An Inflatable L-Band Microstrip SAR Array

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Introduction: Inflatable structures have been identified as one of the enabling technologies to achieve low mass, high packaging efficiency, and reliable deployment for future NASA spaceborne synthetic aperture radar (SAR) array antennas. A current L-band SAR antenna development, with aperture size of 10 m x 3 m, is required to have the capabilities of dual-linear polarization, 80-MHz bandwidth, electronic beam scanning, and less than 100 kg of mass. An inflatable concept, which employs the inflatable tubular frame structure to support a multilayer, thin membrane, microstrip array radiating aperture, has been identified. It uses a "roll-up" concept '1], shown in Fig 1, for deploying the thin membranes to form a planar array aperture. To demonstrate this concept, two contracts were independently given to ILC Dover, Inc. and L'Garde Corp. for each to construct a **1/3 size (3.3** m x 1.0 m) fictional model with an inflatable structure at L-band frequency. JPL provided both contractors with the antenna RF design and the etched thin membranes. The ILC Dover model has been delivered to JPL and gone through a series of deployment and RF tests[2,3]. This is believed to be the first inflatable array antenna ever developed. This paper presents the mechanical and electrical constructions of this inflatable array and its test results.

Antenna Description: As shown in the photo of Fig. 2, the antenna consists of: 1) rectangular inflated-tube frame structure, 2) membrane surfaces with microstrip patch elements and patch excitation circuit, 3) central mounting plate and support box with inflation bottle, which also simulates the spacecraft and 4) membrane-support catenary structure. The inflated tube frame has a diameter of 13 cm and is made of 10-mil thick urethane coated Kevlar material. The tube structure has imbedded steel coil spring to produce a smooth and controlled deployment. The inflatant bottle, made of lightweight composite material, is housed inside the central support box and has a regulator to inflate and maintain tube pressure at 5 psi. The radiating surface, with 3.3 m x 1.0 m size, has three layers of thin membranes, each made of 5-micron copper on a 2-roil Kapton sheet. The top layer, with l/3-width strip sketched in Fig. 3, was etched to form 6 x 16 microstrip patches and microstrip power dividing lines to generate a horizontally polarized field. The middle ground plane layer, shown in Fig. 3, has slots etched away with one slot situated below each top-layer patch. The bottom layer has the microstrip lines that excite the top-layer patches to provide a vertically polarized field through the middle-layer slots. The spacing required between the top and middle layers is 1.27 cm and between the middle and bottom layers is 0.635 cm. The central structure has honeycomb panels for setting the membrane spacings, supporting RF feed probes, and attaching to the box that contains the inflatant bottle. For each polarization, there are six RF feed probes which allow future interface with T/R modules and phase shifters for beam scanning in the broad-beam direction. The connection between the inflated tubular frame and the membranes is made by a series of catenary mylar cords at equally spaced points along the edges of the membrane layers. The spacings between the three membranes are maintained by the tension of the catenary cords (after the structure is inflated), the central honeycomb spacing panels, and small spacing blocks at each of the catenary points. The antenna has a total mass of 15 kg with an average of 4.3 kg/m^2, which includes the inflation system and its support box (total 9 kg). It is projected that the full size (10 m x 3 m) array would have an average mass of 1.7 kg/m^2. The membrane surface achieved the required global flatness of less than ±1 cm. The required spacing tolerance of ±0.075 cm between the top two membranes was achieved; but between the bottom two membranes was not quite achieved. This spacing problem, which can be improved, will be discussed in the presentation.

RF Test Results: For the horizontally polarized membrane (top layer), the measured input return loss is given in Fig. 4. The antenna is shown perfectly tuned at 1.241 GHz and has a good impedance match at the design frequency of 1.25 GHz. The bandwidth achieved, defined as a VSWR of better than 2:1, is slightly wider than the required 80 MHz. The measured isolation between the two orthogonal feed ports is greater than 40 dB within the required bandwidth. The radiation patterns measured in both principal planes at 1.25 GHz are given in Fig. 5. Sidelobe levels of -14 dB in the azimuth plane and -12 dB in the elevation plane are reasonable for this uniformly distributed array. The cross-pol level of less than -20 dB within the main beam region is also considered acceptable for the radar application, Patterns measured at frequencies from 1.21 GHz to 1.29 GHz are very similar to that shown in Fig. 5. The measured peak gain at 1.25 GHz is 25.2 dB which indicates an aperture efficiency of 52% and is considered quite good as a first demonstration model. The vertically polarized membrane (bottom layer) did not perform as well. Its two principal-plane patterns are given in Fig. 6. The cause of its imperfection and possible corrective measures will be presented in the symposium.

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References:

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3, R, W. Lingo and C. R. Sandy, "Proof-of-Concept Demonstration Model of the Roll-Up Array Antenna," JPL Contract no, 960836, Final Report, September 1997.

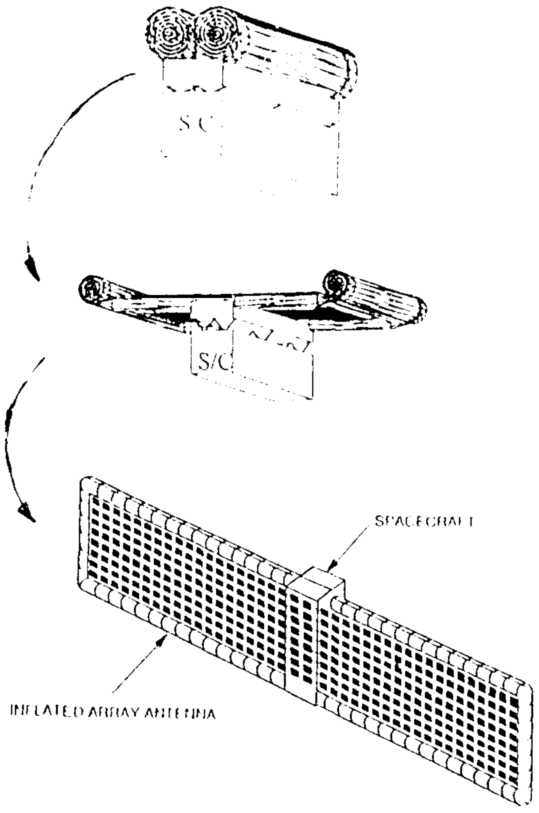

Figure 1. Inflatable array “roll-up” concept.

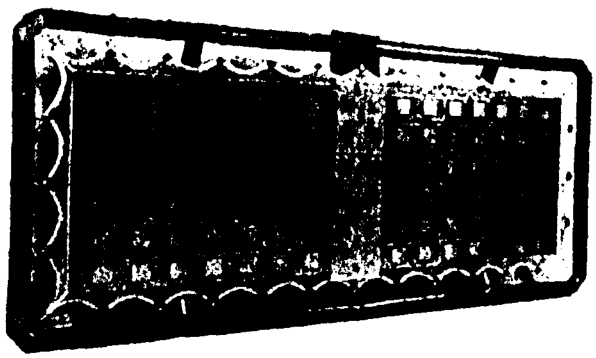

Figure 2. Photo of 3.3 m x 1.0 m L-band Dual-polarized inflatable array.

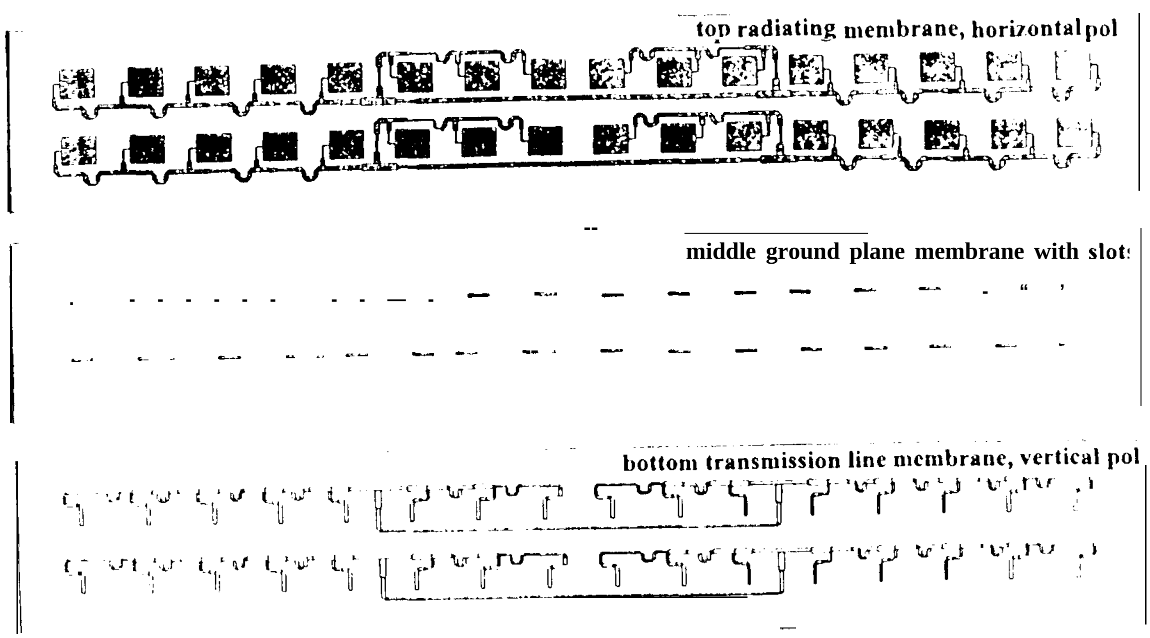

Figure 3. Design drawings of portion of the 3 membrane layers.

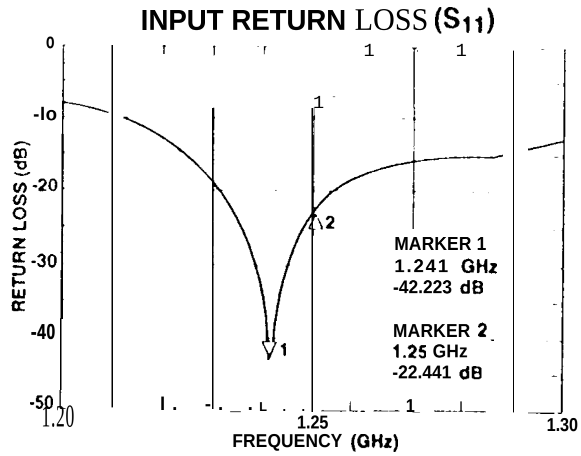

Figure 4. Measured input return loss for the horizontally polarized port.

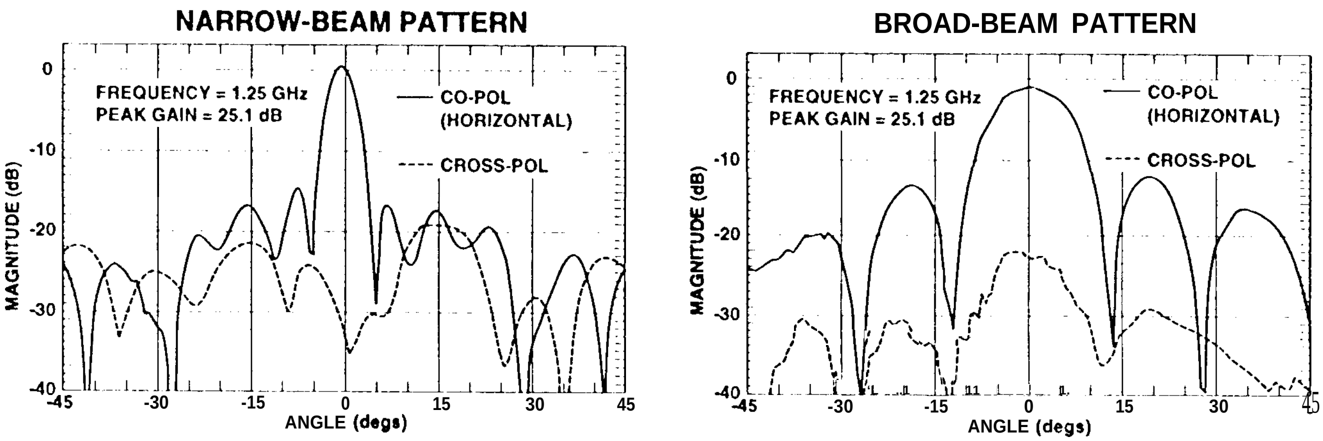

Figure 5. Measured two principal-plane patterns for the horizontally polarized port.

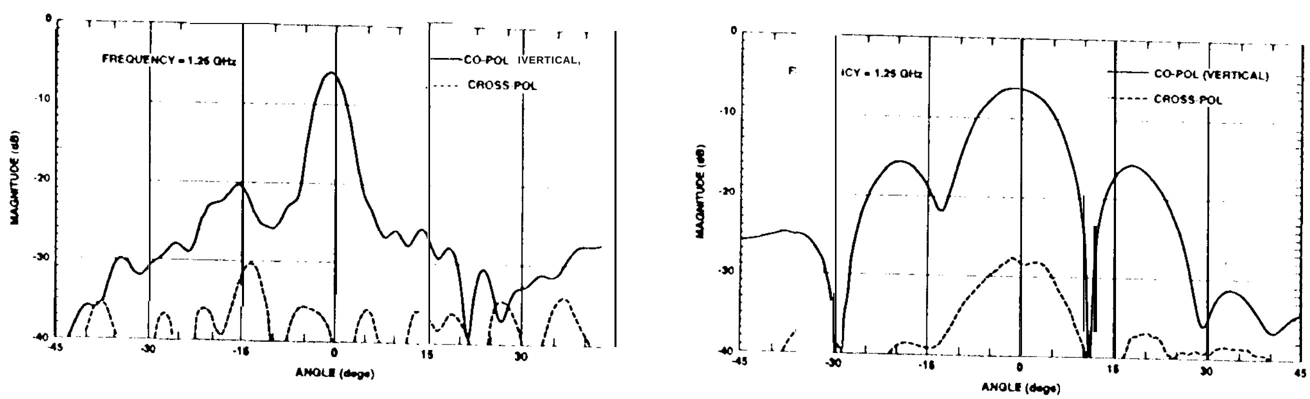

Figure 6. Measured two principal-plane patterns for the vertically polarized port.