CHARACTERIZATION OF FIBER OPTIC MICROWAVE LINK WITH MONOLITHIC INTEGRATED OPTOELECTRONIC UPCONVERTER

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INTRODUCTION

Transmission of microwave and millimeter wave signals over optical fiber has been the subject of intense research for the past few years, mainly due to the large bandwidth and low loss of the optical fibre. In a fiber optic microcellular system, the central and base stations are connected with optical fiber. The amplitude of a laser diode at the central station is modulated by radio subcarrier. After transmission via optical fibres, the modulated optical signals are detected, amplified and radiated at the base stations for serving the mobile users [1]-[3]. The key issues in such as system are how to generate and transmit the radio subcarrier, especially when millimeter wave subcarrier frequencies are used. Direct modulation of a laser diode up to millimeter wave frequency is impractical due to the bandwidth limiting effect of laser relaxation frequency. Optical generation of radio signals with sufficient stability and spectral purity is difficult and expensive.

The Optoelectronic Mixer (OEM) is a very attractive candidate for optical signal detection and frequency conversion applications. With the OEM, the signal carried by the optical carrier is converted directly to a desired frequency range in the process of detection [4]-[6], thereby eliminating the need for a high speed laser diode. This allow the transmission of much higher carrier frequencies and as a result much greater signal bandwidths. We reported a monolithic integrated optoelectronic mixing receiver previously for both frequency down- and up-conversion applications [7]-[8]. In this paper, we examine the performance of a fiber optic link employing the OEM as a frequency up-converter.

SYSTEM DESCRIPTION

The OEM used in our study consists of a Metal Semiconductor Metal Photodetector (MSM-PD) followed by an MESFET transimpedance preamplifier [7]. It is easily shown that the responsivity of the MSM-PD is a nonlinear function of the voltage applied. Assuming that the input modulated optical and electrical signals to the MSM-PD are $P_M[1+m\mathrm{Cos}(\omega_M t)]$ and $V_{LO}\mathrm{Cos}(\omega_{LO}t)$, where ω_M is the modulation signal frequency, P_M the power of modulated optical carrier, m the optical modulation index, ω_{LO} and V_{LO} the frequency and voltage of the electrical local oscillator (LO), respectively, it can be shown that the output signal current of the OEM consists of components with frequencies of ω_M, ω_{LO}, $\omega_M \pm \omega_{LO}$ and other higher order terms.

The fiber optic microwave link with the OEM is characterized using the Impulse Response Identification System (IRIS). IRIS is a general purpose radio test set developed to acquire impulse response data from radio channels in real time. IRIS has been used to perform channel characterization employing standard system identification techniques. The device under test is assumed to be time invariant and has impulse response h(t); the output response y(t) to an arbitrary input x(t) is given by

$$y(t) = \int_{-\infty}^{\infty} x(t - \nu)h(\nu)\, d\nu \quad (1)$$

If we multiply both sides of (1) by $x^*(t + \tau)$ we get

$$y(t)x^*(t + \tau) = \int_{-\infty}^{\infty} x(t - \nu)x^*(t + \tau)h(\nu)\, d\nu \quad (2)$$

The cross correlation function of y and x* is given by

$$R_{xy}(\tau) = \int_{-\infty}^{\infty} R_{xx}(\tau - \nu)h(\nu)\, d\nu \quad (3)$$

and if x(t) is white noise then

$$R_{xy}(\tau) = \int_{-\infty}^{\infty} \delta(\tau - \nu)h(\nu)\, d\nu = h(\tau) \quad (4)$$

All of the above operations involve additions and subtraction with regard to the phase characteristics of the system and probing pulse. As a result examination of the phase characteristics of the input and output signal will give an indication of the phase linearity of the system near the carrier frequency of interest as well as the amplitude characteristic. In this case x(t) is approximated by a PRBS sequence which is not white in the statistical sense but will illuminate an adequate amount of spectrum near the carrier frequency of interest.

EXPERIMENTAL RESULTS

To test the OEM as a modulator required that a comparative study be done against a device whose characteristics were known. In this case the modulator to be compared to was the RF modulator in the IRIS System (an HP 8780a Vector modulator operated in scalar mode). Data was captured using a correlation technique implemented by injecting a binary pseudo noise sequence into the modulator as a baseband probing signal. The signal was translated to the carrier frequency of interest and the output from the modulator was fed by cable to the input of the IRIS receiver.

The transmitter and receiver were connected together at the antenna ports with cables (this is referred to as back to back mode). In one case the transmitter was an electronic RF modulator with standard RF mixers. In the other case the transmitter was configured as shown in figure 1(a) with the electronic RF upconverter replaced by the optical link (The LD, fibre OEM and LO). The baseband probing signal was a 25 MB/s Maximal Length Pseudo Random Binary Sequence (PRBS) of fundamental length 511 bits. This signal was modulated onto a 200 MHz IF and then upconverted to 1800 MHz through the OEM modulated with a LO of 1600 MHz in the hybrid RF/Optical experiment and through an electronic modulator in the comparison. The received signal was down converted to baseband (complex) and sampled at rate four samples per bit. The baseband signal was correlated with the original PRBS sequence using a modified FFT algorithm. The RF bandwidth of the system was restricted to 50 MHz to remove LO feed through.

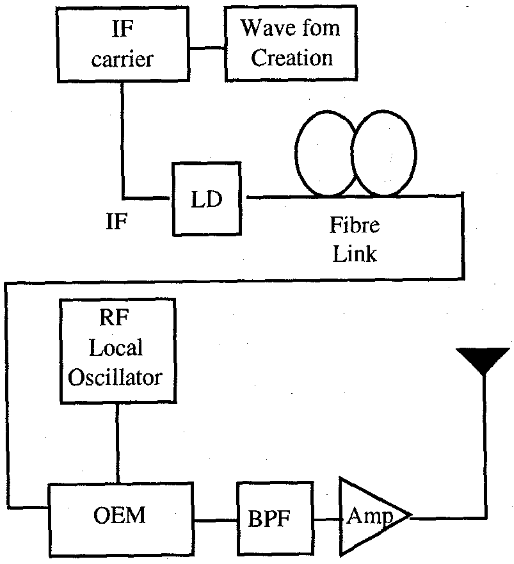

Figure 1(a). Hybrid Transmitter

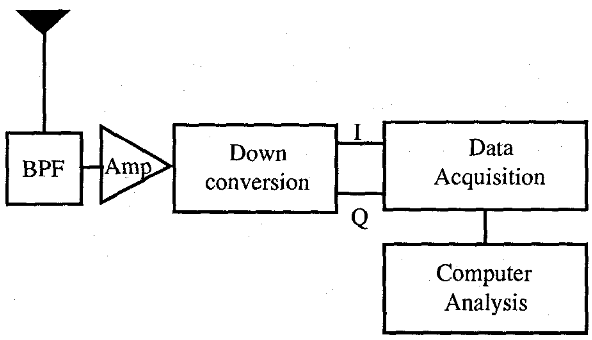

Figure 1(b). IRIS Radio Receiver

Figures 2 and 3 show the results of back to back probes of the RF and hybrid RF/Optical systems. The profiles are similar to each other to about 30 dB below the maximum signal level. This indicates that the optoelectronic devices have little effect on the amplitude characteristic of the probing signal. Additionally the pulse spread at 30 dB below the peak in each case is about 90 nS. Theoretically the base spread on a correlation triangle recovered from a PRBS auto correlation is 2 bit (or chip) intervals which in this experiment is 80 nS.

The phase characteristics of the complex delay profiles is shown in figures 4. These phase profiles were recovered by calculating the FFT of a correlated profile and recovering the phase

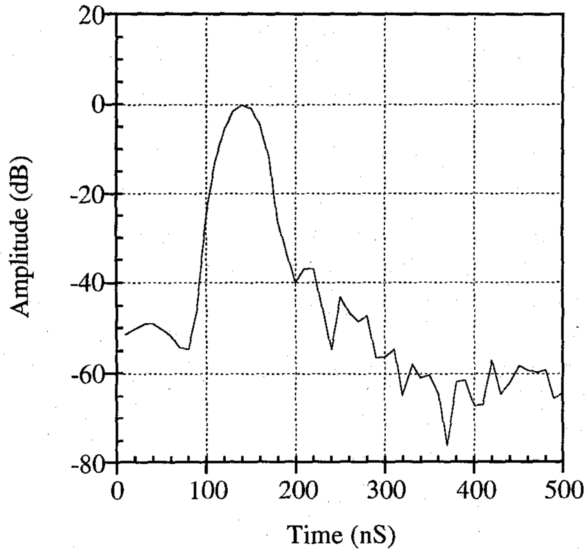

Figure 2. Normalized Delay Profile of RF System

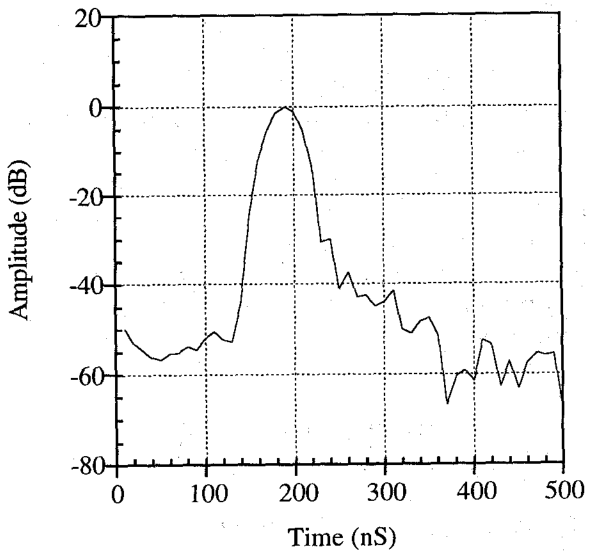

Figure 3 Normalized Delay Profile 0f Hybrid RF/Optical System

response. The mod(2π) characteristic of the phase profile has been removed. The actual slope of the phase profile gives a figure proportional to the electrical delay of the test system. The rippling observed on the phase profile is likely an effect of the FFT calculation. The important characteristic of the profiles are that the slopes are fundamentally linear and very similar. This indicates that the OEM behaves much like the electronic modulator and as such performs transparently in a hybrid RF/Optical system. If nonlinearities were present in the system the phase characteristics would likely be quite distorted and the amplitude profile would have spurious peaks in the 'quiet' areas where no energy should be found based on circuit delay parameters.

Finally Fig.5 shows the unwindowed FET of the impulse response plots in Fig.2 and 3. This power spectrum is typical of a self correlated PRBS sequence. This result can be interpreted to show that the optoelectronic components in the hybrid link have clearly had minimal effect on the characteristics of the probing pulse.

CONCLUSIONS

The hybrid RF/Optical link as defined above serves as a effective moderate bandwidth trunking device while simultaneously allowing modulation of the trunked signals up to very high frequencies using an optoelectronic mixer. In this preliminary study we have shown that a low-cost optical system carries out the above function while introducing minimal signal distortion over that of standard radio modulation devices. This offers potential for a low-cost solution to the problem of distribution of millimeter wave radio signals in buildings for application in PCN and wireless LAN applications.

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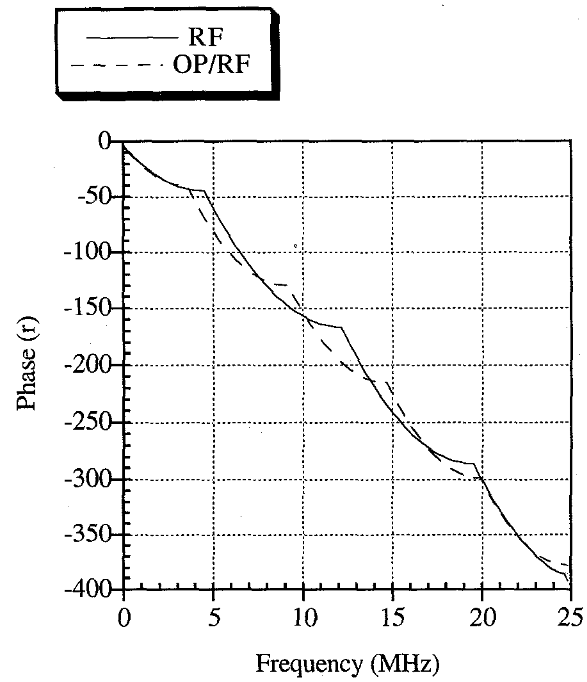

Figure 4 Phase profile of RF and Hybrid RF/Optical System

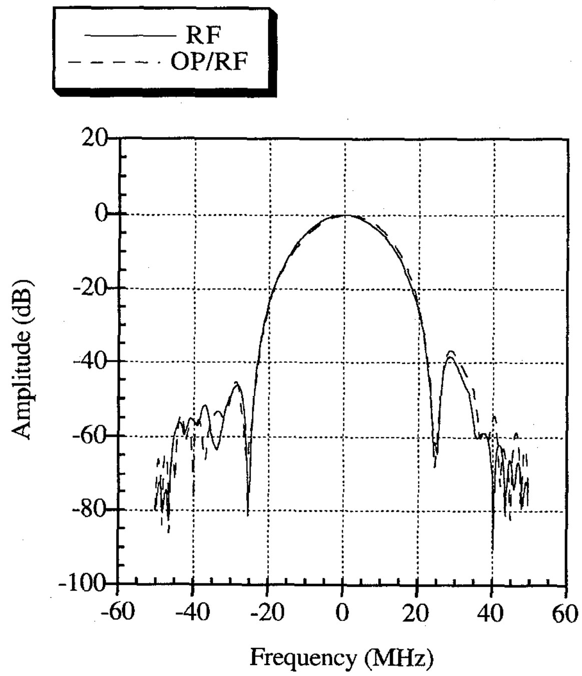

Figure 5. Power spectrum of RF and hybrid RF/Optical systems