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A Novel Planar Cylindrical Waveguide-to-Planar Transition for Transceivers at 2.45/5.8 GHz band

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1. Abstract

A novel planar waveguide-to-planar transition will be presented. This transition will be used to realize a RFID antenna which can be embedded inside metallic objects. Two designs of the transition will be presented. The first transition is for 2.45 GHz and achieves better than 10 dB return loss to a 50 Ohms system in the frequency band from 2.3 GHz to 2.6 GHz. The other transition is for 5.8 GHz and achieves better than 16 dB return loss in the band from 5.75 GHz to 5.85 GHz.

2. Introduction

In the last ten years, RF-identification became a dominant technique for storing and remotely retrieving data. This technique was mostly used in the trading phase. To facilitate this remote data communication, a RFID tag is attached or inserted inside a product. A major challenge arises when the object to be identified is a metallic object due to the reflecting nature of metallic surfaces. So the integration of the communication modules inside the component proved to be a challenging task. In this work, a novel planar cylindrical waveguide-to-planar transition will be showed as a method to design antennas which can be embedded in metallic objects.

3. System description

As described in [1] the communication structure of the mobile part consists of an antenna, a power supply unit and a microcontroller. Fig. 1 shows a metallic workpiece whose manufacturing quality should be monitored and its operating conditions should be stored. The harsh operating conditions necessitate the embedding of the RFID system inside the metallic object [2]. The cavity where the communication module will be placed can be modelled by a one side short circuited cylindrical or rectangular waveguide. An objective of the project described above is to design a planar transition, which transforms the electromagnetic fields from the planar mode to the suitable circular waveguide mode and vice versa and to position it parallel to the cavity circular cross section.

4. Planar waveguide-planar transition

Fig. 2 shows the electric and magnetic field distribution of the fundamental mode in a one side short-circuited cylindrical waveguide. To transform the waves from the waveguide mode to the planar mode, the transition shown in Fig. 3 is used [3]. It consists of two arms, and each arm is composed of a loop and a monopole. The loops support the fundamental mode magnetic field where it is maximum at the walls, while the monopoles support the fundamental mode electric field where it is maximum in the middle.

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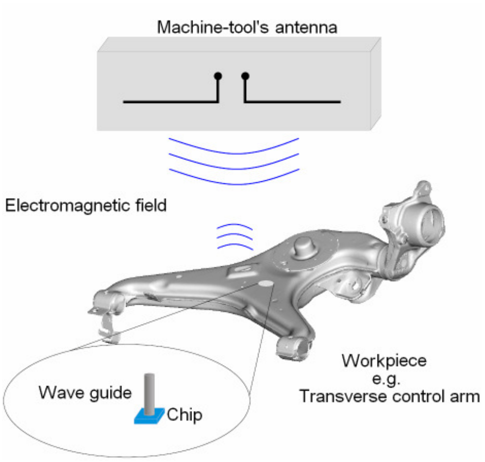

Figure 1: A typical application scenario of future RFID systems integrated in metallic objects during their manufacturing processes.

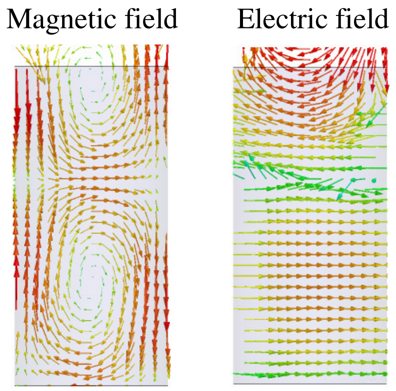

Figure 2: Field distribution in a one side short circuited cylindrical cavity with metallic boundaries.

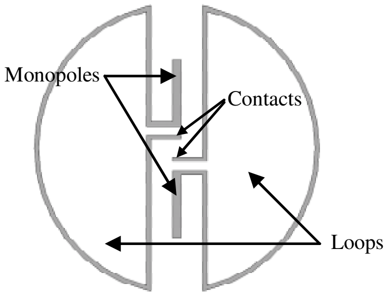

Figure 3: Planar waveguide-to-coplanar line transition.

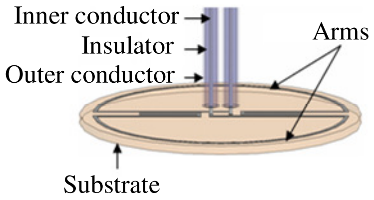

Figure 4: Contacting the transition using coaxial cables inner conductors.

5. Measuring techniques

To measure the transition input impedance, a two-port measurement with a vector network analyzer has been done, as shown in Fig. 4. However, the measurement accuracy is expected to be affected, since the coaxial cables inner conductors must be extended to contact the transition contacts. To take the resulting parasitic effects into account, an equivalent circuit of the cables end has been developed, as shown in Fig. 5. In this model, it is assumed that the main parasitic effects are: the capacitance between inner conductor and outer conductor of each cable, the capacitance between both inner conductors of both cables and the inductance resulting from the extension of each inner conductor. The equivalent network of the whole measurement setup is shown in Fig. 6. The values of the parasitic components can be obtained from 3D-simulations. Using the inverse ABCD-matrices of the capacitances C_{o1} and C_{o2} and of Cable1 and Cable2, the S-matrix [S] at the reference planes A-A’ is given by the equation

$$[S] = g^{-1}\left\{[A_{Co1}]^{-1} \cdot [A_{Cable1}]^{-1} \cdot [A_m] \cdot [A_{Cable2}]^{-1} \cdot [A_{Co2}]^{-1}\right\} \qquad (1)$$

where $[A_m] = g[S_m]$, $[S_m]$ is the measured S-matrix at ports 1 and 2, g the S-to-ABCD matrix transformation function and g^{-1} is the inverse function of g. Assuming a symmetrical measurement setup as well as a symmetrical transition structure, the transition input impedance is given by:

$$Z_{in} = \frac{1}{\dfrac{1}{Z - 2j\omega L} - j\omega C_i} \qquad (2)$$

with $Z = 2Z_0 \dfrac{1 + S_{11} - S_{12}}{1 - S_{11} + S_{12}}$ [4], $L = L_1 = L_2$ and $Z_1 = Z_2 = Z_0$.

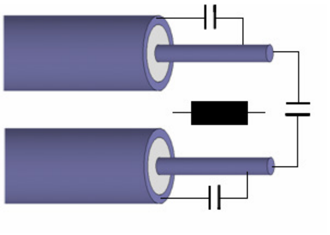

Figure 5: The parasitic effects due to the cables ends are modelled with lumped capacitances and inductances

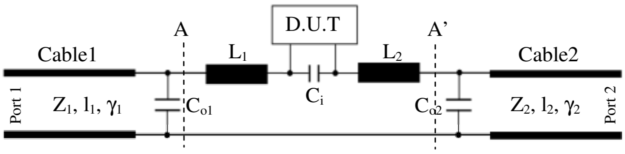

Figure 6: Measurement setup including circuit model of parasitic effects

6. Measurement results

The used one side short circuited cylindrical waveguide is made of brass with a diameter of 85 (36) mm and a height of 175 (70) mm for the 2.45 (5.8) GHz frequency band, where it should work as antenna. The proposed transition to couple the cylindrical waveguide to a transceiver with a 50 Ohms differential input port, has been realized by etching a FR4 (Arlon AR 450) substrate with a thickness of 1 mm (.76 mm) for the 2.45 (5.8) GHz band. The substrate relative permittivity is about 4.4 (4.5) with and copper thickness of 35 µm. The transition is placed 62 (25) mm over the metallic bottom and its dimensions are shown in Fig. 7. For the measurements identical semi-rigid cables EZ86 have been used. The extended inner conductors are equal with a length of 2 mm. The simulations of the parasitic equivalent circuit components provide following values: $C_{o1} = C_{o2} = 0.075pF$, $C_i < 0.01pF$ and $L_1 = L_2 < 1.8nH$. Fig. 8 shows its return loss and input impedance real and imaginary part together with the simulation results.

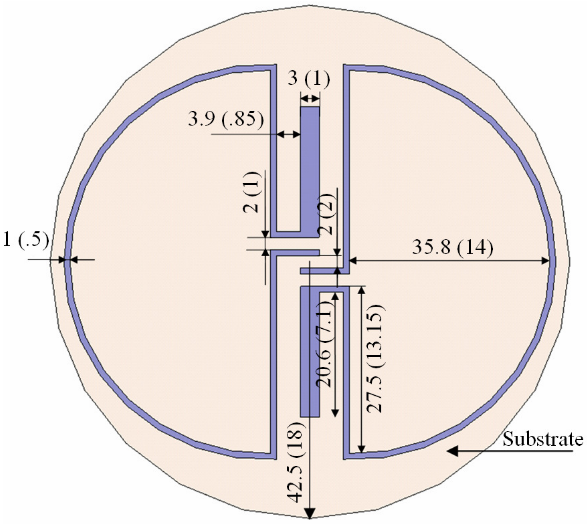

Figure 7: Geometrical sizes of the realized 2.45 (5.8) GHz-band transition for a cylindrical cavity with 85 (36) mm diameter. The unit is mm.

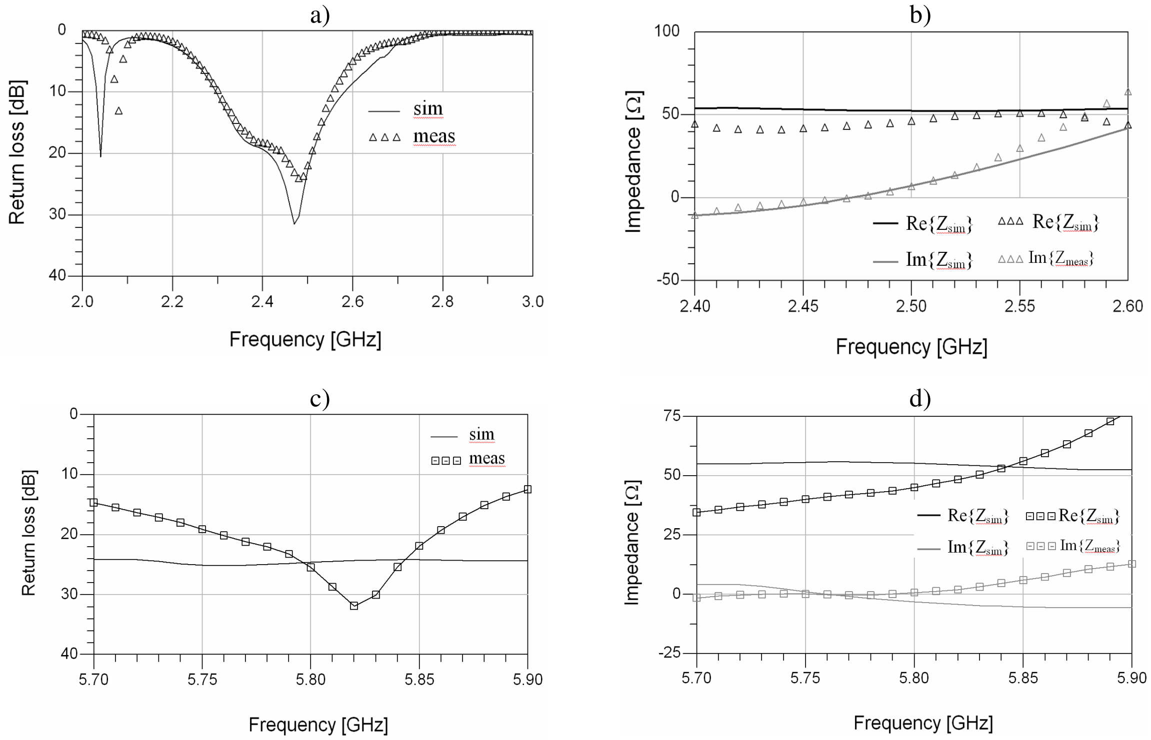

Figure 8: a) Simulated and measured return loss of the 2.45 GHz transition, b) Simulated and measured transition real and imaginary part of the 2.45 GHz transition, c) Simulated and measured return loss of the 5.8 GHz transition, d) Simulated and measured transition real and imaginary part of the 5.8 GHz transition.

7. Conclusions

A novel planar transition for coupling a cylindrical waveguide to a planar transmission line composed of loops and monopoles on a substrate is proposed and a deembedding method to remove parasitic effects by measuring differential impedances using a two-port vector network analyzer has been presented. It has been shown that the realized transition can be matched to a transceiver with a 50 Ohms differential input impedance working at the 2.45 GHz or 5.8 GHz band. This transition permits an easy integration of embedded radio wave communication systems into metallic objects at 2.45 GHz or 5.8 GHz band.

Acknowledgments

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