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정지궤도위성용 L대역변환반의 PCB EM 해석을 통한 최적화

김기중* · 고현석**

The Optimization using PCB EM interpretation of GEO satellite's L Band Converter

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요 약

본 연구는 위성통신 중계기의 L대역변환반의 PCB EM 분석을 하고, 불요파에 대한 취약 부분에 대해 최적화하였다. 위성중계기 안에는 L대역변환반 뿐만 아니라 전원반, 디지털신호처리반, TM/TC 제어반 등 다양한 기능 및 블록이 연동될 때 원치 않는 신호 성분으로 인해 잡음성분이 증가되어 전체 시스템 성능 저하를 야기 시킬 수 있다. EM 시뮬레이션 툴을 사용한 PCB 공진해석은 보드 상에서 공진에 취약할 수 있는 부분에 대해 쉽게 분석을 할 수 있고, 다양한 시뮬레이션을 통해 최적의 설계를 할 수 있다. 또한 PCB에 포트를 설정하여 원하는 블록을 쉽게 분석할 수 있는 장점이 있다.

ABSTRACT

This study is the analysis and verification process of the L-band satellite communications repeater thought PCB & circuit EM analysis. System performance can be vulnerable to various spurious inside the L-band satellite transponder, power conversion board, digital signal board, TM/TC board, such as control panels and blocks that are linked signal components when the winch is increased due to the noise component. So the whole system can cause performance degradation. PCB resonance analysis and EM simulation can be easily analyzed for a variety of optimal. Also, by setting the ports on the PCB, H/W designer wants to can easily analyze system.

키워드

EM Simulation, L Band Converter, SI, PI, GEO Satellite, PCB

전자장 해석, L대역변환기, 신호 무결성, 전원 무결성, 정지궤도 위성, 인쇄회로기판

Ⅰ. Introduction

Digital transponder of the Satellite divided into two sections by frequency domain. One is RF system that operate the system using narrow banded high frequency signals. Another is rapid digital system that operates the system using base band digital signals. Satellite Digital transponder coverts high frequency to L-band signal by rapid digital channel processing. It has advantages for

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frequency re-usage. It is also intelligence transponder system that using sub-channel switching.

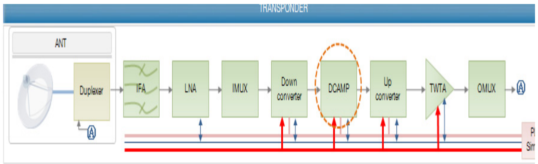

Fig. 1 X-band digital satellite transponder

In Fig 1, The X-band transponder's structure is shown. It is made up with Duplexer, IFA(Input Filter Assembly), LNA(Low Noise Amplifier), Up/down converter, DCAMP(Digital Channel AMPlifier) and TWTA(Traveling Wave Tube Amplifiers). DCAMP is the most important part of the digital transponder. It performs digital signal processing like digital channel switching, multicasting by coverting the L-band signal to baseband signal. L-band converters of DCAMP change frequency between digital and X-Band. Digital Channel Processing board and L band converters share common power supply board. It probably causes many interference signal. In addition, Non-ideal power supplied to the system and interference comes from signal delivery also can boost this problem. So to reduce the problem from the interference, we should consider both of them [1]. Pre-inspection and assurance processed by EM simulation is important for EM development stage. At the past time we repeated same process for building the new board. We designed board by thumb of rules and have a time to tune for the interference using real board. And re-design it. It require lots of development times and one of reason for growing development cost. Before making the PCB, Assurance process for the design using 3D EM simulation is very essential. Especially developing transponder is necessary to use this process. Because, there are variety of long delivery and high price component. In the high reliable satellite system, it needs to be analyzed thoroughly about signal interference. From Up/Down Link signal and L band converter which transfers into L band in the satellite communication system, to digital signal process board, signal band which is used is very wide, so we have to minimize interference between each block. In order to do that, by EM analysis of PCB level, we have to consider signal interference analyzation at the design step. In this study, we will analyze unwanted signal of L-band converter in the GEO satellite system through PCB resonance analysis. And, by extracting S-parameter over the LNA block, we will draw a conclusion from the exact simulation signal wave form.

II. Body

2.1 L-band converter's multi-layer PCB structure and resonance analysis

L-band converter's PCB is made up with 4-layer. Generally, metal layer is consist of copper, and the spaces between each layer are filled with FR4.(dielectric material, FR4 permittivity 4.8)

Name	Type	Film	Material	Thickness (mm)	Elevation (mm)
Top	METAL	POSITIVE	copper	0.03429	0.86487
Dielectric_1	DIELECTRIC		FR4_epoxy	0.254	0.61087
InnerLayer2	METAL	POSITIVE	copper	0.03429	0.57658
Dielectric_2	DIELECTRIC		FR4_epoxy	0.254	0.32258
InnerLayer3	METAL	POSITIVE	copper	0.03429	0.28829
Dielectric_3	DIELECTRIC		FR4_epoxy	0.254	0.03429
Bottom	METAL	POSITIVE	copper	0.03429	0

Fig. 2 L-band converter's PCB stacking structure

We conduct resonance analysis using EM Simulation tool, on circuit that is consisted of PCB structure shown in Fig 2. In the analysis result, if the part has a lot resonance wave form, it means that specific signal energy is concentrated on it, and it is also vulnerable to power noise and other forms of unwanted signal.

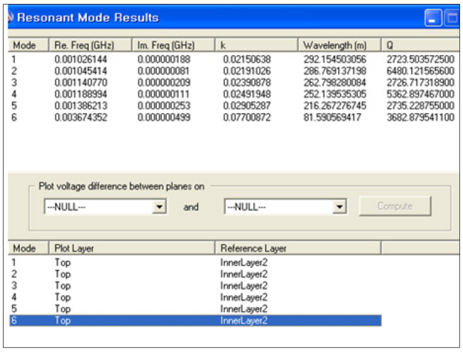

Fig. 3 PCB's resonance frequency

Fig 3. is the resonance analysis result of the L-band converter's PCB between 10KHz and 10GHz frequency range. The result is expressed by resonance sharpness(Q value) value and resonance frequency. If Q value is high, it means that sharp resonance exists, and if Q value is low, it means that relevant resonance frequency is spread wide apart. The result of the resonance analysis shows that Q value is relatively high at the low frequency range. That is, we can expect that low frequency range is vulnerable to power noise, and resonance will be occurred on power feeder line [2]. In this study, we analyzed the resonance frequency through the resonance signal form. It takes much time to simulate for finding resonance frequencies of all layer, at least it need to study about the each characteristic roughly. This thesis has dealt with the resonance frequency for each layers.

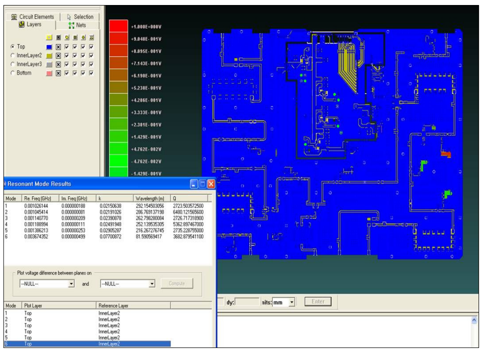

Fig. 4 +5V supply point's resonance simulation plot

Fig 4. shows sharp frequency resonance of 1MHz ~ 3MHz at the +5V supplying point. This resonance frequency can be vulnerable to the power switching noise, but if we apply decoupling capacitor, it can be minimized [3].

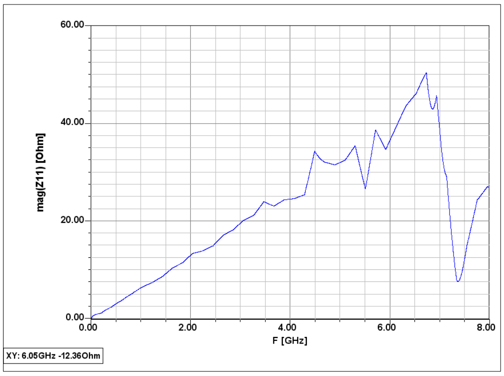

Fig. 5 Impedance character between +5V's line and AGND

Fig 5. shows impedance characteristic curve between +5V and AGND before inserting decoupling capacitor, that is, under the initially designed PCB condition.

Fig 6. shows S-parameter characteristic after connecting to the decoupling capacitor 10uF in order to reduce the impedance between +5V line and AGND.

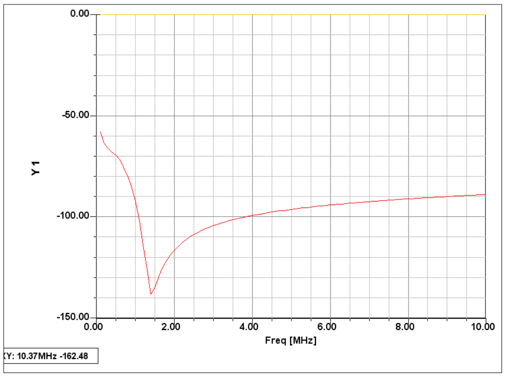

Fig. 6 Character between +5V and AGND after connecting to the decoupling capacitor(S11)

It shows that impedance is lower by connecting to the only one decoupling capacitor. However, if we can tickle with the position, number, and value of the decoupling capacitors, the whole frequency band's impedance can be even lower. That is, by the resonance point produced by decoupling capacitor's ESR(Effective Series Resistance) and ESL(Effective Series Inductance), we can adjust the whole impedance [4].

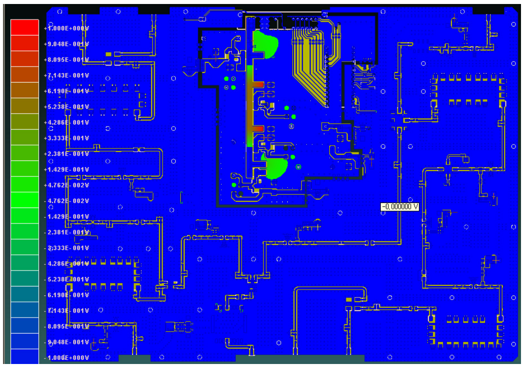

Fig. 7 Resonance simulation plot about the +15V power line

Fig 7. shows the resonance signal form +15V power line. Mainly, resonance over 1MHz band becomes the resonance over the whole +15V line, and has impact on the around GND. This resonance signal form showed continual resonance phenomenon if we connect it to the decoupling capacitor. So, when we made the +15V line's thickness thinner, and had resonance analysis, not only +15V line's but also around GND had no resonance.

When some circuit works in the system board, it may cause power noise. In order to prevent those power noise have an effect on the other blocks, decoupling capacitor is generally inserted. When decoupling capacitor is used, it stores the power to help suppling the power stably by shorten the path from power line to component that consume power [5].

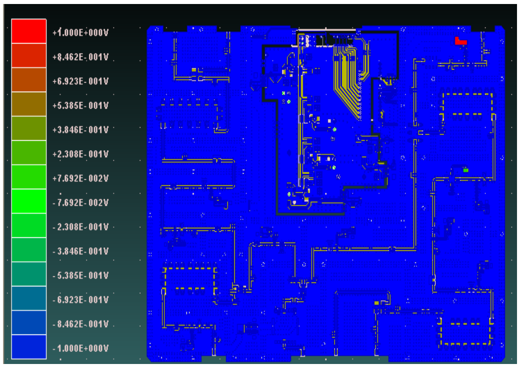

Fig. 8 Impedance analysis according to the decoupling capacitor

Capacitor's ESL is connected to the C in series, so the frequency which makes series resonance exists, and about the frequency which is over to the resonance frequency, impedance caused from L increase gets higher, so it can no longer work as a decoupling capacitor. This phenomenon is called Self Resonation Frequency. Fig 9. shows YUDEN's capacitor impedance characteristic of 1nF. In here self resonance frequency is 60MHz, and as frequency increases, capacitance changes into inductance.

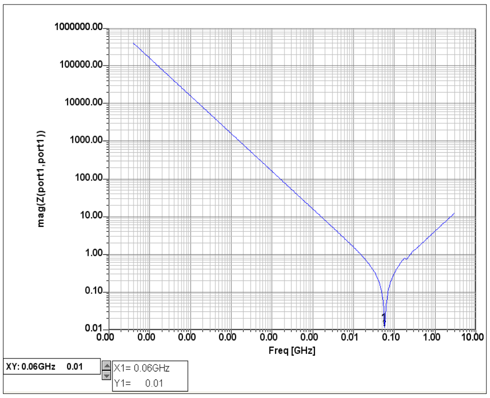

Fig. 9 Impedance characteristic of the YUDEN company's 1nF capacitor (1608 size EMK)

$$Z_T = \frac{(Power\,Supply\,Voltge) \times (Allowed\,Ripple)}{Current} \quad (1)$$

Equation (1) shows how to calculate target impedance on the system board. For example, under the condition (when a board's voltage is 3.3V, and system's allowing permitted ripple is 15%, and maximum power consumption is 2A), system board's target impedance will be calculated to 82.5mΩ [2].

In this paper, the supply voltage of L-band converter is 15V and it regulated to 5V from 15V and provided MMICs. The consumed current is about 4A in L-band converter. It requires 5% ripple. To calculate target impedance using Equation (1), it is resulted to less than 62.5mΩ.

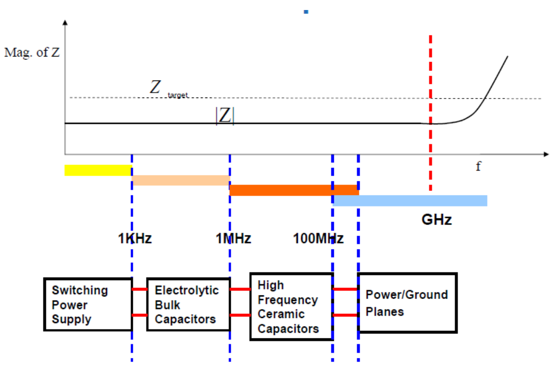

Fig. 10 Target impedance on the system board

Board's target impedance needs to be adjusted from GHz under the low frequency, so system's unwanted signal and noise can be diminished. In oder to do that, we have to use decoupling capacitor and according to the type of decoupling capacitor, influential frequency range on the impedance profile is designated, and according to the type of capacitor, influential frequency range on the power net's impedance is different, so when capacitor's figure and number are appropriately chosen and arranged, optimization of the target impedance can be produced [7].

By using EM Simulation verification method mentioned so far, We designed L-band converters, and did system's EMI test as a final step. And EMI test configuration is shown below.

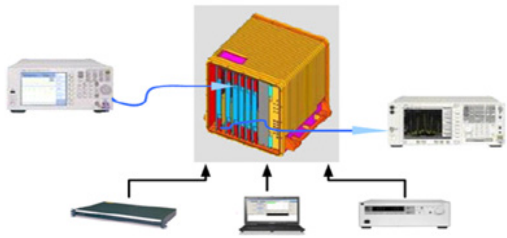
Fig. 11 EMI Test Block Diagram(DCAMP)

As shown in EMI test result graph, the system's interference characteristic was satisfied for requirement in the X band EMI requirement standard (7 ~ 8GHz).

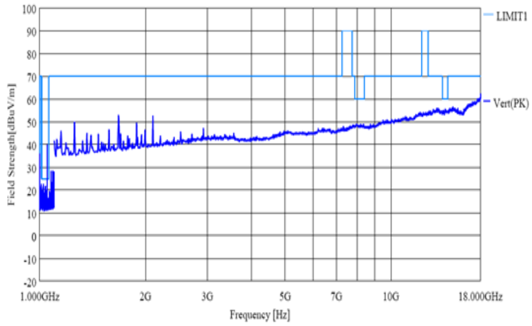

Fig. 12 EMI test result graph(1~18GHz)

2.2 EM Analysis on L-band converter's LNA and Filter Block

Practically, in a circuit simulation, PCB board's condition and analysis on the power line can not be done correctly. In this chapter, simulation was made by EM simulation tool, from L-band converter's LNA to low pass filter. Power supply is made from outside, +15V, and then rectified to +5V in the L-band converter, and through 3rd layer board's lane, supplies power to LNA. At that time, we extract S-parameter and watch signal form with connecting appropriate decoupling capacitor.

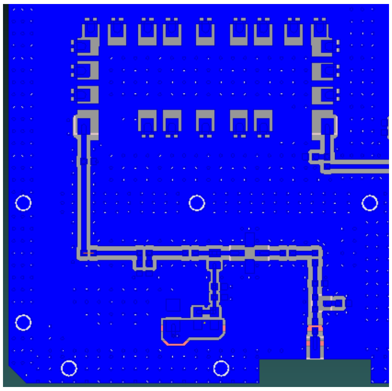

Fig. 13 LNA and filter block

Fig 13. shows L-band converter's LNA and filter block. LNA's power supply is made through the 3rd layer's inside board's circuit line.

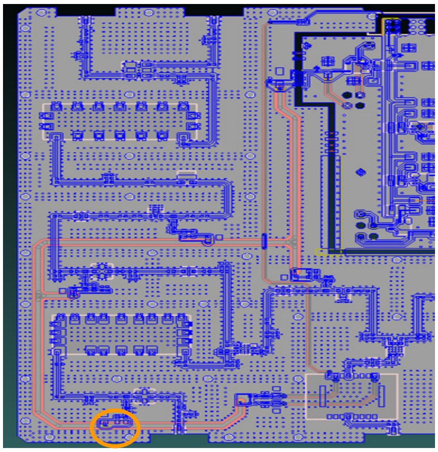

Fig. 14 +5V power line inside the 3rd layer which is supplied to LNA

Fig 14. shows PCB inside the 3rd layer board and it shows longer power line because it's amplification and other different active circuit use +5V commonly. So, we extracted S-parameter on the +5V's line and studied.

As it's seen in Fig 15, Power circuit gets longer, when we watch only pure +5V power lane's s-parameter, resonance is made from many different frequency band. So, decoupling capacitor has to be used appropriately in order to adjust the target impedance on the system board. In addition, about the decoupling capacitor's frequency, if we insert the ESL, ESR component, we can make the result of the practical simulation [8].

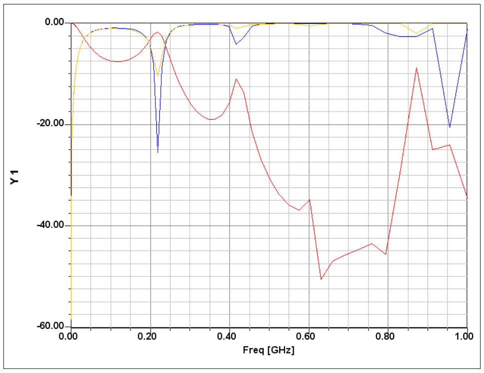

Fig. 15 S-parameter(S21, S11) of the +5V power line(EM analysis)

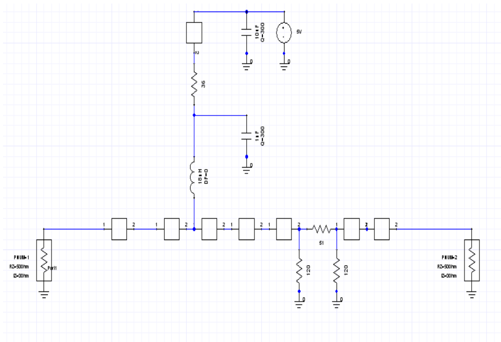

Fig. 16 LNA and filter block

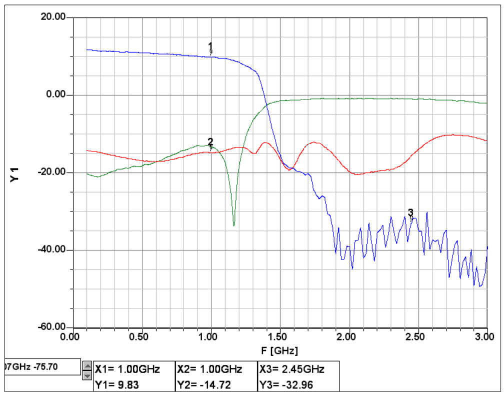

Fig. 17 EM analysis of LNA and filter block(S21, S11)

Fig 17. is three plots of the LNA's signal with connecting decoupling capacitors derived by EM analysis to extract S-parameter of the each line of the LNA block [9] [10]. When EM analysis about the power line which supplies power to LNA is done, we can have the result into block form and make correct simulation, and practical tuning.

Ⅲ. Conclusion

This thesis dealt with PCB EM analysis on the satellite communicate transponder's L-band converter, and analysed about effect of the resonance frequency and drew optimization.

In the satellite communicate transponder, not only L-band converter, but also power block, digital signal handling block, TM/TC control block, other functions and blocks can cause noise when they are combine with and can make the whole system's efficient decline [11] [12].

EM simulation tool can make easy analysis about the vulnerable part for the resonance frequency on the board. Through various simulation, the best design can be made. Also, this tool give the function for setting port to simulate PCB, ant this tool's function provide analysis more easier to the block.

We can prevent the L band frequency and X Band interference used in the system by EM simulation before build boards. So, After building PCB and assemble it, We can check the validity of the simulation by EMI test. If we use EM simulation, we are expected that reducing the development time.

And, as introduced in the chapter 2.2, PCB EM simulation is also work to assurance for the analysis of RF amplifier and filter functional blocks [13].

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