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Radar Pulse Compression Technique for Linear Frequency Modulated Pulses

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***Abstract*— Pulse compression technique is a method of acheaving benefits of short puloses while keeping the peak power within practical limits. This is a method of combining the high resolution capability of a short pulse with the high energy of a long pulse. In this paper we have discussed the process of Radar Pulse Compression using linear frequency modulation (LFM) signals. If the signal to noise ratio (SNR), of a pulse is improved eventually its efficiency increases. In this we will analyze the effects of Time-Bandwidth Product, change in Doppler Frequency, and SNR on LFM waves.**

***Index Terms*— Radar, Linear Frequency Modulated (LFM), Peak Side lobe Level (PSL), signal to noise ratio (SNR), Autocorrelatin Function (ACF), Ambiguity function (AF).**

I. INTRODUCTION

RADAR is an acronym for Radio Detection and Ranging. It is an electromagnetic system that detects and locates the reflective objects like aircraft, ships, vehicles etc. It's operation is based on the principle of radiation of energy into space and detection of the reflected echo from the targets. The angle of reception of echo at the antenna and tracking system of the radar is used to obtain the angle and direction of the target. The target range is a function of delay in the received signal and velocity of the target is a function of signal's Doppler shift. Its most important characteristic is its ability to get target range with greater accuracy in all weather conditions. It can operate in darkness, fog, snow and rain.

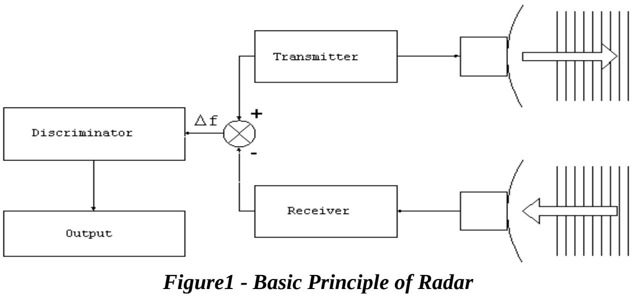

Figure1 - Basic Principle of Radar

Radars are effectively used in air traffic control, radar astronomy, meteorological precipitation monitoring, and also used by defence forces in antimissile systems, air - defence systems, etc. High tech radar systems are associated with digital signal processing and are capable of extracting useful information from very high noise levels.

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II. NEED OF PULSE COMPRESSION

Waveform design is an important area of work in the radar systems development. Two important functions that are obtained by the waveform of a radar system are detection of maximum range and range resolution. The range to a target is a measure of the time taken by a radar signal to travel to the target and back. Range resolution is the ability of the Radar to detect and distinguish between two closely spaced targets. Range resolution depends on the pulse width of the transmitted pulse. The range resolution is given by

$$R_{res} = \frac{c}{2B}$$

Where c denotes the light speed, *B* is the bandwidth of the transmitted pulse.

Therefore smaller the bandwidth/information measure of the transmitted pulse the better is the range resolution. But use of short pulse in radar system has some disadvantages. As we know that the bandwidth of a pulse is inversely proportional to its pulse width, the bandwidth of a short pulse is high. High bandwith will make the system complex. Further, short pulses needs more peak power. A short pulse needs more peak power to accommodate enough energy for its transmission. High power transmitters and receivers are difficult to design because of the constraints on the components to withstand high power. One way to get the solution of this problem is to convert the short pulse into a long one and using some form of modulation to increase the BW of the long pulse so that the range resolution is not compromised. This technique is called Pulse Compression.

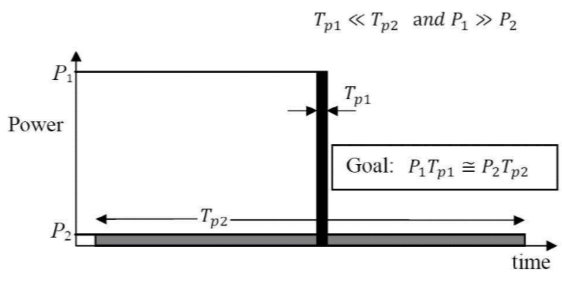

Figure2 - Pulses of different duration and having same energy

Pulse Compression technique is continuously used in Radars and Sonar to increase the range resolution, range detection as well as increase the signal-to-noise ratio (SNR). This is achieved by modulating the transmitted pulse and then correlating the received pulse with the transmitted signal [7].

Linear Frequency Modulation is used in radar systems frequently to achieve wide-operating bandwidths. In this case, the frequency of the transmitted wave either increases (up-chirp) or decreases (down-chirp) with time. The instantaneous frequency is a linear function of time, and hence is called as linear frequency modulation.

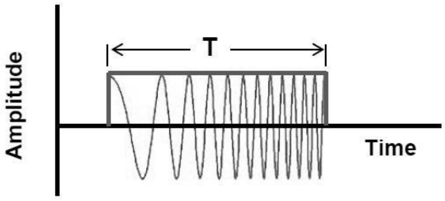

Figure3 - Increasing Frequency (Up chirp)

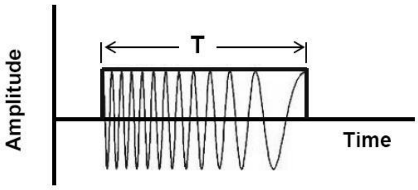

Figure4 -Decreasing Frequency (Down chirp)

III. LITERATURE REVIEW

Radar pulse compresssion is a topic of great interest over past few decades. A lot of research work has been carried out to achieve low side lobes and high range resolution in the radar pulse detection system. Several methods of pulse compression have been used in the past. The most common and popular among them is the Linear Frequency Modulation (LFM) which was invented by R.H Dickie in 1945. The other popular pulse compression techniques include Costas codes, Binary-phase codes, poly-phase codes and non-linear frequency modulation.

Vijay Ramya K. et al. [6], had proposed a technique in which amplitude weighting is applied to a combination of the incoming signal and one-bit shifted version of the incoming signal. Here matched filter is used as the cross correlation between the amplitude weighted signal and the combined signal. This technique produces better Peak Side lobe ratio (PSL) and integrated side lobe ratio (ISL) than all other conventional side lobe reduction techniques. The significant Main lobe splitting which is the main disadvantage in Woo filter is eliminated in this technique and implemented and incurs a minimal signal to noise ratio SNR loss.

The implementation by H.A. Said has distinct advantages compared to other application specific integrated circuits (ASIC). The FPGA provides flexibility, for example, full reconfiguration in milli-seconds and permits a complete single chip solution. Pulse compression radars, in addition to overcoming the peak-power limitations, have an EMC (Electromagnetic Compatibility) advantage in that they can be made more tolerant to mutual interference. This is achieved by allowing each pulse - compression radar that operates within a given band to have its own characteristic modulation and its own particular matched filter [2].

Dodda H.V.S. Rami Reddy et al. [4] has achieved experimental results which confirms that the complementary codes have best characteristic ACF and AF in comparision with all the rest of the codes, reducing the noise levels to almost zero.

Anuja D. Sarate et al. [1] discussed the merits and demerits of different Pulse Compression techniques called LFM, Biphase and Polyphase. Codes are known taking into consideration the important parameters like the mainlobe width, range resolution and PSL.

Table : Comparision of PSL for variousPulse Compression Codes

CODES	PSL(db)
P3	-31.7dB
P4	-31.7dB
Frank	-28.50dB
P1	-28.50dB
P2	-28.50dB
Barker	-22.28dB
LFM	-13.5dB

IV. RESULT AND ANALYSIS

The study is realized by developing the specialized software in Matlab. This software computes PSL and ISL of ambiguity functions of signals under study and visualizes the results. The main quality factors of signals under study are evaluated and visualized. The function of computational algorithm includes the following operations: input of the information for the type and the parameters of codes under study; calculation and normalization of the code autocorrelation function (ACF); computation of the Merit factor; calculation of PSL and ISL, graphical and numerical visualization of the final results. In case of complementary codes two codes are applied to the input; in the block for calculation of ACF a sum of two code's ACF is computed. After that the quality factors PSL and ISL of the minimized ambiguity function are calculated, and, finally, the numerical and graphical results are visualized. The main purpose of this study is to analyze an efficient pulse compression technique having a better (lower) values of *Peak Side lobe Level* and *Integrate Side lobe Level*.

- Peak Side lobe Level (PSL) – is the highest side lobe power level relative to the main lobe:

$$PSL = 10\log_{10}\frac{\text{peak side lobe power}}{\text{total main lobe power}}$$

- Integrated Side lobe Level (ISL) – is the power distributed in all side lobes and defined as:

$$ISL = 10\log_{10}\frac{\text{power integrated over side lobes}}{\text{total main lobe power}}$$

The experimental results are the given below in graphical model.

Here in the graph the compression filter is used for the compression of pulse. And here in this figure5 the intermediate stage of the pulse compression is shown.

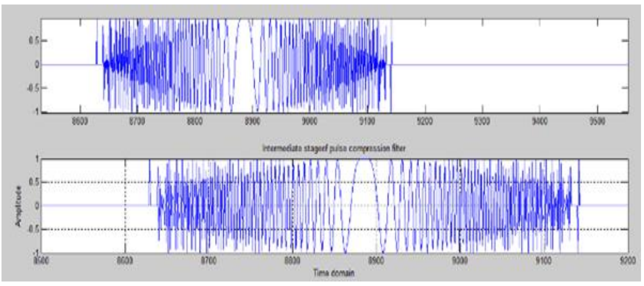

Figure5 –Intermediate stage of pulse compression

In my proposed model, the noise level is subsequenty suppressed and an efficient pulse compression is achieved.

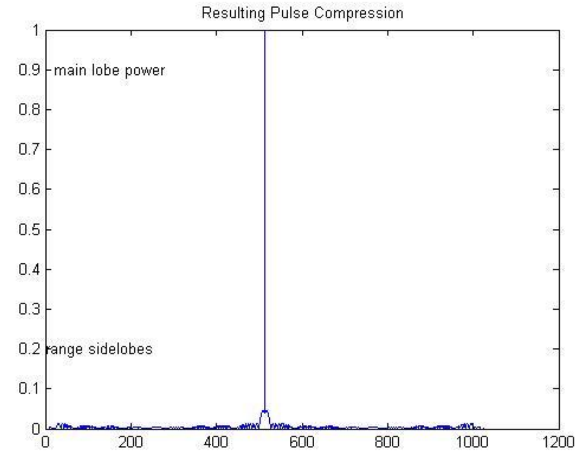

Figure6 –Compressed pulse

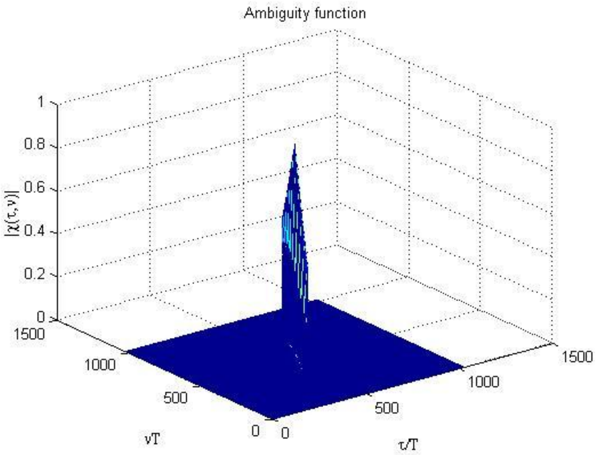

Figure7 –Ambiguity diagram of compressed pulse

V. CONCLUSION

Now-a-days pulse compression has become an inevitable part of Radar system. Based on the results obtained, we conclude that it is a very efficient technique of pulse compression. Through this technique better range resolution is achieved without using the high power transmitters and receivers. The results are obtained by the software Matlab R2014a. This confirms that at the present time and in the future the complementary codes can be successfully used in passive radar systems.

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