Design and Performance Evaluation of Semi-Adaptive 7.8-8.2 GHz Digital Band Pass Filters for SAR Applications

P Yadav[1], A Khare[2] and K Parandham Gowd[3]

[1]Dept of Electronics and communication, ASCE, Bhopal, India- 462031
[2]Dept of Electronics and communication, UIT, RGPV, Bhopal, India – 462031
[3]Aisect University, Bhopal-Chiklod Road, Raisen, Bhopal, India

ABSTRACT

Technologies have advanced rapidly in the field of digital signal processing due to advances made in high speed, low cost digital integrated chips. These technologies have further stimulated ever increasing use of signal representation in digital form for purposes of transmission, measurement, control and storage. Design of digital filters especially adaptive or semi adaptive is the necessity of the hour for SAR applications. The aim of this research work is to design and performance evaluation of 7.8 – 8.2 GHz Bartlett, Blackman and Chebyshev digital semi adaptive filters. For this work XILINX and MATLAB softwares were used for the design. As pert of practical research work these designs were translated using FPGA hardware SPARTAN-3E kit.

These were optimized, analyzed, compared and evaluated keeping the sampling frequency at 20 GHz for 64 order. These filters designed using software were tested by passing a sinusoidal test signal of 8 GHz along with noise and the filtered output signals are presented. Signal to Noise ratios were evaluated, plotted and comparative analysis carried out in this paper.

Keywords – Digital filter, XILINX and MATLAB softwares, Field Programmable Gate Arrays (FPGA), SPARTAN-3E, DSP Chips, DIP switches

1. INTRODUCTION

The extraordinary development in the field of high speed, low cost microelectronic digital IC's over the past few decades has stimulated an ever increasing use of signal representation in digital form for such purposes as transmission, measurement, storage and control. The conversion of a continuous signal to digital form makes possible the numerical manipulation of the data by IC's which is known as digital signal processing which is utmost necessary in the field of synthetic aperture radar(SAR) applications.

For remote sensing and detection applications digital signal processing concerns the techniques of processing the data to remove, for example, unwanted noise components, before the signal is reconstructed into analogue form, known as digital filtering , which is of interest in this research paper.

For real time operation, the complexity of the digital signal processing algorithm is limited by the condition that the numerical manipulation to determine each output sample must be performed in less than the sample period. Thus the design of a real-time filtergenerally involves a compromise between the complex requirements for a complex algorithm and a high sampling frequency.

SAR data is required to be processed in real time, hence these filters are required to operate in real time.

The possibility of low-cost, real-time digital filtering first emerged in the 1970s when general purpose microcomputers were introduced. The early digital filters, however, had limited speed and precision, which restricted their use to low-frequency applications and simple algorithms. In the 1980s, higher cost special purpose known as DSP chips were introduced, which contained much faster arithmetic units and on-chip memory for storing filter coefficients and data. In some cases, on chip A/D and D/A converters were included and subsequently rapid improvements in speed and complexity were made possible by ICs, thus resulting in design of digital filters of today. FPGA series of kits availability clearly helps researchers for taking up practical designs of semi adaptive band pass filters from lower to higher frequencies.

2. PROPOSED DESIGN METHODOLOGY

2.1 Design based on software Principles.

The simulated design methodology is as shown in fig.1. The design process involved the following steps:

(i) MATLAB software tool is used to generate the coefficients required for the operation of the filter.

(ii) Xilinx software tool was used to design the filter.

(iii)Using this research methodology three types of filters namely, Bartlett, Blackman and Chebyshev Finite Interval Response (FIR) semi adaptive digital band pass filters for 7.8 – 8.2 GHz were designed.

(iv) Filter response was derived for the sampling frequency of 20 GHz of order 64.

(v) MATLAB software program was applied for calculating and plotting of SNR

The (FDA) Filter Design and Analysis tool in MATLAB provides the option to design the digital filter to offer the respective response and coefficients to be implemented within the design using VHDL. Filter design can be carried out often selecting various options available in FDA tool for generation of required coefficients for the respective filter from the target menu using the C header option of the FDA tool.

The generated coefficients in the C header files are then used in the VHDL file for the digital filter designing which is to be convoluted with the sampled data of SAR.

2.2 Design based on Hardware principles.

The software based design methodology described above was translated on FPGA kit using SPARTA-3E for the practical experimental work. The inputs and outputs were taken on digital storage oscilloscope. In this research work the following practical circuit design steps was carried out as per methodology shown in Fig.2. The circuit designed using the SPARTAN Logic IC X-C3S, a seven segment display, DIP switches is as shown in Fig.3.

(i) Using this FPGA kit three types of filters namely, Bartlett, Blackman and Chebyshev Finite Interval Response (FIR) semi adaptive digital band pass filters for 7.8 – 8.2 GHz were practically designed.

(ii) The SPARTAN Logic IC contains $4X10^6$ logic gates and has 208 pins. 8 DIP switches were incorporated for selecting various combinations such as frequency of the filter, sampling rates and input signal.

(iii) 16 bit A/D and D/A converters are used for conversion and reconstruction of samples.

(iv) This filter was integrated into the circuit testing system as shown in fig.4.

(v) Here a low power test signal (-5dB) of 8 GHz was mixed with AWGN noise and this mixed signal was passed through designed band filters namely Bartlett, Blackman and Chebyshev for the frequency 7.8 – 8.2 GHz.

In the hardware set up out of 8 DIP switches two are used for input/output, two are for selecting sampling rate and four switches for selecting filter coefficients. These four switches with 16 bit data it is possible to generate 64 sets of filter coefficients.

This technique of using Field Programmable Gate Array with DIP switches as shown in Fig. 4 for selecting sampling rate for noise, test signal and various filter coefficients can be termed as a concept of semi-adaptive filter design. With this semi-adaptive technique depending on the test signal and noise condition particular set can be recalled there by increasing the signal to noise ratio for SAR to enable better detection. Here simulated and generated SAR signals accompanied with random noise is sampled at a frequency of 20 GHz.

Here SPARTAN-3E was used, configured in designing the 3 types of digital filters in this paper. The achieved filter circuit is as shown in figure.3.

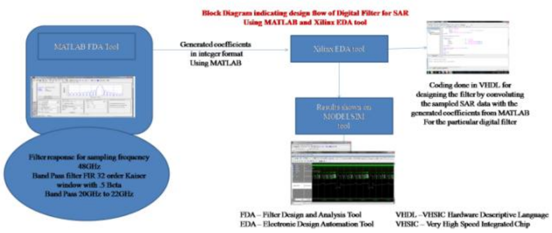

Figure 1. Block diagram of the Design using software methodology.

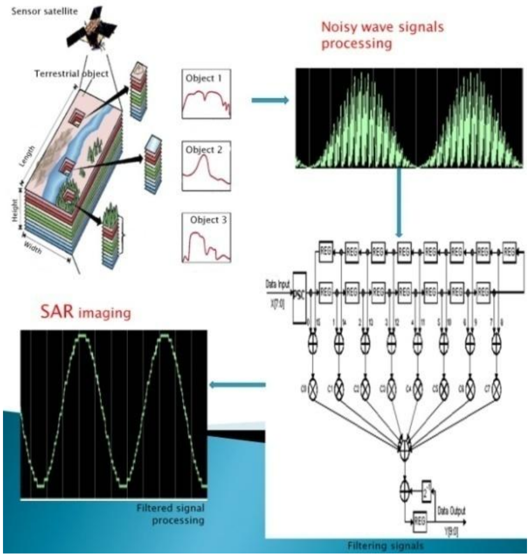

Figure 2. Block Diagram of the Design using Hardware methodology.

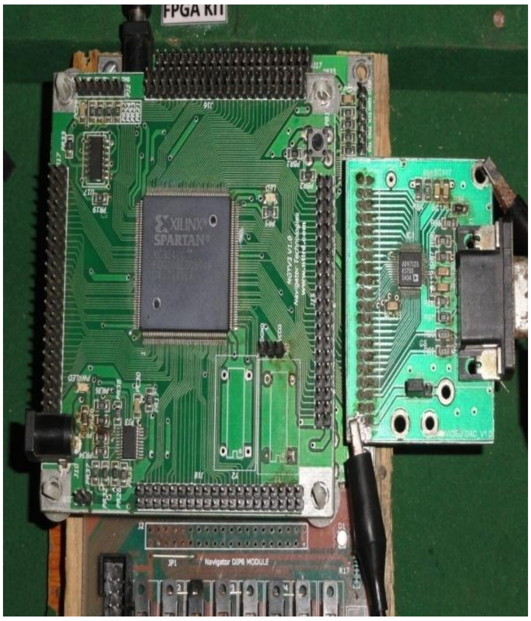

Figure 3. Designed circuit using FPGA kit.

3. RESULTS, ANALYSIS AND DISCUSSION

Block diagrams used in these designs by software and hardware are as shown in figures 1 and 2 respectively. The designed circuit and integrated experimental setup utilized for this research work are depicted in fig. 3 and 4 respectively. The frequency responses of Bartlett, Blackman and Chebyshev FIR band pass filters of order 64 for a sampling frequency of 20 GHz are as shown in figures 5, 6 and 7 respectively. The original sinusoidal test signal of 8 GHz was passed through this 7.8 – 8.2 GHz digital band pass FIR filters of Bartlett, Blackman and Chebyshev of order 64 which was designed using XILINX and MATLAB softwares are as shown in Figures 8, 9 and 10.respectively. The figures 8, 9 and 10 also show the SNR improvement versus iteration number calculated and plotted for Bartlett, Blackman and Chebyshev types of filters.

Practical experimental set up was used to determine various bands at lower frequencies from 190 to 1620 KHz. Though the GHZ range filters are still in evaluation for the system designed using hardware. In this paper one practical result for 380-400 KHz semi adaptive band pass filter, designed using hardware is included in figure 11. Figure 11 shows the test signal of 390 KHz with noise and filtered signals obtained from practical experimental set up using FPGA kit (SPARTAN-3E kit) observed in a two channel digital oscilloscope for the band pass filter of 380-400 KHZ..

It is clearly observed from figure 8 that Bartlett type of digital FIR band pass filter clearly suppresses the noise and the output signals passed with and without noise are exactly comparable. The observations from figures 9 the Blackman filter and 10 the Chebyshev filter indicate that noise is not suppressed completely and output is seen with some noise components and far inferior to Bartlett type of filter of the same design.

From this figures 8 for 7.8-8.2 GHZ filter and figure 11 for 380-400 KHz filter, both are of Bartlett types designed using software and hardware respectively, it is clearly seen that noise is suppressed and the test signal has been passed. The figure.11. shows the input test signal of 390 KHz and filtered output signal which was passed through the 380-400 KHz filter which was designed using SPARTA 3 E kit with logic gates observed in a two channel digital storage oscilloscope. These filters have rejected the noise and are comparable with hardly any differences as per expected lines.

It is seen from the figures 9, the Blackman and 10, the Chebyshev types of filters of software based design, that the original signal is completely mixed with noise indicating inferiority of these filters when compared with Bartlett filter of same design.

It is seen the fig. 3 and 4 that the band pass filter design using SPARTA 3E Kit was clearly translated and achieved practically using the methodology proposed in this paper. It is seen from the figures.8,9 and 10 that the simulated SAR signal clearly passing through the 7.8 – 8.2 GHz window in software based band pass filters, by suppressing the noise levels, presenting the reflected echo of the SAR signal.

From figures 8, 9 and 10 which also shows the SNR improvement factor versus iteration number, it is clearly observed that SNR improvement factors achieved for Bartlett type of filter is 7.742 dB, for Blackman type of filter is 7.743dB and for Chebyshev type of filter is 7.604 dB. Dominance of Bartlett type filter is very clear though it is close to Blackman type of filter from the same design achieved for SNR improvement.

Figure 4. Designed circuit of the proposed methodology.

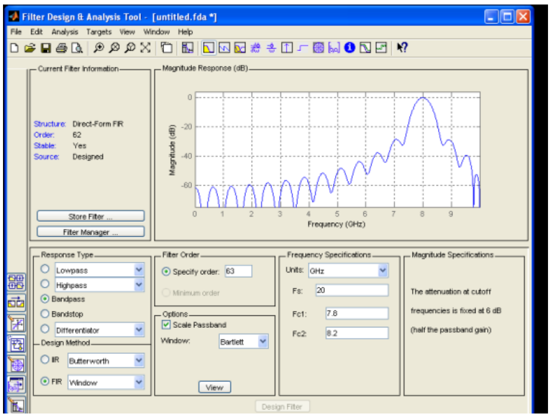

Figure 5. Frequency Response (Bartlett)

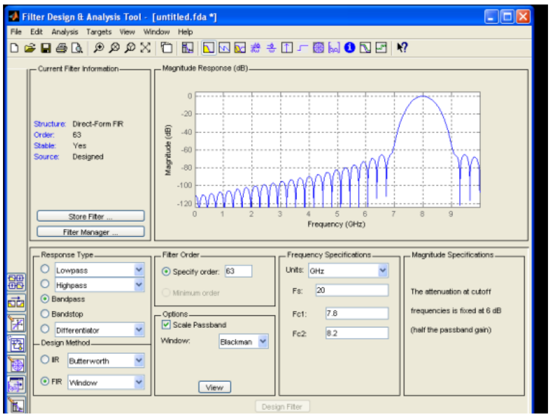

Figure 6. Frequency Response (Blackman)

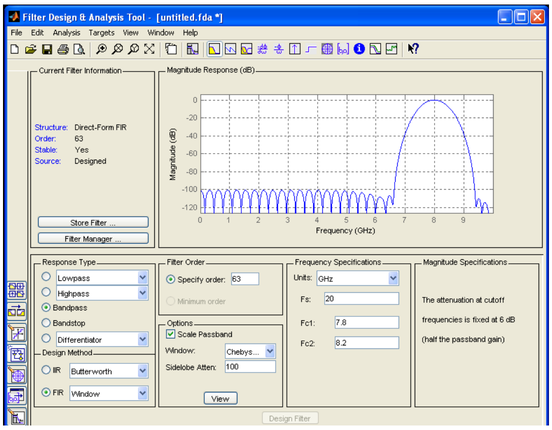

Figure 7. Frequency Response (Chebyshev)

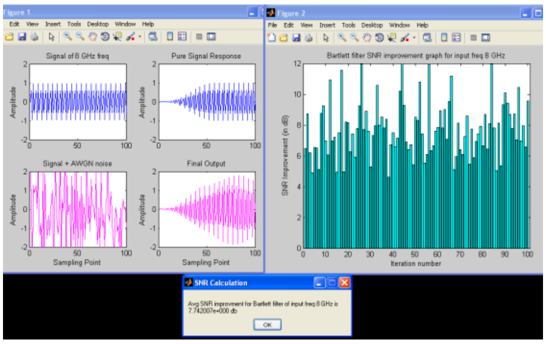

Figure 8. Input signal, signal+ noise, outcomes and SNR improvement (Bartlett)

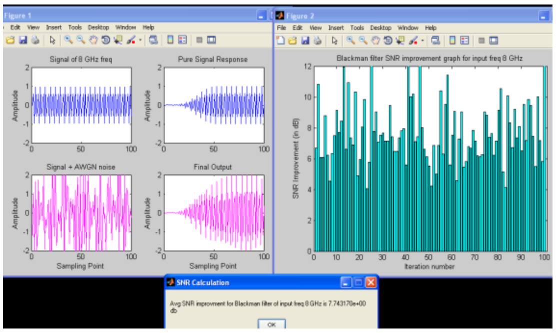

Figure 9. Input signal, signal+ noise, outcomes and SNR improvement (Blackman)

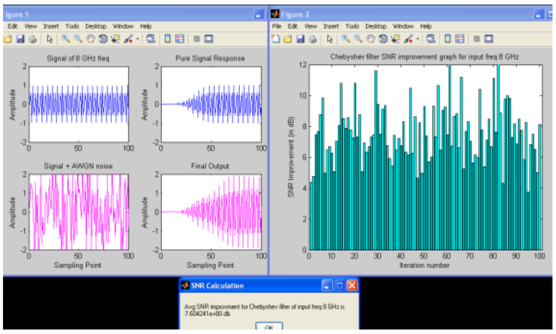

Figure 10. Input signal, signal+ noise, outcomes and SNR improvement (Chebyshev)

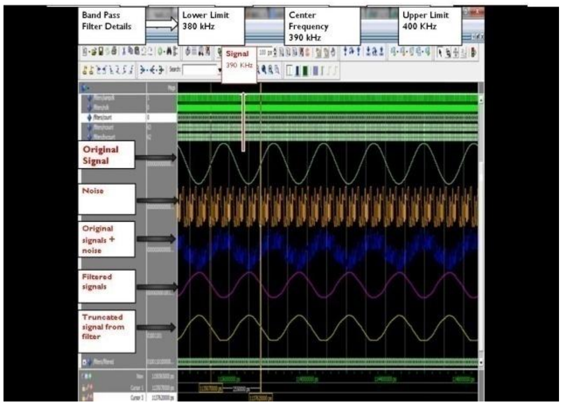

Figure 11. Original signal, noise + signal and filtered signals

4. CONCLUSION

In this research work the XILINX and MATLAB softwares based Bartlett, Blackman and Chebyshev FIR digital 7.8 – 8.2 GHz semi adaptive band pass filters design methodology was successfully translated in to practical one using SPARTAN-3E kit along with A/D, D/A converters and DIP switches and seven segment display for 64 order for a sampling frequency of 20 GHz. The response was successfully obtained for the designed frequency of 8 GHz from the filters designed using software and for lower frequencies for practical. The superiority performance of Bartlett type of filter is clearly observed from both types of design using software tools and FPGA kit practically over Blackman and Chebyshev type of filters from the same designs.

SNR improvement factor of 7.742 achieved for Bartlett is higher than Chebyshev 0f 7.604 and Blackman of 7.743 conforming that better quality GHz range frequency FIR semi adaptive digital band pass filters can be achieved through Bartlett type. These filters are found to be suitable for low frequency SAR applications to mitigate random noise levels and give the desired target response so that resolution and identification of desired objects are achieved. GHz range filters also appear to be suitable which need to be evaluated for FPGA kit based designs.

The SPARTAN-3E digital signal processing chip was successfully configured, designed and achieved for semi-adaptive digital FIR filters and test signal was passed with noise and output clearly obtained as shown in figure 11for low frequency bands especially for Bartlett type. Filters designed in this paper analyzed and evaluated which are comparable and matching well in their responses of filtering out unwanted noise and passing the original signal in the designed frequency band.

In this paper a concept of GHz range frequency digital filters for synthetic aperture radar applications for the purpose of imaging are suitably proposed. High frequency SAR images are deteriorated by speckle noise, so in this paper an attempt is made to design a practical digital filter using SPARTA 3E kit for GHz range frequency SAR applications.

5. FUTURE SCOPE

This experiment on practical circuit design of semi-adaptive digital filters using SPARTAN-3E and software based design using XILINX and Mat Lab softwares for SAR applications shows the possibility to formulate fully adaptive digital filters for Remote Sensing applications such as for Disaster management, mining, Forest management and military applications. These filters will play a crucial role in practical implementation in future SAR noise reduction. In this continued research work GHz range filters are being evaluated using FPGA kit.

6. REFERENCES

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AUTHOR'S PROFILE

Prof. P Yadav is a post graduate from IIT- Kanpur (India) and a research scholar in Electronics Engg. He has served in Indian Air Force as commissioned officer for 25 yrs, and nine yrs, as a technocrat academician in reputed Engg. Institutes. He is an entrepreneur who has ten research papers and many project patents under his name. He is a fellow of IETE.

Dr Anubhuti Khare received her BE in Electronics and Communication from Government Engineering College, Bhopal in 1994. She obtained her M.Tech and Ph D in Electronics and Communication from MANIT, Bhopal. Presently she is working as Associate Professor in E & C Department, UIT, RGPV, Bhopal. She has more than 50 publications to her credit.

K Prandham Gowd obtained his B.Tech in Electronics and Communication Engineering with distinction from S.V. University, Tirupati (India) and **ME** (Microwaves and Radar) from IIT Roorkee. In 1994 he has conducted **RCS Reduction** experiments on coated (by pasting of absorber sheets) and uncoated scaled models of aircraft which is first time in India at IIT Roorkee. He has 42 **research publications and 05 Technical reports** to his credit most of them on **RCS/RCS Reduction/Stealth Technology.** He has one copyright to his credit on **Dynamic RCS Range Validation Procedure from Govt of India**. He is a Life Member of All India Management Association (**AIMA), AeSI and Fellow** of IETE. He had authored a book on Stealth Aircraft Technology.