A New Tracking Demodulator for the Sub-Carrier Multiplexed IM Lightwave Signal

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Abstract

A new tracking demodulator for the intensity-modulated sub-carrier multiplexed light-wave signal is presented. It needs no channel selection filters and the microwave receiver like the conventional sub-carrier multiplexed light-wave system. Instead it uses a novel type of phase-lock technique, which not only demodulates the output but also automatically selects the required channel. With this new technique it is also possible to make the receiving system. Simulation results have been submitted showing excellent agreement with theoretical analysis.

Indexing Terms: Tracking Demodulator, Phase Lock Technique, and SCM System.

1.0 Introduction

Microwave multiplexed direct detection light wave system have been shown to be an attractive approach for providing wide band services. More efficient multi channel transmission can be achieved with one optical carrier using sub-carrier multiplexing techniques. SCM networks provide an attractive approach for utilizing the wide bandwidth of single mode fiber and the electro-optic components, while taking the advantages of commercially available microwave electronics. An important advantage of SCM system is that many base band signals can be transmitted on one optical carrier. This makes the transmitter module and the associated controls considerably simpler and reduces the overall costs and maintenance of the module.

SCM techniques can be used to transmit a very large number of base band signals required for broadband sub carrier network. These SCM systems have the ability to accommodate both analog and digital modulation, to handle voice data, video, digital audio, HDTV and virtually any foreseeable combination of services. Their enormous flexibility makes them very attractive for broadband applications, especially if services are originating from a variety of different service providers, each using different modulation formats and requiring varying amount of bandwidth.

This paper presents a sub carrier modulation scheme with several microwave carriers containing different base band signals in their phase (as angle modulation) to intensity modulate the optical carrier. Each microwave carrier is extracted from the intensity modulated light wave with the help of a new type of phase-lock technique. The corresponding base band signal is automatically demodulated. As far the knowledge of authors, no one has reported in the literature.

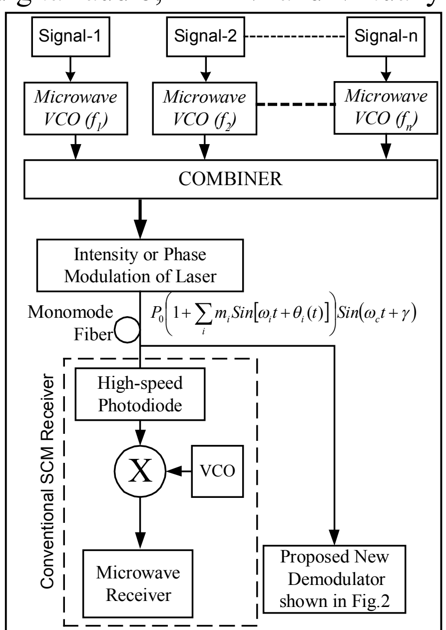

Fig.1: Block Diagram of SCM System

2.0 Microwave Sub Carrier System

A typical microwave sub-carrier multiplexing (SCM) is depicted in Fig.1. Modulating signals '1' through 'n' angle modulate the microwave VCO with carrier frequencies 'f_1' through 'f_n'. After this these modulated signals are power-combined to intensity modulate an optical carrier and is ultimately launched onto a single mode optical fiber. Then at the receiving end, the signal is demodulated. The conventional way is to photo-detect the combined signal in order to separate out the microwave sub carriers, which are then fed to a typical microwave receiver to recover the base band signals. While in the proposed demodulator (as shown in Fig.2), the typical microwave receiver has been dispensed with.

3.0 Proposed SCM Demodulator

The proposed demodulator, called a tracking IM-SCM demodulator is shown in Fig.2. It consists of a MZ intensity modulator, photo-detector, low pass filter and microwave VCO having the facilities for frequency as well as phase modulation ability. The filter output contains the instantaneous phase information of the base band signal and controls the instantaneous phase and frequency of the local VCO. Thereby it tracks the instantaneous phase information of the base band signal. Thus the output of the photo-detector gives the base band signal. This is analytically explained in the section to follow.

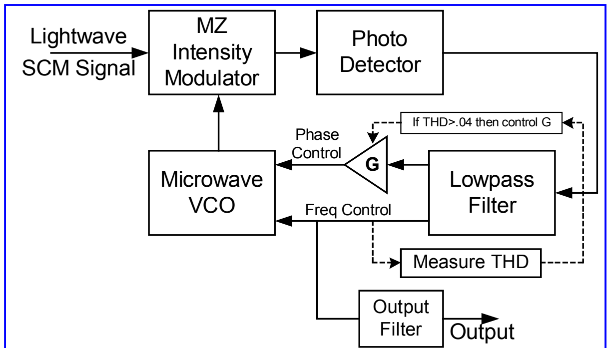

Fig.2: Block Diagram of Proposed New SCM Demodulator which can be adaptive

4.0 Analysis

Let the electric field of the incoming optical signal from a laser which is intensity modulated by an SCM signal is (Fig.1)

$$E = E_0 \sqrt{1 + \sum_i m_i Sin(\omega_i t + \theta_i)} Sin(\omega_C t) \qquad (1)$$

where m_i is the modulation depth in channel 'i'

ω_i is the microwave carrier frequency for channel 'i' and θ_i is the angle modulation for the channel 'i'. Let the output of the VCO is

$$v_0(t) = ACos(\omega_0 t + \psi(t)) \qquad (2)$$

where ω_0 is the VCO output frequency

$\psi(t)$ is the instantaneous phase modulation due to the photo-detector output – a part of which modulates the instantaneous frequency '$\psi_f(t)$' of the VCO and the other modulates the phase of the VCO '$\psi_p(t)$'.

The output of the photo detector is given by

$$v_{ph}(t) = \mu\left\{1 + \sum_i m_i \sin(\omega_i t + \theta_i(t))\right\}\{1 + m_2 \cos(\omega_0 t + \psi(t))\}$$

$$= \mu\left\{1 + \frac{m_1 m_2}{2}\sin\phi + \frac{m_1 m_2}{2}\sin[(\omega_1 + \omega_0)t + \theta_1(t) + \psi] + m_1 \sin[\omega_1 t + \theta_1(t)] + m_2 \cos[\omega_0 t + \psi]\right\} +$$

HOT due to other sub-carriers…………………………………………………………… …(3)

where $\phi(t) = (\omega_1 - \omega_0)t + \theta_1(t) - \psi_f(t) - \psi_p(t)$ ……………………………………..(4)

It denotes the instantaneous phase error between the incoming required sub-carrier signal and the output of the VCO. It is to be noted that $\psi_f(t)$ arises due to frequency modulation, and $\psi_p(t)$ arises due to phase modulation.

Using a low-pass filter and a dc separator, the output of the photo-detector is seen to be $v_\phi = \mu \sin\phi$, where μ is a constant. It is worthwhile to note that the error signals due to other sub-carriers are filtered out because of the presence of the low-pass filter.
Referring to Fig.2 and the output of the filter modulates the instantaneous frequency of VCO, one can write

$$\frac{d\psi_i(t)}{dt} = \mu\beta \sin\phi = K_f \sin\phi \text{ ....(5)}$$

and $\psi_p(t) = \mu\beta_p \sin\phi = K_p \sin\phi$ ....(6),

where 'β' is the frequency sensitivity of the VCO, 'β_p' is the phase sensitivity of the VCO.
Using (4), (5) and (6), it can be easily shown that

$$\frac{d\phi}{dt} = \Omega_0 - K_f \sin\phi(t) - sK_p \sin\phi(t) + \frac{d}{dt}[\theta_1(t)] \text{ ....(7)}$$

where $\Omega_0 = \omega_1 - \omega_0$ is the open loop frequency error. If $\Omega_0 = 0$, then

$$\frac{d\phi}{dt} = -K_f(1 + s\tau_p)Sin\phi + \frac{d}{dt}\{\theta_1(t)\} \text{ ....(8)}$$

where τ_p is the phase modulator time constant. Thus, it is seen that when the phase error is small

$$\phi = \frac{s\theta_1}{s + K_f(1 + s\tau_p)} \text{ ....(9)}$$

That is, when the modulation frequency is small compared to the locking range K_f,

$$\phi \cong \sin\phi = s\theta_1(t) \text{ ....(10)}$$

Thus, the phase detector output, being proportional to $\sin\phi$, and gives the demodulated output $\{s\theta_1(t)\}$ for the channel '1'.

5.0 Numerical Experiment

The proposed demodulator is simulated using MATLAB. The photo-detector output is shown in Fig.3. It clearly shows distortion free output. It is also seen that the additional phase control improves the quality of the demodulated output to a large extent.

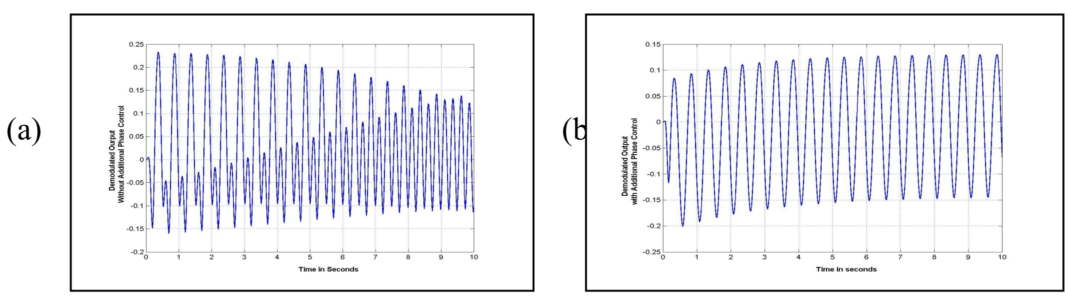

Fig.3: Demodulated Output of the Proposed Sub-carrier Demodulator
(a) When the additional phase control is snapped
(b) When the additional phase control is used

6.0 Conclusion

Excellent demodulated output confirms the philosophy of the new tracking demodulator for the IM sub-carrier multiplexed light wave signal. The effect of the phase control (Fig.3.b) is evident. It is reiterated that the proposed detector does not need if filters as well as a microwave receiver. The dotted connection as shown in Fig.2 can be used to make it an adaptive demodulator. When the total harmonic distortion attains the set-limit, the control of the 'G' parameter is programmed to be stopped. Further work on this aspect will be communicated later.

7.0 Acknowledgement

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8.0 References

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