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Telemetry Ranging System using OQPSK for Space Application

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***Abstract**: Offset Quadrature phase-shift keying (OQPSK) is a variant of phase-shift keying modulation using 4 different values of the phase to transmit. This paper shows how an OQPSK signal is transmitted from base station to the spacecraft with the addition of AWGN (Additive White Gaussian Noise) and then received at Spacecraft. Further the signal is transmitted from Spacecraft and received at base station. The goal is to calculate the time delay of the signal which takes place while transmission from base station to the receiving to base station. We are transmitting the Tausworthe codes i.e. T2B and T4B from the source. When the delays of the components have been determined, the T2B and T4B code can be regenerated clean from the noise. We present here the detailed Simulink model of OQPSK transceiver along with its delay calculation.*
***Keywords**: QPSK, OQPSK, AWGN, Time Delay, MATLAB, Simulink, Modulation, Demodulation, Tausworthe, T2B, T4B*

I. INTRODUCTION

The transceiver is based on the principle of OQPSK for more accurate transmission of data from the base station to the spacecraft. MATLAB Simulink provides a virtual platform for the implementation of different communication systems. It contains a lot of basic building block like clock, time delay, function generator, counter etc required for the development of system. With the help of Simulink, it is possible to verify the result of a system without actual implementation of the hardware. OQPSK and QPSK both are the modulation scheme use in the wireless digital communication. But here we are using OQPSK instead of QPSK because in OQPSK the maximum phase shift is of +/-90 degree which means more data transmission can be done through the same channel which is used in QPSK hence more efficient utilization of channel bandwidth whereas in QPSK maximum phase shifting is limited to 90 degrees only. For more secured and accurate data transmission PN sequence are generated by a logical combination of binary sequence of different length that are cyclically repeated. These sequences are called the Tausworthe sequence or codes i.e. T2B or T4B. The combination logic for the original Taus sequence introduced by NASA is based on the following rule. The ranging sequence chip is a +1 if and only if C1 has a +1 at that position or all five of the sequences C2, C3, C4, C5 and C6 have +1at that position or both.

II. TRANSCEIVER

The transceiver developed here in the Simulink is a radio frequency (RF) transceiver. Transceiver is a device which houses both a transmitter and a receiver in a single module. RF transceiver are positioned mostly in between baseband MODEM and PA/LAN in any wireless communication system. Here PA is power amplifier and LAN is low noise amplifier. The main function of the RF transceiver is to make the information which is to be transmitted in the form of voice/data/video suitable to be transmitted over the wireless medium. RF transceiver is use to convert IF frequency to RF frequency and vice versa. It is used in satellite communication for radio transmission and reception for television signal transmission and reception and in WiMAX/WLAN/ZigBee/ITE networks. As in our case we are using the Tausworthe codes i.e. T2B and T4B for its construction so this transceiver is very useful for military application for more secure data transmission. Practically, RF transceiver is made up of RF mixer, amplifiers, pads and other RF components and implemented using microstrip technology. The transmitter part in RF transceiver is referred as RF up converter and receiver part as RF down converter.

III. QPSK VS OQPSK

Both QPSK and OQPSK are use in digital data transmission for wireless communication. However, we found OQPSK more suitable to use for communication as in QPSK, each pulse represents two bits. Since there are 4 states(symbols), we can assume a

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phase change of 90 degrees per state(on average). However, when two bits change simultaneously, then the phase experiences a change of 180 degrees. The main purpose of OQPSK is to limit the maximum phase change possible in QPSK. In OQPSK, the I and Q bits are offset by half a symbol period(i.e one bit period). This ensures that both bits don't change state at the same time, thus limiting the maximum phase change to 90 degrees and preventing any spurious high frequency components.

IV. DEVELOPMENT OF TRANSCEIVER SYSTEM ON MATLAB SIMULINK

The transceiver block is made up of the basic building block of any communication system. The new thing introduce in this transceiver is the Tausworthe code and OQPSK modulation scheme for authentication of user and digital data transmission respectively. We have generated the Tausworthe Codes i.e. T2B and T4B by implementing the proposed logic
as discussed previously. The Tausworthe code are generated using T2B and T4B algorithm and fed to the correlator block in order to cross correlate the input signal parameters. This block consists of a mapping technique, the computation of the signal is done in time and frequency domain. This correlator block is used here to minimize the number of computations. If the chg is equal to 1 in the correlator block then the condition of correlation get satisfied and the output signal from the correlator block is given as input to the If-Condition block to check whether the input signals get correlated or not. If the correlated signal u1 satisfies the if condition i.e. u1 equal to 1, it is then fed to the logic block. The correlated condition satisfied signal from the IF- condition block and the Tausworth codes is made available to the comparator block that is the logic block. If the signal get satisfied by the conditions of the logic block then it is fed to the data conversion block for generating the Tausworth codes and data signal in same data type i.e. in bit form. The signals are to be transmitted over the channel in bit form only thus data type converter is used here. In addition to this it provides an ease to the data manipulation further in OQPSK system. Now as we are implementing the system on MATLAB- Simulink so our ground and space station are on the same platform. Therefore, both the modulation and demodulation system are present in the same OQPSK system block.

V. OQPSK SYSTEM

The OQPSK system block used in this transceiver system consist of OQPSK baseband modulator ,delay, AWGN channel, OQPSK baseband demodulator, all these blocks plays a major role in secure data signal transmission without any data loss. A OQPSK modulator consist of a serial to parallel converter ,two level converters, two multipliers, a carrier wave generator, a 90 degree phase shifter, a delay device and an adder. The principle of OQPSK is explained further in the paper.

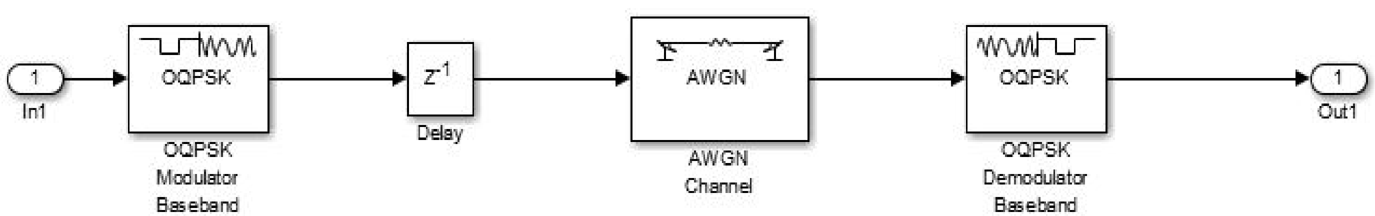

FIG 2:- Block Diagram of OQPSK System

VI. OQPSK MODULATOR AND DEMODULATOR

Quadrature-phase shift keying (QPSK) is a form of phase-shift keying in which four different phase angles are used. In QPSK, the four angles are usually separated by 90° spacing. QPSK or Quadrature PSK is an other form of angle-modulated, constant-amplitude digital modulation. QPSK is an M-ary encoding scheme where N=2 and M=4 (hence, the name "quaternary" meaning "4"). With QPSK, four output phases are possible for a single carrier frequency. Because there are four output phases, there must be four different input conditions. Because the digital input to a QPSK modulator is a binary signal, to produce four different input combinations, the modulator requires more than a single input bit to determine the output condition.
With two bits, there are four possible conditions: 00,01,10,11. Therefore, with QPSK the binary input data are combined into groups of two bits, called dibits in the modulator, each dibit code generates one of the four possible output phases (+45, +135, -45, -135). Therefore, for each two-bit dibit clocked into the modulator, a single output change occurs, and the rate of change at the output (baud) is equal to one-half the input bit rate (i.e. two input bits produce one output phase change). With QPSK because the input data are divided into two channels, the bit rate in either the I or the Q channel is equal to one-half of the input data rate (fb/2). Essentially, the bit splitter stretches the I and Q bits to twice their input bit length. Consequently, the highest fundamental frequency

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present at the data input to the I or the Q balanced modulator is equal to one-fourth of the input data rate (one-half of fb/2=fb/4). As a result, the output of the I and Q balanced modulators requires a minimum double-sided Nyquiest bandwidth equal to one-half of the incoming bit rate (FN=twice fb/4 =fb/2). Thus with QPSK a bandwidth compression is realized (the minimum bandwidth is less than the incoming bit rate). Also, because the QPSK output signal does not change phase until two bits (a dibit) have been clocked into the bit splitter, the fastest output rate of change (baud) is also equal to one-half of the input bit rate. As with BPSK, the minimum bandwidth and the baud are equal. Thus the minimum bandwidth required is B=fb/N.

Offset quadrature phase-shift keying (OQPSK) is a variant of phase-shift keying modulation using 4 different values of the phase to transmit. Taking four values of the phase (two bits) at a time to construct a QPSK symbol can allow the phase of the signal to jump by as much as 180° at a time. This produces large amplitude fluctuations in the signal; an undesirable quality in communication systems. By offsetting the timing of the odd and even bits by one bit-period, or half a symbol-period, the in-phase and quadrature components will never change at the same time. In the constellation diagram shown on the left, it can be seen that this will limit the phase-shift to no more than 90° at a time. This yields much lower amplitude fluctuations than non-offset QPSK and is often preferred in practice.

The next block in this OQPSK system is the demodulator. The OQPSK demodulator works on the same principle as that of modulator which has already been described in the paper, you can visit through the paper for better understanding of OQPSK technique. The OQPSK demodulator baseband block applies pulse shape filtering to the modulated signal received at its input and demodulates the waveform using the offset quadrature phase shift keying (OQPSK)technique. The received input signal at the spacecraft i.e. at the demodulator side is the baseband representation of the modulated signal. For a reliable digital communication of signal from base station to spacecraft the input signal at aircraft must be a discrete-time complex signal. Further the same OQPSK system is used for the reception of signal from spacecraft to ground station i.e. retransmission of signal from spacecraft to base station for delay calculation range calculation tracking of system and other important purpose.

VII. AWGN CHANNEL

It's a simple model of the imperfections that a communication channel consists of. When a certain signal is transmitted into space or atmosphere or copper line to be received at the other end, there are disturbances (aka noise) present in

the channel (space/atmosphere/copper line) due to various reasons. One such reason is the thermal noise by the virtue of electrons' movement in the electronic circuit being used for transmission and reception of the signal.

This disturbance or noise is modelled as Additive White Gaussian Noise. Additive because the noise will get added to your transmitted signal not multiplied. So, the received signal y(t) = x(t) + n(t) , where x(t) was the original clean transmitted signal, and n(t) is the noise or disturbance in the channel. Gaussian (thermal noise) is random in nature, of course noise can't be deterministic otherwise we would subtract the deterministic noise from y(t) as soon as you receive y(t). So, this random thermal noise has Gaussian distribution with 0 mean and variance as the Noise power.

If variance of Gaussian is high then it is bad as it may need to increase the power of x(t) or be satisfied with higher probability of error. 0 mean means that the expected value n(t) during any time interval T is 0. But simply put, it also means that on an average n(t) will take 0 value. And probability of n(t) = 0 is the highest and probability rapidly decreases as you increase the magnitude of n(t). This is a very good thing. White meaning same amount of all the colours or same power for all the frequencies, which means that this noise is equally present with the same power at all the frequencies. So, in frequency domain, Noise level is flat throughout at every frequency.

VIII. RANGE CALCULATION

As per the main purpose of our paper is to calculate the range of the system in which the transceiver is

placed i.e. summation of the time delay caused by the other circuit and environmental factors to the modulated signal to reach from the base station to the spacecraft (T1)and the time delay introduced by the other delay factors to the remodulated signal from the spacecraft to the base station(T2) divided by 2.these T1 and T2 are nothing but the time delay which plays a vital role in the calculation of the range of any system. The delay in uplink signal is calculated by delay block find delay and the delay in downlink signal is calculated by other block named finddelay1.the output from both the blocks find delay and find delay1 are given as input to the block named subsystem which in return gives an output on the scope attached to it .

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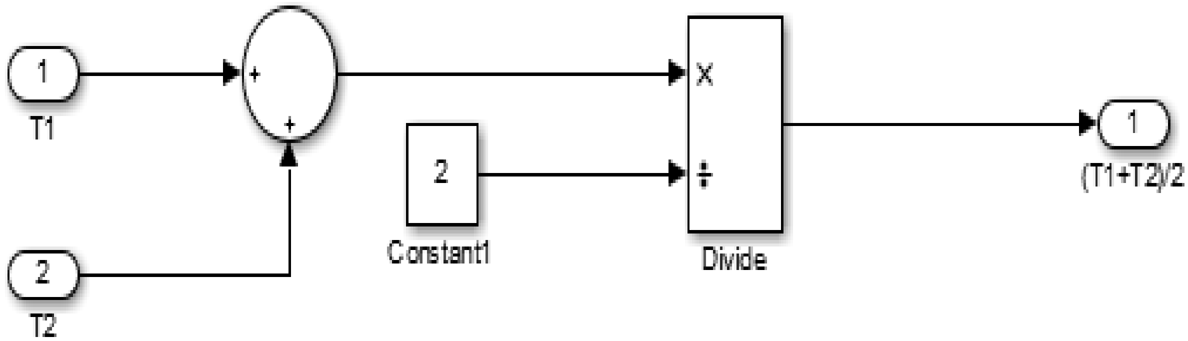

FIG 3:- Block Diagram for Delay Calculation

IX. CONCLUSION

In this paper we have presented the digital design of OQPSK modulator and demodulator with the delay calculation technique. If there is more precise and accurate calculation of delay of signal then, signals can be recovered with the minimum probability of error. Hence, we have added a known delay to the signal transmitted from base station to spacecraft which could be further calculated and used to recover the original signal. We have used Tausworthe codes for the transmission of signals as they are used for pseudo-noise (PN) ranging sequences.

The Simulink model of the circuit is only the starting point when implementing digital radios and even if this works as expected it is not a warranty that the circuit will work in real hardware.

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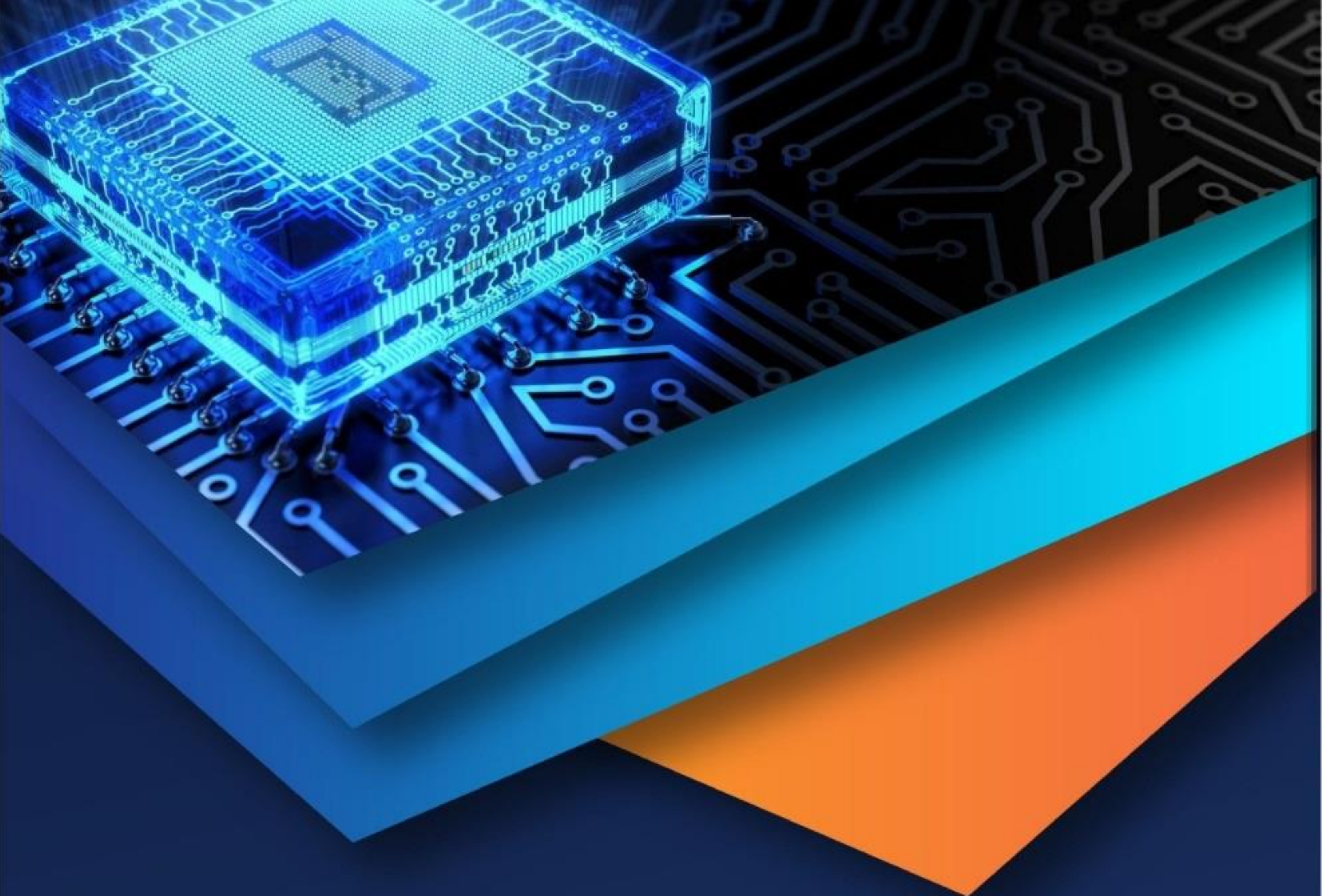

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