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Autonomous system for identification of optical connectors

***Abstract**. RFID identification of fiber optic connectors system is developed. This system should be autonomous and it must allow to be implemented in distribution part of passive optical networks (PON). The conventional power source should not be considered, due to the lack of electricity in PON. Therefore the alternative power source is proposed to power this system. In this paper a demonstrator of identification system with a new light source and the photovoltaic power converter (PPC) is described. New elements provide bigger amount of energy which results in reduction of identification cycle time.*

***Streszczenie**. Opracowywany jest identyfikator RFID złącza światłowodowego. Ten system powinien być autonomiczny i musi umożliwiać wdrożenie w części dystrybucyjnej pasywnych sieci optycznych (PON). Nie należy rozpatrywać konwencjonalnego źródła zasilania ze względu na brak energii elektrycznej w ODN. Dlatego alternatywne źródło zasilania jest proponowane do zasilania tego systemu. Przetwornik fotowoltaiczny (PPC) jest przeznaczony do przekształcania światłowodu o światło pochodzące z energii elektrycznej. Wydaje się, że światło laserowe przekształcane w energię elektryczną jest najbardziej dogodną opcją w ODN. Ponadto w niniejszym artykule przedstawiono zdolność przesyłania energii i danych w pojedynczym światłowodzie wielomodowym (MMF). W tym artykule udowodniono, że realizowany hybrydowy system transmisji światłowodowej umożliwia zasilanie systemu identyfikacji, a także przesyłanie danych. (**Autonomiczny system identyfikacji złączy optycznych**).*

Keywords: identification of optical connectors, RFID, NFC, monitoring system, energy harvesting
Słowa kluczowe: identyfikacja złączy optycznych, RFID, NFC, systemu monitorowania, pozyskiwania energii

Introduction

Optical networks have revolutionized the telecommunications market in the past 30 years. In the most popular standards: Gigabit Passive Optical Network (GPON) and Gigabit Ethernet Passive Optical Network (GEPON) used in Fiber To The x networks (FTTx), part of the distribution network is passive. This means that there is no need to provide power to conducted fiber and to the passive switching points. At the same time, the maintaining and monitoring this expanding passive infrastructure is increasingly important.

Identification of fiber optic connectors and monitoring the changes in FTTx network topology is required by providers of IT services. In papers [1-3] solutions using Radio Frequency Identification (RFID) tags are presented. Simple marking systems of cables and connectors using RFID technology are already commercially available. In all these solutions, the identification system requires a conventional power supply or the presence of operators of telecommunication infrastructure. Because, as previously mentioned, part of the distribution network is passive, the use of conventional power source (AC/DC) is not justified. The alternative power supply – energy harvesting – should be therefore considered during the development process of maintaining and monitoring systems. The latest generation of microprocessor systems and supply circuits with AC/DC, DC/DC converters are high-performance and energy-efficient and need to work less than 1 mW [4,5]. Also the presence of operators is not desired as it increases the cost and does not provide a full automation of the connector identification process. Therefore during the design process of such a system the autonomous and low power communication system must be taken into account. In our previous paper [16] we presented a demonstrator of a fully autonomous RFID monitoring system. In presented system the time needed to perform a single cycle of identification process equals 218 s. In our opinion the time is too long to implement developed identification system in the big optical distribution cabinets (ODC). The total identification procedure in the ODC equipped with 1000 fiber optic connectors takes more than 60 hours. To reduce this time two methods can be considered: a usage of a new, more powerful light source and dedicated photovoltaic power converter (PPC) or changes in communication procedures and protocols in electronic system. Both methods are being developed in our laboratory, however in this paper a detailed description of improved system with a new light source and PPC is given which allows us to obtain significantly reduced identification time.

Table 1. Selected patents on RFID identification systems for telecommunications

Number	Publication date	Title	Assignee	Short description
US 2006/0148279 A1 [10]	6 June 2006	Telecommunications patching system that utilizes RFID tags to detect and identify patch cord interconnections	CommScope Solutions Properties, LLC	Each patch panel has RFID reader. Each adapter has a receiving antenna. Front and back connectors have the same identification number.
US 2014/0138431 A1 [11]	22 May 2014	System and method for providing power and communication link for RFID managed connectivity using removable modules	Tyco Electronics UK LTD	Tags are integrated with the connector and the antenna is integrated with the adapter. Additionally, the adapter has LED diode informing about the status of the connection.
US 7,772,975 B2 [12]	10 August 2010	System for mapping connections using RFID function	Corning Cable Systems, LLC	Connectors are equipped with various elements that cause tag activation. Antenna of tag can be placed on the connectors or adapters.
US 8,248,208 B2 [13]	21 August 2012	RFID-based active labeling system for telecommunication systems	Corning Cable Systems, LLC	The active label is a combination of display and rewritable RFID tag. It can be placed on the frame of a telecommunications cabinet.
US 2010/0079248 A1 [14]	1 April 2010	Optical fiber connector assembly with wire-based RFID antenna	Corning Incorporated	Planar antenna is placed on the back side of the connector. It is connected to the 12cm long cable distributed along the optical fiber

Cables and connectors identification methods

The detailed description of cables and connectors identification methods has been already given by us [15, 16]. The passive methods described by the standard TIA/EIA-606-A were given. Great number of different active methods using e.g. LED diodes [6], QR codes [7], augmented reality [8], or even RFID techniques [2,9-10] were described. The cable infrastructure routing is constantly monitored in near real time, with information automatically relayed from the individual nodes to a digital mapping and management system. The information about cable infrastructure is automatically relayed from the individual connectors to a computerized management system. There are many papers from R&D centers of big companies such as Tyco Electronics or Corning [10-14] about the RFID connector tracking and identification systems. In Tab. 1 the short summary of this works is presented.

In none of the mentioned above methods and papers alternative energy sources were used. The electric power supply in all given examples must be provided. However we believed that hence the ODC and switching points in PON are passive it is hard to implement the identification system in such points of network. Therefore the alternative energy source is required. In previous paper [15] a number of experimental tests on the selected commercially available transducers, and RF/DC and DC/DC converter were presented. The most reasonable way to obtain the energy in passive ODC is the conversion of light into electric power. We are developing system in which one of optical ports in ODC is used as power over fiber (PoF) port to power supply whole identification system. Such a system is described below.

Supply system configuration and measurement setup

System architecture

The schematic diagram of the system is presented in Fig. 1. The 800-1700 nm FGA01FC photovoltaic power converter from Thorlabs was used as a DC/DC converter. The converter was installed in PoF fiber optic adapter. As a light source (LS) FLS-600 from EXFO was chosen. The light was distributed from LS to PPC through single-mode optical fiber (SMF) G.652 class. Power management integrated circuits (PMIC) S6AE102A from Cypress were used to control and manage the energy in the system. Due to the fact that provided by PPC electric energy can be insufficient for the system to operate in constant mode the energy is stored in the supercapacitor DMF3Z5R5H474M3DTA0 from Murata. System management and communication in IS is implemented by the Programmable System on Chip (PRoC) module with microcontroller ARM cortex M0 SoC and integrated transceivers Bluetooth Low Energy (BLE). The use of CYBLE-022001-00 with programmable SoC architecture provides a possibility to design the energy-efficient architecture of peripherals. As a RFID/NFC transceiver the CR95HF module acting in 13.56MHz band was used. The UART provides the communication with the host controller. The identification of single fiber connector is started when the voltage on capacitors achieve 3.24 V. Then V_{DD} voltage supply is activated by Power Management IC. After that, UART communication between RFID reader (CR95HF) and Cyble-022001-00 module is checked and the required radio communications protocol for RFID tag is set. In the next step antenna placed on fiber optic adapter is automatically enabled and it starts emitting the energy. If there is a connector with a tag within antenna range, the tag ID number will be send to BLE module. To save the energy we decided to disable the RFID reader in the next step. In the last step the notification about the event is sent by Bluetooth wireless communication to e.g. a host controller. In [16] we proved that the execution of a single identification cycle requires 15.6 mJ of energy.

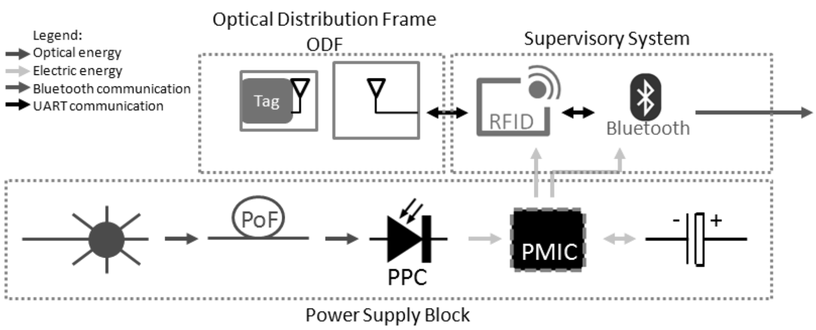

Fig.1. Identification system of fiber optics connectors with WDM alternative power supply

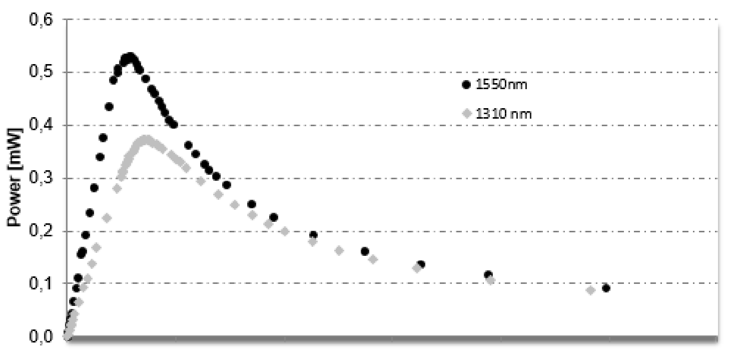

Fig.2. The influence of matching load RLOAD on the output power POUT of photovoltaic power converter FGA01FC for 1310 nm and 1550 nm wavelengths

Results and discussion

Measurement setup and procedure

To investigate the power offered by PPC the indirect method was used. Current and voltage were measured with electrometer Keithley 6514. All waveforms were recorded with dynamic signal analyzer NI DSA PCI 4462.

The influence of matching load R_{LOAD} on the output power P_{OUT} of PPC FGA01FC, investigated for two wavelengths: 1310 nm and 1550 nm is presented in Fig. 2. The 0.37 mW peak of output power for the wavelength 1310 nm is observed at R_{LOAD} 410 Ω while for 1550 nm the 0.53 mW power peak is obtained at the loads exceeding 300 Ω.

Discussion

The fulfillment of the postulate of full autonomy IS with respect to the power required to balance the energy stored in the capacitor. The energy available in the capacitor C_S with the capacitance C_S = 470 mF is determined by the dependence $E_S = 0.5\ C_S{*}(V_{DDH} - V_{DDL})^2$ and equals 58.6 mJ hence V_{DDH} = 3.3 V and V_{DDL} = 2.8 V. Execution of a single identification cycle requires 15.6 mJ of energy which allows to perform three identification cycles having fully charged capacitor. The maximum output power of FGA01FC converter acting at 1310 nm wavelength is P_{PPC} = 0.37 mW at R_{LOAD} 410 Ω the time needed to fully charge the capacitor is ca. 158 s while the time t_c required to perform single identification cycle is t_c = 42 s. For the 1550 nm obtained output power is bigger P_{PPC} = 0.53 mW at R_{LOAD} 300 Ω which results in reduction of time required to charge the capacitor 110.5 s and the time t_c = 29.5 s.

The FGA01FC converter maximum efficiency is 35%. The LS FLS-600 is typically used during e.g. the attenuation measurements of PON but not in data transmission. Conventional LS dedicated to data transmission in PON offers more optical power e.g. 2.5 mW (Cisco SFP module SFP-10G-ZR-S). Thus, the available potential electric power P_{OUT} of PPC equals 0.88 mW which allows to perform identification cycle every 18 seconds.

Summary

To implement identification system based on energy harvesting sources into big ODC, the reduction of the identification time t_c had to be obtain. Therefore the new light source and new PPC has been used to supply discussed system. Presented power supply provides maximum peak power of 0.53 mW, while the total energy of 15.6mJ is sufficient to enable the identification cycle. In described identification system it is possible to identify two connectors during one minute. This means that we managed to reduce the t_c time more than seven times in comparison to the previous system.

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