State of the art techniques for Transmission of FECG Signal using MIMO-OFDM

D.Preethi, R S Valarmathi

Abstract - The fetal electrocardiogram (FECG) extracted during labor or prenatal phases of pregnancy should essentially contain precise information exclusive of noises that can help doctors. The major constraint in achieving the precise information is the interference of external noises with the maternal ECG (MECG). To circumvent such noises in biomedical data processing, FIR filters using array multiplier is employed. In order to compensate the higher delay and power dissipation modified HPM based modified booth multiplier is reviewed and validated along with rest of the multipliers for better performance and high speed operations. MIT-BIH Arrhythmia Database is used for carrying out the filtering process with the ECG signal information. In continuation to the filtering of noises, MIMO - OFDM transceivers are also validated for effective transmission of extracted FECG signals. The area and power dissipation are reduced by an extent to 80.4% while simulated in Xilinx ISE 9.1 and Cadence Virtuoso.

Keywords: Fetal electrocardiogram, Programmable FIR filters, Array multiplier, HPM based modified booth multiplier, OFDM

I. INTRODUCTION

Congenital heart defects occurs because of any one of the following factors such as inherited disorder, genetic syndrome or environmental factors that needs to be periodically tracked on examining the Fetal electrocardiogram signals at the stage even when baby is in womb. It is critical and an essential requirement to prevent the heart damages caused to the fetus or the mother using the QRS peaks for obtaining the precise information about the maternal ECG (MECG) signal. The detection can be done from maternal abdomen by placing electrodes and also there are two methods as of how the examination could be carried out: (i) Ausculation and (ii) Electronic Fetal Monitoring Instruments through recording of heart beat.

A. Internal Fetal Monitoring Vs. External Fetal Monitor

Internal fetal heart rate monitoring uses a wire-like electrode that firmly clings on to either the fetal scalp or any other part of the body via a monitor. Internal monitoring is predominately used when compared to external monitoring as it provides more consistent and reliable transmission of the fetal heart rate without any disturbances such as patient movement.

External fetal heart rate monitoring uses medical equipments such as fetoscope or Doppler ultrasound. These methods are used at regular intervals during labor to count the fetal heart rate.

The non- invasive mode of monitoring FECG otherwise called as External Fetal Monitoring is commonly used until or otherwise invasive mode of monitoring is required during labour.

B. Frequency Range of Noise Signals

The sources of noise causing disturbances during monitoring of the below listed abnormalities include: (i) the inclusion of the Maternal ECG (MECG) signal with the FECG (ii) power - line interference (iii) muscle contractions (iv) respiration (v) skin resistance and (vi) instrumental noise.

The frequency of the maternal signal ranges 1.16-1.35Hz and fetal heart lies between 2Hz-2.66 Hz. For the various cardiac arrhythmias, the spectrum of frequencies ranges from 1 to 20 Hz. As the frequency constantly heaps from low to high, the amplitude decreases accordingly and diminishes at 12 Hz. In spite the spectra does not get disturbed either by high-frequency components more than 20 Hz or very low-frequency components pretty less than 1 Hz. As discussed before the signals that affect the detection of normal ECG is tabulated as below:

Table 1: Characteristics of Noises affecting FECG signal

S.No.	Type of Noise	Amplitude [peak-to-peak ECG amplitude in %]	Duration	Frequency [Hz]
1	Power line interference	50	20ms	50
2	Muscle contraction	10	50ms	10 k
3	Electrode contact	50	1s	50
4	Patient movement	500	100 - 500 ms	0.5 - 100
5	Electrosurgical	200	1 - 10s	100 k - 1 M

In section II a detailed review regarding the prominent strategies to reduce different categories of noises with different filtering procedures and transceivers are analyzed followed with designing and simulation of various

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D.Preethi, Assistant Professor, Department of Electronics and Communication Engineering, Bannari Amman Institute of Technology, Sathyamangalam, Erode, Tamil Nadu, India (Email: prettz_d@yahoo.in)

R S Valarmathi, Senior Professor & Dean Faculty Development and Industry Relations, Department of Electronics and Communication Engineering, Bannari Amman Institute of Technology, Sathyamangalam, Erode, Tamil Nadu, India (Email: atrmathy@gmail.com)

algorithms and filter architectures. The best suitable filter architecture is concluded after an insight comparison and for eliminating noise sources in section IV.

II. EXISTING METHODOLOGIES

A. Adaptive Noise Canceling (ANC)

The recording up of ECG signal of both the mother and fetal using a 4000 Hz sampling rate has been simulated for which the heart rate is advertently taken as 89 beats per minute, and the maximum voltage of the signal would be 03.50 mill volts. On comparison with the heart beat of mother, fetus will have higher rate of 120 to 160 beats per minute but has weaker amplitude than the maternal ECG. It is noticed that once the signal is measured from the maternal signal, it tends to interfere immediately with the fetal ECG signal; hence a suitable noise canceller should eliminate the influence of MECG from FECG. Since the FHR is measured from the mother, maternal noise either due to the movement or respiration that gets added on to the fetal heart rate. The only propagation path being the chest to abdomen for the maternal signal to interfere with the FECG, a FIR filter with 15 random coefficients is assumed.

A.1 Adaptive Filter

Adaptive filter being a linear filter is programmed using optimization algorithm for some applications even when some parameters are not known in prior and are varying [6]. An optimum performance can be attained on using this filter just on modifying its transfer function so that cost function can be minimized for next iteration [9]. The cost function generated is the mean square of the error signal.

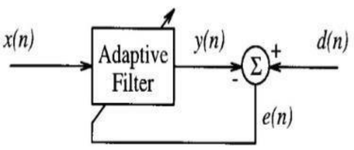

Fig.1. Representation of Adaptive filter

B. Multipliers

The following multipliers are replaced in the place of array multipliers in adaptive FIR filter to reduce area and power thereby also to increase its speed and performance.

B.1 Baugh Wooley multiplier

The Baugh-Wooley is regularly arranged signed multipliers, with a multiplier ‘A’ and multiplicand ‘B’ as in the below equations (1) and (2) which are to be multiplied to generate the end result as in equation (3) where a_i and b_i are the bits and a_{n-1} and b_{n-1} being the sign bits respectively. The product of these two terms would be 2*n bits and its binary weight ranges between 2^0 to 2^{2n-1}.

$$A = -a_{n-1}2^{n-1} + \sum_{i=0}^{n-2} a_i 2^i \text{........(1)}$$

$$B = -b_{n-1}2^{n-1} + \sum_{i=0}^{n-2} b_i 2^i \text{.........(2)}$$

$$P = A * B = (-a_{n-1}2^{n-1} + \sum_{i=0}^{n-2} a_i 2^i) * (-b_{n-1}2^{n-1} + \sum_{i=0}^{n-2} b_i 2^i)\text{.........(3)}$$

B.2 Booth multiplier

The 'M'-bit signed two's complement form multiplier with implicitly bits below the least significant bit is examined with a condition y-1=0 over a range from 0 to M −1. The product accumulator remains unchanged whenever the two bits are equal; multiplicand times 2i is either added to P when yi = 0 and yi−1 = 1or subtracted from P when yi = 1 and yi−1 = 0. The multiplication starts to begin between LSB to MSB traversing from i = 0 being multiplied with 2i.

B.3 HPM based Baugh Wooley and Booth multiplier

The High Performance reduction tree constructed with half adders and full adders with the primary partial product bits used in computing the product of the multiplier from the bits carried out of the multiplier tree. The partial products and the inverted products in Baugh Wooley multiplier using HPM [11], are manipulated using AND and NAND gates respectively whereas in the Modified Booth multiplier using HPM as in Fig. 2, encoder and decoder are used.

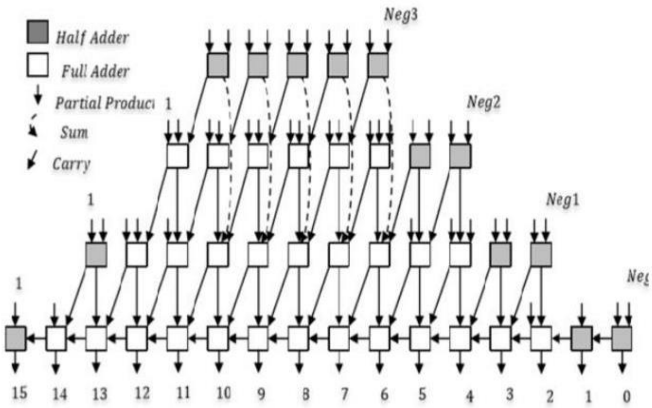

Fig.2. Representation of HPM based Booth Multiplier [11]

C. MIMO OFDM Transceiver

The transmitter kernel of the MIMO OFDM transceiver section in Fig.3 comprises of convolution encoder that combines the patterns of redundancy in order to improve the signal to noise ratio for decoding across the receiver end [12]. The complex values that are generated from interleaving are then mapped in accordance with the modulation type from QPSK mapper for transmit diversity and therefore requires two antennas. The space time diversity encoder is used for encoding the data which is later then fed to the Inverse Fast Fourier Transform (IFFT) to initiate the further processes of OFDM modulation. In order to remove burst error, interleaver is incorporated to improve the recital of error control codes. OFDM is preferred over other methods of modulation techniques as it completely eliminates the multipath effect and also removes the traces of lnter Symbol Interference (ISI). As it is the data stream that is being also transmitted and processed the information tends to overlap with the neighboring data by the incurring of noise around the transmitter section. Hence in order to avoid such interferences, guard band is introduced in between the symbols to avoid Inter- Carrier Interference (ICI).

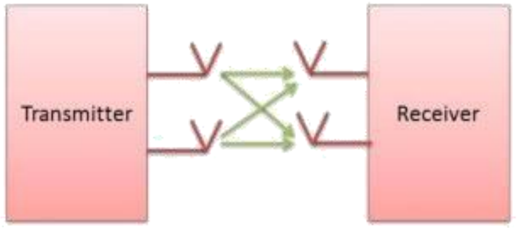

Fig.3. Representation of MIMO Section

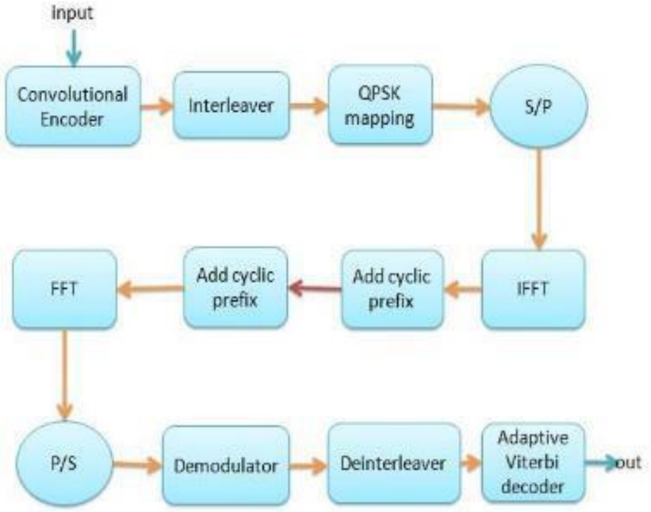

Fig.4. Block diagram of MIMO Section

Once the data is received at the receiver end, the cyclic prefix added along the transmitted data is chucked off and then fed to the FFT for the conversion process of time domain into frequency domain. All the concurrent data's that were encoded has to be likely decoded back using the Maximum Likelihood Detector. This process of detection at the receiving end is meant for detection of symbols into bit stream that was transmitted by the process of QPSK mapping. The bits are detected as '00' for I and Q values being located at quadrant l and similarly for the remaining three combinations follows. The four set of bits are once again converted into a serial bit stream and then given to a deinterleaver and followed by the retrieval of original data sequence using Adaptive Viterbi decoder.

C.1 Convolutional encoder

The convolutional input bit stream and impulse response of the encoder are the essential key parameters that decides the output performance of convolutional encoder. In order to perform the task of encoding the architecture consists of memory element 'm' and modulo-2 adder. The output from such an encoder at any cause is dependent on the present input and past output. For instance if there is an information 'i' from a total of U_i which is mapped on coded symbol 'c' of m bits by the encoder, then the code rate is calculated using the formula by R=i/m, where i and m denotes the total number of bits in the information symbol and encoded symbol respectively. The polynomial in the block diagram dictates the inter connections of the encoder to the modul0-2 adder. This encoder is used for its simpler design and sparse hardware requirements.

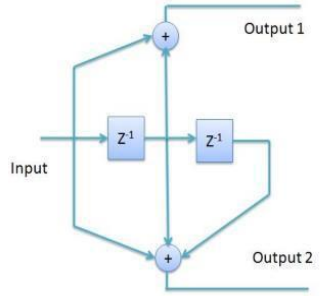

Fig.5. Graphical representation of Convolutional encoder

The Fig.5 denotes the graphical representation of a feed forward encoder with one input, two shift registers and two outputs respectively.

C.2 Interleaver

To generate equal symbols in different temporal order at the output an interleaver is required. It takes input from a predefined symbol as the input and generates output using a simple hardware circuitry. Interleaving is used to disperse bit sequence of a bit stream to mitigate presence of burst errors that is carried over during transmission. However errors sometimes tend to disintegrate the local concentration of many errors. Not limiting to any number of errors in a single code word, error correcting codes can detect and trace the errors provided they are not huge in number. The condition might occur during two different cases such as wireless communication channels and in concatenated coding as in Adaptive Viterbi decoders. The interleaving finds its application in communication systems as it demands for signal processing technique and also recently in concatenated turbo coding.

C.3 QPSK Mapping

In Quadrature phase shift keying the signal shifts are separated by 90 degree along the different state of phases. Information that is hooked on the modulator gets segregated along into two different channels. The signal shifts in increments from 45° to 135°, -45° (315°), or -135° (225°) with a difference of 90°. Two bits being simultaneously transmitted one per channel and in addition that channel does the modulation of a carrier frequency with the frequencies being same, but has a phase offset of 90°. The calculation for the effective transmission of data is analyzed using bandwidth efficiency results in two bits/second/Hz.

C.4 Deinterleaver

In deinterleaver either of the path along the transmitting or receiving end is active during any given instance of time and this is similar to the memory as in Ultra Wide Band (UWB) applications. The address across the input is same for both Deinterleaver and Interleaver having an output address for an exact data rate used for writing onto memory as sequentially read is being extracted for generating the read address. The data from Interleaver and Deinterleaver is then finally written to memory using the multiplexing technique.

C.5 Viterbi Decoder

As Maximal Likelihood algorithm is too complex to search all available paths, Viterbi algorithm performs Maximal Likelihood decoding is used as it reduces complexity, enhances the early rejection of unlike paths at each transmission stage and reduces decoding complexity on eliminating trellis path.

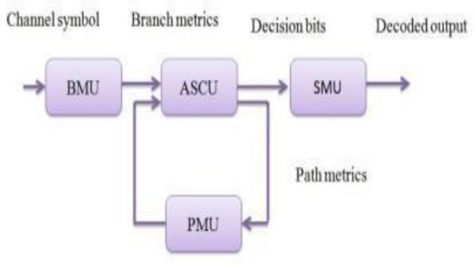

Fig.6. Block diagram of Viterbi decoder

C.6 Adaptive Viterbi Decoder

The average number of computations required per encoded bit and the required memory are drastically reduced while using Adaptive Viterbi Decoder Algorithm. Every path gets retained in memory only if its path metric falls under threshold T. The number of survivor paths is N_{max} per stage and once if it is greater than the number of retained paths T is iteratively reduced for the current stage until the total number is equal or less than N_{max}. It is used for high performance reliable communication.

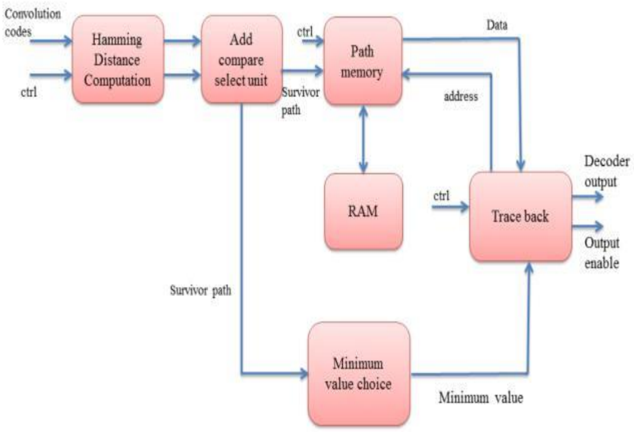

Fig.7. Block diagram of Adaptive Viterbi decoder

III. SIMULATION RESULTS AND DISCUSSION

A. MATLAB Simulation Tool

The Filter Design and Analysis Tool has an user interface from MATLAB workspace for adding, moving or deleting poles and zeros to design and analyze digital FIR or IIR filters by predefining filter specifications. Magnitude, phase response and pole-zero plots of filters are can also be analyzed in same manner. It is also used for. As shown in the above Fig. 8, the required filters designed for a required coefficient of filters are obtained based on the suitable algorithms. Linear filter using LMS algorithm and Equiripple has been allocated for numerous pass frequencies. The coefficients are extracted using FDA tool for different assumptions are coded in VHDL upon allocating storage space for memory and letting the rest of the filter design including multiplier blocks and the delay are designed.

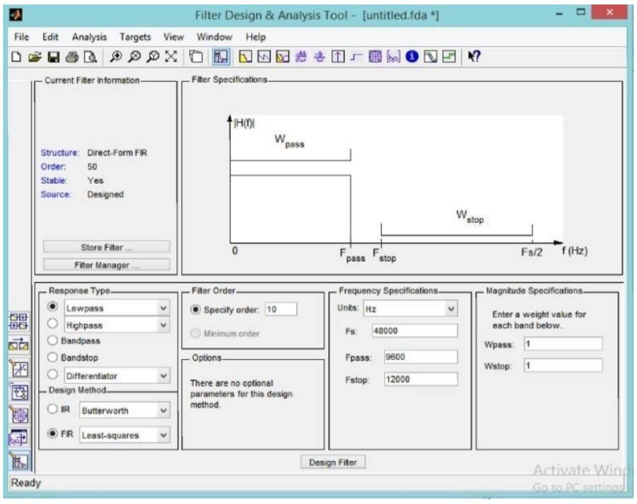

Fig. 8 Obtaining the coefficients of filter in MATLAB

Adaptive Multiband Filter

As the human ECG has different frequencies, adaptive filter provides efficient way of filtering. Henceforth multiband filters in addition to that of increase in filtration of noise provide accurate output at numerous rates of frequency ranges.

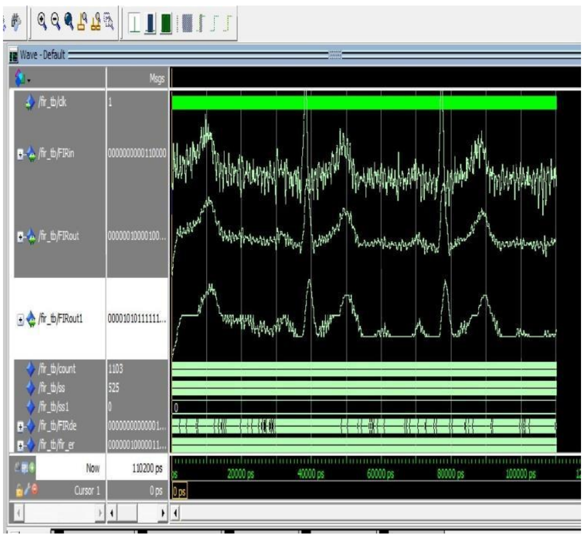

Fig.9. Adaptive Multiband filter output

In Fig.9, it is understood that compared to any other filter that is dealt the noise is reduced more efficiently using adaptive multiband as it retrieves the input signal devoid of noises. The effective filtration takes place whenever the number of levels and pass bands heaps gradually beyond threshold. The first level output signal generated is fed as an input for the second phase of filtration. Eventually the resultant has clear and accurate peaks of required ECG signal.

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Table 2: Comparison of Area and Time analysis of various FIR Filters using HPM Technique

	Low Pass filter	Multiband filter	Unsignesd Coeff. filter	Adaptive band stop filter	Adaptive multiband filter
AREA ANALYSIS					
Register	227	245	237	219	217
LUT	1808	1879	1589	1634	1622
Flip flop LUT pairs	1822	1858	1600	1648	1626
Bonded IOB	49	49	49	49	49
Fan out of non clock nets [ns]	4.21	4.19	4.16	4.27	4.31
TIME ANALYSIS					
Time [ns]	46.20	38.81	39.16	36.76	39.43

In the above Table 2, it is evident that the FIR filter using unsigned coefficients consumes less area when compared to other filters and also consumes less time to complete the process. Noise removal is good in adaptive filter design and produces efficient output. Hence there is a tradeoff between efficiency, area, time and power consumption. Whenever the above parameters are not properly chosen, effective output is less. As the preference is given for higher accuracy and efficiency in FECG signal Adaptive filters should be used predominantly.

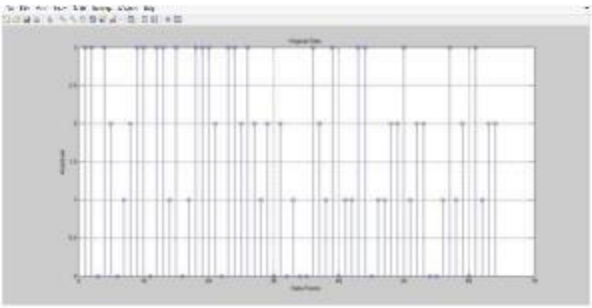

Fig.10a. Input signal

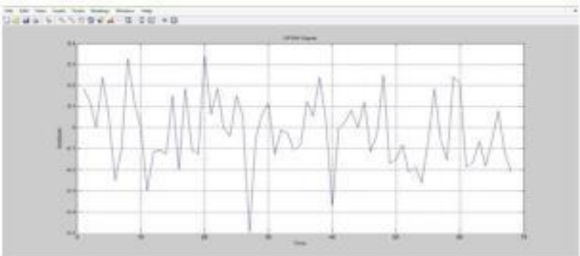

Fig.10b. OFDM Signal

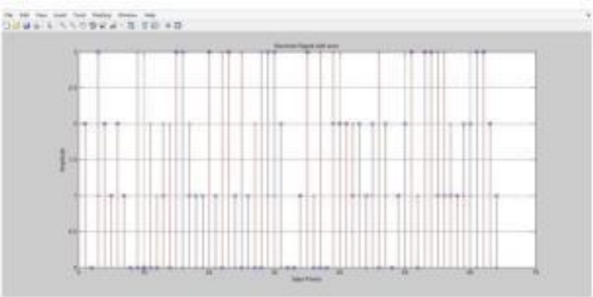

Fig.10c. Output signal with error

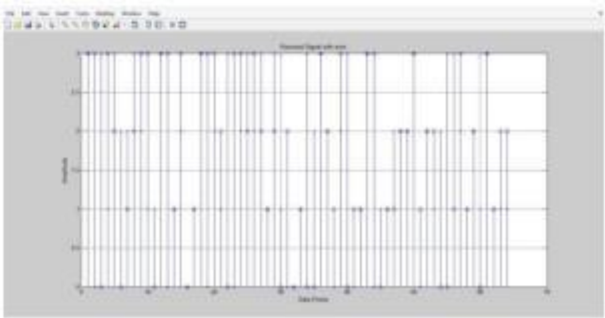

Fig.10d. Output signal without error

The figures 10a to 10d represent the output of MIMO-OFDM simulated through the MATLAB. This depicts the general process as of an input signal fed into the transceiver being decoded for error at the receiving end in order to calculate the bit error rate. It is noticed that the transmitted signal is verified against and without the noise. As discussed earlier the data rate and accuracy has increased on using Adaptive Viterbi decoder for efficient transmission.

IV. CONCLUSION

Finally, the FECG signal is extracted using adaptive multiband filter for higher accuracy on comparison with other filtering methods used and also the efficiency of the signal is calculated. Here the usual array multipliers of filters are replaced and implemented with booth multipliers so that memory requirements can be drastically reduced. Xilinx ISE 14.2 simulator is used for calculating the effectiveness of the algorithms and filter techniques. Validation of MIMO-OFDM is done and the results simulated verify the same as the binary source enters the Convolution encoder; the error correcting code avoids and completely eliminates the burst error at the transmitter. Along the receiving side, deinterleaver and Adaptive Viterbi decoder retrieves the same information that was transmitted along the channel.

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