

A Dual Polarization, Active, Microstrip Antenna for an Orbital Imaging Radar System Operating at L-Band

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Introduction A highly successful Earth orbiting synthetic antenna aperture radar (SAR) system, known as the SIR-C mission [1, 2, 3], was carried into orbit in 1994 on a U. S. Shuttle (Space Transportation System) mission. The radar system was mounted in the cargo bay with no need to fold, or in any other way reduce the size of the antennas for launch. Weight and size were not limited for the L-Band, C-Band, and X-Band radar systems of the SIR-C radar imaging mission; the set of antennas weighed 10,500 kg, the L-Band antenna having the major share of the weight. This paper treats designing an L-Band antenna functionally similar to that used for SIR-C, but at a fraction of the cost and at a weight in the order of 250 kg. Further, the antenna must be folded to fit into the small payload shroud of low cost booster rocket systems. Over 31 square meters of antenna area is required. This low weight, foldable, electronic scanning antenna is for the proposed LightSAR radar system which is to be placed in Earth orbit on a small, dedicated space craft at the lowest possible cost for an efficient L-Band radar imaging system. This LightSAR spacecraft radar is to be continuously available for at least five operational years, and have the ability to map or repeat-map any area on earth within a few days of any request. A microstrip patch array, with microstrip transmission lines heavily employed in the aperture and in the corporate feed network, was chosen as the low cost approach for this active dual-polarization, 80 MHz (6.4%) bandwidth antenna design.

Antenna Aperture A 10.8m by 2.9m antenna aperture produces the ground foot print to satisfy system operation factors. The payload shroud sizes for low cost booster rockets indicated the choice of eight 2.9m x 1.35m panels. Hinged together, the panels form the required aperture in space but for launch they are folded together in a stack. Each of the eight panels has 32 four-patch element clusters with 32 probe connection points for each polarization. Combining of those probe connection points is discussed in a later section. Flight qualified deployment systems were identified to perform the function of unfolding the eight panels and forcing them into flat alignment. The design steps for the panels used to form the large array can be restated as:

1. As a substrate for single layer microstrip lines and patch elements, employ the mechanically proven stiffness and thermal behavior of specially designed 1.37cm thick, honeycomb core rigid panels. The result is the panel cross section shown in Figure 1.
2. Design to have the square patch radiators, the Vertical polarization (V pol) patch excitation lines, and the Horizontal polarization (H pol) patch excitation lines all on the same plane. That allowed photo etching all these elements at the same time on 0.05mm thick Kapton clad with 5 micron thick copper.

3. Feed the four-patch clusters of radiators to get V pol with one microstrip divider circuit. A second microstrip circuit feeds the same four-patch elements for V pol. One probe feed comes out for each polarization as shown in Figure 2.
 4. Use the back side of the copper coated Kapton ground plane as the ground plane for some stages of the V pol and H pol corporate feed networks.
- This approach yielded the low cost and low weight objectives.

The size of the aperture and the 1.25 GHz center frequency for the radar translates into 1024 individual patch radiating elements being required. Electronic scanning of this antenna is over such limited angles from broadside that patch radiators could be fed in groups to form a subarray. Figure 2 shows that the microstrip power divider for V pol has a number of widths. The line impedances, ranging from 100 to 200 ohms, the lengths of lines, and the step discontinuities in line widths are designed to yield 50 ohms at the probe feed point and while producing uniform illumination of the four-patch radiators of the subarray. The probe-to-patch path lengths to the inboard patches vs. the outboard patches differ by 2π radians but over the 80 MHz radar bandwidth the four patches can be said to be in phase for vertical polarization. A similar manipulation of line widths and lengths yields 50 ohms at the plane of the H pol probe, as well as equal amplitude and quasi equal phase for the H pol mode of the same four-patch subarray. The 10.8m x 2.9m array employs 256 of these four-element groups.

What has been achieved, *all etched on a single layer*, is microwave circuitry that provides 1.) equal power division to the patch radiators, 2.) uniform phase, 3.) dual polarization, 4.) matched 50 ohm feed points for each subarray in each polarization, and 5.) high isolation between the V pol and H pol ports of each four-patch subarray.

Corporate Feeds Figure 3 shows the face of one half of one of a 2.9m x 1.35m panel, and radiation patterns for that half panel after the microstrip corporate feed was attached to obtain equal amplitude and phase for every patch radiator. Each full 2.9m by 1.35m panel has 32 probes, for each polarization, coming out of the panel's back surface. In the "Science Mission" version, a lower resolution version of the LightSAR mission, there is one dual channel T/R module for every four H/V pairs of the probes, i.e., every 16 patch elements. The T/R modules have built-in phase shifters for beam scanning. Smaller beam scan angles are needed and thus larger phase quantization is allowed in the aperture. As a result, for each polarization each panel has the layer of eight 4-way power dividers indicated in Figure 1. These power dividers are all carried out in microstrip in order to avoid the weight and costs of individual phase matched cables, their connectors, and separate power dividers. One 4-way microstrip power divider is shown in Figure 4. The divider's 50 ohm microstrip lines, 1.473mm in width on a 0.508mm thickness of Duroid 5870, $\epsilon_r = 2.33$, form a power divider with power division equal within 0.1 dB, and phase equality within ± 3 degrees. These results are highly repeatable from unit to unit once the transparency for photo etching is created. Probes, coming through from the array face, pass through holes in the ends of the microstrip divider arms for soldering.

Other power dividers, similar to Figure 4, have different path geometry for different levels of the overall corporate feed. Figure 5 shows a microstrip inverter which allows switching the ground plane side of microstrip as one adds layers of the corporate feed assembly.

Summary By designing patch radiators and feed circuits for two polarizations all on one plane, the antenna designer is able to photo etch several functions all on one layer. This is in contrast to schemes such as using slot coupling for one polarization and probe coupling for the other polarization. Reducing the number of layers reduces costs and weight in patch array panels. Further, forming array's corporate feed network by several stages of etched microstrip circuits on thin substrates results in great cost savings. Corporate feeds formed with a quantity of individually phase matched cables and a multiplicity of discrete power divider components are expensive in parts costs, parts management, parts handling, and final assembly time. The present antenna design is compatible with both lower resolution radars that employ only 64 T/R modules, or the version of the system that employs 256 T/R modules.

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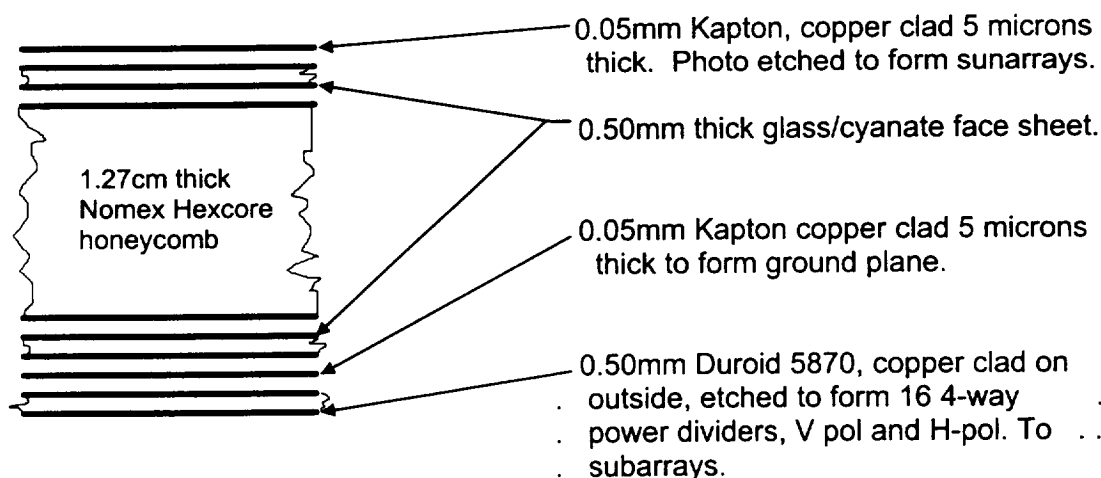


Figure 1. Cross section of rigid panel for array.
Film adhesive sheets not shown.