Visit to SMA and Bosma

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Abstract:

Attached is a description of a visit I made to the SMA testing site and the panel manufacturer, Bosma corporation.

Visit to the testing site for the SMA array

I. Introduction

On the 28th of April, I visited the SMA testing site at Haystack near Boston. The purpose of my visit is to discover how the array antenna structure and its transporter had been designed, to see, first-hand, the erected antenna structure and other required equipments, and to discuss the phase- and pointing-related problems with array engineers. My contacts were Eric Silverberg, the project manager, and Bill Bruckman, the project engineer.

II. Antenna status

At Haystack testing site, I observed two unfinished antenna structures. The CFRP backup structure was evident at one of these antennas, however, the feed support, surface panels and receiver room had yet to be constructed. The other structure had an insulated receiver room, but no dish. I got the impression that the project was well underway. The only problem I saw was the delay in panel finishing(see separated part of this memo for discussion).

The antenna structures are compact and very stiff. The main support structure was composed of five-inch-thick solid plates. The azimuth bearing part is also stiff. The antenna base was bolted to the foundation with six screws -- three primary and three auxiliary. The auxiliary screws provide only one half the support force of the primaries. The dish was constructed of CFRP tubes, special bowl-like joints were used as tube connections. The central hub of the dish is a CFRP cylinder attached to a CFRP bottom plate. This particular design was used in place of a cone-shaped CFRP structure because the latter is difficult to fabricate.

The tetrapod was constructed of 50 x 200 CFRP tubes. Since the tetrapod is not located on the edge of the dish, the total blockage of the tetrapod is 7 %. Heating elements are imbedded in tetrapod and secondary mirror to avoid icing problems. One completed secondary mirror assembly was in the lab. Its enclosure is made of aluminum and a steel structure is used from the defining plane to the support point. The secondary mirror, which weighs a total of approximately 40 Kg, can move in three axes, in addition to chopping

III. Transporter

The transporter has a fork-like structure in which the antenna fits. The antenna can then be lifted by three hooks attached to the fork structure which is raised hydraulically. The transporter has three groups of six wheels; in each group, the two wheels are connected by hydraulic linkage. This gives the vehicle maximum stability and it is able to travel well across unpaved terrain. The vehicle's lifting power is limited to about 66,000 Ibs. The transporter also contain a power supply for the receiver system. The transporter has been tested onsite. The original cost of the vehicle was $300,000; currently, the price is $500,000.

IV. Foundation

Since the site in Hawaii is volcano ash, the foundation represents a problem for phase and pointing requirements. As a result, the project engineers have constructed concrete bases which are 5 meters in diameter and five feet deep. The cost for one base is $60,000. Testing has proven that if the base is above ground level, serious thermal deformation results. However, the base had to rise approximately 20 cm above ground level in order to operate effectively. This 20 cm of exposed base will be insulated in the future.

V. Tools for backup structure assembly

A cantilever truss has been built for accurately assembly of the backup structure and panels. Laser alignment is used to set the panel accurately.

VI. Air condition for thermal control

The air condition equipment is located at the site, The volume of the equipment is about 1 meter x 2 meters x 3 meters.

VII. Discussion with Silverburg and Bruckman

The following represents a summary of the discussion I had with Eric Silverberg and Bill Bruckman:

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Q. In your design, what is the major source for errors in
phase and pointing?

A. The error budget is almost equally divided between the dish
and the base. The base is a significant source of the phase
and pointing errors. At the Hawaii site, the ground is full of
ash and, therefore, it is not very rigid. So we have had to
design a big concrete base which is not cheap. We have
observed a 4 arc sec in pointing just from an indoor concrete
pier. Some antennas claim a 1 arc sec pointing accuracy. But
the problem is the time interval for such pointing. Most
telescopes have to change the fitting coefficients every one
or two hours.

Q. Why you use solid five-inch plates instead of hollow
sections?

A. The plate is a lot cheap. And for bending due to the high
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wind, the truss section is the main factor in reducing deformation. we need large section area of the truss anyway.

Q. Have you consider moving the tetrapod on the edge of the dish in order to reduce antenna temperature?

A. There are several effects that need to be considered when determining the optimum attachment radius for the tetrapod:

1. geometric blockage;
2. additional antenna temperature; and
3. surface error due to the varying force on the backup structure at the attachment points.

We chose support points to minimize the gravitationally and wind induced phase errors and this results in 7 % blockage. We believe that by shaping the trusses of the tetrapod, we can have an antenna temperature as low as the BIMA antenna.

Q. I heard that your CFRP tubes have problems. Is it true?

A. Yes, the tubes has a wall thickness problem; the deviation is about 1 mm now. It should not produce problem for the dish. We even thought that we might be able to use solid CFRP bars in the dish. We also ordered a set of weaved tubes which are about twice as expensive than as the extruded ones. The thermal performance of extruded tubes is better, and they are cheaper than metal tubing. The assembly of the dish only takes a few hours.

Q. What is the temperature range inside your cabin?

A. about 0.8 degrees C.

Q. Since your supporting structures are thermal controlled, the temperature change may cause your dish bottom to wrap. What have you done to control this problem?

A. We design the dish bottom with two flexible pins which connect to the supporting structure. That way, the pins don’t deform the dish.

Visit of Bosma Co. and Morris Bean Co.

On May 1, 1995, I visited both the Bosma Company and Morris Bean Company. Bosma Company is the contractor of the SMA panels and Morris Bean is a foundry where the aluminum was cast. The purpose of my visit was to explore the manufacture resources which might be available for the MMA.

Bosma Machine and Tool Corporation is located in Tipp city, Ohio. The company started as a family business in the 1950s, today they employ about 90 people. The company has a large number of very large planers, the largest one being 264 inches. They also have some boring mills and numerical controlled machines. The main bossiness is to machine precision bases, gear boxes, concrete breakers and other products. The company is capable of producing products which require heavy machining and would be able to cut the models for the panel casting. Bosma has one small 3D measuring machine of approximately 15 x 20 inches, since panel manufacturing is a new business for them. However, they have heavily invested in the machines necessary to effectively accomplish panel manufacture. Panel measuring is contracted out, at a cost of $65 per hour.

Figure 1 shows the central equipment of their panel manufacture process. The main machine contains a flat granite table(up to 0.02 micron accuracy), a swing fan plate and an x-z tool with a range of 600 mm in z direction and >3,000 mm in the x direction. All the rails are to 1 micron accuracy. The swing plate has one end fixed by a needle bearing; it floats above the granite table with the help of three air bearings(each about 1 micron thick). The swing plate is driven by a motor with crank linkage. The cutter is fixed on the x-z rail.

Bosma experienced several problems regarding panel manufacture. They blamed most of these problems on the casting company, Harmony Company in Pittsburgh(contact: Nick Plesz, 412/452-5811).Bosma claims the produced casting is not correctly shaped and say that "wrapping" is the main problem. However, from what I observed, I believe they have other problems, such as: 1) the machine, cutting tool, and panel vibrating and 2) a possible computer software bug. As of the date of I visit, they had yet to produced a good panel. However, they are in a position to do the final cutting. The testing cutting on the date of my visit produced an rms of 7.2 microns for an innermost panel(4.8 microns rms if the innermost 100 mm is excluded). In the past, they had fixed the machine, stiffened the tool carrier and applied damping for thin panels. The damping is composed of thin lead plate and a kind packing foam on the back of the panel.

The panel I observed is kinematically supported by three measuring balls in the same position it will assume on the antenna dish. The cutting tool is ring shaped, constructed of carbon alloy and is about 8 mm in diameter. Before cutting, the panel surface is well- greased. Each cutting run lasts about an hour. Since the SMA has made the panel thick and stiff(now it weighs 23 Kg/m^2), the surface requirement of 6 microns can be reached by Bosma company.

We discussed the possibility of using square panels if an offset design is used. Bosma suggests this would result cost savings of 20-25 %. Modification of their machinery would be necessary, but would not be significant. Bosma suggests that an optimum size would be about 1.5 square meters.

The SMA panel casting is done at a smaller company where, according to Bosma, the panel size is limited and capacity is low. Therefore, Ben Bosma, the vice-president of the company showed me a nearby casting firm-- Morris Beam Company. The company is 20 minutes from Bosma’s location. It has been in operating for more than 60 years. The main products are turbine wheels, truck-tire model and other precision parts. Their casting has been limited to floor casting, low pressure casting. The principle of low pressure casting is the same as gas pumping. The liquid aluminum is put under pressure to fill the model on the top of the container during casting. The minimum thickness achieved is less than 2 mm. Metal inserts are widely used to achieve good quality crystallization. The size of the casting could be well over one meter square. If square panels are used panel shape could be realized by changing metal inserts only. The firm also has the facilities to accomplish heat treatment.

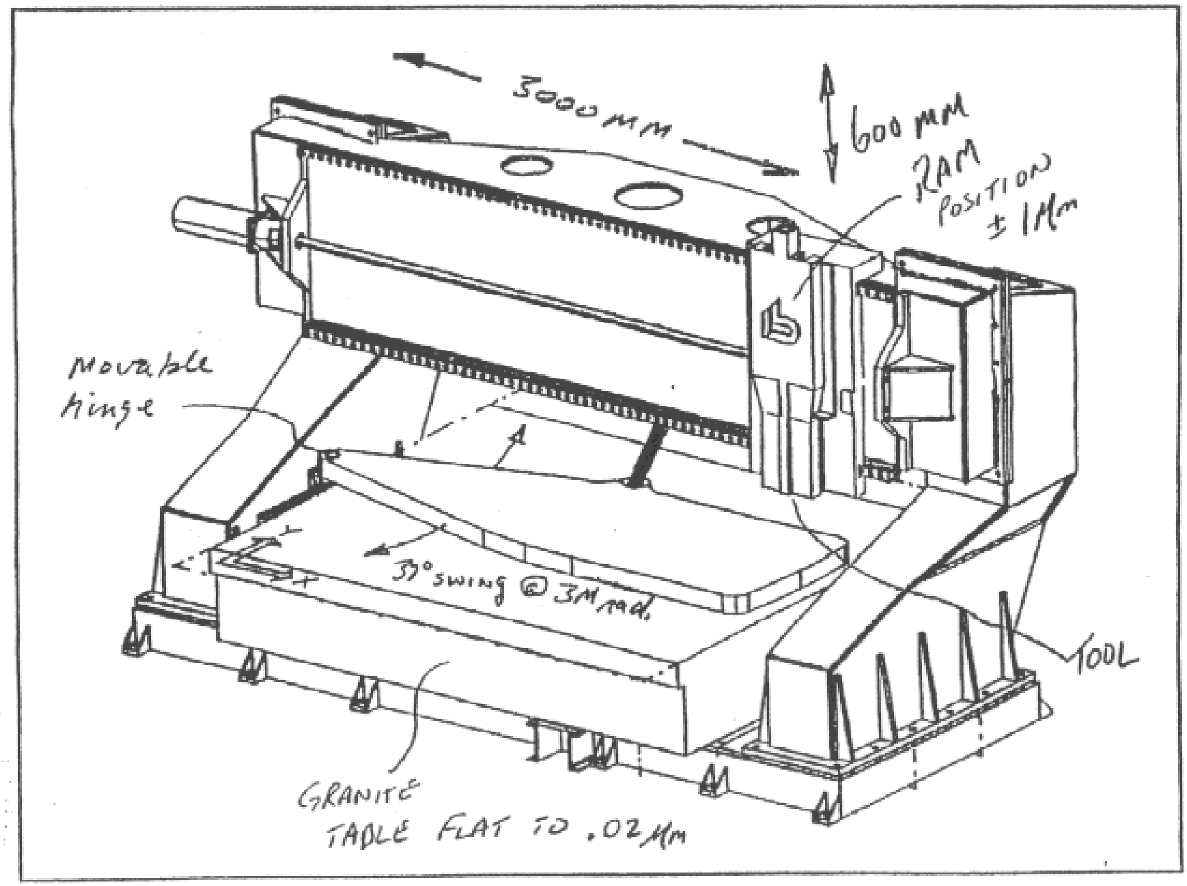

Figure 1. Schematic drawing of Bosma panel machine.

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