**Focus Measurement for the Fore-optics of CHAI**

1. **The optics**

The fore-optics of the CHAI receiver is used to converge the output beam of the SIS mixer and match the receiver beam to the required telescope illumination angular range. Since the pixel spacing is 10mm which is fixed by the mixer Mechanical design, the modification of the mixer beam changes the ratio of pixel spacing () and the reciver beam waist () that is related to the ratio of telescope beam spacing () on the sky to the beam angular size ().

A red pipe with brown and tan background

Description automatically generated with medium confidence

Figure 1. 3D model and Gaussian beam propagation of the Fore-optics of CHAI.

The fore-optics uses the Cassegrain layout (**Fig.1**), one ellipsoid reflector and a hyperboloid mirror, to individually convert 0.916mm beam waist of the mixer to 3.333mm for each pixel at 475GHz. If assuming the illumination edge taper is around 18dB**,**  and ,are respectively:

The schematic of the optics is shown in Fig. 2.

A diagram of a graph

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5

21.21

11.052

8.696

Figure 2. Schematic of the Fore-optics.

The uncertainty of the position of the beam waist of the mixer horn causes significant changes in the beam waist position of the optics, which may affect the telescope focusing and reduce the efficiency. Therefore, the beam waist position of the mixer horn must be measured experimentally.

1. **Method and 1:3 Scale-up Model.**

We scale up the fore-optics and mixer horn, making them three times larger than the original model, because the large model can provide a larger margin for tolerating the measurement errors. The operating wavelength is also scaled up to 1.89mm (158.333GHz). Fig. 3 is the optics of the scale model.

A graph of a line graph

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Figure 3. 1:3 scale-up model.

The position of the input beam waist can be derived from the best focus for a source located close to the optics. Fig. 4 illustrates the relationship between the beam peak power and the feedhorn position offsets, also depicts the variations of the best focus point with respect to different source-detector separations.

The best focus point for a given source-detector distance can be found by tuning the feedhorn position along the optical axis, until the maximum power is measured. The optimal mounting position of the horn for the CHAI receiver can be calculated numerically.

A graph with colored lines and numbers

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Figure 4. Best focus positions for the source at distances of 0.5, 0.75, 1.5, 2.5 and 1000 meters.

* **Approximate Parabolic relationship or A trigonometric function.**

Directly and precisely measuring the best focus point is virtually unattainable, with the horn offset of 0.5mm from the optimal position, the power of beam peak undergoes a mere 0.15% change.

* **Effect of the inaccuracy of feedhorn beam size**

The inaccuracy in the feedhorn beam size may also affect the measurement. Luckly, the simulations indicate that the beam size changes do not impact the beam focus measuring, see Fig. 5. We also can see that for a smaller input beam waist size the detected power converges faster with adjusting the feedhorn position.

A graph with colored lines and numbers

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Figure 5. The best focus point of the fore-optics with beam waist size of 2.2, 2.475, 2.75, 3.025 and 3.3 mm.

1. **Experimental Setup**

The mixer is replaced by a VDI source module. The output beam from the source together with the feedhorn is collimated through the fore-optics, see Fig.6. A pyroelectric detector is placed at 0.7, 1.0, 1.5, 2 and 2.5 meters away from the fore-optics and records the beam intensity. For short separation distance the

A close up of a machine

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Figure 6. Setup of the fore-optics best focus measurement.

1. **Tests**