

メタルフリーオールオプティカル電界センサの技術紹介と 商品化への課題 —電界センサにおける SAR 値測定への応用—

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あらまし 本講演では、弊社が日本電信電話株式会社より技術移管され、商品化を進めている電界センサの技術内容及びその商品化における課題について説明する。当社の電界センサの特徴は、メタルフリーであること広帯域な周波数応答性を保有している点が挙げられ、主に無線機器から発せられる電磁波計測「SAR（比吸収率）測定」に注力した我々の取り組みについて紹介する。

キーワード メタルフリー、オールオプティカル、プローブ、SAR 値、携帯端末、電界センサー、電磁波吸収率

Metal-free All-optical Electric-field Sensor Technology and the Challenges for Commercialization —Application for Cellular Mobile Phone SAR Measurement —

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Abstract We describe a recently commercialized metal-free, non-invasive, all-optical electro-optic (EO) probe with a broad frequency response. This is based on the core technology licensed from Nippon Telegraph and Telephone Corporation, and we have been awarded a NEDO innovation development grand for the commercialization of this technology. The primary application of this commercial probe is for the measurement of the Specific Absorption Rate (SAR) of electro-magnetic waves emitted from cellular mobile phones. The 3-axis EO-probe contains no metallic elements at all, allowing a completely non-invasive measurement of electric field well beyond 18GHz.

Keyword All-optical metal-free probe, cellular mobile phone, electro-magnetic specific absorption rate, e-field sensor.

1. Introduction

The recent exploding worldwide market growth of cellular mobile phones, wireless-equipped tablets and notebook computers etc is creating a new era with environment full of wireless devices. In the first quarter of 2012, an estimated of 139 million smart

phones have been shipped worldwide, a 44% increase compared to the same quarter in the previous year. It is forecasted that, in 2012, there will be 11% increase in the shipment of mobile terminals and out of the smart phones will see an increase of 17% to 520 million units. These mobile devices uses frequency bands from 300MHZ to 3GHz, and the concern on radio frequency safety towards human health, in

particular the Specific Absorption Rate (SAR), is becoming an important issue that required regulation from official authorities. Non-invasive measurement of electric-field distribution around mobile devices is required for accurate assessment of SAR.

Alnair Labs has licensed the electro-optic (EO) probe technology from NTT Corporation and awarded a NEDO innovation development grant for the commercialization of the EO probe specifically for SAR measurement applications. Optical electric-field sensor [1-5] has been of much interest in applications where conventional metallic antenna-type probe fails to perform due to their invasiveness. Applications such as antenna characterization, specific absorption ratio (SAR) measurement [2][3] for cellular mobile phone safety standard, electromagnetic compatibility (EMC) and so on, calls for high precision measurement of the 3-dimensional vector field distribution around the object under test.

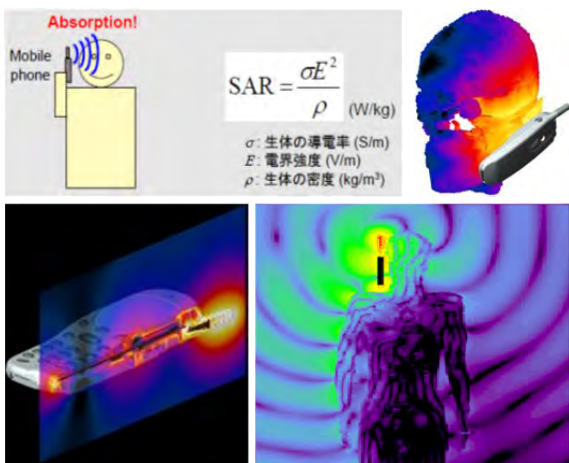


Figure 1. Specific Absorption Rate (SAR)

Optical electric-field sensors in the market are mostly based on Lithium-niobate waveguide Mach-Zehnder interferometer type configuration [1][4] with frequency response up to 10GHz, where sensor element such as dipole antennas are attached on the waveguide to enhance probe sensitivity and directivity. The presence of the metallic sensor element will disturb the surrounding electric-field and hence distorting measurement results.

A completely non-invasive, non-metallic EO probe has been demonstrated [3] for SAR measurement. Miniaturized tip-on-fiber EO probe has

also been realized [5]. In this paper, we report a 3-axis non-invasive EO probe based on the tip-on-fiber configuration with broadband frequency response over 18GHz.

2. Configuration of the EO-Probe

The photograph of of the 3-axis EO probe is show in Figure 2, and the probe construction is depicted in Figure 3.

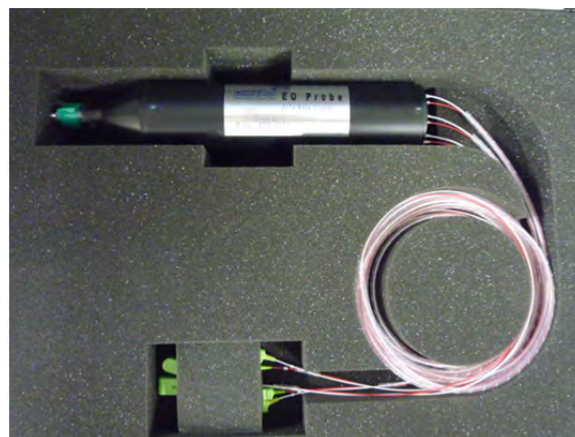


Figure 2. Photograph of the 3-axis EO-Probe

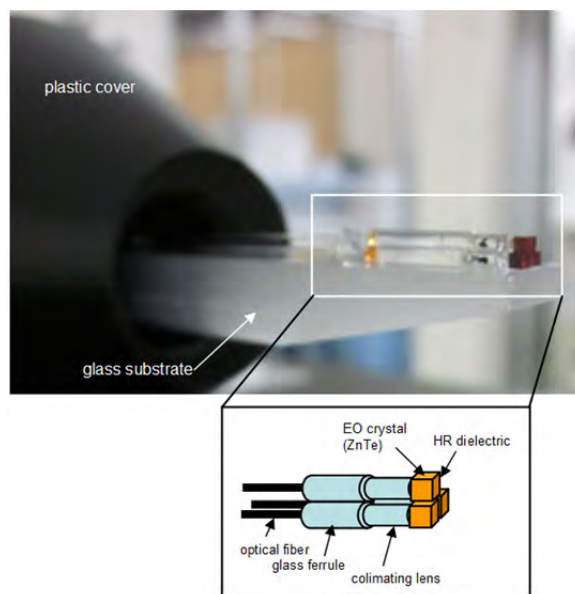


Figure 3. Construction of the EO-Probe tip.

The probe is based on a glass substrate with a plastic housing. 3 pieces of 1x1x1mm ZnTe crystals are used as the electro-optic sensors. The principle of the electric-field sensor is well described in [5]. An

input laser light at $\sim 1550\text{nm}$ is launched with a circular polarization, via a graded index collimating lens, incident to the corresponding crystal that has a HR dielectric coating at the end-facet to reflect the light back to the fiber. Each of the 3 crystals has its sensing axis aligned to one of the predetermined direction (X, Y, or Z). Incident electric-field will cause changes to the state of polarization of the reflected light. An all-optical polarization analyzer is constructed with miniaturized optics inside the probe main-body housing. The returning light from each of the 3 crystals are coupled back to 3 high-speed photo-detectors, respectively for the measurement of the vector electric field strength.

3. Experimental Setup

The performance of the probe is measurement using the experimental setup as shown in Figure 4. 1550nm CW laser with 80mW output power is launched into the EO probe (model: EOP-200), and the returning signal from the EOP-200 is detected using a high-speed photo-detector with frequency response of 1MHz – 18GHz. An optical low-noise optical amplifier (EDFA model: LNA-200) is inserted together with an narrow band optical filter for the suppression of the amplified spontaneous emission (ASE) from the optical amplifier.

An RF signal generator with 16dBm output power is used to drive an antenna placed close to the tip of the probe with different orientation to suit the axis of measurement. The signal from the photo-detector is measured using an RF spectrum analyzer.

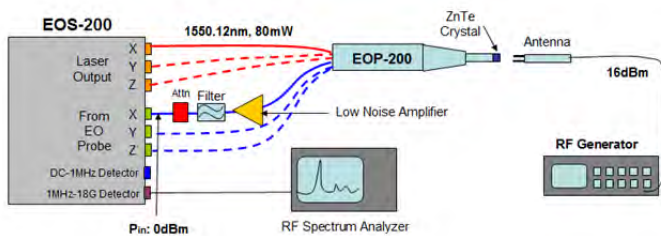


Figure 4. Experimental setup.

It is evident that the signal-to-noise ratio and hence the sensitivity of the measured signal can be greatly enhanced with the low-noise optical amplifier and optical filter (Figure 5).

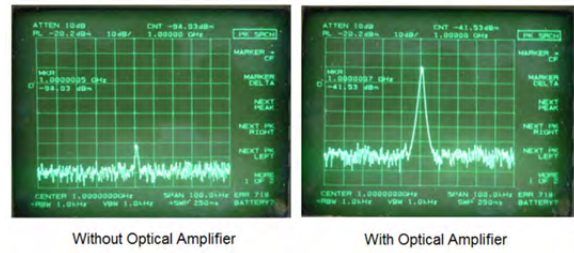


Figure 5. Sensitivity enhancement with optical amplifier.

4. Results and Discussions

The frequency response of the EO probe is measured and the results are shown in Figure 6. The frequency response shows a broadband response from 1MHz to 18GHz, limited only by the photo-detector response. Z-axis has higher sensitivity due to its orientation favoring a closer placement of the test signal antenna. The results also suggested that the EO probe has a trend to have less sensitivity at lower frequency $< 1\text{MHz}$. Indeed the EO probe has poor response for DC field. This can be explained by the fact that the crystal has no metallic contact and therefore a continuous DC electric-field would create a static charging effect, reversing the internal field in the crystal and results in reduction of the Pockel's effects.

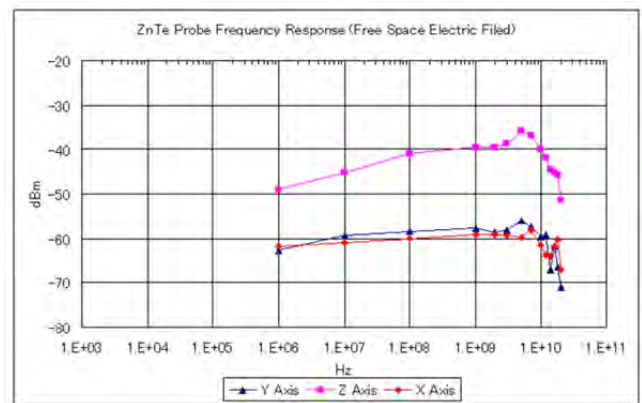


Figure 6. Frequency response of the 3-axis EO-Probe.

5. The Challenges

The key technical and commercial challenges for a successful commercialization of the developed EO probe are recognised to be:

(1) Probe Sensitivity

Despite all the advantages offered by the EO probe over

conventional antenna probe, i.e. non-invasiveness, compact size, broadband response, time-domain/phase sensing capability and so on, the one of only drawback of current EO probe is its sensitivity. Over the course of the project, we have put in great effort to improve its sensitivity and have achieved a level close to that for commercial deployment. It is possible to incorporate small dipole antenna to improve its sensitivity close to that of commercial antenna probe, however, this defeats the purpose of an all-optical, metal-free design of the EO probe. We are now working on a new configuration to further improve the probe sensitivity.

(2) *Low-Frequency Response*

Another technical challenge of the EO probe is the poor low-frequency response, particular below 1MHz range. It is difficult to use the EO probe for DC field measurement. There are ways to enhance the low-frequency response of the EO probe to a few Hz response, however, that would also involve plating electrodes onto the EO crystal, again defeating the purpose of an all-optical, non-metallic design.

(3) *Calibration and Standardization*

In order to commercialise such EO probe, it is required that a calibration process to be defined and developed to ensure the accuracy and traceability. Furthermore, professional associations and organizations should also work on a unified standardization of such EO probe for a successful commercialization.

(4) *Cost*

Last but not least, the production cost of such EO probe and its associated measurement tools and equipment should also be controlled and reduced to a level acceptable for mass deployment.

6. Summary

We have introduced a metal-free all-optical E-field sensing probe for accurate and non-invasive measurement of SAR. The demonstrated commercial 3-axis EO probe is completely non-metallic and therefore non-invasive. The EO probe has a broadband frequency response >18GHz, limited by the photo-detector used in the receiver. The frequency response can be further improved by using faster photo-detector.

This technology is important for mobile phone safety inspection and in view of the current rapid

increase in the number of mobile phones and other radio devices around. We expect the commercialization of this technology to play a key role in the future for safety standard test, and factory inspection test and measurement.

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