NISAR Flight Feed Assembly: Evolution of the Design from Initial Concept to Final Configuration

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***Abstract*—NISAR (NASA ISRO SAR, National Aeronautics and Space Administration, Indian Space Research Organization, Synthetic Aperture Radar) is an Earth science project currently in its final development phase at NASA Jet Propulsion Laboratory (JPL) and at ISRO. Due for launch in 2022 it will assess how our planet changes overtime by measuring differences in the Earth's solid surface due to factors like climate change, movement and melting of glaciers, earthquakes, land-slides, deforestation, agriculture and others. The enabling instrument for this mission is a dual band radar (L-Band and S-Band) that feeds a 12m deployable mesh reflector. This paper describes the evolution of the L-Band feed design from its initial concept to the final flight configuration. Two major aspects of the design are discussed in this paper: the TNC connector configuration and the upper patch attachment mechanism.**

***Index Terms*—patch antenna, TNC connector.**

I. INTRODUCTION

NISAR is a collaboration between NASA and ISRO, with JPL developing the L-Band radar and ISRO developing the S-Band radar. By employing a repeat pass interferometry scheme while using a sweep SAR technique, NISAR will image the entire planet solid surface with a 12-day repeat pass strategy over the course of a 3-year mission. The L-band feed is an array of 12 dual-polarization (horizontal and vertical) elements. Each array element is composed by 2 patches radiating in phase. Each patch is configured in a stacked patch configuration to broaden the bandwidth and is fed by two feeding points for each polarization. Overall, the L-Band feed is a 2x12 patch array where each patch pair forms a single array element. Two patch pairs make one LFTA (L-Band Feed Tile Assembly) or tile, so the full array, or L-FRAP (L-Band Feed RF Aperture), is made by 6 tiles [1].

Each LFTA is built with a supporting aluminum frame, a dielectric feeding network board with 4 independent connectors (2 for V-Pol and 2 for H-Pol), and 4 stacked patches in an air-patch configuration. The assembly is completed with a radome made by a rigid shell covering a foam insert. Since the feed array is exposed to space while in flight, the radome was added to the design in order to limit the temperature gradients across the feed. Given the 12-day repeat strategy employed by the mission, performance stability over time and under all operating conditions was one of the key driving requirements.

Fig. 1 shows a sketch of the NISAR observatory with all its major components and sub-systems.

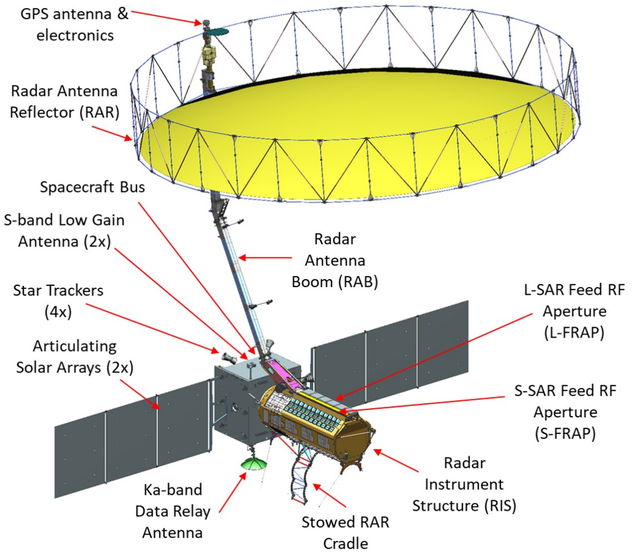

Fig. 1, View of the deployed NISAR instrument. The 6-tile L-Band feed array is visible on the top deck of the IRIS (Integrated Radar Instrument Structure).

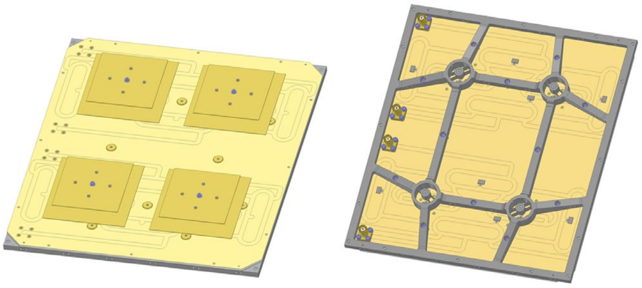

Fig. 2, Top (left) and bottom (right) view of a single LFTA without radome. At left the 4 stacked patches are visible. At right, the supporting frame and the 4 TNC connectors can be observed on the bottom side.

Fig. 2 shows a single LFTA without radome, while Fig. 3 shows a cross section of a complete LFTA with the details of the patch stack-up. The two patches in Fig. 3 are fed in phase, at both polarizations, and radiate as one element of the array. In [3] more details about this antenna design are discussed with particular emphasis on the near-field antenna measurement campaign.

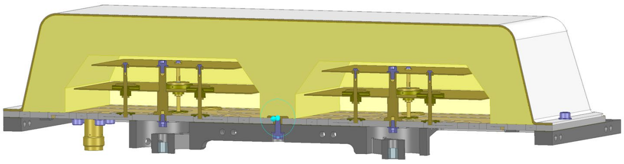

Fig. 3, Cross section of one LFTA exposing the geometry of a patch pair composing one element of the feed array. The radome foam (yellow) is covered by a rigid shell painted white.

II. TNC CONNECTORS

At the TNC connector area, power coming from a coaxial cable is transferred into the feeding network board with a coax-to-stripline transition. This is the highest concentration of power in the assembly. Right after this transition, the power splits in two and then in two again through rat races and power splitters to feed two stacked patches at four different points, two feed points per stacked patch, fed 180° out of phase.

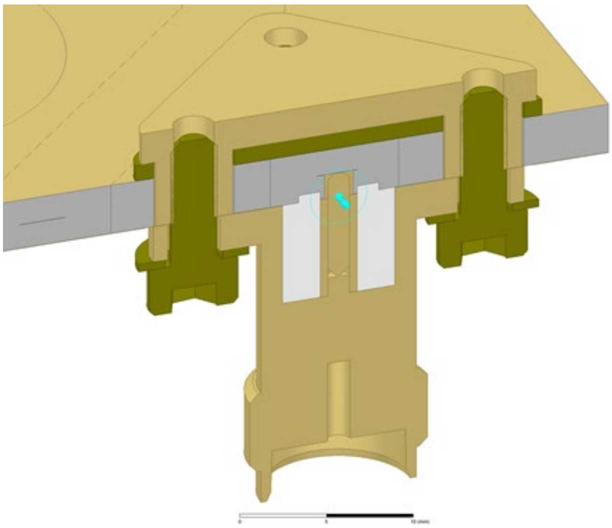

Fig. 4, Cross section of initial design for TNC connector transition with a cylindrical step in the Teflon piece of the TNC connector mating a grove in the board.

From a power perspective, the highest potential for high power breakdown is at the connector. Another consideration that went into the initial concept of the connector attachment to the board is Passive Inter-Modulation (PIM). At the beginning of the project, the antenna sub-system had a PIM requirement. Therefore, the transition was designed to avoid metal-to-metal contact where possible. Eventually that requirement was deleted and the design was allowed to evolve in a different way. Fig. 4 shows a section of the initial design. The TNC connector Teflon insert is machined with a cylindrical step that fits in a groove in the board to avoid high power breakdown. The connector flange is vented to prevent ionization in case any material out-gasses in the transition. The connector is mounted directly onto the board and screwed into a nut plate supported on a dielectric gasket. The screws are made of dielectric. In this configuration there is no metal-to-metal direct line of sight between center conductor and ground to avoid multipaction. Ionization is prevented by venting the transition so that it's very unlikely to accumulate enough pressure. The only metal-to-metal contact is between the gold-plated board and the gold-plated connector flange so that the possibility of PIM is reduced to a minimum.

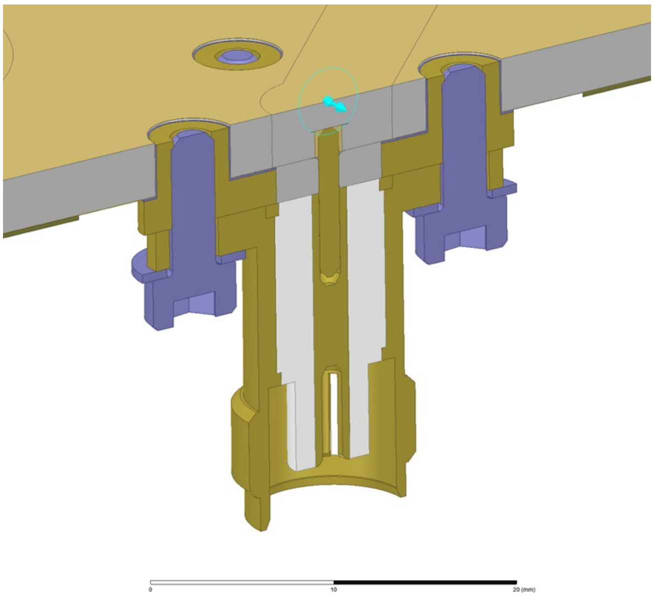

Fig. 5, Final configuration of the TNC connector transition with an RTV washer between the TNC connector and the board.

Fig. 5 shows the final configuration of the transition. The connector has now a flat Teflon interface with the board, the board doesn't have the groove in it anymore and the nut plate is now mounted directly under the connector and soldered to the board. An RTV washer (in grey around the TNC pin) fills the volume between the board and the Teflon piece. The screws are now stainless steel. The design in Fig. 4 evolved into that in Fig. 5 over the course of several iterations. Now the design is certainly mechanically stronger and more robust. The two configurations (and the other iterations in between) were fabricated and tested, including RF testing, high power testing and environmental testing. They all behaved similarly from an RF point of view, with the final design offering a slightly better return loss.

From a mechanical perspective though, the final configuration is somewhat superior. The original design relied on a tight tolerance between the Teflon interface of the connector and the board to prevent high power breakdown. Any issue with the stepped interface would have caused problems. Even if the tolerance stack-up of the various parts in Fig. 4 had a positive margin at every temperature in our environment, in the end we opted for a simpler interface like that in Fig. 5. Here the gap between the inner conductor and the ground is closed by the RTV washer which is soft by design and squeezes in place once the connector is mounted and torqued down. In particular, the dimensions of the RTV washers are such that, once squeezed, they fill the remaining volume completely and keeps a tight fit at every temperature. This way, the interface is easier, there is no delicate tolerance to account for and the soft nature of the RTV washer absorbs any other imperfection of the interface. Another critical tolerance stack-up was due to the location of the mounting plate for the connector. In Fig. 4 the Rogers board is sandwiched between the mounting plate and the connector. The length of its threaded bosses through the board were designed such that, once the connector mounting screws were torqued, there would be an initial load across the board to keep the interface tight at all temperature and prevent RF leakage. It worked as expected but given the soft nature of the Rogers material and the fact that the screws in this case were made of dielectric, this design still carried some risk, especially with a large number of thermal cycles. With the design in Fig. 5 we flipped the plate and mounted it directly under the connector on the same side, so that now the TNC connector mounts directly onto a solid metal piece as opposed to a soft Rogers board. Plus, the mounting plate is soldered directly to the board and through its mounting holes which are now plated, making it a much stronger anchoring mechanism. Last but not least, the use of stainless steel screws now insures a solid contact and reduces risk.

III. UPPER PATCH ATTACHMENT

With reference to Fig. 3, once the decision to go with air patches was made early in the project, the design has been fairly stable. The baseline design always included a larger lower patch capacitively coupled to its four feeding points and directly attached to a center post for strong mechanical support and suppression of the second harmonic.

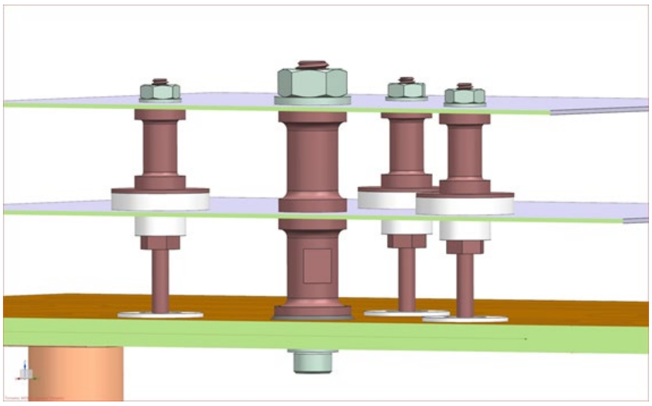

Fig. 6, Early concept of the patch stack-up where the various parts were screwed together with nuts into threaded fittings.

The upper patch directly connected to those five points. The original concept for attaching the patches is shown in Fig. 6, where the various components were screwed together except for the feeding points into the board. Because of the PIM requirement mentioned in the previous section, that concept was dropped early on and the nuts and threaded fittings were replaced with solder joints. A detailed structural analysis was done in order to make sure that those solder joints were strong enough to survive launch and the following long series of thermal cycles once in space. Hundreds of small coupons were also tested at different temperatures after a series of different thermal cycles to verify that the structural analysis results were correct. The baseline design was then modified into what's shown in Fig. 7 where all connections were soldered.

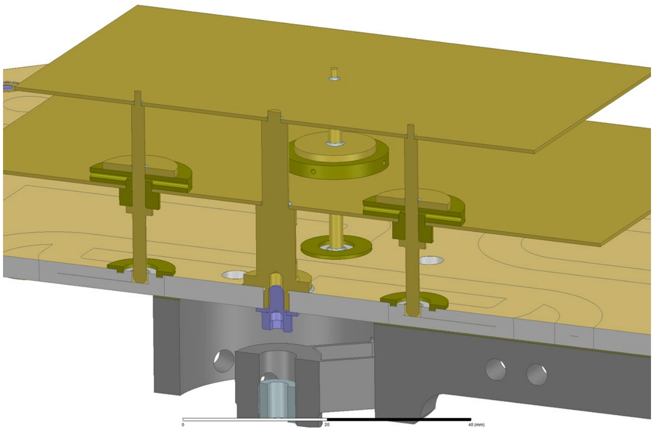

Fig. 7, Patch stack-up configuration where all joints are soldered including the upper patch.

Despite all of the work done, one of the complete assemblies of our Engineering Model (EM) program developed some cracks in the upper patch soldered joints during environmental testing. This forced a redesign of the upper patch joints. Since the PIM requirement had been removed from the requirements at that time, we could go back to using small screws to attach the upper patch without changing the rest of the design. This time though, a small screw would thread into a tapped hole rather than a nut into a threaded fitting like in Fig. 6. Fig. 8 shows the final design which passed random vibration tests (see Fig. 9) and is the final flight configuration.

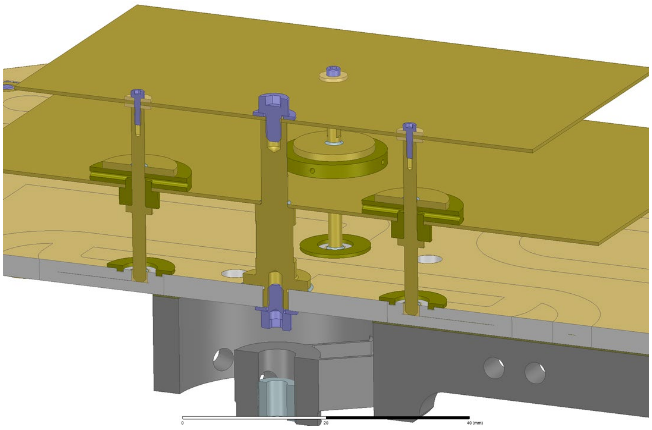

Fig. 8, Final configuration with upper patch secured by fasteners.

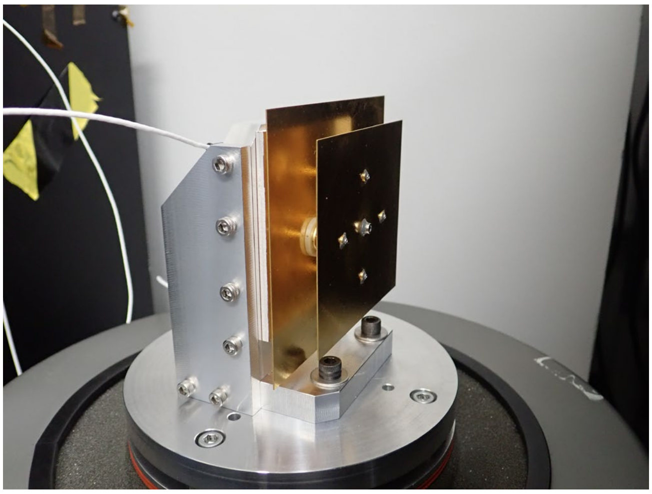

Fig. 9, Single patch coupon used for testing the final patch configuration during a random vibration test.

This latest iteration didn't come without unwanted complications of course. While on one side we could use the screws on the top patch since the PIM requirement was removed, at the same time we had to make sure that any second or third harmonic signal, potentially self-generated by the antenna, once added to the worst case harmonic signals coming from the TRM modules at those harmonics, would still remain below the level enforced by a requirement from the National Telecommunications and Information Administration (NTIA). To go around this issue we performed a worse case analysis which demonstrated that any significant higher order harmonics generated by the top patch fasteners would, when combined with the TRM harmonics, result in secondary patterns from the NISAR reflector that are below the levels required by the NTIA.

IV. CONCLUSIONS

This paper discussed how two important aspects of the NISAR feed antenna design evolved over time from initial concept to final configuration. For every flight project, design details change overtime and evolve into the launched configuration. How this process happens and why can be a good source of lessons learned. The tight link between requirements and RF and mechanical design is another interesting aspect of this paper.

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