PIM Interference Testing Methods of Satellite Communication Components and Setting up of the testing system

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Abstract

The PIM(passive intermodulation) interference testing methods of satellite communication components was discussed in this article. According requirements and characteristics of satellite communication components, main indexes of signal separation devices were given to design a PIM interference testing system. Based on indexes and low PIM crafts and technologies, main devices were produced and the testing system was setting up. After calibration the system achieved the goal of design with an experiment.

1. Introduction

The phenomenon of intermodulation generated by passive components was generally called passive intermodulation (PIM)[1], which becomes important interference to high power multiple channels communication with the continuous developments of satellite communication systems. The PIM phenomenon had been identified caused by ferromagnetic nonlinearity and contact nonlinearity after 40 years of research, but PIM interference (PIMI) remains a problem in many communication systems, especially in satellite components such as antennas.

2. Testing Methods of Satellite Communication Components

2.1 The definition of PIM

PIM is caused by two or more RF carriers mixed in passive components such as connectors, antennas and cables. The non-linear characteristic of components will make this happen while ideal linear ones will not. In order to further illustrate the properties of PIMI, an example is given as follow.

Frequencies of two tone signals are expressed as f1 and f2, then the possible frequencies of PIMI can be described by Equation (1) no matter the nonlinear model[2,3].

$$fIM = |mf1 \pm nf2|. \quad (1)$$

In the formula, m and n are positive integrals, and m+n is the order of PIMI. Usually the even-order interferences won't fall in the receiver bandwidth, but the odd ones will. The diagram of frequency spectrums of even-order interferences is shown as Figure 1. PIMI testing system generally tests the order of 3rd, 5th, 7th and 9th, for satellite communication systems that will test the 17th and higher ones.

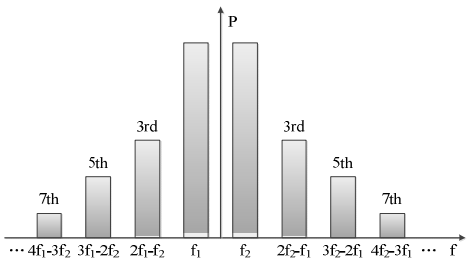

Fig.1 The diagram of frequency spectrums of even-order products

2.2 Testing Methods of Satellite Communication Components

Some passive components such as connecter are appropriate using reflection test method, which is as follow.

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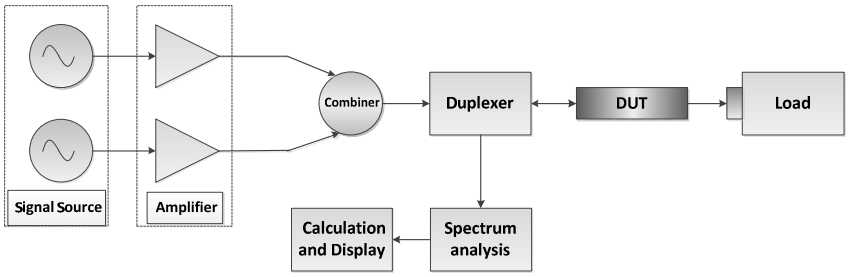

Fig.2 The reflection PIMI testing method

The others especially antennas must be tested by different ways, with auxiliary antennas in anechoic chamber. Polarized antenna must be tested by a kind of transmitting way, which was shown in the figure 3th.

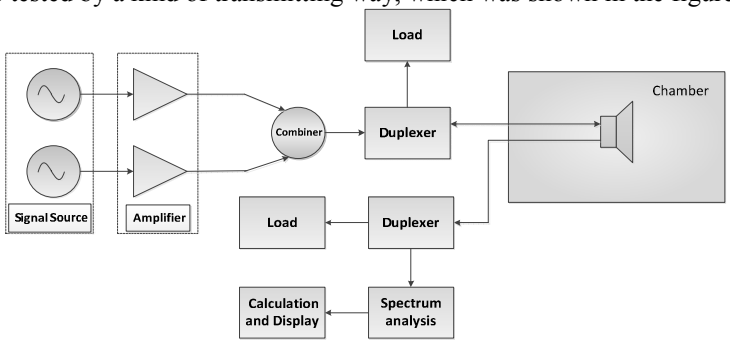

Fig.3 The polarized antenna PIMI testing method

For mesh antenna, extra low PIM antennas were necessary. A mesh antenna was shown in the figure 4th, and the testing method was shown in the figure 5th.

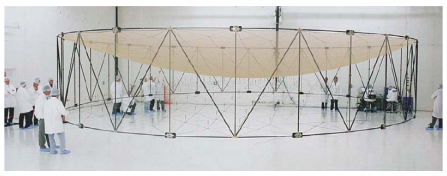

Fig.4 A mesh antenna of AstroMesh

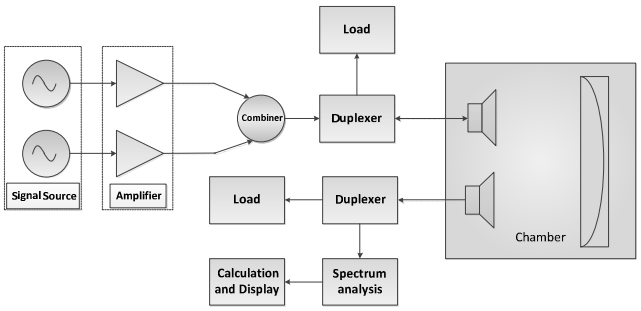

Fig.5 The testing method of A mesh antenna

3. Low-PIM crafts and the testing system design

For the figure 2, figure 3 and figure 5, it could be seen that the system be composed of a spectrum analyzer, two signal sources, two amplifiers, and a signal separation device. The device comprised two duplexers, a combiner, which as the same as the load, cables and connectors needed low residual PIMIs besides conventional electrical characteristics. Therefore low-PIM crafts should be the most important craft for PIMI testing system. In general, in order to guarantee the PIM characteristics, basic processes of all referred devices are as follow.

3.1 Low-PIM crafts

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At first the ferromagnetic nonlinear can be caused by ferromagnetic material devices, so nonmagnetic brass is widely used for low-PIM devices. Brand of foreign material is C36000 which is better than domestic nonmagnetic brass for containing less iron, while brands of HPb69-1 and 3602 are not suitable for PIMI testing system.

Second, silver is selected for plating with appropriate thickness, of which the standard present is 5.08μm. Figure 6 is a high-powered energy spectrum analyzer and the analysis report of a connecter with 3rd PIM being -168dBc. From the report, it is sure that surface of the connector is silver nearly one hundred percent. Gold plating is not adopted for cost. Its biggest advantage is easier to store than silver one. Ternary alloy by cuprum(Cu), tin(Sn) and zinc(Zn) is not

adopt either for better performance. Because nickel is ferromagnetic material, cuprum instead of nickel is used or plating base.

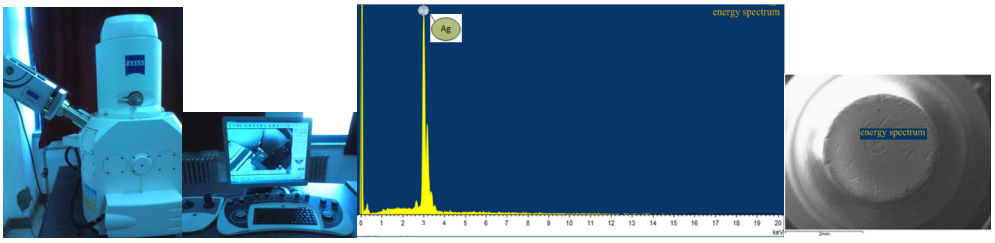
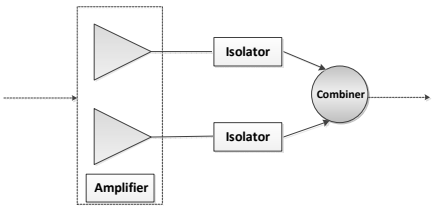


Fig.6 The high-powered energy spectrum analyzer and a report of a connecter (3rd PIMI is-168dBc)

The above are the basic processes for producing or selecting devices of a PIMI testing system, in addition the welding, the assembly, and other processes are also very important, but those are not the focus of this article. The focus should be crafts for system setting up, so devices of a system will be introduced separately.

3.2 The combiner of the signal separation device

The role of the combiner is mixing the two-way signals to produce the required two-tone signal. It should produce PIMIs and leak active IM interferences as small as possible, which will fall into the receiver. A method is given to solve this problem: add isolators between the combiner and amplifiers to avoid active IM by amplifiers. Isolators locate as figure 7.



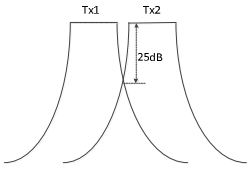


Fig.7 The extra isolators to prevent active intermodulation Fig.8 The filter of the combiner

Because isolators are ferromagnetic devices, two paths of the combiner have to maintain certain isolation by the combiner. And this will improve another matter: second-harmonic generation. The second harmonic of a signal will modulate with the other signal, and the even interferences will fall in testing pass-band. The isolation is more than 25dB, which is an empirical value. And the isolation and isolators are integral. Figure 8 is the filter pass-band of the combiner, in which T means through.

3.3 The diplexer of the signal separation device

An example is given to explain their design process. The design goal of PIMI testing system was to make the 3th residual PIM be less than -165dBc.We used AV4036A spectrum analyzer. The typical value of 3rd PIMI of the analyzer is less than -88dBc @ 2 x -30dBm (The receiver level). Generally, if the receiver level is 1dB bigger, the 3rd PIMI will be about 3dB bigger. Set the mutual inhibition of the diplexer is X dBc, and then the 3rd PIM could be expressed as

$$PIM3 \approx (-30-88-43)+3[(43-X)+30]. \quad (3)$$

If the residual PIM being less than -165dBc, the mutual inhibition should be less than 74.33dB. 75dB was chose at the end. Figure 9 is the filter pass-band of the diplexer, in which R means reflection.

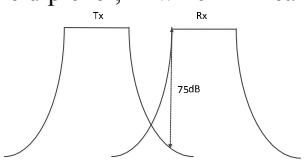


Fig.9 The filter of the duplexer

3.4 System setting up and testing

Based on above analysis, a PIMI testing system was setting up with goal of 3th PIMI being less than -165dBc. Two signal sources were AV1442A; amplifiers were AV3810E; the spectrum analyzer was AV4036A. The subsystem

contained a combiner and a diplexer, which could achieve reflection or transmission PIM testing. System connection method is shown as figure 10, and the principle prototype is shown as figure 11.

After calibration using a power meter, the principle prototype could realize reflect test and transmission test. the swept frequency and the power also could control by GPIB port. Set the working frequency is fL ~ fH and bandwidth is W, then filter band-passes of the combiner and the diplexer shown in figure 8 and figure 9 were as follow.

$$\text{Tx1: } f_L \sim (f_L + f_H)/2 - \Delta; \quad \text{Tx2: } (f_L + f_H)/2 + \Delta \sim f_H; \quad \text{Tx: } f_L \sim f_H. \tag{4}$$

The 3rd PIM would fall in

$$[f_L - \mathrm{W}, f_L + \mathrm{W}/2\text{-}\Delta) \cup (f_H\text{-}\mathrm{W}/2\text{+}\Delta, f_H + \mathrm{W}]. \tag{5}$$

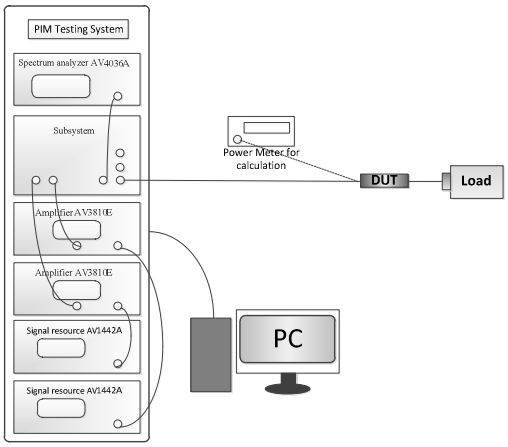


Fig.10 The setting up of PIM testing system

Fig.11 A picture of principle prototype

So the Rx could be chosen from above band. Figure 12 is testing result of a -153dBc standard, and figure 13 is the result of testing a -171dBc load. It could be seen from the figure 10th that the curve was smooth and the value was about -110dBm (-110-43=-153dBc), so the system satisfied the requirement of uncertainty. Adding the result of figure 13, the residual PIM of the system was less than -166.7dBc which met the design standard.

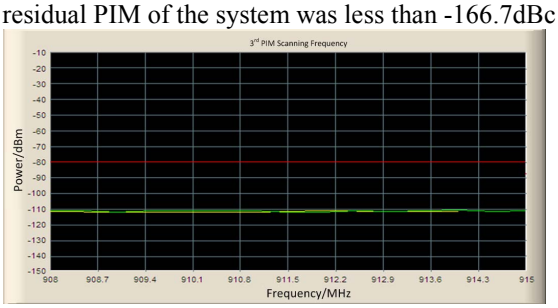


Fig.12 Result of testing standard

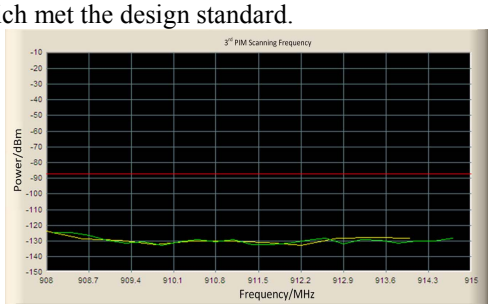


Fig.13 Result of testing the 3rd residual PIM

4. Conclusion

Using un-ferromagnetic materials and silvering certain thickness for most of devices, adding two isolators between amplifiers and combiner, setting appropriate filters of combiner and diplexer, reducing the minimum connectors. With those processing a PIMI testing system was setting up for Satellite Communication Components, whose 3th residual PIM was -166.7dBc, which achieved the design goal.

6. References

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