Simultaneous All-Optical Down Conversion of WDM Radio-Over-Fiber Signals

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Abstract
To meet the explosive demands of high-capacity and broadband wireless network access, advanced cellular based wireless networks have trends. Inthis project, we discussed A full-duplex radio-on-fiber transport system based on wavelength-division-multiplexing and optical add–drop multiplexing techniques, as well as proper length of dispersion compensated fiber (DCF) is proposed. Over a combination of single-mode fiber and DCF transmission, received power signal strength and bit-error-rate values were obtained in our proposed system. Such a proposed full-duplex radio-on-DCF system is suitable for the long-haul microwave optical links.

1. Introduction

RADIO over fiber (RoF) system is one of the most attractive systems for future broadband wireless communication having a high data rate at a microwave or millimeter wave frequency band because of the advantages of an optical fiber including the low-transmission loss and ultra wide bandwidth [1]–[3]. For this broadband wireless communication system, a cell size has to be reduced, since the transmission loss of the microwave or millimeter wave in a free space is very high.

To cover a wide service area, numerous picocells are required, and thus, lots of remote antenna stations (RASs) covering each picocell have to be connected to a central station (CS). For a reduction in the total cost of the RoF system, the role of the RAS is simplified, and that of the CS becomes complicated including a data modulation/demodulation and up/down conversion. A wavelength division multiplexing-based (WDM-based) RoF system is suitable for implementing cost-effective microcell- or picocell-based broadband wireless communication systems, since the system can support numerous RASs by sending radiation-ready WDM optical radio frequency (RF) signals over an optical fiber having ultralow loss and ultra wide bandwidth characteristics.

2. RoF Basics

Radio-over-Fiber technology enhance the use of optical fiber links to distribute RF signals from a central location (head end) to Remote Antenna Units (RAUs). Radio over Fiber (ROF), which combines the advantages of wireless radio and fiber optical communications, has been considered as a potential candidate for the distribution of broadband services. Application systems employing ROF consist of central station (CS) and remote base stations (BSs). To adapt the DCF [2] into the 1550-nm operation, fiber chromatic dispersion can be compensated by a short length of DCF with large dispersion of negative sign, and total dispersion of systems is reduced. A successful deployment of radio-on-DCF transport system depends on the availability of simple architecture. Considering the architecture of radio-on-DCF transport systems, in which a large number of remote BSs are connected to a single CS, the complexity is obviously a considerable concern. In this project an architecture of a full-duplex radio-on-DCF transport system based on wavelength-division-multiplexing (WDM) and optical add–drop multiplexing techniques is proposed and demonstrated.

WDM and optical add–drop multiplexing techniques can simplify the network architecture and improve the deployment of BSs since they enable full-duplex operation on one fiber. Each BS is addressed by an individual wavelength using an optical add–drop multiplexer (OADM) [4]. After a combination of 40-km single-mode fiber (SMF) and DCF transmission, and bit-error-rate (BER) values were obtained.

3. Limitations of RoF Technology

In ROF, Dynamic Range (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 (e.g. 80 dB). 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.

The noise sources in analogue optical fiber links include the laser's Relative Intensity Noise (RIN), the laser's phase noise, the photodiode's shot noise, the amplifier's thermal noise, and the fiber's dispersion. In Single Mode Fiber (SMF) based RoF, chromatic dispersion may limit the fiber link lengths and may also cause phase de-correlation leading to increased RF carrier phase noise.

3.1 RoF Links

Unlike conventional optical networks where digital signal is mainly transmitted, ROF is fundamentally an analog transmission system. Actually, the analog signal that is transmitted over the optical fiber can either be RF signal, IF signal or baseband (BB) signal. For IF and BB

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transmission case, additional hardware for up converting it to RF band is required at the BS.

At the optical transmitter, the RF/IF/BB signal can be imposed on the optical carrier by using direct or external modulation of the laser light. However, here are some limitations because of non-linearity and frequency response limits in the laser and modulation device as well as dispersion in the fiber.

3.2 RoF Link Configurations

In this section we discuss a typical ROF link configuration, which is classified based on the kinds of frequency bands (baseband (BB), IF, RF bands) transmitted over an optical fiber link. Here we assume that a BS has its own light source for explanation purpose BS can be configured without light source for uplink transmission. In each configuration of the figure, BSs do not have any equipment for modulation and demodulation, only the CS has such equipment. In the downlink from the CS to the BSs, the information signal from a public switched telephone network (PSTN), the Internet, or other CS is fed into the modem in the CS.

The signal that is either RF, IF or BB bands modulates optical signal from LD. As described earlier, if the RF band is low, we can modulate the LD signal by the signal of the RF band directly. If the RF band is high, such as the mm-wave band, we sometimes need to use external optical modulators (EOMs), like electro absorption ones. The modulated optical signal is transmitted to the BSs via optical fiber. At the BSs, the RF/IF/BB band signal is recovered to detect the modulated optical signal. The recovered signal, which needs to be up converted to RF band if IF or BB signal is transmitted, is transmitted to the MHs (mobile host) via the antennas of the BSs.

For the uplink from an MH to the CS, the reverse process is performed. The signals received at a BS are amplified and directly transmitted to the CS by modulating an optical signal from a LD by using an EOM. In the configuration (b) and (c), the signals received at a BS are amplified and downconverted to an IF or a baseband frequency and transmitted to the CS by modulating an optical signal from a LD by using an EOM. In the configuration (d), the signals received at a BS are amplified and downconverted to an IF or a baseband frequency and transmitted to the CS by directly modulating an optical signal from a LD.

4.3 Experimental Setup

For down-link transmission, the CS is composed of two distributed feedback (DFB) laser diodes, one electroabsorption modulator (EAM), one erbium-doped fiber amplifier, and two microwave signal generators.

The radio-on-DCF transport systems exploit the available bandwidth of 1530–1560 nm to address multiple BSs. As many BSs are deployed, all down-link wavelengths are employed within the wavelength range of 1530–1560 nm. These two DFB laser diodes provide two optical carriers to the EAM. The 3-Mb/s data streams are mixed with 9.98-GHz and 10.02-GHz microwave carriers to generate the binary phase-shift keying data signals. The resulting microwave data signals are then supplied to the EAM, and a low bias voltage is also fed into the EAM. The bandwidth of the EAM possesses a 3-dB frequency of 12 GHz; it means that 9.98- and 10.02-GHz microwave signals can be transmitted through the optical links.

Both optical carriers are amplified and fed into the fiber transmission network. The appropriate wavelengths are dropped by the OADM in BS1 and BS2, as illustrated in Fig 4.2. The OADM, with 40-dB add–drop channel isolation, consists of one fiber Bragg grating located between two optical circulators.

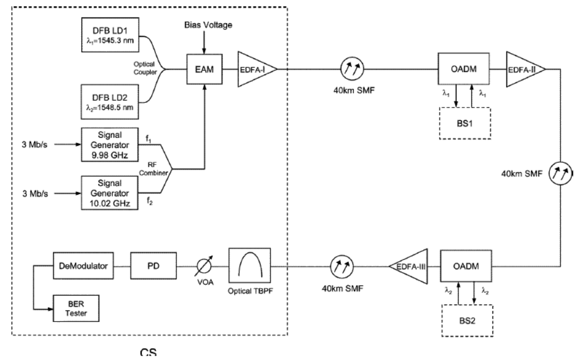

Fig: 1. Experimental Configuration of our proposed full-duplex radio-on-DCF

The down-link data signal level is adjusted by a variable optical attenuator (VOA), detected by a broadband photodiode (PD), separated off by a 1/2 RF splitter, and provided to the spectrum analyzer and demodulator. The fundamental signal and third-order distortion terms are investigated by two-tone signal at 10 GHz with a 40-MHz separation. The DCF used in the experiment has a large negative dispersion of 475 ps/nm/km over 1530–1560 nm.

Transport system based on WDM and optical add–drop multiplexing techniques demodulated and fed into a BER tester for BER analysis. For up-link transmission, a 3-Mb/s up-link data stream is modulated and up-converted to 9.98/10.02 GHz. The up-linkdata signals are added to the fiber transmission network and transmitted to the CS over a combination of) DCF and 40-km SMF transmission, where they are separated using an optical tunable bandpass filter.

4. Simulations and Results

4.1 Performance Evaluation of Received Power vs Wavelength without DCF

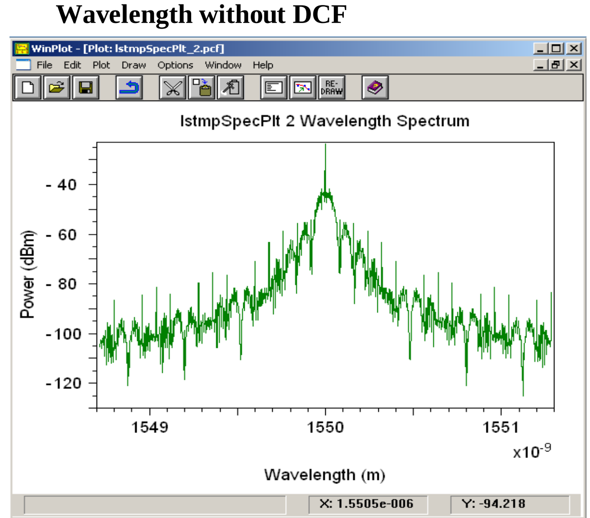

Fig: 2. Received Power Vs Wavelength without DCF

In a direct modulation scheme incorporating an EAM with chirp parameter, the received RF power is given by

$$P_f \propto \cos^2\left\{\frac{\pi L D \lambda_c^2 f^2}{c\left[1-\frac{2}{\pi}\tan^{-1}(\alpha)\right]}\right\} \qquad (1)$$

Where L - fiber length, D - dispersion coefficient, λ - optical carrier wavelength and f - RF frequency. By combining the SMF and DCF with different dispersions like 350,400,420ps/nm, the total dispersion has the nearest zero ps/nm. Over a long-haul fiber transmission, without DCF, fiber chromatic dispersion will result in a large RF power degradation. With DCF, RF power degradation will be overcome due to the dramatic decrease of fiber chromatic dispersion.

5.2 Bit Error Rate of down link BER: (csto BS)

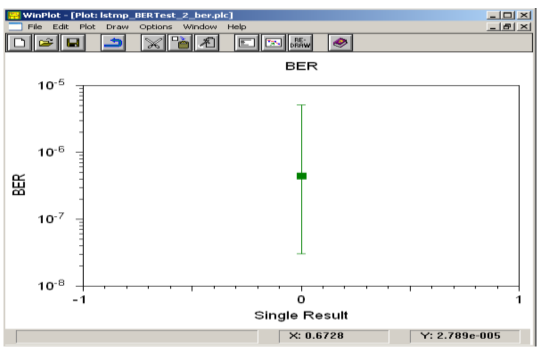

Fig: 3. Down link BER (bit error rate)

5.3 Eye diagram of without DCF

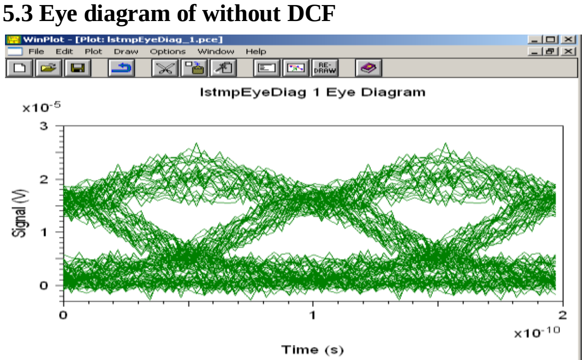

Fig: 4. Eye Diagram without DCF

5. Conclusion

A full-duplex radio-on-DCF transport system employing WDM and optical add–drop multiplexing techniques was proposed and demonstrated. RF power degradation due to the fiber chromatic dispersion was overcome by employing the proper length of DCF, resulting in low BER. Our proposed system is suitable for the long-haul microwave optical links.

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RoF is a very effective technology for integrating wireless and optical access. It combines the two media; fiber optics and radio, and is a way to easily distribute radio frequency as a broadband or baseband signal over fiber. It utilizes analog fiber optic links to transmit and distribute radio signals between a central CS and numerous BSs. In the future as new RoF technologies emerge and their applications become more diverse and less costly. It has three conspicuous features that make it quite different from conventional wireless networks: (1) it is transparent to bandwidth, modulation of RF signals and protocol, (2) simple and small BSs, and (3) centralized network architecture.

In contrast to research efforts devoted to physical layer in this area, little attention has been paid to upper layer network architecture and system resource management issues using its centralized architecture. For instance, the CS in a RoF network has global knowledge of current network status and can dynamically control network resources. The studies suggest that RoF based networks could address difficult issues that are hard to solve with the conventional approaches originated from distributed wireless network architecture. Thus, RoF based wireless networks could be much more efficient in terms of system resource management as compared to conventional wireless networks. In this sense RoF is a promising technology for future high-capacity and broadband multimedia wireless services.

OPTSIM 4.5 Introduction

OptSim has a wide and growing library of components, which are included for your convenience in the component palette, at the left of the design area. With the LIB button you can access to the secondary library, which contains less frequently used components, and all user-defined components. These components allow you to extend OptSim simulation capability to:

- Complex modulation formats such as PSK, DPSK, FSK, and QAM, as typically used in CATV applications
- Carrier and clock recovery for these formats
- Complex digital and analog signal processing
- Generation of several signals formats, both deterministic (sinusoidal, square and sawtooth wave)
- Systems simulation such as Voltage Controlled Oscillators, Phase Locked Loops and many others.

LIB components do not have any control on the parameter ranges. You should use these components paying attention to the parameter ranges, which are specified in the component Help pages. While incorrect parameter values for components belonging to the main library are detected as soon as the parameters are inserted into a dialog window, they may generate runtime error when this happens for LIB components.

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