



Study on EMC Influence of Zhu Rong Rover UHF Band Communication System

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Abstract. As a complex communication system, the rover has multi-band communication, and very low signal-to-noise ratio (SNR) communication puts forward high requirements on electromagnetic compatibility (EMC). In this paper, the influence of the wireless radiation in the UHF band transceiver on the receiving link is analyzed theoretically, including interference source research, interference path analysis and anti-interference ability improvement research. At the same time, a feasible engineering solution is proposed, and the experimental verification is completed, which provides a solution to the electromagnetic compatibility (EMC) problem of high-sensitivity complex communication in the future.

Keywords: Electromagnetic compatibility (EMC) · Wireless radiation · High sensitivity · Anti-interference improvement

1 Introduction

As a complex communication system, the rover has multi-band communication, including UHF band relay communication, X-band relay communication and X-band ground communication, etc. At the same time, it also has different frequency band detection radar and complex power conversion. As a result, the electromagnetic compatibility of multi-system communication is highly required by the rover. In the aspect of T&C subsystem, in order to be applied in the field of deep space exploration, both UHF relay communication and X-band communication are in a very low signal-to-noise ratio (SNR) communication state. Unnecessary radiation interference will seriously affect the communication ability of each band system and reduce the communication margin.

The UHF transceiver is one of the components of the core communication link of Mars exploration. The main function of the transceiver is to provide the radio frequency channel between the surround and the landing rover, establish the relay communication link, and complete the autonomous link construction between the two devices-2. The UHF link adopts PCM (Bi-Phase-L)-PM modulation and demodulation mode. There is a strong carrier component in the PM signal spectrum, and the carrier synchronization and tracking of the receiver can be realized by extracting the carrier component. This

modulation method has low anti-interference ability. When the interference signal enters the carrier locking frequency range, the carrier false lock will be generated, which affects the normal acquisition and tracking, and deteriorates the demodulation sensitivity of the UHF link. The following Table 1 gives the parameters and characteristics of UHF transceiver.

Table 1. The parameters and characteristics of UHF transceiver

Parameter	Value
Protocol	CCSDS Proximity-1
Architecture	Software radio
Mode	Full-duplex operations modes
Mass	4.0 kg
Noise Figure	3.5 dB (Full-duplex)
DC Power	58 W (Full-duplex)
Frequency Bands	390–405 MHz; 435–450 MHz
Symbol Rates	1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048 ksp/s
Coding	K = 7, 1/2 convolutional
Interfaces	1553B for Monitor & Control; LVDS for High-Speed Data

Through the whole device wireless test, the presence of wireless electromagnetic radiation in the UHF transceiver leads to carrier mislocking in a certain channel, resulting in interference and affecting the normal function implementation. In this paper, the influence of wireless leakage in UHF band transceivers on the receiving link is analyzed theoretically and effective solutions are proposed.

2 Mechanism of Electromagnetic Radiation Interference

Radiation interference is the radiation signal produced by two equivalent antennas inside electronic products:

1) the first is a equivalent antenna signal loop, the loop is equivalent antenna radiation, the radiation source is flowing in the loop of the current signal (the current signals is usually normal work, it is a sign of a differentia mode), as shown in Fig. 1, if the loop flow in the area of S loop current strength is I, the frequency signal for F, is in free space, In free space, the radiation intensity at the distance D from the loop is:

$$E = 1.3 SIF^2 / D \tag{1}$$

where: E is the electric field intensity (unit: $\mu v/m$); S is the area of the loop in cm^2 ; I is the current intensity in A; F is the signal frequency in MHz; D is the distance in m.

If the signal is alternating, the loop where the signal is located will generate radiation. When the current size and frequency of the product signal are determined, the

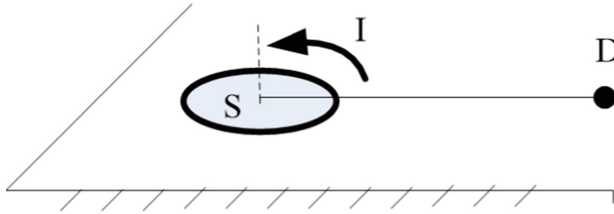


Fig. 1. Loop equivalent radiation antenna

radiation intensity generated by the signal loop is related to the area of the loop. Therefore, controlling the area of the signal loop can effectively control the EMC radiation interference.

2) Another equivalent antenna model or dipole antenna is a monopole antenna (as shown in Fig. 2), the equivalent of the antenna of cable conductor is usually a product or other long conductor size, the source of radiation is the long conductor size cable or other equivalent antenna in the flow of common-mode current signal, it is usually not cable or work long size conductor of the useful signal, Rather, it is a parasitic “useless” signal. Controlling the size of the common-mode current that produces common-mode radiation is the key to suppress radiation emission.

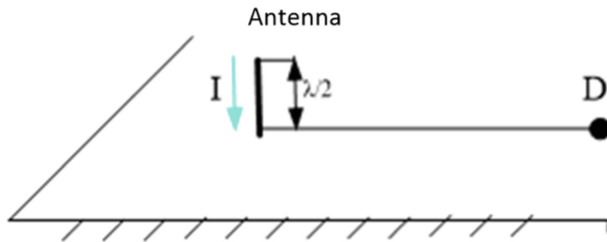


Fig. 2. Conductor equivalent radiating antenna

If a signal with current I and frequency F flows through the antenna, then the radiation intensity generated at distance D from the antenna is:

When $F \geq 30$ MHz, $D \geq 1$ m and $L < \lambda/2$: $E \approx 0.63ILF/D$

When $L \geq \lambda/2$: $E \approx 60 \cdot I/D$

Where: E is the electric field intensity (unit: $\mu\text{V/m}$); I is the current intensity (unit: A); F is the signal frequency in MHz; D is distance, in m; L is the length of the cable in m.

In electronic products, in addition to product features the information expressed by the circuit principle diagram, there are more unknown information, such as the signal lines and parasitic capacitance and parasitic inductance between signal lines, signal lines, with reference to the parasitic capacitance, between the signal wire lead inductance and so on, these parameters are frequency-dependent parameters, and the value is smaller, in the case of dc or low frequency, Usually negligible, but in the high frequency range considered by radiation emission, these parameters will have an increasingly important

impact. Is the reason makes these parasitic in the equivalent antenna in the product with A kind of common-mode current expectations, its current strength is very small or below level (usually in mA μ A level), but it is the product of the main causes of radiated interference, can be seen from the type, when the product in the equivalent antenna is greater than the length of the signal in the frequency of $1/2$, The radiation intensity generated by the antenna is only related to the common mode current on the antenna.

Through a lot of practice, it is proved that the radiation interference problem in most products is caused by the equivalent monopole antenna or dipole antenna in the product. Especially with the application of multilayer PCB technology, the signal loop area is controlled to be smaller and smaller, and the radiation generated by the normal working signal loop is more and more limited. On the contrary, the radiation interference generated by the equivalent monopole antenna becomes more and more important for EMC interference as the product becomes more and more complicated.

3 Analysis of EMC Impact Measures

EMC interference radiation control measures mainly involve three aspects: reduce the interference intensity generated by the interference source, cut off the interference signal propagation path, and improve the interference ability of the interfered object.

3.1 Interference Source Analysis

Any signal can establish its relationship between time domain and frequency domain by Fourier transform, as shown in the following equation:

$$H(f) = \int_0^T x(t)e^{-j2\pi ft} dt \quad (2)$$

where $x(t)$ is the time-domain waveform function of the signal, $H(f)$ is the frequency function of the signal, $2\pi ft = \omega$, ω is the angular frequency, f and is the frequency. Digital signals in products are mostly trapezoidal impulse functions (rising along time t), pulse width is t), and its spectrum analysis diagram is shown in Fig. 3, which contains two turning points, one is $1/\pi t$, the other is $1/\pi t_r$. The low end of the spectrum is constant, decreasing at -20 dB/10 octave after the first turning point and -40 dB/10 octave after the second turning point. Therefore, in circuit design, under the condition of ensuring the normal function of logic, increase the rise time and fall time as much as possible, which is helpful to reduce the high-frequency noise. However, because of the existence of the first turning point, those periodic signals with very steep rise edge and low frequency will not have high harmonic noise of higher level.

Because the spectrum of each sampling segment is the same, the spectrum of periodic signal is discrete, but it is characterized by high intensity at each frequency point, which is usually called narrowband interference. And aperiodic signal, because the spectrum of each sampling segment is not the same, so its spectrum is very wide, and the emphasis is weak, usually called broadband noise. In the general system, the clock signal is a periodic signal, and the data line and address line are usually aperiodic signals, so the cause of the system radiation emission exceeds the standard is usually the clock signal.

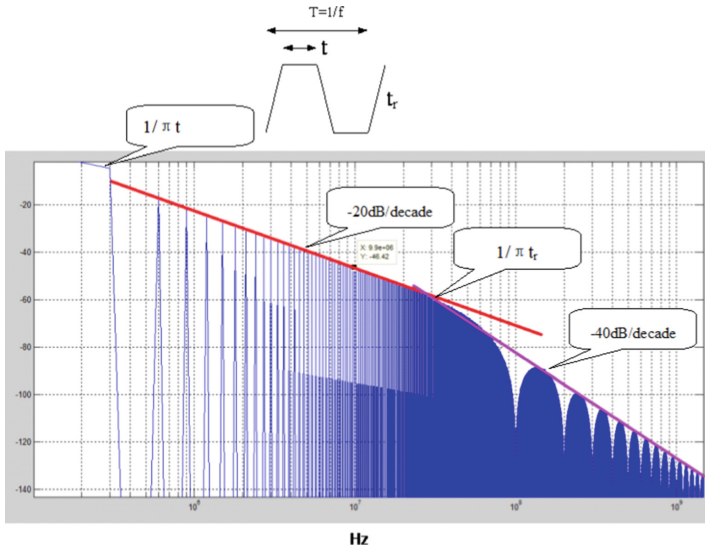


Fig. 3. Spectrum diagram of trapezoidal impulse function

According to the calculation, the main interference sources of the UHF transceiver are: the fundamental frequency signals and related harmonic components generated by the baseband digital clock circuit, the clock signals and harmonic components generated by the FPGA internal DCM core frequency division and frequency multiplication, the IF signals and harmonic components of DA output, and the IF frequency and harmonic components of AD output. In addition, there are many nonlinear devices in the digital circuit of UHF band transceiver, which will lead to useful signal and useful signal, useful signal and useless signal, useless signal and useless signal mixing frequency, and produce more useless frequency components. Multistage frequency components are mixed to form intermodulated frequencies, including frequencies of 43X.XX MHz, which are radiated out by radiation path, and enter the receiver system by receiving antenna through wireless transmission, resulting in false lock of channel 2 and affecting the normal function.

3.2 Interference Path Analysis

The interference path of radiation leakage ultimately affects the receiver system. By comparison, the receiver has no such interference state in the wired case. Meanwhile, based on the detection of radiation intensity, the intensity of radiation interference is mainly concentrated in the front end of the rover, and there is a cable outlet hole nearby, and the UHF antenna is also concentrated in this area, as shown in Fig. 4 and Fig. 5. After verification and comparison, EMC radiation leakage has the following characteristics:

- 1) The strongest radiation is concentrated in the cable exit hatch;
- 2) Through the wireless path coupling into the UHF band antenna, and then affect the receiver;

3) EMC radiation leakage is correlated with the on-off state of a single machine.

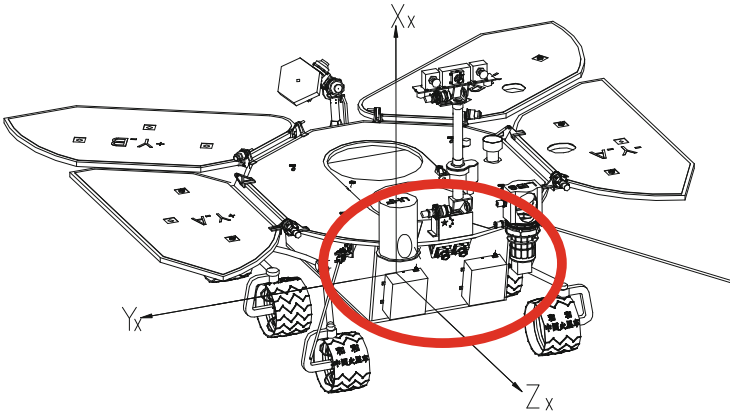


Fig. 4. Position of the strongest UHF interference signal of the rover

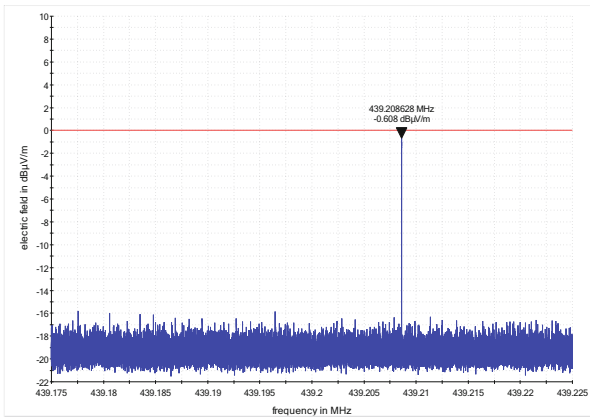


Fig. 5. Spectrum of radiation interference

After investigation, multi-signal crossover is found in the internal cables of the low-frequency electrical connector of the transceiver. Harmonics exist between the data and the clock, and intermodulation occurs in the frequency domain, generating intermodulation signal. The intermodulation radiates through the low-frequency connection cable, forming a strong radiation source, resulting in overerror of RE102.

4 Improvement of Anti-interference Ability

1) Interference path optimization

EMC interference signals are mainly caused by external low-frequency cable radiation. After verification, the interference channels can be reduced by strengthening cable

shielding. The EMC radiation can be effectively suppressed by fully shielding the connection lines of single machine and multiple tubes, as shown in Fig. 6. After the test verification, the radiation interference has been significantly reduced. The signal leakage decreases by more than 10 dB, which can meet the requirements of the communication system. The EMC test results are shown in Fig. 7.

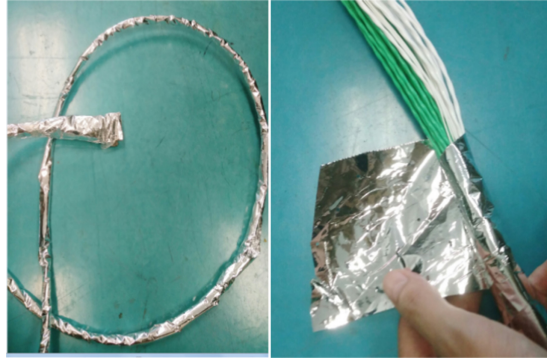


Fig. 6. Cable optimization diagram

2) Communication system optimization

Radiation leakage caused the receiver performance degradation problem, exposed a number of weak points of the communication system, including:

- a) It is susceptible to interference clutter under high sensitivity conditions;
- b) After mis-trapping, it cannot exit effectively and has poor anti-interference.
- c) Useful signal and interference signal can not be effectively distinguished.

In UHF band communication, the channel is mislocked due to interference clutter. The interference signal is less than the required threshold and within the receiver margin. Because there is no exit mechanism in UHF band communication, useful signals cannot be captured and tracked normally in the process of mislocking. At this time, the useful signal is larger than the interference signal.

In terms of system optimization, the joint decision mechanism is added, and the communication exit mechanism is introduced to improve the communication reliability of the system. The joint decision of carrier lock tracking and bit synchronization lock tracking can set a good decision timeout time. After the timeout, the acquisition and tracking process is re-initiated.

Based on the CCSDS protocol, the standard protocol of single carrier + idle sequence + information + tail sequence is followed in the normal communication process of UHF (see Fig. 8). In this framework, the timeout recapture protocol is introduced. Through simulation, test and joint trial, it is verified that this mechanism has no impact on normal communication. This measure effectively improves the reliability of communication system and strengthens the anti-interference ability of Mars relay system.

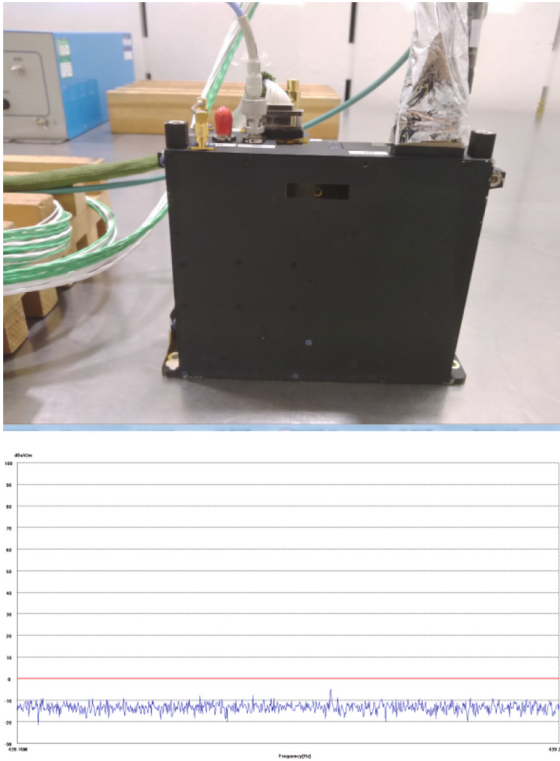


Fig. 7. Radiation diagram of EMC after optimization

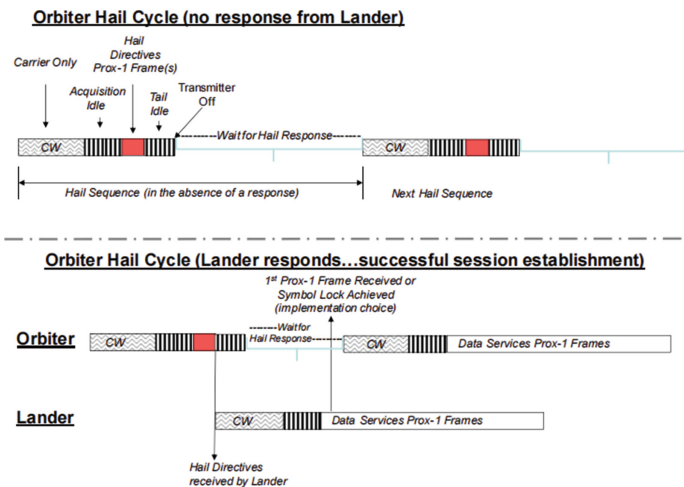


Fig. 8. Diagram of the communication process

5 Conclusion

In this paper, the radiation interference problems encountered in the Mars UHF band communication link are analyzed, and effective measures are proposed.

1. Optimizing the interference source, cutting off the interference signal propagation path: Cable optimization;
2. Improving the anti-interference ability, etc., to minimize the impact of EMC: The timeout recapture protocol is introduced.
3. Through analysis and test, the modification of measures can effectively reduce the impact of radiation interference, and improve the anti-interference ability of UHF band communication system. At the same time, the improved measure can provide data support and application method accumulation for the subsequent design of wireless systems.

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