3D 시뮬레이션과 측정값을 이용한 Q-band 정밀 초소형 동축 어댑터의 설계

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Design Approach of Q-band Precision Subminiature Coaxial Adaptor Using 3D Simulator and Its Experimental Results

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Abstract : This paper presents the design approach and test results of the Q-band precision subminiature coaxial adaptor based on transmission line theory using multi-step impedance and air-holes to increase its cutoff frequency. In order to increase the frequency performance, the adaptor is designed with hooked structure, fixing step, multi-air-holes, and outer conductor. The return loss increments due to the hooked structure and multi air-holes are minimized to 2 dB and 1.5 dB, respectively. A VSWR(Voltage Standing Wave Ratio) of <1.2 is obtained from DC to 40 GHz, while guaranteeing the durability of the adaptor from room-temperature(25°C) to 120°C.

Key Words : Hooked Structure, Multi-Air-Holes, Multi-Step Impedance, Precision Subminiature Coaxial Adaptor, Q-band

1. Introduction

During the late 1950's and early 1960's, 7-mm coaxial transmission lines with standard SMA connectors were only used for frequencies between 10 and 12 GHz. In the mid 1960's the U.S. Department of Commerce established the Joint Industry Research Committee for the Standardization of Miniature Precision Coaxial Connectors (JIRF/SMPCC). The result of that effort yielded a voluntary product standard in 1972 [1]. The air transmission line size was reduced to 3.5 mm to extend the mode-free operation of that line to 36 GHz. Currently, with increasing demand for high speed data transmission rates, the operation frequency of commercial communication systems is increasing to achieve wider band-width [2]. Thus, the development of micro/mm-wave products was proposed in the U.S., Europe, and Asia.

In this article, the Q-band precision subminiature coaxial adaptor is designed (on the basis of transmission line theory) and fabricated. In order to accomplish the Q-band cutoff frequency, a multi-step impedance technique with air-layers is considered and applied. Moreover, for commercial purposes, its durability must be satisfied at high temperature so that the hooked structure and step transition satisfying the IEC Standards are used.

2. Design of Precision Subminiature Adaptor

Subminiature adaptors are commonly used in low-power applications at higher microwave frequencies, particularly in the Ku, K, Ka and Q-bands. In this paper, the coaxial adaptor is designed using a rexolite-filled 50 ohm coaxial line. The structure of the coaxial adaptor is depicted in Fig. 1. This coaxial adaptor consists of an inner conductor, dielectric material, and air holes. The coaxial adaptor is designed to operate in the Q-band and is capable of providing much higher cutoff frequency using arbitrary surface discontinuities inside the adaptor shown in Fig. 2. In addition, adding an air layer and step transition to the adaptor as shown in Figure 1 enhances its high frequency performance.

When the stepped-discontinuity structure was added, the inductance per unit length of transmission line is decreased and the capacitance per unit length is increased. Also, the cutoff frequency was increased as a result of the discontinuity. To avoid the problem of having an infinite VSWR, the arbitrary length between T1 and T2 (in Fig. 2) should be as long as possible. The length l appearing on the transmission line is on the order of hundreds of micrometers and is a very important parameter controlling the VSWR characteristics of the connector, because it is a part of deciding the discontinuity size for 50 ohm matching [3].

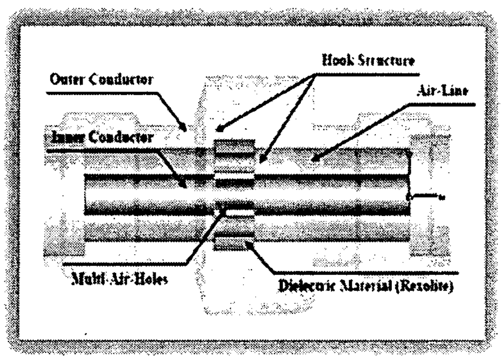

Figure 1. Cross-sectional View of the Coaxial Adaptor

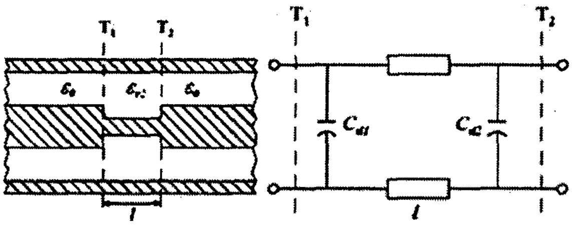

Figure 2. Compensated Coaxial Dielectric Bead Support

3. Simulation Results

In this paper, the degradation in RF performance of the adaptor is minimized by simulation the multi-air-holes and hooked structure using a 3D simulator. CST based on the finite element method was used to perform the simulation. Dielectric material, depicted in Figure 3, was fabricated with multi-air-holes to enhance the high frequency performance.

According to Figure 4(a), the simulated return loss and VSWR increases as the frequency increases but they are <-20 dB for return loss and <1.2 for VSWR in the Q-band and also from DC to 40 GHz. Figure 4(b) shows the time dependent reflection(TDR) simulation result. TDR result shows the variation of line impedance by time. The peak means the varied impedance by rexolite dielectric material in the whole structure of the air-line.

4. Measurement Results

This adaptor was measured after heating it at 120°C for 1 hour and then measured again after the adaptor was cooled back to room temperature. The measurement was performed using a network analyzer (Agilent 8510C) by connecting 50 ohm termination to the adaptor.

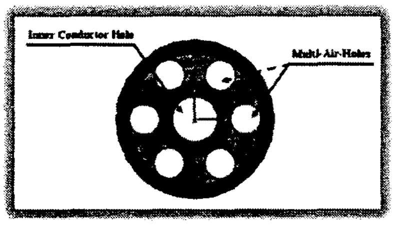

Figure 3. Compensated Coaxial Dielectric Bead Support

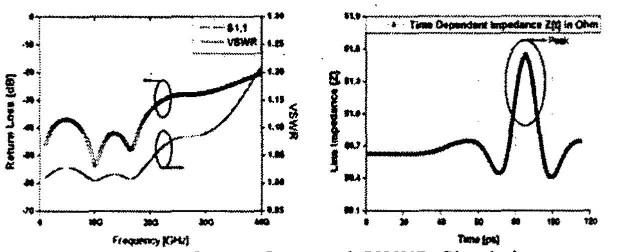

Figure 4(a). Return Loss and VSWR Simulation
(b). Time Dependent Reflection Simulation

Figure 5(a) shows measured VSWR as a function of frequency at room temperature and at 120°C. The VSWR around 40 GHz marks 1.2, therefore, the adaptor is expected to be available up to 40 GHz. Furthermore, after subjecting the adaptor to a temperature of 120°C for 1 hour the measurement was performed again to qualify it for use as a commercial product. Very little difference in the VSWR was recorded between room temperature (25°C) and 120°C. Also Figure 5(b) shows measured return loss as a function of frequency at room temperature and at 120°C.

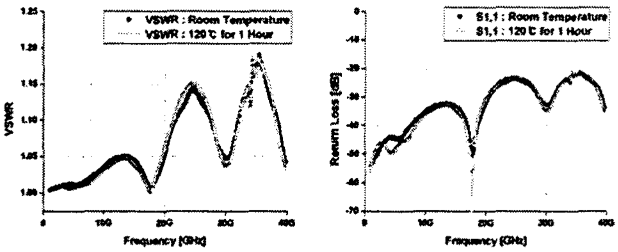

Figure 5(a). VSWR at Room Temperature and 120°C
(b). Return Loss at Room Temperature and 120°C

5. Conclusion

In this paper, a reliable Q-band miniature precision adaptor was designed and fabricated using the characteristic impedance of a coaxial line, the discontinuous transmission line, and the characteristics of multi-air-holes interfaces. The VSWR was less than 1.2 from DC to 40 GHz and was realized by adopting the slit construction. The reliability is confirmed by the electrical and environmental test. So this Precision Subminiature Coaxial Adaptor can be use for Q-band RF module or system applications.

Acknowledgement

This research was supported by Nano IP/SoC Promotion Group, 3D Micro-system Packaging of Seoul R&BD Program, the MKE (Ministry of Knowledge Economy).

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