Clover Polarimetric Detector - A Novel Design of an Ortho-Mode Transducer at 150 and 225 GHz

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Abstract- **This paper presents the design of an ortho-mode transducer (OMT) to separate two orthogonal linearly polarized signals traveling in a circular waveguide with frequency channels at 150/255 GHz band. Simulations (in HFSS) are presented to determine the optimal probe geometry and feed impedance to achieve good coupling to the optimized probes over a wide bandwidth with corresponding feed impedances for telescopes operating at 150 and 225 GHz. The results show that at 150 GHz band, the return loss can reach below -20 dB from 126 GHz to 180 GHz with the cross polarization reach below -40 dB. At 225 GHz band, the return loss can reach below -20 dB from 190 GHz to 260 GHz with the polarization isolation more than 32 dB.**

I. INTRODUCTION

The existence of primordial gravitational waves in the universe is a fundamental prediction of the inflationary cosmological paradigm, and determination of the level of this tensor contribution to primordial fluctuations is a uniquely powerful test of inflationary models. The project CLOVER is to measure this tensor contribution via its effect on the B-mode polarization of the Cosmic Microwave Background (CMB) down to a sensitivity limited by the foreground contamination due to lensing. This project comprises three independent telescopes operating at 97, 150 and 225 GHz.

OMTs have traditionally been adopted at lower frequencies and measurements of a scale-model OMT has been presented in [1] at 1-2 GHz. This paper presents a design of an OMT to separate two orthogonal linearly polarized signals traveling in a circular waveguide. The design concept compromises two key issues: The first is to design a four-probe OMT that can be integrated with a set of TES detectors, the waveguide needs to be split in order to get he OMT signals out to the detectors. The second issue is to design a planar structure that will couple well to the rectangular probes.

II. DESCRIPTION OF THE MODEL

The design concept has been illustrated in Fig. 1 showing four rectangular probes in a circular waveguide. The waveguide has a $\lambda/4$ backshort section behind the probes. The first design challenge is in order to insert the OMT probes and get the signals out to the TES detectors; a break is required in the waveguide which results in a loss of signal propagating out of the gap between the incoming waveguide and the backshort section. The waveguide has been split leaving a total gap of 20 µm between the upper waveguide and the lower waveguide. A thin 1 µm membrane which has a solid conducting ground plane starting from the edge of the waveguide wall and extending a distance of $\lambda/4$. The free standing membrane therefore is a circular window of radius 1.32 mm. The membrane is supported on its silicon frame which is not metallised. The change in impedance from the metallised membrane to the unmetallised membrane/silicon acts as an open circuit for the TEM modes propagating in the gap between the two waveguide sections. This causes modes that correspond to a wavelength λ (2 mm for 150 GHz channels) not to propagate out of the gap. The simulation in HFSS shows the good coupling to the probes and good performance of the system, as shown in Fig. 2. However, the choice of coupling line is limited by constraints on the dimensions of the lines due to the fabrication. A minimum line width of 2 µm was chosen for microstrip signal lines and the maximum thickness of the insulator used in the microstrip design has been limited to be 400 nm. This combined with the dielectric constant of the insulators (SiO_2) as well as the effects of the superconducting penetration depth means that the maximum microstrip line impedance is 27 Ω. Therefore we approached the full design: assume the probes represent ideal 50 Ω source impedance, a $\lambda/4$ section of microstrip with an impedance of 27 Ω to couple to an output microstrip line with an impedance of 25 Ω.

III. SIMULATION RSULTS

The simulations have been conducted to evaluate the performance of the designed models for a frequency range of 100-180 GHz for 150 GHz channels and 180-280 GHz for 225 GHz channels where the fabrication requires tight tolerances. Fig. 2 shows the simulation results for 150 GHz channels.

In the simulation, the input is single polarisation aligned

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with probe 1 and 3. It can be observed that the two traces of polarised pair probes overlapped perfectly at -3 dB each. The power is divided equally between them. The other two depolarised traces are below -42 dB through the band. The return loss is below -30 dB from 128 to 170 GHz. For 225 channels, the polarised probe 1 and 3 overlapped perfectly with the power divided equally into the two probes and the other depolarised pair probes are below -50 dB through the band. The return loss is below -30 dB from 187.5 to 252.5 GHz.

IV. OPTIMIZATION OF THE 4-PROBES PLANAR OMT

The design of the planar OMT needs to be modified to accommodate fabrication and mounting tolerances. First modification is to increasing the size of the gap between the input waveguide and the backshort flange from 20 µm to 60 µm to accommodate tolerancing of machining, silicon substrate thickness and mounting of the chip (glue thickness); the other main modification is to add an air gap between the silicon substrate and the metal backshort with a total of 65 µm to accommodate the differential thermal contraction of the silicon and the metal flange and overetching of the silicon during processing.

As a result of scaling the design with fixed manufacture criteria, a higher level of power leaking into the gap was introduced compared with the previous designs. This higher level of power also enhanced a resonant feature at the lower end of the band, for 150 GHz channels as example it is at around 130 GHz. The simulation result is shown in Fig. 3. To solve this problem, radial slots were cut in the input waveguide and backshort flange at 45 degree to the probes, this effectively increases the circumference of the ring resonator and moves the resonance to lower frequency. This also gives a lower in-band reflection than cutting the ground plane. It can be observed that the resonance has shifted from 130 GHz to lower frequency at 115 GHz.

V. CONCLUSION

Based on the simulation results from HFSS for both 150 and 225 GHz channels, the microstrip design is seen to yield good performance. The final model for 150 GHz channels has been iterated to test the performance loss due to fabrication and mounting errors and is seen to give acceptable performance over a 75% bandwidth with a return loss below -20 dB. The forward transmission coefficient for the depolarized opposite pair probes are below -50 dB through the band from 129 GHz to 174 GHz. The power leakage through the air gaps is below -28 dB through the band. The test of prototype devices is currently on going in Cambridge Cavendish Laboratory.

REFERENCES

Bock Douglas "Measurements of a scale-model ortho-mode transducer", *BIMA Memo 74*, 1999.

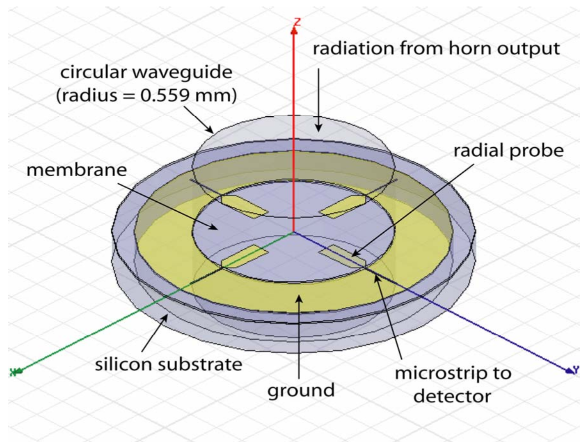

Fig. 1: 4-probes OMT in circular waveguide at 150/225 GHz

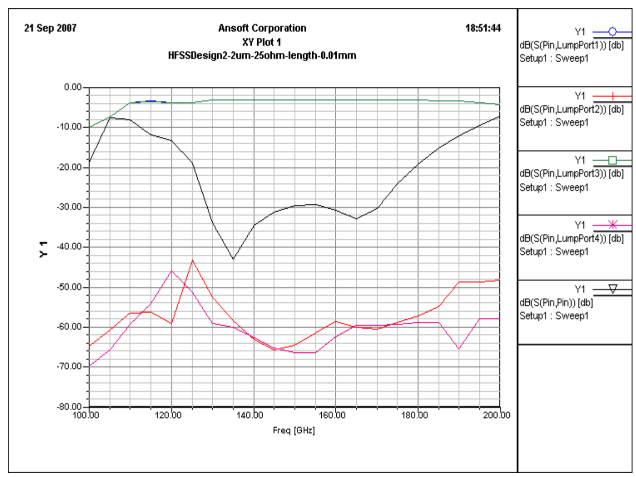

Fig. 2: S-parameters for 4-probes OMT for 150 GHz channels

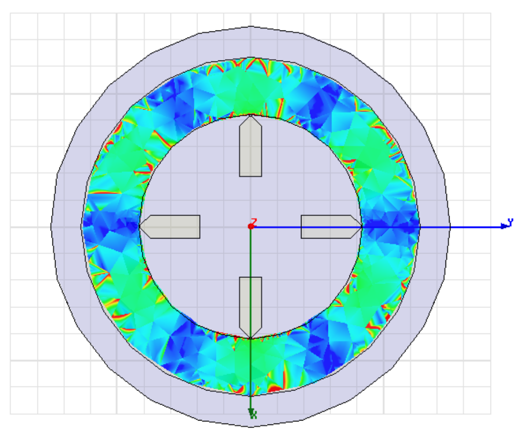

Fig. 3: Simulated field in backshort at 130 GHz (top view)

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