THE HIGH SENSITIVE THREE DIMENSIONAL OPTICAL E-FIELD SENSOR FOR TIME DOMAIN MEASUREMENTS

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Abstract: NEC-TOKIN developed an E-field measurement sensing system, using new principles. The sensor head of this system consists of $LiNbO_3$ crystal and optical fibre. No metal parts are used except for the antenna elements.

This sensor can measure not only E-field strength but also frequency and phase. The feature of this system are: minimal disturbance of the surrounding E-field, high-accuracy (uncertainly within 1dB), wide dynamic range up to 80dB, measurement ability of any kinds of modulations such as AM, FM, CDMA and so on. We further more improved this sensor to achieve high sensitivity. It will be more useful for time domain measurements.

Key words: $LiNbO_3$ crystal, E-field sensor, immunity test, optical modulator

1. Introduction

The optical modulator made of $LiNbO_3$ crystal has been in use for optical telecommunications for higher rate modulation up to 40GHz. And some research has been done for E-field measurement. [1]

NEC-TOKIN have started the development applying LiNbO3 optical modulator to E-field measurement in 1990. Features of this sensor are shown below:

(1) This sensor needs no coaxial metallic cables for transmitting signals.
  -Minimal disturbance of or to the surrounding E-field.
  -Minimal signal attenuation and frequency deviation compared with the use of coaxial cable.

(2) The sensor head has no metal parts except for antenna elements.
  -Minimal disturbance of or to the surrounding E-field.
  -We can achieve precise isotropy because of precise directivity.

(3) This sensor head consists of only passive devices, and it needs no power supply.
  -Sensor head size is very small.

We report the outline of the E-field sensor especially, high sensitivity model for time domain measurements.

2. Principle of sensor

2.1 Structure of the optical E-field sensor head

The outline structure of sensor head is shown in figure 1. This figure explains the principle of the sensor of 1axis. This sensor head is composed of $LiNbO_3$ crystal, metal electrode for antenna and optical fibre with glass ferrule. The optical wave-guide is shaped on the $LiNbO_3$ crystal with Titanium thermal diffusion process. The layout of this wave-guide is called Mach-Zehnder interferometer. The $LiNbO_3$ crystal exhibits the Pockels effect. If an E-field is applied to this crystal, its refractive index is modulated. This modulation caused the speed of optical wave on the wave-guide to go faster or slower. The Mach-Zehnder interferometer converts this optical wave speed modulation to amplitude modulation. Because of this effect, we can observe the E-field signal as an optical amplitude modulation. To minimize the sensor head dimensions, we use the reflective type optical modulator structure. A non-modulated laser optical wave is guided from optical fibre to optical modulator, and this optical wave is modulated with E-field, then the modulated optical wave is reflected at the mirror, and returns via the same optical fibre to the detector unit.

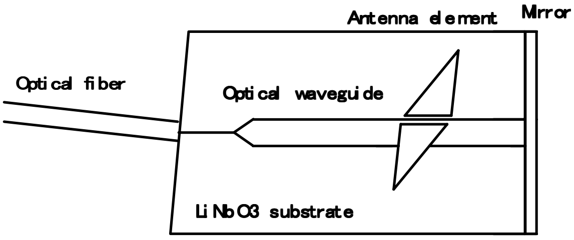


Figure1. structure of E-filed sensor head

2.2 Principle of the optical E-field sensor

The relation between the E-field input signal and the optical output signal is shown in Figure 2. The horizontal axis shows the input voltage. The vertical axis shows the optical output amplitude. The length of the two wave guides shown in Figure 1 are slightly different to each other, which gives a bias point. The most sensitive bias point is 45 degree of sine curve.

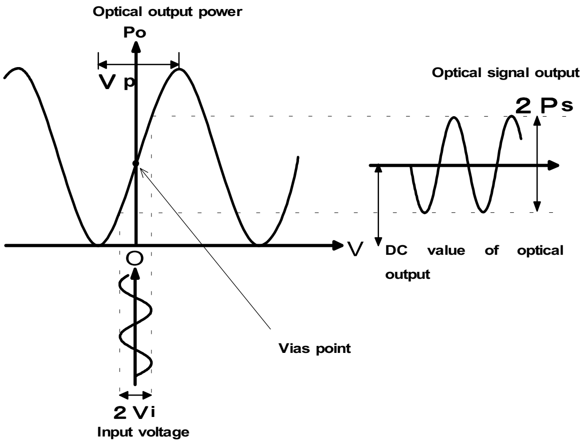


Figure 2. The relation between E-field input signal and optical output signal

2.3 Isotropic composition

We assemble 3 sensor chips to achieve the isotropic characteristic as shown in Figure 3. For isotropic, we angled the antenna electrode about 54.7 degree as shown in figure1.

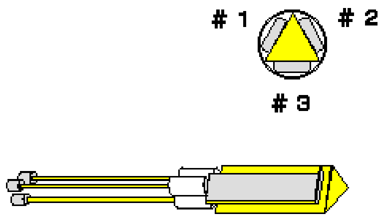


Figure 3. Isotropic composition

With this structure, The sensor head size is 30mmdia. and 70mm long. Antenna electrode are 12.5mm x 2.

2.4 System diagram of the optical E-field sensor

The system diagram for the optical E-field sensor is shown in Figure 4. The non-modulated optical wave is generated by two laser diodes, combined to give the required power. A dual polarized optical wave is output by the optical combiner.
The optical wave is transmitted to the sensor head through a single mode optical fibre. The LiNbO3 sensor head is optical polarization sensitive, but a orthogonally polarized optical wave can supply the same optical power to the sensor head in any case of polarization rotation in the single mode fibre. For isotropic measurement, this system switches the optical switch to select one of the X, Y, Z sensor chips. The PC calculates the isotropic E-field amplitude such as the root mean square of X, Y, Z.

3. Specifications of optical E-field sensor

3.1 Frequency response

A typical frequency response of the optical E-field sensor from 100kHz to 1GHz is shown in Figure 5. Because of the miniature size of the dipole, the frequency response is very flat, within +/- 5dB.

3.2 Sensitivity and dynamic range

The sensitivity and dynamic range are shown in Figure 6.

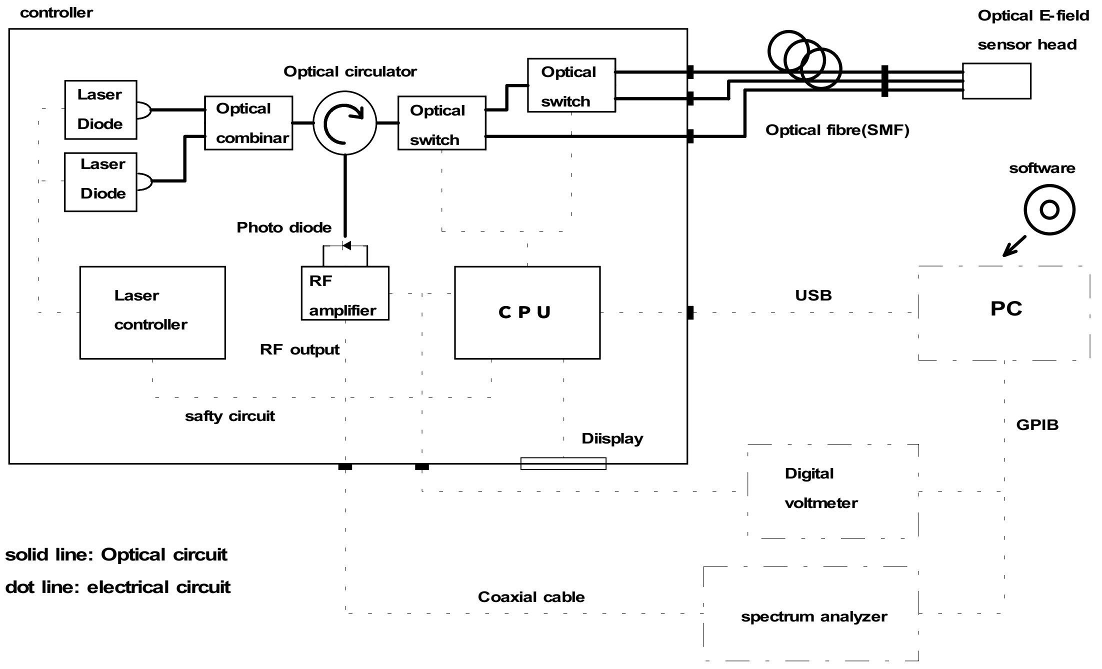


Figure 4. The system diagram for the optical E-field sensor

3.3 Isotropy

Typical isotropy of the optical E-field sensor is shown in figure 7.

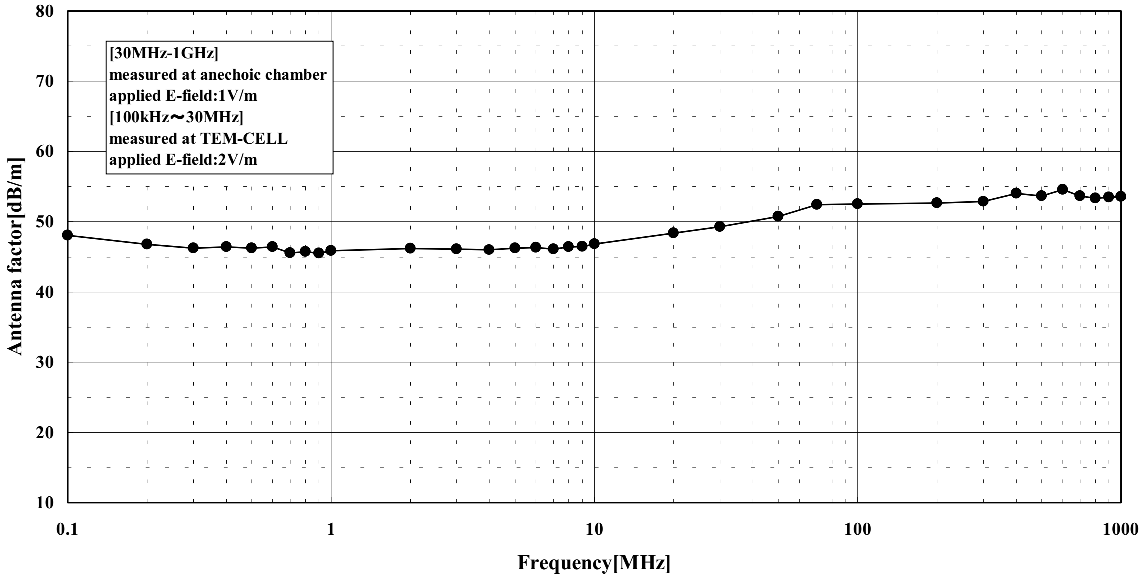


Figure 5. Frequency response.

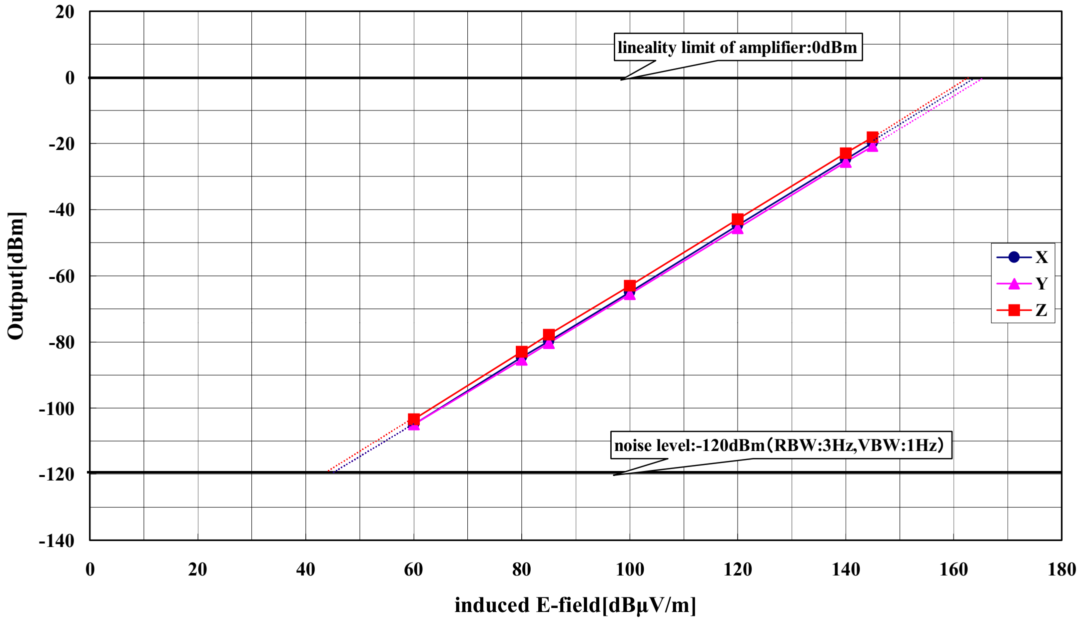


Figure 6. The sensitivity and dynamic range.

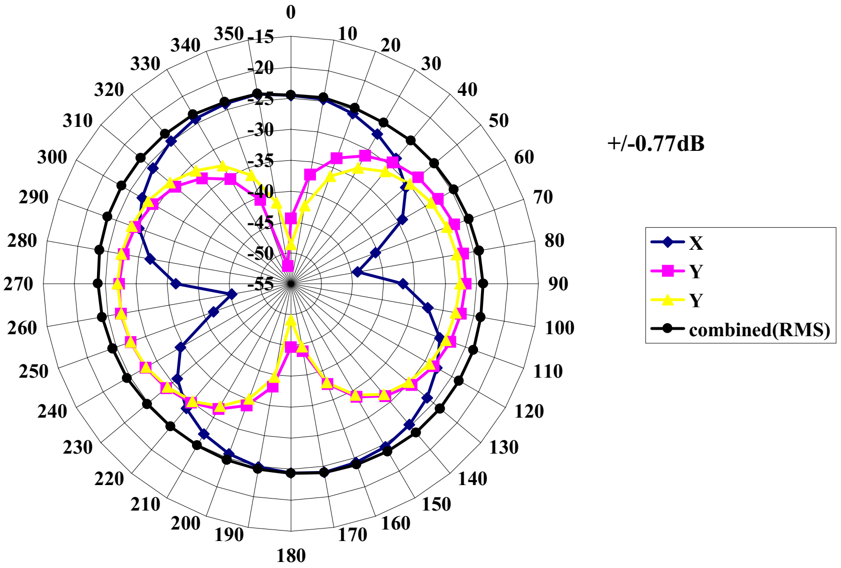
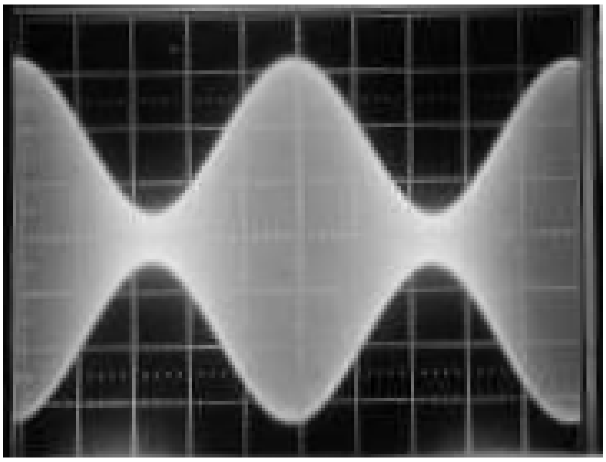


Figure 7. Isotropy



condition: x-axis:0.2msec/div
y-axis:0.2V/div

Figure 8. Display output of sensor on oscilloscope

4. Measurement example of time domain

We measured the E-field signal with optical E-field sensor. The induced E-field is AM modulated signal.Carrier frequency is 10MHz. Modulation ratio is 80% (1kHz). Figure 8 shows the display of oscilloscope. It shows that optical E-field sensor can faithfully reproduce the induced E-field signal.

5. Conclusion

We have improved our miniaturized three dimensional E-field sensor to be more high sensitive. It can measure the induced E-field faithfully and reproduce the signal on time domain. This sensor may be very useful for automotive immunity test and so on.

Acknowledgements

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References

[1] Kuwabara, N, Tajima, K, Kobayashi, R, Amemiya, F, 1992, “Development and analysis of electric field sensor using $LiNbO_3$ optical modulator.”, *IEEE Trans. on EMC*, **34**, pp. 391 - 396.