High sensitivity electric field sensor using Mach-Zehnder interferometer

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HIGH SENSITIVITY ELECTRIC FIELD SENSOR USING MACH-ZEHNDER INTERFEROMETER

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1. Introduction

Recent progress in electromagnetic compatibility (EMC) has created a need for a wide-band electric field sensor for measuring electromagnetic pulses and the performance of the EMC measurement facilities[1] Electric field sensors using optical modulators are expected to be used such measurements because they operate over a wide-band frequency range and most of the composed materials are nonmetallic. However, the sensitivity and the frequency response need to be improved. This paper proposes an electric field sensor that uses a Mach-Zehnder interferometer which achieves these improvement.

2. Configuration

The configuration of the new sensor is shown in Fig.1. It consists of an optical source, a pair of optical fibers, an optical modulator, sensor elements, and a photodetector. The screw attached to the sensor is used to tune the optical bias angle. When an electromagnetic wave is applied to the sensor elements, a voltage is induced across the gap. The modulator modulates the optical power according to the voltage. The electric field strength is obtained by measuring the modulated optical signal.

3. Performance

The sensitivity of the sensor is shown in Fig.2. To achieve high sensitivity over a wide frequency range, the sensor employs a Mach-Zehnder interferometer whose half-wave voltage is less than 3 V and whose optical bias angle is tuned to get the best sensitivity. The minimum detected electric field strength of the sensor with approximately 10cm long resistive elements is about 0.3mV/m at 200Hz resolution bandwidth, and good linearity is obtained from 0.3mV/m to 30V/m.

The frequency response of the sensor is shown in Fig.3. This sensor uses approximately 10cm long resistive element to suppress the resonance caused by the element. This is almost flat from 1kHz to 1GHz.

The resonance due to the elastic wave in the substrate reduces the performance of the frequency response. By employing a new substrate shape to reduce the resonance caused by the elastic wave, the sensitivity deviation was reduced from 4 dB to 1 dB[2]. The sensitivity of the sensor drifts due to temperature changes caused by accumulation of charge between the electrodes of the interferometer. A conductive layer is formed on the $LiNbO_3$ substrate to discharge the accumulated charge. The deviation of this sensor is within 2 dB from 5 to 45 degrees[3].

This sensor can be used to evaluate the performance of EMC measurement facilities and for measuring electromagnetic pulses generated by electrostatic discharges. Future problems are the further improvement of sensitivity and the development of new applications.

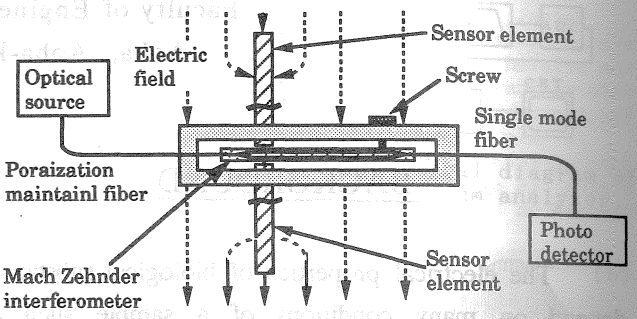

Fig.1 Configuration of electric field sensor using optical modulator

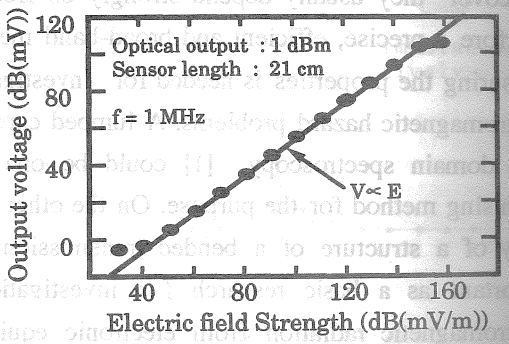

Fig.2 Sensitivity of the electric field sensor

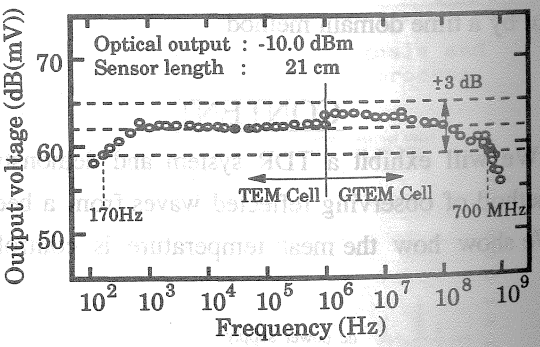

Fig.3 Frequency response of the sensor.

Reference

[1]M. Tokuda and N. Kuwabara;"Recent progress in fiber optic antennas for EMC measurement", IEICE Trans. Commun., Vol.E75-B, No.3, March 1992
[2]N. Kuwabara and R. Kobayashi;"Frequency response improvement of electric filed sensor using optical modulator", IEEE IM Tech. Conf., Hamamatsu, May 1994.
[3]R. Kobayashi et. al;"Optical-bias-controlled and temperature-stabilized electric field sensor using mach-zehnder interferometer", IEEE Int. Symp. EMC-94/SENDAI, Sendai, May 1994.