OPTIMIZATION OF U-SLOT MICROSTRIP PATCH ANTENNA USING GENETIC ALGORITHM

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***Abstract*— In this work, an extensive design study of a u-slot microstrip patch antenna for dual band operation will be presented. This antenna consists of microstrip patch with U-slot. Feeding techniques namely probe-feeding and co-planar waveguide feeding have been used and the results compared. Genetic Algorithm has been used to optimize the antenna parameters. The simulated results indicate that using co-axial feeding technique co-planar waveguide feeding results in a tremendous increase in bandwidth with Genetic Algorithm over other algorithms.**

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I. INTRODUCTION

A patch antenna (also known as rectangular microstrip antenna) is a type of radio antenna with a low profile, which can be mounted on a flat surface. It consists of a flat rectangular sheet or "patch" of metal, mounted over a larger sheet of metal called a ground plane. The assembly is usually contained inside a plastic radome, which protects the antenna structure from damage. Patch antennas are simple to fabricate and easy to modify and customize.

Due to the integration of many mobile communication systems like WLAN, GSM, UMTS, PCS etc. there is a need for multi frequency antennas with high bandwidths (BW). Simple microstrip antennas would be unable to fulfil these requirements because of their narrow BW. Several techniques as listed in [1] are used for introducing a broadband behaviour in microstrip antennas: capacitive compensation [2], thicker substrates [3], reactive matching networks [4], and stacked patches [5]. Stacked patches [1], [5] present many degrees of freedom (driven and parasitic dimensions, feeding point, gap between patches). An antenna has been reported in which a U-slot loaded patch antenna [6, 18]. In this u-shaped slot on a microstrip patch is optimized using Genetic Algorithm.

II. GENETIC ALGORITHM

Genetic algorithms are very different from most of traditional optimization methods. Genetic algorithms need design space to be converted [7] into a genetic space. So, genetic algorithms work with a coding variable. The computer science field of artificial intelligence, a genetic algorithm is a search heuristic that mimics the process of natural evolution. This heuristic (also sometimes called a meta-heuristic) [8] is routinely used to generate useful [10] solutions to optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover. The use [11, 12] of genetic algorithms in optimizing microstrip patch antennas is relatively recent, with the majority of research occurring in the past few years. The objective is to create novel, non-intuitive shapes that full fill the optimization criteria, such as a broad bandwidth, dual frequency, or small physical dimension [13].

A genetic algorithm was used to determine the patch length and width and feeding point in the design of a coaxially fed circularly polarized [14] rectangular patch antenna. The fitness function was derived from the cavity model and evaluated such antenna characteristics as input impedance, [15] effective loss tangent, and axial ratio.

III. DESIGN CONSIDERATIONS AND ANTENNA CONFIGURATION

Microstrip Patch calculations

Given relative permittivity ε_r, height h of the substrate and the [16, 17] operating frequency f_r the design of the microstrip patch proceeds as follows:

Finding the width of the patch

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

Here c is speed of light and f_r is the resonant frequency

Finding the effective dielectric constant

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+12\frac{h}{W}}}$$

Taking into account the fringing effect

The fringing fields along the width of the structure are taken as radiating slots and the patch antenna is [11] electrically seen to be a bit larger than its physical size.

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)}$$

Calculating the effective length of the patch

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_r}}$$

Calculating the actual length of the patch

$$L = L_{eff} - 2\Delta L$$

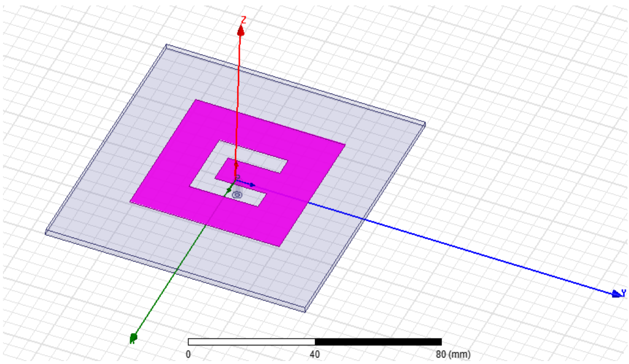

Figure 1 Un-optimized U-Shaped microstrip patch antenna Geometry.

IV. RESULTS

In addition, some adjustments with the parameters are necessary during the optimization process. Based on optimization configuration, three variables are being optimized. Then a general optimization function can be written in MATLAB as given below:

$$Fitnessfunction = @(x)\left\{(x(1) - 90)^{-2} - \left(\frac{1}{0.7} * x(2)\right) + \cos(x(3))\right\}$$

where, $x(1)\rightarrow$ Substrate height, $x(2)\rightarrow$ U-slot length and $x(3)\rightarrow$ U-slot width.

This function then given to the Genetic Algorithm with number of variables as:

X = ga (Fitnessfunction, 3); //ga→ genetic algorithm method used in MATLAB 2012a.

So, to obtain the optimized values of parameters $x(1), x(2), x(3)$ 1000 iterations are generated.

The optimized model with optimized values can be designed in HFSS.

U-slot length, U_{lo} = 24.8 mm

U-slot width, U_{wo} = 3 mm

Dielectric substrate height, S_{ho} = 3.2 mm

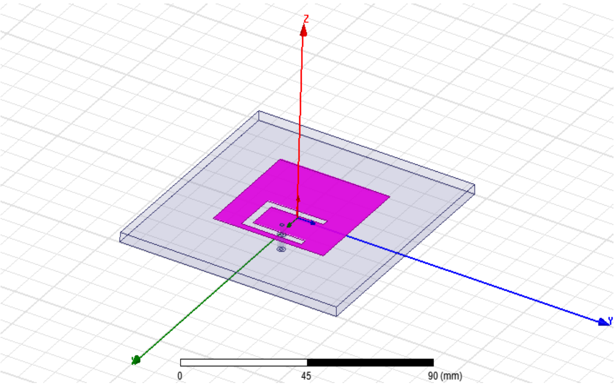

Figure 2 optimized U-Shaped microstrip patch antenna Geometry.

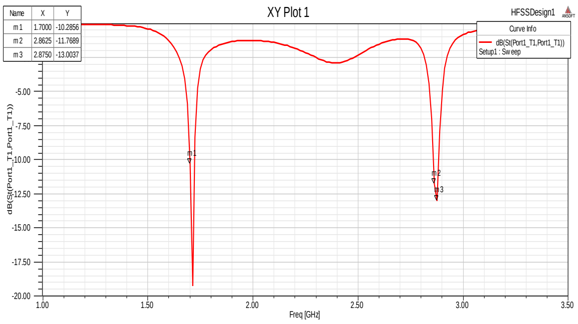

Figure 3 Return loss plot for the optimized U-slot patch antenna

Figure 3 shows the graph of return loss with optimized parameters. It is analysed from the graph itself that there is significant increase in percentage bandwidth. It shows approximately 41% bandwidth from 1.7 to 2.85 GHz. This antenna can be used for wide band applications.

Voltage Standing Wave Ratio is the ratio of maximum radio-frequency voltage to minimum radio-frequency voltage on a transmission line. The VSWR for the proposed antenna is less than the 2dB. The obtained value is 1.9084 from Figure 4.13.

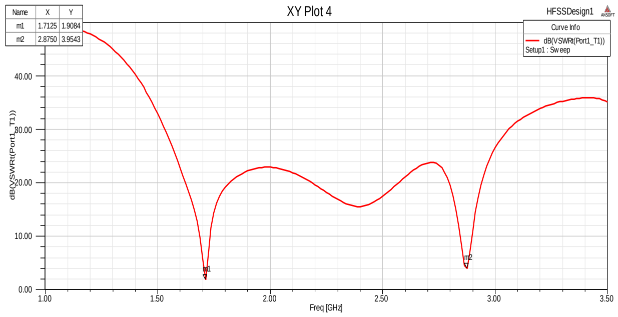

Figure 4 VSWR Plot for optimized U-slot patch antenna.

An antenna radiation pattern is a 3-D plot of its radiation far from the source. Antenna radiation patterns usually take two forms, the elevation pattern and the azimuth pattern.

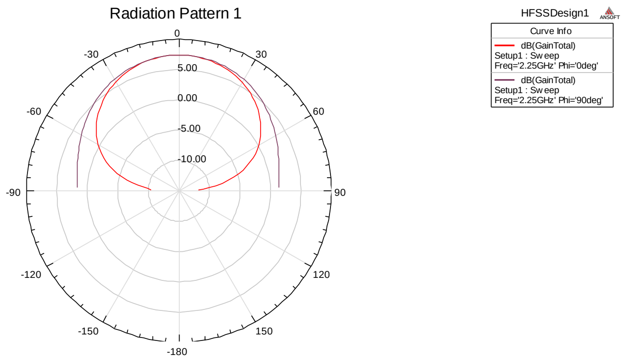

Figure 5 Radiation pattern plot for the optimized U-slot patch antenna.

V. CONCLUSION

Genetic Algorithm has proven very successful in examining for optimal solution in many areas where conventional model based methodology is hard to be implemented. By implementing the Genetic Algorithm, the antenna design optimisation is shown to generate alternative optimal solutions in order to provide another possible solution, which may satisfy other requirements for the particular design. The techniques and processes of the optimisation for U-slot patch microstrip antenna by using Genetic Algorithms are successfully demonstrated.

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