Spread Spectrum-Digital Beam Forming Radar with Single RF Channel for Automotive Application

Soumyasree Bera, Samarendra Nath Sur
Department of Electronics and Communication Engineering,
Sikkim Manipal Institute of Technology, Sikkim, India
[soumyasree.bera, samar.sur]@gmail.com

Rabindranath Bera
Department of Electronics and Communication Engineering,
Sikkim Manipal Institute of Technology, Sikkim, India
rbera50@gmail.com

Abstract— Conventional Digital Beamforming (CDBF) is an important and well established technique used severely in today's Radar having high SNR performance. But the main barrier towards the implementation of CDBF is the Cost, Size, Weight and Power (CSWAP) requirement as it urges for a large number of T/R transceiver modules including up/down-converter, DAC/ADC etc per element. And at high frequency the limitation is further increased both cost wise as well as area available for heat dissipation. This can be solved by utilising single channel DBF

***Index Terms*—DBF, SS,CDBF**

I.INTRODUCTION:-

The constraints regarding the CDBF can be reduced to a great extent by utilising Spread Spectrum Digital Beamforming (SSDBF) which involves reduction of the CSWAP and the scalability in bandwidth-and-frequency limitations by incorporating "one digital transceiver per element". Therefore now the system can have fully capable digital beamforming with minimum hardware. SSDBF enables low-cost/low-profile/low-power digital beam forming phased arrays with a single up/down-converter, DAC/ADC for the entire sub-array.

At the transmitter, baseband phase shifter can reduce further cost. At the receiver, aggregated return signal can be coherently combined to recover the complex baseband-equivalent of the RF signal of each element. The SSDBF is flexible with respect to the type of waveform and can be adapted according to the practical situation thus improving the radar performance. In this report, we describe the simulated model of SSDBF method for a radar application.

<u>Block Diagram of Conventional Multi-Channel SSDBF:</u>

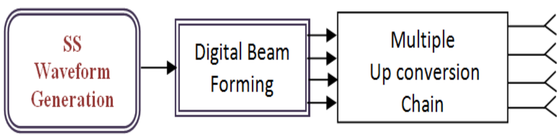


Fig 1(a) : Radar Transmitter

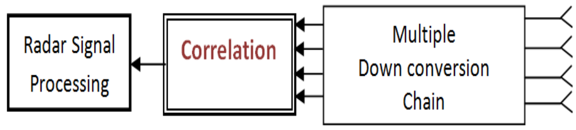


Fig 1(b) : Radar Receiver

Fig 1 shows the conventional DBF technique with SS technique having multiple RF up-conversion / down-conversion chain. The first step is the generation of SS waveform. After generation of SS waveform, baseband phase shifter will be applied for digital beam formation followed by RF up-conversion. Each antenna element has its own RF up-conversion chain.

In the receiver similar RF chain for each antenna element is present for proper down-conversion followed by radar signal processing.

<u>Block Diagram of Single-Channel SSDBF:</u>

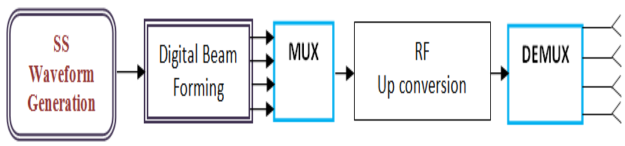


Fig 2(a) : Radar Transmitter

The system transmitter is as shown in Fig 2(a). The multiple channels at the output of the phase shifter will then be multiplexed and passed for further up-conversion to RF level. RF up-converted signal again demultiplexed and forwarded to the multiple antenna.

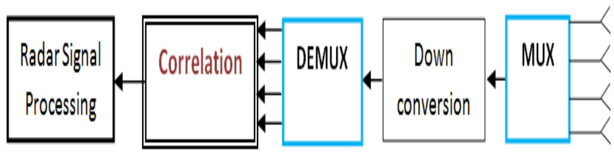


Fig 2(b) : Radar Receiver

The block diagram of the system is as shown in the figure above. In the receiver, the first job is to multiplexing the incoming signal from all the antenna elements. The multiplexed data then will be down-converted to baseband level and again de-multiplexed. Then each path data to be correlated and coherently combined before proceeding for further signal processing.

The system performance using this single RF channel technique is comparable with that of the multi channel SSDBF.

II. SSDBF Schemes:-

Baseband Code:

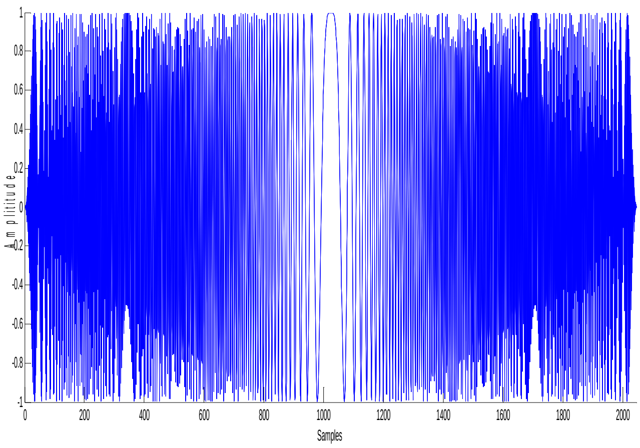
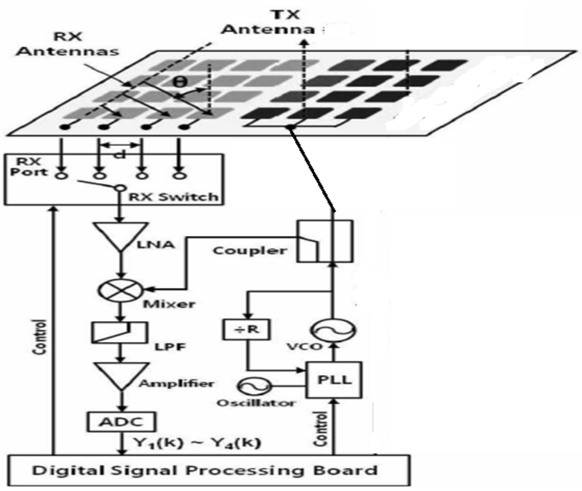


Fig.3: - waveform of P4 Polyphase code

As shown in above figure polyphase code (P4) will be used as spreading code with length of 2046. And this leads to a processing gain of 33dB (Approx.).



Simulation

Table 1:- RADAR SPECIFICATION

Waveform Polyphase	P4 code
Bandwidth	100 MHz
Array type	10x10 uniform rectangular array
RF frequency	24 GHz
Range	200m

Comparison between Radar Beamforming performance for multi-channel and single-channel RF:-

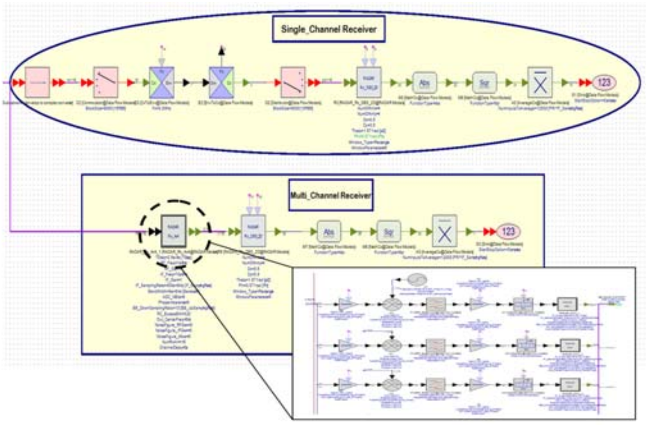


Fig 4: SystemVue model for multi-channel as well as single-channel SSDBF receiver.

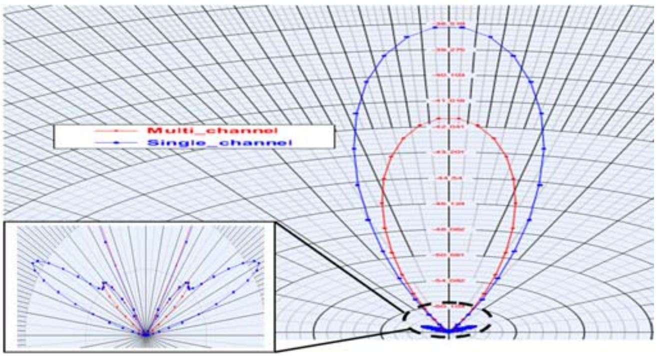


Fig 5: Multi-channel as well as Single-channel SSDBF receiver beam formation.

As seen in the figure above due to the use of single channel down-conversion, there is slight degradation in the antenna beam as the side lobe has higher power content than the side lobe of the multiple channel down-conversion.

Table 2: Comparison between Multichannel and Single Channel SSDBF

	Multichannel SSDBF	**Single channel DBF**
Main Lobe	-41.8 dB	-38.5 dB
Side Lobe	-64 dB	-63 dB
Beamwidh	22^o	20^o

End-to End Simulation of SSDBF radar with only Rx DBF:

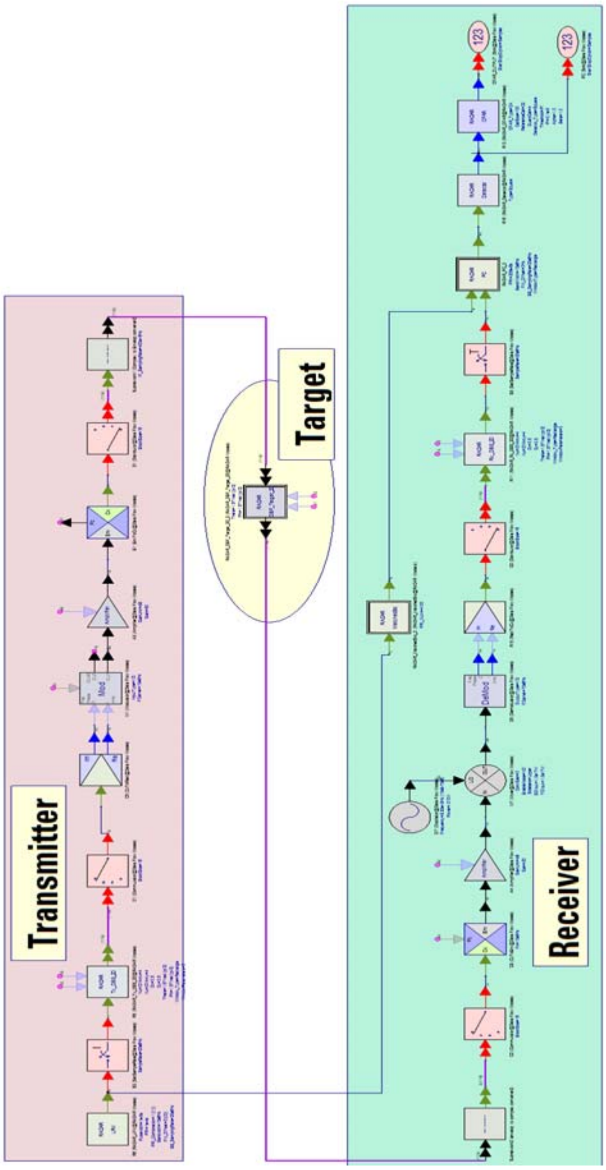


Fig 6:-End-to End Simulation of SSDBF radar with both Tx and Rx DBF.

Detailed description of the Model:-

A. Transmitter:-

Spread Spectrum waveform generation is the first step that has been performed. Polyphase code (specifically P4) is used to as spreading code. The code thus generated has the specified bandwidth and details as mentioned in radar system specification. After baseband generation the next step is beam formation. In this system, baseband beam formation has been considered. After DBF, the data for each of the element has been multiplexed since single up-conversion subsystem is a criterion of the system followed by IF level up conversion i.e. at 70MHz. The output of the IF level is being fed to the RF subsystem. In RF Subsystem, the signal is again up-converted to RF level using RF mixer (i.e. at 24GHz). The RF signal is then amplified using amplifier and transmitted using Antenna. After RF conversion demultiplexing is a vital operation so as to provide feed for each antenna element.

B. Receiver:-

SSDBF is the concept that is being developed using the discussed model. Hence the receiver is considered to have antenna array. The multi-channel output is merged using a multiplexer. The multiplexed data is first passed through a LNA followed by down-conversion from RF to IF and further IF to baseband level. Then the baseband data is again demultiplxed and forwarded to radar signal processing segment.

- **Radar Signal Processing:-**
  The basic radar signal processing incorporated in the system are as explained below

➢ **Correlation:-**

Correlation is the one of the vital part of the system that provides uniqueness to this Radar system. There are two inputs to the correlation block- Received IF signal, Transmitted IF signal. The first operation of correlation block is bit by bit synchronism of the Received and Transmitted IF signal so that correlation can be made possible.

The distance between the vehicles to the target can be calculated from the traveling time of the reflected wave using the following formula:

$$R = C.Td /2 \quad \text{----------------------- (1)}$$

where R is the distance, C is the speed of light and Td is the traveling time to the target and back. Therefore, in order to calculate the distance, it is necessary to measure Td.

➢ **Constant False Alarm Rate:-**

Constant False Alarm Rate (CFAR) is a signal processing tool used for the improvement of the quality of the radar image by nullifying the noise or clutter return that may still be present even after correlation. The algorithm can set the threshold adaptively according to the level of background intensity. The threshold in a CFAR detector is calculated using the initial false alarm rate and the information of the background. The main purpose of it is to further cleaning the target from noise thus increasing the SNR of the signal. The output of the correlator block is fed to this block and at the output a better target is observed.

III. RESULTS

Target Detection using Single channel SSDBF:-

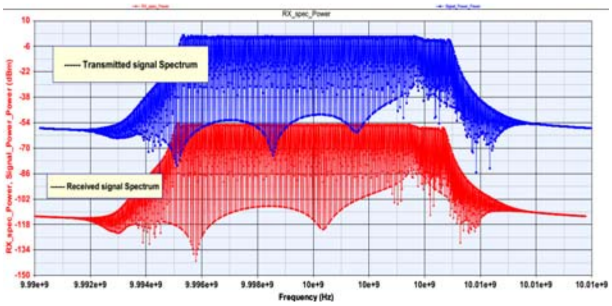


Fig 7: Transmitted and Received Spectrum.

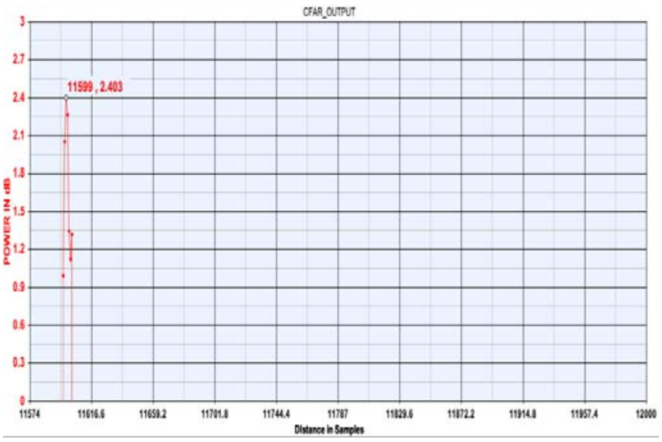


Fig 8: Target Detection at 200 meter.

Radar Performance under Interference:-

SSDBF radar utilises waveform of length 2*1023. This length provides a processing gain of 33dB. Hence the jamming margin of the radar is 33 dB.

In this performance test, the radar transmitter signal power is kept fixed so is the target property. The only change that has been done is the addition of an interfering signal and its power is incremented slowly to notice the change in radar performance. The Signal to Interference Ratio (SIR) is noted.

Generation of Interference:

A different code is taken having 100 MHz bandwidth and up-converted to 24GHz. This interfering signal is added to the target return so as to create a situation where the receiver receives the combined signal of target return and the interference signal.

Case 1:- Signal to Interference ratio = 30dB

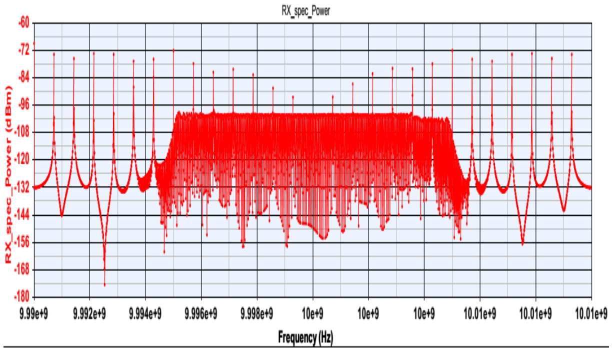


Fig 9: Received Spectrum.

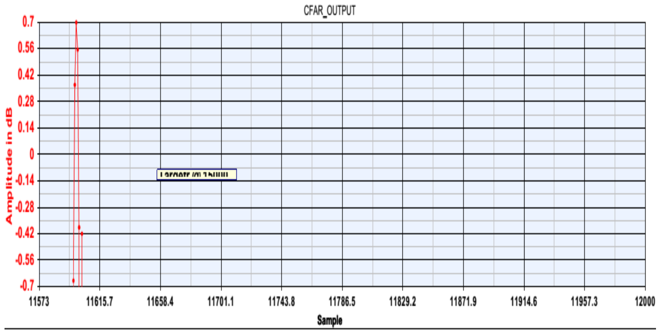


Fig 10: Target Detection at 200 meter.

Conclusion: Target is detected properly even in the presence of interference with slight decrease in the target peak amplitude.

CONCLUSION

Hence this is a viable technique that can be very effective in reducing the cost, size problem. Also performance these two techniques are comparable to each other.

REFERENCES:

[1] Skolnik, Radar Handbook, 2nd ed. McGraw-Hill,Inc. 1990

[2] D. Curtis Schleher, MTI and Pulse Doppler Radar, Artech House, Inc. 1991

[3] Dingqing Lu and Kong Yao "Importance Sampling Simulation Techniques Applied to Estimating False Alarm Probabilities," Proc. IEEE ISCAS, 1989, pp.598-601

[4] "Spread Spectrum Digital Beamforming (SSDBF) Radar", Dr. Marcos A. Bergamo, Applied Radar Inc., 200 Wheeler Road, Burlington, MA 01803, USA, E-Mail: mbergamo@appliedradar.com, 978-1-4244-5128-9/10/$26.00 ©2010 IEEE

[5] Agilent SystemVue 2011.10

[6] Matlab R2013a

BIODATA OF AUTHORS

Ms. Soumyasree Bera: Born in 1988 at Kolaghat , West Bengal, INDIA. She received her B. Tech from Sikkim Manipal Institute of Technology, Sikkim Manipal University, in the year 2011. Currently she is working as Faculty in the Department of Electronics & Communication Engineering, in same college. Her area of Interest includes Remote Sensing, Mobile Communication, and Advanced Digital Signal Processing.

Prof.(Dr.) Rabindranath Bera: Born in 1958 at Kolaghat , West Bengal, INDIA. Received his B.Tech, M. Tech & Ph.D degree from the Institute of Radiophysics & Electronics, The University of Calcutta, in the year 1982,1985 & 1997 respectively. Currently working as Ex-Dean(R&D), Professor and Head of the Department,Electronics & Communication Engineering, Sikkim Manipal Institute of Technology, Sikkim

Mr. Samarendra Nath Sur: Born in 1984 at Hooghly, WestBengal, INDIA. Received M.Sc. (Electronics Science) from Jadavpur University in the year 2007 and completed M.Tech from Sikkim Manipal University. Currently working as Asst Professor, E&C Dept, Sikkim Manipal University, India. Broadband Wireless Communication, Remote Sensing are the area of specializations.