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Design of K Band Transmitting Antenna for Harbour Surveillance Radar Application

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Abstract — In this paper a K-band transmitting horn antenna is designed for the harbour surveillance radar application. To increase the coverage area of the FMCW radar, one of the key factor is the transceiver system. Transceiver system includes the transmitting and the receiving antenna. The antenna is of great importance in a radar system. In the previous works the antenna such as switched antenna, planar differential antenna, azimuth 60º are used. To reach long distance we are in need of antennas having high gain and high directivity antenna. The highly directional antennas are horn antenna and dish antenna. Hence in this paper a horn antenna is chosen and it is designed at the operating frequency of 24GHz (i.e. K band). Thus we are going to increase the gain of the FMCW radar and also the range of coverage area. The design and simulation are carried out in the Ansoft HFSS software. The antenna parameters such as gain, directivity and the radiated energy are obtained for the designed horn antenna. Also in this paper these parameters are compared with the horn antenna operating in X-band and Ku-band. The performance of the system is improved by increasing the frequency range. The harbour surveillance is the main application focused in this paper.

Keywords — FMCW radar, harbor surveillance, HFSS software, Ku-band, K-band, transceiver system, X-band.

I. INTRODUCTION

It is very important to monitor the surroundings in the harbour surveillance. At any time there may be an attack. Hence for continuous monitoring the RADARS [7] [8] are used. Among the radars if frequency modulated continuous wave radar [3] means we are able to monitor it continuously. The main issues in the design of an FMCW radar [4] are the antenna selection and the operating frequency. Thus in this paper an antenna is selected and it is designed and simulated by using the Ansoft HFSS software. The antenna is tested in different operating frequencies. It is shown that the antenna operating in Ku band will cover larger area than the other antennas.

The rest of this paper is organized as follows. In Section 2, the Selection of antenna and its dimensions. Section 3 presents detailed description of the design of the antenna. Experiment results and discussions are described in Section 4. In Section 5 the designed antenna performance such as gain, directivity and radiated energy [10] is compared with the other bands. Finally, the conclusion and further enhanced are given in Section 6.

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II. SELECTION OF ANTENNA AND ITS DIMENSIONS

The beam width should be narrow to cover long distance and it is advisable to have highly directional [2] antenna. We shall use a number of antennas like planar differential antenna, azimuth, and optical beam forming antenna, patch antenna, horn antenna and dish antenna. Among these antenna in this paper we chosen horn antenna [1] [5] because of its narrow beam width and high gain. Fig. 1 shows the simple horn antenna.

The dimensions includes the width, height and the slant length. The width of horn [6] should always be greater than that of the height. The width of the aperture in the E-field is given by;

$$\text{Aperture E} = \sqrt{2\lambda LE}$$

Where LE is the slant length.

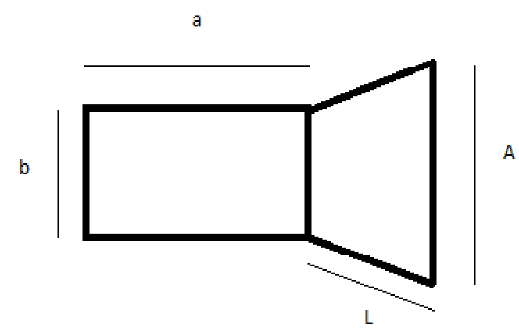

Fig. 1 Simple Horn Antenna

III. TRANSMITTING HORN ANTENNA DESIGN FOR HARBOUR SURVEILLANCE FMCW RADAR

Here the horn antenna is designed by selecting the frequency range.

Step 1: The operating frequency should be selected. Then find the wavelength for that particular frequency. $\lambda = c / f$

Step 2: The next step is to calculate the dimensions of the horn. With the help of the wavelength the dimensions are calculated.

$a = 0.7\lambda$
$b = 0.3\lambda$
Slant length, $LE = 2\lambda$
$A = 2.08\lambda$
$B = 1.4\lambda$

Thus the dimensions of the antenna are estimated.

TABLE I
ANTENNA DIMENSION

S. No.	Variables	Range
1	Frequency	24GHz
2	Wavelength	12.5mm
3	A	8.75mm
4	B	3.75mm
5	L_E	25mm
6	A	26mm
7	B	17.5mm

Step 3: Draw the antenna in the software [9]. Then the initial setup such as boundaries and the excitations are assigned. The main thing is that the radiation should be at far-field. Thus the transmitting horn antenna is designed.

Step 4: Next, set the operating frequency for analyzing. Give initial frequency and final frequency and also the step frequency.

Step 5: Simulate the designed antenna and create the result report.

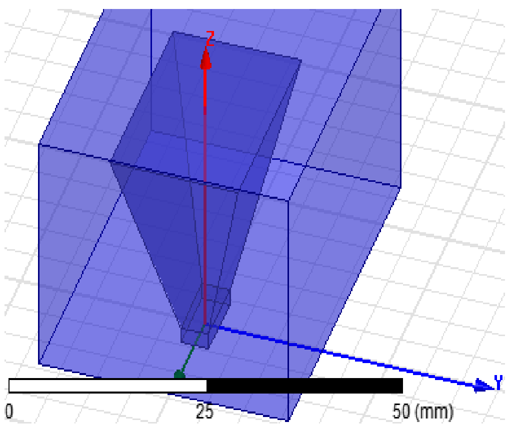

Fig. 2 Designed Horn Antenna

IV. MEASURED RESULTS

The range of operating frequency chosen is 24GHz. For analyzing the starting frequency is 22GHz and the stop frequency is 25GHz. The step size chosen is 0.5GHz. Before analyze it is advisable to validate the whole design.

The designed antenna is surrounded by a box to give radiation field. The radiation pattern, data table, 3D polar plot, XY plot for the gain, directivity and the radiated energy are obtained.

The Fig. 3 (a) gives the radiation pattern of the gain for the designed horn antenna and the Fig. 3 (b) gives the radiation pattern of the radiated energy for the designed antenna. The Fig. 3 (c) is the radiation pattern of the directivity.

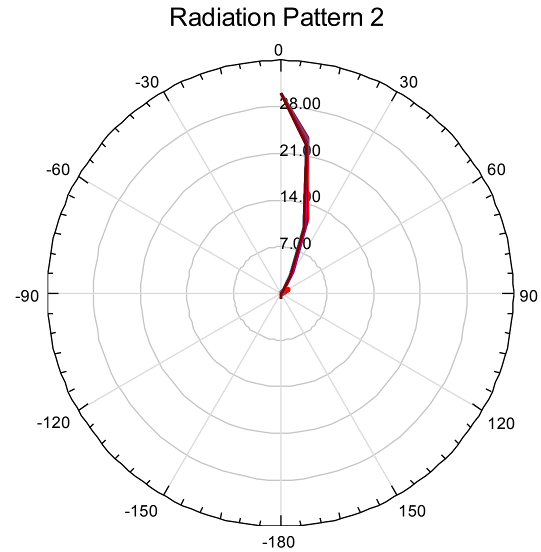

Fig. 3 (a) Gain

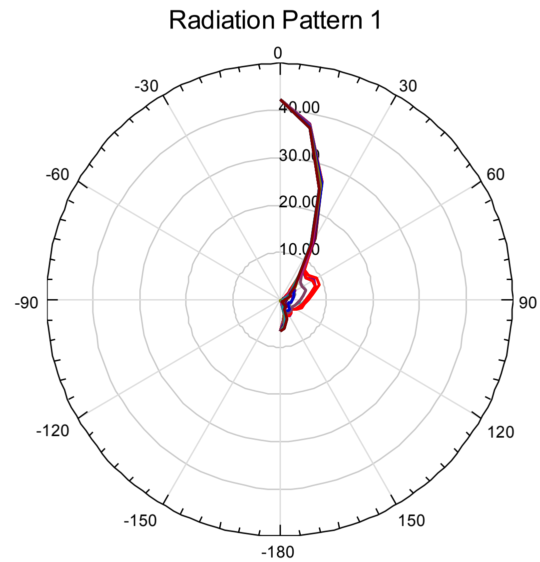

Fig. 3 (b) Radiated energy

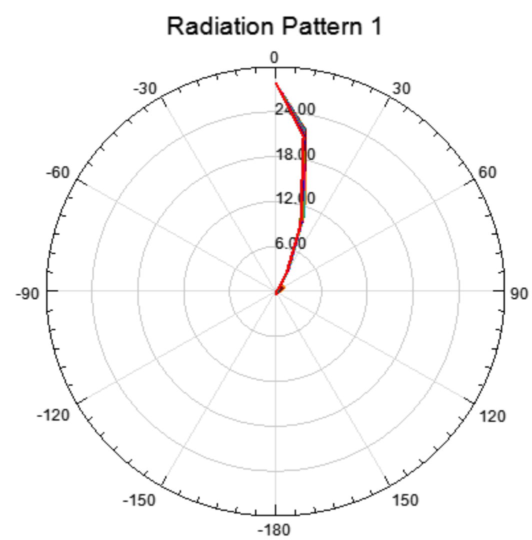

Fig. 3 (c) Directivity

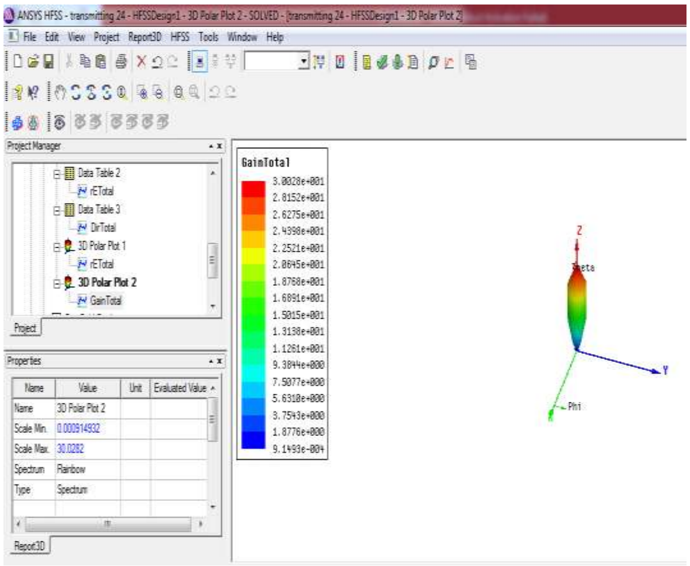

Fig 4 (a) 3D polar plot - Gain

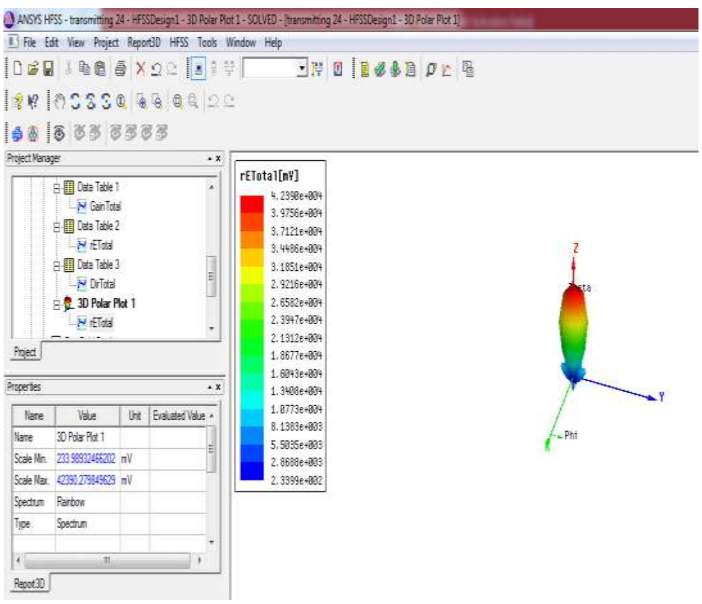

Fig 4 (b) 3D polar plot – radiated energy

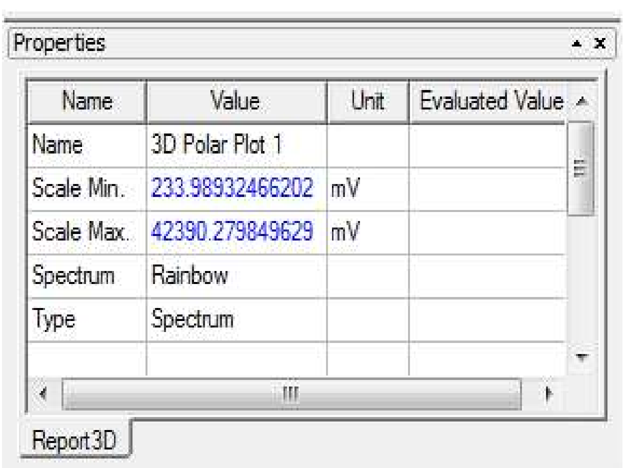

Fig 4 (c) Scale value of radiated energy

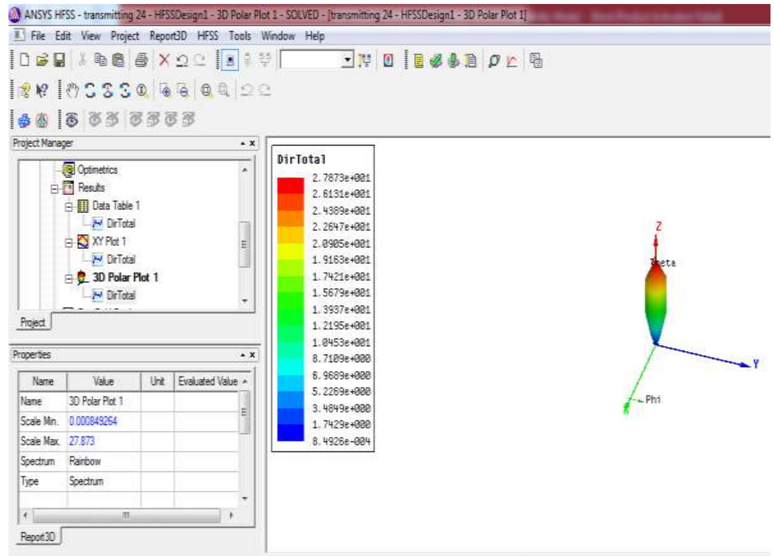

Fig 4 (d) 3D polar plot – Directivity

The Fig. 4 (a) shows the 3D polar plot of the gain for the designed antenna. The Fig. 4 (b) shows the 3D polar plot of the radiated energy for the designed horn antenna. The minimum radiated energy obtained for the designed antenna is 233.98mV and the maximum radiated energy obtained is 42390.27mV. The Fig. 4 (c) gives the radiated energy values. The Fig. 4d gives the 3D polar plot of the directivity.

The Fig. 5 (a) shows the XY plot of the gain for the designed horn antenna operating at 24 GHz. The Fig. 5 (b) shows the XY plot of the radiated energy for the same designed horn antenna operating at 24GHz.The Fig. 5 (c) shows the XY plot of the directivity.

The overall gain value for different theta and phi value are given in the Fig. 6 (a). The theta ranges from 0 degree to 170 degree and the phi value is at 40 degree and 50 degree gain total.

The radiated energy for different theta and phi values are given in the Fig. 6 (b). The theta ranges from 0 degree to 170 degree and the phi value is at 40 degree and 50 degree. The directivity for different theta value ranges from 0 degree to 170 degree and the phi value at 40 degree and 50 degree are shown in the Fig. 6 (c).The directivity is closely related to the gain because of high directional horn antenna.

V. Comparative Study of Antenna at X-Band, Ku-Band and K- Band

As mentioned earlier antenna is of great importance in the radar system. The horn antenna is designed for three frequency band and the simulated results are compared in Table II. The antenna performance is validated by three parameters such as gain, directivity and the radiated energy.

For the x-band the range of operating frequency chosen is 10GHz. For Ku-band the operating frequency chosen is 18GHz and for k-band it is 24GHz. The antenna we chosen is horn so that there will be minimum loss and so the directivity is closely equal to the gain.

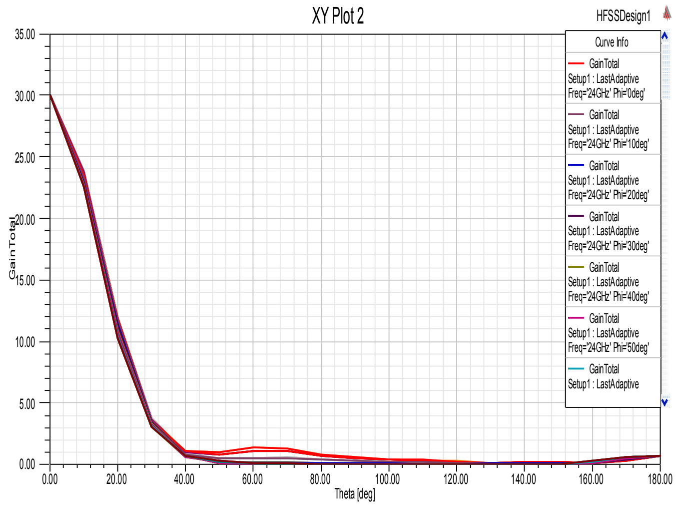

Fig 5 (a) XY plot – Gain

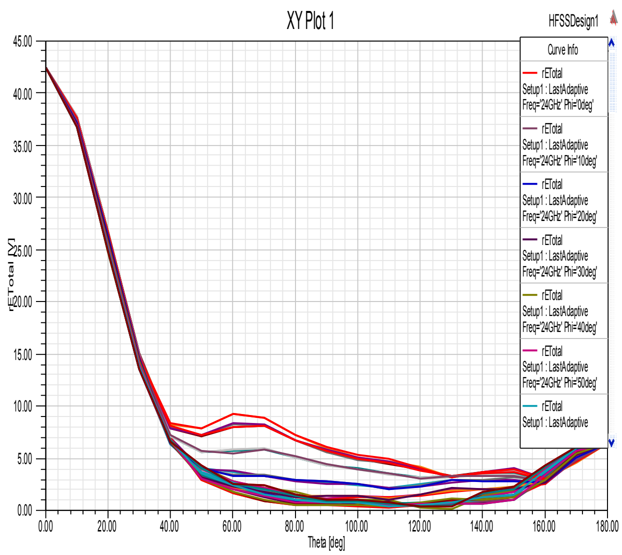

Fig 5 (b) XY plot – Radiated Energy

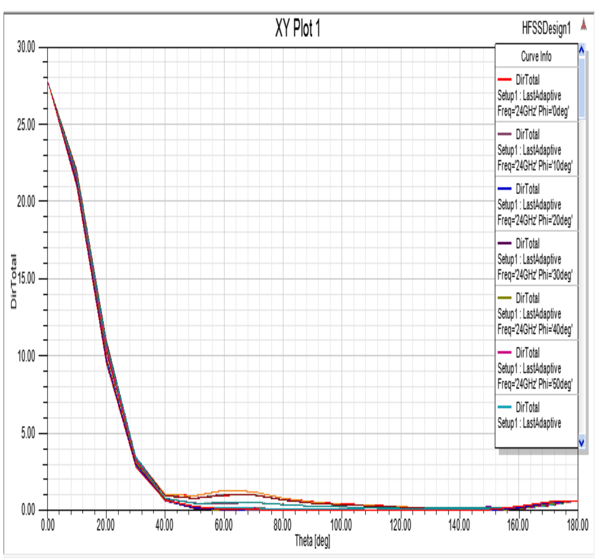

Fig 5 (c) XY plot – Directivity

HFSSDesign1

	Theta [deg]	GainTotal Setup1 : LastAdaptive Freq='24GHz' Phi='40deg'	GainTotal Setup1 : La... Freq='24G...
1	0.000000	30.028208	30.028208
2	10.000000	23.045971	23.234312
3	20.000000	10.958381	11.275433
4	30.000000	3.454854	3.611883
5	40.000000	0.794800	0.778526
6	50.000000	0.142457	0.163449
7	60.000000	0.051420	0.106296
8	70.000000	0.015449	0.055637
9	80.000000	0.006053	0.035806
10	90.000000	0.004780	0.026070
11	100.000000	0.007672	0.033657
12	110.000000	0.002728	0.026798
13	120.000000	0.005422	0.039247
14	130.000000	0.014426	0.070882
15	140.000000	0.022332	0.075560
16	150.000000	0.028259	0.078291
17	160.000000	0.130765	0.115585
18	170.000000	0.493621	0.448826

Fig 6 (a) Data table – Gain

HFSSDesign1

	Theta [deg]	rETotal [V] Setup1 : LastAdaptive Freq='24GHz' Phi='40deg'	rETotal [V] Setup1 : La... Freq='24G...
1	0.000000	42.390280	42.390280
2	10.000000	37.136338	37.287776
3	20.000000	25.607947	25.975755
4	30.000000	14.378595	14.701729
5	40.000000	6.896527	6.825555
6	50.000000	2.919735	3.127467
7	60.000000	1.754147	2.522087
8	70.000000	0.961512	1.824662
9	80.000000	0.601859	1.463793
10	90.000000	0.534845	1.249036
11	100.000000	0.677580	1.419184
12	110.000000	0.404066	1.266341
13	120.000000	0.569601	1.532513
14	130.000000	0.929116	2.059538
15	140.000000	1.156031	2.126413
16	150.000000	1.300410	2.164498
17	160.000000	2.797351	2.629977
18	170.000000	5.434985	5.182512

Fig 6 (b) Data table – Radiated Energy

Data Table 1 HFSSDesign1

	Theta [deg]	DirTotal Setup1 : LastAdaptive Freq='24GHz' Phi='40deg'	DirTotal Setup1 : La... Freq='24G...
1	0.000000	27.872975	27.872975
2	10.000000	21.391878	21.566702
3	20.000000	10.171858	10.466154
4	30.000000	3.206887	3.352645
5	40.000000	0.737754	0.722648
6	50.000000	0.132232	0.151718
7	60.000000	0.047729	0.098667
8	70.000000	0.014340	0.051643
9	80.000000	0.005619	0.033236
10	90.000000	0.004437	0.024199
11	100.000000	0.007121	0.031241
12	110.000000	0.002533	0.024874
13	120.000000	0.005033	0.036430
14	130.000000	0.013390	0.065795
15	140.000000	0.020730	0.070137
16	150.000000	0.026231	0.072672
17	160.000000	0.121379	0.107289
18	170.000000	0.458192	0.416612

Fig 6 (c) Data table – Directivity

A. X-Band (10GHZ) Frequency Band

From the Table II the maximum gain that can be achieved in the x-band is about 28.07dB. The minimum radiated energy is 210.36mV and the radiated energy maximum value obtained is 41758.20mV. The directivity of this horn antenna at this frequency band is 27.12dB.

B. KU-Band (18GHZ) Frequency Band

From the Table II the maximum gain that can be achieved by this horn antenna is 29.08dB. The minimum radiated energy is 413.87mV and the maximum radiated energy is 41764.29mV. The directivity at this frequency band is 27.44dB.

C. K-Band (24GHZ) Frequency Band

Our own designed horn antenna Operating at 24GHz the gain we achieved is 30.02dB. The minimum radiated energy is 233.98mV and the maximum radiated energy is 42390.27mV. The directivity at the k-band is 27.87dB. This values are depicted in the Table II. From this comparison we came to know while increasing the frequency range the gain, directivity and the radiated energy will increase.

VI. Conclusion and Future Work

In this paper a K band transmitting horn antenna for the harbour surveillance radar application is designed and simulated by using the Ansoft HFSS software. The gain, directivity and the radiated energy are the main parameters analyzed. The result is compared with the X-band and Ku-band. It is shown that the gain of 24GHz horn antenna is improved while comparing to 10GHz and 18GHz. The directivity and the radiated energy also improved a lot. Hence it assures that the distance coverage will increase when we use the designed antenna in the radar for transmission. Because of horn high gain is achieved and this will improve the efficiency of the radar system.

TABLE II
Comparison of Horn Antenna at Different Frequency

Parameter	X-Band		Ku-Band		K-Band	
Gain (dB)	28.07		29.08		30.02	
Directivity (dB)	27.12		27.44		27.87	
Radiated Energy (mV)	Min	Max	Min	Max	Min	Max
	210.38	41758.20	413.78	41764.29	233.98	42390.27

In future the same horn shall be designed for receiving the radio signal after reflected from the target. Otherwise the dish antenna shall be designed for both the transmitting and the receiving of radar signals.

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