The Analysis and Countermeasures of Mobile Terminal RE or RSE Problem

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Abstract. Considering the electronic product stability and personal safety, most countries strictly formulate a lot of EMC compulsory certification standards in the field of information technology. However, during the authentication testing of the mobile terminals, the problem of Radiated Emission (RE) or Radiated Spurious Emission (RSE) occurs often and it is usually difficult to be solved. In this paper, reasons that result the RE and RSE problems of mobile terminals are analyzed at first. The architecture of related test system is introduced. A new method to solve the problems is proposed. And then, detailed experimental countermeasures and process are illustrated to solve the problem. Finally, some design guidance for RE/RSE problem is concluded. This paper has shown that our method is an effective way to eliminate or decrease the probability of RE/RSE problem for mobile terminal design.

Keywords: Mobile terminal · RE · RSE · EMC

1 Introduction and Background

It is usually that engineers apply high speed microprocessor in the electronic products, but these digital circuits running in the product will produce strong electromagnetic emission to other circuits of itself or other devices. So it may cause bad stability or failure to pass EMC (Electro Magnetic Compatibility) authentication [1]. In consideration of the electronic product stability and personal safety, most countries formulated a lot of EMC compulsory certification standard in the field of information technology [2, 3].

For mobile communication terminals, EMC tests mainly include: CE (Conducted Emission), RE (Radiated Emission), CSE (Conducted Spurious Emission), RSE (Radiated Spurious Emission), CS (Conducted Susceptibility), RS (Radiated Susceptibility), EFT/B (Electrical Fast Transient Burst), de-sensitivity problem, and etc. In the process of certification test, RE and RSE fail occurs often and it is usually difficult to be solved. It will not affect the stability of the mobile terminal, ignored easily in the early develop stage, but it usually occurs in the product certification test. The mainly reason

This work has been supported by the Discipline of Computer Science and Technology of Shanghai Polytechnic University (Grant No. XXKZD1604).

W. Xu et al. (Eds.): NCCET 2018, CCIS 994, pp. 59–67, 2019.
https://doi.org/10.1007/978-981-13-5919-4_6

for it is insufficient design considerations in early development stage. And it is difficult and time-consuming to be rectified in authentication test stage. Finally, it will affect the market plan of the product at last. So we can conclude that solving and avoiding the RE/RSE problem is very important for the research and development of mobile terminals.

2 Theoretical Analysis

2.1 RE/RSE Analysis

RE (Radiated Emission) test is mainly measure the radiated electromagnetic wave energy of the mobile terminal, which is plugged in the charger. The Chinese standard define that the test frequency range of GSM communication mode is 30 MHz–6 GHz, and the other communication mode tests are 30 MHz–1 GHz, but the European standard is 30 MHz–6 GHz for all modes of mobile phones.

RSE (Radiated Spurious Emission) test is mainly test the radiated energy of harmonic component, non-harmonic components and parasitic components of communication radio wave [4, 5]. The measuring frequency range is 30 MHz–4 GHz, and the test settings and limits are slightly different according to the communication band. The details can be found in the 3GPP test specification.

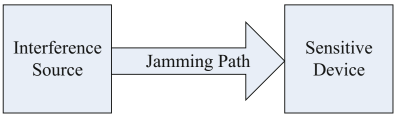

Fig. 1. EMC 3 factors

Both RE test and RSE test are belong to the EMC test. EMC means that in the electromagnetic environment, the equipment can work well, but can't be interfered by other devices, at mean time, it also does not interfere other devices working. The generation of EMC problem is often dealt with from the three factors: interference source, jamming path and risk sensitive device (see Fig. 1). Lack of any one of three factors does not cause an EMC problem, so the solution of the EMC problem can start from these three aspects and only need to deal with one at sometimes. The EMC problem includes two aspects: electromagnetic interference (EMI) and electromagnetic sensitivity (EMS). EMI is the interference to other devices or systems; EMS is the work capability to tolerate other interference [1, 2].

2.2 Test System

RE/RSE authentication test system diagram is showed on the Fig. 2. In addition to software configuration and testing methods, the obvious difference between RE test and RSE test is that the RE test need to plug the charger, but RSE does not need. Taking the test system as a whole, the interference source is the device under test (DUT), the jamming path is space radiation, and the interfered device is the EMC measuring system. Among them, the equipment, measuring antenna and microwave chamber are the standard configuration of the authentication system. Except running abnormally, it cannot be rectified, so solving the RE and RSE problems must be considered from the terminal side. From the jamming path, the interference may be radiated through the communication antenna, and it may be also radiated through the PCB trace or the internal connector line of the terminal or the external charger connector line [6–9].

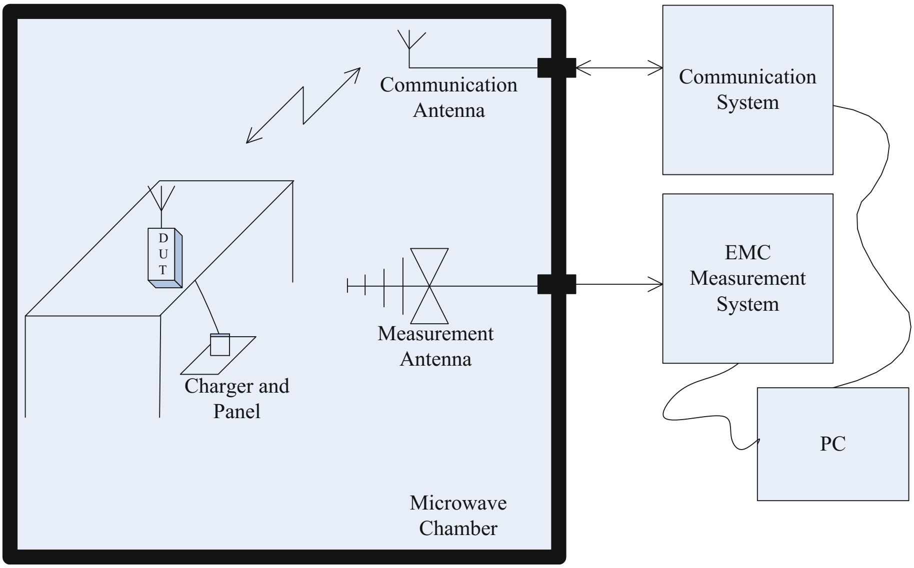

Fig. 2. The RE/RSE certification test system

2.3 Countermeasures

If we could weaken or eliminate any one of the three factors of EMC, the EMC problem cannot be generated. Therefore, the optimization of EMC performance is within these three aspects. The common optimization method of RE/RSE performance is listed as below:

1. Reduce the working voltage, current or power of the interference source.
2. Change the working frequency of the interference source, so that it does not produce interference wave of the corresponding test frequency.
3. The spread spectrum technology which does not affect the source working performance can be applied also.
4. Add resistor, inductor, magnetic bead and common mode inductor between the interference source and the sensitive device, can weaken or block the corresponding interference signal.
5. Add capacitors, RC filter, LC filter, EMI device and special filter, can weaken or block the corresponding interference signal also.

6. On the jamming path, we should strengthen isolation and shielding also, which include shielding cover, shielding box, shielding line, protecting the PCB signal line by use GND shielding [7, 8], and so on.

The means list above, 1–3 is based on weakening interference sources signal, and the 4–6 is the diverting or blocking of EMI signals based on the jamming path.

By the way, the selection of all kinds of EMC elements is also an experience technology. We described briefly two kind of universal elements: magnetic beads and capacitance. For magnetic beads selection, we considered mainly on DC resistance, AC resistance, cut-off frequency and so on (from the specification of the book). For capacitance selection, we considered mainly on the self-resonance frequency.

3 Experimental Analysis and Rectification Process

According to the theoretical analysis of the first section, we know that we find the three factors of EMC interference is the premise for us to identify the root cause and resolve the EMC problem. If we confirmed the interference source and the jamming path of the RE/RSE, the problem could be solved quickly and effectively. Based on some practical experience of analysis and rectification for RE/RSE problem, the following experimental steps are recommended.

Step 1. Judge whether the interference source is a Radio Frequency (RF) circuit or not at first.

At first, we describe the RF circuit and its character that can help us analyze the interference caused by RF circuit as shown in Fig. 3. A RF circuit is normally a nonlinear system, where $y(t)$ is the output, $x(t)$ is the input, the relation of them can be described by the Eq. (1) [10].

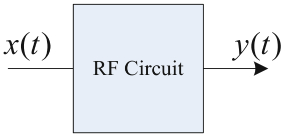

Fig. 3. The RF circuit

$$y(t) = c_1 x(t) + c_2 x^2(t) + c_3 x^3(t) + \ldots \quad (1)$$

Assume $x(t)$ is a sine wave single tone, $x(t) = Acos(\omega t)$, we can get $y(t)$ in the following express.

$$y(t) = \frac{c_2 A^2}{2} + \left(c_1 A + \frac{3c_3 A^3}{4}\right) cos(\omega t) + \frac{c_2 A^2}{2} cos(2\omega t) + \frac{c_3 A^3}{4} cos(3\omega t) + \ldots \quad (2)$$

Assume $x(t)$ is two signal, $x(t) = A_1cos(\omega_1 t) + A_2cos(\omega_2 t)$, we can also get $y(t)$ expression of $cos(m\omega_1 \pm n\omega_2)$, where m, n is the signed integer number [10].

In Eq. (2), $10\ log\left(\frac{c_2A^2}{2}\right) = 20\ log\left(\frac{c_2A}{2}\right)$ and $10\ log\left(\frac{c_3A^3}{4}\right) = 30\ log\left(\frac{c_3A}{4}\right)$. So, if the amplitude of input signal changes λ dB, the harmonic amplitude will change 2λ dB and the third harmonic will change 3λ dB. In the other word, the harmonic signals' amplitude in dB is also multiple of the input signal's amplitude.

Whether the interference is the radiation of the radio frequency circuit or not, can be judged by experience at first. The interference signal below 500 MHz is generally not produced by the radio frequency circuit, but the interference signal which frequency is integer multiple of the communication frequency and its amplitude in dB is also multiple of the useful RF signal, is usually generated by the RF circuit. Of course, there are exceptions, non-harmonic signals may also be generated by RF circuits, such as intra-band and out-band mixing interference which can be described by expression of $cos(m\omega_1 \pm n\omega_2 \pm \cdots)$, side band interference caused by incorrect timing of RF switch (see Fig. 4, RE test results of a GSM900 frequency band). So in addition to experience judgment, it is also necessary to observe the interference signal changing by reducing the power of the terminal or setting to the idle state or even closing the transmit circuit or changing the communication channel.

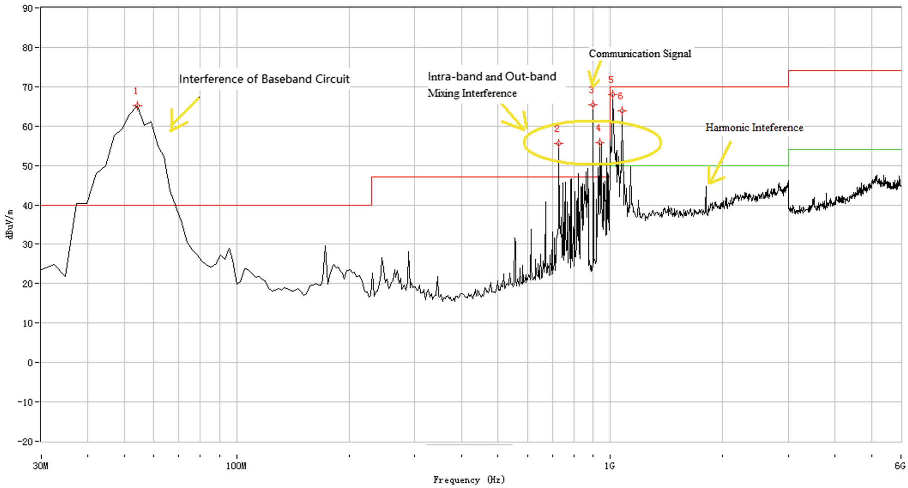

Fig. 4. RE test result of GSM900 band of a telephone

If the interference frequency changes with the communication channel of the terminal, or the amplitude of the interference decreases with the communication power, the interference source can be preliminarily determined by the RF circuit, and then the Step 2 is continued. Conversely, if it does not change due to the change of channel and transmission power, it can be basically determined as interference of other circuits, and we can jump to Step 3.

Step 2. Determinate whether it is the radiation of the communication antenna or not on second.

Whether it is the radiation of antenna or not can be judged by adding attenuator or filter to the interface between communication antenna and RF circuit.

If the power at the interference frequency point is smaller after added the attenuator or filter, it means that the interference is the radiation of the communication antenna [11], so we can jump to Step 5, and conversely, the interference of the RF circuit may be radiated through other circuits, and the Step 3 is continued.

Step 3. Determine which function of the circuit is radiated again.

One by one, remove the functional circuit with the components of the metal lead or plug, in order to determinate which part of the circuit is the interference source. For mobile phones, there is usually charger (RE test), Speaker, Receiver, Microphone, LCD, battery, GPS antenna, Bluetooth antenna, and various interface sockets and so on. For wireless fixed telephones, there is usually charger (RE test), handle, hand-free Microphone, hand-free speaker, LCD, HOOK key, battery and so on. If a component is removed, the RE/RSE problem is solved or the amplitude of interference is reduced, and we can jump to Step 5. If it is not found, continue Step 4.

Step 4. Further locate the interference source on the PCB circuit.

To analyze the problem continually, we need to localize the interference source on PCB with near-field RF probe and spectrum analyzer. The common interference circuits are DC/DC circuits, all kinds of circuit power supplies, amplifier circuits, clocks, DSP, audio and other analog circuits and high-speed circuits. In the shielding room, after the mobile terminal powered on and communicated, we can use the magnetic field probe to detect the strong interference area, and then use the electric field probe to find the strong interference position, record the result, go to Step 5.

Step 5. Further test to determine the root interference source.

According to the previous analysis results, after dealing with it, we continue do the RE/RSE test.

If the antenna is judged to be radiated source by the Step 2, it is necessary to continue to check the metal parts near the antenna in the shell (remove or add the absorbing material for the test). After eliminating the interference of the structure, we need to solve the problem from the RF circuit.

If in Step 3, 4, we judged that a functional circuit is the source, we can add filters (series magnetic bead and shunt capacitance etc.) or shielding scheme (using copper skin for wrapping) according to the interference frequency point. If the solution is not clear the problem thoroughly, after added the strongest weak interference means, we can jump to Step 4 to continue to find the root interference sources and other strong interference sources. Because it is undeniable that sometimes there are more than one interference sources or more than one jamming path.

Step 6. Rectification on the interference source or the jamming path.

Based on the experiment bellow, we can basically identify the source of interference or the jamming path, and use the common method mentioned in the second section to continue the experiment to solve the RE/RSE problem directly.

Different interference sources or jamming paths will bring different corrective means. The processing of various situations is listed as follows:

Case One. If the interference signal is radiated by the antenna and reflected by the structure, we can deal with the structural parts, such as attaching wave absorbing material, removing metal coating, and grounding [11].
Case Two. If the interference signal is radiated by the antenna, but not reflected by the structure, we can do conducted spurious emission test at first. If the margin to limit of spurious emission is not enough, we can adjust the PA output matching circuit, RF parameters, RF filter or filter to the RF power supply, and replaced with better spurious performance elements. If the margin is sufficient and the interference frequency is far away from the working frequency, we can add the filter to the antenna port, and change the antenna shape, and adjust its matching circuit when it is just a little over the limit. Of course, when the transmitting power is high enough, it can also reduce power properly, but that must be kept enough margins for the 3GPP test speciation.
Case Three. If the interference signal is radiated by the functional circuits, we can shield it by add grounding shielding, series inductor/magnetic bead/EMI filter, magnetic ring and shunt capacitor.
Case Four. If the interference signal is directly radiated by the circuit on the PCB, we can add a copper skin shielding, a series of inductors/magnetic beads, and a shunt capacitor, or reduce the interference power, or change the working frequency through software (such as reducing the working voltage, using the spread frequency technology, etc.) [6–9].

When we selected one of all the above means, the productivity and cost of the production should be considered, so that the products can be authenticated at the same time without losing their competitiveness.

4 Design Considerations for RE/RSE

After completed RE/RSE problem analysis and rectification, we need to consider how to rectify it in mass production. Although there are various countermeasures for improvement, time consumption is often unavoidable. For example, we should modify the PCB in order to add the series inductor, the shunt capacitance, and the EMI filter. In the same way, if the structure component causes the problem, it is not only possible to modify the PCB, but also possible to redesign the structure mold. And so on, we will take a fixed time cycle using all these countermeasures to deal with the problems, so it will delay the time to market of products and even lose valuable orders. Therefore, we should pay more attention to the matters improving RE/RSE performance in design. Some design recommendations for RE/RSE could be list as following:

- In the early design time, it is the first thing that we place the antenna and the functional components, and reduce interference between each other as much as possible, and ensure good grounding design of the metal structure.
- For using the component with metal lead, we can add EMI compatible circuit design to the interface on the PCB, and string the magnetic ring to the component leads line. We can use EMI compatible circuit such as stringing the resistor and

shunting the capacitor on the hook key, stringing the EMI device to the LCD, stringing the magnetic beads and shunting the capacitor to the audio interface, adding magnetic rings to the charger line and the USB line, etc. [12].

- Recommend to weaken the mutual interference by placing far away from each other between high speed digital circuits, analog circuits and RF circuits [13].
- Adding the shielding box around the strong interference circuit or the sensitive circuit is also recommended.
- Choosing the suitable element of better performance in harmonics emission and spurious suppression (PA, duplexer).
- Optimized the trace and adding the filter to the chip power supply, especially the RF power, is recommend [6, 8, 13].
- Branching the baseband circuit and RF circuit power in the root source on the PCB trace line [9], and adding series bead, is recommend also.
- Minimizing the current loop of power supply is also a good mean.
- Adding the matching resistance (22 Ω to 51 Ω) on the output end of high speed signal bus, clock signal and so on, is also necessary sometimes. And the NC (Not Connected) bypass capacitor can be added in design also, which can be normally changed to several pF to 10 uF if need.
- The clock line, RF line and other sensitive lines on the top or bottom of the PCB, maybe act as the antenna of interference signal. So we should shield them by adding ground wire or plane around them.
- Due to space constraints, if the strong interference signal line or sensitive line cannot be wrapped by grounding, we can layout them as far as possible to the other lines and keep them unparallel. If it is impossible to avoid, we need comply with the 3W principle.
- Paving copper plane on the periphery of the board and connect it to GND net, can reduce unnecessary radiation.

5 Conclusions

This paper describes and analyzes the generation mechanism of RE and RSE problems of mobile terminals at first. And then detailed experimental countermeasures and process is given to solve the problems. Finally, some design guidance for the RE/RSE problem is concluded. This paper provides a method for solving the RE/RSE problem of mobile terminals, so that we can avoid the problem as much as possible in the design, and can solve these problems in an effective way during the certification testing.

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