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RADIO OVER FIBRE LINK FOR SHORT RANGE WIRELESS COMMUNICATION

Лисюк О., Годзишевський К., Ящишин Є. Передача радіосигналу по оптичному волокну на короткі відстані. Розглядається концепція технології передачі радіосигналу по оптичному волокну в безпроводових системах зв'язку короткого діапазону дії. Для поліпшення продуктивності систем зв'язку розглядається використання фотонної антени. У роботі використовуються деякі реалізації фотонних антен. Технологія RoF зв'язку з використанням фотонних антен дає можливість передавати модульовані радіосигнали, наприклад стандартів WLAN або LTE, для забезпечення безпроводового радіодоступу усередині будівлі.

Ключові слова: радіосигнал, оптичне волокно, RoF, безпроводові комунікаційні системи, фотонна антена, WLAN, LTE, безпроводовий радіодоступ

Лисюк А., Годзишевский К., Ящишин Е. Передача радиосигнала по оптическому волокну на короткие расстояния. Рассматривается концепция технологии передачи радиосигнала по оптическому волокну в беспроводных системах связи короткого диапазона действия. Для улучшения производительности систем связи рассматривается использование фотонной антенны. В работе используются некоторые реализации фотонных антенн. Технология RoF связи с использованием фотонных антенн дает возможность передавать модулированные радиосигналы, например стандартов WLAN или LTE, для обеспечения беспроводного радиодоступа внутри здания.

Ключевые слова: радиосигнал, оптическое волокно, RoF, беспроводные коммуникационные системы, фотонная антенна, WLAN, LTE, безпроводной радиодоступ

Lysiuk A., Godziszewski K., Yashchyshyn Ye. Radio over fibre link for short range wireless communication. A concept of Radio over Fibre (RoF) link for short range wireless communication systems has been presented. To improve the link performance a photonic antenna has been introduced. Some realizations of transmitting and receiving photonic antennas have been used. The RoF link with photonic antenna is capable of distributing microwave modulated signal, e.g. of WLAN or LTE standard, to provide wireless radio access inside a building.

Keywords: radio over fibre, RoF, wireless communication systems, photonic antenna, WLAN, LTE, wireless radioaccess

I. Introduction. Now a days a continuous progress in a new generation services offered to the users of the communication systems led to the need for very rapid development of both backbone and access networks. The strongest growth is visible for wireless systems, which offer mobility, flexibility, ease of installation and modernization of the network. Modern wireless devices: mobile phones, laptops, tablets stimulate the development of services that combine simultaneous transmission of voice, data and multimedia content, resulting in the need to ensure the requirements for the transmission parameters for each of them. These requirements include: high capacity system, the ability to achieve high data rate transmission, the security of transmitted information, system reliability, scalability and flexibility. As a response to the growing needs a combination of optical and microwave domains properties have been used in numerous applications of Radio over Fibre systems [1, 2]. These systems allow the use of the advantages of fibre optic communication, while leaving the benefits of wireless transmission, such as flexibility and the ability to rapidly develop and modify the structure of the network.

II. Radio over Fibre architecture. The RoF technique involves the transmission of radio frequency signals between one Central Station (CS), and a number of Remote Antenna Units (RAU) – Fig. 1. The use of RoF technology is a promising way to distribute wireless signals within buildings, e.g. to provide Internet access in public places such as railway stations, subway tunnels, airports, universities, shopping centres and sports facilities. Wide bandwidth and low loss of optical fibres allow the gradual introduction of new transmission standards, which can assume other broadcast frequencies and higher data rates. The specific architecture of the system will allow making these changes without interfering with the already created infrastructure.

CS manages the operation of the whole system and is responsible for the main signal processing functions, such as modulation, demodulation, signal encoding. RAU station acts as a simple network element, responsible only for the conversion of the optical signal to electrical domain and vice versa. Communication between RAU and CSis provided by a secure, wired, optical infrastructure while between the RAU and the user terminal the traditional wireless radio transmission is used.

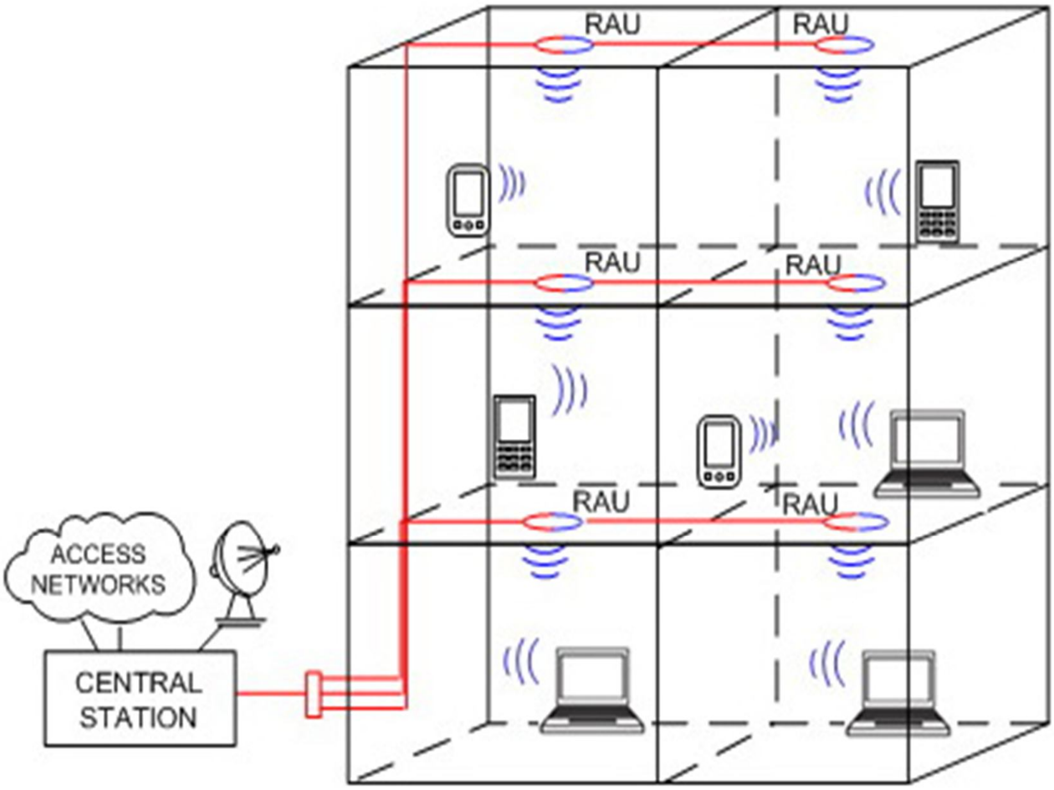

Fig. 1. Radio over Fibre system for distribution of wireless signal within buildings

To reduce the installation and maintenance costs of RoF systems, it is imperative to design a compact and low-cost RAU. This may be achieved by using the photonic antenna, which concept is based on direct integration of high-speed optoelectronic components with microwave antennas [3].

III. Photonic antenna concept. In conventional wireless systems the last or first part of transmitting/receiving link is a microwave antenna. This antenna is fed mostly by means of microstrip line or microwave cable, in which the signal is transmitted in both directions. To introduce the fibre-optic link to transmission system the appropriate antenna has to be used. In Fig. 2 two concepts of transmitting radio-fibre link have been presented. The simplest solution is to use photodiode module accompanied by a traditional microwave antenna (hybrid link Fig. 2a). It is also possible to eliminate, from the path, the redundant RF connectors and directly connect microstrip radiator with optoelectronic device (photonic antenna, Fig. 2b).

The definition of photonic antenna can be formulated as follows: the antenna working in the microwave band, to which or from which the signal is carried by means of optical fibre. Optical media is connected to the photodiode or the laser for opto-electronic and electro-optic conversion. Because of the unilateral nature of opto-electronic devices integrated photonic antenna may be only the transmitting or receiving antenna.

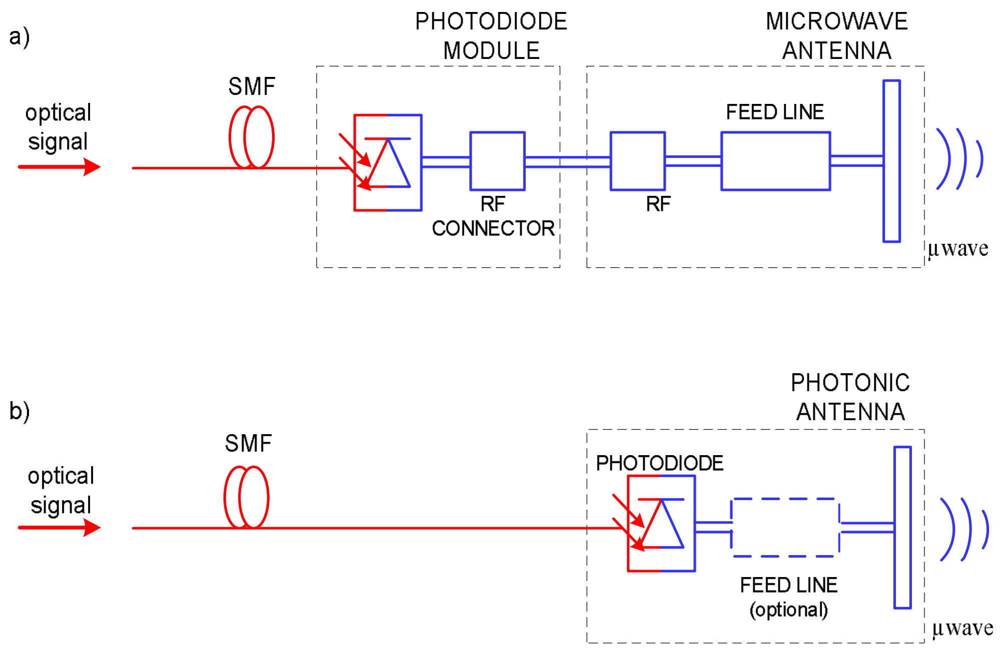

Fig. 2. Hybrid (a) and photonic (b) transmitting radio-fibre link

When a signal after the opto-electronic conversion is sent directly to the input port of the radiator it is a transmitting photonic antenna. If the signal is received by the radiator and then modulates the optical carrier of a laser a receiving photonic antenna is considered. Photonic antennas are characterized by: light weight and small size in the absence of RF cables and connectors; the possibility of the remote antenna control due to low loss in optical fibre (below 0.2 dB/km); immunity to electromagnetic interference in connection with the use of optical fibres.

Due to the ease integration with electronic devices common type of microwave antenna used for the integration in radio-fibre systems is the patch antenna. Depending on the antenna structure the photodiode or laser diode can be connected to the micro strip feed line of the radiator or directly mounted in the feeding point. A DC bias for optoelectronic devices is delivered to the antenna together with the modulating microwave signal. In order to obtain the correct operation the laser diode should be polarized in the forward direction and the photodiode in reverse.

IV. Photonic antenna realizations and measurements. In our realizations of photonic antennas only commercially available optoelectronic components have been used. Due to small size, easy polarization and low cost the laser diode and photodiode in coaxial pigtailed packages have been chosen. The selected parameters of FOL13F1MWI-R4-F7/FOL15F5MWI-R4-F7 laser diode from *Furukawa* Electric and PPDA-F photodiode from *Agx Technologies* are summarized in Table 1.

Proposed transmitting and receiving photonic antennas are based on E-shaped microwave radiator. The radiator has been designed on ROGERS4003C dielectric substrate with permittivity $\varepsilon = 3.55$. In order to extend the frequency range of operation the substrate, on which the radiator is placed, and a ground layer are spaced apart at a distance of h=5.5 mm. The microwave antenna operates between frequencies 2,34 GHz ÷ 2,92 GHz, in which the reflection coefficient falls below –10 dB. Such frequency range covers the 2.4 GHz ISM/ band, where IEEE 802.11b/g standards work and the selected bands of LTE system. In the band the antenna reaches a gain value of 10 dBi. High gain can reduce or compensate electro-optic and opto-electronic conversion losses.

Photonic antennas involve pigtailed laser diode and photodiode described above in receiving mode and transmitting mode, respectively.

Selected parameters of optoelectronic components **Table 1**

Parameter	Value	Parameter	Value
laser type	DFB	photodiode type	PIN
peak wavelength	1310 nm/1550 nm	wavelength range	1100 nm÷1650 nm
RF bandwidth	3 GHz	RF bandwidth	3 GHz
RIN noise	-154 dBc	optical Return Loss	-45 dB
optical connector	FC/APC	optical connector	FC/APC
slope efficienty s_L	0,14 W/A	responsivity	0,85 A/W (@ 1310 nm) 0.95 A/W (@ 1550 nm)
output optical power (max)	4 mW	input power saturation	10 mW
output isolation	30 dB	capacitance	0.6 pF

The ground layer in both constructions is a one side metallization of FR4 substrate, on which on the other side a polarization circuits for optoelectronic devices are placed. The bias circuits consist of: DC socket; fixed 5V voltage stabilizer (IC1); inductance (L1 = 88 nH), which separate DC and microwaves and in receiving antenna additional resistor (R = 50 Ω) to limit the current flowing through laser diode.

In Fig. 3 the front, side and rear view of transmitting photonic antenna is shown.

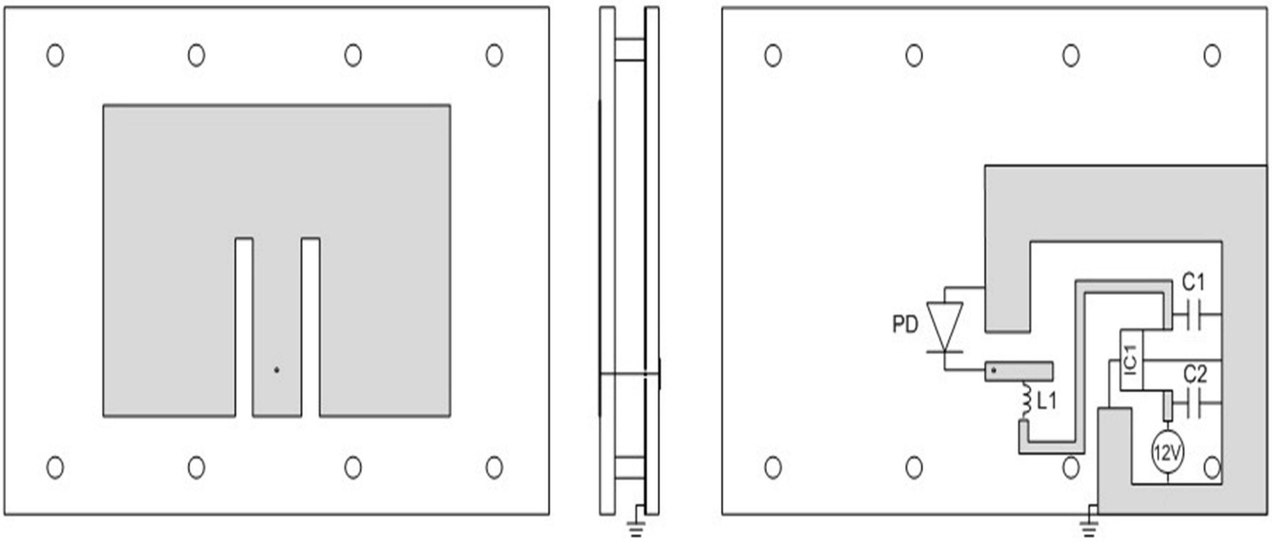

Fig. 3. Front, side and rear viewof transmitting photonic antenna

The gain of both transmitting and receiving photonic antenna have been measured and compared with the gain of microwave radiator (Fig. 4). The gains of photonic structures consist of laser diode or photodiode conversion losses, the gain of microwave radiator and small losses due to microstrip path between optoelectronic device and radiator.

In the case of transmitting antenna the gain value corresponds to the microwave type, because only small losses of O/E conversion are introduced to the link (the responsivity of the photodiode is 0.95 A/W at 1550 nm optical wavelength). The opposite situation is with receiving antenna integrated with laser diode. Electro-optic conversion losses are high (about 17 dB), because of small slope efficiency value of a laser diode (table 1).

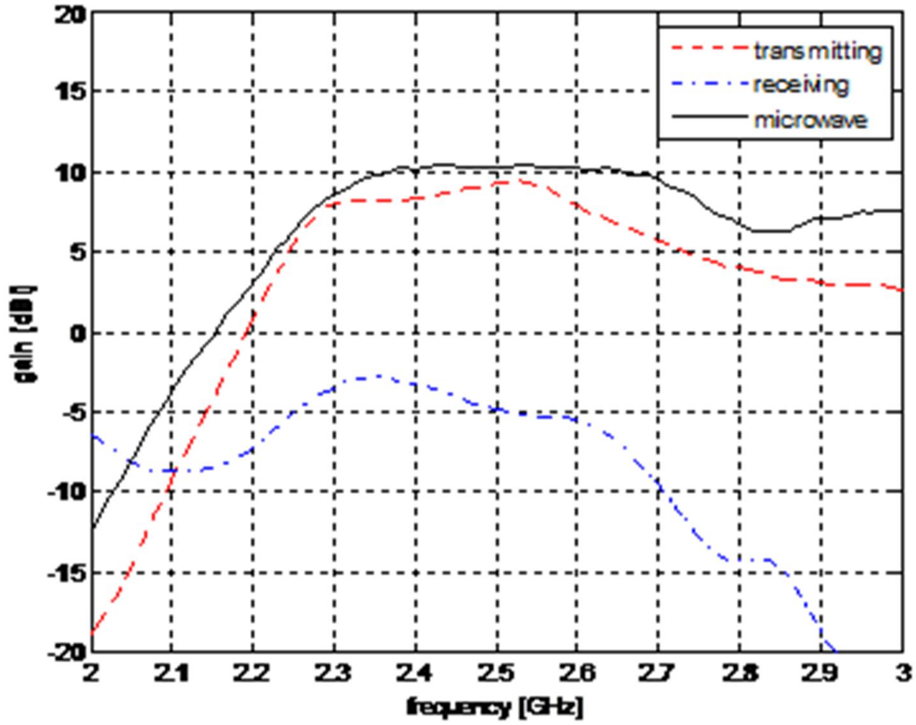

Fig. 4. Measured gain versus frequency for transmitting, receiving photonic antenna and microstrip antenna

The receiving photonic antenna gain can be easily improved with the use of microwave low noise amplifier between laser diode and the radiator [4]. A HMC667LP2 monolithic microwave integrated circuit from *Hittite* company has been used in the design. The bandwidth of the amplifier is 2,3÷2,7 GHz and should not limit the bandwidth of the photonic antenna. The device is characterized by 19 dB gain and 0.75 dB noise figure. Because of the same bias voltage and low current consumption the laser diode and the amplifier can be supplied from the same DC source.

The front and back view of realized receiving antenna with preamplifier is shown in Fig. 5.

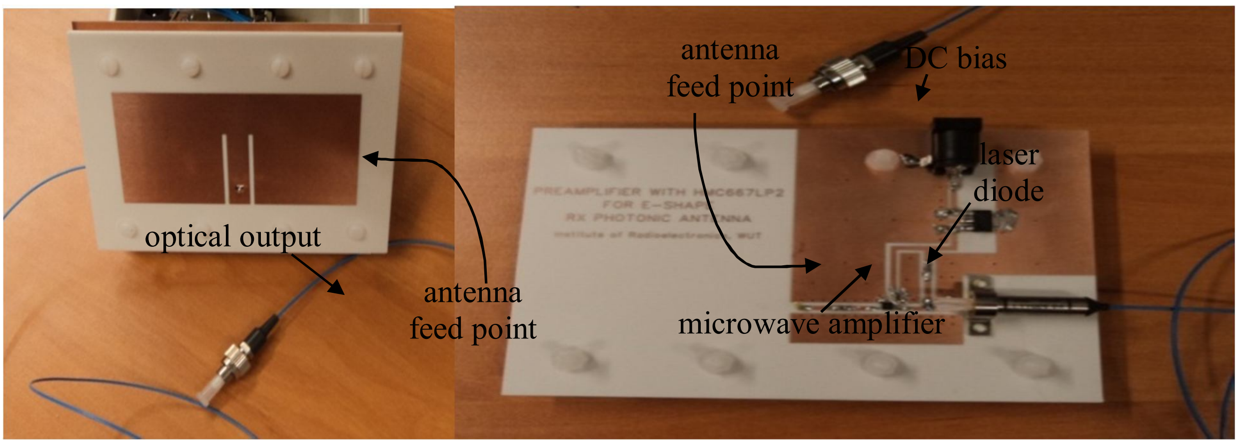

Fig. 5. Front and back view of photonic receiving antenna with preamplifier

The amplifier increases the gain of receiving antenna (Fig. 6) and not increases significantly the cost of the whole device. Although it should be mentioned that in the scenario with amplifier the received signal cannot exceed –20 dBm, so the user terminal cannot be placed in the nearest area of the receiving antenna.

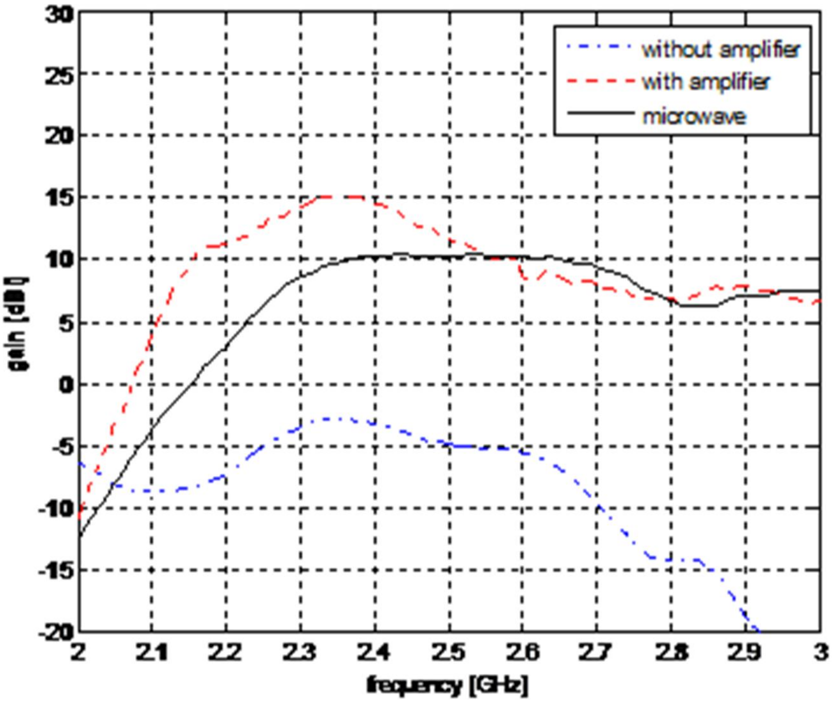

Fig. 6. Measured gain versus frequency for receiving photonic antenna with and without amplifier and microstrip antenna

V. Conclusions. To conclude, radio-fibre links are capable of transmission microwave modulated signals to provide full coverage inside a building. An idea of photonic antenna can be used to simplify the structure of RoF system and reduce the number of RF cables and connectors. Different structures of antennas can be designed to fulfil specific needs of a system. A lot of work still need to be carried out on the development of integrated structures that will effectively convert modulated optical signal to microwave signal.

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