

## **FPGA Implementation of Radio Navigation Based on MicroBlaze**

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### **ABSTRACT**

In modern aviation, navigation is an important technology. So far, equipped in almost all the military and civil airports, radio navigation system is the most widely used navigation devices in aviation. At present, radio navigation still has priority in short-range navigation of civilian and military aviation in our country. Also, due to the imperfect landing system device in the existing aircraft, radio navigation system is of vital importance in ensuring safety in Plane's homing and approaching.

In the actual navigation test, to simulate the RF signal of combined antenna in radio navigation, various signal generators are often designed to satisfy performance of navigation system and meet technical requirements. Meanwhile, the signal generator must adjust signal types, parameters and work modes timely according to the navigation system requirements. Therefore, signal generator must have the feature that signal can be generated flexibly, parameters change quickly, signal spectrum stay stabilized, and the system is reliable, etc.

The proposed system adopts Micro Blaze soft processor as the control core of generator to communicating command with PC. which can satisfy each requirement in actual application of testing and debugging on navigation.

The important role in navigation test, radio navigation generator is widely used in the people/military plane. But traditional equipment composed of analog circuit Presents low accuracy and poor reliability. A new kind of digital navigation signal generator is designed. It receives data and commands from PC by MicroBlaze embedded soft processor of Xilinx Company and demodulates information to control FPGA load different softwares to generate various navigation signals, which fully meets general radio navigation system test technical requirements by giving full play to the system hardware and software advantages and fulfilling design targets such as the accuracy, flexibility and expansibility. Therefore, providing a new idea for radio navigation system. this generator can be widely

applied to debugging use on people/military plane radio navigation.

Using FPGA instead of an ASIC gives also flexibility for reconfiguration, which is a need for the Software Defined Radio (SDR) concept. Modelsim Xilinx edition will be used for simulation. The Xilinx ISE will be used for synthesis; place & route and bit file generation. Xilinx Spartan 3E family FPGA board will be used testing the logic. The chipscope pro analyzer is used to display the captured set of results.

**Keywords-***DDS signal generation, UART,FPGA, Micro blaze.*

### **1. INTRODUCTION**

In modern aviation, navigation is an important technology. So far, equipped in almost all the military and civil airports, radio navigation system is the most widely used navigation devices in aviation. At present, radio navigation still has priority in short-range navigation of civilian and military aviation in our country. Also, due to the imperfect landing system device in the existing aircraft, radio navigation system is of vital importance in ensuring safety in plane's homing and approaching.

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## 2.BLOCK DIAGRAM OF IMPLEMENTING MODULES

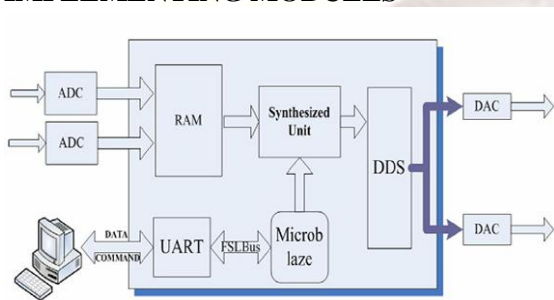


Fig.1: Processing modules of FPGA

### 2.1 DESIGN SCHEME OF DIGITAL SIGNAL GENERATOR OF RADIO NAVIGATION

According to different technical requirements of navigation, the generated signal is basically formed by the carrier signal, low frequency modulated signal and audio modulated signal. Therefore, in this scheme, the signal generator adopts direct digital frequency synthesizer (DDS) technology to design precise clock reference source, word length of frequency and phase accumulator and sine function table to generate the modulated sine signal whose frequency variation scope, step length change and precision meet the requirements in overall design. Large-scaled FPGA is used in this system to realize accurate DDS ,

ADC converter is used to convert the external signal to be modulated by carrier signal, and the soft embedded processor MicroBlaze communicates with PC by RS422/232 as the control core, figure is the overall scheme of digital signal generator of radio navigation. The control software of PC wrote in VC6.0 communicates with the generator through RS422/232 is in charge of transmitting control command to set frequency, azimuth angle, channel, working mode and other parameters of navigation signal and receiving status and data of the generator after every change. In this system, as a master unit MicroBlaze sends parameters to FPGA after demodulating data from PC while FPGA generates accurate navigation signal to high-speed DAC converter as the ground

floor synthesis unit. Meanwhile, multiple clock signals used in the system are generated in phase lock logic part of FPGA from external oscillator.

### 2.2 DIRECT DIGITAL SYNTHEZIZER

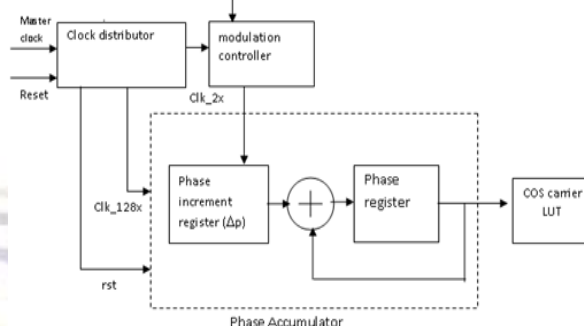


Fig.2

Playing an important role in navigation test, radio navigation generator is widely used in the people/military plane. But traditional equipment composed of analog circuit presents low accuracy and poor reliability. A new kind of digital navigation signal generator is designed in this paper. It receives data and commands from PC by MicroBlaze embedded soft processor of Xilinx company and demodulates information to control FPGA load different softwares to generate various navigation signals, which fully meets general radio navigation system test technical requirements by giving full play to the system hardware and software advantages and fulfilling design targets such as the accuracy, flexibility and expansibility. Therefore, providing a new idea for radio navigation system design and test, this generator can be widely applied to debugging use on people/military plane radio navigation.

A Direct Digital frequency Synthesizer (DDS) design and prototype suitable for space-borne applications is presented. The design is targeted for use in the uplink section of the RF subsystem of the New Horizons Pluto spacecraft currently under design at APL. Design and analysis of the digital portion of the DDS is presented along with experimental data from the prototype system, which was implemented using an FPGA and a discrete digital to analog converter.

Direct Digital frequency Synthesizers (DDS) are a common component in a variety of communication systems, especially those requiring fast frequency hopping, low power dissipation, and small form factor.

A DDS at its simplest is a clock-dividing counter, termed the phase accumulator, which generates a digitized ramp waveform. This ramp is converted to a sine-wave representation and subsequently translated to the analog domain by a digital to analog converter (DAC). Subsequent filtering of the DAC output can be used to remove the high frequency components that arise from the data conversion process. Fig. illustrates the



conceptual system with a j-bit accumulator output truncated to a k-bit ROM address space and a m-bit DAC. DDS performance is measured in a number of ways. Some are fairly generic, including power dissipation and maximum input clock rate and output frequency. Others are more specific, relating to minimum frequency step size and to the spectral purity of the DDS output. The DDS output spectrum reflects the fact that a DDS effectively samples a sine wave output. As a result, inaccuracies due to finite word length effects as well as Nyquist sampling considerations cause the output spectrum to contain energy at frequencies other than the fundamental. These peaks, termed spurs, determine the signal to noise level of the DDS, which is defined as the Spurious Free Dynamic Range (SFDR). Non-idealities in the DAC can further degrade the SFDR as well. In general, peaks which are closer in frequency to the fundamental present more problems than peaks further out, simply because they are more difficult to attenuate with an output low pass filter.

### 2.3 IMPLEMENTATION OF DDS

In this project we are using Direct Digital Synthesizer for generation of the carrier signal. All we know about that by using DDS we can generate a carrier signal in the form of sine or cosine or sine cosine. Xilinx itself generate the core for DDS that is IP core generation. In that we should select options about the carrier or signal frequency in MHz and phase offset and data width and the phase increment register data width depends on the data width or we can have an option like programmable then we can give the phase offset and frequency levels through the program. And we are taking the carrier signal from the DDS and we do the modulation like AM, FM, QPSK, BPSK. And in FM technique we are taking DDS signal as the message signal and we are generating the carrier by using the Hardware Description Language.

The Analog to Digital Module Converter Board (the AD1™) converts signals at a maximum sampling rate of one million samples per second, fast enough for the most demanding audio applications. The AD1 uses a 6-pin header connector, and at less than one square inch is small enough to be located at the signal source. The AD1 converts an analog input signal ranging from 0-3.3 volts to a 12-bit digital value in the range 0 to 4095. The AD1 has two simultaneous A/D conversion channels, each with a 12-bit converter and filter. Each channel can sample a separate stream of analog signals. The AD1 can also convert a single stream of analog signals using only one channel. Each channel has two 2-pole Sallen-Key antialias filters with poles set to 500 KHz. The filters limit the analog signal bandwidth to a frequency range suitable to the sample rate of the converter. The AD1 uses the SPI/MICROWIRE™ serial bus

standard to send converted data to the host system. The serial bus can run at up to 20 MHz. The AD1 has a 6-pin header and a 6-pin connector for easy connection to a Digilent system board or other Digilent products. Some system boards, like the Digilent Pegasus board, have a 6-pin header that can connect to the AD1 with a 6-pin cable. To connect the AD1 to other Digilent system boards, a Digilent Modular Interface Board (MIB) and a 6-pin cable may be needed. The MIB plugs into the system board, and the cable connects the MIB to the AD1. The AD1 can be powered by voltage from either a Digilent system board or an outside device. Damage can result if power is supplied from both sources or if the outside device supplies more than 3V. Rst is used to reset module or clear previous data, clk is used for the synchronization, when the rising edge of clk is '1' then count is a counter, go on counting from '0' to '15' if count is '0' then data present in shift registers (signal's) will be forced on to the output's pdata1, if count is above '3' then inputs will be forced on to shift register's (signal's) from LSB to MSB till the count '15' by shifting 1 bit for each count. CS will '1' for the count of "15". Pelk will be '1' for 0 to 8 counts and '0' for the rest of count's i.e it is  $clk/16$

As we know that the analog to digital converter is used to convert the analog signal into the digital samples. And we are using the 12 bit A/D converter means at the ADC output we get the 12 bit sample values of the analog signal. Here we are giving a message signal (Modulating signal) through ADC. It is 2-channel ADC means we can give 2 inputs at a time and here we are connecting the input to the ADC from the Function Generator by giving the frequency levels and selecting a wave (sine or sawtooth, Square, etc) and constant voltage levels

### 3. BLOCK DIAGRAM OF UART

The UART block diagram for the FPGA implementation is shown in Fig. It consists of 4 blocks namely transmitter, receiver, enable generator and baud generator. The UART transmitter and receiver are designed in the same block which is shown in below. The UART is a serial interface with a frame format of start bit of active low '0' at the beginning and 8 bit of information with a stop bit of active high '1' signal at the end. The operation of UART is controlled by Clock signal which is fed from external crystal. Baud generation section is a clock divider ckt, FPGA board clock runs at 50MHz, but UART transfer data at predefined standards that had to be maintained, in present system is designed for a rate of 9600/sec (i.e  $50 \times 10^6$  is scaled down for 9600). Generates a 9600 pulses for a sec, this implies the speed of UART is 9600 bits per sec. another clock with a 16 times faster is required to the receiver section so that the data will not be corrupted, baud out is given to the enable generator section. Enable Generator this section

receives baud\_clock signal as a enable signal and gives enable out signal to the transmitter section as a enable input signal. This signal is used to synchronize the transmitter section when ever the data is to be transferred. The transmitter block is responsible for the transmission of serial data from UART. It takes 8-bit data from the receiver section in parallel and sends data in serial form. Data inserted between start and stop bits. An optional parity bit also may be used for error detection. state machine for transmitter is shown in Fig.

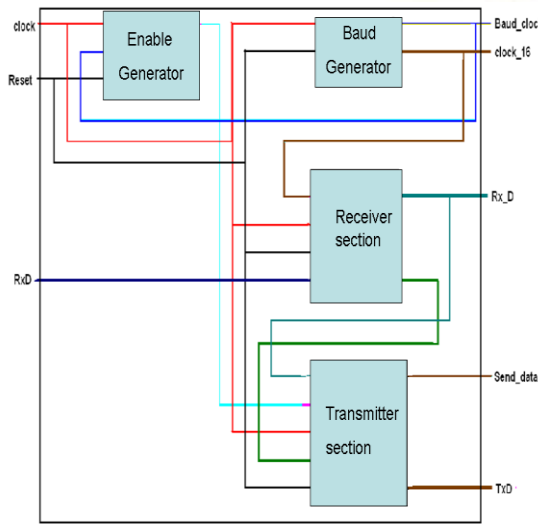


Fig.3

Transmitter stays in IDLE state unless transmit enable (tx\_enable) is made as '1'. The data transmission starts with tx\_enable = 1. As mandated by the protocol, a '0' is transmitted to indicate start of transmission or start bit. This is done in START state. Then data bits 0 to 7 are transmitted in states DATA0 to DATA7. If parity is enabled in configuration register, the data is attached with parity in PARITY state. Then transmitter enters STOP state and sends a '1'. This indicates the completion of transmission. Then the transmitter enters the IDLE state and waits for next data transmission. UART receiver handles reception of data from RS232 port. main functions of receiver block are to convert the serial data to parallel data, check the correctness of data from parity and store the received data. UART receiver state machine is shown in Fig. The receiver is in IDLE state by default. When the serial data pin goes low, indicating the start bit, the state machine enters DATA0 state. The data is received, one bit at a time from LSB to MSB in states DATA0 to DATA7. If parity is enabled, the state machine checks the parity bit received against the parity obtained from received data. If the data received is fine, the data\_rx (data\_rx\_done) bit is set to '1' and the receiver goes back to IDLE state again. top module is a combination of uart and a selected image

processing applications. Type of operation is selected by slider switches on the FPGA board each and every block is explained in detail below.

#### **4. REALIZATION OF DIGITAL SIGNAL GENERATOR OF RADIO NAVIGATION BASED ON MICROBLAZE**

##### **4.1 HARDWARE PLATFORM:**

Xilinx XC2V1000 of Virtex - II platform is adopted in this system which has 40 dedicated multiplier blocks, up to 93,184 look-up tables (LUTs) or cascadable 16-bit shift registers, 3 Mb of dual-port RAM in 18 kbit block SelectRAM resources and up to 1.5 Mb of distributed SelectRAM resources and clocks up to 420MHz internal, presenting a strong computing ability and high speed data throughput capacity[9]. Also an in-system programmable configuration PROM XCF04SV020C is used for FPGA configuration in this system. The MicroBlaze embedded processor soft core is a reduced instruction set computer (RISC) optimized for implementation in Xilinx FPGAs. It is highly configurable, allowing users to select a specific set of functionality required by designs to build their own hardware platform [10]. Fast Simplex Link (FSL) bus is a uni-directional point-to-point channel bus used to perform fast communication between any two design elements on the FPGA when implementing an interface to the FSL bus. First create a hardware system whose core is MicroBlaze under the integrated environment of XPS using Base System Builder (BSB) wizard, then follow the guide of EDK to add a peripheral of system with UART IP core connected by MicroBlaze FSL bus, use the Platform Generator to generate embedded system's netlist document (.NGC) based on Microprocessor Hardware Specification (.MHS), and finally use the synthesized tool XST to constitute the whole hardware platform of the system [11]-[12]. ADC converter is mainly used for acquiring external low frequency signal. AD9218 with dual 10-bit channels of ADI company is selected in this system which works under 2.7V-3.6V and operates up to 105MSPS conversion rate [13]. DAC converter is mainly used for generating rf modulated signal. AD9760 with single 10-bit channel of ADI company supporting update rates up to 125MSPS is chosen in this system, whose single supply ranges from 2.7V to 5.5V.

Design of PC Software Main task of PC software is to generate control command for frequency, azimuth angle, work mode, channel selection and other information which can be distinguished by command head and transmitted by RS422/232 to signal generator for the corresponding digital navigation signal. 2.2.2 Design of FPGA processing modules Main task of FPGA hardware is to produce precise modulated rf modulated signal. The tasks are included as follows: 1) receiving



carrier frequency, azimuth angle and other Relevant control commands from MicroBlaze; 2) generating audio signal, carrier signal and azimuth angle signal; 3) receiving two channel low frequency signal from ADC converter; 4) synthesizing navigation signal and transmitting it to DAC converter according to the command from PC. The processing modules of FPGA is shown in figure. Design of MicroBlaze processing First define software systems using Microprocessor Software Specification (.MSS) readable text files which describe driver information of all peripherals. Once the system software is defined, use the Library Generator to build system-specific library C functions that map basic C functions to peripherals and to configure the C libraries. Then write the corresponding receiving program code to 380 achieve MicroBlaze control function using the function libraries in SDK integrated environment. In the end, package the hardware structure and application software of UART controller based on MicroBlaze into ISE as a sub-module and complete software design of MicroBlaze controller. The software process flow is shown in figure.

#### 4.2 IMPLEMENTATION OF MICROBLAZE

In our project the Microblaze place a main important role. It is a soft core processor. and we know about the two type processors, those are Microblaze and the Power Pc. The main difference between the microblaze and power pc is ,microblaze is a soft core processor and the power pc is a hard core processor.

**Microblaze:** Which is a soft core processor, the some part of the fpga will acts as a microblaze processor by implementing the hardware description language means by the vhdl code we are making act of some part of fpga as microblaze. So it is called as soft core processor. No need of any external hardware circuitry.

**Power Pc:** It is hard core processor, means it is different than microblaze. In this we should require the external hardware by connecting this external hardware of the power pc to the fpga we can use the processor. Then the circuit complexity may increase.

So in this project we are implementing Microblaze soft core processor only. And this processor will take the information from the Pc by using UART. So from the we receive the commands in hexa,ascii format. By using these commands only we can change our parameters of modulation techniques like setting frequency ,setting azimuth angle, changing work mode, self testing and output RF signal. This function we will implementing by coding. According to these commands the modulation techniques are select in the synthesized unit.

#### 5. NUMERICAL TEST AND SIMULATION

Due to the diversity of technique requirement of navigation signal, the main task of generator is to generate different kinds of rf modulated signal. Take Automatic Direction Finder (ADF) signal for example, it is in form of  $V = E \{ m + M \cos(Qt + \theta) + v \} \cos C / t$  E is the signal amplitude, m is a constant, M is modulation index, Q is frequency of low frequency modulated signal, e is the azimuth angle, Va is the audio modulated signal and We is the carrier frequency [1]. Assume  $E = 1, m = 0.3, Q = 2.7 \times 10^4, e = 0, c = 3 \times 10^8$ , the frequency of audio signal is 1020Hz and the sample frequency is 40MHz and simulate the ADF signal in MATLAB software, the result is shown in Fig. Take another signal for example, the signal of Very high frequency Omnidirectional Range (VOR) can be expressed as  $V = U R_m [1 + m A \cos(Qt - e) + m \cos(n.t + m \cos Qt)] \cos at U$  Rm is the amplitude of reference phase signal, e is the azimuth angle, Q is the angular frequency at 30Hz, Qs is the angular frequency at 9960Hz, m A is the modified factor of variable phase signals, m f is the modulation index, m is modulation of reference phase signal and W is the angular frequency of carrier signal. [1] Due to that the frequency of VOR signal is too high and the hardware is limited in performance, we assume  $U R_m = 1, m = 1, m = 0.3, m = 1, e = 60, w = 271 \times 10^6$ , the sample frequency is 40MHz, VOR signal is simulated in MATLAB software and the result is shown in Fig. Use the PC software to control the system to generate the ADF signal in the same condition with the MATLAB simulation and connect the generated ADF signal to the oscillator. The real ADF signal waveform is shown in Fig. which is almost the same with the simulated signal in Fig. Then connect the real ADF signal to the spectrum analyzer, the minimum resolution of the signal is up to 0.01Hz. Similarly, generate the VOR signal in the same condition of simulation in MATLAB and connect it to the oscillator. The real VOR signal waveform is shown in Fig. which is almost the same with the simulated signal in Fig. Then connect the real VOR signal to the frequency analyzer, the minimum resolution of the real signal is up to 0.01Hz.

## 6. FINAL SIMULATION RESULTS

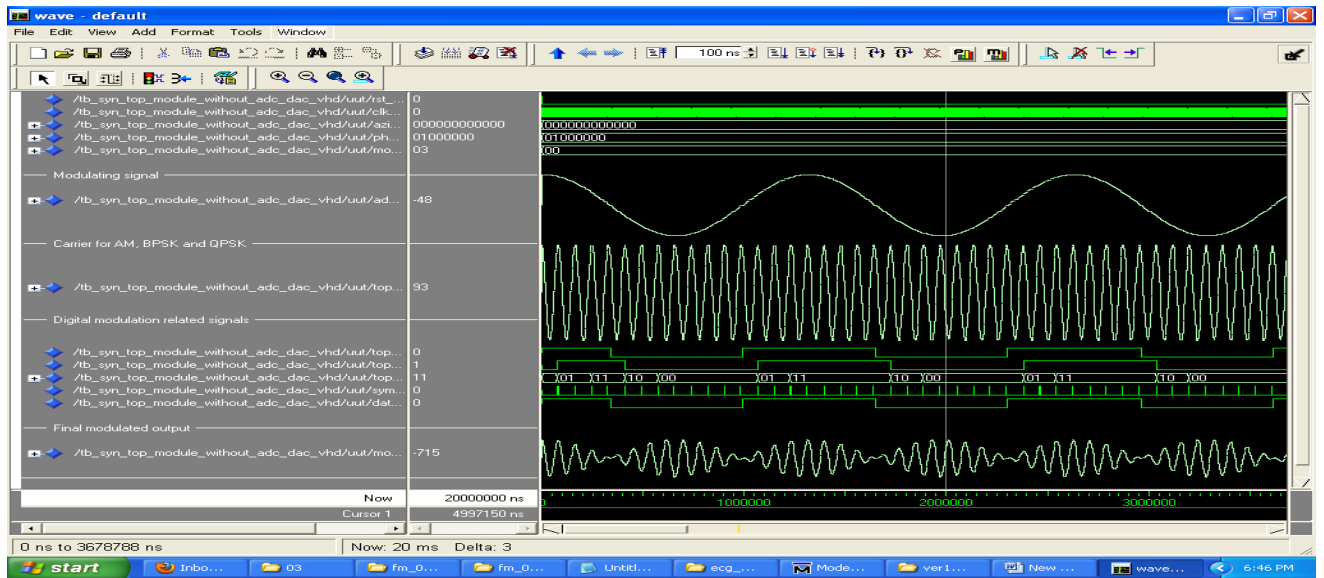


Fig.4.A.M

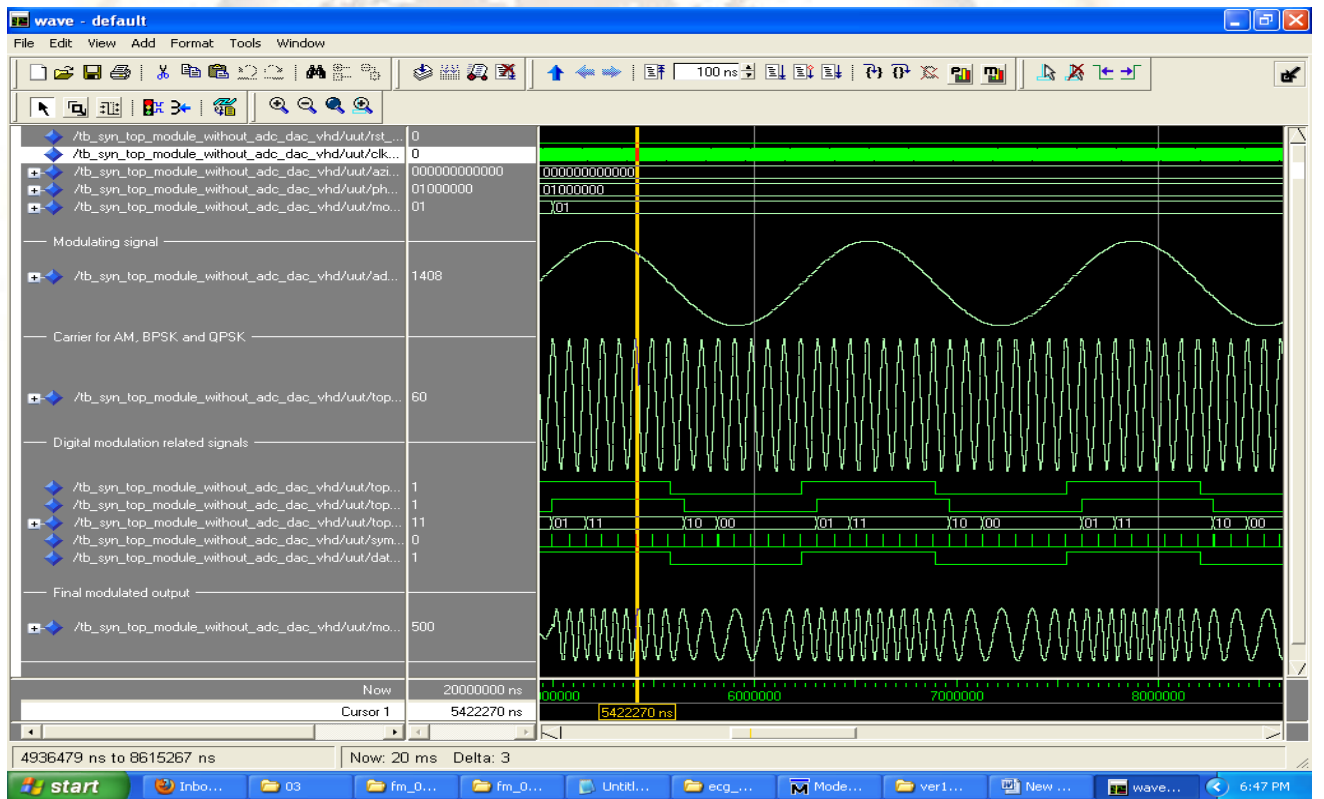


Fig.5.F.M

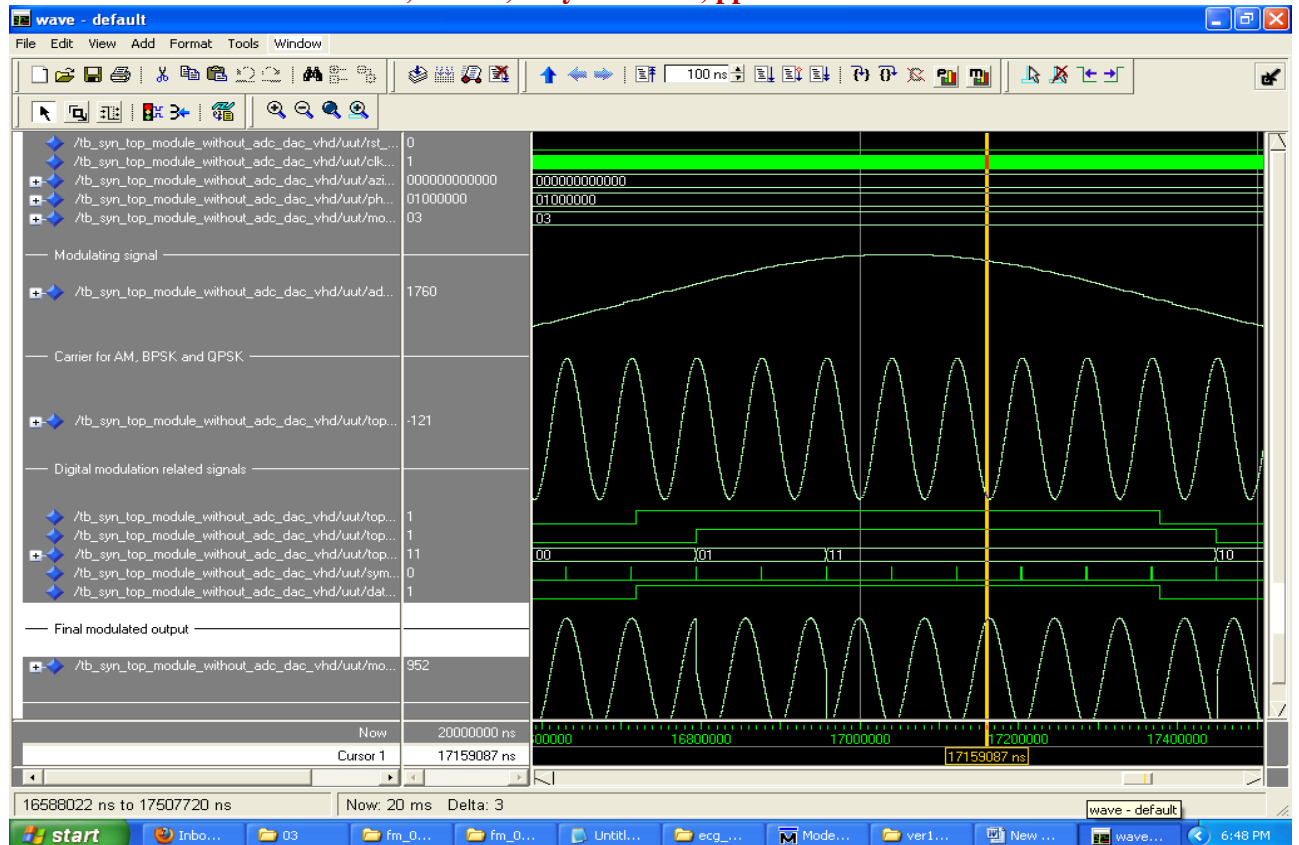


Fig.6.QPSK

## 7. APPLICATIONS

- Aviation, navigation and other equipment.
- Software defined radios for military applications.

## 8. ADVANTAGES

- Full digital techniques can give room for full reconfigurability of the MODEM for different specifications.
- DDS based carrier synthesis has no limitation for tracking the signal of even wideband signal.
- FPGA based implantation will result in extremely high speed and also can provide room for adding additional hardware blocks.

## 9. TOOLS AND HARDWARE

- Simulation software - Modelsim Xilinx Edition (MXE)
- Synthesis, P&R - Xilinx ISE
- On chip verification - Xilinx Chipscope
- Hardware - Xilinx Spartan 3 Family FPGA board

## 10. CONCLUSION

In this paper, the digital signal generator of radio navigation is implemented by soft processor MicroBlaze whose key portion is

achieved in a single FPGA chip, which overcomes the disadvantage of low accuracy and flat tuning in traditional methods. Simultaneously, various kinds of signals can be loaded in this system, obtaining more flexibility and better expandability. Through the numerical test and simulation results, the veracity and precision is confirmed. Favorable result has been acquired in practical application.

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Cache CacheLbIJ Indicator Rf signal  
Output PC .

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