Design and Analysis of Rectangular and U Slotted Patch for Satellite Communication

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ABSTRACT
This paper presents Microstrip antenna in the application for a satellite band microwave communication system for super high frequency (SHF), at a frequency range of 4.0 Ghz – 6.0Ghz. Currently, most security, research and education platforms are equipped with SHF communication systems. For their operational requirements, a design study is needed for the development of a light weight, low volume, low profile antenna. Hence, in this paper, bandwidth enhancement techniques such as, use of various substrate with low relative dielectric constant (ε_r), size of antenna as well as U slotted patch antenna with coaxial probe feed technique are discussed and explained using optimization program in java and the genetic algorithm is developed.

IndexTerms-- Microstrip antenna, communication, dielectric constant, frequency, bandwidth, java program, algorithm,Optimization program, genetic algorithm, SHF, U slot.

1. INTRODUCTION
Because of the booming demand in wireless communication system and satellite communication, microstrip patch antennas have attracted much interest due to their low profile, light weight, ease of fabrication and compatibility with printed circuits. However, they also have some drawbacks, such as narrow bandwidth, low gain spurious feed radiation limited power handling capacity . To overcome their inherent limitation of narrow impedance, bandwidth and low gain, many techniques have been proposed and investigated, e.g., for probe fed stacked antenna, microstrip patch antennas on electrically thick substrate, slotted patch antenna and stacked shorted patches using optimization program in java and the genetic algorithm. When we change the shape of a microstrip 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 shown in figure 4, and optimization program to analyze the gain of a rectangular microstrip 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 microstrip antenna. According to the probability of mutation, the chromosome are chosen at random and any one bit chosen at random is flipped from ‘0’ to ‘1’ or vice versa. After mutation has taken place, the fitness is evaluated. Then the old generation is replaced completely or partially. This process is repeated. After a while all the chromosome and associated fitness become same except for those that are mutated. At this point the genetic algorithm has to be stoppedThe Genetic Algorithm program, for the optimization of microstrip antenna using this program ,The bandwidth is analyzed by changing the substrate material at the frequency range 4 GHz to 6 GHz and introducing the slots U. The results are simulated with java optimization program . Stack configuration with 2 patches, driven and parasitic, and the use of the various substrate loading technique increases the bandwidth of the antenna ranging from 48%-63%.

2. ANTENNA CONFIGURATION
The configuration of the proposed patch antenna parasitic and driven is illustrated in Figure1 and Figure 3 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 microstrip 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 Hammerstad [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:

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

Or

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

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

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

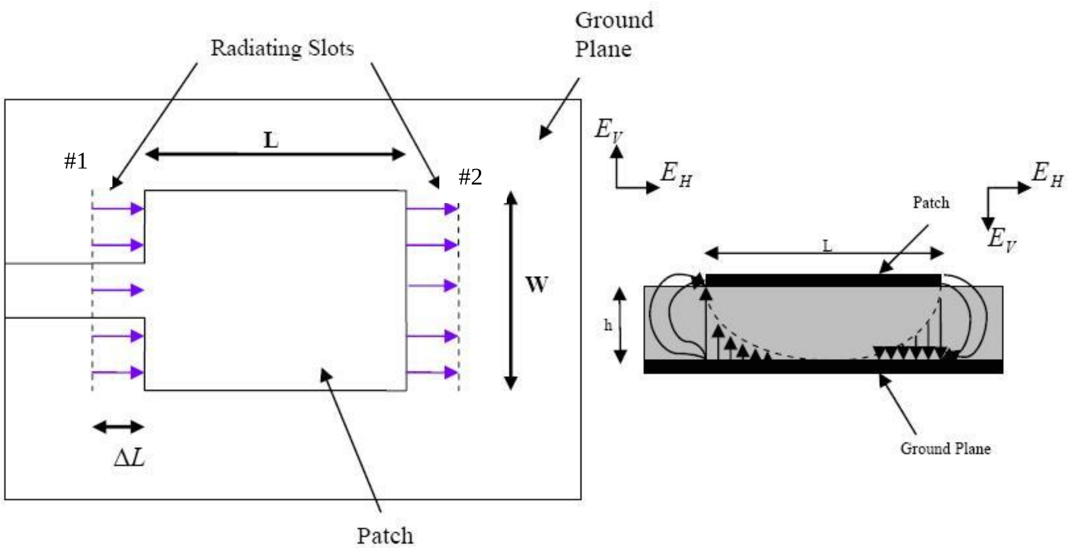

Figure-1 Rectangular Microstrip Antenna

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

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

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

The Cunductance G and susceptance B as shown in Figure 2. The slots are labeled as #1 and #2. The equivalent admittance of slot #1, based on an 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.

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

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

where fr is the resonant 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 microstrip 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[Ɛr-1/Ɛr2)(W/L)(h/λo)] (6)

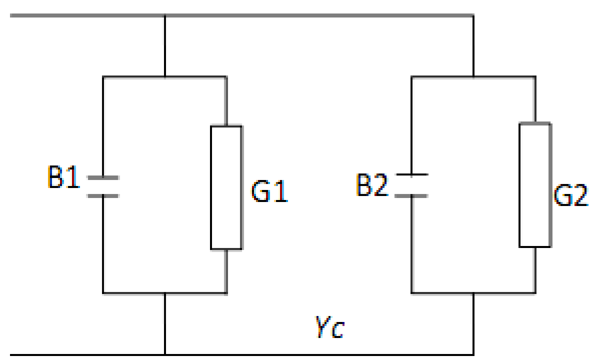

Figure-2 Transmission model of rectangular patch

3. DESIGN AND THEORITICAL CONCIDERATION OF U SLOT

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 = 5 GHz

b. Lower bound frequency, flow =4 GHz

c. Upper bound frequency, fhigh = 6 GHz

Slot thickness E and F is defined as:

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

Slot width D:

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

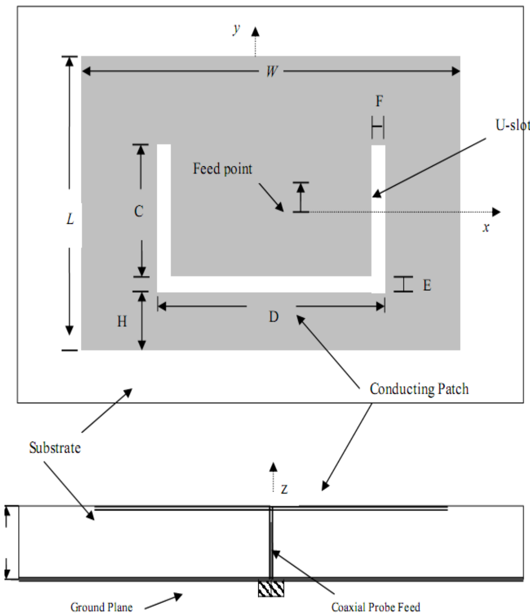

Figure -3 U Slotted Microstrip Antenna

4. OPTIMISING PARAMETER

Using the optimization program, the user can set the lower bound and upper bound frequency to derive the bandwidth, while the dielectric constant is varied, Height = 10 mm of patch antenna. The optimized lower bound frequency, f low = 4 GHz, upper bound frequency, f high =6 GHz ,Resonant Frequency Fr=5 Ghz , wire resistance =50 ohm is selected ,after going through various substrate values using the optimization program the design parameters has derived and the bandwidth has been optimized.

When ε_r = 2.2, Height = 10 mm , lower bound frequency, f low = 4 GHz, upper bound frequency, f high =6 GHz ,Resonant Frequency Fr=5 Ghz is selected for the parasitic patch and driven patch the computed results are shown in Table1 as:

Table 1

Normal Patch Readings		U slot patch readings	
Dielectric constant	2.2	Slot width	13.046
Width	23.717	Slot height	7.115
length	12.836	Effective dielectric constant	1.774
Input impedance	151.30	Height of slot from base	2.877
Effective Dielectric constant	1.8437	Paracitic patch length	4.736
Feed point location	3.9159	Slot width E=F	1.0
Bandwidth(MHz)	1440.698	Bandwidth(MHz)	3869.1

When ε_r = 2.32, Height = 10 mm , lower bound frequency, f low = 4 GHz, upper bound frequency, f high =6 GHz ,Resonant Frequency Fr=5 Ghz is selected for the rectangular and U slot patch the computed results are shown below in table 2:

Table 2

Normal Patch Readings		U slot patch readings	
Dielectric constant	2.32	Slot width	12.808
Width	23.28	Slot height	6.9853
length	12.504	Effective dielectric constant	1.849
Input impedance	154.11	Height of slot from base	2.387
Effective Dielectric constant	1.926	Parasitic patch length	4.546
Feed point location	3.840	Slot width E=F	1.0
Bandwidth(MHz)	1460.4	Bandwidth(MHz)	3995.1

When ε_r = 2.6, Height = 10 mm , lower bound frequency, f low = 4 GHz, upper bound frequency, f high =6 GHz ,Resonant Frequency Fr=5 Ghz is selected for the rectangular and U slot patch the computed results are shown in Table3 as:

Table 3

Normal Patch Readings		U slot patch readings	
Dielectric constant	2.6	Slot width	12.309
Width	22.36	Slot height	6.708
length	11.79	Effective dielectric constant	2.025
Input impedance	160.48	Height of slot from base	1.406
Effective Dielectric constant	2.117	Parasitic patch length	4.128
Feed point location	3.674	Slot width E=F	1.0
Bandwidth(MHz)	1484.2	Bandwidth(MHz)	4253.3

When ε_r = 3.0, Height = 10 mm , lower bound frequency, f low = 4 GHz, upper bound frequency, f high =6 GHz ,Resonant Frequency Fr=5 Ghz is selected for the rectangular and U slot patch the computed results are shown as given below in Table 4

Table 4

Normal Patch Readings		U slot patch readings	
Dielectric constant	3.0	Slot width	11.707
Width	21.21	Slot height	6.363
length	10.924	Effective dielectric constant	2.27
Input impedance	169.16	Height of slot from base	0.306
Effective Dielectric constant	2.387	Parasitic patch length	3.668
Feed point location	3.463	Slot width E=F	1.0
Bandwidth(MHz)	1484.9	Bandwidth(MHz)	4576.7

If we increase the height=10mm of the patch for εr=3.1 the bandwidth can be increased up to 63%. lower bound frequency, f low = 4 GHz, upper bound frequency, f high =6 GHz ,Resonant Frequency Fr=5 Ghz is selected for the rectangular and U slot patch the computed results are shown in Table5 :

5. CONCLUSION

Hence, it is proven by the results by changing the permittivity and introducing the slot (U) to the rectangular microstrip antenna, for the resonant frequency 5 GHz at the frequency range 4 GHz to 6 GHz, and introducing the slot U the optimized results are obtained. The Genetic Algorithm shown in figure 4 also analyzes the gain of a rectangular microstrip antenna.The results are simulated with java optimization program .

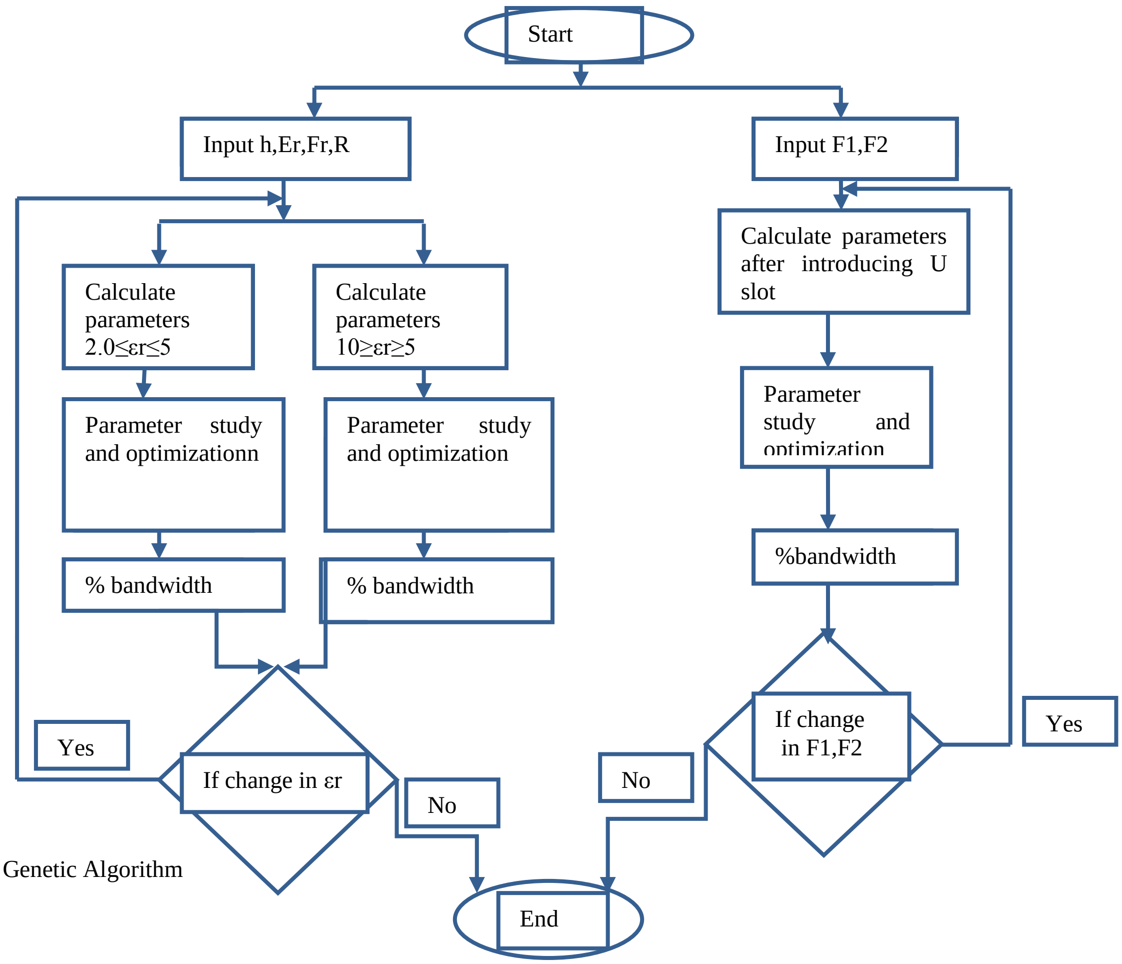

Figure-4 The Genetic Algorithm

Table 5:

Normal Patch Readings		U slot patch readings	
Dielectric constant	3.1	Slot width	11.573
Width	20.95	Slot height	6.28
length	10.727	Effective dielectric constant	2.335
Input impedance	171.26	Height of slot from base	0.074
Effective Dielectric constant	2.454	Parasitic patch length	3.462
Feed point location	3.414	Slot width E=F	1.0
Bandwidth(MHz)	1481.4	Bandwidth(MHz)	4655

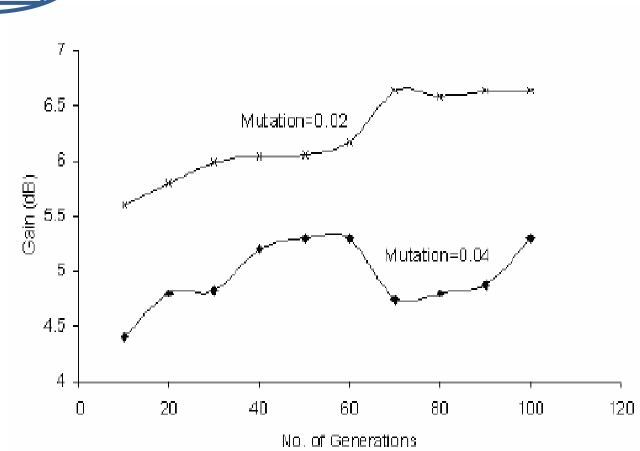

Figure-5 Variation of gain of a MSA for different mutations

In fig. 5, the gain is optimized at a frequency of 5 GHz. Both the length and width of the patch antenna were varied from 10 mm to 60 mm. The dielectric constant and height of the substrate were varied from 2 to 3.5. The maximum gain of 7.29 dB was obtained when length and width of the antenna was 10 mm and 23 mm respectively. The dielectric constant and height of the substrate at this configuration with 2 patches, driven and parasitic, and the use of the various substrate loading technique increases the bandwidth of the antenna ranging from 48%-63% .

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