Very Long Microstrip Array Feeds of a Membrane Reflector for the Advanced Precipitation Radar*

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__Abstract__ – Very long microstrip arrays have been developed at the Ku- and Ka-band frequencies. Each array having an electrical length of about 110 free-space wavelengths is used to feed a deployable thin-membrane cylindrical reflector for a spaceborne precipitation radar application. These arrays, designed for 0° and 30° fixed beam directions, achieved peak sidelobes of –20 dB and average sidelobes below –30 dB with peak cross-pol levels below –20 dB. Several unique challenges were encountered during the development of these very long arrays, such as the strong coupling between very long power divider lines, the strong leakage radiation from the lengthy transmission lines, and the lack of computer analysis capability of these electrically large arrays.

__Introduction__ - As part of the overall NASA Earth science research effort, Jet Propulsion Laboratory (JPL) is developing a lightweight, dual-frequency, dual-polarized, wide-swath scanning, large-aperture deployable antenna technology for the next generation spaceborne precipitation radars [1,2]. This Advanced Precipitation Radar Antenna (APRA), depicted in Fig. 1, utilizes a 5.3m x 5.3m cylindrical parabolic reflector with two electronically scanned Ku- and Ka-band phased linear array feeds to provide global rainfall measurements at 2 km horizontal resolution over a cross-track scan range of up to ±37°. The two-frequency radar beams with very low sidelobe requirement will allow unambiguous retrieval of the parameters in the raindrop size distribution. The large-aperture reflector will be a deployable thin-membrane surface with surface precision justified for the Ka-band application. To facilitate this antenna technology development, JPL is currently developing a half-size (2.6m x 2.6m) technology demonstration model. Two key challenging areas are: a deployable thin-membrane cylindrical reflector to achieve the required surface accuracy of 0.2 mm RMS and electrically very long linear feed arrays to achieve the required low sidelobe level of less than –30 dB. This paper addresses specifically the feed array technology development [3].

__Antenna Concept and Design__ - The microstrip antenna approach is selected for the feed arrays due to its relative simplicity of fabrication, lower mass and smaller size when compared to other types of antennas, such as the slotted waveguide array. In order to achieve two matched beams (i.e., equal beamwidths and pointing directions) from the cylindrical reflector for the two frequencies (13.6 GHz and 35 GHz), the Ku-band array, for the half-size model, has to have a length of 2.6m with 166x2 elements while the Ka-band array must have a length of 1.0m with 166 x 4 elements. To achieve the required 37° beam scan along the long-dimension of each array, 166 T/R modules with phase shifters are needed. These amplifier modules, illustrated in Fig. 2, will alleviate the problem associated with the high insertion loss of the microstrip power divider lines and phase shifters. Because of their high cost, the modules and phase shifters are not implemented in this stage of the development. Several fixed-beam arrays are developed to demonstrate the very-

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feed array technology. To minimize the insertion loss and the needed real-estate of the microstrip power dividers, a combination of parallel/series feed and subarray technology is used. A total of four arrays were developed – two for Ku-band with 0° and 30° tilted beams and the other two for Ka-band with 0° and 30° tilted beams. The design drawing of the Ku-band array with 0° tilted beam is illustrated in Fig. 3, while that for the Ka-band array is shown in Fig. 4. As can be seen, the parallel microstrip power divider design is used to distribute power to all subarrays for stable bandwidth consideration. Within each subarray, series microstrip power divider is used, for space compactness consideration, to distribute power to five smaller subarrays. Each smaller subarray consists of a vertical "stick" of 2 patch elements for the Ku-band array and 4 elements for the Ka-band array. In order to achieve the required amplitude and phase precisions for the very low-sidelobe requirement, several key issues were encountered in the array development. One was that significant amount of mutual coupling occurred between the very long power divider lines. Second was that the relatively large amount of leakage radiation from the power divider lines raised the sidelobes to an unacceptable level. Third was the lack of efficient computer software to analyze and design this large microstrip array as a whole unit. To resolve these issues, it was determined that, in order to reduce line couplings, the parallel power divider lines need to be separated much further apart than the conventional required separation for smaller arrays. It was also determined that absorbing materials or T/R modules can minimize the effect of leakage radiation from the power divider lines. Finally, commercially available moment-method based software was used to analyze subsections of the complete array and, through fab/test iterations and array amplitude/phase diagnostics, the microstrip array development was successfully accomplished.

<u>**Measurement Results**</u> – For Ka-band, the radiation pattern measured at 35.0 GHz for the 0°-scanned case is given in Fig. 5, where it shows a near-in sidelobe peak at –20 dB level with an average sidelobe level of about –30 dB. The –3dB beamwidth is 0.62°. The cross-pol peak within the main beam region is –22 dB and is –30 dB outside the main beam. Fig. 6 gives the measured co-pol and cross-pol patterns for the 30° scanned ka-band array, where it shows the near-in sidelobe peak, as well as the far-out sidelobe peaks, at –18dB level. The far-out sidelobes are considered as the grating lobes due to phase and amplitude imperfections between major subarrays (major subarray consists of 5 small subarrays; small subarray spacing is $0.63\lambda_0$ and major subarrays spacing is $3.15\lambda_0$). The main beam has a –3dB beamwidth of 0.72°. The cross-pol peak within the main beam region is –22 dB, and is at the level of –30 dB outside the main beam region. The Ku-band arrays performed similarly as the Ka-band arrays. Their measured patterns will be shown during the presentation. From these measured results one can conclude that it is feasible to have large microstrip array to achieve reasonable pattern performance at very high microwave frequencies.

References:

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2. Y. Rahmat-Samii, J. Huang, B. Lopez, M. Lou, E. Im, S. Durden, and K. Bahadori, "Advanced precipitation radar antenna", Earth Science Technology Conference (ESTC), College Park, Maryland, June 2003.
3. J. Huang, Y. Rahmat-Samii, S. Durden, and E. Im, "Very long Ku- and Ka-band microstrip arrays for advanced precipitation radar application", PIERS Symposium, Nanjing, China, Aug. 2004.

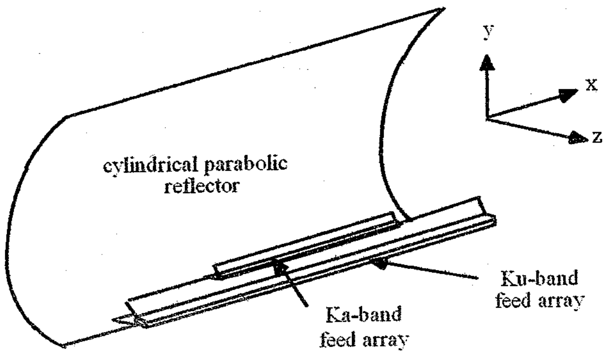

Figure 1. Configuration of the daul-band cylindrical reflector antenna

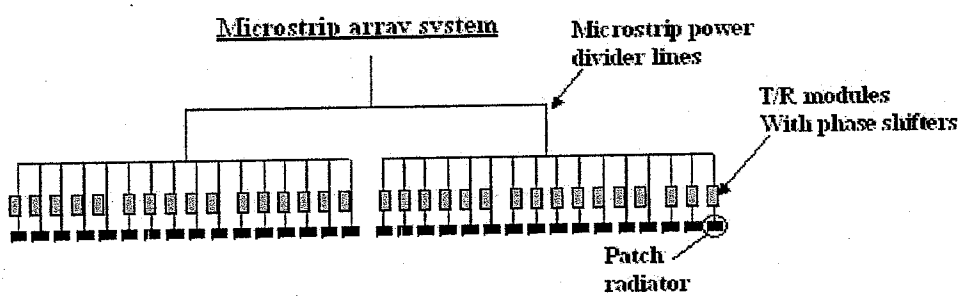

Figure 2. Concept of a linear microstrip array using T/R modules

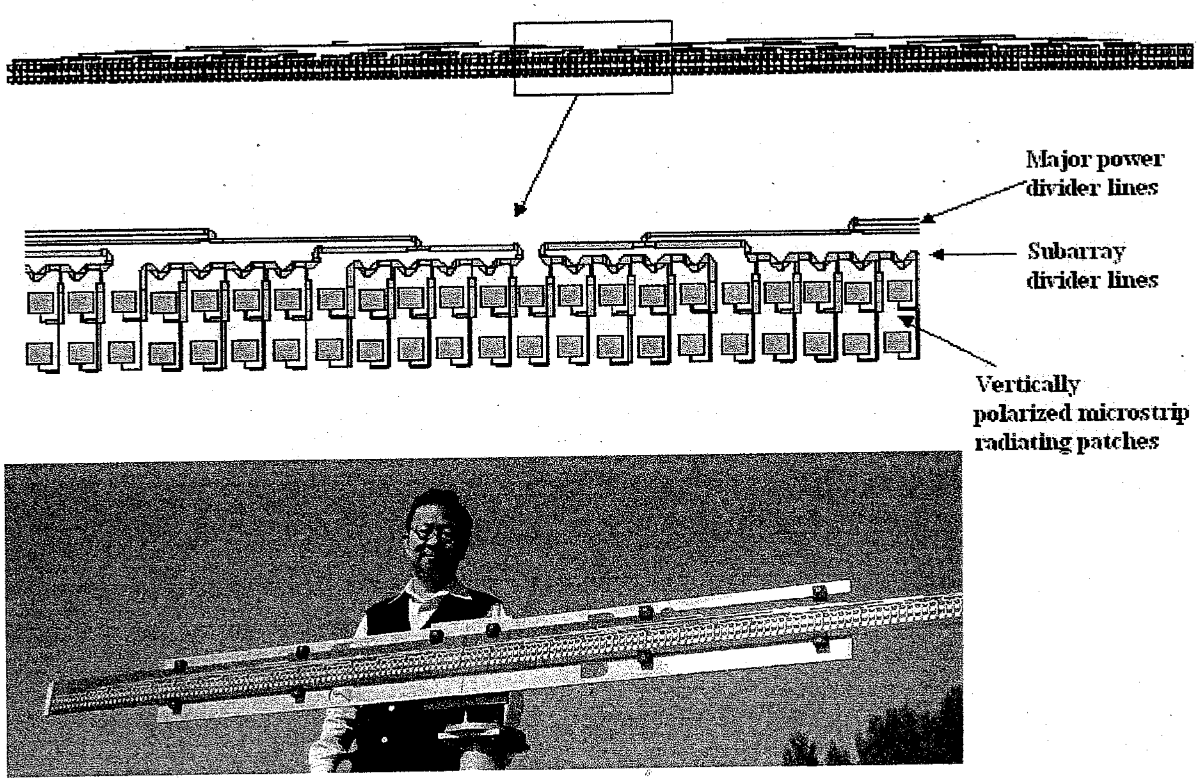

Figure 3. Design drawings and photo of the Ku-band array with 0° beam tilt.

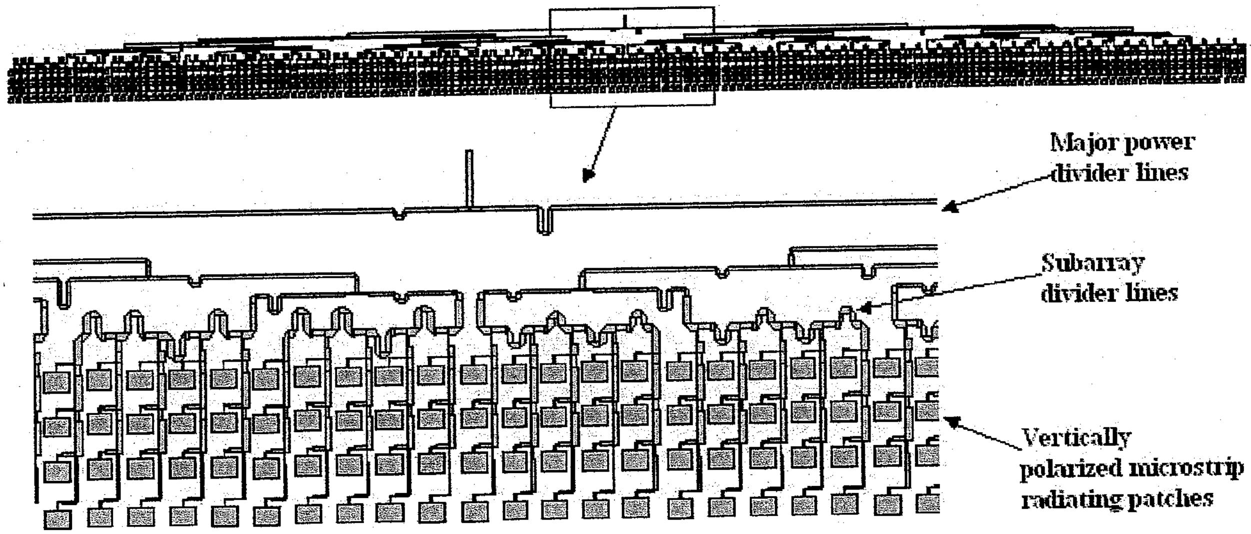

Figure 4. Design drawings of the Ka-band array with 30° beam tilt.

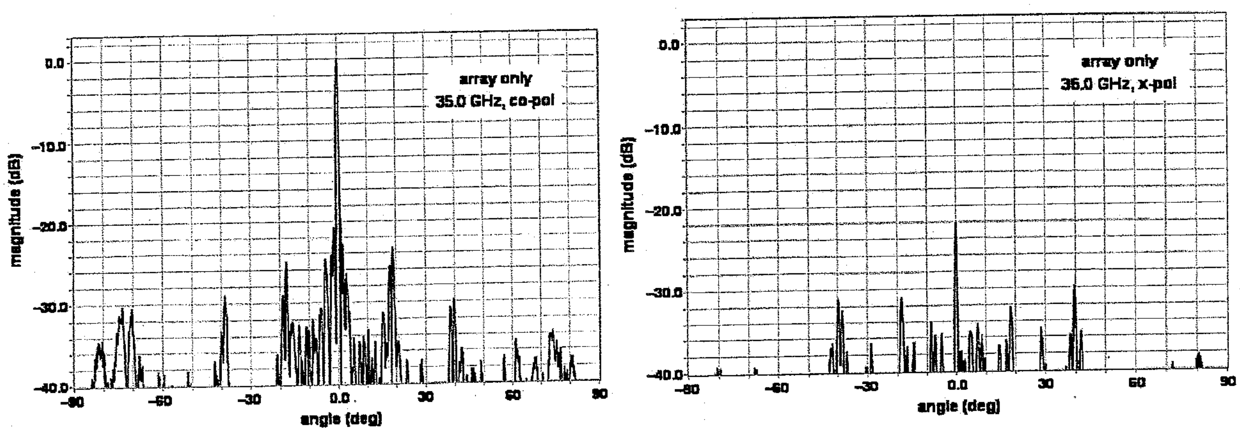

Figure 5. Measured co-pol and x-pol patterns of the Ka-band array with 0° beam tilt.

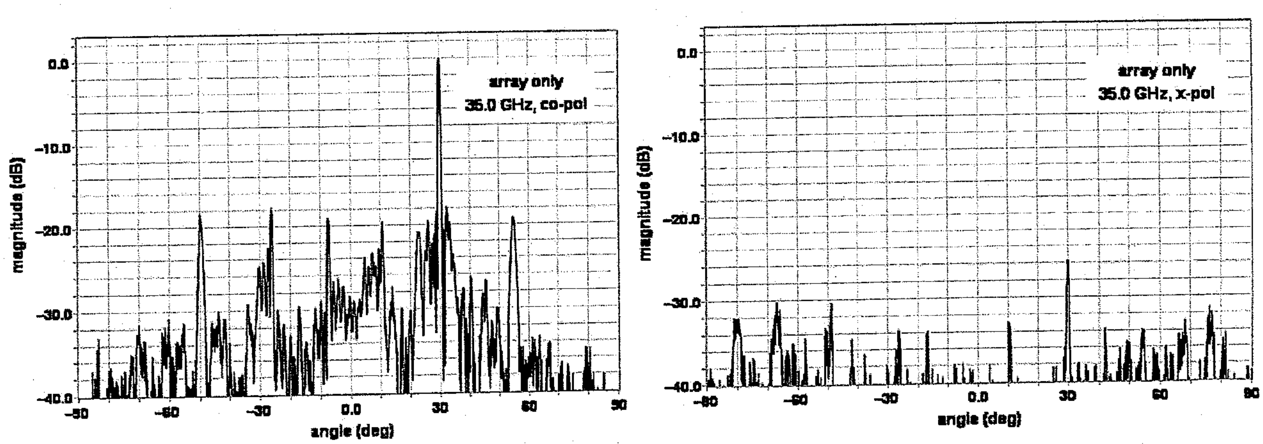

Figure 6. Measured co-pol and x-pol patterns of the Ka-band array with 30° beam tilt.