BOOK OF PROCEEDINGS

INTERNATIONAL UNIVERSITY OF SARAJEVO

ORGANISING COMMITTEE

General Chair:
Taha Imeci
International University of Sarajevo

Technical Program Chairs:
Tarik Namas
International University of Sarajevo

Finance Chair:
Ibrahim Inal
International University of Sarajevo

Short Course/Tutorial Chair:
Atef Elsherbeni
Colorado School of Mines

Local Arrangements Chair:
Senad Hodzic
International University of Sarajevo

Conference Secretariat:
Adnan Beganovic
International University of Sarajevo

Website Administrators:
Osman Gursoy
International University of Sarajevo

REVIEWERS

Erdem Demircioglu

Mehmet Zubeyr Unlu

Kamil Karacuha

Ahsan Altaf

Erdogan Alkan

Bilal Tutuncu

Ali Almisreb

Tahsin Durak

DUAL RESONANCE PATCH ANTENNA WITH A SLIT AND SLOT

Kenan Kazic
Department of Electrical and Electronics Engineering
Int. University of Sarajevo

Zeliha Merve Cetinok
Information Technology Sciences in Sports
Marmara University

***Abstract*— This paper will be showing a microstrip patch antenna with a rectangular slit and slot. The antenna designed and simulated on an air substrate with dielectric constant of 1 and operates at 10.7 GHz with gain of 8.5 dB at theta = 35 degrees and 6.65 GHz with gain of 9.1 dB. Input match (S11) is -7.9 dB at 6.65 GHz and -13.3 dB at 10.7 GHz. A parametric study is conducted to find the optimum point of air thickness which is located on top of the dielectric, forming microstrip structure.**

Keywords—Dual-resonance patch, high frequency, Microstrip patch antenna, GHz, dB.

I. INTRODUCTION

The field of electromagnetics had a tremendous opening with the introduction of artificial negative index medium (metamaterials) and its feasibility in microstrip patch antenna structures [1]. Tuning of patch antenna at a particular resonant frequency is becoming very important in order to make it applicable in different communication purposes [2]. 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 [3]. The enhancing bandwidth and size reduction mechanism that improves the performance of a conventional microstrip patch antenna [4]. In many wireless communication applications such as telemetry and communications, aviation, naval communications, automatic guidance of intelligent weaponry, radar, GPS systems, micro strip antennas are used because of its advantages and also makes them popular. This structure of an antenna is simple to manufacture and versatile in nature [5].

II. ANTENNA GEOMETRY

Geometry of rectangular patch antenna is shown in Fig. 1. Top thickness is 11mm while dielectric thickness is 1mm. Dielectric constant of the following antenna is concluded to be 1. The antenna has a slot at the top left corner and a longer slit next to that at the top right corner which changes current distribution and affects resonance frequencies

On the bottom left corner of the antenna a port has been added with resistance of 50 Ohms.

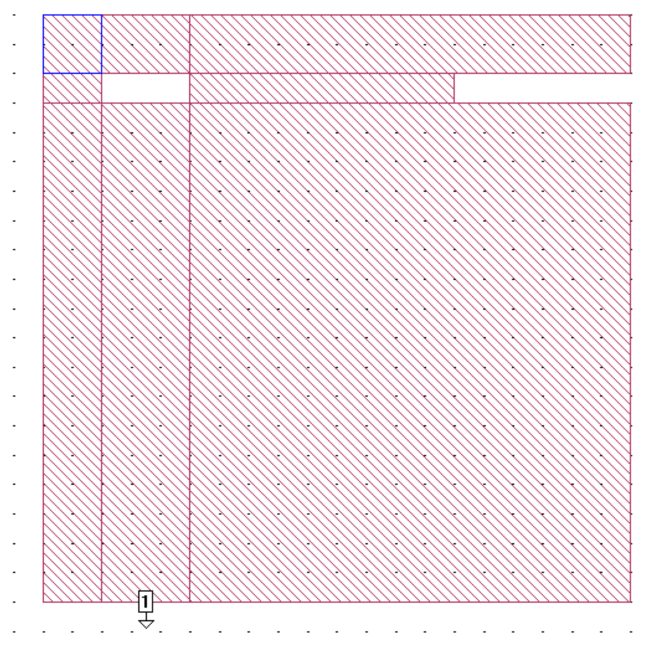

Fig. 1.Top view of the antenna

III. ANALYSIS RESULTS

Analysis and designs have been performed by using Sonnet software. S11 is -7.9 dB at 6.65 GHz and -13.3 dB at 10.7 GHz as seen in Figure 2. The gain pattern of the antenna at 9.1 dB at 6.65 GHz is shown in Fig. 3. Maximum gain received is 8.67 dB at 10.73 GHz with air thickness of 11.4 mm. The gain values at different operating frequencies and different thicknesses are tabulated in Table I.

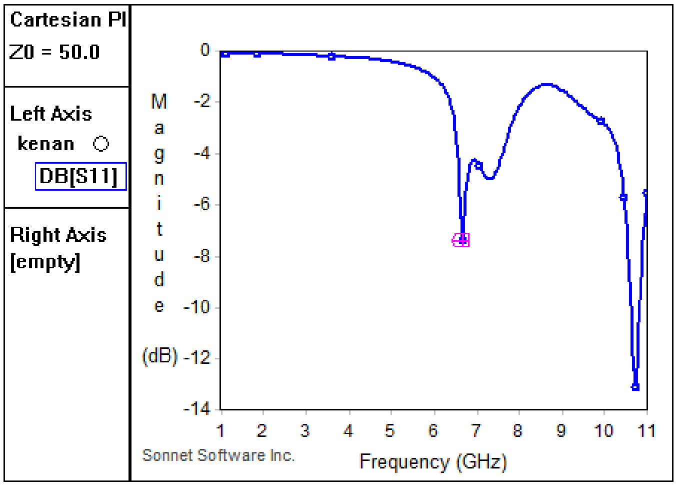

Fig. 2. Input match of the antenna.

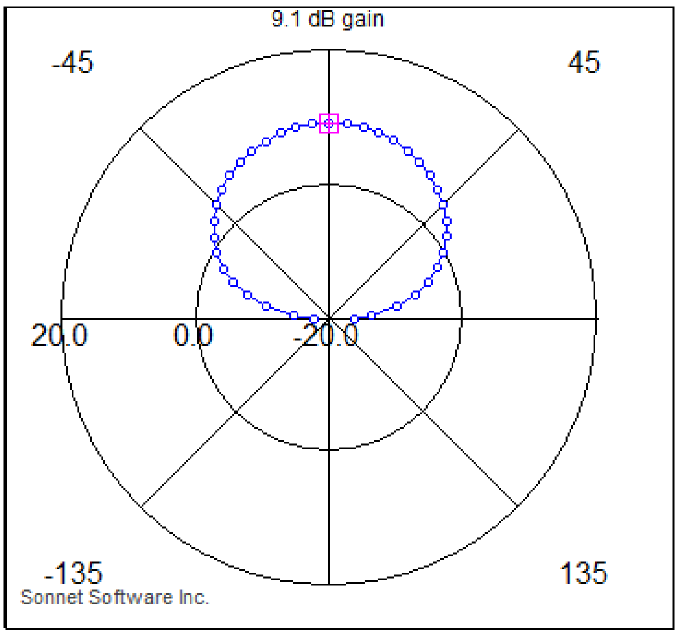

Fig. 3. Radiation pattern at 6.65 GHz

TABLE 1 Comparison of air thickness, Gain vs. Frequency

Thickness (mm)	11	11.4	11.7	10.7	10.5	10,3
Frequency (GHz)	10,70	10,73	10,72	10,65	10,68	10,72
Gain (dB)	7,67	8,67	8,62	8,5	8,02	8,45

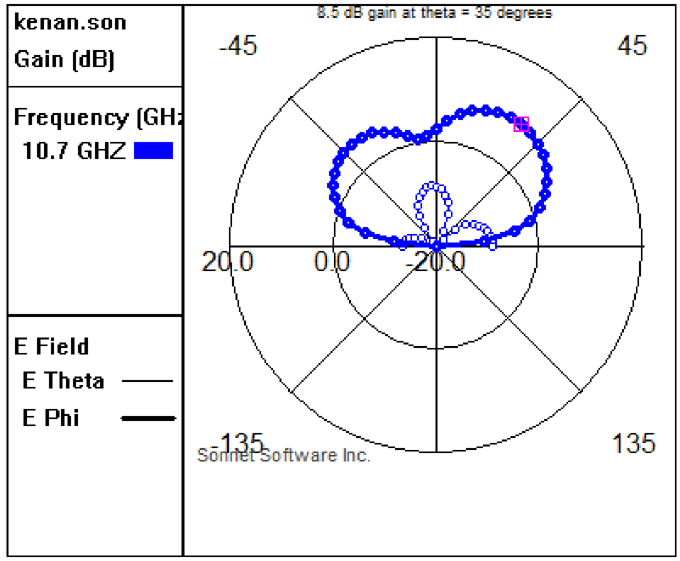

Fig. 4. Gain pattern of the antenna at 10.7 GHz.

IV. Conclusion

In this paper, a rectangular patch antenna was designed and simulated, using Sonnet software. At 10.7 GHz, the gain of the antenna is 8.5 dB at theta = 35 degrees. Gain values at different operating frequencies and different thicknesses are shown in Table 1. The simulation results are final at this stage, thus I will proceed with my research and studies.

References

[1] A. Bendaoudi, Z. Mahdjoub, "Comparative study of patch antenna slot slit-ring resonators on different substrate materials" *2018 Photonic Network Communication* , 2018, pp. 195-203.

[2] A. K. Bordoloi, P. Saikia, "Tuning of Dual Frequency Patch Antenna with Shorted Slit in S-Band", IRACST International Journal of Computer Networks and Wireless Communications, May-June 2019, vol. 9, No. 3, pp. 2250-3501.

[3] A. Rani, A.K. Gautam, "Improvement in Gain and Bandwidth of Rectangular and U Slot Loaded Patch", International Journal of Computer Science Issues, pp.283-288, November 2011.

[4] H. K. Gupta, P. K. Singhal, P. K. Sharama, V. S. Jadon, "Slotted Circular Microstrip Patch Atenna Designs for multiband Application in Wireless Communication" *2012 International Journal of Engineering and Technology*, 2012, pp. 158-167.

[5] H. R. Kharat, M. D. Khetmalis, S. H. Pimpalgaonkar, R. Shamalik, "Design and Analysis Of Compact U Slot Microstrip Patch Antenna For Wireless Applications" *2016 Internatonal Journal of Wireless Networks and Communications*, 2016, pp. 7-14.

Difficulties in Patch Antenna Production & Prototyping in Turkey

G. Kemal Oğuz
Department of Industrial Policies and Technology Management
Istanbul Commerce University
Istanbul, Turkey

***Abstract*—In this paper, difficulties in microstrip antenna production and prototyping in Turkey are analyzed. High-quality dielectric substrates are developed and manufactured by western originated companies. Thus, the dielectric substrate with high-grade characteristics is hard to find for Turkey and developing countries. Import is the only option and quite costly. Choosing a domestic dielectric substrate is inevitable, however insufficient for many cases.**

Keywords—exchange rate fluctuation, monetary narrrowing, Turkey, developing countries, Covid-19, difficulties, prototyping, manufacturing, microstrip patch antenna, dielectric substrate, telecommunication systems.

I. INTRODUCTION

Within recent decades, microstrip patch antennas have been quite popular, and they have widely taken part in telecommunication. Furthermore, patch antennas are lighter, smaller, and more durable than other antennas (dish, yagi, loop, whip, et cetera) apart from all, patch antennas implementable in almost every condition and shape. Hence, microstrip patch antennas are highly typical in almost every sector including military applications. They are utilized in almost every field, from aviation, mobile devices, wearable devices, and implants to radar systems, etc. Accordingly, in the near future, patch antennas will take over conventional antennas in every area. In this context, this growth has increased the interest in microstrip patch antenna studies in research groups and laboratories.

The dielectric substrate's (double-sided RF laminate) specifications indicate that dielectric constant and actual physical thickness are essential elements of the patch antenna's radiation characteristics. The dielectric substrate with high-grade characteristics is hard to find for Turkey and developing countries. Since import option is quite costly. Choosing a domestic dielectric substrate is inevitable, however insufficient for some applications. As it is in every project, cost and efficiency are a vital part of the project design. Therefore, the ratio of cost is more important for Turkey and developing countries due to floating exchange rates. Consequently, monetary narrowing, undesired exchange rate fluctuation and recent coronavirus (COVID-19) pandemic broadly hit the research, prototyping, manufacturing, testing, and the supply chain of the microstrip patch antenna industry.

II. GROWING INTEREST IN MICROSTRIP PATCH ANTENNA

Telecommunication systems are an important part of our daily life. In everyday life, mobile phones are widely used and are part of the telecommunication system. Mobile phones are widely hailed for their technological benefit to mankind, the ease it creates in doing daily chores, and most of all, bridging of information as well as communication gaps among people [1]. In this context, the most important part of the telecommunication systems is microstrip patch antennas. Patch antennas are highly preferred; the most significant reason for these is that patch antenna can be designed according to any condition. In addition, patch antennas are durable and manufactured easier and more affordable than other antennas. As they are widely used in many fields, studies and developments on these antennas have increased. They are designed and manufactured in universities, research groups, RF laboratories, small-scale industry, and production facilities affiliated to large-scale companies. Accordingly, there are companies that produce and develop RF substrates that are essential in the patch antenna prototyping. By conducting researches, companies develop RF materials for antennas to be used for different purposes. Some of the USA based companies that have developed high-quality materials are Rogers Corp, Taconic and Arlon EMD.

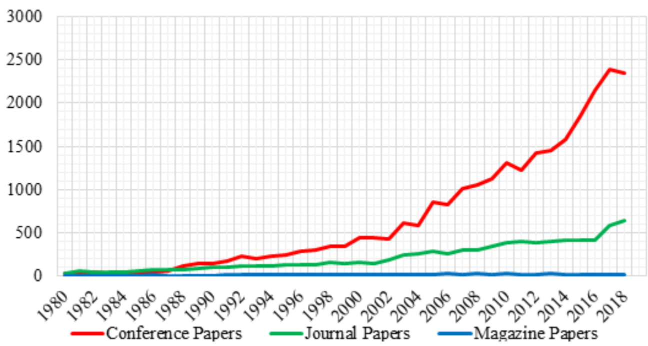

Fig. 1 Number of patch antenna papers indexed Library between 1980-2018

As shown in figure 1, according to the data gathered manually from [2, Fig. 1], there has been a great increase in antenna research and studies since the 1980s. In the 80s golden era of personal computers accelerated the dielectric substrate (double-sided laminate) development. New discovered substrate used in patch antenna to meet with new communication methods frequency requirement. Moreover, this development also reduced the cost of microstrip patch antenna [3]. In this sense, this increase is also developing in parallel with the development of high-quality substrates. In this sense, this increase is also developing in parallel with the development of high-quality substrates. Furthermore, the rapid progress of telecommunication and satellite communication systems has accelerated the antenna studies. As described in [4], the development of PCB production and the increase of portable devices have led to the need to produce RF circuits cheaper. Increased computerization in the 1980s accelerated the antenna design, and the modeling process became easier. Consequently, the researchers worked on techniques and new approaches to increase the bandwidth of patch antennas, reduce losses and increase efficiency.

III. The Effect of Currency Fluctuation on Antenna Design and Prototyping in Turkey

Exchange rate is the ratio of two separate currencies. Undesired foreign exchange rate variation effects are crucial in developing countries. Moreover, variations in the exchange rate directly impact the entire process of business and industrial policies in developing companies with import dependency [5]. The main element in microstrip patch antenna design and prototyping is the double-sided laminate (dielectric substrate). However, unfortunately, high-grade, low dielectric constant substrates are not available in Turkey's domestic market. Import is the only option. In this context, this circumstance effects patch antenna project budgeting, research, design, and prototyping process.

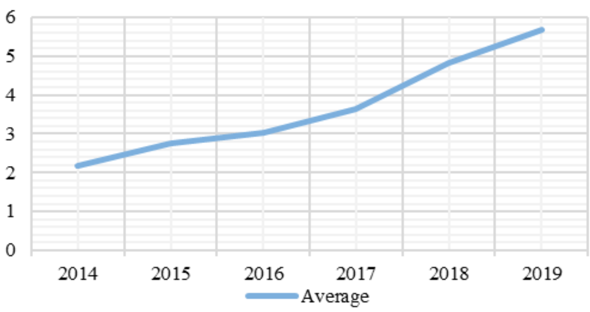

Fig. 2 Average USD/TRY exchange rates between 2014-2019

Figure 2 shows the data gathered manually from [6, Fig. 2] and it is nominal part of USD/TRY exchange rates between 2014-2019. The data is based on the exchange rate on the last day of each month. As will be noticed, the fluctuation has stimulated since May 2018. As seen in the general average, the increase continues and almost stable. When this situation is correlated with the growing interest in patch antennas shown in figure 1; the following situation arises, this negative increase is inversely proportional to the growing interest in microstrip patch antennas. This is a concrete indicator of a disadvantage for Turkey and other developing countries.

TABLE I. PRICE COMPARISONS FOR RF SUBSTRATES

Name	**Dielectric constant**	**Dimensions**	**Thickness**	**Price**
RT/duroid 5870	2.33	202 x 228mm	0.254mm	$73.09
Taconic TLX-9	2.5	305 x 457mm	0.760mm	$109.25
Rogers Corp. CuClad 217	2.17	228 x 305mm	0.380mm	$95.38

Table 1 shows the current high-grade dielectric substrate prices have taken on [7, Tab. 1]. As shown in the table, high-grade substrates are quite costly. It is directly associated with the negative impact of the currency fluctuation on patch antenna design and prototyping. Furthermore, it was observed that the import of dielectric substrates was affected by the price increase caused by the exchange rate fluctuation. This situation displays an increase in project costs in developing countries, including Turkey.

IV. Conclusion

In past decades, demand in patch antennas has risen because of patch antennas producible via conventional PCB techniques, light, configurable in almost every shape and condition, and durable than conventional antennas. The dielectric substrate is the backbone or the main element of patch antenna. Since the performance parameters and the dimensions of patch antennas are developed over the characteristics of the dielectric substrate. It is very important to be able to obtain high characteristic substrates moreover, substrates from the domestic market are insufficient for projects that require a high-grade characteristic. High-grade substrates are generally produced, developed and distributed by the USA originated companies. Therefore, the supply of substrate depends on imports. Supplying dielectric substrates have become more challenging than before, due to unexpected fluctuations in exchange rates, monetary narrowing, and unexpected COVID-19 pandemics. This unusual situation slows down the semiconductor and other industries all over the world. Due to the measures taken at the factories, the workforce has been divided, and production is carried out on duty. As a summary, risky disruptions happen in the supply chain. Within this context, in this study, the difficulties affecting microstrip patch antenna production and design process in Turkey were examined by making the necessary literature research and benefiting from the author's microstrip antenna design and manufacturing process experience.

References

[1] Sk, K., Js, S., R. N., “Challenges Faced During Designing, Simulation of Microstrip Patch Antenna in HFSS and Testing After Fabrication,” International Journal for Research in Applied Science & Engineering, Vol. 4, Issue 4, pp. 844-847, 2019.

[2] "IEEE Xplore® Digital Library," Accessed on: Mar. 20, 2020. [Online]. Available: https://ieeexplore.ieee.org/Xplore/home.jsp.

[3] Paul, L. C., Hosain, S., Sarker, S., Prio, M. H., Morshed, M., & Sarkar, A. K., "The Effect of Changing Substrate Material and Thickness," American Journal of Networks and Communications on the Performance of Inset Feed Microstrip Patch Antenna, Vol. 4, Issue 3, pp. 54-58, 2015.

[4] Patel, B. D., Narang, T., & Jain, S., "Microstrip Patch Antenna-A Historical Perspective of the Development," Conference on Advances in Communication and Control Systems, pp. 445-449, 2013.

[5] Kandil, M., & Dinçer, N., "The effects of exchange rate fluctuations on economic activity in Turkey," Journal of Asian Economics, Vol. 18, pp. 466-489, 2007.

[6] "Central Bank of Turkey," Accessed on: Mar. 10, 2020. [Online]. Available: https://www.tcmb.gov.tr/wps/wcm/connect/EN/TCMB+EN/Main+Menu/Statistics/Exchange+Rates/Indicative+Exchange+Rates.

[7] "R F. Elettronica Web Site," Accessed on: Jan. 12, 2020. [Online]. Available: https://www.rf-microwave.com/en/home/.

Rectangular Patch Antenna at Ku-Band

Metehan Berk
Department of Mechanical Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina

***Abstract*— A rectangular patch antenna is introduced in this paper. The presented antenna consist of rectangular shaped patch with via feeding. The antenna is designed and simulated using a planar 3D Electromagnetic Simulation tool, called Sonnet Suites. The antenna was placed on an air substrate of 2.42 mm of dielectric thickness and operates between 10.8 and 11.15 GHz with gain of 7 to 9 dB. Proposed antenna could be used in the receiving band of Ku-Band.**

Keywords—Rectangular patch, Microstrip patch antenna, Ku –Band, via feeding.

I. INTRODUCTION

An antenna is an element used for transmitting antenna is to be had in several exceptional size and shapes, and all of them operate in line with the equal fundamental concepts of electromagnetics. Many forms of portable electronic devices, such as mobile phones, GPS receivers, pagers, palm digital devices, telematics unit in vehicles and laptop computers, need an efficient and powerful antenna for communicating wirelessly with other constant or mobile verbal exchange units. A microstrip patch antenna is a type of antennas that develop a low profile, i.e. thin and easy to fabricate, which gives a remarkable benefit over traditional antennas[1,2]. Patch antennas are planar antennas used in wireless links and other microwave applications. Microstrip can be using photolithography techniques. It is easily falsified into linear or planar arrays and readily integrated with microwave integrated circuits. There are several techniques to feed microstrip antenna. These techniques are divided into two groups contacting and non-contacting. The contacting feed technique such as coaxial cable and microstrip line, while the non-contacting such as coaxial cable and microstrip line while the non-contacting such as proximity coupling and aperture coupling [3,4,5]. Therefore, it is necessary to increase the bandwidth of the antenna by truncating edges of the patch, using elliptical or triangular patch, and cutting a slot on the patch. Slotted microstrip antenna has better bandwidth, input match, gain, and directivity compared with non-slotted microstrip patch antenna. A rectangular patch which is presented in this paper is working in Ku-Band and simulated in Sonnet electromagnetic software.

II. ANTENNA GEOMETRY

The geometry of the rectangular patch antenna is shown in Fig. 1. The size of the antenna is 11×10 mm. The antenna is designed on air as a dielectric substrate whose thickness is 2.40 mm.

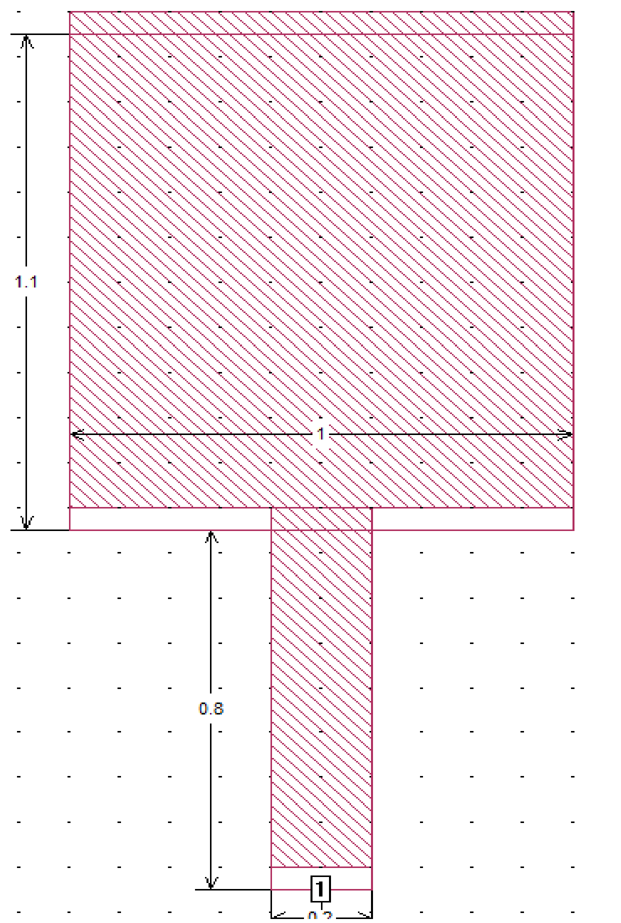

Fig. 1.Picture of the antenna (cm)

III. Analysis Results and Parametric Study

The antenna is modeled and analyzed using the Sonnet software program. The input match (S_{11}) of the antenna is shown in Fig. 2 between 8 GHz and 15 GHz. The input match is less than -10 dB between 110.8 GHz and 11.15 GHz. The radiation pattern of the antenna at 11.1 GHz is shown in Fig. 3. The maximum gain value at 11.05 GHz is 8.9 dB at theta = 0 degrees while cross polarization level is less than -10 dB.

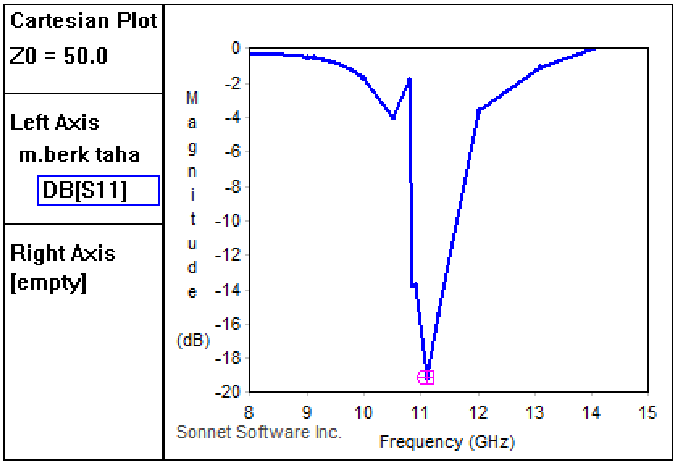

Fig. 2. Input match of the antenna.

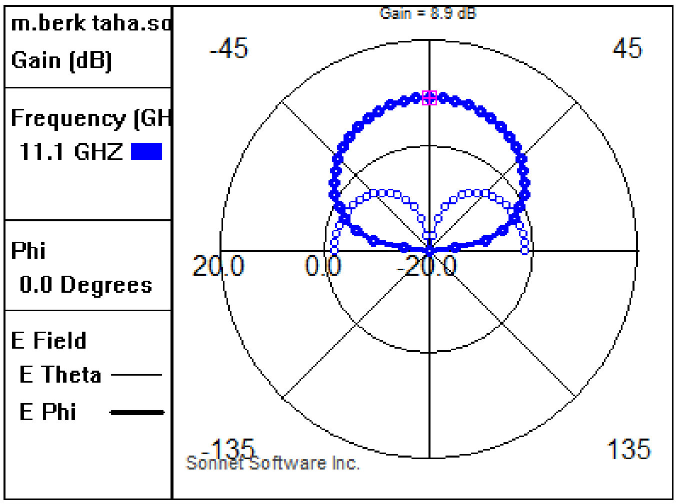

Fig. 3. Gain pattern of the antenna at 11.1 GHz.

The gain values at different operating dielectric constants and thickness are tabulated in Table I. and Table II. As seen in tables, S11, frequency and gain values are not changing much which shows antennas fabrication tolerances are within acceptable levels.

TABLE I. PARAMETRIC STUDY OF DIELECTRIC THICKNESS

Dielectric thickness (mm)	**2.33**	**2.37**	**2.40**	**2.43**	**2.47**
S11 (dB)	**-20.89**	**-19.23**	**-19.07**	**-18.78**	**-18.26**
Frequency (GHz)	**11.15**	**11.1**	**11.1**	**11.1**	**11.1**
Gain (dB)	**8.89**	**8.95**	**8.94**	**8.92**	**8.89**

TABLE II. PARAMETRIC STUDY OF DIELECTRIC CONSTANT

Dielectric constant (mm)	**0.98**	**0.99**	**1**	**1.01**	**1.02**
S11 (dB)	**-20.01**	**-18.71**	**-19.07**	**-21.19**	**-14.01**
Frequency (GHz)	**11.05**	**11.1**	**11.1**	**10.9**	**10.8**
Gain (dB)	**9.14**	**8.85**	**8.94**	**7.97**	**7.51**

IV. Conclusion

In this paper, a rectangular patch antenna designed, simulated on Sonnet Software. According to analysis results, the antenna operates between 10.8 GHz and 11.15 GHz. At 11.1 GHz, the gain of the antenna is 8.94 dB while input match (S11) is – 19 dB. A parametric study was conducted for the dimensions of the dielectric thickness and constant. The planned future work is fabrication of the antenna.

References

[1] C.A. Balanis(2008)," Antenna Theory:Analysis and Design", 2nd edition.Wiely .

[2] IEEE Transactions on Antennas and Propagation (Volume: 48 , Issue: 6 ,Jun 2000) L.Boccia,and.D.Massa,G.Amendola,(2005)" Shorted Elliptical Patch Antennas with Reduced Surface Waves on Two Frequency Bands",IEEE Transaction on Antenna and propagation.Vol.53,pp.1946-1956

[3] STUTZMAN, w. L., and THiELE, G. A.: 'Antenna theory and design' (John Wiley & Sons, 1981), p. 397

[4] Z.N. andM.Y.W.Chia Chen,(2006)"Broadband Planar Antenna Design and Applications", JhonWiely& sons.

[5] M. John, B. Manoj and S. Rodrigues, "Design of slotted rectangular microstrip patch antenna operated in ISM band using RT-Duroid substrate," 2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), Chennai, 2016, pp. 3076-3080.

Reverse E-Shaped Patch Antenna with multiple slits

Merjem Begovic
Electrical and Electronics Engineering
International University of Sarajevo, Sarajevo, Bosnia and Herzegovina

***Abstract*— In this paper, a microstrip antenna is presented. The presented antenna is designed with reverse E-shaped patches on three sides. The antenna is simulated Sonnet Software. The antenna is designed on an Aluminum substrate and operates at 8.82 GHz with gain of 5.129 dB, with S11 value of -17dB.**

***Keywords*—Microstrip patch antenna, reverse E-shaped slot, multiple slits**

I. Introduction

Rapid growth in mobile communication systems requires use of low profile, light weight, simple low-cost antennas in order to meet the needs of increasing data demand. Those systems that transmit antennas in their free space can tie-up mobility, accessibility and can have sufficient range without amplification. Microstrip antenna was not developed until 1970 when the revolution in electronic circuit miniaturization started [1]. Choosing the right antenna depends on the requirements of the application such as frequency band, gain, cost, coverage, weight, etc. [2]. Microstrip patch antennas have been used in wireless application for a long time due to their advantages such as being low-cost, their simplicity etc. But, still, they have disadvantages such as narrow frequency band and low gain, which could be modified and increased with many proposed methods in literature [3]. A low gain microstrip patch antenna consists of a conducting patch and a ground layer separated by a dielectric substrate.

In literature, various types of patch antennas have been designed to meet the requirements in many applications. The rectangular patch shape is the most popular one, as it can be easily analyzed and modified in order to get desired results. Many studies have been published in the field about wideband microstrip patch antennas for wireless communication i.e. [4] [5].

The authors of [6] used the concept of complementary antennas where the planar antenna is presented with a U-shaped metal reflector in order to achieve unidirectional propagation. The antenna was low profile, high frequency band and high gain over the operational frequency range. In [7] a wideband slot antenna was designed with multiple metal back reflectors.

Interest in multi-band antennas is increasing to reduce the number of antennas used while combining multiple applications. In order to increase bandwidth, multiple techniques are implemented, such as: using frequency selective surface, using thicker profile for folded shorted patch antennas, the use of slots, the use of thicker substrate, E-shaped patch antenna, etc. [2].

In this paper a new antenna design is proposed. The design is simulated and analyzed for gain, and the results are tabulated for some frequencies.

The geometry of the low gain antenna is shown in Fig. 1. The size of the antenna is 75×84 mm. The antenna is designed on an Aluminum (96%) dielectric substrate whose thickness and permittivity are 1.6 mm and 4.4, respectively. The antenna is designed with reversed E-shaped patches on three sides. The box in the simulation program is 10 times bigger than the patch, which makes an effect on the gain and bandwidth value.

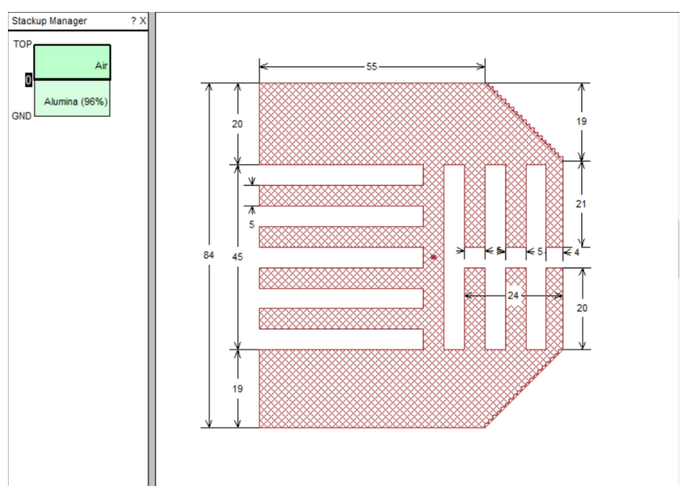

Fig. 1. Top view of the antenna

II. Analysis Results

The antenna is modelled and analyzed using the Sonnet Software program. The input return loss (S_{11}) of the antenna is shown from 4 GHz to 10 GHz in Fig. 2. S_{11} has magnitudes values less than -10 dB between 6.82 GHz and 9.96 GHz.

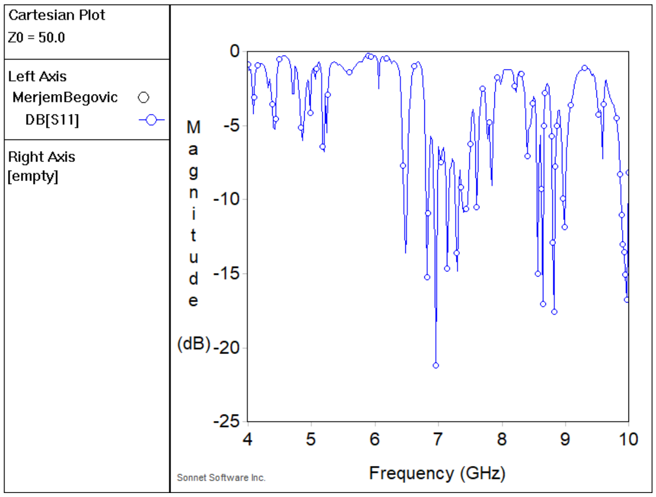

Fig. 2. Input match of the antenna.

The gain pattern of the antenna at 8.82 GHz is shown in Fig. 3. The maximum gain value at 8.82 GHz is 5.129 dB. The positive gain values at different operating frequencies are tabulated in Table I.

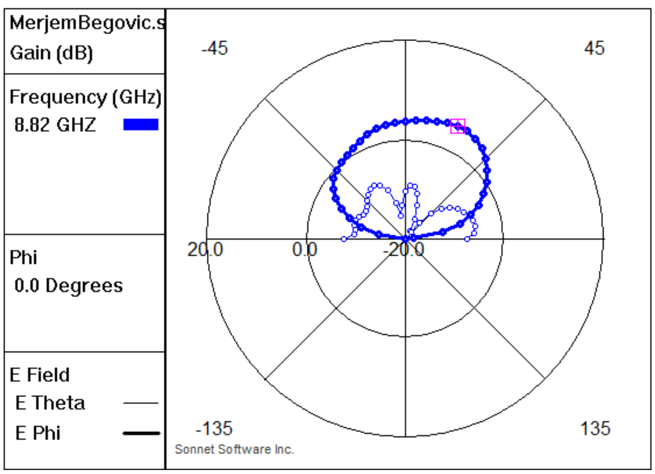

Fig. 3. Gain pattern of the antenna at 8.82 GHz.

TABLE 1 Comparison of Gain vs. Frequency

Frequency (GHz)	**Gain (dB)**	**Theta (θ)**
6.82	0.115	5
6.96	**2.122**	**10**
8.64	**1.274**	
		0
8.82	**5.129**	**25**
9.96	**2.59**	**-40**

III. Conclusion

In this paper, a reversed E-shaped patch antenna, with multiple slits is designed and simulated on an Al (96%) substrate. According to analysis results, the antenna operates between 6.82 GHz and 9.96 GHz. At 8.82 GHz, the gain of the antenna is 5.129 dB. For further works, the antenna should be fabricated and measurements should be compared to the simulated results.

IV. Bibliography

[1] M. K. Bhanarkar and A. A. S. &. V. V. Navarkhele, "Low Gain Microstrip Patch Antenna for Wireless Applications," in *NCMTA-2013*, At Azad college, Aurangabad, 2013.

[2] R. KARLI and H. AMMOR, "A SIMPLE AND ORIGINAL DESIGN OF MULTI-BAND," *International Journal of Microwaves Applications,* p. 4, 2013.

[3] C.-L. Mak and H. W. &. K.-M. Luk, "High-Gain and Wide-Band Single-Layer PatchAntenna for Wireless Communications," *IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY,* p. 8, 2005.

[4] P. Ranjan & S. Mishra, "Design of Circularly Polarized Rectangular Patch Antenna with single cut," in *Conference on Advances in Communication and Control Systems*, 2013.

[5] N. J. Shimu & A. Ahmed, "Design and performance analysis of rectangular microstrip patch antenna at 2.45 GHz," in *5th International Conference on Informatics, Electronics and Vision (ICIEV)* , Dhaka, 2016 .

[6] M. L. &. K.-M. Luk, "A low-profile wideband planar antenna," *IEEE Transactions on Antennas and Propagation,* vol. 61, p. pp. 4411–4418, 2013.

[7] X. Gao and Y. Q. &. Y. C. Jiao, "Design of multiplate back-reflector for a wideband slot antenna," *IEEE Antennas and Wireless Propagation Letters.*

Octagonal Shaped Patch Antenna with a Rectangular Slot

Hüseyin Karaağaç
Department of Electrical and Electronics Engineering
International University of Sarajevo, Sarajevo, Bosnia and Herzegovina

Abstract— **In this work octagonal shaped microstrip patch antenna is designed and simulated. Anlaysis are done while changing explicit parameters, which incorporates for the most part geometry and some material attributes like dieletric thickness and constant. This antenna structure has some advantages and applications in industry. The goal of the study was dual band patch antenna. Results are as follows: S11 parameter is -12.8 dB for 3.94GHz, with 5.2 dB gain.**

Keywords—octagon patch, Microstrip patch antenna, return loss, slot.

I. INTRODUCTION

Microstrip patch antennas (MPA) are a class of planar antennas which have been researched and developed extensively in the last four decades. They have become favorites among antenna designers and have been used in many applications in wireless communication systems, both in the military sector and in the commercial sector.[1] Microstrip patch antennas are low cost, flexible and highly efficient. Different shapes and sizes of Microstrip patch antennas are available in the field of communication.[2]

In this paper, a compact design of an octagonal-shaped patch antenna (MPA) with the resonance frequency of 3.94 GHz is introduced. Microstrip technology is used for simplicity and ease of fabrication. The design and simulation are performed using method of moments based electromagnetic simulator Sonnet Software. The simulation resulted in the return loss plot and gain plot that satisfy the set requirements. The compact size and affordable materials make the antenna suitable for wide applications.[1][3]

The study and the design of octagonal patch antenna is presented in this research paper. We begin first with schematic model of the octagonal patch antenna. After the simulations, a parametric study was studied and we finish by conclusion of our work.[4]

II. ANTENNA GEOMETRY

The geometry of the fabricated octagon slot antenna is shown in Fig. 1. The size of the antenna is 34×32 mm. antenna was designed by feeding it from bottom-center The antenna is designed on a dielectric substrate whose thickness and permittivity are 2.2 mm and 1.6, respectively. It has a symmetrical structre which means that the denoted lengths and widths are repeatable through the design. Highest gain and the lowest input match were obtained at 3.94GHz. The antenna was placed in a box whose size is approximately ten times larger than the antenna's size itself, and the top cover was chosen to be free space.

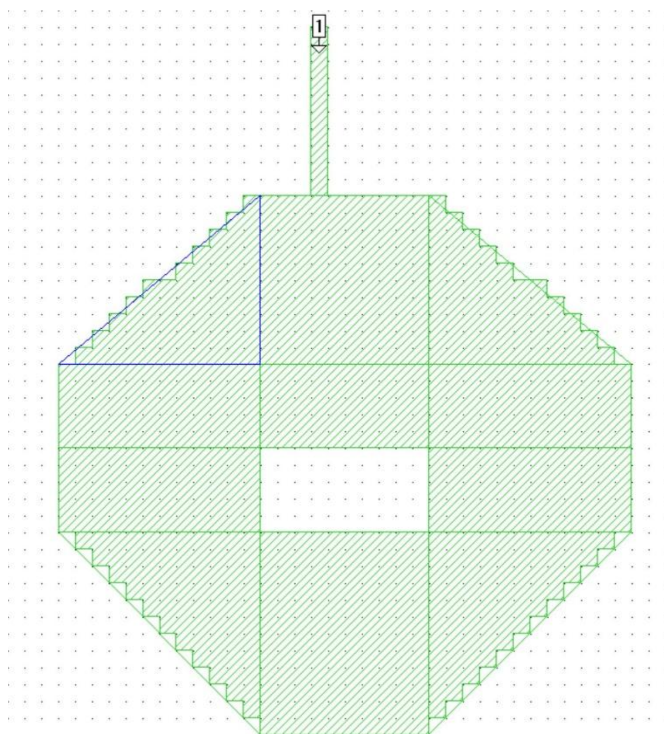

Fig. 1.Picture of top view of the antenna

III. ANALYSIS RESULTS

The antenna is modelled and analyzed using the Sonnet software program. The input match (S_{11}) of the antenna is shown in Fig. 2. The input match is less than -10 dB at 3.94

GHz. Fig. 3 has the radiation pattern of the antenna with 5.2 dB co-pol and -15 dB cross-pol

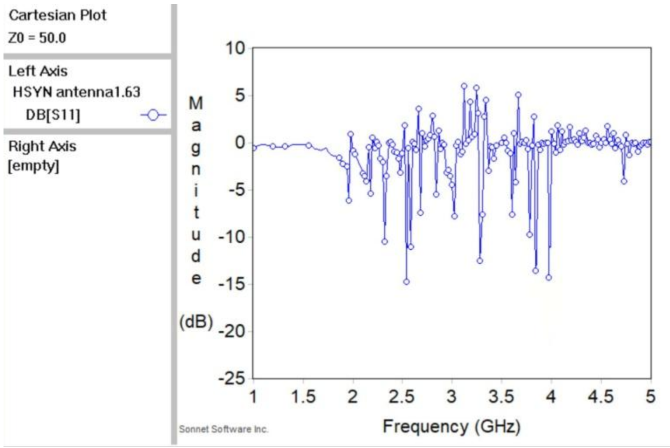

Fig. 2. Input match of the antenna.

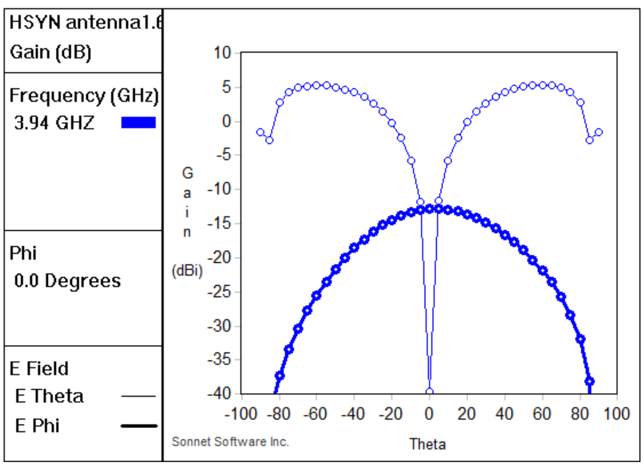

Fig. 3. Gain pattern of the antenna at 3.94 GHz.

Table I and II show the parametric study of the dielectric. As seen, gain and input match are in acceptable levels for fabrication tolerances.

TABLE I: CHANGE OF DIELECTRIC THICKNESS

Dielectric thickness (mm)	**1.6**	**1.63**	**1.61**	**1.59**	**1.57**
S11	**-12.8**	**-12.9**	**-13.9**	**-12.7**	**-12.6**
Gain(dB)	**5.25**	**5.22**	**5.30**	**5.23**	**5.20**

TABLE II. CHANGE OF DILECTRIC CONSTANT

Dielectric constant	**4.4**	**4.41**	**4.39**	**4.38**	**4.42**
S11	**-12.8**	**-13.0**	**-12.5**	**-12.3**	**-13.2**
Gain(dB)	**5.25**	**5.28**	**5.22**	**5.19**	**5.31**

IV. CONCLUSION

Microstrip antennas have become a rapidly growing area of research. Their potential applications are limitless, because of their light weight, compact size, and ease of manufacturing [5]. In this paper, a wideband octagon patch antenna is designed and simulated. According to analysis results, the antenna operates at 3.94 GHz. At 3.94 GHz, the gain of the antenna is 5.2 dB with -12.8 dB input match. Next goal is fabrication of the antenna.

REFERENCES

[1] Kai Fong Lee,Kwai Man Luk andHau Wah Lai, Microstrip Patch Antennas Introduction,vol.2(1), 1-23, August 2017

[2] Swagata B. Sarkar, Design and Analysis of Multiband Octagonal Microstrip Patch Antenna with Different Annular Ring Department of Electronics and Instrumentation Engineering, Sri Sai Ram Engineering College, India, vol.1(1), 1, 2016

[3] B. Abirami and M. Shalini, “Designing of S shaped microstrip patch antenna for broadband application using slotting technique,” International Journal for Research in Applied Science & Engineering Technology (IJRASET), vol. 4(11), 2321-9653, November 2016

[4] Houda Werfelli, Khaoula Tayari, Mondher Chaoui, Mongi Lahiani, Hamadi Ghariani Design of Rectangular Microstrip Patch Antenna National Engineers school of Sfax Laboratory of Electronics and Technology of Information, vol.1(1), 1 , 2016.

[5] J. M. Patel, S. K. Patel and F. N. Thakkar, “Comparative analysis of S-shaped multiband microstrip patch antenna,” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 2(7), 2320 – 3765, July 2013

A Compact Microstrip Patch Antenna for X-Band

Mehmet Yusuf Imeci
Department of Electrical and Electronics Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina
mehmedyusufimeci@gmail.com

***Abstract* – A compact rectangular microstrip patch antenna is introduced in this paper. The input match and the gain of the antenna at the center frequency of 8.52 GHz, is respectively 45dB and 5dB. A 1.6mm thick FR4 material is used as the substrate for this work. The antenna might be used in applications of microwave devices in X-Band including satellite communications, radars, terrestrial broadbands, space communications, amateur radios, and molecular rotational spectroscopy.**

Keywords—X-Band, radiation pattern, microstrip patch antenna.

I. INTRODUCTION

Due to widespread applications ranging from cell phones to wearable technologies, antennas play an important role in our daily lives. Direct broadcast satellite (DBS), refers to satellite television systems. In these systems, end users receive content directly from a geostationary satellite. Antennas for DBS systems are usually in the form of a dish, which can offer high directive gain over 30 dB [1]. Antennas are also a significant part of wireless communication systems. Parabolic reflectors, patch antennas, slot antennas, and folded dipole antennas, are just a few examples of the types of antennas. Each type has its own specialized property for a particular application. Antennas could be classified as the backbone and the driving force behind the recent advances in wireless communication technology [2]. Studying antennas and wave propagation phenomena using interactive graphics and animations nowadays, has become a fundamental tool for describing and understanding electromagnetic concepts [3]. The Radio Frequency Identification (RFID) technique is supported by Wal-Mart, and is becoming one of the most popular wireless communication techniques in the world. RFID has several benefits relative to the traditional bar-code technique, such as non-contact reading, longer reading range, anti-pollution properties, longer lifetime, and larger information carrying capacities [4]. The electromagnetic spectrum being employed for communication outside the visible region through the use of radio, has been very recent in human history. One of humankind's greatest natural resources, is the electromagnetic spectrum, and the antenna has been instrumental in harnessing this resource. [5].

II. DESIGN STEPS & SIMULATION RESULTS

Figure 1 has the top view of the antenna. The antenna is built on a 1.6mm thick FR4 substrate. The dielectric constant is $\varepsilon_r = 4.4$ for this material. The size of the antenna is 16 x 12 mm. Dimensions of the feeding line of the antenna is 4 x 16 mm.

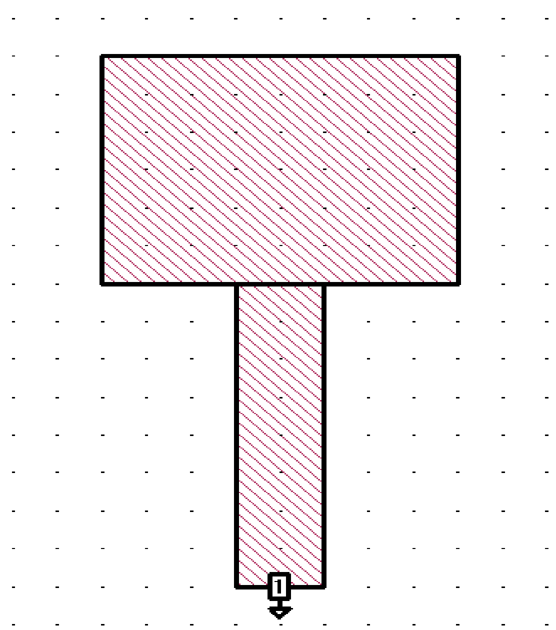

Fig. 1. Top view of the antenna

The design is simulated from 1 GHz to 11 GHz. The S11 of the design is shown in Figure 2 where one can see that the design has a return loss of about 45 dB at 8.52 GHz.

As you can see from the radiation pattern of the antenna shown in Figure 3, the main beam has two intermediate patterns of 5 dB at θ = ± 60⁰. The cross polarization level is a little bit high around -3.87 dB.

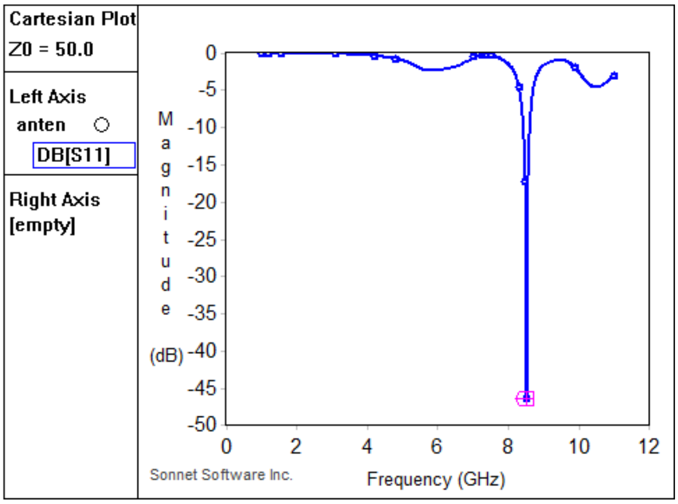

Fig. 2. S11 of the antenna

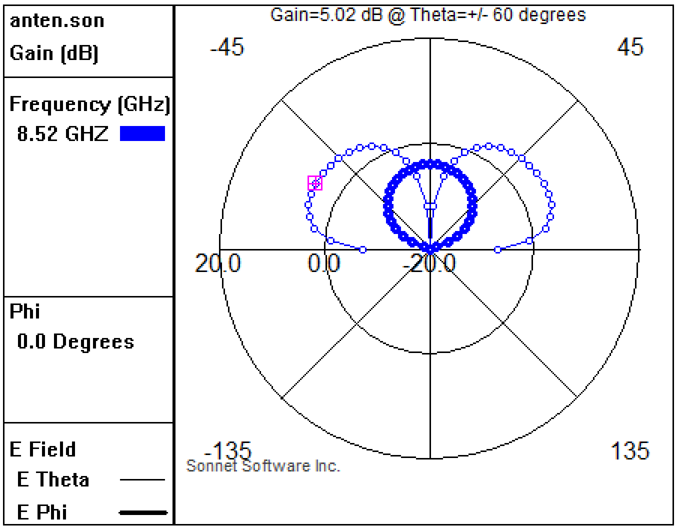

Fig.3. 3D view of the antenna

III. Parametric Study

In order to see the fabrication tolerances of the dielectric substrate, a parametric study is conducted by changing the dielectric thickness and dielectric constant.

TABLE I. CHANGING THE DIELECTRIC CONSTANT

ε_r	[S11] (dB)	Gain (dB)	Frequency (GHz)
4.45	-37.80	4.99	8.48
4.43	-33.19	4.97	8.50
4.40	-45.01	5.00	8.52
4.37	-30.42	4.92	8.54
1.55	-32.35	5.01	8.58

TABLE II. CHANGING THE DIELECTRIC THICKNESS

Dielectric thickness (mm)	[S11] (dB)	Gain (dB)	Frequency (GHz)
1.65	-29.42	4.98	8.50
1.63	-33.19	4.97	8.50
1.60	- 45.01	5.00	8.52
1.57	-39.07	5.04	8.54
1.55	-28.82	5.02	8.54

IV. Conclusion

in this paper, a rectangular microstrip patch antenna was designed and simulated by using a planar 3d electromagnetic simulation tool, called sonnet suites. the designed antenna has a very good return loss performance according to the simulation. the return loss of the antenna is 45 db. the electric field θ polarized gain is 5 db, and the frequency is 8.52 ghz. in this work, it is also shown, how manufacturing tolerances associated with the material thickness, and the dielectric constant, may affect the performance of the antenna. an antenna with this performance, can be used in applications of microwave devices in x-band.

ACKNOWLEDGEMENT

We would like to thank Sonnet Software Inc. for providing home licenses in the COVID-19 period [6].

REFERENCES

[1] K.S. Aung, S.S. Mon, “Comparison of Rectangular and Truncated Rectangular Patch Antenna for Ku-Band”, Volume3, Number 2PP 159-166.

[2] K.O Odeyemi, D.O Akande and E.O Ogunti, “Design of S-Band Rectangular Microstrip Patch Antenna”, European Journal of Scientific Research Vol. 5, No.1, pp. 72-79 2011.

[3] K.O Odeyemi, D.O Akande and E.O Ogunti, “Matlab Based Teaching Tools for Microstrip Patch Antenna Design”, journal of telecommunications, volume 7, ıssue 2, March 2011.

[4] E. T. Aye, C.M. Nwe, “Rectangular Microstrip Patch Antenna Array for RFID Application using 2.45 GHz Frequency Range”, International Journal of Scientific and Research Publications, Vol. 4, Issue 6, June 2014.

[5] P.Subbulakshmi, R.Rajkumar, “Design and Charecterization of Corporate Feed Rectengular Microstrip Antenna”, 2013 IEEE

International Conference on Emerging Trends in Computing, Communication and Nanotechnology (ICECCN 2013).

[6] Sonnet Suites, v16, Syracuse, New York.

Slotted Heart-shaped 4.77dB Microstrip Coupler

Muna Abu Jaber and Aida Bevrnja

Department of Electrical and Electronics Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina

Abstract - This paper introduces a new configuration of a slotted heart-shaped 4.77dB Microstrip Coupler. The design achieved a wide frequency range from 4.32 GHz to 7.06 GHz. The coupler's response is analyzed using Sonnet [1], planar 3D electromagnetic simulation software. The results taken from the software are presented as s-parameters. Applications of this device could be found in wireless 3G networks

Keywords—slotted; coupler; microstrip; open stubs; 4.77dB; Sonnet software

I. INTRODUCTION

Microstrip couplers are very important elements in many microwave circuits, such as balanced amplifiers and data modulators. Among those, the most popular ones are starting with 3dB, 4.77dB, 6.02dB, 10dB, 20dB [2] and 30dB. There are different types of structures in the industry for different applications, [3], such as a 3-way power divider, which can be achieved when a 4.8dB coupler and 3dB hybrids are cascaded.

In this work, we made a slotted 4.77dB coupler scheme using Sonnet software. The goal of achieving a wide frequency range and stable coupling amplitude was set. Therefore, if the gotten results were not satisfactory, optimizations were applied until simulation results were adequate.

II. SIMULATION RESULTS

In this paper, our main goal was to make a working 4.77dB microstrip coupler. The top view of the coupler with necessary dimensions is shown in Fig. 1.

The circuit with 0.3mm thick copper metal is made on top of a dielectric RO4350B with thickness of 3mm and dielectric constant of 3.36.

The dielectric above our circuit is air, and as shown in Fig. 2., for simulation purposes we put its thickness more than 3 times the thickness of the dielectric below, which is 20mm. The total circuit box size is 20mm by 20mm by 23mm.

After simulating this circuit, we have gotten a relatively good response. If we take our bandwidth limits from 4.32GHz to 7.06GHz, which is 2.74GHz bandwidth, the S12, which is our coupling, has an amplitude balance of 0.472dB, with the highest amplitude of -4.513dB and the lowest of -4.985dB which can be seen in Fig. 3.

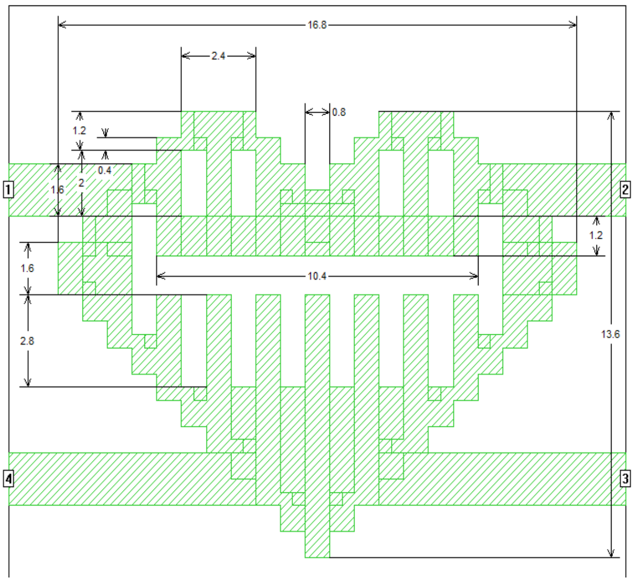

Fig. 1. Top view and dimensions of the coupler (mm)

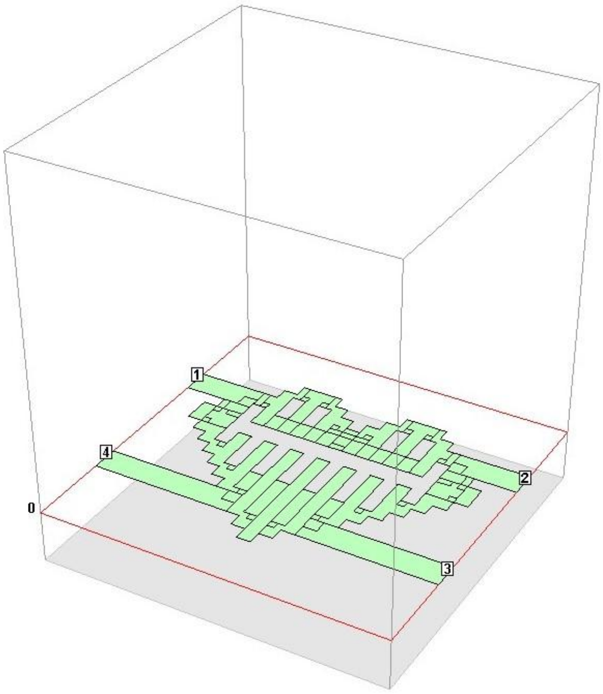

Fig. 2. 3D view of the coupler

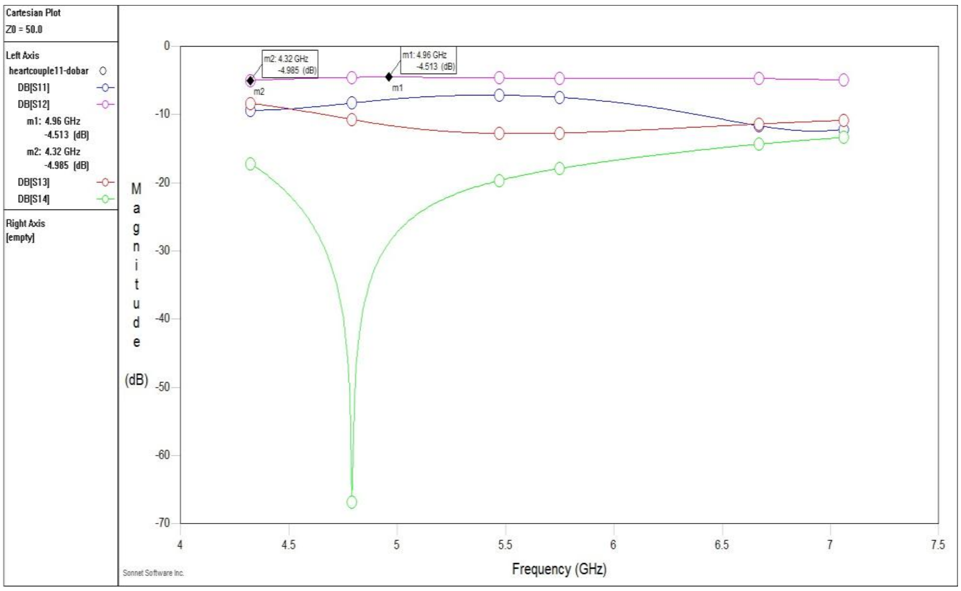

Fig. 3. 4.32 GHz – 7.06 GHz Analysis

But, the S11, which is our reflection, is not under -10dB throughout the entire bandwidth. The highest S11 is at 5.42GHz with a value of -7.13dB. However, if we take our bandwidth limits from 6.4GHz to 7.06GHz, which is 0.66GHz bandwidth, both, S11 and S12, are good and stable in that region. The S11 is always under -10dB and S12 has a lower amplitude balance of 0.269dB, where the highest amplitude is -4.69dB and the lowest is -4.96dB, which can be seen in Fig. 4.

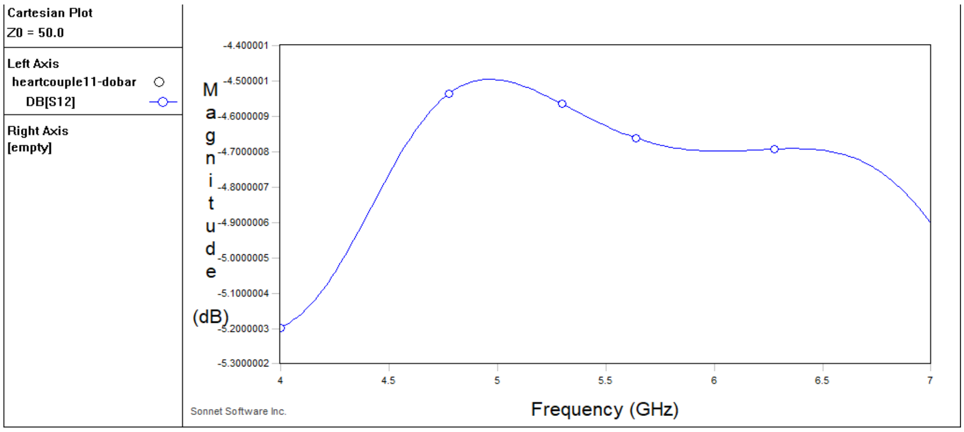

Fig. 4. Close up on coupling

III. Parametric Study

For our 4.77dB coupler, parametric study was done by increasing and decreasing all stubs simultaneously, each time by 0.1mm up to 0.3mm.

TABLE I. PARAMETRIC STUDY OF STUBS' LENGTH CHANGE

Stubs' length (mm)	Amplitude balance (dB) - the difference between the highest and the lowest around 4.77dB
2.5	0.621
2.6	0.512
2.7	0.496
2.8 (original)	0.472
2.9	0.448
3.0	0.38
3.1	0.669

For increasing the stubs' length 3 times by 0.1mm, the amplitude balance varies as shown in Table 1. With first two stubs' increases, the amplitude balance decreased, but after the third increase, the amplitude balance became significantly higher than the original one (+0.197dB). As for the reflection, by each stubs increase, our highest reflection increased (+0.064dB in total), not much, but it should be taken into consideration. For decreasing the stubs' length 3 times by 0.1mm, each time the amplitude balance has risen, +0.3mm yield +0.149dB in amplitude balance. However, the highest reflection with each stubs' decrease got lower (-0.031dB in total). From this gathered data about stubs change, we can conclude that the most reliable results lay in the original stubs' length, but that a slight change will not heavily affect our coupling.

For increasing the slots' length 3 times by 0.1mm, the amplitude balance increases insignificantly (0.016dB), while the highest reflection change is negligible (+0.006dB). For decreasing the slots' length 3 times by 0.1mm, the amplitude balance inconsiderably decreases (0.011dB), while the highest reflection change is hardly noticeable (-0.016dB). From this and data from Table 2, we can conclude that the change in slots' length does not consequently alter the coupling process.

TABLE II. PARAMETRIC STUDY OF SLOTS' LENGTH CHANGE

Slots' length (mm)	Amplitude balance (dB) - the difference between the highest and the lowest around 4.77dB
2.5	0.461
2.6	0.468
2.7	0.472
2.8 (original)	0.472
2.9	0.48
3.0	0.484
3.1	0.488

IV. Conclusion

The slotted heart-shaped 4.77dB Microstrip coupler was designed and simulated. With its compact size of 2cm by 2cm by 3mm it offers good coupling on a broad bandwidth of 4.74 GHz, from 4.32GHz to 7.06 GHz, with a stable amplitude balance of 0.472dB. The results acquired by simulations also show reflection between -7.130dB and -14.404dB which considered acceptable. With everything being considered, our coupler met the acceptable requirements and parameters according to the simulation results of Sonnet software

V. Acknowledgement

We would like to thank Sonnet Software, Inc. for providing our university with their program that we have used to make simulations for our coupler.

VI. References

[1] Sonnet Software, version 15.53, www.sonnetsoftware.com, 2014

[2] T. P. Budka, and R. A. Flynt, “Alignment tolerant stripline directional couplers”, IEEE MTT-S Digest, 1997.

[3] S. T. İmeci, K. S. Bayram, A. Z. Zeytinoglu, “20-dB hybrid stripline coupler”, ACES Conference Finland, April 2010.

Design and Analysis of Compact Dual Patch Antenna

Amina Puran
Faculty of Engineering and Natural Science
Department of Electrical and Electronics Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina
aminapuran@gmail.com

Abstract - In this paper a high gain dual resonance patch antenna is designed and simulated. Analysis is done while changing geometry and dielectric thickness. Main advantage of this type of antenna is its compact structure. Due to its dual characteristics it is very demanding in the communication industry which makes designing and analysing this type of antenna more alluring. Values for S11 parameters are: -10.97dB and –30dB for 4.94GHz and 7.38GHz, respectively. Gain exceeds 8.85dB and 6.59dB for 4.94GHz and 7.38GHz, respectively. Characteristic impedance of the feed line is 50Ω.

Keywords: Microstrip patch antenna, Microstrip feed line, radiation pattern, via fed

I. INTRODUCTION

Antenna is an important part of the communication system. The performance of the communication link depends upon the performance of the antenna. Microstrip patch antenna is compact, low-cost and usually excels has high efficiency. Its geometry consists of the ground plane and radiating patch with dielectric substrate between them. Designed antenna shown in Figure 1 has high gain and low input impedance which makes it efficient and profitable. These advantages make them outstanding when it comes to the communication industry, as part of satellites, remote sensing systems and radars [1].

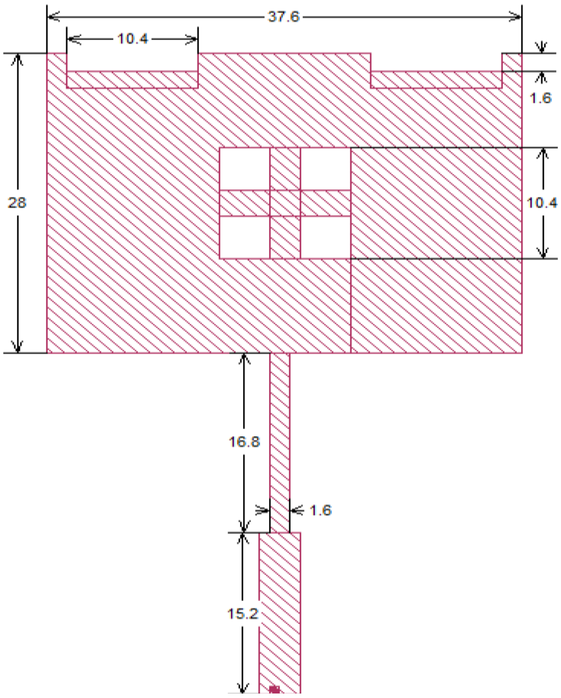

Figure 1. Dual Resonance Patch Antenna

The modern research on this type of the antennas is used to assist the curing of breast cancer. Different approaches as array of the microstrip patch antennas are used to improve efficiency of the device. Mostly arrays are used to perform the functions which one single element can't do and to increase the directivity and return loss [2]. The size of the antenna which is analysed and designed in this paper together with other characteristics is given as follows:

a) box size: 500mm x 500mm
b) cell size: 0.8mm
c) frequency range: 4GHz to 9 GHz

Design and analysis are obtained by using sonnet software [3].

II. DESIGN AND ANALYSIS

Dual characteristic is obtained by compilation of rectangular slits as can be seen from Figure 1. While the main role in improving the performance of the antenna had a gap with cross at the center which also can be seen in Figure 1. Dimensions of the antenna represented in figure 1 show the compactness of it and note that all of the dimensions are given in mm. Via feeding method is used in order to increase overall performance of the antenna and to simplify manufacturing of the antenna. Output signals are shown in Figure 2 (S11) and Figure 3 (gain). While designing we aim for the high absolute value of the input match (s11) since it represents the measure of the power absorbed by load.

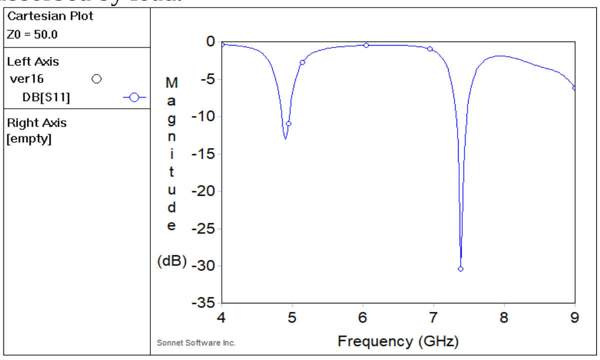

Figure 2. Input match response of dual resonance patch antenna

Gain is the representation of the power density concentrated in a particular direction [4]. It is alluded to the isotropic reference antenna which radiates equally to all directions. Further, gain is given in the dB.

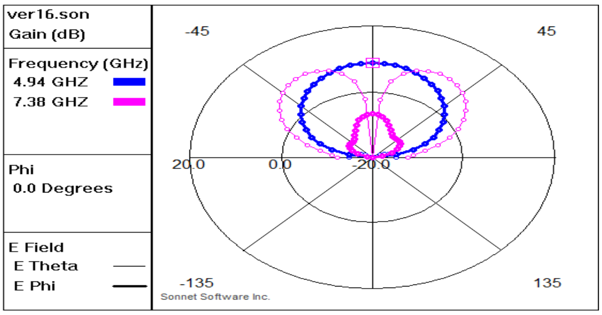

Figure 3. Gain response of dual resonance patch antenna

III. PARAMETERS VARIATIONS

In order to find optimum design adjustments which include geometry and dielectric thickness are done. Analysis on the dual resonance patch antenna includes changing the width of the gap with cross inside (table 1), slit's length changes (table 2), dielectric thickness (table 3) and port location (table 4). We observed the frequency at which S11 magnitude and gain occurs. From table 1 we can conclude that the best performance is for gap width of 10.4mm.

TABLE I GAP WIDTH CHANGES

WIDTH (mm)	Frequency (GHz)	S11(dB)	Gain(dB)
7.2	5.04	-16.47	8.88
	7.42	-19.32	5.71
8.8	4.98	-15.48	8.82
	7.42	-22.01	5.92

10.4	4.94	-10.97	8.85
	7.38	-30.33	6.59
12	4.8	-10.73	8.56
	7.32	-24.07	7.08
13.6	4.74	-8.71	8.39
	7.12	-17.26	6.13

Table 2 shows the changes of the slits length. They are located at the right and left upper corner of the antenna. Slits on both sides are perfectly symmetrical and work as a pair which means that changes in one slit reproduce change on other slit. Slit width of 1.6mm gives the best performance.

TABLE II SLIT LENGTH CHANGES

LENGTH (mm)	Frequency (GHz)	S11 (dB)	Gain(dB)
0.8	4.88	-10.99	8.76
	7.48	-23.25	7.28
1.6	4.94	-10.97	8.85
	7.38	-30.33	6.59
2.4	4.96	-13.35	8.81
	7.24	-23.50	5.25
3.2	4.98	-13.77	8.77
	7.06	-18.41	3.15
4	5.02	-14.86	8.81
	6.82	-13.94	2.19

Changing of the dielectric thickness is shown in table 3. Dielectric thickness of 20 produces best performance but it is too thick for microstrip antennas. With all trade off we concluded that results are that the best dielectric thickness for this design is 10mm.

TABLE III CHANGING DIELECTRIC THICKNESS

Dielectric thickness (mm)	Frequency (GHz)	S11 (dB)	Gain(dB)
5	4.92	-20.45	6.45
	7.28	-15.26	5.30
10	4.94	-10.97	8.85
	7.38	-30.33	6.59
15	4.92	-10.00	9.55
	7.38	-24.32	7.04
20	4.92	-9.54	10.44
	7.38	-19.88	7.48

IV. CONCLUSION

Design demonstrated in this paper represents a simple, affordable and compact device. It is an important part of the communication wireless technology. However, excitation of surface waves which occur in the substrate layer is a disadvantage of patch antennas [5]. Further, it is the main reason why choosing proper design and dielectric thickness is important. Simulations are done in one minute which manifests high speed response. Values for S11 parameters are: -10.97dB and –30dB for 4.94GHz and 7.38GHz, respectively. Gain exceeds 8.85dB and 6.59dB for 4.94GHz and 7.38GHz, respectively.

ACKNOWLEDGMENT

We would like to thank the Sonnet software team for providing us with a license which gave us the ability to work from home during the pandemic of coronavirus.

REFERENCES

[1] S. S. Ferouani, Z. Z. Bendahmane and A. A. T. Ahmed, “Design and analysis of dual star shape slotted patch antenna”, June 2017
[2] G. Pravin, A. K. Rastogi, “Design and analysis of the single and dual fed patch antenna array”, Department of Physics and Electronics, Barkatullah University Bhopal (M.P.), India, 2018 Jetir February 2018, volume 5, issue 2
[3] Sonnet Suites, ver. 17.52. Szracuse, New York
[4] S. T. Imeci, “Design and manufacture of patch antennas”, International University of Sarajevo, Sarajevo 2017
[5] A. Choudhary, P. Kumar, A. Kumar. “Design and analysis of microstrip Patch antenna with elliptical slot”, Discovery, 2015

Microstrip Notch Filter Design at 3.5 GHz for 5G

Ahmet Fehim Uslu
Electronics and Communication Engineering
Halic University
İstanbul, Turkey
https://orcid.org/0000-0002-7627-4863

***Abstract*— There are design steps of a microstrip bandstop filter whose operating frequency is around 3.5 GHz between the range of announced 5G spectrum are described in this document. The design requirements for this filter have been determined by examining the studies carried out by many researchers and values close to them. Depending on these requirements the bandstop microstrip filter circuit is designed in accordance with the microstrip notch filter model, which consists of coupled microstrip discontinuities and open ended L-type resonator stages. The analysis results of microstrip notch filter which is obtained by using a high-performance 3D EM analysis software named CST Studio Suite® support the design requirements.**

Keywords— microwave filter, notch filter, microstrip, 5G, Richard transform

I. Introduction

RF and microwave filters are widely used to separate desired and unwanted signals from each other in a wide range of areas, from cellular radio broadcasting to civil and Military radar applications [1]. Since conventional LC (Inductance-Capacitance) filters cannot meet the high frequency requirements used in GSM, television and satellite communications, microwave filters are needed. Within the scope of this article, a microstrip bandstop filter design were made according to scattered parameter modeling techniques using LC filters design techniques based on the frequencies regulated for 5G and the filter responses were compared with the design requirements. Fifth-generation telecommunications technologies named as 5G, in order to meet the new requirements in the wireless communication sector, especially in the field of cellular mobile communication and to overcome the deficiencies in existing system infrastructures; has been announced as a new generation solution that includes spectrum arrangements, advanced hardware and software technologies. While developing the equipment of 5G technology, RF and microwave filter technologies have increased their importance as they require more complex designs.

II. Design of the Notch Filter

A. Filter Degree and Prototype Circuit Element Values

Firstly, filter degree is calculated according to Chebyshev approach by using: $n=[(L_{As}+L_R+6)/(20\log(s+(s^2-1)^{1/2}))]$ based on the requirements as follows passband ripple $0.05<L_{Ar}<3$ dB, return loss $L_R=11$ dB, stopband attenuation $L_{As}=32$ dB, passband frequency $f_o=3.55$ GHz, stopband bandwidth $(BW)_s=540$ MHz, passband bandwidth $(BW)_p=800$ MHz, source and load impedance $Z_0=50\ \Omega$. The element values were calculated based on the set of equations given below considering the filter

degree.

$$g_0 = 1.0$$
$$g_1 = \frac{2}{\gamma}\sin\left(\frac{\pi}{2n}\right)$$
$$g_i = \frac{1}{g_{i-1}}\frac{4\sin\left[\frac{(2i-1)\pi}{2n}\right]\sin\left[\frac{(2i-3)\pi}{2n}\right]}{\gamma^2+\left(\sin\left[\frac{(i-1)\pi}{n}\right]\right)^2}\ (i=2,3,\ldots,n) \tag{1}$$

Since the operating frequency of the filter is: $f_o=3.55$ GHz and $f_o>500$ MHz, distributed parameter circuit elements should be used in the design [2]. Because of high frequency and distributed parameter modeling, the Richard transformation given by: $Z_{in}=jZ_0\tan(\theta)=SZ_0$ should be applied on Chebyshev prototype elements. The Richard transformation coefficient is calculated as in: S=j1.58 using the following equation: $\theta=(\pi/3)(f/f_o)$ and $S=j\tan(\theta)$. During this process, the value of passband lower corner frequency: f_{pL}=3,15 GHz is assigned to f and lower corner frequency of the stopband: $f_{sL}=3.28$ GHz is assigned to f_o. By applying Richard transform to Chebyshev prototype element values, equivalent lowpass prototype circuit components were obtained. This is done by multiplying each Chebyshev element value by S. At this point, element transformation operations such as frequency scaling, impedance scaling is performed to obtain an applicable circuit of a lowpass microstrip filter instead of a bandstop microstrip filter, based on the approach described below. Here the p-plane is the complex frequency plane and the *t*-plane is the new complex frequency plane with Richard variables; Interestingly, the low-pass filter response plot in the *p*-plane may indicate both the low-pass and band-stopping filter response in the *t*-plane. Similarly, the *p*-plane high-pass filter response graph can be transformed into both high-pass and band-pass filters in the *t*-plane [3]. From this point of view, inverse normalization processes were applied to the low pass prototype filter elements obtained as a result of Richard transformation by using: $L_n=((Z_0/g_0)(\Omega_c/(2\pi f_c))g_n$ and $C_n=(g_0/Z_0)(\Omega_c/(2\pi fc)g_n$. Inductive reactance X_L and capacitive reactance X_C values were obtained from the inductance and capacitance values obtained as a result of these calculations by using: $\omega=2\pi f_o$, $X_C=1/(C\omega)$, and $X_L=(L\omega)$.

B. Physical Lengths of Microstrip Discontinuities

After the above described procedures are completed, for calculating the physical lengths of microstrip discontinuities, the relative operating frequency of the microstrip filter, f_o=4.92 GHz, was used to find λ_0 from the $\lambda_0=c/f_o$ then λ_g was reached from $\lambda_g=\lambda_0/(\varepsilon_{re}^{1/2})$. β was obtained from $\beta=2\pi/\lambda_g$. After these the effective lenght of the microstrip line was attained via $\theta=\beta l_e$ by using the value of θ based on $\theta=(\pi)(f/f_o)$. When using that formula passband lower corner frequency f_{pL}=3.15 GHz is assigned as f and stopband lower corner frequency f_{sL}=3.28 GHz is assigned as f_o. Due to the fringing effect, the electrical lengths of the microstrip structures behave like longer compared to their physical dimensions at the cut frequency. Hence the applicable physical lengths of microstrip lines was calculated via $l=l_e-2\Delta L$. The length of the fringing effect edge is indicated ΔL and calculate via: $\Delta L=0.412h[(\varepsilon_{re}+0,3)(W/h+0,264)/((\varepsilon_{re}-0,258)(W/h+0,8))]$. Calculated inductive and capacitive reactance values of each element were used to find the line width of *W* by using empirical and semi-empirical formulas given below:

$$W/h = u$$

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10}{u}\right)^{-ab}$$

$$a = 1 + \frac{1}{49}\ln\left(\frac{u^4 + \left(\frac{u}{52}\right)^2}{u^4 + 0.432}\right) + \frac{1}{18.7}\ln\left[1 + \left(\frac{u}{18.1}\right)^3\right] \tag{2}$$

$$b = 0.564\left(\frac{\varepsilon_r - 0.9}{\varepsilon_r + 3}\right)^{0.053}$$

$$Z_c = \frac{\eta}{2\pi\sqrt{\varepsilon_{re}}}\ln\left(\frac{F}{u} + \sqrt{1 + \left(\frac{2}{u}\right)^2}\right)$$

$$F = 6 + (2\pi - 6)exp\left(-\left(\frac{30.666}{u}\right)^{0.7528}\right)$$

h is the thickness of high frequency laminates, Z_c is characteristic impedance..

III. Calculated Values and Simulation Results

The physical lengths of the microstrip filter and the important values obtained during all these design steps are given in Table I.

Table I Physical measurements of prototype filter elements as a result of inverse normalization.

n	Chebyshev g_n	Richard g_n	$Z_n(\Omega)$	W_n(mm)	L_n(mm)
1	2.345	3.698	13.523	19.201	9.65
2	1.045	1.648	82.415	1.256	13.086
3	3.273	5.161	9.688	28.714	9.510
4	1.087	1.715	85.744	1.130	13.202
5	3.146	4.961	10.079	27.389	9.546
6	0.779	1.23	61.427	2.487	12.253

The electrical lengths of the elements are designed as half wavelengths so that the low-pass filter response can transform into a bandstop filter response according to the Richard transform. The main line section where the coupling effect is observed is designed to be the same as the widths of the L-type resonators [4]. However, as shown in Fig. 1., three L-type resonators of different widths and the mainline sections in which the coupling effect appears are repeated to have an axis of symmetry. Unfortunately, it affects wave transmission due to reflections occurring at the right angle bend interface and passing waves become weaker. So that L-type resonators are designed as mitered bend [5].

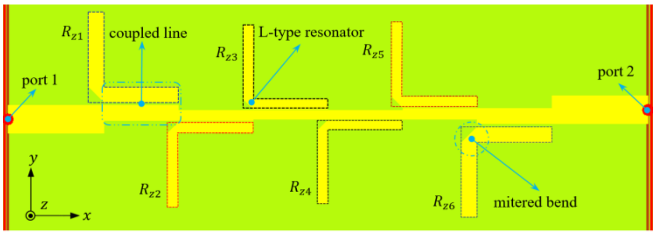

Fig. 1. Configuration of Notch filter elements.

Lengths of microstrip discontinuities are fixed at 9.65 mm to realize coupled lines and L-type resonators. The physical lengths of the L-type resonators and the mainline sections coupling them are fixed to the length of the microstrip line discontinuity that realizes the C_1 conductance. The line widths of these microstrip discontinuities were calculated by using impedance values Z_1 = 66.9 Ω for R_{z1}, Z_2 = 77.5 Ω for R_{z2}, Z_3 = 82 Ω for R_{z3}. The width of the ground plane and the dielectric layer is taken as $\lambda_0 \cong 60.71$ mm in full wavelength according to the propagation of the wave in space. Rogers RT / duroid® 6006 laminates whose thickness h = 2.5 mm and dielectric constant ε_r = 6.15 was used in the design. The conductive surface thickness is t = 0.02 mm.

After completing the design steps, the simulation results which given Fig. 2. were obtained by running the Notch filter in CST Studio Suit program frequency domain solver tool

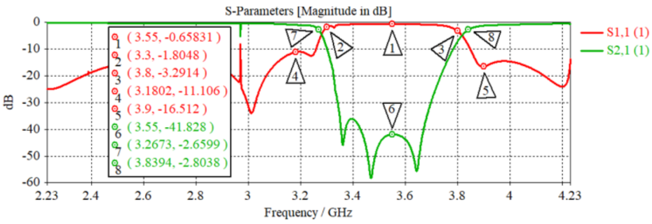

Fig. 2. Amplitude/Frequency response of the filter

When these results are examined, it is seen that the amplitude/frequency graph has values close to the targeted requirements.

IV. Conclusions

In this study, a bandstop microstrip notch filter that provides the design requirements at 3.4-3.7 GHz, one of the announced 5G frequency spectrum ranges, was designed. Within the scope of the article, the design steps are discussed in detail. The filter response was compared with the specified design requirements and as a result, it was observed that very close values were reached.

References

[1] I. C. Hunter, Theory And Design Of Microtvave Filters, in IET Electromagnetic Waves Series, vol. 48, Professor P.J.B. Clarricoats and Professor E.V. Jull, Eds, London: The Institution of Engineering and Technology, 2006, pp.1-2.

[2] R. Ludwing ve P. Bretchko, RF Circuit Design Theory and Applications, NJ: Prentice Hall, 2000, pp.37–41.

[3] J.-S. Hong, Microstrip Filters for RF/Microwave Applications, 2nd ed. dü., NJ: John Wiley & Sons, Inc, 2011, pp.62–65.

[4] J. d. D. Ruiz, J. Hinojosa ve A. Alvarez-Melcon, “Microstrip notch filters based on open interconnected split ring resonators (OISRRs),” Springer-Verlag, Berlin, vol. 112, pp. 263-267, May 2013.

[5] A. Abramowicz, “Nearly Perfect Right Angle Bends,” IEEE Xplore. Poland, pp.1-3, Sept. 2008 [17th International Conference on Microwaves, Radar and Wireless Communications, Poland, 2008.

Microstrip Dual Bandpass Filter

Haris Memić
Department of Electrical and Electronics Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina
harismemic7@gmail.com

ABSTRACT

Modern wireless communication systems usually operate at more than a single band and that is the reason why we today have dual and multiband bandpass filters. This paper deals with microstrip dual bandpass filter with center frequencies 3.2 GHz and 5.6 GHz with S-parameters of S11 = -33.92 dB and S21 = -0.56 dB for frequency of 3.2GHz and S11 = -9.49 dB and S21 = -0.51 dB for frequency of 5.6 GHz

Keywords: Bandpass Filters, Multiband, Microstrip dual bandpass filter

I. INTRODUCTION

Bandpass filters have important role in wireless communication systems. Signals that are received and transmitted have to be filtered on certain center frequency.[1] A high-performance filter in wireless communication systems is required to have a small size, low insertion loss, sharp roll-off, and high suppression level in the stopband.[2] Our geometry is a modified version of geometry used in the paper we took as reference. [3] The change we made is increasing width of middle layer from 0.78 mm to 2 mm. Figure 1 shows the top view of the filter. Dielectric thickness is 0.76 mm and air width above that layer is 5.76 mm. Start and stop frequency was set at 2 GHz and 6 GHz respectively. We simulated the project in Sonnet software to obtain the values of S11 and S21. For frequency of 3.2 GHz S11 = -3.44 dB and S21 = -2.61 dB, and for frequency of 5.6 GHz S11 = -1.52 dB and S21 = -5.27 dB. These results are not suitable because S11 needs to be lower and S21 needs to be higher and at frequency of 5.6 GHz value of S21 is lower than value of S11 which cannot be the case.

In order to get better results parametric study is done. Geometry is changed so the better response could be obtained.

Simulations were performed by Sonnet software; a 3D planar electromagnetic simulator. [4]

II. SIMULATION RESULTS AND PARAMETRIC STUDY

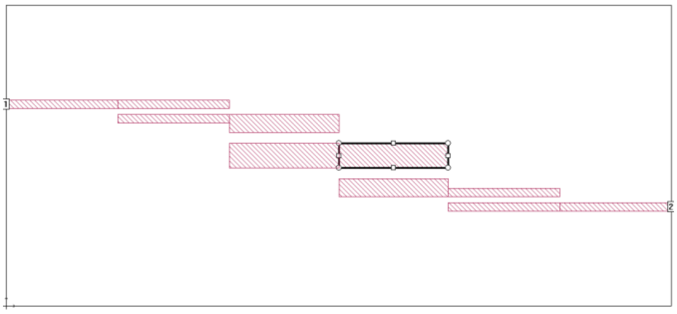

Fig.1 Top view of the filter

Figure 1 shows the top view of the filter. First variation in geometry was changing the width of middle layer. It was increased by 0.1 mm (originally 2 mm). Values of S11 and S21 obtained with different lengths are shown in the tables 3 and 4. Figure 2 shows the magnitude versus frequency graph for S11 and S21.

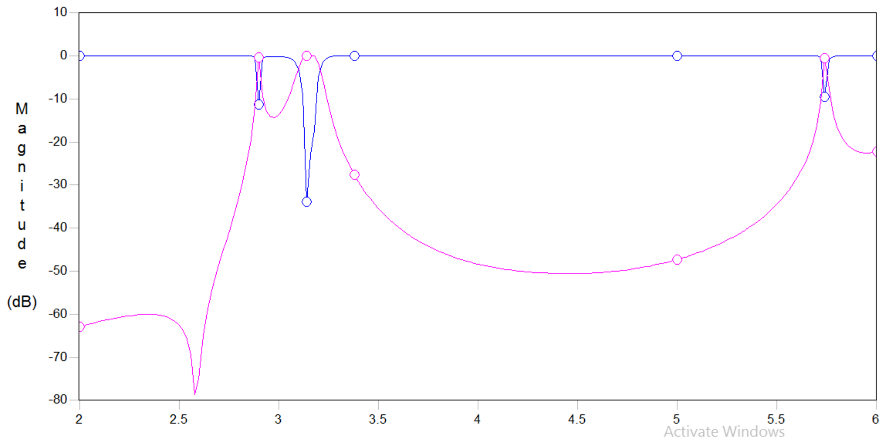

Fig.2 S11 vs S21 (final geometry)

Parametric study was conducted by changing the width and the length of the center stub and can be seen in Tables I, II, III and IV.

TABLE I. CHANGE OF WIDTH 3.2 GHz

Length = 9.1 mm (3.2 GHz)		
Width	S11	S21
2.1	-12	-0.07
2.2	-11	-0.07
2.3	-11	-0.07
2.4	-10.3	-0.08
2.5	-9.7	-0.09

TABLE II. CHANGE OF WIDTH 5.6 GHz

Length = 9.1 mm (5.6 GHz)		
Width	S11	S21
2.1	-4.23	-2.07
2.2	-13.62	-0.19
2.3	-7.27	-0.90
2.4	-4.12	-2.16
2.5	-26.55	$-9.605E^{-3}$

2.4 mm was chosen as the new width of middle layer and now its length was altered to choose the final geometry.

TABLE III. CHANGE OF LENGTH 3.2 GHz

Width = 2.4 (3.2 GHz)		
Length	S11	S21
8.80	-3.32	-0.16
8.90	-4.94	-0.422
9.05	-8.91	-0.13

9.15	-12.23	-0.039
9.20	-14.59	-0.013
9.25	-17.83	$-1.27E^{-3}$
9.30	-33.92	-0.56
9.40	-28.13	-0.035

TABLE IV. CHANGE OF LENGTH 5.6 GHz

Width = 2.4 (5.6 GHz)		
Length	S11	S21
8.80	-6.16	-1.21
8.90	-8.01	-0.76
9.05	-5.63	-1.41
9.15	-2.82	-3.23
9.20	-2.90	-2.90
9.25	-4.81	-1.73
9.30	-9.49	-0.51
9.40	-6.13	-1.21

Best results are obtained with width of 2.4 mm and length of 9.30 mm. This dimension is chosen for our final geometry.

III. CONCLUSION

This paper deals with designing of microstrip dual bandpass filter at center frequencies of 3.2 GHz and 5.6 GHz. After choosing the initial geometry parametric study was performed in order to meet the design specifications. Geometry in which width of the middle layer is set to be 2.4 mm and length is 9.30 mm is the best among all other variations performed when we consider both frequencies and was chosen for our filter. At 3.2 GHz frequency values of S-parameters are: S11 = -33.92 dB and S21 = -0.56 dB, and at 5.6 GHz frequency: S11 = -9.49 dB and S21 = -0.51 dB.

REFERENCES

1. R. Taoufik, N. A. Touhami and M. Agoutane, “Designing a Microstrip coupled line bandpass filter”, International Journal of Engineering and Technology, 2 (4) (2013) 266-269
2. M. Alaydrus, “Designing Microstrip Bandpass Filter at 3.2 GHz”, International Journal on Electrical Engineering and Informatics - Volume 2, Number 2, 2010
3. Khani S, Makki SVAL-D, Mousavi SMH, Danaie M, Rezaei P. Adjustable compact dual-band microstrip bandpass filter using Tshaped resonators. Microw Opt Technol Lett. 2017;59:2970–2975.
4. Sonnet Suites, ver. 17.52, Syracuse, New York.

Speech File Compression by Eliminating the Unvoiced/Silence Components

Mehmet Zübeyir ÜNLÜ, Arda ŞAHİN
Department of Electrical and Electronics Engineering
İzmir Institute of Technology, İzmir, TURKEY
ardasahin@std.iyte.edu.tr, zubeyirunlu@iyte.edu.tr

***Abstract*— The main objective of this study is to have the noise component of the speech signal eliminated and at the same time, to compress the speech signal by storing the locations and durations of the silence regions. The separation between the voiced, unvoiced, and silence regions are done by using the Short Time Energy (STE) and Zero Crossing Rate (ZCR) methods.**

All operations in this study can be done by using the User Interface (UI) developed on MATLAB. These operations include voice recording, playing the recording, eliminating the unwanted regions, playing the modified recording, saving as original or compressed and loading a compressed recording.

***Keywords —Speech file compression, Zero Crossing Rate, Short Time Energy, noise elimination*.**

I. INTRODUCTION

A typical voice recording consists of three main regions: Voiced regions where the speech of interest is mainly stored on, unvoiced regions which contains the low amplitude sections from the source that is unrecognizable, and the silence parts which only contain the unwanted noise. Main objective of this study is to separate and eliminate the unvoiced and silence regions and compress the speech signal. The locations and durations of these signal parts will be stored for the reconstruction purpose also.

This study also includes developing a UI that has been created on MATLAB software. Typical view of the UI can be seen below:

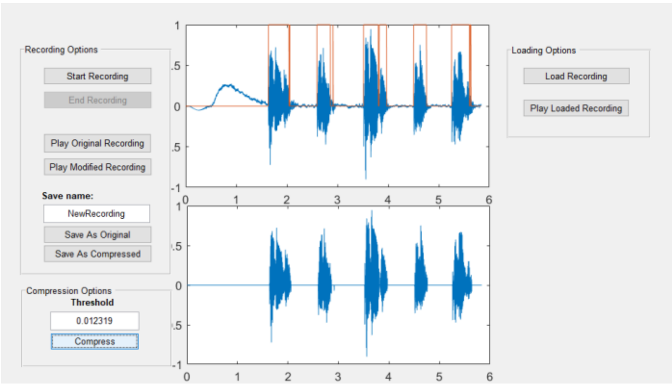

Figure 1. UI of the study

II. METHODOLOGY

The process is started by the user with recording. After recording step has been performed, the original speech waveform can be obtained as shown in Figure 1.

A. Eliminating the Unvoiced/Silence Regions with an Offset

The first course of action is eliminating the unvoiced and silence parts which have an offset. These parts should be removed before using the STE because STE cannot recognize these regions as unvoiced/silence regions [1,2]. As an example, the figure below shows a sample of a voice recording that has unvoiced/silence regions with offset.

$$E_n = \sum_{m=n-L+1}^{n} [x(m)w(n-m)]^2 \qquad (1)$$

Here, E is the energy of the signal, and $x(m)$ is the signal in above the formulas, L is the window length and $w(n\text{-}m)$ is the window function [1].

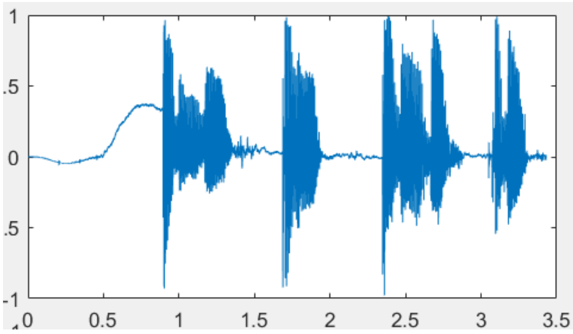

Figure 2. A Sample of a Voice Recording.

The main tool for eliminating these regions is Zero Crossing Rate (ZCR) [1-3]. Basically, ZCR of a speech signal indicates the number of crossings that have been done from zero for a specific windowed signal. For the windowing, a rectangular window has been used with a width of "Sampling Rate/1000", which corresponds to 1 millisecond of a speech sample.

$$Z_n = \sum_{m=-\infty}^{\infty} |sgn[x(m)] - sgn[x(m-1)]| w(n-m) \quad (2)$$

where sgn(x[m]) is the sign function of the speech signal. An example of ZCR graph of a speech signal can be shown in Figure 2.

We can see from the Figure 3 that the number of crosses in unvoiced/silence regions with offset are zero because their offset prevents them from crossing the zero point. With this knowledge, regions with zero ZCR will be eliminated if they are long enough.

B. Adaptive Threshold Value for STE

The threshold value can manually be selected by the user. But to give a reference, the threshold value is initially selected by the program. This way, the voiced, unvoiced, and silence regions can be decently separated without knowing the amplitude of the noise.

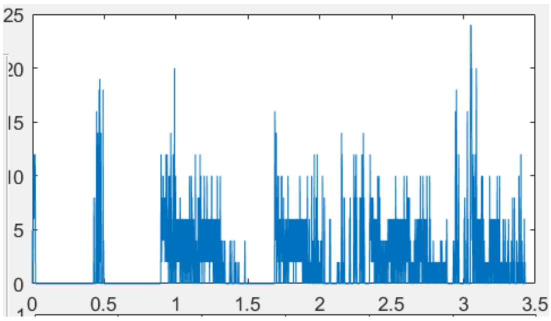

Figure 3. ZCR of a speech signal

In order to determine the value of the threshold, first the STE of the speech signal has been obtained with a fixed threshold value. The value of threshold for this part is selected higher than the typical amount to make sure that all the noise component of the signal falls below the threshold value. After the decision, the parts below the threshold will significantly contain unvoiced and silence regions.

Next the mean value for all STE points below the threshold region are obtained. This value will be assumed to be the average STE for the noise component. Finally, this value will be multiplied by 1.5 to cover the "above average" parts of the noise region.

C. Separating the Unvoiced/Silence Regions

After the threshold value is obtained, the STE of the speech signal will once again be obtained but this time, the threshold will be determined by the currently selected threshold value. The STE of the speech sample on Figure 2 can be shown in Figure 4.

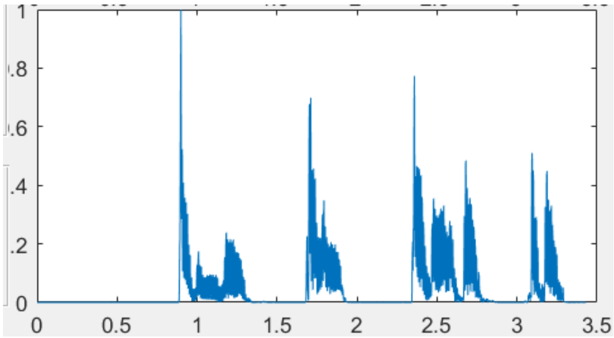

Figure 4. STE of the speech signal in Figure 2

For this sample, the length of the window is smaller than the ideal length since the ripples of the STE are too large. These ripples may cause the oscillatory decisions at the output, which is unwanted. To prevent this, new sections must be longer than 10ms to be decided as the new section. The decision result can be seen below. The areas contained in the orange rectangles are considered as the voiced regions [4]. After the separations, the amplitudes of all unvoiced and silence regions will be assigned as zero. The finalized waveform can be seen in Figure 6.

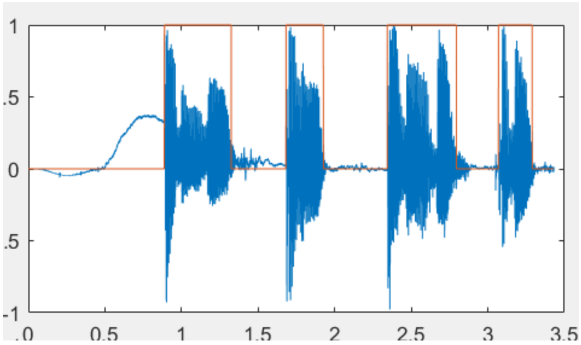

Figure 5. Decision of the speech signal in Figure 2

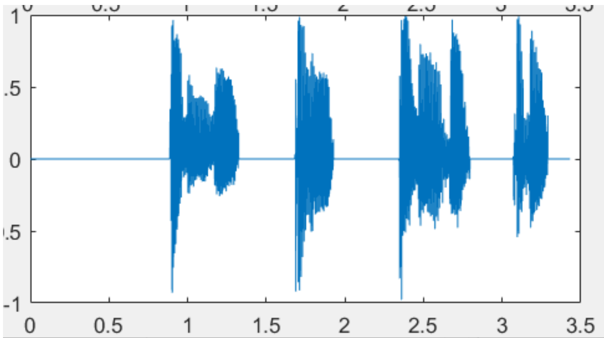

Figure 6. Finalized Form of the speech signal in Figure 2

D. Wave File Compression

After the voiced and unvoiced regions are separated, first the information about the number of trailing zeros in the signal (it has to have the length of at least 20 samples to be worth compressing) will be written at the start of the wave file. Next, information regarding the starting locations and the length of the trailing zeros will be written right next to the actual data.

After these points have been written, all trailing zeros will be removed from the voice recording. This way, our wave file is compressed with the amount depends on the length of the silence regions.

E. Wave File Reconstruction

After reading the compressed wave file, first initial information will be extracted from the audio data. Then, at the initial locations given by the initial information, trailing zeros will be replaced to the signal. The final signal will be a combination of voiced regions and silences.

III. CONCLUSION

Despite the fact that, there are much better lossy audio compressions like .mp3 format, which can compress at least %75 of the wave file [5]. This project was a great way to implement some of the concepts that have been thought on the “Speech Processing” lectures.

There are some alternatives that may have improved the resulting audio quality of this project. First, the length of the window can also be adaptive instead of a fixed length. This would have minimized the probability of oscillatory decisions.

One of the other alternatives are changing the silence parts with artificial noise components. This may prevent the speech sound truncated at silence parts.

REFERENCES

[1] L. R. Rabiner and R. W. Schafer, Theory and Applications of Digital Speech Processing, Prentice- Hall Inc., 2011

[2] T. F. Quatieri, Principles of Discrete - Time Speech Processing, Prentice Hall Inc, 2002

[3] R.G, Bachu & S., Kopparthi & B., Adapa & Barkana, Buket. (2010). Voiced/Unvoiced Decision for Speech Signals Based on Zero-Crossing Rate and Energy. 10.1007/978-90-481-3660-5-47.

[4] Goh, Z., Tan, K.-C. & Tan, B. T. G. (1999), Kalman filtering speech enhancement method based on a voiced-unvoiced speech modeI, IEEE Transactions on Speech and Audio Processing, Vol. 7, No. 5, pp 510-524.

[5] Kleijn, W. B. & Haagen, J. (1994), Transformation and decomposition of the speech signal for coding, IEEE Signal Processing Letters, Vol. 1, No. 9, pp 136-138.

Performance Analysis Multi-Radio Multi-Channel Wireless Mesh Network for Industrial Environments

Abdullah Salih BAYRAKTAR
Gebze Technical University
Computer Engineering
Kocaeli, Turkey
asbayraktar@gtu.edu.tr

Hasari ÇELEBİ
Gebze Technical University
Computer Engineering
Kocaeli, Turkey
hcelebi@gtu.edu.tr

***Abstract*—Data transmission of wireless mesh networks in industrial environment was examined in the study. Multi-Channel Multi-Radio mesh networks have been simulated using 802.11g (WiFi) standard providing a high bandwidth. In the installed topology, there are end nodes that can access the target with a single hop, as well as end nodes that allow data transmission by hopping up to four hops. The effect of the change in the number of radios, the distribution of channels in the network and the location of the node where all data is transmitted in wireless communication were examined. It has been observed that the increase in the number of radios and the proximity of the data analysis node to the center increased the performance. In addition, it has been noted that the method of channel assignment has affected the accessible bandwidth.**

Keywords—Multi-Radio, Multi-Channel, Mesh Networks, I-IoT, Multi-Hop

I. INTRODUCTION

Due to the superiority of Multi-Radio Multi-Channel (MRMC) wireless mesh networks compared to other networks, their usages have been constantly increasing. Its features such as high bandwidth, good coverage, self-installation, load balancing, reasonable cost, reliability and durability reveal the reason of such preference. MRMC mesh networks are used at home, in the offices, in first aid activities and in the defense industry [1]. MRMC mesh network technologies entered into the area of industrial production with Industrial 4.0 and Industrial-IoT studies [2]. Mesh networks using MRMC reveal more efficient results than star and tree topologies [3].

In mesh networks, each node is expected to be able to connect to a large number of nodes simultaneously and support hopping data transmission. The 802.11g standard of the 802.11 (WiFi) family widely used in high-bandwidth wireless networks is also one of the widely preferred media access protocols in mesh networking. 802.11g uses the algorithm of CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) for media access. This algorithm is based on the fact that all nodes using the same channel throughout the communication get the right to use the line by contention. The channel's bandwidth usage is negatively affected by the contention, latencies and waits, caused by this contention. This contentious environment is made contention free by means of MRMC in the studies of mesh networks [4].

In this study, communication scenario (e.g. robot welding) of collaborative running robot sets on production lines was discussed. Performance tests and topological improvements have been made for the topology to meet transmission requirements by using mesh networks of sensors and image data from robots. The effect of the number of radios such as single, double, triple, quadruple and the location of the Data Analysis Center (DAC), the node the data will be transmitted, on bandwidth and end-to-end packet latency were examined.

II. NETWORK ARCHITECTURE

Production is carried out with robots on mass production lines and within precise time frames in industrial facilities. In this study, the transmission of data received from the robots working in groups of four is simulated by using a mesh network and hoping one to four times in an area of 2500x650 square meters.

The designed network (Figure 1) has 4 Mesh Stations capable of routing also MRMC feature and forming the main backbone and 16 End Nodes with Single-Radio Single-Channel (SRSC) capability. One of the mesh stations is also selected as DAC where data from all end nodes was collected.

The communication was tested by means of UDP packets containing 1000 bytes of data. The fact that UDP is a connectionless protocol provides a test environment isolated from connection setup and transmission controls. In addition, all radios (interfaces) of each Mesh Station were assigned a single MAC (Media Access Control) address. Otherwise, packets are eliminated due to the address mismatch.

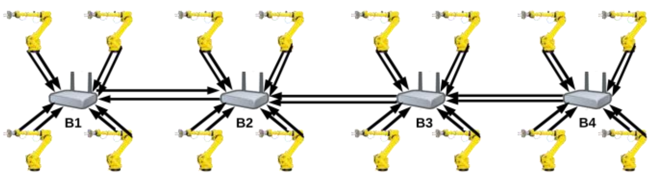

Fig. 1. Designed network architecture and routing flow.

Dynamic routing and channel assignment problems worked intensively in mesh networks, were not examined since the designed system was a built-in one. Channels were assigned on a fixed basis and intra-channel interference was ignored. The routing rules created using the Ad Hoc on Demand Distance Vector (AODV) version 2 routing algorithm and shown with arrows in Figure 1 are manually entered into the routing table (static). This assignment removed the occurrence and changing effect of the routing table.

III. SIMULATION STUDY

Five different network architectures were established using the 802.11g standard in the OMNET++ simulation environment. Network naming was performed with radio type (single, multiple), radio number and channel distribution information (b:backbone, e:end node). The traffic density scenarios shown in Table 1 have been tested for all of these architectures:

- Single radio (SingleRadio_1): one channel has been allocated for end nodes and main backbone.
- Dual radios (MultiRadio_2_1e1b): one channel have been reserved for both end nodes and main backbone.
- Three radios (MultiRadio_3_1e2b): one channel for the end nodes and two channels for main backbone.
- Three radios (MultiRadio_3_2e1b): two channels for the end nodes and one channel for main backbone.
- Four radios (MultiRadio_4_2e2b): two channels have been reserved for both end nodes and main backbone.

Finally, the impact of DAC's location on performance was measured. The case of selecting DAC close to the center of the network architecture (B2) or at the edge (B1) has been examined for all five network architectures.

TABLE I. SCENARIO TABLE

Scenario No	Packet Interval (ms)	Expected Packet Count
1	1000	80
2	500	160
3	100	800
4	50	1600
5	10	8000
6	5	16000
7	1	80000
8	0,5	160000
9	0,3	266656

IV. RESULTS AND DISCUSSION

In Figure 2, the bandwidths, calculated at the application layer, that can be accessed in DAC according to the scenarios are shown. A latency chart calculated as end-to-end packet latency for SRSC and MRMC scenarios is shown in Figure 3.

First of all, the SRSC network architecture was established and all scenarios in Table 1 were simulated. As shown in Figure 3 (SingleRadio_1-B1, -B2), major latency of approximately 2 seconds was observed between scenarios 5 and 9. When Figure 2 is examined, it has been seen that increasing the number of radios is improving the accessible bandwidth. The MultiRadio_4_2e2b has the highest performance.

When the latency graph in Figure 3 is examined, it is observed that the saturation latency of four and three (2e1b) radio simulations are clustered around 0.12 seconds, and the saturation latency of two and three (1e2b) radio simulations are clustered around 0.22 sec. An increase in the number of radios reduces the latency. In addition, when three radio architectures are specifically evaluated, it appears that latency improvements can be made by improving channel assignment methods.

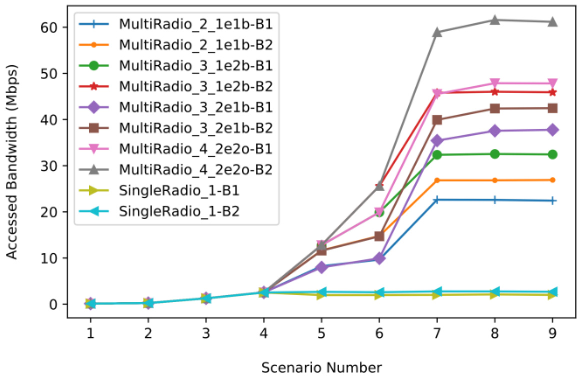

Fig. 2. Accesed bandwidth on DAC.

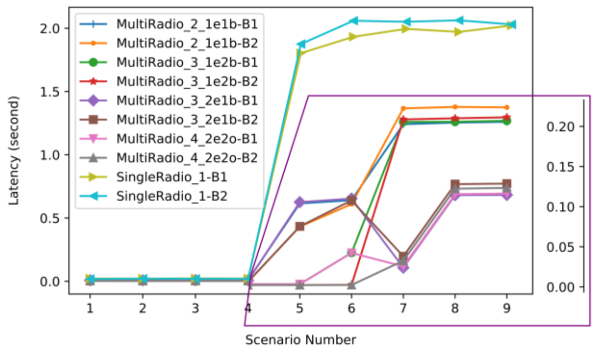

Fig. 3. End-to-end packet latency.

For all network architectures in Figure 2, moving DAC to the center of the network (B2) has visibly increased the bandwidth. In addition, when the three radio network graphics in Figure 2 are examined, it has been observed that the accessible bandwidth of 2e1b-B2 is more than that of 1e2b-B2. However, the accessible bandwidth of 2e1b-B1 is less than that of 1e2b-B1. In addition, when three radio architectures are specifically evaluated, it appears that improvements can be made by improving channel assignment methods.

V. CONCLUSION

The simulation results have shown that, the increase in the number of radios and the proximity of the data analysis node to the center greatly increased the data transmission performance. In addition, it has been noted that the method of channel assignment has positively or negatively affected the accessible bandwidth.

REFERENCES

[1] I. F. Akyildiz, X. Wang, and W. Wang, "Wireless mesh networks: asurvey,"Computer Networks, vol. 47, no. 4, pp. 445–487, 2005.

[2] N. Gabaçlı and M. Uzunöz, "IV.Sanayi Devrimi: Endüstri 4.0 ve Otomotiv Sektörü," International Congress on Political, Economic and Social Studies, no. 3, pp. 149–174, 2017.

[3] Y. Koç, "Topologic performance comparisons of zigbee based sensor network used for a smart tracking system, "Erciyes Üniversitesi Fen Bilimleri Enstitüsü Fen Bilimleri Dergisi, vol. 31, pp. 165 – 171, 2015.

[4] A. Musaddiq and F. Hashim, "Multi-hop wireless network modelling using omnet++ simulator," inInternational Conference on Computer, Communications, and Control Technology (I4CT), 2015, pp. 559–564.

Dual Resonance Bandpass Filter

Šejla Džakmić
Department of Electrical and Electronics Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina
sdzakmic@ius.edu.ba

Abstract **– This paper presents a design of dual resonance bandpass filter using Sonnet Suites Simulator. A parametric study shows the impact of choosing appropriate configuration characteristics. In that context, the performance of suggested filter design is enhanced by adding short center stub. This is a dual resonance bandpass filter design, with center frequencies $7.8\ GHz$ and $9.3\ GHz$. At the first resonance, the obtained return loss (S_{11}) is -28.87 dB and insertion loss (S_{21}) is -0.05 dB. The results at second resonance are -8.97 dB and -2.74 dB for mentioned losses respectively. Proposed filter design is analyzed with air thickness of 0.36 mm and dielectric constant $\varepsilon_r = 1$. Besides good simulation results, the compact size and simple design are the main benefits of the proposed configuration.**

Keywords—Dual resonance; bandpass filter; Sonnet software

I. INTRODUCTION

For the recent several years, a rapid development and progress in modern wireless communication technologies causes higher requirements for new designs of digital microwave components. In that context, multiband filter design, as one of the most significant component, imposes to the researchers worldwide. The authors from [1] and [2] describe dual resonance bandpass filter design using Defected Microstrip Structure (DMS). It is proposed to integrate two DMSs with short circuit stub, to produce high attenuation and good selectivity [1]. The performance can be improved by using dual-mode dual-band bandpass filters with stubs loaded coupled line [2]. The parametric study showed that characteristics and behavior of dual band resonance has a significant ratio of the resonant bands, enabling such filter to be used in many modern wireless communications. In [3] parallel-coupled and vertical-stacked configurations are presented. It describes resonant characteristics of an SIR and discusses how SIR dimensions are adjusted to have resonances at two designated center frequencies of the dual-band response. An interesting design of bandpass filter is based on Slow-Wave Resonant Cell with Dual-Resonance [4]. String slow-wave effect causes ultra-wide stopband response. Meanwhile, the nested inter-digital defected ground structure (DGS) utilized under the T-stub can allocate dual-resonance with a compact size. Good dual passband filtering, with return losses higher than $20dB$, without any external impedance transformer feeds, is obtained by design from [5]. An inspiring balanced dual-band bandpass filter design is described in [6]. According to the presented stub-loaded theory, the first differential- mode resonance can be independently designed by the loaded stubs, while not affecting the second one. Bandwidths of the dual band can be independently controlled, as well.

II. DESIGN METHODOLOGY AND SIMULATION

The dual resonance band-pass filter design presented in this paper has configuration as shown in Figure 1.

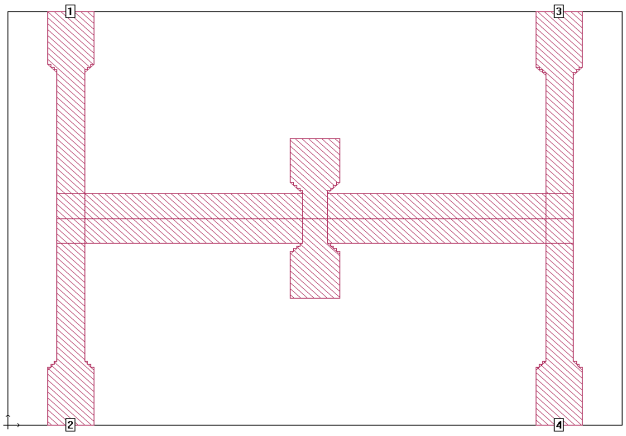

Fig. 1 . Configuration of the proposed dual band-pass filter

It consists of four ports, each placed at the edge of vertical stub long 15 mm. Those short circuit stubs are connected by two horizontal stubs 33.6 long. Each has width of 1.8 mm. Four vertical stubs are expanded for 45° at the ends, right after 10.6 mm.

Filter design performance is enhanced by adding center stub without any free space between. It is also observed that dimensions of the center stub and the width of the gap between the horizontal lines and stub itself, affect the filter performance. After few design variations applied, the best results are obtained when center stub has dimensions of 3.2 mm width and 4.0 mm length. Figure 2 shows the simulated results of S- parameters. Filter design is simulated with a relative dielectric constant of 1. The thickness of the substrate is 0.36 mm. The whole backside of the substrate is the ground plane. The width of the configuration is approximately 34.8 mm with height 30.0 mm. The filter box has dimensions 55.0 mm by 30.0 mm.

III. PARAMETRIC STUDY

For the performance validation, the proposed dual bandpass filter design is simulated with the bandwidth from 6 GHz to 10 GHz. Center frequencies are placed at 7.8 GHz and 9.3 GHz, with passband bandwidths $\Delta_1 = 25$ % and $\Delta_2 = 8$ %. To meet design specifications several modifications are applied to the initial filter prototype, in terms of air thickness, dielectric constant, and design dimensions as well. After few simulations, it is noticed that the best results are obtained when relative dielectric constant (air thickness) is 1. Return loss for this configuration is S_{11} at first resonance is $-28.87\ dB$, while insertion loss S_{21} is $-0.05\ dB$ at the same resonance. At the second resonance, $S_{11} = -8.97\ dB$ and $S_{21} = -2.74\ dB$.

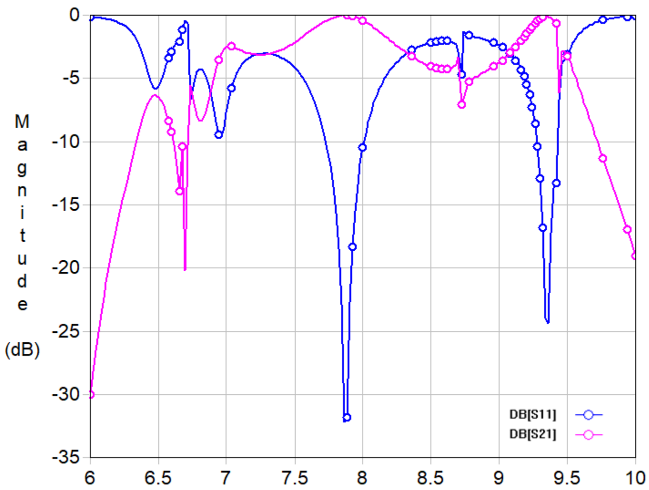

Fig. 2. Band-pass filter simulation response

TABLE I. RESULTS WITH DIFFERENT AIR THICKNESS

Air thick-ness (mm)	f_1 (GHz)	S_{11} (dB)	S_{21} (dB)	f_2 (GHz)	S_{11} (dB)	S_{21} (dB)
1.15	7.84	-31.94	-0.13	9.66	-7.47	-2.83
1.25	7.82	-32.53	-0.05	9.58	-14.42	-2.09
1.0	**7.86**	**-28.87**	**-0.05**	**9.64**	**-8.97**	**-2.74**
1.5	7.8	-36.15	-0.06	9.5	-12.32	-2.35
1.75	7.8	-32.81	-0.06	9.5	-12.19	-2.29
2.0	-7.78	-38.12	-0.061	9.46	-12.12	-2.29

Due to the resonant frequency values, it is observed that this is a medium bandwidth dual resonance bandpass filter, with high quality factor values. This will be more explained in future work. The parametric study shown in tables II and III show the effect of changing design dimensions. As it was explained in previous section, the center stub configuration has the greatest effect on parametric analysis results. The best results are obtained for center stub dimensions being $4.0 \times 3.2\ mm$, without any gap. Most of the other configurations resulted with many reflections and instabilities.

TABLE II. RESULTS WITH DIFFERENT CENTER STUB WIDTH

Center stub width	f_1 (GHz)	S_{11} (dB)	S_{21} (dB)	f_2 (GHz)	S_{11} (dB)	S_{21} (dB)

(mm)						
2.2	7.88	-27.51	-0.02	9.42	-7.98	-1.89
2.6	7.84	-34.13	-0.07	9.5	-9.42	-3.14
3.2	**7.86**	**-34.12**	**-7.7e-3**	**9.26**	**-20.59**	**-0.48**
2.8	7.86	-34.33	-0.01	9.36	-27.27	-0.04
3.0	7.86	-32.89	-9.2e-3	9.36	-22.12	-0.03
3.1	7.86	-36.89	-0.01	9.32	-23.39	-0.14

TABLE III. RESULTS WITH DIFFERENT CENTER STUB LENGTH

Center stub length (mm)	f_1 (GHz)	S_{11} (dB)	S_{21} (dB)	f_2 (GHz)	S_{11} (dB)	S_{21} (dB)
4.4	7.88	-36.82	-0.02	9.26	-14.91	-1.41
4.2	7.88	-34.08	-0.03	9.3	-19.89	-0.55
4.0	**7.86**	**-37.84**	**-0.02**	**9.34**	**-24.14**	**-0.23**
3.8	7.86	-34.66	-0.01	9.36	-24.66	-0.09
3.4	7.89	-39.42	-0.02	9.44	-14.8	-2.7
3.2	7.88	-32.23	-0.27	9.4	-11.23	-2.3

IV. CONCLUSION

In this paper, a novel dual resonance bandpass filter design is proposed. Filter description is given in details, including the results of various changes applied to the initial filter design. It is designed and optimized in Sonnet Suites Simulator to verify the proposed structure. The simulation of the suggested configuration led to very successful results, having dual resonances centered at $7.8\ GHz$ and $9.3\ GHz$, with the bandwidths $\Delta_1 = 25\ \%$ and $\Delta_2 = 8\ \%$ respectively. The performed return and insertion losses are $S_{11} = -28.87\ dB$ and $S_{21} = -0.05\ dB$, at first resonance, and $S_{11} = -8.97\ dB$ and $S_{21} = -2.74\ dB$ for the second one, respectively. The proposed filter design is proved to be very efficient and applicable in wireless communications. The future plan is to fabricate proposed filter design on microstrip, measure the results and compare it to the simulation results.

REFERENCES

[1] M. A. Mutalib, Z. Zakaria, N. A. Shairi, S. W. Yik, Y. E. Maskurin, and M. K. Zahari, “Dual-band bandpass filter using defected microstrip structure (DMS) for WIMAX applications,” *J. Telecommun. Electron. Comput. Eng.*, vol. 9, no. 1–5, pp. 111–114, 2017.

[2] J. Xu and W. Wu, “Compact microstrip dual-mode dual-band band-pass filters using stubs loaded coupled line,” *Prog. Electromagn. Res. C*, vol. 41, no. May, pp. 137–150, 2013.

[3] J. T. Kuo, T. H. Yeh, and C. C. Yeh, “Design of microstrip bandpass filters with a dual-passband response,” *IEEE Trans. Microw. Theory Tech.*, vol. 53, no. 4 I, pp. 1331–1336, 2005.

[4] Z. Zhang, B. Yang, H. Qian, and X. Luo, “Dual-band bandpass filter based on slow-wave resonant cell with dual-resonance,” *2016 IEEE MTT-S Int. Conf. Numer. Electromagn. Multiphysics Model. Optim. NEMO 2016*, vol. 3, pp. 5–6, 2016.

[5] S. Sun and L. Zhu, “Compact dual-band microstrip bandpass filter without external feeds,” *IEEE Microw. Wirel. Components Lett.*, vol. 15, no. 10, pp. 644–646, 2005.

[6] X. Wu, F. Wan, and J. Ge, “Stub-Loaded Theory and Its Application to Balanced Dual-Band Bandpass Filter Design,” *IEEE Microw. Wirel. Components Lett.*, vol. 26, no. 4, pp. 231–233, 2016.

ARTIFICIAL INTELLIGENCE IN CRIMINAL INVESTIGATION

Burak M. GÖNÜLTAŞ
Social Work Department
Sivas Cumhuriyet University
Sivas, Turkey
ORCID Number: 0000-0001-9132-1464

***Abstract*— In the present study, it is aimed to discuss how AI can be used in criminal investigation process and to put forward to importance of AI in effectiveness of criminal investigation with compiling method. The main factors are as follows: increasing crime rates, increases in the number of investigations, complications of crimes, difficulties and disruptions in KM due to the increase in the density of information, time constraints and the nature of the investigation process that is almost entirely over the investigator. On the other hand, the functions of AI applications for KM, information integration and decision-making processes are important factors. In terms of crime investigation, AI can contribute to KM, information discovery and decision-making processes of investigators and the legal infrastructures of these elements are discussed.**

Keywords— Criminal investigation, artificial intelligence, knowledge management

I. Introduction

Today, crimes and methods of committing crime are changing and being complex [1]. Increasing crime rates and reactions in the society increase the importance of new, effective and alternative methods in combating crime. One of them is the use of Computer Technologies (CT). From the point of view of crime investigation, CTs are expected to support the information infrastructure and decision-making processes of crime investigation through the collection, analysis of crime information and making the crime-related data available. Thus, access to quality information can enable investigators to choose effective strategies and tactics in a timely manner [2].

The main element of crime investigation is the management of information and knowledge [3]. Information management, on the other hand, mostly runs through the investigator. However, it should be taken into consideration that personal mistakes that may occur in the process, due to the crime investigation being mainly conducted through the investigator, may lead to loss of rights, to ruin the work and to betray the sense of justice. In this context, supportive methods are needed to help minimize personal errors. One of the technological methods that can be utilized in managing information is thought to be artificial intelligence applications. Because, the crime investigation, which is one of the areas where information technology is used, is quite compatible with the promising development areas of artificial intelligence and this compatibility has an important potential especially in investigating [4]. Artificial intelligence can provide accurate and effective information and enable decision makers to make the right decisions [5], [6], [7]. The use of databases specific to crime has been effective in investigating serious crimes such as murder or organized crime. In this context, the study aimed to discuss the contribution of the "artificial intelligence" practices that are thought to be effective in the importance, dimensions and activation of information management in crime investigation and the legal dimension of this contribution, and to provide suggestions for future criminal investigation practices.

II. Methodology

This study compiled national and international literature on the subject as a methodology.

III. Results and Discussion

Artificial intelligence can contribute to crime investigation by providing assumption support to decision-making processes of investigators, information management, information discovery. However, it should not be expected that artificial intelligence can replace investigators totally. Therefore, the main finding of this study is that artificial intelligence can support the investigator in crime investigation, thus enabling investigators can conduct investigations more effectively. In order for artificial intelligence to contribute to the crime investigation process;

Depending on the use of machine learning methods, algorithms of investigation processes should be developed in order to investigate crimes.

Retrospectively, versions from previously investigated samples should be constituted. For this purpose, sufficient samples should be determined. In terms of intuitive reasoning, artificial intelligence, with the processing of large amounts of information, increases the ability to learn based on newly acquired knowledge, thereby reducing the likelihood of errors in the research-investigation process. For this reason, it should be supported with continuous information.

Within the framework of the information in the existing databases, crime scene information, victim information and experiences obtained from the cases resolved in the past, AI can support the production of hypothetical formulations that can contribute to the decision-making process related to the incident. AI can assist investigators to make beneficial and productive decisions or to help them make their decisions by helping to produce possible and likely legal and rational assumptions (abductive reasoning) that investigators use in decision-making processes during the investigation process, and also during the investigation process.

It can also provide an objective presentation of what and how is done during the investigation process for court processes after investigation.

AI applications and data can contribute more effectively to the transparency and accountability of the investigation process. Thus, it is possible to contribute to the validity and reliability of crime investigations in the eyes of the parties and the public.

AI can help to keep the experiences gained in investigations, the ways in which investigations are carried out, and the ways of resolving interesting cases in a certain and standard format, thus contributing to their training for the professional development of newly participating in investigative units.

In addition, investigator-based knowledge management can help the nature of a more collective structure. By constituting file tracking programs and calendars related to unsolved files, enabling the tracking of files can be facilitated (Table 1).

IV. Conclusion

In this context, algorithms and their legal infrastructure must be determined for AI. Thus, thanks to these algorithms, AI can assist the investigator's decision-making processes during the investigation process. In order for AI to work effectively, as much information as possible should be entered into the system, and the formats and legal infrastructures should be established for the entry of this data into AI.

TABLE I. AI SUPPORTING FOR CRIMINAL INVESTIGATION

Beneficiary in terms of criminal investigation	**Supporting of AI**
Data bases	Integration for data mining
Knowledge Management	Effective knowledge management via integration
Decision making process	Assumptions via artificial neurol network
Trainings	Probable approaching and investigating technics
Trials-courts	How probable technics are used
Unsolved-unidentified cases	Scheduling and planning of working those cases
The parties of cases and public	Validation and reliability of investigation

References

[1] Önder, Ş.G. ve Gönültaş, M.B. (2005). Suçlu profilleme ve Türkiye'deki genel durumu. *Polis Bilimleri Dergisi, 7*(4), 35-58.

[2] Chen, H. ve Xu, J. (2006). Intelligence and security informatics. *Annual Review of Information Science and Technology (ARIST)*, 40, 229-299.

[3] Gönültaş, M.B. (2018). Türkiye'de Kayıp ve Kaçırılan Çocuklar Sorununa Bütüncül Yaklaşım. Ankara: Nobel Yayınları.

[4] Alzou'bi, S, Alshibly, S and Al-Ma'aitah, M. (2014). Artificial intelligence in law enforcement, A review, *International Journal of Advanced Information Technology, 4*(4): 1-9.

[5] Brahan, J.W., Lam, K.P., Chan, H. ve Leung, W. (1998). AICAMS: artificial intelligence crime analysis and management system. *Knowledge-Based Systems, 11*(5), 355-61.

[6] Chen, H., Schroeder, J., Hauck, R. V., Ridgeway, L., Atabakhsh, H., Gupta, H., Boarman, C., Rasmussen, K. ve Clements, A. W. (2002). COPLINK Connect: information and knowledge management for law enforcement. *Decision Support Systems*, 34, 271–285.

[7] Chen, H., Moore, R., Zeng, D., ve Leavitt, J. (Eds.). (2004). Intelligence and security informatics: Proceedings of the Second Symposium on Intelligence and Security Informatics. Berlin: Springer.

Dual-Band Rectangular Patch Antenna With Three Metal Additions

Šejla Salihović
Electrical and Electronics Engineering
International University of Sarajevo, Sarajevo, Bosnia and Herzegovina

***Abstract*— In this paper, a microstrip patch antenna with 4 rectangular patches is presented for Long Term Evolution (LTE) and networks communication and Broadband Wireless Access (BWA) application. The presented antenna consist 1 big and main rectangular patch and 3 small patches. The antenna designed on a Rogers RT5870 substrate operates at 4.66 GHz with gain of 5.21 dB and S11 of -22.68 dB which is suitable for LTE and BWA application. Also, at frequency of 6.6 GHz the gain is 6.99 dB and S11 is -19.75 dB.**

Keywords—Rectangular patch, Microstrip patch antenna, Wideband

I. Introduction

The increasing need for communication and information encourages the development of technology in the field of telecommunications, especially wireless communication systems [1]. Recent advances in compact mobile and wireless handsets demand multi-frequency and multiband compact size antennas with broadband and high gain performance. In the field of telecommunications, microstrip antenna is one of technology that allows small sized antennas to perform well [2]. Microstrip antennas have attracted a lot of attention due to rapid growth in wireless communications area, because they have very simple installation [3,4]. Modifications in patch geometries are required to make antennas work. Rectangular patch is the most popular shape, because it is the simplest to analyze, and modify to produce a range of impedance values, radiation patterns, and frequencies of operation. The bandwidth of the antenna should be increased to avoid problem with narrow band. Microstrip patch antennas are frequently used in textile materials because of their many advantages, such as low profile, light weight, and conformity [5]. However, this kind of antennas suffer from important issues in their design process, causing severe limitations in their practical applications [5].

II. Antenna Geometry

A rectangular shaped microstrip patch antenna with addition of 3 rectangular metals is presented here in Figure 1 and simulated using the Sonnet Suites program. The operating frequency of the presented antenna is 4.66 GHz with gain of 6.9 dB.

The geometry of the dual-band antenna is shown in Fig. 1. The size of the antenna is 3.96×2.98 cm. The antenna is designed on a Rogers RT5870 dielectric substrate whose thickness is 0.287 cm. The length of the lower and upper patch is 3.2 cm and height of the patch on the right side is 2.6 cm. The changed lengths and heights of the patches on the side of the main patch are shown in Table I. The antenna is consisted of an one big rectangular patch and three rectangular patches on the 3 sides of the main patch.

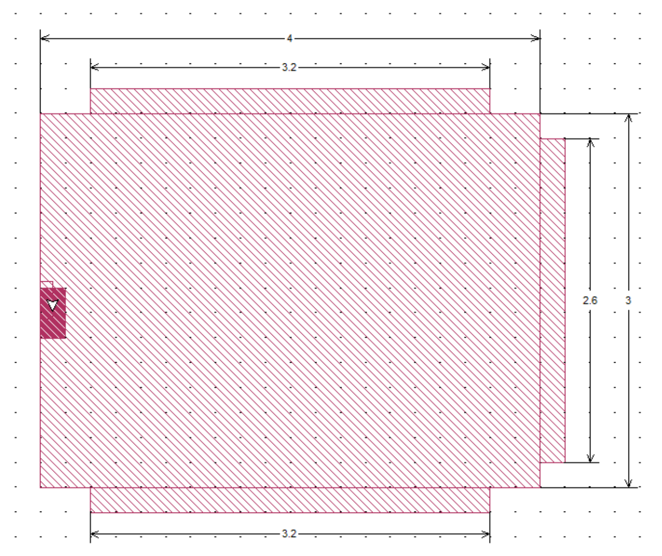

Fig. 1 Schematic Diagram of the antenna

III. Analysis Results

The antenna is modelled and analyzed using the Sonnet Suites program. The input match (S_{11}) of the antenna is shown between 3 GHz and 7 GHz in Fig. 2. The input match is less than -10 dB at 4.66 GHz and 6.6 GHz. The gain pattern of the antenna at 4.66 GHz is shown in Fig. 3. The maximum gain value at 4.66 GHz is 6.9 dB. The gain values and S11 values at different operating frequencies are tabulated in Table I.

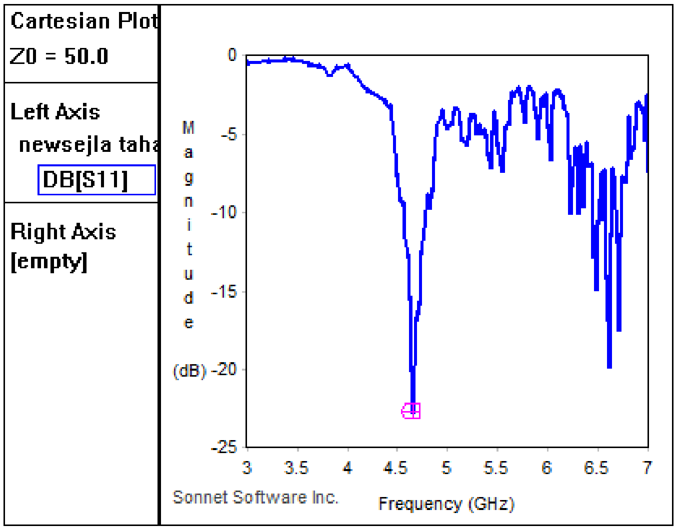

Fig. 2. Input match of the antenna.

As it is seen in Figure 2, the gain has two wide beams at θ = ±45 degrees.

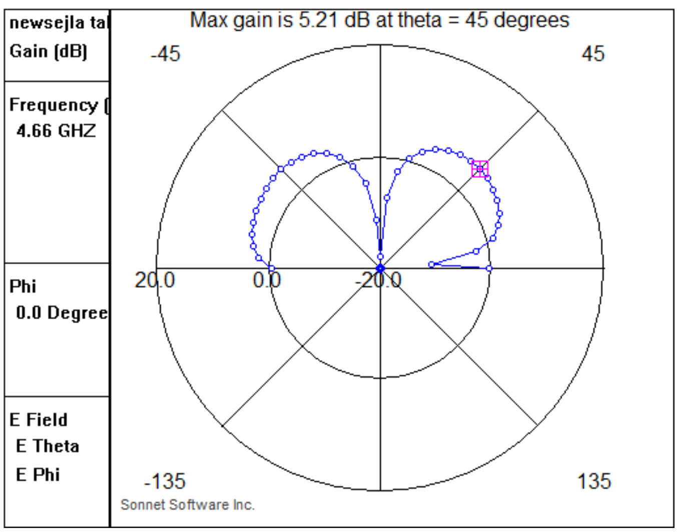

Fig. 3. Gain pattern of the antenna at 4.66 GHz.

As it is seen in Figure 3, the gain has three spot beams at θ = 5 degrees and -75 degrees and 60 degrees. Cross polarization levels are less than -20 dB's for both radiation pattern graphs.

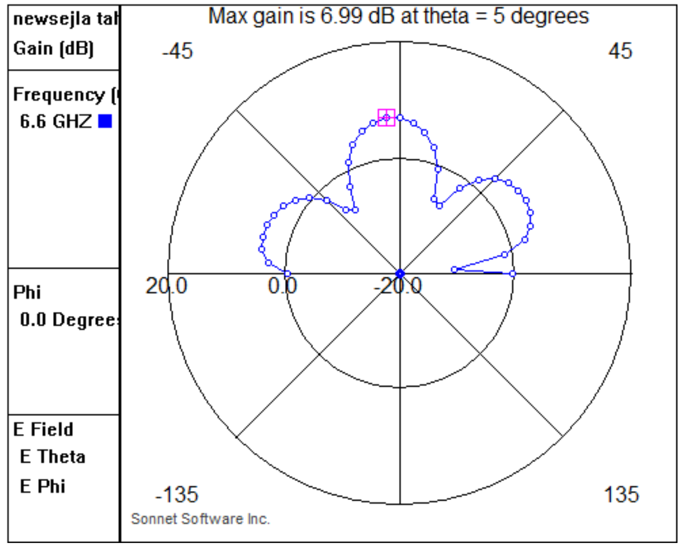

Fig. 4. Gain pattern of the antenna at 6.6 GHz.

TABLE I. Parametric Study Of Changing The Width

	a	***b***	***c***	***d***
Width (cm)	**3**	**3.1**	**3.3**	**3.4**
Frequency (Hz)	**4.66**	**4.66**	**4.66**	**4.6**
	6.6	**6.6**	**6.5**	**6.5**
Gain (dB)	**5.26**	**5.20**	**5.19**	**6.83**
	7.30	**7.51**	**4.85**	**5.66**
S11 (dB)	**-17.99**	**-17.10**	**-19.12**	**-15.50**
	-18.38	**-18.77**	**-18.59**	**-20.22**

TABLE II. Parametric Study Of Changing The Length

	e	***f***	***g***	***h***
Lenght (cm)	**2.4**	**2.5**	**2.7**	**2.8**
Frequency (Hz)	**4.58**	**4.66**	**4.66**	**4.66**
	6.46	**6.5**	**6.5**	**6.5**
Gain (dB)	**7.51**	**5.21**	**5.19**	**5.18**
	0.19	**3.19**	**4.72**	**5.45**
S11 (dB)	**-12.83**	**-19.01**	**-17.65**	**-16.96**
	-14.75	**-15.82**	**-20.83**	**-25.83**

IV. CONCLUSION

In this paper, a dual-band rectangular microstrip patch antenna is designed and simulated. According to analysis results, the antenna operates between 4.66 and 6.6 GHz. At 4.66 GHz, the gain of the antenna is 6.9 dB. The antenna operated frequency range from 4.66 to 6.6 GHz is suitable for wireless communication applications. The S11 of frequency of 4.66 GHz is -22.68 dB and gain is 6.21 dB, in case of frequency of 6.6 GHz the S11 is -19.75 dB and gain is equal to 6.99 dB. The lengths of the patches were changed and the gain values at different frequencies are compare.

REFERENCES

[1] A. Faroqi, F. Zaelani, R. Kariadinata and M. A. Ramdhani, "On The Design of Array Microstrip Antenna with S-Band Frequency for Radar Communication," *IOP Conference Series: Materials Science and Engineering,* vol. 288, pg. 1, 2018.

[2] N. Ismail, F. Oktafiani, F. Makmur, F. F. Ramadhan, M. A. Ramadhani and I. Taufik, "Dual-band rectangular microstrip patch antenna for LTE and BWA application", *IOP Conference Series: Materials Science and Engineering,* vol. 434, pg. 1, 2018.

[3] D. Nalbantoglu and A. Yanik, "A multi-band rectangular patch antenna for wireless communications", *Antennas & Propagation,* pg. 4, 2004.

[4] M. A. Layegh, C. Ghobadi and J. Nourinia, "The optimization design of a novel slotted microstrip patch antenna with multi-bands using adaptive network-based fuzzy inference system", *Technologies MDPI,* vol. 5, pg. 1, 2017.

[5] C. C. Gomez, R. S. Montero, D. M. Villanueva, P. L. Lopet-Espi and S. S. Sanz, "Design of a multi-band microstrip textile patch antenna for LTE and 5G services with the CRO-SL ensemble", *Applied Sciences,* vol. 10, pg. 2, 2020.

HF Slitted Inset Fed Microstrip Patch Antenna

Mustafa Indžić
Department of Electrical Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina

***Abstract* – In this paper, design and simulation of a slitted inset microstrip patch antenna is studied. A rectangular shaped antenna is introduced with an indents at the top, sides, and corners and an inset which has grounded port at the bottom end. The aim of the research is to introduce a new configuration of microstrip patch antenna design. S11 at 25.75 GHz gets -37.89 dB while gain is 6.63 dB**

***Keywords:* Inset Fed, Slitted, Microstrip Patch Antenna**

I. INTRODUCTION

Antenna miniaturization has been the significant issue of numerous studies for nearly 70 years. Recently, most of the cell devices industry and several academic institutions have been focusing to reduce the form factor of different types of antennas while trying to maintain satisfactory matching properties and operating bandwidth. These miniaturization techniques are related to changing the geometrical and physical properties of the antenna [1]. Broadband application performing various tasks and wireless gadgets have come out to be a fundamental part of our day by day correspondence life. Therefore, the requirement for low profile wideband has been scaled down [2]. Printed (microstrip patch) antennas are the most important types of antennas. There are several categories of the microstrip patch antennas, such as a square radiating element, triangular, semicircular, but the most common is rectangular element [3]. There are also other shapes such as perturbed square or circular patches which are used for special purposes such as to generate circular polarization with single feed, to get double resonances etc. Microstrip patch antennas are used in a broad range of applications such as satellite, missiles, cellphones, aircrafts, biomedical systems. They have several attractive properties like low profile, easy to fabricate, easy to feed, can be put in an array or incorporate with other microstrip elements, economic efficiency. On the other hand, there are some disadvantages like narrow bandwidth which can be enhanced, efficiency is limited (conductor and dielectric losses), efficiency may be lower than other antennas, low power handling capacity, etc. [4]. The design and analysis in terms of gain, efficiency and return loss of rectangular patch antenna with an indent is presented in this research paper. Simulations are obtained from the software called Sonnet Suites [5]. The analysis of the designed antenna will be presented briefly in further sections.

II. DESIGN STEPS OF MICROSTRIP PATCH ANTENNA

Figure 1 presents the top view of the proposed microstrip patch antenna with all dimensions:

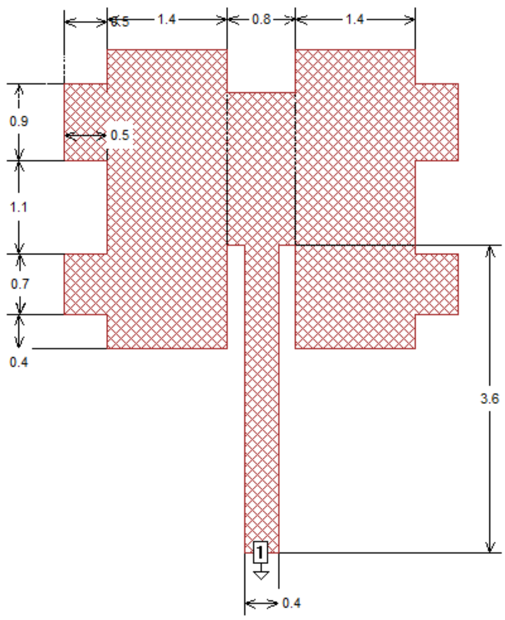

Figure 1. – Top view of Microstrip Patch Antenna

In table 1, as it can be seen in Figure 1, width and length of feeding line, inset fed and indents are shown. So, these are the parameters of the antenna:

TABLE 1:DIMENSIONS OF THE ANTENNA

Name	Width (mm)	Length (mm)
Feeding line	0.4	3.6
Corner indents (x4)	0.5	0.4
Indent (top / sides)	0.8 / 0.5	0.5 / 1.1
Inset fed	0.2	1.07

In Figure 2, the 3D view of the antenna is shown. The dielectric is chosen to be Rogers RT5870 with ε_{rel}=2.33 and its thickness is 0.3 mm while air layer is twenty times bigger and its thickness is 6 mm. Simulation results that were found are: S11 at 25.75 GHz gets -37.89 dB while gain is 6.63 dB when air layer is 20 times bigger than dielectric thickness. Cross polarization level is less than -15 dB.

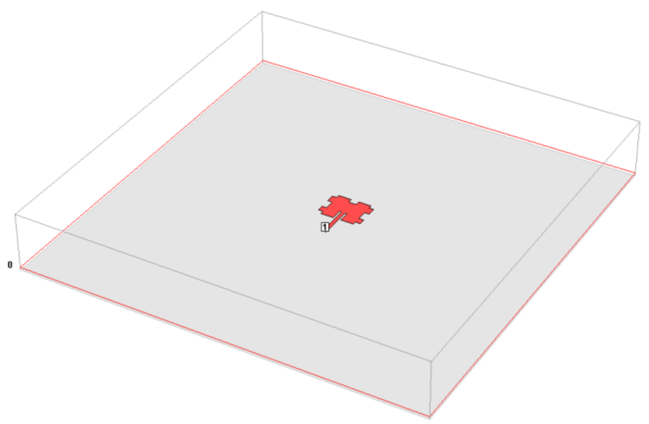

Figure 2. – 3D view of Microstrip Patch Antenna

III. Parametric Studies

In Table 2 it is observed how the frequencies are changing while changing different dielectric and air thicknesses. S11 and gain are observed to make it good as possible.

TABLE 2: SIMULATED RESPONSE FOR DIFFERENT DIMENSIONS

Dielectric / Air thickness (mm)	Frequency (GHz) / S11 (dB)	Gain (dB)
0.2 / 3	26.25 / -32.98	6.89
0.25 / 5	26.0 / -31.74	6.77
0.3 / 6	25.75 / -37.89	6.65
0.3 / 3	25.75 / -29.82	6.89
0.35 / 7	25.5 / -25.09	6.33

In Figure 3, Frequency vs S11 graph is shown and in Figure 4, E_{theta} and E_{phi} (radiation pattern) graph is shown.

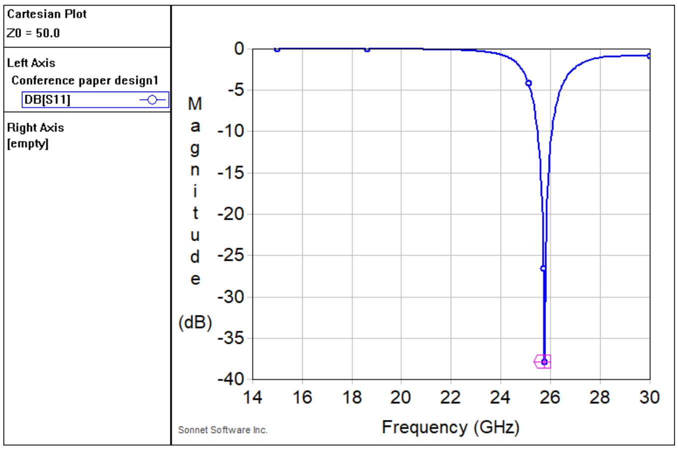

Figure 3. – Frequency vs S11 Graph

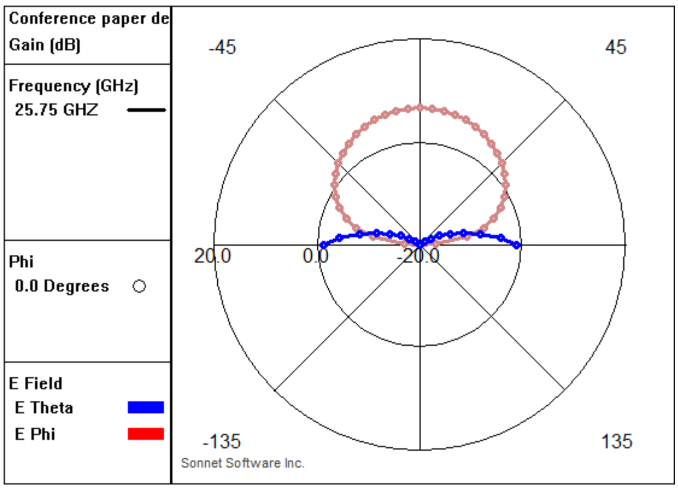

Figure 4. – E_{theta} and E_{phi} Graph

After many simulations in the parametric study, the antenna with 0.3 mm dielectric thickness and twenty times bigger air layer was found to have the best S11 and tied-best Gain, so it has been chosen as a proposed design. With small changes, the measurement and output of the antenna vary.

IV. Conclusion

In this work, a Slitted Inset Fed Microstrip Patch Antenna is designed and simulated. Simulation was performed in a 3D planar high-frequency electromagnetic software called Sonnet. The performance of the antenna is observed based on its S11 parameter (return loss) and the gain. S11 at 25.75 GHz gets -37.89 dB while gain is 6.63 dB. The research methods included operational requirement analysis, parameter sensitivity analysis, optimization analysis, software simulation and antenna testing procedures.

V. References

[1] Misbah Abdelsalam Misbah Omar, Abdalla Mohamed Elgnai Zayid, Essam Hassan Abuo Samra, Design and Analysis of Millimeter Wave Microstrip Patch Antenna for 5 G Applications, IEEE Circuits and Systems Conference, March, 2019

[2] Ranjan Mishra, Raj Gaurav Mishra, R. K. Chaurasia, Amit Kumar Shrivastava, Design and Analysis of Microstrip Patch Antenna for Wireless Communication, International Journal of Innovative Technology and Exploring Engineering, May, 2019

[3] Houda Werfelli, Khaoula Tayari, Mondher Chaoui, Mongi Lahiani, Hamadi Ghariani, Design of Rectangular Microstrip Patch Antenna, 2nd International Conference on Advanced Technologies for Signal and Image Processing, March, 2016

[4] Imeci, Ș. T., Design and manufacture of Patch Antennas. Sarajevo, BiH: International University of Sarajevo, 2017

[5] Sonnet Suites, www.sonnetsoftware.com, ver.16.56

Microstrip Lowpass Filter at 12 GHz

Kenan Kazić
Department of Electrical and Electronics Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina
kazickeno@gmail.com

***Abstract* – In this paper a symmetric low pass filter that has cut off frequency at 12 GHz is designed and simulated. While simulating there were some changes to existing ones on the market and tried to improve performance with changing some data that will be shown in Tables. While conducting the parametric study, there were some minor changes in S11 and S12. Finally, adding extra stubs to the geometry, helped to meet the design specifications.**

Keywords—low-pass filter; microstrip; extra stubs; symetrical structure; Sonnet software.

I. INTRODUCTION

Filters play important role in electronics where they are used to eliminate frequencies on specific range bands. There are many types of filters but most important ones are band-pass (BP); band-stop (BS); low-pass (LP) and high-pass (HP) filters. Low pass filter is used to reject the nonlinearity of the power amplifier and to reject the higher frequencies with high pass filter to realize wideband band-pass filter. [1]

Microstrip lowpass filter is good for this project because it is easy to analyze and easy to manufacture which is the main purpose of current design.

Featuring this design it consists of trial and error, with the conclusion that the best design consist of four high vertical stubs, two extended columns after and before ports and three wide stubs in central region. During the process of analyzing we came to a conclusion for placing extra stubs on extended stubs after ports to further increase filtering capabilities and apply mirror effect.

II. DESIGN AND SIMULATION RESULTS

The required filter specifications should be characterized as following: Low-pass filter (LPF), High-pass filter (HPF) or Band-pass filter (BPF) which is required cut-off frequency, rate and passband characteristics. This filter design is Low-pass filter with cut-off frequency of 12 GHz.

The filter is simulated using RT/duroid 5880 substrate with parameters of dielectric constant ε_r = 2.2, thickness h=1.575 mm and loss tangent Tan δ =0.0009. [4]. The simulations were done by using plainar 3D electromagnetic software called Sonnet suits. [5]

The second step is designing the filter, where we examined the possibilities on improving ones that are currently on the market. While designing it, experiments were conducted in terms of adding extra metal on the longest stubs, the length and width of stubs, which made tremendous impact in the outcome frequencies of the filter and the box was shortened to make analysis time for the Sonnet software [5] less to process. Top view of the filter is seen in the figure 1.

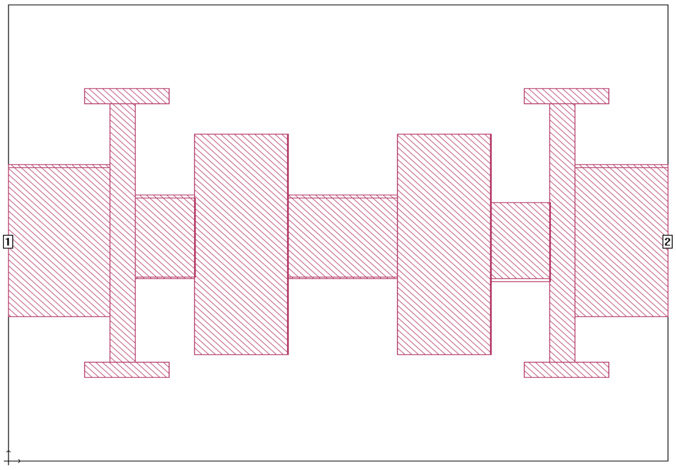

Fig. 1. Top view of the filter.

The side effects are the high insertion loss in the passband and increased circuit size [2]. However, it was possible to regulate the response and still keep the desired characteristics. Therefore, two passbands were created in the range from 0.1 GHz to 12 GHz. The simulated filter response can be seen in Figure 2. The passband covers bands from 0.1 to 2.5 GHz and from 4.5 to 12 GHz with an insertion loss between 0.1–12 [dB].

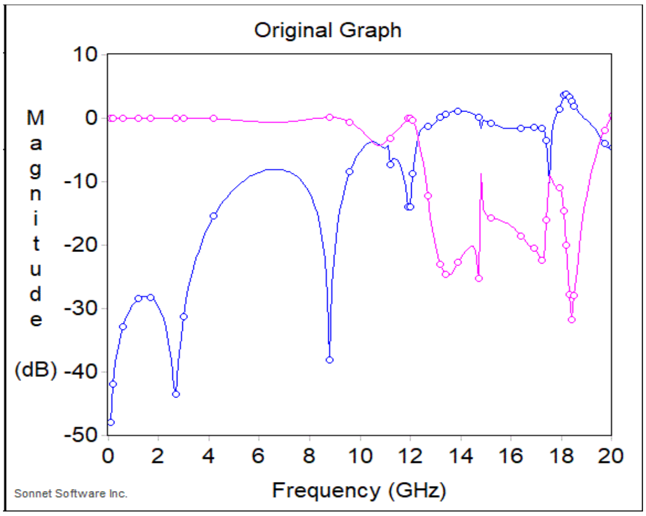

Fig. 2. Low-pass filter response (simulated)

Passing regions depend on the different parts of the schematic. The middle microstrip line (without stubs) is the one that generates low-pass filter with very high cut-off frequency around 12 GHz. When stubs are added, they provoke the rejection band to appear in the low pass region, which, in total, ends up being band-stop filter response.

The height of the open stubs is based on the wavelength at the mid-band frequency. With the application of fractal shape on the middle line the distance between the four open stubs shortens, so the initial filter size is reduced.

The whole backside of the substrate is the ground plane. The width of the feed line is approximately 8.03 mm and the open stubs are 0.75 mm wide. The four open stubs are 8.5 mm long and the separation between the centers of the two open stubs is 2.77 mm. The filter box is very small with the total size of 19.5 mm x 15 mm.

In spite of the non-expected performance, it still satisfies the set requirements. For the different performance, the change in the configuration can be made. The next paragraph offers the possible modifications.

III. Configuration Variations

Variations in size of the open stubs, as well as in the line connecting them, result in interesting responses. Some of the changes in filter schematics may involve:

- the height of the open stubs, which affects the frequency of the band-pass region. If they are shorter, band-pass region moves to the right, that is, it occupies higher frequencies;
- the number of the open stubs, which affects the width of the band-stop region. By cascading more open stubs onto the microstrip line wider rejection bandwidth and the deeper rejection may be obtained.
- main configuration variation is made with four extra pieces of metal on two high stubs.

The filter response may be improved in terms of insertion losses that should be decreased. That can be achieved by increasing the width of the open stubs or increasing the width of the line entering the ports, as they affect the S_{12} magnitude.

TABLE I- CHANGE IN STUB DIMENSIONS

STUB DIMENSIONS	S12 [dB]	S11 [dB]
2.5 x 0.5 mm	-0.5 GHz	-11.5 GHz
2.6 x 0.6 mm	-0.459 GHz	-13.93 GHz
2.7 x 0.7 mm	0.006 GHz	-13.5 GHz
2.4 x 0.4 mm	0.3165 GHz	-14.008 GHz
2.3 x 0.3 mm	-1.582 GHz	-5.0982 GHz

TABLE II- CHANGE IN ε_r

ε_r	S12 [dB]	S11 [dB]
2.2	-0.5059 GHz	-10.174 GHz
2.15	-0.0763 GHz	-13.637 GHz
2.1	-0.0129 GHz	-14.0493 GHz
2.25	-0.529 GHz	-8.512 GHz
2.3	-1.65 GHz	-4.7365 GHz

TABLE III- CHANGE IN THICKNESS

THICKNESS	S12 [dB]	S11 [dB]
1.575 mm	-0.0129 GHz	-14.0493 GHz
1.570 mm	0.0112 GHz	-13.959 GHz
1.560 mm	0.00697 GHz	-13.770 GHz
1.580 mm	0.0143 GHz	-14.135 GHz
1.585 mm	0.0155 GHz	-14.2172 GHz

IV. Conclusion

Low pass filter is introduced after the microstrip bandpass filter. Thus, the final circuit constituted of MMR BPF and LC low pass filter has performances satisfying the specification. [3] Its region of operation allows the high speed communications. To remove the unwanted frequency bands from the microwave and radio frequency signals a band-stop filter (BSF) plays a very important role in wireless communication systems. The open stub method ensured the two passband regions, while fractal structure ensured the smooth response and small box size. The agreement between simulated and measured results has been achieved.

ACKNOWLEDGEMENT

We would like to thank Prof. Dr. Taha Imeci from International University of Sarajevo (IUS), Electrical Engineering department for guidance in the project.

REFERENCES

[1] I. Mansour, H. Elhennawy, A.S.T. El-dein, "Design of Stepped Impedance Microstrip Low Pass Filter with DGS" International Journal of Engineering Research and Development, vol. 10, issue 7, pp. 58-67, July 2014

[2] B. H. Ahmad, M. H. Mazlan, M. N. Husain, Z. Zakaira, N. A. Shairi, "Microstrip Filter Design Techniques: An Overview" ARPN Journal of Engineering and Applied Sciences, vol. 10, no. 2, pp. 901-907, February 2015

[3] T. Fan, Y. Yao, "Design of 12-14.1 GHz Bandpass Filter with Stub Loaded" Journal of Engineering Research and Application, vol. 6, issue 6, pp. 31-33, June 2016

[4] I. Mansour, H. Elhennawy, A.S.T. El-dein, "Design of Stepped Impedance Microstrip Low Pass Filter with DGS" International Journal of Engineering Research and Development, vol. 10, issue 7, pp. 58-67, July 2014

[5] Sonnet Suites, version 17.52 Syracuse, New York

Extractive Text Summarization with Grey Wolf Optimization Algorithm

Ebru DUDAK, Pakize ERDOGMUS
Duzce University, Computer Engineering,
Duzce, TURKEY
ebrududak@hotmail.com
pakizeerdogmus@duzce.edu.tr

***Abstract* — Today, text summarizing techniques play a major role in extracting relevant information from big data. The present article tests the success of single text summarization of the intuitive Gray Wolf Optimization Algorithm (GWO). The results were measured with the ROUGE evaluation metric by combining statistical keyword extraction methods such as sentence ranking and word length with cluster extraction of GWO. In the study we tested with the BBC News dataset, GWO experimentally demonstrates that it performs well in the inferential text summarization techniques in line with the results obtained. The results also reveal the cluster success of GWO with an average of 57.27 for ROUGE 1 and an average of 45.62 for ROUGE 2.**

***Keywords* — Gray Wolf Optimization Algorithm, extractive text summarization, GWO, rouge metric**

I. Introduction

Text summarization is the process of automatically creating a compressed version of the text document that represents the main idea of the text and the essence [1]. The need for text summarization increases with the rapid and continuous increase in textual information sources in many fields. It can be useful for various applications such as automatic text summarization, document indexing, question answering systems, help systems and document classification.

Text summarization techniques are divided into two as extractive and abstractive according to the output of the system. Text summarization techniques are divided into two as single and multiple document summaries according to the number of entries of the system. Single and extractive text summarization technique was used in the study. In the article, a summarizing technique has been developed using the sentence clustering feature of GWO.

II. RELATED WORKS

The earliest work on text summarization is based on sentence analysis and various approaches have been tried, including statistical learning approaches. Summarizing success of heuristic algorithms and classification techniques has been tested in many studies.

The Wang et al. Used neural networks to train and learn the relevant features of sentences that should be included in the summary of text documents [2]. Fattah and Ren applied a genetic algorithm (GA) and mathematical regression (MR) based model to obtain a suitable combination of feature weights [3]. In the recent past, deep learning methods have also been applied in text summarization and a high success rate has been achieved. Sinha et al. used simple multi-layered networks [4].

Young et al. [5] proposed complex neural network architectures for text summarization. With the latest technology in abstractive deep learning systems, as well as seq2seq models of encoder-decoder architectures, repetitive neural networks (RNNs) have been used in text summarization [6].

III. GWO

Gray Wolf Optimization Algorithm is one of the population-based optimization algorithms developed with inspiration from nature. Simulating the hunting behavior of gray wolves, GWO was developed by Mirjalili in 2014[7]. GWO, which is used in the solution of continuous and discrete optimization problems, has also been studied by combining it with other heuristic algorithms. [8].It is also presented as a new solution approach for nonlinear systems of equations [9]. GWO has been successfully applied for the solution of many engineering problems such as classification, system definition and filter design, feature selection.

GWO starts with random solutions as much as the number of solutions in the given ranges of variables. Each solution represents the position of the wolves in the search space. The variable number of the problem corresponds to the size of the search space. Using the three best solutions in iteration, the average value of these three solutions and the positions of all wolves are updated. It is repeated until it reaches the maximum iteration. In the beginning, it starts to search with the solution of random wolves (search agent) in the given ranges of the variables. Each wolf's behavior examines three main steps: searching for prey, encircling prey, and attacking prey. Gray wolves are divided into alpha (α), beta (β), delta (δ) and omega (ω). The pseudo code of the gray wolf optimization algorithm is given in Figure 1.

```
Start the Gray Wolf Populations
Assign parameters A, a, C
Calculate the suitability value of each wolf
Identify first, second and third best solutions
while (t <maximum iteration)
        for each agent
Update position
       end
       Update a, A, C values
       Update the fitness values of each wolf
       Update first, second and third best solutions
       t = t + 1;
end
```

Fig. 1. Pseudo code of the GWO algorithm

IV. MATERIAL AND METHOD

The study, which aims to summarize text with the Gray Wolf Optimization Algorithm, was carried out with a laptop with Windows 10 operating system, i7 processor, 16 GB RAM. In order to determine the importance of each sentence in the document, features that are very common in inferential text summarization, such as the position of the sentence, the frequency of the term, and the similarity with the title, were chosen. Clustering was performed with these features included in the scoring and GWO. The data set and other details used in the study are included in the sub-headings.

A. Data Set

In this article, 2004-2005 BBC News data set was used as data set [10]. The data set consists of 2225 English documents from the BBC News website corresponding to news in five current areas from 2004 to 2005. The news is divided into five classes: Business, Entertainment, Politics, Sports and Technology. In the study, a total of 30 news items randomly selected from each news branch were tested.

B. Preprocessing

Before creating the summary, a series of steps are required to process the documents in advance. These steps consist of dividing the document into sentences, removing stop words, uppercase / lowercase transformation (lowercase transformation), and punctuation. All documents have been passed through these preprocessing stages.

C. Scoring Text Sentences

Four features are used to calculate the scores of the relevant text sentences. These are sentence position, sentence length, frequency of terms, and similarity to the title. When the necessary calculations for each feature are applied separately, the system collects them and calculates one point for each sentence and sorts them in descending order.

D. Sentences Selection with GWO

The sentences whose weights are calculated are clustered with the parameters entered with the help of GWO and a summary is created. In the study, the reduction ratio of the texts was determined as 60%. This rate is the closest reduction rate to the summary created by the human eye in the data set. This rate also affects the number of clusters to be created.

The values of other parameters used in the study are as follows. SearchAgents_no: 5, Max_iteration = 300, alpha = 0.1, n_grid = 10, beta = 4, gamma = 2 (Recommended values for the algorithm were used.)

V. EXPERIMENTS ANS RESULTS

The Ngram association statistic (ROUGE) was used to evaluate the similarity of the sample summary obtained from the experiments and the human sample summary and the success of the study. ROUGE (Recall-Oriented Understudy for Gisting Evaluation) was developed by Lin in 2004 using the Perl programming language [11]. Rouge is a measurement method based on the number of common words of the two documents to be compared. ROUGE has five different measurement modes: ROUGE-N, ROUGE-L, ROUGE-S, ROUGE-W, ROUGE-SU. ROUGE-N. In this study, ROUGE-1 and ROUGE-2 measurements were applied. In order to evaluate the cluster success of GWO's text summaries, all operations were applied with k-means. Comparison of the results obtained is made in Table 1.

TABLE I. COMPARISON OF SUMMARY SUCCESSES OF GWO AND K-MEANS

	GWO		**K-MEANS**	
Document Number	***ROUGE-1***	***ROUGE-2***	***ROUGE-1***	***ROUGE-2***
1	49.71	47.50	43.53	45.81
2	54.05	49.38	68.92	4135
3	87.52	62.96	67.50	54.72
4	49.09	42.62	58.18	46.68
5	59.28	54.32	62.32	47.27
6	61.54	50.23	45.23	41.12
7	53.04	48.98	58.34	47.17
8	53.17	41.12	53.47	40.04
9	68.99	51.38	74.29	56.12
10	68.75	57.83	50.12	32.18
11	65.23	53.33	46.67	38.46
12	41.82	33.78	50.20	40.66
13	60.45	55.06	56.67	43.06
14	52.34	38.55	48.45	31.54
15	58.14	41.24	68.04	51.28
16	52.83	45.76	60.00	34.49
17	58.70	47.17	54.35	45.28
18	64.52	59.38	64.52	58.33
19	50.47	41.18	54.13	43.02
20	67.12	54.24	63.12	53.17
21	57.47	51.58	60.12	51.56
22	58.67	39.73	48.38	35.54
23	54.12	37.35	48.57	39.76
24	54.87	40.91	51.68	33.46
25	56.23	42.29	51.69	41.37
26	58.12	44.78	56.72	33.12
27	52.12	33.57	48.19	37.45
28	48.34	38.22	54.15	41.29
29	58.45	47.23	48.99	43.27
30	53.45	40.12	50.17	38.23
Average	57.27	45.62	55.64	40.76

According to the ttest results, although there is no significant difference in text summarization using GWO with Kmeans in ROUGE1, this difference is significant in Rouge 2 ($p = 0.005$).

Results The GWO has been shown to be a successful tool for text summarization. Also in the study, a successful clustering was made even with the minimum number of solutions. In future studies, it is planned to test with different feature weights and solution numbers in order to increase the success rate.

REFERENCES

[1] Hovy E, Lin CY. Automated text summarization and the SUMMARIST system. In: Proceedings of a workshop on held at Baltimore, Maryland: October 13-15, 1998. Association for Computational Linguistics; 1998. p. 197–214.

[2] J.B. Wang, P. Hong, J.S. Hu, ”Automatic Keyphrases Extraction from Document using Neural Network”, Springer-Verlag LNAI 3930, pp.633-641, 2006.

[3] M. Mendoza, S. Bonilla, C. Noguera, C. Cobos, E. León, Extractive singledocument summarization based on genetic operators and guided local search, Expert Syst. Appl. 41 (9) (2014) 4158–4169.

[4] Sinha, A., Yadav, A., Gahlot, A., 2018. Extractive text summarization using neural networks. arXiv preprint arXiv:1802.10137.

[5] T. Young, D. Hazarika, S. Poria, E. Cambria Recent trends in deep learning based natural language processing. IEEE Comput. Intell. Mag., 13 (3) (2018), pp. 55-75

[6] Sumit Chopra, Michael Auli, and Alexander M Rush. 2016. Abstractive sentence summarization with attentive recurrent neural networks.pages 93–98.

[7] Seyedali Mirjalili, Seyed Mohammad Mirjalili, Andrew Lewis, Grey Wolf Optimizer, In Advances in Engineering Software, Volume 69, 2014, Pages 46-61, ISSN 0965-9978.

[8] Chao Lu, Shengqiang Xiao, Xinyu Li, Liang Gao, An effective multi-objective discrete grey wolf optimizer for a real-world scheduling problem in welding production, In Advances in Engineering Software, Volume 99, 2016, Pages 161-176, ISSN 0965-9978.

[9] Erdogmus, Pakize. (2019). A New Solution Approach for Non-Linear Equation Systems with Grey Wolf Optimizer. Sakarya University Journal of Computer and Information Sciences. 1. 1-11. 10.35377/saucis.01.03.475565.

[10] http//mlg.ucd.ie/datasets/bbc.html

[11] C. Lin, Rouge: A package for automatic evaluation of summaries, Text Summarization Branches Out: Workshop Held in Conjunction with ACL’04, pp. 74-81, ACL Press, Stroudsburg,PA,2004

10 dB Microstrip Hybrid Coupler

Mehmet Yusuf Imeci, Metehan Berk
Department of Electrical and Electronics & Mechanical Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina
mehmedyusufimeci@gmail.com, mthnberk01@gmail.com

***Abstract* – A 10 dB hybrid microstrip coupler is introduced in this paper. The simulated frequencies are between 1 GHz and 3GHz. The bandwidth of the coupler is between 1.5 GHz and 2.34 GHz. When the thickness of the dielectric was 1.51mm, S13 was -10.01 dB. The center frequency was 1.93 GHz and the input match, S11 was -28.48 dB, the isolation, S14 was -36.20 dB and the thru port, S12 was –0.46 dB.**

Keywords—10 dB, hybrid coupler, microstrip

I. Introduction

Couplers are widely used important technological devices in our day and age. There is a wide range of intervals of dBs when it comes to manufacturing couplers. There are 10 dB and 20 dB couplers etc. 10 dB couplers are quite commonly used. Couplers are essential components for applications in virtually all RF and microwave transmission systems, such as power and VSWR measurements, signal sampling for monitoring or testing, equal or unequal power division, phase shifting (particularly 900 and 1800), feed-forward signal injection, isolation of signal sources [1]. Microwave couplers are crucial devices and are used in many microwave subsystems, such as power amplifiers, phase shifters, modulators and power dividers and so on [2]. Weakly coupled broadband directional couplers are key components of many microwave measurement systems [3]. The directional couplers are an important component of the RF integrated circuit and measurement systems which are used in various fields like communication, radar, satellite etc. [4]. To obtain wide bandwidths and tight coupling, multi-hole couplers have to be used [5].

II. Design Steps & Simulation Results

Figure 1 has the top view of the coupler. As you can see, we have added four tuning stubs in the beginning of the coupler section in order to get a better input match. Figure 2 has the S parameters of the coupler. In this graph you are shown the values of the parameters of S11 (the input match), S12 (thru port), S13 (coupling), and S14 (isolation). The parameters as you can see is presented on the curves and linear line. As it is seen coupling is -10 dB in between f= 1.5 – 2.34 GHz. Thru port is almost 0 dB throughout the band. Isolation and input match are well below -30 dB. S11 is blue, S12 is magenta, S13 is red, S1 is green.

Figure 3 has the 3D view and figure 4 has the angle between the coupled and thru ports. It is shown in figure 4 that there are 90 degrees phase difference between these two ports which makes the coupler hybrid type.

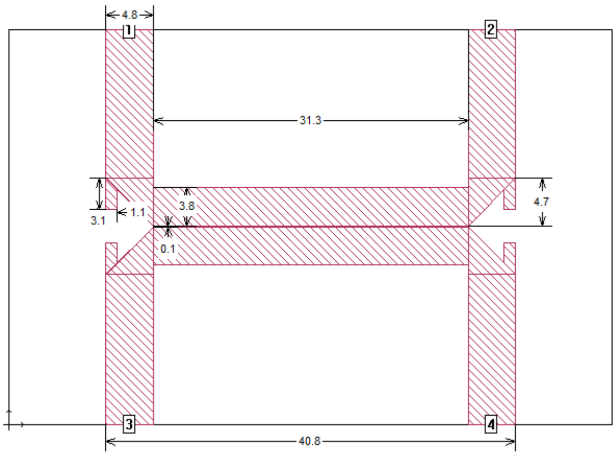

Fig. 1. Top view of the coupler

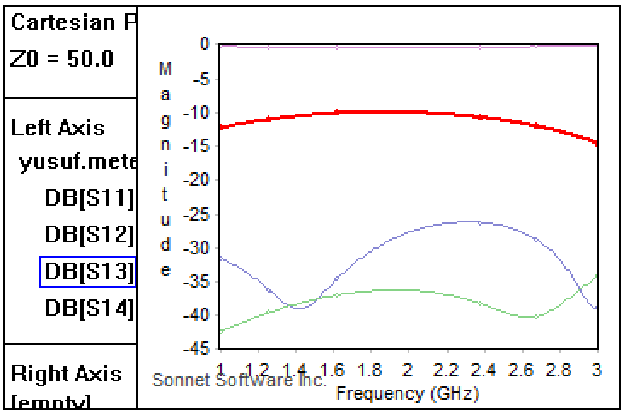

Fig. 2. S Parameters of the coupler

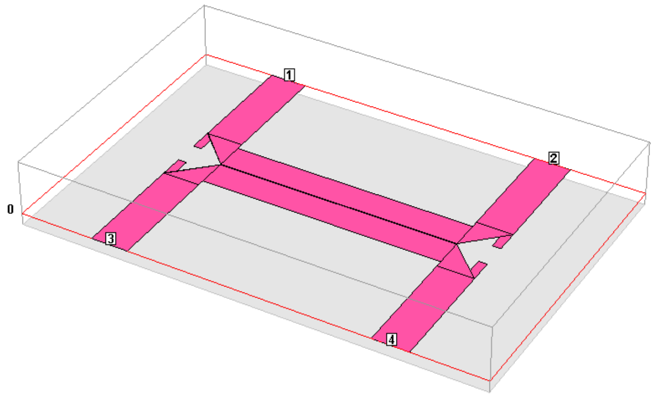

Fig.3. 3D View of the coupler

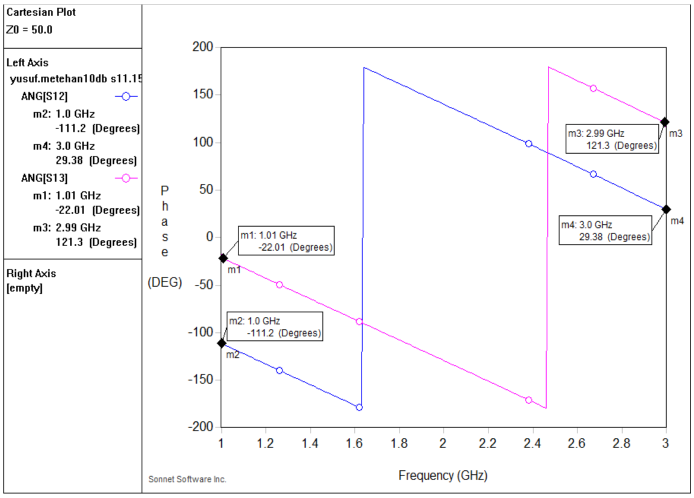

Fig.. 4. Phase difference

III. Parametric Study

In order to check the fabrication tolerances the coupled lines dimensions were changed and finally the result of 31.2 x 4.2 has been decided to be used. Coupling is varied between 9.54 and 10. 86 dB which shows amplitude balance as 1.32 dB within those two parametric studies performed. After that, thickness of the dielectric layer was changed and variations of the S Parameters is presented in Table I. As seen in table I, the thru port is around -4 dB. Input match (S11) and isolation (S14) are changing between -32 dB and -37 dB. Those values ensure that the conducted parametric studies have successfully yielded the expected results.

TABLE I. CHANGING THE DIELECTRIC THICKNESS

Dielectric thickness (mm)	[S11] (dB)	[S12] (dB)	[S13] (dB)	[S14] (dB)
1.51	-35.47	-0.41	-10.44	-33.72
1.53	-36.60	-0.43	-10.27	-34.51
1.55	- 36.00	-0.42	-10.30	-35.42
1.57	-32.24	-0.44	-10.14	-35.72
1.59	-31.81	-0.44	-10.17	-36.41

IV. Conclusion

In this work a 10 dB microstrip hybrid coupler is designed and simulated. The simulation results show coupling bandwidth of almost 900 MHz. Input match and isolation are less than -30 dB. A parametric study was conducted for the dimensions of the coupled lines as well as the dielectric thickness. The planned future work is to fabricate the coupler.

ACKNOWLEDGEMENT

We would like to thank Sonnet Software for providing license in our lab [6].

REFERENCES

[1] A.S. Al Zayed, Z.M. Hejazi, A.S. Mohra, “A Microstrip Directional Coupler With Tight Coupling And Relatively Wideband Using Defected Ground Structure”, ACES Journal, VOL. 25, NO. 10, October 2010

[2] M. Kumar, SK. N. Islam, G. Sen, S.K. Parui, S. Das, “Design of Miniaturized 10 dB Wideband Branch Line Coupler Using Dual Feed and T-Shape Transsmition Lines”, Radioengineering vol. 27 NO. 1. 2018

[3] B.L. Berrocal, J. de Oliva Rubio, E.M. Segura, A.M. Martir, I.M. Fernandez, “High Performance 1.8-18 GHz 10 dB Low Temperature Co-Fired Ceramic Directional Coupler”, Progress In Electromagnetics Research, PIER 104, 99-112 2010

[4] A. Jain, Anurag, R.P. Yadav, “Design and Development of coaxial line based 2 kW, 10-30 dB variable dual directional coupler”, International Microwave and RF Conference 2017

[5] P. Meyer, JC Kruger, “Wideband Crossed Guide Waveguide Directional Couplers”, International Microwave Symposium 253-256 vol 1. 1998

[6] Sonnet Suites, ver 17.52, Syracuse, New York.

Tri - band Rectangular Microstrip Patch Antenna

Šejma Kubura
Department of Mechanical Engineering
International University of Sarajevo, Sarajevo, Bosnia and Herzegovina

***Abstract*— In this paper a rectangular microstrip patch antenna is designed and simulated. The antenna is simulated using Sonnet Suites. Geometry of the antenna is simple with via feeding on one edge. Resonance frequencies are 9.6 GHz, 5.67 GHz and 3.86 GHz which is suitable for the C band portion of the electromagnetic spectrum in the microwave range of frequencies. Gain for those values are 6.49 dB, 7.2dB and 4.77 dB. The main idea is to design an antenna with low cost and big sprectrum of usage in terms of frequncy bands.**

***Keywords*—Rectangular patch, Microstrip patch antenna, via feed, tri-band.**

I. INTRODUCTION

Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated. [1]

Radar systems have been used for various applications such as monitoring and remote sensing. Radar remote sensing techniques have become interesting to researchers. Ultra Wideband radar system based on the transmission of short duration pulses [2]. The principle of this radar is transmitting a short duration pulses and then detecting the reflected pulse response.In the UWB radar system, an antenna plays a very important place. This is one among the important features of the transceiver chain. An antenna both transmitting and receiving the pulse wave. The last element is designed to radiates and receiving a signal carrying an information to be processed. [3].

II. ANTENNA GEOMETRY

The geometry and the top view of the antenna is shown in Fig. 1. The size of the antenna is 4.8×4.1 cm. The antenna is designed by Rogers RT5870 with thickness of 0.287 mm. The feeding of the antenna is located at the left edge with a rectangular modeled and simulated via. This geometry is simple, based on it cost will be low. Via can help us to use lowest memory. The design of a low profile, wide band multiband patch antenna is very complicated. The fact is that the lowest antenna profile, the widest impedance bandwidth.

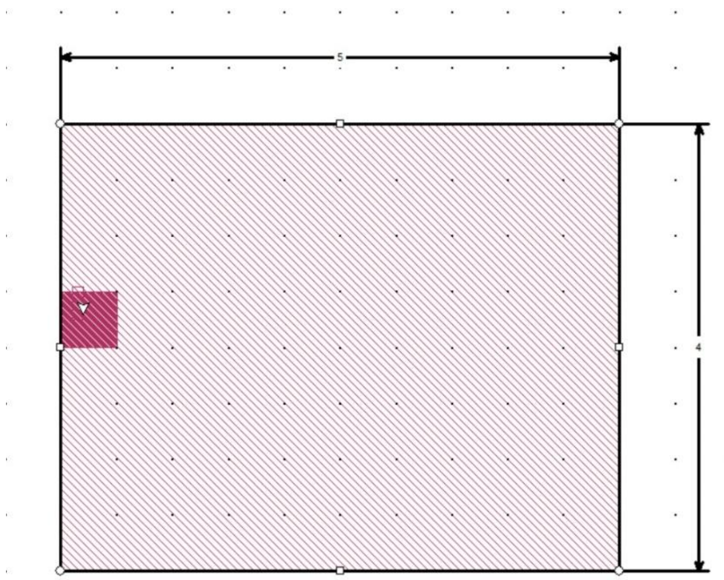

Fig. 1.Picture of the antenna

III. SIMULATION RESULTS

The antenna is modelled and analyzed using Sonnet Suites. The gain values at different operating frequencies are tabulated in Table 1 and 2. Table 1 and 2 proves the fabrication tolerances of the antenna is good enough. Fig. 2 has the input match of the antenna.

DIELECTRIC THICKNESS cm	FREQUENCY GHz	GAIN dB	S11 dB
0.275	3.80	5.03	-7.17
0.290	3.85	6.55	-17.76
0.295	3.86	6.49	-18.60
0.300	3.83	6.71	-16.25

Table 1. Parametric study of changing the dielectric thickness

DIELECTRIC CONSTANT	FREQUENCY GHz	GAIN dB	S11 dB
2.17	3.98	7.52	-15.29
2.20	3.92	7.19	-16.79
2.25	3.95	6.49	-14.23
2.27	3.91	6.85	-16.03

Table 2. Parametric study of changing the dielectric constant

As it is seen in Fig 3, the gain has three spot beams at θ = 0 degrees and ±40 degrees. As it is seen in Fig 4 the gain has three spot beams at θ = 0 degrees and ±70 degrees. Fig 5 shows the gain pattern of two wide beams at θ =±45 degrees. While cross polarization is a bit high in Fig 3, it gets very low in Figures 4 and 5.

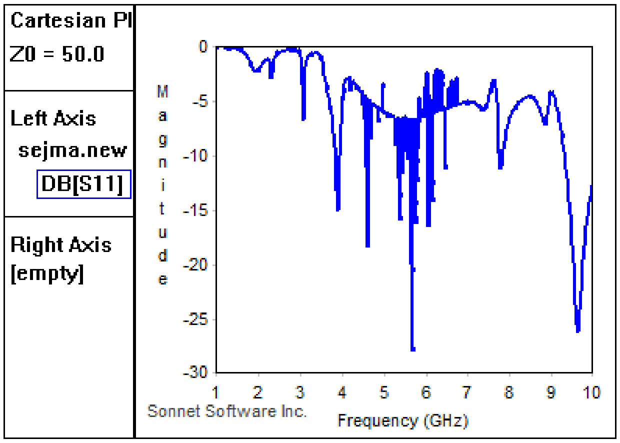

Fig. 2. Input match of the antenna.

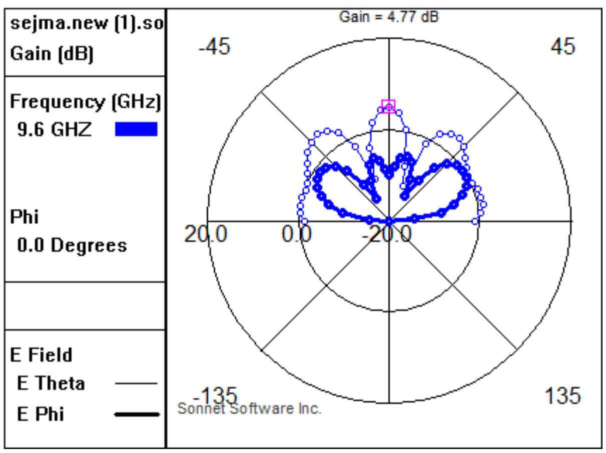

Fig. 3. Gain pattern of the antenna at 9.6 GHz.

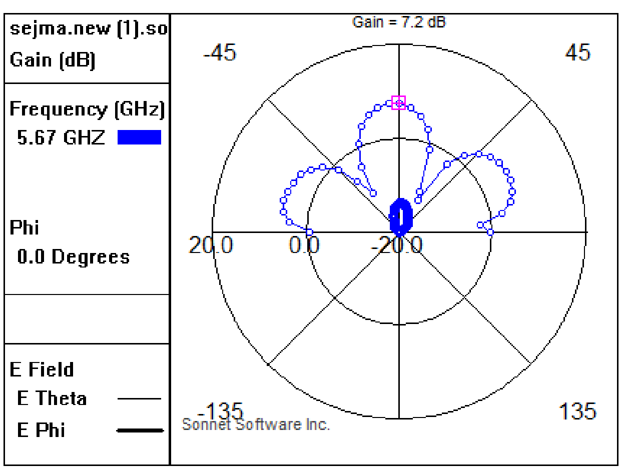

Fig 4. Gain pattern of antenna at 5.67 GHz.

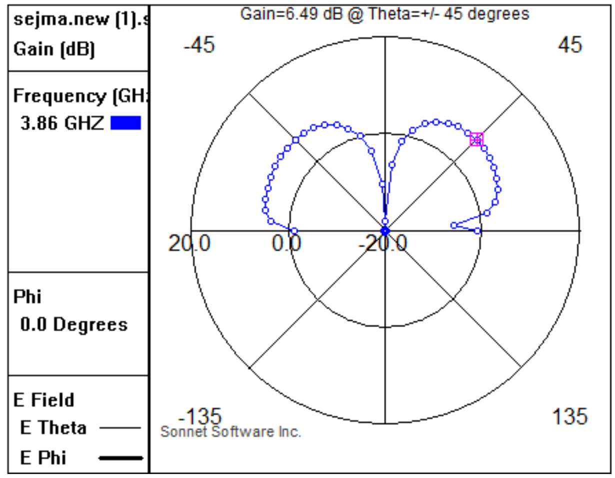

Fig. 5. Gain pattern of the antenna at 3.86 GHz.

IV. CONCLUSION

In this paper, a rectangular patch antenna with simple geometry and tri resonances were presented. A parametric study was conducted to see the changes in dielectric thickness and the dielectric constants. Those results were shown in Tables and ensures that fabrication tolerances of the antenna is inacceptable levels. According to simulation results, the antenna operates between 3.86 and 9.6 GHz. Resonance frequencies are 9.6 GHz, 5.67 GHz, 3.86 GHz. Gain for those values are 6.49 dB, 7.2dB and 4.77 dB. Next step is fabrication of the antenna.

REFERENCES

[1] D. Nalbantoglu and A. Yanik, “A multi-band rectangular patch antenna for wireless communications”, 2004.

[2] "Intelsat, SES, Eutelsat and Telesat Establish the C-Band Alliance (CBA), a Consortium to Facilitate Clearing of U.S. Mid-band Spectrum for 5G While Protecting U.S. Content Distribution and Data Networks" (Press release). SES. September 27, 2018. Retrieved November 2, 2018.

[3] Mcewan T.E. Ultra-Wideband Radar Motion Sensor. 5,361,070. US Patent. 1994 Nov 1;

[4] T. Imeci and A. Saral, Corners Truncated Microstrip Patch Antenna, Haliç University, Department of Electronics and Communication Engineering, ACES, Tampere, Finland, 2010.

[5] M. A. Layegh, C. Ghobadi and J. Nourinia, “The optimization design of a novel slotted microstrip patch antenna with multi-bands using adaptive network-based fuzzy inference system”, 2017.

Microstrip Band Stop Filter with a Rectangular Patch Inside a Square

Harun Efendic
Department of Electrical and Electronics Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina

Abstract **– In this paper microstrip band stop filter is designed and simulated. Some improvements have been made to increase the efficiency of the filter. The center frequency of the band stop filter is at 4 GHz which reaches as low as -73 dB. The bandwidth of the stop band is starting from 1.975GHz to 6.8GHz.**

Keywords—microstrip filter, low pass filter, band stop

I. INTRODUCTION

According to the importance of microstrip low pass filters in microwave applications, presenting new structures to improve the performance of former filters is necessary. Based on this motivation, numerous methods have been utilized so far that each one has focused on a particular aspect of the filter performance [1]. Bandstop filters are the key components in a microwave communication frontend to isolate frequency band located within a wide pass-band [2]. Also today Ultra Wideband (UWB) attracted a lot of interest in the research community and in the industry. It offers the potential for low cost, excellent range resolution capabilities, low-power transmissions, high data rates, and robustness for multipath fading. The simple transceiver circuitry compared to one complicated in a narrowband transceivers have also been seen promising, as they can be manufactured at a lower price [3].

II. FILTER DESIGN

Filters have low losses and high selectivity. Bandstop filter (BSF) play a major role of filtering out undesired frequencies and passing the desired signals, most of them have open-circuited stubs and shunt stubs of a quarter-wavelength [4]. In our design we used classicall filter design. Then we made a square by adding and connecting a parallel rectangulars. Than one new rectangular was placed inside existing one, in order to improve a significance level. Many modified techniques exist to design wideband BSFs apart from conventional shunt stub and coupled-line band reject filters. However the structure of a circuits are complex and large in the most of those cases [5]. In [1] Compact Microstrip Lowpass Filter using Stepped Impedance Spiral Resonator that has a high but narrow rejection in the stopband was designed. Coupled lines for implementing filters have been widely used for a long time. In [4] the filter with only two meander prototype parallel coupled lines of different electrical lengths and characteristic impedances in shunt has been shown The coupling of our filter is 10dB, while 4GHz is the center frequency. Our substrate permittivity (Ɛr) is set to be 2. While the substrate thickness (h) is 0.3 mm.

III. SIMULATION RESULTS

Variations in the size of the rectangular patch inside a square, as well as, of the square pillars have an important impact on our simulations. We changed substrate permittivity (Ɛr) to different values of 3.5 and 7 simulated between different frequencies. The best results are obtained at substrate permittivity (Ɛr) of 2.

Also, we changed the substrate thickness (h) to 0.7mm and the center frequencies of the stop band were placed at 2.25GHz and 8GHz. It is also obvious that when we change the size of square and rectangular we obtained different Bandwidth of a BSFs. Also, S12 changed at different square and rectangular sizes.

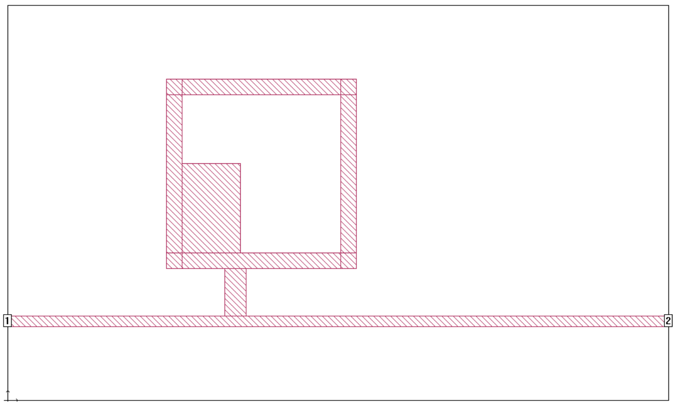

Fig. 1. Design of the filter

In the above picture the longest part of a filter is with the dimensions of 25mm x 0.4mm. The big square part is made of four equal pillars with the dimensions of 7.2mm x 0.6mm, while the inside rectangular dimensions are 2.2mm x 3.4mm. Finally the dimension of a filter that connects the other two parts is 1.8mm x 0.8mm. In the below tables we designed, simulated and tested all these various combinations in order to obtain the best results. We tried many different things, by changing substrate permittivity (Ɛr) and substrate thickness h. The goal was to find the highest S11, at the lowest possible S12.

TABLE I CHANGES IN THE LENGT OF RECTANGULAR PATCH

Size (mm x mm)	S11	S12 (1.35GHz)	BW (BSF)
1.2 x 3	-11.876	-0.290	3.45 GHz
1.4 x 3	-11.592	-0.313	3.475 GHz
1.8 x 3	-11.030	-0.358	3.525 GHz
2.2 x 3	-10.490	-0.405	3.6 GHz

In the above table the size of a rectangular patch inside a square patch were changed. As can be seen the best results were obtained when the size was 2.2mm x 3mm, because the Bandwidth was at its highest point of 3.6GHz. Now in the below table, we changed a width size, while we kept the length of 2.2mm constant.

TABLE II CHANGES IN THE WIDTH OF RECTANGULAR PATCH

Size (mm x mm)	S11	S12 (1.35GHz)	BW (BSF)
2.2 x 2.8	-10.695	-0.387	3.55 GHz
2.2 x 2.6	-10.902	-0.367	3.525 GHz
2.2 x 3.2	-10.285	-0.427	3.625 GHz
2.2 x 3.4	-10.024	-0.448	3.675 GHz

Now in the above table we can see that the highest bandwidth is when the rectangular patch is 2.2mm x 3.4mm long.

TABLE III CHANGES IN THE SIZE OF A SQUARE PATCH

Size (mm x mm)	S11	S12 (1.35GHz)	BW (BSF)
7.2 x 0.4	-12.560	-0.282	3.375 GHz
7.2 x 0.6	-10.078	-0.448	3.675 GHz
7.2 x 0.2	-15.032	-0.136	2.5 GHz
7.2 x 0.3	-13.800	-0.184	3.15 GHz

In the above table the pillar size that shapes the square are changed in order to obtain the best result. The best filter result was obtained at the size of 7.2mm x 0.6mm, with the Bandwidth of a 3.675GHz.

As said in [4] Bandwidth and rejection level of the filters of the bandstop filter can be designed by choosing different even- and odd-mode characteristic impedances values of the coupled lines.

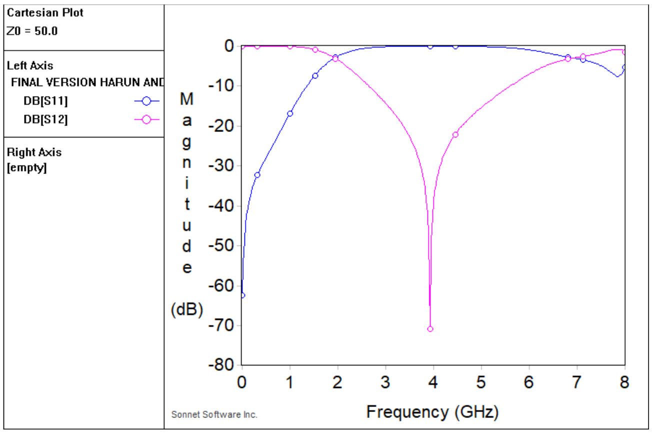

Fig. 2. Simulated response of a Band-stop filter

IV. Conclusion

In this article, a Band stop filter, with a rectangular patch inside a square was designed. As a result of analyzes and simulations, the band stop filter bandwidth extended from 1.975GHz to 6.8GHz. In order to improve our results, we performed some parametric studies, and we obtained the best possible result. When we increased the size of our filter we got the highest bandwidth of 3.675GHz which was our best result.

V. References

[1] S. Majidifar, S.Vehab Al-Din Makki, A.Ahmadi, and S.Alirezaee, “Compact Microstrip Lowpass Filter using Stepped Impedance Spiral Resonator,”, Fourth International Conference onComputational Intelligence and Communication Networks (CICN), November 2012,

[2] M.K.Zahari, B. H. Ahmad, N. A. Shairi,W. Peng Wen, “Reconfigurable Matched Bandstop Filteer,” IEEE International RF and Microwave Conference”, pp. 230, December 2011

[3] L.BalaSenthilMurugan, S.Antony Anbu Raja, S.Deeban Chakravarthy, N. Kanniyappan, “Design and Implementation of a Microstrip Band-Stop Filter for Microwave Applications,”, International conference on modeling, optimization and computing , Procedia Engineering 38 (2012) 1346 – 1351.

[4] D. Cui, Y. Liu, Y. Wu, S. Lie, and C. Yu, “A Compact Bandstop Filter based on two Meandered Parallel-Coupled lines,” Progress In Electromagnetics Research, Vol. 121, 271-279, 2011

[5] C. Somdotta Roy, Kr. Parui Susanta, D. Santanu, “Design of a Compact Wideband log Log Periodic Spur Line Bandstop Filter,” International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3, Issue-1, October 2013

Microstrip 3 dB Coupler

Vildana Buljubašić
Department of Computer Sciences and Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina
vildana.b1@gmail.com

***Abstract* - This paper is introducing a configuration of the 3 dB coupler. Upon optimizing space, price and performance, the final design is composition of two parallel open-circuits. The coupler operates in high frequencies with wide bands. The coupler is working within the frequency band of 0.2-4GHz. Compact size and low price enable the wide application of this coupler configuration. These frequencies allow the operation in unlicensed frequency spectrum popular for high speed communications.**

Keywords - coupler; Sonnet software;

I. INTRODUCTION

Nowadays, there is huge need for higher transfer of everything. That is implemented also to the electromagnetics and couplers. Coupling is desirable transfer of energy from one medium to another. The process is done through metallic wires or an optical fiber. In this work, metallic microstrip wires are used. The 3 dB coupler is used in a variety of applications in the system, and its type and shape are various as well [1]. A very commonly used basic element in microwave system is the directional coupler. Sampling the forward and reverse travelling waves through a transmission line or a waveguide is its basic function. The common use of this element is to measure the power level of a signal [2]. Easier solution to achieving broader bandwidth is to use symmetrical coupler, which is presented here [3]. One of the reasons for using stripline configuration is that microstrip directional couplers suffer from poor directivity due to characteristic of inhomogeneous dielectric [4]. Generally good performance and 90^o phase shift between the coupled port and through port is obtained in the narrow bandwidth [5].

In this paper, a microstrip coupled line coupler is consisted of two parallel open-circuits with a gap between them and three sections. Microstrip technology is used for simplicity and ease of fabrication. The design and simulation are performed using method of moments based electromagnetic simulator Sonnet Software.

II. DESIGN AND SIMULATION

This coupler is made of two parallel open circuits with three sections microstrip coupled line. Its structure is symmetric so all reflection coefficients and transmission coefficients will be identical. The coupler is a four-port device. In this case, we used some of the following properties and methods. Some values were changed in order to prove that our configuration will work properly in many cases. The configuration of coupler can be seen in Figure 1.

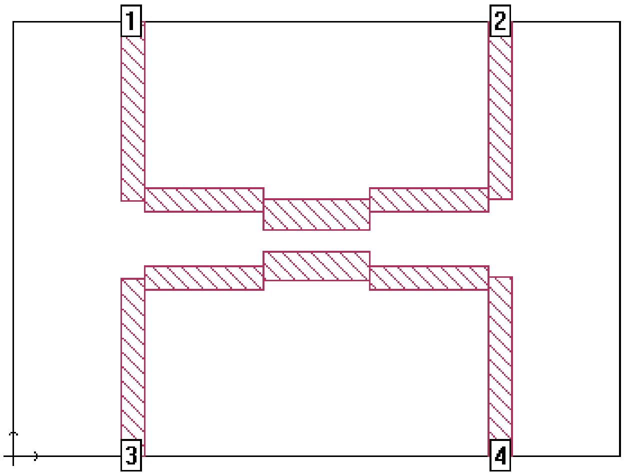

Fig. 1. Configuration of the proposed coupler.

Coupler was simulated under the current frequency from 0.2 GHz to 4.0 GHz. Dielectric thickness is 1.7 mils and ε-r is 4.7. After analyzing, response data is shown in Figure 2. Blue and purple curve (magnitudes) are intersecting in two spots, and in those two spots simulations were recorded.

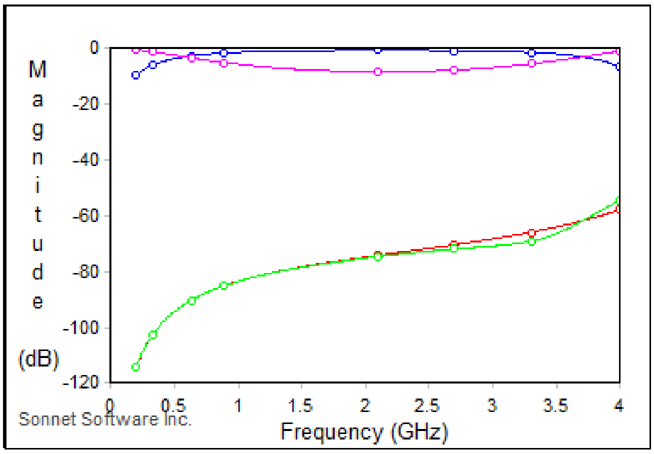

Fig. 2. Response data of the coupler (simulated).

Using Sonnet Software, I measured the 90-degree phase shift at 0.2 GHz. Generally, branch-line couplers are 3dB, and four port directional couplers are having a 90º phase difference between its two output ports [6]. This phase shift is shown in the following figure:

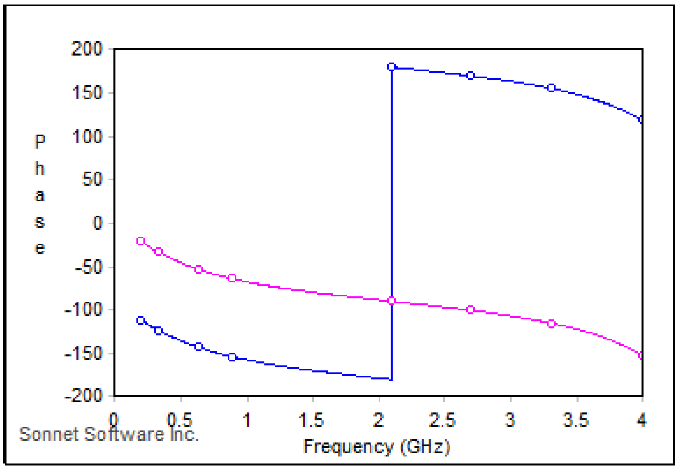

Fig. 3. Phase shift of the configuration

Filter box is 600 x 430 mils. The four open stubs are 23 mils wide, and 177.6 mils long. Separation is 342 mils between them, and two circuits are 20.95 mils separated. Separation between circuits was most important for each new analysis. Stubs were in fixed positions during simulations, except for two parallel in the middle. Their width was the same, only height was changed for the simulation purposes.

III. Configuration Variations

With set configuration, when manipulating with the data we can change, like thickness, frequency, etc., results are supposed to be similar, meaning without big deviations. Average values of spots recorded were following:

TABLE 1: RECORDED SIMULATIONS (AVERAGE)

Mils	Thickness	ε-r	Ratio1 (dB)	Frequency 1 (GHz)	Ratio2 (dB)	Frequency 2 (GHz)
	1.6	4.7	3.008	0.562	3.006	3.51
	1.7	4.7	3.016	0.596	3.002	3.494
204.2	1.7	4.7	2.98	0.576	2.978	3.68

This means that set configuration is good and that current is flowing regularly (no big deviations).

If original structure is changed results will vary. Modifications that also can affect in result changes are related to the width and height of the stubs, number of stubs, distance between them etc.

IV. Conclusion

This coupler meets the requirements of good performance. By changing some geometry of the coupler, we can achieve different results that in final output have no big deviations which proves the correctness of the proposed design. If it comes to fabrication, due to its suitable size, fabrication will not be a problem.

Acknowledgement

I would like to thank Professor Doctor Şehabeddin Taha İmeci for his valuable guidance.

References

[1] Pil-yong Lee, Duck-ki Baek, Jong-hee (Marting) Park, Eun-seok Choi, “Design of 3dB Directional Coupler for Ka-Band Input Multiplexer of Satellite Payload Applications”, 2018 International Symposium on Antennas and Propagation (ISAP 2018), October 23-26, 2018

[2] Dr. H. Matzner, S. Levy, D. Ackerman, “Experiment 5 – Coupler Design”, June 2009

[3] Özlem A. Şen, Celal Dudak, Tunuhan Kırılmaz, “Novel Broadband 3 dB Directional Coupler Design Method”, WSEAS Int. Conference on Circuits, Systems, Signal and Telecommunications, Gold Coast, Australia, January 17-19, 2007

[4] Chul-Soo Kim, Young-Tae Kim, Seung-Hoon Song, Wan-Soo Jung, Kwang-Yong Kang, Jun-Seok Park, Dal Ahn, “A design od Microstrip Directional Coupler for High Directivity and Tight Coupling”, Microwave Conference, 2001. 31st European

[5] Priyansha Bhowmik, Tamasi Moyra, Partha Kumar Deb, “Size Miniaturization of 3 dB Branch Line Coupler by using Open Stubs”, 2nd International Conference on Signal Processing and Integrated Networks (SPIN), February 2015

[6] Parul Davar, “Analysis of Microstrip Branchline Coupler using Sonnetlite”, International Journal of Electronics & Communication Technology, IJECT vol. 3, Issue 1, Jan.-March 2012

Perturbed Triangular Patch Antenna With Elliptical WideBand Slot at 16.95 GHz

Elif Nur Kuralay, Şakir Kandönmez, Suheyl Sağman,
Electrical and Electronics Engineering
Istanbul Commerce University
Istanbul, Turkey
kuralayelif@gmail.com, sakirkandonmez@gmail.com,
suheylsagman@gmail.com

Taha Imeci
Electrical and Electronics Engineering
Int. Univ. of Sarajevo
simeci@ius.edu.ba

Abstract— In this paper, a microstrip antenna with an elliptical slot, triangular and elliptical patches is presented for wireless communication systems. The presented antenna consist of triangular and elliptical shaped patches, and an elliptical slot. The antenna is simulated using the Sonnet Software. The antenna designed on a FR-4 substrate operates at 16.95 GHz with gain of 8.31 dB which is suitable for wideband wireless communication systems and mobile equipment.

Keywords—Triangular patch, Elliptical slot, Microstrip patch antenna, Wideband

I. INTRODUCTION

Recent advances in compact mobile and wireless handsets demand multi-frequency and multiband compact size antennas with broadband and high gain performance. In order to use these antennas in communication systems, modifications in patch geometries are required [1]. Electrically thick dielectrics increase bandwidth, however, they introduce impedance matching challenges [2]. Rectangular patch is the most popular shape, can be easily analyzed, and modified to produce a range of impedance values, radiation patterns, and frequencies of operation. The conventional microstrip patch antennas have a disadvantage as they cannot work in a very wide band. Many studies have been performed to have wideband microstrip patch antennas for wireless communication [3-4]. Therefore, it is necessary to increase the bandwidth of the antenna by truncating edges of the patch, using elliptical or triangular patch, and cutting a slot on the patch. Slotted microstrip antenna has better bandwidth, return loss, gain, and directivity compared with non-slotted microstrip patch antenna [5].

In order to increase bandwidth of the antenna, an elliptical slot on the patch, and triangular and elliptical shaped patches are used in this work. A perturbed triangular microstrip patch antenna with an elliptical slot is presented here, simulated using the Sonnet electromagnetic software, and fabricated on a FR-4 substrate. A wide operating bandwidth is achieved by cutting an elliptical shaped slot on the patch. The operating frequency of the presented antenna is 16.95 GHz with 16% bandwidth which is suitable for wireless communication

II. ANTENNA GEOMETRY

The geometry of the fabricated elliptical slot antenna is shown in Fig. 1. The size of the antenna is 18×25 mm. The antenna is designed on a FR-4 dielectric substrate whose thickness and permittivity are 1 mm and 4.4, respectively. The angles of the elliptical slot (γ, φ) and elliptical patches (θ, σ, α, β) are shown in Fig. 1 and tabulated in Table I. The antenna consists of an elliptical slot, an elliptical patch, and triangular patches with truncated corners.

Fig. 1.Picture of the fabricated antenna

III. ANALYSIS RESULTS

The antenna is modelled and analyzed using the Sonnet software program. The return loss (S_{11}) of the antenna is shown between 15 GHz and 18 GHz in Fig. 2. The return loss is less than -10 dB between 15.3 GHz and 17.9 GHz. The bandwidth of the antenna is around 2.6 GHz (16%). The gain pattern of the antenna at 16.95 GHz is shown in Fig. 3. The maximum gain value at 16.95 GHz is 8.31 dB. The gain values at different operating frequencies are tabulated in Table I.

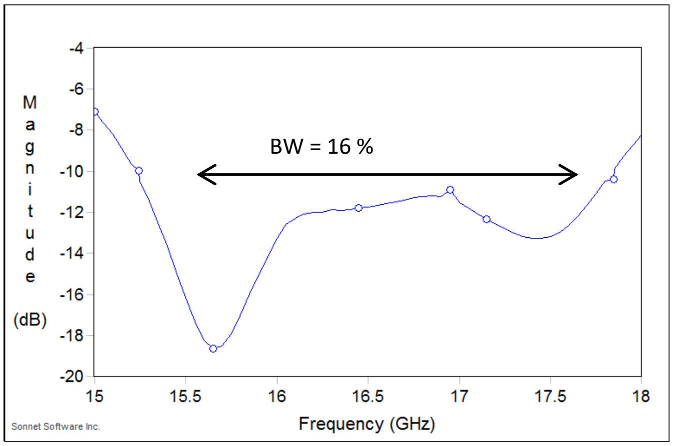

Fig. 2. Return loss of the antenna.

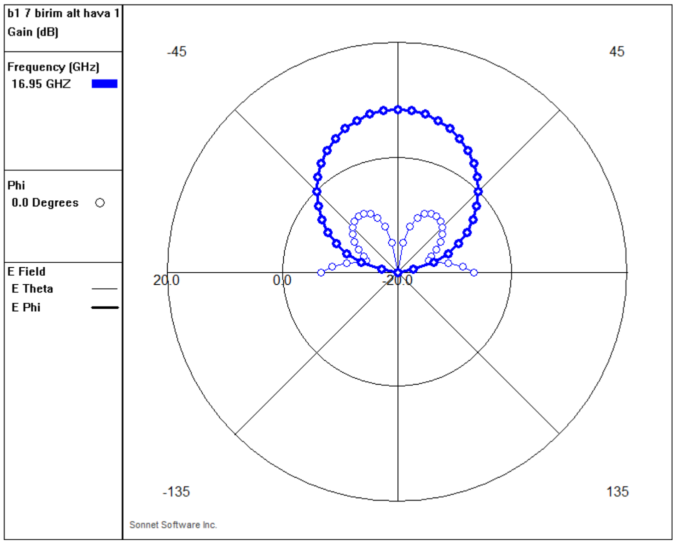

Fig. 3. Gain pattern of the antenna at 16.95 GHz.

TABLE 1 COMPARISON OF GAIN VS. FREQUENCY

	β	α	σ	θ	γ	φ
Degree	**78,69**	**68,2**	**135**	**153,43**	**168,7**	**28,01**
Frequency (GHz)	**16,66**	**16,28**	**17,2**	**15,65**	**17,28**	**17,12**
Gain (dB)	**7,67**	**5,67**	**6,02**	**4,5**	**7,02**	**7,45**

IV. CONCLUSION

In this paper, a wideband perturbed triangular patch antenna with an elliptical slot is designed, simulated and fabricated on a FR-4 substrate. According to analysis results, the antenna operates between 15.3 GHz and 17.9 GHz. At 16.95 GHz, the gain of the antenna is 8.31 dB. The antenna operated frequency range from 15.3 to 17.9 GHz is suitable for wireless communication applications. The simulation results were not compared with the measured results because the Network analyzer that used in the lab. does not work properly. Whenever the presented antenna is measured, the measured and simulated results will be compared.

REFERENCES

[1] B. Sharma, K. G. Jangid, D. Bhatnagar, V. Sharma and K. B. Sharma, "Compact dual band microstrip patch antenna for Wi- Max communication systems," *2014 International Conference on Signal Propagation and Computer Technology (ICSPCT 2014)*, Ajmer, 2014, pp. 741-744.

[2] R. Garg, P. Bhartia, I. Bahl, A. Ittipiboon, Microstrip Antenna Design Handbook. 2001: Artech House.

[3] P. Ranjan and S. Mishra, “Design of Circularly Polarized Rectangular Patch Antenna with single cut”, Conference on Advances in Communication and Control Systems, pp.174-177,2013.

[4] N. J. Shimu and A. Ahmed, "Design and performance analysis of rectangular microstrip patch antenna at 2.45 GHz," *2016 5th International Conference on Informatics, Electronics and Vision (ICIEV)*, Dhaka, 2016, pp. 1062-1066.

[5] M. John, B. Manoj and S. Rodrigues, "Design of slotted rectangular microstrip patch antenna operated in ISM band using RT-Duroid substrate," *2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*, Chennai, 2016, pp. 3076-3080.

Designing Park Sensor System Which Detects Vehicles And Analysis Of This System

Ahmet Faruk KARAKEBELİOĞLU
R&D and Inovation Department
Isbak A.Ş.
Istanbul, Turkey

Özkan EREN
Faculty of Technology
Marmara University
Istanbul, Turkey

Hasan KÖTEN
Institute of Graduate Studies
Istanbul Medeniyet University
Istanbul, Turkey

Hüseyin ALP
R&D and Inovation Department
Isbak A.Ş.
Istanbul, Turkey

***Abstract*—Many problems have been seen in cities because of increasing vehicle density. One of these problems is vehicle density in parking lots. People look for empty parking area and they spend too many time. While people look for empty parking area, CO_2 (carbon dioxide) emission and energy consumption increase due to density in parking lots. We worked to solve these problems by doing Magnetic Car Park Sensor. Magnetic Car Park Sensor is the system which is detect cars in car parks. After cars detected with the system, system sends information to center server and we can see information data in system interface. System helps to people to find empty parking lots. As people find empty car park area fastly, the energy consumption and CO_2 emission are decreased significantly.**

Keywords—CO_2 emission declining; vehicle detecting; sensor system; smart city technologies

I. INTRODUCTION

Academic studies were done to car detect anywhere. Some of them were done by the cameras [1] which can detect cars on any area. Another studies were done by sensor [2].

In our study, we designed car park sensor to detect cars in car parks. Firstly, we looked for academic studies to understand which systems designed before. We saw that software is too important for system's performance [3]. Classification of cars is done with software in some studies [4]. But accuracy of detection is not stable in many studies [5]. When we started our studies, we searched components like MCU (microcontroller unit), magnetic sensor and communication module. We chose our components. We started schematic design of our project. We read datasheets of these components to do schematic design. After the schematic design, we started PCB (Printed Circuit Board) design in PCB designing program. We sent system's software to MCU which is in PCB. We tried functional working of system in electronic laboratory and real area. We looked system's conclusion by evaluating energy consumption and CO_2 emission.

II. THEORY

To develop this system, we must do schematic, PCB and box design in PC (personal computer) programs and we need to try these components in real areas.

a. Schematic Design

Before we started to schematic design, we selected required components. System's schematic design has three schematic page. These are sensor, CPU (Central Processing Unit) and communication pages. System's schematic design was designed with one PCB design program. One battery supply energy of system which is 3,6Volt. Another schematic page is magnetic sensor page. Magnetic sensor module has to three axis sensor. Module takes sensor's informations and sends to CPU. We did connection between module and CPU to communicate these IC (Integrated Circuit)'s. Third schematic page is a communication page. We use NB-IoT (Narrow Band Internet of Things) module in this page. We selected one NB-IoT antenna and we added antenna to this page.

b. PCB Design

First, we put our main components to our PCB for best positioning. We decided to put CPU and communication module to PCB's top layer. Because these have got too many connect. It must be very close. We put our magnetic sensor to PCB's top layer properly. Magnetic sensor must be on PCB's top layer. Because magnetic sensor will detect car. There must not be any barrier in front of sensor to get best performance from sensors. Our PCB also has NB-IoT communication which require antenna and RF routing. We selected one RF (Radio Frequency) designing tool on internet [6]. We enter our PCB's parameters to RF design tool to use Coplanar wave guide with ground in RF route. Results of simulating:

- Characteristic Impedance: 52,63ohm
- RF signal loss: 0,0488dB
- Delay: 0,1440ns

We found 50ohm for RF route with these parameters.

c. Working Tests of Device

First, working tests were done with object which includes metal. We looked that PCB was detecting metal object and it was sending detecting information to center. Then, we try doing these tests with a car on car parks. We set the PCB with its box to a car park and we observed that PCB was detecting car on park or not. We saw that PCB is working correctly. Therefore, there was not any problem PCB working.

Software is working with this algorithm. When the cars came to the car parks, device is detecting this car and we can see car detecting information on software. Magnetic sensor has three axes which x, y, z. If three axis's values are upper than 200. We can see "ARAÇ VAR" in software. If three axis's values fall below 100. We can see "ARAÇ ÇIKTI" in software. Therefore, we can understand that car park is empty or not.

d. Analysis Of Environment Conditions Which The Device Will Work And Device's Box Designing

Magnetic Park Sensor system works in ground. Top of device will be ground level. Therefore, system will face with too many bad conditions such as highest weather temperatures, lowest weather temperatures, water contact, another things which can fall on the sensor device, pressure which can occur when cars are passing on sensor device. All of these condition are very big risks for magnetic park sensor device.

We considered these risks while we were designing device's box. Because system may set too many different cities. For example, we can see different climate situations in Turkey. This system may set in east of Turkey which can be cold especially in winter or this system may set in south of Turkey which can be very hot in summer. Therefore, we preferred polyamide material for device's box. This material is a very stable, a bit hard and rigid. Box has got five feet to stay stable in box's place. Box has got 12 slots in side edges of box. These slots also are used to hold box in its places. These slots' height is 55milimeter. Another important point is water proof of box. We used oring gasket between box and box's cover. If we tighten the box's screws sufficiently. Box don't take water inside. Box passed IP68 test and we took IP68 certificate for device's box.

III. Results And Discussion

a. Detection of System's Benefits – Decreasing CO_2 Emissions of Cars

We wanted to calculate CO_2 emission calculations when the system is installed and not in the car park. First, we found Florya Social Facilities Car Park. This car park's density is changing according to days of week and hours of day.

If one person wants to find empty car park area in Florya Social Facilities Car Park. He must search empty car park area by going approximately 200mm. We did calculations by thinking that people use this car park once a day.

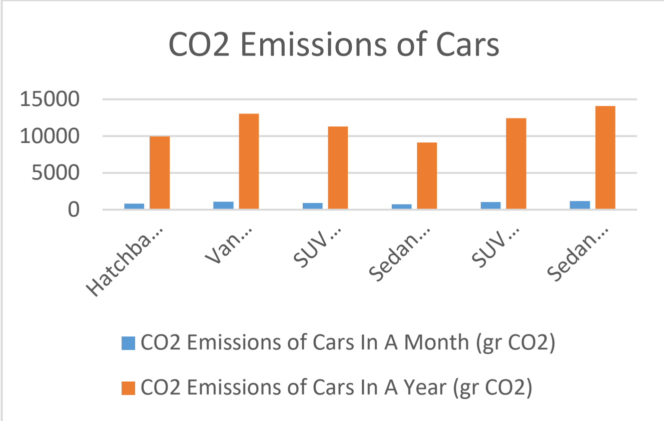

Fig. 3. CO_2 Emissions of Cars, Before System Isn't Installed On The Car Park

Graphic and table which are above show us CO_2 emissions of cars before system isn't installed on the car park. Then, we wanted to find out how much CO_2 emissions are reduced, if this system is installed in the car park. We detected that if the system is installed Florya Social Facilities Car Park, people will find empty car park area by going approximately 40m. We did calculations according to this situation and we found these values:

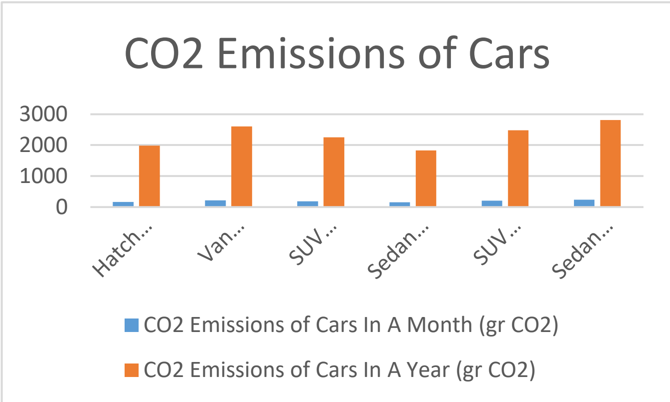

Fig. 4. CO2 Emissions of Cars, After System Is Installed On The Car Park

b. Detection of System's Benefits – Decreasing Fuel Consumptions of Cars

Second benefit of this system is decreasing fuel consumptions of cars. Because times of searching empty car park area of car users decreased, fuel consumptions of cars are decreasing significantly. Thus, we obtain too many fuel saving with this system. We selected Florya Social Facilities Car Park to calculate fuel saving of cars. We did calculations for 6 car types which is selected. We took fuel costs in 16.04.2019 for Istanbul in one seller's web site:

Gasoline cost: 6,99TL(Turkish Liras)/lt

Diesel cost: 6,36TL/lt

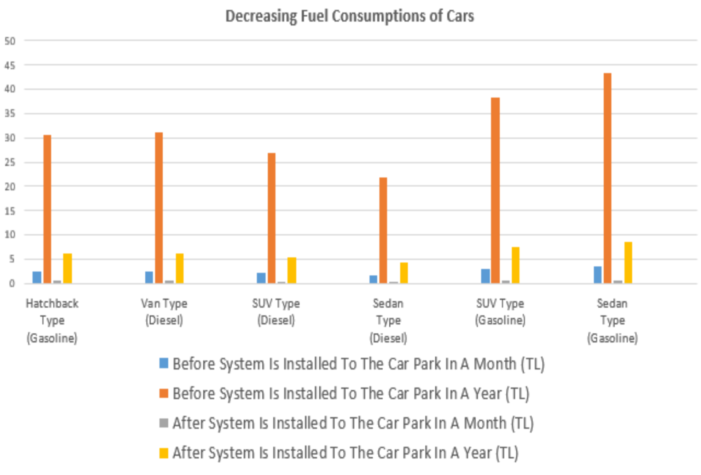

Fig. 5. Decreasing Fuel Consumption of Cars, After System Is Installed On The Car Park

IV. Conclusion

In this study, we wanted to design a device which can detect vehicles which is in the park, to decrease empty car park area searching time. After we designed the device, we did some calculations to find benefits of device. Because, empty car park area searching time by drivers decreased, we can obtain these benefits from system, such as decreasing CO_2 emissions, decreasing fuel consumptions, saving time, decreasing people's stress. We selected 6 car type to calculate this benefits. We selected Florya Social Facilities Car Park to calculations. We calculated that cars' CO_2 emissions, before the system is not installed to the car park. We made the calculations again after the system is installed to the car park. We made calculations of energy saving. We saw that after system is installed to the car park, we obtain significantly CO_2 emissions reduction and energy saving.

In this study, calculations are made for one car of selected types. If we think that, all cars which is in the city, use the system, we can obtain too many energy and CO_2 emission saving from the system. If the system is installed to all car parks of city, energy savings and CO_2 emissions savings reach maximum level. This situation is very important for our environment.

References

[1] M. Karakaya and F.C. Akıncı, (2017), Şehirlerin dijital dönüşümü: görüntü işleme yöntemlerinin boş park yerlerinin tespitinde kullanılması, 34th National Informatics Congress Proceedings Book. Ankara: Atılım University, 69-73.

[2] A. Akbaş, İ. Kösesoy, İ. Delibaşoğlu, (1-2 December 2011), GMR sensörler ile gerçek zamanlı trafik verilerinin elde edilmesi için bir gömülü sistem tasarımı, National Public Transport Symposium and Exhibition, İstanbul: Istanbul Metropolitan Municipality, 53-57.

[3] S. Gürbüz, (2012), Dikgen eşleştirme algoritmasıyla ferromanyetik hedef konumlama ve tanıma, 20th Signal Processing and Communications Applications Conference (SIU), Ankara: IEEE.

[4] S. Thirumal and M. Ushakiranmai, (2015), Design portable sensors system for vehicle counting, classification and speed measurement in traffic junctions, International Journal Of Professional Engineering Studies, Semantic Scholar.

[5] F. Yalçınlı, (2013), Algılama ve özellik çıkartma tabanlı manyetik araç sensörü tasarımı, Selçuk University, Graduate School Of Natural Sciences.

[6] Coplanar Waveguide Analysis/Synthesis Calculator, http://wcalc.sourceforge.net/cgi-bin/coplanar.cgi.

[7] Opet Petrolcülük A.Ş., (2019). Fuel Prices for Istanbul, https://www.opet.com.tr/istanbul-akaryakit-fiyatlari.

Design and Analysis of Dual Band Pass Filter

Amina Puran

Faculty of Engineering and Natural Science Department of Electrical and Electronics Engineering International University of Sarajevo

Sarajevo, Bosnia and Herzegovina
aminapuran@gmail.com

Abstract- In this work dual band meandered line bandpass filter is designed and simulated. Anlaysis are done while changing specific parameters, which includes mostly geometry and some material characteristics like dieletric thickness and metal types. This filter has compact structure which is one of the main benefits. It has many applications in industry and that is what makes work on it very interesting. Values for S11 parameter are -20.70dB and -41.72 dB for 4.9GHz and 5.5GHz, respectively. Values for S12 parameter are -0.03dB and -2.91e-4dB for 4.9GHz and 5.5GHz, respectively.

Keywords: filter, dual bandpass filter, microstrip, cut-off frequency, Q factor, microwave

I. Introduction

Dual bandpass filter is a simple design of microstrip filter. It is very compact with box dimensions 40x40mm. Main applications of this type of filter are in manufacturing wireless transmitters and receivers [1]. Real circuit of dual band pass filter would combination of the low-pass filter and high-pass filter, which means that at certain range of frequency we will have two reversed signals. In practice ideal band-pass filter does not exist so we expect certain loss in ouput signal [2]. Frequency ranges are given in dB which is the most convenient way for our design and analysis. Since this is dual band-pass filter we have two cutt-off frequencies. Important characteristics of every band pass filter is Q factor. Our design has low Q factor which means that it gives narrow band pass frequency range. This important factor gives us possibility to name our design narrow band pass filter. Main characteristics of design are given as follows:

- Dielectric constant ε_r=4.4 (Quartz-fused)
- Frequency range of 4.8-4.9GHz and 5.4-5.5GHz
- Box size 40x40mm
- Cell size 0.2x0.2 mm

II. Design Methodology

Design is shown in figure 1 while output response is shown in figure 2. Output signal gave satisfactory results with input match S11 and transmission coefficient S12. However, it would be better if we got wider band. For future work we recommend work on that issue. Design and analysis are done in Sonnet software [3].

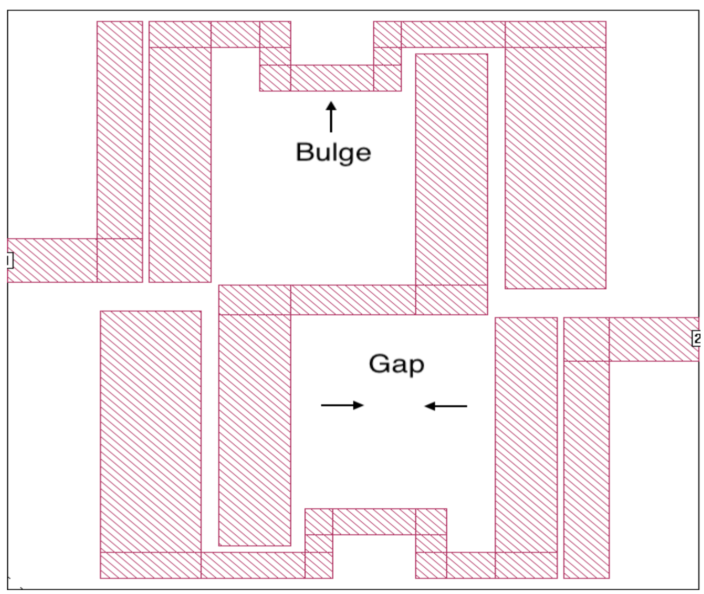

Figure 1. Design of the Dual Band Pass Filter

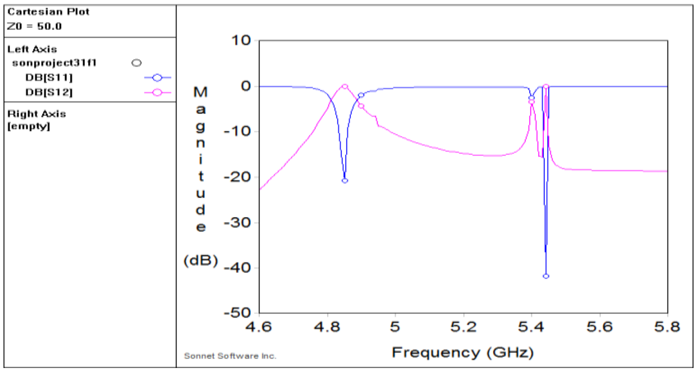

Figure 2. Output signal of the Dual Band Pass Filter simulation

As measure unit millimeters are chosen since those are the most convenient according to European standards and our proposed design. For dielectric material Fr-4 with dielectric constant 4.4 is chosen since it is commonly used, easiest for fabrication and gives good performance. Similar situation is with choosing the metal type of the filter. Copper is found to be the best since it is cheapest and gives good performance. Source impendance is given as usual common value of 50 Ohms. For cell size, 0.2 mm is taken. It gives fast response of simulation since our box size is quite small. If you choose larger than simulations take much more time to finish, making filter slower and unstable with huge deviations in ouput signal.

III. Parameters Variations

As mentioned above main studies are done examining the changes in geometry. The main parameters to evaluate the performance of any filter are S-parameters, input match, insertion loss and VSWR (Voltage Standing Wave Ratio). The S parameters are important concept in microwave design since it is easy to measure and indicate the results of output signal. Note that values for S parameters are given in decibels (dB). Output of the signal is shown in Figure 2 in the form of Cartesian plot. Blue line represents S11 (input match) and pink S12 (insertion loss or attenuation of the signal). Table I, II and III provides information about signals while changing distance of the bulge, gap and dielectric thickness respectively. Increasing the bulge distance resulted in very unstable results for S11 parameter in 2nd frequency range. Although, changes in other parameters are quite predictable.

TABLE I CHANGING DISTANCE OF THE BULGE

Distance	S11	S12	S11	S12
0.3mm	-20.70	-0.03	-41.72	-2.9e-4
0.32mm	-22.63	-0.02	-21.37	-1.3e-4
0.34mm	-22.44	-0.02	-17.39	-0.07
0.36mm	-20.19	-0.04	-19.63	-0.04
0.38mm	-17.84	-0.07	-14.28	-0.16

As mentioned above, even small changes in geometry affect final output signal. Filters are sensitive devices. From all geometry changes we have done, largest changes are in variety of bulge and gap (look figure 1). We were decreasing the gap width and results are shown in Table 2.

TABLE II CHANGING THE GAP WIDTH

Gap	S11	S12	S11	S12
11.8mm	-20.70	-0.03	-41.72	-2.9e-4
12.0mm	-20.07	-0.04	-16.19	-0.10
12.2mm	-30.20	-4.1e-3	-2.93	-3.09
12.4mm	-33.50	-1.9e-3	-2.12	-4.12
12.6mm	-27.09	-8.4e-3	-9.4	-26.72

Referent dielectric thickness is 1.60. We made very small changes in increasing and decreasing that value by 0.1mm. Results are shown in Table 3.

TABLE III CHANGING DIELECTRIC THICKNESS

Dielectric T.	S11	S12	S11	S12
1.58mm	-35.85	-1.1e-3	-18.40	-0.06
1.59mm	-28.37	-4.2e-3	-12.03	-16.39
1.60mm	-20.70	-0.03	-41.72	-2.9e-4
1.61mm	-18.09	-0.06	-10.03	-16.21
1.62mm	-23.07	-0.01	-16.75	-1.02

IV. Conclusion

Dual Band Pass with our proposed design is affordable, simple, small, compact device. This type of the filter plays huge rule in wireless communication and microwave technologies [4]. Simulations in Sonnet software are done in 2 minutes which represents the high-speed response. This feature is quite important for various applications. When designing and analyzing filters we must know that there is no perfect filter. There are many different influences from components of which filter is composed that affect output signal. However, we can design components in a way to get signal near ideal. Values for S11 parameter are -20.70dB and -41.72dB for 4.9GHz and 5.5GHz respectively. Values for S12 parameter are -0.03dB and -2.91e-4dB for 4.9GHz and 5.5GHz, respectively. However, bendwith can be optimized using different techniques. These filters have applications also in signal processing. From results we can obtain that this filter has its losses. However, they are very small so can be neglected. Filter with narrow band-pass are found demanding in modern technologies [5].

ACKNOWLEDGEMENT

We would like to thank to International University of Sarajevo for providing us software accessibility.

REFERENCES:

[1] G. Sharma, S. Sharma, S. Bhullar, N. Kumar, S. Chauhan, "Design and simulation of compact hairpin band pass filter", International Journal of Modern Communication Technologies & Research (IJMCTR), ISSN:2321-0850, Volume-2, Issue-4, April 2014

[2] D. Yadav, T. Moyra, K. Debbarma, "Microstrip Hairpin Bandpass Filter with Improved Out of Band Performance", Conference Paper, March 2014

[3] Sonnet Suites, ver. 17.52. Szracuse, New York

[4] G.-L. Wu, W. Mu, X.-W. Dai, and Y.-C. Jiao, "Design of Novel Dual-Band bandpass filter with microstrip meander-loop resonator and CSSR DGS", National Key Laboratory of Antennas and Microwave Technology Xidian University, Xi'an 710071, China

[5] N. N. Hussain, J. K. Ali, "A New Narrow Band Dual-Mode Miniaturized Bandpass Filter for Wireless Communication Systems", Eng. & Tech. Journal, Vol.27, No.10, 2009

A 6 dB Microstip Coupler

Ows Wael Albitar & Ejub Bilajbegovic
Department of Electrical and Electronics Engineering
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina

***Abstract* - This paper introduces a new configuration of the microstrip 6 dB coupler with a new design. In the following paper we examine and study a coupler which operates on high frequencies which are between 9GHz to 11GHz. The results of the following experiment are shown using Sonnet software with excellent performance of the coupler with great isolation characteristics.**

Keywords—microstrip coupler; high frequinces ; Sonnet software

I. Introduction

Couplers nowadays are most popular in the field of radio technology filters, The recent progress in the wireless communications and radar systems is accompanied with the increasing demands on the broadband passive microwave components with high electrical characteristics [1]. The coupler is usually used to split the input signal and the distributed power and they are made up of four ports, each port has its own functions in the coupler. The frequency shift in the reflected waves, due to the motion of an object toward (or away from) the receiver, results in a signal at low frequency [2].

In this paper, we show the response of a 6 dB coupler which works with the frequencies of 9GHz to 10.5GHz on sonnet, However, the microstrip directional couplers suffer from poor directivity due to characteristic of the inhomogeneous dielectric including both dielectric substrate and air in microstrip transmission lines [3]. In addition, it is difficult to achieve tight coupling owing to impractical spacing between the coupled lines in conventional edge coupled microstrip couplers [4]. But in real life it is not as easy as the calculation work to achieve the aimed goals, and even if the aimed values are achieved in a simulation program such as sonnet, when it goes to the fabrication part, it will not be as accurate as wished, therefor, some actions need to be made in order to have our coupler work as close as wished, some tables are made with small changes of design parameters to make sure that the coupler performs its functions as it supposed to do so. This performance is then enhanced by subsequent signal processing which, after amplification, is digitized using an analogue/digital convertor. Simulations were performed by using planer 3D electromagnetic software, called Sonnet [5].

IV. Design and simulation results

The 6 dB coupler design in this study is designed in Sonnet software which is made up of 4 ports with each port with its own function, port 1 works as the input work in the coupler, port 2 behaves as the transmitted port, while port 3 is the coupled port, and the final port does the isolation part in the coupler. The configuration can be seen in Figure 1.

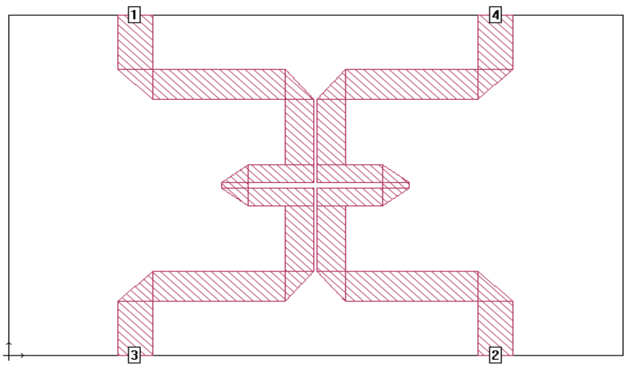

Fig. 1. Configuration of the proposed 6 dB coupler

Conventionally, All simulations performed are created and analyzed in the Sonnet software, the resulting image is Fig. 2, which gives us an image of the frequency of the coupling between 9 and 11 GHz. In the picture it is easy to see that coupling is about 6dB, more precisely it varies between 6.35dB to 6.25dB, where 6.35dB is the result of the measurement at the beginning or 6.25dB at the end of the graph. In the picture you can also see that the isolation generated by four ports of our coupler is around 25dB. At the beginning it is around 15dB, with the increase of the GHz also the value of the isolation increases. In our simulation we analyzed S11, S12, S13 and S14, as shown down in the figure. The green linear line corresponds to S13, which is stable through the analyzed range. S11 is represented by the blue line, and S12 by the purple line. Those lines are steeply declining as the inductance is increasing. S14, which is red line, is stable. If the impedance is increasing a shift of the center frequencies will occur, which is not shown in figure 2. Throughout changing our values, we realized a sharply frequency shifts before the 9GHz mark, which might be a result of a simulation error. All measured results with different values are near the original result differing in 0,5dB, and did not change the frequencies much.

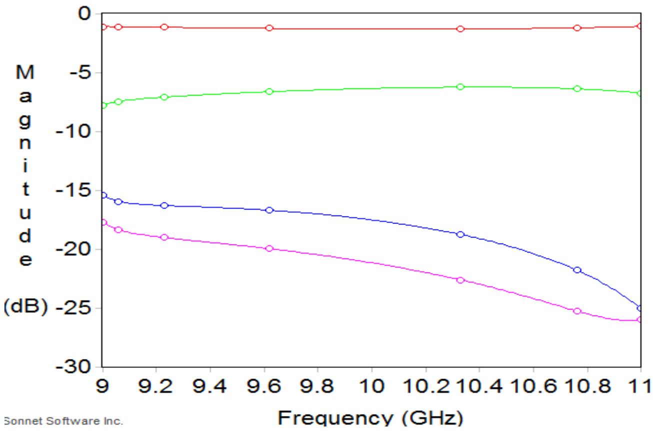

Fig. 2. Results of the simulation

Relative phase difference in the coupler plays an important role in the design of a microstrip coupler as it shows the importance of achieving dimension extraction in order to accomplish a great network performance using the microstrip coupler. In our case, ports s11 and s14 were used as the output ports and the relative phase difference is approximately 90° as it is shown down below in figure 3.

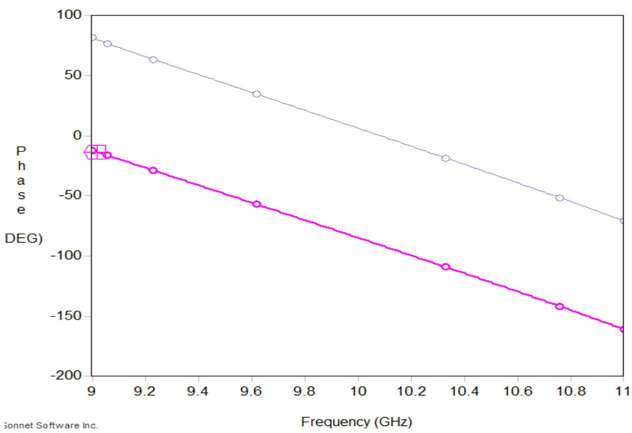

Fig. 3. Phase difference between the output ports

V. Parametric Study

In the following parametric study, using different variations and dimensions which are as close to the main dimensions to have our coupler work as designed even after going through the fabrication process of the coupler.

One of the most important components to take into consideration while designing the coupler is the dielectric both its thickness and density as we have the thickness shown in Table II with 0.76mm as our main value and density of the dielectric is shown in Table III with 3.5 as our main density, which plays a big role in our study, the dielectric is the electrical insulator which is being polarized by the applied electrical field. We have also taken into consideration separation of lines at the center which separates the upper and the lower ports between each other by changing their

dimensions with 0.5mm each time as we have 0.3mm as our main dimension which is shown in Table I as S1. Lastly, we took the length of the meander lines at the center into account as well by moving it 1mm each time as we standardize 3.2mm as our main length which is shown in Table IV as S3.

Table I SEPARATION LINES

S1 VALUES (mm)	**COUPLING (dB)**	
	9 Hz	**10 Hz**
0.4	**-6.41**	**-6.36**
0.3	**-6.41**	**-6.32**
0.3	**-6.35**	**-6.25**
0.25	**-6.30**	**-6.18**
0.20	**-6.29**	**-6.16**

Table II DIELECTRIC THICKNESS

ETH Values(mm)	**COUPLING (dB)**	
	9 Hz	**10 Hz**
0.8	**-6.09**	**-5.99**
0.78	**-6.21**	**-6.11**
0.76	**-6.35**	**-6.25**
0.74	**-6.45**	**-6.39**
0.72	**-6.64**	**-6.54**

Table III DIELECTRIC DENSITY

ER VALUES (Density)	**COUPLING (dB)**	
	9 Hz	**10 Hz**
3.6	**-6.32**	**-6.30**
3.55	**-6.33**	**-6.27**
3.50	**-6.35**	**-6.25**
3.45	**-6.37**	**-6.23**
3.40	**-6.39**	**-6.22**

Table IV LENGTH OF MEANDER LINES

S3 VALUES (mm)	**COUPLING (dB)**	
	9 Hz	**10 Hz**

3.4	**-6.48**	**-6.73**
3.3	**-6.29**	**-6.32**
3.2	**-6.35**	**-6.25**
3.1	**-6.36**	**-6.14**
3.0	**-6.42**	**-6.07**

VI. CONCLUSION

The 6 dB coupler which we have constructed meets the requirements for a coupler which has great performance, low losses, economical with its low costs. The region which this coupler operates is from 9GHz to 11GHz which results in a magnitude of 6 dB which could be used in several future projects in fields such as radio technology.

ACKNOWLEDGEMENT

We would like to thank Professor Sehabeddin Taha Imeci for his guidance throughout the process of simulating the coupler and writing its paper.

REFERENCES

[1] V. S. Nune , B. S. Babu1 “design of a 6db directional coupler using defected ground structure”/ International Journal of Engineering & Science Research, IJESR/ Vol-4/Issue-7/541-546/July 2014

[2] V. V. Shekhovtsov, V. A. Sledkov, G. P. Pischenko, M. G. Pischenko, M. B. Manuilov, Southern Federal University “design of broadband strip-line directional couplers with improved “, 2014 24th Int. Crimean Conference "Microwave & Telecommunication Technology" 7-13 September, Sevastopol, Crimea, Russia

[3] G. Sanna , G. Montisci , Z. Jin, A. Fanti, G. A. Casula, “Design of a Low-Cost Microstrip Directional Coupler with High Coupling for a Motion Detection Sensor” , Electronics 2018, 7, 25.

[4] S.S. Pai , M. Kumar , K. Singh, “Design and Performance Analysis of lumped and distributed 6-dB micro strip coupler topologies at S-band” International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) Volume 6, Issue 5, May 2017

[5] Sonnet Suites, version 17.52, Syracuse, NY.

Tri Resonance Multi Slot Patch Antenna

Kemal Temur, Sehabeddin Taha Imeci
International University of Sarajevo - Department of Electrical and Electronics Engineering

Abstract: In this work, tri resonance multi slot microstrip patch antenna which operates at three center frequencies of 11 GHz, 11.9 GHz, 15.7 GHz is designed and simulated. As a commercial simulation tool, Sonnet Suites a planar 3D electromagnetic simulator was used. Details of the simulation results are presented and discussed. As a result, an input match of -6.88 dB at the resonance frequency of 11 GHz, an input match of -37.12 dB at the resonance frequency of 11.9 GHz, an input match of -29.49 dB at the resonance frequency of 15.7 GHz were observed. The gain was observed as 8.25 dB at 11 GHz and 4.82 dB at 11.9 GHz. Also, the gain was observed as 7.07 dB at 15.7 GHz. The patch have several symmetric slots and it's well known that slots change the current distribution of the patch antenna.

Keywords: Sonnet Suite, patch antenna, multislot, multi resonance.

I. INTRODUCTION

The demand for conformability, portable, low cost, light weight antennas has increased in this high-tech era. Microstrip antennas are attracting much attention in broad range of multifunctional wireless communication systems [1].

The patch and the ground plane may have various geometric configurations and input impedances are usually 50 Ω or 75 Ω. Thus, tri resonance micro slot patch antenna that can operate at more than one frequency are desired. A single wide-band antenna may fulfill the requirement but on account of receiving more than one frequency band at the same time and consequently is prone to interference [2].

They have some limitations, especially narrow bandwidth. So different antennas that are needed for different applications will cause a limited space problem. Re-searchers think that multiband antennas provide solutions. A multi-band antenna can be made by changing the antenna shape [3].

There are numerous and well-known methods to increase the bandwidth of antennas, including increasinge of the substrate thickness, the use of a low dielectric substrate matching and feeding techniques, frequency change and the use of slot

antenna geometry. Many techniques have been reported to reduce the size of microstrip antennas at a fixed operating [4].

Multi slot antenna would allow a single to resonate at multiple frequencies, so that by adjusting their number, shape, width and their positions with respect to each other within the patch, the selection of the desired set of bands is easily achieved the main purpose is to desing a microstrip patch antenna systems in the range of 11 to 22GHz [5].

These different studies have been reported in the literature studies of antennas with different frequency and bandwidths.

II. MICROSTRIP PATCH ANTENNA

The geometry of the slot antenna is shown in Fig. 1. The size of the antenna is 48x64 mm. The antenna is designed on dielectric substrate whose having a thickness and permittivity are 1 mm and 4.3, respectively. The antenna consists of square slots and rectangle slots.

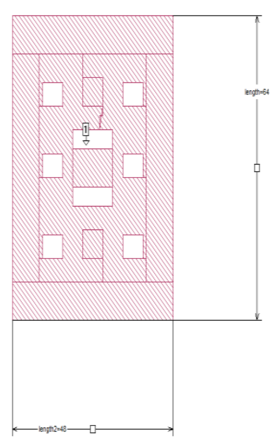

Fig. 6. The top view of the antenna

III. ANALYSIS RESULTS

Input match as a result of simulations performed was observed as shown in Figure2.

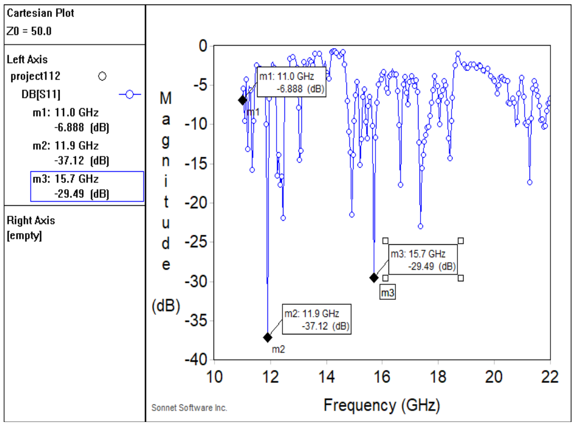

Fig. 2. Input match of the antenna

The simulated and measured radiation patterns of the antenna at its resonance in the elevation-cut plane (phi = 0° and phi = 90°) have been illustrated[6].In the frequency of 11 GHz, as can be seen in Figure 3, 8.25 dB directional gain at ϴ =∓60° was obtained the electric field ϴ polarization. Cross polarization level is less than –5dB.

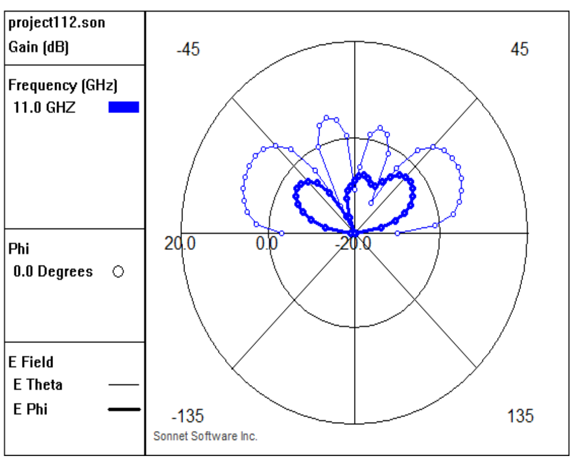

Fig. 3. Radiation pattern of antenna at 11 GHz

In the frequency 11.9 GHz with a input match value of -37.12 dB, as seen in Figure 4, 4.82 dB directional gain was obtained in the electric field ϴ polarization at theta =45°. Cross polarization level is less than –7dB.

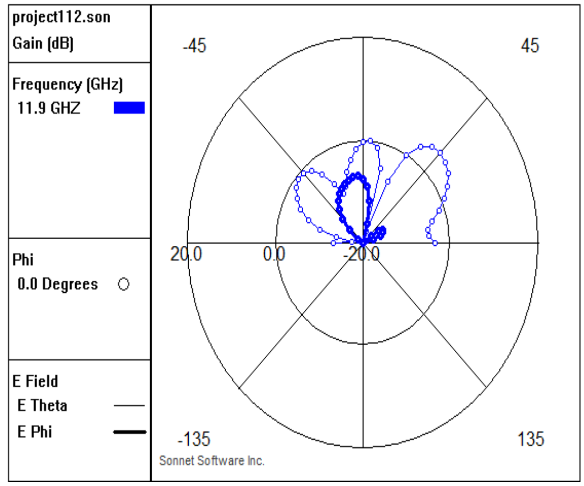

Fig. 4. Radiation pattern of antenna at 11.9 GHz

In the frequency 15.7 GHz with a input match value of -29.49 dB, as seen in Figure 5, there was a 7.077 dB directional gain at theta = 0° in the electric field ϕ polarization. Cross polarization level is less than –9 dB.

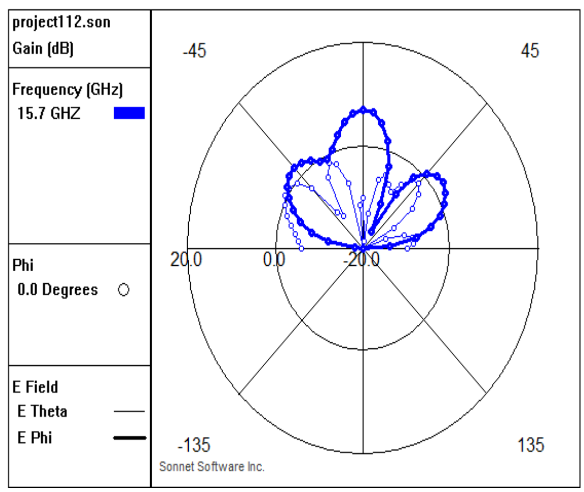

Fig. 5. Radition pattern of antenna 15.7 GHz

A parametric study was conducted in order to see the fabrication tolerances of the antenna. The changes which are; slot size, dielectric thickness, dielectric(air) thickness and dielectric constant; made in the patch geometry helped to improve design parameters such as return loss, gain, resonance frequency and impedance[7]. The optimization of the air layer thickness results are seen in Table 1.

TABLE 1 OPTIMIZATION OF THE AIR LAYER THICKNESS

Air thickness (mm)	Magnitude (S11:dB)	Resonance Freq.(GHz)	Gain(dB)
11	-6,88	11	8,25
	-37,12	11,9	4,82
	-29,49	15.7	7.07
11.25	-5,44	11	8.24
	-39.02	11,9	4.85
	-29.95	15.7	7.08
11.3	-6.79	11	8.24
	-39.42	11.9	4.86
	-30.048	15.7	7.08

IV. CONCLUSION

In this paper, a tri resonance multi slot patch antenna have been presented[8]. Different methods for miniaturization of a square microstrip patch were studied and a novel fractal patch with multiple-slots was developed[9].In this design, a microstrip patch antenna that is desired to run between 11-22 GHz frequency values has been realized. Gains observed in 3 frequencies. At 11 GHz, the gain of the antenna is 8.25 dB and at 11.9 GHz the gain of the antenna is 4.82 dB and, also at 15.7 GHz the gain of the antenna is 7.07 dB.

V. REFERENCES

[1] J. J. Tiang, M. T. Islam, N. Misran and J.S. Mandeep, Cırcular Mıcrostrıp Slot Antenna For Dualfrequency Rfıd Applıcatıon. Progress In Electromagnetics Research, Vol. 120, 499–512, 2011.

[2] K. M. Younus, K. H. Sayidmarie, A Tri-Band Frequency Reconfigurable Slot Antenna for Wireless Applications. Aces Journal, Vol. 35, No. 2, 2020.

[3] Md. Samsuzzamana, M. T. Islamb, M. R. I. Faruque, “Dual-band Multi Slot Patch Antenna for Wireless Applications”. Journal of telecommunications and information technology. 2013.

[4] S. K. Patel, Y. P. Kosta, “Meandered Multiband Metamaterial Square Microstrip Patch Antenna Design”. Waves in Random and Complex Media 22(4):475-487. DOI: 10.1080/17455030.2012.723837, 2012.

[5] S. Mingle, I. Hassoun, “Compact Fractal Slots of Multi-Resonant Patch Antenna Base on Smith Chart Configuration”. 10th International Conference on COMmunication Systems & NETworkSAt: India, 2018.

[6] Jana, B. Sinhamahapatra, S. Dey, A. Das, B. Datta, M. Mukherjee, S. K. Chowdhury and S. Chatterjee, “ Single Layer Monopole Hexagonal Microstrip Patch Antenna for Satellite Television” International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2, Issue-6, January,2013.

[7] N. Keskin, U. Saka and T. İmeci, “U-Shaped Microstrip Patch Antenna” 28th Annual Review of Progress in Applied Computational Electromagnetics, April 10-14, 2012

[8] K.-F. Lee, K.M. Luk, “Design of small size wide bandwidth microstrip patch antenna” IEEE Antennas and Propagation Magazine 45(1):75 – 83, 2003.

[9] A. Aggarwal, M. V. Kartikeyan, “Pythagoras Tree: A Fractal Patch Antenna For Multı-Frequency And Ultra-Wıde Band-Wıdth Operatıons” Progress In Electrompatnaikagnetics Research C, Vol. 16, 25,35, 2010.