32nd URSI GASS, Montreal, 19-26 August 2017

Size Reduction and Bandwidth Enhancement of Aperture Coupled Based Microstrip Antenna by Using Meander Line Slot

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Abstract

In this paper, a development of aperture coupled based microstrip antenna using meander line slot is presented. The proposed antenna constitutes of 2 substrate layers which are separated by a common ground plane. A Meander line slot is loaded to the antenna patch to reduce the dimension of the proposed antenna design. The antenna characteristics before and after applying a meander line slot are numerically investigated. Compared to the reference antenna design, using a meander line slot loaded to the antenna patch, it can achieves several performance improvements. These improvements are not only in terms of size reduction, but also in terms of bandwidth enhancement and antenna efficiency.

1. Introduction

In recent development of microwave and millimeter systems, microstrip technology becomes the prominent solution due to its advantages, such as low-profile configuration, light weight, low cost and easy integration with monolithic components [1]. Development of compact microstrip antenna is no exception in this regard. However, a conventional microstrip antenna suffers from a number of drawbacks, like low radiation efficiency and spurious radiation from the feeding network. Hence, another microstrip configuration is required to isolate the radiation between radiator and feeding network.

Aperture-coupled based microstrip antennas offer better isolation between radiating patch and feeding network by using different substrate layers which are separated by a common ground plane. The use of different substrates gives additional degree of freedom to optimize antenna and feeding network independently by adjusting thickness or permittivity [2].

On the other hand, miniaturizing antenna dimensions for modern microwave systems is indispensable due to the demand for mobility feature for many microwave applications. In order to reduce antenna dimensions, there exist numerous miniaturized antenna designs in literature. Several techniques in antenna miniaturization typically utilize high dielectric permittivity of the substrate [3] or meander line slot incorporated into the antenna design [4, 5]. Brocker in [4] employed a meandered slot loaded to the patch for creating dual-band antenna with a significant size reduction. It is reported that by using this technique, the antenna dimension can be reduced by 64%. However, the achievable operating bandwidth was still narrow. Another meandered line based antenna design to miniaturize antenna dimension was proposed by Kim in [5]. In this design, the meandered slot was loaded to the patch and a used stripline for feeding. This proposed design causes difficulties when active components have be integrated with the antenna. None of these proposed design are implemented in the aperture coupled configuration which provide more degree of freedom for optimization.

Meander line based aperture coupled antenna were reported in [6, 7]. In [6], Wang proposed an aperture coupled antenna using a combination of meander line slot at the patch and H-shaped slot to couple a radiation field from the feeding line on the bottom of the lower substrate to the radiating patch on the top of the upper substrate. To maintain this the antenna radiation efficiency, the meandered patch was fabricated from a single-side of a thin-film superconductor. However, this technique still exhibited narrow achievable antenna bandwidth and is complicated in manufacturing. Another technique to reduce the dimension of an aperture-coupled antenna was proposed by Lee in [7]. The miniaturization of the proposed antenna was achieved by using a bow-tie profile with a meander slot loaded at the ground plane. But the air gap between lower and upper substrate needs a very accurate adjustment to maintain the antenna performance.

The challenge of reducing the dimensions of an aperture coupled antenna is to maintain both its antenna radiation efficiency and its operating bandwidth. In this paper, we propose a simple aperture-coupled microstrip antenna. In order to reduce the antenna dimension, a meander line slot is loaded to the antenna patch. Apart from the size reduction, wider bandwidth and higher efficiency are achieved by adjusting the parameters of antenna configuration.

2. Proposed Antenna Configuration

The geometrical configuration of the proposed aperture-coupled antenna is illustrated in Figure 1. The proposed antenna consists of two identical substrates which are separated by a common ground plane. These two identical substrates has a relative dielectric permittivity of 3.2 with the dimensions of w_s and l_s for substrate width and length, respectively. The thickness of these substrates is 0.508 mm and 0.762 mm for lower (h_1) and upper (h_2) substrate layer, respectively. The patch radiator which has a dimension of l_p and w_p is printed on the top side of the upper substrate, while the feeding line with dimensions of l_{feed} and w_{feed} is printed on the bottom side of lower substrate. The radiation field from the feeding line is coupled through a thin rectangular slot on the common ground plane. The dimension of thin rectangular slot is l_{ap} for the length and w_{ap} for the width. The thin rectangular slot is located to the center of the radiator patch. For the purpose of size reduction analysis, a meander line slot is loaded to the antenna patch. The meander line has N fingers with both finger gap and width is g_m and w_m, respectively. Meanwhile, the finger length is l_m. For the basic design of the proposed aperture-coupled antenna, the geometrical configuration in [8] is referred.

The best characteristic of the proposed antenna can be achieved by matching the radiator patch and the feeding line. This matching can be obtained by choosing and adjusting the parameters of the substrates, the width and length of the patch, feeding line, meander line slot, the size of the coupling slot, and, most importantly, the offset of coupling slot in respect to the center of the radiator patch.

3. Numerical Results and Discussion

After defining the geometrical configuration of the proposed antenna, a numerical analysis was conducted with the aid of Electromagnetic CAD in order to obtain the best performance of the proposed antenna design. The proposed antenna performances are numerically analyzed in terms of return loss, antenna bandwidth, radiation efficiency, antenna gain, radiation pattern and side lobe. For the purpose of comparing the achievable size reduction, the antenna performance without the meander line slot (Antenna A) was firstly analyzed following by the antenna with meander line slot (Antenna B).

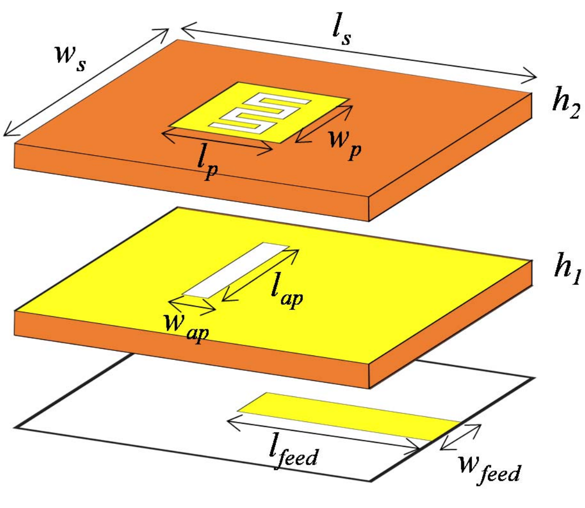

Figure 1. Aperture Coupled Microstrip Antenna with Meandered Slot

In order to obtain final dimension parameter of Antenna A to exhibit the best antenna performance, several parametric analyses were conducted. The final dimension of the proposed antenna without loading the meander line to the radiating patch is represented in Table 1. The final geometrical dimension of Antenna A exhibits reasonable antenna performance in terms of return loss and radiation pattern as depicted by the blue dashed line in Figure 2 and Figure 3, respectively. At -10 dB return loss, the antenna operational bandwidth is 290 MHz. Meanwhile, by referring to -3 dB gain loss, the beam width of 88.4° is achieved. In addition, this final design of Antenna A can achieve the antenna gain and side lobe suppression of 6.22 dBi and -9.3 dB, respectively, as well as an antenna radiation efficiency of 92%.

Afterwards, as the purpose of this paper is to present the advantages of meander line slot to miniaturize antenna dimension, the final geometrical dimensions of Antenna B is also numerically analyzed. In order to achieve the desired antenna dimension, we first changed the dimension of patch and substrate as represented in Table 1. Through parametric analyses in the Electromagnetic CAD, it was shown that the resonant frequency will shift to the higher frequency. In order to shift the resonant frequency back to the intended frequency, a further parametric analysis regarding the dimension of the meander line slot was conducted. This analysis showed that the most important parameters that influence the resonant frequency behavior are the number meander fingers, N, and the finger length, l_f, together with the coupling aperture to ensure that the radiation field is sufficiently coupled to the radiating patch. As the final dimension is represented in Table 1, Antenna B has a smaller overall dimension than Antenna B with a reduction factor of 36%.

In terms of return loss and radiation pattern, antenna B exhibits better performance than Antenna A, as depicted by the red solid line in Figure 2 and Figure 3, respectively. Antenna B has wider bandwidth of 400 MHz, a smaller beam width of 87.8° and a higher efficiency of 97%. However, Antenna B exhibits a lower gain of 5.27 dBi and a higher side lobe with only -5.1 dB suppression.

Table 1. The Proposed Antenna Dimension

Parameter	Antenna A (mm)	Antenna B (mm)
w_s	15	12
l_s	15	12
w_p	7.27	6.5
l_p	7.27	6.5
w_{ap}	1	1
l_{ap}	3.7	4.45
w_{feed}	1.224	1.224
l_{feed}	7.5	7.4
g_m	-	0.125
w_m	-	0.125
l_m	-	3.75
N	-	6

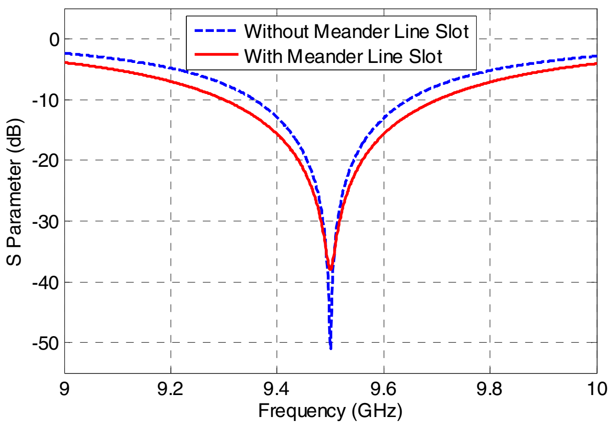

Figure 2. Comparison of S-Parameter

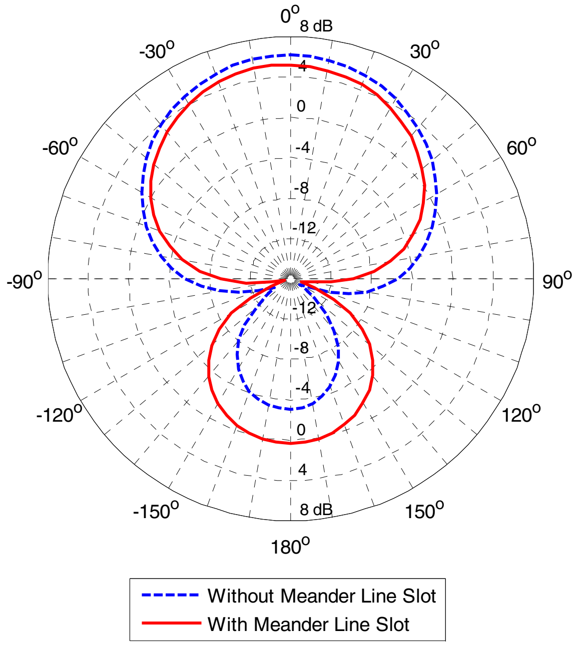

Figure 3. Comparison of Radiation Pattern

Table 2. Comparison of Antenna Performance

Parameter	Antenna A	Antenna B
Bandwidth (MHz)	290	400
Gain (dBi)	6.22	5.27
Beamwidth (degree)	88.4	87.8
Side lobe (dB)	-9.3	-5.1
Efficiency (%)	92	97

4. Conclusions

The development of an aperture-coupled microstrip antenna using a meander line slot has been described. The use of a meander line slot loaded to the antenna patch in the proposed antenna configuration has been investigated and shows various advantages. It not only reduces the antenna dimension by the factor of 36%, but also widens the antenna bandwidth by the factor of 38% and increases the antenna efficiency to 97%.

5. References

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