IMPLEMENTATION OF A FPGA BASED GENERAL PARAMETERIZABLE MODULATOR

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Abstract— **This paper deals with design anddevelopment of a generalized parametrizable modulator (GPM) that can perform Gaussian minimum shift keying(GMSK) modulation and Quadrature Phase Shift Keying(QPSK) modulation in a reconfigurable baseband modulatorfor software defined radio (SDR) architecture. GMSK is the underlying modulation scheme for the Global System for mobile(GSM) standard, while QPSK technique is the basic modulationscheme for Code Division Multiple Access (CDMA) standard.**
Although GMSK is an inherently non-linear modulation technique, the present work uses a linearly approximated GMSK technique to take the advantage of the simplicity of the filter structure. The normalised error in amplitude as a function of modulation index and bandwidth time product has been simulated thus capable of working at a data rate that satisfies the requirements of almost all 2G and 3G air interface standards.The proposed GPM architecture is implemented on a Spartan 3E starter kit.

Keywords— **GPM, GMSK, QPSK, GSM, CDMA, SDR *architecture.***

I. Introduction

Next generation wireless systems lead to an integration of existing networks forming a heterogeneous network. Re-configurable systems will be the enabling technology sharing hardware resources for different puposes. Our understanding of a software radio is that of a transceiver, the functions of which are realized as programs running on a suitable processor if feasible. On the hardware, different transmitter/ receiver algorithms, which usually describe transmission standards, are implemented in software [3]. The routines are written in such a manner that standards can be loaded via parameter lists. This procedure guarantees that the transmission standards can be changed quickly, if necessary (interstandard handover).

The following characteristic properties of a software radio can be identified.

1) Its functionality is determined by software.

2) On its hardware, different standards can be executed, controlled by parameter lists.

3) All standards are looked at as members of one family. Software radios can be classified into the following categories

1) Multiband radio (MBR): The radio can be used over a wide frequency region (in an extreme case from 1.5 MHz to 30 GHz).

2) Multirole Radio (MMR): Different transmission, connection and networking protocols are realized on a powerful, software configurable digital signal and control processor platform.

3) Multifunction Radio (MFR): Multimedia applications (voice, data, fax, video) are supported.

We mainly consider commercial software radios, which are used as MMR and MFR in mobile communication systems and which support services reaching from speech to multimedia applications. The main difference from military software radios is that the transmission frequencies of commercial software radios fall entirely into the ultra-high-frequency (UHF) region, especially into the frequency band from 800 to 2200 MHz allocated to mobile communication systems.

Transceivers, as suggested by their name, consist of a transmitting and a receiving branch.. In the receiving direction, the signal is amplified, mixed to an IF and subsequently processed by the IF section. Within the IF section, the signal is bandlimited, A/D converted, and low-pass filtered. Within the base-band signal processing, the signal is demodulated and decoded. The data processing takes care of the connection monitoring and of the upper layers" tasks within the International Organization for Standardization/Open Systems Interconnect (ISO/OSI) model Thus transceivers for multiple standard software defined architecture are in demand, so that maximum hardware can be reconfigured for different standards to reduce the hardware complexity and also the development cost and time to market

Research in the area of software radio systems has led to the development of many general as well as specific software radio implementations [1]. A common modulator, by which one can realize different modulation schemes, has definite advantage if it is implemented in a reconfigurable structure. One can exploit the scope for using common modules for more than one such scheme. To achieve communication anywhere, anytime with a single terminal, it is important to define a “software defined radio” approach for all cellular standards. European countries use GMSK modulation in the popular 2G cellular standard GSM. However, GMSK is based on nonlinear modulation. For the ease of hardware implementation, a linear version of GMSK, the performance of which differs insignificantly from that of the exact GMSK, has been adopted in the present work. IS-95 and other CDMA standards use QPSK (quadrature phase shift keying), DQPSK (differential QPSK), OQPSK (orthogonal QPSK) and π/4-QPSK. It is important to combine GMSK, which is a TDMA standard, with CDMA standard in order to achieve multiple standard communications with a single terminal.

The Generalized Modulator:

QPSK modulators and their modifications, e.g. DQPSK, are implemented by a linear I/Q modulator structure. A modulation method is called linear if the principle of superposition applies in the mapping of the digital bit sequence into successive waveforms. In contrast, GMSK, used for GSM, is a nonlinear modulation mode that cannot easily be realized by a general linear system. Since we aim at a common base-band signal-processing structure for all standards under consideration, the linear approximation of GMSK has been proposed as modulation for GSM within a software radio.

Linear Approximation to GMSK:

GMSK is a special kind of MSK modulation which is a 2-level FSK with modulation index 0.5 [4]. The frequency pulse filter of a GMSK signal is the well-known Gaussian pulse, which causes a bandwidth reduction but also leads to a (controlled) ISI. The quantities of ISI and of bandwidth reduction mainly depend on the bandwidth time product (BT product) of the pulse. For GSM, the bandwidth time product is chosen as BT, which results in an efficient bandwidth reduction but also calls for an equalizer in the receiver. On the other hand, an equalizer has to be implemented into a GSM receiver anyway because of the mobile multipath channel and the used symbol rate of 270.833kbit/s.

GMSK has been widely applied in mobile wireless communication due to its compact spectrum and constant envelope signal feature that greatly eases the requirement for power amplifier linearity. This is the modulation scheme in which the phase of the carrier is instantaneously varied by the 'modulating' signal (i.e. the information to transmit). GMSK is a spectrum efficient modulation scheme, and it is adopted as the modulation standard of GSM systems.

According to Laurent [3], any phase modulation can be

expressed as the sum of a finite number of time-limited amplitude modulation pulses. Laurent's concept can be fruitfully applied for design of the modulator and the demodulator of the GMSK scheme. GMSK can be regarded as a 2-level FSK modulation with modulation index of 0.5. The complex envelope of a GMSK modulated signal that involves an NRZ data stream is given by

$$e(t) = \exp[\, j2\pi h \sum_{n=0}^{\infty} u_n \int_{-\infty}^{t} g(\tau - n\tau) d\tau \,]$$

Where with the aim of reduction of bandwidth of the GMSK waveform, the impulse response that is used is given by

$$g(t) = \frac{1}{2T}\ rect\left(\frac{t}{T}\right) * h_{Gauss}(t)$$

Where T is bit duration, rect (x) is the familiar rectangular function of unit amplitude and unit duration centered at x = 0, and $h_{Gauss}(t)$ is the well-known Gaussian impulse response with bandwidth time product (BT product). In practice, one can express the complex envelope of a GMSK signal with L = 4 (where L is the length of the frequency impulse measured in number of bit periods) as superposition of eight impulses Some benefits of the above structure proposed by Wiesler are a reduced size of the hardware platform and fast performance by changing the air interface for a system of handover. The linear approximated GMSK is used in the SDR environment because this enables a common I/Q modulator for all second generation systems.

The complex envelope of a GMSK modulated signal e(t) consists of a linear part $e^{lin}(t)$ and a nonlinear part $e^{nlin}(t)$. It has been established in, that 99% of the total signal energy is contained in the linear component $e^{lin}(t)$. A linear approximation for e(t) can be written as

$$e(t) \approx e^{lin}(t) = \sum_{k=0}^{\infty} z_n C_o(t - kT)$$

The higher order impulses, viz. to are neglected and only is included in linearized GMSK. As accounts for about 99% of signal energy, this leads to a minor loss in accuracy. The phase of the linearized GMSK is slightly more than that of the exact GMSK. The deviation shown by linearized GMSK (in phase and magnitude) compared to exact GMSK is within acceptable limits in GSM standard. If BT product decreases beyond 0.3, then the phase distortion increases. So, for lower BT product this linearized version of GMSK cannot be used. Linearization error in amplitude is inversely proportional to the magnitude of the BT product.

Linearization error in amplitude is inversely proportional to modulation index (h). In a typical Bluetooth application, which is based on this and uses lower modulation index (in the range of 0.28- 0.35), the error is still limited because of using higher BT product namely 0.5 [6].

II. ARCHITECTURE OF THE GENERALIZEDPARAMETRIZABLE MODULATOR

The generalized parametrizable modulator (GPM) design consists of six blocks namely, the Register Block, the Input Switch Block, the GMSK Block, the QPSK Block, the Output Multiplexer (Mux), and the Final Adder Block [7]. In the GMSK core block, a single ROM is sufficient to store the filter parameters because it involves only positive values in the filter coefficients. The GPM Register Block and the Final Adder Block have been kept common for both the modulation schemes. Signal is used for selecting one of two modulation schemes, viz. GMSK (with SEL=1) and QPSK (with SEL=0).

There is one more select line to select the appropriate filter weights in the ROM block. Input switch is used to separate the

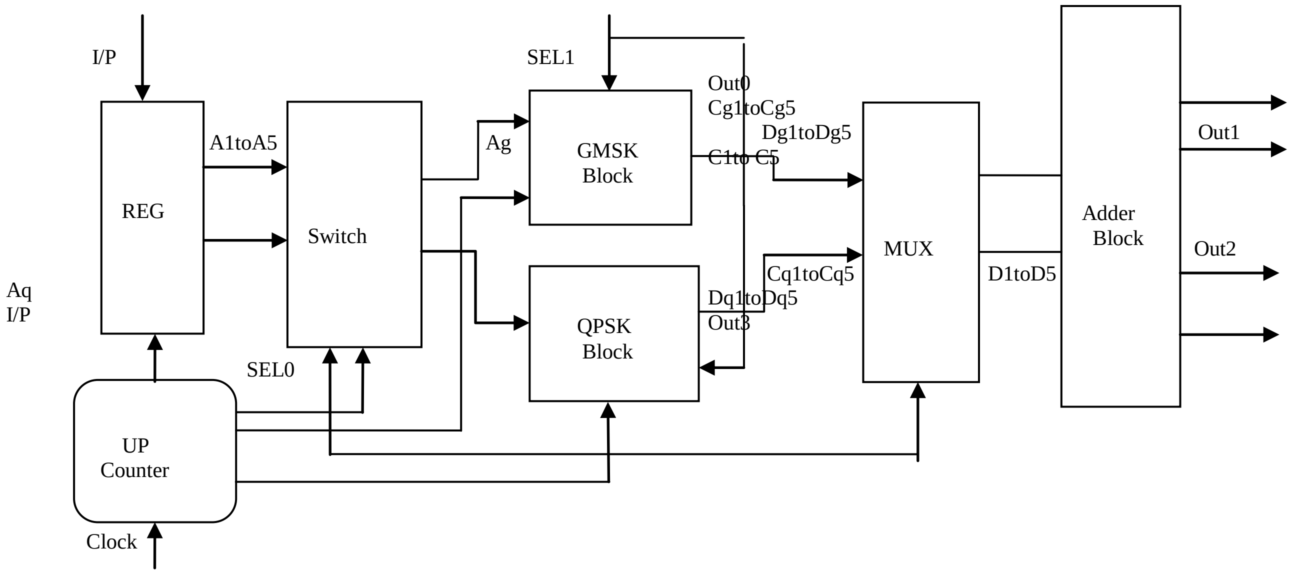


Fig.1 BLOCK DIAGRAM OF GPM

input data coming from general register based on the signal SEL. Output Mux is used to select the signals coming from the GMSK core block and the QPSK core block based on the signal SEL. The final adder block is common for both the modulation schemes. Core blocks of the two modulation schemes are separated. In this GPM, one should mainly concentrate on the distribution of clocks. Different modules run at different speeds. For example, in the case of GMSK, the ROM values are picked at a rate eight times faster than that of the arriving data. A 5-bit up-counter is used to generate different clock signals which are used to control the operating speed of the modules. Output of the up-counter is from the outputs of the up-counter, one gets the different signals with frequencies equal to one-half, one-fourth, one-eighth, one-sixteenth and one-thirty second of that of the clock.

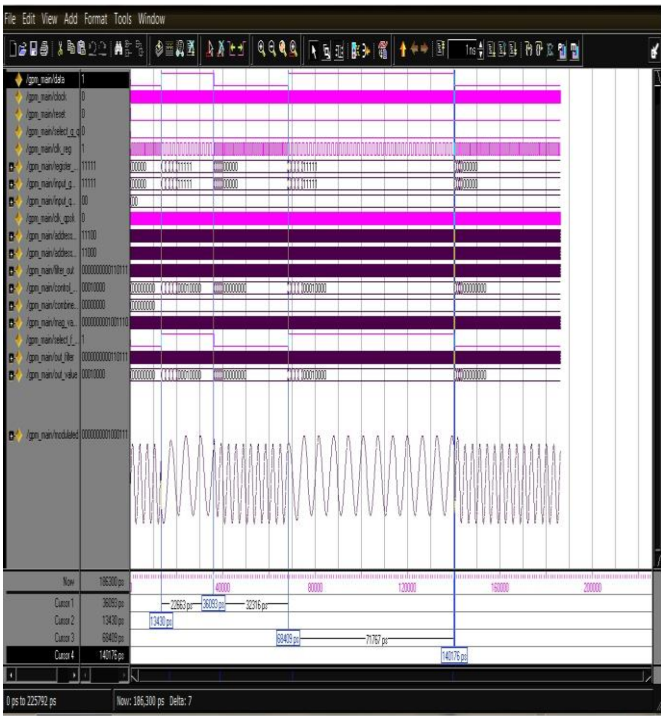
Based on the requirement, we distribute these outputs. The register block is controlled by, the clock-by-8 signal. For, the GPM is supposed to receive a bit of information at an interval equal to eight times the period of the basic clock. Clock-by-16 and clock-by-32 signals are given to the input switch block as an input. These two clocks are used for GMSK and QPSK blocks for different applications. Based on the select line, these clock signals are switched to those blocks.

For selecting the samples from the GMSK ROM block, we use the clock-by-8, clock-by-4 and clock-by-2 signals. By means of these three signals, the C0 filter coefficients are selected. For QPSK block however, we need to use clock-by-16, clock-by-8 and clock-by-4 signals (i.e.) for selecting the RRC and RC filter coefficients. In the register block, the most recent five bits - of information are stored. These five bits of information are used as input to the filter used in GMSK modulation. For QPSK modulation, one uses the first two signals and for in-phase and quadrature components.

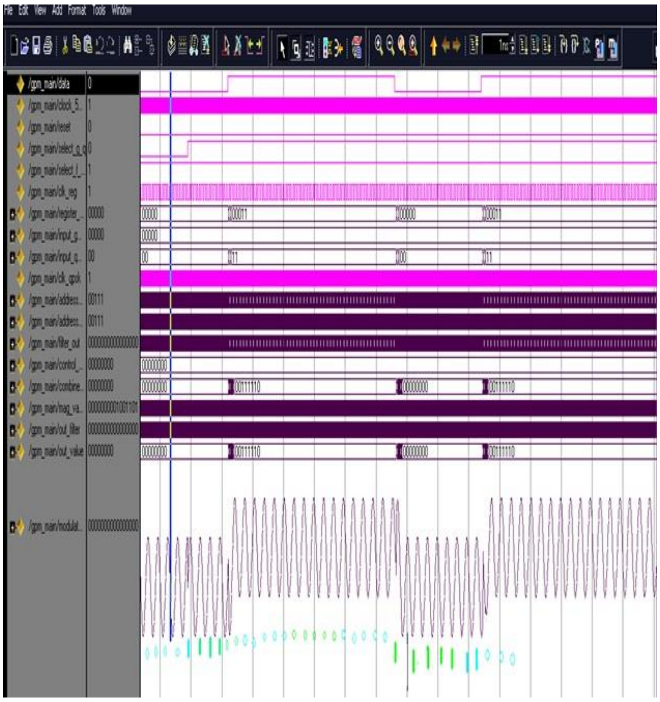
III. IMPLEMENTATION OF GPM FOR QPSK AND MSK USING XILINX & RESULT

The proposed reconfigurable modulator has been implemented in Xilinx FPGA environment and can be evaluated using Spartan 3E starter kit. The waveforms and the logic simulation results for the QPSK and GMSK modulation schemes used in the GPM using Xilinx 9.1 and Modelsim 6.2 are shown below and the device statistics shows that percentage utilization of components such as Flip flop and number of LUTs which is 1% which is suitable for the proposed GPM as in to reduce the hardware complexity of the modulator.

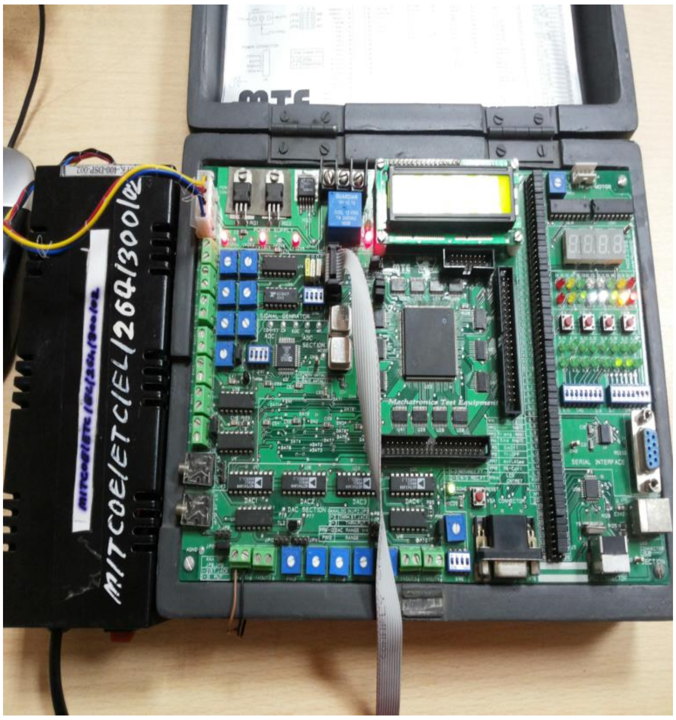
1. GMSK Simulation Result:



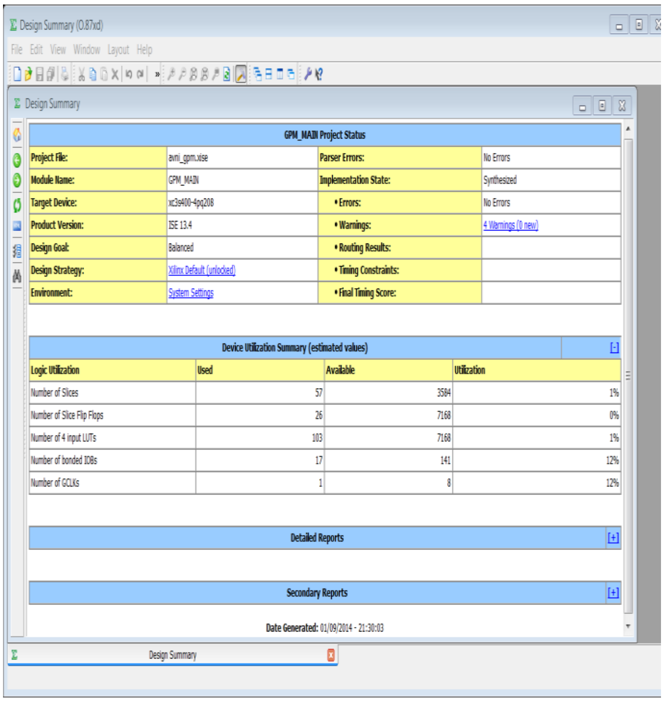
2. QPSK Simulation Result:



3. Spartan 3 Kit Results:



4. Device Utilization Summary:



IV. Conclusions

The design of a GPM suitable for multiple-standard SDR environment, that can perform GMSK as well as QPSK modulation techniques in a reconfigurable hardware structure, is presented in this paper. With a view to reduce the hardware complexity, a linearized version of inherently non-linear GMSK modulation scheme has been adopted in the present work. Performance demonstrated by the QPSK modulator is been satisfactory. Performance of the GMSK modulator in terms of eye diagram has been given. The proposed GPM, which has been found by simulation is thus suitable for being integrated in all 2G and 3G air interfaces.

References

[1] A. Wiesler, and F.K. Jondral, "A software radio for second- and third generation mobile systems", IEEE Transactions on *Vehicular Technology*, vol.51, Issue 4, pp. 738 - 748, July 2002.

[2] J. Mitola, "The Software Radio Architecture," *IEEE Communications Magazine*, vol.33, pp. 26-38, May 1995.

[3] P. Jung, "Laurent's Representation of Binary Digital Continuous Phase Modulated Signals with Modulation Index 1/2 Revisited", *IEEE Transaction onCommunications*, vol.42, no. 2/3/4; pp.221-224;1994.

[4] A. Wiesler, R.Machauer and F.Jondral, "Comparison of GMSK and linear approximated GMSK for use in Software Radio", *proceedings of the 5th IEEE international symposium on spread spectrum techniques & application(ISSSTA)'98,* vol.2/3, pp.557-560, Sep 1998.

[5] E. Buracchini, "The Software Radio Concept", *IEEE Communications Magazine*, vol.38, pp.138-143, Sept 2000.

[6] A. A. Kountouris, C. Moy, L. Rambaud, and P. Le Corre, "A Reconfigurable Radio Case Study: A Software based Multi-standard Transceiver for UMTS, GSM, EDGE and BlueTooth", *IEEE Vehicular TechnologyConference*, 2001.

[7] JagadeeshGurugubelli, IndrajitChakrabarti and SaswatChakrabarti, "Design and implementation of a generalizedparametrizable modulator for a reconfigurable radio", *IEEE Region 10 Conference TENCON*, 2009.

[8] J. Brakensiek, B. Oelkrug, M. Bucker, D. Uffmann, A. Droge, and O.M. Darianian, "Software radio approach for re-configurable multi-standard radios", *The 13th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, vol.1, pp.110 - 114, Sept 2002.

[9] E. L. Org, and R. Cyr, "Software Defined Radio Architectures for Mobile Commercial Applications", *Proceeding of the SDR 06 Technical Conference and Product Exposition*, 2006.