Reconfigurable Channel Interference Reduction for Vehicular Communication Applications

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Abstract— Vehicular Communication systems, an application of wireless communication is an increasing area of communication between the vehicles and other roadside infrastructure in which allocation of wireless channels are used to share information among vehicles and infrastructure and hence these channels are used for the development and implementation of vehicular communication systems. The 10 MHz wide channels in 5.9GHz spectrum band are reserved for this purpose by two main protocols the WAVE standards proposed by IEEE in the United States and ETSI ITS-G5 in Europe. But still the cross –channel interference affect the vehicular communication systems. So to reduce these problems, this paper presents the implementation of two-stage low pass equiripple FIR filter, target to be integrated with digital baseband receiver chain of vehicular communication platform. The proposed filter has been developed using Matlab and Xilinx DSP Tools and implemented with XST software using Spartan 3E and Virtex 2p FPGA device to ensure the minimum delay generated in operation and to show the effectiveness of the proposed filter. The results show that the processing speed is efficiently optimized up to 19.70 % for stage 1 and 10.50 % for stage 2 using virtex 2p over Spartan 3E with maximum area utilization.

Keywords- *Intelligent Transportation Systems; Vehicular Technology Society; Inter Channel Interference; FIR Filters; MATLAB.*

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I. INTRODUCTION

Vehicular Communication System plays a major role in the Intelligent Transportation System (ITS) which enable the users to make safer and effective use of transport networks and aim to provide innovative services relating to different modes of transport and traffic management. In short, its main aim is to enhance the road safety and traffic efficiency. Vehicular networks help in increasing the time available to make decisions or helps to react in case of traffic hazards by enhancing the driver's field of view. Wireless Communication technologies plays an important role in developing Intelligent Transportation System, for instance, radio modem communication on Ultra High Frequency and Very High frequencies are used extensively for short and long range communication within ITS. There are two main protocols for short range and long range communication that enable exchange of data between vehicles and among the vehicles and the road-side sites. Short-range communications can be accomplished using IEEE 802.11 protocols, specifically WAVE standard being promoted by the Intelligent Transportation Society of America and the United States Department of Transportation..Long communications can be accomplished using infrastructure networks such as WiMAX (IEEE 802.11p), Global System For Mobile Communications, or Third Generation. Long-range communications unlike the short-range protocols require vast and very costly infrastructure. These protocol stacks rely on IEEE 802.11 p standard, a modification to the IEEE 802.11 Wi-Fi reference. For example,to reduce the effects of Doppler shift and multipath propagation bandwidth is reduced from 20 MHz to 10 MHz. The two standards Wireless Access in Vehicular Environments protocol stack in USA and the European Telecommunications Standards Institute in Europe, differ in ITS reference architecture but both can have multi-channel operations example few channels are used for safety-purpose and others are assigned for non-safety applications like commercial services. Limited spectrum leads to simultaneous communications in the surrounding channels causing adjacent channel interference. So the best remedy will be to avoid the use of nearby channels without taking into account the effect of spectrum resources wasting. Therefore to reduce Adjacent Channel Interference, in this paper we will use the design of a two stage Finite Impulse Response (FIR) filter, which helps in the reduction of the unwanted components of the received signal [1, 2].

Adjacent Channel Interference badly affects the transmission and receiving operations in case of the nearby channels. Therefore the Federal Communications Commission (FCC) in the United States and the European Conference of Postal and Telecommunications Administrations (CEPT) in Europe, allocated a dedicated spectrum band at 5.9 GHz (Fig. 1) so that the vehicular communications do not suffer from any type of interference from unlicensed devices. . Adjacent Channel Interference does not allow the use of adjacent channels simultaneously and its impact mainly depends on the considered configuration, transmitted power, transmitter-to-

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receiver and interferer-to-receiver distance ratio. The Adjacent Channel Interference problem mainly occurs in dual-radio device having adjacent located antennas operating simultaneously. Therefore, it is very necessary to mitigate the effects of Adjacent Channel Interference.

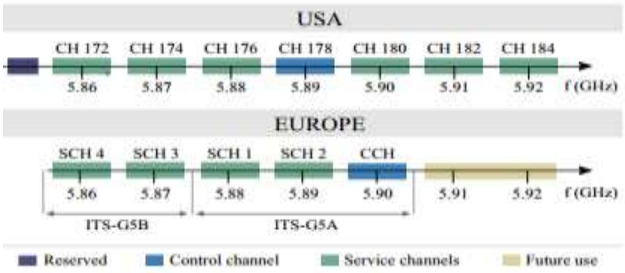

Figure1 . Spectrum allocation for vehicular communication [2].

Allocation of spectrum- - In Europe out of 50 MHz wide spectrum 30 MHz is given to ITS G5A services such as road safety measures, and 20 MHz is given to ITS G5B for general purpose services, while America has allocated 75 MHz spectrum for IEEE wave operation having seven different channels and a control channel is provided for implementing road safety and control measures. The remaining channels are designated as Service Channels SCH. The channel that is used for road safety and efficiency is SCH1. In America, in order to reduce the capacity for road safety messages SCH 172 was allocated and in Europe it is compulsory to have two radios in each vehicular communication platform, so that at least one radio always tuned to the dedicated safety channel [3, 4].

The multi-channel architecture is useful in context of output performance, but the contemporaneous use of adjacent channels may led to interference. This is called adjacent channel interference and may detroit the effective communication on a particular channel by interfering signals from the nearby channels. As a result, it is necessary to reduce the effect of ACI in vehicular communication radio links. Therefore for this we will use design of a two stage Finite Impulse Response (FIR) filter that helps in the reduction of the unwanted components of the received signal. At the same time, it also take into consideration the utilization of very few digital hardware and only a small delay is introduced in the receiver chain of the ITS-G5 station. There are some major harmful consequences of ACI increased packet error rate (PER) that lead to SINR (Signal-to-Interference plus Noise Ratio) degradation, lower transmission.

In the first case, packets from the adjacent channels interferes with packet received by a node in the channel; as a result, this will cause the loss of packet and large values of PER which may result in incorrect processing. The second mentioned effect occurs when a node misperceives the channel to which it wants to send the frame as busy due to simultaneous transmission in the adjacent channel. This channel busy indication is given by the Clear Channel Assessment (CCA) mechanism. ACI mainly depends on the configuration, transmission power, transmitter-to-receiver to interferer-to-receiver distance ratio. ACI occurs in ITS-G5A spectrum if data is send to SCH2 and CCH or SCH1 channels simultaneously. To reduce ACI some remedies have been suggested such as controlling the transmission power, avoiding communications in adjacent channels, advancement in the spectral mask i.e., spectrum emission mask defines the out-of-band energy allowed for a transmitting device. This spectral mask is defined up to 15 MHz far from the center frequency. But all these remedies have pitfall for instance, transference power reduction may led to coverage holes, hostile transmissions results in resource wastage, using spectral mask would be costly [5]-[8].

II. MULTIRATE FILTER

Advantages of using finite impulse response Filters-The benefit of using finite impulse response filters is that they have finite response and are linear phase filters that is their phase delay and group delay are independent of the frequency. Their hardware implementation is very easy and simple as well as the methods that are used to calculate the filter coefficients are linear and very efficient. They are very well suited for multi-rate applications and they can be implemented using fractional arithmetic also. Because of the linear phase they are stable filters. They are simple to implement. On the whole in the Digital Signal Processing processors a single instruction is used for the FIR filter coefficient computation. The Digital Signal Processing filters must be implemented with a fewer number of bits that is finite arithmetic. The use of this fewer number of bits can cause adverse problems due to the use of feedback in case of infinite impulse response filters, but finite response filters can be implemented with fewer number of bits, as they do not use feedback and can help the users to face no practical problems in designing these filters. In many applications we require that signals at one sampling rate required to be changed into another signal at another sampling rate. For instance, in audio systems, three different sampling rates are employed: 39 KHz in broadcasting, 47.1khz in digital compact disk and 49 KHz in digital audio tape and many different applications as well. Now sampling rates conversions of these signals in three alternate sampling rates is required in many situations [9]-[11].

The two basic sampling rate changing devices are used in addition to conventional adder, multiplier ,look up tables etc. for altering the sampling rate. The process of increasing sampling rate is called up sampling and the process of decreasing the sampling rate is called down sampling. But after up sampling the spectrum band limited to the lower frequency region does not look like low frequency spectrum due to the addition of zero valued samples between non –zero samples of baseband signal (original signal). This process is called imaging because we get an additional image of the input

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spectrum. Therefore we have to use an additional low pass filter to remove the additional images and fills in zero valued samples with interpolated sample values. Now this low pass filter along with the up-sampler is called Interpolator. Similarly while down sampling there is a problem of aliasing. Similarly we have to use low pass filtering to remove the effect of aliasing. This low pass filter along with down sampler is called Decimator. Now based on the previous discussion we have concluded that the signals in the adjacent channel could adversely affect the messages at the receiver end. Therefore there is a need to filter the interfered signal in order to increase the probability of correct message received and to avoid the false blocking transmission effect. Therefore in this paper, we will define design of two stage low pass filter finite impulse response equiripple filter so as to filter the interference due to the adjacent channels [12]-[15].

The first stage constitutes an interpolated finite impulse response filter(IFIR), which is more efficient than a simple finite impulse response filter, since it can achieve steeper slopes and less distortion with the same filter order and also it helps in reducing memory and computational requirements. However, Interpolation can results in undesired pass bands. So there is a requirement of another low-pass filter to eliminate unnecessary pass bands. Now second low-pass filter is not so powerful, that is need a lower filter order, and it could be implemented with polyphase decomposed architecture(DFIR). The advantage of polyphase architecture is that it helps to reduce the memory and computational requirements especially when convolution is performed after down sampling that is consuming few FPGA resources and taking benefit of the decimation factor of 4 that could be applied to the I/Q samples [16].

III. PROPOSED DESIGN SIMULATION

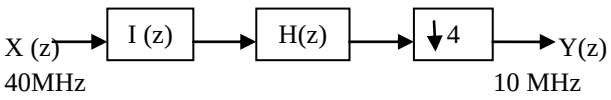

Figure2. Two stage FIR Equiripple Low Pass Filter

The signal X(z) represents the digital raw I/Q samples at the FPGA input (fig.2). I(z) corresponds to the impulse response of Interpolated FIR (IFIR)filter, that results in the narrow transition band . The second stage consists of the polyphase decomposed filter H (z), taking advantage of the decimation factor of 4, that aims to eliminate unnecessary pass bands because of interpolated filter. Finally,Y(z) represents the filtered output that will be given to the digital receiver chain. Firstly we will design the filters in MATLAB to find out the filter coefficient and try to do its FPGA implementation and try to find out the number of adders, multiplers,look up tables and time delay units needed for its hardware implementation. First a simple low pass FIR equiripple filter is designed without applying an interpolation factor and then an interpolation factor of 3 is applied. The complete specifications used in the fdatool for this filter with minimum order are presented in Table I.A pass band frequency of 4.14 MHz was specified instead of 5 MHz, so as to reduce cross channel interference. A minimum filter order of N=29 was obtained with the specifications given in Table1.The frequency response of the IFIR filter is presented in Fig. 3.

TABLEI. IFIR PARAMETER

RESPONSE TYPE	LOWPASS
Filter order(minimum order)	29
Design method	FIR equiripple
Sampling frequency (Fs)	40 MHz
Absolute pass band	3*4.14 MHz
Frequency(Fpass)	12.42 MHz
Normalized pass band	3*0.207 Π rad
Frequency(wpass)	0.621 Π rad
Absolute stop band	3*4.88 MHz
Frequency(Fstop)	14.64 MHz
Normalized stop band	3*0.244 Π rad
Frequency(wstop)	0.732 Π rad
Pass band attenuation(Apass)	0.5 dB
Stop band Attenuation(Astop)	40 dB

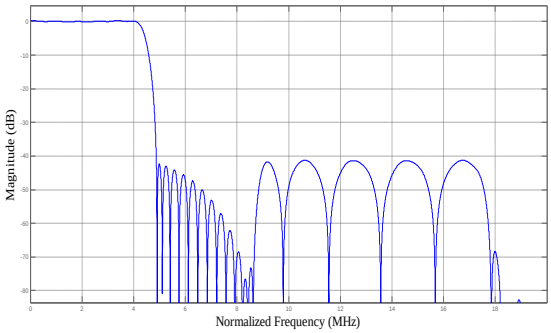

Figure3. Magnitude Response of IFIR

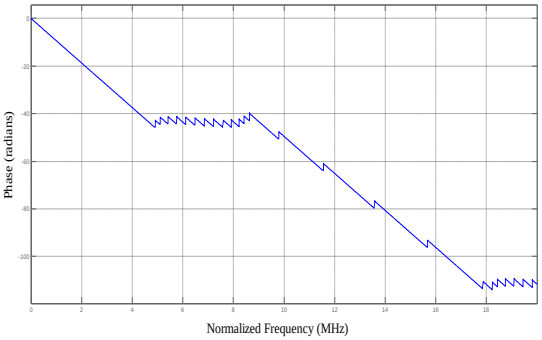

Figure4. Phase Response of IFIR

The undesirable pass bands resulting from the interpolation process can be easily noticed, occupying a baseband spectrum between 0.45 and 0.9 π rad/sample in normalized units. Now, these undesirable pass bands have to be eliminated by the second low-pass filter H(z). This filter was also created in fdatool with the specifications given in Table II. In this case, a FIR Equiripple filter of order N=7 is designed so as to eliminate the replicas starting at 9 MHz The frequency response of this second filter is shown in Fig. 4.

From the fig 4. it can be seen that the transition band is more relaxed and the attenuation in the stop band is lower than the case of the IFIR filter, because a lower filter order of 7 was used. By using a polyphase decimator filter the filtering operation can be performed at 10Msps instead of 40 Msps.

TABLE II. DFIR FILTER PARAMETERS

RESPONSE TYPE	LOWPASS
Filter order(minimum order)	7
Design method	FIR equiripple
Sampling frequency (Fs)	40 MHz
Absolute pass band frequency (Fpass)	4.14 MHz
Normalized pass band frequency (wpass)	0.207 Π rad
Absolute stop band frequency (Fstop)	8.42 MHz
Normalized stop band frequency (wstop)	0.421 Π rad
Pass band weight value (Wpass)	10
Stop band weight value (Wstop)	1

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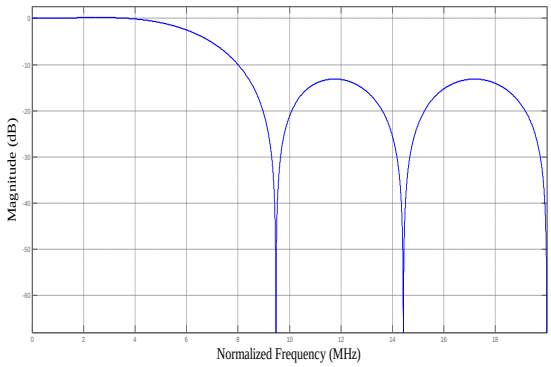

Fig 5. Magnitude Response of DFIR

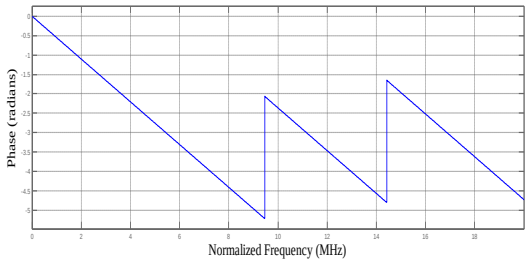

Fig 6. Phase Response of DFIR

IV. DESIGN SYNTHESIS

This two stage low-pass filter design shown in fig. 2 could be easily implemented in hardware (FPGA) using simple processing blocks, like adders, multipliers and registers for the time delays. To find the maximum operating frequency and resources used, the two stage filter is implemented on Spartan 3E and virtex 2p FPGA device using Distributed Arithmetic technique. The performance of proposed design with Spartan 3E and virtex 2P has been shown.

TABLE III. IFIR PERFORMANCE COMPARISON

Device Utilization Summary				
	Spartan 3E		Virtex 2p	
Logic Utilization	***Used/ Available***	***Utilization***	***Used/ Available***	***Utilization***
Number of slice flip flops	378/4,896	7%	476/2,816	16%
Number of 4 input LUTs	1,867/4,896	38%	1,958/2,816	69%
Number of occupied slices	1,204/2,448	49%	1,282/1,408	91%
Total no. of 4 input LUTs	1,873/4,896	38%	1,962/2,816	69%
Number of bonded IOBs	51/66	77%	51/140	36%
Maximum operating frequency	87.896MHz		109.464MHz	

TABLE IV. DFIR PERFORMANCE COMPARISON

Device Utilization Summary				
	Spartan 3E		Virtex 2p	
Logic Utilization	***Used/ Available***	***Utilization***	***Used/ Available***	***Utilization***

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Number of slice flip flops	417/4,896	8%	416/2,816	14%
Number of 4 input LUTs	523/4,896	10%	520/2,816	18%
Number of occupied slices	385/2,448	15%	385/1,408	27%
Total no. of 4 input LUTs	537/4,896	10%	534/2,816	18%
Number of bonded IOBs	53/66	80%	53/140	37%
Maximum operating frequency	147.602MHz		164.935MHz	

After implementing the design using ISE software, timing simulations can be performed on the proposed design.The waveforms gives the information about the delay constraints of the circuit and also ensures that the circuit performs as is expected. It helps in verifying the circuit and also ensures that there are no faults present in the design.

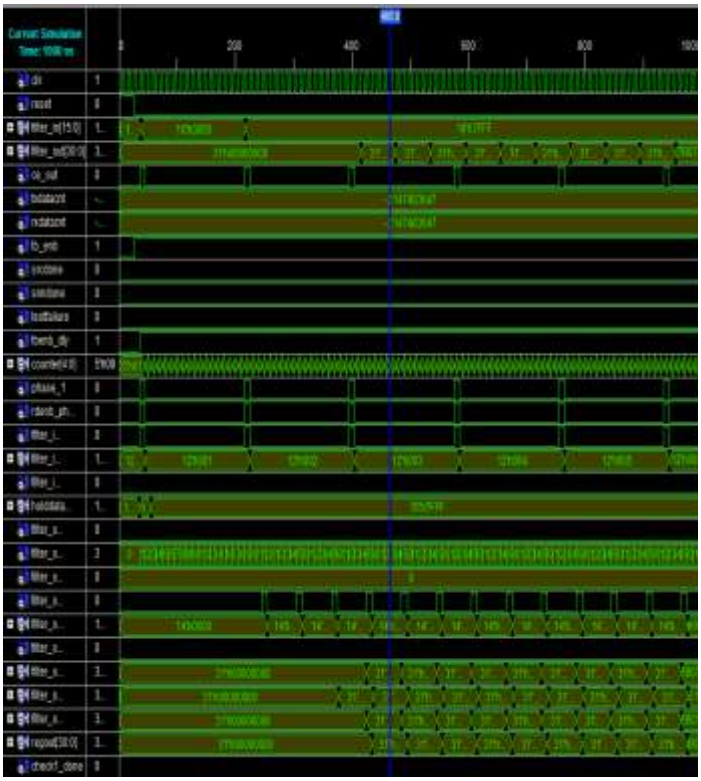

Fig 7. Waveform of IFIR

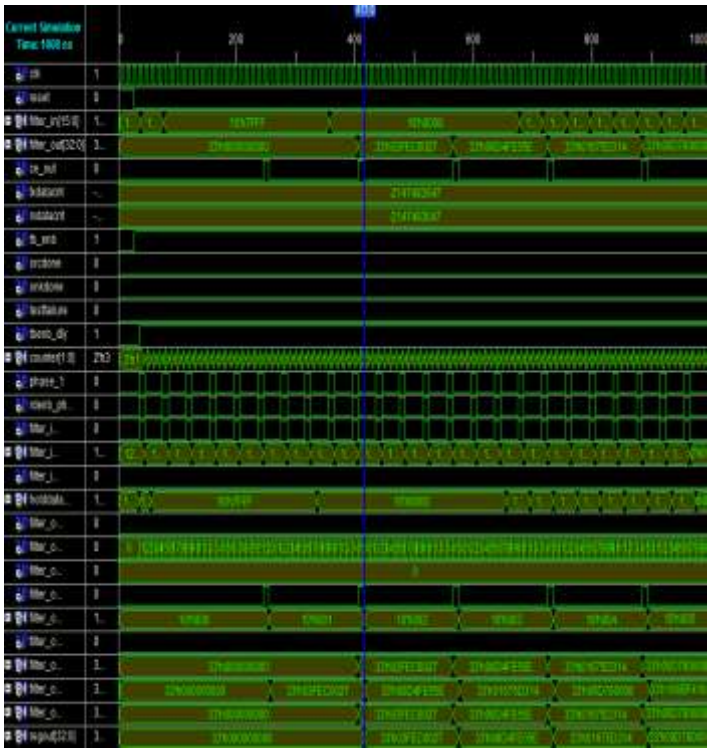

Fig 8. Waveform of DFIR

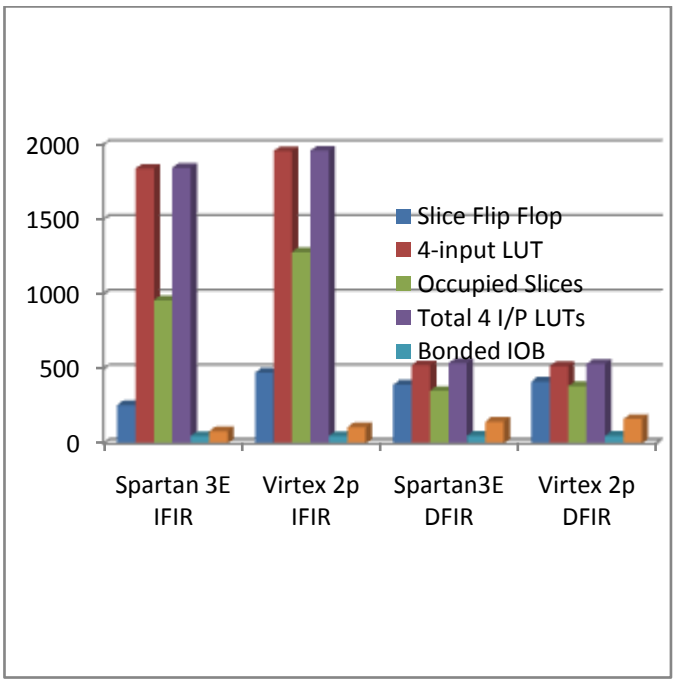

Fig 9. Comparison Bar Graphs

V. CONCLUSION

In this paper, a two stage FIR equiripple filter is proposed for vehicular communication systems. An interpolated FIR filter was designed followed by a decimated FIR filter and it can be seen that the transition band is more relaxed and the attenuation in the stop band is lower than the case of the interpolated filter .. The results are simulated and tested using Xilinx DSP tool. The two stage filter is synthesized on vertex

2p based target device using distributed arithmetic technique. The results show that stage 1 of the two stage filter can operate at a maximum frequency of 109.464 MHz and stage 2 can operate at a maximum frequency of 164.935 MHz covering maximum area to provide area effective solution for vehicular communication systems.

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