The effect of SMA connector implementation on a two-layer Ku-Band Microstrip Antenna

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Abstract—Using a connector to the antenna structure in the fabrication process influences on the measured antenna characteristics. This effect can be considerable in high frequency antennas. Some influences depend on how the connector is implemented. This paper models and investigates the effect of the implementation of the SMA connector, in a two-layer microstrip antenna in Ku-band. The simulated and measured return loss level, radiation patterns and gain of the antenna are considered and compared.

Keywords- connector implementation; microstrip antenna; two-layer structure

I. INTRODUCTION

In high frequency antennas, as the wavelength decreases, the antenna characteristics are more sensitive to fabrication process and tolerances. The effective factors can be divided into two categories: the tolerance in fabricating the antenna itself, and the effect of devices such as 50-ohm connectors added to the antenna for test.

In microstrip antennas, because the characteristic impedance of microstrip lines is very dependent on the widths of tracks [1], the fabrication tolerance not only affects the nominal frequency of the antenna, but also changes the antenna input impedance; consequently, an impedance mismatching is observed between the antenna and its feed. The problem can be intensified by adding an external connector to the antenna feed track. Also, as the frequency increases, the diffraction from discontinuities and junctions increases resulting in energy dissipation and undesirable radiations, and even a narrow gap in fabrication may cause a lot of problems. Besides the difficulties in soldering the external connector to the antenna feed, in high frequencies the electrical size of the connector is large, and may be considerable respect to the antenna dimensions; this can cause the reflectivity effect of the metal flange of the connector leading to a disorder in the antenna radiation pattern.

In this paper, a proximity coupled-fed, U-Slot microstrip antenna is considered [2], and after the description of the antenna structure, the effect of adding a 50-ohm, tab terminal SMA connector, on antenna main characteristics, i.e. the RL (return loss) level and radiation pattern, is investigated. Because of the two-layer structure, embedding the connector tab between the layers is a challenge. Some possibilities for implementation method are considered and compared. The measurement results, for both RL level and radiation pattern, are presented and compared with simulations.

II. ANTENNA STRUCTURE

As shown in Fig. 1, the proximity coupled-fed antenna consists of two dielectric substrates. The rectangular patch with a U-shaped slot is printed on the top interface – of the patch substrate-, and the bottom interface – of the feed substrate - is used as the metal ground. A feed line is embedded between two substrates, to excite the U-slot patch through electromagnetic coupling. In order to decrease alignment error between patch and feed-line, the feed is etched under the same substrate (the patch substrate). Fig. 2 is the top view of the proposed antenna, which shows the radiating U-slot patch and the feed-lines simultaneously.

![Figure 1. The geometry of the proximity coupled-fed microstrip antenna.](image-url)
III. Connector Implementation

In order to feed the antenna, the antenna must be connected to an standard 50-ohm SMA connector. The first step is to match the antenna feed-line to a 50-ohm microstrip line. It can be done by a quarter-wave transformer, as shown in Fig. 2, and then to solder the external SMA to the 50-ohm line. The common coaxial-to-microstrip transition is that the coaxial central pin is laid on the microstrip line, and the shield is connected to the ground plane of the structure [3], [4]. Although using rear-mounted connectors is an alternative (especially for structures that clearance is not available around the edge of substrate) [5], but it requires right-angled bend, which implies for transitions to avoid the return loss in discontinuities, and also requires high care in fabrication, which is not easy to reach, especially in multi-layer structures.

If the common coaxial-to-microstrip transition is used, while the microstrip line is covered by another substrate, a new challenge is to embed the coaxial pin between layers. For this case, the tab terminal type SMA is a good choice, in which the thin rectangular tab, lies along with the microstrip line and also needs the minimum space to be embedded between the layers.

For the proposed antenna, a tab terminal type SMA, with 0.13mm-thick tab [6], was used. The thickness is considerable respect to the substrates thicknesses (it is equal to about 25% of the feed substrate and 16% of the patch substrate). It causes a large gap between the layers, after connector implementation. However, in fabrication, it was tried to minimize this air gap, by pressing the layers and gluing all around the substrates' edges, which results in a smaller curved gap between the layers. The fabricated antenna is shown in Fig. 3.

IV. The Effect of the Connector on the Antenna Characteristics

A. Antenna Return Loss

The simulation result of S11 (dB) of the antenna without adding any connectors is presented in Fig. 4. To consider the SMA connector in the modeling, the curved gap between the layers can be modeled by a step. So a two dimensional step in the feed substrate, which remains a thin empty cube around the connector tab, is used for this modeling as shown in Fig. 5 (the upper layer is not shown in the figure). The simulation results presented in Fig. 4 is for the case that the width and length of this cube are supposed to be three times and two times of the width and length of the connector tab, respectively.

In fabrication, a thin gap is unavoidable between the antenna structure and the SMA flange (Fig. 6); this gap is not only inevitable but also necessary, because if there is no gap, the ground plane of the antenna touches the SMA conductor internal pin, whom radius is 0.615mm, which is more than the lower substrate thickness (0.508mm). At high frequencies, this gap can be a source of energy leakage and destroy the RL level, but the effect is not so serious if this side gap is small. The resultant S11 (dB) diagram for a 50μm side gap is shown and compared with previous cases in Fig. 4; also the corresponding measurement result is presented. The difference between simulation and measurement results, can be described by the high dependency of antenna RL level on the fabrication tolerances, which affect the length and width of different parts of the antenna that play an important role in determining frequency response of the antenna.
The gap between the layers can be prevented by embedding the connector tab completely inside one of the layers. Depending on the feed-line etched on which substrate, the other substrate can be carved for the connector tab to be embedded in. In the case that the feed-line is etched on the lower substrate, and the connector tab is accommodated in the upper one as shown in Fig. 7, the S11 (dB) diagram, depicted in Fig. 9, is approximately similar to the case that there was a cube gap between the layers. Although, if the feed-line is etched behind the upper substrate (in order to reduce the alignment error), embedding the connector tab in the lower substrate as shown in Fig. 8, deteriorates the S11 level so much (Fig. 9). This is sensible, because the characteristic impedance of the microstrip track with the previous width is no more corresponding to 50 ohms on a substrate with the new reduced height, the resultant mismatching will increase the RL level. In this case, if the widths of the connector tab and the 50-ohm microstrip line are reduced to a new width, with which the characteristic impedance of 50 ohms on a substrate with new height can be achieved, the S11 level improves, as shown in Fig. 9.

B. The Antenna Radiation Pattern

In Fig. 10 and Fig. 11, the measured radiation patterns in E-plane and H-plane at 16.7 GHz, are shown; also for comparison, the simulation results for the case that no connector is added to

Figure 7. Embedding the connector tab completely inside the upper layer.

Figure 8. Embedding the connector tab completely inside the lower layer.

Figure 4. S11 (dB) of the antenna, in simulation and measurement.

Figure 5. The two dimensional step in feed substrate, and resultant cube gap around the SMA tab.

Figure 6. The side gap between the antenna structure and the SMA flange.

Figure 9. S11 (dB) of the antenna, for different cases for SMA tab embedding.
the antenna, are presented there. As expected, the H-plane pattern is always symmetric; however, the connector presence in E-plane causes an asymmetry in radiation pattern in this plane. The large size of SMA respect to the antenna dimensions makes a considerable squint in the E-plane pattern. The SMA conductor flange operates as a reflector and diverts the radiation to the opposite direction; consequently, it causes the radiation to be more focused in one direction. As a result, the antenna gain increases. Fig. 12 compares the simulation results for the antenna gain, with and without the SMA connector, and also with measurement results. All the results are considered at the antenna axis of symmetry. Without the connector, the simulated gain is smooth over the pass-band, and is the average of 7.5dB, but as expected, when the connector is added, the gain increases considerably, especially at higher frequencies.

![Figure 10. The co-polarized E-plane radiation pattern at 16.7GHz.](image)

![Figure 11. The co-polarized H-plane radiation pattern at 16.7GHz.](image)

V. CONCLUSION

The effect of an SMA connector on the RL level and the radiation pattern of a two-layer microstrip antenna was investigated. The RL level mostly depends on how the connector tab is embedded in the structure, and the pattern is squinted, due to the reflectivity effect of the connector’s large flange. The total gain is also increased.

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