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Research Article

Microstrip Patch Antenna Design for Military Satellite Communication

Mustafa Koçer[1*], Mustafa Emre Aydemir[2]

[1] Istanbul Esenyurt University, Engineering and Architecture Faculty, Electrical and Electronics Engineering Department, Istanbul, Turkey (ORCID: 0000-0003-4551-4788)
[2] Istanbul Esenyurt University, Engineering and Architecture Faculty, Electrical and Electronics Engineering Department, Istanbul, Turkey (ORCID: 0000-0003-3634-1782)

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Abstract

In this paper, a broadband and high gain microstrip patch antenna was designed with a microstrip feeding technique to operate in the electromagnetic spectrum in the X-band in the frequency range of 7.2 - 8.4 GHz, which is allocated for use in military satellite communication. In this design, Rogers RT / duroid 5880 material with a thickness of 3.175mm, dielectric coefficient of 2.2 and tangent loss (tan δ) of 0.0009 was selected and simulated on the HFSS program. Since the antenna sizes calculated by numerical methods are difficult to adjust to operate in appropriate frequency ranges, the dimensions of the antenna designed using the genetic algorithm, which is a part of artificial intelligence optimization algorithms, have been optimized to work in the desired frequency ranges. According to the designed antenna simulation results, it operates in the frequency ranges of 7.06 - 8.41 GHz and the designed antenna has a bandwidth of approximately 1.35 GHz = 17.25%. At 7.825 GHz center frequency, the antenna's gain is approximately 7.2 dB. In order to increase the bandwidth of the designed antenna, a second antenna design was realized by optimizing the dimensions of the antenna covered with copper and microstrip feeding. The second antenna designed as a result of the changes made on the antenna operates in the frequency ranges of 6.74 - 9.69 GHz and the designed antenna has a bandwidth of approximately 2.95 GHz = 37.7%. At the central frequency of 7.825 GHz, the antenna's gain is approximately 6.63 dB.

Keywords: Microstrip Patch Antenna, Genetic Algorithm, HFSS, Military Satellite Communication, Antenna Design, X-Band, Broadband

Askeri Uydu Haberleşmesi için Mikroşerit Yama Anten Tasarımı

Öz

Bu bildiride, elektromanyetik spektrumunda X bandında askeri uydu haberleşmesinde kullanılmak üzere tahsis edilmiş olan 7.2 – 8.4 GHz frekans aralıklarında çalışması için geniş bantlı ve yüksek kazanca sahip bir mikroşerit yama anten mikroşerit besleme tekniği ile tasarımı yapılmıştır. Bu tasarımda alttaş olarak kalınlığı 3.175mm, dielektrik katsayısı 2.2 ve tanjant kaybı(tan δ) 0.0009 olan Rogers RT/duroid 5880 malzemesi seçilmiş olup HFSS program üzerinde simülasyonu yapılmıştır. Nümerik yöntemler ile hesaplanan anten boyutları uygun frekans aralıklarında çalışması için ayarlanmasının zor olması nedeniyle yapay zeka optimizasyon algoritmalarının bir parçası olan genetik algoritma kullanılarak tasarlanmış antenin boyutlarının optimizasyonu yapılarak istenilen frekans aralıklarında çalışması sağlanmıştır. Tasarlanan anten simülasyon sonuçlarına göre 7.06 – 8.41 GHz frekans aralıklarında çalışmaktadır ve tasarlanan anten yaklaşık olarak 1.35 GHz = %17.25 bant genişliğine sahiptir. 7.825 GHz merkez frekansında antenin kazancı yaklaşık olarak 7.2 dB' dir. Tasarlanan antenin bant genişliğini artırmak amacı ile antenin bakır ile kaplı yama ve mikroşerit beslemenin boyutları optimize edilerek ikinci bir anten tasarımı gerçekleştirilmiştir. Anten üzerinde yapılan değişiklikler sonucunda tasarlanan ikinci anten 6.74 – 9.69 GHz frekans aralıklarında çalışmaktadır ve tasarlanan anten yaklaşık olarak 2.95 GHz = % 37.7 bant genişliğine sahiptir. 7.825 GHz merkez frekansında antenin kazancı yaklaşık olarak 6.63 dB' dir.

Anahtar Kelimeler: Mikroşerit Yama Anten, Genetik Algoritma, HFSS, Askeri Uydu Haberleşmesi, Anten Tasarımı, X-Bant, Geniş Bant

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[*] Corresponding Author: Istanbul Esenyurt University, Engineering and Architecture Faculty, Electrical and Electronics Engineering Department, Istanbul, Turkey, ORCID: 0000-0003-4551-4788, mustafa.kocer3442@gmail.com

1. Introduction

Microstrip antennas are compatible with MMIC designs with easy production and low cost using modern printing technology. Due to the need for low profile antennas in application areas such as satellites, aircraft, missiles, microstrip antennas with small dimensions are actively used in these areas (Pozar, 1992). However, microstrip antennas have narrow bandwidth and low gain compared to other antennas. In this study, it is aimed to design a broadband and high gain antenna that covers the entire downlink frequency 7.25-7.75 GHz and uplink frequency 7.9-8.4 GHz allocation for use in military satellite communication using optimization techniques. The designed antennas were optimized with genetic algorithm and simulated on the HFSS program.

2. Material and Method

2.1. Microstrip Patch Antenna

Microstrip antennas were first put forward by G. A. Deschamps in 1953 but patented by Gutton and Baissinot in 1955 (Deschamps, 1953; Warren & Gary, 1998). Nevertheless, the microstrip antennas, patented until the 1970s, were not taken seriously. The first microstrip antenna was demonstrated by the work done by Howell in 1972 and by Musson in 1974 (Munson).

There are substrate materials whose dielectric constants are generally in the range of $2.2 \leq \boldsymbol{\varepsilon}r \leq 12$ for use in microstrip antenna design. A substrate with high thickness and low dielectric constants is often used to achieve good design performance. Thus, high bandwidth and good efficiency are achieved.

Microstrip Antennas are formed with substrate, patch, ground and radiation plane as seen in Figure 1.

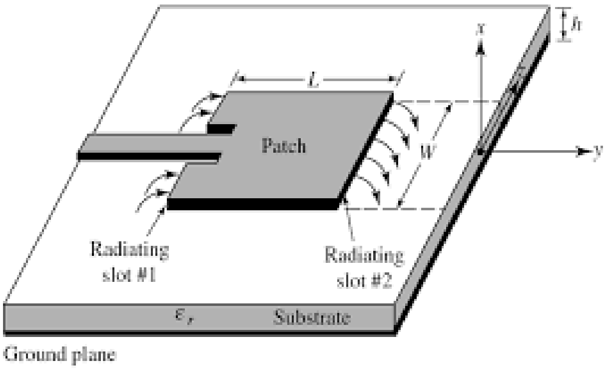


Figure 1. Microstrip Patch Antenna

2.2. Microstrip Patch Types

Microstrip antennas are named according to the patch shapes used at the top of the dielectric material during the design phase. The patches used in microstrip antennas are shown in Figure 2. Among these, the most common square and rectangular patch is used. In this project, a rectangular patch was chosen as the patch shape.

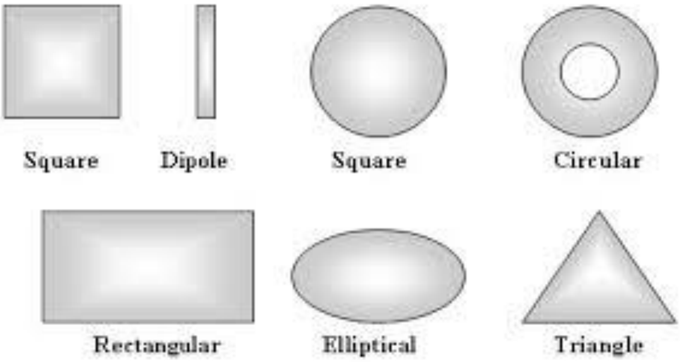


Figure 2. Patch Types for Microstrip Antenna

2.3. Microstrip Feed Types

There are many techniques used to feed microstrip antennas (Pozar, 1992). The most common of these are microstrip line, coaxial probe, aperture coupling and proximity coupling (Bahl & Bhartia, 1980; Carver & Mink, 1981; Katehi & Alexopoulos, 1984). In this design, a microstrip feed is preferred, which provides slightly more bandwidth and does not disrupt the planarity of the antenna. The antenna given in Figure 1 was made with the microstrip feeding technique.

2.4. Genetic Algorithm

The optimization algorithm used is a genetic algorithm based on the survival of individuals with high suitability value by transforming an evolutionary process into a computer environment. The idea of a genetic algorithm was introduced in 1975 by J. Holland. As a result, he developed this algorithm with his friends and published the book "Adaptation in Natural and Artificial Systems" (HOLLAND, 1975). There are individuals who represent the solution of the problem in genetic algorithms and there is a fitness function that controls whether these individuals are suitable for the solution of the problems. As a result of the fitness function, individuals with high values are introduced to the cross operator and produce new individuals called children. Individuals with low suitability value in a new population to be created as a result of this process are removed from the population. Flow chart of genetic algorithm is shown in Figure 3.

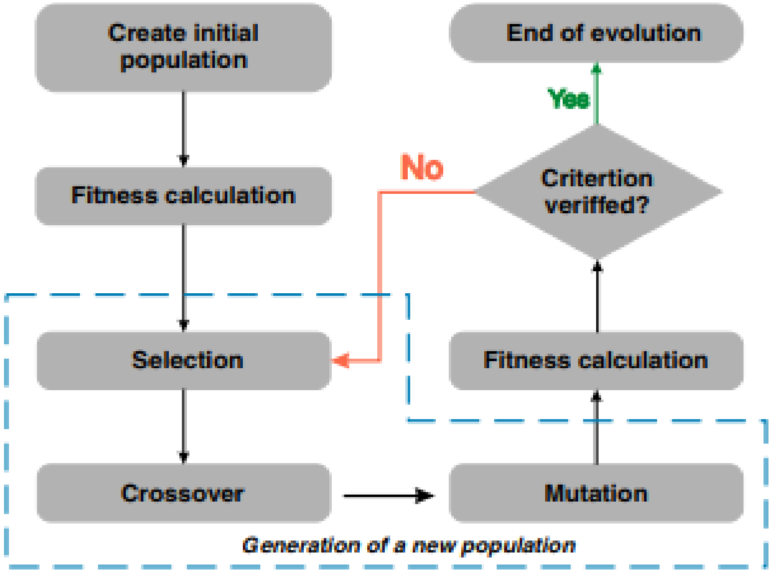


Figure 3. Genetic Algorithm Flow Chart

2.5. Antenna Design

In this design, the antenna's bandwidth is required to be at least 1.2 GHz for military satellite communication. In order to obtain high bandwidth, the materials used in the antenna design were examined, and as a result, Rogers RT / duroid 5880 material with dielectric constant 2.2 and 3.175mm height was selected. For the antenna whose resonance frequency is determined as 7.825 GHz, the dimensions of an ideal antenna were found with the formulas used in the microstrip antenna design.

Formulas Used in Antenna Design;

Speed of Light $C = 3 * 10^{8}$

Patch Width $(W) = \frac{c}{2xfr} x\left(\frac{\varepsilon r+1}{2}\right)^{\frac{-1}{2}}$

Effective Dielectric Constant $(\varepsilon_{e}) = \frac{\varepsilon_{r}+1}{2} + \frac{\varepsilon_{r}-1}{2} x \left(1+12\frac{h}{w}\right)^{\frac{-1}{2}}$

Extension Length

$$(\nabla l) = 0.412x\left(\frac{(\varepsilon_{e}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{e}-0.258)(\frac{W}{h}+0.8)}\right)$$

Effective Length $(L_{eff}) = \frac{c}{2x f_{r} x \sqrt{\varepsilon_{e}}}$

Length $(L) = L_{eff} - (2 x \nabla l)$

Substrate Length $(L_{g}) = 6h + L$

Substrate Width $(W_{g}) = 6h + W$

2.5.1. First Antenna

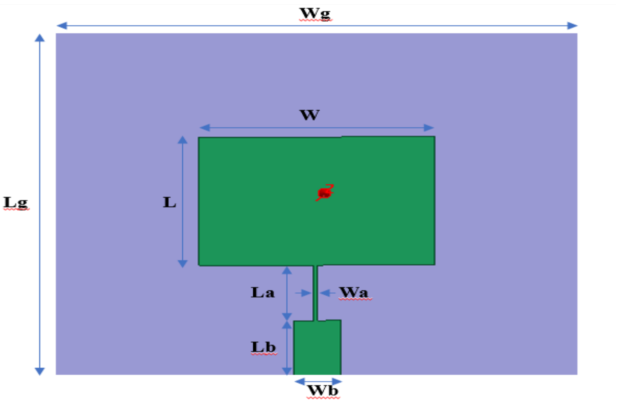


Figure 4. Dimensions of the First Antenna Designed

Designed with 50 ohms input impedance using the above formulas, the 1st antenna is optimized with genetic algorithm, then Wg = 34.19mm, Lg = 29.72mm, W = 15.14mm, L = 10.87799615mm, Wa = 0.125mm, La = 4.7925mm, Wb = 3mm, Lb = 4.7325mm results were found.

2.5.2. Second Antenna

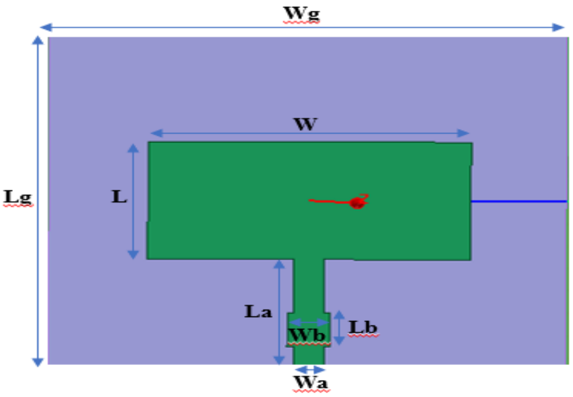
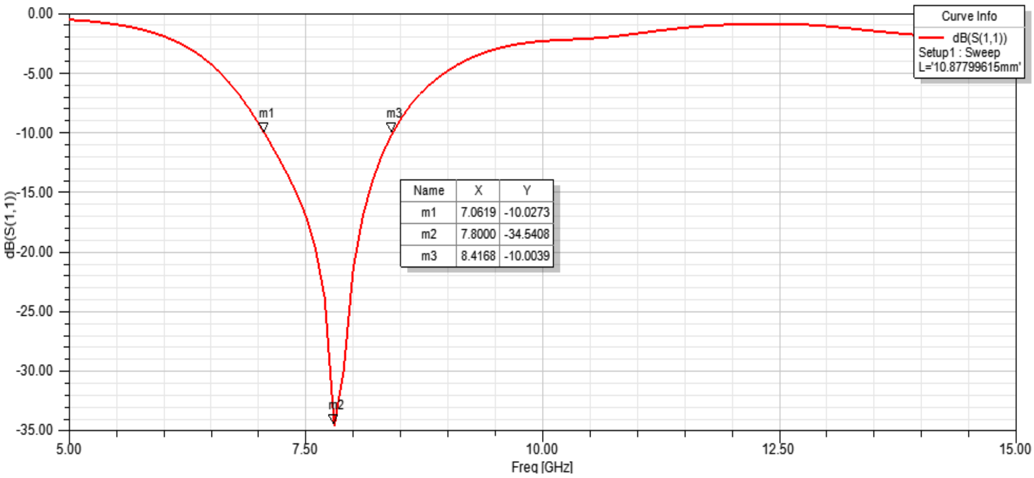


Figure 5. Dimensions of the Designed 2nd Antenna

In order to increase the bandwidth of the 1st Antenna designed, the patch dimensions of the 1st Antenna were optimized by keeping the search space wide and as a result Wg = 34.19mm, Lg = 29.72mm, W = 21mm, L = 10.45mm, Wa = 1.946mm , La = 9.635mm, Wb = 2.8mm, Lb = 3mm results were found.

3. Results and Discussion

3.1. First Antenna



Name	X	Y
m1	7.0619	-10.0273
m2	7.8000	-34.5408
m3	8.4168	-10.0039

Figure 6. S11 Graph of the 1st Antenna

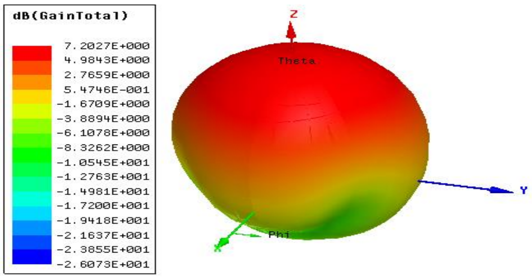


Figure 7. 1st Antenna Gain Graph

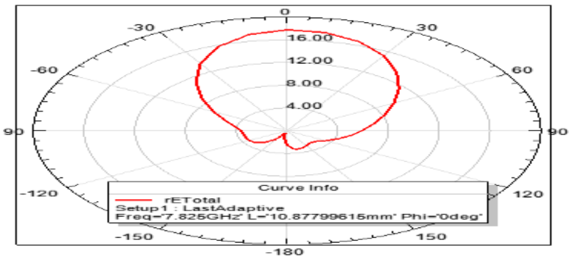


Figure 8. Radiation Pattern of the 1st Antenna

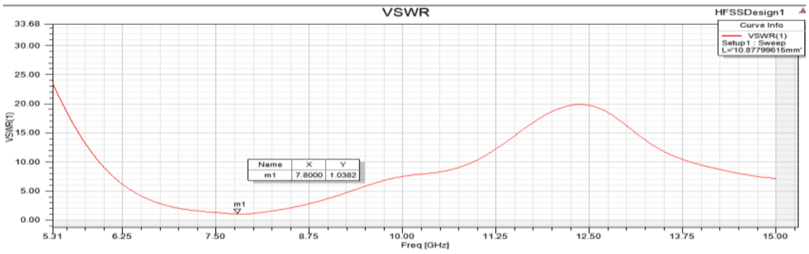


Figure 9. 1st Antenna VSWR Value

The 1st Antenna designed according to this design operates in the frequency ranges of 7.06 - 8.41 GHz. The 7.8 GHz center frequency has -34.5 dB return loss, 7.20 dB gain and 1.03 standing wave ratio

3.2. Second Antenna

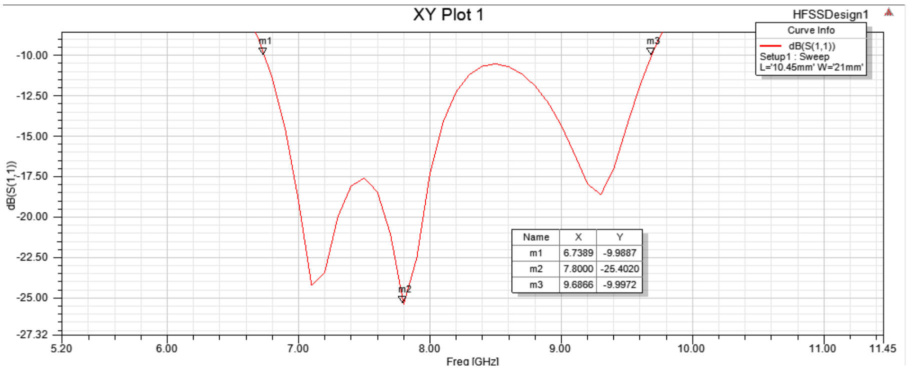


Figure 10. S11 Graph of 2nd Antenna

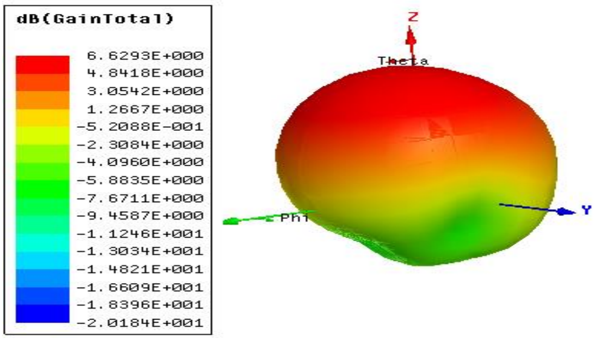


Figure 11. 2nd Antenna Gain Graph

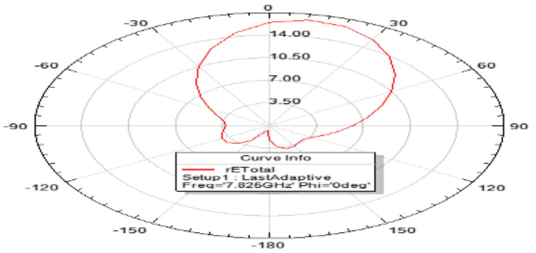


Figure 12. Radiation Pattern of 2nd Antenna

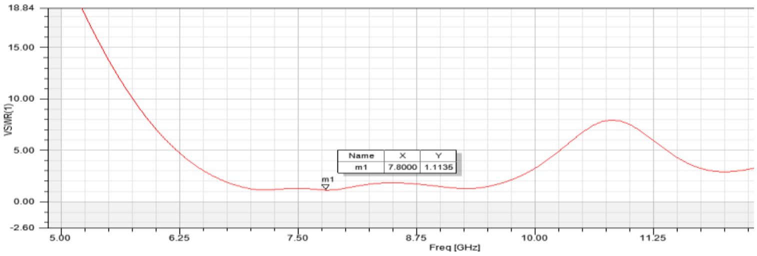


Figure 13. VSWR Value of the 2nd Antenna

As a result of the changes made on the designed antenna, the 2nd Antenna operates in the frequency ranges of 6.73 - 9.69 GHz. The 7.8 center frequency has -25.4 dB return loss, 6.63 dB gain and 1.11 standing wave ratio.

The 1st Antenna designed as a result of the studies, covers all the up and down frequency ranges allocated for military satellite communication and has a bandwidth of 1.35 GHz = 17.25%. The 2nd Antenna, designed as a result of the changes made on the 1st Antenna, operates in the frequency ranges of 6.74 - 9.69 and has a bandwidth of 1.6 GHz more than the 1st Antenna.

4. Conclusions and Recommendations

In this study, it is aimed to design a microstrip patch antenna operating in the range of downlink frequency 7.25-7.75 GHz and uplink frequency 7.9-8.4 GHz allocated for military satellite communication.

Antenna dimensions have been optimized by using a genetic algorithm for the designed antenna to operate in suitable frequency ranges, and as a result, the antenna has been enabled to operate in the desired frequency ranges.

Antenna sizes were optimized to increase the bandwidth of the designed antenna, resulting in a bandwidth increase of 1.6 GHz compared to the first antenna. It is evaluated that the two antennas designed in this way can be used for military satellite communication.

5. Acknowledge

I would like to thank Assoc. Dr. Mustafa Emre Aydemir, who shared his valuable information with me and assisted me in the realization of this study.

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