Proceedings of International Conference on Astronomy and Space Science
Celebrating 20th Anniversary of Korea Space Science Society, Jeju, 2004

DESIGN CONSIDERATION OF MULTIPACTOR PHENOMENA BASED ON S-BAND DIPLEXER FOR SATELLITE APPLICATIONS

Seung-Woon Choi†, Day-Young Kim, Ki-Ho Kwon, Tae-Byeong Chae, and Jong-In Lee
Satellite Electronics Dept., Satellite Technology Division, KARI, Daejeon 305-333, Korea
E-mail: antelch@kari.re.kr

(Received September 25, 2004; Accepted October 1, 2004)

ABSTRACT

This review is concerned with the MP (multipactor) phenomena of the diplexer for RFDU DM of next generation satellite. The MP discharge is serious problems to design RF components in space applications such ase damage of physical structure, performance degradation, and mission failure of the satellite. In this work, we employed the 3D finite element method (FEM) to calculate the critical gap points and adopted ESTEC curve, MP susceptibility zone, to analyze the maximum handling RF power in the diplexer. And this work also recommends that one should design the tx filter of the diplexer which is more wider bandwidth upto the points to escape the ears of the group delay especially the cavity type of RF components in space applications.

Keywords: multipactor, diplexer, interdigital BPF, group delay

1. INTRODUCTION

The RF hardware in space born communications should be taken into account with extreme space environment such as high/low temperature, vacuum, and thermal stress. The high power level of RF components in vacuum can make the multipactor discharge phenomena (Hatch & Williams 1954).

That is an avalanche-like increase of free electrons due to secondary electron emission which comes from when electrons synchronized with the input electric field hit the wall of the RF components. As a consequence, it can damage the physical structure of the equipment and can also be responsible for the performance degradation, and finally can make the mission failure of the satellite. Especially the previous paper reported that the S-band diplexer was detected by the noise of multipactor discharge at 5 Watts input power for CONTOUR (Perry 2003).

In this paper, a diplexer based on interdigital cavity BPF type in s-band is adapted and considered in order to analyze the multipactor phenomena for RFDU DM of next generation satellite, KARI. The design frequency is 2.034 GHz, 2.209 GHz and operating bandwidth (OB) is ±15 MHz for each Rx and Tx part respectively. But we change design bandwidth (DB) ±30 MHz in only Tx part to escape the MP phenomena.

†corresponding author

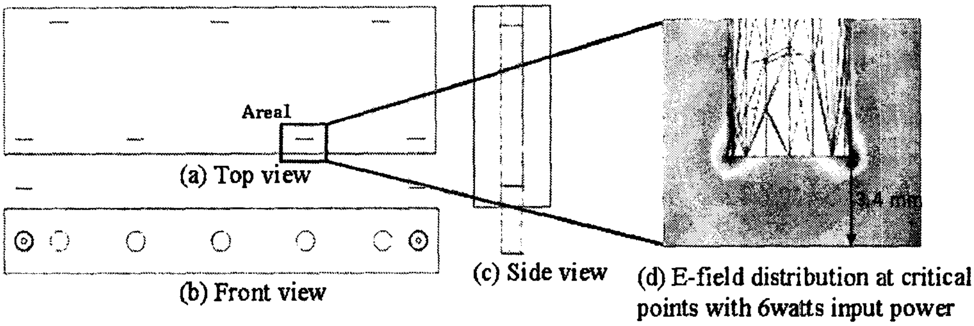

Figure 1. Layout of Tx part of diplexer and its field distribution at the critical point with 6 watts input power.

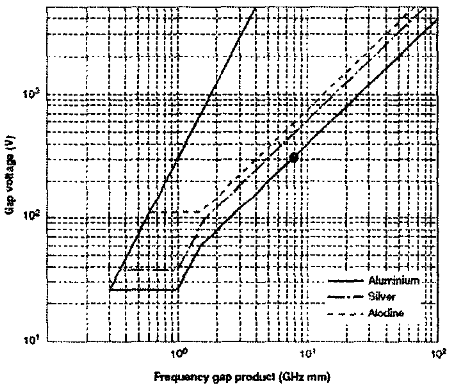

Figure 2. MP susceptibility zone (Hatch & Williams 1954).

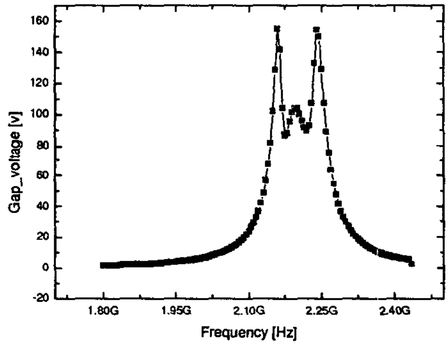

Figure 3. Gap voltage of critical region of Tx part with normalized input power.

2. MULTIPACTOR ANALYSIS

As mentioned above, MPs play an important role to design the RF passive components such as waveguide, cavity and AFN structure. And there exist lots of methodologies to analyze of MPs. In our work, this diplexer is designed with 5 pole cylinder cavity type filter and we adapted the method to analyze the MP calculating using of the calculation of the field distribution at the most sensitive points, area1, of the diplexer as shown in Figure 1.

(a) Gap volgate calculation at critical points from E-field intensity

In order to get the threshold gap voltage, we used the multipactor susceptibility zone made by Hatch & Williams from ESTEC (Hatch & Williams 1954). From this chapter and the threshold gap voltage (Vth) is plotted on the graph as shown in Figure 2 and its value is about 318 volts with 7.48 GHz · mm of F×d product (Woode & Petit 1990). As above Figure 1, the gap voltage is calculated by integral of E-field through the critical gap distance, 3.4 mm using Eq (1) and Eq (2) and then this gap voltages are shown in Figure 3.

$$E(t) = R_e \left(\sum_i E(f_i) e^{j(2\pi f_i t + \phi_i)} \right) \tag{1}$$

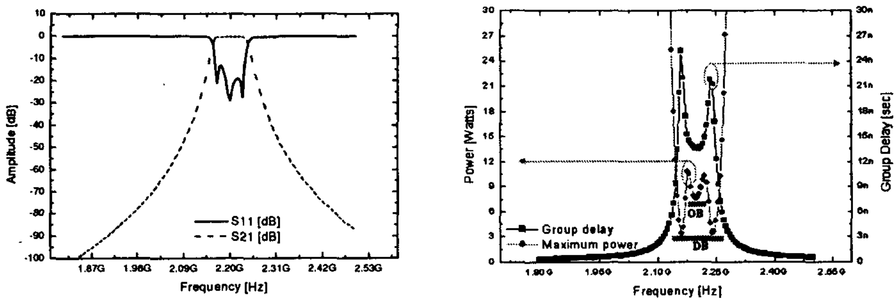

Figure 4. Characteristics of tx filter with amplitude, maximum handling power and group delay response.

$$V_{gap} = x\varepsilon(0,\omega_i)|_{max} \int_l E_y(x,y,z=z_i;\ \omega)\cdot dy \tag{2}$$

Next to evaluate the power handling capability of the device, the VMF (Voltage Magnification Factor) is employed (Ludovico & Accantino 2002) and finally we can calculate the handling power without MP discharge, VMF and Pmax can be defined as

$$VMF(z_i,\omega) = \frac{V_{gap}}{V_{in}} \tag{3}$$

$$P_i(\omega) = \frac{V_{th}^2(h_i,\omega)}{2Z_o(\omega)VMF^2(z_i,\omega)} \tag{4}$$

(b) Analysis of Maximum handling power with group delay

As above Eq (3), it is noted that the maximum RF input power are reported as shown in Figure 4. This figure shows some particular appearance with the variation of operating frequency in terms that MP is more critical at band edges rather than middle of band pass frequencies because of the effects of the group delay of diplexer. Group delay is defined as the negative of the first derivative of the phase with respect to frequency as follows $\tau_d = -d\theta/d\omega$.

The sharp increases in group delay at the ends of the passband, about 26 and 22 nano-seconds respectively in this case, are characteristic of filters that have been optimized for skirt selectivity based on chebyshev filter response.

In our case, these group delay 'ears' reponses can make the power consumption accumulation at band edges, so these effects finally give rise to reducing the power handling capability bandwidth as shown in Figure 4. Therefore, one who design the RF components with high input power in vaccum condition should design the diplexer considering more wider design bandwidth (DB) of tx filter to avoid the handling power fluctuation from the results of group delay response. The graph shows that the maximum power of DB is about 3 watts and that of OB is about 7.5 wats.

3. CONCLUSIONS

The MP discharge was calculated and analyzed with 3D FEM and ESTEC curve of frequency gap product in S-band diplexer for RFDU DM of next generation satellite. The critical points of the structure are employed to analyze the MP phenomena. This work eventually shows the relationship of maximum handling power and group delay response of tx filter, and recommands the design tricks that the diplexer should have larger design bandwidth than operating bandwidth of tx filter upto out of ear of group delay.

REFERENCES

Hatch, A. J., & Williams, H. B. 1954, IEEE Applied Physics, 25, 417
Ludovico, M., & Accantino, L. 2002, IEEE MTT-S Digest, pp.2077-2080
Perry, M. M. 2003, ESTEC workshop, Noordwijk, The Netherlands
http://www.estec.esa.nl/conferences/03C26/papers/a002.pdf
Woode, A., & Petit, J. 1990, ESA J., 14, 467