# Implementation of Active Sonar Transmit Signals

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***Abstract*— Task of active sonar system is to gather information about a target by processing reflections or echo from the target. Active sonar uses different types of pulses to detect the target. Transmitted signals include pulsed continuous waves, linear frequency modulated signals, non-linear frequency modulated signals and stepped frequency modulated signals. The choice of waveform will determine the ability of the system to extract information concerning range and velocity resolution.The power amplifier (PA)which are driven by pulse width modulated signal, is a key element in transmitter systems, aimed to increase the power level of the signal at its input up to a predefined level required for the transmission purposes. Pulse Width Modulation (PWM) provides an intermediate amount of electric power between fully on and fully off. This paper work comprises the exploration of different methods to convert various active sonar transmit signals to pulse width modulated signals. The simulation of these methods, their implementation (using customized NP-PPC board and Virtex®-6 FPGA ML605 Evaluation Kit) for different types of active sonar transmit signals and performance comparison of each method, is carried out so that a better performance can be achieved with accuracy and less power consumption.**

***Index Terms*—Sonar, Power PC, PWM**

## I. INTRODUCTION

Sonar, acronym for Sound Navigation and Ranging uses underwater sound for detection, classification and location of underwater targets. They are broadly classified into two major types namely, Passive and Active Sonar. Passive sonar listens to the sound radiated by a target using a hydrophone and detects signal against a background of the ambient noise of the sea and self-noise of the platform. Active sonar uses a projector to generate a pulse of sound which travels through water to a target and is returned as an echo to the hydrophone which is detected against a background of noise and reverberation. Since the time between the transmission of the pulse and the reception of an echo can be measured and speed of sound in water is known the range of the echoing target can be measured.

A typical signal generation circuit which consists of a high end processor generates a signal with particular frequency, pulse length and pulse repetition rate. The signal is then given to the power amplifier for amplification. The power amplifiers in turn are connected to sonar transducers element which generally consists of piezo-crystals for excitation. The power amplifier (PA) is a key element in transmitter systems, aimed to increase the power level of the signal at its input up to a predefined level required for the transmission purposes which are driven by switched mode power supply. The switch mode technology basically uses Sine Pulse Width Modulation (SPWM) for modulating the transmission signal into high frequency signal. Pulse Width Modulation (PWM) provides an intermediate amount of electric power between fully on and fully off. PWM circuits output a square waveform with a varying on to off ratio. The average ratio can vary from 0 to 100 percent. This on time (TON) to off time period (T) ratio is called as duty cycle, which is expressed in percentage. Therefore, by this scheme, a variable amount of power is transferred to the load. The main advantage of PWM over the linear regulator is its efficiency. For example, at 50% level PWM will use 50% of power that is almost transferred to load but on the other hand in linear regulator control scheme 50% of load power consumes 71% of full power where 50% of power goes to the load and the remaining 21% is dissipated as heat.



## II. ACTIVE TRANSMIT SIGNALS

Active sonar uses different types of pulses to detect the target. Transmitted signals include pulsed continuous waves, linear frequency modulated signals, non-linear frequency modulated signals and stepped frequency modulated signals. The choice of waveform will determine the ability of the system to extract information concerning range and velocity resolution. Range resolution is inversely proportional to bandwidth. Active sonar performance on the other hand, depends also on reverberation rejection. Hence, ability of a waveform to reject reverberation and noise assumes significance. Multiple active sonar systems operating within the same premises will give rise to interference, the degree of mutual interference between waveforms will also assume due importance and all these depends on pulse design.

## III. PULSE WIDTH MODULATED SIGNAL GENERATION

PWM is a process whereby information-bearing signals are represented as variations in the width of high frequency pulses. The duration of each pulse is a function of the input signal amplitude.

### *A. Triangular Method of Intersection*

In the triangle intersection technique, the reference modulation wave is compared with a triangular carrier wave or a saw tooth carrier wave and the intersections define the switching instants as shown in Fig.1.Whenever the carrier signal changes from less than the reference voltage to greater than the reference voltage, the output voltage of the comparator changes state. If the reference voltage is greater than the carrier signal, the state of PWM signal will be high. On the other hand, the state of PWM signal is set to low. Changing the values of the reference voltage could vary the duty cycle of PWM output signal. Within every carrier cycle, the average value of the output voltage becomes equal to the reference value.

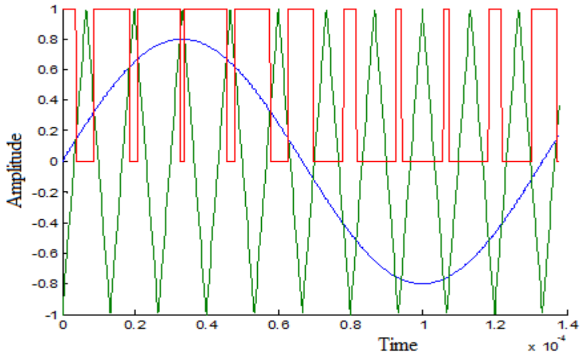


Fig.1. Triangular intersection method of PWM generation

Triangular intersection method is the simplest way to generate a PWM signal, which requires only a saw tooth or a triangle waveform and a comparator. The sonar signal is generated for the frequency of 7.5 KHz. For the generation of PWM signal the carrier (triangular wave) frequency is selected as 16 times the signal frequency to obtain maximum intersection points so that the signal can be reconstructed faithfully without any distortion. Intersection method requires generation of triangular wave in high frequency and needed to compare each sample of the signal with carrier which is a time consuming task. Conversion of nonlinear frequency modulated signal requires a non-linear triangular waveform or saw tooth waveform to get a PWM signal with higher resolution, which increases the signal generation time.

*B. Direct Digital Technique*

In direct digital technique which employs the regular sampling technique, the instantaneous voltage of the signal is directly converted into the output pulses with its duration proportional to the instantaneous voltage. This is a carrier less generation method used for the generation of PWM. Here the instantaneous amplitude of the signal is changed into corresponding duty cycle of the PWM signal and duration of the pulse is set by the sampling frequency of the signal. This can be represented by using the Fig .2 shown below.

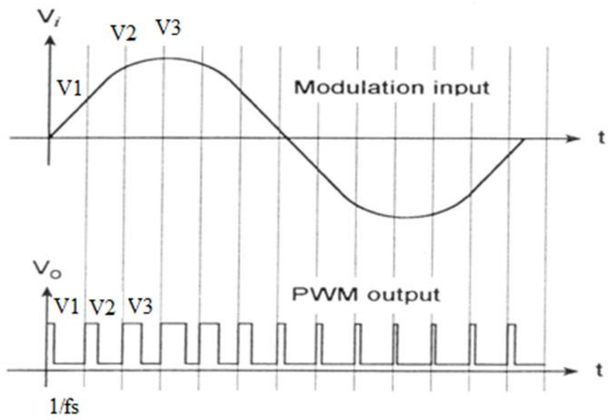


Fig.2. Direct Digital Technique of PWM generation

*C. Counter Based PWM Signal Generation*

In counter based digital PWM, the duty cycle is compared with the counter value, and the DPWM signal is generated. In Sine pulse width modulation the duty cycle is a function of instantaneous amplitude of the reference signal. A 10 bit duty cycle will be in the range of 0 to 1023. The transformation of analog to digital is performed by quantizing the reference signal to duty cycle. The ramp signal is generated using a counter. The resolutions of PWM are finite. In other words, PWM has better output regulation and less or no limit cycle oscillations. Counter based PWM has modulation delays. These delays occur when there is a change in duty cycle. The counter can be either up counter, down counter, or an up-down counter, depending on the modulation scheme. When the counter counts down, then it depicts the leading edge modulator. When the counter counts up, then it depicts the trailing edge modulator. When the counter counts up and down, then it depicts the dual edge modulator. The input clock frequency (Fclk) of the counter is directly proportional to switching frequency (Fsw) and number of bits (n). According to the relationship can be expressed as follows, Fclk = Fsw * 2n. Fig.3 shows block diagram of a leading edge pulse width modulation using counter.

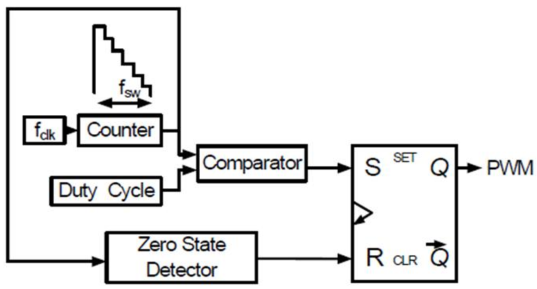


Fig.3. Counter based method of PWM generation

## IV. Pulse Width Modulated Signal Generation

This is also a carrier less generation method used for the generation of PWM, which is similar to the direct digital technique. Here the instantaneous voltage of the signal is

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changed into corresponding duty cycle and duration of each pulse is set by the centre frequency of the reference signal. Here only 16 samples for single cycle of a given sine wave taken which corresponds to the phase 2π/32 rad (11.25) to 31π/16 rad (348.75) with a difference of 2π/16 rad (22.5). Here the carrier and the reference signal itself is need not to generate. So the memory requirement is less as compared to the previous method but have a lower resolution when compared to other methods. The method of generation of PWM is shown in Fig 4.

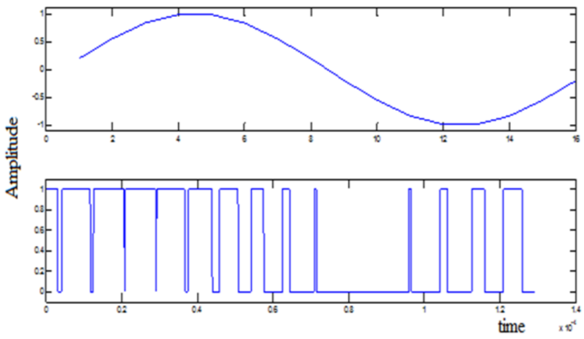


Fig.4. Modified Digital method of PWM generation

## V. RESULTS

Commonly used active transmit signals are generated using NP-PPC 8640 VPX boards. The generated signals can be converted into pulse width modulated signals either using NP-PPC 8640 VPX board or VIRTEX®-6 ML605 Evaluation Kit. The execution time for the generation of PWM signals with different methods are listed in Table 1. When FPGA is used for conversion of the generated signal into pulse width modulated signal, quantized values of the signal stored in ROM are used. Fig.5.shows the CRO output for stepped frequency modulated signal and Fig.6.shows the frequency spectrum.

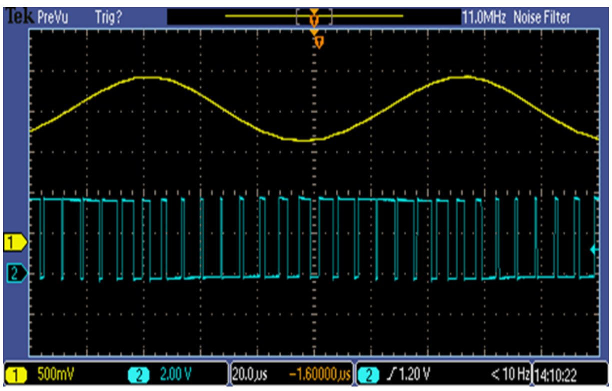


Fig.5.shows the CRO output for stepped frequency modulated signal

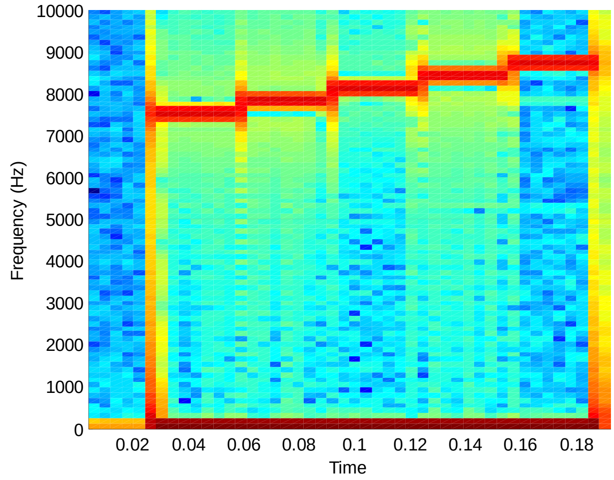


Fig.6. Spectrogram of stepped frequency modulated signal

TABLE I. EXECUTION TIME FOR PWM SIGNAL GENERATION

| **PWM generation Method** | **Signal generation Time** | **Carrier Signal Generation Time** | **PWM Generation Time(Sec)** |
|---|---|---|---|
| Triangular intersection method | Depends on type of the signal | 3.067799 | 0.370333 |
| Direct Digital Method | Depends on type of the signal | No carrier is generated | 0.024373 |
| Modified Direct Digital Method | No transmit signal is generated | No carrier is generated | 0.041917 |
| Counter Based Method | Reads from ROM | | $8x10^{-9}$ |



## VI. CONCLUSION

Sonar, an underwater equivalent of radar, exploits acoustic energy for detection, localization, tracking and classification of underwater targets. Active sonar has the knowledge of the signal to be detected. The characteristics of several types of active sonar waveforms have been investigated. These waveforms include the continuous wave pulse, linear frequency modulated signal, hyperbolically frequency modulated signal, and stepped frequency modulation. These signals are implemented by using PowerPC based boards. These generated signals can be converted into pulse width modulated signals which when given to the switching amplifier is used to active sonar transmission. Different Methods are used for the generation of PWM signals. This include triangular intersection method, direct digital method, modified direct digital method which uses NP-PPC 8640 for the generation purpose. The total time for generating PWM signals using triangular intersection method include the time for the generation of transmit signal, the generation of triangular wave and the time for comparison of each samples. The memory requirement is also high for this method since the output is stored to an array which is high in the number of samples. At the same time direct digital method does not require any carrier. When a PWM signal is generated using an FPGA the only delay is clock to pad delay which is about 8ns. In case of modified direct digital method number of samples required is less and the signal itself is need not to be generated. This reduces the execution time and memory requirement. Thus modified direct digital method provides an optimal solution to generate PWM signals to interface with switched mode power amplifiers for signal transmission in active sonar system.

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