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# Electromagnetic field near power line for a power line communication system

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**Abstract:** LCL and LCTL frequency characteristics for the balanced pair cable of power line communication system were measured for the several grounding conditions such as no, input side and output side groundings. In consequence, it is clear that the input side grounding for LCL became the worst, but the output side grounding for LCTL became the worst, and the tendency of the LCTL frequency characteristics is different from that of LCL.
The Leaked E-field characteristics from the balanced pair cable were measured and calculated for the several grounding conditions, and it is revealed that the measurement and calculation results for the maximum additional amount of the leaked E-field compared with no grounding is also about 20dB by the input side grounding. In addition, it turns out that the leaked E-field becomes also large as LCTL gets worse, and the relation between LCTL and the leaked E-field depends on the grounding conditions such as no, input side and output side groundings.
Key words; Power line communication, LCL, leaked electromagnetic field, grounding and method of moment

## 1. Introduction

Recently, the high-rates communication system is called for with increase in Internet user. Power Line Communication (PLC) draw keen attention as a high-rates communication system. PLC transmits data using the conventional power line laid in order to supply commercial electric power both in and outside the home as a substitute for telecommunication line. Old PLC was used home interphone or data transmission at low rates for controlling home electric appliances. But PLC is expected as means of home network or access network construction because the construction cost of wire is unnecessary and the high-speed data transmission about 10Mbps~100Mbps is possible by technical innovation, such as development of OFDM (Orthogonal Frequency Division Multiplex) technology and advancement of error correcting code control system. However in order to realize such high-speed data transmission, it is necessary to use frequency band higher than the frequency band approved under the present establishment. The frequency band that can be used by the present PLC is to 10~450kHz, though in consideration of future improvement in the speed, there was strong request that expands the frequency band to 2~30MHz, and investigation of deregulation was made during April to July 2002 [1]. However, if the high frequency signal of MHz band is poured into a power line, radiated disturbance from the power line may affect surrounding electromagnetic environment. The 2~30MHz zone is used for the existing radio of aviation and ship, existing short-wave broadcasting, and then it is possible to affects their operation and reception. Especially in Japan, strong disturbance may be revealed as compared with many foreign countries, because the 100V power distribution system currently supplied to ordinary homes is almost installed on overhead, and is grounded one side of the pair power line in pole transformer. Therefore, it is important to study on grounding condition of the power line for PLC in Japan.

In this paper, we study the relation between the grounding condition of the power line and leaked field property from the power line. First, the transmission characteristics including the degree of unbalance about earth and a leaked electric field (abbreviated to E-field) from a transmission line are measured. Next, the leaked electric field is calculated by using the method of moment (abbreviated to MoM), and compared with the measurement result.

## 2. Measurement method

Several kinds of characteristics are measured by using the model that is reduced to the actual power distribution system. Installation form of power line is the gate form as shown in Fig. 1, and the size and kind of power line are listed in Table 1.

Table 1 Properties of measured power line

| Kind of power line | $\phi$1.6mm pair VVF cable |
|---|---|
| Total length of power line | 6.5 m |
| Length of overhead part | 3.0 m |
| Height of overhead part | 1.5 m |

The VVF (Vinyl insulated and Vinyl sheathed Flat type) cable with a conductor diameter of 1.6mm is used for the power line. Electrical signal from sending end of a network analyzer is impressed to one side terminal of VVF cable that is called as input side in this paper. Conversely, other side terminal, which connected to receiving end of the network analyzer, is called as output side. The power line can be assumed as a balanced line, but measuring cable of the network analyzer is coaxial cable, that is, unbalanced cable. Therefore, a balun is needed to connect between balanced cable and unbalanced cable each other. There is a connector, which convert unbalance to balance in the balun used for the measurement. And this balun has the middle point (center tap) by the balance side. Thus, if measuring instrument is connected to the center tap, common mode voltage can be measured.

We examine three types of grounding conditions as follows;

(1) No grounding
Both input and output sides of power line are not bonded to a ground plane in an anechoic chamber.
(2) Input side grounding
One wire of balanced power line at the input side is bonded to the ground plane.
(3) Output side grounding
One wire of balanced power line at the output side is bonded to the ground plane.

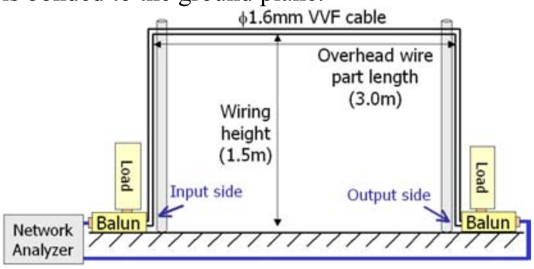


Fig.1 Appearance of measurement system

### 2.1 LCL measurement

LCL is one of the measures of the degree of unbalance to the earth, and it is expressed as the ratio of differential mode voltage to common mode voltage at input side port. The ratio is measured by the network analyzer.

### 2.2 LCTL measurement

LCTL is also one of the measures of the degree of unbalance to the earth, and it is the ratio of differential mode voltage at the input port to common mode voltage at the output port. The ratio is also measured by using the same network analyzer as the LCL measurement.

### 2.3 Leaked electric field measurement

Figure 2 shows the measurement system for leaked E-field characteristics. The whole measurement system is set up in the semi-anechoic chamber that has the metal ground plane on the floor. The measured power line as shown in Fig.1 is set on the metal ground plane, and E-field from the power line is measured a biconical antenna. The measurement frequency band is taken between 30~300MHz according to allowable frequency band of biconical antenna. The biconical antenna is set at the distance of 3.0m apart from the input side of measured cable and the height of 1.0m on the floor. The signal is impressed by the network analyzer to the one side terminal of power line that calls as the supply side. Another side terminal is matched by 50 Ω that calls as the terminus side. And the network analyzer measures the insertion loss *ATT* between the balun and the biconical antenna. The leaked E-field intensity $|\boldsymbol{E}_i|$ from the power line is obtained by the following equation [2][3].

$$|\mathbf{E}_i| = 114 + E[dBV] + 20\log_{10} B_T - ATT[dB] + AF[dB/m] \quad (1)$$

$E$ is the voltage impressed by the network analyzer. $B_T$ is the voltage conversion factor of balun as shown in equation (2), and the matched resisters of this balun have 50 Ω at the unbalance side and 100 Ω at the balance side.

$$B_T = \sqrt{50/100} = 1/\sqrt{2} \quad (2)$$

*AF* is the antenna factor of the biconical antenna. In order to normalize the leaked E- field intensity $|\boldsymbol{E}_i|$ to the impressed voltage $E$, we define the voltage E-field conversion factor *CF* of power line as shown in the following equation (3).

$$CF\ [dB/m] = |E_i|\ [dB\mu V/m] - E\ [dB\mu V] \quad (3)$$

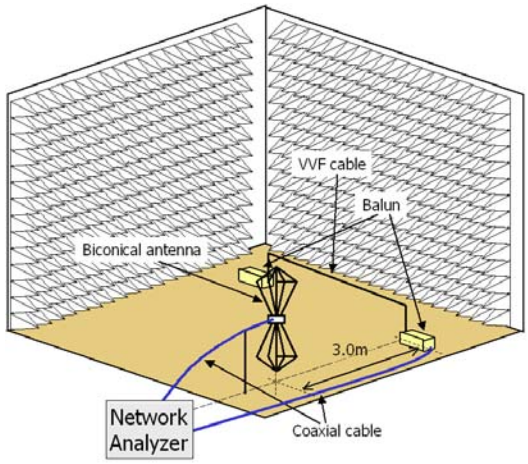


Fig.2 Measurement system for leaked E-field

### 3. Calculation method of the leaked electric field

The leaked electric field from the power line is also calculated by the MoM, in order to verify the validity of measurement data. If the calculation model of the power line is balanced perfectly, common mode current does not flow, and then the leaked E-field vanish theoretically. However, actual power line has some unbalanced ingredients by imperfect production and installation. It is very difficult to theoretically calculate these imperfections, and then we obtain the imperfection element by using the measurement data of the leaked E-field characteristics. The unbalance elements consisted of the suitable distributed constant along to one line of the pair lines is inserted so that the calculation results of the leaked E-field characteristics fit to measurement result of that. In consequently, when inductance difference ($\Delta L$) of 900mH/m and capacitance difference ($\Delta C$) of 9nF/m are inserted as unbalance elements between 2 lines, calculation and measurement results were most fitted.

Both sides of the power line are terminated by balun, and a model of balun is shown in Fig.3. The balanced input resistance of balun and the unbalanced output resistance to the power line can be assumed to form Y circuit consisted of three 50Ω resistances, and then the unbalanced output resistance is connected to ground plane. Therefore, terminus resistances of each wire $Z_{SC1}$, $Z_{SC2}$, $Z_{RC1}$ and $Z_{RC2}$ for the power line as shown in Fig.4 are as follows;

$$Z_{SC1}=Z_{SC2}=Z_{S1}+Z_{CT1}/2=50+50/2=75\Omega \quad (4)$$

$$Z_{RC1}=Z_{RC2}=Z_{R1}+Z_{CT2}/2=50+50/2=75\Omega \quad (5)$$

Voltage sources $E_{D1}$ and $E_{D2}$ are computed from the impressed power by the network analyzer, taking into consideration about the voltage conversion factor of balun $B_T$.

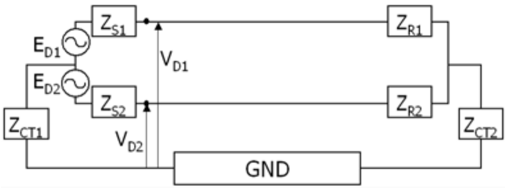



Fig.3 Differential transmission system equivalent circuit

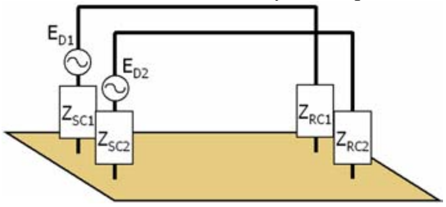



Fig.4 Calculation model of the power line

## 4. Measurement and calculation results

### 4.1 LCL measurement result

The LCL characteristics were measured in order to verify the influence on the degree of balance to earth by grounding. LCL characteristics are shown in Fig.5. In the LCL frequency characteristics on no and output side groundings has resonance as frequency becomes higher. As for the no grounding, the LCL characteristic is changing by 20dB/dec to frequency. In input side grounding or output side grounding, it goes sideways to frequency. With the difference of the grounding condition, LCL on the input side grounding influences potently and became the worst. LCL depends to the position of grounding, and LCL is influenced most strongly when grounding at the position near the measuring point to detect the common mode voltage. On input side grounding, in order to ground at the position near the measuring point, LCL became to be the worst. On the other hand, since the grounding position of the output side grounding is far from the measuring point, degradation of LCL is not so much comparing with that of input side grounding.

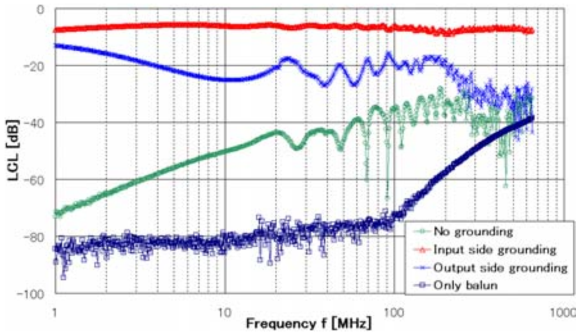



Fig.5 LCL characteristics of the power line

### 4.2 LCTL measurement result

LCTL characteristics are shown in Fig.6. In this case, for the LCTL frequency characteristics on no and input side groundings, the influence of resonance appears somewhat as frequency becomes high. With the difference of the grounding condition, LCTL on the output side grounding became the worst because the measuring point is near the grounding position for the output side grounding. From the results mentioned above, it is clear that this tendency of the LCTL characteristics is different from that of LCL.

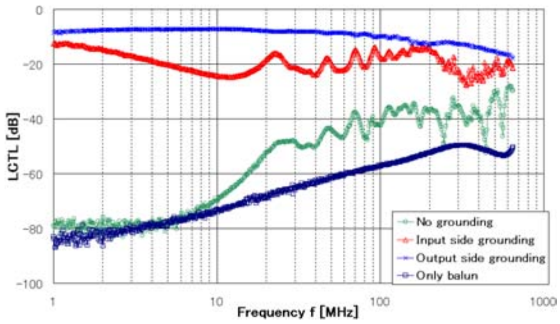
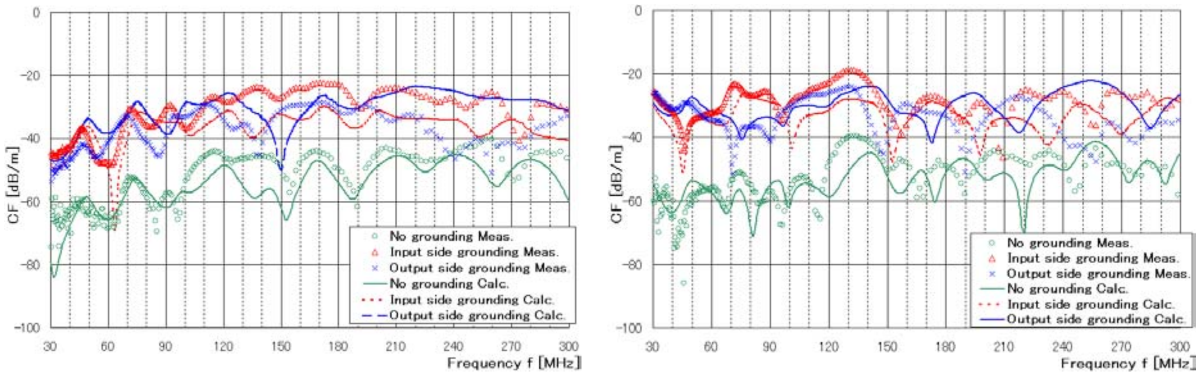



Fig.6 LCTL characteristics of the power line

### 4.3 Leaked electric field measurement result

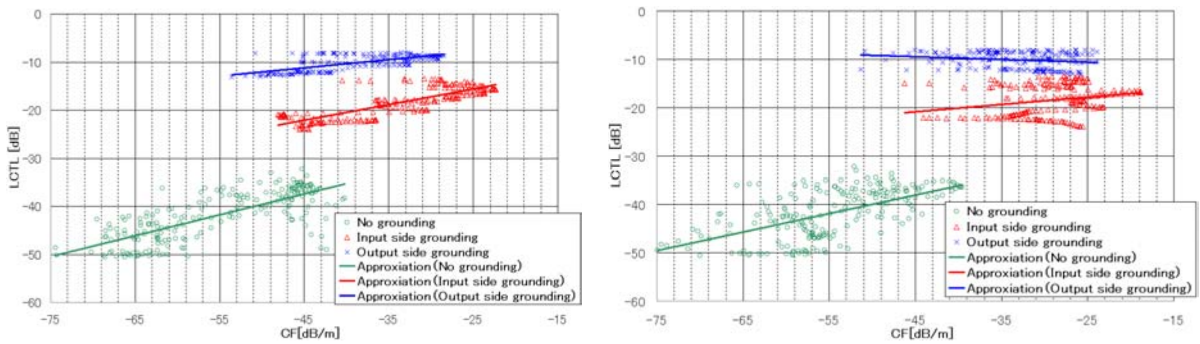
Leaked E-field characteristics are shown in Fig.7. Figure7 (a) shows the result for the horizontal polarization, and (b) is for the vertical polarization. When one of the pair cable was grounded at the input side, it is revealed experimentally from Fig.7 that the leaked E-field becomes large and it's maximum additional amount compared with no grounding is about 20dB in both horizontal and vertical polarizations.

In Fig.7, the solid line, the dotted line and the dashed line are the calculation results corresponding to no grounding, input side grounding and output side grounding respectively. Although neither resonance frequency nor concrete value for the each grounding conditions agree with the measured values, it turns out that the tendency of calculation results is approximated to that of the measured results. Moreover, the calculation results for the maximum additional amount of the leaked E-field compared with no grounding is also about 20dB and the same that as the measurement results. Therefore, it is confirmed that calculations of leaked E-field from




(a) Horizontal polarization (b) Vertical polarization

Fig.7 Measured and calculated values of the leaked E-field




(a) Horizontal polarization (b) Vertical polarization

Fig.8 Relation between LCTL and E-field

power line are possible by MoM for various grounding conditions. The straight line approximated by the least-squares method to the distribution of value is also shown. From Fig.8, It is revealed that the leaked E-field becomes also large as LCTL gets worse, and the relation between LCTL and the leaked E-field depends on the grounding conditions such as no, input side and output side groundings.

### 5. Relation between LCTL and leaked electric field

In the differential mode transmission system such as PLC and ADSL (Asymmetric Digital Subscriber Line) in, if LCTL of the balanced cable become to be worse, the leaked E-field from the balanced cable becomes large [3]. Therefore, when LCTL depends on each frequency, it can be known from measured value how much the leaked E-field would be radiated from the balanced cable according to LCTL. Figure 8 shows the relation between LCTL and the leaked E-field, and (a) is for the horizontal polarization and (b) for the vertical polarization.

### 6. Conclusion

LCL and LCTL frequency characteristics for the balanced pair cable of power line communication system were measured for the several grounding conditions such as no, input side and output side groundings. In consequence, it is clear that the input side grounding for LCL became the worst, but the output side grounding for LCTL became the worst, and the tendency of the LCTL frequency characteristics is different from that of LCL.

The Leaked E-field characteristics from the balanced pair cable were measured and calculated for the several grounding conditions, and it is revealed that the measurement and calculation results for the maximum additional amount of the leaked E-field compared with no grounding is also about 20dB by the input side grounding. In addition, it turns out that the leaked E-field becomes also large as LCTL gets worse, and the relation between LCTL and the leaked E-field depends on the grounding conditions such as no, input side and output side groundings.

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