DSP IMPLEMENTATION OF (10, 1) BINARY OFFSET CARRIER MODULATION FOR IRNSS APPLICATION

K. L. Sudha
Professor, Dept. of ECE, Dayananda Sagar College of Engineering,
Bangalore-India

Asharani, Komala K S, Abhishek D K, Likith R
Students, Dept. of ECE, Dayananda Sagar College of Engineering,
Bangalore, India

ABSTRACT

Binary Offset Carrier-modulated signals are widely used in current and next-generation global navigation satellite systems (GNSSs). IRNSS (NavIC), Indian regional navigational satellite systems uses composite signal in which one BPSK signal with two sine BOC (5, 2) modulated signals are combined. The main idea behind using BOC modulation is to reduce the interference with BPSK modulated signal, which has a sinc shaped spectrum and have most of their spectral energy concentrated around the carrier frequency. BOC-modulated signals have low energy around the carrier frequency and spectral lobes further away from the carrier. It also helps in resisting multipath effects and other types of noise in the channel. This paper presents generation of (10, 1) BOC signal which provides wide spectral separation for IRNSS application, and analyses its spectral characteristics. The simulated system is implemented on TMS DM6437 which is a high end video processing DSP kit.

Key words: GNSS, IRNSS, BPSK, SINC Function, BOC


http://www.iaeme.com/IJECET/issues.asp?JType=IJECET&VType=8&IType=4
1. INTRODUCTION

Binary Offset Carrier modulation (BOC modulation) was developed by John Betz in order to allow interoperability of satellite navigation systems. It is currently used in the US GPS system, Indian IRNSS system and in Galileo. IRNSS—also called NavIC—is Indian Regional Navigational Satellite System which is a 7 satellite constellation built by India. [1, 2] IRNSS system uses Binary Phase Shift Keying modulation (BPSK) for transmission for SPS (Special positioning Service). Here the power is high at the center frequency. To overcome concentration of power at one frequency, Binary Offset Carrier (BOC) modulation is used for RS (Restricted Service) where the power is distributed among higher frequencies. Splitting frequency band nature of the BOC modulated signals can realize the spectrum separation with the BPSK signals in the similar band. IRNSS system uses sine phased coded BOC modulation technique. BOC has advantages over BPSK such as more energy efficiency, less loss, less interference and better performance [3]. This paper describes the generation and detection of (10, 1) BOC modulated signal for NavIC application. Spectral characteristics are analysed and compared with present IRNSS system, and is showed that it provide more spectral space for adapting other signals. Hardware implementation aspects using DSP is discussed for real time scenario.

2. LITERATURE SURVEY

IRNSS is an independent provincial satellite navigation system developed by ISRO (Indian Space Research Organization). The space segment consists of seven satellites. 3 satellites in GEO (Geostationary Orbit) at 32.5°, 83° and 131.5° East, 4 satellites in geosynchronous orbit placed at inclination of 29° with longitude crossing at 55° and 111.75° East. The spectrum of signals is a combination of BPSK and BOC (5, 2) modulation in the L-band. [1, 2]. Ref [3, 4, 5] deals with different types of BOC signals, their spectrum and their advantages over with conventional PSK modulations through simulations. A new family of faded harmonics modulations, cosine faded harmonics binary offset carrier modulations, is designed to account for the spectral overlap among global navigation satellite system (GNSS) signals by the authors and reported in ref [6]. Multiplexed binary offset carrier (MBOC) spreading modulation is recommended by the GPS-Galileo Working Group in Ref [7]. Liu et all. in reference[8] describes about general BOC (GBOC). GBOC modulations can offer additional degrees of freedom for shaping the signal’s spectrum and provide superior performance in code tracking, multipath and compatibility compared to other BPSK and BOC modulations. GBOC modulations provide potential opportunities for GNSS modernization and construction. Ref [9, 10] gives details about L1C code generation

3. PROPOSED SYSTEM

Binary offset carrier (BOC) is a group of spread spectrum modulation introduced for the subsequent invention of Global Navigation Satellite System. The design of BOC signal is dependent on the spectral properties of these signals. BOC signal avoids multipath, interferences, and provides enhanced spectral sharing of owed bandwidth with existing signals or upcoming signals of same class. Main design parameters of BOC modulation are sub-carrier frequency $f_s$ (in MHz) and spreading code rate $f_c$ (in Mcps). These parameters provide autonomy to planned signal power within the particular parts of the owed band to decrease interference with the reception of other signals. This leads to splitting of the standard BPSK spectrum in two symmetrical components with no power at carrier frequency. Hence we get two main lobes shifted from the carrier frequency by an amount equal to the sub-carrier frequency.
Modulation scheme adapted in IRNSS, each carrier is modulated with 3 signals namely
1. The SPS (Standard Positioning Service) data channel using BPSK (1) with chipping rate of 1.023MHz,
2. RS (Restricted/Authorized Service) Data channel with BOC (5, 2) using 2.046MHz ranging code and 5.115 MHz subcarrier
3. Pilot channel which likewise uses BOC (5, 2).[1,2]

IRNSS satellite have an atomic clock on-board with a nominal reference frequency $f_0$ i.e. 1.023 MHz, from which all the components of generated navigation signals are derived. In case of BOC signal, the carrier frequency $f_0$, the sub-carrier $f_s$ and the PRN code rate $f_c$ are chosen as multiple of $f_0$.

\[ f_s = m f_0 \]
\[ f_c = n f_0 \]

Hence BOC signal is indicated as BOC ($m,n$) modulation and for the sake of simplicity $m$ and $n$ are always considered as natural integers.

As the BOC modulation is a square subcarrier modulation where a signal $d(t)$ is multiplied by a rectangular subcarrier of frequency $f_s$, which splits the spectrum of the signal into two parts. The BOC- modulated signal $S_{BOC}(t)$ can be represented as

\[ S_{BOC}(t) = d(t) \cdot \text{sign}(\sin(2\pi f_s t)) \]

In BOC modulation, the number BOC samples per chip is represented by $N_{BOC}$ factor and is defined as

\[ N_{BOC} = \frac{2 f_s}{f_c} \]

In this paper, the second signal of IRNSS is modified by considering a ranging code of 1.023 MHz with 10.23MHz subcarrier to generate BOC (10,1). i.e The DSSS signal is additionally multiplied with a bipolar binary square signal as subcarrier. Considering BOC (10,1) gives a wide separation with BPSK signal and interference between the SPS and RS data can be reduced.

The generation of PRN codes for SPS/RS in IRNSS is based on Gold codes. But for RS data channel code generation in this work is based on Maximum length sequence as well as L1C code which is a prime number based sequence and is used in GPS. The length of 10230 was chosen because the chipping rate of 1.023MHz in the L1C or the L5 frequency band is an integer multiple of 10230.
Generation of signals follows the steps given below:

- PN sequence of 1023 bit is generated and is used for spreading the navigational data and is called C/A code.
- L1C signal is generated using Legendre sequence and Weil sequence. A Legendre sequence of 10223 bit is generated and is shifted and x-ored with itself to get Weil sequence. Adding 7 bit Legendre sequence in proper position, 10230 bit L1C code is obtained.
- The obtained L1C code is x-ored with C/A code. The resulting signal is multiplied with the carrier signal and we get BOC modulated signal.

Block diagram in figure (2) explains the process detailed above.

**Figure 2** Block diagram of BOC Modulation

**Generation of C/A code and L1C code:**

C/A code is generated using 10 bit ML sequence generator shown in the fig(3). The length of the sequence is $2^{10}-1=1023$.

![10 bit maximum length sequence generator](image)

**Figure 3.** 10 bit maximum length sequence generator

To generate L1C code, first Legendre sequence is generated using following steps:

Select a prime number of length $p$, and generate Legendre sequence indices using the equations given below.[10,11]

$L_n = [L_{n-1}+(2n-1)] \mod(p)$, $L_1=1$

Legendre sequence is defined as

$$L_s = \begin{cases} 
1 \text{ if } k \in L_n \\
-1 \text{ if } k \notin L_n 
\end{cases}$$

And $k$ varies between $0$ and $n$

After generating Legendre sequence, Weil sequence is generated by Shifting Legendre sequence and x-oring it with the same. In this work, Legendre sequence is generated for 10223 bits. To generate 10230 bit L1C code, 7 bit Legendre sequence is added to Weil sequence to get proper ACF value.
4. SIMULATION AND EXPERIMENTAL RESULTS

The simulation tool used for simulation of this work is MATLAB-10. Figure (4) shows sample data, generation of M-Sequence, L1C code and BOC modulated signal in MATLAB for a small portion of data.

4.1. Power Spectral Density

(PSD) is the frequency response of a random or periodic signal, which tells us distribution of average power as a function of frequency. The PSD is the Fourier transform of the auto-correlation function.

Power spectral densities of the system which we have described, i.e BOC (10, 1) signal and the IRNSS signal with BOC (5,2) is shown below in fig(5) and Fig(6). It is evident that the spectral separation is wide and power is still less. It is clear that with (10, 1) BOC, Improved spectral sharing of the allocated bandwidth with existing signals or future signals of the same class can be achieved. It reduces mutual interference on common carrier frequencies. It improves signal tracking accuracy in noisy and multipath environments.

![Figure 4 BOC modulated signal](image-url)
5. HARDWARE IMPLEMENTATION

The hardware used to implement this work is TMS DM6437 DSP kit. DM stands for digital media. DM6437 device is based on 3rd generation high performance very long instruction word which makes DSP an excellent choice for digital media applications. It supports added functionality and has an expanded instruction set. It uses TMS320DM6437 Processor which works with 600MHz and executes 5600 MIPS. [11, 12]
**Figure 8 Real Time Implementation of BOC Modulation**

Fig (7) shows internal block diagram of DSP kit and Fig(8) gives connection of DSP kit to PC and real time hardware implementation. Coding is done with embedded C in CC studio environment. Results obtained are shown in fig9) which is similar to MATLAB simulation.
5. CONCLUSION

The present day Global Navigation Satellite System aims at interoperability among the existing Satellite Navigation systems i.e. GPS, GLONASS and GALILEO, IRNSS. This interoperability requires new modulation schemes such as Binary Offset Carrier Modulation. In this paper, a new scheme for BOC modulation is suggested and it is found that high powers are achieved at higher frequencies away from the centre frequency using the BOC(10,1) modulated signals. These high powers obtained are due to the splitting of the peak at the centre frequency. Hence due to the superior spectral characteristics, BOC (10,1) modulation can be used for IRNSS signal generation, so that the required interoperability can be achieved in modernized Global Navigation Satellite System. This work also shows implementation of proposed system on DSP Kit for real time application.

As future scope, we can extend this study to MBOC, GBOC to achieve more advantages in multiple GNSS signals and multipath environment.

REFERENCES

[1] ISRO-IRNSS-ICD-SPS-1.0, irnss.isro.gov.in/


DSP Implementation of (10, 1) Binary Offset Carrier Modulation For IRNSS Application


