A Realizable Active Array Antenna Configuration For Fighter Aircraft Having Decent Radar Performance

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Abstract – **In this paper the design of the AAAU from the aspects of realization of the array and its radiation pattern performance is addressed. The Transmit\ Receive Module (TRM) being the basic building blocks constrain the design of the array. Three different configurations of AAAU based on three different TRM building blocks is presented. The Constraints of TRM and AAAU configuration aspect is dealt in section 2. Section 3 presents the radiation pattern parameters of the three configurations. Section 4 is the conclusion and presents the optimal solution which is realizable and has decent performance.**

Keywords: AAAU, TRM, SLL

I. INTRODUCTION

The Active Electronically Scanned Array (AESA) radar in the most suitable radar for fighter aircraft. The Antenna for the AESA is the Active Array Antenna Unit (AAAU) where in the amplitude and phase of each radiating element can be altered in real time to get required performance. The AAAU can obtain the best gain in Transmit (Tx), best Side lobes in Receive(Rx), Fan beam in Transmit [1], low sidelobe level in transmit [2], Adaptive nulling in Rx, cosecant squared beam and relevant beam shapes in real time. The AESA Radar for the fighter aircraft is quite challenging where in the AAAU need to be fitted into the nosecone of the aircraft. This results in limitation on the aperture and depth of the AAAU. Due to the conical shape of the radome the more the depth of AAAU the lesser the aperture available for radiation. Also the aperture available for AAAU is small and constrained by the circular/elliptical shape. X-Band frequency is best suited to get the required performance with the available aperture in the nose cone of the fighter aircraft.

II. CONSTRAINTS ON THE TRM AND AAAU CONFIGURATION

The TRM is the basic building block of the AAAU. The center frequency typically used in the fighter radar is around 10 GHz. This required inter element spacing close to 15 mm for obtaining electronic scanning of $\pm 60^0$ in both azimuth and elevation. Each TRM feeds a radiating element. The TRM should have a width close to 15 mm where in the required DC voltage, RF signal and digital controls need to be routed through suitable connectors. The necessary FPGA, Monolithic Microwave integrated Circuit(MMIC) and Bias circuitry also need to be accommodated in the TRM. This constrains the TRM design.

A DTRM(Dual TRM) where in 2 TRMs are packaged and QTRM (Quad TRM) wherein 4 TRMs are packaged reduce the complexity of fabrication.

QTRM is most suitable for ease of fabrication in X- band since the digital controls can be suitably bunched in SDI (Serial Data-in) and SDO(Serial Data Out) with a common FPGA controlling all 4 TRMs and suitable Nano-D connector can be used. In QTRM there can be two options which are feasible having two RF inputs (each input feeding two TR channels) and Single RF input (feeding all four TR channels).

The optimal arrangement of the AAAU for easy fabrication and assembly is based on grouping TRMs as a linear array and stacking them side by side to form the planar array. The linear array is referred to as the Plank. The triangular grid arrangement is obtained by staking the planks in a zig-zag fashion. The plank unit houses the plank controller PCB, RF power combiners and the liquid manifold. The plank controller PCB houses the FPGA and DC to DC converters to feed the TRMs which require the 8V(voltage for transmit PA, 5V(operating voltage for MMICs), 3.3V(DC for FPGA) and -5 V (Gate bias for MMICs). The RF power combiners for feeding RF to TRMs and the necessary liquid cooling manifold is also part of the plank unit.

Three configuration as shown in Fig. 1 to Fig.3 are considered in this paper. Configuration I with QTRM having single RF input Configuration III with monopack TRM. For ease of comparison all the AAAUs are configured with 800 elements. The maximum number of TRMs per plank is 32 and minimum number is 16. Realizing a plank with TRMs less than 16 is not practically feasible. The Table 1 show the arrangement of planks in AAAU.

Table 1 Three AAAU configurations with 800 elements

QTRM(Single RF I/P)				QTRM(Dual RF I/P)				Monopack TRM			
Sl No.	TRMs in Plank	No. of planks	Total TRMs	Sl No.	TRMs in Plank	No. of planks	Total TRMs	Sl No.	TRMs in Plank	No. of planks	Total TRMs
1	32	12	384	1	32	8	256	1	32	6	192
2	24	12	288	2	28	6	168	2	30	4	120
3	16	8	128	3	24	8	192	3	28	6	168
Total planks and TRMs		32	800	4	20	6	120	4	24	2	48
				5	16	4	64	5	22	4	88
				Total planks and TRMs		32	800	6	20	4	80
								7	18	4	72
								8	16	2	32
								Total planks and TRMs		32	800

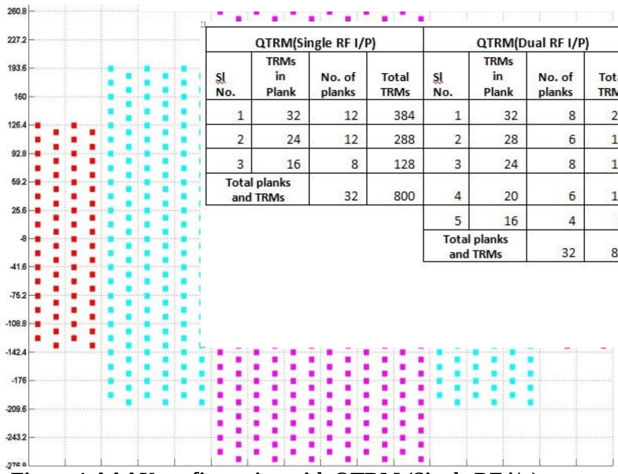


Figure 1 AAAU configuration with QTRM (Single RF i/p)

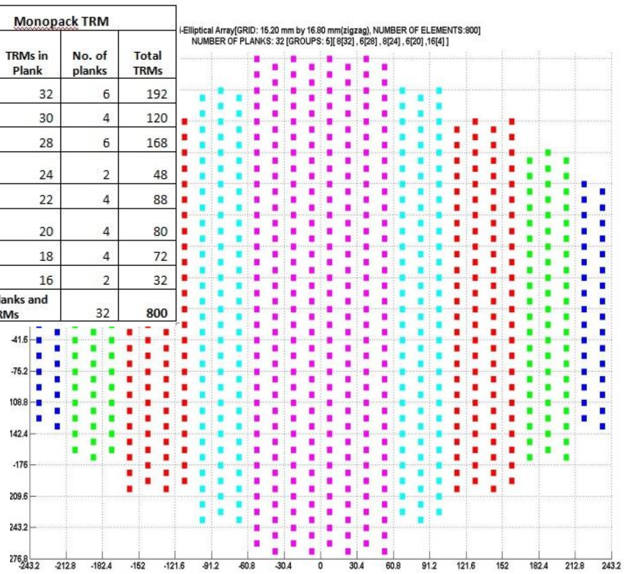


Figure 2 AAAU configuration with QTRM (Dual RF i/p)

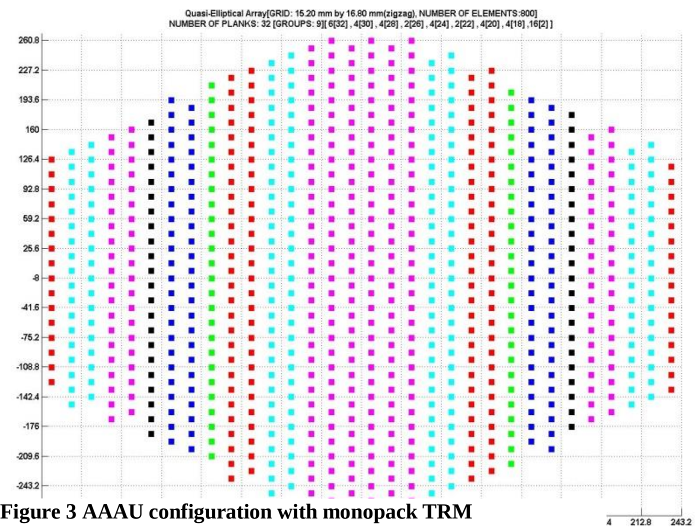
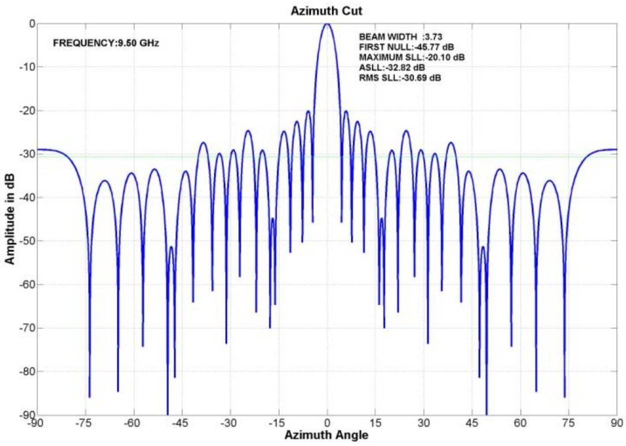


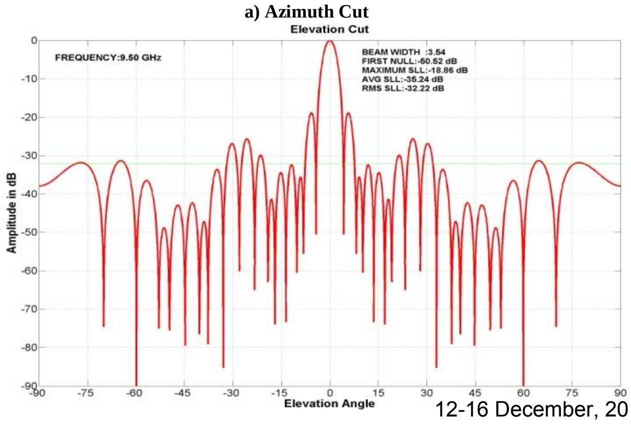
Figure 3 AAAU configuration with monopack TRM

III. ARRAY PERFORMANCE IN TRANSMIT AND RECEIVE

The array performance on the radiation pattern in the transmit mode and receive mode of operation is obtained by comparing the Beam width, Max SideLobe Level (MSLL), Average SLL(ASLL) and RMS SLL(RSLL) using an octave/matlab program for computing the array factor of an arbitrary two-dimensional array [3]. The Azimuth and Elevation cut patterns in the transmit mode of operation for the QTRM(Single RF I/P), QTRM(Dual RF I/P) and monopack TRM are shown in Fig. 4 to Fig. 6 respectively.

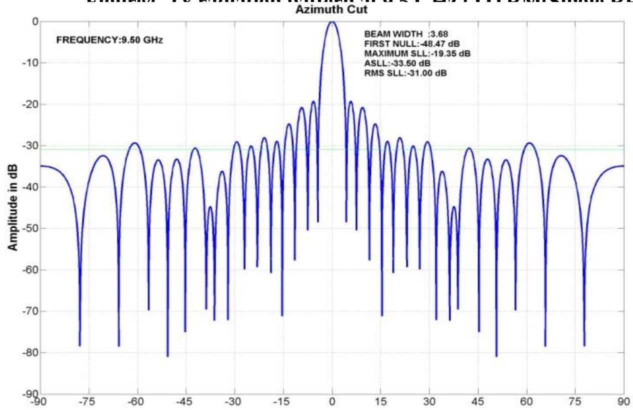


a) Azimuth Cut

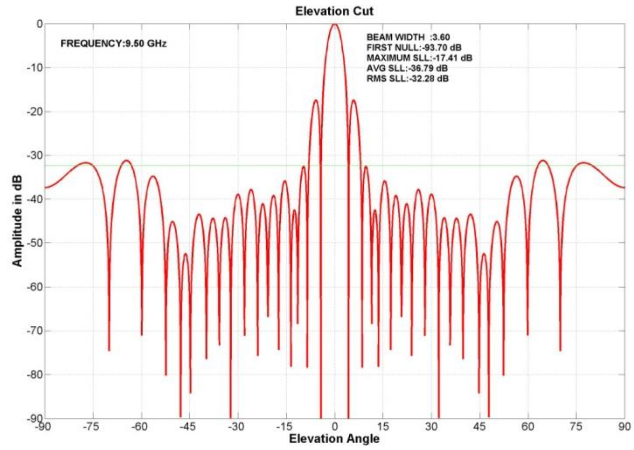


b) Elevation Cut

Figure4 Tx radiation pattern at 9.5 GHz (QTRM(Single RF I/P)

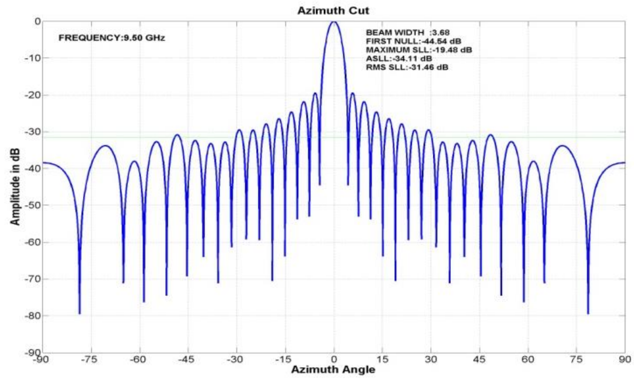


a) Azimuth Cut

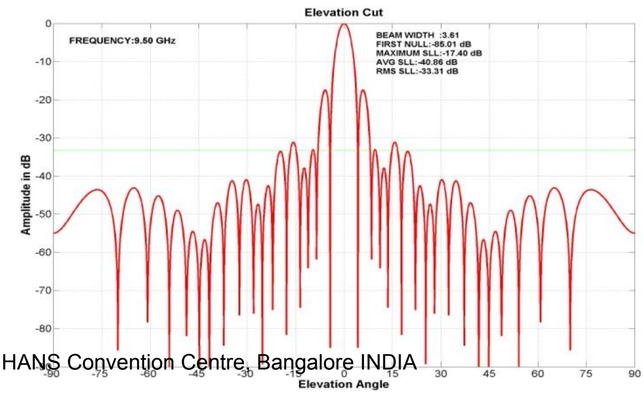


b) Elevation Cut

Figure 5 Tx radiation pattern at 9.5 GHz (QTRM(Dual RF I/P)



a) Azimuth Cut



b) Elevation Cut

Figure 6 Tx radiation pattern at 9.5 GHz (Monopack TRM)

across the array for three configurations of AAAU.

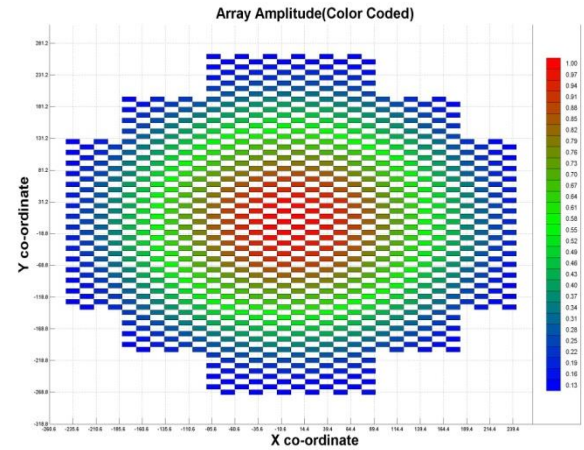


Figure 7 Amplitude distribution QTRM(Single RF i/p)

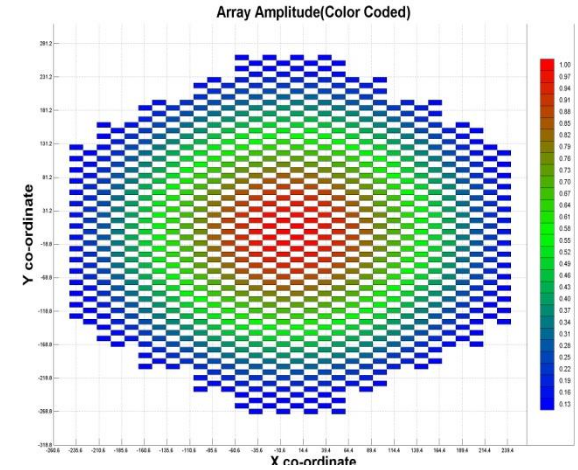


Figure 8 Amplitude distribution QTRM(Dual RF i/p)

Figure8 Amplitude distribution QTRM(Dual RF i/p)

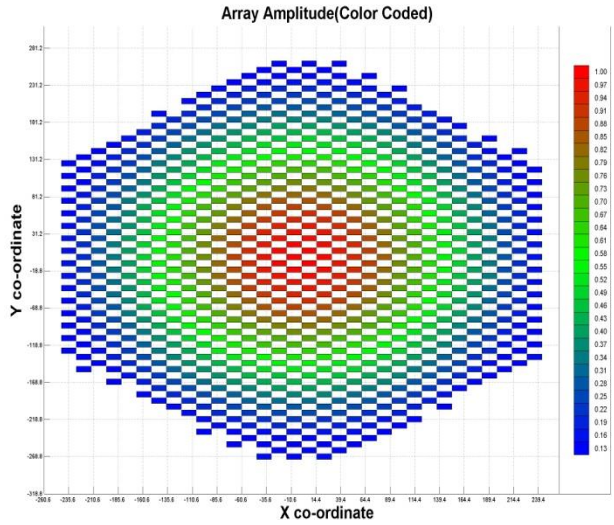
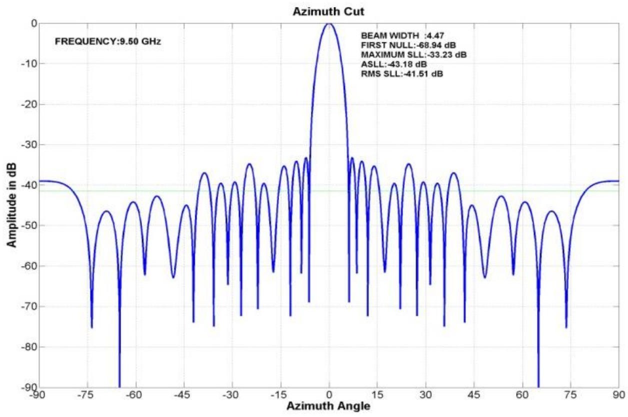
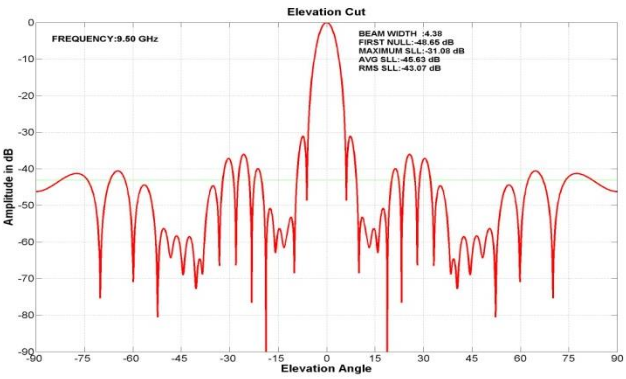


Figure 9 Amplitude distribution monopack TRM

The [illegible] d of the AAAU with QTRM (Single RF I/P), QTRM(Dual RF I/P) and monopack TRM are shown in Fig. 10 to Fig.12 respectively.

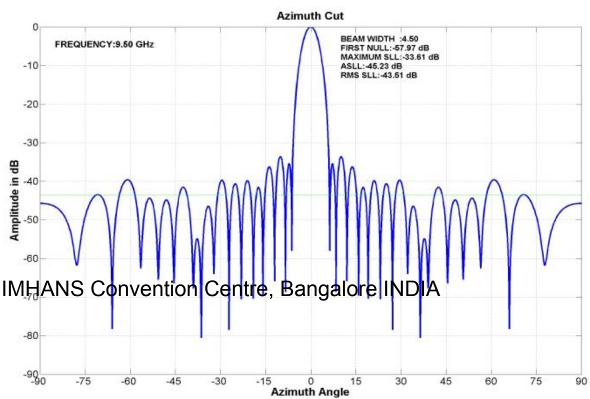


a) Azimuth Cut

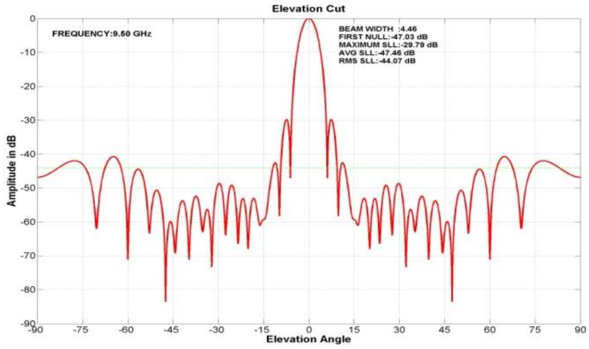


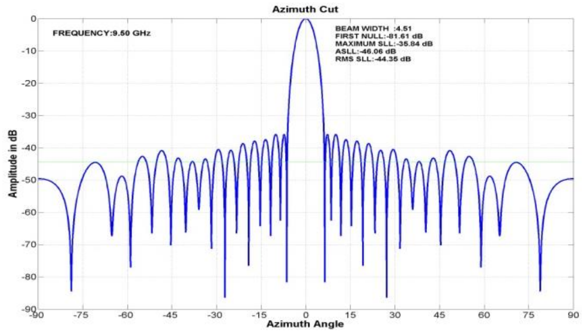
b) Elevation Cut

Figure 10 Rx radiation pattern at 9.5 GHz (QTRM(Single RF I/P)

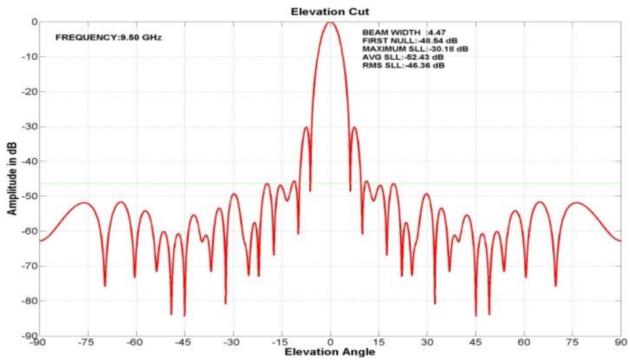


a) Azimuth Cut





a) Azimuth Cut



b) Elevation Cut

Figure12 Rx radiation pattern at 9.5 GHz (MONOPACK TRM)

The 3D radiation pattern intensity of the AAAU in receive mode with QTRM (Single RF I/P), QTRM(Dual RF I/P) and monopack TRM are shown in Fig. 13 to Fig.15 respectively.

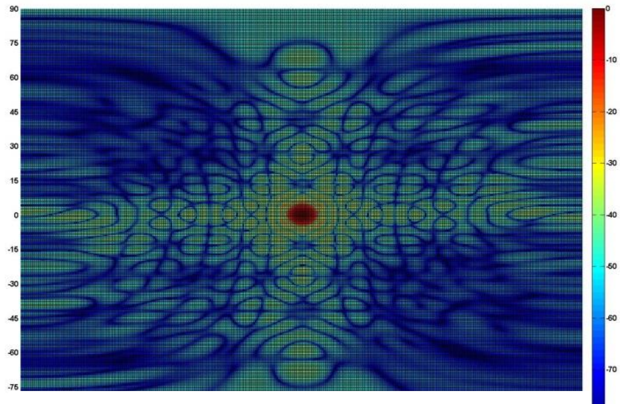


Figure 13 3D Radiation pattern of QTRM(Single RF i/p)

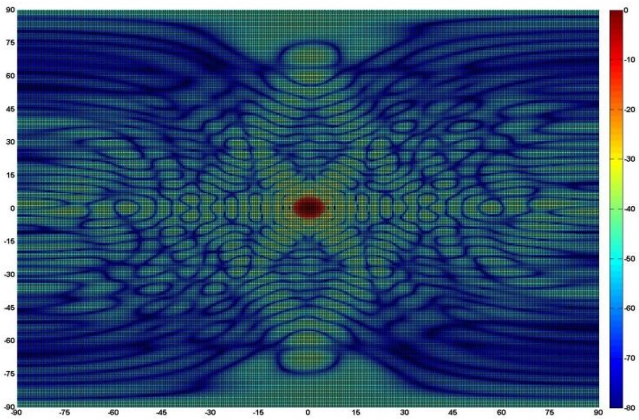


Figure 14 3D Radiation pattern of QTRM(Dual RF i/p)

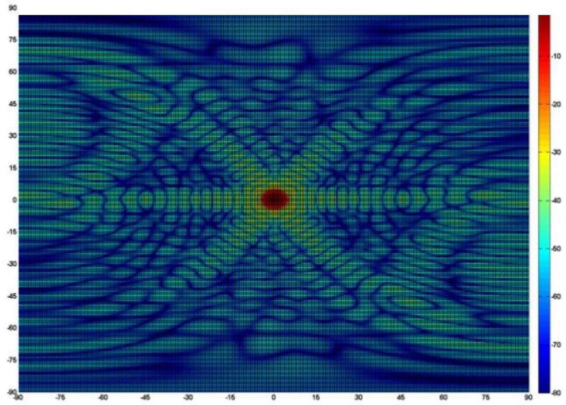


Figure 15 3D Radiation pattern of Monopack TRM

The Table 2. Show the antenna pattern parameters for the three configurations. The approximate directivity of the array is calculated using the formula mentioned in equation 1 below.

Gain = 10* $\log_{10}$(3000/(Az BW * El BW)) **(1)**

Table 2. Pattern parameters of the three AAAU configurations

Configuration	Mode	Gain (dB)	3D SLL (dB) ASLL	3D SLL (dB) RSLL	Pattern cut	Beam Width (Degrees)	MSLL (dB)	ASLL (dB)	RSLL (dB)
QTRM (Single RF I/P)	Transmit	34.01	-50.67	-41.74	Azimuth	3.55	-20.1	-33.38	-31.11
					Elevation	3.36	-18.86	-36	-32.67
	Receive	32.30	-59.21	-47.13	Azimuth	4.25	-33.22	-43.76	-41.97
					Elevation	4.16	-31.09	-46.67	-43.72
QTRM (Double RF I/P)	Transmit	34.00	-49.93	-41.66	Azimuth	3.49	-19.35	-34.03	-31.31
					Elevation	3.42	-17.41	-37.38	-32.66
	Receive	31.97	-59.46	-46.92	Azimuth	4.27	-33.61	-45.73	-43.86
					Elevation	4.46	-29.79	-47.46	-44.07
Monopack TRM	Transmit	33.98	-50.71	-42.03	Azimuth	3.5	-19.48	-34.65	-31.75
					Elevation	3.43	-17.41	-41.19	-33.55
	Receive	32.16	-60.63	-49.61	Azimuth	4.29	-25.83	-46.48	-44.66
					Elevation	4.25	-30.19	-52.87	-46.62

CONCLUSION

The Suitability of AAAU configurations for Radar application based on the antenna pattern parameters is studied. Table 2 show that the 3D ASLL and RSLL is better in case of monopack TRM, followed by QTRM with Dual RF I/P and then the QTRM with single RF input. The RSLL and ASLL are important in case of fighter radar for Air-to-Ground and Air-to sea modes where in the target echo competes with the ground/sea clutter return excited by the side lobes of the array.

The AAAU built on the QTRM with single RF input is amicable for fast realization, followed by QTRM with Dual RF Input. Hence the AAAU with QTRM having single RF input can be utilized for quick proto typing and validation of the radar performance at different modes of operation with a marginally lower range. The 3D SLL performance of the QTRM with single RF input and QTRM with Dual RF input is comparable.

The monopack TRM based array is highly complex in terms of RF manifold network and mechnical tolerances required on the plank mechanicals. Due to the width constraint the monopack TRM realization result in increased depth of TRM which inturn limits the aperture available for the array.

The QTRM with single RF Input is compromise between the radar performance and the realization point of view and hence can be used for rapid prototyping of the Radar.

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