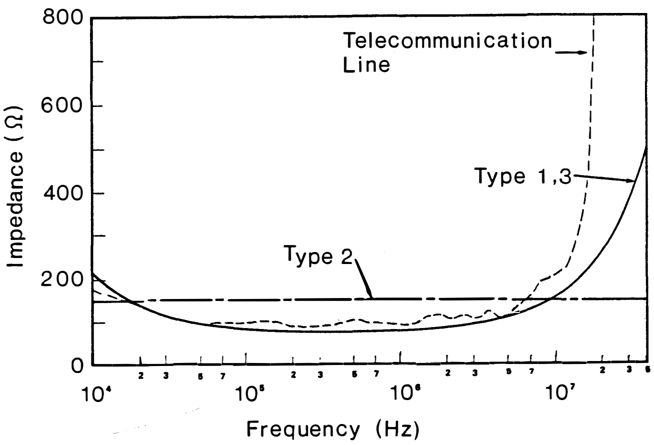


Fig.5 Frequency characteristics of input impedance at the telecommunication line end and the asymmetrical impedance of type 1 and 2.

that the inductance of wire, connecting equipment to cable and ground, influences the input impedance above 5 MHz.

Two types of asymmetrical impedance are designed to simulate the impedance between conductors of balanced pair and ground. The impedance of type 1 is represented by LCR series circuit(L=4μH, C=40nF, R=60Ω), and the impedance of type 2 is represented by a resistance (R=150Ω). The frequency characteristics of two types impedance are also shown in Fig.5. The impedance of type 1 roughly simulates the frequency characteristic of the measured input impedance. The impedance of type 2 is lower than the input impedance below 20 kHz and above 10 MHz, and higher than the input impedance from 20 kHz to 10 MHz.

The interference voltages of NT have been measured with the probes for these two types asymmetrical impedance, and the results are compared with the interference voltages appeared at the interfaces of the telecommunication line.

The test set-up used to measure interference voltages of the equipment are shown in Figs.6(a) and (b). The test set-up for probes are shown in Fig.6(a). One probe is inserted between NT and SLT, and two probes are inserted between NT and TE. NT and the probes are set in a shielded chamber to avoid external noise.. During measurement, NT is operated by SLT and TE. Furthermore, NT, probes and cables set on the conducted ground plane, and the distance from NT to the probe is set at 1m.

The telecommunication line used for the experiment is shown in Fig.6(b). The NT is operated by SLT and TE, which are set apart from NT at a distance of 400m to suppress the noise from SLT and TE. The interference voltages V_1 are probed by the FET front-end high-impedance probe of input impedance 1MΩ//2pF.

The experimental results are shown in Figs.7(a), (b) and (c). The interference voltage, which appears at NT terminal connected to SLT, is shown in Fig.7(a). Here, the frequency regions where the ambients noise is greater than the

Table 1 Requirements and characteristics of a probe for measuring interference voltage of equipment connected to the ISDN I430 system.

Term		Requirements	Probe
Condition for EUT operation	Transmission loss	6-50dB(Variable) (Nyquist frequency)	2-50dB(Variable) (Nyquist frequency)
	Transmission bit rate	>320kb/s	>1.5Mb/s
	Transmission line loss compensation	Square root of frequency	Square root of frequency
	Longitudinal conversion loss	>60dB(10-320kHz)	>70dB(10-320kHz) >40dB(0.32-30MHz)
Attenuation for common mode voltages			>40dB(0.1-30MHz)

interference voltages generated by NT, are neglected. The interference voltages measured by the probes within types 1 and 2 asymmetrical impedance are shown in Figs.7(b) and (c) respectively. Figure 7 shows that the voltages measured by the probes within types 1 and 2 asymmetrical impedance almost agree with the voltages appearing at the interfaces of telecommunication line. Consequently, since the probe circuit should be simple, the asymmetrical impedance should be represented by a resistance.

3.4 Measurement error caused by LCL of line

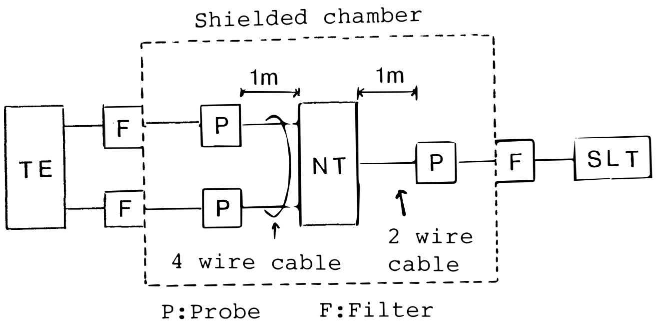
The equivalent circuit of the EUT and telecommunication line is approximately represented by the circuit in Fig.8. In Fig.8, I_n shows the common mode interference current source in EUT, and dZ shows the unbalance in the telecommunication line. Using Fig.8, the relation ship between normal mode voltages E(Signal voltage) and the interference voltages V is approximately given by

$$V = (V_1 + V_2)/2$$
$$= E\frac{dZ/Z}{4} + I_n Z \qquad (2)$$

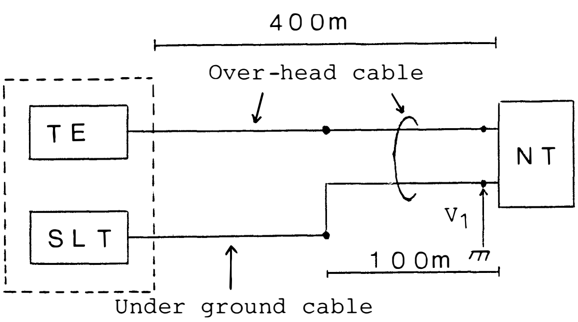
where

$$dZ << Z. \qquad (3)$$

In Eq.(2), the first term represents the interference voltages caused by the unbalance in the telecommunication line, and the second term represents the interference voltages caused by the unbalance in the EUT.

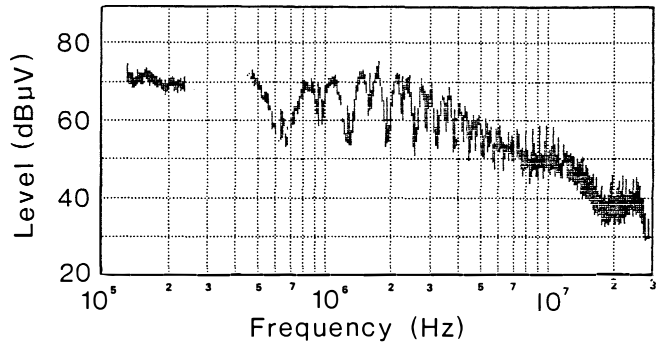


(a) Test set up for measuring the interference voltages by the probes.

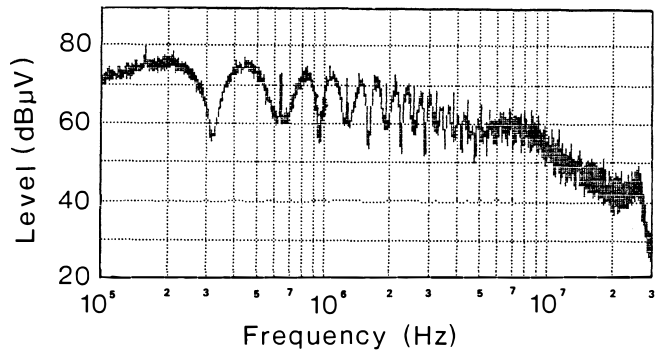


(b) Test set up for measuring the interference voltages appearing at the telecommunication line interface.

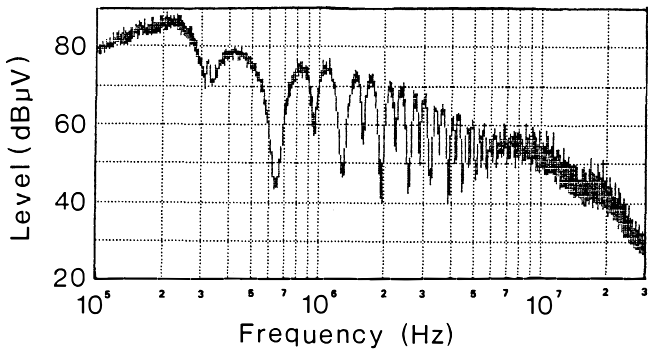
Fig.6 Test set up for measuring the interference voltages.



(a) Interference voltages at telecommunication line interface.

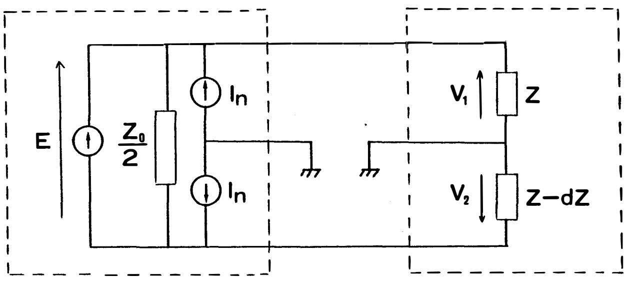


(b) Interference voltages measured by the probe within type 1 asymmetrical impedance.



(c) Interference voltages measured by the probe within type 2 asymmetrical impedance.

Fig.7 Interference voltages at the telecommunication line interface and the probes within types 1 and 2 asymmetrical impedance.



Z0:Characteristic impedance of cable

Fig.8 Equivalent circuit of the equipment and telecommunication line.

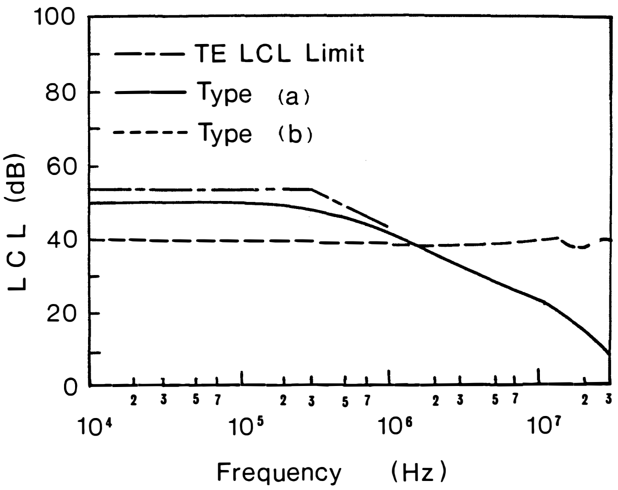


Fig.9 Frequency characteristics of Longitudinal Conversion Loss(LCL) for types (a) and (b) probes.

For analog signal telecommunication, only the second term should be considered because the signal frequency is completely below the measurement frequency. However, for digital signal telecommunication, both terms should be considered because the signal frequency overlaps the measurement frequency.

Since probes for measuring interference voltages at the interfaces of telecommunication lines only measure the second term in Eq.(2)[5], a method of measuring the first term of Eq.(2) should be considered. The methods are:

(1) Designing a probe which simulates the telecommunication line unbalance, and measuring the interference voltages.

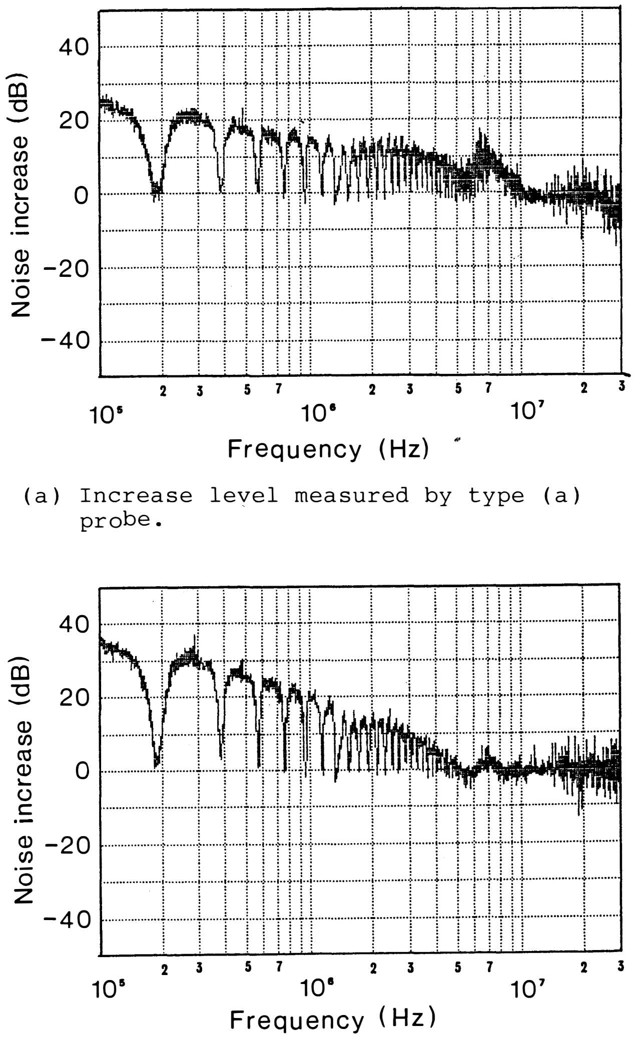
(2) Measuring the normal mode voltages and calculating the interference voltages using Eq.(2).

These two methods were investigated. The results are as follows.

Two types of probes, whose unbalances simulate the LCL on telecommunication line, are designed. The LCL of the probes are shown in Fig.9, where the LCL is measured by CCITT method[6]. In Fig.9, the type (a) curve simulates the LCL specification (broken line) of TE connected to 4-wire passive bus[2], and the type (b) curve simulates the LCL characteristics of a 4-wire passive bus with many TE connected. The increase in interference voltage compared with the data in Fig.7(c) are measured, and the results are shown in Fig.10. Figure 10 shows that the interference voltage increases in the frequency range up to 10 MHz and its value at 100 kHz is about 25dB for type (a) and 35 dB for type (b).

The interference voltages calculated from normal mode voltages are compared with the interference voltages for only common mode interference voltages. The interference voltages for only common mode are shown in Fig.11(a), and the interference voltages calculated from normal mode voltage are shown in Fig.11(b). The equation used in the calculation is given by

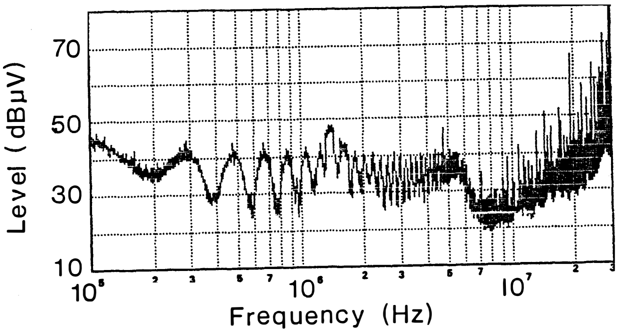
$$V(dB\mu V) = E(dB\mu V) - LCL(dB). \qquad (4)$$



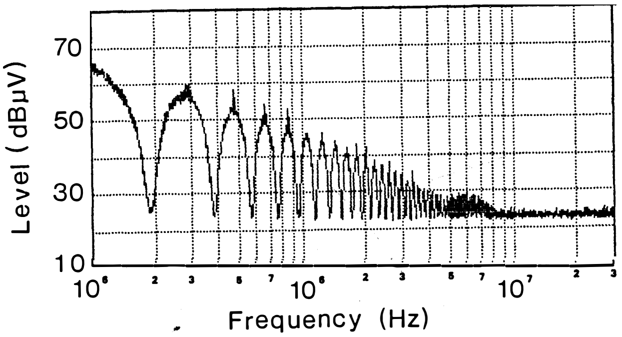
(a) Increase level measured by type (a) probe.

(b) Increase level measured by type (b) probe.

Fig.10 Relation between the interference voltage increase and LCL of the line.



(a) Common mode interference voltages.



(b) Calculated interference voltages from the normal mode voltages when LCL is 54 dB.

Fig.11 Interference voltages of the equipment for ISDN.

In the calculation, 54 dB is selected as the LCL value. Figure 11 shows that the interference voltages calculated from the normal mode voltages are greater than the interference voltages for only common mode interference voltages and the level difference is about 20 dB at 100 kHz. This value almost agrees with the level increase in Fig.10(a).

The above investigation shows that the measurement error due to LCL of telecommunication line increases when the equipment for digital telecommunication system is measured. Therefore, the interference voltages for ISDN equipment should be measured by the probe considering line LCL, or the interference voltages should be calculated from the normal mode voltages based on the line LCL.

4. Conclusion

Noise emission from the equipment for ISDN system should be considered because ISDN system uses high bit-rate digital signals for telecommunication. This report investigated a probe for measuring the interference voltages at the interfaces of telecommunication lines. The results of the investigation are as follows.

(1) The interference voltages measured by the probes for the asymmetrical impedance of LCR series circuit and a resistance almost agree with the voltages appearing at the interfaces of telecommunication line. Therefor, the symmetrical impedance should be represented by a resistance, since the probe circuit should be simple.

(2) The measurement error caused by the LCL of telecommunication lines increases when the equipment for digital telecommunication system is measured. Therefor, the measurement of interference voltages of ISDN equipment should use a probe considering line LCL, or the interference voltages should be calculated from the normal mode voltages by the line LCL.

In future, the relationship between the interference voltages and the radiated field strength should be clarified.

Acknowledgment

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