Transmission Simulation and Shielding Design of Microwave for EAST Bolometer diagnostic system

Yanmin Duan *, Zhengkun Hao, Liqun Hu, Songtao Mao

Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, Anhui , China

Abstract: The metal foil resistive bolometer signals are found to be interfered by low hybrid wave
in EAST experiment. The performance of microwave transmission and shielding are studied using the simulation software HFSS (High Frequency Structure Simulator). It is possible for microwave stray in the vacuum vessel to reach the sensors through the front collimating aperture which is bared without any shielding at present. Shielding properties of Circle holes with different diameter are compared for low hybrid wave at 2.45GHz and 4.6GHz. The result shows that a hole with diameter less than $\lambda/30$ can shield the microwave well to ensure the coupled E field bellow 4V/m near the sensor which is evaluated as the equivalent power of sensor background noise. The parameter of shielding metal mesh is chosen for EAST bolometer according the simulation results.

Key words: Metal foil resistive bolometer, microwave shielding, HFSS simulation

1. Introduction

The Experimental Advanced Superconducting Tokamak (EAST) is a fully superconducting tokamak with ITER-like divertor geometry. It can achieve both single null (SN) and double null (DN) diverter configurations [1-2]. The plasma facing components (PFC) have been improved to molybdenum (Mo) tiles for main chamber wall with upper tungsten divertor and lower graphite divertor [3]. The RF auxiliary heating system include three subsystems: LHW system at 2.45GHz and 4.6 GHz, ICRF system at 27MHz and ECRH system at 140GHz. The unabsorbed RF wave can be reflected multiply by the in-vessel components and then affected some diagnostic systems. The bolometer diagnostic is broad -band sensitive and easily experiences RF interference during LHW or ECRH heating [4-6].The microwave transition property is simulated and the shielding design are studied for EAST bolometer system in the article.

2. Bolometer diagnostics on EAST

Bolometer diagnostic is the basic diagnostic for nuclear fusion experiment, which has been used to determine the total radiated power and the radiation emission profile in magnetically confined plasma. The metal foil resistive bolometer system on EAST consists of 3 cameras with a total of 48 channels [7]. The middle camera with 32 channels views main plasma with a spatial resolution of ~4 cm and the two edge cameras, each with 8 channels, view the upper and lower divertor region separately with a spatial resolution of ~3cm, as shown in figure 1. The metal foil resistive bolometer choose Pt material as the absorbing foil and resistors. It has a wide spectral response from infrared to soft X-ray with the advantage of independence on photon energy. Additionally, it is also sensitive to neutral particles, as well as microwave. The bolometer sensors are fixed in an enclosed shielding box with three bared collimating aperture of 3×10 mm, which is installed in the adjacent diagnostic port of LHW antenna, as shows in figure 2. So it is important to shield the microwave interference for the bolometer measurement system.

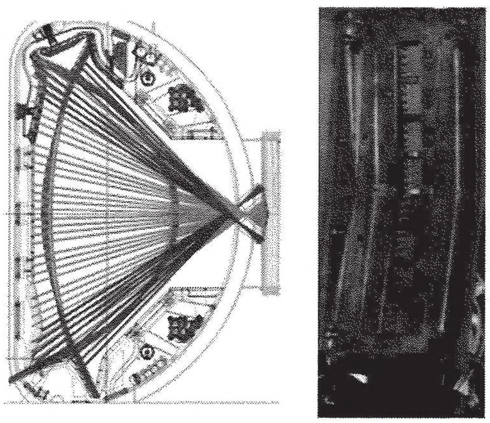

Fig.1 viewing chords geometry of resistive bolometer on EAST

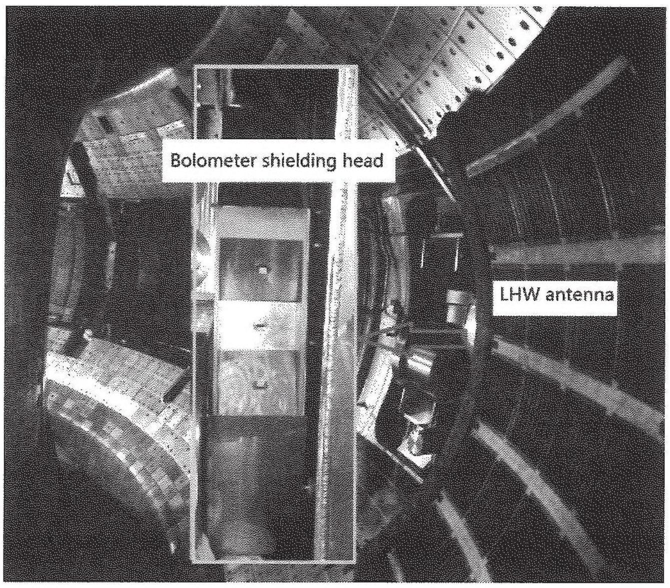

Fig. 2 Enclosed bolometer shielding box with bared collimating apertures

The metal foil bolometer signals are found to be interfered by low hybrid wave at 2.45GHz and 4.6GHz in 2014 EAST experiment. The interfered signals of bolometer have the same trend as LHW reflected waveform sometimes or have a very high voltage. It is confirmed by testing that microwave stray in the vacuum vessel can reach the bolometer detector through the front apertures, and then are absorbed by metal foil bolometer detector.

3. Transmission simulation and shielding design

The dynamic range of bolometer output voltage ranges from 0.01V to 10V. Here, the background noise of the system is 0.01V at the normal gain 1000. The equivalent power of background noise absorbed by detector is evaluated and then the coupled microwave E field through aperture can be deduced on the assumption that the signals completely come from the interfered wave. The lower limit of coupled E fielding through aperture is about 4V/m. So, the shielding design to ensure the E fielding below 4V/m is necessary and effective.

The simplified model of bolometer sensors shielding box in the vacuum vessel is built in the software platform HFSS (high frequency structural simulator). The real size of bolometer shielding head are reconstructed and a larger square chamber is built as the vacuum, as shown in figure 3. The microwave with 100kW power are injected from a front port. The vacuum is large enough to reflect the injected wave multiply in order to achieve isotropic polarization. The properties of microwave transmission and shielding through apertures with different size are simulated. The result show that the coupled E filed near the bolometer sensors increase with the aperture size whether the aperture position is in front side or in the reverse side. Instead of the shielding size of $\lambda/4$, the result shows that a hole with $\lambda/30$ can shield the stray microwave effectively with a low E field bellow 4V/m inside the sensor shielding box. The simulation result is given in figure 4. It is verified that the present bared aperture of 3×10mm cannot shield the microwave at 2.45GHz and the metal mesh in front of the aperture is necessary.

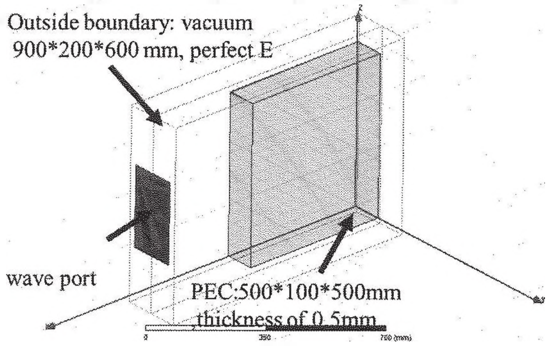

Fig.3 The simplified model of bolometer sensors shielding box

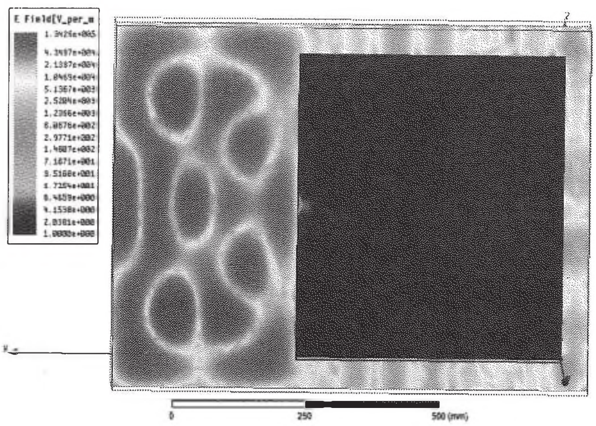

Fig. 4 The coupled E filed distribution in the vacuum and bolometer shielding box with hole of $\lambda/30$

Research found that metal shielding meshes can shield the microwave efficiently with well-designed parameters [6]. The spacing g and the wire diameter d of mesh grid are two critical parameters. According the long wave transmission theory formulas in reference [6], microwave transmissions fraction as function of mesh grid parameters g/λ and g/d are showed in figure 5. It shows that the microwave transition fraction increases with g/d and g/λ. However, the balance between the screening efficiency and the photon transmission is also important. The best parameter g/d~3 perform good shielding and moderate photon transmission with maximum ratio of photon transmission fraction to microwave transmission fraction. The simulation result shows that the E field near bolometer sensors through mesh grid with g/λ~3 /80 and g/d~3 is about 0.5V/m, as shown in figure 6.

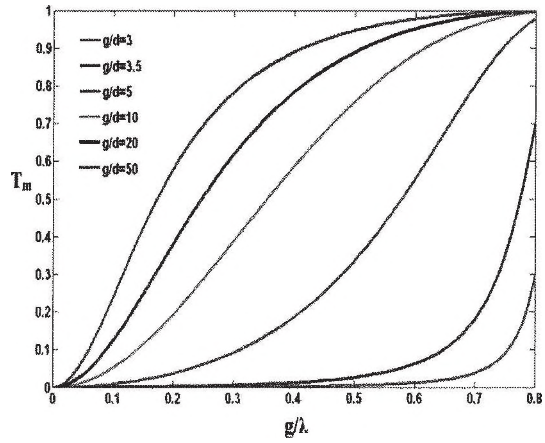

Fig. 5 Microwave transmissions at 2.45GHz as function of mesh grid parameter

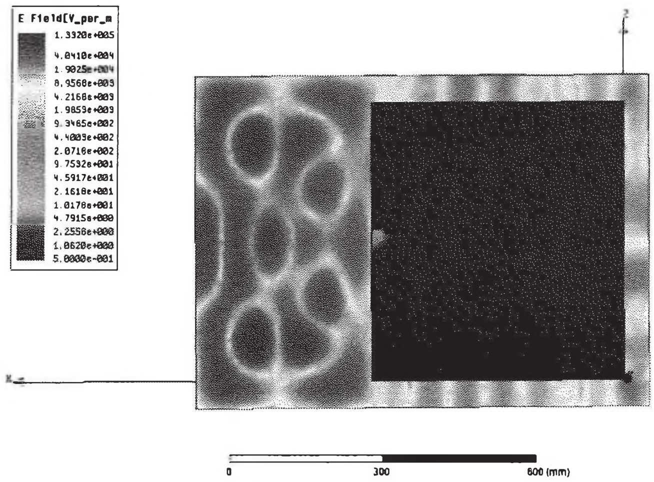

Fig. 6 The coupled E filed distribution in the vacuum and bolometer shielding box with mesh grid parameter g/λ~3 /80 and g/d~3

4 Summary

The properties of microwave transmission and shielding through bolometer front apertures with different size are simulated based on the HFSS software platform. The mesh grid in front of aperture for microwave shielding are analyzed. The spacing g and the wire diameter d of mesh grid are two critical parameter. Good shielding performance can be achieved in the condition of g/λ~**3** /80 and g/d~3 for EAST low hybrid wave at 2.45GHz. In consider of the 140GHz and 4.6GHz LHCD in the next round of EAST experiment, the metal mesh with spacing g~0.635mm and wire diameter d~0.15 are installed in front of the collimating aperture. The optical transmission fraction is 60%.

Acknowledgments

This work was partly supported by the JSPS-NRF-NSFC A3 Foresight Program in the fieldof Plasma Physics (NSFC No.11261140328)

References

[1]Y. Wan, et al, Nucl. Fusion, 40(2000)1057.

[2] B.Wan, et al., Nucl. Fusion **53** (2013) 104006.

[3] Y. T. Song, et al., IEEE Transactions on Plasma Science, 42(2014) 415.

[4] A. Huber, et al., Fusion Engineering and Design 82 (2007) 1327.

[5] D. Hathiramani,et al., Fusion Engineering and Design 88 (2013) 1232.

[6] D.Zhang,et al, 38th EPS Conference on Plasma Physics (2011) P5.056.

[7] Y.M.Duan, et al., Rev. Sci. Instrum. **83** (2012) 093501.