RF Circuit EMI Suppression and EMC Analysis

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Abstract. The radio frequency circuit will generate strong electromagnetic interference in the process of signal transmission, and its own resistance to electromagnetic interference is weak, and the radio frequency circuits operating in the same electromagnetic environment are prone to mutual interference. Therefore, it is necessary to analyze the electromagnetic interference effect of radio frequency circuits, and then find effective suppression measures, build a good public electromagnetic environment, realize electromagnetic compatibility, and ensure the reliability of signal transmission. This research first briefly introduces electromagnetic interference and electromagnetic compatibility and then analyzes the key points of electromagnetic interference suppression in radio frequency circuits. On this basis, the specific application of electromagnetic interference suppression and electromagnetic compatibility technology of radio frequency circuit is discussed. It can serve as a guide for the design of the radio frequency circuit by analyzing the characteristics and suppression mechanism of the electromagnetic interference of the radio frequency circuit. To ensure the suppression impact of electromagnetic interference, various suppression measures are broadly implemented in accordance with the three components of electromagnetic interference. The electromagnetic compatibility-based design of RF circuits can reduce the mutual interference of RF circuits in the system and guarantee the stability and dependability of signal transmission.

Keywords: RF circuits; EMI; EMC; suppression mechanisms.

1. Introduction

Radiofrequency is referred to as RF, and radio frequency signals need to be used in radio frequency circuits for access control, wireless communication, radar detection, and other fields [1]. Taking the model of wireless communication transceivers as an example, the model includes basic facilities such as a transmitting circuit, receiving circuit, and antenna, and this circuit can be used in the personal communication network or local area network. With the development of electronic technology, the requirements for electronic circuit design are getting higher and higher. At present, frequency resources are becoming tighter and tighter, and the signal frequency is not increasing. High-frequency electronic circuits are gradually replacing medium and low-frequency circuits. High-frequency electronic circuits are constantly being developed [2]. The operating frequency of the routing circuit is continuously increasing, and the requirements for circuit design are also constantly improving. At the same time, the rapid development of wireless communication technology has promoted the wide application of radio frequency circuit technology, in which the performance of the radio frequency circuit determines the quality of the entire equipment, and the anti-interference performance of the radio frequency design circuit directly affects the stability and reliability of the circuit system safety.

In the process of signal transmission, the radio frequency circuit will actually produce obvious electromagnetic interference problems. If the anti-interference design is not paid attention to in the design process of the radio frequency circuit, the whole system will be unable to work in the later stage [3]. As far as the radio frequency circuit itself is concerned, it does not have a strong anti-interference ability. At the same time, if different radio frequency circuits operate in the same environment, there will be signal interference problems between them. Therefore, an appropriate method must be adopted to reasonably suppress the electromagnetic interference of the radio frequency circuit, so as to ensure the high quality of the signal capability to achieve the purpose of transmission.

In radio frequency circuits, electromagnetic compatibility performance is one of the important circuit performance evaluation indicators. The smaller the wavelength and the higher the frequency, the easier it is to generate corresponding electromagnetic interference. It is necessary to solve the electromagnetic compatibility problem of the circuit, but the electromagnetic compatibility design may conflict with the heat dissipation design. While ensuring other performances, improve the electromagnetic compatibility of the device. Compatibility, which puts forward higher requirements for electromagnetic compatibility design of RF circuits, structures, cables, etc. [4]. Therefore, this paper studies the methods and measures to improve the electromagnetic compatibility of radio frequency circuits, aiming at the causes of electromagnetic interference in radio frequency circuits and anti-interference measures..

2. EMI and EMC Literature Analysis

At present, many scholars are conducting research on electromagnetic interference and electromagnetic compatibility of radio frequency circuits. In order to further improve the economic benefits of products, in the research and development of radio frequency circuits, the most critical technology is to reduce the electromagnetic interference received by the system and avoid the mixing of interfering signals with the signals that the radio frequency circuit needs to receive and process. The usage of anti-interference design mainly includes the following aspects, shielding design, circuit grounding design, and wiring design [5-8].

However, the difference is that in the above design of [5], the unit circuits are grouped according to their different degrees of sensitivity to electromagnetic compatibility in use, and the components of the parts that are susceptible to interference in the circuit should be avoided as much as possible in the layout. Turn on EMI. In addition to the above common design, in [6], in order to improve the electromagnetic compatibility performance of the radio frequency circuit, the structure of the circuit is improved to realize the suppression of electromagnetic interference in the radio frequency circuit. Ref. [7] uses the layout of components to design according to the principles of physical partition and electrical partition to achieve the suppression of electromagnetic interference. Ref. [8] adds a differential mode choke coil or a parallel capacitor-inductor filter between the signal line and the power line in the design of the RF circuit to reduce noise.

By analyzing the different suppression methods of electromagnetic interference and electromagnetic compatibility in the literature, it can be concluded that comprehensive measures must be taken from EMC suppression, filter design, shielding design and grounding design to effectively suppress electromagnetic interference.

3. RF Circuit EMI and EMC Analysis

3.1 Overview of EMI and EMC principles

3.1.1 EMI principle

Electromagnetic interference (EMI) specifically refers to the reduction of functional performance indicators of electromagnetically sensitive equipment under the condition of electromagnetic interference, which in turn affects the normal use of the equipment [9]. In this case, it is easy to cause the reliability of the equipment to decline, resulting in abnormal system functions and failure of functions. Therefore, in the application process of electromagnetic sensitive equipment, electromagnetic interference suppression and protection must be done well. Through the analysis of electromagnetic interference, an effective suppression mechanism is adapted to form an EMI suppression standard to ensure the normal operation of the system. At present, relevant international organizations have formulated electromagnetic compatibility standards and spectrum allocation specifications, which stipulate the limit value of electromagnetic interference emission and require limit the electromagnetic interference emitted by equipment. From the perspective of the electromagnetic interference mechanism, its three elements include the source of electromagnetic

interference, the coupling path of interference transmission, and the sensitive equipment affected by interference.

3.1.2 EMC principle

Electromagnetic compatibility (EMC) mainly studies the operation mechanism of multiple devices in the same electromagnetic environment, and the devices are not interfered by other devices and will not interfere with other devices at the same time [10]. Combined with the content of electromagnetic interference, EMC specifically means that sensitive equipment is not allowed to cause or be affected by other electromagnetic emission equipment in the same electromagnetic environment during electromagnetic emission, resulting in performance degradation. To achieve the goal of electromagnetic compatibility, it is necessary to analyze the three elements of electromagnetic interference.

3.2 Electromagnetic Interference Analysis

From the perspective of the three elements of electromagnetic interference, to effectively suppress electromagnetic interference, it is necessary to suppress the interference source, weaken the coupling path of the interference signal, and enhance the anti-interference ability of the equipment [11]. Specifically, it is necessary to have a good power plane and ground reference plane, reasonably layer the signal, do a good job of wiring, and reduce the interference signal that the sensitive equipment may receive by taking measures such as erecting a metal shield and isolating strong interference sources. Through the comprehensive application of the above-mentioned technologies, the anti-interference ability of the equipment is improved, and a good public electromagnetic environment is created. In addition, in the process of RF circuit product design, it is also necessary to carry out electromagnetic compatibility simulation analysis and signal integrity analysis to clarify the possibility of electromagnetic interference problems, and to suppress them from the source to improve the electromagnetic compatibility of products. The analysis of electromagnetic interference is the primary work to solve the electromagnetic interference of radio frequency circuits. The frequency of the radio frequency circuit is generally above 300MHz, and the electromagnetic radiation ability is strong. The interference signal can be regarded as a radiation field, which can be transmitted through a medium such as air, affecting the interfered circuit. The radio frequency circuit itself is a device with strong interference ability and weak anti-interference ability, and necessary electromagnetic interference suppression measures need to be taken.

3.3 RF Circuit EMI Suppression Requirements

In the process of signal transmission in RF circuits, electromagnetic interference (EMI) problems are prone to occur. Combining the three elements of EMI, in order to achieve the goal of EMI suppression, the following aspects must be clarified:

(1) Analyzed from the perspective of the interference source, the radio frequency circuit is usually in a higher frequency band, so there will be high-frequency components in it, and then there will be a more obvious space radiation capability.

(2) Analyzed at the level of path coupling. During the operation of the radio frequency circuit, the EMI problems generated by it are basically completed by means of electromagnetic fields, magnetic fields, and electric fields.

(3) From the perspective of protecting sensitive equipment, the RF circuit contains many devices with sensitive characteristics, such as voltage-controlled oscillators, mixers, RF amplifiers, etc., so EMI problems will occur and affect the quality of signal transmission.

Combining the analysis of the above three aspects, it can be determined that the EMI problem in the radio frequency circuit is the most common and obvious phenomenon, and technical methods such as EMC must be applied in it, so as to effectively avoid the EMI problem in the radio frequency circuit.

4. RF Circuit EMI Suppression and Application of EMC

Electromagnetic interference source, interference propagation path and sensitive equipment are called three elements of electromagnetic interference. To prevent it from forming electromagnetic interference, it is necessary to weaken the interference source, suppress the interference propagation path, and reduce the sensitivity of the receptors [12]. The radio frequency circuit board includes a transmitting circuit area, a receiving circuit area, and a frequency source circuit. In the transmitting circuit area, there is a high-power, large-signal amplifier as a source of strong radiation interference, and in the receiving circuit area, a sensitive, small-signal LNA becomes a highly sensitive sensor. Potential electromagnetic interference sources and potential electromagnetic sensitive devices are in the same space, and electromagnetic interference will be generated as long as they pass through the propagation path of electromagnetic interference. The components on the RF circuit board transmit energy through electromagnetic field space radiation and are coupled to the printed circuit board wires, resulting in signal distortion and performance indicators that cannot be achieved. In order to effectively suppress electromagnetic interference, comprehensive measures should be taken in terms of grounding design and other aspects.

4.1 EMC Suppression Method

Combined with the above analysis of EMI in RF circuits, it can be determined that EMI suppression has a strong necessity and urgency. In such a case, relevant personnel can apply EMC, but they need to master the design method of EMC, and then give full play to the role of EMC to achieve the purpose of EMI suppression [13]. Specifically, we can start from the following aspects:

(1) In the process of RF circuit design, in addition to meeting the functional indicators, it is necessary to reduce the high-frequency component of the signal as much as possible, and more practical devices with slower signal slew rate.

(2) Reasonably design the position of PCB high-frequency components, try to stay away from circuits with weak anti-interference ability, and avoid external connectors, cables, and gaps.

(3) Ensure high-speed signal impedance matching and reduce high-frequency reflection and radiation.

(4) Decoupling capacitors are used to prevent the power supply layer and ground layer noise from being suppressed at the power supply pins.

(5) Appropriately divide the stratum to avoid crosstalk radiation from interference signals to sensitive circuits.

(6) Three times the line width should be reserved beside the high-speed wiring, and multiple sets of grounding holes should be set outside the three times line width to provide a return path for high-frequency signals to reduce radiation.

4.2 Shielding suppression method

In terms of shielding design, metal isolation is used between two different spaces to protect their respective areas and prevent EMI from being transmitted from one space to the other through the electromagnetic wave, magnetic field, electric field, etc. [14]. Specifically, appropriate shielding bodies can be used to shield interference sources with interference properties, such as components and radio frequency circuits, so as to ensure the purpose of circuits, protection equipment and prevention of electromagnetic field diffusion, that is, to suppress EMI. In this process, based on the grasp of EMI characteristics, the most appropriate shielding body should be made of metal, mainly because it has the characteristics of strong radiation ability and short wavelength, and the use of low impedance metal materials can effectively absorb electromagnetic waves generated in space. However, it is difficult to avoid problems such as gaps, and signal input and output ports when selecting metal shielding bodies. At this time, a special band electromagnetic sealing gasket should be added to enhance the effectiveness and integrity of the signal shielding structure. In addition, when using the shielding method to suppress EMI, the conductor passing through the shielding body should

also be avoided, otherwise, the effect of the shielding body will be destroyed, and the effectiveness of EMI suppression cannot be guaranteed.

4.3 Grounding suppression method

In the practical design and application of RF circuits, the EMI suppression methods mainly include three categories: grounding design, shielding design, and filtering measures. Among them, the grounding design is specifically to connect the low reference frames of all circuit devices together to obtain a common reference point and keep the circuit level and functional characteristics stable [15]. In the design process of RF printed circuit board, the independent power supply layer and the ground are generally taken as reference planes, which can reduce the impedance of signal return, thereby shortening the return path and controlling the electromagnetic interference. In general, the distance between the power reference plane and the edge of the printed board shall be less than the distance between the ground plane and the edge of the printed board, so as to avoid interference caused by electromagnetic field radiation of the power layer, and at the same time play a shielding role to prevent external electromagnetic interference.

4.4 Filter suppression method

Filter suppression is the best way to achieve EMI suppression in RF circuits [16]. Specifically, the high-order harmonic components in the RF circuit must be suppressed by filtering, and the conducted interference level must be optimized and controlled to achieve the goal of EMI suppression. In the power supply circuit, if the inductance element is used as the filter device, it can only be used in the narrow signal frequency, mainly because the inductance element will have obvious self-excited vibration in the high-frequency band, and the capacitive characteristics are very obvious, so it is difficult to achieve the EMI suppression goal. Therefore, in the process of designing filter suppression, the magnetic beads should be used to effectively eliminate RF noise, and the magnetic beads can only pass-through DC, so as to suppress high-frequency signals and ensure the EMI suppression effect in RF circuits.

5. Conclusion

The anti-interference design of radio frequency circuits is an important link to improving the anti-interference ability of wireless communication equipment. A Radiofrequency circuit board is an indispensable part of wireless communication electronic equipment. Its anti-electromagnetic interference ability is the key to determining whether the electronic equipment can work reliably. Therefore, EMI suppression must be fully considered when designing RF circuits. Through the analysis of the characteristics and suppression mechanism of the electromagnetic interference of the radio frequency circuit, it can provide a reference for the design of the radio frequency circuit. According to the three elements of electromagnetic interference, different suppression measures are comprehensively adopted to ensure the suppression effect of electromagnetic interference. RF circuit design based on electromagnetic compatibility can minimize the mutual interference of RF circuits in the system and ensure the stability and reliability of signal transmission.

References

[1] Peter Eby, International Business Machines Corporation; Researchers Submit Patent Application, "Interposer for ESD, EMI, and EMC", for Approval. Journal of Engineering, 2013,10:15-20.
[2] Mohammed Saleh Al Salameh. Electromagnetic interference and electromagnetic compatibility. Journal of Chemical Engineering & Process Technology, 2021, 12(5) : 21-21.
[3] Shaikh Noah . Hypoglossal Nerve Stimulator Failure from Electromagnetic Interference with Effective Lead Crossover. Ear, nose, & throat journal, 2022, : 140-145.
[4] Liu Haizhou. Leaf-structured Carbon Nanotubes/Graphene Aerogel and the Composites with Polydimethylsiloxane for Electromagnetic Interference Shielding. Materials Letters, 2022, 313-318.

[5] Zhou Yi, Yang Xiaoli, . Research on electromagnetic interference suppression technology of power supply system in electromagnetic compatibility darkroom. Wireless communication technology, 2022,31 (02): 55-58.
[6] LV Lei, Liu Xiaojie, Li Yinan. EMI suppression and EMC of RF circuits. Electronic technology and software engineering, 2019 (04): 81-84.
[7] Cheng Long. EMI suppression and EMC analysis of RF circuits . Electronic world, 2018 (10): 136-140.
[8] Jiang Li. EMI suppression and EMC analysis of RF circuits . Electronic quality, 2018 (02): 68-73.
[9] Wang Yuanchang, Li Xiaolin. EMC and EMI system analysis . Electronic mechanical engineering, 2001 (05): 37-40.
[10] Pushpa Thomas. Electromagnetic interference shielding effectiveness of in situ-synthesized ultrafine SiC- and Al2O3-reinforced AA6061 aluminum matrix composites. Journal of Materials Science: Materials in Electronics, 2022, 33(7) : 3774-3785.
[11] Devi Nishu , Ray Suprakas Sinha. Electromagnetic interference cognizance and potential of advanced polymer composites toward electromagnetic interference shielding: A review. Polymer Engineering & Science, 2022, 62(3) : 591-621.
[12] Chen Yongsheng. Electromagnetic interference shielding and microwave absorption materials: A virtual special issue. Carbon, 2022, 186 : 320-322.
[13] Fang Kai . Detection of weak electromagnetic interference attacks based on fingerprint in IIoT systems. Future Generation Computer Systems, 2021,45(11) : 2929-2935.
[14] Gizatullin Z M , Nuriev M. G. Methodology and Models for Physical Simulation of Electromagnetic Interference on the Example of the Interference-Resistance Analysis of Vehicle Electronic Devices. Journal of Communications Technology and Electronics, 2021, 46(6) : 722-726.
[15] Paś Jacek, Rosiński Adam ,Białek Kamil. A Reliability-Exploitation Analysis of a Static Converter Taking Into Account Electromagnetic Interference. Transport and Telecommunication Journal, 2021, 22(2) : 217-229.
[16] Cai Shichuan, Wang Yu. Application of EMI filter in EMC design of communication power supply . Communication power supply technology, 2018 (01): 9-21.