Solitons–An Alternative to Mobile Communication

Hrudhai Rajasekhar[1], Kshama Nambiar[2], Pooja R Raju[3]

[1]Department of Electronics and Communication Engineering, PES Institute of Technology – Bangalore South Campus, Bangalore, India
hrudhai98@gmail.com

[2]Department of Electronics and Communication Engineering, PES Institute of Technology – Bangalore South Campus, Bangalore, India
kshamanambiar98@gmail.com

[3]Department of Electronics and Communication Engineering, PES Institute of Technology – Bangalore South Campus, Bangalore, India
pooja.rraju98@gmail.com

Abstract: ***Mobile phones may be becoming thinner but at the rate at which it is progressing, we need to find alternatives to certain components to reduce the size. This paper is about finding alternatives to those components. One such component is a filter. The work of a filter is to eliminate the extra noise and disturbance created when the frequencies carrying a signal through a sine wave get merged with other frequencies. While eliminating frequencies close to the required frequency, the filter also eliminates parts of the required frequency causing loss of data. We also use, square waves in digital signals for computing. A square wave has a very wide spectrum like white light. The abrupt changes of square wave run at very high frequencies which are extremely fast for the system to process. This creates a distortion, which affects the performance of the mobile phone. We need to find alternatives, that can overcome these two problems and at the same time, reduce the bulkiness of the mobile phone. Solitons are the perfect alternatives. A soliton, is a bell-shaped wave, which reaches the peak at the required frequency and decays towards blank space at the remaining frequencies. Solitons also tend to be more immune to noise and distortion. This feature of solitons makes it easy to process and transmit at the same time, eliminating the use of filters. Soliton, which is a vast topic for research can be useful in not just computing and communication but with further research, can replace the display of mobile phones and produce a display with vivid colours and excellent clarity while consuming lesser power then LEDs. Soon, we may be able to have an all soliton mobile phone.***

Keywords: Solitons, Mobile Phones, Thickness, Filters

1. Introduction

Due to the rapid development in technology, mobile phones are becoming thinner gradually, but to what extent can we reduce the thickness? If people want phones thinner than what we already have, we may have to remove or replace certain components from mobile phones. Analysing which components can be removed is not an easy task considering the fact that all the components are essential for the working of a mobile phone. The other option we have is, replacing components with alternatives that do not consume as much space. [1]

One such component which we are talking about, is a filter. A filter is used to remove the background noise accumulated while transmitting sine waves. We can notice from various eye diagrams that the noise in a sine wave is extremely high and this affects the transmitted signal if not filtered. An eye diagram is an oscilloscope display in which a digital signal from a receiver is repetitively sampled and applied to the vertical output, while the data rate is used to trigger a horizontal sweep. [2]

Here is one such eye diagram of the noise present in a sine wave under different conditions.

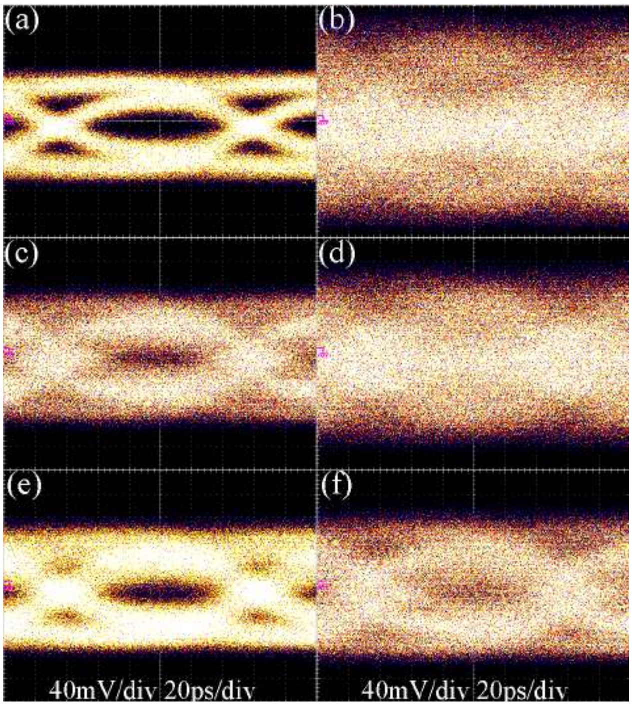

Figure 1

a) Both optical relay and amplitude are matched
b) Signal and Interference noise without cancellation
c) Optical Delay is not matched with 1.8mm mismatch
d) Optical Delay is not matched with 3.6mm mismatch
e) Amplitude is not matched with 1.4dB mismatch
f) Amplitude is not matched with 2.8dB mismatch [3]

The figure below shows the eye diagram of a square wave. A square wave also shows noise and distortion but not as much as that of a sine wave.

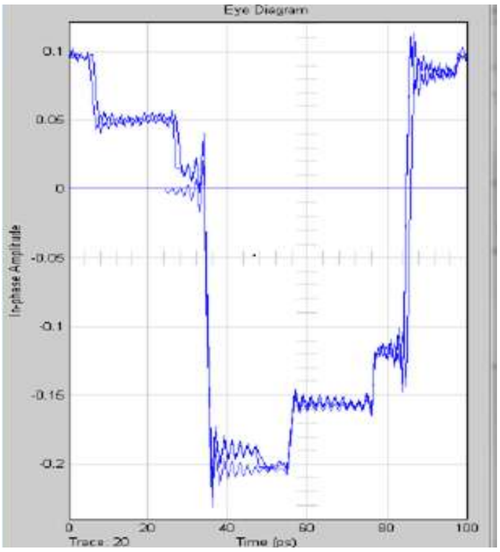

Figure 2: Eye diagram of a square wave

These graphs show that there is a lot of noise present in a sine wave which needs to be filtered out. We need to find an alternative to sine wave, which does not accumulate much noise and remains the same with no loss in data.

2. Spectral Comparison

Let us analyze the spectra of a sine wave and a square wave. In a sine wave, the spectrum is extremely narrow and shows a value only when it reaches its peak or maximum value. The rest of the wave gets distorted due to noise and reduces the quality of the signal transmitted. To overcome this narrow spectrum, filters are used in a sine wave which also removes the noise. Here is a graph depicting the sine wave spectrum.

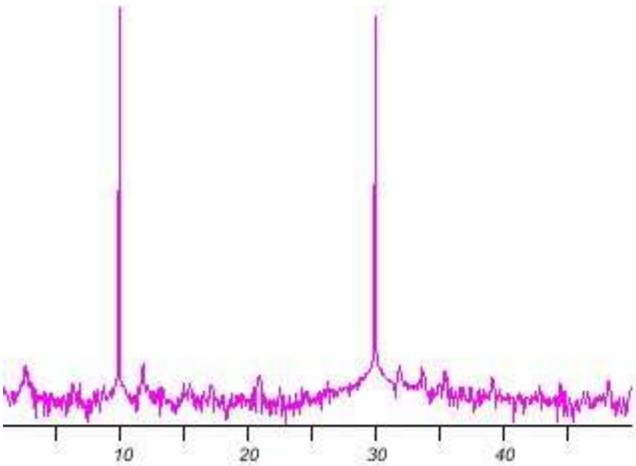

Figure 3: Spectrum of a Sine Wave [4]

As you can see, at 10 and 30 on the x axis, the wave reaches its peak. You can also notice how narrow the spectrum of a sine wave is making it difficult to carry a signal without distortion. These distortions are more predominant at Gigahertz and Terahertz frequencies.

A square wave is used in digital communication and works in 0s and 1s(binary). A square wave is used for communication within the mobile phone. Let us take a look at the spectrum of a square wave. A square wave spectrum is extremely wide as it relies on a maximum and minimum value alone i.e. 0 and 1. This spectrum is too broad for transmitting waves.

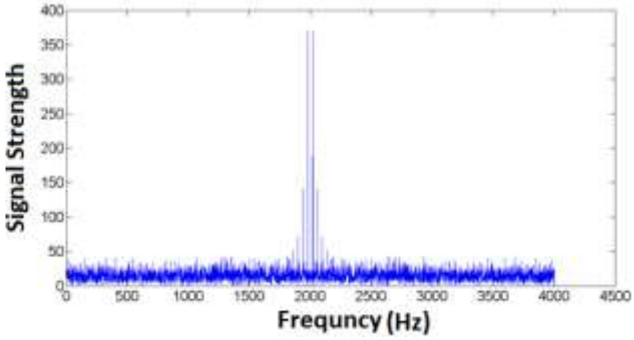

Figure 4: Spectrum of a Square Wave

The analysis of these two frequently used waves shows that signals cannot be transmitted directly and have to be enhanced or rectified to produce a favourable output. This brings us to the topic of filters. A filter is an electrical device used for suppressing waves of frequencies that are not required. There are mainly three types of filters, namely low pass, high pass and band pass.

A low pass filter permits frequencies below a certain frequency to pass through. A high pass filter permits frequencies above a certain frequency to pass through. A band pass filter permits frequencies between a certain range to pass. When a wave passes through a filter, the filter scans the different frequencies present in the wave. According to the type of filter and its setting, it allows a certain type of frequency to pass through. This helps in removing unwanted frequencies which contain noise and distortion.

Every mobile phone has a filter to enhance the signal received. The signal received is filled with noise and distortion which makes it difficult to process the signal. The work of a filter is to remove this unwanted noise and provide the receiver with the enhanced output of a signal.

Let us take a look at the spectrum of a sine wave before and after filtering.

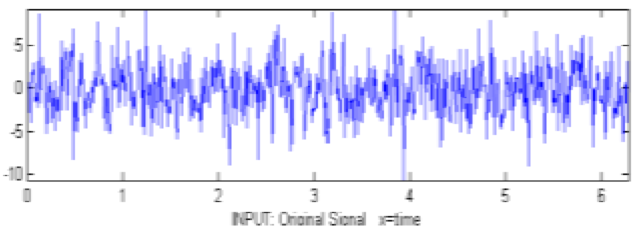

Figure 5: Sine Wave Before Filtering [5]

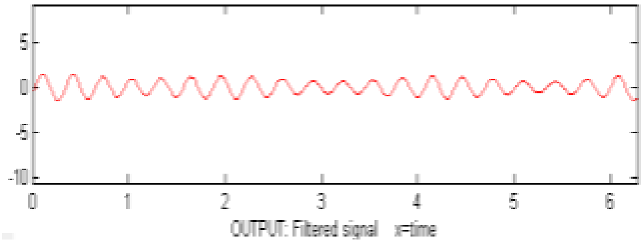

Figure 6: Sine Wave after Filtering [5]

These two figures clearly show the distortion present in a sine wave and highlights the need for filters for processing a sine wave. The question is, is there any alternative wave which does not require filtering and can carry the same amount of data without any loss?

3. Solitons

A soliton is a bell-shaped wave which retains its shape while propagating at a constant velocity. [6] Solitons have lesser dominance of high frequency components while being transmitted. According to optical communication, a soliton is defined as a solution to a Non-Linear Schrödinger Equation depicting pulse propagation in optical fibers.

Solitons are a mathematical characterization of the balance between dispersive and non-linear effects of pulse propagation in optical fibers. A soliton pulse is seen as a one-dimensional time varying signal rather than a wave.

The mathematical equation for a soliton is given by the hyperbolic secant function of the ratio of the time shift and time scaling of the wave. [7]

$$A(t) = \text{sech}\,((t - S)/W$$

Here, (t – S) represents the time shift and W represents the time scaling. The spectrum for a soliton is in between the spectra of a sine wave and a square wave in terms of thickness. It is neither as thin as a sine wave spectrum nor is it as thick as a square wave spectrum.

It has an exponentially decaying spectrum due to the continuously integrable nature of its temporal profile. Given below is the waveform for a typical soliton wave. This shows that the wave peaks only when necessary.

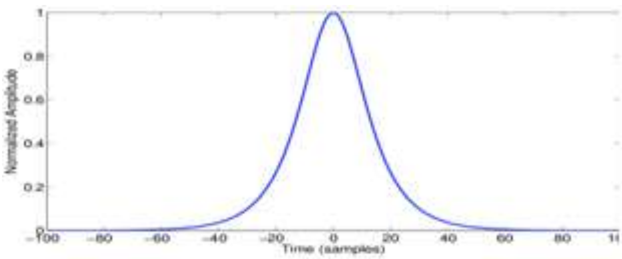

Figure 7: Soliton Waveform [7]

A soliton does not carry much distortion and noise as compared to a sine wave or a square wave. As seen in the spectrum below, a soliton propagates similar to a sine wave or a square wave.

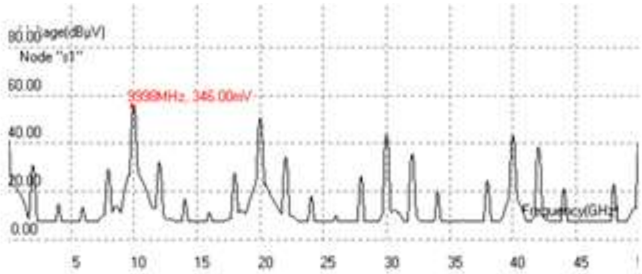

Figure 8: Spectrum of a Soliton [7]

Let us now take a look at the comparisons of the eye diagrams of a soliton with a sine wave and a square wave.

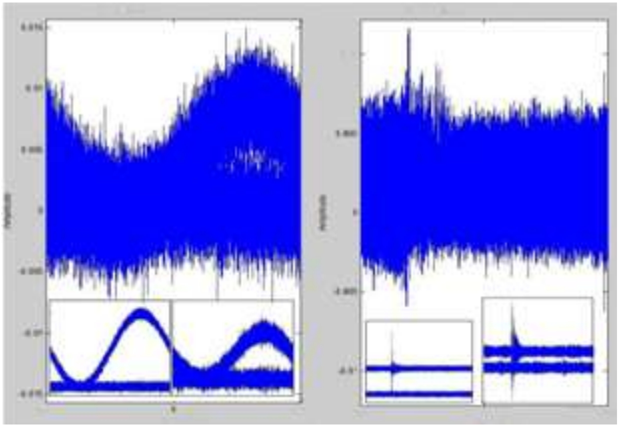

Figure 9: Spectral Comparison of Sine Wave and Square Wave

This figure shows the eye diagram for a square wave. The distortions are noticeable in this eye diagram. In the figure given below, the distortions are extremely low as compared to a sine wave or a square wave. This eye diagram represents a soliton.

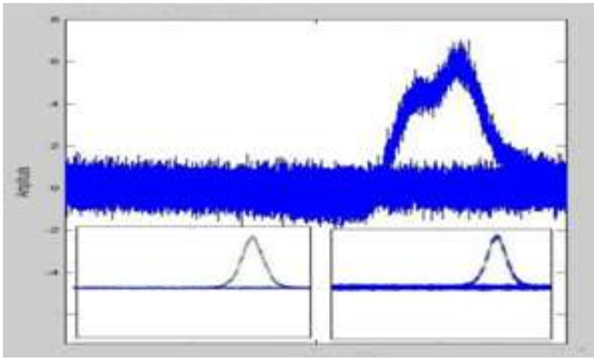

Figure 10: Spectral Comparison of Soliton

Using these diagrams, we can also analyse the Bit Error Rates of a soliton and a sine wave. Bit Error Rate is the rate at which errors occur in the transmission of digital data.

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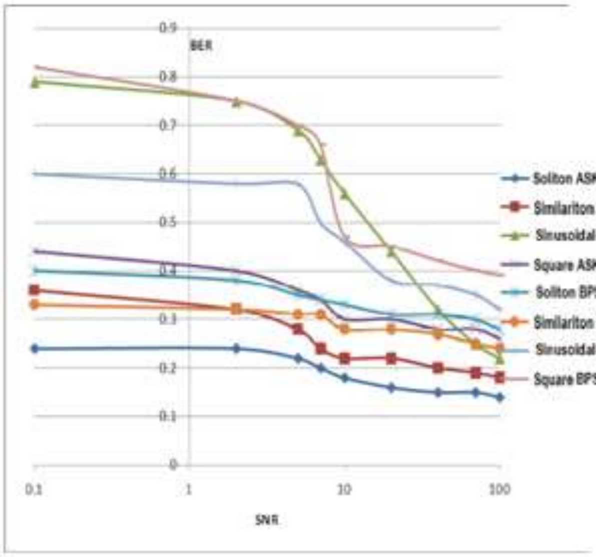

Figure 11: Bit Error Rate Comparison of Sine, Square Waves and Solitons[8]

This graph shows the comparison between the Bit Error Rate of various waveforms. As you can notice, the Bit Error Rate of a sine wave is the highest among all the waveforms at almost 80%. The Bit Error Rate for a square wave is comparatively low and the Bit Error Rate of a soliton is the lowest of all the waveforms at around 20%. This difference in Bit Error Rate of a sine wave and a soliton is extremely high.

From this data, we can assume that a soliton is less prone to accumulating noise and distortion during transmission, as compared to a sine wave or a square wave.

4. Soliton Modulation

After making the assumption that solitons carry lesser noise, let us see how a soliton can be modulated for transmission of signals.

There are two main modulations, namely Amplitude Modulation and Frequency Modulation. In Amplitude Modulation, the amplitude of the carrier wave is varied while keeping the frequency and pitch constant. In Frequency Modulation, the frequency of the carrier wave is varied while keeping the amplitude and phase constant.

The simulation below conducted on LabVIEW shows how the soliton wave is modulated as a carrier wave and used for transmitting signals. The simulations conducted are communication system simulations with optical fibers and OFDMs. [8]

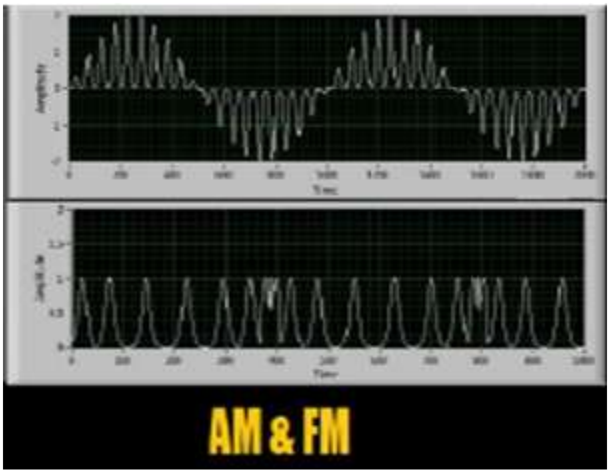

Figure 12: Soliton Modulation [8]

The major advantage of using solitons as a carrier wave is their extremely short pulse duration. These short impulses make it possible to modulate the soliton with the smallest amount of data.

Solitons can also be used for transmitting digital data in the form of 0s and 1s i.e. binary. The variation of the soliton pulses can be seen in the graph below.

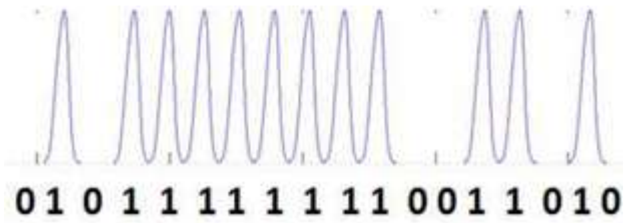

Figure 13: Soliton as Binary [7]

This graph shows the variation of soliton pulses for binary data. The pulse reaches its peak at 1 and remains null at 0.

This proves that solitons are versatile waves and can definitely be used for communication in mobile phones.

5. Conclusion

From all the data above, we can say the solitons are in fact more versatile than sinusoidal or square waves. These bell-shaped waves can not only be used for communication but also for digital data transmission.

Solitons accumulate lesser noise than both sinusoidal waves and square waves and hence eliminates the need to use filters in mobile phone communication. By eliminating the use of filters, the thickness of mobile phones can be reduced to a good extent. These solitons can serve a dual purpose by carrying digital data as well thus reducing the number of components even more.

Solitons can become the future of mobile technology with its multiple advantages and variety of features.

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Author Profile

Hrudhai Rajasekhar is currently completing his B.E degree in Electronics and Communication at PES Institute of Technology – Bangalore South Campus.

Kshama Nambiar is currently completing her B.E degree in Electronics and Communication at PES Institute of Technology – Bangalore South Campus.

Pooja R Raju is currently completing her B.E degree in Electronics and Communication at PES Institute of Technology – Bangalore South Campus.