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Design and Simulation of a Composite Digital Modulator

Soumik Kundu
School of Engineering & Technology, West Bengal University of Technology

Abstract

In a communication system, modulators play an important role in transmitting signal from one place to *another. Different modulators are used for different types of communication. If we combine a set of modulators together into single modulators, the single composite modulator so obtained can be used for different communication purpose. And this may lead to minimization of cost and effort for developing modulators. With this idea in hand, an experimental research for design and simulation of a composite modulator model has been presented in this paper. The concept of union of directed graphs of four digital modulator models has been invested for combining four digital modulators.*

Keywords **-** *Binary Modulation, Composite Modulation, MATLAB Simulation, Modulator, Shift Keying Modulation.*

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I. INTRODUCTION

Transformation of a signal into a form suitable for its transmission is called *modulation*. In a *digital carrier communication*, a digital signal transmitted with the help of a *carrier signal*. These carrier signals are usually sinusoidal. The transmission of the digital signal is done by varying or switching the *amplitude, frequency* and *phase* of the carrier in accordance to the digital bit information. In this way the carrier signal carrier the required information bits for transmission. The variation of the carrier signal properties, transforms the carrier signal into a digitally modulated signal, where the modulating signal is the digital bit. This process of transformation is called *digital modulation* [1].

A *modulator* is a part of a communication system, which is used to facilitate the modulator for transmitting information in form of signals (digital or analog). It helps in transmission of signal with lower frequency by shifting the signal's lower frequency spectrum to higher frequency spectrum, using a high frequency carrier signal. In order, to develop a modulator, the following components of a communication system are required [2]

1) The *information* to be transmitted in form of signals (digital or analog).
2) A *carrier* wave (usually sinusoidal) that carries the information.
3) A *channel* through which data travels.
4) A *modulation scheme* that is used by the modulator to modulates the incoming data onto the carrier wave.

With these four components, a modulator model is designed which is *Composite*, as it consists of a combination of four binary modulators. The idea of union of directed graphs of four modulators has utilized in the design. In [3], a technique for combining phase and amplitude modulation had been proposed which result in increase bandwidth of the modulated signal. Thus we can say that the conjunction process helps to gain better performance from a communication system. Generally, there are three basic properties of a signal namely, amplitude, frequency and phase which are changed independently during the modulation process. The three modulator used for designing the composite modulator are taken from binary modulation of these properties. QPSK modulator is most widely used in modern communication system for its better performance with design and simulation [4], and for this reason it has been used as the fourth modulator of the composite modulator.This paper focuses on the design process involved in the simulation of the composite modulator model. At first the design of four individual modulators are presented. Afterward, the design of the composite modulator is shown where the concept of directed graphs of modulator model is used. Finally, the simulation result and design analysis are shown.

II. DESIGN OF COMPOSITE MODULATOR

Designing a particular modulator is based on designing of its model, which takes inputs from two sources *Binary Data Stream Generator* (*information*) and *Carrier Sinusoidal Signal Generator* (*carrier*). Here, MATLAB SIMULINK is used for designing the models of four modulators namely Binary Amplitude Shift Keying (BASK), Binary Frequency Shift Keying (BFSK), Binary Phase Shift Keying (BPSK) and Quadrature Phase Shift Keying (QPSK). So, simulink models of four modulators along with the parameters of the components used in each modulator is presented in the next subsections followed by the design of simulink model of composite modulator.

2.1 Design of Simulink model for Binary Amplitude Shift Keying (BASK)

In BASK, the amplitude of the carrier is changed in response to information and all else is kept fixed. Bit 1 is transmitted by a carrier of constant amplitude. To transmit 0, we change the amplitude keeping the frequency constant [1]. So, to design its simulink model, a binary bit stream is taken as input to BASK modulator which is multiplied by an unit delayed sinusoidal carrier. This product gives required BASK signal.

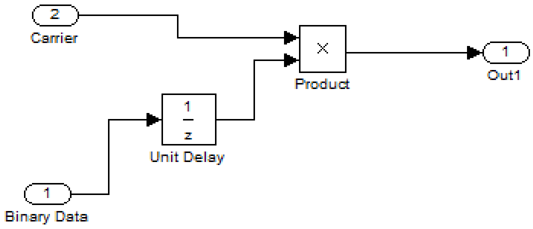

Fig 1. BASK Simulink Model

2.2 Design of Simulink model for Binary Frequency Shift Keying (BFSK)

In FSK, we change the frequency in response to information, one particular frequency for a 1 and another frequency for a 0 [1]. So for its simulink model, two sinusoidal carriers with two different frequencies are used as input to the modulator along with an input binary bit stream. These three inputs are sent to a switch, which superpose two carrier signals alternatively in accordance with the binary bit stream.

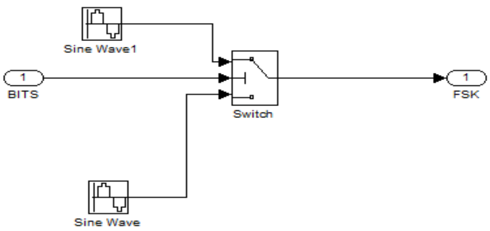

Fig 2. BFSK Simulink Model

2.3 Design of Simulink model for Binary Phase Shift Keying (BPSK)

In PSK, we change the phase of the sinusoidal carrier to indicate information. Phase in this context is the starting angle at which the sinusoid starts [1]. To transmit 0, we shift the phase of the sinusoid by 180 degrees. Phase shift represents the change in the state of the information in this case [4]. So for its simulink model, two sinusoidal carriers which are different in terms of phase shift of 180 degrees are sent to a switch along with input binary bit stream, and thereby, BPSK signal is generated.

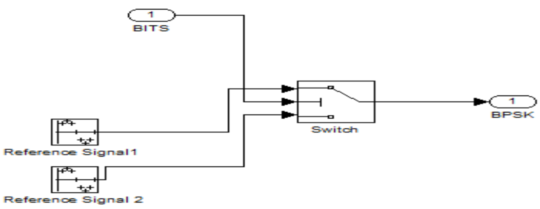

Fig 3. BPSK Simulink Model

2.4 Design of Simulink model for Quadrature Phase Shift Keying (QPSK)

This modulation scheme is characterized by the fact that the information carried by the transmitted waves is contained in the phase [4]. In quadrature phase modulation (QPSK), the phase of the carrier takes on one of the equally spaced values, such as $\pi/4$, $3\pi/4$, $5\pi/4$ and $7\pi/4$ [1]. The simulink model of the QPSK modulator is presented in the Fig. 4. The serial information bit stream is converted into parallel bit stream and from which *even* and *odd* bits are generated. Now, even bit is moved in parallel with the odd bits to *NRZ encoders* from *bipolar even* and odd bits are generated, Then, the even bits are multiplied with cosine basis function and even with the sine basis. And finally these two values are added to get the QPSK signal value.

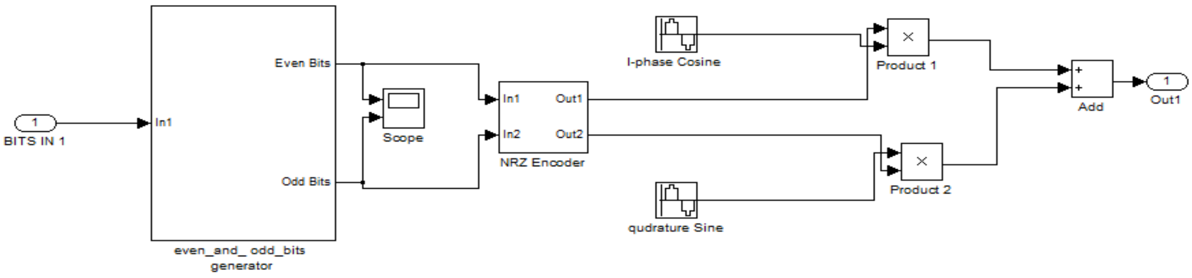

Fig 4. QPSK Simulink Model

2.4 Design of Directed Graph of Composite Modulator

With the four simulink models in hand, four directed graphs of the four modulators are designed with following nomenclatures:

S1- Input binary bits
S2- Reference Sine wave signal 1
S3- Reference Sine wave signal 2
SW- Switch
UD- Unit Delay
P- Product
P1- Product 1
P2- Product 2
AD- Adder
SUB1- Even and odd bit generator
SUB2- NRZ Encoder
O1- Output Signal for BASK Modulator
O2- Output Signal for BFSK Modulator
O3- Output Signal for BPSK Modulator
O4- Output Signal for QPSK Modulator

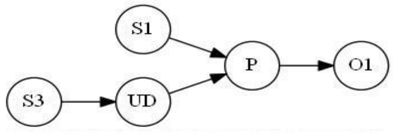

Fig 5. Directed Graph of BASK Modulator

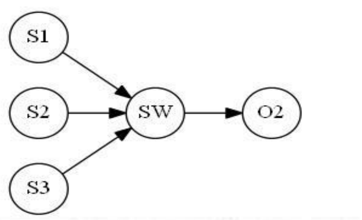

Fig 6. Directed Graph of BFSK Modulator

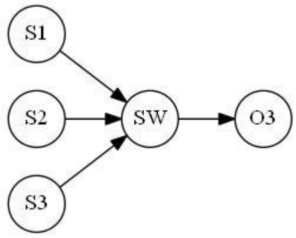

Fig 7. Directed Graph of BPSK Modulator

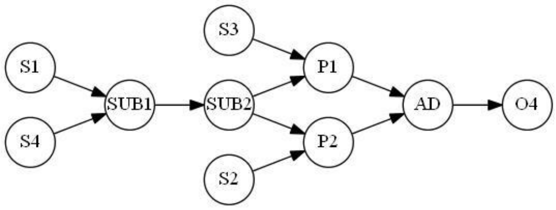

Fig 8. Directed Graph of QPSK Modulator

Using each of the four directed graphs, the directed graph of the composite modulator is designed by the union operation of these four directed graphs. As a result, some of the common components like the input to the modulator is reduced.

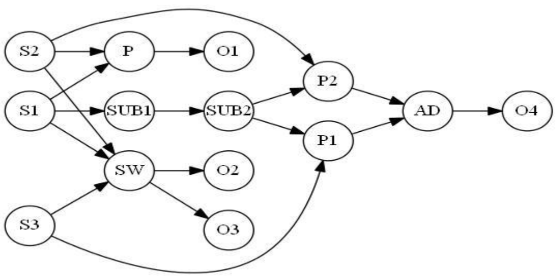

Fig 9. Directed Graph of Composite Modulator

Finally, following this directed graph the simulink model of the composite modulator is designed.

The simulink model of the composite modulator and its subsystem are shown in fig. 12 and fig. 13 respectively. The *distinct* components of each of the four modulators are *merged* while similar components are taken *once*. The output this modulator model is controlled by a *multi-port switch* with four input ports connected to four modulated signals along with a constant input. According the value of this constant the multi-port switch outputs one of the four modulated signals at a time. The constant value ranges from 1 to 4.

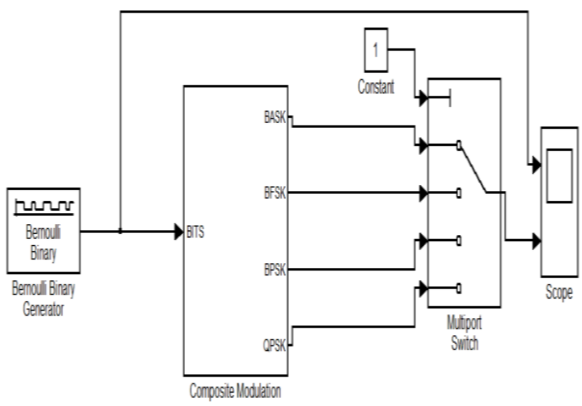

Fig 10. Simulink Model of Composite Modulator

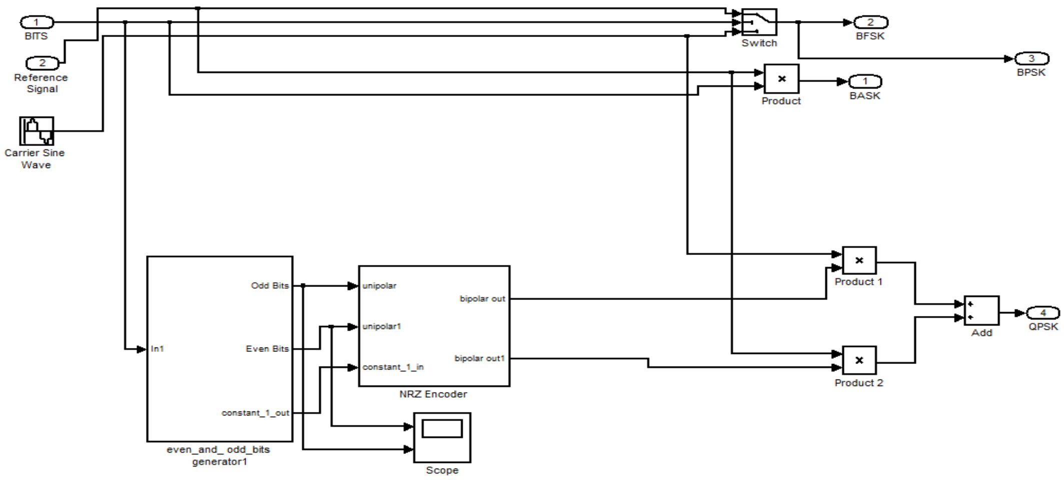

Fig 11. Simulink Model of Composite Modulator Subsystem

III. Simulation Results

As mentioned in the previous section, by changing the constant input for generating the control signal of the multi-port switch, four modulated signals are obtained explicitly. So, on simulation these four modulated signals are plotted on the output scope viewer component of the composite modulator model. The viewer shows a amplitude versus time graph of each modulated signals. In the following set of figures reveals snapshots of output scope viewer of the input binary digital signal along with the modulated signal.

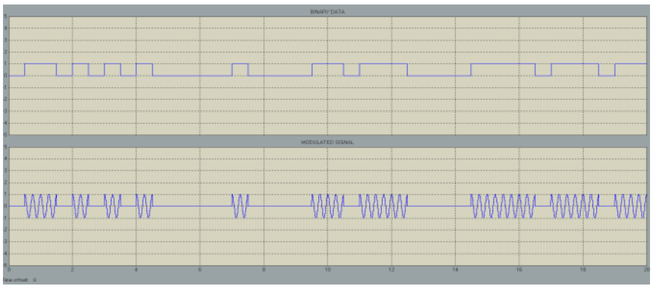

Fig 12. Output Scope when Control Signal of Multiport Switch = 1 (BASK)

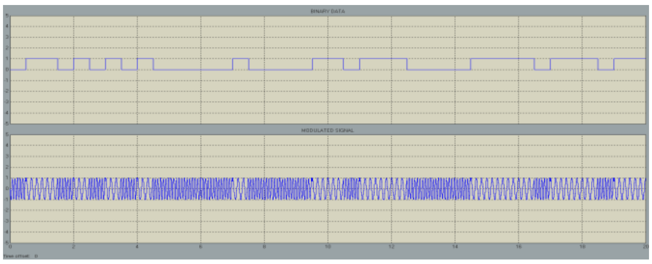

Fig 13. Output Scope when Control Signal of Multiport Switch = 2 (BFSK)

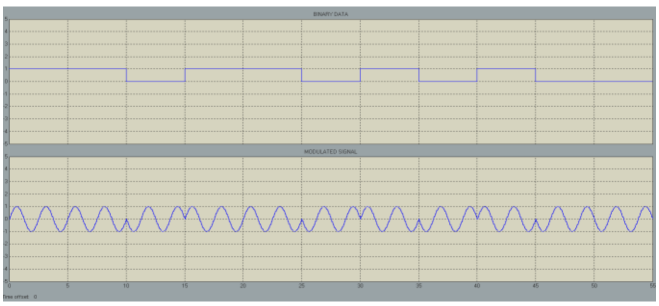

Fig 14. Output Scope when Control Signal of Multiport Switch = 3 (BPSK)

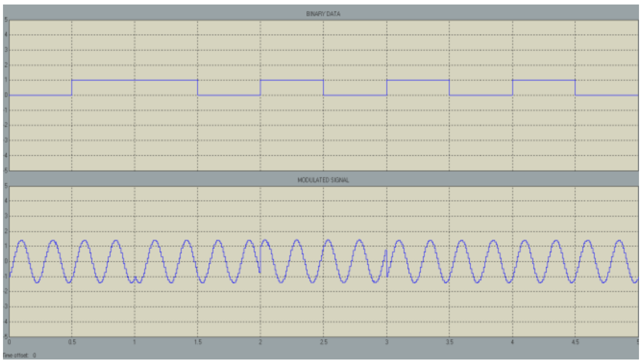

Fig 15. Output Scope when Control Signal of Multiport Switch = 4 (QPSK)

IV. DESIGN ANALYSIS

The design analysis of model for individual modulation scheme and the composite modulation scheme has been presented in this section. So, first we find out *number of common components* used in all modulation schemes followed by *bar chart analysis* in fig. 16. With this information in hand, we finally calculate the *reduction percentage in terms of number of components used* in each model.

Here, in the analysis, we have used the notation *Component name(n)* which means n^{th} multiplicity of the particular component.

Number of components used in BASK Modulation ($\mathbf{C}_{\mathbf{BASK}}$) =*Data Generator(1)+ Product(1) + Sine Wave generator(2) = 4*

Number of components used in BFSK Modulation ($\mathbf{C}_{\mathbf{BFSK}}$) =*Data Generator(1)+ Switch(1) + Sine Wave generator(2)= 4*

Number of components used in BPSK Modulation ($\mathbf{C}_{\mathbf{BPSK}}$) =*Data Generator(1)+ Switch(1) + Sine Wave generator(2)= 4*

Number of components used in QPSK Modulation ($\mathbf{C}_{\mathbf{QPSK}}$) = *Data Generator(1)+ Product(5) + Sine Wave generator(2) + Constant(5) + D Flip flop(3) + Adder(3) + Logical Operator(3) = 21*

Total number of components used in all modulations($\mathbf{C}_{\mathbf{ALL}}$) = $C_{BASK} + C_{BFSK} + C_{BPSK} + C_{QPSK} = 4+4+4+6+21 = 39$

Number of components used in Composite Modulation
($\mathbf{C}_{\mathbf{COMP}}$) = *Data Generator(1)+ Product(3) + Sine Wave generator(2) + Constant(2) + D Flip flop(3) + Adder(3) + Logical Operator(4) + Switch(1) = 19*

Percentage of reduction in terms of number of components used =
$100 \times (1 - (C_{COMP}/C_{ALL})) = 100 \times (1 - (19/39)) = \mathbf{51.28\ \%}$

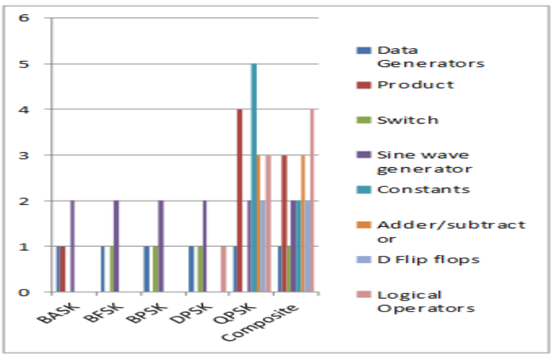

Fig 161. Bar Chart Analysis of the Composite Modulator in terms of number component used

V. Conclusion

From the results and analysis of the experimental works presented in this paper, we can conclude that a composite modulator model is designed for simulation, by combining the components of the four digital modulator models using the concept of directed graphs. While combining these components, some of them have been found to be common in all four modulator models. So, those common components are removed from the composite modulator model. This resulted in a reduction of 51.28% in the design of the composite modulator model. By performing this experiment, we emphasize the fact that a single modulator a can be developed that will generate multiple modulated signals. Eventually, this development will reduce the cost, time and effort in developing modulators.

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