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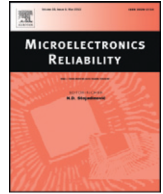

Damage effects on low noise amplifiers with microwave pulses

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ABSTRACT

The damage effect experiment is carried out to the low noise amplifiers (LNAs) based on Bipolar Junction Transistor (BJT) and Pseudomorphic High Electronic Mobility Transistor (PHEMT) by microwave pulse injection experiment platform. The essence of the LNA damage with microwave pulses is the damage to the core semiconductor device. The influence rule upon the damage power of the LNA by different microwave pulse widths and pulse numbers is obtained. The injection, reflection and output waveforms are measured by high frequency oscilloscope and the typical damage waveforms of the LNA are analyzed. Inspection is made on the damaged semiconductor device by a scanning electron microscope (SEM) and the microscopic damage images of the semiconductor devices with different pulse widths and pulse numbers are analyzed in comparison.

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1. Introduction

With the electromagnetic environment becoming more and more complicated and continuous promotion of the integration level of the electronic systems, the susceptibility issues of electronic systems to electromagnetic pulses are more and more prominent [1]. The narrow-band microwave pulse [2] is benefited by the development of pulsed power technology and high power microwave sources, with the output power up to several GW and the pulse width about 100 ns [3]. The threat to the electronic systems by narrow-band microwave pulse cannot be ignored. LNA, as the core and most vulnerable device in RF front end of receiving system, is used to amplify weak signals. The vulnerability experimental research of European electrified railway traffic management system is reported under microwave pulse radiation [4]. The results show that the LNA is the vulnerable device in the system. The damage effect of LNA with microwave pulses is more concerned [5–7]. The experiment of LNA based on BJT injected with microwave pulses is reported in reference [8–9], in which the damage characteristics of transistor are presented with different microwave pulse parameters and injection pins. The failure analysis on damaged Gallium Arsenide High Electronic Mobility Transistor Monolithic Microwave Integrated Circuit (GaAs HEMT MMIC) LNA caused by microwave pulses is reported in reference [10].

The semiconductor devices used in LNA include Metal Semiconductor Field Effect Transistor (MESFET), BJT, Metal Oxide Semiconductor Field Effect Transistor (MOSFET), HEMT and PHEMT. BJT and PHEMT are widely applied at the present stage. Since the BJT is made from Si, it has the advantages such as mature process and low price, etc. It is widely used in the fields such as Global Position System (GPS), analog and digital cellular telephones, cordless telephones, radar detectors, pagers and Satellite Antenna Television (SATV) tuners, etc. Generally, the material for PHEMT is GaAs. Based on the material and structural features of GaAs PHEMT, it has the advantages of high electron mobility, high cutoff frequency, low-noise figure and high gain. Accordingly, with the increasing maturity and manufacturability of GaAs PHEMT technology, GaAs PHEMT have been extensively inserted for both commercial and military applications. Commercial applications include home and office wireless local area networks (WLANs), local multi-point distributed systems (LMDSs), cellular handsets, automotive radars, satellite ground terminals and so forth. Military GaAs PHEMT are mainly used as receivers and transmitters for satellite communications phased-array applications, ground based military radar and ground based phased array and communications.

The damage effect experiment is carried out to the LNA based on BJT and PHEMT. The influence rule upon the damage power of the LNA by different pulse parameters is obtained. The typical damage waveforms of the LNA are analyzed and the microscopic damage images of the semiconductor devices with different pulse parameters are analyzed in comparison.

2. Experiment setup

The experimental objects are LNAs in two different types based on BJT and PHEMT. The single-stage amplified LNA based on BJT and its schematic diagram are shown in Fig. 1(a) and (b). The BJT is circled in the picture, whose model number is BFG425W. The peripheral circuit includes the static biasing circuit of transistor and the input and output match circuits. The LNA is the common emitter amplified circuit. The base of BJT connects with the input terminal of the LNA, the collector

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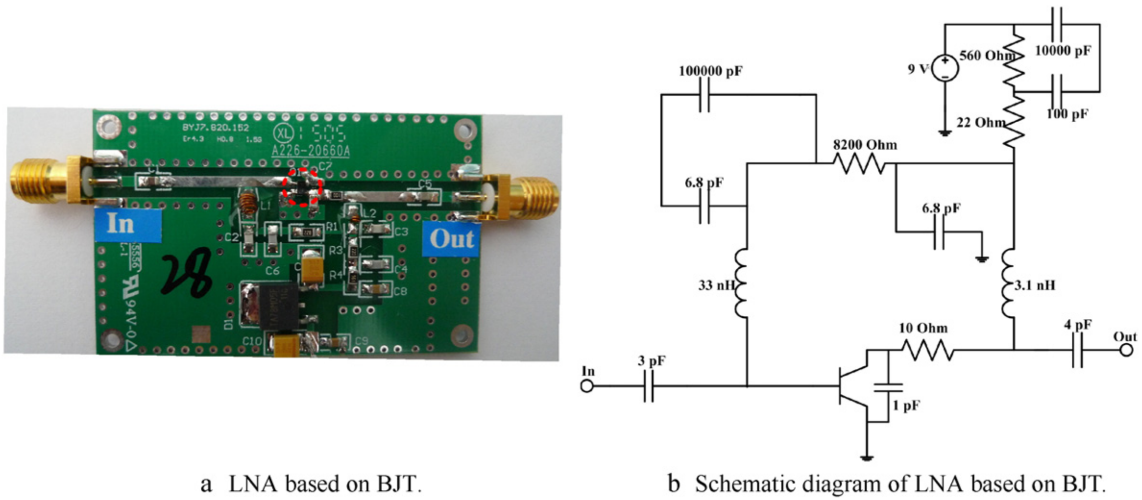
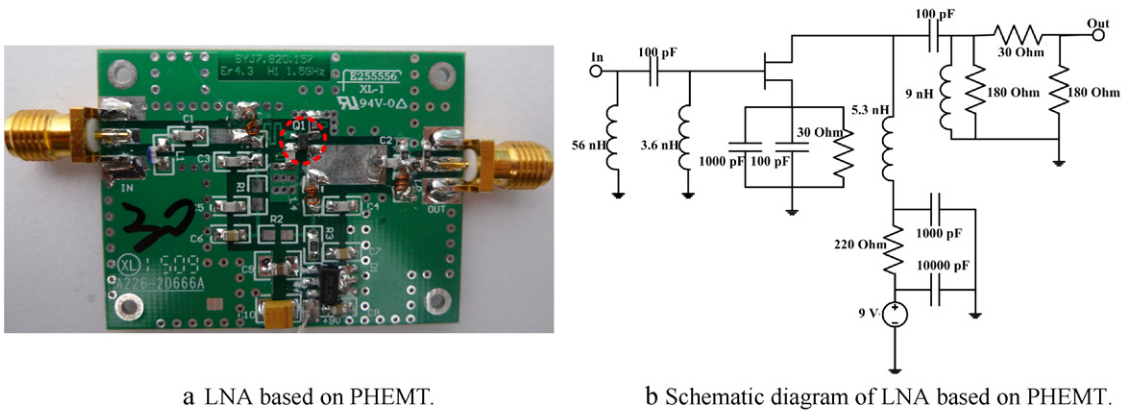


a LNA based on BJT. b Schematic diagram of LNA based on BJT.

Fig. 1. (a) LNA based on BJT. (b) Schematic diagram of LNA based on BJT.



a LNA based on PHEMT. b Schematic diagram of LNA based on PHEMT.

Fig. 2. (a) LNA based on PHEMT. (b) Schematic diagram of LNA based on PHEMT.

connects with the output terminal and the emitter connects with the ground. The DC supply voltage of the LNA is 9 V and the working current is 10 mA. The central frequency is 1.5 GHz, the gain is 16 dB, the noise figure is 1.85 dB and the reflection coefficient is less than −10 dB. The single-stage amplified LNA based on PHEMT and its schematic diagram are shown in Fig. 2(a) and (b). The PHEMT is circled in the picture,

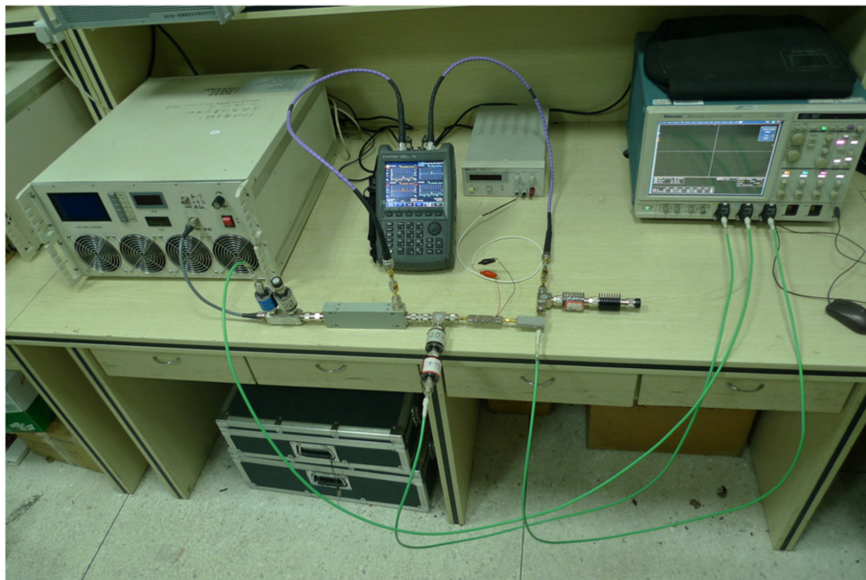


Fig. 3. Equipment of injection experiment system.

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