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RESEARCH ARTICLE

Advantages and Limitation of Radio over Fiber System

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Abstract: Radio over Fiber technology (RoF), an integration of wireless and Fiber optic networks, is an essential technology for the provision of un tethered access to broadband wireless communications in a range of applications including last mile solutions, extension of existing radio coverage and capacity, and backhaul. This paper gives the brief introduction of radio over fiber technology used in communication system. In this paper applications and limitation of the radio over Fiber technology are discussed. Some technologies which are used to transfer radio signal over Fiber are also explained in this review paper. Some ideas of using radio over Fiber technology in wireless technology are also introduced in this paper

Keywords—component; formatting; style; styling; insert, ROF technology, IFOF, BBOF, Wireless, Bandwidth

Introduction

Radio over fiber technology is becoming increasingly important for wireless market in order to support the ever growing data traffic volumes. Optical wireless networking connectivity can typically be achieved using radiofrequency (RF) or optical wireless approaches at the physical level. The RF spectrum is congested, and the provision of broadband services in new bands is increasingly more difficult. Optical wireless networking offers a vast unregulated bandwidth that can be exploited by mobile terminals within an indoor environment to set up high speed multimedia services [1].The concept radio over Fiber means to transport information over optical Fiber by modulating the light with the radio signal. This modulation can be done directly with the radio signal or at an intermediate frequency The need for increased capacity per unit area leads to higher operating frequencies(above 6 GHz) and smaller radio cells, especially in in-door applications where the high operating frequencies encounter tremendously high losses through the building walls[1-2]. RoF uses highly linear optical Fiber links to transmit and distribute radio frequency (RF) signals from a central location where the base stations are situated to remote antenna units (RAUs). This allows the RAUs to be extremely simple since they only need to contain optoelectronic conversion devices and amplifiers. Several concepts of radio over Fiber system have been studied and each of them seems to be

attractive because of low loss and extremely wide bandwidth. To reduce the system installation and maintenance costs of such systems, it is imperative to make the radio antenna units as simple as possible. This may be achieved by consolidating signal processing functions at a centralized head end, through radio-over- Fiber technology.
The basic radio over Fiber system is depicted in figure 1.

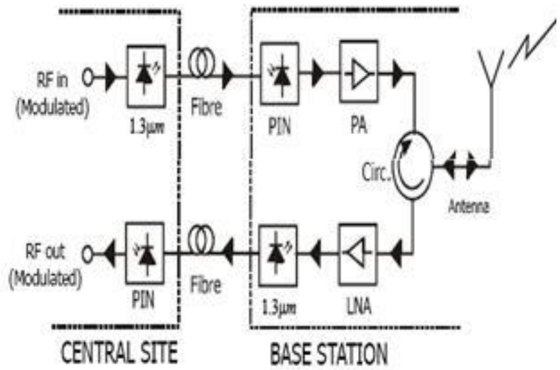

Figure 1 Basic ROF system

RoF systems centralize the RF signal processing function in one shared location (headend), and use optical Fiber link to distribute the RF signals to the RAUs or BSs. In network architecture, the CS performs all switching, routing and network operations administration maintenance(OAM). Optical Fiber network interconnects a number of simple and compact antenna BSs for wireless distribution. The BS has no processing function and the main function of the BS is to the optical signal to wireless and vice versa.

Techniques used for Rof

There are several optical techniques for generating and transporting microwave signals over Fiber. The RoF techniques may be classified into three categories – namely RF-over-Fiber (RFoF), IF over-Fiber (IFoF), or baseband over-Fiber (BBoF)[3]. RFoF involves the transmission of the actual RF signal over the Fiber. However, in IFoF and BBoF the desired microwave signal is generated at the RAU through up-conversion with a LO, which is either provided separately at the RAU, or is transported remotely to the RAU. Therefore, depending on the transmission method used, the RAU may be more complex or simpler. The techniques used for transporting radio signal over Fiber are explained in the following sections.

(i) By Direct method: The simplest method for optically distributing RF signals is simply to directly modulate the intensity of the light source with the RF signal itself and then to use direct detection at the photo detector to recover the RF signal. Direct method is depicted in figure no 2 and 3. This method falls under the IM-DD, as well as the RFoF categories. There are two ways of modulating the light source[3-4]. One way is to let the RF signal directly modulate the laser diode's current. The second option is to operate the laser in continuous wave (CW) mode and then use an external modulator such as the Mach-Zehnder Modulator (MZM), to modulate the intensity of the light. After transmission through the Fiber and direct detection on a photodiode, the photocurrent is a replica of the modulating RF signal applied either directly to the laser or to the external modulator at the head end [2,5].The photocurrent undergoes trans impedance amplification to yield a voltage that is in turn used to excite the antenna. If the RF signal used to modulate the transmitter is itself modulated with data, then the detected RF signal at the receiver will be carrying the same data. The modulation format of the data is preserved. The advantage of this method is that it is simple. Secondly, if low dispersion Fiber is used together with a (linearised) external modulator, the system becomes linear. One drawback of the RFoF or IM-DD technique is that it is difficult to use for high frequency mm-wave applications. This is so because to generate higher frequency signals such as mm-waves, the modulating signal must also be at the same high frequency. A further disadvantage of RFoF is that it is susceptible to chromatic dispersion, which induces frequency-or length-dependent amplitude suppression of the RF power.

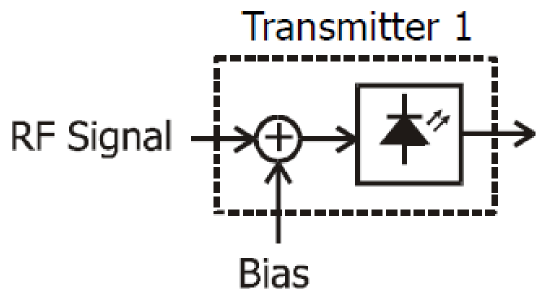

Figure 2 Direct Intensity Modulation Method By laser.

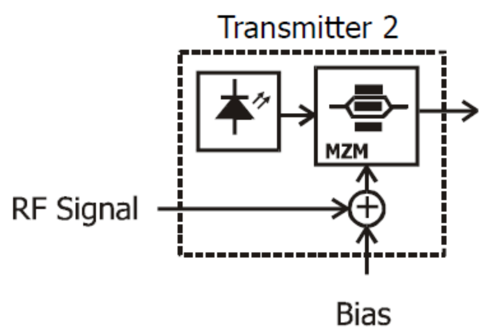

Figure 3 DIM Method By External Modulator

(ii) Remote Heterodyne Detection: Most RoF techniques rely on the principle of coherent mixing in the photodiode to generate the RF signal .These techniques are generally referred to as Remote Heterodyne Detection (RHD) techniques depicted in figure no. 4. While performing O/E conversion, the photodiode also acts as a mixer thereby making it a key component in RHD-based RoF systems. There are several ways of generating the two optical carriers for coherent heterodyning. One approach is to use an optical phase modulator to generate several optical side bands, and then selecting the required components. Another approach is to use two separate laser sources. The two laser diodes are made to emit light at frequencies (wavelengths) separated by the required microwave frequency[6]. Using optical heterodyning, very high frequencies can be generated, limited only by the photo detector bandwidth. Remote heterodyning has an inherent advantage concerning chromatic dispersion. If only one of the two optical carriers is modulated with data, system sensitivity to chromatic dispersion can be reduced greatly. This is not possible in direct intensity modulation based methods, where the two optical sidebands end up both being modulated with data. Another important attribute of RHD is that it permits low-frequency data modulation at the head end since high-frequency electro-optical components are not required. A further advantage of optical heterodyning is that it is capable of producing signals with 100% intensity modulation depth. The major drawback of RHD is the strong influence of laser phase noise and optical frequency variations on the purity and stability of the generated RF carriers.

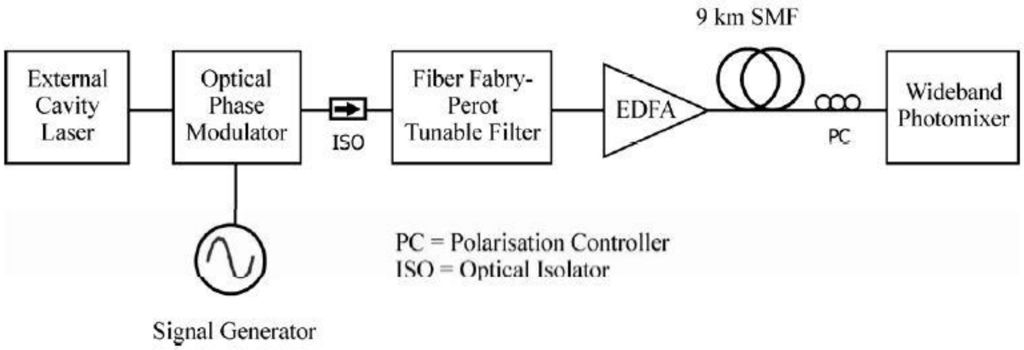

Figure 4 Remote Heterodyning by Using a Filter.

(iii) Optical FM-Filter System: The Optical FM-Filter technique is a single-laser technique that involves modulating the optical frequency by applying an electrical signal to one of the laser's terminals. This generates a series of optical spectral lines (sidebands) all spaced by the drive frequency. Two sidebands, separated by the required mm wave are then selected. The selected sidebands subsequently impinge on the surface of the photodiode and mix coherently to generate the desired RF signal. The advantage of optical Fm filter system is that the FM-Filter technique, is capable of generating high frequency mm-wave signals with very narrow line width. The major disadvantage lies in the fact that the sideband selection system must accurately track any shifts in the position of the sidebands. In addition to this, very selective (high-Q) optical filtering is required which will increase the complexity of the ROF system.

(iv) Optical Frequency/Phase Locked-Loops (OFLL/OPLL): As the names suggests, OFLL strives to maintain the required mean frequency offset. It does not suppress small-scale frequency variations caused by phase noise. On the other hand, OPLL is able to track small scale phase perturbations as well. A packaged OPLL system based on semiconductor lasers capable of producing microwave signals up to 14 GHz which is shown in figure 4. The main advantage of these techniques is that it is capable of producing high quality RF signals with narrow line width. OPLLs also have good temperature tracking capabilities. In addition, OPLLs exhibit a wide locking range. On the other hand, OFLL techniques have the advantage that they can be realized with standard and fairly inexpensive DFB lasers [6-7]. The main disadvantage of OFLL techniques is that they generate microwave signals. The major drawback of OPLLs is that they require far more complex laser structures such as 3-contact DFBs.

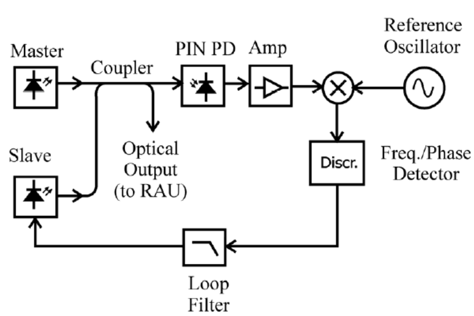

Figure 5 Principle of Optical Frequency-/Phase-Locked Loop

(v) Dual Mode Lasers: As stated earlier the major drawback of optical heterodyning-based techniques is the sensitivity to phase noise of the two heterodyning signals, and the dependence of the RF beat signal on the polarization state difference of the two heterodyning carriers. Several techniques used to improve beat signal phase noise have been described. A dual mode laser designed to test the viability of this technique showed that direct electrical injection at a sub-harmonic of the beat frequency was still needed in order to generate a pure mm-wave. The main advantage of the DML approach is that it does not require complex feedback circuitry as does the different optical injection locking methods discussed above. However, the method has limitations regarding tenability, because of its narrow locking range.

Advantages of ROF Technology

Some of the advantages and benefits of the RoF technology are discussed follow:

(i) Low Attenuation Loss: Electrical distribution of high-frequency microwave signals either in free space or through transmission lines is problematic and costly [8]. Therefore, distributing high frequency radio signals electrically over long distances requires expensive regenerating equipment.

(ii) Large Bandwidth: Optical Fibers offer enormous bandwidth. There are three main transmission windows, which offer low attenuation, namely the 850 nm, 1310 nm, and 1550 nm wavelengths.

(iii) Immunity to Radio Frequency Interference: Immunity to Electromagnetic Interference (EMI) is a very attractive property of optical Fiber communications, especially for microwave transmission. This is so because signals are transmitted in the form of light through the Fiber[9]. Because of this immunity, fiber cables are preferred even for short connections at mm-waves.

(iv) Easy Installation and Maintenance: In RoF systems, complex and expensive equipment is kept at the head end, thereby making the RAUs simpler. For instance, most RoF techniques eliminate the need for a LO and related equipment at the RAU. In such cases a photo detector, an RF amplifier, and an antenna make up the RAU. Modulation and switching equipment is kept in the headend and is shared by several RAUs. This arrangement leads to smaller and lighter RAUs, effectively reducing system installation and maintenance costs.

(v) Multi-Operator and Multi-Service Operation: RoF offers system operational flexibility. Depending on the microwave generation technique, the RoF distribution system can be made signal-format transparent [9]. For instance the Intensity Modulation and Direct Detection (IM-DD) technique can be made to operate as a linear system and therefore as a transparent system.

LIMITATIONS OF ROF TECHNOLOGY

Since RoF involves analogue modulation, and detection of light, it is fundamentally an analogue transmission system. Therefore, signal impairments such as noise and distortion, which are important in analogue communication systems, are important in RoF systems as well [10]. These impairments tend to limit the Noise Figure (NF) and Dynamic Range (DR) of the RoF links. DR is a very important parameter for mobile (cellular) communication systems such as GSM because the power received at the BS from the MUs varies widely That is, the RF power received from a MU which is close to the BS can be much higher than the RF power received from a MU which is several kilometers away, but within the same cell.

CONCLUSION

In this paper the review of the ROF technology has been explained in which some techniques which use radio over fiber technology are also explained. The main advantages of the ROF technology are low attenuation loss, large bandwidth and easy installation and maintenance. The main drawback of the ROF technology is signal impairments such as noise and distortion which should be eliminated in the future.

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