Comments on Mark Walker's Catadioptric Camera for the SKA Element Antenna

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Mark Walker has suggested in [1] a catadioptric* optical design as a possible solution to the SKA antenna problem. The main impetus for this study was to find an alternative design with similar imaging properties to the Luneburg lens while overcome the supposed technical difficulties in realising the latter. While the aim was laudable, the catadioptric optical design proposed by Mark and illustrated in Fig. 1 below has, unfortunately, major flaws which exclude it from serious consideration as an alternative to the Luneburg lens for SKA applications. It is an interesting curiosity non-the-less.

Firstly, for a given collecting area, the physical size of the Luneburg lens and the correcting lens in the catadioptric design in Fig. 1 will be identical. To a good approximation, this correcting lens is in fact a Luneburg lens with a long focal length. Thus, the assumed difficulty with regard to refractive index gradient applies equally to Mark's correcting lens. This, together with weight and loss consideration, are the very problems we are planning to overcome with out artificial dielectric proposals. Given the wider range of refractive index required by our Luneburg lens, it will be a little heavier (as a consequence of the increased 'doping' of the supporting foam material for higher permittivities) than the same sized correcting lens in the catadioptric case but the differences are likely to be of little consequence once we are successful in realising our artificial dielectric material. Furthermore, given that the maximum value of permittivity required by Mark's correcting lens is likely to be ~ 1.17 or greater, to manufacture this lens with low-weight, low-loss materials will depend precisely on the type of artificial dielectrics we are pursuing for our Luneburg lens design. (Commercially available low-loss foam dielectrics have a maximum dielectric constant of around 1.06.) Thus, the problems of manufacturing the correcting lens in the catadioptric design (essentially a Luneburg lens with a long focal length) appear to be little different in practice to that for, what is in our case, a shorter focal length Luneburg lens.

Secondly, the proposed catadioptric design is very inefficient optically ranging from 0% - 50% compared to the Luneburg lens design of 50% - 100%; i.e., the minimum (optical) efficiency of the latter being equal to the maximum obtainable from the catadioptric design. For example, from [1] an optimum design (where the normalised focal surface, f, is set at 0.67) the maximum efficiency is 44% for an unvignetted field-of-view of 96º after which the efficiency falls off rapidly to zero. Compare this to the Luneburg lens where, in a practical design, we will have an optical efficiency of 100% for an unvignetted field-of-view of ~ 120º (the worst case is 90º) after which the efficiency falls off slowly to 50% at 180º. Another problem in the catadioptric design is the need for a large (expensive) spherical reflector that is underutilized substantially as indicated by the low optical efficiency. As the correcting lens is substantially smaller than the spherical reflector, more than half of the energy collected by this reflector will not be focused by the optics. Some of this unfocused energy will inevitably appear in the vicinity of the focal plane and will be difficult to select out.

But perhaps the most serious objection is the fact the any feed and associated equipment will be in the direct path of the incoming signal. While this may not be a major problem with a single

* The term "catadioptric" refers to optical systems where both refractive and reflective elements are utilised

feed system, it negates the main purpose of going to a Luneburg lens or a catadioptric design where many feeds are to be used for simultaneous multibeaming. This will not be possible in any extended sense for the catadioptric case as the increased blockage would create many problems, not the least being a substantial decrease in an already low efficiency system. Suggestions such as plasma feeds to avoid blockage are simply naïve. In addition, the focal plane is likely to be very close to the surface of the correcting lens requiring the feed system to be buried inside this lens. Even for a single feed system this would not be a trivial problem. By contrast, feed systems for the Luneburg lens are placed away from the surface on the underside of the sphere providing simpler lens construction, an unblocked aperture, and plenty of room and access for the feed system and front-end electronics.

[1] Mark Walker, "Catadioptric camera with a wide field of view," Submitted to JOSA. A copy is available at http://www.atnf.csiro.au/SKA/techdocs/Catalogue.html

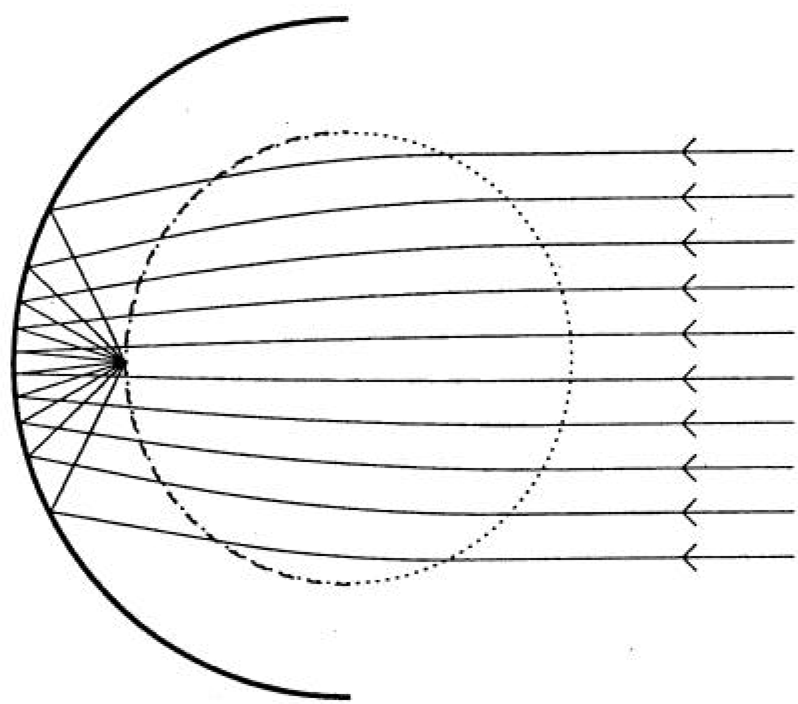

Fig. 1 The catadioptric optical system proposed in [1]