

EFT Immunity Test and Damage Localization of C-band Limiters

Jiacheng Ma ^{1, a, *}, Bin Liu ^{2, b}, Deren Feng ^{1, c}, Weiheng Shao ², Shan Xue ²,
Liuxing He ¹, Zongqi Cai ², Caixu Yu ¹, Jinxin Zhang ¹, Zhenli Zhu ¹, Hui Li ²,
and Wenrui Ding ¹

¹ School of Electrical and Information Engineering, Anhui University of Technology, China;

² China Electronic Product Reliability and Environmental Testing Research Institute (CEPREI).

^{a, *} 3234962431@qq.com, ^b 18565275917@163.com, ^c fdr@ustc.edu.cn

Abstract. In this paper, the EFT immunity experimental platform of C-band RF limiter is designed, and then electromagnetic immunity test and device damage analysis are carried out. When the voltage of the EFT interference source exceeds 900V, the device experiences increased insertion loss. When the interference continues to increase to 1000V, the device is damaged. Failure localization was carried out for the failed sample. Failure Location Using Electromagnetic Emission Measurement Techniques. By analyzing the emitted electromagnetic field map (EMF), it was concluded that PIN diodes are more susceptible to damage. The device was then disassembled and the failed component replaced, proving the accuracy of the location of the failure point.

Keywords: PIN limiter; EFT; damage characteristics.

1. Introduction

With the miniaturization and integration of electronic devices, the electromagnetic environment is becoming more and more complex. For their anti-interference ability also put forward higher requirements[1]. EFT immunity test is a test in which a cluster of many fast transient pulses is coupled to the power, signal, and control ports of an electronic device. It is characterized by short rise time, short duration, high amplitude and repetition frequency, which are difficult to overcome by electronic equipment in the long term.

The limiter is an important receiver front-end device that can receive high-power signals without causing damage to the receiver[2]. When the limiter receives a low power signal, the limiter is characterized by low insertion loss[3]. This time the output signal of the limiter is slightly smaller than the input signal. When the power of the input signal is greater than the power at which the limiter starts to operate, the limiter is characterized by high insertion loss.

Therefore EFT electromagnetic immunity testing of limiters is necessary. In this paper, a C-band single-tube PIN limiter is used for the study. EFT electromagnetic immunity tests are performed on it. Study the insertion loss of the device and the variation of the output power after it is damaged in and localize the point of failure.

2. Structure and Parameters of Limiter

The limiter under test in this paper is a single-tube PIN limiter, and the schematic and physical diagrams are shown in Figure 1.

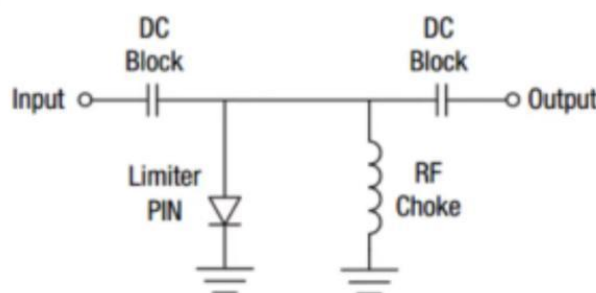


Figure. 1 Schematic diagram and physical drawing of the limiter

The main parameters of the limiter are as follows: applicable frequency band 10M~6GHz; starting level $\geq 10\text{dBm}$; insertion loss $\leq 5\text{dB}$; output standing wave 1.2.

3. EFT immunity test

3.1 Experimental System Design

The system is laid out as shown in Figure 2 in carrying out the EFT immunity experiment. The oscilloscope is used to monitor the input voltage waveform of the interference source. Putting the EFT voltage magnitude from 200V onwards in the experimental. Increase it by 100V each time and inject it once until it is 4800V. The pulse frequency of the interference signal is 5KHz, the repetition time is 300ms, the number of spikes is 75, the test time is 120s, the pulse width is 50ns and the rise time is 5ns.

Limiter performance test after each interference injection. As shown in Figure 3. The RF signal source outputs a 7dBm and 20dBm continuous wave, which has a frequency of 2GHz. The first power meter monitors the power of the input limiter signal, ensuring that the input signal to the limiter is either 7dBm or 20dBm each time. The power of the output power of the limiter is monitored with a second power meter[4].

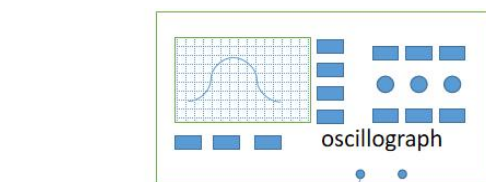


Fig. 2 Layout of injection experiment

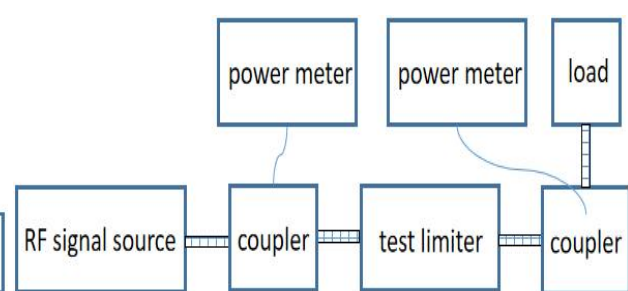


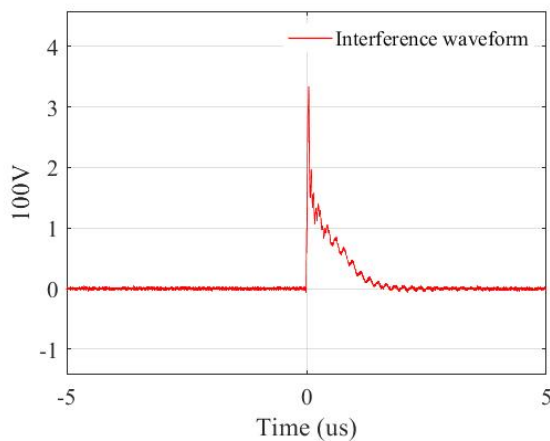
Figure. 3 Layout of Performance Test

3.2 EFT Injection and Limiter Performance Testing

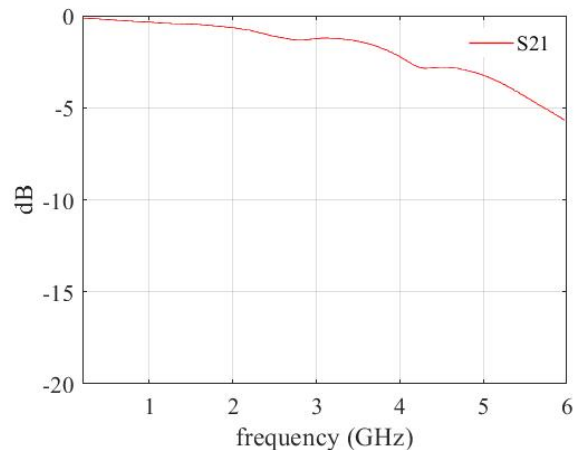
In order to investigate the EFT damage threshold and performance degradation characteristics of the module, the following steps were conducted:

- 1) First the initial S21 parameters of the module are measured with a vector network analyzer. Determine that it has an insertion loss of 0.65 dB at 2 GHz. Again, as in Figure 3 using a power meter, the module is given a large 20dBm signal and tested for its output power of 13.22dBm.
- 2) After setting the EFT size shown in Figure 2 to 200V (EFT source range 200V~4800V). Inject the nuisance signal into the limiter module. The number of nuisance pulses is 75. Remove the module at the end of injection then test the S21 parameters and output power. Observe there is any change in the insertion loss and output power of the module at 2 GHz.
- 3) If the insertion loss and output power of the module do not change, then increase the EFT by 100V, repeat the injection, and then test the performance again.
- 4) If there is a large change in the insertion loss or output power of the limiter after step 3, then the module degradation is recorded in relation to the pulse size and number. If the EFT increases to 4800V and the module does not show degradation, then increase the number of pulses to 100 and continue from step 2.

After going through the above experimental steps, it is found that no damage occurs to the limiter when the number of EFT pulses is 75 and the size is below 900v. The insertion loss of the tested limiter is basically the same as the initial size, and the output power is still 13.22 dBm. The insertion loss slightly increases to 2.1dB at 900V. The insertion loss increases to 11.8dB at 1000v, and the output power decreases from 13.22dBm to 7.26dBm (Figures 4 to 5).

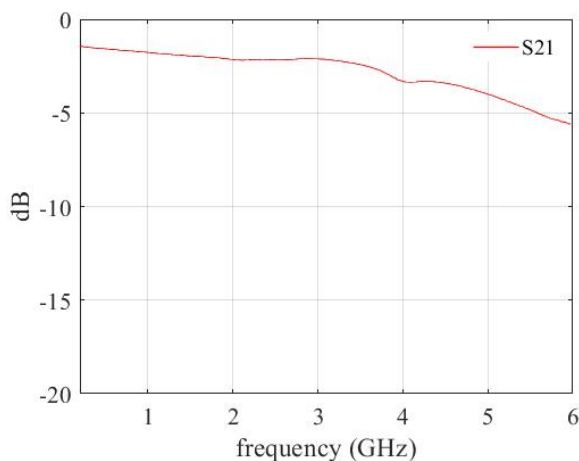


a) incident wave

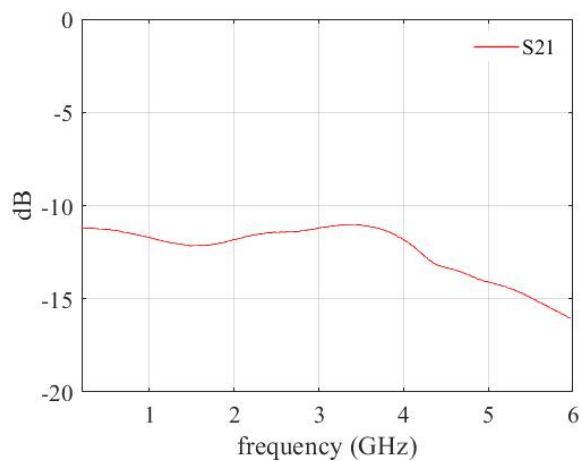


b) limiter

Figures. 4 EFT injection waveform and limiter initial S21



a) 900v

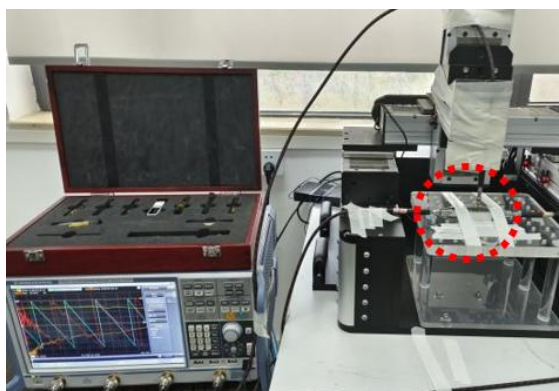


b) 1000v

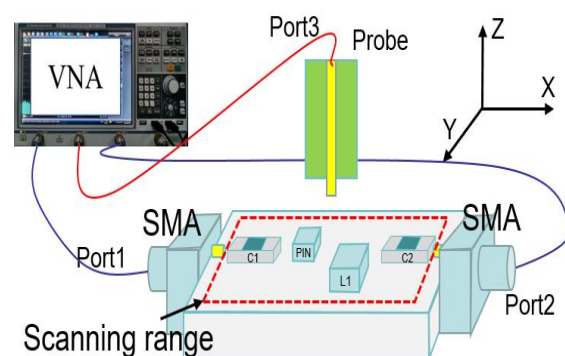
Figures. 5 The S21 of the limiter after an EFT injection of size 900v and 1000v

3.3 Internal damage location of limiter

There are several sub-individual components within the module. This makes perfect sense in EFT immunity testing to find out which component is damaged within the module. In this paper, a vector network analyzer is utilized for near field scanning. The emitted EMF map of the module is given by controlling the electric field probe through a computer and a test bench. As shown in Figure 6.



a) Physical diagram



b) Red circle schematic diagram

Figure. 6 layout of Near-field scanning system

By analyzing the emitted EMF map, it was analyzed that the PIN diode is more likely to be damaged in the EFT immunity test, which leads to degradation of the device performance. As in Figure 7[5].

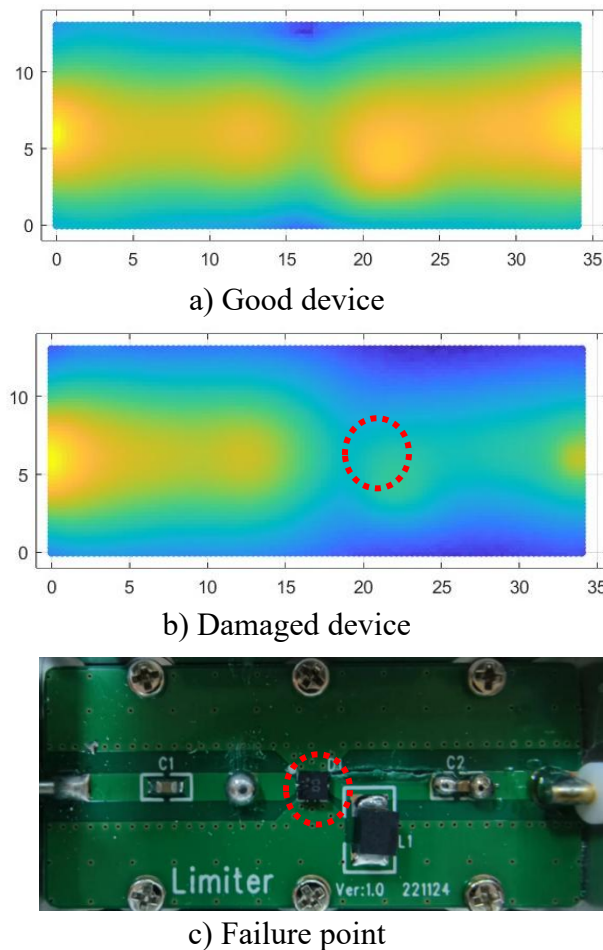


Figure. 7 emitted electromagnetic field map

To check this guess, the PIN diode in the damage module was removed and replaced with a new one, leaving the rest of the original intact. Then use the VNA to test S_{21} of the damaged module after replacing the PIN diode, as shown in Figure 8. The performance of the device was found to be much improved after replacing the PIN diode. At 2 GHz, the insertion loss of the module is 11.8 dB before replacing the PIN diode and 2.2 dB after replacement. The insertion loss of the limiter is much lower. This proves the accuracy of the failure point.

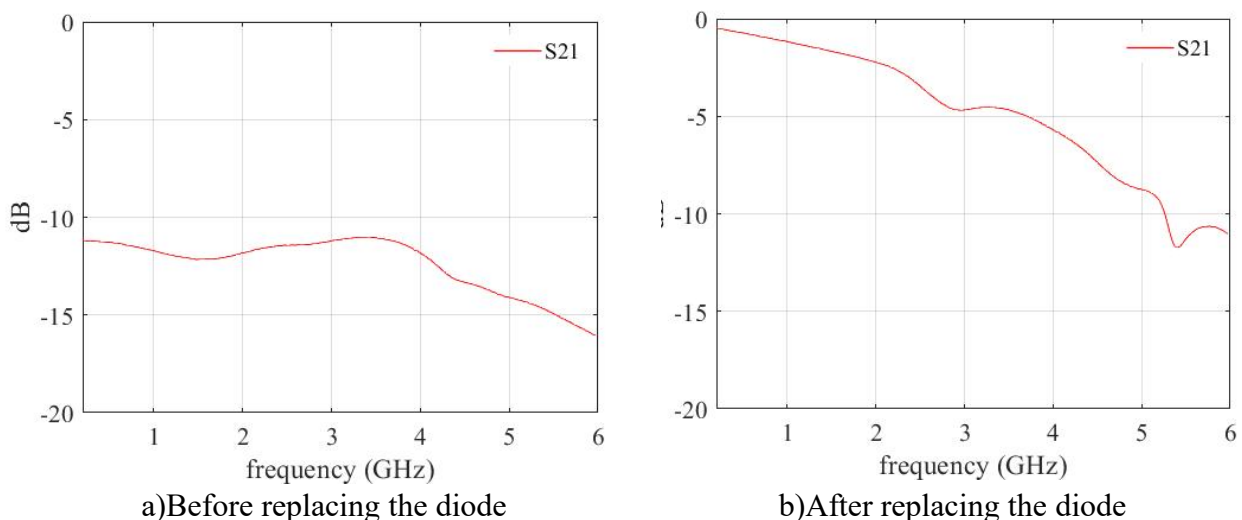


Figure. 8 S_{21} before and after replacing the PIN diode

4. Summary

The damage threshold of a C-band limiter depends mainly on the size of the voltage level of the EFT. At constant pulse width and number of pulses and EFT greater than 900 V, the insertion loss of the limiter increases slightly. The insertion loss increases to -11.95 dB as the EFT is increased to 1000 V. The limiter output power decreases to 7.26 dBm when the input is a large 20 dBm signal. The above results indicate that the insertion loss increases when the EFT interference produces a slight damage to the limiter. The output power of the limiter will drop when large damage is caused. In addition, through electromagnetic emission measurement techniques and replacement of components, it was clarified that the vulnerable component inside the module was the PIN diode.

References

- [1] Xu T, Chen X, Du Z, et al. The effect of frequency on the thermal effect of high power microwave pulses on a PIN limiter[C]//International Symposium on Electromagnetic Compatibility. 2010: 401-404.
- [2] Looney J, Conway D, Bahl I J, et al. An examination of recovery time of an integrated limiter/LNA[J]. IEEE Microwave Magazine, 2004, 5 (1) : 83-86.
- [3] Skyworks Solutions Inc . PIN limiter diodes in receiver protectors [OL] . [http: / /www.skyworksinc. com](http://www.skyworksinc.com), 2006-07-09.
- [4] WANG Y, CHEUNG K P, CHOI R, et al. An accurate capacitance-voltage measurement method for highly leaky devices-Part II [J] . IEEE Transactions on Electron Devices, 2008, 55 (9) : 2437-2442.
- [5] W. Shao et al., "Asymmetric Calibration and Characterization for Diff-Port Magnetic Field Probing System," in IEEE Sensors Journal, vol. 23, no. 10, pp. 10559-10567, 15 May15, 2023, doi: 10.1109/JSEN.2023.3265773.