Journal of Materials Science and Engineering B 7 (3-4) (2017) 77-80
doi: 10.17265/2161-6221/2017.3-4.004

DAVID PUBLISHING

# Design of Band Stop Filter with Frequency Selective Surfaces Analysis by Implementing the Golden Ratio Rule

Mehmet Duman[1] and Merve Güney Duman[2]

*1. Electronics and Communication Engineering, Faculty of Engineering, Kocaeli University, Kocaeli 41380, Turkey*

*2. Mathematics, Faculty of Art and Sciences, Sakarya University, Sakarya 54000, Turkey*

**Abstract:** The designs which are made with FSS (frequency selective surfaces) analysis can be in different shapes and sizes. Square, round, plus, triangle, snowflake etc. are some of them. In this article, BSF (band stop filter) is designed by using FSS with the Golden Ratio Rule which is found by Fibonacci. In Golden Ratio Rule, each number is the sum of two numbers coming before that number and the ratio of every sequential number equals approximately 1.618, exact 1.618 at last. In design, Golden Ratio Rule is used while forming thickness, width and length. All of the simulations are run in CST (computer simulation technology) computer program between 700 MHz and 1,700 MHz in frequency domain section. There is not any active or passive component in the design. Only 80 cm × 130 cm copper plate and the shapes over it, the BSF with 1.35 GHz CF (center frequency) and 41 MHz BW (bandwidth) frequency is formed and has become ready to perform. If shapes and sizes are changed while preserving the ratio, it can be reachable different CF and BW frequencies. After obtaining the OF, the design will block the electromagnetic effects in accordance with BSF, and electric or magnetic waves cannot transmit from the copper plate, as a result; harmful side effects can be stopped.

**Key words:** BSF, frequency selective surfaces, Golden Ratio Rule.

## Nomenclature

| | |
|---|---|
| FSS: | frequency selective surfaces |
| BSF: | band stop filter |
| BPF: | band pass filter |
| CST: | computer simulation technology |
| UHF: | ultra high frequency |
| MHz: | megahertz |
| GHz: | gigahertz |
| IEEE: | The Institute of Electrical and Electronics Engineering |
| LNA: | low noise amplifier |
| PA: | power amplifier |
| RADAR: | radio detection and ranging |
| dB: | decibel |
| BW: | bandwidth |
| CF: | center frequency |
| OF: | operating frequency |

**Corresponding author:** Mehmet Duman, Ph.D. student, research assistant, research fields: microwave and millimeter wave engineering, electromagnetism, antennas and active circuits.

## 1. Introduction

The BSF (band stop filter) and BPF (band pass filter) are very important sections of the electronic circuits especially in electromagnetics. These filters can be designed by singular elements like capacitors, inductances and resistors. Moreover, with only microstrip lines, filters can be designed easily. In this paper, the BSF is designed with another technique which is FSS (frequency selective surfaces) analysis. There are some shapes on the copper plate and FSS analysis is applied to the plate. CST (computer simulation technology) Computer Program is used to simulate the filters. The shapes on plate are designed by using Golden Ratio Rule that is found by Fibonacci. The Golden Ratio Rule FSS technique is absolutely new and unique technique. The shape looks like solenoid on the 80 cm × 130 cm copper plate. 1.35 GHz is the CF (center frequency) of the filter and it has 41 MHz BW (bandwidth) frequency. The simulations were done between 700 and 1,700 MHz, UHF and L band according to IEEE standards. Thanks to this FSS unit the un-wanted signals can be stopped between OF limits.

## 2. Dimensions and Characteristics

The copper plate has 1 mm thickness and 80 mm × 130 mm dimensions as mentioned. There are 5 quarter circles on the plate. Each quarter circle connected to the other. The circles are designed and subtracted from the plate in compliance with the golden ratio rule.

### *2.1 Dimensions*

The quarter circles expand and merge each other from the bottoms consecutively. In Fig. 1, all unit are given. If the dimensions change, the BW frequency and CF can be different. The desirable frequency will be reachable by tuning the dimensions. The inner and the outer radii of the circles are given in Table 1.

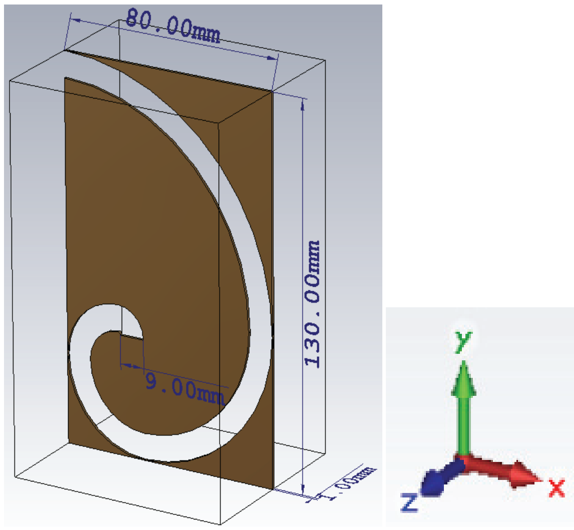


**Fig. 1 Dimensions of the copper plate and the shape on it.**

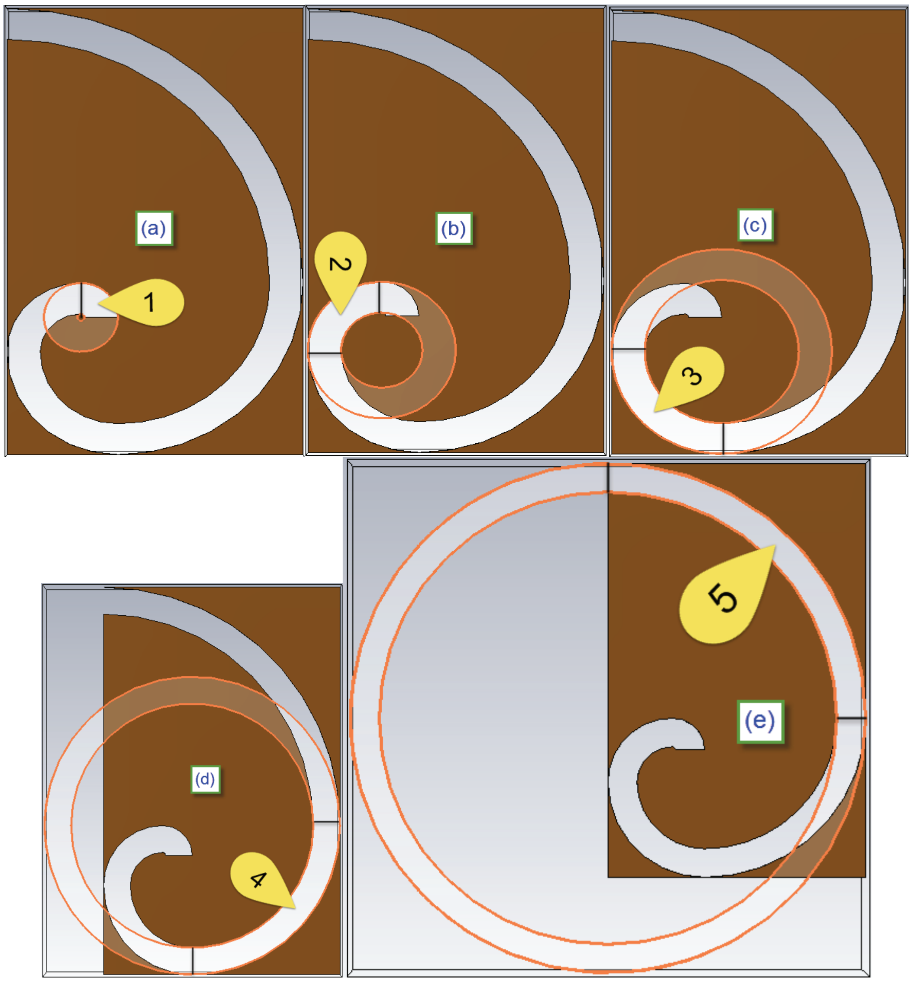


**Fig. 2 (a-e); 1-5; quarter circles.**

**Table 1 Circles dimensions.**

| Circle number | Inner radius [mm] | Outer radius [mm] |
|---|---|---|
| 1. Circle | 1 | 10 |
| 2. Circle | 11 | 20 |
| 3. Circle | 21 | 30 |
| 4. Circle | 41 | 50 |
| 5. Circle | 71 | 80 |

*2.2 Characteristics*

The analyses and simulations are run on the CST computer program. In this program, the type of plate can be chosen. The copper material was used in this design. It is lossy metal in the design and the other figures of merits are given below.

Type: Lossy Metal

Mue: 1

El. Cond.: 5.96e + 007 [S/m]

Rho: 8,930 [kg/m$^3$]

## 3. Golden Ratio in Shapes and Copper Plate

Fibonacci's Golden Ratio Rule is used and implemented both shape and plate.

*3.1 Rule in Shape*

The solenoid or spiral shape is seen on the plate or in Fig. 3. Both of them are very similar and indicator of the Golden Ratio Rule. In the nature as galaxies, plants, animals, insects ect., the Golden Ratio can be observed. In architecture, such as pyramids and mosques, the Golden Ratio Rule can be observed too.

*3.2 Rule in Plate*

$$1, 1, 2, 3, 5, 8, 13, 21, 34, \ldots \quad (1)$$

It is the Fibonacci Sequences in Algebra Discipline. Each number is the sum of two numbers coming before that number. The ratio of sequential numbers is 1.618 at last (infinite or far enough). This special number, 1.618, was obtained from most of the part of the copper plate. Values of a, b, c and d in Fig. 3 are given in Eq. (2). The values may be different from design to design but the ratio should be the same.

$$a = 13,\ b = 8,\ c = 5,\ d = 3 \quad (2)$$

$$a = b + c,\ b = c + d \quad (3)$$

$$\frac{a+b}{a} = \frac{21}{13} \cong 1.618,\ \frac{a}{b} = \frac{13}{8} = 1.625 \quad (4)$$

$$\frac{b+c}{b} = \frac{13}{8} = 1.625,\ \frac{b}{c} = \frac{8}{5} = 1.6,\ \frac{c}{d} = \frac{5}{3} = 1.666 \quad (5)$$

## 4. Results and Simulations

Unless width of the plate, width and length of the shape, type of the plate etc., are changed, the CF and BW frequency and $S_{11}$ value (input reflection coefficient) remain same. When different values of frequency are needed, the FSS unit can be designed again easily. $S_{11}$ value should be under -20 dB for good and useful BSF, in this design it is -66.1 dB. The calculation of BW is shown in Eq. (7).

$$\text{Center Frequency} = 1.356 \text{ GHz} \quad (6)$$

$$1.376 - 1.335 = 41 \text{ MHz} \quad (7)$$

The important section of the input reflection coefficient graph can be seen in Fig. 4. This BSF can be used in active circuits (LNAs, oscillators, mixers, PAs) or passive circuits (video amplifiers or normal electric circuits). It can also be used with microstrip structures and complex units as RADAR.

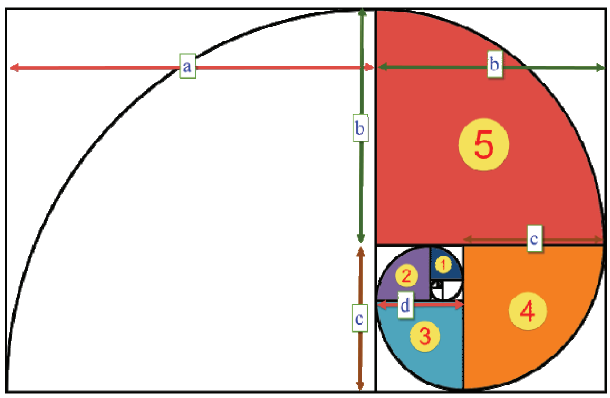


**Fig. 3 Geometric rule shape in FSS.**

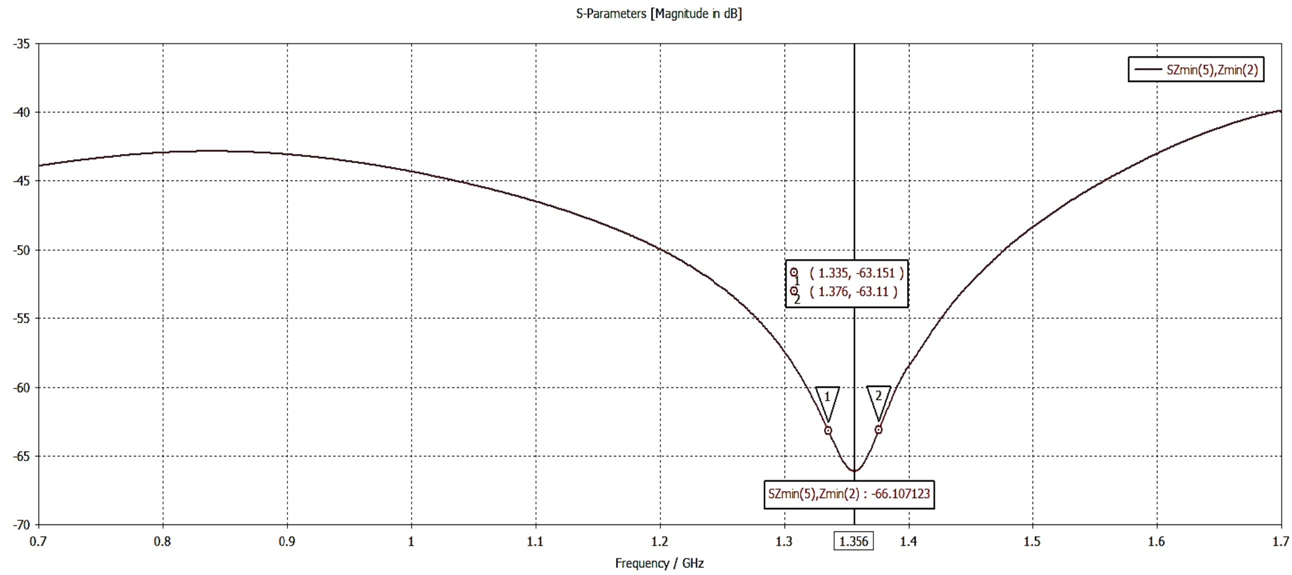


**Fig. 4 The graph of the CF, BW frequency and $S_{11}$ in dB for the BSF designed with FSS analysis.**

## Acknowledgments

The authors express their thanks to the Düzce University and TÜBİTAK for their supports and assistances.

## References

[1] Balanis, C. A. 2013. *Anten Teorisi Analiz ve Tasarım*, (3rd ed.). Nobel Publishing, Wiley.

[2] Munk, B. A. 2000. *Frequency Selective Surfaces: Theory and Design.* New York: Wiley.

[3] Cripps, S. C. 1999. *RF Power Amplifiers for Wireless Communications*. Boston: Artech House.

[4] Pozar, D. M. 1998. *Microwave Engineering*. Hoboken: John Wiley & Sons Inc.

[5] Cheng, D. K. *Field and Wave Electromagnetics*, (2nd ed.). Syracuse University, New Jersey: Addison-Wesley Publishing Company.

[6] Duman, M. 2016. "Altın Oran Kuralı ile Oluşturulan Metal Plaka Bant Geçiren Filtre ve Altın Oran Kuralı'nın Filtreye Etkisi." In *24. SİU,* Zonguldak, Turkey.

[7] Duman, M., and Güney Duman, M. 2017. "Design of Band Stop Filter with Frequency Selective Surfaces Analysis by Implementing the Golden Ratio Rule." In *ICETI,* Sarajevo.

[8] Duman, M., Güney Duman, M., and Güney, T. 2016. "Akıllı Sistemler için Frekans Seçici Yüzey Analizi ile Oluşturulmuş Bant Durduran Filtre Tasarımı." In *ASYU,* Düzce, Turkey.