Project Scope and Needs Assessment

EML 4551C – Senior Design – Fall 2011 Deliverable 1

Team # 6

Interlocking Mechanism for Solid Reflector

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With:

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Introduction

This document details the scope of the contract between Mr. Gustavo Toledo ("the sponsor") and FAMU-FSU Senior Design Team 6 (Solid Panel Interlocking Mechanism, "Panel Team") for the production of a prototype high surface accuracy tangential deployable reflector dish for interstellar antennae applications. Devices of this nature are used to send and receive K_u band EMF transmissions, and require an aperture (Diameter of dish) of 4-10m. Special considerations must be further made for a space based application to accommodate restrictions on weight and volume, and to ensure function with zero maintenance.

Figures 1 and 2 below show a concept generation provided by the sponsor to help explain the aim of the project. The second figure illustrates the technology currently in use, generally known as a radial rib reflector. This technology consists of an elastic fabric type material that is stretched across a rigid frame. Such an approach offers excellent stowed volume, minimal weight, and reliable operation which explain why the method is the current standard. However, as one can imagine, the fabric skin "kinks" as it passes over each rib such that the reflector surface does not perfectly follow the ideal parabolic shape. This deviation, known as the Surface Accuracy, is expressed as a tolerance with units of length. Low surface accuracy results in lower efficiency and increased signal degradation as compared with reflectors of the same aperture that possess higher surface accuracy. High surface accuracy is achieved more easily with a solid reflector.

Solid reflectors have some rigid material that is cast, molded, rolled or otherwise shaped to match the chosen ideal parabolic shape. The use this solid material makes extremely high surface accuracies possible, but they generally require a rigid framework to support the mass of the dish. In space applications however, mass is an issue for different reasons than for ground based applications, and adequate structural support can be achieved with minimal bracing. Figure 1 shows the general aim of the project; to produce a tangentially deployable solid reflector. The concept consists of multiple panels which are initially stacked. These panels rotate about a central point, translating in plane, thus achieving tangential deployment.

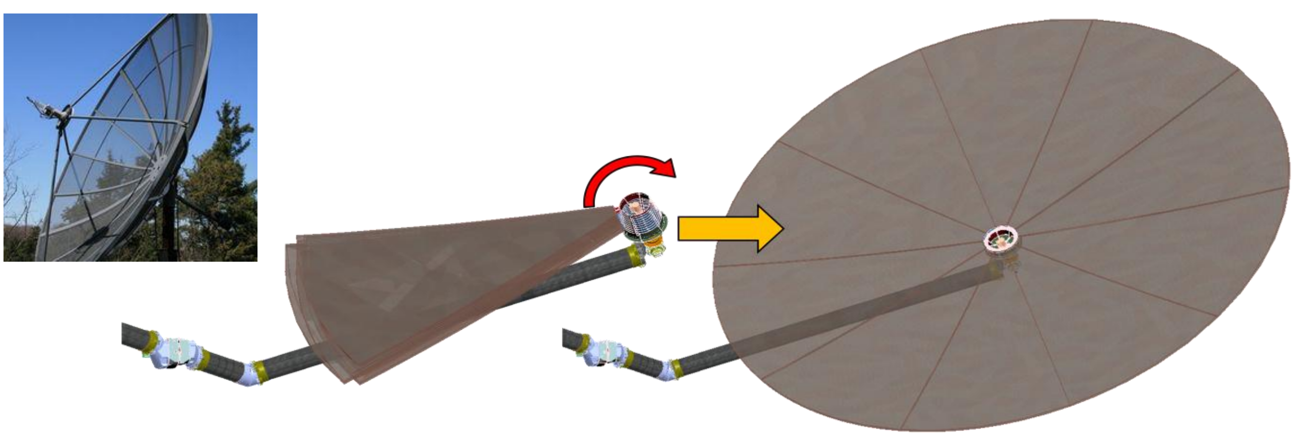

Figure 1. Concept illustration for a solid, paneled, tangentially deployable reflector, courtesy of Harris Corp.

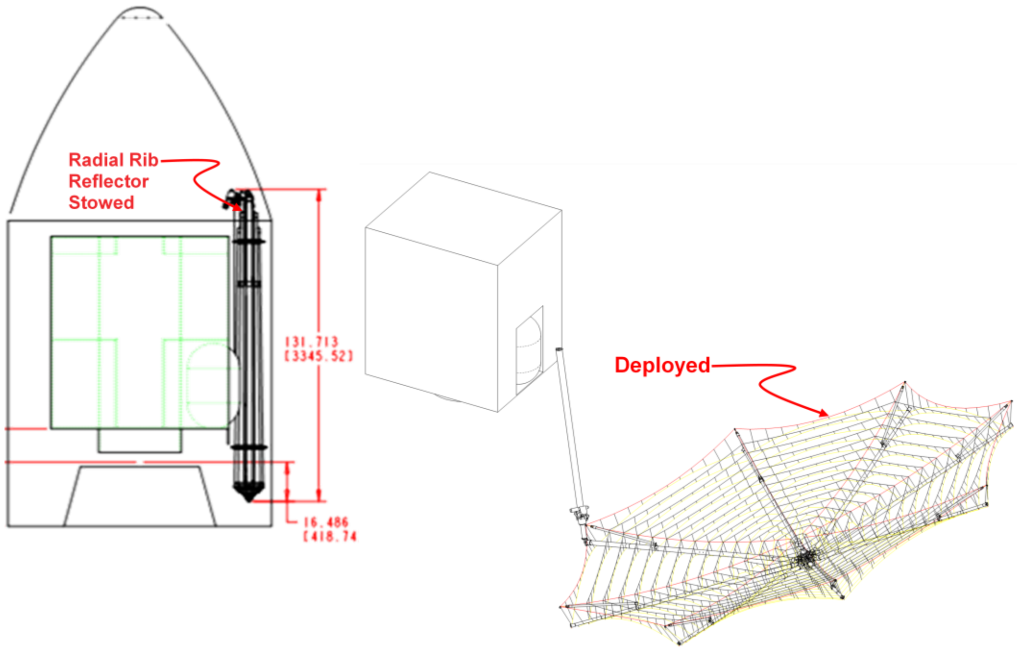

Figure 2. Schematic illustration of a Radial Rib Reflector in stowed and deployed state, courtesy of Harris Corp.

The tangentially deployable solid reflector concept consists of two sub systems:

1. ***Hub Mechanism:*** This system drives and synchronizes the deployment of the panels. *See Team5 for more detail.*
2. ***Panel Interlocking Mechanism:*** This system controls the manner in which each panel connects to its adjacent panels. **This is the focus of this and all subsequent documents prepared by Team 6 (Panel Interlocking Mechanism).**

The resulting function of these subsystems will be that the paneled reflector can be stored in a volume comparable to that of reflectors of a radial rib design. The reflector must then be cable of autonomously deploying. This deployment must include alignment and locking of the individual panels; interstellar applications will not allow for post deployment positioning of the panels, such that a misaligned panel would render the dish inoperable. The final deployed reflector must be capable of exhibiting higher surface accuracy and performance than comparable radial rib designs.

Project Scope

To illustrate the scope of the contract between our team (Panel Interlocking Mechanism) and Harris Corp., we first consider the overall project scope, and then detail our role within that project. A high level project process for the development of a flight ready, deployable solid reflector is:

1. Needs Assessment Harris Corporation have identified the need for a solid reflector alternative to radial rib reflectors that exhibits improved surface accuracy.
2. Concept Generation Harris will employ several approaches to develop high level possible options that satisfy the needs assessment
3. Concept Analysis Here the individual high level concepts are investigated to determine feasibility. **The entire scope of the contract with Team 6 lies within this set.**
4. Idea Selection After reviewing the conclusions formed in the previous step, a single approach will be selected for further development.
5. Final Design The final design including manufacturing processes and material suppliers are specified.
6. Prototype Construction and Concept Verification Full scale model is produced and tested to verify design and production processes.
7. Manufacture and Installation The final product is constructed and installed.
8. Quality Assurance The unit is checked to ensure successful implementation before being launched into space.

As introduced by the process map above, the scope of the FSU-Harris contract is for several students to assist with analysis of a particular concept; a tangentially deployable solid reflector. The general aim of such a concept analysis is to equip the project lead (Harris Corp) with the information necessary to make an informed selection between designs. Together, the FAMU-FSU students are to produce a physical model that demonstrates the kinematics of a particular concept, the tangentially deployable reflector.

The focus of this team is the interlocking design for the rigid panels of the reflector system. The panels of the final working model must possess the ability to interlock with each adjacent panel and maintain a final side by side alignment. Although the final prototype does not have to demonstrate autonomous storage of the panels, it should be designed with the capability of going from its final deployed position back to its initial configuration. Thus, the latching design must also allow for disconnect and repetition.

The joint focus of both groups is to have a final working prototype for a collapsible, solid reflector. This prototype will use rotational and then translational motion to autonomously achieve its deployed position. The final model for the system will possess the ability to work while exhibiting 1g forces, and will be designed with the anticipation of experiencing and maintaining functionality in a 0g environment as well. Both groups will maintain the efficiency of the system as well as follow appropriate safety measures for design.

Needs Assessment

We are working alongside a second group and will commutatively be designing and constructing a working prototype for a solid, collapsible reflector with autonomous deployment capabilities. Our focus is the latching mechanism used to hold the panels in their fully deployed configuration, while their focus is the design of the hub mechanism used to position the panels. The final goal is to produce a working prototype that demonstrates the autonomous mechanical capabilities of the hub and panel system to later be scaled to a larger model.

Problem Statement

Our center of attention is on the latching mechanism used to engage and hold the panels in their final, flush positions. The panels are initially in a stowed position stacked on top of each other as can be seen below in figure 1.

Figure 3 shows the stowed positioning of the panels in which they rest on top of one another.

The hub mechanism will first use rotational motion to move the panels from their stacked position to their desired radial positions as can be seen below in figure 2.

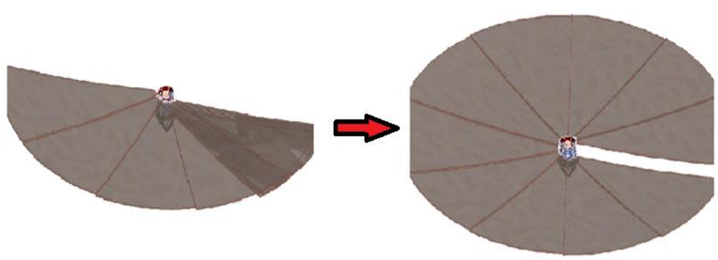

Figure 4 : Left) The hub initially uses rotational motion to move the panels from their stacked positions. Right) The geometry of the panels once they have finished the rotational motion phase.

Once the rotational phase of motion has completed, each panel will then be in its desired radial position. However, due to the initially stacked geometry of the panels, there is a vertical offset between panels which makes a second phase of motion necessary. In this phase, linear motion will be used to bring the panels to their fully deployed, flush positions (figure 3).

Figure 5 shows the panels in their fully deployed configuration in which the panels are both vertically and horizontally flush with one another.

The latching mechanism will be designed to engage in the linear motion phase of deployment. Ideally, it will be a passive design. It must securely hold each panel flush with their two adjacent panels and must be a reliable design.

By the project's end, our latching design in conjunction with the hub mechanism design will be used to create a working prototype for a reflector system. Said prototype should be scalable to the desired dimensions for the actual system. It must meet the size, shape and movement requirements that were set forth prior to the commencement of the project.

Objectives

- Create a working prototype of solid reflector system
  - Should be scalable to desired dimensions for actual system
  - Should demonstrate systems performance
    - Move from stowed to fully deployed configuration using hub
    - Latching mechanism will keep adjacent panels in flush, defined position
  - Must meet size, shape and movement requirements previously set forth
- Method in which the system attains its fully deployed position will consist of 2 stages:
  - Rotation
  - Linear Translation
    - Design must facilitate both motions
    - Must recognize when rotational sequence is over and transition to linear motion
    - Must avoid snagging
- Method in which panels latch onto one another
  - It is during linear translation that interlocking mechanism must engage

- Must maintain final position for prolonged period of time
- Doesn't need to be reversible, but ideally is resettable

Methodology

Once we have developed an understanding of the intended design, ideation can begin to turn into an actual working prototype. We will have to determine the best way to interlock the panels. This design must hold the panels together in a final, flush position, while also being capable of separating. Magnets along with a cup and cone design have been recommended, but we will have to do research for alternative methods to determine the best choice. The chosen latching design has to be carried out independently by the system, and will be chosen with intentions for use in space.

Once the panels are fully designed, we must choose the intended dimensions for the prototype, as it needs to be scalable to a larger solid reflector. It must be kept in mind that these panels must be able to initially hold a stowed, stacked position and then maintain a final deployed configuration in which they are side by side. Panels must be mountable to the hub, and the connection of the two components must be designed to ensure that the panels have enough support in a 1g environment. Although we are focusing on the latching mechanism while there are others focusing on the hub mechanism, communication between everyone throughout the entire design process is vital as the two components will come together to form a final working model and must be designed accordingly so.

Testing these designs of both the individual parts as well as the system as a whole is vital to this project. Once the panels have been designed and materialized, their interlocking capabilities can be tested. The design behind their connection must ensure each panel is keeping both adjacent panels in their defined final positions. Once the hub is ready, we will test the system as a whole. A successful design is dependent on both parts of the system working together to formulate a working model of a solid reflector system possessing an initial stowed position, and having autonomous capabilities to achieve its final deployed position. Throughout testing if and as problems are encountered, the proper design alterations will have to take place. Devising a schedule that ensures enough time for testing to achieve a successful design is imperative.

Constraints

Function:

- Reflector for space based applications capable of autonomous deployment.
- Solid-skin rigid panels

Constraints:

- Total budget of $2,500.00
- Prototype will be a scale of the actual size
- Panels connect to form dish shape characteristic of parabolic reflector antennae.
- Minimal compacted volume
- Panels must be mountable to hub mechanism

- Panels must be able to hold both a stowed (stacked) and deployed (spread out) configurations
- position and use rotational and then linear motion to achieve a final deployed configuration
- Panels must be flush and interlocked in deployed position
- Deployment operation must be reliably repeatable

Objective:

- Minimize mass of panels
- Optimize stowable space
- Demonstrate a working prototype

Free variables:

- Material of panels
- Area of panels
- Interlocking mechanism (magnets recommended)

Expected Results

The expected result of the FSU-Harris partnership is the completion of a scaled prototype that demonstrates autonomous deployment of a rigid panel deflector dish utilizing the patented bi-directional motion. Our contribution to the prototype will be to:

1. **Ensure the panels reach the correct deployed position**. *The panels must not catch or snag during deployment. Once hub motion completes, the panels should be correctly aligned with each other and the hub; the seams between panels should be flush. The panels should reach this position with a high degree of reliability.*
2. **Ensure the panels are securely held in the deployed position.** *Once deployed, the panels should be capable of retaining their alignment while exposed to the operational conditions of a satellite; the seams should not unintentionally separate, the individual panels should maintain their initial geometry, and the panels should not separate from the hub.*

The emphasis of this project is to provide a proof of concept for the patent being applied for by Harris Corporation. We expect to have a fully working prototype of a deployable solid reflector by the end of this project. The prototype will be a scaled model of an actual solid reflector, but it will fully demonstrate the mechanics and the design of the deployment. The working prototype will be able to redeploy whenever necessary.

Justification/Background

All satellite communications systems consist of two basic elements: the satellite itself and a ground station. Applications of satellite communication systems today include:

- ***Traditional Telecommunications*** Providing a link between transoceanic communications systems, or to geographically remote regions and countries with less developed communications infrastructure.
- ***Cellular*** Providing additional bandwidth for ground based cellular networks.
- ***Marine Communications*** Providing links to ships at sea.
- ***Airborne Communications*** Providing passengers of commercial airlines access to land based telecommunications networks.
- ***Global Positioning*** Services enabling navigational equipment for broad field of applications.
- ***Television Signals*** Since the 1960's satellites have connected broadcast television company's network hubs and their subsidiaries. The ability to receive the same satellite signal at home arose in the 1970's, marking the beginning of the Direct To Home (DTH) industry.

Of the applications, perhaps the simplest example illustrating the background for this Interlocking Panel Mechanism project is satellite systems for television signals. Currently, two technologies are commonly employed, one utilizing the lower frequency C-band and the other utilizing the higher frequency Ku-band range of microwaves.

The lower frequency range of C-band transmissions (approx 4-8GHz) provides increased signal stability, offering improved signal resolution even in heavy rain (rain fade) or snow (snow fade) conditions over Ku-band. However, a C-band receiver dish must be approximately 3m (~10 ft) in diameter, affectionately earning C-band systems the nickname "BUD" or Big Ugly Dish systems. While some broadcast television subscribers do install at-home BUD receiving systems, the more common application of C-band based communication is to have local broadcast-cable stations, which receive the C-band signal from the television company and disseminate the broadcast via cable to subscribers at their homes. This broadcast-cable system approach has proven to be an affective competitor in the Direct To Home (DTH) television market. However, reducing the receiving dish size would make home receivers more practical than running kilometers of cable to location where the raw signal is already being sent.

Ku-band systems (frequencies of approx 12-18 GHz) use receiving dishes as small as 0.45m (18 in) making them suitable for DTH applications. Cable systems do have some advantages; a Ku-band system requires slightly higher power for transmission, and additional error correction measures are required to compensate for signal degradation due to rain or snow fade. However, both C and Ku-band systems are common, and many Hybrid satellites are in orbit today carrying receiver/transmitter systems for both frequency ranges. Our team is part of the process for constructing a new type of dish for space applications. Now that we are familiar with C-Band and Ku-Band systems that we are designing for, we can derive some general criteria for the design.

For both C and Ku band systems, the satellite requires a dish reflector with an aperture of approx 3.5m (11.5 ft). The reflector must also have low mean surface deviation (>0.001") and good performance/efficiency (percent of EMF incident on the reflector that does not reach the receiver). There are two types of reflectors commonly used: mesh and solid. Mesh reflectors consist of compliant material stretched over radial symmetric rigid ribs. These reflectors have the advantage of being collapsible, but minute adjustments are required to achieve a suitable mean surface deviation and performance is generally lower. Solid reflectors typically require rigid frameworks that support a dish consisting of one solid piece or multiple solid panels. The use of solid pieces for the reflecting surface allow for excellent mean surface deviation and efficiency, but without being collapsible, typical solid reflectors are not suitable for space applications.