SAR ANTENNA DEVELOPMENT IN CANADA

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1. Introduction

The Canadian Space Agency, CSA, has undertaken several projects over the last decade to endeavor the position of the Canadian industry in the field of SAR antenna technologies. Future SAR antenna will require performance, which exceed today's SAR capabilities. The future SAR antennas will have to provide higher resolution capabilities, dual-band for increased selectivity and dual-polarization to allow HH, HV, VH and VV configurations. Furthermore, the antenna will have to be smaller in size and lighter in weight. This paper summarizes the progress done by the Canadian Industry under the CSA sponsorship to advance the state-of-the-art in the field of SAR antenna. Three different concepts, a dual-band dual-polarization SAR antenna, a membrane antenna and a reflector antenna will be presented together with the Radarsat 2 SAR antenna architecture.

2. Dual-Band Dual Polarized SAR Antenna

Dual-band SAR antennas have the potential of increasing the information content of spaceborne SAR systems. Recent studies show that the combination of L & C band frequencies provides improved characterization data. It has been demonstrated that the overall size of a direct radiating panel can be minimized by developing an aperture that can be shared between multiple frequency bands and multiple polarization channels [1-3]. Figure one shows a picture of a breadboard dual band dual polarized radiating panel consisting of 1024 C-band and 64 L-band radiating elements implemented in a window configuration. The array was implemented using microstrip technology for both C-band and L-band radiating elements. The printed radiator is of particular interest due to its compact size, which allows close spacing of elements as well as windowing of elements corresponding to multiple bands and multiple polarization. The panel consist of the following layers: a C-band azimuth and impedance matching layer, a ground plane with coupling slots for C-band elements layer, a L-band vertical polarization feed layer with lower resonator for both band and an upper resonators layer for both bands. An exploded view of the sub-array layers is shown in Figure 2. The array is comprised of eight radiating panel layers supported by a lightweight aluminum frame. The eight panels drop into the openings in the frame and they are bonded in place with a standard adhesive. The array frame is designed specifically for range testing and is not representative of flight hardware. Similarly, the array panels themselves are not designed to meet the environmental requirements of flight hardware; they are simply proof of concept to verify the electromagnetic characteristics achievable with this printed dual-band dual polarized structure.

The measured test results showed that the combination of windowed patch and patch elements provides the required polarization purity and bandwidth. The cross polarization level of the array is near -25 dB in both bands. The bandwidth is of the order of 200 MHz at C-band for a 20 dB return loss, and 70 MHz at L-band for a 15 dB return loss for both horizontal and vertical polarization, with a radiating panel thickness of only 0.44" and a mass of 2.8 kg per square meter, excluding support and stiffening structures. This new lightweight, low profile and rigid structure is ideal for distributed amplification.

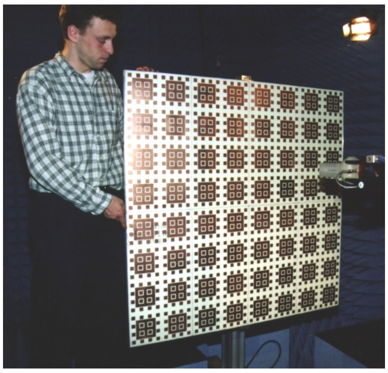

Figure 1. Picture of the L & C Band Panel

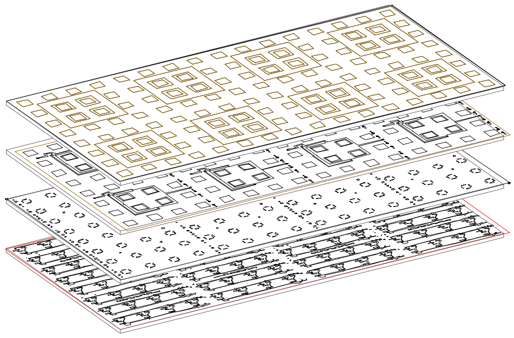

Figure 2. Exploded view of the sub-array layers

3. **Membrane lens**

The membrane lens concept offers a possibility of realizing extremely lightweight, large aperture antennas for space applications. A membrane antenna can easily be stowed in a small canister at launch as shown in figure 3. One of the major advantages of the lens, as compared to other forms of antenna, is that the electrical performance is relatively insensitive to the precise aperture profile. Another advantage of the lens relative to a reflecting surface is the absence of an onerous requirement for a geometrical offset, in order to avoid aperture blockage effects due to the primary feed. The lens consists of three planar surfaces, an input surface, a ground-plane surface, and an output surface, each being realized on its individual membrane. The input and output surfaces carry the patch radiator arrays. These are interconnected by 'bootlace' circuits, which pass through holes cut in the central ground-plane membrane (a lens can also be implemented without bootlace circuits, but with a performance penalty [4]).

The breadboard L-band lens of figure 4 was assembled from Kapton and polyester film materials. A central 1.1m x 1.1m area of the 3.1m square membranes was populated by radiating patches. The 3.1m square breadboard assembly has been fully characterized by measurements on a planar near-field facility with a 1.5m*1.5m probing capability. With a PNF measurement, the antenna does not rotate. Thus, even with the given 1g. test environment, it is unlikely that the antenna profile will undergo a distortion whilst the test is in progress. For membrane testing, the fields were probed at three different displacements in front of the antenna aperture. This made it possible to reduce errors (otherwise estimated at 0.15 dB to 0.5 dB for absolute gain determinations), due to a multiple bounce between the test probe and the membrane aperture.

In general, a membrane lens antenna offers most of the functionality of the more traditional offset reflector design. The membrane is capable of generating pencil beams, or shaped beams. Realized gain for the membrane will be very similar to that for a reflector of the same aperture size. The one proviso relates to bandwidth. In general, very large membrane lenses generating very high gain beams operate over a limited bandwidth.

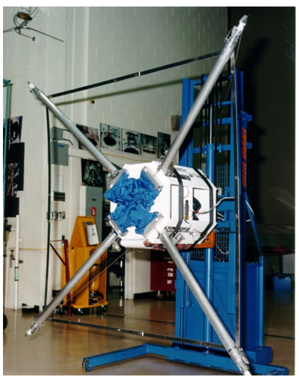

Figure 3. Membrane Antenna In Stowed State.

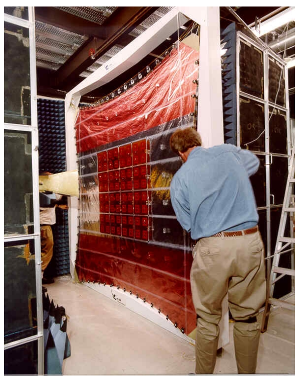

Figure 4. Membrane Antenna Deployed for NF Measurements

4. Reflector Antenna Concept for SAR

Most SAR antennas proposed for the next generation SAR satellites are of the planar arrays type. For those using printed radiators at C-Band and higher, the arrays must be active due to high losses. At L-Band, passive printed arrays may be used if the requirements are simpler, i.e. single polarisation. A passive slotted-waveguide array at C/X bands has low potential for enhancements such as dual-frequency or simultaneous dual-polarisation. For these reasons, an alternative antenna designs concept, like a large deployable membrane reflector fed by a linear phased array feed, was considered. Figure 5, shows the concept antenna in a deployed configuration.

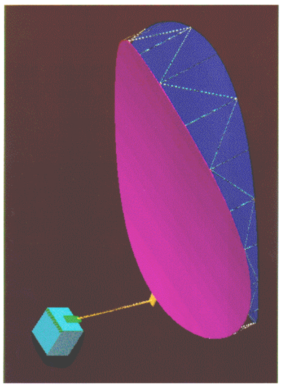

Figure 5. Reflector unfolded.

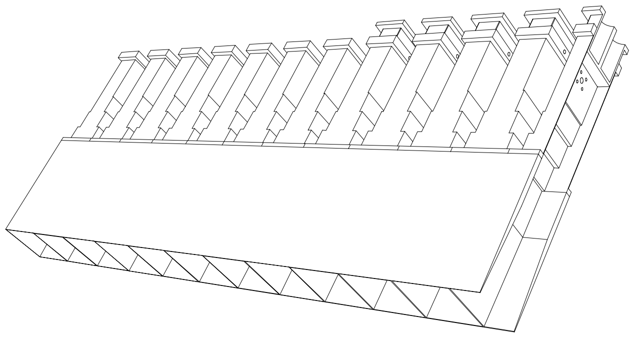

Figure 6. Linear horns feed array

In this design, the elevation beam shaping and steering can be done as in the Radarsat 1 planar array, by independent phase control of the feed elements. The azimuth pattern requirement is a narrow pencil beam without stringent sidelobe specifications. A space-fed reflector is an efficient way of obtaining a large aperture size with Low Mass and without an intervening feed network. The advantages of a reflector antenna make it attractive for many applications, from small-SATs to futuristic complex systems.

To assess the advantages of a reflector, a comparison with Radarsat 1 was conducted. The reflector antenna was thus designed to meet the Radarsat 1 RF specs. The RF performance was found generally better for the reflector, but the most obvious advantage is a lower mass (over 50% reduction). A reflector antenna was then investigated to meet specifications that are more ambitious, dual frequency and dual polarization, and incidence angles up to 65° in C-Band and 50° in L-Band.

A linear array feed, as seen in figure 6, was fabricated. The phase distribution is controlled by a phase-only BFN similar to Radarsat 1. The feed array is located along the focal axis near the spacecraft, and it is non-deployable with an offset geometry rather than center-fed reflector, avoiding blockage by the feed. The horn phases are digitally controlled by variable ferrite phase shifters (VPS).

The mass comparison with Radarsat 1 was established as follow: 71kg for the feed assembly, 114 kg for the reflector, 52.5 kg for the reflector boom and 32.5 kg for the tie-down assembly, for a total mass of 270 kg compare to 750 kg for Radarsat 1. A reflector with more ambitious specifications would include for dual frequency, C-Band plus L-Band, two parallel dual-polarized linear horn arrays located side-by-side in the focal region. Each frequency would have an elevation BFN (e.g. integrated waveguide at C-Band, integrated TEM-line at L-Band) with controllable VPS. For dual-polarization, with simultaneous reception of HP and VP, each horn would be fed by an OMT, and there would be a BFN for each polarization for a total of two C-Band BFN's and two L-Band BFN's. That is a relatively small increment in mass and complexity with respect to the single-polarization design and much less so than for a planar array design with the same capabilities.

5. Radarsat 2 SAR Antenna

The Radarsat 2 SAR payload requirements were defined to develop a high performance SAR antenna that would produce results of the highest-resolution commercially available and long awaited. Some of the RADARSAT-2 innovations & improvements are a 3-metre ultra-fine resolution, left- and right-looking capability and fully polarimetric imaging modes.

The baseline design for each antenna panel is an integrated structure to which all components are mounted. Components include subarrays, T/R modules, elevation power distribution networks (EPDNs), azimuth power distribution networks (APDNs), CDUs, harness and thermal hardware. T/R modules, EPDNs and CDUs are mounted in recesses in the front panel with covers bolted over the openings. Each subarray is mounted to the front panel and the APDN and harness are mounted in a recess on the back panel. Figure 7 is showing the antenna mechanical design concept.

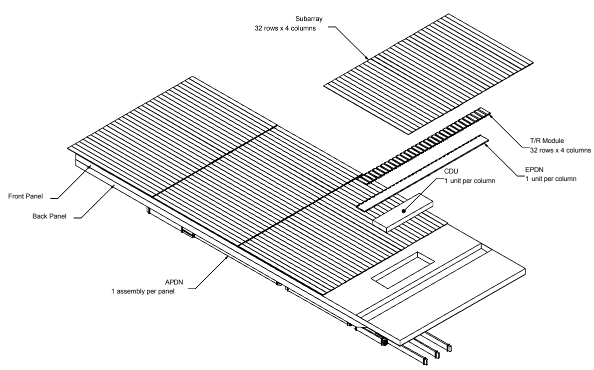

Figure 7. SAR Antenna Mechanical Design Concept

The identical structure is used for both inner and outer panels with the panel structure divided at the midplane into top and bottom halves. The integrated structure bonded with tongues and grooves. The SAR antenna subarrays RF design consisting of 20 linear elements will either be a square patch configuration with stripline feed for minimum mass and low RF loss, or a stacked square patch configuration for wider band and smaller sensitivity to manufacturing and material tolerances.

6. Conclusion

Work conducted by the Canadian Industry over the past few years, in collaboration with the Canadian Space Agency, in the field of SAR antenna technologies has resulted in major innovative technology development. Three different concepts were presented as well as the Radarsat 2 SAR antenna.

7. References

[1] G. Séguin, T. Pellerin, P.C. Strickland, L. Shafai, 'Dual-Band Dual-Polarized Microstrip Array Test Bed For Satellite Based Sar', 21st ESTEC Antenna Workshop on Array Antenna Technology, Noordwijk, The Netherlands, May 6-8, 1998

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