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Integrated Hybride DBF Vehicular Radar

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Abstract— ***This paper addresses the development efforts towards spread spectrum digital beam forming vehicular radar. Lot of limitation for Conventional radar system; to overcome this problem we are using CSWAP technique for the design of fully integrated Hybrid DBF vehicular Radar. So planar array structure based microstrip antenna which is digitally controlled by DSP or FPGA board is the important part of this work. Lot of works carried out by us that is Antenna radiation pattern, element pattern, power pattern, array factor, antenna e-scanning and beam formation, digital beam formation using different combination of elemental patch and side lobe reduction using different windowing techniques is the major part of this work .The car fitted at the front with single 77GHz will take joint decision of LRR as well as SRR [1]. So in the channel lot of polluted signal like interference, clutter noise arises in the receiver portion of this radar to avoid this proper choice of waveform is very important part also of the SSDBF vehicular Radar at the transmitter side .We have tested different orthogonal codes like Barker, Frank,Gold,P1,P2,P3,Px. and their performance analysis.***

Index Terms—Cost, Size, Weight and Power (CSWAP), Conventional Digital Beam forming (CDBF) ,Spread Spectrum Digital Beam forming (SSDBF) Electronically Scanned Array (AESA), DAR (Digital Array Radar),AF(Array Factor) ,Minimum Variance Distortion less Response (MVDR) ,linearly Constrained Minimum Variance (LCMV)

I. INTRODUCTION

Most current research and development programs in the field of digital beam forming are concerned with systems that operate in the traditional microwave or millimeter wave frequency bands. Recent trends in Conventional Beam forming (CBF) and Adaptive Beam forming (ABF) [2] techniques for Active Electronically Scanned Array (AESA) radar have been much studied and the possibilities for expanding the capability of such radar systems towards automotive radar application in ITS is still challenging work for the scientists.

However, there is an enormous amount of work required to take optimization algorithms like genetic and particle swarm algorithms are the important for side lobe and clutter suppression and hardware implementation is very difficult to put into operation them in real-time in a Digital Signal Processor (DSP) Board on automotive radar systems. Electronic scanning antennas are increasingly working in communication and radar systems to meet the performance of modern systems.

High speed non-sequential scanning, multi target capability and reconfigurability are the main attractive properties of these antennas.

On the other hand, some drawback has to be overcome, as performance degradation with scanning and power losses. The main disadvantages are the creation of digital beam forming use in radar, communications and RF sensing systems is the Cost, Size, Weight and Power (CSWAP) requirement of Conventional Digital Beam forming (CDBF) as it calls for a full digital transceiver including up/down-converter, DAC/ADC, memory and digital interface per element. Important practical limitations of CDBF to high bandwidth applications are the high sampling rates of the ADCs and consequent high-rates and complexity of the digital busses. Spread Spectrum Digital Beam forming (SSDBF) [3] overcomes the above limitations of CDBF by "eliminating" the requirement of "one digital transceiver per element" while enabling fully capable digital beam forming with minimum hardware (and consequently minimum volume and heat dissipation) per element. Specifically, SSDBF enables low cost/low-profile/low-power digital beam forming phased arrays that scales in frequency in Microwave and Millimeter range. The aim of our work is to estimate the desired direction of multi target in terms of Doppler frequency and delay estimation from different azimuth and elevation angle unwanted clutter, noise elimination ;interference suppression[4] and anti-jamming capability is the desire goal of our work. Now based on antenna configuration; for the detection in target there will be ambiguity arises due to gratings lobes. So the sub array elements should be sampled properly with the correct element spacing to avoid gratings lobes. Another important aspect regarding Ambiguity in the sense proper choice of spreading codes. Lot of simulation works have done on orthogonal codes having good autocorrelation property for detection of moving as well as static target.Fig-1 shows the general block diagram of the DBF [5] Radar .We have simulated 77GHz carrier frequency based linear array as well as planar array microstrip antenna using Matlab and Ansoft software are already tested.Using SystemVue software we are able to scan electronically the beam in azimuthal and elevation angle successfully .

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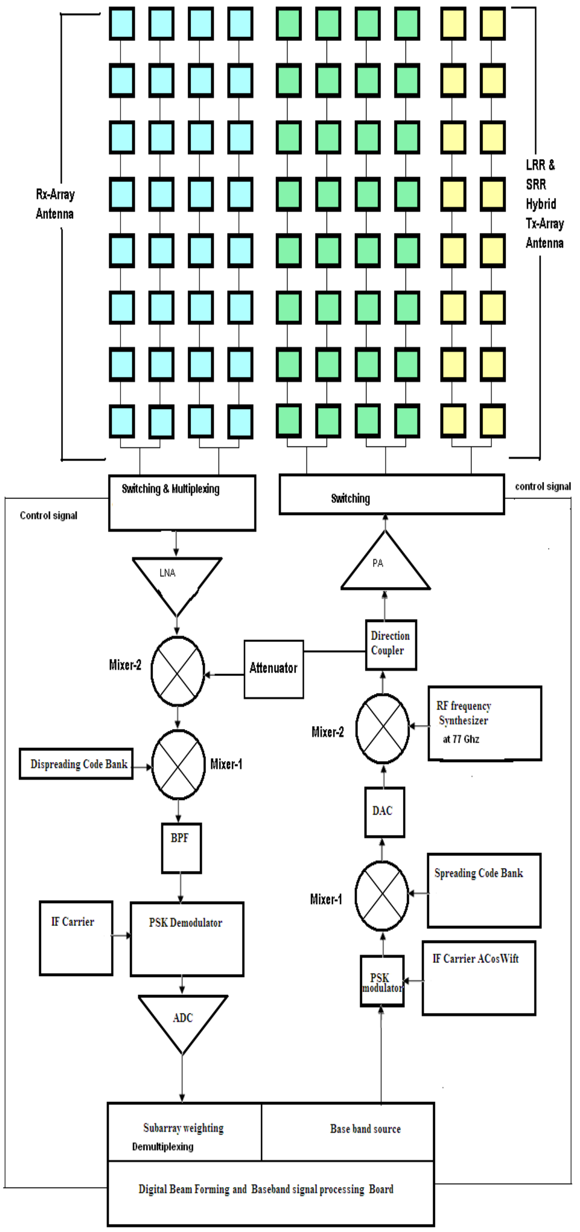

Fig.- 1: Block Diagram of Spread Spectrum Digital Beam Forming Radar

II. PATTERN EXPRESSION WITHOUT ELECTRONIC SCANNING

Here we have taken one-dimensional array of M elements which are uniformly spaced with a spacing of d. The overall length of the array, L, is equal to Md. The elements are centered about

X = 0, and their position can be denoted as

$x_m = (m - 0.5(M+1))d \quad m = 1, 2, \ldots\ldots, M$

$$AF = \sum_{m=1}^{M} A_m\, e^{i\frac{2\pi}{\lambda}x_m \sin\theta} \qquad (1)$$

From equation (1);

at $\theta = 0^o$ AF has maximum value is M which is the number of element in the linear array. A good expression for modeling the element pattern is a cosine function raised to a power that is called the element factor (EF). Now expression for the Element Pattern

$$EP = \cos^{\frac{EF}{2}}\theta \qquad (2)$$

at $\theta = 90^o$ for real application EP $\neq 0$ because of Element Factor.The complete pattern representation for the array is found using pattern multiplication .So total pattern;

F (θ) = AF. EP

$$= \cos^{\frac{EF}{2}}\theta \sum_{m=1}^{M} A_m\, e^{j\frac{2\pi}{\lambda}x_m \sin\theta} \qquad (3)$$

Here EP is same for all elements but this is not true for conformal array P_{EP} which is element power pattern is EP^2, EP is the voltage representation which is EP = $\sqrt{P_{EP}}$

III. PATTERN EXPRESSION WITH ELECTRONIC SCANNING

An ESA has the ability to scan the beam so that the beam has a maximum at other angles ($\theta \neq 0^o$), so the scan angle will be denoted as θ_0 .For scanning the beam of the array requires adjusting the phase or time delay of each elements in the array secondly expanding the complex voltage at each element $A_m = a_m\, e^{j\emptyset_m}$;

Where $\emptyset_m = -\frac{2\pi}{\lambda}x_m \sin\theta_0$.

So by applying the appropriate phase at each element, the ESA beam can be moved spatially without physically moving the entire array. So overall pattern can now be expressed as from equation (1) becomes

$$F(\theta) = \cos^{\frac{EF}{2}}\theta \sum_{m=1}^{M} a_m\, e^{j\left(\frac{2\pi}{\lambda}x_m \sin\theta - \frac{2\pi}{\lambda}x_m \sin\theta_0\right)} \qquad (4)$$

Electronic scan can be categorized as phase steering or time delay steering. For phase steering, each element has a phase shifter and applies the appropriate phase as a function of frequency and scan angle. A characteristic of phase shifters is that their phase delay is designed to be constant over frequency. The pattern expression for phase delay steering becomes

$$F(\theta) = \cos^{\frac{EF}{2}}\theta \sum_{m=1}^{M} a_m\, e^{j\left(\frac{2\pi}{\lambda}x_m \sin\theta - \frac{2\pi}{\lambda}x_m \sin\theta_0\right)} \qquad (5)$$

For ESAs that employ both of phase and time delay, both forms of delay must be adjusted. This applies to sub arrayed ESA.

IV. PHASE DELAY STEERING

Each element has a phase shifter and applies the appropriate phase as a function of frequency and scan angle.

$$F(\theta) = \cos^{\frac{EF}{2}}\theta \sum_{m=1}^{M} a_m\, e^{j\left(\frac{2\pi}{\lambda}x_m \sin\theta - \frac{2\pi}{\lambda}x_m \sin\theta_0\right)} \qquad (6)$$

$\lambda = \frac{c}{f}$, $\lambda_0 = \frac{v}{f_0}$; F (θ) is maximum when $f = f_0$

that means it is in tuned condition, but under detuned condition overall Array Pattern will be disturbed and no longer maximum will occurred at particular scan angle. Phase shift delay formulation

$$AF = \frac{\sin M\pi d\left(\frac{\sin\theta_0}{\lambda_0} - \frac{\sin\theta}{\lambda}\right)}{\sin \pi d\left(\frac{\sin\theta_0}{\lambda_0} - \frac{\sin\theta}{\lambda}\right)} \qquad (7)$$

V. TIME DELAY STEERING

$$F(\theta) = \cos^{\frac{EF}{2}}\theta \sum_{m=1}^{M} a_m\, e^{j(\sin\theta - \sin\theta_0)}$$

Time delay formulation antenna Array Factor can be written as

$$AF = \frac{\sin M\pi d\,(\sin\theta - \sin\theta_0)}{\sin \pi d\,(\sin\theta - \sin\theta_0)} \qquad (8)$$

For x= $\pm\frac{\pi}{2}$, $\frac{\sin x}{x} = \frac{2}{\pi}$

$$AF \approx \frac{\sin M\pi d\left(\frac{\sin\theta_0}{\lambda_0} - \frac{\sin\theta}{\lambda}\right)}{\sin \pi d\left(\frac{\sin\theta_0}{\lambda_0} - \frac{\sin\theta}{\lambda}\right)} \qquad (9)$$

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So from denominator of equation (9) can be written as

$$M\pi d\left(\frac{\sin\theta_0}{\lambda_0}-\frac{\sin\theta}{\lambda}\right)=x=\pm\frac{\pi}{2} \qquad (10)$$

When $\theta=\theta_0\pm\frac{\theta_{BW}}{2}$;and replacing the values of θ in equation (10) can be written as

$$M\pi d\left(\frac{\sin\theta_0}{\lambda_0}-\frac{\sin(\theta+\frac{\theta_{BW}}{2})}{\lambda}\right)=\frac{\pi}{2} \qquad (11)$$

$$M\pi d\left(\frac{\sin\theta_0}{\lambda_0}-\frac{\sin(\theta-\frac{\theta_{BW}}{2})}{\lambda}\right)=-\frac{\pi}{2} \qquad (12)$$

Now Subtracting equation (12) from (11) can be written as

$$\frac{M\pi d}{\lambda}2\sin\frac{\theta_{BW}}{2}\cos\theta_0=\pi \qquad (13)$$

Using sine small angle approximation,

$$\theta_{BW}=\frac{\lambda}{Md\cos\theta_0} \qquad (14)$$

Equation (14) is valid for both phase shifter and time delay steering, and for $\theta_o = 0$ is the typical equation used to estimate ESA beam width.

If M ↑ then θ_{BW} ↓
and if d ↑ then θ_{BW} ↓
and if $\cos\theta_0$ ↑ then θ_{BW} ↓
and if f ↑ then θ_{BW} ↓

where L =aperture length

$$\theta_{BW}=\frac{\lambda}{L\cos\theta_0} \qquad (15)$$

This is valid for phase shifter and time delay steering .More general expression for beam width is

$$\theta_{BW}=\frac{k\lambda}{L\cos\theta_0} \qquad (16)$$

where k =beam width factor, which Varies depending on the aperture distribution K= 0.886 for 3dB beam width.

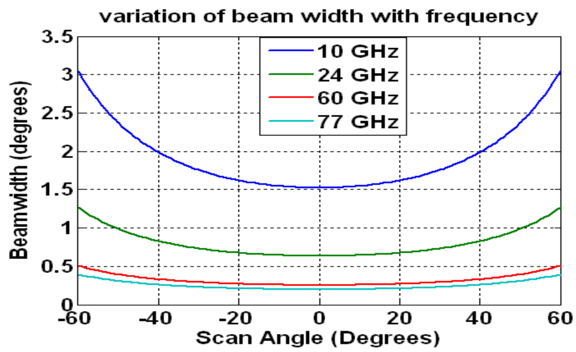

Fig2: Beam width as a function of scan angle and operating frequency.

From the above graph (Fig:1) it is clear that the beam width is inversely proportional to frequency, aperture length, and the cosine of the scan angle. A more generalized expression for the beam width is

$$\theta_{BW}=\frac{K\lambda}{L\cos\theta_0};$$

where k is the beam width factor and varies depending on the aperture distribution. Now at 77Ghz and 60Ghz operating frequency the beam width is less than .5 degree which is like pencil beam and very much applicable to long distance tracking for automotive vehicular radar which will be located at the center of the front side of the vehicle. Generally two 24Ghz Radar which is treated as **Short Range Radar** is required for left and right side looking for the vehicle because for driver's opposite side is very difficult to control collision avoidance .One **Long Range Radar** [6]which should be fitted on the center position of the Automotive Vehicle at 77Ghz as per CALM forum. This Radar will track long distance for target vehicle detection. We are interested only single 77Ghz Radar which will operate on both SR(Short Range) and LR(Long Range);only configuring based on Array Antenna . At tune frequency of ESA, $f = f_0$, AF is Maximum ;But $f = f_0 + \Delta f$ AF is not Maximum So there is an associated pattern loss at the commanded scan angle. This phenomenon is commonly referred to as beam squint.It is very much important that Array with the longer length has a smaller beamwidth and suffers more loss (at the commanded scan angle of 30°). So in term of frequency AF,

$$AF\approx\frac{\sin\frac{M\pi d}{c}(f_0\sin\theta_0-f\sin\theta)}{\frac{M\pi d}{c}(f_0\sin\theta_0-f\sin\theta)} \qquad (17)$$

IBW (Instantaneous Band width) $=f=\frac{c}{Md\sin\theta_0}=\frac{c}{L\sin\theta_0}$;

now if f ↑ M ↓
and if f ↑ d ↓
and again if f ↑ L ↓
and if f ↑ $\sin\theta_0$ ↓.

For more general, IBW $=\frac{Kc}{L\sin\theta_0}$, where k =beam width actor, Varies depending on the aperture distribution.

VI. ARISES OF GRATING LOBES

The elements in a phased array if not sampled property with the correct element spacing, will generate grating lobes, which are simply periodic copies of the main beam.The grating lobe location is a function of frequency and element spacing.

$$AF_{max}=\pi d\left(\frac{\sin\theta_0}{\lambda_0}-\frac{\sin\theta}{\lambda}\right)=\pm p\pi \ , \qquad (18)$$

where p =0, 1….

$$\sin\theta_{GL}=\frac{\lambda}{\lambda_0}\sin\theta_0\mp p\frac{\lambda}{d} \qquad (19)$$

Location of main beam $=\frac{\lambda}{\lambda_0}\sin\theta_0$ and Location of Grating lobe $=p\frac{\lambda}{d}$ If $\lambda\rightarrow\lambda_0$ and $\theta_0=0°$

$$\sin\theta_{GL}=\mp p\frac{\lambda}{d} \qquad (20)$$

This gives the grating lobe locations when the main beam is not scanned. To find the element spacing required for grating lobe free scanning to 90°.

We set $\theta_{GL}=90°$. And p =1.

$$\pi d\left(\frac{\sin\theta_0}{\lambda_0}-\frac{\sin\theta}{\lambda}\right)=\pm p\pi \qquad (21)$$

and $d=\frac{\lambda}{1-\sin\theta_0}$ (22)

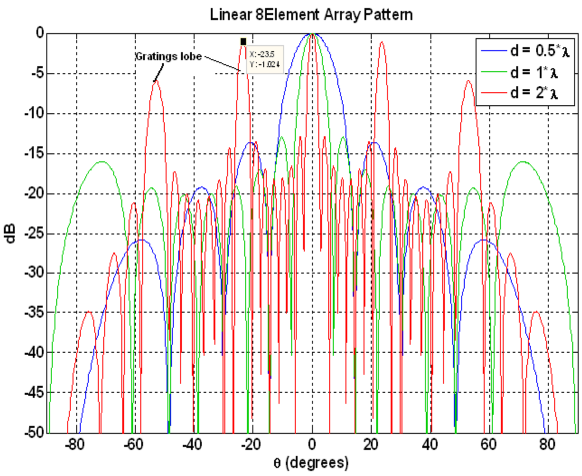

Fig:3; Simulation parameters for 77 Ghz Operating frequency

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Table-I

Power Level of the Grating Lobes(dB)	Element Spacing	3dB Beam Width (degree)	Angular Position of Gratings Lobes(degree)
-13.62	0.5* λ	13	+21 and -21
-12.99	1* λ	7	+10.25 and -10.25
-1.02	2* λ	2.5	+23 and -23

VII. ARRAY TAPERING

Most of the radar application the first side lobe should be very much less than 13.46 dB below the main lobe.Our goal is to reduce the side-lobes and the array must radiate more power towards the center not to the edges.So this is done by proper choice of windowing or Tapering technique. Now from the **Fig4** it is clear that tapering reduces sidelobes lebels [7]at the expanse of widening the main beam.We have taken different tapering sequence but the choice of tapering sequence is based on trade-off between sidelobe reduction and main beam widening ; this can be achieved using different optimization algorithms also ;here Taylor tapering efectively best with respect to other sequence.

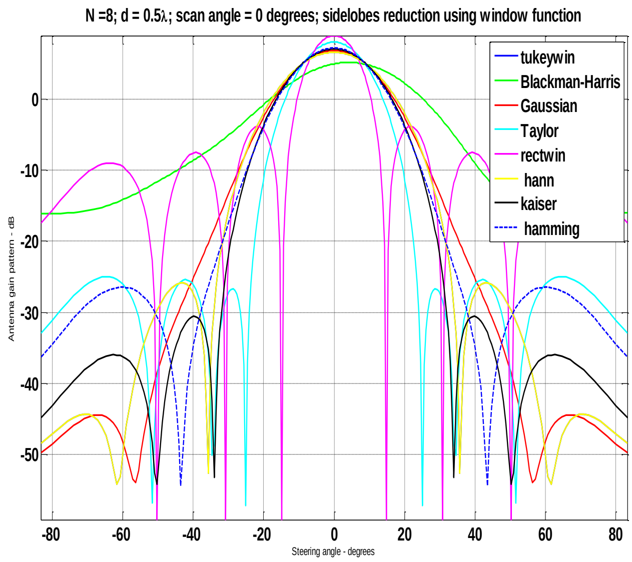

Fig4:- .Side Lobes Suppression using Window technique

VIII. OPTIMAL BEAM FORMER

For applying digital beamforming to a narrowband signal received by an antenna array[8]. Three beamforming algorithms are suitable one is phase shift beamformer (PhaseShift), another is minimum variance distortionless response (MVDR) beamformer, and the linearly constrained minimum variance (LCMV) beamformer.The null steering scheme requires knowledge of the directions of interference sources, and the beam former using the weights estimated by this scheme does not maximize the output SNR. The optimal beam forming method overcomes these limitations and maximizes the output SNR in the absence of errors. It should be noted that the optimal beam former, also known as the minimum variance distortion less response (MVDR) beam former, which does not require knowledge of directions and power levels of interferences as well as the level of the background noise power to maximize the output SNR. It only requires the direction of the desired signal.But this is totally analog beam forming we are trying to develop digital beam forming based on the help of Matlab and System Vue software and then we are trying to expand hardware implementation of this system . MVDR algorithm has better resolution than beamscan when there is no sensor position error. we applied beamscan and MVDR to estimate both azimuth and elevation angles using a Array antenna. The choice of the beamformer depends on the operating environment. Adaptive beamformers provides superior interference rejection compared to that offered by conventional beamformers. When the knowledge about the target direction is not accurate, the LCMV beamformer [9] is preferable because it prevents signal self-nulling.

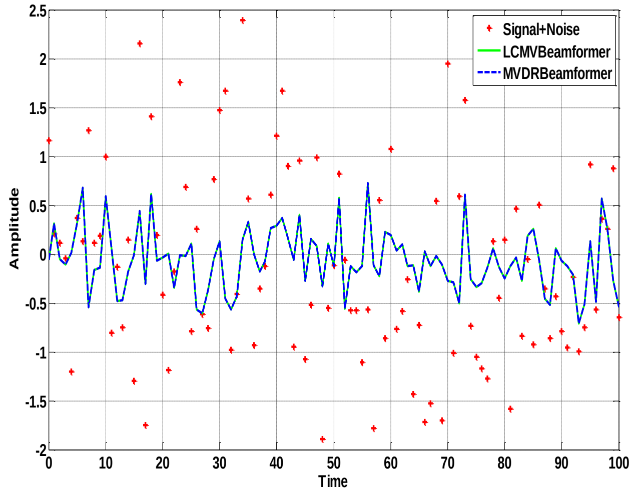

Fig.5:-: Analog Time delay Beam forming

IX. SUBARRAYS AND PARTIAL DIGITAL BEAM FORMING

The requirement for multiple receiving beams arises with modern multifunction radar systems. A cluster of narrow pencil beams to cover the observation space illuminated by a broader transmit beam due to high angular resolution and to improve Doppler resolution between different targets and between targets and clutter. Multiple beams steerable within a narrow angular sector may be applied for super resolution. Multiple independent beams steerable within the complete field of view may be applied for interference suppression.

An important concept for beam forming which is also useful for automotive special radar tasks by active array processing is based on partitioning the receiving array into a suitable number of sub arrays. Within each sub array are summed the outputs of neighboring antenna elements after phase steering. The phase steering is controlled by DSP Board which generates 3 bit cyclic code based on Galois Field addition method or any other orthogonal codes like Frank, Barker, etc..This code will shift the steering angle as well as multi beam will also shift according to generated code On the receiving side a multiple-beam antenna has to provide a continuous coverage of the illuminated space. This is necessary to avoid wasting of any transmitted energy. Additionally, the multiple beams deliver the direction information of detected targets. The received energy from targets has to be integrated for each resolution cell during an adequate time interval which may be selected, for example, as being equivalent to the usual radar scanning period.

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Digital beam forming (DBF) is an enabler for generating multiple simultaneous ESA[10-11] beams with full aperture gain. By adjusting the digital weights, multiple beams can be created simultaneously. This is extremely beneficial because each of these beams has full aperture gain. This is illustrated in Figure 3. The same issues with IBW exist with DBF. In order to minimize this effect, the sub array aperture length is designed to match the IBW required. Here we have taken 8 elements for each sub array

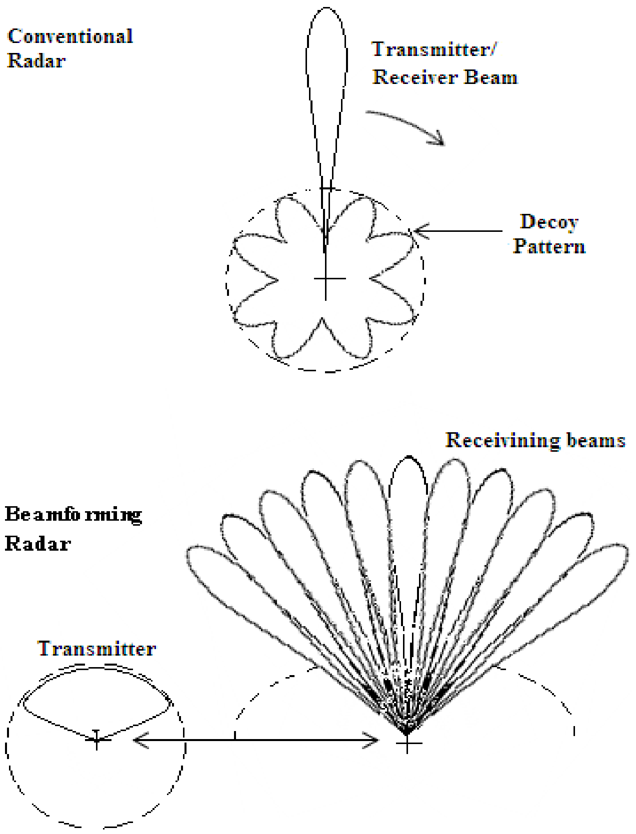

Fig6:-. Antenna Pattern for conventional and DBF Radar

X. T/R MODULE AT MILLIMETER WAVE FREQUENCY

As requirements on new radar systems continue to shift towards multifunctional capabilities on top of increased sensitivity, resolution, and update rates, the use of active electronically scanned arrays (AESA) with some level of digital beam forming has become more common. Fortunately, digital components and systems are expected to become more and more capable of meeting this challenge in the years to come. Additionally, wide-band gap semiconductors like GaN assure to extend the performance limits to transmit/receive (T/R) functionality with higher power transmitters, better efficiency, and more robust receivers. **Figure 7** is a diagram of power-handling capability of different T/R module substrates versus frequency. Gallium Nitride (GaN) and silicon carbide MMIC chips have the potential to increase the T/R module power by one or two orders of magnitude. SiC technology offers 1-10 kW in the low-GHz frequency band with better thermal conductivity than GaAs. GaN modules work from a little less than 10 kW below 10 GHz to a little less than 100W above 100 GHz. It is capable of reduced chip size, broad bandwidth, and higher operating voltage. SiGe and CMOS offer low-power, low-cost, high-performance T/R modules. GaN based solid state device can be used as high frequency source of LRR radar at 77Ghz.

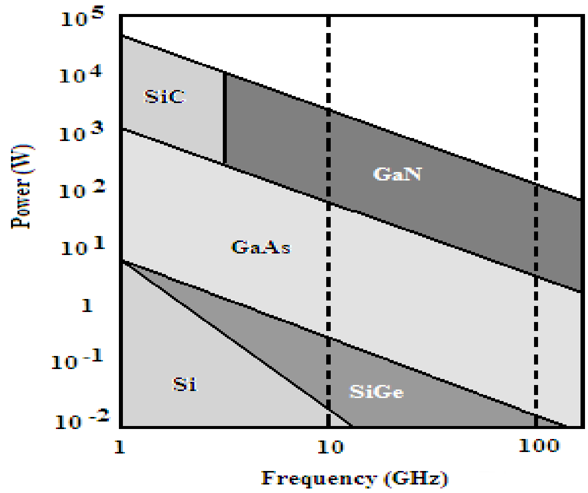

Fig7:- Solid state power handling versus frequency for several substrate materials.

Digital beam forming (DBF) is similar to the use of T/R modules, except the T/R module contains an analog-to-digital (AD) converter that outputs a digital signal directly to the computer. It has the advantages of improved dynamic range, ease of forming multiple beams, adaptive nulling, and low side lobes. Like T/R modules, the AD converter can be either centralized or distributed. The corporate feed performs analog beam forming and converts the signal to digital once all the signals are combined and converts the analog signals to digital signals at each element. **Fig.1** shows an array architecture in which the sub arrays do analog beam forming and the signals from the sub arrays are changed to digital signals. This approach can increase the bandwidth of the array through digital time delay instead of hardware time delays. DBF is simulated using Matlab software because the digital receivers are costly, large, and heavy and require calibration. A full DBF array has the most flexibility and the least amount of feed hardware, because all weighting and combining is done in software.

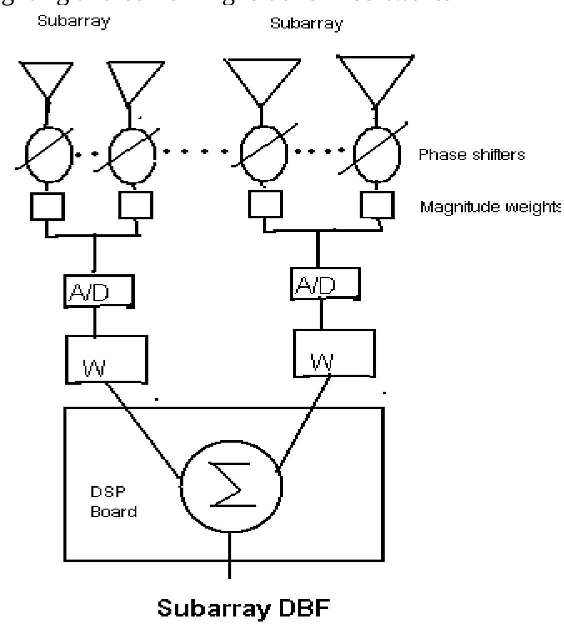

Fig.8:-Digital beam forming at each element.

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Table-II

Simulation Parameters	Beam1	Beam2	Beam3	Beam4	Beam5
Aperture Gain	-0.62 (db)	-0.625 (db)	0 (db)	-0.625 (db)	-3.135 (db)
Squint Angle	-6deg	-3deg	0deg	3deg	6deg
Side lobe Label Reduction	-3.86 (db)	-2.88 (db)	-3.31 (db)	-2.88 (db)	-15.19 (db)

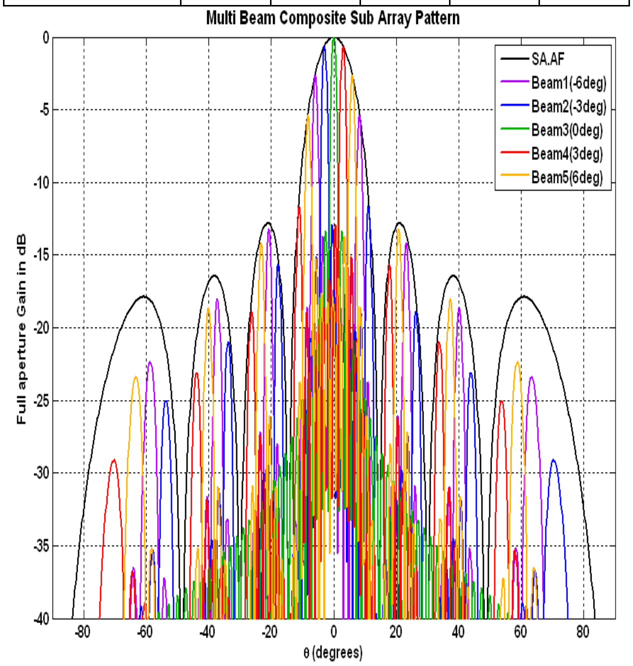

Fig.9:- Multiple simultaneous beams with full aperture

Switch line phase shifters add line lengths to increase the phase of the signal when bit n of an N bit phase shifter is a 1, then the signal is delayed by travelling an additional $180^0/n$ in phase. So for 3 bit phase shifter with input [1 1 0] has an additional phase delay of 270^0.An extra bit can be padded for sign bit for which will steered the beam in positive as well as negative azimuth or elevation angle. MEMS or PIN diode can be used in RF beam forming. MEMS switches have low losses, high isolation, high linearity, small size, low power consumption, and low cost and are broadband. RF MEMS switch already developed by Radant Technologies.Side lobe reduction and Aperture Gain for Multi Beam Digital Beam Forming Array [12]

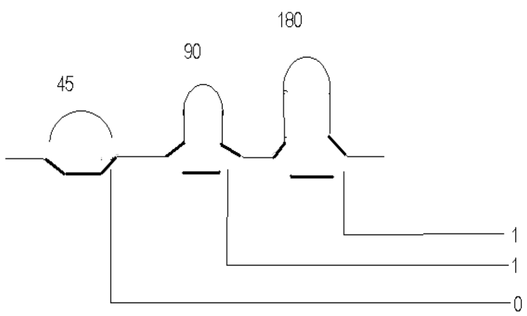

Fig 10: Diagram of switch line phase shifter

XI. ARRAY ANTENNA BEAM STEERING

One of the great features of an ESA is the ability to electronically scan the beam. However, there is no free lunch. One of the primary impacts of electronic scan is the array pattern loss due to the EP roll-off, which has been previously discussed. However, an additional impact of electronic scan is the broadening of the main beam. As the beam is scanned the beam broadens at the rate of $\frac{1}{cos\theta}$. The beam is steered away from the array bore sight or normal to the face of the array experiences gain loss. This loss is due to the fact that the array effective aperture becomes smaller and consequently broadening of beam width. In order to limit this scan loss array should not scan electronically beyond 60 degree scan angle. **Fig10** shows an ESA pattern at several scan angles. The broadening of the main beam with increasing electronic scan is shown below.

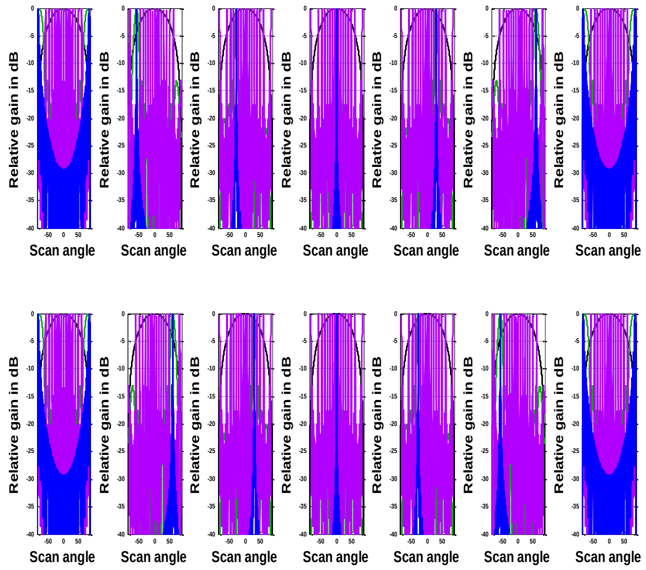

Fig.11:- 3bit digital beam steering for 16 sub-array element for the phase quantization at theta angle from left -90 -60 -30 0 30 60 90 90 60 30 0 -30 -60 -90 30 -60 -90

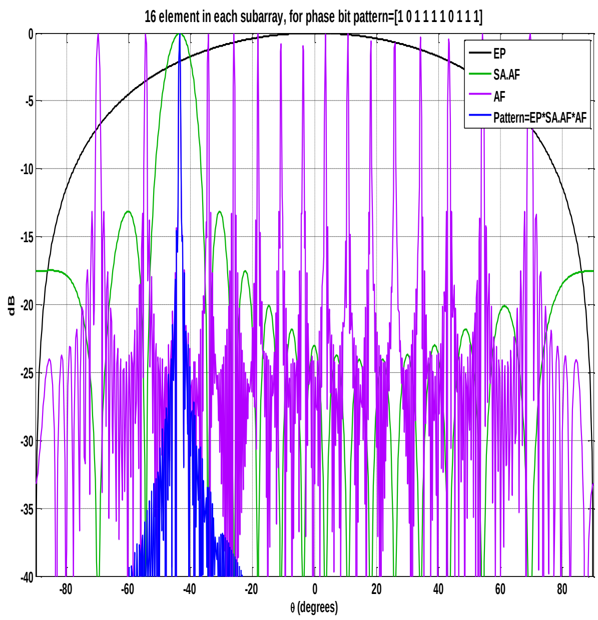

Fig12:-Power pattern at (-41) degree scan angle.

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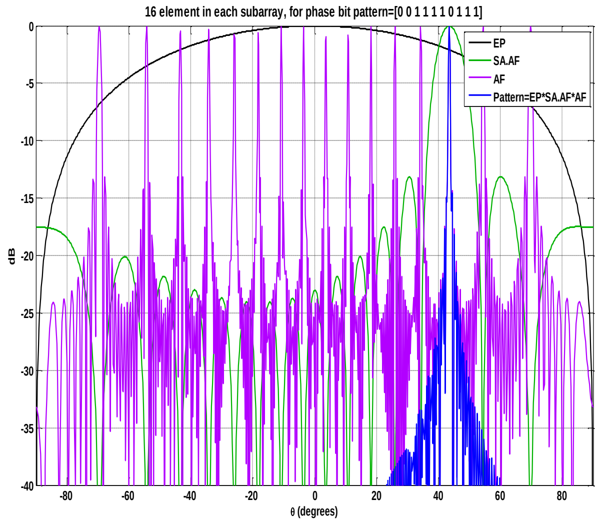

Fig13:- Power pattern at (41) degree scan angle.

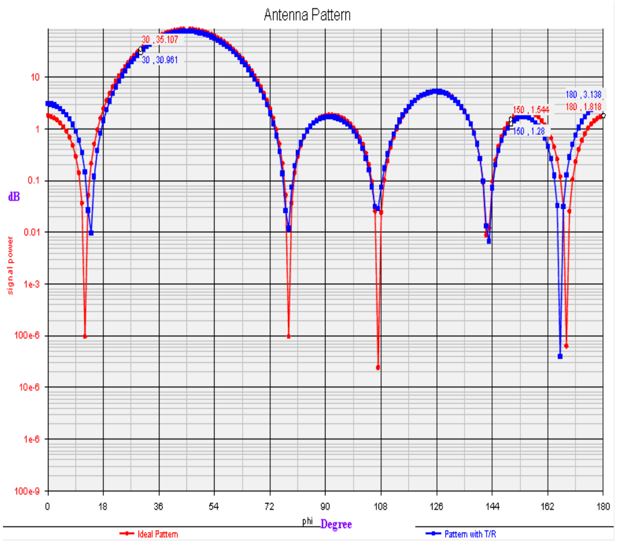

Fig14:-Using SystemVue Beam Steered orientation, Phi = 0.5*(pi/2) = 45° Red: Ideal Pattern, Blue: Transmitted Pattern

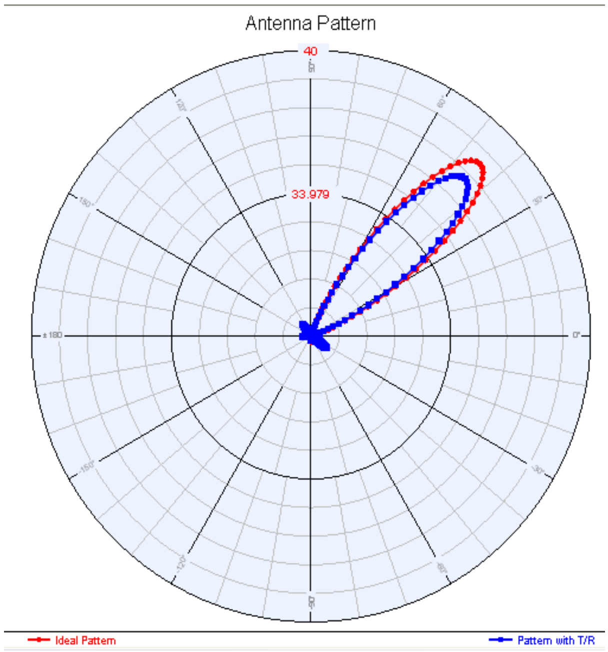

Fig.15:- Beam Steered orientation=45°
Red: Ideal Pattern, Blue: Transmitted Pattern

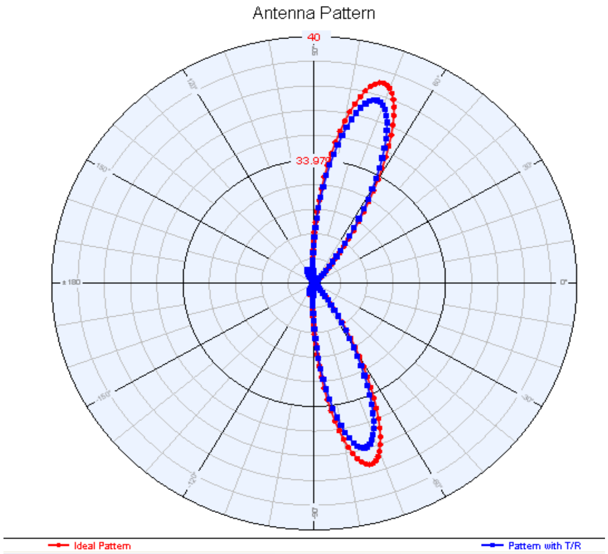

Fig.16:- Beam Steered orientation=72° using SystemVue

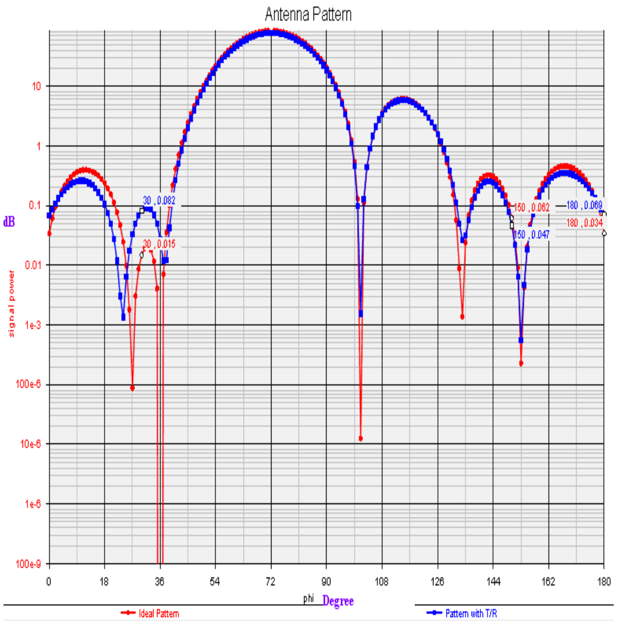

Fig-17:Beam Steered orientation, phi = 0.8*(pi/2) = 72°Red: Ideal Pattern, Blue: Transmitted Pattern using SystmVue

XII. TARGET DETECTION

Target detection[13-14] in wireless channel is very critical because of lot of parameters like noise ,clutter, interference .lot of techniques can be used for clutter elimination like CFAR,CA-CFAR and noise elimination techniques like LMS and NLMS filtering techniques [15-16].Now for multi target detection resolution is the main factor in terms of angle, range, velocity here we have tried angular separation of the different target as small as possible we have simulated for three target in different azimuth and elevation angle and using different orthogonal having good auto and cross co-relation properties maintained and predication for all configuration have tabulated in given Table-III and graph. FM and Stepped LFM are better for analog domain but in digital domain Frank, and different polly phase code is better for good angular resolution. We have plotted in broadside angle.

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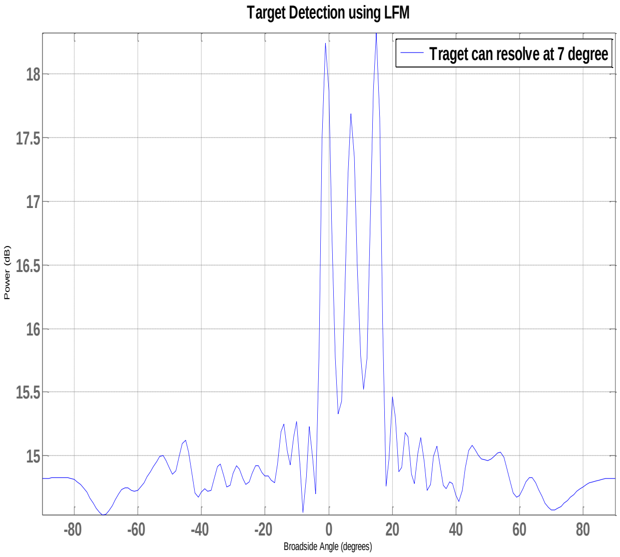

Fig18:-Target detection using LFM

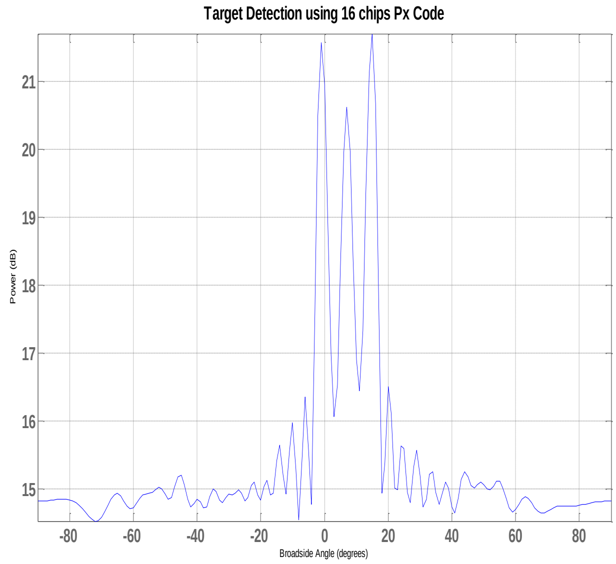

Fig19:-Target Detection using Px

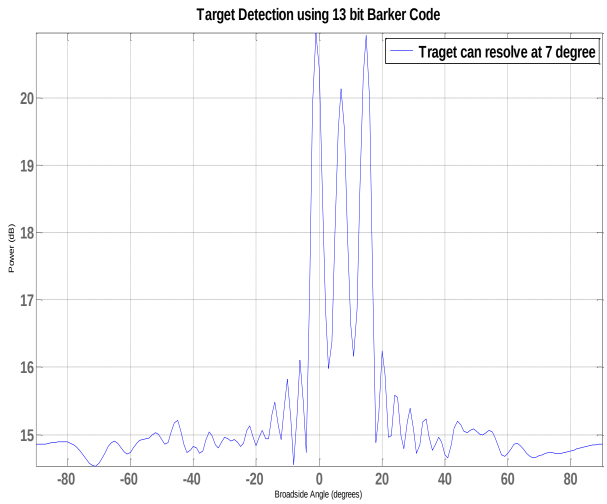

Fig20:-Target Detection using Barker Code

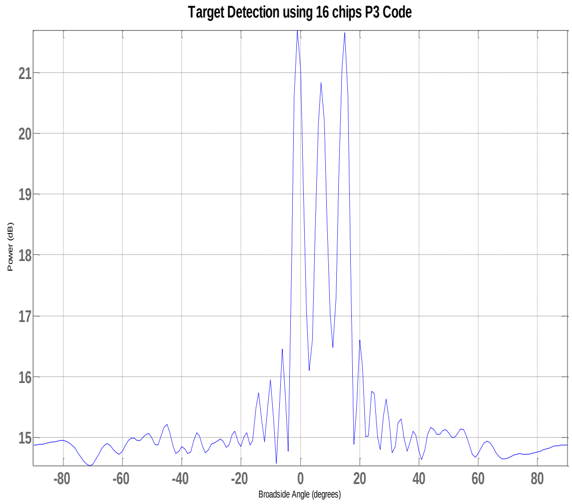

Fig21:-Target Detection using P3 Code

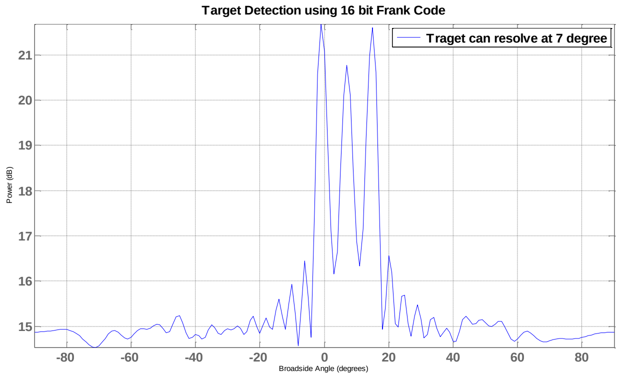

Fig22:-Target Detection using Frank Code

TABLE III

Code/Wave	Number of Element in Linear Array	Azimuth Angle Resolution(degree)	Peak Power(Main Lobe) Max(dB)	Min(dB)	Side Lobes Power Reduction from Main Lobe(dB)	Difference of Maximum Peakpower and Sidelobe power
	8	±25	14.28	13.36	10.57	3.71
	10	±20	16.25	15.23	11.56	4.69
	20	±10	21.94	21	15.6	6.34
Stepped FM	30	±7	26.16	25.22	19.04	7.12
	8	±25	9.925	9.511	9.217	0.708
	10	±20	11.13	10.71	10.25	0.88
	20	±10	15.22	14.87	13.36	1.86
Linear FM	30	±7	18.2	17.81	15.56	2.64
	8	±25	11.37	10.96	9.53	1.84
	10	±20	13.13	12.31	10.5	2.63
	20	±10	17.99	17.28	14.12	3.87
P1	30	±7	21.86	21.04	16.75	5.11
	8	±25	11.43	10.88	9.641	1.789
	10	±20	12.87	12.34	10.57	2.3
	20	±10	17.86	17.25	14	3.86
P2	30	±7	21.72	20.87	16.68	5.04
	8	±25	11.94	11.35	9.678	2.262
	10	±20	13.59	12.93	10.65	2.94
	20	±10	18.58	17.96	14.23	4.35
P3	30	±7	21.61	21.01	16.78	4.83
	8	±25	11.88	11.22	9.67	2.21
	10	±20	13.43	12.86	10.71	2.72
	20	±10	18.63	17.91	14.15	4.48
P4	30	±7	21.61	21.21	16.98	4.63

XIII. AMBIGUITY ARISES ON DBF RADAR SYSTEM.

Waveform design and ambiguity function are important tools for the performance analysis of radar systems. So before design of RADAR either in Monostatic, Bistatic or Multistatic Ambiguity test is very important for enhanced radar performance in terms of target detection, resolution, accuracy of range and velocity measurements, and clutter suppression.

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The ambiguity function of a waveform represents exactly the output of the matched filter when the specified waveform is used as the filter input. This exact representation makes the ambiguity function a popular tool for designing and analyzing waveforms. This approach provides the insight of the resolution capability in both delay and Doppler domains for a particular waveform. Digital Array Coded Radar which emits coherent orthogonal (or incoherent) waveforms to form a focused beam, and also affect the range and Doppler resolution so proper choice of waveform is very critical for this coded Radar. Based on digital beam forming at 77 GHz gratings lobes are the main reason for the arising of ambiguity for the detection of true target. That means we should very much carful about design level of array antenna elemental spacing to avoid grating lobes. Fig.3 shows that ,if we keep the elemental spacing of the order of (lambda/2)then chance of arising grating lobes are very much less. Another point is very much important is side lobes .There are lot of side lobes reduction technique such as windowing techniques another is Tapering technique like Taylor Tapering and Bayliss tapering. Now based on applied orthogonal code like most popular Barker, Frank code that is proper choice of coding is the very important for decision making of moving as well as static objects range and velocity. Lot of simulation studies carried over by us using different orthogonal codes to get good Doppler and delay resolution to get the exact value of target velocity and Range.

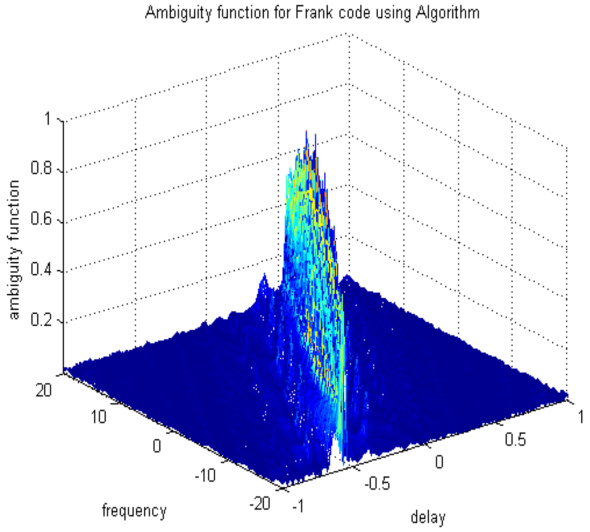

Fig.:-23:-Ambiguity function for frank code

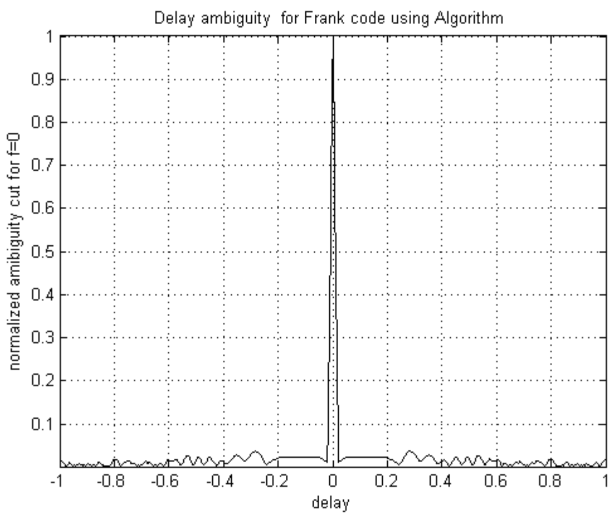

Fig.24:- Delay Ambiguity for frank code

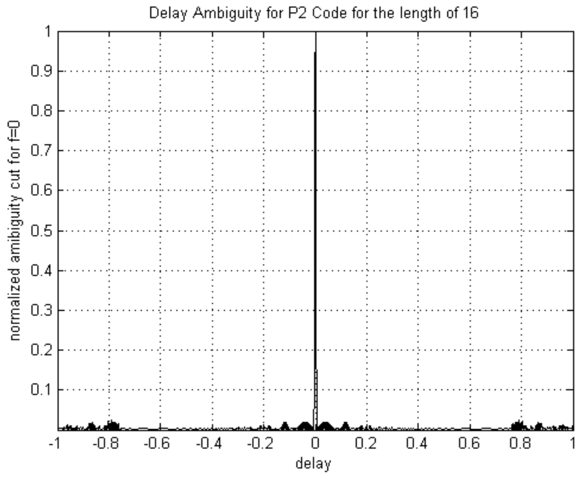

Fig25:-Delay Ambiguity for P2 Code

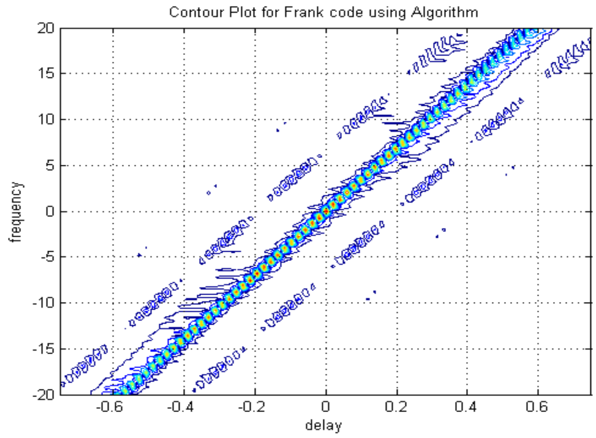

Fig26:-Contour plot for frank code

COMPARISON OF PROBABILITY OF DETECTION (PD) BETWEEN DBF RADAR AND NORMAL RADAR:

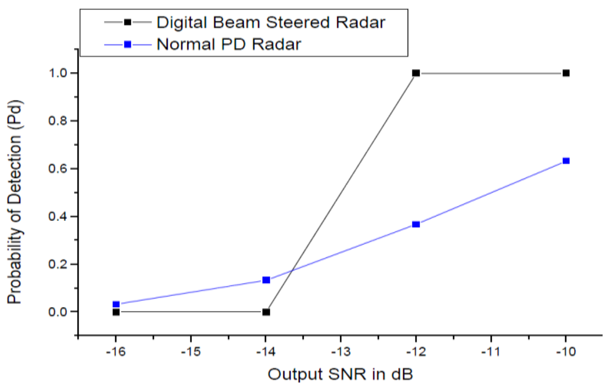

Fig27:- The Probability of Target Detection is 100% ambiguity free in case of a Digital Beam Former Radar w.r.t a normal Radar within the negative SNR zone of -12dB to -10dB

XIV. CONCLUSION

Still now we are trying to implement hardware realization of Integrated Hybrid DBF Radar. Already using X-band Doppler radar portable module fitted with car which is car battery operated can detect moving car and speed of the car and car counting.

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That is field trail we have completed using X-band Doppler radar module. We have taken different orthogonal code for spreading and ambiguity test in terms of range and velocity resolution and side-lobe suppression technique is working satisfactorily. Now we are trying to implement this Radar using MUX and DMUX at RF level and and DBF antenna fabrication

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