Measurement Method of Near Electric field from LED Bulb and Power Line

Takashi Kasuga, Yukiya Saito, Takumi Ohashi, Shohei Yamada
Department of Electrical and Electronic Engineering,
Nagano National College of Technology
Nagano-shi, Japan
kasuga@nagano-nct.ac.jp

Hiroshi Inoue
Akita Study Center,
The Open University of Japan
Akita-shi, Japan
inoueh@gipc.akita-u.ac.jp

Abstract—The electromagnetic noise radiated from LED bulb and power line becomes one of cause of the EMI problems. The limits value of the magnetic radiation noise from the light illuminated products is established by the measurement of large loop antenna. However, the near magnetic field around the LED bulb was not detected. In this study, the near electric field from LED bulb and power line is measured by monopole antenna. The near electric field from 1 to 300 MHz can be measured by two types of monopole antennas. The characteristic of the near and far electric field is coincided with the frequency characteristics of the impedance of the power line. Since the power line operates the monopole type antenna, and the radiation electromagnetic wave is an electrical mode, the measurement of the near and far electric field must be needed to estimate the electromagnetic noise from LED bulb.

Keywords—EM noise, LED bulb; near electric field; monopole antenna; FDTD method

I. INTRODUCTION

The Light Emitted Diode (LED) lamps are widely used to save the energy of the lighting equipment. The power conditioner included in the inverter circuit to convert from AC 100V to DC are implemented in a large majority of the LED bulbs. As the switching frequency of the inverter circuit is several 10 kHz, the electromagnetic noise due to the harmonic signal of the switching frequency was observed up to 300 MHz, and larger than the FM radio signal [1]. The electromagnetic noise radiated from LED bulb may make the EMI problems at wide frequency band.

The regulation value for the light illuminated products is specified in CISPR 15, and the near magnetic field must be measured by large loop antenna below 30 MHz band. However, near magnetic field was not detected [1, 2], because the light illuminated products in the CISPR 15 are the filament lamp and fluorescent lamp started by glow tube, and does not include the LED lamps implemented the inverter circuit. The near electric field around the LED bulb could be detected by bow-tie antenna. But, because the antenna factor of the bow-tie antenna is not defined, a quantitative measurement method of the near electric field noise must be needed.

The purpose of this study is to establish the measurement method of near electromagnetic noise radiated from LED bulb and power line. The noise radiation mechanism and the major component of the noise radiated from LED bulb and power line are also discussed. The near electric fields from LED bulbs available in the market are measured by monopole antenna. The near three antenna method [3, 4] is used to calibrate the monopole antenna. The near electric field is measured by two types of monopole antenna. The far electric field noise is also measured according to the CISPR 22. The electric and magnetic field distribution around the LED bulb and power line is calculated by Finite Difference Time Domain (FDTD) method.

II. MEASUREMENT SETUP OF NEAR ELECTRIC FIELD

Thirteen LED bulbs available in the market are used. Figure 1 shows the measurement setup of the near electric field from LED bulb. The length of power line is 1.55m. The near electric field radiated from LED bulb is measured by two types of monopole antennas. The monopole antenna is set on
Figure 2 shows the monopole antennas using in this study. The length of one antenna using in this study is 50 mm and a diameter is 0.9 mm, and the length of other antenna is 300 mm and diameter is 5.0 mm, respectively.

Figure 3 shows the antenna factors of the monopole antennas measured by using the near field three antenna method [4, 5]. The antenna factor of 300 mm long antenna (300-antenna) is lower than that of 50 mm. Below 250 MHz, the antenna factor of the 300-antenna decreases at a ratio of 20 dB/dec in inverse proportional to the frequency. At the 250 MHz, the length of 300-antenna is coincided with the quarter wavelength of 250 MHz. The antenna factor of 50 mm long antenna (50-antenna) also decreases at a ratio of 20dB/dec below 700 MHz. When the distance between 300-antennas is changed as 100, 300 and 500 mm, a large variation on the antenna factor is not existed. However the small variability is observed at the 500 mm because of the S/N derogation. Since measured and FDTD calculated results of near electric field are corresponded within ±3 dB higher than 50 MHz as 50-antenna, and at 1 to 70 MHz in 300-antenna, the electric field can be measured using these monopole antennas at this frequency bands [5].

III. IMPEDANCE OF POWER LINE

The impedance of the power line observed from bayonet base is measured and calculated by FDTD method. The impedance of the power line is measured by the impedance analyzer (Agilent E4991A) through the SMA connector attached to the bulb bayonet base. The plug of the power line is shorted by short connector. Figure 4 shows the FDTD calculation model. The observation point of the impedance of the power line in the FDTD calculation is the noise source. The LED bayonet cap is modeled by metallic rectangle box. One power line is connected with rectangle box. Figure 5 shows the impedance of the power line. When the relative dielectric constant $\varepsilon_r$ of power line cover made of polyvinyl chloride (PVC) assumes as 3.6 in FDTD calculation, the measured and calculated results are coincided. The resonance and anti-resonance phenomena are observed. The first resonance and anti-resonance frequencies are 55 and 85MHz, respectively.

IV. NEAR ELECTRIC FIELD OF LED BULB AND POWER LINE

The electric field from thirteen LED bulbs have been measured by two types of monopole antennas at 1 to 300 MHz, and calibrated by antenna factor. Figure 6 shows the near electric field around LED bulb and power line. The electric fields of LED 1st, 9th and 13th, which indicates larger electric field value in thirteen LED bulbs used in this study, are shown.
The near electric field below 50 MHz is large. The cause of the electric field below 50 MHz is estimated the harmonic signal of inverter clock. However, large electric field is observed at 100, 120, 150 and 180 MHz. The electric field at wide frequency band can be measured continuously using two type monopole antenna.

Figure 7 shows the calculated results of the near electric and magnetic field above the power line at 50 mm from LED bulb. The Gaussian pulse is applied to power line. The calculated electric and magnetic fields are normalized by Gaussian pulse as follow equations.

\[
E(f) = \frac{E_0(f)}{V(f)}, \quad H(f) = \frac{H_0(f)}{V(f)}
\]  

Where, \(E_0(f)\) and \(H_0(f)\) are calculated result of electric and magnetic field by FDTD, \(V(f)\) is Gaussian pulse spectrum. At 55 MHz, the electric field is null. On the other hand, the magnetic field is largest at same frequency. 55 MHz is the resonance frequency from Fig.5. The near electric field is large at anti-resonance frequency, and the near magnetic field is large at resonance frequency.

The measured electric field is also resonant characteristics from 70 to 300 MHz band. The resonant phenomena from 70 to 300 MHz band are coincided with calculated near electric field.

Figure 8 shows the top view of the measurement setup of the far electric field for horizontal and vartical component from LED bulb and power line. The radiated far electric field is measured in anechoic chamber (Nagano Prefecture General Industrial Technology Center) in accordance with the CISPR 22. The LED bulb and power line are set on the wood turn table. The AC 100 voltage power is supplied though the Line Impedance Stabilization Network (LISN). The LISN is used to stabilize the power impednace. The electric field at 30 to 1000 MHz is measured by biconical and log-periodic antennas.

Figure 9 shows the measured results of the far electric field from LED 1st, 9th and 13th. (a) is horizontal component, and (b) is vertical component.

V. FAR ELECTRIC FIELD MEASUREMENT

In the CISPR 15, the radiation magnetic field below 30 MHz must be measured by large loop antenna. However, the
magnetic field was smaller than background noise [2]. Also, the electric field radiation from 70 to 300 MHz has relationship with impedance of power line. The electric and magnetic field radiation from LED bulb and power line must be made clear using calculation method.

The electric and magnetic field radiation from LED bulb and power line are calculated by FDTD method. To estimate the radiation effect from LED bulb and power line, the wave impedance \( \eta \) is estimated from calculated electric and magnetic field distribution.

\[
\eta = \frac{E_z}{H_y} \text{ [\Omega]} \tag{2}
\]

Where, \( E_z \) is electric field for z-axis, and \( H_y \) is magnetic field for y-axis component, respectively. The electric field as z-component is the near electric field from LED bulb measured by monopole antenna. The theoretical wave impedance at far field is \( 120\pi \Omega \). In the near field, when the wave impedance is larger \( 120\pi \Omega \), the radiation source is estimated the electric field radiation type antenna. Figure 10 shows the wave impedance around the power line. (a) is 55 MHz as the resonance frequency, and (b) is 85 MHz as the anti-resonance frequency. The height for z-axis is the same as surface of power line. Figure 11 shows the space distribution for the wave impedance for y-axis at \( x=1.45m \) from plug. In the most of the analysis area, the wave impedance is larger than \( 120\pi \Omega \). The near magnetic field is only observed on the power line, and the electric field is radiated from power line. The power line operates as the monopole type antenna, and the radiation electromagnetic wave is an electrical mode. The measurement of the near and far electric field must be needed to estimate the electromagnetic noise from LED bulb.

The measurement method of near electric field and the noise radiation mechanism from LED bulb and power line is estimated by measurement and FDTD calculation.

In the near field, the electric field from 1 to 300 MHz band can be measured by monopole type antennas. The frequency characteristic of electric field from 70 to 300 MHz band has relationship with resonance frequency of power line. The large near and far electric field from several LED bulbs and power line can be observed. Since the radiation electromagnetic wave is estimated an electric mode, the power line operates as the monopole type antenna. The measurement method of the near electric field is needed to estimate the electromagnetic noise from LED bulb.

In the future, the electric field radiation and voltage noise transmitted on the power line from a number of LED bulbs must be studied.

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