A NEAR-FIELD ALIGNMENT TECHNIQUE AT MILLIMETER AND SUB-MILLIMETER WAVELENGTHS

Ming-Tang Chen, C. Edward Tong*, D. Cosmo Papa*, and Raymond Blundell*

Institute of Astronomy and Astrophysics, Academia Sinica, Taipei, Taiwan 11529.
*Harvard-Smithsonian Center for Astrophysics,60 Garden St., Cambridge, MA 02138.

ABSTRACT

We have employed a portable near-field scanner operating at millimeter and sub-millimeter wavelengths to map the 2-D amplitude and phase patterns of a radio beam. Combined with a numerical transform, we have developed a novel alignment procedure to diagnose the alignment error in a complex receiving system. The optics of a multi-band, superconducting receiver has been aligned using this technique.

INTRODUCTION

At millimeter and sub-millimeter wavelengths, beam waveguides are often used to link transmitting or receiving modules to reflector antennas. Alignment of these beam waveguides is usually performed either by mechanical means or with laser beams. However, the presence of quasi-optical components, such as dielectric lenses, wire grid polarizers and beam splitters, that may be opaque or offer little reflection at visible wavelengths, present challenges to rigorous alignment of complex beam waveguides. In this paper, we demonstrate that a near-field measurement system can be used to verify and diagnose the alignment of millimeter and sub-millimeter systems *in situ*. In particular, we have developed a technique in which small scatterers are introduced into the beam as position markers. The positions of these scatterers relative to the center of the beam can be determined from the measured near-field data, thereby allowing us to infer whether the beam is well centered, displaced or tilted.

We have applied this novel radio-wave alignment technique in our laboratory to align the receiver optics associated with the 230 and 300 GHz superconducting receiver [1, 2] of the Sub-Millimeter Array (SMA), a radio interferometer of eight 6-m dishes currently under construction. The observation of celestial objects on the telescope confirms that the alignment these pre-aligned receiver modules are excellent. The following sections show the alignment procedures carried out in the 230 GHz channel.

MEASUREMENT RESULTS AND ALIGNMENT PROCEDURES

Figure 1 shows the raw data of an initial scan before the alignment. It can be seen that both the amplitude and the phase patterns do not peak at the origin, suggesting that the beam is both displaced and tilted. By processing the data numerically, we determine that the beam has been displaced by 6.5 mm and has a tilt of 1 degree to the optical axis.

In order to pinpoint the cause of the misalignment, we have introduced a pair of small absorbers into the beam at known locations. The absorbers used in our experiment are about 2 mm square. Two scans are then made: one with the absorbers and another without. The 2 sets of raw data are then subjected to a near-field transform [3] that yields the complex beam profile at the plane of the absorbers. By taking the difference of the amplitude profiles with and without the absorbers, we obtain an image of the 2 absorbers. Since the positions of the absorbers are known, we can infer the displacement of the beam in the plane of the scatterers.

Owing to the finite size of the absorbers and the difficulty in positioning them very accurately, we typically use 2 runs of a pair of absorbers positioned diametrically across the optical axis. Fig. 3 shows the resultant differential amplitude maps. Because of diffraction and the limited scan area, the size of the absorbers appears to be much bigger than their actual size. In addition, they are fairly weak compared to the main beam. The fact that they are well resolved shows that we have sufficiently high signal-to-noise ratio. The center of each absorber can be determined by locally fitting a quadratic amplitude profile to the differential map. A line joining the centers of the absorber pair can then be drawn. The intersection of the 2 center lines from the 2 runs gives the optical axis of the beam in the plane of the absorbers. Extensive measurements have been carried out using this method. We have found that we can determine the position of the center of the beam from the optical axis to an accuracy of

0.3 mm at a distance of 1.5 m from the near-field scan plane.

Using this approach, we have been able to adjust the optical components in our 230 GHz receiving system to line the radio beam to the designed optical axis. Fig. 4 shows the final beam pattern measured at the near-field scan plane after the alignment procedure. Comparing this measured vectorial beam pattern to the designed pattern we obtain a power coupling coefficient of 0.974, showing that good beam alignment has been obtained.

CONCLUSION

We have successfully used a near-field measurement system as an alignment tool for a beam waveguide system for 230 and 300 GHz receiver modules. This technique is useful in the alignment of complex beam waveguide system at millimeter and sub-millimeter wavelengths.

REFERENCES

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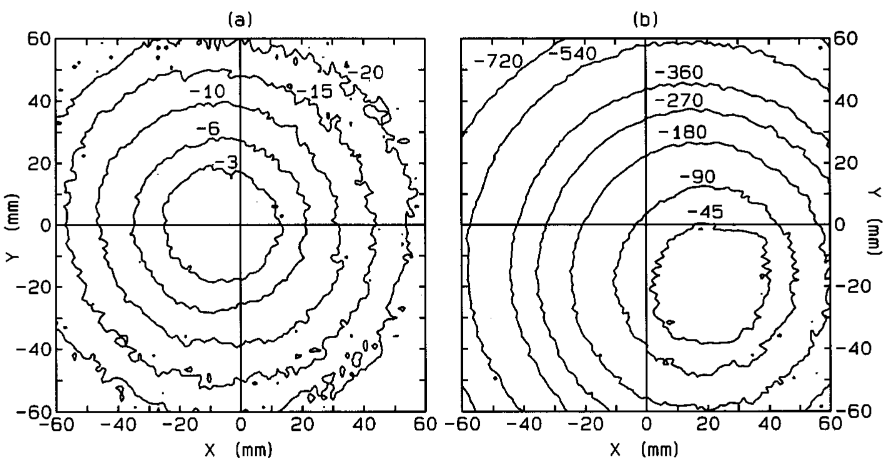

Figure 1 (a) Amplitude (in dB) and (b) phase (in degrees) contour plots of the initial near field scan data at the scan plane located at about 1.5 m from the cryostat window.

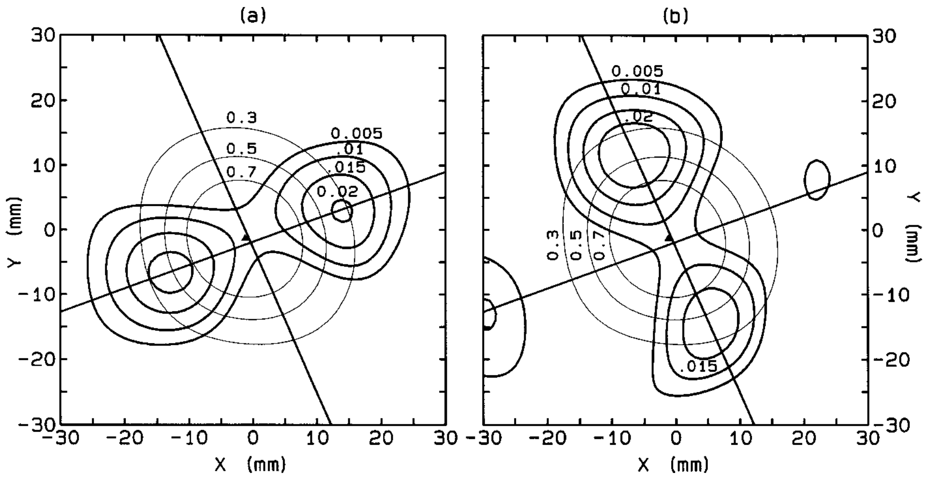

Figure 2 Differential linear amplitude maps showing a pair of small absorbers placed 1.5 m from the near-field scan plane. The amplitude pattern of the beam itself is shown in lighter contours and its center is marked by Δ. On each plot we also show the pair of straight lines joining the centers of the absorbers. The magnitudes of the contours are normalized to the peak amplitude of the beam.

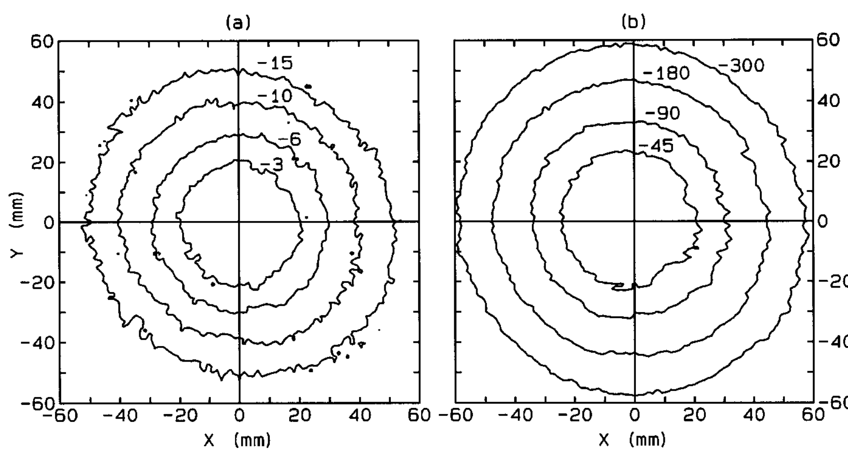

Figure (a) Amplitude (in dB) and (b) phase (in degrees) contour plots of the final near field scan data at the scan plane after the alignment procedure.