Antenna Cost Modeling For Large Arrays

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The traditional power-law model for the cost of a steerable, microwave reflector antenna is of the form $C = C_0(d/d_0)^\alpha(f/f_0)^\beta$, where C is the cost of construction, d is the diameter, f is the maximum operating frequency, $\alpha = 8/3$, $\beta = 1/3$, and C_0 is the cost of an antenna of diamter d_0 and maximum operating frequency f_0 (P. Blacksmith and A. Schell, *IEE (London) Conference Publications*, **21**:135–139, 1966). The model is derived from first principles on the assumption that total cost is proportional to that of the bulk materials. Sometimes empirical or *ad hoc* values are used for the exponents, rather than the theoretical values.

Such a model is valid only for large antennas, where fabrication and assembly costs do track those of the bulk material, but only if the construction technology is kept fixed. To obtain a model that is valid over a wider range of sizes, technology cannot be kept fixed. There are breakpoints were different construction methods or materials become feasible and desirable, creating step changes in minimum cost vs. d. As size is decreased, cost decreases monotonically, but not as fast as the cost of materials because costs of important components like motors, gears, and controls becomes determined by their fabrication complexity rather than their materials. Even within the traditional model's valid range, it is extraordinarily difficult to obtain a reliable value for C_0 so as to estimate absolute cost. Costs for existing antennas are difficult to compare because of differences in what is included in reported costs; differences in the bookkeeping methods of the responsible organizations (e.g., how non-recurring engineering is treated); and variations in circumstances, like the number of identical units produced. Estimated costs, even when provided by experienced companies and based on precise performance requirements, are unreliable and vary by factors of several because of commercial biases and because insufficient engineering effort is expended in the absence of a firm order. And finally, except for very small antennas ($d < 3\,\mathrm{m}$), there is virtually no experience in designing steerable antennas to take advantage of cost savings in mass production. (The Allen Telescope Array is beginning to provide the first such experience.) For these reasons, the traditional model cannot be used to determine the optimum antenna size in a large array like the proposed DSN Array or SKA.

This paper describes what is currently known about the cost of mass-produced antennas over the size range $d = 1\,\mathrm{m}$ to $100\,\mathrm{m}$, and will suggest what work is needed to produce a better model. It is an updated and extended version of an earlier URSI paper (L. D'Addario, North American Radio Science Meeting, Ottawa, July 2007; `http://www.astro.caltech.edu/USNC-URSI-J/Ottawa_presentations/Affordable_Ultra-large_Collecting_Area_for_Wide-field_Radio_Astronomy_Imaging/URSI194_DAdarrio.pdf`).