Improvement in Gain and Bandwidth of Rectangular and U Slot Loaded Patch

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Abstract

This paper discusses analysis and optimization for rectangular and U slit or slot loaded micro strip antenna. For analysis, many parameters have been varied to optimize the resonant frequency 15 GHz, upper frequency 21GHz and lower frequency 9 GHz. The dielectric permittivity of the substrate is considered 4.8. In this paper we specially emphasize on the height of the substrate. By changing the height of the substrate from 1mm to 3.2mm. The patch will be fed by a micro strip transmission line, which usually has a 50Ω impedance. The antenna is usually fed at the radiating edge along the width (W) as it gives good polarization, however the disadvantages are the spurious radiation and the need for impedance matching [1]. This is because the typical edge resistance of a micro strip antenna ranges from 150Ω to 300Ω [2]. The bandwidth is optimized from 754.13 to 4196.50 MHz for rectangular patch and 949.90 to 207099.33 MHz for parasitic patch.

Keywords: Microstrip antenna, dielectric constant, frequency, bandwidth, slit, algorithm, Optimization program, genetic algorithm, polarization, U slot.

1. Introduction

The micro strip antenna concept dates back about 56 years in the U.S.A by Deschamps [1] and in France by Gutton and Baissinot [2] . In late 1960's additional studied were undertaken by kaloi, who studied basic rectangular and square configurations. Microstrip Antennas have attached much interest due to their low profile like compact in size, light weight, low cost on mass production, ease of installation, compatible with MMIC designs. However major two limitations in their applications are narrower bandwidth and low gain in comparison to that of other Microwave Antennas Introducing U slot or slit in rectangular radiating patch is simple and efficient method for obtaining the desired compactness, multiband and broadband properties since these shapes radiates electromagnetic energy efficiently. A new Rectangular micro strip patch Antenna loaded with U slit (Figure-4) is analyzed and carefully examined in this paper When we change the shape of a micro strip antenna and it is covered with a dielectric layer , its properties like resonance frequency, gain are changed which may seriously degrade or upgrade the system performance . Therefore, in order to introduce appropriate correctness in the design of the antenna, it is important to determine the effect of dielectric layer and shapes on these antenna parameters. This paper describes the use of Genetic Algorithm (Figure-2) , and optimization program to analyze the gain of a rectangular micro strip antenna. Genetic Algorithm is a class of search techniques that use the mechanisms of natural selection and genetics to conduct a global search of the solution and this method can handle the permittivity and the shape (U) slot of the rectangular micro strip antenna. The Genetic Algorithm program, for the optimization of micro strip antenna using this program ,The bandwidth is analyzed by changing the height of the substrate material at the resonant frequency 15 GHz , upper frequency 21GHz and lower frequency 9 GHz. In this paper we specially emphasize on the height of the substrate. By changing the height of the substrate from 1mm to 3.2mm . The patch will be fed by a micro strip transmission line, which usually has 50Ω impedance. The antenna is usually fed at the radiating edge along the width (W) as it gives good polarization, however the disadvantages are the spurious radiation and the need for impedance matching [1]. This is because the typical edge resistance of a micro strip antenna ranges from 150Ω to 300Ω [2]. The results are simulated with java optimization program.

2. Antenna Configuration

The configuration of the proposed patch antenna parasitic and driven is illustrated in Figure1 and Figure 4 respectively. For the U-slotted patch, the slots are embedded to the rectangular patch.

Where, L and W are the length and width of the patch. ε_r is the dielectric constant, ΔL is the length due to the fringing field .The fringing fields along the width can be model as radiating slots and electrically the patch of the micro strip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance *ΔL*, which is given empirically by Hammers tad [1] as:

$$\Delta L = 0.412h \frac{(\varepsilon reff + 0.3)(W/h + 0.264)}{(\varepsilon reff - 0.258)(W/h + 0.8)} \quad (1)$$

The effective length of the patch Leff now becomes:

$$Leff = L + 2\,\Delta L \quad (2\text{-a})$$

Or

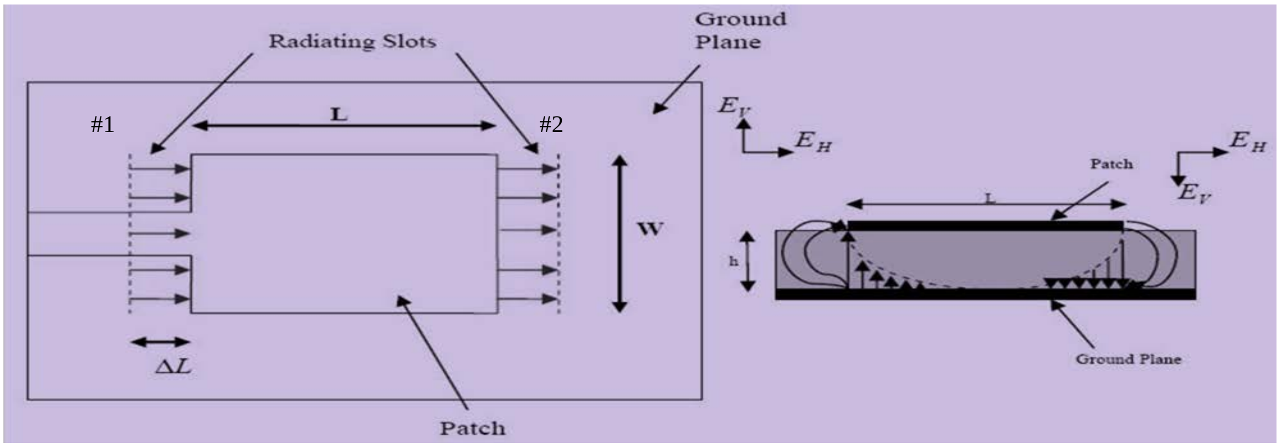

Figure-1 Rectangular Microstrip Antenna

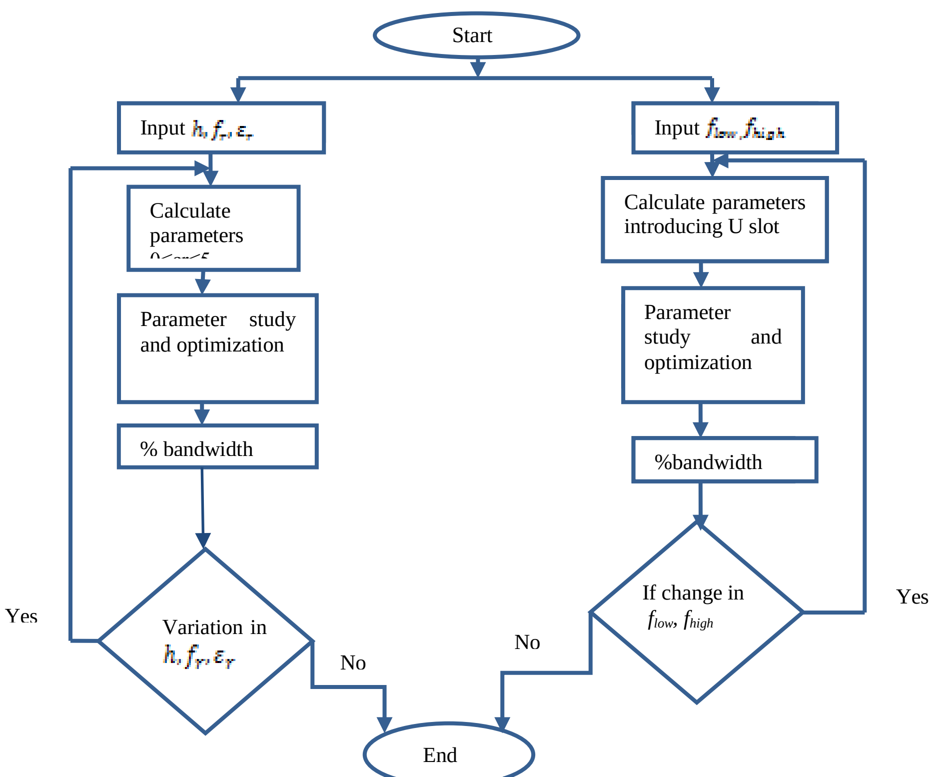

Figure-2 Genetic Algorithm

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For a given resonant frequency fo, the effective length is given as:

$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{reff}}} \qquad (2\text{-}b)$$

For a rectangular Microstrip patch antenna, the resonance frequency for any TMmn mode is given by James and Hall [2] as:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{1/2} \qquad (3)$$

The width W is given by Bahl and Bhartia [3] as:

$$W = \frac{c}{2 f_o \sqrt{\frac{(\varepsilon_r + 1)}{2}}} \qquad (4)$$

The Conductance G and susceptance B as shown in Figure 2. The slots are labelled as #1 and #2 in figure1. The equivalent admittance of slot #1, based on a finitely wide, uniform slot is given by [1]

Y1 = G1 + jB1. Since slot #2 is identical to slot #1

Hence Y2=Y1, B2=B1, G2=G1.

The self conductance can be calculated using the following expressions

$$G_1 = \frac{I_1}{120\pi^2}$$

Where I_1 is the integral defined by:

$$I_1 = \int_0^{\pi}\left[\frac{\sin\left(\frac{k_o W}{2}\cos\theta\right)}{\cos\theta}\right]^2 \sin^3\theta\, d\theta$$

$$= -2 + \cos(X) + X S_i(X) + \frac{\sin(X)}{X}$$

Where: $X = k_o W$
$k_o = 2\pi/\lambda_o$
S_i = sin integral

Total impedance Zin= (1/Yin) = Rin= (1/2G1)

%BW= ((fhigh - flow)/fo) 100 (5)

Where of is the operating frequency, while fhigh and flow are the frequencies between the magnitude of the reflection coefficient of the antenna is less than or equal to 1/3. In general, bandwidth is proportional to the volume, which for a micro strip antenna at a constant resonant frequency can be express as

BW ~ volume = area x height = length x width x height

An empirical formula by Jackson and Alexopolus for the bandwidth (VSWR<2) is

BW=3.77[εr-1/εr2) (W/L) (h/λo)] (6)

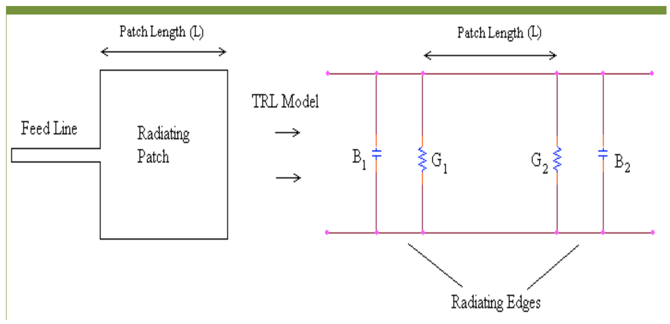

Figure-3 Transmission model of rectangular patch

3. U Slit Loaded Rectangular Patch Microstrip Antenna

This design procedure is a set of simple design steps for the rectangular U-slot mircostrip patch antenna on microwave substrates. Determine centre frequency, fo Set center frequency as fo and the lower and upper frequency bounds of the bandwidth as flow and fhigh, respectively.

a. Center frequency, fo = 15 GHz

b. Lower bound frequency, flow =9 GHz

c. Upper bound frequency, fhigh = 21 GHz

Slot thickness E and F is defined as:

$$E = F = \lambda / 60$$

Slot width D:

$$D = \frac{C}{2 f_{low}\sqrt{\varepsilon_{reff}}} - 2(L + 2\,\Delta L - E) \qquad (7)$$

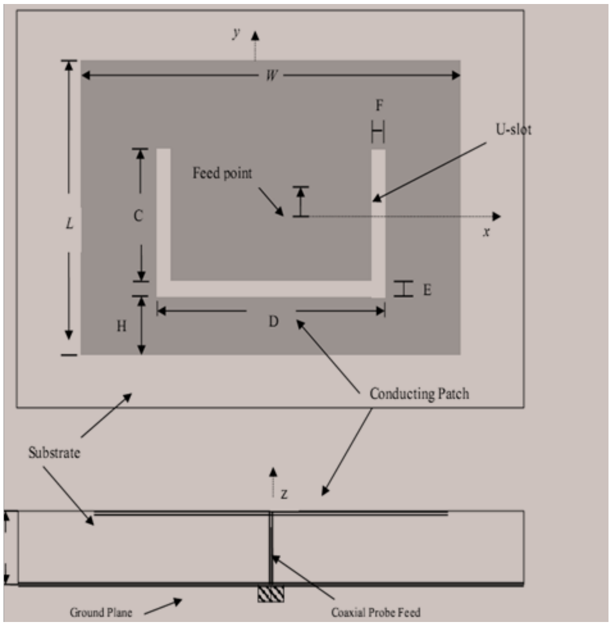

Figure -4 U Slotted Microstrip Antenna

4. Bandwidth Optimization

Using the optimization program, the user can set the lower bound and upper bound frequency to derive the bandwidth, while the dielectric constant is 4.8 and height is varied from 1 mm to 3.0 mm of patch antenna. The optimized lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz ,Resonant Frequency Fr=15 GHz , wire resistance =50 ohm is selected ,after going through varied height of substrate values using the optimization program the design parameters has derived and the bandwidth has been optimized. Results are plotted in figure 5.

When εr = 4.8 Height = 1 mm, lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz, Resonant Frequency fr=15 GHz, wire resistance =50 ohm is selected for the parasitic patch and driven patch the computed results are Bandwidth=754.130Mhz, PP(Bandwidth)=949.90MHz, and Impedance=203.700 ohm. Table1 as:

When εr = 4.8 Height = 1.2 mm , lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz ,Resonant Frequency fr=15 GHz , wire resistance =50 ohm is selected for the parasitic patch and driven patch the computed results are Bandwidth =942.11Mhz,PP(Bandwidth)=1261.63Mhz, and Impedance=203.700 ohm.

When εr = 4.8 Height = 1.4 mm , lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz ,Resonant Frequency fr=15 GHz , wire resistance =50 ohm is selected for the parasitic patch and driven patch the computed results are Bandwidth=1143.84Mhz,PP(Bandwidth)=1640.49MHz, and Impedance=203.700 ohm.

When εr = 4.8 Height = 1.6 mm , lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz ,Resonant Frequency fr=15 GHz , wire resistance =50 ohm is selected for the parasitic patch and driven patch the computed results are Bandwidth=1360.20Mhz,PP(Bandwidth)=2106.97,and Impedance=203.700 ohm.

When εr = 4.8 Height = 1.8 mm , lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz ,Resonant Frequency fr=15 GHz , wire resistance =50 ohm is selected for the parasitic patch and driven patch the computed results are Bandwidth=1592.24Mhz,PP(Bandwidth)=2696.14,and Impedance=203.700 ohm.

When εr = 4.8 Height = 2.0 mm, lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz, Resonant Frequency fr=15 GHz, wire resistance =50 ohm is selected for the parasitic patch and driven patch the computed results are Bandwidth=1841.16Mhz, PP(Bandwidth)=3454.80, and Impedance=203.700 ohm.

When εr = 4.8 Height = 2.2 mm , lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz ,Resonant Frequency fr=15 GHz , wire resistance =50 ohm is selected for the parasitic patch and driven patch the computed results are Bandwidth=2108Mhz,PP(Bandwidth)=4465.86 ,and Impedance=203.700 ohm.

When εr = 4.8 Height = 2.4 mm , lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz ,Resonant Frequency fr=15 GHz , wire resistance =50 ohm is selected for the parasitic patch and driven patch the computed results are Bandwidth=2395Mhz,PP(Bandwidth)=5873.98,and Impedance=203.700 ohm.

When εr = 4.8 Height = 2.6 mm , lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz ,Resonant Frequency fr=15 GHz , wire resistance =50 ohm is selected for the parasitic patch and driven patch the computed results are Bandwidth=2703Mhz,PP(Bandwidth)=7960 ,and Impedance=203.700 ohm.

When εr = 4.8 Height = 2.8 mm , lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz ,Resonant Frequency fr=15 GHz , wire resistance =50 ohm is selected for the parasitic patch and driven patch the computed results are Bandwidth=3055Mhz,PP(Bandwidth)=11358.59,and Impedance=203.700 ohm.

When εr = 4.8 Height = 3.0 mm , lower bound frequency, f low = 9 GHz, upper bound frequency, f high =21 GHz ,Resonant Frequency fr=15 GHz , wire resistance =50 ohm is selected for the parasitic patch and driven patch the computed results are Bandwidth=3393.19Mhz,PP(Bandwidth)=17836.34,and Impedance=203.700 ohm.

5. Conclusion

Hence, it is proven by the results by changing the height and introducing the slot (U) to the rectangular micro strip antenna, for the resonant frequency 15 GHz and the lower bound frequency 9GHz and the upper bound frequency 21GHz, the bandwidth get changed. The %change in bandwidth of rectangular and parasitic patch with respect to the height is shown in table 1. The dielectric constant of the substrate (glass epoxy) is 4.6, at resonating frequency 15GHz. The impedance is 203.70Ω.

Table 1:

Increment in Height of the Substrate in mm	Increment in %Bandwidth (Rectangular Patch)	Increment in %Bandwidth (Parasitic Patch)
1 – 1.2	24.92	32.81
1.2 - 1.4	21.41	30.0
1.4 – 1.6	18.91	28.43
1.6 – 1.8	17.05	27.96
1.8 -2.0	15.63	28.13
2.0 – 2.2	15.50	29.26
2.2 – 2.4	13.60	31.15
2.6 – 2.8	12.87	35.52
2.8 – 3.0	13.0	42.68
3.0 – 3.2	11.0	57.02

The parameter h is increased of Rectangular and parasitic patch the result shows, as we increase the height of the substrate the bandwidth upgrades continuously within the limitation of the design parameters of the proposed antennas as shown in chart1.

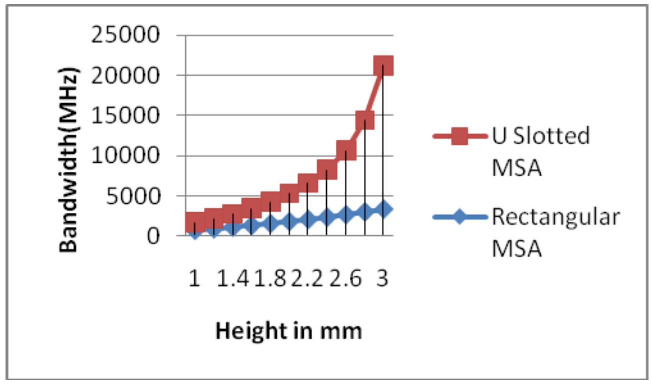

Figure 5:Variation of Bandwidth with height

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