Vol. 46 No. 3 Journal of the Communications Research Laboratory November 1999
Printed in Tokyo, Japan pp. 309-310

LONG FOCAL DEPTH IMAGING OVER A LONG RANGE

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ABSTRACT

Imaging with long focal depth over a long range is achieved by using a simple galilean telescope with an eyepiece that has specified spherical aberration. Simulation and experimental imaging results using this technique are compared to those of the conventional technique.

1. Introduction

It has recently been reported [1] that a nearly nondiffracting light beam can be generated by launching it from a telescope with an eyepiece that has spherical aberration, which modifies the wavefront of the light beam emitted from the telescope into a shape similar to the conical wavefront of the well known nondiffracting Bessel beam.

When used for imaging, such a telescope has a long focal depth in the image domain, and a long field of view in the object domain. In this paper, simulation and experimental imaging results using this technique are reported for the case of a 5 cm telescope.

2. Principle and Simulation

For a telescope with an eyepiece that has specified spherical aberration, the outer regions of a converging wavefront leaving the telescope is modified into a conical shape. Hence, the wavefront will not converge to a single point, but will overlap over a linear region. When used for imaging purpose, the telescope has therefore a long focal depth.

The imaging performance of this new technique can be studied, and compared with that of the conventional technique by computer simulation. The propagation of the wave after leaving the telescope can be calculated by solving the Fresnel diffraction integral. The point spread function of the telescope system can be obtained by finding the intensity distribution when a parallel beam incident onto the telescope. Then by convolving the point spread function with the object function of the target, the images formed can be simulated. For a stark and simple target of three bars, which is the basic pattern that appears in the US Air Force resolution chart, of dimensions 12.5 mm x 2 mm, images formed are simulated for the telescope systems with an aperture of 5 cm, when the target is placed at various distances. For the system using the new technique, computer simulation results show, in Fig. 1, that resolved images are formed at distances from 60 m to 370 m. The blurring effect of the sidelobes of the point spread function can also be seen in Fig. 1. For the system using conventional technique, similar results, in Fig. 2, show that images can only be resolved from 250 m to 300 m. Here, we have used the Rayleigh criterion of 73.5 % intensity at the midpoint between the peak intensities of the images of the bars as the criterion of resolution. So, in this case, the conventional technique has a field depth of 50 m, whereas the new technique has a field depth of 310 m, which is about six times longer. Similar results are obtained when the conventional system is focused to other distances.

3. Experimental Results

Imaging with a 5 cm telescope has been carried out. Imaging results using this technique when a mesh target is placed at 300, 200, 100 and 60 m are shown in Fig 3. These images are better resolved over the whole range than similar results obtained with the conventional technique, as shown in Fig. 4.

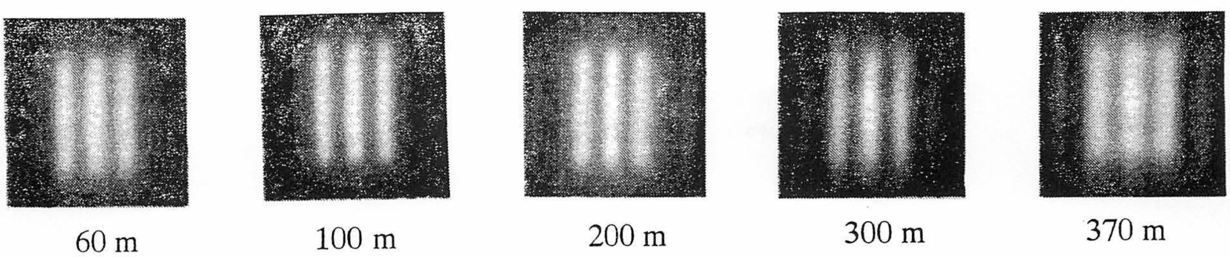
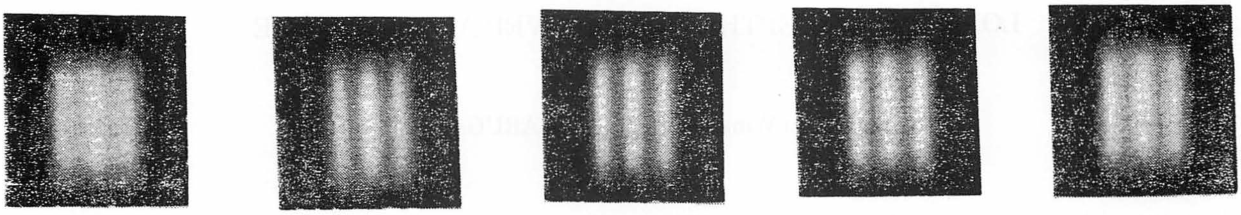
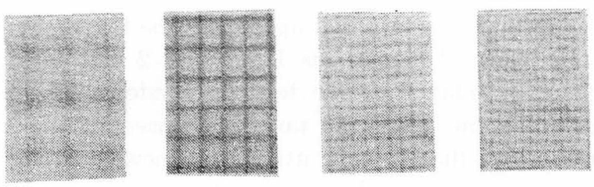


Fig. 1



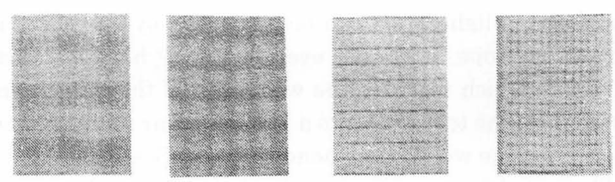
240 m 250 m 280 m 300 m 320 m

Fig. 2



60 m 100 m 200 m 300 m

Fig. 3



60 m 100 m 200 m 300 m

Fig. 4

4. Conclusion

Simulation and experimental results shows that, using this new technique, a Galilean type telescope with a 5 cm aperture can produce resolved images of a simple and stark object over a much longer distance than the conventional technique. High resolution imaging over a longer range can be obtained by using telescopes of larger aperture, e.g., a 10 cm telescope would extend the range to the km order.

Because of its large field or focal depth, a telescope system using this technique can perform high resolution imaging over a long range without focus adjustment.

References

1. T. Aruga, Appl. Opt. 36, 3762 (1997).

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