Design of computer interface for programmable phased array

FINAL REPORT

By

NEHA CHOPRA
031079

MAY 2007

Submitted in partial fulfillment of the Degree of Bachelor of Technology

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY
WAKANAGHAT

CERTIFICATE

This is to certify that the work entitled, **"Design of computer interface for programmable phased array"** submitted by **Neha Chopra** in partial fulfillment for the award of degree of Bachelor of Technology in **Electronics and Communication Engineering** of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

Dr.Tapas Chakravarty

[redacted] **professor,**

Department of Electronics and Communication Engineering

Jaypee University of Information Technology,

Waknaghat, solan.

Acknowledgement

I cordially thank for the support of Prof. Tapas Chakravarty who apart from guided me through the project by providing me immense knowledge that made the project understandable encouraged me during the various stages of the development of the project.

Neha Chopra
(Neha Chopra).

CONTENTS

ABSTRACT

In this project a programmable beam-switching algorithm for linear and planar phased array antenna is presented. Using microcontroller the planar array can be steered over 49 directions over to complete the hemisphere. Each element is connected to delay lines and switching module. The bits at microcontroller output after being amplified by driver circuit are fed to the switching modules which control the insertion of fixed phase tapering. Switching is performed on a unique set of delay lines to steer the beam in particular direction in the horizon. For high frequency application PIN diode is used as a switch. Suitable time delays are inserted by switching ON/OFF RF switches. Using this concept, one can generate SUM pattern, DIFFERENCE pattern as well as a combination of these two. It is shown that SUM-DIFFERENCE pattern has interesting applications in radar namely calibration of beam pointing accuracy and blind speed elimination in a delay line cancellation method. In total 12 bits are used to select 49 beam positions with some bit patterns being redundant.

1

Introduction

The term ***phase array*** means an array of elements with the phase of each element being variable, providing *control of the beam direction* and pattern shape including side lobes [1].

An objective of phased array is to accomplish bean steering; it's implemented by loading suitable phase tapering between the elements. Phase tapering among the elements can be inserted by addition of phase delay in the master oscillator used as a local oscillator both in transmit and receive path. On the other hand phase tapering can also be implemented by inserting delay lines between successive elements in an array. In recent times, tapped-delay line antenna structures are being proposed to design wide-band adaptive arrays [2].

An **antenna array** is a plurality of active antennas coupled to a common source or load to produce a directive radiation pattern. Usually the spatial relationship also contributes to the directivity of the antenna. Use of the term "active antennas" is intended to describe elements whose energy output is modified due to the presence of a source of energy in the element or an element in which the energy output from a source of energy is controlled by the signal input.

Planar array: - Planar array antennas, like dish antennas, are also mechanically steered but they use a flat rather than concave receiver to gather the reflected radar energy. A flat panel reflector scatters the radar energy impinging on it from hostile radars, rather than sending it back as a well focused beam.

Planar arrays use an array of very simple slot antennas. They achieve their focusing effect by introducing and manipulating a time delay into transmissions from each antenna. A complex network of microwave waveguides on the rear surface of the array is used to achieve this. The controlled time delays result in a desired fixed beam shape with much smaller side lobes compared to a concave reflecting antenna. The key to slotted array antennas is the time delay caused by waveguides. The signal that they transmit is in phase.

Since a planar array antenna is a flat plate, it tends to act like a flat panel reflector to impinging transmissions from hostile radars and thus produce a lower radar signature than a concave antenna.

However, mechanical steering of planar array antennas continued to be a problem.

Beam steering:-

It's the changing the direction of the main lobe of a radiation pattern. In radio systems, beam steering may be accomplished by switching antenna elements or by changing the relative phases of the RF signals driving the elements. In optical systems, beam steering may be accomplished by changing the refractive index of the medium through which the beam is transmitted or by the use of mirrors or lenses.

In the present work, a beam steering planar array has been conceived. Using 12 bits a programmable switching module is able to steer beam in 49 directions over the hemisphere. The detailed schematic is presented in following section.

2

Schematic

The schematic diagram of the micro-controller controlled switched-delay line phase shifting system for the control of phase shifts between N numbers of antenna elements and L number of levels in a phase array are shown in fig.1. The rectangular boxes represent the various delay elements in terms of a finite delay T. The delay elements are interconnected between the different levels by two pairs of switches which are PIN diodes for RF transmission. The delay elements are so chosen that the sum of the delays associated with 0 switch and 1 switch for all subsystems is $P(N-1)T$ where $P = 1, 2, 3, \ldots, L$. The logical status of the 0 and 1 switch are complementary. The power is fed to the system through a power splitter. In the following paragraph a compact antenna array consisting of six elements is considered.

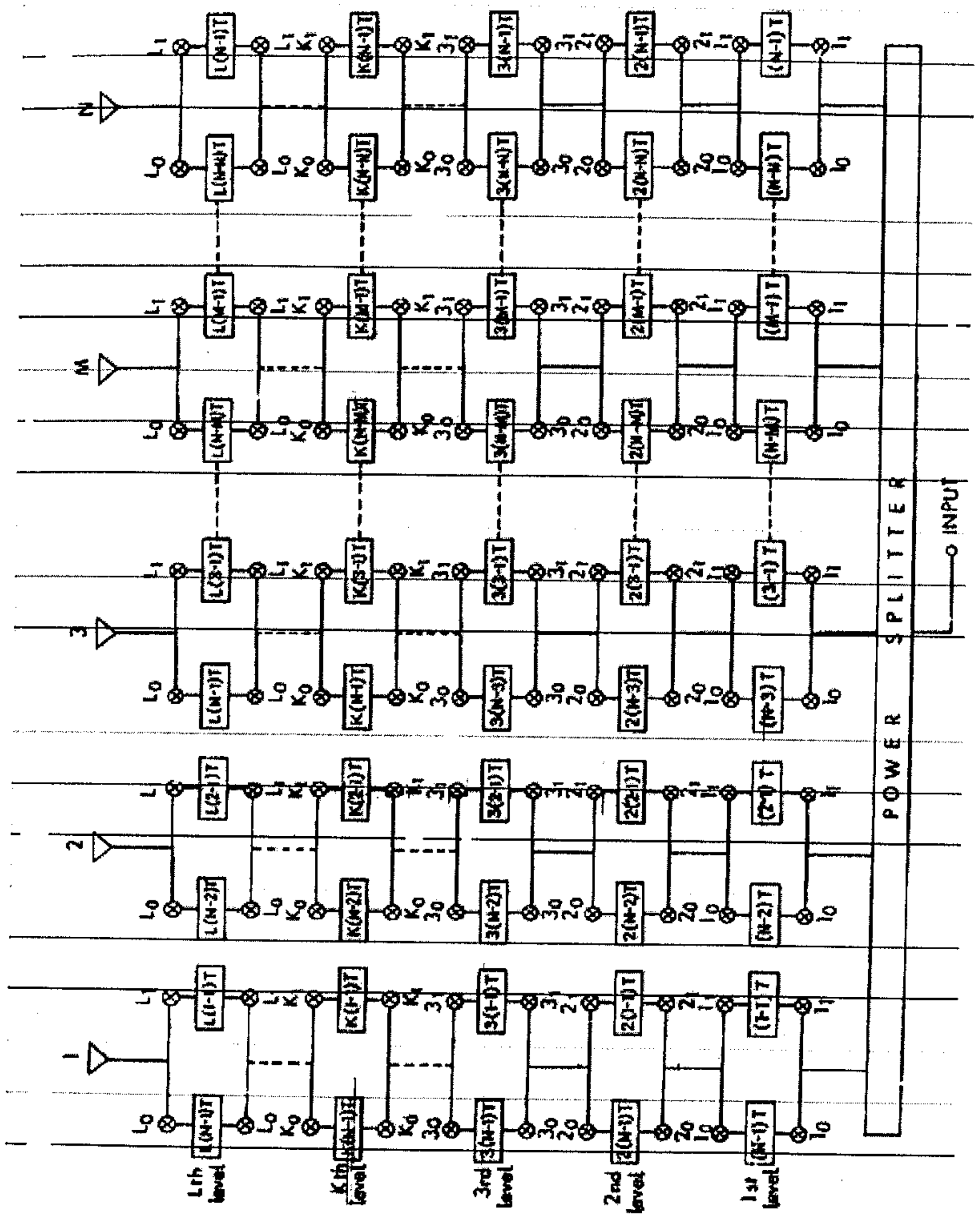


Fig1 Schematic of N element linear antenna array with L levels of switched-delay units

Now in fig.2 the schematic diagram for a **six element linear array.** Each element is connected to two DP3T (double-pole-three throw) switches where the switches are controlled by voltage obtained from driver circuit, which translates the bit pattern obtained from micro-controller output. A DP3T switch module can be constructed using PIN diodes. The control voltages (*A, B, C*) of the DP3T switch are obtained through micro-controller. The limiting condition in this case is at-least and at-most one switch can be ON at a time. This condition therefore demands that some bit patterns to be redundant. The antennas in planar array are arranged in two dimensional matrix forms. It can be considered as an array of linear arrays. Here for heuristic approach, 6 × 6 planar array is taken into account. So there are six numbers of linear arrays separated by fixed distance'd' and for each linear array, antenna elements are also separated by a distance '*d*'.

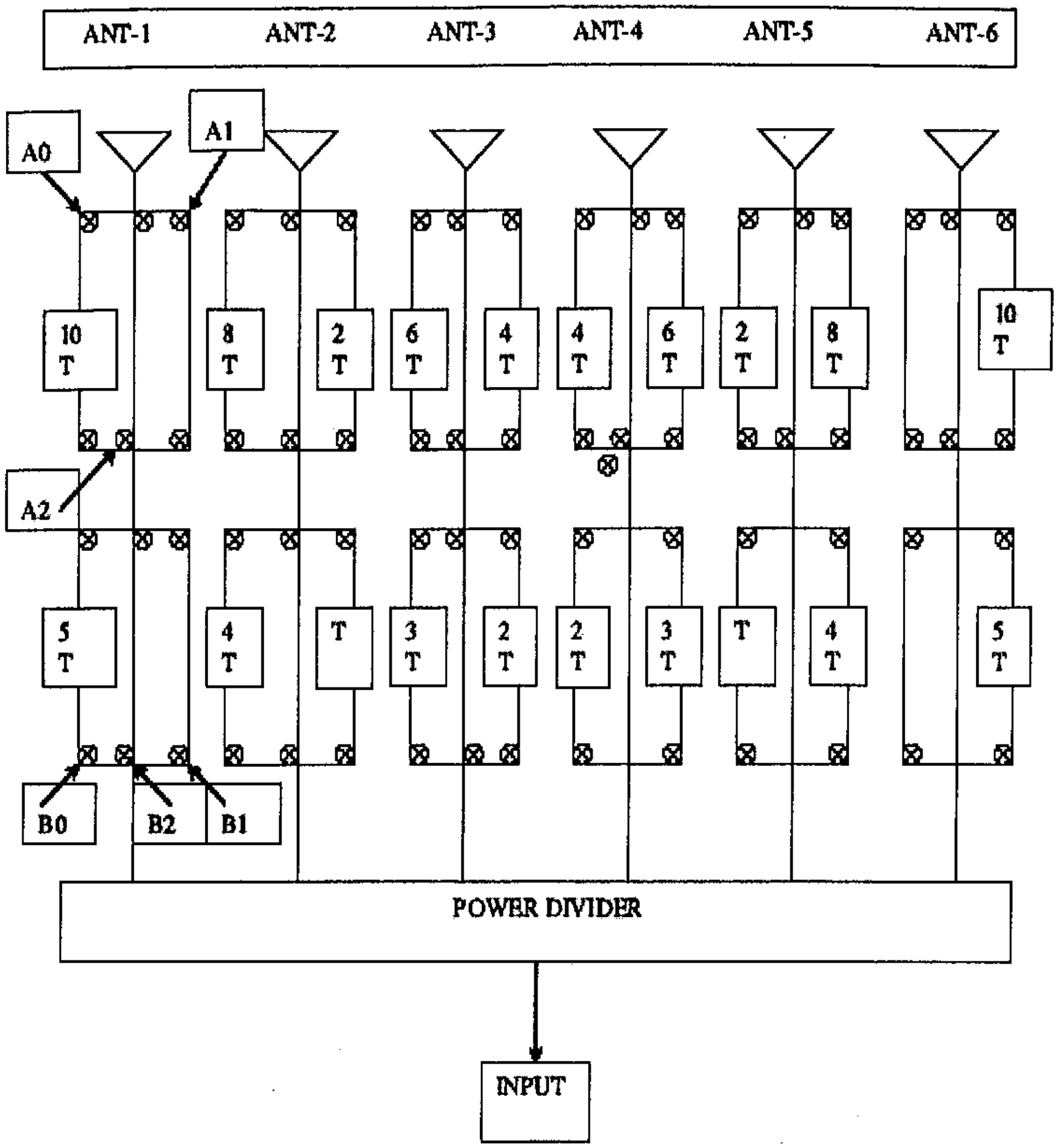


Figure 2. A six element linear array with delay distribution.

The look up table for different calculated inputs and outputs from fig.2 of **LINEAR PAHSE ARRAY** is as follows-

DIFFERENT OUTPUTS WHEN INPUT A0=D

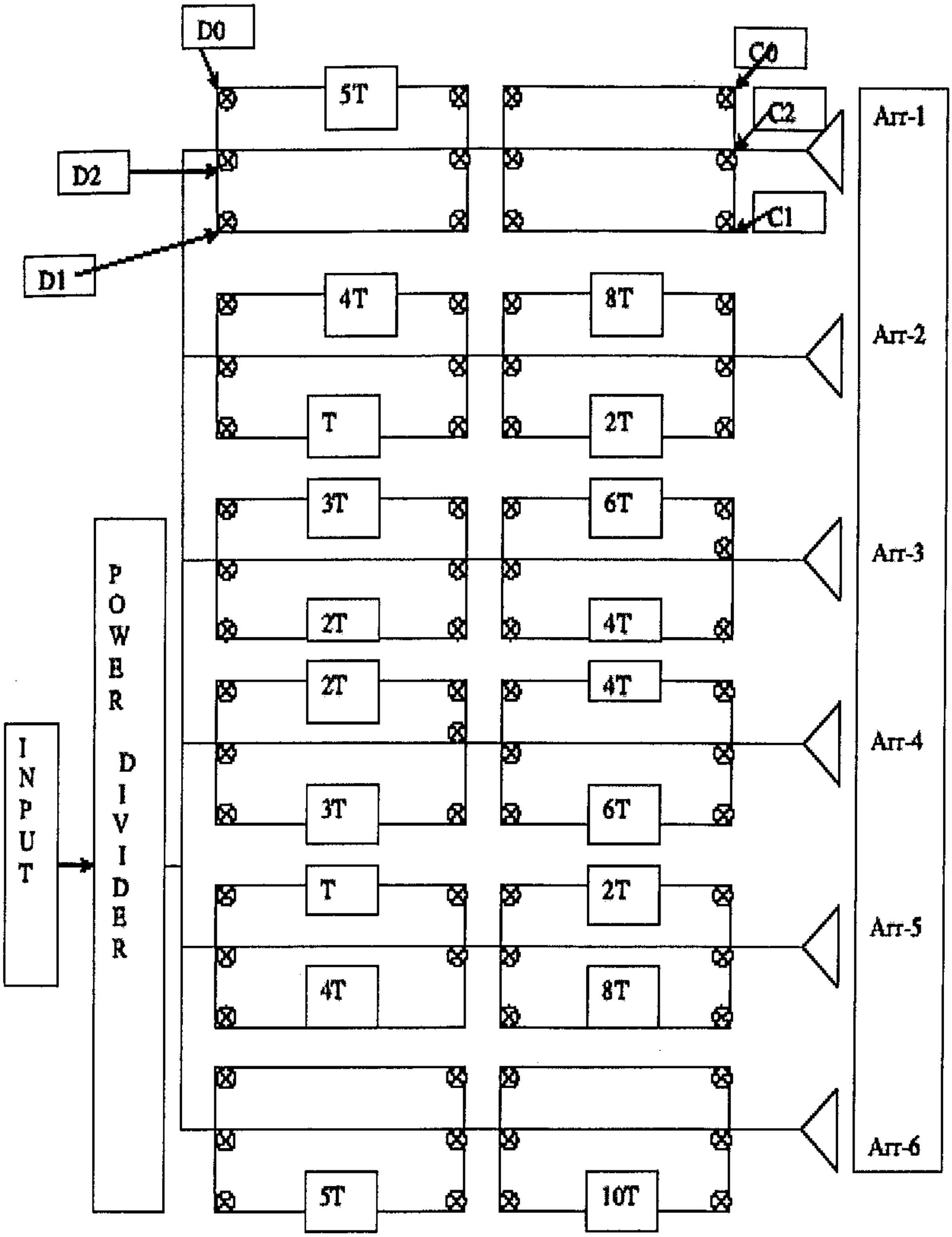
ANTENNA	A0=D	A0=D	A0=D
1.	B2=10DT	B1=10DT	B0=15DT
2.	B2=8DT	B1=9DT	B0=12DT
3.	B2=6DT	B1=8DT	B0=9DT
4.	B2=4DT	B1=7DT	B0=6DT
5.	B2=2DT	B1=6DT	B0=3DT
6.	B2=D	B1=5DT	B0=D

DIFFERENT OUTPUTS WHEN INPUT A1=D

ANTENNA	A1=D	A1=D	A1=D
1.	B2=D	B1=D	B0=5DT
2.	B2=2DT	B1=3DT	B0=6DT
3.	B2=4DT	B1=6DT	B0=7DT
4.	B2=6DT	B1=9DT	B0=8DT
5.	B2=8DT	B1=12DT	B0=9DT
6.	B2=10DT	B1=15DT	B0=10D

DIFFERENT OUTPUTS WHEN INPUT A2=D

ANTENNA	A2=D	A2=D	A2=D
1.	B2=D	B1=D	B0=5DT
2.	B2=D	B1=DT	B0=4DT
3.	B2=D	B1=2DT	B0=3DT
4.	B2=D	B1=3DT	B0=2DT
5.	B2=D	B1=4DT	B0=DT
6.	B2=D	B1=5DT	B0=D



gure 3. A six by six element planar array with delay distributions

This two dimensional array is fed by delay line circuits in $\pm X$ (East-West) direction (as shown in Fig. 2) and $\pm Y$ (North-South) direction. This is displayed in Fig. 3 which is a **6 by 6 element planar array**. The corresponding PIN diode switches are designated by "*A*" & "*B*" (in series) and "*C*" & "*D*" (in series) for the planar array. The RF inputs from the antennas are fed to all the inputs of "*A*" switches and RF outputs of "*A*" switches are combined and fed to "*B*" switches. Thus, for RF to traverse the complete path, one switch each from *A* & *B* is to be closed. Similar is the case for *C* & *D*. The controls of "*A*" switch, for example, are designated by *A*0, *A*1, *A*2. A typical switching pattern of the *A*0, *A*1, *A*2 (*C*0, *C*1, *C*2) & *B*0, *B*1, *B*2 (*D*0, *D*1, *D*2) is shown in the Table 1. From Table 1, it is seen that the beam can be tilted in both East-West and North-South directions using independent control of *A-B* and *C-D* switches respectively. As stated earlier, only one switch is ON at any instant for "*A*", "*B*", "*C*" and "*D*" switches, keeping all others OFF. Therefore nine combinations are offered for each series (*A-B* and *C-D*), out of which two combinations are redundant (as it is duplicating $+T$ & $-T$ delay). So effectively, forty-nine beam positions can be achieved in such way for a planar array.

Table 1. Switching Pattern for 6 x 6 planar array.

T=Unit delay

A0/C0	A1/C1	A2/C2	B0/D0	B1/D1	B2/D2	Progressive Delay
0	0	1	0	0	1	0
0	0	1	0	1	0	T in East/South Direction
0	1	0	0	0	1	2T in East/South Direction
0	1	0	0	1	0	3T in East/South Direction
1	0	0	0	0	1	-2T in West/North Direction
1	0	0	0	1	0	-T in West/North Direction
1	0	0	1	0	0	-3T in West/North Direction

To keep the beam in center position, the following bit pattern is taken in account:
$A0 = 0$, $A1 = 0$, $A2 = 1$, $B0 = 0$, $B1 = 0$, $B2 = 1$
&$C0 = 0$, $C1 = 0$, $C2 = 1$, $D0 = 0$, $D1 = 0$, $D2 = 1$
For other beam positions, first Y direction array is loaded with suitable delays by switching C & D appropriately then X direction linear array are switched on using A & B bit pattern. For a planar phased array, the following relations hold true [3]

$\beta x = -kdx \sin \vartheta 0 \cos \varphi 0$ (1) and

$\beta y = -kdy \sin \vartheta 0 \sin \varphi 0$ (2) where $\theta 0$ is the **elevation angle** measured from zenith and $\varphi 0$ is the **azimuth angle** measured from $+X$ (East) direction in anti-clockwise rotation. Here βx and βy are progressive phase shift; dx and dy are inter-element spacing in X & Y direction respectively. For this case,
$dx = dy = d$.
Solving simultaneously
$\text{Tan}\ \varphi 0 = \beta x / \beta y$ (3)
$\sin 2\ \vartheta 0 = (\beta x / kd)^2 + (\beta y / kd)^2$ (4)
For the present case, analysis is carried out considering $d = 0.78\lambda$ and any arbitrary frequency. We also consider that unit delay T corresponds to a phase shift of $\pi/4$ radians.

The look up table for different calculated inputs and outputs from fig.3 of **PLANAR PAHSE ARRAY** is as follows-

DIFFERENT OUTPUTS WHEN INPUT A0=D
AND T=Π/6

ANTENNA	A0=D	A0=D	A0=D
1.	B2=1.67ΠD	B1=1.7ΠD	B0=2.5ΠD
2.	B2=1.33ΠD	B1=1.5ΠD	B0=2ΠD
3.	B2=ΠD	B1=1.33ΠD	B0=1.5ΠD
4.	B2=0.67ΠD	B1=1.167ΠD	B0=ΠD
5.	B2=0.33ΠD	B1=ΠD	B0=0.5ΠD
6.	B2=D	B1=0.83ΠD	B0=D

DIFFERENT OUTPUTS WHEN INPUT A1=D
AND T=Π/6

ANTENNA	A1=D	A1=D	A1=D
1.	B2=D	B1=D	B0=0.833ΠD
2.	B2=0.33ΠD	B1=0.5ΠD	B0=ΠD
3.	B2=0.67ΠD	B1=ΠD	B0=1.167ΠD
4.	B2=ΠD	B1=1.5ΠD	B0=1.33ΠD
5.	B2=1.33ΠD	B1=2ΠD	B0=1.5ΠD
6.	B2=1.7ΠD	B1=2.5ΠD	B0=1.7ΠD

DIFFERENT OUTPUTS WHEN INPUT A2=D
AND T=Π/6

ANTENNA	A2=D	A2=D	A2=D
1.	B2=D	B1=D	B0=0.833ΠD
2.	B2=D	B1=0.167ΠD	B0=0.67ΠD
3.	B2=D	B1=0.33ΠD	B0=0.5ΠD
4.	B2=D	B1=0.5ΠD	B0=0.33ΠD
5.	B2=D	B1=0.67ΠD	B0=0.167ΠD
6.	B2=D	B1=0.833ΠD	B0=D

On calculating the **azimuth** *(φ0)* and **elevation angles** *(θ0)* for different values of **βx** *and βy* and then on calculating value for *kd* i.e. *k*=2Π/λ, *d*=λ/2 so ***kd*=Π**. On putting values in equation 3 & 4 as shown above ,we get the **beam positions** for **all** the **four quadrants** in the following table shown below:-

βx	**βy**	**Φ0(azimuth angle)**	**ϑ0(elevation angle)**
Π/2	Π/4	63.43°	33.987°
Π/2	4Π/5	68.19°	70.63°
Π/2	5Π/6	30.96°	104.10°
Π/2	7Π/10	35.537°	120.18°
Π/2	3Π/5	39.80°	129°
Π/2	3Π/25	75.96°	149.13°
Π/2	2Π/5	51.34°	220°
Π/2	7Π/10	35.53°	240.18°
Π/2	21Π/25	30.76°	258°
Π/2	9Π/10	30.17°	319.16°
Π/2	7Π/40	70.709°	328°

On calculating the different switching patterns for different outputs when inputs to A0, B0, C0, D0, A1, B1, C1, D1 are as follows in the following tables-

DIFFERENT OUTPUTS WHEN INPUT A0=B2=B1=B0=D, C0=D2=D1=D0=D

ANTENNA	A0=B2=D C0=D2=D	A0=B1=D C0=D1=D	A0=B0=D C0=D0=D
1.	10DT	10DT	15DT
2.	8DT	9DT	12DT
3.	6DT	8DT	9DT
4.	4DT	7DT	6DT
5.	2DT	6DT	3DT
6.	D	5DT	D
PROGRESSIVE DELAY	2T	IT	3T

These progressive delays occur when we move from left to right i.e. when we move in "X" (east to west) direction and when we move from bottom to top i.e. "Y" (south to north) direction.

DIFFERENT OUTPUTS WHEN INPUT A1=B2=B1=B0=D, C1=D2=D1=D0=D

ANTENNA	A1=B2=D C1=D2=D	A1=B1=D C1=D1=D	A1=B0=D C1=D0=D
1.	D	D	5DT
2.	2DT	3DT	6DT
3.	4DT	6DT	7DT
4.	6DT	9DT	8DT
5.	8DT	12DT	9DT
6.	10DT	15DT	10D
PROGRESSIVE DELAYS	2T	3T	1T

These progressive delays occur when we move from left to right i.e. when we move in "X" (east to west) direction and when we move from bottom to top i.e. "Y" (south to north) direction.

DIFFERENT OUTPUTS WHEN INPUT A2=B2=B1=B0=D, C2=D2=D1=D0=D

ANTENNA	A2=B2=D C2=D2=D	A2=B1=D C2=D1=D	A2=B0=D C2=D0=D
1.	D	D	5DT
2.	D	DT	4DT
3.	D	2DT	3DT
4.	D	3DT	2DT
5.	D	4DT	DT
6.	D	5DT	D
PROGRESSIVE DELAY	0T	1T	1T

These progressive delays occur when we move from left to right i.e. when we move in "X" (east to west) direction and when we move from bottom to top i.e. "Y" (south to north) direction.

For all the above calculated progressive delays we calculate these delays by putting different values of **'T'** where the delay is **unit progressive delay** 'T' and calculating the **elevation (*θ*0)** and **azimuth angles (*φ*0)** for all possible values in the **first quadrant**. The following table gives us all the possible values required:-

βx	βy	Φ0	ϑ0	A0			A1			A2		
				B2	B1	B0	B2	B1	B0	B2	B1	B0
				2T	1T	3T	2T	3T	1T	0T	1T	1T
				FOR UNIT DELAY T								
Π/10	Π/10	45°	8.1301°	0.2	0.1	0.3	0.2	0.3	0.1	0	0.1	0.1
Π/8	Π/8	45°	10.182°	0.25	0.125	0.375	0.25	0.375	0.125	0	0.125	0.125
Π/6	Π/6	45°	13.6323°	0.33	0.17	0.5	0.33	0.5	0.167	0	0.17	0.17
Π/4	Π/4	45°	20.7048°	0.5	0.25	0.75	0.5	0.75	0.25	0	0.25	0.25
Π/10	Π/8	38.65°	9.21142°									
Π/10	Π/6	30.96°	11.2076°									
Π/10	Π/4	21.8014°	15.8201°									
Π/8	Π/10	51.34°	9.21142°									
Π/8	Π/6	36.869°	12.0246°									
Π/8	Π/4	26.565°	15.6201°									
Π/6	Π/10	59.036°	11.2076°									
Π/6	Π/8	53.130°	12.0246°									
Π/6	Π/4	33.69°	17.485°									
Π/4	Π/10	68.198°	15.6201°									
Π/4	Π/8	63.43°	16.2308°									
Π/4	Π/6	56.30°	17.485°									

Now we calculate these delays by putting different values of 'T' where the **progressive delay** is **'2T'** and calculating the **elevation** ***(θ0)*** and **azimuth angles** ***(φ0)*** for all possible values in the **first quadrant**. The following table gives us all the possible values required:-

βx	βy	Φ0	$\vartheta 0$	A0			A1			A2		
				B2	B1	B0	B2	B1	B0	B2	B1	B0
				2T	1T	3T	2T	3T	1T	0T	1T	1T
				FOR UNIT DELAY 2T								
2Π/10	2Π/10	45°	16.4299°	0.4	0.2	0.6	0.4	0.6	0.2	0	0.2	0.2
2Π/8	2Π/8	45°	20.7048°	0.5	0.25	0.75	0.5	0.75	0.25	0	0.25	0.25
2Π/6	2Π/6	45°	28.1255°	0.66	0.33	1	0.66	1	0.33	0	0.33	0.33
2Π/4	2Π/4	45°	45°	1	0.5	1.5	1	1.5	0.5	0	0.5	0.5
2Π/10	2Π/8	38.65°	18.672°									
2Π/10	2Π/6	30.96°	22.875°									
2Π/10	2Π/4	21.8014°	35.582°									
2Π/8	2Π/10	51.34°	18.672°									
2Π/8	2Π/6	36.869°	24.624°									
2Π/8	2Π/4	26.565°	33.9879°									
2Π/6	2Π/10	59.036°	22.875°									
2Π/6	2Π/8	53.130°	24.624°									
2Π/6	2Π/4	33.69°	36.936°									
2Π/4	2Π/10	68.198°	35.582°									
2Π/4	2Π/8	63.43°	33.9879°									
2Π/4	2Π/6	56.30°	36.936°									

Looking at the above tables we can make out and calculate all the possible values ***(θ0)*** and ***(φ0)*** and can make out all the possible progressive delays for any value of **'T'**.

3

Different approach of beam steering and scanning

In this project a different approach of beam steering and scanning is realized. This method of beam steering is also used in different application areas like SUM and DIFFERENCE pattern generation, blind speed elimination, and shaped beam pattern generation. Unlike the traditional phase-shifter method, the stress is laid on simple method of beam steering using true delay line. True delay lines inserts progressive phase gradient in between antenna elements and by designing a proper switching matrix, a programmable beam steering and beam synthesis is achieved in a simple manner. Above all, it imparts a real flexibility in bandwidth or designing a wideband phased array system. We have also briefly discussed the prospects of programmable time-delay based system in different application areas. By using a special delay-line based switching matrix in a planar array, programmable SUM pattern and DIFFERENCE pattern can be generated. These patterns together are utilized for calibration of the array. Using a hybrid matrix of delay line and phase shifters, a method of conical scanning is also possible.

1. ANTENNA SCHEMATIC AND GENERATION OF SUM PATTERN

The six by six planar antenna schematic with time delay units is shown in Fig.1. There are six antenna arrays with each array connected to delay units in the layers named as D, E, F. Each array has six elements connected to delay matrix named as A, B and C. Thus, for RF to traverse the complete path, one switch each from A, B, and C is to be closed [1]. Similar is the case for E, F and D. It is necessary to outline that in the present schematic when one particular switch say D_0 is ON thereby inserting 5T delay in the left-most array, the corresponding switches with other arrays are also ON thereby inserting 4T, 3T, 2T, T and 0T. By judicious choice of switch selection, progressive phase gradient in ±X and ±Y direction can be introduced. Table 1 lists the switch position ("1" for ON) and corresponding progressive delay. From Table 1 it is seen that the beam can be tilted in both East-West and North-South directions using independent control of A, B, C, D, E, F switches. For a planar phased array, the following relations hold true [2]:

$$\beta_x = -kd_x \sin\vartheta_0 \cos\phi_0 \qquad (1)$$

and

$$\beta_y = -kd_y \sin\vartheta_0 \sin\phi_0 \qquad (2)$$

where θ_0 is the elevation angle measured from zenith and ϕ_0 is the azimuth angle measured from +X (East) direction in anti-clockwise rotation. Here β_x and β_y are progressive phase shift, d_x and d_y are inter-element spacing in X & Y direction respectively. For this case, $d_x = d_y = d$. Solving simultaneously

$$\tan\phi_0 = \frac{\beta_x}{\beta_y} \qquad (3)$$

$$\sin^2\vartheta_0 = (\frac{\beta_x}{kd})^2 + (\frac{\beta_y}{kd})^2 \qquad (4)$$

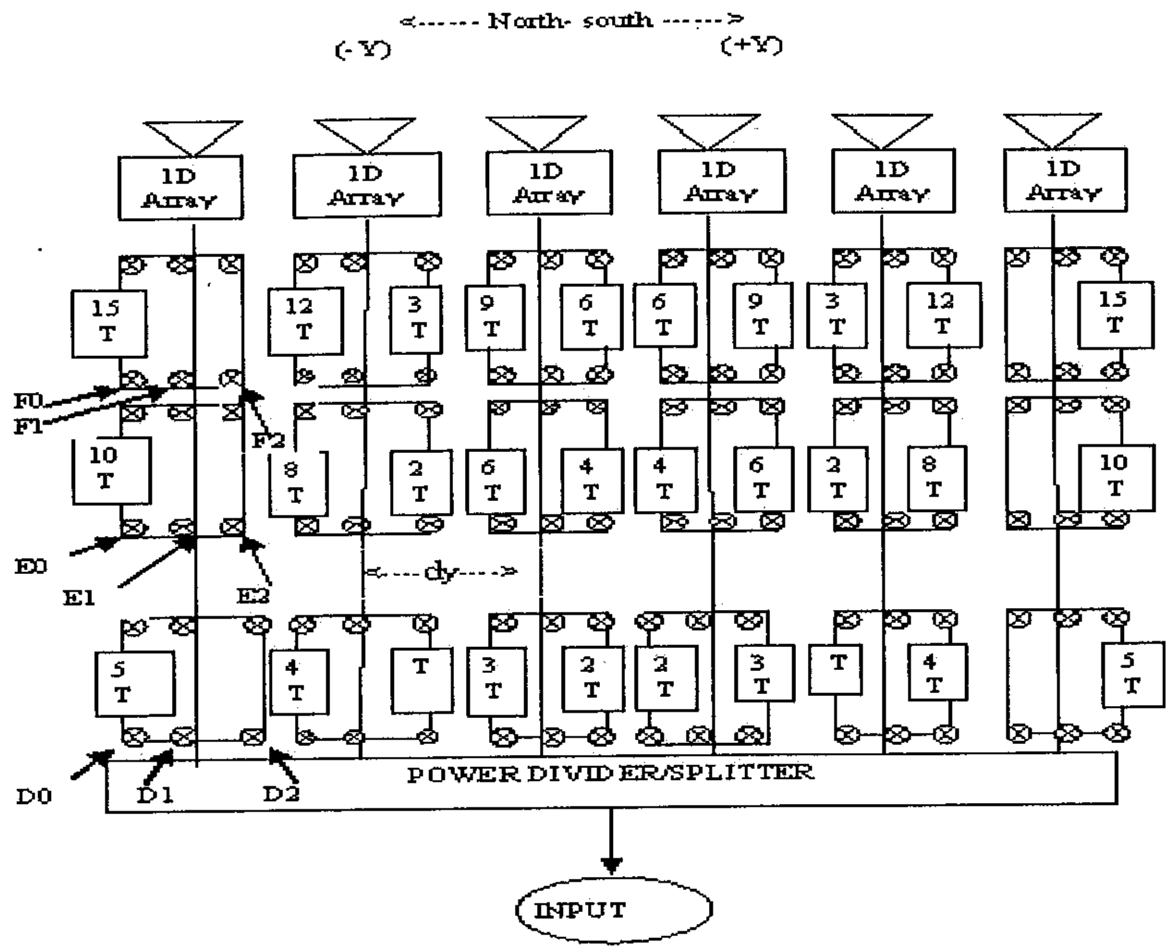


Fig. 1 A planar array with time delay units.

We can set some representative parameters as: dx = dy = 0.78λ and $T=\pi/4$ radian and switch controls as: $A_0 = 0$, $A_1 = 1$, $A_2 = 0$, $B_0 = 0$, $B_1=1$, $B_2 = 0$ and $C_0 = 0$, $C_1 = 0$, $C_2 = 1$ for linear array to obtain +T in -X direction (or East) and $D_0 = 0$, $D_1 = 1$, $D_2 = 0$, $E_0 = 0$, $E_1 = 0$,$E_2 = 1$ and $F_0 = 0$, $F_1 = 0$,$F_2 = 1$ for 3T in -Y direction (or South) for planar array. Substituting the values of $\beta_x = -\pi/4$ and $\beta_y = -3\pi/4$ in expressions (3) and (4) we get $\theta_0 =$ 30.449 from zenith and $\varphi_0 = 71.565$. (Towards North) So the resultant beam is tilted at 30.449^0 from broadside direction at 71.565^0 on East-North direction.

Table1. Switching pattern for 6 × 6 planar array.

T=Unit delay

A_0 / D_0	**A_1 / D_1**	**A_2 / D_2**	**B_0 / E_0**	**B_1 / E_1**	**B_2 / E_2**	**C_0/ F_0**	**C_1 / F_1**	**C_2 / F_2**	**Progressive Delay (Direction)**
0	1	0	0	1	0	0	0	1	+T in *East/South*
0	0	1	0	1	0	0	1	0	+2T in *East/South*
0	1	0	0	0	1	0	0	1	+3T in *East/South*
0	0	1	1	0	0	0	0	1	+4T in *East/South*
0	0	1	0	1	0	0	0	1	+5T in *East/South*
0	0	1	0	0	1	0	0	1	+6T in *East/South*

2. GENERATION OF DIFFERENCE PATTERN

In this unique scheme, a DIFFERENCE pattern can be generated and centre null position scanned in steps on either side of zenith. Consider the control switch position as follows. The progressive time delay units in $+X$ direction are 0, $2T$, $4T$, $12T$, $14T$, $16T$. This results in a DIFFERENCE pattern with Null position at 19.471° in the West. Figure 2 displays the pattern. Similar to changing the control bits $A2$ & $B2$ to "1" result in a DIFFERENCE pattern at bore sight. The delay units for null at zenith is 0, 0, 0, $6T$, $6T$, $6T$.

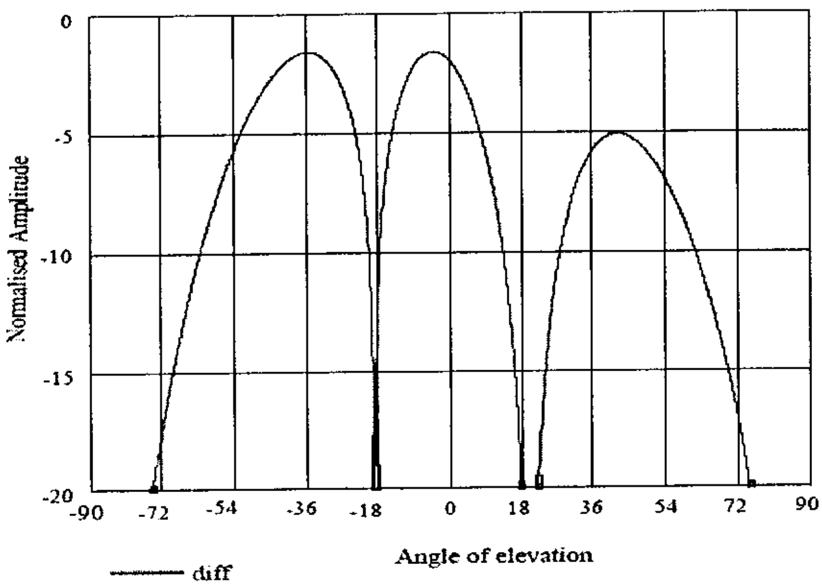


Figure 2 A display of DIFFERENCE pattern at 20 degree west direction.

3. CALIBRATION TECHNIQUES

Utilizing of true-time delays along with RF switches incorporate delay errors in beam steering. Therefore there is need to calibrate the large phased arrays. In an interesting approach to far-field measurements and calibration of very large sized array antenna, radio source has been used [3]. The noise temperature of the radio source Virgo-A (3C 274) was measured in the receive mode during its transit over the radar. The source under consideration should have appropriate right ascension and declination to be able to pass through the antenna array beam. The atmospheric radar had 256 Yagi elements operating at 53 MHz. In this paper, a conceptual variation to similar far-field measurements is presented. In this proposed method suitable selection of delay unit result in either SUM pattern or DIFFERENCE pattern. The SUM-DIFFERENCE pattern can be utilized for measurement of primary accuracy. This is demonstrated in the following sections:

For measurement of beam pointing accuracy of less than 0.5°, a broad beam SUM pattern will not suffice. It is necessary to have a sharply pointed beam looking up at the target. This can be generated using SUM-DIFFERENCE pattern. Toggling the control bits in synchronization to a 1 KHz clock, the alternate SUM pattern and DIFFERENCE pattern are obtained and the difference in amplitude of the detected signal is taken. It is evident that for the resultant narrow beam, the measurement of beam pointing accuracy is much more meaningful.

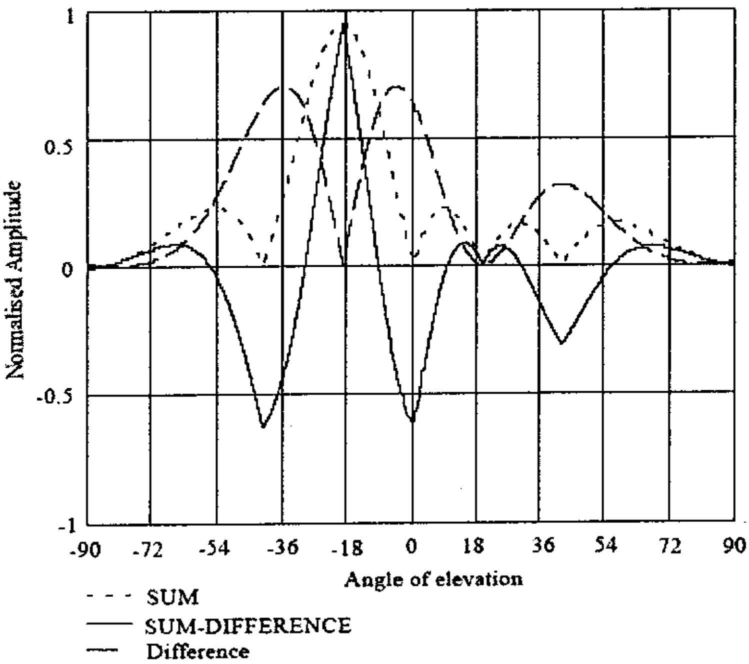


Figure 3 The SUM, DIFFERENCE and SUM-DIFFERENCE plots.

4
Applications

Phased array applications:-

Phased array antennas are widely used in diverse areas of application from radar engineering to modern satellite and mobile communication etc. Conventionally, a phased array antenna uses phase-shifters for electronically steering the beam in any desired direction and for other multifunctional capacity. But the efficiency of phased array antenna having phase-shifters is constrained for several reasons. They have limited range of frequency of operation which is dependent on phase-shifter characteristics. They have a complex control circuitry for switching the phase-shifters and also overheads on the cost of designing a phased array system.

The other applications of phased array would be delay line cancellation, conical scan, and shaped beam generation.

The phased array technology itself allows several controlled phase shifters to be installed at the same time as radiators, i.e. solder-mounted on the same printed-circuit board, which increases the cost of antenna, though. For this reason, it is of vital importance for a mass user, as opposed to a military one, to assess wherein lays novel phased array functionality and what is the price for that complication.

The application of phased-array technology to the satellite system is one promising method to overcome the effects of rain-attenuation.

Phased array has also found its way into many new markets and industries. While many of the earlier applications originated in the nuclear industry, new applications such as pipeline inspection, general weld integrity, in-service crack sizing, and aerospace fuselage inspection are becoming quite common. These applications have pushed phased array technology to new and improved levels across the industrial spectrum: improved focusing, improved sizing, better inspections, and more challenging applications. Progress is being made terms of code compliance also.

5

Advantages

Phased arrays can offer several advantages over other aperture technologies supporting submarine communications functions. First, they can make more efficient use of limited stowage space. Reflector antennas must be housed in a radome to protect them from hydrostatic pressure. This radome must be large enough to cover the entire volume mapped by the antenna at all pointing directions. This results in 'wasted volume' -volume that forces the antenna aperture to be smaller in order to accommodate it physically. Additionally, the radome must be thick to remain strong enough to withstand the pressure. This thickness often results in greater signal attenuation. If
Submarines are severely constrained by their limited volume available for communications and others. The submarine environment places severe constraints on any antenna system.
Phased arrays have been used by many companies we can just have an idea by following-

Colby Instruments is an industry leader in the design and manufacture of high-precision programmable microwave and RF delay line instruments and modules. Their products include a patented design that offers the highest precision resolution available for any instrumentation electromechanical delay line while also offering excellent repeatability. Each delay line model in their Programmable Delay Line (PDL) series is programmable via remote interface or local control. Only the highest performance products and components available in the industry are used in the design and manufacture of all of our products.

Programmable Delay Lines are also used as Phase Shifters in many microwave and RF signal applications where the requirement to electrically delay or phase shift signals to a high degree of accuracy and precision is of critical importance. Their new PDL-100A Programmable Delay Line Series of instruments lead the industry in offering delay resolution to 0.50 picoseconds accuracy (or phase shift precision to 0.18 degrees per 1 GHz signal frequency).

Their focus on engineering design excellence has produced high precision products with a proven performance history. Typical product applications for the Programmable Delay Line instrument include test and measurement, Defense systems, fiber optics, Telecommunications, Government, high precision timing and synchronization applications, microwave and high frequency RF phase shifting, phase noise analysis, University research, and laser research facilities.

Another company which uses phased array applications is Narda microwave-east L3 communications Company is part of a 12 $ billion electronics company serving the military and commercial communications markets . For 50 years, narda has developed and manufactured state of the art RF and microwave components, MIC's , multifunctional assemblies, and subsystems. The company has been a technology leader offering advanced products in the frequency range of DC to 60 Ghz for both commercial and military applications.

Many company products are detailed in its catalogue and are available from stock. The company maintains the world's largest inventory of RF and microwave components. These products include couplers, power dividers attenuators, RF switches, power monitors and more .Narda also offers multifunctional microwave integrated circuits and sub assemblies which integrate and combine active and passive components. These products are typically custom designs for specific customer requirements and include switches, oscillators, synthesizers, amplifiers. Today, the Narda brand also includes fiber optic modulator drivers and oscillators applications.

Conclusion

In this project, a conceptual schematic of delay unit based programmable phased array is presented. The delay units are inserted in the RF path by switching ON respective switches. Apart from electronics steering of SUM pattern, this method can also be used to generate DIFFERENCE pattern which in turn can be steered. Therefore it is possible to generate SUM-DIFFERENCE pattern which has narrower beam width. Using SUM-DIFFERENCE pattern one can calibrate the array as well as eliminate blind speed in a delay line cancellation method. Other applications of such schematic are also presented.

References

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