A COMPARISON OF DIFFERENT RADIO OVER FIBRE SYSTEM CONCEPTS WITH REGARD TO APPLICATIONS IN MOBILE INTERNET AND MULTIMEDIA

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ABSTRACT

The paper presents a comparison of different radio over fibre system concepts with regard to applications in broadband services transmission. Several concepts of radio over fibre systems have been studied around the world, and each of them seems to be very attractive because of low loss and extremely wide bandwidth necessary for mobile broadband services. Commercial deployment of the millimeter-wave optical links for future mobile broadband services depends on the expected full costs of the systems. The paper discusses an impact of development of new technologies on possibility of commercial deployment of the systems.

INTRODUCTION

New wireless broadband networks are needed for high – speed Internet access and mobile multimedia. These services require broadband networks with bandwidth higher than 2 Mbit/s per radio channel. New broadband air interfaces are needed for transmission, and higher microwave bands and millimeter-wave bands are used for its allocation [1]. The radio over fibre technologies can be used for millimeter-wave signal distribution in cellular systems between the base station controller and remote base transceiver stations, or for the „last mile" delivery of broadband data. Several concepts of radio over fibre systems have been studied around the world. The differences between them concern mainly methods of generation and distribution of the millimeter-wave signal over standard single mode fibre. The following main approaches to generation and transmission of the digitally modulated millimeter-wave carriers over the fibre can be distinguished:

- external modulation of continuous wave laser light in the central station and direct detection at base transceiver stations,
- optical heterodyning at the base station,
- optical transport of modulated carriers of intermediate radio frequency with up-conversion to the millimeter- wave band at the base station.

In systems using the first of the mentioned approaches the external modulation generates millimeter -wave subcarrier multiplexed optical double sideband signal. This kind of signal is severely affected by chromatic dispersion of an optical link [2]. Various ways are used to overcome this problem: optical filtering of one of the sidebands [3], single sideband modulation [4], dispersion compensation using a fibre Bragg grating [5], or optical phase conjugator [6]. The systems using self-heterodyning were specially developed to overcome the degrading effect of the chromatic dispersion. This effect is negligible when using the third approach, because of low frequency of the carriers transmitted [7]. There is no need for using complex and specialised sources on the transmitter side and expensive high frequency photodiodes in receivers. The up-conversion of intermediate radio frequency signal, carrying digital information, to the millimeter-wave band is performed with high-quality local oscillator at the base station. The remote local oscillator is controlled with an optically-supported phase-locked loop. A reference signal for the phase loop is delivered optically together with data signals. The fibre link in this approach is relatively simple and can be constructed from off-the shelf components. A disadvantage of this approach is an increased complexity of the base transceiver station. To support broadband mobile Internet and real time multimedia access the radio over fibre link should fulfill several technical requirements. Broadcast services or two way interactive services should be provided. In cellular systems the hierarchical cell structure should be used. For millimeter-wave frequencies cell radia from 100m to several km are expected. This means that great number of micro- and picocells has to be used. Each cell should have one dedicated base station which should be as inexpensive as possible. All studied and demonstrated optical millimeter-wave systems seem to be very attractive because of low loss, particularly when using erbium doped optical amplifiers. Moreover, they assure an extremely wide bandwidth necessary for mobile broadband services. Commercial deployment of the millimeter-wave optical links for future mobile broadband services depends on the expected full costs of the systems. We discuss here the impact of development of new technologies on possibility of commercial deployment of the radio over fibre systems for mobile broadband services delivery.

NEW TECHNOLOGIES AS TOOLS FOR COST LOWERING

Amongst the discussed approaches to optical distribution of the digitally modulated millimeter-wave carriers we distinguish two ways for cost lowering. One consists of lowering costs of the base station, and another one prefers lowering costs of the fibre link. In the later case the advantages of the using of optical amplifiers can even be questioned, because of relatively short spans of the fibre link needed for distribution of millimeter-wave signals in cellular architectures. The trade-off involved in simplifying the optical link results however in increased complexity of the base stations. In this case the base station should be implemented using millimeter-wave integrated circuit technology to provide cost benefits compared to discrete millimeter-wave component solution. If one prefers to design the base transceiver station as cheap as possible then the use of system with external modulation of continuous wave laser in transmitter and direct detection in receiver should be rather preferred. In this case one is forced to use new sophisticated optical components to fully exploit potential advantages of the optical distribution of millimeter-wave signals. In our view the future choice of the proper way depends on development of two technologies: the millimeter wave integrated circuits on one hand, and new optical components on the other hand. In the latest case we have for example technology of fibre Bragg gratings that has tremendous potential for having an impact on fiber optic communication in general. The chirped fibre grating based technique has proved as dispersion compensating means for optical links transmitting broadband millimeter wave signals of 28 GHz, 42 GHz and 60 GHz. Microwave video distribution systems and future broadband mobile services systems operate respectively in those frequency bands. Fibre grating dispersion compensating device should be used in each fibre link distributing millimeter–wave signals, that means large number of the devices used in the network. But technology of UV-induced fibre gratings makes possible relatively cheap mass production.

One of the most recent technological steps to simplify transceiver base station is the newly developed 60 GHz band electroabsorbtion transceiver [8]. This hybrid integrated transceiver module is based on electroabsorbtion device fabricated with quaternary multiquantum well semiconductor. The module has two independent rf ports: one to introduce millimeter- wave modulating signal, and second one used as an output of photodetector. The electroabsorbtion transceiver has moreover two optical ports coupled with standard single mode fibre pigtails, used as an optical input and output respectively. The transceiver module was successfully applied in full-duplex radio on fibre system for 60 GHz band [8]. We believe that similar simple transceiver modules could be developed for another millimeter wave bands allocated for cellular transmission. It seems to be even easier to construct the reliable transceivers for millimeter-wave bands lower than 60 GHz. Using the devices similar to mentioned above transceiver unit greatly simplifies the base station complexity in cellular system because of combining integration of optical and mm-wave functions. On transmitter side external modulation of DFB laser can be used. The fibre link in this case should incorporate some means for dispersion compensation. Further progress of simplifying the base station could eventually bring integration of transceiver and antenna modules.

The alternative promising radio over fibre approach bases on optical transport of modulated carriers at intermediate frequencies (lower microwave frequencies), with up-conversion to millimeter –wave band at base stations [7,9]. A high-quality millimeter-wave local oscillator is required at the base station to diminish a phase noise added by up-conversion. Sufficient frequency stability can be achieved using optically-supported phase-locked loop, or frequency multiplication at the base station. With careful system design the both solutions allow to achieve link capacity, required for distribution of broadband digital signals. Nevertheless the base stations in both cases are more complicated than in approach of optical transport of millimeter waves, where the functions of the base station include simply photodetection, amplification, and emission of millimeter-wave. The base station in the case of optical transport of intermediate frequencies has to contain more electronic of millimeter-wave band. Fortunately we observe recently a real progress in development of monolithic millimeter-wave integrated circuit technology (MMIC) [10]. Millimeter-wave integrated circuit technology can be regarded as an extension of microwave integrated circuit technology, however difficulties arise because of shorter wavelength. Recent advances in semiconductor technology coupled with exploding market in satellite and wireless communications and sensor domains have lead to the development of MMIC technology of new quality. Examples are GaAs MMIC performing radio frequency functions in communications bands to 40 GHz and above, SiGe monolithic travelling-wave amplifier of 67 GHz bandwidth, and active integrated antennas in which circuitry and antenna are integrated. In fabrication of modern millimeter-wave integrated circuits are also used micromachined passive structures and new hybrid integration and packaging technologies. All this gives a strong impact on possible evolution of the base stations of radio over fibre systems of the second approach discussed in the paper.

CONCLUSIONS

The review of the recent development in technology of sophisticated optical components on one hand and millimeter-wave integrated circuits on the other hand allows us to expect a promising future for commercial deployment of radio over fibre system in mobile Internet and broadband multimedia networks. These technological achievements correspond to both main system solutions of radio over fibre transmission of broadband digitally modulated millimeter-wave signals discussed in the paper. Actually it seems that both solutions could find wide applications in mobile Internet and multimedia networks.

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