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Optical coherent technologies in next generation access networks

Author(s): Katsumi Iwatsuki; Katsutoshi Tsukamoto

This paper reviews optical coherent technologies in next generation access networks with the use of radio over fiber (RoF), which offer key enabling technologies of wired and wireless integrated and/or converged broadband access networks to accommodate rapidly widespread cloud computing services. We describe technical issues on conventional RoF based on subcarrier modulation (SCM) and their countermeasures. Two examples of RoF access networks with optical coherent technologies to solve the technical issues are introduced; a video distribution system with FM conversion and wired and wireless integrated wide-area access network with photonic up- and down-conversion.

Optical signal processing for wireless transmission

Author(s): Tetsuya Kawanishi

Millimeter-wave bands are attracting attention because of the availability of wideband for high-speed transmission. However, due to the limitation of the performance of electric signal processing, it is rather difficult to modulate and demodulate millimeter-wave signals with high-speed baseband modulation. In this paper, we describe optical signal processing for high-speed modulation of millimeter-wave, based on high-speed and precise lightwave control. In optical fiber communication systems, various types of modulation formats, such as quadrature-amplitude-modulation, are reported to achieve high-speed transmission. Optical two-tone signals can be converted into millimeter-wave signals by using high-speed photodetectors. This technique can be used for distribution of stable reference signals in large-scale antenna arrays for radio astronomy. By using the millimeter-wave signal generation technique and the optical advanced modulation formats, we can achieve high-speed modulation of millimeter-waves, where the carrier frequency and bit rate can be over 90GHz and 40Gb/s, respectively.

Adjustable transfer function optical filter for microwave applications

Author(s): N. Madamopoulos; J. Kuang; A. Prescod

All-optical techniques for microwave and radio frequency (RF) signal processing has attracted considerable attention in recent years. An important optical component in these all-optical signal processing techniques is the optical filter. Tunable optical filters with a variety of transfer functions have been proposed. However, adjustability of the optical filter transfer function is required to provide an extra degree of control. This adjustability of the shape of the transfer function has not been addressed adequately in the literature. In this paper, we report on the theoretical basis for an all-fiber based adjustable transfer function optical filter. In particular, we model the optical filter using FO-circuit transfer matrices and Jones matrices to fully describe the state of polarization changes of the optical signals through the optical filter. The filter is based on an all fiber Michelson Gires-Turnois interferometer (MGTI). The Gires-Turnois resonators (GTRs) required for the formation of the MGTI are realized by pairs of fiber-loop mirrors (FLMs) in the two arms of the Michelson interferometer. The optical reflectivity of the GTRs is control via adjustment of the polarization in the fiber loop mirrors. We show that arbitrary transfer functions can be realized by adjusting the reflectivity of the FLMs as well as the cavity length of the fiber based GTRs.

Coherent OCDMA communication systems

Author(s): Xu Wang

Coherent optical code division multiple access (OCDMA) technique, where encoding and decoding are based on the phase and amplitude of optical field instead of its intensity, is receiving much attention for the overall superior performance over incoherent OCDMA and the development of compact and reliable en/decoders (E/D) such as spatial light phase modulator (SLPM), superstructured fiber Bragg grating (SSFBG) and multi-port array waveguide grating (AWG)-type E/D. In this paper, we will discuss several recent progresses in coherent OCDMA: a. Novel coding technology such as multi-phase-level SSFBG encoder, 50x50 multiport en/decoder and reconfigurable time domain spectral phase en/decoding; b. New signal modulation formats in OCDMA including DPSK, DQPSK, CSK and M-ary CSK; and c. Field trials of high capacity WDM/OCDMA systems.

VCSEL-based optical transceiver module operating at 25 Gb/s and using a single CMOS IC

Author(s): Gil Afriat; Lior Horwitz; Dror Lazar; Assaf Issachar; Alexander Pogrebinsky; Adee Ran; Ehud Shoor; Roi Bar; Rushdy Saba

We present here a low cost, small form factor, optical transceiver module composed of a CMOS IC transceiver, 850 nm emission wavelength VCSEL modulated at 25 Gb/s, and an InGaAs/InP PIN Photo Diode (PD). The transceiver IC is fabricated in a standard 28 nm CMOS process and integrates the analog circuits interfacing the VCSEL and PD, namely the VCSEL driver and Transimpedance Amplifier (TIA), as well as all other required transmitter and receiver circuits like Phase Locked Loop (PLL), Post Amplifier and Clock & Data Recovery (CDR). The transceiver module couples into a 62.5/125 um multi-mode (OM1) TX/RX fiber pair via a low cost plastic cover realizing the transmitter and receiver lens systems and demonstrates BER < 10^{-12} at the 25 Gb/s data rate over a distance of 3 meters. Using a 50/125 um laser optimized multi-mode fiber (OM3), the same performance was achieved over a distance of 30 meters.

Power balancing effect on the performance of IMPACC modulator under critical coupling (CC), over coupling (OC), and under coupling (UC) conditions at high frequency

Author(s): Benjamin B. Dingel; Nicholas Madamopoulos; Andru Prescod; R. Madabhushi

IMPACC (Interferometric Modulator with Phase-modulating and Cavity-modulating Components) is ultra-linear optical consisting of a phase modulator and a ring resonator on different arms of a Mach Zehnder interferometer (MZI). External control of the RF power split ratio from an input radio frequency (RF) signal into the two separate arms of the interferometer has been shown to add (1) design flexibility, (2) the ability to achieve high spurious free dynamic range (SFDR) of more than 130 dB, when compared to the single-ring RAMZI (Resonator-assisted MZI) and (3) compensate parameter deviation due to manufacturing imperfection. Our previous reports have assumed that the Optical power split ratio of the input optical signal into the two arm of MZI is balanced with a 50:50 split ratio due to the optical splitter or optical coupler. Here, we investigate three issues. First, we report the negative effect of unbalanced power of the input optical signal on the SFDR performance of IMPACC. Second, we utilize the inherent compensate technique of IMPACC to counteract this effect. Third, the power unbalanced effect is reported at high RF modulation frequency (23GHz) for three different conditions of the ring resonator (RR) namely, critical coupling (CC), over coupling (OC), and under coupling (UC). Lastly, we compare the performance of IMPACC to the single-ring RAMZI with traveling-wave electrode design under sub-octave operations.

Optical transport technologies in mobile broadband radio systems

Author(s): Yukio Horiuchi

A flexibly configurable radio access network architecture is expected to provide low-cost mobile broadband services. The radio access network architecture has changed drastically thanks to the evolution in optical fiber communication technologies. This paper describes optical transport technologies that contribute to the efficient deployment of broadband radio access systems.

Transportation of a microwave environment over networks and the applications

Author(s): Yozo Shoji

The concept of the transportation of a microwave environment over networks using a digitized Radio-on-Fibre (DRoF) technique as well as the concept of in-network microwave processing, which could make the concept of "wired and wireless network virtualization" into a reality, is discussed. The new applications to a radio-on-demand service (RoD), software-defined radio-aware network (SDRAN), and microwave environments cloud are introduced. 10-Gbps Ethernet based microwave-to-network interface converter (MiNIC) are developed and the transportation of multiple digital TV broadcasting signals is demonstrated. It is shown that the MiNIC should use more than 8-bits resolution in digitization of a microwave environment when 7 channels of TV signals are included in it. The concept of remote microwave environments observation over networks is demonstrated, where the frequency channel and received signal strength indication (RSSI) of the detected digital TV broadcasting signals are remotely monitored.

Pricing by timing: innovating broadband data plans

Author(s): Sangtae Ha; Carlee Joe-Wong; Soumya Sen; Mung Chiang

Wireless Internet usage is doubling every year. Users are using more of high

bandwidth data applications, and the heavy usage concentrates on several peak hours in a day, forcing ISPs to overprovision their networks accordingly. In order to remain profitable, ISPs have been using pricing as a congestion management tool. We review many of such pricing schemes in practice today and argue that they do not solve ISPs' problem of growing data traffic. We believe that dynamic, time-dependent usage pricing, which charges users based on when they access the Internet, can incentivize users to spread out their bandwidth consumption more evenly across different times of the day, thus helping ISPs to overcome the problem of peak congestion. Congestion pricing is not a new idea in itself, but the time for its implementation in data networks has finally arrived. Our key contribution lies in developing new analysis and a fully integrated system architecture, called TUBE (Time-dependent Usage-based Broadband price Engineering) that enables ISPs to implement the proposed TDP plan. The theory, simulation, and system implementation of TUBE system is further complemented with consumer surveys conducted in India and the US, along with preparations for a field trial that is currently underway.

Analog photonic link by using DFB lasers operated in the low laser threshold current region and external modulation

Author(s): A. García-Juárez; I. E. Zaldívar-Huerta; J. Rodríguez-Asomoza; R. Gómez-Colín; A. G. Rojas-Hernández; D. Berma- Mendoza; R. Gómez-Fuentes; A. Vera-Marquina

In this paper we describe an analog microwave photonic link system used to transmit simultaneously two TV signals. The experimental setup is composed mainly by two distributed feedback (DFB) laser diodes emitting at 1500 nm. When DFB lasers are operated in the low laser threshold current region, relaxation oscillation frequencies are obtained. Relaxation oscillations in the laser intensity can be seen as sidebands on both sides of the main laser line. The optical emissions generated in each laser are combined and amplified by using an Erbium-Doped Fiber Amplifier (EDFA). Next, the amplified optical signal is detected by a fast photo-detector using direct detection method and as result of this photo-detection microwave signals are generated. Microwave signals obtained by this technique are used as electrical carriers to transmit analog TV signals over 30 km of standard optical fiber by using a Mach-Zehnder modulator (MZM). At the end of the optical link the modulated light is photo-detected in order to recover efficiently and successfully the analog TV signals.

Evaluation on a costless 60-GHz OFDM-based indoor wireless over multimode fiber green system employing a photonic integrated smart antenna

Author(s): S. Mikroulis; P. Sotiropoulos; E. Pikasis; G. Agapiou

A 60GHz wireless over fiber indoor system is proposed and evaluated, using a microwave/optical/wireless converged analysis. In order to promote a cost-efficient deployment multimode fiber indoor infrastructure is employed, and a photonic integrated patch antenna combined with a $LiNbO_3$ modulator scheme for all-optical frequency up-conversion are studied. Using, a 3Gb/s Orthogonal Frequency Division Multiplexing (OFDM) based IEEE 802.15.3c prestandard, and OM-4 graded index multimode fiber (GI-MMF) transmission of 100m, an acceptable performance, in terms of Error Vector Magnitude (EVM) is calculated for a wireless coverage in the order of 10m. A possible system topology is proposed which apart from fulfilling the wired-wireless and low cost requirements, utilizing a FTTB single mode fiber (SMF) feeding and MMF indoor deployment, is appropriate for future green system scenarios through λ-reuse and photonic integrated antenna scheme without post amplification.

Temperature impairment characterization in radio-over-multimode fiber systems

Author(s): C. Vázquez; D. S. Montero

An emerging theme in next-generation access research includes seamless wireline-wireless convergence addressed by Radio-over-Fiber (RoF) technologies. Optical cabling solutions offer the possibility for semi-transparent transport through the access network microwave to mm-wave radio carriers commonly employed for creating high-capacity picocell wireless networks, attending present demands from the wireless technologies, with portable/mobile devices converging with photonics. Advanced RoF techniques can efficiently generate and transport such carriers, and deliver them to simplified antenna stations or radio access points (RAPs). Thus, they can convey high data rates in comprehensive modulation formats on multiple-GHz carriers in MMF networks. Selective mode-launching schemes combined with the use of narrow linewidth optical sources are experimentally demonstrated to enable broadband RF, microwave and mm-wave transmission in short- and middle-reach distances over silica-based multimode optical fibers (MMFs); and are reviewed in this paper. However, arbitrary operating conditions, such as the temperature dependence in the fiber link, impose a great challenge for the extension of the RoMMF technology. Temperature impairment characterization is analyzed over the broadband transmission bands that are present, under certain operating link conditions, in the frequency response performance of MMF to support multiple GHz carrier delivering schemes, thus contributing to fault link prevention.

Visible light communication in dynamic environment using image/high-speed communication hybrid sensor

Author(s): Keita Maeno; Mehrdad Panahpour Tehrani; Toshiaki Fujii; Hiraku Okada; Takaya Yamazato; Masayuki Tanimoto; Tomohiro Yendo

Visible Light Communication (VLC) is a wireless communication method

Visible Light Communication (VLC) is a wireless communication method using LEDs. LEDs can respond in high-speed and VLC uses this characteristics. In VLC researches, there are two types of receivers mainly, one is photodiode receiver and the other is high-speed camera. A photodiode receiver can communicate in high-speed and has high transmission rate because of its high-speed response. A high-speed camera can detect and track the transmitter easily because it is not necessary to move the camera. In this paper, we use a hybrid sensor designed for VLC which has advantages of both photodiode and high-speed camera, that is, high transmission rate and easy detecting of the transmitter. The light receiving section of the hybrid sensor consists of communication pixels and video pixels, which realizes the advantages. This hybrid sensor can communicate in static environment in previous research. However in dynamic environment, high-speed tracking of the transmitter is essential for communication. So, we realize the high-speed tracking of the transmitter by using the information of the communication pixels. Experimental results show the possibility of communication in dynamic environment.

Energy efficient lighting and communications

Author(s): Z. Zhou; M. Kavehrad; P. Deng

As Light-Emitting Diode (LED)'s increasingly displace incandescent lighting over the next few years, general applications of Visible Light Communication (VLC) technology are expected to include wireless internet access, vehicle-to-vehicle communications, broadcast from LED signage, and machine-to-machine communications. An objective in this paper is to reveal the influence of system parameters on the power distribution and communication quality, in a general plural sources VLC system. It is demonstrated that sources' Half-Power Angles (HPA), receivers' Field-Of Views (FOV), sources layout and the power distribution among sources are significant impact factors. Based on our findings, we developed a method to adaptively change working status of each LED respectively according to users' locations. The program minimizes total power emitted while simultaneously ensuring sufficient light intensity and communication quality for each user. The paper also compares Orthogonal Frequency-Division Multiplexing (OFDM) and On-Off Keying (OOK) signals performance in indoor optical wireless communications. The simulation is carried out for different locations where different impulse response distortions are experienced. OFDM seems a better choice than prevalent OOK for indoor VLC due to its high resistance to multi-path effect and delay spread. However, the peak-to-average power limitations of the method must be investigated for lighting LEDs.

The Smart Room: a 100 Mb/s integrated optical access point transceiver for indoor visible light communication

Author(s): Ninrat B. Datiri; Ali Mirvakili; Chirag Sthalekar; Enjin Fu; Chenguang Xi; Shahan Nercessian; Twinkle Shah; Benazeer Noorani; Valencia J. Koomson

Recent developments in visible light communication (VLC) technology have solidified utilizing light-emitting diodes (LEDs) for not only illumination, but also optical wireless communication. This paper presents a novel optical access point transceiver that features addressable arrays of LEDs and photodetectors. The transmitter array enables combined illumination control and serial data transmission for an array of 16 LEDs producing an aggregate data rate of 100 Mb/s. The receiver consists of a 16-element array of broadband receiver channels. Designed in a 0.5 µm CMOS process to enable miniaturization and VLC system integration, the transceiver is capable of processing multiple user requests.

Hybrid positioning with lighting LEDs and Zigbee multihop wireless network

Author(s): Y. U. Lee; S. Baang; J. Park; Z. Zhou; M. Kavehrad

A simple, accurate, secure, long-lasting, and portable hybrid positioning system is proposed and designed in this paper. It consists of a lighting LED that generates visible light data corresponding to position information of a target and a Zigbee wireless network communication module with low power, security, and service area expansion characteristics. Under an indoor environment where there is 23.62m distance between an observer and the target, the presented hybrid positioning system is tested and is verified with the functions of Zigbee three hop wireless networking and visible light communication (VLC) scheme. The test results are analyzed and discussed.