GAIN AND BANDWIDTH ENHANCEMENT FOR RECTANGULAR PATCH MICROSTRIP ANTENNA

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PERIÓDICO TCHÊ QUÍMICA
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GANHO E MELHORIA DA LARGURA DE BANDA DE FRAGMENTO RETANGULAR DA ANTENA *MICROSTRIP*

GAIN AND BANDWIDTH ENHANCEMENT OF RECTANGULAR PATCH MICROSTRIP ANTENNA

تحسين التحصيل وعرض الحزمة للهوائي الشريطي المستطيل

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RESUMO

As antenas de *microstrip* são muito populares para enviar e transmitir ondas eletromagnéticas em muitos sistemas de comunicação. A antena *microstrip* tem vantagens e desvantagens, como qualquer outro tipo de antena. Dentre as vantagens estão o baixo peso, configuração plana de baixo perfil, baixos custos de fabricação e fácil conexão com circuitos de microondas. A antena remota é adequada para aplicações que são sistemas de comunicação sem fio, telefones celulares, *pagers*, sistemas de radar e sistemas de comunicação via satélite. A antena proposta foi projetada e simulada via HFSS. O substrato da antena, que está entre o remendo dos dois condutores e o plano do solo, é Duroide da constante dielétrica de ε_r = 2,2 e perda tangente de tan δ = 0,0009. As dimensões são 20 mm para comprimento e largura; a altura é de 1,5 mm. O patch das dimensões são 16 mm e 15 mm para comprimento e largura, respectivamente. Neste artigo, a nova técnica foi introduzida para aumentar o ganho e a largura de banda da antena de microponto retangular. Uma nova técnica baseia-se no tratamento de um adesivo como monopolo; o estudo paramétrico feito pela variação do parâmetro é a altura do adesivo em relação ao substrato. O ganho e a largura de banda aumentam quando o ângulo entre a borda do patch e o substrato é aumentado. Embora o ganho tenha aumentado para o ângulo de inclinação de até 20° e depois tenha diminuído suavemente com o aumento do ângulo, os resultados simulados mostram uma mudança significativa na comparação de ganho e largura de banda com a antena de reticulação retangular tradicional. Os resultados mostram um aumento do ângulo de inclinação, aumento da largura de banda e ganho. Esta antena pode ser usada na banda K para aplicativos de comunicação sem fio.

Palavras-chave: *Microstrip, ganho, largura de banda, antena monopolar, banda K*

ABSTRACT

Microstrip antennas are very popular for sending and transmitting electromagnetic waves in many communication systems. The microstrip antenna has advantages and disadvantages, like any other antennas. There many benefits like low weight, low profile planar configuration, low costs of fabrication, and easy to connect with microwave circuits. The patch antenna is suited for applications, which are wireless communications systems, cellular phones, pagers, radar systems, and satellite communications systems. The proposed antenna is designed and simulated via HFSS. The antenna substrate, which is between the two conductors' patch and ground plane, is Duroid of the dielectric constant of ε_r = 2.2 and tangent loss of $\tan\delta = 0.0009$, the dimensions are 20 mm for both length and width; the height is 1.5 mm. The patch of sizes is 16 mm and 15 mm for length and width, respectively. In this article the new technique has been introduced to enhance the gain and bandwidth of the rectangular patch microstrip antenna, a new technique is based on creating a patch as a monopole, the parametric study done by varying the parameter δ is the height of the patch concerning the substrate. The gain and bandwidth are increased when the angle between the patch edge and the substrate is increased. While the benefit increased for tilt angle up to 20° and then decreased smoothly with angle increased, the simulated results show a significant change in the gain and bandwidth comparison with traditional rectangular patch microstrip antenna. The results show an increasing tilt angle increased bandwidth and gain. This antenna can be used in the K band for wireless communication applications.

Keywords: *Microstrip, Gain, Bandwidth, Monopole antenna, K-band*

الملخص

للهوائي الشريطي العديد من الخواص الجيدة و اخرى غير الجيدة، مثل اي نوع من الهوائيات الاخرى. هناك العديد من المزايا مثل خفة الوزن و شكل مستو بسيط و قلة كلفة التصنيع وسهولة الربط مع الدوائر المايكروويية. الهوائي المشع مناسب للتطبيقات مثل انظمة الاتصالات اللاسلكية و الهواتف النقالة و الاستشعار و انظمة الرادار و انظمة الاتصالات الفضائية. الهوائي المقترح صمم وتمت محاكاته بواسطة برنامج " High Frequency Structure Simulator" HFSS. المادة العازلة بين المادتين الموصلة (المشع والقاعدة) للهوائي هي نوع تجاري Douriod تمتلك ثابت عزل ε_r =2.2 وظل فقد كهربائي $\tan\delta = 0.0009$، ابعادها 20 mm لكل من الطول والعرض، ارتفاع المادة العازلة هو 1.5 mm. ابعاد الجزء المشع من الهوائي 16 mm و 15 mm للطول والعرض على التوالي. قدمت في هذا البحث تقنية جديدة لتحسين التحصيل وعرض الحزمة للهوائي الشريطي المستطيل، تعتمد التقنية الجديدة علة معاملة الهوائي كقطب احادي، تمت دراسة تأثير العامل δ، وهو ارتفاع المشع عن الطبقة العازلة. ازداد كل من التحصيل وعرض الحزمة عند زيادة الزاوية الى ما فوق 20^o وتزداد بزيادة الزاوية فوق ذلك، نتائج المحاكاة بينت تغيير معنوي في التحصيل وعرض الحزمة مقارنةً بالهوائي الشريط المستطيل الاعتيادي. يستخدم هذا الهوائي في الحزمة الترددية K لتطبيقات الاتصالات اللاسلكية.

الكلمات المفتاحية: هوائي شريطي، التحصيل، عرض الحزمة، هوائي احادي القطب، حزمةK

1. INTRODUCTION:

Microstrip antenna is the tool for sending and transmitting electromagnetic waves as a part of the communication systems. Each antenna has advantages and disadvantages, like any other antennas. There many gains such as low weight and profile planar configuration, low fabrication costs, the capability to integrate with microwave circuits. The microstrip patch antenna is very well suited for applications such as wireless communications systems, cellular phones, pagers, Radar systems, and satellite communications systems (Patil, 2012). On the other hand, the disadvantage of narrow bandwidth is, however, the main drawback of the microstrip patch antenna (Xiong *et al.,* 2012).

Many techniques have been introduced and developed to enhance bandwidth and gain for the microstrip antenna due to its disadvantages which listed previously from many researchers (Kharade and Patil, 2012; Islam *et al*., 2013; Ms. Priyanka and Srivastava, 2013; Urgunde *et al.,* 2014; Saurabh *et al.,* 2013; Bhardwaj *et al.,* 2014; Rabbani and Ghafouri-Shiraz, 2014; Kumar *et al.,* 2014). The primary technique to the enhanced bandwidth of the microstrip antenna which is using slots in patch or ground plane or both, other methods are based on utilized from the metamaterial concept to broadening the bandwidth impedance of the antenna, while, many researchers are using the configurable patch or ground plane (Arora *et al.,* 2017; Pothugunti and Viswanadham, 2017; Al-Ahmadi and Khraisat, 2019; Bhanumathi and Swathi, 2019; Al-Shaheen, 2019), different methods are presented rather than the previous are mentioned (Bakr *et al.,* 2019; Satyanarayana and Shankaraiah, 2018; Bhukya and Pabbu, 2019).

The concept of the modified monopole antenna to enhance both the gain and bandwidth of the rectangular patch microstrip antenna in comparison with the traditional one was used.

The idea of this proposed antenna was to allow several modes to be excited on the antenna's patch at the same time. This was achieved by making the two edges of the patch to be movable by varying the angle between the edeges and the antenna's substrate. This bring about to get an optimum angle, which is provided the best antenna performanece such as bandwidth and gain.

2. MATERIALS AND METHODS:

To design the patch antenna, the formulas of the rectangular patch antenna were used (Figure 1), as follows from Equations1 to 7 (Balanis, 2016). The length of a rectangular patch antenna is in the range,

$$0.333\lambda < L < 0.5\lambda \qquad \text{(Eq.1)}$$

where λ being the free-space wavelength. While the thickness of the patch is usually in between,

$$0.003\lambda_o \le h \le 0.05\lambda_o \qquad \text{(Eq.2)}$$

The dielectric constant of the substrate (ε_r) is typically as; $2.2 \le \varepsilon_r \le 12$. The parameters of a Rectangular Microstrip Patch Antenna for practical design are described in Equations 3-6 as:

1. The width(W_p)

$$W_p = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} \qquad \text{(Eq.3)}$$

2. The effective Dielectric constant (ε_{reff})

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1+12\frac{h}{W}]^{\frac{1}{2}} \qquad \text{(Eq.4)}$$

3. The correction length due to the fringing fields of Microstrip antenna is

$$\Delta L = 0.412\frac{(\frac{W}{h}+0.264)(\varepsilon_{eff}+0.3)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \qquad \text{(Eq.5)}$$

4. The length of the patch is

$$L_p = L_{eff} - 2\Delta L \qquad \text{(Eq.6)}$$

where

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \qquad \text{(Eq.7)}$$

In the case of microstrip antenna, the bandwidth BW of the antenna is proportional to its quality factor Q and given by (Kumar and Ray, 2003) (Equation 8),

$$BW = \frac{VSWR-1}{Q\sqrt{VSWR}} \qquad \text{(Eq.8)}$$

where VSWR is voltage standing wave ratio. The percentage bandwidth of the patch antenna in terms of its dimensions and substrates parameters is given as Hamad, 2012 (Equation 9).

$$BW\% = \frac{Ah}{\lambda_0}\sqrt{\frac{W}{L}} \qquad \text{(Eq.9)}$$

where A is between 180 to 220 according to the ratio of the substrate height and dielectric constant and the operating frequency as Equation 10

$$A = \begin{cases} 180; & \frac{h}{\lambda_0\sqrt{\varepsilon_r}} \leq 0.045 \\ 200; & 0.045 \leq \frac{h}{\lambda_0\sqrt{\varepsilon_r}} \leq 0.075 \\ 220; & \frac{h}{\lambda_0\sqrt{\varepsilon_r}} \geq 0.075 \end{cases} \qquad \text{(Eq.10)}$$

The proposed antenna was designed and simulated via the High-Frequency Structure Simulator (HFSS). This software resolves the Maxell's equations in the near field based on the two different numerical methods one of them is finite element method and the other is method of moment MoM to solve the integrodifferential equations to find the current distribution and the near and far-field component of the electric and magnetic fields. Add to that the circuit parameters such as the scattering matrix, Voltage Standing Wave Ratio (VSWR) and input impedance, etc. The software has a graphical tool to demonstrate the results in graph mode in two and three dimensions. Also, one can animate the current and field distribution on the structure under the test. The antenna substrate Duroid of the dielectric constant of ε_r = 2.2 and tangent loss of $\tan\delta = 0.0009$, the dimensions are 20 mm for both length and width; the height is 1.5 mm. The patch is selected to be perfect electric conductor PEC, which is suitable for simulating the antenna; the dimensions of patch are 16 mm and 15 mm for length and width, respectively, as shown in Figure 2. The ground plane dimension is the same as the substrate dimensions; the material used to simulate the ground plane to study the variation of the electric field is also the PEC.

The antenna is a probe center feed coaxial cable connector to achieved 50 Ω input impedance to get a proper impedance matching between the antenna and other microwave circuits. The HFSS provides a parametric study to get the optimum parameters to get excellent performance for the antenna, by varying the angle between the patch edge and the substrate to change the angle between 0^o to 70^o (Figure 3).

3. RESULTS AND DISCUSSION:

Using the HFSS software to simulate the effect of the proposed antenna in the K band applications, the result of the traditional patch antenna is shown in Figure 4 which is illustrate the return loss, it can be seen from the Figure the proper impedance matching was achieved the reflection coefficient, return loss, is about -50 dB, which is reflected that the maximum power transfer to the load (antenna). It can also be seen that the bandwidth is about 0.82 GHz at 12.26 GHz resonance frequency. Now the parametric study was done by varying the parameter δ, which is done by it to get the sufficient angle between the edge and the substrate, as shown in Figure 5. The range δ is from 0.5 to 7.5 to vary the angle θ from 3.5^o to 70^o, the effect of this parameter on the proposed antenna performances, such as the return loss, and the realized gain of depicted of the some selected cases, in Figure 6.

It can be seen from Figure 6 that the bandwidth increased with an increased tilt angle, while the gain increased for tilt angle up to 20^o, the increase in both gain and bandwidth is due to allow the surface currents and the fringent field to many exciting modes and then contribute to enhancing them. And then decreased with angle increased, as depicted in Figure 7. After the proposed antenna simulated via HFSS with parametric study by varying the angle as observed previously, the results showed the importance of both gain and bandwidth. It can be seen that the bandwidth is increased up to 9 GHz when the angle increased. Also, the gain increased up to 5 dB. The complete results are listed in table 1.

4. CONCLUSIONS:

Microstrip antenna has many disadvantages, such as the narrow bandwidth. In this paper, the concept of the modified monopole antenna to enhance both the gain and bandwidth of the rectangular patch microstrip antenna in comparison with the traditional one was used. The idea of this proposed method is to varying the angle between two sides of the patch to get the optimum angle to get the best bandwidth and gain. The results show that increase tilt angle increased bandwidth and gain is about 8 dB in the range of movable patch sides of 10 to 30^0, the bandwidth is about 0.82 GHz at 12.26 GHz resonance frequency. This antenna can be used in the K band frequency applications.

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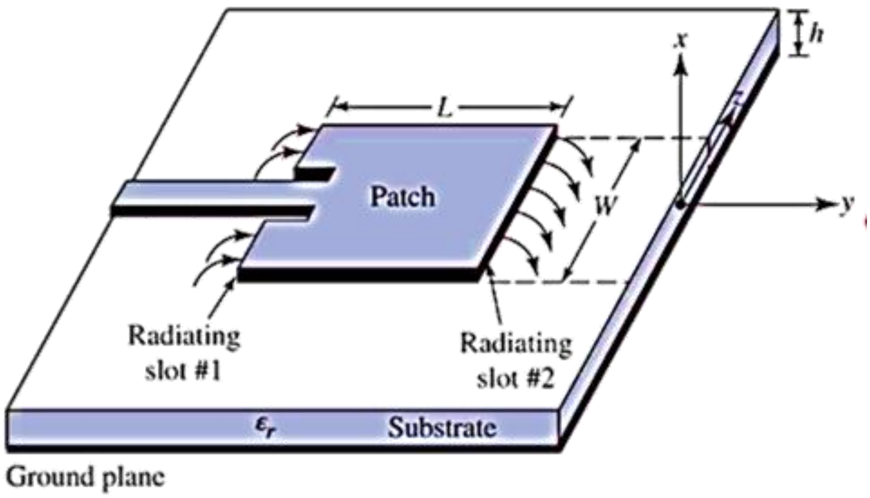


Figure 1. *Rectangular patch microstrip antenna.*

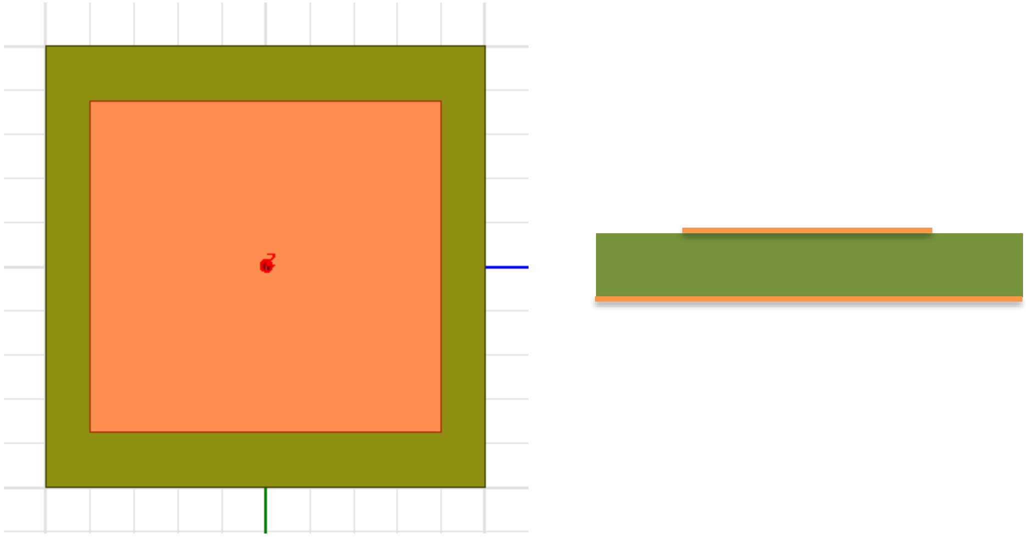


Figure 2. *Proposed antenna with angle* $\theta = 0°$.

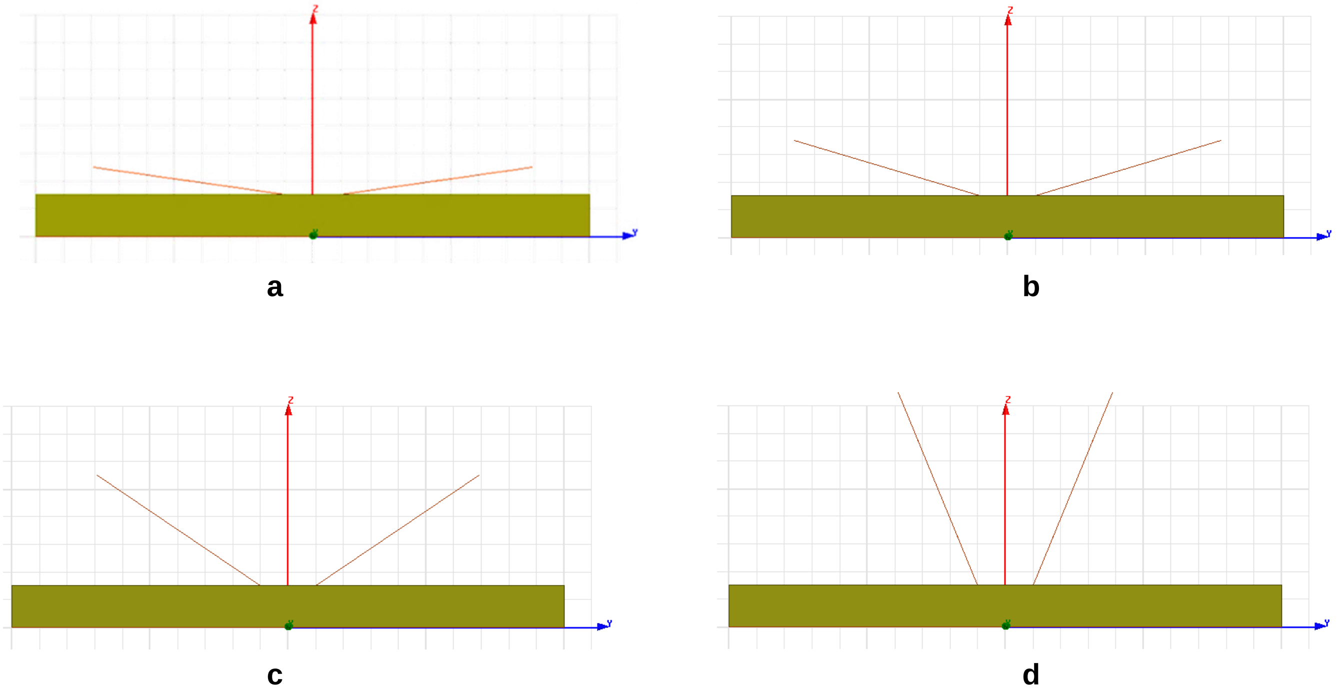


Figure 3. *Patch tilts concerning the substrate (a) $\theta = 7^0$, (b) $\theta = 14.5^0$, (c) $\theta = 30^0$ and (d) $\theta = 61^0$.*

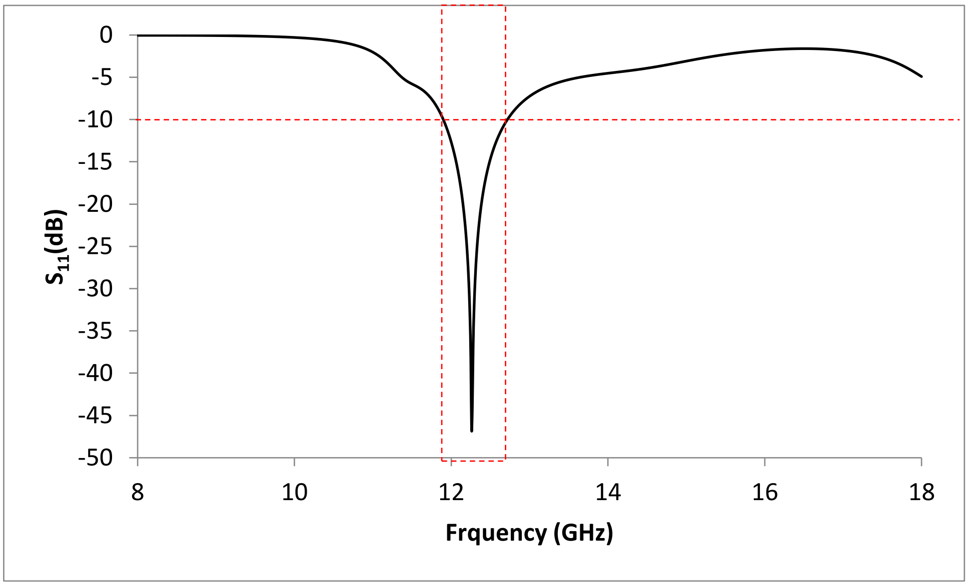


Figure 4. *The return loss of the traditional antenna.*

$$y = L\cos\theta$$

$$\theta = sin^{-1}(\delta/L)$$

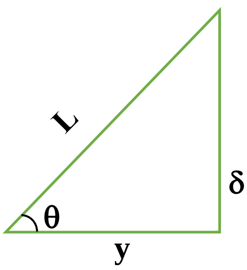
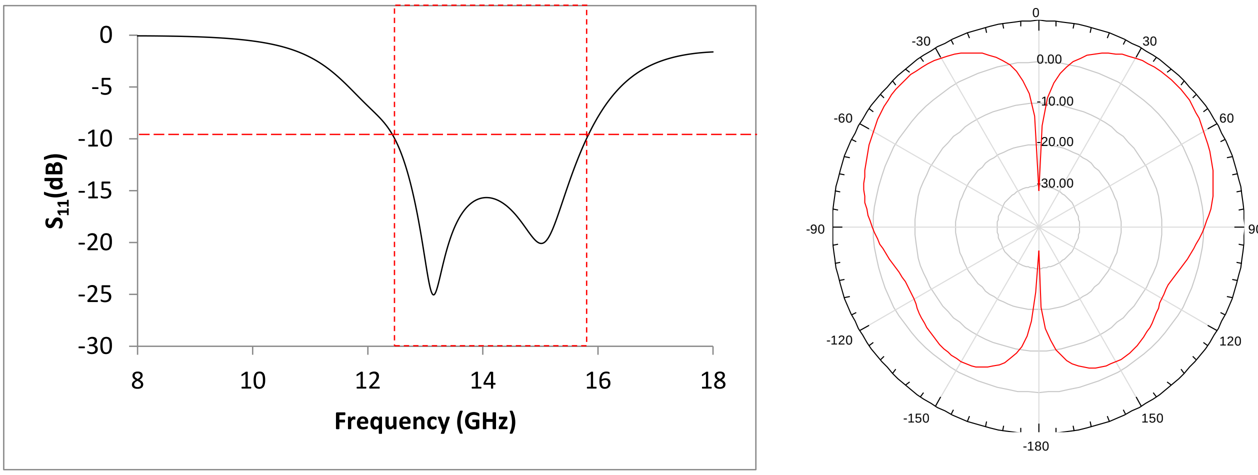
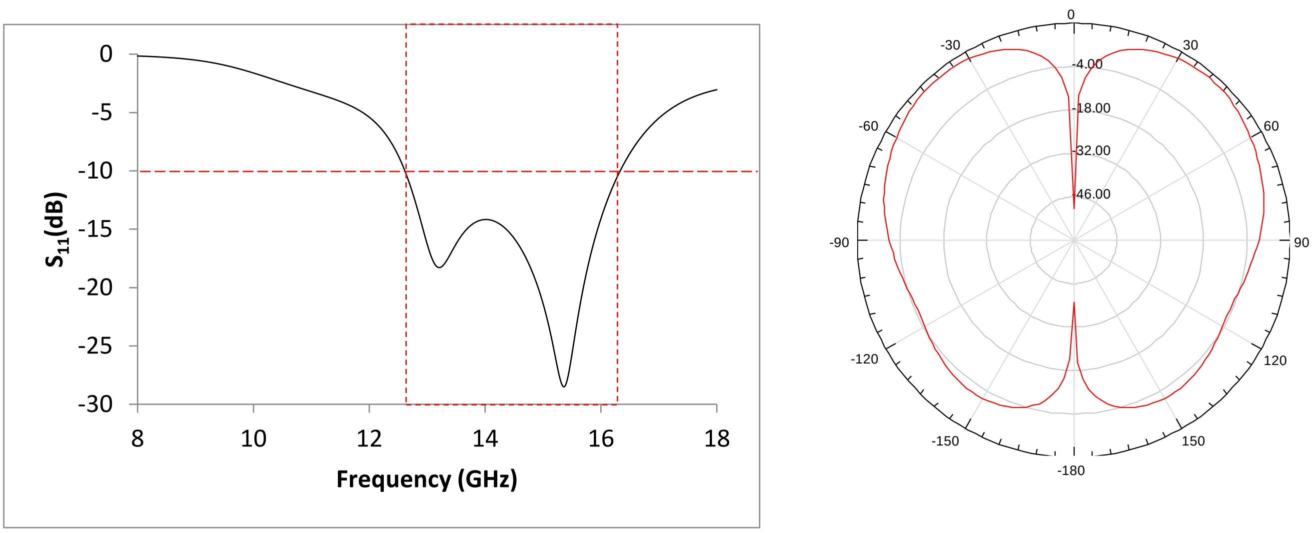


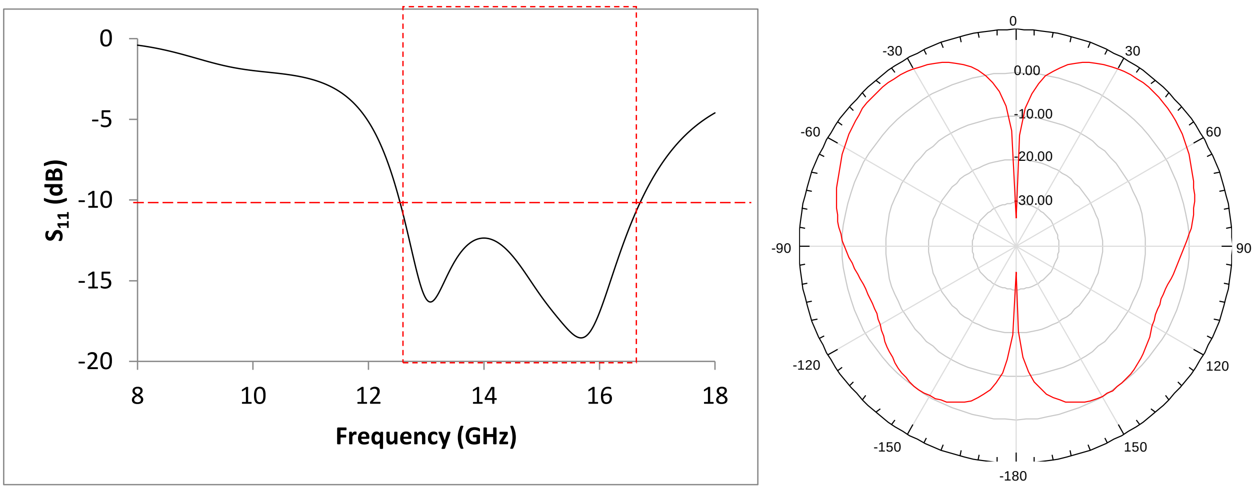
Figure 5. *Patch geometry.*


0
-5
-10
-15
-20
-25
-30
S11(dB)
8
10
12
14
16
18
Frequency (GHz)
0
-30
30
-60
60
-90
90
-120
120
-150
150
-180
0.00
-10.00
-20.00
-30.00

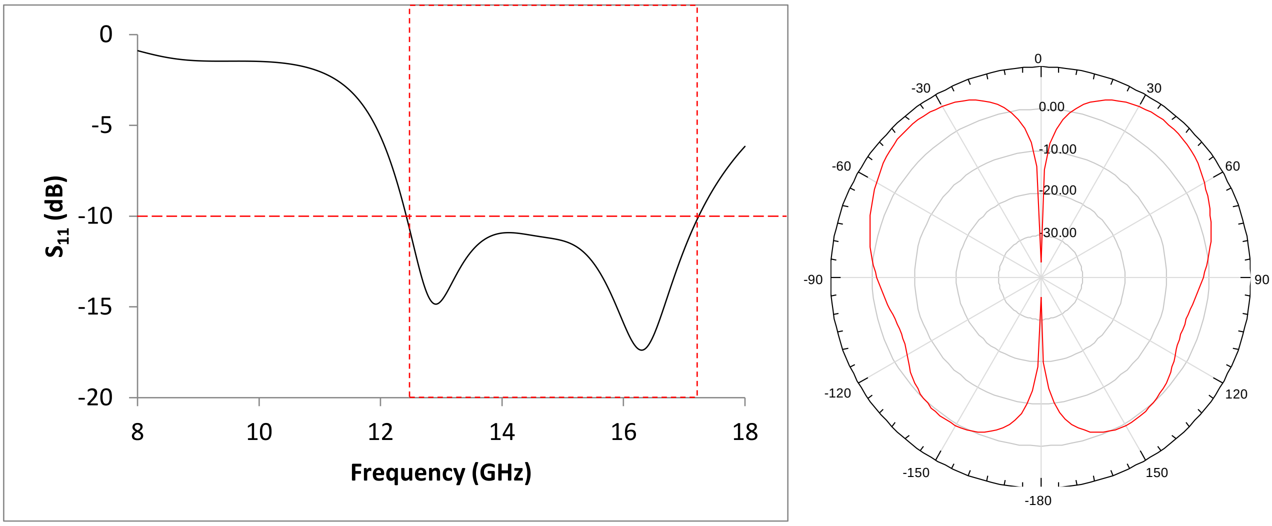
a


0
-5
-10
-15
-20
-25
-30
S11(dB)
8
10
12
14
16
18
Frequency (GHz)
0
-30
30
-60
60
-90
90
-120
120
-150
150
-180
-4.00
-18.00
-32.00
-46.00

b


0
-5
-10
-15
-20
S11 (dB)
8
10
12
14
16
18
Frequency (GHz)
0
-30
30
-60
60
-90
90
-120
120
-150
150
-180
0.00
-10.00
-20.00
-30.00

c



d

Figure 6. *Return loss and realized gain vis. tilt angle; (a) $\theta = 70^0$, (b) $\theta = 14.5^0$, (c) $\theta = 30^0$ and (d) $\theta = 61^0$*

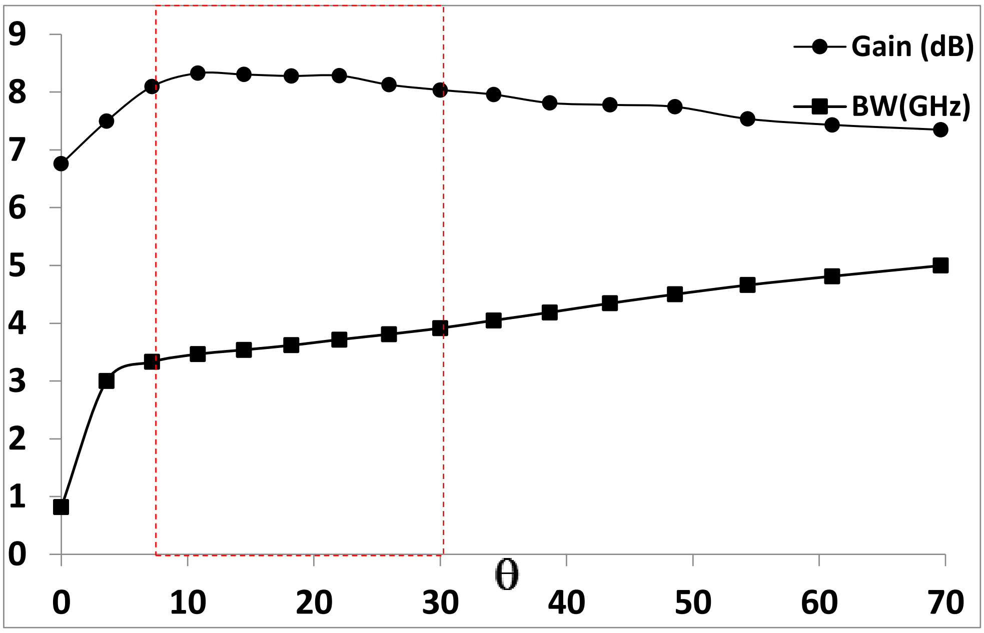


Figure 7. *Bandwidth and realized gain vis. angle θ.*

Table 1. *Bandwidth and realized gain vis. angle θ*

δ	θ (deg.)	BW (GHz)	Gain (dB)	δ	θ (deg.)	BW (GHz)	Gain (dB)
0	0	0.8182	6.7599	4	30	3.9147	8.0379
0.5	4	3.0008	7.4961	4.5	34	4.0489	7.9583
1	7	3.3300	8.0968	5	39	4.1884	7.8125
1.5	11	3.4645	8.3279	5.5	43	4.3447	7.7799
2	14	3.5400	8.3051	6	49	4.5006	7.7464
2.5	18	3.6180	8.2797	6.5	54	4.6597	7.5373
3	22	3.7169	8.2847	7.0	61	4.8132	7.4334
3.5	26	3.8097	8.1282	7.5	70	4.9973	7.3485