Experimental Study of Optical Modulation Probe for 85 kHz Electric Field Measurement in Human Body Equivalent Liquid Phantom

Yuichi Nagumo, Keisuke Konno, Qiang Chen
Graduate School of Engineering
Tohoku University
Sendai, Japan
nagumo-y@ecei.tohoku.ac.jp

Jerdvisanop Chakarothai, Kanako Wake, Soichi Watanabe
NICT
Tokyo, Japan

Abstract—**An optical modulation probe system for measurement of 85 kHz electric field strength in human body equivalent liquid phantom is designed and fabricated. The proposed system is composed of an optical modulator and a ferrite bar antenna. The optical modulator reduces interference of conducting cables while the ferrite bar antenna enhances the sensitivity of the system. It is demonstrated that the sensitivity of the probe with the ferrite bar antenna is enhanced when the probe is in air.**

Keywords-Optical modulator; human body equivalent liquid phantom; Low Frequency

I. INTRODUCTION

Human exposure to the low-frequency electromagnetic (EM) field of an electric-vehicle (EV) charging system by a wireless power transfer (WPT) system should be assessed accurately in advance because the system deals with high power. Electric field strength is should be assessed according to the guidelines [1]. It is expected that the measurement of internal electric field strength suffers from low sensitivity of a probe at low frequency band and interference of a conducting cable.

An optical modulator has been introduced to reduce the interference of the conducting cable [2]. No conducting cable is necessary because a probe is connected to the optical modulator via an optical fiber. One of the disadvantages of the optical modulator is low sensitivity which comes from impedance mismatching between the probe and the optical modulator. Although various studies have been performed, they have only focused on a probe working in free space at MHz/GHz band [3][4].

In this paper, an optical modulator probe system for measurement of low frequency electric field strength in human body equivalent liquid (HBEL) phantom is designed and fabricated. The probe system is composed of an optical modulator and ferrite bar antenna. Electric field strength in air is measured by using the fabricated probe at 85 kHz and enhanced sensitivity of the probe is demonstrated. This paper is enhancement of references [5] and [6].

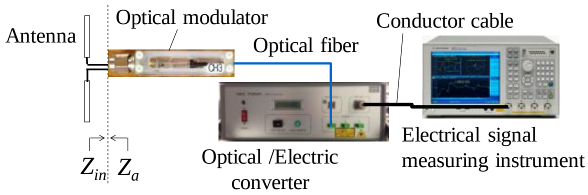

Figure 1. Optical modulation probe measurement system.

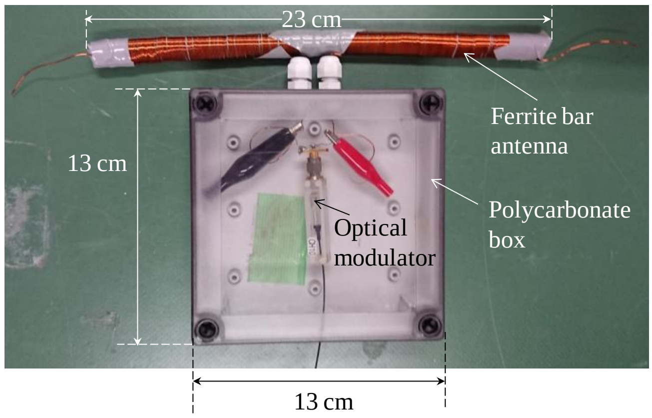

Figure 2. Photograph of fabricated probe.

II. DESIGNED PROBE SYSTEM

Here, a high sensitivity probe system is designed via conjugate impedance matching approach [4]. Optical modulation probe measurement system is shown in Fig.1. According to conjugate matching theory, receiving power of the probe is maximized once the following equation is satisfied [4].

$$Z_a = Z_{in}^* \quad (1)$$

The fabricated probe is shown in Fig.2. The probe is composed of the optical modulator and ferrite bar antenna. Input impedance of the optical modulator is Z_{in} = 1.7×10^5 — j2.2×10^5 Ω at 85 kHz while that of 23 cm length small dipole inside HBEL (NaCl solution : 0.074 mol/L ≈ 0.4 %) is Z_a = 40 — j3.3 Ω at 85 kHz, respectively. The ferrite bar antenna works as an antenna with an impedance matching circuit. The polycarbonate box is used to cover the modulator not to contact the medium.

III. Measurement Results

Electric field strength was measured by using the fabricated probe at 85 kHz. As shown in Fig.3, receiving power of the fabricated probe w/ small dipole or w/ ferrite bar antenna in air was measured. A dipole antenna of 23 cm length was used as a transmission antenna. Measurement parameters are shown Table I.

Receiving power of the probe w/ small dipole or w/ ferrite bar antenna in air is shown in Fig.4. As shown in Fig.4, although receiving power of the probe decreases as r increases, it is found that curves of receiving power are the same each other except for 5~8 dB shift, approximately. Enhanced sensitivity of the fabricated probe system over conventional one has been demonstrated in air. Table II shows receiving power of the probe at r = 10 cm and mismatching loss between the antenna and the optical modulator. As shown in Table II, the receiving power of the probe increase as mismatching loss decrease.

IV. Conclusion

In this paper, an optical modulator probe system for measurement of low frequency electric field strength in human body equivalent liquid phantom has been designed and fabricated. The designed system is composed of an optical modulator and ferrite bar antenna. Electric field strength in air was measured by using the fabricated probe at 85 kHz. It has been demonstrated that the sensitivity of the probe is enhanced by implementing the ferrite bar antenna.

Acknowledgment

This work was partially supported by the Ministry of Internal Affairs and Communications, Japan.

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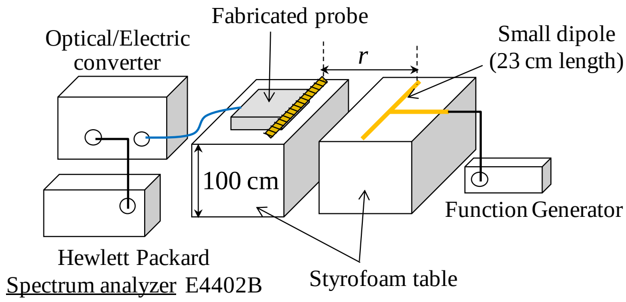

Figure 3. Experimental setup.

TABLE I. Measurement Parameter

Incident power	22 dBm
Frequency	85 kHz
Spacing between antennas	r = 5~50 cm

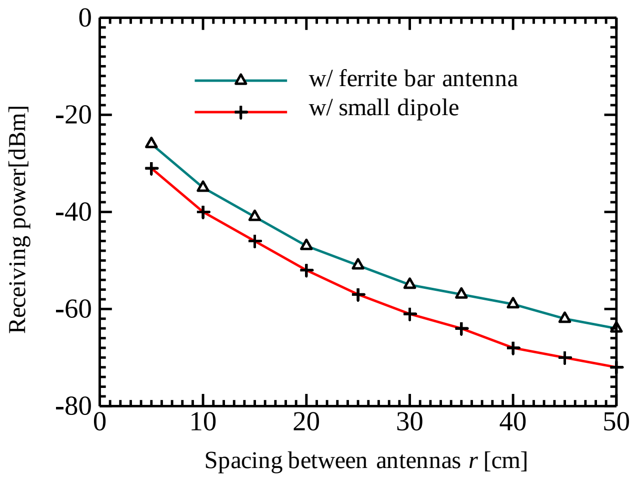

Figure 4. Receiving power of the probe in air.

TABLE II. Receiving Power of The Probe and Mismatching Loss

	Receiving Power (dBm)	**Mismatching Loss (dB)**
w/small dipole	— 40	16.3
w/ ferrite bar antenna	— 35	14.1
Ratio	5	— 2.2