INVESTIGATION OF EMBEDDING IMPEDANCE CHARACTERISTIC FOR A 660-GHZ WAVEGUIDE SIS MIXER

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Abstract With the help of an electromagnetic field simulator(i. e. , HFSS) and a lumped-gap source method similar to the quasi-optical antennas, the embedding impedance of a 660-GHz waveguide SIS (Superconductor-Insulator-Superconductor) mixer was thoroughly investigated from 600 to 720GHz. The effects of the junction's feed-point displacement(including horizontal and vertical offsets), chip thickness and backshort length were analyzed and calculated. The results indicate that the simulated embedding impedance of the mixer is around 35Ω over the working frequency range, which can match the SIS junction in a large bandwidth. The feed point location of the SIS chip has little effect on the embedding impedance, while the chip thickness obviously does. These results will benefit the development of waveguide SIS mixers.

Key words embedding impedance, SIS mixer, sub-millimeter, lumped gap source.

660-GHz 频段波导型 SIS 混频器嵌入阻抗的特性研究

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摘要 基于三维电磁场仿真软件 HFSS 和类似于准光学天线的集总源法,对一 660GHz 超导混频器的嵌入阻抗在整个600-720GHz 的工作频带范围内进行了详细的分析研究.同时,还系统地分析计算了 SIS 结芯片的馈点偏移(包括水平偏移和垂直偏移)及芯片厚度和背向短路器长度变化所产生的影响.分析结果表明,该混频器的嵌入阻抗为35Ω 左右,而且在整个工作频带内变化缓慢,能够实现宽频带匹配. SIS 结芯片馈点的位置对嵌入阻抗没有太大的影响,但芯片厚度的影响非常明显.这些结果对超导 SIS 混频器的研制有很好的指导意义.

关键词 嵌入阻抗,SIS 混频器,亚毫米波,集总源.

Introduction

It is quite common that developed SIS (superconductor-insulator-superconductor) mixers of the fixed-tuned type, which are very beneficial to practical applications (e. g. ,radio astronomical interferometers), can't measure a performance as good as the theoretically simulated one, especially at sub-millimeter wavelengths. Inaccurate embedding impedance of the mixer (i. e. ,the mixer impedance seen by the SIS junction) might be accounted for one major reason for this difference. Hence, it is important to have a reliable method in characterizing the embedding impedance of SIS mixers. In addition, it is necessary to understand how the embedding impedance of SIS mixers is influenced by the mixer's structural parameters as a fabricated SIS mixer(including the mixer mount and the SIS junction chip) often differs slightly with its simulated model.

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With the help of an electromagnetic field simulator (i. e., HFSS)[1], here we thoroughly investigate the embedding impedance of a 660-GHz waveguide SIS mixer (refer to Fig. 1)[2], which is being developed jointly with the ASIAA group in Taiwan for the SMA (Sub-Millimeter Array) project. A lumped-gap-source port method, which takes the junction's feed point as a lumped gap source port, was adopted for simulation.

It is well known that for sub-millimeter waveguide SIS mixers, it is difficult to precisely align the feed point of the SIS junction chip in waveguide and the thickness of a lapped SIS junction chip might differ from the designed one. The reactance of the embedding impedance for an SIS mixer is believed to be dependent upon the mixer's backshort length. It is therefore of particular interest to study the effects of the junction's feed-point displacement, the chip thickness and the backshort length on the embedding impedance of the simulated SIS mixer.

1 Simulation Method

Concerning the structure at the junction's feed point (refer to Fig. 2) of the 660-GHz waveguide SIS mixer, it is not suitable to settle a convertion port such as waveguide and microstrip ports there, which can be easily treated by the HFSS simulator. To calculate the mixer's embedding impedance (i. e., the impedance seen at the feed point), we practically treated the feed point as a lumped-gap-source port, which is rather similar to the case of quasi-optical antennas, as the width and gap distance of the feed point are both much smaller than the working wavelength. Here the source port width was taken as the width of the thin-film impedance transformer (refer to Fig. 2) that is directly connected to the feed point as we think most electromagnetic field is concentrated on there, while the source port height was taken as the gap distance. The structural parameters of the mixer mount simply followed its original design[3], and the dielectric constant of the junction chip substrate (quartz) was assumed to be 4.45[4]. The complex reflection coefficient Γ at the feed point for source impedance Z_0, which can be specified arbitrarily, is calculated by HFSS. Thus, the feed point impedance is $Z_0 * (1+\Gamma)/(1-\Gamma)$.

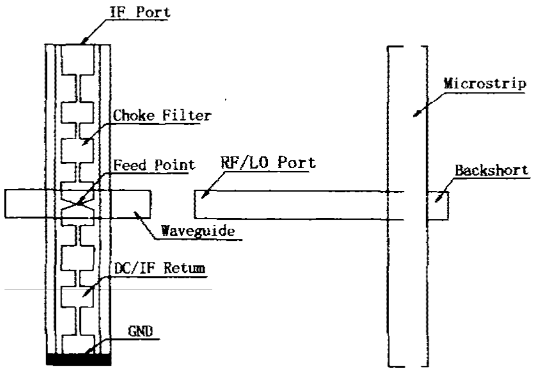

Fig. 1 Geometry of a 600-720GHz SIS mixer mount
图 1 600-720GHz SIS 混频器的结构

2 Simulation Results

With the help of the HFSS simulator, the embedding impedance of the 660-GHz waveguide SIS mixer including its two choke filters on the IF and ground sides was simulated by assuming the feed point (10.56 μm × 2.0μm, ≪ λ @ 660GHz) as a Lumped-gap-source port. The waveguide and IF ports were the other two ports for simulation. To understand the dependence of the embedding impedance on the size of the lumped-gap-source port, the embedding impedance was firstly calculated at 660GHz for different source port widths with its height fixed as 2.0μm. Obviously, the feed point impedance varies with the width of the lumped-gap-source port, as shown in Fig. 3. The fact is that the lumped-gap-source port has uniformly distributed field. We suggest that its width should be taken as that of the impedance transformer (3.8μm) connected between the feed point and the junction tuning circuit.

The embedding impedance of the 660-GHz waveguide SIS mixer was then calculated for a lumped-

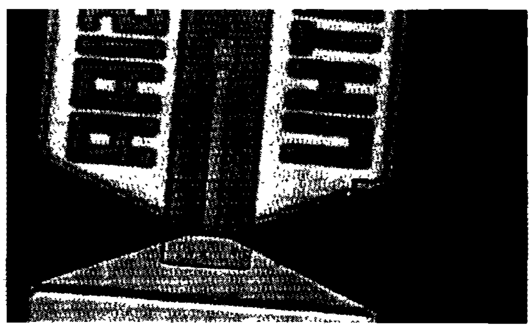

Fig. 2 Photograph of an actual SIS junction chip (part) for the 600-720 GHz SIS mixer
图 2 600-720 GHz SIS 混频器结芯片的照片

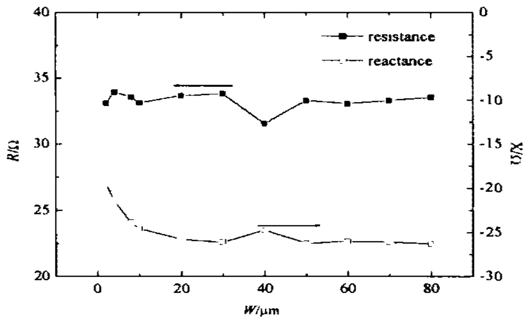

Fig. 3　Embedding impedance at 600GHz *vs* feed point width

图 3　嵌入阻抗与馈点宽度的关系(600GHz)

gap-source port measuring 3. 8μm x 2. 0μm for different frequencies. As plotted in Fig. 4, the calculated resistance is well close to 35Ω, while the reactance is around-30Ω.

By changing the position of the feed point in waveguide in both horizontal and vertical directions, we investigated the effect of the feed-point position on the mixer's embedding impedance. It is noticed that the two choke filters shift correspondingly, but not other structures of the mixer. It is just the model of the situation when the junction chip is aligned in the mixer mount. The simulated results are demonstrated in Fig. 5 for different horizontal and vertical shifts of the feed point. It is clear that the variation of the mixer's embedding impedance is not considerable for the feed point position displacement.

We also calculated the mixer's embedding impedance for different substrate thicknesses of the junction chip. As exhibited in Fig. 6, the embedding impedance change is rather evident when the quartz substrate thickness is reduced down to 30μm from 40μm.

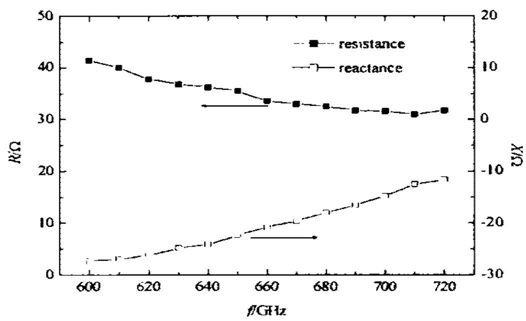

Fig. 4　Embedding impedance as a function of frequency

图 4　嵌入阻抗与频率的关系

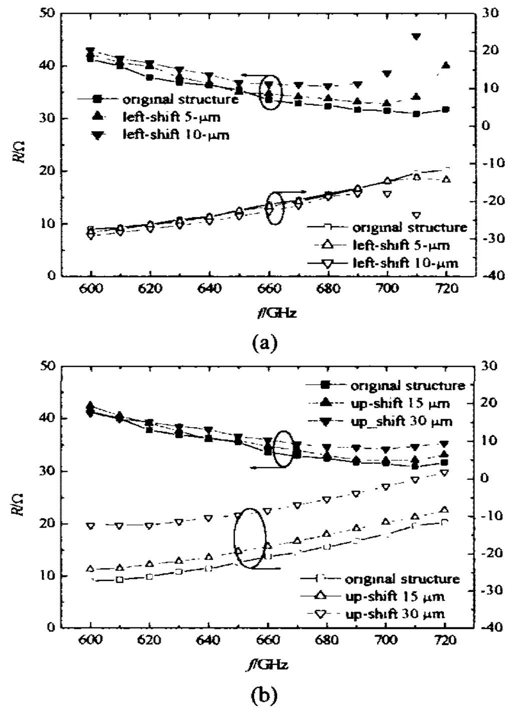

Fig. 5　Embedding impedance simulated for different feed point displacements
(a) horizontal offset　(b) vertical offset

图 5　不同馈点偏移的嵌入阻抗
(a)水平偏移(b)垂直偏移

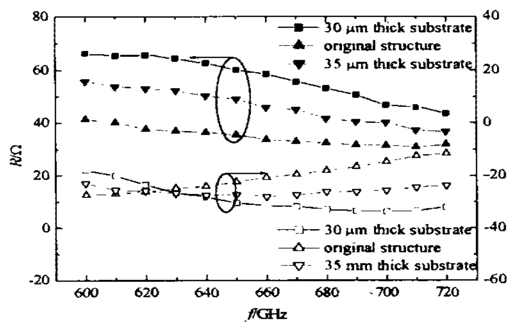

Fig. 6　Embedding impedance simulated for different junction chip thicknesses

图 6　嵌入阻抗随结基片厚度的变化

Finally, the embedding impedance of the SIS mixer was calculated for different backshort lengths , which is the distance from junction chip to the bottom of waveguide. The results are plotted in Fig. 7. It is clear that the mixer's backshort length does affect the reactance of the mixer's embedding impedance, but not as significantly as expected. By contrast, the resistance is more dependent upon the backshort length. It appears that by means of adjusting the backshort

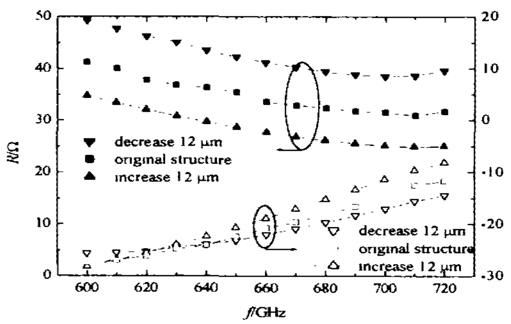

Fig. 7 Embedding impedance simulated for different backshort lengths
图 7 嵌入阻抗与反向短路器长度的关系

length, we may not change the frequency response of the mixer's embedding impedance to some extent.

3 Summary

The embedding impedance of a 660-GHz waveguide SIS mixer has been numerically studied with a lumped-gap-source method. It has also been found that the mixer's embedding impedance is not affected considerably by the junction chip displacement, but by the substrate thickness of the junction chip and back-short length. The results presented here are of good use for the development of waveguide SIS mixers.

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References

[1] Getting Started: *An Anternna Problem*. Pittsburgh: Ansoft Corporation, 1999, 3 — 4

[2] Shi S C, Chin C C, Wang M J, *et al.* Development of a 670-GHz SIS mixer for SMART. In: *Proc.* 12th *Int. Symp. On Space THz Tech.*, San Diego, CA, Feb. 2001, 215 — 222

[3] Blundell R, Tong C E, Barrett J W, *et al.* A fixed-tuned low noise SIS receiver for the 600GHz frequency band. In: *Proc.* 6th *Int. Symp. On Space THz Tech.*, Pasadena, CA, Mar. 1995, 295 — 304

[4] Goldsmith Paul F. Quasioptical systems. New York: *IEEE press*, 1997, 82 — 83