Soliton Carriers in CDMA and OFDM Communication Systems

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Abstract:
The concept of solitons has been successfully utilized in optical communications to handle signal distortion. In this light, the present work explores modulation using soliton carriers and subsequently, prototype wireless communication system based on Orthogonal Frequency Division Mutiplexing (OFDM) and Code Division Multiplexing (CDMA) at 11GHz involving Additive White Gaussian Noise Channel is implemented using LabVIEW. The performance of Soliton carriers are compared with sinusoidal counterparts using eye diagrams. The low distortion values observed for solitons form the novelty of the present work. (**Keywords**: Solitons, OFDM, CDMA Modulation)

1. Introduction

It is a well-established fact that the most significant problem encountered in state-of-the-art communication systems is signal distortion, with contributions due to many factors such as intermodulation distortion, noise, nonlinearity, transmission losses and multipath fading effects [1-6]. In the domain of optical communications, similar problems have been handled efficiently, thanks to the concept of optical solitons, which are hyperbolic secant based solutions to the Nonlinear Schrodinger Equation describing pulse propagation in optical fibers [7]. Seen as a balance between linear dispersive and nonlinear effects, solitons are able to propagate for long distances undergoing minimal distortion [7]. Similar properties are observed for solitons in other aspects of nature, such as protein folding, tsunamis and neuron action potentials [8-10].

In this light, the present work explores the feasibility of solitons as carriers for telecommunication systems, albeit from a signal-oriented perspective. Firstly, various modulation schemes using soliton based carriers are explored. Following this, prototype telecommunication system at 11GHz using Orthogonal Frequency Division Mutiplexing (OFDM) and Code Division Multiplexing (CDMA) are designed and implemented in LabVIEW with the channel simulated using Additive White Gaussian Noise and Rayleigh models for multipath fading. The performance of soliton carriers are compared with sinusoidal counterparts using eye diagrams. The ubiquitous nature of solitons, coupled with the lower distortion values observed forms the novelty of the present work.

2. Electrical Solitons

Most optical soliton solutions derived from the Nonlinear Schrodinger Equation consist of a temporal hyperbolic secant function based profile, defined as follows [7]:

$$A(t) = A_0 sech\left(\frac{t-S}{W}\right) \tag{1}$$

where A_0 denotes the peak amplitude and S and W denote the pulse shift (time offset) and width (measured at half-peak value) respectively. This signal represents a bell-shaped curve and is plotted in Fig. 1.

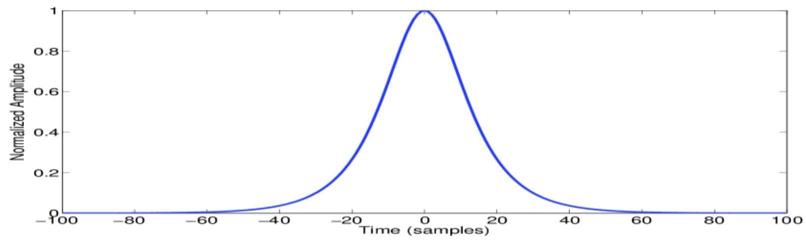

Figure 1 The Hyperbolic Secant Signal

It is possible to replace the sinusoidal signal carrier in modulation schemes with a train of solitons, and this is shown for various modulation schemes in Fig. 2.

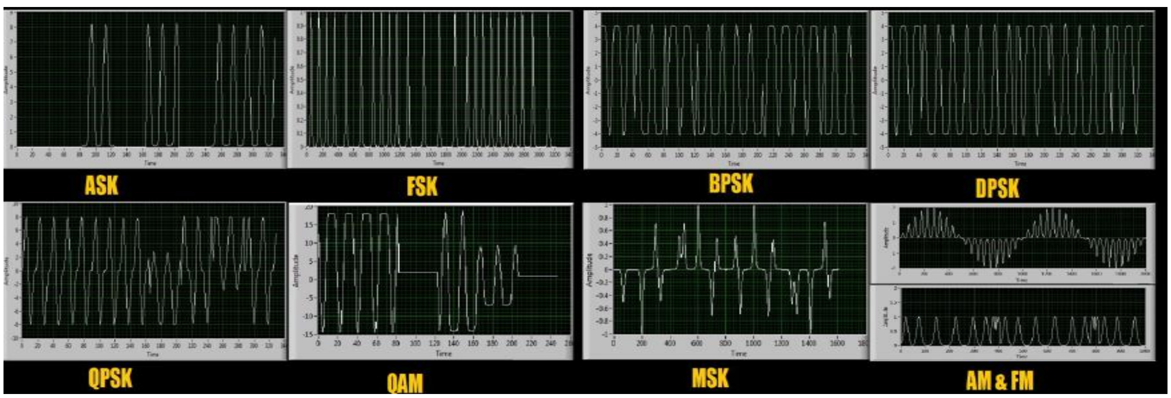

Figure 2 Modulation using soliton carriers

3. OFDM and CDMA using Solitons

In order to assess the performance of soliton carriers, prototype OFDM and CDMA communication systems are implemented in LabVIEW, with the block Diagram shown in Fig. 3 and 4 [11,12].

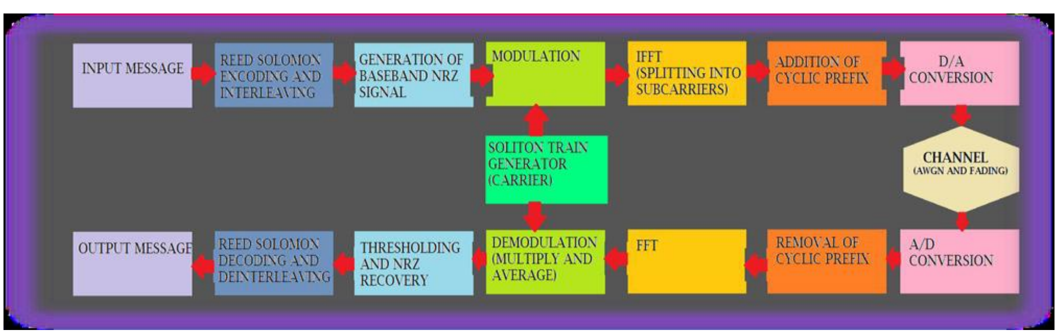

Figure 3 Soliton OFDM Block Diagram

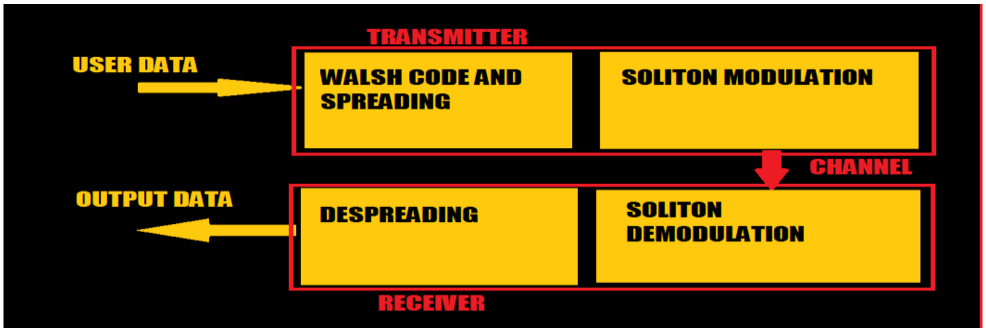

Figure 4 Soliton CDMA Block Diagram

The operating frequency is set to 11GHz, and the channel is simulated using Additive White Gaussian Noise and Multipath Fading using Rayleigh Channels [11]. The SNR is set to -5dB, simulating worst-case channel conditions.

4. Performance Assessment

The performance of soliton and sinusoidal carriers in the proposed OFDM and CDMA systems are compared using eye diagrams, plotted for different modulations in Fig. 5.

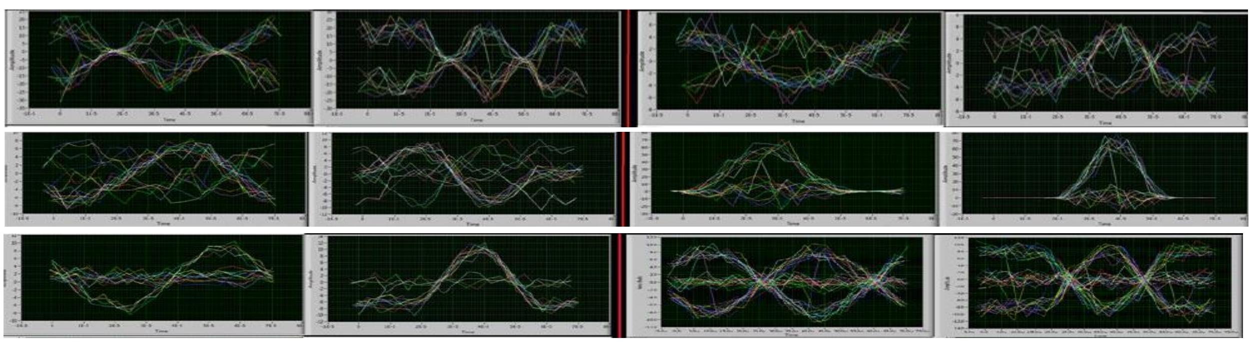

Figure 5 Eye Diagrams for sine (left pane) and soliton (right pane) carriers in BPSK OFDM and DPSK OFDM (top row), QPSK OFDM and ASK OFDM (middle row) and QAM OFDM and BPSK CDMA (bottom row)

The performance assessment is quantitatively obtained by tabulating the Eye heights and Timing jitters for different modulations, shown in Fig. 6 along with a graph comparing Eye heights as a function of SNR for sine and soliton BPSK.

TITLE	EYE HEIGHT		IMPROVEMENT IN EYE HEIGHT(%)	NOISE MARGIN (%)		TIMING JITTER (%)		SNR/ Eb/N0 MAINTAI-NED	BIT ERROR RATE (%)
TYPE	SOLITON	SINE	SOLITON/SINE	SOLITON	SINE	SOLITON	SINE	BOTH	SOLITON
ASK	40	30	33.33	40	31.5	9	15	-5	44.66
BPSK	22	15	46.67	44	33	6	13	-5	15
DPSK	5	3	66.67	38.5	26	7.5	15	-5	38
QPSK	13	9	44.44	72	56.2	4.5	9	-5	29
8-QAM	11	9	22.22	55	50	9	15	-5	24
DETAILED BPSK	3	2	50	18	15	6	18	22	38
DIRECT MICROWAVE BPSK	500	350	42.85	50	25	11	22	15	38
CDMA	13	12	8.33	62	60	10	15	20	37.5

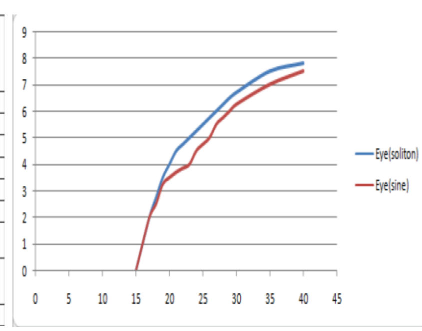

Figure 6 Eye Diagram Performance Assessment for Soliton and Sine OFDM/CDMA

It is seen from the results that soliton based modulations outperform sinusoidal counterparts both in eye heights and timing jitters, thus enabling one to achieve low distortion state-of-the-art communications such as WiMax using soliton based carriers.

5. Conclusion

Based on the successes enjoyed by the soliton concept in optical communications, the present work proposed a signal-oriented perspective of the soliton, with the exploration of soliton based modulation techniques. Following this, LabVIEW implementations of Soliton based OFDM and CDMA systems are presented, comparing the performance with sinusoidal carriers using eye diagrams. It is seen that soliton carrier based implementations outperform the sinusoidal counterparts in terms of low distortion, thus enabling them to be used as efficient carriers in state-of-the-art communication systems such as WiMax.

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