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A KIND OF COAXIAL RESONATOR STRUCTURE WITH LOW MULTIPACTOR RISK

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Abstract—Spacial coaxial resonator plays an important role in spacial system. However, its multipactor effect has not been reported so far. This paper presents a novel type of coaxial resonator structure with low multipactor risk. Compared with conventional coaxial resonator structures, the proposed structure improves the multipactor threshold of filters nearly 3 dB. Experimental results and 3D full-wave analysis show good accordance with the predicted characteristics.

1. INTRODUCTION

Multipaction is a nonlinear effect that may appear in microwave devices operating with high power and lowpressure conditions (lower than 1.3×10^{-3} Pa), resulting in resonant electron avalanche between the inner metal surfaces of a component. Multipaction takes place while certain field conditions are satisfied (including amplitude, frequency, and phase) caused by secondary electron emission [1]. The multipacting avalanche may give rise to degradation of signal and destruction of device. Given above reasons, multipactor is a critical issue in the design of microwave devices for space application [2], which has attracted much more attention from the scientific communities [3, 4].

Based on parallel plate theory, multipactor susceptibility curves are standard for the design of multipactor for space applications [5]. To save the development time and reduce the cost of space hardware, it is indispensable to assess multipactor risks before fabrication.

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Multipactor software, capable of predicting multipactor threshold, is applied to several types of transmission lines, such as waveguide, coaxial, and micro-strip line. Its theoretical basis is parallel plate approximation that can be used to design real microwave component if the gap size is much smaller compared to its dimensions and only fundamental mode is considered. Multipaction breakdown on passive waveguide components has been reported in [6–8], and the multipactor threshold of coaxial transmission lines has been demonstrated in [9, 10]. To our best knowledge, multipaction of spacial coaxial resonator structures has not been reported so far. However, spacial coaxial resonator plays an important role in spacial system and its multipaction may affect the performance of the whole special system. This motivates us to study the multiapction effect of spacial coaxial resonator and explore new type of spacial coaxial resonator structure with low multipaction risk.

In this paper, a novel type of coaxial resonator with low multipactor risk is demonstrated. The proposed coaxial resonator is installed in the narrow band filter (L-band). The multipactor threshold has been improved by optimizing the coaxial resonator capacitance distribution. 3D full-wave analysis shows that the multipactor threshold of filters with low multipactor-risk resonators is nearly 3 dB higher than that using normal structure coaxial resonators. These results accord very good with experimental measurements.

2. THE STRUCTURE AND ANALYSIS

The proposed advanced structure with low multipactor risk is shown in Fig. 1(a). For comparison, conventional coaxial resonator is also demonstrated in Fig. 1(b). Their geometrical parameters can be found in Fig. 1(c) and Fig. 1(d) respectively. Both structures have the same parameters except for the minimum gap. Under the same frequency, d_1 is larger than d_2 is, and the characteristic impedance of d_1 is also larger than that of d_2.

According to Multipactor software, the characteristic impedance of a product is constant, the frequency increases and the structure gap increases with the increase of multipactor threshold voltage. If the testing frequency and the minimum gap are constant, the multipactor threshold power of a structure increases with the decrease of characteristic impedance.

The different parts of the transmission electron microscope mode resonator have different characteristic impedances, specially at the end of the inner cylinder of the resonator. The minimum characteristic impedance of the gap in resonators with constant outside parameters

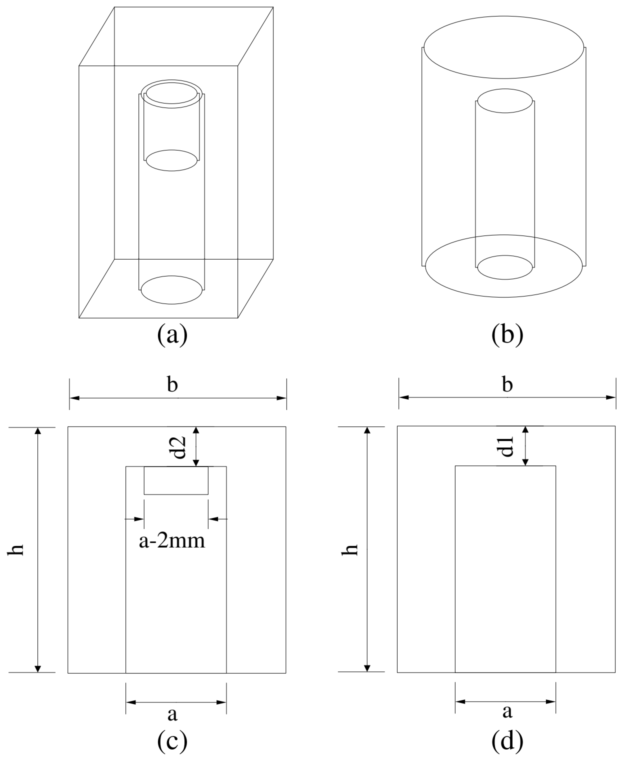

Figure 1. (a) Low multipactor-risk coaxial resonator structure. (b) Convention all coaxial resonator structure. (c) Cross section of the structure in (a). (d) Cross section of the structure in (b).

can be reduced by changing the structure of the resonator, which in turn improves the multipactor threshold power of the entire filter. The square outer cavity is replaced by a circle outer cavity to reduce the effect of unloaded Q.

3. ELECTRICAL DESIGN

To compare multipactor threshold power of the two types of coaxial resonators in Fig. 1, two types of third-order filters with the same performance were designed. More than three filters of each type had been manufactured. It should be noted that all filters have the same outside parameters.

The filter design begins with the generation of a suitable prototype. The coupling matrix of the third-order Chebyshev prototype with 0.01 dB ripple response is presented as $M01 = M34 =$

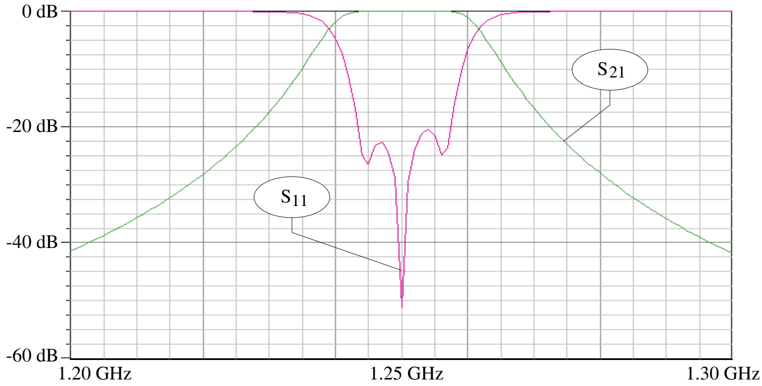

Figure 2. Simulation results of the two types of third-order filters via HFSS.

Table 1. Experimental results of filter.

PARAMETERS	DESIGNED	MEASURED
Centre frequency	1.25 GHz	1.25 ∼ 1.255 GHz
Operation band	10 MHz	≤ 10.3 MHz
Insertion loss	≤ 0.4 dB	≤ 0.36 dB
Loss Variation	≤ 0.2 dB	≤ 0.18 dB
Rx/Tx VSWR	≤ 1.2	≤ 1.19 dB

1.13755 and $M12 = M23 = 1.10102$. The center frequency is at 1.25 GHz, and the bandwidth is 10 MHz. The design has been validated by 3D full-wave simulations. The physical dimensions of the entire filter were also checked. Return loss is found to be more than 20 dB with an insertion loss of less than 0.4 dB. Simulation results of the two types of filters are shown in Fig. 2.

4. HIGH POWER HANDLING CAPABILITY

In order to predict high power handling capability, the analysis for PIM and multipactor should be performed. Therefore, the filter should be manufactured by proper material with the minimum number of contact junctions and no tuning screws. The filters of this paper with different coaxial resonators were machined from aluminum alloy, and then silver plated. The filters didn't have any frequency tuning screw.

The peak voltages of two kind filters were calculated by HFSS and the numbers of peak voltages are summarized as shown in Table 2. The SC structure has the least peak voltage. When the input power is same, lower peak voltage means higher multipactor threshold.

Table 2. Analysis of peak voltage.

Structure	Frequency	Gap	Peak Voltage (V/W)
Fig. 1(a)	1.25 GHz	3.45 mm	81.37
Fig. 1(b)	1.25 GHz	6 mm	148.69

5. EXPERIMENTAL RESULTS

Theoretical results and measured results are shown in Table 1. It can be seen that experimental results accord very well with theoretical design. A very small shift of central frequency is attributed to the absence of a frequency tuning screw.

Next, we examine the multipactor risk of the two resonator structure in Fig. 1. The peak voltages of the two types of filters were calculated by using high-frequency structure simulator (HFSS). The peak voltages is shown in Table 2, in which a low peak voltage means a high multipactor threshold. It is clear that the proposed advanced structure in Fig. 1(a) has low multipactor risk compared to the conventional structure in Fig. 1(b).

To validate the theoretical results, experiment has been carried out and the measurement results is demonstrated in Table 3. Obviously, experimental results accords well with simulation results.

Table 3. Experimental results of multipactor threshold power.

Structure	Measured Results
Fig. 1(a)	70 W
Fig. 1(b)	150 W

6. CONCLUSION

In this paper, a low multipactor-risk coaxial resonator structure is proposed and experimentally demonstrated. It is found that the multipactor threshold of the coaxial resonator may be improved by reducing the characteristic impedance of the minimum gap. This can be achieved by changing the structure of the inner conductor. The multipactor threshold is improved nearly 3 dB when the proposed coaxial resonator structure is applied to the L-band filter. Experimental results accords very well with the predicted characteristics.

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