Simulation of the ATA Antenna Element Primary Beam Pattern for the Purpose of Investigating the "Dog's Sunglasses" Anomaly

Robert Ackermann

2009-01-28

This article briefly presents initial but compelling results from a simple computer model that investigates the effects of a direct photon path from the ATA antenna primary surface to the feed focus.

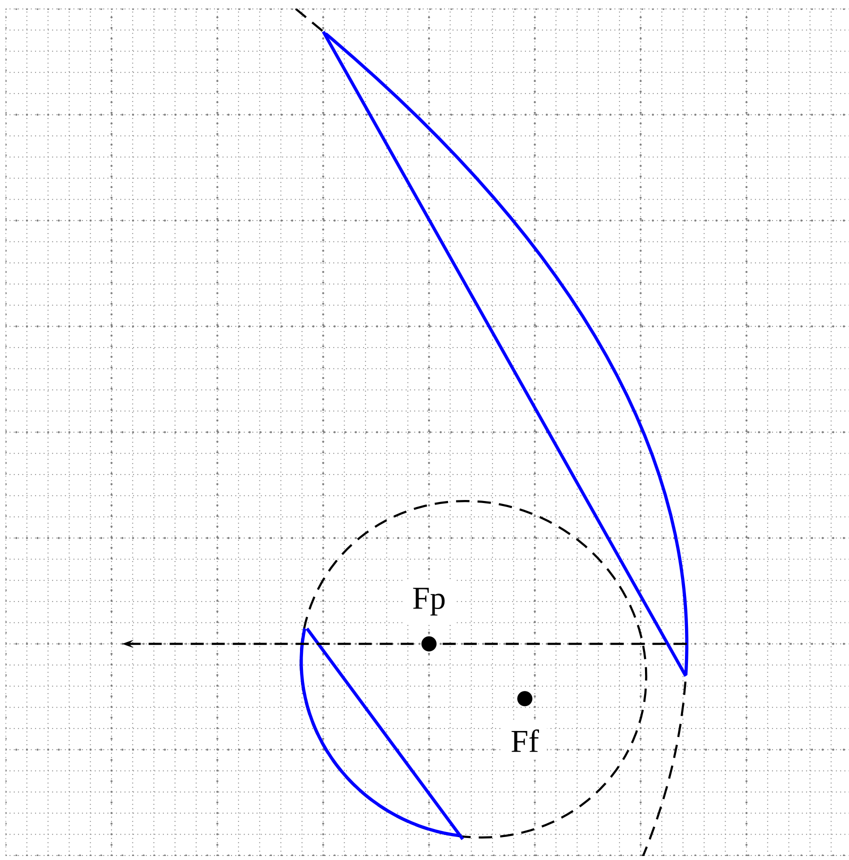

Figure 1: side view of ATA antenna reflectors

Figure One (1) diagrams a side view of an ATA antenna sliced down its middle. The large primary surface is a section of a paraboloid with focus Fp. The smaller secondary surface is a section of an ellipsoid with one focus co-located with the primary focus (Fp) and the other focus at the feed focus (Ff). The secondary surface translates the primary focus (Fp) to the feed focus (Ff) such that the feed can be tucked behind the secondary without a view to ground and its associated noise.

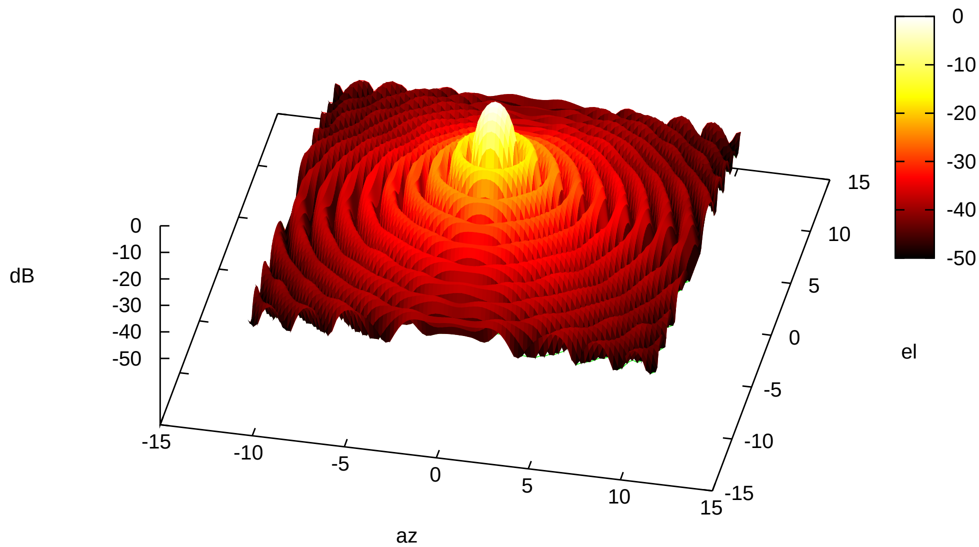

Figure 2: ideal ATA antenna beam pattern (2400 MHz)

Figure Two (2) images an ideal ATA beam pattern computed by integrating, for each (az,el) pointing, phase contribution over all paths from a distant source to each point on an evenly segmented primary and then to the primary focus. The secondary, for simplification and to reduce computation in the model, is considered a perfect translator from the primary focus to the feed focus and is additionally considered to be perfectly illuminated by the feed.

(next page)

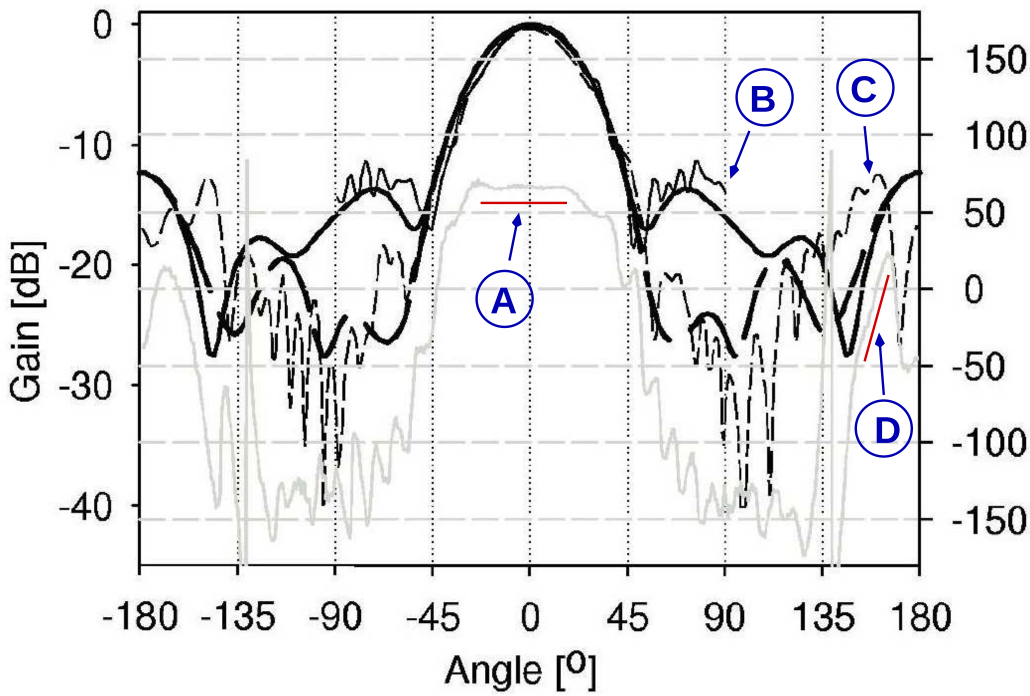

Figure 3: ATA range-measured feed pattern

Ideally, the feed would only illuminate the secondary; however, the ATA feed has a significant rear lobe which additionally illuminates a portion of the primary. Figure Three (3), extracted from ATA Memo 45, ”Non-planar Log-periodic Antenna Feed for Integration with a Cryogenic Microwave Amplifier,” graphs a range-measured E-plane (thin solid black line), H-plane (thin dashed black line), and phase (thin solid gray line) profile of one polarization of an ATA feed. The graph is overlaid with simulated E-plane and H-plane profiles (thick solid and dashed black lines) computed at that time of the measurement and subsequent analysis. The E-plane measurement (B) is limited to 90 degrees. The H-plane measurement exhibits a rear lobe (C) with a null near 180 degrees. The null may be due to blockage of the front resonating section of the feed by the pyramid when viewed from the rear along the feed axis. Due to the central null, the rear lobe is approximated using a donut pattern by the model associated with this article. Additionally, and this proves through experiments with the model to be a significant parameter, the rear lobe exhibits a large negative phase slope (D). In contrast, the front lobe, as desired, illuminates the secondary with flat phase (A). The negative rear lobe phase slope I suggest can be viewed alternatively, if the phase were artificially held constant, as distorting the primary surface: in this case, curling the primary surface in around the rear of the feed.

(next page)

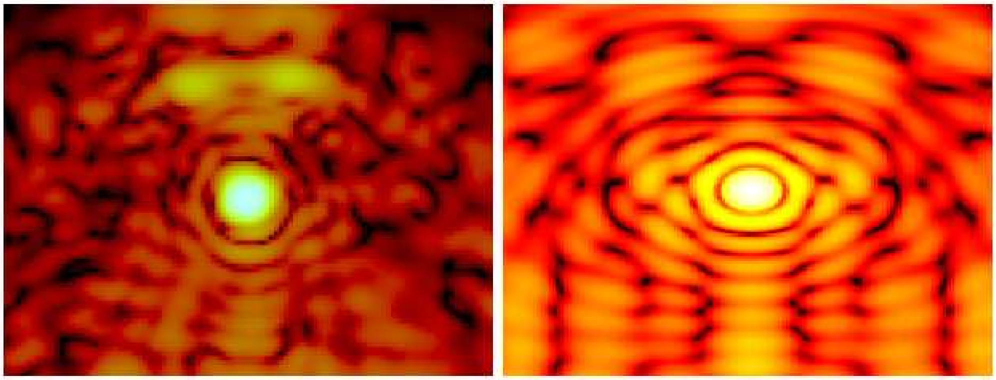

Figure 4: measured beam pattern (left) and simulated beam pattern (right)

Figure Four (4) displays, side-by-side, a real measured beam pattern (left), courtesy of Gerry Harp, and a simulated beam pattern (right) generated by the model associated with this article. The (az,el) pointing range is approximately 20 degrees each side. The source frequency is 2400 MHz. The simulated beam pattern was constructed by adding to the ideal beam pattern, for each (az,el) pointing, integration over all paths from a distant source to each point on an evenly segmented primary and then directly to the feed focus, bypassing the secondary, while attenuating and phase rotating the contribution of each path based on its axis angle into the rear lobe feed pattern model. Dynamic range and color keys between the two images are not identical; furthermore, the relative power between the ideal beam and the effects of direct primary to feed path contribution are not accurately modeled. However, it is remarkable (given the simple nature of the model), and not likely to be coincidental, that both images demonstrate similar features: dual dog's sunglasses lenses above the main lobe, multiple vertical striations crosscut by sidelobes below the main lobe, and general inner sidelobe ring interference.

In conclusion, some observations can be made from conducting experiments with the model and by thinking in general about the direct primary contribution theory:

- the relationship between source wavelength and rear lobe phase slope along with constructive and destructive interference between the two paths to the feed (from secondary and direct from primary) will cause beam pattern anomalies to change shape and intensity with respect to source frequency

- the rear lobe pattern is not likely to be symmetrical around the feed axis as modeled; therefore, the vertical and horizontal feed polarizations will illuminate the primary surface differently (e.g., there is no substantial primary surface below the feed) which will cause beam pattern anomalies to change shape and intensity with respect to the various combinations of source polarization and power detection (X^2, Y^2, and X^2+Y^2)