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HIGH-STABILITY CONNECTION METHOD FOR THE INNER CONDUCTOR OF HIGH-POWER VACUUM COAXIAL RESONATOR

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Abstract—This paper presents a stable grounding technique for the inner conductor of a coaxial resonator in vacuum and high-power condition applications, where the inner and outer conductors of the coaxial resonator are connected by a flange plate. When this novel technique is applied, the stable and unified microwave grounding ability is increased by making the stress on the contact surface uniform, the reliability of space products is improved by reducing the deformation of the rod-end at a transverse vibration load of 10 g by 75%, and the unstable tiny cracks of the high-power component are fully eliminated.

1. INTRODUCTION

With continuous development in communication technology, the capability of satellite platforms and power availability of satellite payloads have been significantly improved. The passive components of a coaxial resonator suitable at low frequencies are widely utilized because of the increasing use of vacuum high-power components. High-power passive components should be designed to meet the desired electrical property, and the potential troubles caused by heat dissipation, electromagnetic leakage, and passive intermodulation (PIM) during high-power transmission should be considered in the design process. Multipactor in the vacuum has been considered for high-power components. All the above-mentioned considerations can

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be reflected in the structural design of specific components to lower potential risks [1–6].

In an electromagnetic simulation software, all connected metal surfaces are in the same potential or are connected to the same ground as shown in Figure 1(a). In the actual research, however, a metal with the same potential should be designed for the corresponding connection. The connection effect can directly determine if a high power will cause problems or affect the electrical property of the material.

The coaxial cavity is composed of three metals applied in the project, where an integrated-metal structure can only be achieved through the corresponding connections, as shown in Figure 1(b). Connection 1 in Figure 1(b) is between the top plate and the outer conductor, where a screw is usually fastened for connection. The relative thin plate for cover should be selected properly, and a desirable metal connection can be achieved based on its own flexibility and on an appropriate pressing force of a pan head screw. The gap between the top plate and the resonant pole is caused by the strong electric field of the coaxial resonator, where the connection defect has very little influence on the resonator property and can be easily discovered and adjusted during low-signal test. After regulation, the risk of negative effect during a high-power condition is low. Therefore, the connection between the top plate and the cavity is efficiently solved and will not be further discussed in this paper.

The connection of the resonant pole and the cavity is located in the strongest magnetic field in the coaxial resonator, as shown in Figure 1(b). The connection defect can lead to large electromagnetic leakage, and PIM can be generated at high-power working conditions. An undesirable connection status could affect the vacuum power capacity and decrease the threshold value of the multipactor.

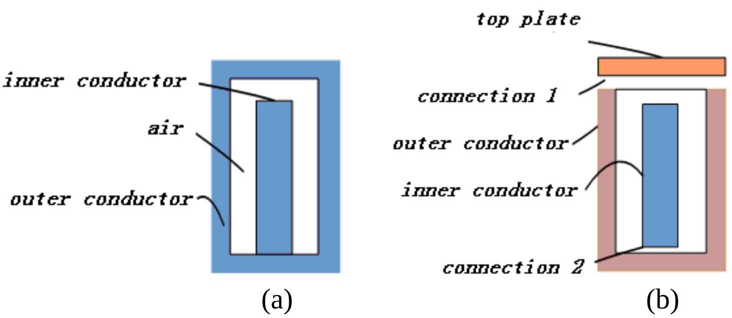

Figure 1. Connection status sketch of coaxial resonator.

Meanwhile, the installation situation of the resonant pole in the cavity could affect the performance of the coaxial resonator. First, the installation should not be vertical to the ground so that the resonator frequency and the multipactor threshold value are not affected. Second, the high-power component has a strict EMC requirement. Each joint should be electromagnetically protected to minimize electromagnetic leakage, and a conductive adhesive is generally used to strengthen the metal connection. When a conductive adhesive coating is applied at Connection 2, the volatilized gas from the conductive adhesive penetrates the thread gap of the resonance pole base into the resonator cavity. This penetration may lead to potential secondary pollution, which may lower the multipactor threshold value of the product. The aforementioned adverse effects could hardly be detected in low-power tests and could only be discovered at a loading power condition in a vacuum. The discovered defect could hardly be improved using the current treatment, and this problem needs to be solved properly in future research. Therefore, the proper connection method to connect the resonant pole and the cavity in the design phase is the key issue in designing a vacuum-powered coaxial resonator.

An inner-conductor grounding method suitable for a vacuum-powered coaxial resonator is proposed in this paper. The proposed method can create a stable and reliable contact for the resonant pole and the cavity metal by using a flange connection between the inner conductor (resonant pole) and the cavity shell in the coaxial resonator. Moreover, the proposed method can reduce the occurrence of connection defects and can avoid electromagnetic leakage and PIM at high-power working conditions. In case where a connection defect occurs, the stable connection defect can be easily treated and recovered. The flange connection can also improve the bearing capacity of connection fittings. If the resonant pole is oversized and overweight, a properly sized flange can facilitate a good connection.

2. TYPICAL CONNECTION METHOD FOR THE INNER CONDUCTOR OF A COAXIAL RESONATOR

2.1. Typical Methods Used for the Mechanical Connection of the Inner Conductor

A screw is generally used to connect the inner conductor and the cavity in the coaxial resonator. As shown in Figure 2(a), a single screw penetrates through the unthreaded hole at the cavity bottom, with complete occlusion with the internal thread of the inner conductor. A screw is used to form a metal connection between the cavity and the inner conductor and to enclose the coaxial cavity.

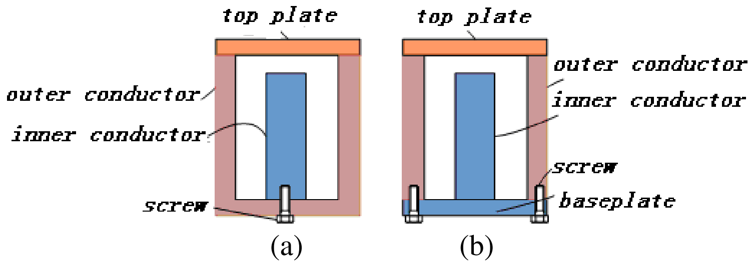

Figure 2. Typical inner conductor connection sketch of a coaxial resonator.

This method is simple, convenient, and feasible; thus, it is the most common method applied. However, if the coaxial resonator is required to work continuously for ten years at a high-loading power, the connection between the inner conductor and the cavity needs to be more reliable and stable. In this situation, this method may cause hidden problems to arise. First, if the bottom of the inner conductor or the cavity has roughness defects, complete contact between the two surfaces may not be achieved using only a single screw. Contact with stress leads to electromagnetic leakage and PIM generation at high-power working conditions. Second, the vertical degree of the inner conductor in the cavity could be achieved by a reasonable distribution of factors, which include the flatness of the inner conductor and the cavity as well as the vertical degree of the inner thread of the inner conductor. When the product quantity reaches a particular amount, the incompatibility chances of these parameters may be significant. The parameter deviation could cause the inner conductor in the cavity to be inclined, which can change the key size of the designed multipactor threshold value, i.e., the space between the inner conductor and the cavity. Consequently, the actual multipactor threshold value may decrease. Third, if the electromagnetic leakage of the inner conductor is not prevented, secondary pollution may exist on the coaxial cavity through the gap and may lower the multipactor threshold value. Last, if the inner conductor is relatively long or heavy and if the fastening ability of a single screw is undesirable, the inner conductor needs to be redesigned.

Figure 2(b) shows an inner conductor connection method that is suitable for a coaxial resonator at high-power working conditions. The inner conductor and the baseplate of the filter were fabricated as a single unit, and a screw was used to fasten and connect the baseplate and the cavity. The inner conductor and the baseplate have different components of the same metal, and they do not have any connection defects. The baseplate and the cavity were connected by rows of screws for easy adjustment, thereby preventing and reducing connection defects. Through this method, hidden problems during contact caused by a single screw connection can be avoided. However, the fabrication cost is high when all the inner conductors are formed in the same baseplate. Moreover, the method also has a high technical demand on fabrication and assembly accuracy. The baseplate thickness is typically ten times than that of the inner conductor, which results in deformation during fabrication, inclination of the inner conductor in the cavity, or connection defect at the screw joint.

2.2. Welding Connection for the Inner Conductor of a Coaxial Resonator

Welding is a common technology used in metal connection. In the coaxial resonator, braze welding can be performed to connect the screw in all areas in Figure 2. A soft solder is indispensable during welding. However, welding could cause potential problems to arise in the coaxial cavity at high-power working conditions. The residual volatile gas of the soft solder residue is a critical threat to the attached gas in the vacuum and could produce low-pressure discharge. The threshold value of the low-pressure discharge is significantly lower than that of the multipactor. The internal surface of the components would be greatly damaged after discharge, which would significantly decrease component performance. Different metal elements exist in the solder, and these remain in the connection after the welding is completed. This condition is a potential risk to the PIM generated at high-power working conditions. Therefore, welding connection should be avoided in the coaxial cavity at high-power vacuum conditions.

2.3. Flange Connection Method for the Inner Conductor of a Coaxial Resonator

A flange plate connection is proposed in this paper to connect the coaxial inner conductor and the base-plate and to solve the abovementioned deficiencies and hidden problems. Figure 3 shows the sketch of the inner conductor with a flange plate. Figure 4 presents the installation sketch. The detailed methods are as follows: 1) the inner conductor with a flange plate was designed, where the height of the inner conductor is equal to the total value of the inner conductor thickness in the resonant cavity and that in the base-plate. 2) The round hole diameter at the central location of each cavity bottom is slightly larger than that of the inner conductor, around which four

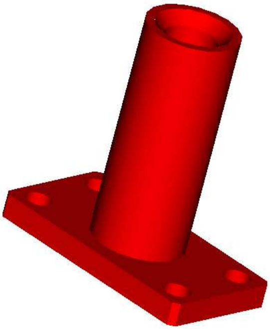

Figure 3. Inner conductor with flange plate.

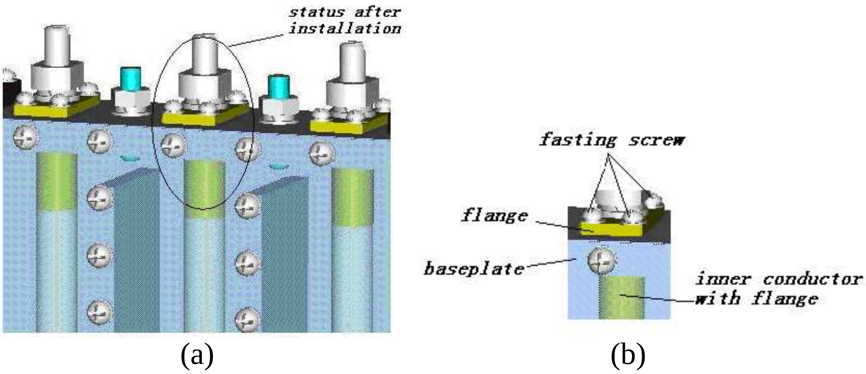

Figure 4. (a) Sketch for flange connection and installation; (b) Connection status sketch of the installation detail.

threaded holes are created at the center of the flange for fastening. 3) The inner conductor with a flange plate penetrates the round holes, with a flange connection outside the baseplate. After installation, the flange is located at the outside of the baseplate.

The use of a flange plate to connect the resonant pole and the resonant cavity yields the following advantages: 1) the flange connection between the inner conductor and the baseplate has numerous contacts and tight connection, which could guarantee a stable connection, reduce electromagnetic leakage, and avoid unstable electrical properties caused by inappropriate connection. 2) The baseplate opening diameter is larger than that of the inner conductor. The vertical degree of the inner conductor in the cavity is only related to the vertical degree of the flange and the inner conductor as well as to the flatness of the baseplate outer surface, and has little relation to the assembly condition. Therefore, the risk of inclination is insignificant. The stable vertical position of the inner conductor in the cavity is used as the basis to guarantee that the actual threshold value is consistent with the designed threshold value. 3) Given the flange of the inner conductor is outside the cavity, the volatile gas of conductive rubber does not enter the cavity during the EMC conductive solid sealing process to pollute the coaxial cavity. Thus, the risk of decreased multipactor threshold value is lower. 4) The fabrication and assembly via the method are easy, and the structure is flexible. Nevertheless, good fastening and bearing capacity in circumstances where the inner conductor is overweight and oversized are still achieved.

3. ANALYSIS OF THE THREE TYPES OF MECHANICAL CONNECTIONS

The decomposed connections of the three modes of connection are shown in Figure 5. The worst condition of the transverse direction was considered, and axial and transverse mechanical vibration simulation analyses were conducted on the three structures.

All four kinds of filters with TNC connectors have the same outer size, which is 146 mm × 34 mm × 71 mm. The resonators in all filters had a coaxial line geometry of almost 75 Ω, and the minimal gap in the resonator was the open end of the inner cylinder to the outer cavity.

Connection mode (b), which adopts screw fastening between the

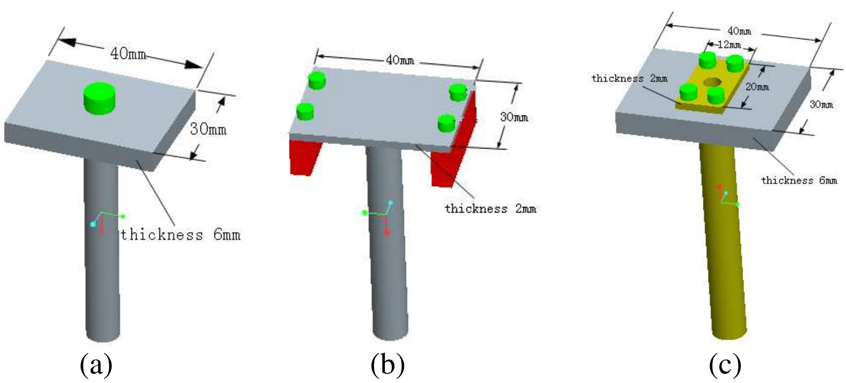

Figure 5. Mechanics analysis diagram of the three modes of connection, (a) and (b) correspond to the two connection ways shown in Figure 2, and (c) corresponds to the flange earthing method proposed in this paper.

entire floor and the wall, has a screw fastening force of less than half of that of (a). The contact stress is dotted, the rod-end deformation is similar with that of mode (a) at a transverse vibration load of 10 g, and the mechanical state is relatively unstable. Connection mode (c), which adopts external flange-type screw fastening, has a smaller screw fastening force than mode (b). The stress on the contact surface is uniform, the contact state is stable, the rod-end deformation is 1/4 that of that the other two modes at a transverse vibration load of 10 g, and the mechanical state is stable and reliable.

In summary, the connection method proposed in this paper achieves good mechanical performance, helps solve hidden dangers at high-power vacuum working conditions, and is a reliable and valid space-borne coaxial product connection method.

4. EXPERIMENTAL VERIFICATION

To verify the method introduced in this paper, the flange grounding design was used in almost 73 test pieces at high power conditions. Among which, 90% of the pieces were tested via the multipactor

Table 1. Mechanics analysis result of the three types of mechanical connections.

Modes	Screw pre-tightening force (N)	Maximum contact stress (MPa)	Deformation (mm)	
			Longitud-inal	Transver-se (Max)
A	2500	76.91	0.01	0.0089
B	800	30.927	0.006	0.0086
C	800	25.698	0.005	0.0022

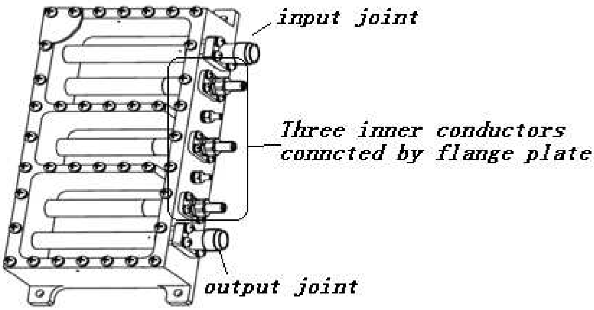

Figure 6. Structural diagram of a typical test piece.

Figure 7. Typical test piece photo.

threshold experiment. All results had no obvious decrease in the threshold value of the multipactor caused by grounding.

The test piece consists of three-order vacuum high-power coaxial filters assembled by two input/output resonant poles and three coaxial inner conductors with flange connection. Figure 6 shows the typical structure, and Figure 7 presents the photo of the test piece.

5. CONCLUSION

A stable grounding method for the inner conductor of coaxial resonator suitable for vacuum and high-power conditions is introduced in this paper. The coaxial resonator can have stable and unified microwave grounding ability by using a flange to connect the inner and outer conductors of the coaxial resonator. The electromagnetic leakage caused by unstable tiny cracks in the high-power component can be avoided. Verticality deficiency, which is difficult to control during the installation of the inner conductor and the cavity surface, can be solved. The entry of secondary pollution into the cavity, which is caused by the volatile gas of conductive rubber during electromagnetic protection, can be prevented. Furthermore, the bearing capacity for the fastening mechanism can be strengthened to solve problems of the inner conductor related to size and weight.

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