Microwave Characteristics of SiC as a Blackbody Source for Radiometric Calibration

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Abstract— **Design of pyramidal blackbody source in the desired frequency range of 60-90 GHz, using the CST Microwave studio is presented. Silicon Carbide (SiC) blackbody source is being developed for the radiometric calibration at Institute of Plasma Research. Parametric study of pyramidal blackbody source is accomplished by changing the various dimensions of the structure. The final design of the structure and its characteristic performance, deduced from the simulations, in the desired frequency band has been described.**

Keywords— **Blackbody, Calibration, CST Microwave Studio, Radiometer.**

I. INTRODUCTION

At millimetre and sub millimetre wavelengths high quality absorbing loads are typically fabricated for better absorption of the incident radiations. These are in general made from carbon loaded polyurethane foams that provide a very low return loss or ferrite base as per the application. These foam based absorbers have a variety of applications like calibration targets, within anechoic chambers or as absorbing apertures.The wave incident on these absorbers is attenuated because of the material of the absorber as well as the concept of multiple internal reflections. Between the cones or the grooves usually made in the absorbers, the wave undergoes multiple internal reflections and in every point of incidence with the absorbing material it gets absorbed or attenuated. A most common technique utilized for radiometer calibration is by using black bodies at two different temperatures i.e. a high temperature and a low (say LN2) temperature, to get a better signal to noise ratio. A black body is a perfect emitter or absorber of radiations. However, these absorbers can be operated at room temperature or can be cooled to liquid nitrogen temperatures but are unable to withstand high temperatures. Thus, arises the need to develop a black body source for radiometer calibration that can withstand high temperatures working in the microwave range.

We have designed and simulated a silicon carbide based black body source using CST microwave studio. This paper portrays the steps taken to design a black body source similar to a microwave absorber with excellent reflection coefficients at the desired microwave frequency. Further simulations are done to determine the performance of this source at still higher frequencies.The designed source will be further manufactured and utilized as a calibration target for the calibration of a 60-90 GHz radiometer system

II. DESIGN OF BLACKBODY

Blackbody refers to an object or system which absorbs the entire radiation incident upon it and re-radiates energy in the desired frequency range. The black body source described here, works in the millimetre and sub millimetre wavelength range. Since this black body source would be used as a high temperature calibration target for radiometric calibration the material chosen should have high thermal conductivity and stability at such high temperatures. Analysis shows that Silicon Carbide (SiC) is a good suite for such an application because of its outstanding thermal conductivity, low thermal expansion rate and good emissivity in the desired microwave region.

This paper provides design concept of pyramidal blackbody, similar to a microwave absorber, using CST Microwave studio software. The dimensions of the pyramidal structure are varied to obtain a better return loss.Fig.1.shows the basic design of a pyramidal microwave absorber.

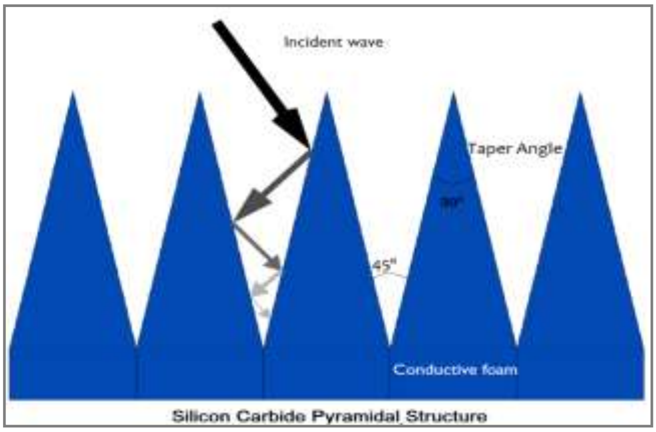

Fig: 1 Reflection in Pyramidal Structure

CST microwave studio is well known software for 3D electromagnetic simulations. It is based on the Finite Integration Technique (FIT) method of simulations. Using the CST microwave studio helps us to realize the EM propagation of the waves inside the designed structure.

Keeping in mind the basic pyramidal structure, we shall vary the integral dimensions of the pyramid for a better S_{11}.Firstly, the angle of the pyramid as well the base (length and breadth of the square base) of the pyramid is varied as shown in Table. I

TABLE I

RETURN LOSS FOR VARIED PYRAMID ANGLE AND BASE LENGTH

Pyramid Angle	Pyramid Base (mm)	Total length	S_{11}
20^0	10×10	100mm	±32dB
20^0	15×15	100mm	±37dB
20^0	20×20	100mm	±40dB
30^0	10×10	100mm	±35dB
30^0	15×15	100mm	±38dB
30^0	**20×20**	**100mm**	**±41dB**
40^0	10×10	100mm	±33dB
40^0	15×15	100mm	±36dB
40^0	20×20	100mm	±40dB

The analysis of the above parameters shows that a pyramid with 30⁰ cone angle and a square base of 20×20 mm dimensions gives reflectivity of 41dB.

Freezing the parameters of cone angle and square base we now vary the base length of the pyramid to determine its effect on the reflection coefficient. Fig.2a.and 2b.show the graphs of S_{11} obtained for the above simulation.

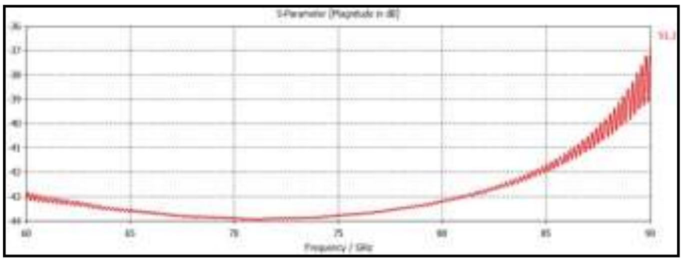

Fig: 2a. S_{11} parameter for 150 mm base length.

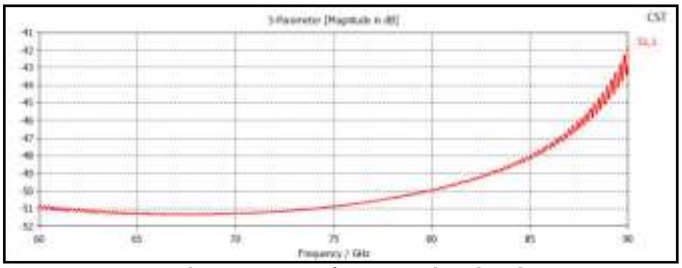

Fig: 2b. S_{11} parameter for 200 mm base length.

From the above figures one can realize that the base length has strong variations on the reflection coefficients of the designed structure. We now vary the height of the pyramids for a still better return loss with the best parameters of base length, shape and cone angle obtained till now. Table II. Shows the variations on S_{11} due to change in pyramid height.

TABLE: II

S_{11} FOR VARIED PYRAMID HEIGHT

Pyramid Angle	Pyramid Height	Pyramid Base	Total length	S_{11}
30^0	9mm	20×20	200mm	±39dB
30^0	11mm	20×20	200mm	±37dB
30^0	13mm	20×20	200mm	±44dB
30^0	**18mm**	**20×20**	**200mm**	**±52dB**

The above analysis of varying the various dimensions of the pyramid for best achieved S_{11} of +52 dB, deduces to a structure with dimensions as shown in table below. The figure also shows the defined structure.

TABLE: III

FINAL DIMENSIONS OF PYRAMIDAL BLACKBODY

Parameter	Dimension
Pyramidal height	18mm
Pyramidal Angle	30⁰
Pyramidal base length	20×20mm
Dimension of structure (4 Pyramid)	80×80mm
Total Length of structure	200mm

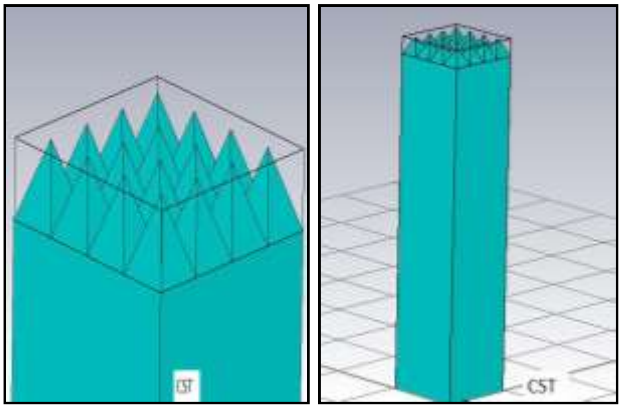

Fig.3.The front-top and side view of the designed absorber.

The above results obtained are for the frequency range of 60-90 GHz, which is the frequency range of the radiometer to be calibrated using this pyramidal silicon carbide base black body source. Similar simulations were performed for higher frequency range and it was observed that results for S_{11} even got better. Table.4 shows the return loss simulated for the similar pyramidal structure for a higher frequency range of 90-150GHz.

TABLE: IV

S_{11} RESULTS OF FREQUENCY 100 – 150 GHz

Pyramid Angle	Pyramid Height	Pyramid Base	Total length	S_{11}
20⁰	28mm	20×20	200mm	±49dB
30⁰	**18mm**	**20×20**	**200mm**	**±53dB**
40⁰	12mm	20×20	200mm	±51dB

Since the simulations were taking good enough time to simulate at high frequencies, we broke the simulations in varied frequency range as shown below in fig. 4, 5 and 6.

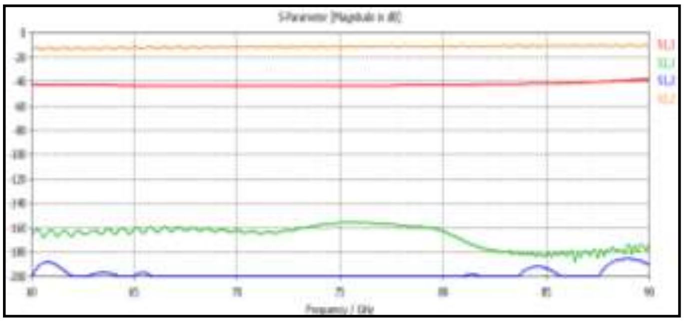

Fig: 4 S-parameters for Pyramidal structure (60-90GHz)

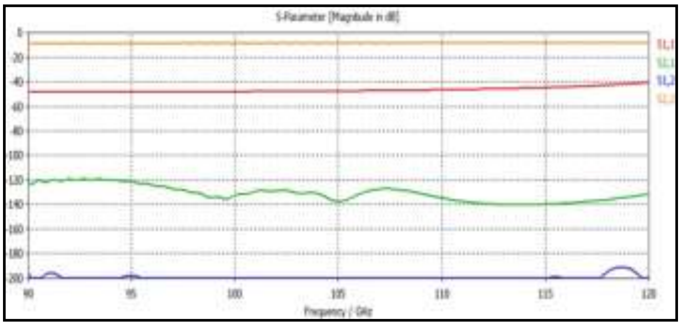

Fig: 5 S-parameters for Pyramidal structure (90-120GHz)

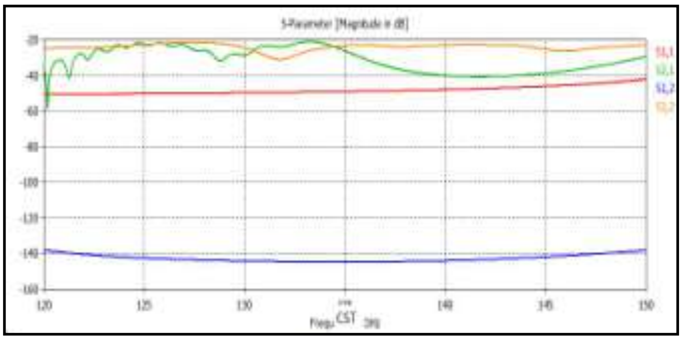

Fig: 6 S-parameters for Pyramidal structure (120-150GHz).

Also one can note that as the S_{12} parameters gets better with the wave getting attenuated as it passes through the thickness of the absorber the S_{21} drops significantly with frequency.

III. RESULTS

From the analysis of the silicon carbide pyramidal absorber in the desired frequency range of 60-90 GHz the desired s-parameters are achieved. Also, it can be seen that they get better with increase in frequency.

IV. CONCLUSIONS

The design of Pyramidal blackbody source using CST microwave studio software has been simulated successfully. The reflection coefficient so obtained is above 50 dB within the desired frequency range of 60-90GHz. It was observed that when we keep on increasing the length of the whole structure then the reflectivity also increases. Apart from this, increasing frequency range also increases the reflectivity of the blackbody source and thus can be used for radiometric calibration.

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