NON LINEARITY REDUCTION IN LASER DIODE BY MEANS FEED-FORWARD LINEARIZATION FOR FREE SPACE OPTICAL LINK AT 2.4GHZ

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ABSTRACT Free-space optics, sometimes referred to as optical wireless, is the area in telecommunications research that has seen rapid development over the last several years, which is capable of offering high-bandwidth services over relatively short distances at attractive costs and obtains broadband communication. The dilemma in employing this technology is the performance reduction due to the nonlinearity present in the directly modulated optical transmitter, hence causes the inband, harmonic and intermodulation distortion (IMD) in the modulated signal. The technique of feedforward distortion compensation provides the better solution because it can minimize the (IMD3) in modulated optical signal operating at wavelength 1550nm, also reduces all the other higher orders of distortions. In this paper a novel design for the free space optical link utilizing OFFLS (optical feed forward linearization system) which reduces non-linearity of the optical transmitter up to 17dB i.e. laser diode at carrier frequency 2.4GHz for the IEEE 802.11b/g standard and wavelength of 1550nm employing the feedforward linearization technique is presented.

I. INTRODUCTION

Recently, various wireless access systems have been developed in order to establish broadband wireless communication networks. The optical wireless communication systems which use light wave instead of the electric wave for the data transmission medium attract much attention (R. S. Tucker, 1992), (Marconi Instruments, 1995). It is because that lightwaves are obstructed only by physical obstacles. In addition, there is no electromagnetic interference between other electronic equipments.

Free space optics also called free space photonics (FSP) provides one of better solution for the high bandwidth requirements for broadband services. The benefit of the transmission of high frequency signals by using this optical wireless technology is the low cost, as compared to the conventional coaxial cable, with that, it provides fiber-optic connectivity without requiring physical fiber-optic cable FSO is a line-of-sight technology that uses invisible beams of light to provide optical bandwidth connections that can send and receive voice, video, and data information at bandwidths up to 1.25 Gbps. The problem in this technology is the reduction in the performance due to the nonlinear behavior of the laser transmitter i.e. directly modulated laser diode. Direct modulation of laser diode has limited dynamic range due to intermodulation distortion products present in the laser output intensity spectrum (D Hassin & R. Vahldieck, 1990).

Non linear distortion produce by the semiconductor laser such as intermodulation distortion (IMD) can also give rise to inter channel interference which degrades the quality of the received signal. Intermodulation distortion is the result of two or more signals interacting in a non linear device to produce additional unwanted signals. These additional signals (intermodulation products) occur mainly in devices such as amplifiers and semiconductor laser diode (Marconi Instrument, 1995). The major concern here is the IMD3 which is the two tone 3rd order intermodulation distortion near the carrier, all other distortion can be cancelled by using band pass filters.

Many techniques are being used to reduce the non-linearity of the semiconductor laser transmitter, such as feedback (or closed loop), phase-shift harmonic cancellation (PSHC), predistortion, quasi-feedforward and feedforward. The feedback and PSHC techniques have considerable limitations and are not really serious options for optical cellular systems. Predistortion networks have had limited success since they must be matched to individual lasers and must take into account the strong frequency dependent distortion generated by semiconductor laser diodes and other undesired effects such as laser aging. Quasi feedforward linearization schemes require matched lasers, which are very difficult to obtain. Even though feedforward is a relatively complicated and sensitive scheme we consider it a promising linearization solution especially in view of the demand for high channel capacity

light wave systems (J. H. Seo , Y. K. Seo & W. Y. Choi, 2001). Feedforward technique is the only one of the correction techniques that needs some adaptation for use in a free space system. Most of the non-linear correction techniques that have been established for optical communication were originally developed for microwave high power amplifier links.

2. FEEDFORWARD IMPLEMENTATION

The feedforward method for non-linearity improvement is basically developed for the lightwave systems. The performance of an optical transmission system depends greatly on the nonlinearity of a laser diode. Since the intermodulation distortion generated by the laser non-linearity can cause spectral re-growth some form of distortion compensation is required. Figure. 1 shows the proposed optical feedforward-linearization system.
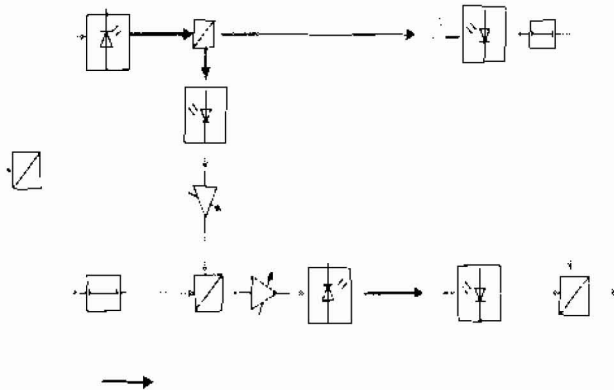

Fig. 1 Block diagram of feedforward linearization system

Conceptually the system consists of two loops, the first loop is signal-cancellation or error determination loop and the second loop is error-injection loop Considering the first loop first, the RF input signal is split into two paths at the electrical splitter, where one modulates the primary laser diode circuit LD1, whereas the other is the error-free reference path. Due to the nonlinearity of laser diode circuit LD1, the modulated optical output signal contains IMD products. The output is split into two path and then is detected using a photodiode circuit PD1, followed by a variable gain inverter amplifier A1. The output of inverter amplifier A1 containing signal and distortion products, together with the intensity noise generated in laser LD1, is subtracted from the error-free reference path at electrical combiner C1.

The resulting output signal ideally should consist of the error signal only (A. B. Maiteeg , S. M. Idrus & H. Harun) (i.e., the nonlinear distortion products and the detected noise of the primary laser LD1). The resulting output signal is 180° phase shifted and injected into the distortion-

cancellation loop and modulating the secondary laser LD2. The modulated optical output signal from laser LD2 is an optical representation of the error signal (i.e., distortion products) at the output of the primary laser LD2 but inverted in sign. Since laser LD2, is directly modulated with the low-level distortion products, it can be assumed to operate linearly and not generate significant distortion of its own .The output of laser LD2 is detected by photodiode PD1 and is combined with signal from photodiode PD2.Both the signal-cancellation and the distortion-cancellation loops require correct amplitude and phase for the cancellation of the carrier signal at the electrical combiner C1, and distortion products at the receiver photodiode PD2. This is facilitated with variable attenuators and variable-gain amplifiers for amplitude matching and fine tuned with electrical phase shifters for phase matching.

3. SIMULATION SECHEME

This section describes the simulation arrangement of feedforward linearization and explains the tuning and testing of the system. Optical communication systems are increasing in complexity on an almost daily basis. The design and analysis of these systems. which normally include nonlinear devices and non-Gaussian noise sources, are highly complex and extremely time-intensive; as a result, these tasks can now only be performed efficiently and effectively with the help of advanced new software tools. OptiSystem is innovative optical communication system simulation software that designs, tests, and optimizes virtually any type of optical link in the physical layer of a broad spectrum of optical networks, from analog video broadcasting systems to intercontinental backbones.

The simulation is done using commercial software Optisystem version 7.The system consist of two directly modulation laser that modelled by laser rate equation. Laser L1 wavelength is 1529 nm, with a mean optical output power of 2 mW (3 dBm) at 38-mA bias current .Laser L2 is of the same type as Laser 1. but it operates at 1532 nm. to avoid optical interference at the transmitter. Because the effects of amplitude- and phase tuning parameters are interrelated, in order to fine tune the whole system, it is necessary to first tune the signal-cancellation loop and, then, the distortion-cancellation loop. If the two paths in the carrier-cancellation loop have the same frequency response, then a complete cancellation of the fundamental signal should be obtained at the output of subtractor. The cancellation will be broadband to the extent that the frequency-dependent gain and phase shifts of the two parallel branches are identical. Frequency response of the loop was measured for amplitude and phase matching with the reference path connected and disconnected.

For the distortion-cancellation loop, the electrical reference signal is temporarily removed. The distortion-cancellation loop is optimized and tested. Frequency responses of the loop for amplitude and phase matching are

measured with the laser L2 path connected and disconnected. The difference between these frequency responses is the suppression ratio, which indicates the performance of the distortion-cancellation loop.

4. RESULTS AND DISCUSSION

Figure 2 shows the detected RF spectrum with out feedforward technique at the carrier frequency of 2.4 GHz, third order Intermodulation distortion IMD3, which is at channel spacing of 1 MHz near the carrier is quite high about -76dBm, which can agitate the original signal aud cause reduction in performance. The input power to the system is about 37dBm, wavelength used for the modulation of the laser diode is 1550nm which is optimum for optical communication, the length of the link is set to the 0 km.
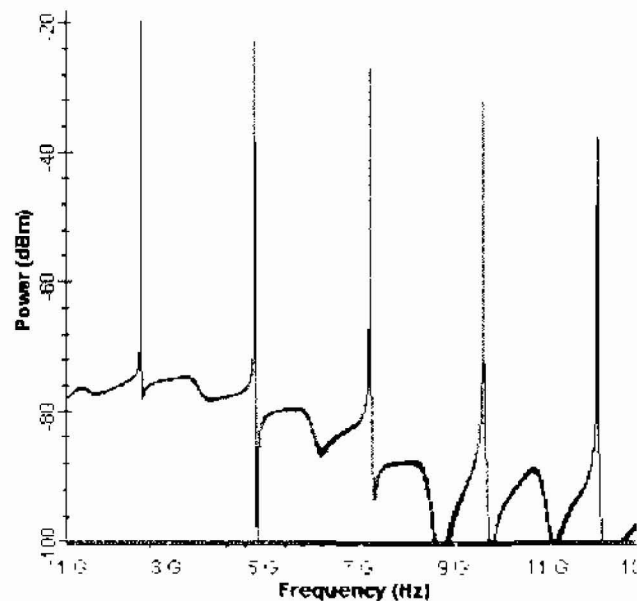

Fig. 2 Detected RF Spectrum without Feed forward Linearization

Figure 3 shows the detected RF spectrum with using feed forward linearization at same carrier frequency 2.4 GHz. The third order intermodulation distortion IMD3 is reduced by 17dB i.e. the received power at IMD3 is about -93dBm. where as all other parameters are same which is mentioned above for the system simulated without feed forward linearization. The intermodulation distortion is compensated at the same received carrier power level which is about -20dBm,

The performance of the feedforward linearization has been assessed and in Figure 3 the results show approximately 17 dB suppression in IMD3 around 2.4 GHz with the channel spaced by 1MHz. Further suppression of

the IMD to the noise floor level can be achieved by more accurate phase and amplitude matching.
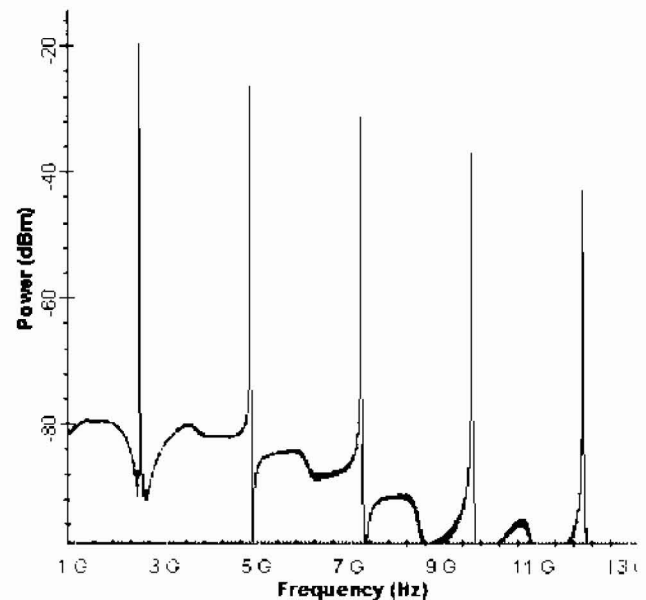

Fig.3 Detected RF Spectrum with Feed forward Linearization

Figure 4 shows the higher order of intermodulation distortion products IMD4 and IMD5 are also suppressed to a little extent by using feedforward linearization. where the received power amplitude level of the carrier is same.
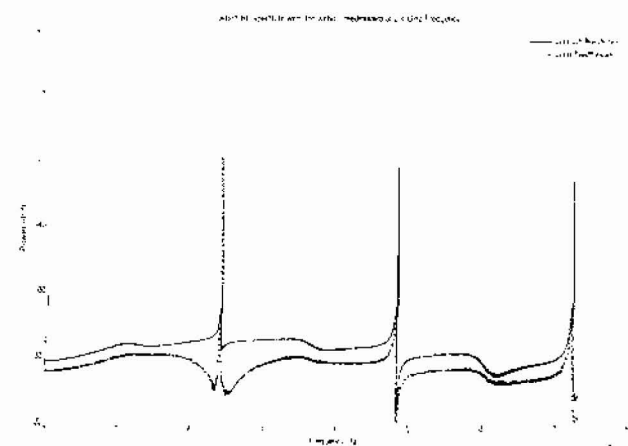

Fig. 4 Detected RF Spectrum With and Without Feedforward Linearization at 2.4 GHz Frequency

CONCLUSION

In this paper, the feedforward linearization technique has been demonstrated to reduce the intermodulation distortion IMD at the frequency 2.4 GHz required Wire LAN (WLAN) which utilize IEEE 802.11b/g standard by using a directly modulated laser diode, hence achieving 17-dB IMD3 suppression. Further improvements will make the feedforward a wideband system to cover the IEEE802.11a frequency range around 5.2 GHz The system is simulated by using a commercial software OptiSystem by Optiwave and hence the IMD3 reduction of 17-DB is obtained.

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