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TECHNICAL REPORT

colour inside

Transmitting equipment for radiocommunication – Radio-over-fibre technologies for electromagnetic-field measurement – Part 2: Radio-over-fibre technologies for electric-field sensing

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Part 2: Radio-over-fibre technologies for electric-field sensing

FOREWORD

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IEC TR 63099-2, which is a Technical Report, has been prepared by IEC technical committee 103: Transmitting equipment for radiocommunication.

The text of this Technical Report is based on the following documents:

Draft TR	Report on voting
103/184/DTR	103/186A/RVDTR

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 63099 series, published under the general title *Transmitting equipment for radiocommunication – Radio-over-fibre technologies for electromagnetic-field measurement*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

This document provides information on the current and latest applications for electric-field sensing using radio-over-fibre technology. Electric-field measurement systems are covered, which are practically in use or will be used soon. It will be beneficial to system developers and system users in the fields of electric-field measurement. As a Technical Report, this document contains no requirements and is informative only.

TRANSMITTING EQUIPMENT FOR RADIOCOMMUNICATION – RADIO-OVER-FIBRE TECHNOLOGIES FOR ELECTROMAGNETIC-FIELD MEASUREMENT –

Part 2: Radio-over-fibre technologies for electric-field sensing

1 Scope

The purpose of this part of IEC 63099 is to provide information about the current and latest applications for electric-field measurement that use radio-over-fibre technologies. System configurations, specifications, and measurement examples of each electric-field measurement system are included. The theoretical background of electric-field measurement and calibration method of electric-field sensors are beyond the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEEE Std. 145-2013, *IEEE Standard for Definitions of Terms for Antennas*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEEE Std. 145-2013 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
O/E converter
optical to electrical converter
converter which directly converts optical signals into electrical signal

Note 1 to entry: A photo-diode is generally used as an O/E converter device

3.1.2
isotropy
uniform sensitivity for all spherical direction

Note 1 to entry: Sometimes it is misunderstood as equivalence of each axis sensor of 3-axis.

3.1.3
TEM-Cell
transverse electromagnetic field cell waveguide which can generate a certain level of uniform electric-fields in the cell

3.2 Abbreviated terms

DUT	device under test
EO	electro-optic
LD	laser diode
LN	lithium niobate
LNA	low noise amplifier
O/E	optical to electrical
OMI	optical modulation index
PD	photodiode
PMF	polarization maintaining fibre
P1dB	1 dB power compression point
SMF	single-mode fibre
TEM	transverse electromagnetic-field
TIA	transimpedance amplifier
VCSEL	vertical cavity surface emitting laser

4 Practical examples of electric-field sensing system using RoF technologies

4.1 Overview

A lot of electric-field sensing systems using RoF technology are proposed. This document introduces the system configuration, specifications, examples of measurement results of typical electric-field sensing systems which are already commercialized.

4.2 Features of electric-field sensing system using RoF technologies

Electric-field sensing systems using RoF technologies have many features as follows:

- minimal-invasiveness to electric-field;
- electrical smallness;
- good isotropy;
- high linearity.

4.3 List of implementation examples

The following list shows the examples of implementation of electric-field measurement systems using RoF technology:

a) 3-axis electric-field sensor using LN optical modulators, described in 4.4;
b) bulk-type electric-field sensor using ZnTe optical modulators, described in 4.5;
c) electric-field probes using VCSEL, described in 4.6.

4.4 3-axis electric-field sensor using LN optical modulators

4.4.1 System configuration

Figure 1 shows the system configuration of the 3-axis electric-field sensor using an LN optical modulator. The sensor consists of a sensor head, controller, single-mode optical fibres for signal transfer, and a spectrum analyser for signal analysis. Figure 2 shows the structure of the sensor head. It uses an LN optical modulator, in which antenna elements are formed on the crystal substrate. These three LN optical modulators are arranged onto the three sides of a triangle prism, obtaining isotropy [1][1]. In other words, the three LN optical modulators are arranged so that they are at right angles to each other, and their maximum radiation angle from the optical waveguide is 54,7°, thus achieving isotropy. The controller consists of an optical source, optical circulator, optical switch, O/E converter, and control circuit. Un-modulated light emitted from the optical source passes through the optical circulator and optical switch, and is guided to the sensor head. The LN optical modulator on each axis is selected by the optical switch, and the light, which has been intensity-modulated via a spatial electric-field, returns to the optical circulator, and is guided to the O/E converter. It is possible to measure the output on each axis after O/E conversion with a spectrum analyser and measure the electric-field strength E by applying the following formula.

$$E = \sqrt{E_x^2 + E_y^2 + E_z^2} \tag{1}$$

where E_x is the electric-field strength on the X axis; E_y is the electric-field strength on the Y axis; and E_z is the electric-field strength on the Z axis.

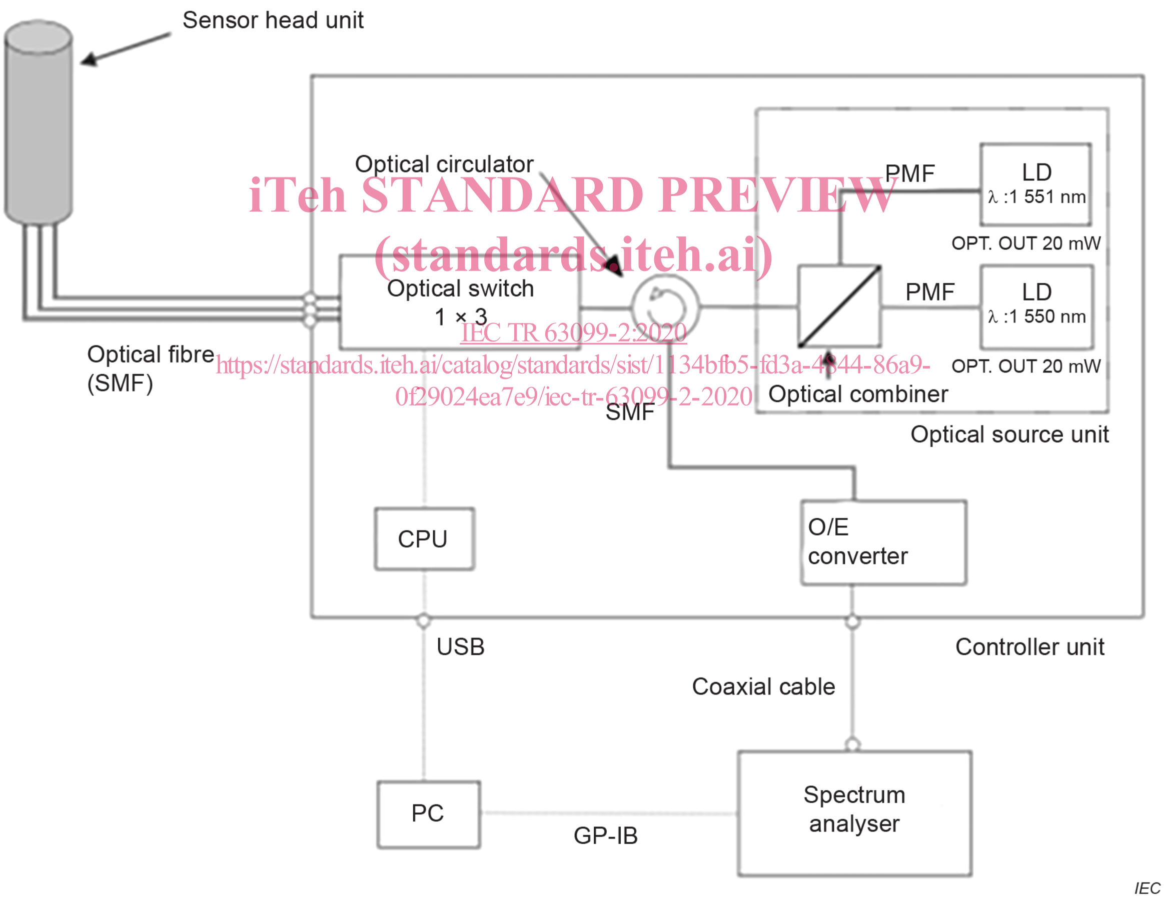

Figure 1 – System diagram of the optical E-field sensor

[1] Numbers in square brackets refer to the bibliography.

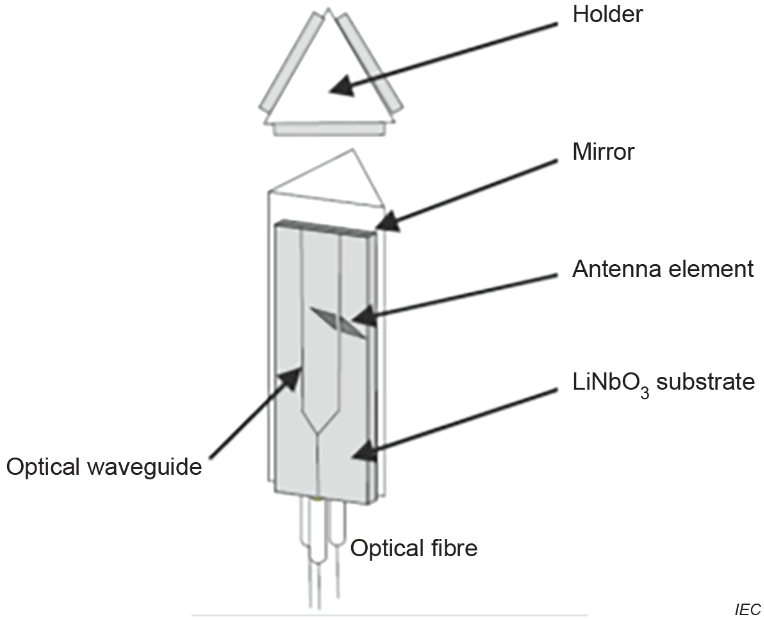

Figure 2 – Structure of the sensor head unit

4.4.2 Specifications

Table 1 shows the specifications of a 3-axis electric-field sensing system using the LN optical modulator models SH-03EX and SH-10EX of Seiko Giken Co. Ltd[2]. Figure 3 shows the appearance of the 3-axis electric-field sensing system.

Table 1 – Specification of 3-axis electric-field sensing system using LN optical modulator

Item			Specification				Remarks
			Minimum	Type	Maximum	Unit	
Frequency range	SH-03EX		0,1		3 000	MHz	
	SH-10EX		0,1		10 000		
Measurement E-field strength	SH-03EX	< 300 MHz	0,06		100	V/m	S/N when minimum input: ≥ 6 dB at 301 MHz (RBW: 10 Hz,VBW: 1 Hz)
		≥ 300 MHz	0,002				
	SH-10EX	< 300 MHz	0,3		500		
		≥ 300 MHz	0,01				
Isotropic	SH-03EX				±1	dB	Impressed E-field strength: 6 V/m at 301 MHz
	SH-10EX						

2 SH-03EX and SH-10EX of Seiko Giken Co. Ltd are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of these products.