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“Indoor” Protection of Electronic Systems by Means of High-Pass Negative Feedback

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An extremely simple first order RC high-pass filter is suggested to suppress harmful radio frequency oscillations, induced by high power electromagnetic pulses. Specifically, a broadband single stage transistor amplifier with a parasitic wiring inductance and also the parasitic junction and mounting capacitances are investigated both numerically and experimentally in the very high and ultrahigh frequency bands.

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1. Introduction

Radio frequency weapons (RFW) mitigation is a challenge to the designers of the electronic equipment. Depending on the power the RFW can make harm to electronic devices in several ways: (1) by thermal destroying the electrical circuits, (2) by breakdown of the active elements (transistors and integrated circuits (ICs)), (3) by causing the interference effects. Electrical circuits due to the wiring inductances and mounting capacitances, also junction capacitances of the active devices have rather high resonance peaks in the microwave range. For example, a three stage broadband transistor amplifier characterized by 18 dB gain in the main working band can have parasitic gain up to 50 dB in the resonance region. This can result in excess voltages across the active elements and consequently in the breakdown of their junctions or in unacceptably high noise level due to the intermodulation effects.

Many of the RFW are overviewed in the *Jane's Unconventional Weapons Handbook* [1]. Various types of electronic oscillators [2–9] producing ultrawide band chaotic waveforms can be also used in the RFW.

Electronic equipment can be protected against RFW in three main ways [10]: (1) shielding of the equipment and the place where this equipment is located (“outdoor” protection), (2) protecting input circuits (“front-door” protection) and (3) protecting interior circuits (“indoor” protection). The “front-door” and the “indoor” can be either passive or active electronic units. For example, various voltage and current limiters, based on non-crystalline semiconductors [11], superconductors [12] and magnetic materials [13–15] are used as the “front-door” protectors. The best protection effect is achieved when all these measures are applied simultaneously.

In this paper, we describe an extremely simple “indoor” feedback technique of suppressing microwave oscillations in electronic equipment, specifically in very high and ultrahigh frequency broadband amplifiers.

2. Negative feedback protector

For simplicity we consider a single stage transistor amplifier and replace the collector node of the transistor with a current source I_k (Fig. 1). The element R is a collector resistor, L is a parasitic wiring inductance, C is a parasitic capacitance including both the junction capacitance of the transistor and the mounting capacitance, R_L is the resistance of the loading stage. The “collector” in Fig. 1 (bottom) is grounded via the first order high-pass filter $R_f C_f$ that plays the role of a local negative feedback circuit.

Similar technique exploiting passive RC filters has been used for controlling unstable steady states (unstable nodes and unstable spirals) in chaotic dynamical systems [16–18]. We note, however, that the systems considered in [16–18] are unstable circuits, actually oscillators. Thus the role of the RC filters is to stabilize the unstable nodes and/or unstable spirals, i.e. to make them stable nodes

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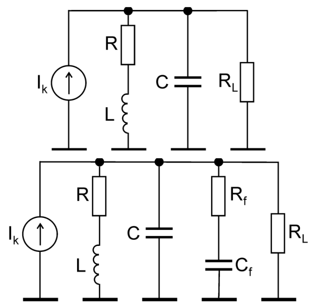

Fig. 1. Equivalent circuit diagrams. (top) Without protector, (bottom) with protector.

and/or stable spirals. The "amplifier" in Fig. 1 (top) is a stable circuit. The corresponding steady state is a stable spiral. The $R_f C_f$ filter in Fig. 1 (bottom) converts the steady state from a previously stable spiral to a stable node.

3. Simulation results

The circuits in Fig. 1 have been simulated numerically using the PSpice based Electronics Workbench simulator. The results are shown in Figs. 2 and 3.

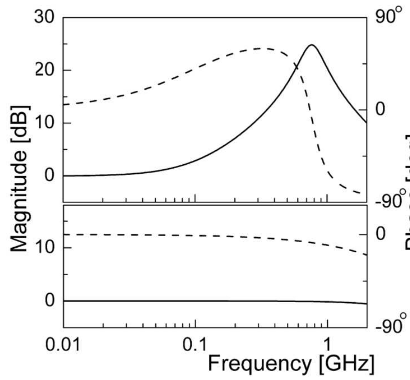

Fig. 2. Frequency characteristics: magnitude (solid line) normalized to low frequency value, and phase (dash and line). (top) Without protector, (bottom) with protector. Circuit element values: $R = 20\ \Omega$, $C = 1.5$ pF, $L = 30$ nH, $R_L = 1$ kΩ, $R_f = 20\ \Omega$, $C_f = 75$ pF.

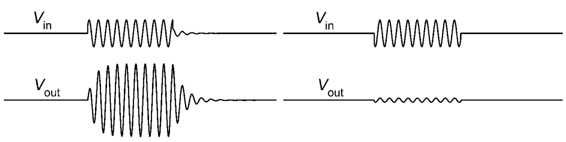

Fig. 3. Response to a radio-wave pulse (carrier frequency $f = 770$ MHz). (left) Without protector, (right) with protector. Circuit element values are the same as in Fig. 2.

4. Experimental results

Experimental frequency characteristics presented in Fig. 4 are in qualitative agreement with the numerical simulations.

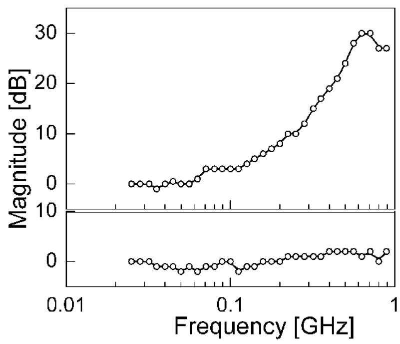

Fig. 4. Experimental frequency characteristics: magnitude normalized to low frequency value. (top) Without protector, (bottom) with protector. Circuit element values are the same as in Fig. 2.

5. Conclusions

An RC filter grounding a collector node of a transistor in a broadband microwave circuit can effectively suppress parasitic resonance thus making the electronic equipment more resistant to high power electromagnetic pulses. In addition, the RC filter considerably flattens the phase characteristic. Though the last property is not very important for the RFW mitigation, it might be useful for designing broadband low phase distortion amplifiers for the chaotic oscillators.

Acknowledgments

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