MICROLENSES FOR A FLY'S EYE IMAGING ARRAY.

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Abstract: The potential use of microlenses for imaging at millimeter-wave frequencies is investigated by analyzing the focussing properties of dielectric spheres. Our calculations show that the spheres of dielectric constant 12, with a quarter-wave matching layer, exhibit good focussing properties down to a radius of about one free-space wavelength.

Introduction.

Substrate lenses have been used extensively in millimeter-wave imaging systems [1],[2]. Original systems consisted of a single large hemispheric or hyperhemispheric lens on whose focal plane the imaging array was constructed. Microlenses are lighter and should have lower loss. They may be configured as arrays in imaging systems. Imaging requires sampling at intervals of about one free space wavelength [1]. Microlenses seem best suited for such a system, where each imaging element would be configured to have its own small substrate lens. The demagnification properties of the lens enables one not only to have an antenna but also most of the support circuitry on the focal plane of a single lens. These lenses give the array a fly's eye appearance as shown in **fig. 1**.

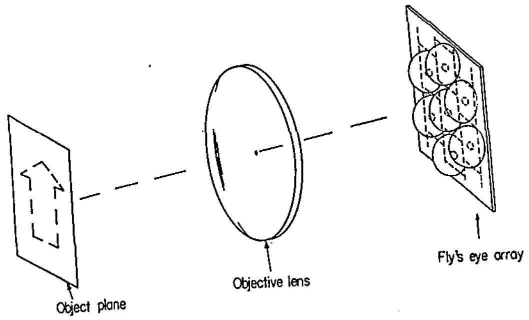

Fig.1 Fly's eye imaging array.

Method and Results.

Our analysis is based on the theory of Mie [3],[4], for scattering by dielectric spheres. In Mie's theory the fields are expanded as a sum of spherical modes, consisting of Ricatti-Bessel functions and associated Legendre functions. We extended Mie's theory to find the fields of a focussed beam as shown in **fig. 2**. A focussed beam may be assumed to be a part of a converging spherical beam which may be decomposed into a angular spectrum of plane monochromatic waves. Therefore by integrating the results of Mie's theory over this spectrum we get the fields of the focussed beam.

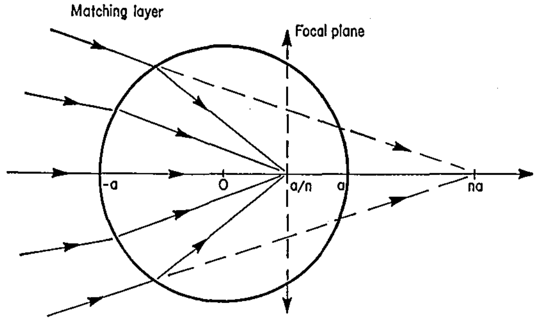

Fig.2 Focussing by spherical lens.

We also derived analytical expressions for the fields along the optical axis and in the focal plane from the diffraction integral [5]. The latter was a modification of the fields given by Zah [6], which are independent of the substrate lens size. In these calculations the lenses were assumed to be covered by anti-reflection coatings [7].

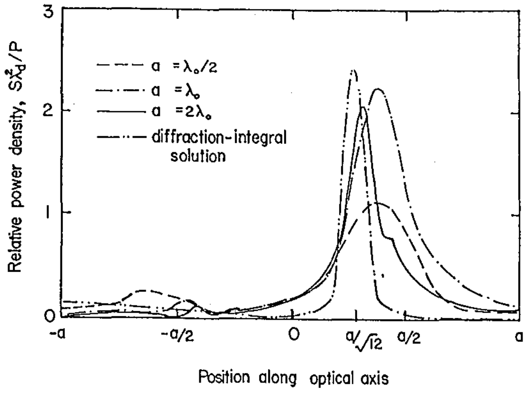

Fig.3 Relative power density vs the distance along the axis.

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Fig. 3 shows the relative power density plotted against the distance along the optical axis, for different sizes of lenses. The relative power density is defined as $S\lambda_d^2/P$, where **S** is the component of the Poynting vector along the optical axis, λ_d the wavelength in the dielectric and **P** the total incident power. The graphs show for a radius of $\lambda_0/2$ the maximum drops to 50% of the maximum for large radii. The graphs also show a broadening along the optical axis when the radius is decreased. These observations clearly indicate degradation in the focussing power of the substrate lens. The solution of the diffraction integral is also plotted in this graph.

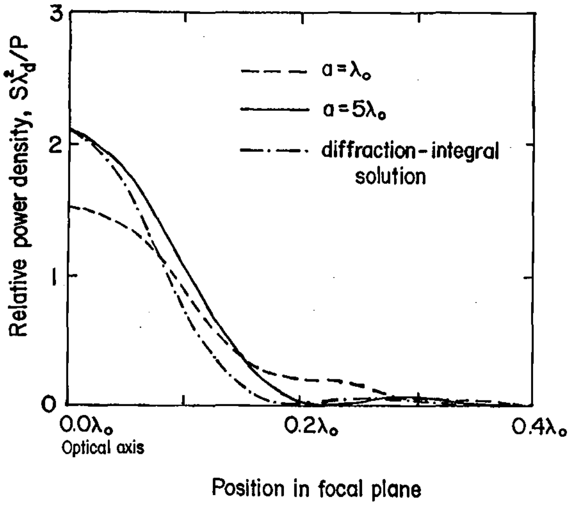

Fig.4 Relative power density vs distance in the focal plane.

Fig. 4 shows the relative power density in the geometrical focal plane. Also shown is the power density calculated by the diffraction integral. These plots are consistant with the correspondence of diffraction theory and electro-magnetic theory, for large radii. This graph also shows that smaller lenses have lower power density, but the width of their patterns in the focal plane, change very slightly.

Fig. 5 shows the maximum of the relative power density and its position plotted against the radius of the lens. In **fig. 5** (lower) it is interesting to note that the graph has a maximum. **Fig.5** (upper) we note that for large radii the position of the maximum tends towards the geometrical focal point.

Discussion.

The graphs indicate clearly that a dielectric sphere may be used for aplanatic imaging of a converging beam for radii down to one free-space wavelength. Below this radius the focussing power deteriorates rapidly as the sphere scatters most of the incident radiation.

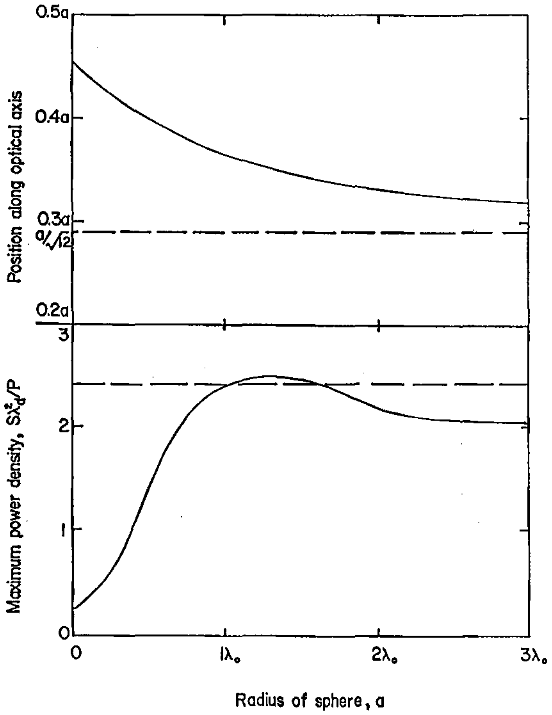

Fig.5 The maximum power density vs the radius of the lens (lower), and the position of the maximum vs the radius (upper).

Acknowledgements.

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