

# DSP based implementation of a Configurable Composite Digital Transmitter

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**Abstract**— The latest trend in communications for real time implementation of different transmitters, is a prime contributor to the effort being invested in designing and implementing a Composite Transmitter. In this paper, an experimental analysis for the DSP based implementation the composite transmitter, which consists of a combination of four digital modulation schemes, has been presented. Extension of the digital domain by implementing and modifying different modulation schemes in software using the same hardware platform of configurable Digital Signal Processor, has been shown.

**Index Terms**— Binary Modulation, Composite Transmitter, Digital Signal Processing, Modulator, Sampling, Shift Keying Modulation, Signal Processor, Signal-to-Noise Ratio.



## 1 INTRODUCTION

TRANSMITTERS are part of communication systems. Development of a transmitter mainly focuses on developing modulators which are part of the transmitter subsystem. A modulator is the transmitter subsystem, which is used to facilitate the transmitter for transmitting information in form of signals (digital or analog) [1], [2]. 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 components of a communication system which are required are the information to be transmitted in form of signals (digital or analog), a carrier wave (usually sinusoidal) that carries the information, a channel through which data travels and a modulation scheme that is used by the modulator to modulates the incoming data onto the carrier wave with a fixed frequency limit imposed by the channel.

With these four components, a transmitter is developed which is *Composite* and *Configurable*. This transmitter consists of a composite modulator, which is built with a combination of four digital modulation schemes (BASK, BFSK, BPSK, QPSK). This composition is achieved by union of four modula-

tion schemes [3], [4]. For this reason, this transmitter is named as Composite. A configurable system is a system whose output can be changed without changing its hardware architecture using software tools. Digital Signal Processors (DSPs) provide this configurable environment by using a software tool named as Integrated Development Environment (IDE). An IDE provides the basic platform of coding and debugging. In this experiment for implementing the composite transmitter in DSP, the IDE used is Code Composer Studio (CCS). CCS acts as a C compiler that compiles and executes program codes written in C programming languages [5]. It also provides emulation with the Digital Signal Processor. So, composite transmitter C source code is executed in CCS and thereby, output transmitted signals are captured in an oscilloscope.

## 2 IMPLEMENTATION OF THE COMPOSITE TRANSMITTER

In this section the details of the implementation the composite transmitter system in DSP processor is presented. As mentioned in the design section, the composite transmitter consists of four digital modulators with the modulation schemes of amplitude shift keying, frequency shift keying, phase shift keying and quadrature phase shift keying respectively. These four modulation schemes are used as algorithms for source codes written in C which are run on the DSK. The arrangements of the devices in implementation like connection between the DSK board and PC, connection between DSK and input function generator and output oscilloscope are mentioned in the following subsection.

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tion schemes [3], [4]. For this reason, this transmitter is named

We know a transmitter system consists of a input signal to be transmitted, a modulator that will modulate the input signal, a channel through which the modulated signal is transmitted, and a carrier that carries the signal. In this experiment, the analog input signal is taken from a function generator, which is a *square wave* signal with the amplitude 1V (approx.), the modulator is the C source code run on the DSK and the channel used is a wired channel of stereo cables. The modulation program is written in C. This program consists of four modules for four digital modulation schemes. It is run on DSK board using the software Code Composer Studio (CCS), as mentioned in the previous chapter. The composite transmitter source code is *polling based* program. A polling based program is a non interrupt driven program which continuously polls or tests whether or not data are ready to be received or transmitted, while the function *comm\_poll()* calls the appropriate functions to initialize the DSK [5]. The functions *input\_sample()* and *output\_sample()* are used to input and output data respectively. We know, an input signal to the DSK is analog. TLV320AIC23 (AIC23) Onboard Stereo CODEC converts this analog signal into digital signal using the process of sampling and quantization [5]. The *input\_sample()* function returns samples of the input signal. This samples are compared with a threshold value 0, in order to generate the binary bit stream of 0s and 1s. Though the transmitter is composite, we cannot transmit all four modulated signal all together. But here a special mechanism is used to transmit a particular modulated signal at a time. This special mechanism is the use of the *DSK DIP switches* and *LEDs* [5]. As mentioned in the earlier chapter, there four DIP switches, these four DIP switches are used for transmission of four modulated signal, i.e., switch 0 for BASK signal, switch 1 for BFSK signal, switch 2 for BPSK signal and switch 3 for QPSK signal, as shown.

From the basic concepts of modulation, we know that a carrier signal is required to transmit the input signal. In this transmitter system, a sinusoidal carrier of frequency 8000 Hz and 1.6V (approx.) amplitude has been used for this purpose. In the program, sine tables are used for this carrier. These sine tables are generated as header file from a MATLAB M file [5]. The connectivity between the DSK and PC and between the DSK and function generator and oscilloscope is made for emulation and capturing output signals in oscilloscope. The DSK board TMS320C6713 consists of two input channels LINE IN and MIC IN and two output channels LINE OUT and MIC OUT. The input channel LINE IN is connected to a function generator and output channel LINE OUT is connected to an

oscilloscope. Some snapshots of the transmitted signals have been presented in the following Fig. 1.

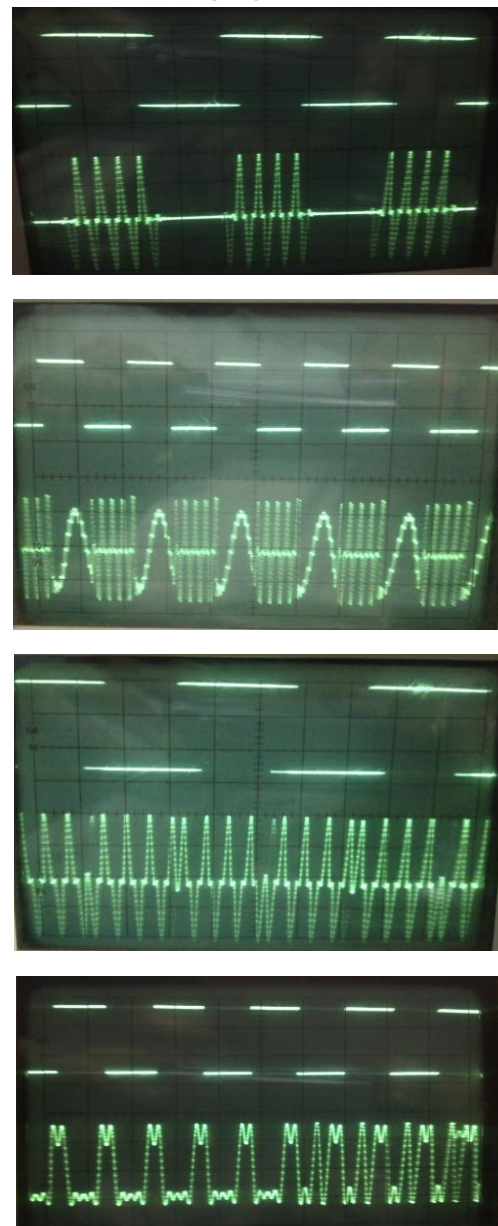


Fig 1. Snapshots of the four transmitted signals taken from oscilloscope

### 3 Development of a Composite Modulation Algorithm

The composite modulation algorithm is developed with the combination of four digital modulation schemes of BASK, BFSK, BPSK and QPSK respectively. The following flowcharts describes the composite modulation scheme along with individual modulation schemes of BASK and QPSK. The flowchart

of the Fig. 2 shows how the composite modulation program works. The program takes two inputs, one is sample values of the input square wave signal taken in variables *buffer* and *buffer1*, and another is the *switch number* of the *pressed DIP switch*. According to the switch number, one of the four modulation program module is *selected*. The selected program module generates the sample values of the modulated signal, which is taken as output.

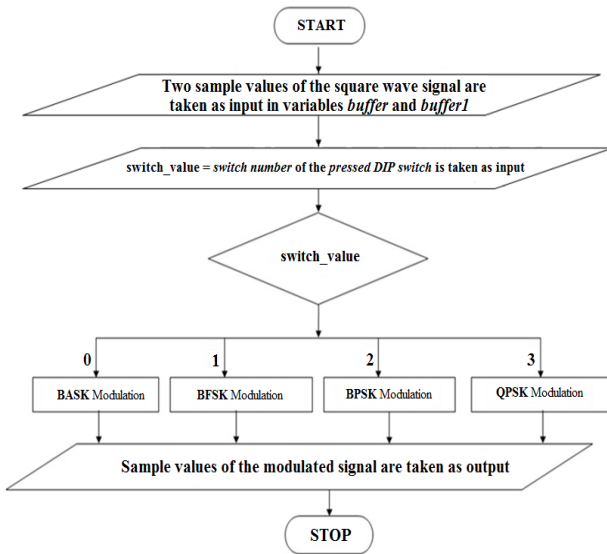


Fig 2. Flowchart of the Composite Modulation Scheme

The following Fig. 3 is the flowchart of BASK modulation program module used in the composite modulation program. A carrier table containing 32 *sample points* of the cosine carrier signal is generated by using the equation (given in the flowchart) at *phase = 0*. As mentioned earlier, the binary bits are generated from the sample values of the input square wave signal. These binary bits are *multiplied* with the sample points of the carrier table to generate the sample value of the BASK modulated signal.

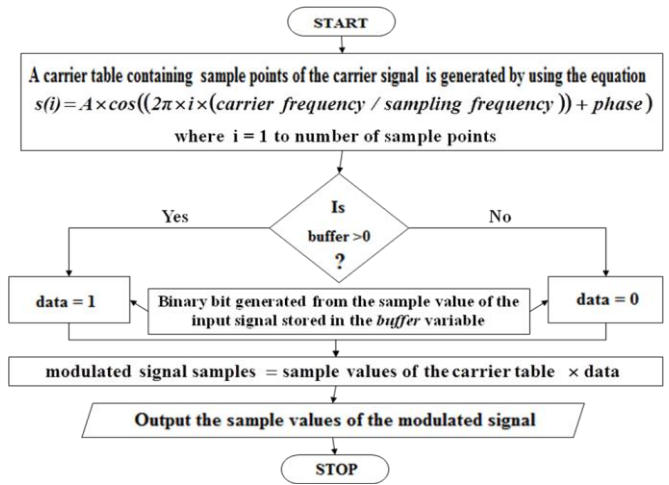


Fig 3. Flowchart of the BASK Modulation Scheme

The flowchart of the QPSK modulation program module of the composite modulation program is present in the following Fig. 4. In the composite modulation program flowchart, it has been shown that two sample values of the input square wave signal are taken as input to variables *buffer* and *buffer1* respectively. The values of these two variables are used to generate an *even* and *odd bit* respectively, using the same logic for generating the binary bit mentioned in flowchart of BASK modulation program module (Fig. 3). These two bits are converted into *bipolar bits* of *-1* or *1* and stored in the variables *bipolar even bit* and *bipolar odd bit* respectively. Then, the *even bipolar bit* is multiplied with the sample points of the *cosine carrier table* and *odd bipolar bit* is multiplied with the sample points of the *sine carrier table*. The two products obtained from the previous calculation, are *added* to get the sample value of the QPSK modulated signal.

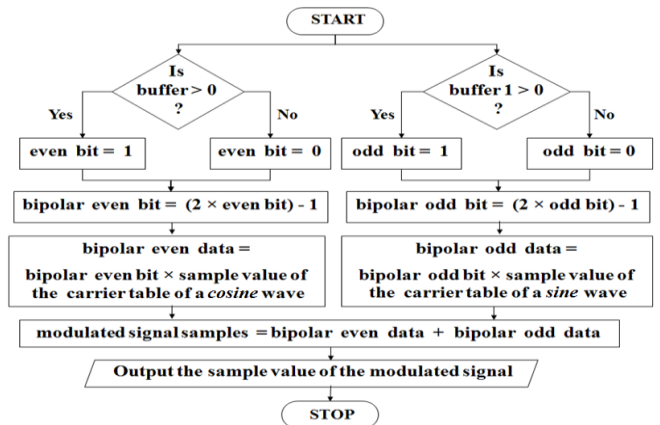


Fig 4. Flowchart of the QPSK Modulation Scheme

## 4 Performance Analysis with Signal to Noise Ratio

Signal-to-noise ratio (often abbreviated SNR or S/N) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power. Noise levels in a digital system are expressed using SNR, which is the ratio of  $E_b/P_n$ , the energy per bit per average noise power spectral density. MATLAB has been used as a tool for determining the SNR and plotting of  $E_b/P_n$  graph.

### 4.1 Signal Power and Energy

Suppose we have a signal  $x(n)$ , where  $n$  is an index of the sample number. We define the instantaneous power of the signal as,

$$P_{ins} \equiv x^2(n) \tag{1}$$

In other words, the instantaneous power of a sample is just the value of that sample squared. Since the units of the sample are volts, the units of the power are watts. A far more useful quantity is the average power, which is simply the average of the instantaneous power of every sample in the signal. For signal  $x(n)$ , of  $N$  samples, we have:

$$P_{ave} \equiv \frac{1}{N} \sum_{n=1}^N x^2(n) \tag{2}$$

By definition, power is the time derivative of energy; or equivalently, energy is the time integral of power. For sampled signals, integration reduces to a summation. Since energy is the product of power and time, the total energy of a signal must be equal to its average power multiplied by its duration. Furthermore, the duration of a signal is its length in samples, divided by the sampling frequency, in samples per second. Therefore:

$$E_b = P_{ave} \cdot t \tag{3}$$

$$= \frac{1}{N} \sum_{n=1}^N x^2(n) \cdot \frac{N}{f_s} \tag{4}$$

$$= \frac{1}{f_s} \sum_{n=1}^N x^2(n) \tag{5}$$

In the DSP implementation of the composite transmitter the sampling rate used is 32 KHz. Twelve files are generated from the execution of the composite transmitter code. These files

contain the modulated signal sample values at three different input signal frequency and carrier frequency of 8 KHz. From these samples 50 samples are taken for the calculation of  $E_b$ .

### 4.2 Noise

In this calculation of signal to noise ratio, the transmitted signal is assumed to be perturbed by an *additive, zero-mean, stationary, white, Gaussian* noise, denoted by  $W(t)$ . The reasons for this assumption are that it makes calculation traceable, and also it is reasonable description of the type of front end receiver noise present in many communication systems. Another assumption is made in this context that is the transmission channel is linear, with a bandwidth that is large enough to accommodate the transmission of the modulated signal. The average noise power  $P_n$  is generally expressed as noise power spectral density of  $N_0/2$ , where the constant  $N_0 = k t \times f_s$  (Boltzmann constant  $\times$  room temperature in Kelvin  $\times$  Sampling Frequency), whose value is  $6.4 \times 10^{-17}$  W/s, taking  $k = 1.38 \times 10^{-23}$  J/°K,  $t = 290^\circ$  K and  $f_s = 32000$  Hz.

### 4.3 Results for performance analysis with signal to noise ratio

By considering the assumptions specified in the previous subsection, the values of SNR for each of the four modulated signals transmitted by the composite transmitter are as follows:

| Type of transmitted signal | Signal Energy ( $P_b$ ) (in dB) | Average Noise Power ( $P_n$ ) (in dB) | Signal to Noise Ratio ( $P_b/P_n$ ) (in dB) |
|----------------------------|---------------------------------|---------------------------------------|---|
| BASK                       | 67.09                           | -161.94                               | 229.03                                      |
| BFSK                       | 67.02                           | -161.94                               | 228.84                                      |
| BPSK                       | 66.89                           | -161.94                               | 228.82                                      |
| QPSK                       | 67.06                           | -161.94                               | 228.94                                      |

Table 1. Table for result of performance analysis with SNR

SNR values obtained are significantly greater than zero, which reveals the fact that the effect of white noise on the modulated signal during transmission is *almost negligible*. The average SNR value for four modulation schemes is 228 dB, which is the maximum acceptable SNR value for a modulated signal transmission in the presence of white noise. Moreover, the SNR value less than zero reveals the fact the noise power is



greater than the signal power, which is not accepted for signal transmission. So, in this case the acceptable range of signal to noise ratio is from 0 to 228 dB. From these results, a graph between  $E_b$  and  $P_n$  is plotted, as shown in the following diagram.

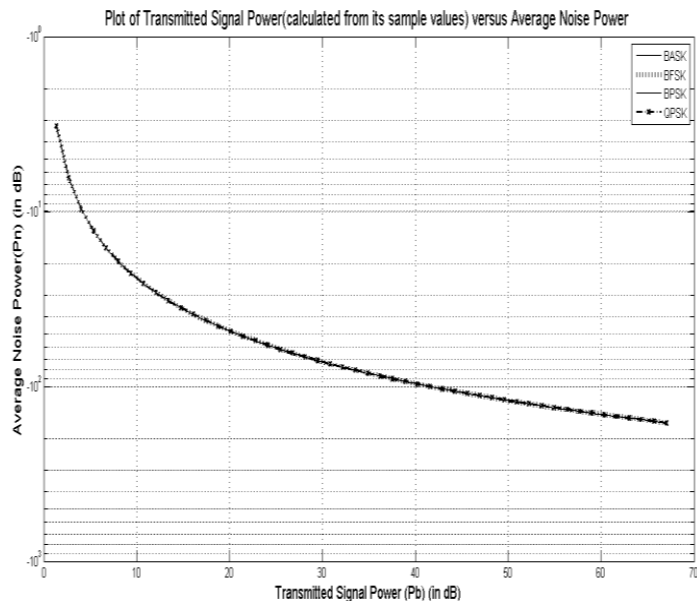


Fig 5. Graph of Transmitted Signal Energy versus Average Noise Power

## 4 CONCLUSION

The idea of composition is utilized in the DSP based implementation of a composite transmitter. For this implementation, a single program containing four digital modulation schemes is executed in the DSK board; from which four modulated signals are generated. It is a very simple implementation compared to conventional methodology in which the transmitters are developed with analog circuitry. It is also a very cost effective as we have implemented four modulation schemes together into a single modulator on the same hardware platform using the switching facility of the DSK board and a software support tool.

## REFERENCES

- [1] J. D. Oetting, A Comparison of Modulation Techniques for Digital Radio, *IEEE Transactions on Communication*, Vol. COM-27, No. 2, pp. 1752-1762, December 1979.
- [2] T. D. Memon, W. Ghangro, Dr. B. S. Chowdhry, A. A. Shaikh, Quadrature Phase Shift Keying Modulator & Demodulator for Wireless Modem, *2nd IEEE Conf. on Computer, Control and Communication*, Kanchi, pp. 1-6, 2009.

- [3] J.C. Pliatsikas, C. S. Koukourlis and J. N. Sahalos, On the Combining of the Amplitude and Phase Modulation in the Same Signal, *IEEE Transactions on Broadcasting*, Vol. 51, No. 2, pp. 230-236, June 2005.
- [4] A. Karamakar, A. Sinha, A novel architecture of a reconfigurable radio processor for implementing different modulation schemes, *3rd IEEE Conf. on Computer Research and Development (ICCRD)*, Shanghai, vol. 1, pp. 115-119, 2011.
- [5] Rulph Chassaing, *Digital Signal processing and Applications with the C6713 AND C6416 DSK*, Hoboken, NJ: John Wiley and Sons, 2005.