Optimization of Microstrip-to-slot Transition for Ultra-wideband Bulk LTSA

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1. Introduction

Tapered slot antennas (TSAs) are used in many applications for example Ground penetrating radars (GPRs) [1][2] and millimeter-wave (MMW) imaging for concealed weapon detection [3][4]. To operate the TSAs, it is necessary to feed them via transitions such as coplanar-to-slot [3] or microstrip-to-slot [4] to guide unbalanced signal to feed TSA which requires balanced feeding.

In the MMW front-end, a bulk linearly tapered slot antenna (Bulk LTSA) [5][6] is proposed to be used as the receiving antenna. Its impedance depends on its fin thickness. The bulk LTSA enables the direct connection between the receiving antenna and a detection circuit without the impedance matching circuit by using the optimized fin thickness to avoid the loss. However, to use the bulk LTSA as the transmitting antenna, we need a balun structure to feed the LTSA antenna. We prefer microstrip-to-slot transition to coplanar-to-slot transition in order to avoid the loop height of the wire bonding assembly that influences the antenna properties such as the radiation pattern and return loss. In addition, the measured fractional bandwidth based on S_{11} of microstrip-to-slot transition in [4] is less than 0.25 although its transmission loss is low, around 1.7 dB at the center frequency. This transition also needs a via hole which works as the quarter-wavelength short stub to achieve low reflection loss in short frequency rage.

In this paper, we investigate the bulk LTSA fed by microstrip-to-slot transition. We find that two via holes in the microstrip-to-slot transition can reduce reflection in wide frequency range and thus we can obtain an ultra-wideband characteristic. Numerical analysis shows a fractional bandwidth of 0.4. We present the effect of microstrip-line width to improve the reflection characteristics. The results indicate that we can obtain an ultra wideband by expanding the microstrip-line width wider than 2.8 mm.

2. Bulk LTSA with Microstrip-to-slot Transition

Figure 1 presents the structure of 34 GHz bulk LTSA fed through a compact microstrip-to-slot transition. We adopted the structural parameters of 76 GHz LTSA and microstrip-to-slot transition for feeding 94 GHz LTSA from Ref. [7] and [4] respectively, and scaled them for 34 GHz band. The metallic fins are 68 mm long with the aperture width of 13 mm. The bulk LTSA has fin thickness of *d* and feeding gap size of 0.2 mm. The impedance of bulk LTSA depends on its fin thickness. From Ref. [6], we can obtain 45 Ω for 1 mm-thick bulk LTSA and 130 Ω for 125μm-thick conventional LTSA. We use microstrip-to-slot transition on thick polytetrafluoroethylene (PTFE) substrate (Duroid). The transition is 3 mm long with 1 mm thick. The lengths of the microstrip and slot lines are 1 and 2 mm, respectively. The transition has two via holes to improve a fractional bandwidth. The positions of via holes play an import role on the reflection characteristic. In this structure, the first via hole (Via_1) is located at 2 mm whereas the second one (Via_2) is at 5.8 mm from the edge of the microstrip-line. The diameter of via hole is 0.4 mm. We chose these positions in such a manner that we can obtain low reflection loss along wide frequency range. We optimize the microstrip-line width (W) to adjust the return loss and the impedance. We also compare the results for d = 1 and 0.125 mm.

3. Numerical Results

Figure 2 shows the frequency dependence of the return loss calculated by Ansys HFSS simulator in the range of 25 – 45 GHz at the feeding point fed through a 50 Ω line. We compare the return loss of 1mm-thick bulk LTSA (d = 1 mm) with 125μm-thick conventional LTSA (d = 0.125 mm). Apparently, the return loss in the case of d = 1 mm shows better matching than the case of d = 0.125 mm.

In the case of d = 1 mm, we vary the value of microstrip-line width W from 2.6 to 3.5 mm. The minimum point in the curve corresponds to the optimum matching. As we increase W, the matching-point frequency becomes higher. All the curves except that for W = 2.6 mm has the reflection larger than -10 dB. We can obtain an ultra wideband by using W larger than 2.8 mm. The curve for W = 3.2 mm shows the best impedance matching with 50 Ω line along 27 – 40 GHz, of which the center frequency is 33 GHz. Thus, we obtain a fractional bandwidth of 0.4 which is larger than the one of 0.25 in Ref. [4].

Figure 3 is the calculated impedance at the feeding point versus frequency fed through a 50 Ω line from 25 to 45 GHz. The resistance (R) and reactance (X) of the bulk LTSA fed by the microstrip-to-slot transition vary according to the frequency. We compare the impedance of bulk LTSA with d = 1 and 0.125 mm as well. The resistance in the case of d = 0.125 mm is about 10 Ω which is much less than the case of d = 1 mm, around 40 Ω. The reactance in the case of d = 0.125 mm is also less capacitive than the case of d = 1 mm.

In the case of d = 1 mm, as we increase W from 2.6 to 3.5 mm, the resistance decreases to 40 Ω in the range of 25 – 34 GHz, while the reactance becomes less capacitive in the range of 25 – 38 GHz and more inductive in 38 – 45 GHz. These results are suggested by S_{11} curves in Figure 2. By adjusting the microstrip-line width to match the impedance of the bulk LTSA, we can improve the reflection characteristic.

4. Summary

This paper proposed the optimization of microstrip-to-slot transition for ultra-wideband bulk LTSA. We found that two via holes can reduce the reflection over a wide frequency range. We can improve the return loss by adjusting microstrip-line width as well. Changing line width wider than 2.8 mm shows an ultra wideband characteristic. We demonstrated that the optimum line width and via hole positions can increase the fractional bandwidth.

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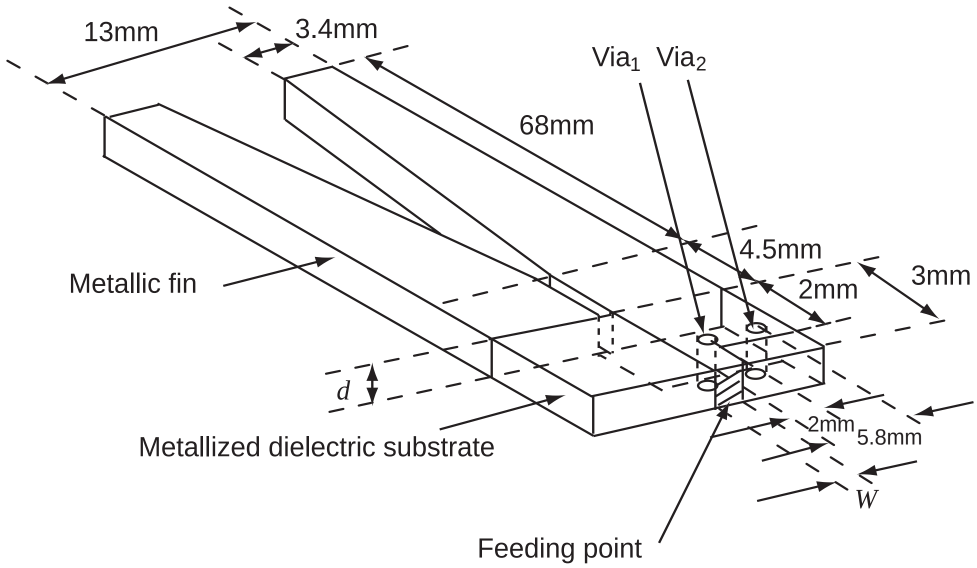

Figure 1: Structure of bulk LTSA with microstrip-to-slot transition

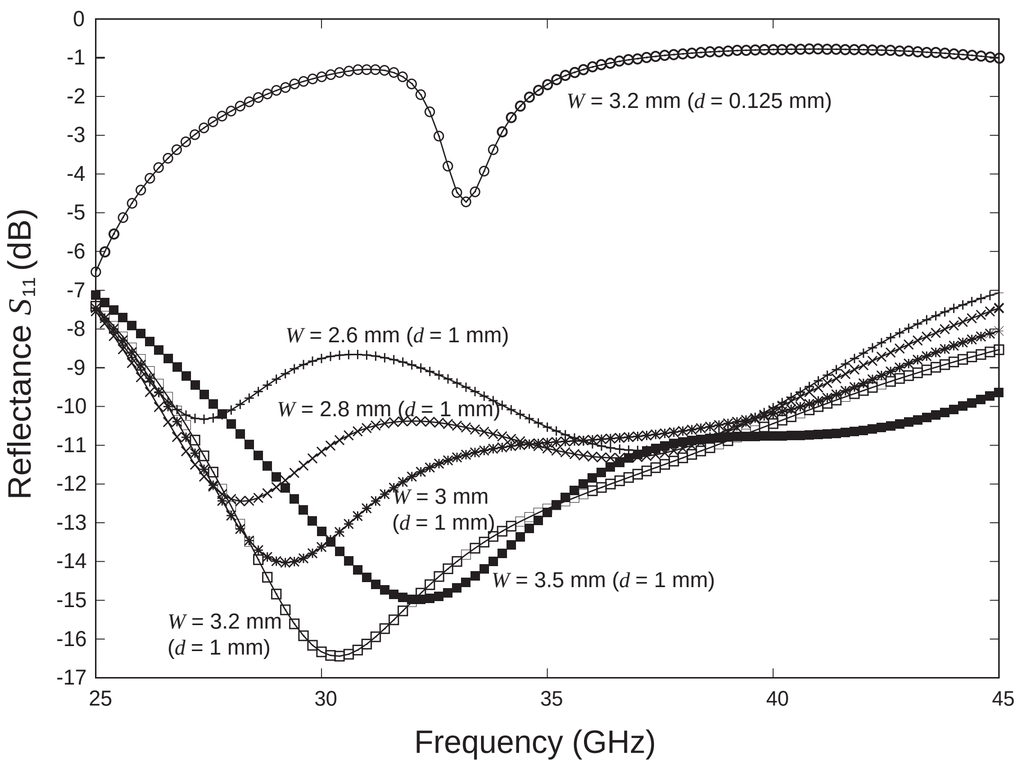

Figure 2: Calculated reflectance S_{11} versus frequency for 50 Ω feedline.

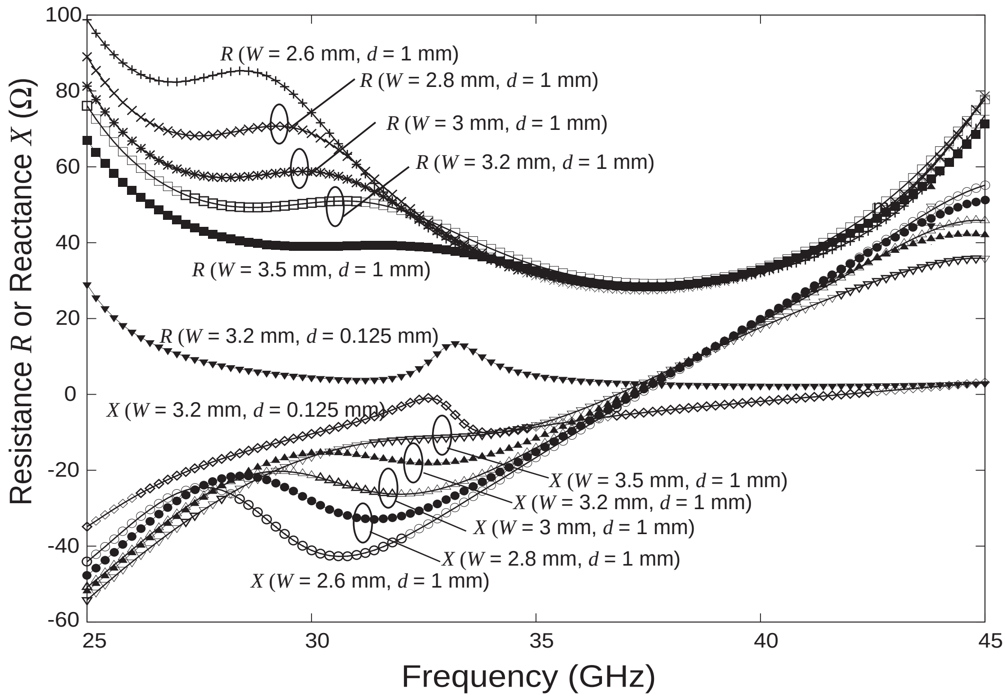

Figure 3: Calculated impedance versus frequency.