A Wideband Thin Film Slot Array Antenna using Mylar Polyester

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Abstract: This paper presents a Slot Array Antenna (SAA) which is fabricated on Thin Film Mylar Polyester (TFMP) substrate. The TFMP is low cost and also flexible material which can bend on curved surface and used for on-body communication system. The prototype antenna consists of microstrip transmission line and periodic slot arrays. For the measurement results, SAA shows dual resonant bahaviors at 2000 MHz and 2200 MHz with similar bidirectional radiation. The bandwidth is 520 MHz or 24.76%. In addition, the average measured gain is around 10.1 dBi at its operation bandwidth. Finally, SAA using TFMP can achieve wideband, high gain and conformal antenna.

Keywords—**Slot array antenna, Mylar polyester, Wideband**

1. Introduction

In the modern communication systems, wide bandwidth, low profile, small size, ease of fabrication, inexpensive and also conformal are essentially requirement in the antenna design for on-body communication system. For microstrip antennas, they have many pleasurable aspects, for example, low cost, low profile, and lightweight. Therefore, because of these aspects that make such antennas are widely used as the most antenna type in microwave, mobile, and satellite communication systems. Nevertheless, the major disadvantages of these antennas are narrow impedance bandwidth and low gain [1]. Consequently, the methods have been presented to enhance bandwidth and increase gain of microstrip antenna by using slot antenna and array method, respectively [1], [2]. So, the increasing microstrip antenna's bandwidth and gain are the important features for advance communication systems.

On the last decade, the research of microstrip antennas emphasized to enhance their bandwidth and gain. Microstrip Slot Antenna (MSA) bring up wider bandwidth, lower radiation loss and less the impact of changing in polarization than patch microstrip antenna. Moreover, the MSA not only can perform bidirectional pattern or unidirectional pattern but also the feeding line is independently from the radiating slot that mean MSA has advantages in term of ease to design and impedance matching [3], [4]. In term of improving the gain of MSA, array method is one of the most technique to increase gain [1]. Furthermore, the slot array antenna has been shown that bandwidth and gain of SAA can be simultaneously improved [5].

This paper presents the wideband thin film slot array antenna using mylar polyester. The proposed antenna compose of SAA, microstrip feed line, and TFMP as substrate which is shown in Figure 1(a). The slot array has 4 slots on a ground plane which is fed by 50 ohms series microstrip feed line. It provides two resonant frequencies and the center frequency at 2100 MHz. Firstly, the length of slots and the position of each slot are studied to find the good optimization in order to get needed impedance matching and wide bandwidth by using commercially available Zeland IE3D simulation software. Finally, with these optimum parameters, the wideband thin film slot array antenna is successfully fabricated and measured.

2. Antenna Configuration and Design

In this section, a single slot antenna (SSA) and a slot array antenna (SAA) have been presented their complements and dimensions. Firstly, SSA is fundamental antenna of SAA which is designed and studied its parameters to optimize a slot for desired frequency. Afterwards, the SAA has been designed and simulated based on parameters which have been optimized in SSA. Both antennas use the dielectric, Mylar Polyester, that has dielectric relative permittivity (ε_r) 3.2 , thickness (*H*) 0.4 mm., and loss tangent (*tan* δ) 0.009. This material is low-cost, flexibility, and thinness rather than existing materials, such as, FR-4. And also, this material has been measured its properties by using keysight 85072A 10 GHz split cylinder resonator [6]. In addition, conductor, copper sheet, has conductivity (σ) 5.8 × 10^7 S/m and its thickness 0.1 mm.

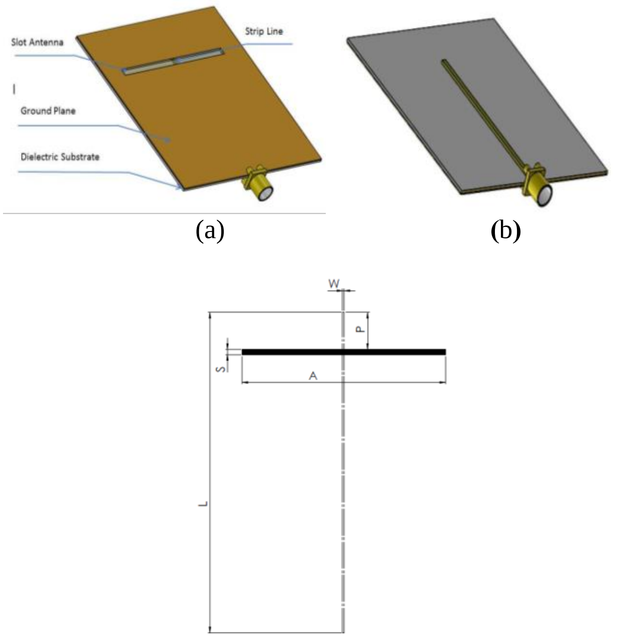
2.1 Single slot antenna (SSA)

As shown in Figure 1(a) and 1(b), A SAA consists of one thin slot placed on ground plane and microstrip line on the other side, respectively. For the microstrip line, the width has been calculated by using Eq. (1) at 2100 MHz which its characteristic impedance (Z_c) is 50 ohms. Although, from calculation, the width (W) is 0.8 mm., the microstrip line of practical antenna is slightly 1 mm. and the length (L) is 184.50 mm. Figure 1(c) shows Single slot structure that has a slot width (S), a slot length (L), and a distance (P) between upper edge of slot and open-end of microstrip line. The slot width is small fraction of a guided wavelength and the length of slot is $n\lambda_g/2$ where n is an interger [7]. Practically, SSA has a slot width of $0.03\lambda_g$ and slot length of $1.34\lambda_g$ for desired resonant frequency at 2100 MHz as shown in Figure 2 and Figure 3.

$$\frac{W}{h}=\frac{2}{\pi}\left\{B-1-\ln(2B-1)+\frac{\varepsilon_r-1}{2\varepsilon_r}\left[\ln(B-1)\right]+0.39-\frac{0.61}{\varepsilon_r}\right\} \quad (1)$$

where: $B=\dfrac{60\pi^2}{Z_c\sqrt{\varepsilon_r}}$

In term of SSA analysis, figure 2 shows the simulated return loss of SSA when its width is changed from 2 mm. to 4 mm. The results from figure 2 shows that slot width has effect on return loss and imphedance of SSA. On the other hand, the slot length affect on resonant frequency that mean the antenna resonance can be controlled by length of slot, as shown in figure 3.



(a) (b)

(c)

Figure 1. Single slot antenna geometry (a) Ground plane side, (b) Microstrip line side, and (c) Single slot antenna parameters

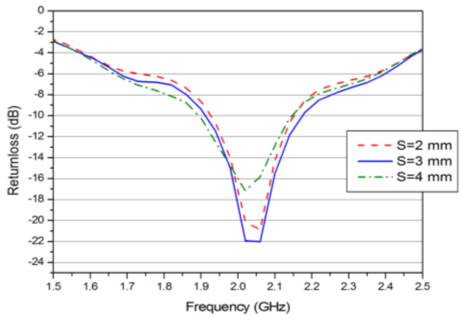


Figure. 2 Simulated return loss with various Slot widths

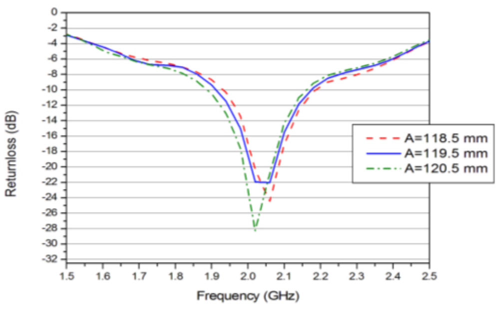
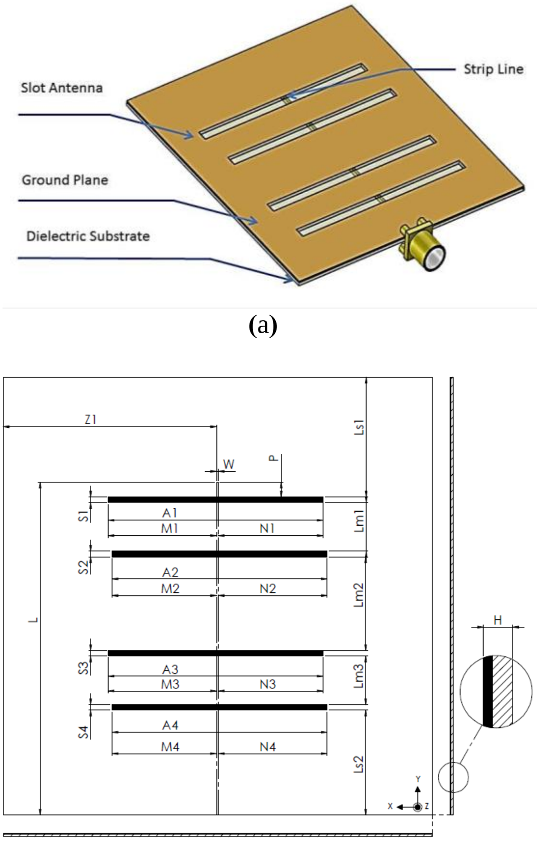


Figure. 3 Simulated return loss with various Slot lengths

2.2 Slot array antenna

The wideband thin film slot array antenna is shown in Figure 4(a). It consist of microstrip line, four radiating slots, dielectric, and ground plane. In term of each radiating slot, the length and width of each slot is the same of SSA. Figure 4(b) shows the parameters which have lengths (A1 – A4), widths (S1 – S4), distances between each slot (Lm1 – Lm3), distances from edge to upper and lower slots (Ls1 and Ls2), and microstrip line is fed center of slots so that N and M is equal. The slot parameters of proposed antenna is demonstrated as shown in Table. 1. For microstrip line, its width is also 1 mm. as same as SSA and its length is longer than microstrip line length of SSA with 184.50 mm. which is used to feed slot array antenna as the series array antenna [1].

For parameter analysis, Figure 5 shows simulated return loss of SAA with changing Ls_1 65.5 mm., 66.5 mm., and 67.5 mm. When Ls_1 increases, the resonant frequency is slightly shifting and its return loss is a bit changing. In addition, Figure 6 shows clearly that Ls_2 has more effect on resonant frequency than Ls_1. Ls_2 is the distance from input SMA port to the first element of slot array. The resonant frequency of SAA shift apparantly to lower frequency when Ls_2 is imporved from 57.2 mm. to 59.2 mm.. and also it affect directly impedance matching.



(a)

(b)

Figure 4. Proposed antenna (a) Complement and (b) Geometry

Table. 1 Slot parameters of proposed antenna

Para meters	Value (mm)	Para meters	Value (mm)
$A_{1,2,3,4}$	119.5 (1.34 λ_g)	N_1	58.25 (0.65 λ_g)
$S_{1,2,3,4}$	3 (0.03 λ_g)	N_2	60.45 (0.68 λ_g)
Lm_1	27 (0.304 λ_g)	N_3	58.25 (0.65 λ_g)
Lm_2	52 (0.58 λ_g)	N_4	60.45 (0.05 λ_g)
Lm_3	27 (0.304 λ_g)	Ls_2	58.20 (0.65 λ_g)
Ls_1	66.50 (0.75 λ_g)	L	184.50 (2.08 λ_g)

where: $\lambda_g = \dfrac{c}{f_r\sqrt{\varepsilon_{eff}}}$ and $\varepsilon_{eff} = \dfrac{\varepsilon_r+1}{2}+\dfrac{\varepsilon_r-1}{2}\left(1+\dfrac{12h}{W}\right)^{-\frac{1}{2}}$

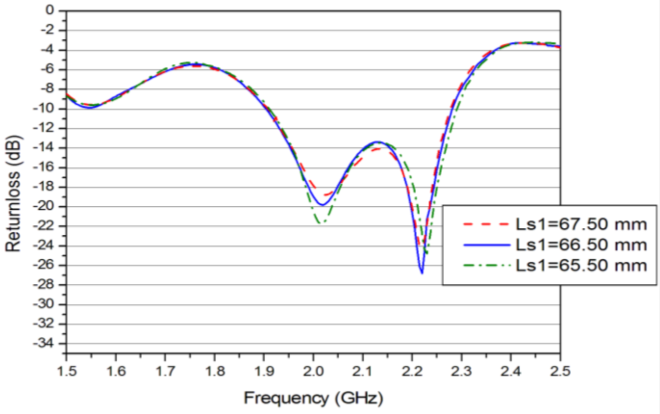


Figure 5 Simulated return loss with various Ls_1

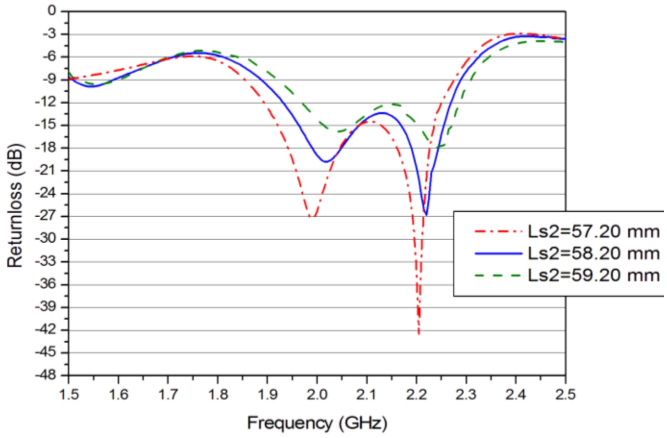


Figure 6 Simulated return loss with various Ls_2

3. Simulation and Measurement

In this section, the simulated and measured results has been presented. Figure 7 shows the return loss result, return loss is lower than -10 dB, which has a bandwidth 450 MHz (1860 – 2310 MHz: 21.42%) and 520 MHz (1875 – 2395 MHz: 24.76%) for simulation and measurement, respectively. Also, two resonant frequencies occur around 2000 MHz and 2200 MHz. As the results, the measured result slightly shifts higher than the simulated results, because of fabricated procedures. Moreover, the simulated and measured gains are shown in Figure 8. The measured gain is lightly higher than that simulation. For simulation, average gain among usable bandwidth is around 8.1 dBi and 8.2 dBi at center frequency 2100 MHz. and Also, average measured gain is about 10.1 dBi during operating bandwidth and the gain at center frequency is 10.61 dBi. In considering the measured 2D radiation patterns of proposed antenna in *xz* plane and *yz* plane at center frequency 2100 MHz are shown in Figure 9(a) and Figure 9(b), respectively. As the result of radiation pattern in *xz* plane and *yz* plane, they clearly confirm that radiation pattern of proposed antenna is bidirectional and maximum radiation patterns are braodside in both directions. co-polarization (solid red line) and cross-polarization (dash blue line) are greatly discrimination. Therefore, it can ensure that this proposed antenna has a linear polarization in vertical direction. Figure 9(c) shows a measured 3D pattern which confirm that this prototype antenna has a birectional radiation pattern. The main lobes of radiation pattern is perpendicular with anttenna plane (broadside direction)

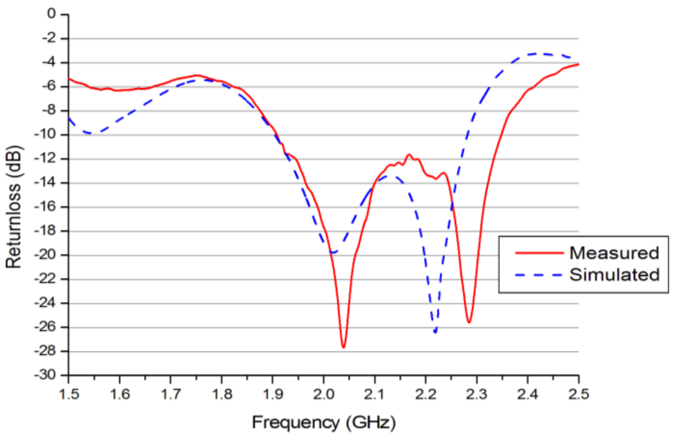


Figure 7. Simulated and measured return loss results

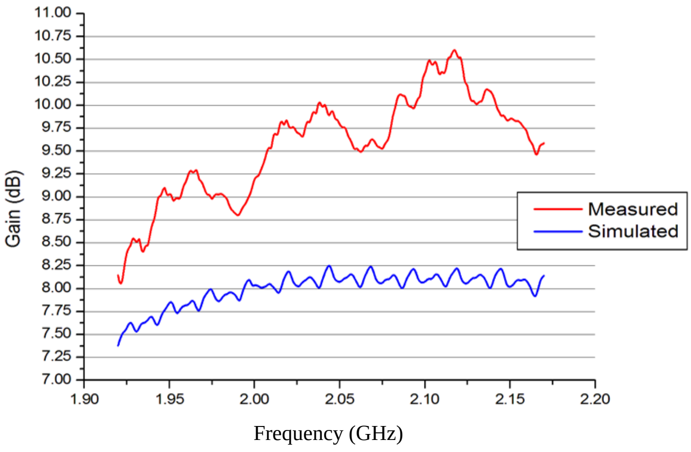
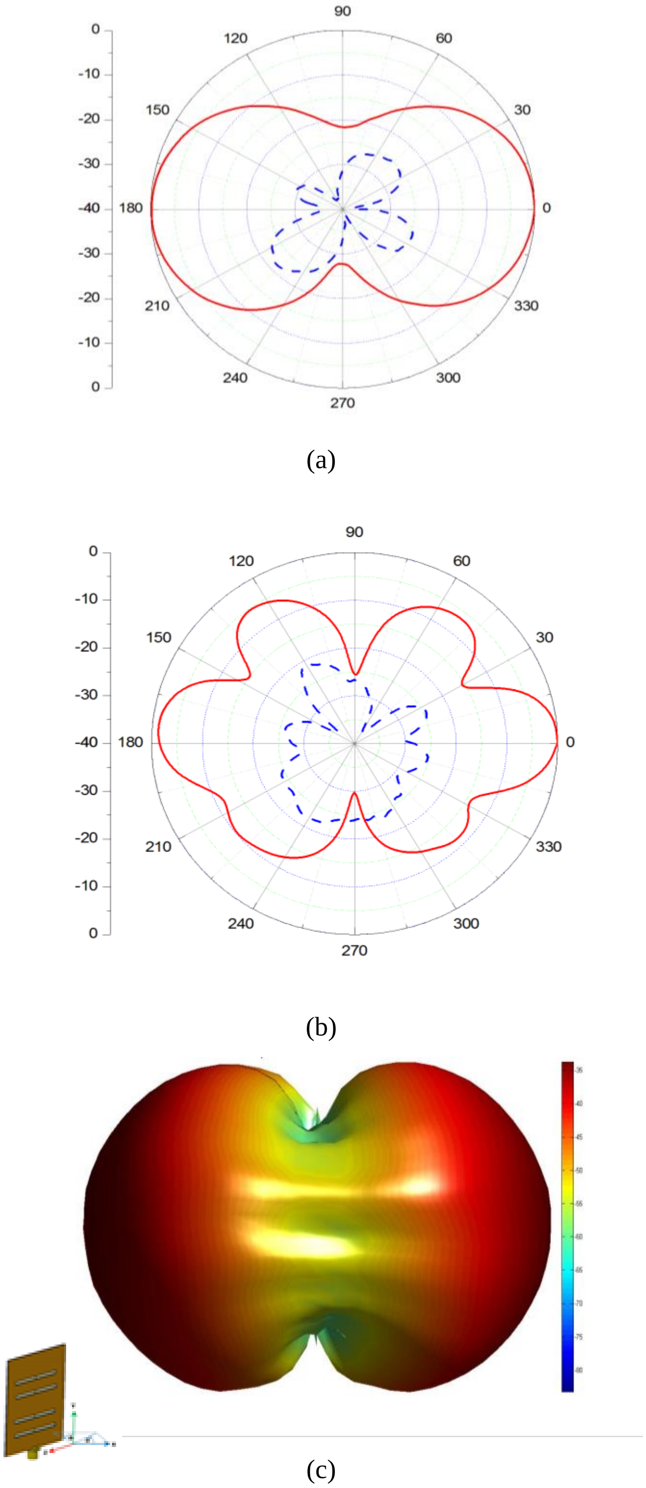


Figure 8. Simulated and measured gain results



(a)

(b)

(c)

Figure 9. Measured radiation pattern at 2100 MHz

(a) xz plane, (b) yz plane, and (c) 3D pattern

4. Conclusions

In this paper, a thin film slot array antenna using Mylar polyester substrate are designed and fabricated for wideband application. The measured impedance bandwidth has great result that cover 1875 – 2395 MHz or 24.76% at center frequency 2100 MHz. In addition, the measured gains are estimated an average 10.1 dBi throughout such bandwidth. Moreover, the proposed antenna performs birectional pattern and provides vertiacal linear polarization. Finally, this is confirmed that the TFMP achieves to design and fabricate wideband thin slot array antenna which can possibly be used to flexible materail for on- body communication.

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