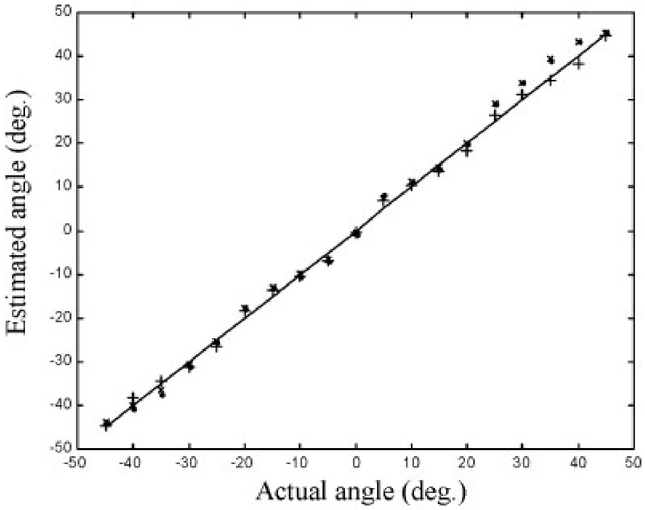

Figure 3 Simulated and experimental DOA estimated angle versus the actual angle (the solid line depicts the ideal estimation): + (i) simulated; × (ii) experimental (SNR = 35 dB); ● (iii) experimental (SNR = 15 dB)

4. CONCLUSION

The feasibility of a novel DOA estimation algorithm for switched-beam antenna systems based on power measurements has been demonstrated. Experimental results, carried out at 60 GHz, agree quite well with the simulated results and fast DOA estimations with reduced complexity are achieved, since no convergence time is required.

ACKNOWLEDGMENTS

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60-GHz RADIO-ON-FIBER DISTRIBUTION OF 2 × 622 Mb/s WDM CHANNELS USING REMOTE PHOTONIC-FREQUENCY UPCONVERSION

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ABSTRACT: *A new distribution scheme of WDM channels in a 60-GHz radio-on-fiber system is demonstrated by using the remote photonic-frequency upconversion technique. The frequency upconversion of WDM data with 60-GHz optical local-oscillator signals is performed remotely at base stations with cross-gain modulation in a semiconductor optical amplifier (SOA) and using square-law photo detection of a photo-diode (PD).* © 2003 Wiley Periodicals, Inc. Microwave Opt Technol Lett 39: 201–203, 2003; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.11169

Key words: *radio-on-fiber system; remote photonic-frequency upconversion; semiconductor optical amplifiers; cross-gain modulation; square-law photo detection*

INTRODUCTION

The fiber-optic transmission of millimeter-wave (MMW) signals has attracted much attention for broadband-radio-access system applications, such as local multipoint distribution services [1], indoor wireless LAN [2], intelligent transportation systems [3], and radio astronomy [4]. Broadband-radio-access systems require a large number of base stations due to their small cell size. The base stations should be compact and simple to implement. The usual approach to transmit MMW signals over fiber-optic links is to employ high-speed external modulators, which results in periodic signal-power suppression due to fiber chromatic dispersion [5].

One alternative approach is to send baseband or intermediate frequency (IF) data that are frequency upconverted at base stations. This approach is not only insensitive to fiber chromatic dispersion, but also is able to utilize wavelength division multiplexing (WDM) networks easily [6]. However, the base stations are more complex and expensive because high-frequency electrical mixers and local oscillator (LO) sources are needed for frequency upconversion.

We have previously demonstrated efficient photonic-frequency upconversion of optical IF signals with optical LO signals using cross-gain modulation in a semiconductor optical amplifier (SOA) and square-law photo detection of a photo-diode (PD) [7, 8]. We have shown that high conversion efficiencies can be obtained over the wide wavelength separation between optical IF and LO signals, as long as they are within the SOA optical-gain-wavelength bandwidth.

DISTRIBUTION SCHEME AND RESULTS

Employing the abovementioned useful features, we experimentally demonstrate a new distribution scheme of two 622 Mb/s WDM channels in a 60-GHz radio-on-fiber (RoF) system. As shown in Figure 1, WDM data are wavelength-selectively distributed to base-stations and one 60-GHz optical LO is shared among base stations.

The optical LO has two optical modes, which are separated by the desired LO frequency of f_{LO} in order to avoid dispersion-

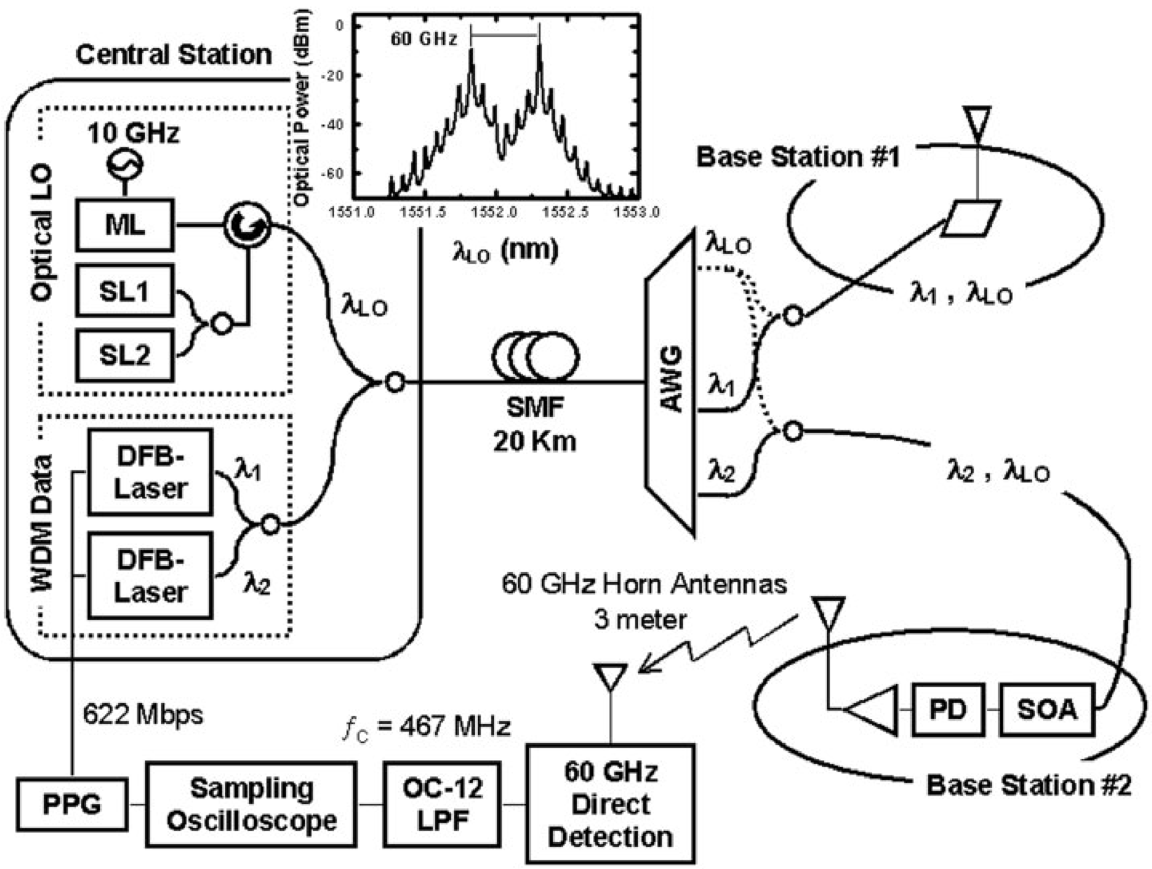

Figure 1 WDM/60-GHz radio-on-fiber distribution configuration. ML: master laser, SL: slave laser, SMF: single-mode fiber, PPG: pseudo-random pattern generator, and AWG: arrayed waveguide grating

induced signal suppression. In the experiment, optical LO signals are produced by the sideband injection-locking technique [9], where two of the sidebands produced by the directly modulated master laser at 10 GHz injection-lock two slave lasers, resulting in two dominant optical modes separated by 60 GHz as shown in the inset of Figure 1. When photo detected, low-noise and stable 60-GHz LO signals are obtained with a single-sideband phase noise of about −90 dBc/Hz at 100-kHz frequency offset in the RF-spectrum. Photonic-frequency upconversion of WDM data signals with optical LO signals is achieved remotely at the base stations, which eliminates the need for high-frequency electrical mixers and LO sources.

Two WDM channels are realized by directly modulating two DFB lasers with a 622-Mb/s NRZ pseudo-random bit sequence and multiplexing with the 60-GHz optical LO signals of different wavelengths. After propagating 20-km-long standard single-mode fiber, the WDM data and LO signals are demultiplexed with an arrayed waveguide grating (AWG) in the wavelength domain. Each WDM channel is delivered to one base station along with the common optical LO signals, as shown in Figure 2. The slight suppression of one of the optical LO modes is due to the fact that

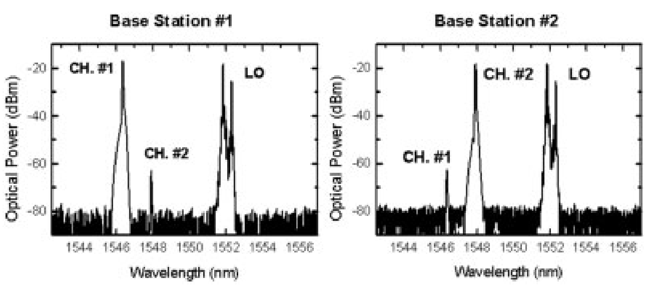

Figure 2 Measured optical spectra for both base stations after AWG

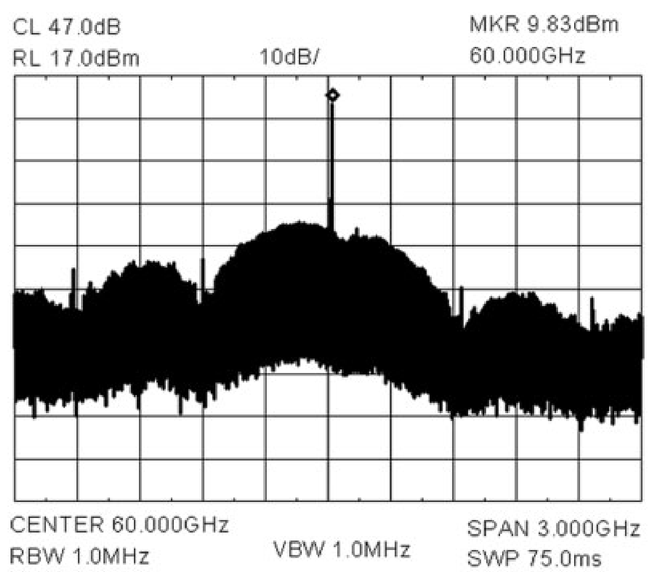

Figure 3 Measured RF spectrum of frequency-upconverted 622-Mb/s data with a 60-GHz optical LO signal for base station #2

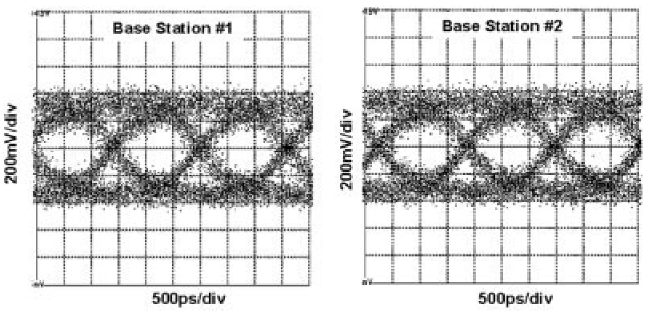

Figure 4 Measured eye diagrams of recovered 622-Mb/s data for both base stations after the 20-km fiber-optic link and 3-m wireless link shown in Fig. 1

the AWG passband (0.4 nm) is less than the mode separation (0.48 nm).

At the base stations, data signals modulate the SOA carrier density as they copropagate through an SOA along with optical LO signals. The modulated SOA carrier density modulates the optical LO signals due to cross-gain modulation. The SOA cross-gain modulation by the optical LO signals is negligible since the f_{LO} of 60 GHz is far beyond the SOA gain-modulation frequency bandwidth. When the modulated LO signals are photo detected in PD, frequency upconversion of data signals to f_{LO} is achieved. Figure 3 shows the measured RF spectrum of the frequency-upconverted 622-Mb/s data with the 60-GHz optical LO signal for base station #2. The spectral asymmetry in Figure 3 stems from the fact that the amplifiers employed in the experiment did not provide flat RF gains at around 60 GHz. The frequency-upconverted data signals are transmitted over 3 m in free space using 60-GHz horn antennas. The received signals are demodulated by direct detection, using a Schottky diode electrically filtered with a standard OC-12 low-pass filter (f_C = 467 MHz). As shown in Figure 3, clear eye-openings are achieved for both base stations.

Although the present demonstration has only two WDM channels, more WDM channels are possible as long as their wavelengths are within the optical-gain wavelength bandwidth of SOA used. In addition, by utilizing different IF frequencies for WDM data, different wireless carrier frequencies can be provided to different base stations.

CONCLUSION

In summary, we have demonstrated a new 60-GHz RoF distribution scheme for WDM channels using the remote photonic-frequency upconversion technique. The frequency upconversion of WDM data signals with 60-GHz optical LO signals was performed remotely at base stations so that high-frequency electrical mixers and LO sources would not be required. This photonic-frequency upconversion process was limited by PD photo-detection frequency bandwidth only. We believe our scheme will be useful in RoF systems, in which one optical LO signal is shared among multiple base stations addressed by their wavelengths.

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DYNAMIC BEHAVIOR OF MEM-MIRRORS FOR TUNABLE VERTICAL CAVITY SURFACE-EMITTING LASERS

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ABSTRACT: *Tunable vertical cavity surface-emitting lasers (VCSELs) are potentially useful for future optical networks. To date, the most successful mechanics to realize wavelength tunability in tunable VCSELs resides in MEM-VCSELs via microelectromechanical (MEM) technology. The key parts to accomplish wavelength tuning in these MEM-VCSELs are controllably movable top mirrors. We present dynamic problems in developing and characterizing these micromirrors. Simulation results of four different mirror shapes with different dimensions are presented.* © 2003 Wiley Periodicals, Inc. Microwave Opt Technol Lett 39: 203–207, 2003; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.11170

Key words: *dynamic; MEM-mirror; VCSEL*

1. INTRODUCTION

Tunable VCSELs with continuous tunability over a wide spectral range have substantial benefits for DWDM applications and are vital to the future of all optical networks. Inventory investment can be reduced and system reliability can potentially be increased, because a few tunable lasers can replace multitudes of fixed-wavelength lasers. The benefits of these devices also include