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A SMALL WIDEBAND ANTENNA PRINTED ON THE SAME LiNbO3 SUBSTRATE AS THE INTEGRATED OPTICAL MODULATOR

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Abstract

This paper describes a developed small wideband antenna. A 9.5 mm long tapered dipole element is printed on the $LiNbO_3$ substrate, on which a Mach-Zehnder interferometer has been formed by an optical waveguide. The sensitivity and frequency response of the antenna are calculated using the moment method, and measured in a known electric field generated by TEM cell and GTEM cell. The measured values closely agree with the calculated ones. The sensitivity of the antenna is almost flat from 100 Hz to 2.5 GHz, and the minimum detection level is 147 dBμV/m(22 V/m).

1.Introduction

Recent progress in EMC technology requires as to measure electromagnetic pulses and electric fields very near to an object. Therefore, a small and wideband antenna has been developed for such EMC measurements. Electric field sensors using electro-optical effect are useful for these measurements[1],[2]. These sensors are expected to produce minimal perturbation of the electric field because they are constructed entirely from non-metallic materials except for the antenna elements.

An electric field sensor with a bandwidth of 1 GHz and a sensitivity of 1 mV/m has been developed[1]. However, its sensor bandwidth and size should be improved to measure electromagnetic pulses.

This paper describes a small wideband antenna directly printed on the $LiNbO_3$ substrate on which a Mach-Zehnder interferometer has been formed by an optical waveguide.

2.Configuration of the Antenna

The structure of the antenna is shown in Fig.1. A 9.5 mm long tapered dipole consisting of two elements is printed by vapor deposition on a 10*40 mm Z-cut $LiNbO_3$ substrate on which a Mach-Zehnder interferometer has been formed by Ti diffusion. The tapered dipole elements are made of chromium with a thickness of $6*10^{-2}$ μm which has chosen to reduce the resonance at the dipole elements. These elements are symmetrical and perpendicular to the optical waveguide. The gap between the elements is 15 μm wide, and 2 mm long.

The optical modulator formed on the $LiNbO_3$ substrate, is constructed with two optical couplers and a pair of waveguides as shown in Fig. 1. The incident optical wave is divided by the former coupler. These waves are propagating in the each waveguides, and are interfered at the latter coupler. The average output power of the latter coupler is represented by

$$I_o=0.5I_i[1+\cos\phi] \quad (1)$$

where, I_i is the incident optical power of the modulator, ϕ is the phase difference between the each waves[1].

When the antenna is placed in an electromagnetic field, a voltage is generated at the dipole element gap by electromagnetic induction. Applying this voltage at the waveguides, the refractive index is changed by the electro-optical effect. Then, the output optical power is modulated because phase difference ϕ in equation (1) is changed by the induced voltage. Therefore, the electric field strength is obtained by detecting the modulated optical signal.

The external view of the small wideband antenna is shown in Fig.2. The antenna case is made of Teflon to minimize distortion of the electric field. A 30 m long polarization maintaining fiber connects the modulator to the light source, and A 30 m long single-mode fiber connects it to the photo detector. This antenna will be able to measure an electric field precisely because it can be constructed entirely from non-metallic materials except for the tapered dipole elements.

3.Calculation of Antenna Characteristics

The equivalent circuit of the small wideband antenna is illustrated in Fig.3. The tapered dipole elements are represented by a voltage source, whose amplitude is expressed by multiplying the external electric field strength E by the effective length of dipole elements h_e, and a driving point impedance Z_a. The interferometer is usually represented by a capacitance C_m. Using this equivalent circuit, a relationship between the external electric field strength E and the output voltage of the O/E converter V_r is given by

$$V_r=0.5\eta I_{out}[1+\cos\{((Eh_e/(1+j\omega C_m Z_a))/V_\pi)\pi+\phi\}] \quad (2)$$

where η is the conversion factor of the O/E converter, ω is the angular frequency, and I_{out}, V_π and ϕ are the output optical power, half-wave voltage, and optical bias angle of the optical modulator, respectively.

In equation (2), h_e and Z_a are calculated using the moment method[3], and C_m, V_π, η, ϕ and I_{out} are measured.

4.Measured Antenna Characteristics

The antenna characteristics were measured in a known electric field generated by a TEM cell and a GTEM cell[4]. A laser-diode pumped Nd:YAG laser whose wavelength is 1.3 μm was used as a light source and a PIN photodiode whose bandwidth is from DC to 15 GHz was used as an O/E converter.

The antenna sensitivity was measured at 29 MHz in the TEM cell. The results are shown in Fig.4. The bandwidth of the level meter which measured an output of the photodetector was 7.5 kHz. In Fig.4, the horizontal axis shows the applied electric field strength, and the vertical axis shows the output of the photodetector. The dots show the measured values, and the solid line shows the theoretical values calculated from equation (2). Since detection noise level of the level meter is 7 dBμV, the minimum detection level of this antenna is 147 dBμV/m(22 V/m). The measured values closely agree with the theoretical ones. This means that the sensitivity of the antenna can be calculated from equation (2).

The antenna frequency response was measured in the TEM cell below 100 MHz and in the GTEM cell above 100 MHz, and is shown in Fig.5. The horizontal axis shows frequency and the vertical axis shows the relative sensitivity, which is defined as the sensitivity normalized by the value at 100 Hz. The dots shows the measured values and the solid line shows the values calculated from equation (2). The measured values almost agree with the theoretical ones, and the measured frequency response is almost flat from 100 Hz to 2.5 GHz. This means that the antenna can be used to measure the electric field strength of electro-magnetic pulses.

5.Conclusion

We have developed a small wideband antenna using a $LiNbO_3$ substrate with a Mach-Zehnder interferometer. The frequency response of this antenna was found to be almost flat from 100 Hz to 2.5 GHz, and the minimum detection level of this antenna was 147 dBμV/m. The sensitivity and frequency response of the antenna were calculated using the equivalent circuit, and these values closely agree with the measured ones.

Acknowledgements

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References

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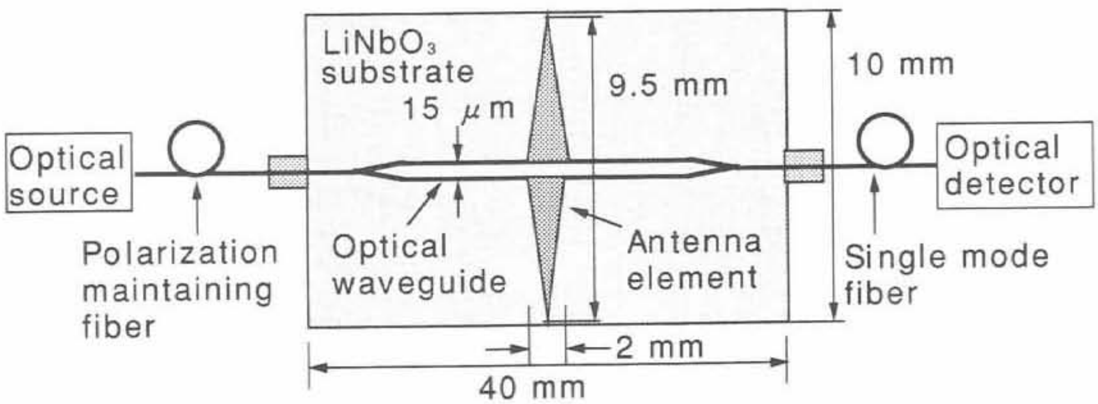

Fig. 1 Structure of the antenna formed on the same $LiNbO_3$ substrate as an optical modulator.

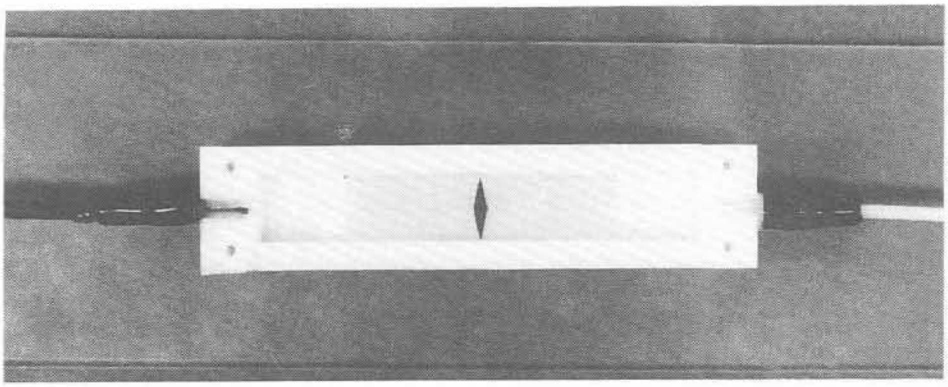

Fig. 2 External view of the antenna.

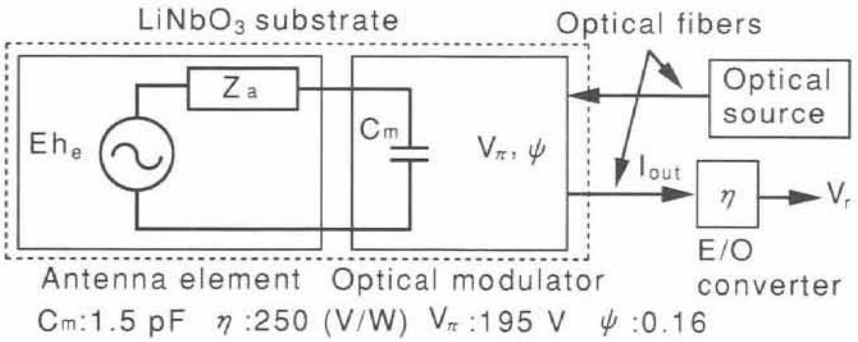

Fig. 3 Equivalent circuit of the antenna

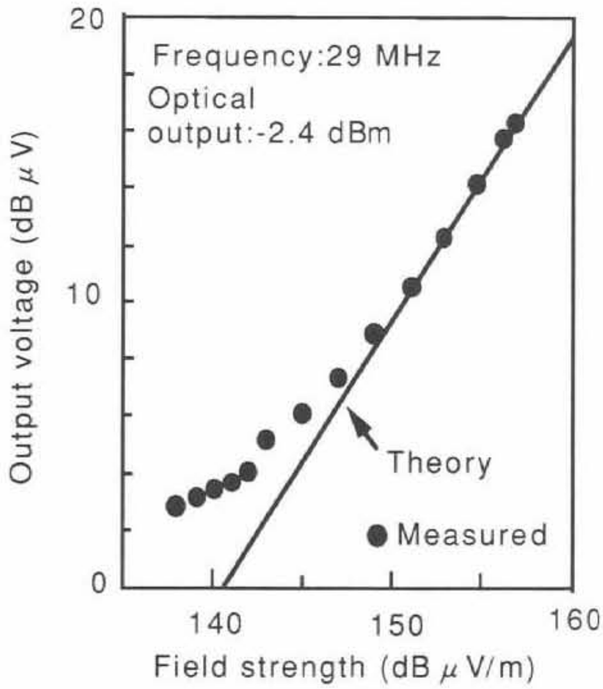

Fig. 4 Sensitivity of the antenna.

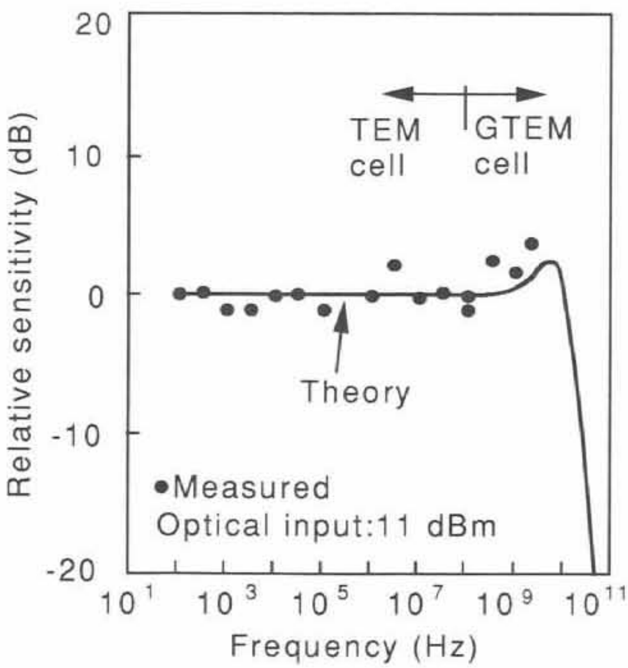

Fig. 5 Frequency response of the Relative sensitivity.