Electromagnetic Interference Characteristics and Reduction Using CISPR11 for a Medical Light Emitting Diode Drive DCDC Buck Converter

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***Abstract*—Recently, many low-power LED (Light Emitting Diode) lighting fixtures that can contribute to a low-carbon society have been installed in clinical settings. However, since Alternating Current (AC) voltage cannot be used directly for LED devices, Direct Current (DC) voltage must be applied LED devices. For this reason, it is necessary for the LED equipment to install an ACDC power converter. A buck converter as an ACDC power converter is applied to the LED equipment, but Electromagnetic Interference (EMI) radiated from it has a strong influence on the wireless communication of a medical place. In particular, EMI radiated emission to medical telemeter systems using wireless communication becomes a significant problem of biomedical signal discontinuations. To investigate the EMI radiated strength, it must be measured using CISPR11 medical equipment international standard (International Special Committee on Radio Interference) on Limits and methods of measurement. This paper is focused on the LED drive DC power converter EMI radiated emission. The CISPR11 measurement EMI disturbance characteristics when a buck type current control DCDC buck converter circuit is used for the lighting of an LED device are shown. It is reported experimental results of EMI radiated emission characteristics improvement by changing the input and output circuit constants of the proposed circuit. Moreover, it is shown that can reduce to the floor noise level (background noise) when an output capacitor is inserted without an input filter.**

***Index Terms*—medical LED, DCDC buck converter, EMI radiated emission, input filter, output capacitor**

I. INTRODUCTION

Recently, many low-power Light Emitting Diode (LED) lighting fixtures that can contribute to low-carbon society have been installed in clinical settings too. Government of Japan (GOJ) policy measures of lighting fixtures for the low-carbon economy are 100% diffusion of highly efficient light such as LED on stock base by FY2030, and improvement of the energy efficiency of an electric equipment by Top-Runner Program. In Strategic Energy Plan of Agency for Natural Resources and Energy on GOJ, to promote improvements of energy efficiency in the sector of buildings and houses, they have added products that contribute to improvement of the energy consumption efficiencies of equipment into Top-Runner Program scope [1]-[3]. Therefore, the Energy Saving Act by GOJ were revised in 2013, low power LED lightings newly have been also added, and to achieve a penetration rate of 100% on a flow basis by 2020 and on a stock basis by 2030 has been mentioned into the plan. In accordance with Baumgartner et al., by 2020, they estimate that LEDs will account for almost 70% of the global general lighting market and more than 70% of the residential lighting market [4]. Because the effect of economic promotions and save energy from 2011, Japanese lighting fixture manufacturers have shifted to becoming mainstay LED lighting fixtures, have significantly reduced the production of the conventional lighting fixture such as the incandescent and fluorescent lamp.

The LED lighting market also includes clinical sites such as hospitals, and LED lighting fixtures have been used in most new clinical settings. However, in clinical sites, wireless medical telemetry systems are used that continuously monitor inpatient vital signals, which is heart rate with cardiac waveform, blood pressure, respiration rate, oxygen saturation rate in blood, and others. In these systems, the patient vital signals on a certain frequency band communicate wirelessly to the vital main monitor located nurse staff station, and maintain patient safety by confirming the radio wave signal stability. GOJ assigns the 420MHz to 450MHz frequency band for such use in 1989. In medical facilities, receiving antennas of wireless medical telemeters are installed in the ceiling or under the ceiling of patient rooms or the corridors of wards. So, it must note that radiated electromagnetic field to wireless medical telemeters may be caused from LED lighting fixtures installed at short distances. It is well known that LED fixtures contain a switching power supply of Power Electronics topologies to achieve low power consumption, which causes electromagnetic field noise emission of electromagnetic interference by the switching power supply mounted in LED lighting fixtures. The artifact noise on electrocardiogram and respiratory waveform was observed when LED lighting fixtures emitting 400MHz band noise were placed next to the patient monitor. In this way, the radiated electromagnetic noise from LED lighting fixtures causes a serious reception failure of medical wireless communications. To insure

Manuscript received May 11, 2021; revised July 29, 2021.

doi: 10.18178/ijeee.9.3.78-82

safe and reliable communication, the range of the installed location must be selected appropriately and the electromagnetic noise source must be eliminated [5]-[8].

Because AC voltage cannot be used directly for LEDs when lighting on LED devices, ACDC power converter is required for the LED equipment. ACDC power converter consists of ACDC convert circuit and DCDC convert circuit, which applies the high frequency switching circuits of power electronics technology. Therefore, EMI radiated noise is emitted from the high frequency switching power convert circuit used in LED lighting fixtures. In addition, it is important that EMI noise radiated not only from the DCDC convert high frequency switching circuit, but also from power supply interface cables by the high frequency switching pulses. The radiated electromagnetic field from LED lighting fixtures of may become a problem in order to these pulses travel on the long cable. Many studied has been presented to reduce these radiated noises. However, the radiation mechanism from interface cables and power lines has not yet been studied enough. Therefore, it is necessary to measure the noise levels of LED lighting fixtures radiated emissions for reduction of the poor reception of medical wireless communications, and confirm the EMI radiated strength [9].

In this paper, when a general DCDC current control buck type converter was used to LED luminescence, it will be confirmed experimentally EMI radiated emission levels with/without an input/output noise reduction filter. The measurement of the radiated electric field strength is measured in a 3m far-field anechoic chamber with setting a DC power supply in its outside. The reduced level of the EMI radiation source will be reported by using the experiment results with fixed the turntable of anechoic chamber by front. To confirm the influence of radiated noise from power cable, it will be measured the radiated emission level with used the cable of same length in Horizontal and Vertical directions. The radiated emission limit standard uses CISPR11 related the frequency range from 30Hz to 1GHz of the ISM (Industrial, Scientific and Medical) radio frequency [10].

II. CISPR11 Standard and Measurment Setup

A. EMI Evaluation Based CISPR11 Standard

CISPR11 is International Standard for electromagnetic compatibility for electromagnetic emission or disturbance from ISM (Industrial, Scientific and Medical) equipment, which has been maintained by the International Special Committee on Radio Interference. This standard cover emission requirements related to the Radio-Frequency (RF) disturbance in the frequency range of 9kHz to 18GHz, and Measurements are performed in frequency ranges where limits are specified. This medical LED lighting fixture defined in CISPR11 Group1 can be measured at a normal distance 3m on a test site as medical electrical equipment. To evaluate EMI of this medical LED lighting fixture, radiated emissions limits 30MHz to 1GHz of CISPR11 Group1is shown in Table I.

TABLE I. Radiated Emissions Limits of ISM Applications

Frequency MHz	3m measuring distance (rated power of ≤ 20kVA)	
	ClassA	ClassB
	Quasi-peak dBμV/m	Quasi-peak dBμV/m
30-230	50	40
230-1,000	57	47

ClassA for industrial is higher emission limits, and is not intended for use in residential environments. ClassB is limits of devices that are suitable for use in residential areas and such areas including medical environments, and they are connected to the public mains. Therefore, ClassB is used as the limits level for the EMI evaluation [10].

B. EMI Measurment Setup

Fig. 1 shows the EMI radiated emission measurement setup in the Anechoic Chamber. EMI radiated emission measurement is performed in the EMI Anechoic Chamber of the Mechanics and Electronics Research Institute (MERI) of Fukuoka Industrial Technology Center (FITC) in Japan. The far-field electromagnetic radiation strength measurement is performed that the distance of Equipment under Test (EUT) and antenna is 3m.

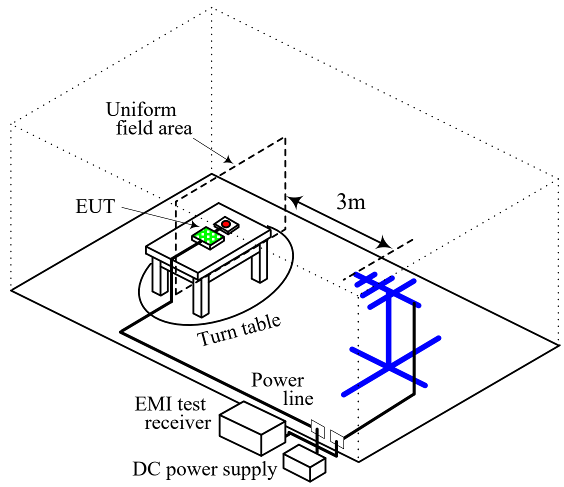

Figure 1. EMI radiated emission measurement 3m Anechoic Chamber.

The EMI antenna uses BiconiLog antenna of the Chase CBL-6111B frequency band 30MHz-1GHz. The EMI test receiver uses ESR7 of Rohde & Schwart. The stabilized DC power supply of EUT uses 7335A of the KIKUSI, which sets to the operator room of the EMI chamber's outside. The antenna moves vertically with following to the height of CISPR11 standard (Fig. 1). The EUT is placed to the center on the wood table, and the power line is placed to the upper and side of the wood table. When EMI is measured, the turntable is not rotated and the wood table is fixed to the front. At this time, the power line of the LED lighting fixture is placed 0.8m horizontally and 0.8m vertically, the noise level measures at this power line location (Fig. 2). The EMI radiation is measured with fixed the turntable of anechoic chamber by front. To confirm the influence of radiated noise from power cable, the radiated emission level with used the cable of same length in Horizontal and Vertical directions is measured (Fig. 1).

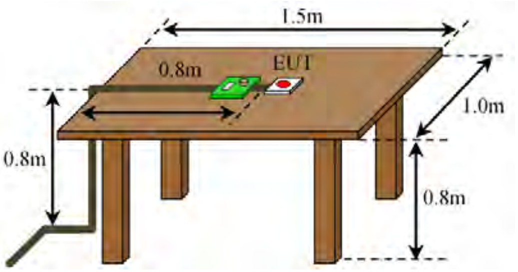

Figure 2. EUT setup on the wood table.

III. LED Drive DCDC Current Control Buck Converter and EMI Measurment

A. DCDC Current Control Buck Converter

A power source to light on a LED device used a DCDC current control buck converter as the EUT of EMI radiated emission measurement. This DCDC current control buck converter is composed of an input filter resister $R1$, an input capacitor $C1$, a freewheeling diode $D1$, an output capacitor C_{LED}, a smoothing inductor $L1$, a current detection resistor R_{SENCE}, a switching device S1 (Fig. 3).

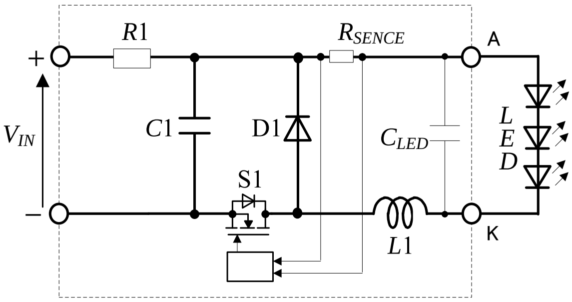

Figure 3. DCDC current control buck converter (EUT).

A Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET: ZXLD1360 LED driver) is used for S1, which performs the LED current control by continues mode. V_{IN} is an input DC power supply. These chip parts of this circuit are located on Printed Circuit Board (PCB). When 24V DC voltage is applied to V_{IN} from a DC power supply, a constant current is flown to LED by the current control of the MOSFET LED driver. The EMI radiated emission is measured with the state that a constant current flown to LED by driving the DCDC buck converter.

B. EMI Measurment Conditions

The circuit constant of the LED drive DCDC current control buck converter is V_{IN}=24V, $R1$=1Ω, $L1$=33μH, $C1$=4.7μF (or 2.2μF), C_{LED}=1μF, R_{SENCE}=0.1Ω. The LED DC current I_{LED} is 500mA, and the MOSFET switching frequency f_s is approximately 500kHz. Using these circuit conditions, the EMI measurement is performed by the Quasi-peak detection as the limit value of the medical equipment EMI standard CISPR11 ClassB 3m Quasi-peak (QP) set to 40dBμV/m (30MHz-230MHz) and 47dBμV/m (230MHz-1GHz). Where, the C_{LED} capacity uses the manufacturer recommendation capacitance value.

The LED drive DCDC current control buck converter has the input filter composed of $R1$ and $C1$. Its output has C_{LED} as the output filter. Because this circuit is the voltage source, $C1$ must be set for the input to keep the input DC voltage constant. In EMI measurement without the input filter, only the input filter resister $R1$ is removed from the circuit. Similarly, in EMI measurement without the output filter, the output capacitor C_{LED} is removed from the circuit. The EMI measurements are performed in the following four patterns (without C_{LED} only, without C_{LED} and $R1$, without $R1$ only, background). Where, the background is the EMI measurement without EUT and power cable. In this measurement results, the EMI radiated emission noise reduction level is compared and discussed about the characteristic difference

IV. Measurment Results and Discussion

A. Buck Ground Noise Mesurment Result

The background noise as floor noise level is measured when the EUT and DC power source line of EMI radiation source is not installed within the Anechoic Chamber. This measured EMI radiation is the base level to comparison with EUT measured results of the EMI noise source. This measurement is performed with nothing within the Anechoic Chamber (Fig. 4, Fig. 5).

Figure 4. Background noise measurement scenery of in Anechoic Chamber (without EUT and DC power source line).

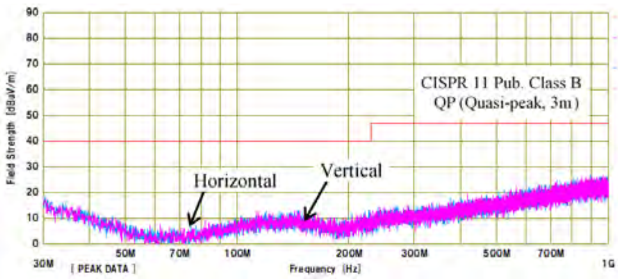

Figure 5. EMI measurement results at background noise nothing EUT and DC power source line (floor noise level).

B. EMI Radiated Noise Mesurment Results

The actual experimental sceneries within 3m EMI Anechoic Chamber are described. PCB and LED device for EUT installs on the center of the wood table. The

PCB is the printed circuit board of 18x26mm for flow the constant DC current from DCDC buck converter, and its size is very small comparison with LED equipment. BiconiLog antenna is set at a distance of 3m from the uniform field area of EUT. During the EMI field strength measurement of the four measurement patterns, the DC current of 500mA flows constantly the LED device (Fig. 6, Fig. 7).

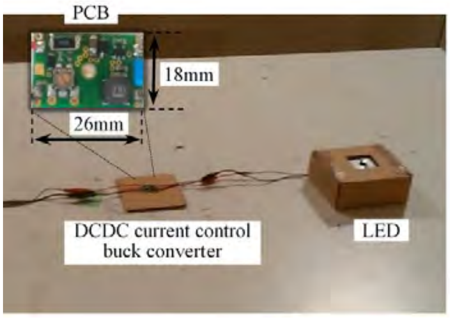

Figure 6. EUT measurement scenery with DCDC current control buck converter circuit (PCB) and LED.

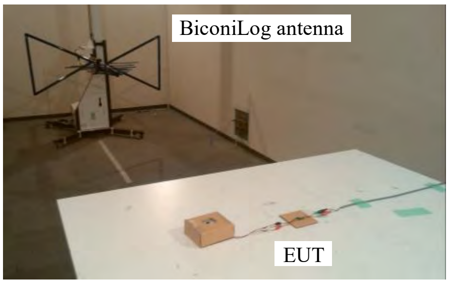

Figure 7. EMI radiated noise measurement scenery of the EUT installed on the wood table (DC power line connection).

Vertical and Horizontal polarization characteristics with/without the input filter resister $R1$ (without the output capacitor C_{LED}) of the buck converter have been measured as the blue-line of Horizontal and the red-line of Vertical. From the waveforms of this Figures, it has been confirmed that the electromagnetic field strength level of the 40MHz to 300MHz frequency range with rising to 40dBμV/m (Fig. 8, Fig. 9).

Especially, it is important that the waveforms of Vertical and Horizontal polarizations were almost the same. For example, it must focus on the result when the output capacitor C_{LED} is not installed at the output of the LED drive DCDC current control converter. This means that there is no relation to the effect of the RC low pass filter with consist of $R1$ and $C1$ by setting the circuit input filter resister $R1$. Regarding to the same waveforms of Vertical and Horizontal, this waveform phenomenon by the EMI power cable effectiveness can be inferred because the cable lengths of Vertical and Horizontal direction are the same 0.8m. Thus, it has been proofed that Vertical and Horizontal field electromagnetic strengths have depended on Vertical and Horizontal direction of same power cable length. In other words, the EMI field strength of the same power cable length was radiated the same magnitude of the electromagnetic field of the Horizontal and Vertical directions in this study situation (Fig. 8, Fig. 9).

Fig. 10 illustrates that EMI radiation noise of Vertical and Horizontal polarizations has been significantly reduced about 40dBμV/m in the frequency range 40MHz to 300MHz by installing C_{LED} at LED drive DCDC buck converter circuit output (without the input filter resister $R1$). From comparison of the results in Fig. 9 and Fig. 10, it has been confirmed that EMI radiation noise has been hardly detected because the effect of C_{LED} installed in the LED lighting circuit output. Therefore, it can be inferred that the proposed LED circuit constant was able to reduce EMI noise radiation by the optimal matching.

Additionally, Fig. 11 illustrates the measurement result in $C1$=2.2μF (without the input filter resister $R1$ and the output capacitor C_{LED}) and the background noise together.

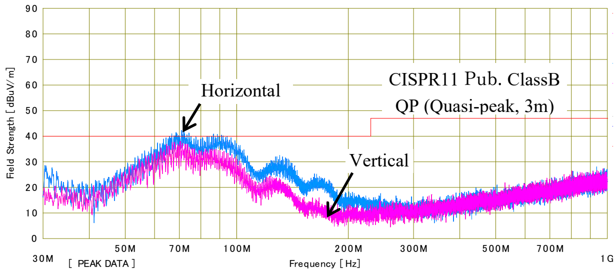

Figure 8. EMI measurement results at $R1$=1Ω, $C1$=4.7μF.

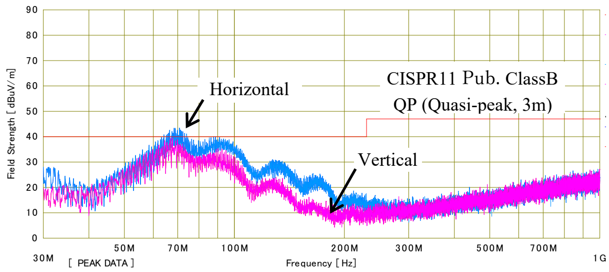

Figure 9. EMI measurement results at $C1$=4.7μF.

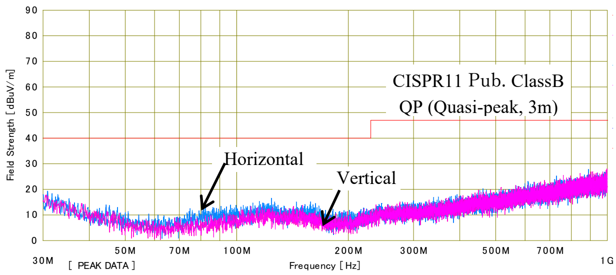

Figure 10. EMI measurement results at $C1$=4.7μF, C_{LED}=1μF .

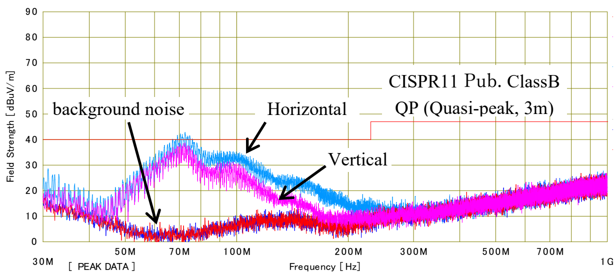

Figure 11. EMI field strength measurement comparison of $C1$=2.2μF and background noise.

The EMI radiation noise has become the same waveforms and has risen to approximately 40dBμV/m like Fig. 9 in the frequency range 40MHz to 300MHz with comparing to the result in background noise. Even if the input capacitor changed to $C1$=2.2μF, it has been proofed that the electromagnetic strengths have depended on the cable length of Vertical and Horizontal directions on the condition of same power cable lengths. By applying the front fixed electromagnetic field quasi peak measurement method, in the condition of the proposed buck converter circuit constant (C_{LED}=1μF) and the 3m distance range from EUT, the LED circuit and power line noise emission from 30MHz to 1GHz frequency band can been reduced. As a result, it will be possible to install and apply it as the medical LED lighting fixture to the clinical site of the medical institution using the proposed circuit constants.

V. Conclusion

EMI disturbance reduction characteristics have been shown when a general buck type current control DCDC converter circuit has been used for the LED lighting equipment. From the experiment results, when the cable lengths of Vertical and Horizontal direction are the same 0.8m and is installed as shown in Fig. 1, it has been confirmed that EMI radiated emission waveforms have become almost EMI radiation of the same level. When it was without the input filter resistor, it has confirmed that EMI radiation can be reduced to the floor noise level by setting the output capacitor 1μF C_{LED}. Not only can comply with the CISPR11 ClassB medical equipment radiation noise limit standard, but also the reported LED DC drive circuit can be installed with the proposed circuit constants in clinical sites of medical institutions without the input filter.

As the next study step, the electric field radiation and voltage noise transmitted on the power line from LED bulbs must be studied more, and it is also important that investigate a low noise LED circuit in more detail for the stable medical wireless communication.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Kiyotaka Fuji conducted the research planning and experiments. The research was organized by Yasuhiko Neba. All of the authors contributed equally in the writing of the paper and all authors had approved the final version.

References

[1] Ministry of the Environment, Japan. (2016). Overview of the plan for global warming countermeasures. [Online]. Available: https: //www.env. go.jp/press/files/en/676.pdf.

[2] Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy, The Government of Japan (GOJ), Japan. (2018). The 5th strategic energy plan. [Online]. Available: https://www.enecho.meti.go.jp/en/category/others/basic_plan/5th/pdf/strategic_energy_plan.pdf.

[3] Japan Lighting Manufacturers Association (JLMA). (2019). Environment lighting growth strategy, lighting vision 2030. [Online]. Available: https://www.jlma.or.jp/en/about/vision/pdf/LV2030_we bEP.pdf.

[4] T. Baumgartner, F. Wunderlich, A. Jaunich, *et al.*, *Lighting the Way:* Perspectives *on the Global Lighting Market*, 2nd ed., Chicago: McKinsey & Company, 2012, pp. 7-8.

[5] K. Ishida, K. Suzuki, E. Hanada, and M. Hirose, "EMC of wireless medical telemeters and noise radiated from light emitting diode lamps," in *Proc. International Symposium on Electromagnetic Compatibility - EMC EUROPE 2017*, Angers, France, 2017, pp. 1-4.

[6] S. Arie, K. Ishida, I. Wu, K. Gotoh, Y. Matsumoto, and M. Hirose, "Statistical characteristics of radiation noise from LED lamps and its effect on wireless medical telemeters," in *Proc. International Symposium on Electromagnetic Compatibility*, Amsterdam, The Netherlands, 2018, pp. 408-412.

[7] E. Hanada, K. Ishida, T. Kudou, "Newly identified electro - magnetic problems with medical telemetry systems," *Przeglad Elektrotechniczny*, vol. 94, no. 2, pp. 21-24, 2018.

[8] K. Ishida, S. Arie, K. Gotoh, E. Hanada, M. Hirose, and Y. Matsumoto, "Electromagnetic compatibility of wireless medical telemetry systems and Light-Emitting Diode (LED) lamps," *Przeglad Elektrotechniczny*, vol. 94, no. 2, pp. 25-28, 2018.

[9] R. Wang, N. Kuwabara, K. Masui, and H. Sato, "Investigation on mechanism of radiated emissions from fan unit model," in *Proc. 18th International Zurich Symposium on Electromagnetic Compatibility*, Munich, Germany, 2007, pp. 437-440.

[10] Industrial, Scientific and Medical Equipment - Radio-Frequency Disturbance Characteristics - Limits and Methods of Measurement, CISPR11 Standard 2015+AMD1:2016+AMD2:2019.

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