Design of Antenna Pedestal for an S-band Sea Clutter Radar

Xiangyu Cheng, Yan Zhang, Zhen Fang, Wenge Chen

***Abstract*—In this paper, a kind of S-band sea clutter radar antenna pedestal's design procedure is shown. By calculating the loads on the turntable, analyzing the needed travel distance of electric cylinder, we complete the antenna pedestal structure design, and verify the feasibilities of drive chains. The structural parts of these mechanisms have a favorable manufacturability, fine rot resistance, and enough light-mass convenient for mobility.**

***Key words*—Antenna pedestal, Loads calculation, Drive chain, Accuracy analysis**

I. INTRODUCTION

AN S-band sea clutter radar is one of the muti-band sea clutter measuring radars, and aimed for measuring backscattering signal by sea surface within a scope of angle. In this paper, we present the design scheme of the antenna pedestal of the S-band sea clutter measurement radar. Antenna shape is rectangular flat form [1]. Detail dimension is 740mm×1510mm. Total heavy is around 300kg. The schematic diagram of radar equipment of the S-band sea clutter is shown as follows (Fig. 1):

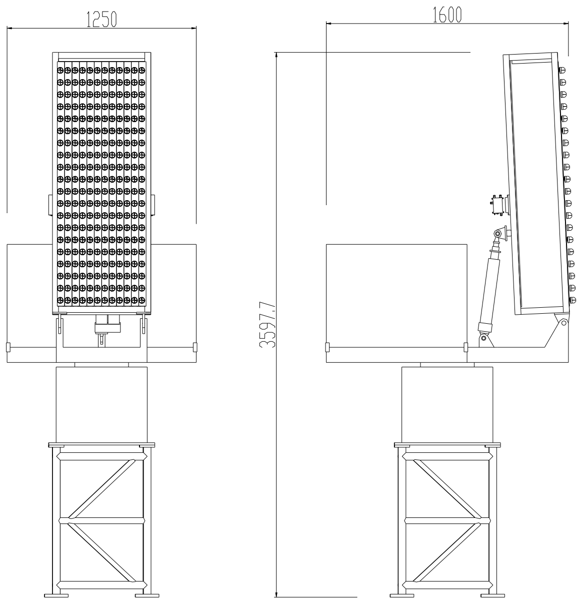

Fig. 1. Schematic 2-D diagram of S-band sea clutter radar

The structure of the radar antenna pedestal [2] adopts azimuth and pitching form. This type of rotary table structure is compact, and has a massive carrying capacity. It is widely used in many kinds of pedestal designing constituted of azimuth rotating platform and pitch mechanism. For this radar, Azimuth rotating platform (Fig. 2) assures antenna turned in an angle of ±160° within a specified accuracy. Pitch mechanism realizes the antenna adjustable in angle of -20° ~10° in pitching direction.

II. AZIMUTH DRIVE DESIGN

A. Initial conditions

The radar azimuth drive mechanism parameter is listed in Table I. In the initial condition of accelerating the platform

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Xiangyu Cheng who works on radar structural design and scientific research for high field magnets is with High Magnetic Field Laboratory, Chinese Academy of Sciences, Hefei 230031, China, and University of Science and Technology of China, Hefei 230026, China, and No.38 Research Institute of CETC, Hefei 230088, China. (corresponding author to provide phone: 86-138-5698-5318; fax: 86-0551-5391111; e-mail: chanceller@163.com).

Yan Zhang is with Anhui Technical College of Water Resources and Hydroelectric Power, Hefei 230601, China (e-mail:zhang3578@sina.com.cn).

Zhen Fang is with High Magnetic Field Laboratory, Chinese Academy of Sciences, Hefei 230031, China (e-mail: 863870346@qq.com).

Wenge Chen is with High Magnetic Field Laboratory, Chinese Academy of Sciences, Hefei 230031, China (e-mail: wgchen@ipp.ac.cn).

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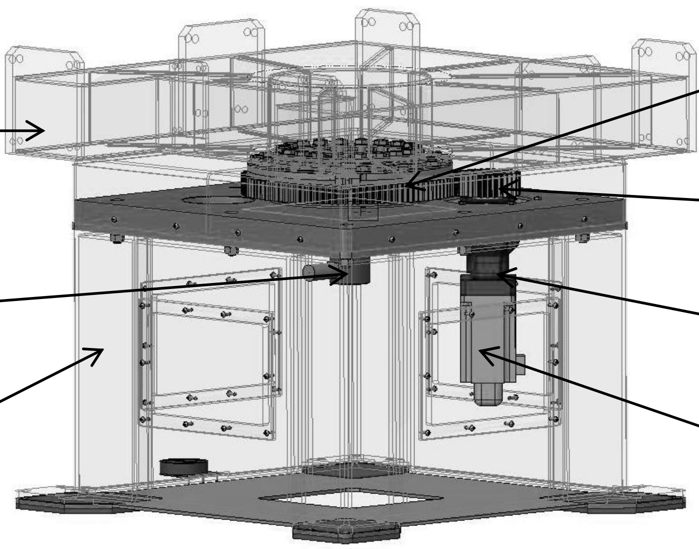

Fig. 2. Driver mechanism of azimuth rotating platform

TABLE I
MOVEMENT MECHANISM PARAMETER

Antenna aperture (m×m)	Weight of azimuth module(kg)	Weight of elevation module(kg)	Azimuth drive inertia (kgm^2)	Antenna characteristic dimension(m)	Air density(kg/m^3)
0.65×1.72	380	150	168.9	0.65	0.125
Run-up time(s)	Rotative bearing ball track radius (m)	Distance of wind press center to bearing center (m)	Distance of upper mass center to bearing center (m)	Gustiness factor	Friction coefficient
2.5	0.28	1.17	0.013	1.44	0.01

to maximum angular speed

$$v = 36° / s(= 0.6283 rad / s)$$

passed by angle 45°, we calculate these items:

Acceleration time

$$t = \frac{2 \times 45°}{36°} = 2.5s$$

Uniform acceleration

$$\varepsilon = \frac{v}{t} = \frac{36}{2.5} = 14.4° / s^2 = 0.2513 rad / s^2$$

From the parameter above, we get

Maximal azimuth moment $M_w = 60Nm$

Azimuth inertia load $M_I = 42.44Nm$

Azimuth friction moment

$$P = mg + \frac{F_D L_0}{D} = 4809N$$

$$M_{fr} = fP\frac{D}{2} = 6.73Nm$$

So, total azimuth load is

$$M_1 = M_W + M_I + M_{fr} = 109.2Nm$$

B. *Azimuth drive chain design*

Firstly, by accessories selection manual, we trial chose the pinion modulus $m = 3mm$, teeth number $Z_1 = 30$,

total speed ratio $i_1 = 70 \times \frac{104}{30} = 242.67$

Secondly, we check the drive moment.

$$M_o = M_E \times i = 2.15 \times 70 = 150.5Nm$$

Note that reduction box rated moment $M_r = 110Nm < M_o$, so the output moment of motor must be limited in low value state by electric digital controlling to match the reduction box.

Thirdly, the azimuth final drive moment is checked. Real output maximal moment

$$T_1 = 110 \times \frac{104}{30} \times 0.9 = 343.2Nm$$

larger than azimuth load

$$M_1 = 109.2Nm$$

That satisfies the device needs.

Finally, output rotate speed is proofread. The maximal rotate speed of azimuth final drive

$$v_1 = \frac{2000}{242.67} = 8.24r/\min$$

That can meet the required destination $6r/\min$.

III. ELEVATION DRIVE DESIGN

We use an electric cylinder [3] and 2 bearing supports to realize elevation drive. The elevation drive system can push the antenna reflector pitch rotating by the electric cylinder (Fig. 3). Through the mechanical analysis, we figure out the reasonable drive load of electric cylinder for convenience to the following model selection.

An equation can be put forward by the mechanism of Fig. 3 as follows

$$GL_G \sin(\theta_1 + \theta) = Fh = F \cdot \frac{L_1 L_2 \sin\theta_2}{L_3} \quad (1)$$

So the thrust load force (2) on electric cylinder derived from (1) is got

$$F = G \cdot \frac{L_3 L_G \sin(\theta_1 + \theta)}{L_1 L_2 \sin\theta_2} \quad (2)$$

The whole length of electric cylinder is

$$L_3 = \sqrt{L_1^2 + L_2^2 - 2L_1 L_2 \cos\theta_2}$$

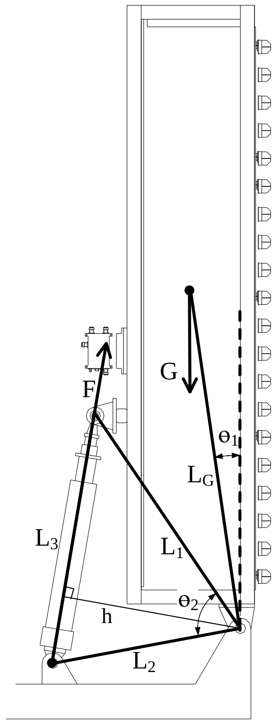

Fig. 3. Mechanical analysis of pitch mechanism

When antenna pitch angle $\theta = 0°$, we get the equations from established structural model as follows

$$\theta + \theta_1 + \theta_2 = 73.9°$$
$$\theta_1 = 7.1°$$
$$\theta_2 = 66.8° \text{(dependent variable)}$$
$$G = 180kgf = 1764N$$
$$L_1 = 734.98mm$$
$$L_2 = 539.35mm$$
$$L_3 = 720.07mm \text{(dependent variable)}$$
$$L_G = 925.18mm$$

Pitch mechanism basic parameter is listed in Table II. By calculating, the diagrams of push force F and total length L_3 to pitch angle θ are separately drawn in Fig. 4.

TABLE II
PITCH MECHANISM PARAMETER

L_1 (mm)	L_2 (mm)	L_G (mm)	G(Kg)	Pitch angle θ
734.98	539.35	925.18	180	-20°~10°

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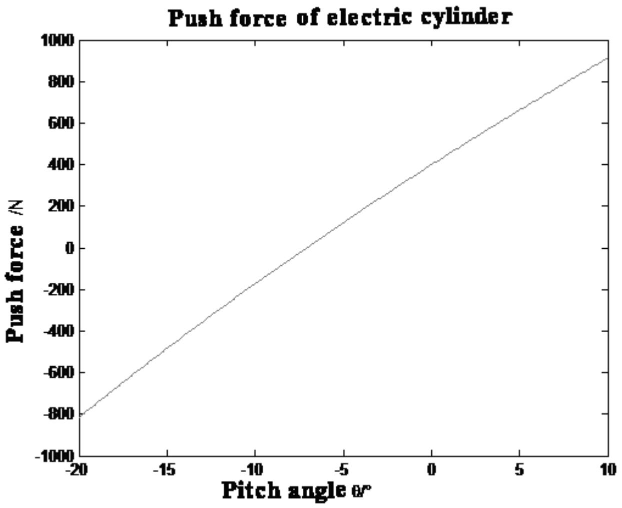
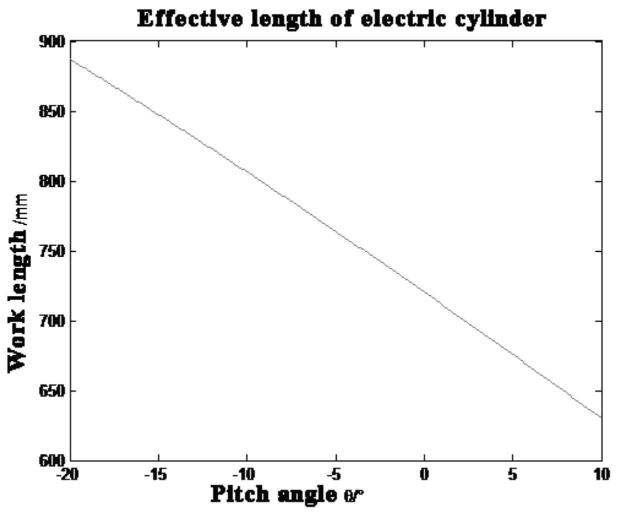
By above character calculated, the model type of electric cylinder should be chosen. The detail final type we choose is JE075S250BT05BM6C1 manufactured by Suzhou Tongjin Precision Industry Co. Ltd. It is verified quite suitable for pitch function requirements latterly.



(a) Push force of electric cylinder



(b) Work length of electric cylinder

Fig. 4. Dynamic character diagram of electric cylinder

IV. CONCLUSIONS

By above calculation and model selection, we designed the optimal 2-D turntable appropriate for S-band measurement radar. The subsequent applications show all of the optimizing calculations are effective. The azimuth and elevation drive chains are verified reasonable. We finally choose cast aluminum material to make the mechanism's main structural parts which have a favorable manufacturability [4], fine rot resistance, and enough light-mass convenient for mobility.

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