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SPECTRUM SENSING BASED RECONFIGURABLE FILTER BANK FOR MULTICARRIER COMMUNICATION RECEIVER

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Abstract

In amulti-standard communication receiver, efficient spectrum sensing unit extract the information of multiple channels available in the wideband input signal .It is proposed that a novel method is employed to extract the required frequency band by reconfigurable polyphase filtering of the received signal and the spectrum sensing techniques is added to detect the availability of the signal in every frequency sub bands. The Spectrum sensing is adopted by verifying the energy levels of the received sub bands.This proposed reconfigurable filter bank multicarrier modulation is implemented using NI USRP 2940SDR system. This FBapproach-based receiver is performed by Xilinx IP cores of FFT. The receiver is tested to produce output for 40MHz clock rate. The proposed receiver architecture performance is implemented with LabVIEW FPGA tool.

Keywords: Polyphase filter,channelizer, spectrum sensing,reconfigurability, energy detection

I. Introduction

Software Defined Radio (SDR) is a promising technology in Signal processing applications. Digital signal processing blocks in communication systems describe the reconfigurable characteristics of the radio receiver. The wideband spectrum-sensing method verifies the status of the frequency band and thus achieves a higher throughput Wide band sensing includes multiple channels (frequency bands) of distinct bandwidths (BWs) and unknown center frequencies. Hardware implementations for wideband systems cannot keep up with demanding bandwidth requirements. Therefore, a channelizer may be used to reduce a band into sub-bands, where each of the sub-bands is processed on parallel channels. The received signal consistswith several sub-channel signals bandwidths and band locations [1] this requires the efficient digital channelizer. Filter banks in channelization play an important role in modern signal processing applications such as audio signaling and image coding due to its extraction of spectral components of input signals. As FFT is the fast computation method of discrete Fourier transform of input signals, FFT transformation is performed across all the channels for each output sample as shown in Fig.1. The polyphase structure through FFT makes effective filtering in channelization. Channelizer is designed for multi-standard operation in [2] as FRM FB and coefficient decimation-based FB. Dynamic channelizer cannot be realized with the regular filtering model. A wideband channelizer withcoefficient modulated FB has been proposed in [3]. This method consists of an analysis section anda synthesis section. The guard band is provided with minimum width as mentioned in [4] can realize dynamic channelization. The FRM technique is an efficient method for implementing linear-phase FIR filters with sharp transition bands in [5] Based on the FB, the wide band spectrum is divided in to multimirror bands, involves with sampling and narrow band filtering of the signals. The spectral leakage property is low comparedwith fast Fourier transform (FFT), then polyphase filter bank (PFB) is performed to wideband spectrum sensing[6]. Energy detection is the commonly adopted for detection of the signal and implementation is simple.The signal to noise ratio performance is poor in this method of signal detection.

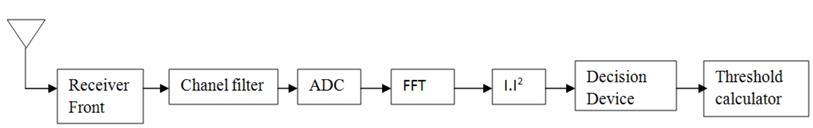

Fig. 1 Block Diagram for energy detection with FFT based spectrum analysis.

II. Proposed system

The reconfigurable and low complexity filter bank (FB) is proposed forthe effective channelization of the wideband input signal[7,8].The proposed FB structure controls thesub band BW. We focused on the detection of the multiple channels using an energy detector-based spectrum sensing implemented with the reconfigurable filter structure.

A reconfigurable FB based channelizer is designed with low complexity for the efficient multi standard communication receiver as shown in Fig.2. The filtering is performed with coefficient decimation, and interpolation in polyphase filter bank structure for the effective decimation process in every iteration. The resultant sub bands from FFT is further processed for energy detection-based spectrum sensing approach. The received signal r(n) is subdivided in to M sub-band signals by channelization process and each sub-band is reduced with the sampling rate 1/M of the incoming input signal. In polyphase structure, the filter coefficient h(n) is divided into M branches as hm(n)., the prototype filter coefficient h(n) is decimated with M to maintain the data rate in a lower level with reduced complexity. The wideband input signal is r(n), the number of sub-bands to be divided is M, and the prototype filter h(n) is a low-pass FIR filter[9,10], with N in length, represented as

$$h(n) = \{h(0), h(1), \cdots, h(N-1)\}. \qquad -(1)$$

N is an integer multiple of M,

L = N/M and L is considered as an integer. The polyphase filtering structure is designed

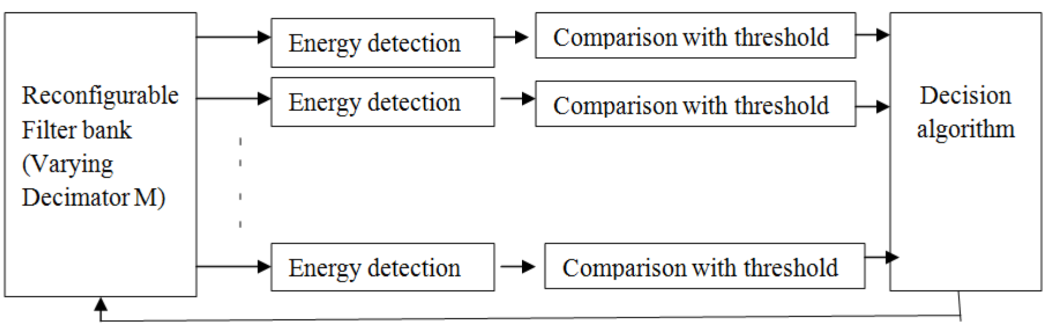

Fig.2 Block diagram of reconfigurable filtering model

for its less computational process and reduced hardware complexity. The prototype filter h(n) has a transfer function H(z), which is defined as:

$$h_m(n)=h(n)e^{j2\pi n/M} \qquad - (2)$$

$$H_m(z)= H(z\, e^{-j2\pi n/M}) \qquad - (3)$$

$$= \sum_{m'=0}^{M-1} H_{m'}(z^M) e^{-\frac{j2\pi n m'}{M}} z^{-m'} \qquad - (4)$$

III.Sub band based spectrum sensing for Reconfigurable filter bank

The received wide band input signal r(n)[7] is filtered by the proposed model, the m-th sub-band gets the received signal as Ym(l) from FFT. Each sub-band selects the same threshold value λ.in energy detection algorithm . if signal energy level Tm is smaller than λ, the sub-band status is considered as idle, represented by "0", and if signal energy level Tm is greater than or equal to λ, then it is considered as the sub-band is busy and it is occupied with energy bands, represented by "1",The above process can be interpreted with equation as follows,

$P(m)d = P(Tm \geq \lambda|H1) = P(H1|H1)$ $P(m)f = P(Tm \geq \lambda|H0) = P(H1|H0)$ [5]

$$P(H_1|H_0) \qquad P_{fa} = \text{prob}[u > \lambda|H_0] \qquad [6]$$

$$P_{fa} = Q\left(\frac{\lambda - \sigma_n^2}{\sigma_n^2/\sqrt{M/2}}\right), \qquad P_d = \text{prob}[u > \lambda|H_1] \qquad [7]$$

System Model

1. Design a polyphase Filter bank. The sub-band number of the PFB is decided by the energy level of sub bands.

2. Wideband input signal is decimated into M. Interpolate the resultant sub band signals for smoother response
3. Detect the presence of useful signal in each sub band by energy detection -based spectrum sensing technique.
4.Combine the adjacent bands which contain signal. Decimate the signal according to the combined sub-band number. M
5.The spectrum detection[11] result of each sub-band controls the adjustment of the FB division on the sub-band number M, the adjustment of the M at the next sensingtime is made and divided into three cases: increasing, decreasing or not changing.

$$\hat{P}_0 = \hat{M}_0/M = (\hat{M}_{00} + \hat{M}_{01})/M$$

$$\hat{P}_1 = \hat{M}_1/M = (\hat{M}_{11} + \hat{M}_{10})/M$$

[8]

IV. **Simulation Results:**

From the reconfigurable filtering architecture above, the computation is calculated. The multiplication is the complex and power consuming process when compared with the existing filtering structure.It is proved that the proposed method provides the best performance in multiplication complexity. The proposed receiver structure is implemented by using LabVIEW 2014 version and the corresponding bit files are generated for the USRP RIO FPGA system.The front panel of the receiver consists of the USRP Parameters, Energy Detector and Debug sub blocks.The debug part is formatted same as with the transmitter In the Energy Detectorsub block, as mentioned in Fig 4 , Pd (Detection Probability) for a specific value of PFA (False-alarm Probability) are calculated and realized.The number of subcarriers represented by N of filter bank is designed from order of the polyphasefilter. The filter impulse response for N = 64 is designed to analyze the complexity for the implementation of filter bank structure. Device utilization is analyzed for the core blocks with and without FFT and filter banks in Table 2.These values provide the FPGA[12-13] device utilization for introducing FFT and filter bank process in receiver design. The effect of PFA on the detection performance is verified for the energy detection, fixing the values of SNR to -10.4 dB and changing thePFA from 0.1 to 1 with a step variation of 0.1.Device utilization and energy consumption of receiver Design on Kintex 7 FPGA in Table II. The design's area is dominated by BlockAM usage, though the FFT core adds considerable logic usage.

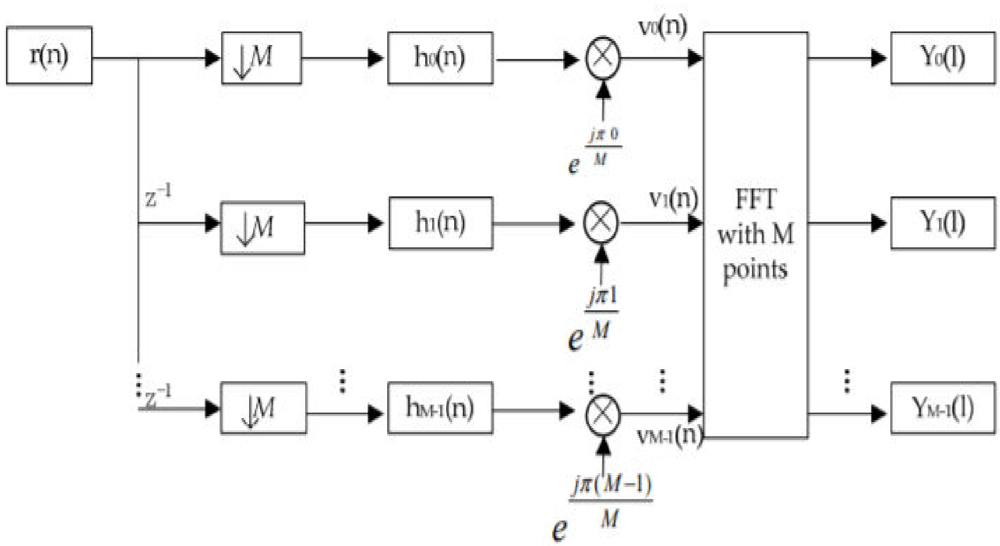

Fig.3 Polyphase Filter bank

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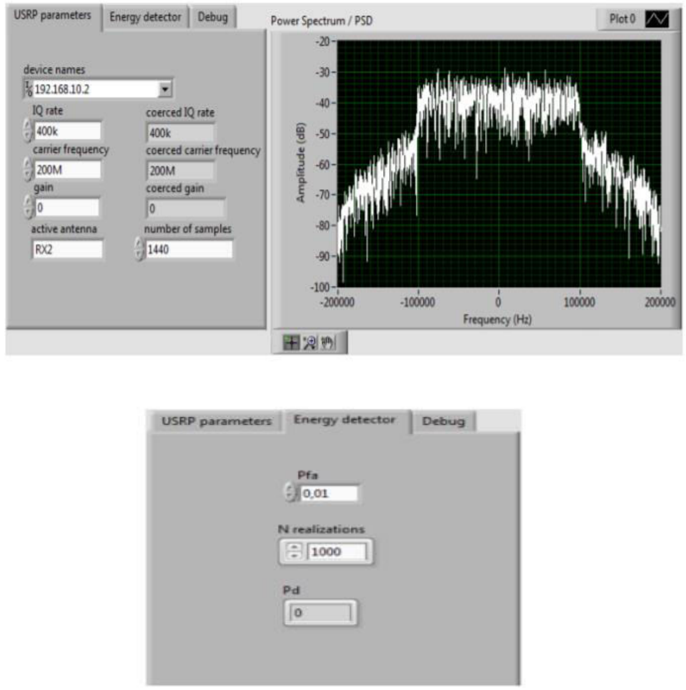

Fig.3 Device specification and receiver performance

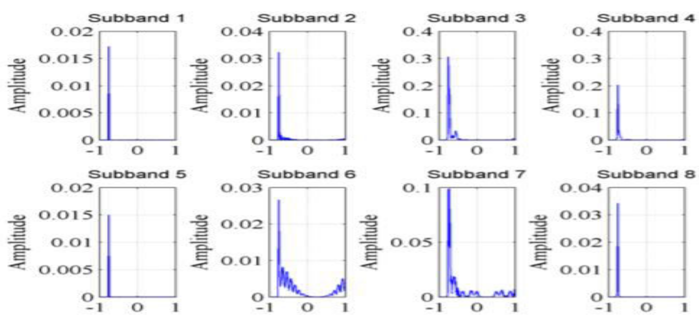

Fig.4 Output waveforms of subbands

Table 1 Receiver Design parameters

Parameter	Receiver Value
Modulation	FFT -Polyphase
Bandwidth	40 MHz
Carrier frequency	2 GHz
FFT size N	Up to 1024

Table II. Device Utilization summary

Device Resource	Without blocks	With Filter banks blocks	Total available
LUT's	28512	35462	254200
Registers	52788	58004	508400
Block RAM	103	302	795
Energy Consumption at 2 Ghz	0.276 W	0.389W	

For a 1024 band implementation. we restricted the maximum filter size with 57 taps, though we expect the clock speed to be reduced when nearing 100% usage. and the status of the signal is verified by the energy detection process is shown in front panel in fig.3 The sub bands from FFT with 8 point is shown in fig.4

V. Conclusions:

Proposed polyphase filter bank-based energy detector for detecting the sub bands of the channels present in wideband input signal. This structure involves the power spectral density calculation using fast Fourier transform . Simulation results shows that the proposed filtering structure is designed with reduced computations for the efficient usage of resources. The reconfigurability computation of the filtering method is efficient in designing the multistrand receiver system.

VI . Future work

Signal can be effectively filtered through learning model can yield a better performance of the receiver in terms of energy detection of sensing the spectrum.

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