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Optimal Design, Analysis and Evaluation of Semi-Adaptive 700-800 KHz Active Band Pass Filter for SAR applications

P Yadav[1,*] and A Khare[2]

[1]Department of Electronics and Communication, SIST, Bhopal, India- 462031.

[2]Department of Electronics and Communication, UIT, RGPV, Bhopal, India – 462031.

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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. In this research work Butter worth digital FIR semi adaptive band pass filter for 700-800 KHz for 128 order Kaiser window with 0.5 Beta was designed using XILINX and MATLAB soft wares. As part of practical research work 700 -800 KHz Butter worth digital FIR semi adaptive band pass filter for 700-800KHz for 128 order Kaiser window with 0.5 Beta was designed using FPGA kit using SPARTAN-3E. These were optimized, analyzed, compared and evaluated keeping the sampling frequency at 5 GHz. Both these filters were tested by passing a sinusoidal test signal of 781 KHz along with noise and the filtered output signals are presented.

Introduction

The tremendous 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 applications(SAR). 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.

SAR data is required to be processed in real time, hence these filters are required to operate in real time. 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 filter generally involves a compromise between the complex requirements for a complex algorithm and a high sampling frequency.

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

Proposed Design Methodology

Simulated Design

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) In this design methodology Butter worth Finite Interval Response (FIR) semi adaptive digital band pass filter for 700-800 KHz Kaiser window with 0.5 Beat of 128 order TAP was used and designed.

(iv) Filter response was derived for the sampling frequency of 5 GHz.

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.

Practical Design

The simulated 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 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.

Tele:

E-mail addresses: Param1959@yahoo.co.in

(i) Butter worth FIR semi adaptive digital band pass filter for frequencies 700 to 800 KHz of 128 order Kaiser window with 0.5 Beta, for a sampling frequency of 5 GHz was carried out.
(ii) The SPARTAN Logic IC contains 4X10-6 logic gates and has 208 pins.
(iii) 8 DIP switches were incorporated for selecting various 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.

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 5 GHz.

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

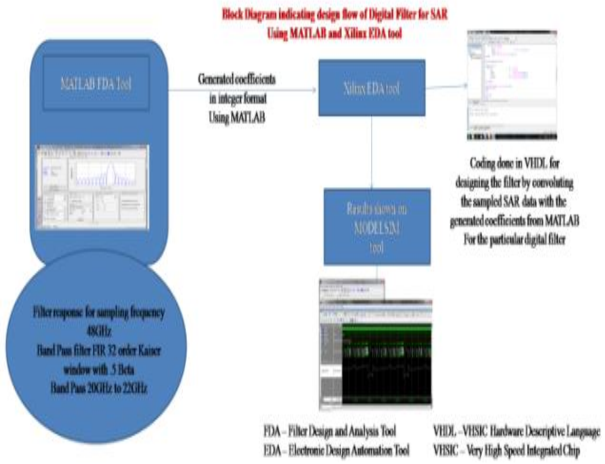

Figure 1. Block diagram of the Design simulation methodology.

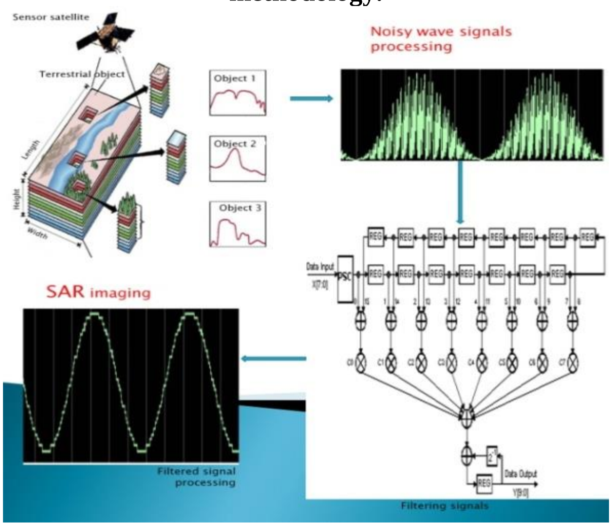

Figure 2. Block Diagram of the Practical Experimentation methodology.

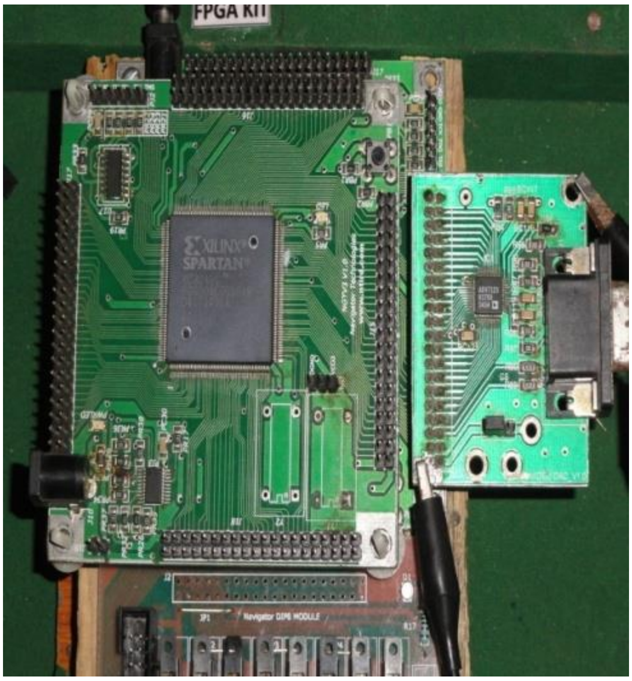

Figure 3. Designed circuit of the proposed methodology.

Results and Discussion

The experimental setup and the designed circuit in this proposed research work are depicted in fig.2 and 3 respectively. The original sinusoidal test signal of 781 KHz was passed through this 700 to 800 KHz digital band pass Butterworth FIR filter of order 128 Kaiser window with .05 Beta which was designed using XILINX and MATLAB soft wares is as shown in Fig.5. From this figure it is clearly seen that noise is suppressed and the test signal has been passed. The figure.6. shows the input test signal and filtered output signal which was passed through the same filter which was designed using SPARTA 3 E kit with logic gates observed in a two channel digital storage oscilloscope. The simulated filter and the practically designed filter have rejected the noise and are comparable with hardly any differences as per expected lines.

The response of the simulated filter for original test signal, noise, test signal mixed with noise and the filterd output signal are clearly shown in fig.5**.** The response of the designed filter using hardware for input test signal and filtered output signal are shown in figure.6.

It is seen from the fig. 6 that the original signal is completely mixed with noise before it is passed through the filter. The output filtered signal is clearly seen in fig.7 which shows that the designed filter of 7 to 9 GHz is clearly achieving the desired results.

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 fig. 5 and 6 that the simulated SAR signal clearly passing through the 700 to 800 KHz window in simulated and practically designed band pass filters, by suppressing the noise levels, presenting the reflected echo of the SAR signal.

It is observed from the fig. 5 and 6 that the filters response for the band pass frequency of 700 to 800 KHz, the test signal of 781 KHz, clearly passing through the filter for 128 order Kaiser window with 0.5 Beta for a sampling frequency of 5 GHz. Further it is observed that from the fig. 5 and 6 that the filter output completely suppresses the noise and passes the SAR signal.

Figure 4. Designed circuit of the proposed methodology.

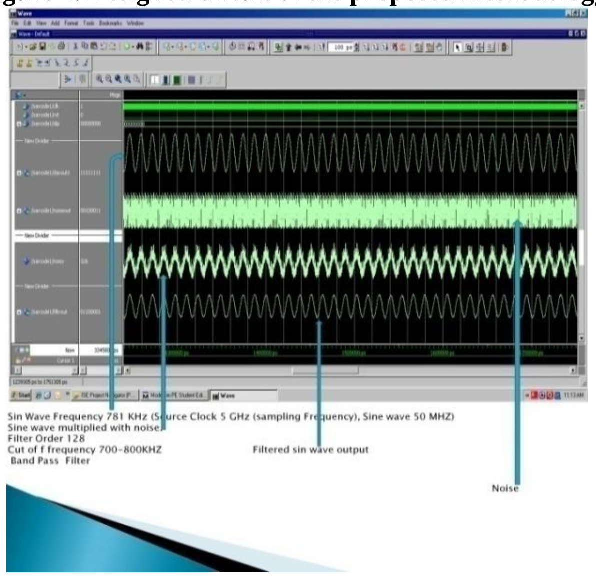

Figure 5. Original, noise, original + noise and output

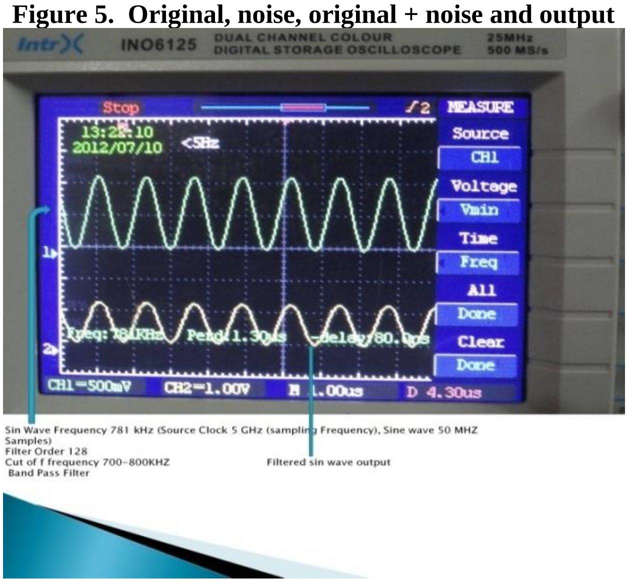

Figure 6. Input and filtered output signals

Conclusion

The results obtained from this design clearly demonstrate that a 700 to 800 KHz band pass Butterworth semi-adaptive digital filter was designed successfully by using SPARTA- 3E kit along with A/D, D/A converters and DIP switches and seven segment display for 128 order Keiser window with 0.5 Beta. Same filter was also designed using MATLAB and XILINXK software tools. The response was successfully obtained for the designed frequency of 781 KHz for 128 order Keiser window with 0.5 Beta for a sampling frequency of 5 GHz from both the filters theoretical and practical.. These filters are 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.

The SPARTAN-3E digital signal processing chip was successfully configured, designed and achieved the semi-adaptive butter worth digital FIR filter of 128 order Kaiser window with 0.5 Beta, practically as well as simulated design using XILINX and Mat lab soft wares. 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 low frequency digital filters for synthetic aperture radar applications for the purpose of deep detection on earth surfaces and deep sea bed are suitably demonstrated. 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 low frequency SAR applications. It is well known that lower frequencies have longer wave length and hence can penetrate deeper in to earth and sea bed for detection applications of SAR.

Future Scope

This experiment on practical circuit design of semi-adaptive digital filters using SPARTAN-3E and simulated design using XILINX and Mat Lab soft wares 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.

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Author's Information

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 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.