Signal Integrity Analysis of Vertical Dual Port Coaxial Connector for Automotive System

Dong-Hyun Kim, Hyunsuk Lee, Hongseok Kim,
Jonghoon Kim and Joungho Kim
School of Electrical Engineering
Korea Advanced Institute of Science and Technology
Daejeon, South Korea
e-mail: billkim@kaist.ac.kr

Jung-Min Park, Ji-min Kim, Kyung-Nam Lee,
Jong-Hoon Woo, Hyeok-Cheol Kwon, and Hoon Kim
VEC Development Center
Korea Electric Terminal Co., Ltd.
Incheon, South Korea
e-mail: pjm@ket.com

***Abstract*—Different designs of vertical dual port coaxial connectors are proposed and analyzed using full wave 3D simulation tool up to 10 GHz. By inserting conducting grounds around the pins, the signal integrity of the vertical dual port coaxial cable connector is improved. The vertical dual port coaxial connector cable assembly can be used to reduce the printed circuit board space required for the connectors and reduce the total cost of coaxial connectors required for automotive system.**

Keywords—RF coaxial connector cable, automotive connector cable, singal integrity

I. Introduction

With the development of audio, video and navigation (AVN) systems and various RF sensors in automotive industry, the signal integrity of the connector and cable assembly for the automotive system must be analyzed to prevent unexpected system failures and to ensure the safety of the drivers and passengers of the automobile. A single port coaxial connector cable assembly has been widely used to deliver RF signal from GPS, audio, infotainment, navigation, Bluetooth and RF sensor units. However, due to increasing number of ports due to increasing number of units included in the automobile, the size of the printed circuit board (PCB) should be increased to make space for more coaxial connectors. Since the connectors are placed on the edge of the PCB, vertically stacking the coaxial connectors can save the space required on the edge of PCB for placing different coaxial connectors for a modern automotive system with more advanced AVN systems and sensors [1] - [5].

In this paper, we propose different designs of vertical dual port coaxial connectors. On top of the commonly used coaxial connector for automotive system, additional coaxial connector is introduced with different types of ground shielding. The two proposed vertical structures of the connectors can both reduce the required space in the PCB of the automotive system unit. The proposed designs are analyzed using full wave simulation tool, ANSYS HFSS, to evaluate the difference between the different connector designs. Insertion loss (S_{21}), return loss (S_{22}) and voltage standing wave ratio (VSWR) are used for evaluation of the electrical performance of the proposed vertical coaxial connectors.

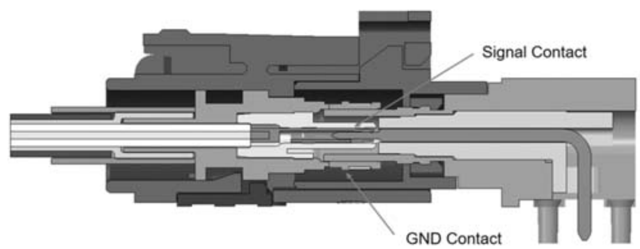

Fig. 1. Design of the mated single port coaxial connector for automotive system. The signal contact and ground (GND) contacts are indicated. The right half of the mated connector will be connected to a PCB, and the left half of the mated connector will be connected to the cable.

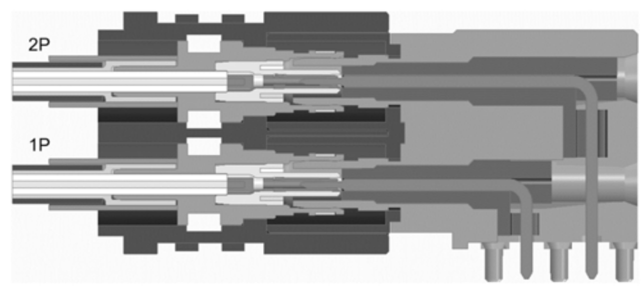

Fig. 2. The first design of the mated vertical dual port coaxial connector for automotive system. The right half of the mated connector will be connected to a PCB board, and the left half of the mated connector will be connected to the cable.

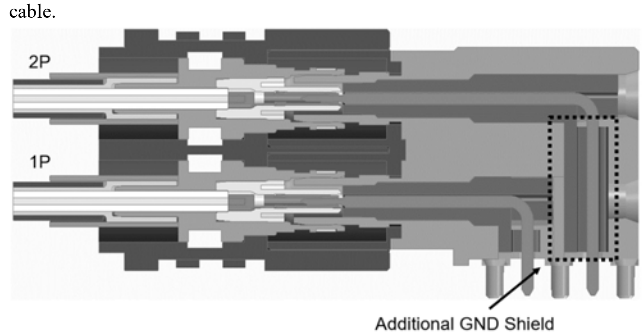

Fig. 3. The second design of the mated vertical dual port coaxial connector for automotive system. Additional ground shielding surrounds the 2P signal pin.

II. THE DESIGN OF VERTICAL DUAL PORT COAXIAL CONNECTORS

The structure of the commonly used single port coaxial connector is shown in Fig. 1. The signal is delivered through the metal pin in the middle, and the signal pin is insulated using dielectric material. The dielectric material is surrounded with cylindrical ground metal. Two designs of vertical dual port coaxial connectors are shown in Fig. 2 and Fig. 3. In Fig. 2 and Fig. 3, 1P refers to the port 1 which has the same size and dimension as the single port coaxial connector shown in Fig. 1, and 2P refers to the additional coaxial connector port added vertically on top of 1P. The structural difference between Fig. 2 and Fig. 3 is that additional conducting ground are inserted between the two signal pins. The differences are highlighted with a dotted rectangular box.

III. SIMULATION SETUP AND RESULTS OF THE VERTICAL DUAL PORT COAXIAL CONNECTOR CABLE ASSEMBLY DESIGNS

The simulation models for full wave 3D simulation (ANSYS HFSS) are shown in Fig. 4 and Fig. 5. The material properties were assigned to each structural components compromising the mated coaxial connectors. The simulation results of the first design and the second design of the vertical dual port coaxial connector are compared in terms of insertion loss (S_{21}), return loss (S_{11}) and VSWR, in Fig. 6, Fig. 7 and Fig. 8, accordingly.

When 1P simulation results of the first and second designs are compared, the results are almost identical. This is simply because the shielding structure surrounding the 1P signal path of the two designs remain unchanged.

2P simulation results of the first and second designs are notably different. As shown in Fig. 6, the simulation result of insertion loss (S_{21}) is reduced for 2P in the second design compared to the first design. The increased ground shielding around the second pin helped to reduce the insertion loss at high frequency range. For example, the second design shows the difference of approximately 3 dB insertion loss at 9 GHz range. The additional ground shield helps to control the impedance of the 2P signal pin. However, at certain frequency range between 5GHz to 6.5GHz, the first design shows approximately 0.5 dB less insertion loss compared to the second design, resulting from different resonance peak locations. Therefore, depending on the frequency range of the application, the vertical two port coaxial connectors can be chosen between the two designs to match needs of the industry. Furthermore, the shielding structure can be modified to further optimize the impedance mismatch through the 2P signal pin.

Fig. 7 shows the simulation results of return loss (S_{11}) for the two designs. Maximum of approximately 10 dB decrease in the return loss can be observed due to the additional ground shield structure. Analogous to the insertion loss, similar trend can be observed around 5 GHz to 6.5 GHz, where the first design shows less return loss, and 1P signals are identical for the two designs.

Fig. 8 shows the VSWR simulation results of VSWR for the two designs. Similar to the analysis given for Fig. 6 and 7, the increased ground shielding around the second pin helped to lower the VSWR at high frequency range. The maximum VSWR value of 8 in the first design is reduced to 4 in between the frequency range of 10 GHz for 2P. However, at frequency range between 5 GHz and 6.5 GHz, the first design shows smaller VSWR value, as well.

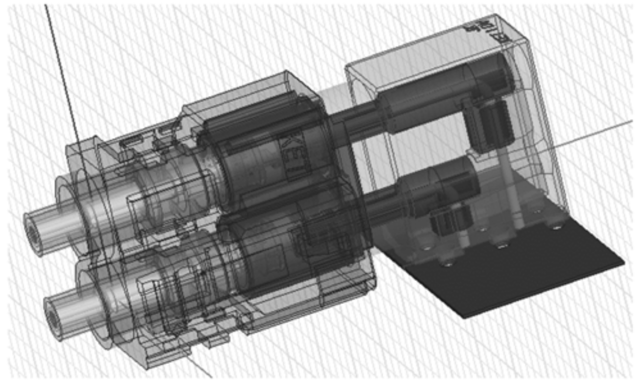

Fig. 4. The full wave 3D simulation setup of the first vertical dual port coaxial connector design for automotive system.

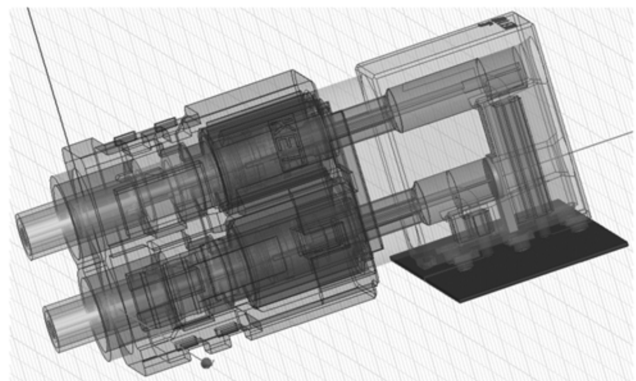

Fig. 5. The full wave 3D simulation setup of the second vertical dual port coaxial connector for automotive system.

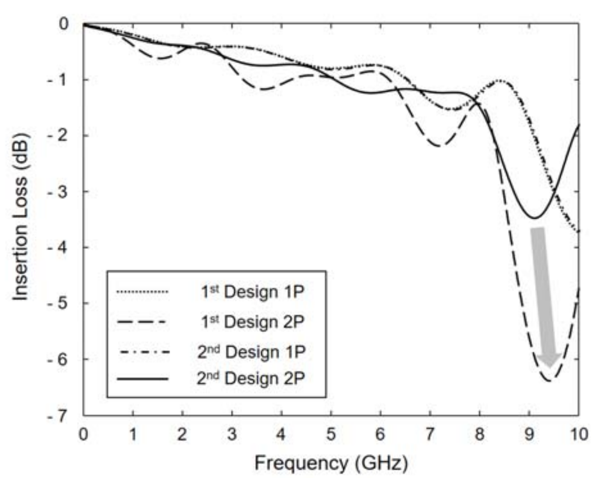

Fig. 6. Insertion loss (S_{21}) of the two different vertical dual port coaxial connectors. Around 9 GHz, the 2P signal pin of the second design shows enhanced electrical characteristic.

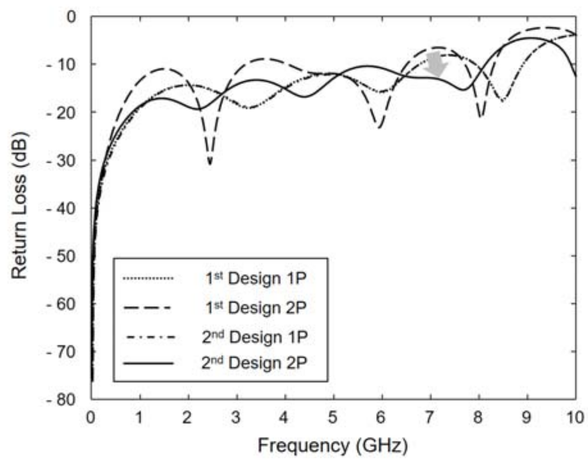

Fig. 7. Return loss (S_{11}) of the two different vertical dual port coaxial connectors. In most frequency range, the 2P signal pin of the second design shows enhanced electrical characteristic.

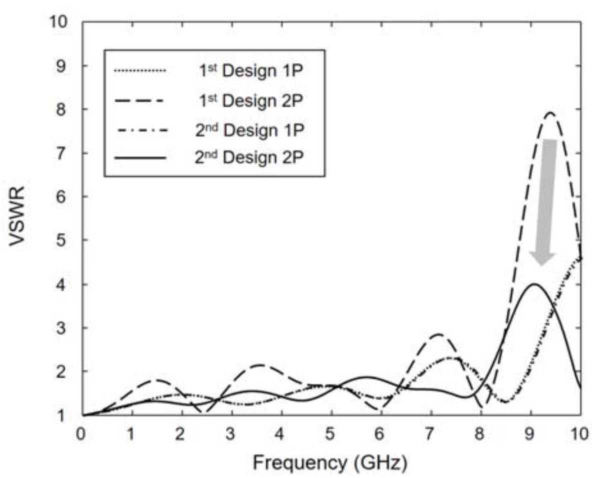

Fig. 8. VSWR of the two different vertical dual port coaxial connectors. In most frequency range, the 2P signal pin of the second design shows enhanced electrical characteristic.

In general, for high frequency applications, the second design shows enhanced electrical characteristics, where the electrical characteristics of the 1P signal and 2P signal are comparable to each other. The first design shows much degradation of electrical performance over 8 GHz range.

IV. Conclusion

In conclusion, the two different designs of the vertical dual port coaxial connectors are proposed and analyzed using full wave 3D simulation tool up to 10 GHz. By changing the ground shielding structures near the 2P signal pin, the electrical characteristics are improved at high frequency range. Due to different resonance locations, at certain frequencies, the first design may exhibit improved electrical characteristics. However, in general, for future high frequency applications, the second design is the suitable solution. Moreover, the proposed structure of the dual port vertical coaxial connector design provides a solution to reduce the PCB space and reduce total cost of the connectors in automotive applications.

Acknowledgment

We would like to acknowledge the technical support from ANSYS (ANSYS HFSS) and the financial support from Korea Electric Terminal Co., Ltd. This work was also supported by the MKE through the International Collaborative R&D Program, “Glass interposer based RF FEM for Next Generation Mobile Smart Phone”, under Grant N0000899. We would like to extend our acknowledgement to the financial support from the R&D Convergence Program of MSIP (Ministry of Science, ICT and Future Planning) and NST (National Research Council of Science and Technology) of Republic of Korea (Grant B551179-12-04-00)

References

[1] Illgen, Thomas, and Stefan Ortmann. "Challenges and Trends in the Engineering of Electric Automotive Systems."

[2] Kim, Hyeon-Seok, et al. "A study on the characteristics of wide bandwidth connector for automotive communication." 2012 IEEE Vehicle Power and Propulsion Conference. IEEE, 2012.

[3] Althoff, Frank, et al. "Robust multimodal hand-and head gesture recognition for controlling automotive infotainment systems." VDI BERICHTE 1919 (2005): 187.

[4] Schoebel, Joerg, et al. "Design considerations and technology assessment of phased-array antenna systems with RF MEMS for automotive radar applications." IEEE Transactions on Microwave Theory and Techniques 53.6 (2005): 1968-1975.

[5] Lewis, Franck L. "Wireless sensor networks." Smart environments: technologies, protocols, and applications (2004): 11-46.