Implementation of a Suitable Modulation Technique for the Detection of a Fast Moving Object

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Abstract
In this paper a suitable digital modulation technique for the detection of fast moving object will be studied and one of the suitable modulation techniques is implemented. The modulated signal is produced by modulating a carrier according to the binary code. The binary code taken here is the Gold code sequence. Such modulated signal of interest is transmitted through AWGN channel. The resulting noisy modulated signal is demodulated using the suitable demodulation technique. The demodulated signal is the Gold code sequence that is given at the transmitter. Both the input and output sequences are compared and the results are plotted. This paper highlights the modulation technique that is best suited for detecting the fast moving object and that modulation scheme is implemented.

Keywords
AWGN, BER Tool, Gold Code Sequence, Matlab, Simulink

I. Introduction
Detection of fast moving object is a challenging task as far as any radar system is concerned. In the last few decades, a major transition from analog to digital communications has occurred and it can be seen in all areas of communications including Radar communications. One of the main reasons is that digital communication system is more robust than an analog one. The digital modulation techniques can be used for detection of an object using Continuous Wave (CW) radar system. This paper compares a few digital modulation techniques more particularly phase shift keying techniques, for their low complexity of design and selects a suitable modulation technique.

The performance of the modulation techniques like BPSK, DPSK, QPSK and QAM are evaluated using BER TOOL and the best technique for the particular application is implemented using Simulink.

The present work generally relates to a radar system and more particularly as a target detection technique. So our interest is on the transmitter section which mainly focuses on the digital modulation technique with a binary code and on receiver section implements the demodulation.

The tools employed are:

1. Matlab R2008a
2. Xilinx System Generator 10.1
3. Matlab Simulink

II. Theoretical Background

A. Gold Code
Gold code sequences are a special class of Maximum Length PN sequences and offer well controlled cross-correlation properties, essentially manageable interference between successive pulses when used for pulse compression radars. Gold codes offer more sequences within each family of codes. Gold code is obtained by performing XOR for two PN sequences as shown in fig. 1.

![Gold Code Generator](image)

B. BER of Modulation Techniques

1. Binary Phase Shift Keying
In coherent binary PSK system, the pair of signals $s_1(t)$ and $s_2(t)$ represents the binary symbols 1 and 0, respectively and are defined by

$$s_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos (2\pi f_c t) \quad \text{For binary ‘0’}$$

$$s_2(t) = \sqrt{\frac{2E_b}{T_b}} \cos (2\pi f_c t + \pi) = -\sqrt{\frac{2E_b}{T_b}} \cos (2\pi f_c t) \quad \text{For binary ‘1’}$$

Where $0 \leq t \leq T_b$, and $E_b$ is the transmitted signal energy per bit, whereas $f_c$ is the frequency of the carrier. The bit error rate for coherent binary PSK is

$$P_e = \frac{1}{2} e^{-\frac{E_s}{N_0}} \left( \frac{E_b}{N_0} \right)$$

As we increase the transmitted energy per bit, $E_s$, for a specified noise spectral density $N_0$, the message points corresponding to symbols 1 and 0 move further apart, and the average probability of error $P_e$ is correspondingly reduced in accordance with the above equation (1) [1].

2. Quadrature Phase Shift Keying
In QPSK, the phase of the carrier takes on one of four values, such as $\pi/4, 3\pi/4, 5\pi/4$ and $7\pi/4$. For this set of values we may define the transmitted signal as

$$s_i(t) = \begin{cases} 
\sqrt{\frac{2E}{T}} \cos (2\pi f_c t + (2i - 1) \frac{\pi}{4}), & 0 \leq t \leq T \\
0, & \text{elsewhere}
\end{cases}$$

Where $i=1, 2, 3, 4$; $E$ is the transmitted signal energy per symbol, and $T$ is the symbol duration. With this interpretation, the even (or odd) bits are used to modulate the in-phase component of...
the carrier, while the odd (or even) bits are used to modulate the Quadrature-phase component of the carrier. BPSK modulation is performed on both the carriers and they can be independently demodulated [1].

As a result, the probability of bit-error for QPSK is the same as for BPSK:

\[
P_e = \frac{1}{2} \text{erfc} \left( \frac{E_b}{\sqrt{N_0}} \right)
\]

(2)

C. Quadrature Amplitude Modulation

QAM conveys two analog/digital message signals by changing the amplitudes of two carrier waves, using the amplitude shift keying/amplitude modulation.

The M-ary QAM is generally defined by the transmitted signal:

\[
s_i(t) = \sqrt{\frac{2E_a}{T}} a_i \cos(2\pi f_c t) + \sqrt{\frac{2E_a}{T}} b_i \sin(2\pi f_c t), \quad 0 \leq t \leq T
\]

The probability of error is:

\[
P_e = \left(1 - \frac{1}{\sqrt{M}}\right) \text{erfc} \left( \frac{3E_{av}}{2(M-1)E_0} \right)
\]

(3)

D. Differential Phase Shift Keying

The DPSK is a special case of non coherent orthogonal modulation with \( T = 2T_b \) and \( E = 2E_b \), when it is considered over two bit intervals. The transmitted signal equals

\[
\sqrt{\frac{2E_a}{T_b}} \cos(2\pi f_c t) \quad \text{for} \quad 0 \leq t \leq T_b.
\]

Where \( T_b \) is the bit duration and \( E_b \) is the signal energy per bit.

The average probability of error or bit error rate for DPSK is given in equation (4) [1].

\[
P_e = \frac{1}{2} \text{erfc} \left( -\frac{E_b}{\sqrt{N_0}} \right)
\]

(4)

III. BER Analysis

As mentioned earlier in the paper, there are many factors that will decide the performance of different modulation techniques. One of the factors that we can consider is the Bit Error Rate (BER). The bit error rate or bit error ratio is the number of bit errors divided by the total number of transferred bits during a time interval.

From the above fig3 it is clear that the BPSK and QPSK have the same BER value, while the DPSK is having better BER when compared to BPSK but the 16-QAM have a BER that is far away from BPSK i.e., QAM is less immune to noise.

So, from the results BPSK, QPSK are considered of having low BER compared to other techniques. To sort out the best technique for our application let us consider the following parameters [1, 5].

<table>
<thead>
<tr>
<th>Modulation type</th>
<th>BER</th>
<th>Bw efficiency</th>
<th>Design complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPSK</td>
<td>( \frac{1}{2} \text{erfc}(Eb/No) )</td>
<td>0.5</td>
<td>Simple to design</td>
</tr>
<tr>
<td>QPSK</td>
<td>( \frac{1}{2} \text{erfc}(Eb/No) )</td>
<td>1</td>
<td>Double that of BPSK</td>
</tr>
<tr>
<td>DPSK</td>
<td>( \frac{1}{2} \text{erfc}(0.4Eb/No) )</td>
<td>2</td>
<td>Complex than BPSK</td>
</tr>
</tbody>
</table>

By considering the complexity we can select the BPSK as a simple and suitable technique for our application.

IV. Binary Phase Shift Keying Theory

In Phase Shift Keying technique, the phase of the carrier is changed according to input the data signal.

A. BPSK Transmitter

BPSK is the simplest form of Phase Shift Keying (PSK). It uses two phases which are 0° and 180°.

\[
\phi_1(t) = \frac{2}{\sqrt{T_b}} \cos(2\pi f_c t)
\]

Fig. 3: BPSK Modulator

To generate a binary PSK signal, we have to represent the binary sequence in polar form with symbols 1 and 0 represented by constant amplitude levels of + \( \sqrt{E_b} \) and - \( \sqrt{E_b} \) respectively. This bit stream is encoded using a Non Return to Zero (NRZ) level encoder. The resulting binary wave (in polar form) and a sinusoidal carrier \( \phi_1(t) \), whose frequency \( f_c = f_c/T_b \) for some fixed integer \( n_c \) are applied to a product modulator. The carrier and the timing pulses used to generate the binary wave are usually extracted from a common master clock; the desired PSK wave is obtained at the modulator output.

B. BPSK Receiver

Fig. 4: BPSK Demodulator
To detect the original binary sequence of 1s and 0s, we apply the noisy PSK signal \( x(t) \) (at the channel output) to the correlator. The correlator output \( x_1 \) is compared with a threshold of zero volts. If \( x_1 > 0 \), the receiver decides in favor of symbol 1. On the other hand, if \( x_1 < 0 \), it decides in favor of symbol 0.

V. Simulink Design

A. Gold Sequence

The code can be implemented using the Xilinx blocks as shown in fig. 5.

![Fig. 5: Gold Code Generation Using XILINX Blocks](image-url)

The main block that is used for the simulation of a design that consists of Xilinx blocks is the Xilinx System Generator. The generated bits are stored by using the registers. According to the polynomial the taps are given. The Assert block decides the rate at which the code is to be produced.

![Fig. 6: Results With Gold Code Generator Using XILINX Blocks](image-url)

B. BPSK Modulation

The BPSK modulation is performed as shown in the fig. 7. According to the input code the output is taken as positive cycle or 180° out of phase cycle as shown in fig. 8 [5-6].

![Fig. 7: BPSK Modulation Using XILINX Blocks](image-url)

C. BPSK System

The fig. 9 shows the BPSK system [5-6] with Xilinx blocks. The channel is taken from the Xilinx Blockset and the output from the channel is multiplied with the carrier that is taken in the input. The output from it is given to the digital FIR filter that is present in the Xilinx block. To perform the filter operation a tool is required, that is FDA tool. The filter parameters defined in that tool and the coefficients are exported to workspace. According to the output of the filter the binary 1 or 0 is decided by the MUX.

The modulated signal is passed through the BPSK AWGN channel (last row in fig. 10). At the receiver the AWGN output signal is multiplied with the carrier (2nd row in fig. 10) that is taken in the input (coherent detection). The carrier multiplied output is given to the Low pass filter. The output of filter is shown in 1st row in fig. 10.

![Fig. 9: BPSK System Using XILINX and SIMULINK Blocks](image-url)

![Fig. 10: BPSK Receiver Output](image-url)
Fig. 11: Input and Output Comparison for BPSK System

The input and output gold codes as shown in fig. 11. The 1st row in fig. 11 is the final output which is delayed from the original gold code shown in 2nd row in fig. 11.

VI. Conclusion

The suitable modulation technique for the estimation of the fast moving object is determined by performing the Bit Error Rate analysis using the BERTool.

The BPSK, QPSK modulations are selected for the better performance they have given by using BERTool. To sort out the suitable one for the scheme, design complexity is considered. By comparing both modulations according to design complexity, the BPSK modulation is simple to design and less complex when compared to QPSK, which is almost double the complexity of BPSK design. The design complexity is one of the main factors in the target detection system because those sets are used various fields of applications like in air, underwater applications, in those conditions the system should be compact. So, BPSK modulation is selected in this paper.

And also a special maximum length sequence is considered i.e., Gold code sequence which is generated from two PN sequences. The BPSK system is designed in Simulink using Xilinx blocks. The results are observed in scope and the output demodulated code is verified with the input code.

The output code is delayed from the input code due to the design properties of the LPF, but the actual output code is same as the input code.

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References


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