# A Test Circuit with Microstrip Filter for Microwave Power Device

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**Abstract:** With the principles of microwave circuits and semiconductor device physics, three kinds of microwave power device test circuits are designed and simulated, whose properties are evaluated by a parameter network analyzer within the frequency range from 3 to 8GHz. The simulated results verify that the test circuit with stepped-impedance filter bias network has a larger bandwidth than that with the radial stub. A microstrip interdigital capacitor is used in the third test circuit to replace the DC block, however, which does not show its advantage during the test frequency band. Based on the simulated results, the stepped-impedance filter test circuit can be used to evaluate microwave power devices in the whole C band, namely from 4 to 8GHz.

**Key words:** filter; radial stub; test circuit; stepped-impedance; interdigital couple capacitor
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## 1 Introduction

Microwave power electronic devices, such as GaN HEMTs[1,2] and HBTs, are key components in radar and wireless communication systems and directly influence communication quality[3]. Because of their high operating frequency, however, it is quite difficult to characterize microwave power devices' performance, especially packaged ones. Since the device needs to be packaged and tested before being integrated into a system, a test circuit with a fixture for the packaged device is absolutely necessary[4]. It acts as an electrical and mechanical interface from the microwave signal test system to the device under test (DUT).

To evaluate a packaged microwave high power device's performance properly, the loss, bandwidth, reflection, oscillating prevention, etc of the test circuit should be considered. In microwave circuits, as it is not always desired that a DC connection also lead RF signals, quarter-wave line, radial stub or surface mounted (SMT) capacitors are often used to block microwave signals in the DC bias circuits of the test circuit. However, the conventional circuits above have the common problem of having a small bandwidth. When facing DUTs designed with larger bandwidths, they cannot evaluate the DUTs properly. This article concentrates on a novel microwave power device test circuit in a printed circuit board (PCB) with a larger bandwidth, in which the stepped-impedance filter network is being used to bias the DUTs. In addition, a microstrip interdigital couple capacitor is adopted to replace the DC block in one of the test circuits, which is intended to reduce the high frequency loss of the DC block[5~7]. By using an Agilent ADS simulator, the simulated results of the filter bias test circuit show an excellent characteristic of bandwidth, which makes it possible to be used in the whole C band, namely from 4 to 8GHz.

## 2 Circuit design

### 2.1 Stepped-impedance filter

Stepped-impedance filters are useful microstrip components[8]. They are often used in a number of microwave circuits, such as amplifiers, oscillators, mixers, etc, to realize low-pass, high-pass or band-pass filters[9,10]. As depicted in Fig. 1, the stepped-impedance filter mainly has three characteristic parameters: the sections $N$, the impedance

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$Z$, and the length $\beta_d$. Based on the transmission line theory[11], the thin high impedance microstrips work as inductive elements, while the wide low impedance microstrips work as capacitive elements. Together with the two elements, a filter is created. By changing the length, impedance and sections of the two elements, the bandwidth of the filter can be controlled. In particular, when the ratio of the high impedance to the low impedance is big, a larger bandwidth of the filter can be obtained. The bandwidth of the filter is also proportional to the sections.

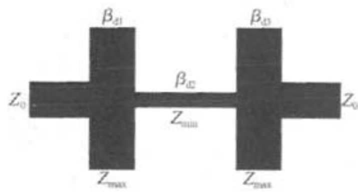

Fig. 1 Characteristic parameters of stepped-impedance filter

## 2.2 Design and simulation

With EDA software, we designed three kinds of PCB test circuits. As can be seen from Fig. 2, they mainly consist of the microwave main line and the DC bias network. The characteristic impedance of the main line in all three circuits is 50Ω. SMT capacitors are used as DC block in circuits a and b. The quarter wave microstrip line, the radial stub, and the DC pads constitute the bias network of test circuit a. The quarter wave microstrip line is intended to be an RFC of the microwave signal. A more extensive description of the radial stub test circuit can be found in Ref. [4]. For the test circuits b and c, with a stepped-impedance filter, the characteristic impedance of the thin and the wide microstrip lines are 125 and 30Ω, respectively, and the corresponding lengths are 9.2 and 8.5mm. With two sections of these circuits, a microwave filter bias network circuit is achieved. Additionally, a microstrip interdigital capacitor is adopted in circuit c to replace the DC block, which is intended to reduce the high frequency loss of the DC block. There are 5 interdigital fingers, each with a length, width, and gap of 15, 0.4, and 0.2mm, respectively.

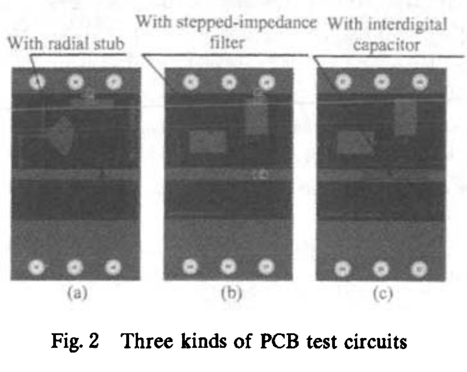


Fig. 2 Three kinds of PCB test circuits

A simulation of the PCB test circuits was carried out with EDA software. The $S$ parameters of the simulation after optimization are given in Figs. 3 and 4. As can be seen from Fig. 3, at the frequencies of 4 and 8GHz, the circuit with radial stub has $S_{11} = -17.07$dB, $S_{11} = -10.97$dB, respectively. The corresponding results of the stepped-impedance filter test circuit b are $S_{11} = -22.16$dB and $S_{11} = -26.68$dB. Across the whole C band, the $S_{11}$ of the filter test circuit is below $-20$dB. However, the $S_{11}$ of circuit c with interdigital couple capacitor fluctuates in the C band and can only be used near 6GHz. As to the $S_{21}$ described in Fig. 4, the test circuit b also exhibits excellent

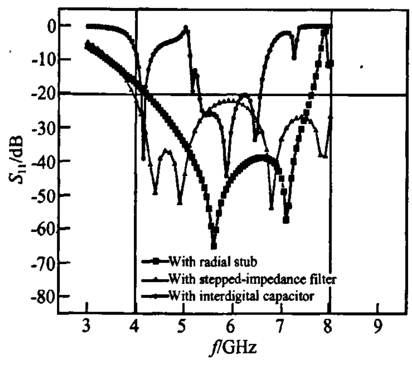


Fig. 3 Simulation results of $S_{11}$ of the circuits

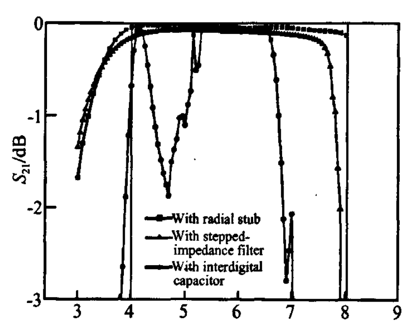


Fig. 4 Simulation results of $S_{21}$ of the circuits

characteristics of $S_{21} = -0.125$dB at 4GHz and $S_{21} = -0.125$dB at 8GHz. The results of the test circuit a are $S_{21} = -0.151$dB at 4GH and $S_{21} <$ $-3$dB at 8GHz. These results indicate that the circuit b with a stepped-impedance filter shows good bandwidth characteristics. The reason is that the stepped-impedance filter has a high ratio of high characteristic impedance to low characteristic impedance, which results in a low $Q$ factor of the bias network. Then a large bandwidth of the circuit can be obtained. Like $S_{11}$, $S_{21}$ of the circuit c also fluctuates. The narrow frequency band characteristic of the circuit c is mainly due to the interdigital couple capacitor, which is very sensitive to the structure parameters. Hence this structure is often used in IC technology, with which precise structures can easily be created.

## 3 Results and discussion

Small signal evaluation of the PCB test circuit was carried out by a parameter network analyzer (PNA). The frequency range is from 3 to 8GHz, and the $S$ parameters of the three PCB test circuits measured are shown in Figs. 5 and 6. From Fig. 5, it is clear that both the reflection and bandwidth of the circuit b with stepped-impedance filter are better than the circuit a with radial stub, which agrees well with the simulation results. The corresponding $S_{11}$ are $-13.88$ and $-8.74$dB at 4GHz, respectively, and the $S_{11}$ of the test circuit with stepped-impedance filter is below $-10$dB across the whole C band, which is better than that of the radial stub one.

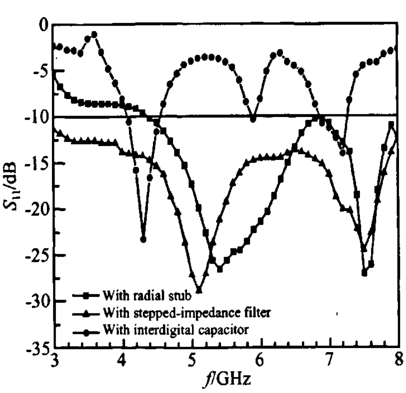


Fig. 5 Small signal test results of $S_{11}$

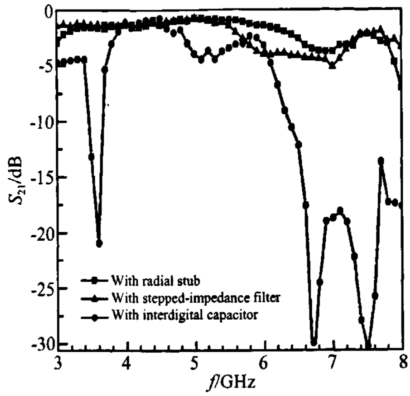


Fig. 6 Small signal test results of $S_{21}$

However, the circuit a and the circuit b both have worse $S_{21}$ characteristic that differ a lot from the simulation results. This is mainly because of the failures in the PCB manufacture process, which destroyed the surface metal of the PCB seriously by changing its physical parameters, such as the thickness and roughness. With the changing of the PCB's physical parameters, the fabricated PCB test circuits may differ a lot from the designed circuits. The test results will thus not be ideal. However, the benefit of the test circuit with stepped-impedance filter is obvious, especially the large bandwidth characteristic, which enables the test circuit to evaluate microwave power devices or other DUTs in a large frequency band. The circuit c has the worst microwave characteristics, which agrees well with the simulation results. The reason has been given above.

## 4 Conclusions

We have researched the testing of microwave power devices. With the theory of microwave circuit and semiconductor device physics, three kinds of PCB test circuits have been designed and compared. The simulation and test results show that a circuit with a stepped-impedance filter can be used to test microwave power devices in the whole C band, which is better than a circuit with a radial stub. By using the designed circuit with a stepped-impedance filter, the need of large bandwidth evaluation of DUTs can be satisfied. The use of an interdigital couple capacitor, which is intended to replace the DC block, failed to exhibit good microwave characteristics. The reason lies in the parameter's sensitivity of the interdigital couple capacitor, which cannot be fulfilled by the PCB fabrication process.

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# 微波功率器件的滤波器测试电路


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**摘要**：在微波电路原理和半导体器件物理的基础上，设计和模拟了三种用于微波功率器件的测试电路，并且设计了与之配套的测试夹具．采用矢量网络分析仪对该测试电路和夹具，在 3～8GHz 范围内进行了小信号测试．模拟和测试结果表明，采用阶梯阻抗滤波器偏置网络的测试电路性能较好，比采用扇形线偏置网络的测试电路具有更宽的带宽．该滤波器偏置电路能够用来在整个 C 波段，即在 4～8GHz 内对微波功率器件进行测试．但是，微带叉指耦合电容没有起到取代贴片隔直电容的目的，原因是该结构对参数精度要求高，而 PCB 制作工艺无法满足这个要求．



**关键词**：滤波器；扇形线；测试电路；阶梯阻抗；叉指耦合电容

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