Indonesian Journal of Education & Mathematical Science
Vol. 5, No. 3, September 2024, pp. 157~164
ISSN: 2715-985X, DOI: 10.30596/ijems.v5i3.16326

Simulation Design Bandpass Filter Microstrip Center Frequency 113 Mhz Using Hairpin Structure

Jonathan Japalti Banjarnahor [1], Muh. Wildan [2], Aringga Zulkarnain [3]
[1,2,3]Politeknik Penerbangan Indonesia, Tangerang, Indonesia
Email: nathnbjrnahor13@gmail.com

ABSTRACT

Bandpass filter is an important component in aviation equipment that functions to pass the desired frequency and to stop unwanted frequencies. In this research, the simulation design was carried out with a bandpass filter microstrip which works on the center frequency 113 MHz using hairpin structure for the receiver navigation analyzer system. This system is one of the systems installed in drone in implementation ground inspection for ILS/VOR equipment. Bandpass filter is designed using a simulation software with various dielectric materials / substrates, such as R04350, FR-4, and RT5880, for comparison purposes. The simulated parameter values obtained include return loss, insertion loss, and bandwidth.

Keyword : bandpass filter, return loss, insertion loss, bandwidth, ILS/VOR, hairpin structure.

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Corresponding Author:
Muh. Wildan,
Teknik Navigasi Udara,
Politeknik Penerbangan Indonesia Curug,
Jl. Raya PLP Curug, Serdang Wetan, Kec. Legok, Kabupaten Tangerang, Banten 15820.
Email: m_wildan@yahoo.com

1. INTRODUCTION

The implementation of air traffic services activities is closely tied to the execution of maintenance and reporting activities. In KP 35 of 2019 regarding Flight Telecommunication Facility Maintenance and Reporting Procedures, it asserts that to sustain the capability, capacity, and quality of flight telecommunication facilities, service providers must carry out maintenance of flight telecommunication facilities in accordance with the provisions specified in this regulation (Direktorat Jenderal Perhubungan Udara, 2019).

Maintenance and reporting activities can be performed through ground inspection and flight inspection activities. Ground inspection is typically conducted by transporting a Portable ILS/VOR Receiver (PIR) equipment to the location of the facility. Keeping up with the advancements of time, new concepts are required, such as the use of Unmanned Aerial Vehicles (UAVs) or drones for ground inspection. This concept's utilization can enhance effectiveness and efficiency (Schrader et al., 2016).

The use of drones itself necessitates several installed systems, one of which is the receiver navigation analyzer system, which also comprises several components. One of these components is the bandpass filter (bpf). Bpf functions to filter the desired frequencies. In the design process, microstrip will be employed to achieve compact size and lightweight characteristics (Lu et al., 2017). The hairpin structure technique is also utilized for comparing different types of materials used in this context.

Table 1. Literature Review

Reference	Parameters					
	Frequency	Return Loss (S11)	Insertion Loss (S21)	Bandwidth	Filter Design	Dielectric Material
(Praludi & Sulaeman, 2016)	3 GHz	≤ -20 dB	≥ -3 dB	200 MHz	Hairpin Structure	RO4350

(Khani et al., 2017)	2.4 5.7 GHz	≤ -20 dB	≥ -1 dB	≥ 70 MHz	T-Shaped Resonator	RT5880
(Fitria Nurjihan & Munir, 2020)	1.52 – 5.53 GHz	≤ -10 dB	≥ -3 dB	4.01 GHz	Defected Ground Structure	FR4
(Fubian et al., 2018)	L-Band	≤ -20 dB	≥ -1 dB	10 MHz	SIR	RT5880
(Orifansyah et al., 2020)	2.3 GHz	≤ -10 dB	≥ -3 dB	100 MHz	Hairpin Structure	FR4
(Astuti & Walesian, 2014)	1.8 GHz	≤ -15 dB	≥ -0.2 dB	60 MHz	Hairpin Structure	ROTMM10i
(Gracia Simatupang et al., 2018)	2.1 GHz	≤ -15 dB	≥ -1 dB	250 MHz	Square Open Loop Resonator	RO3210

A. ***Ground Inspection***

Ground inspection is a testing and assessment carried out on the ground for electronic and electrical aviation facilities equipment utilized in air traffic services (Fatonah, 2014). The ground inspection process is conducted periodically, typically once a month for ILS/VOR equipment (near field or far field) at various observation points.

B. ***Drone***

A drone is an unmanned aircraft that is remotely controlled using a controller or computer. Drones are manufactured in various sizes and capabilities. They are generally classified based on their flying abilities, altitude, range, and payload size (Mozaffari et al., 2019). In this context, drones are utilized to conduct ground inspection on aircraft navigation systems by measuring the radio frequency signals from the Instrument Landing System (ILS) / Very High Frequency Omni-directional Range (VOR).

C. ***Bandpass Filter***

A filter that allows signals within a specific frequency range, known as the passband, to pass through is called a bandpass filter. It is also capable of attenuating signals with lower and higher frequencies, thus, it can be stated that a bandpass filter has two stopbands (Bismoko, 2016).

D. ***Microstrip Line***

Microstrip is a transmission line consisting of a conductor strip (line) and a ground plane separated by a dielectric medium with a dielectric constant ε_r (Rohman, 2019).

E. ***Hairpin Structure***

A hairpin structure filter is a filter with an orderly arranged structure. This filter concept involves bending a microstrip path into two segments resembling the letter "U", with a bending angle of 90 degrees, and then placing them in parallel (Praludi & Sulaeman, 2016).

1. Transmission Line Width (W)

$$u = \frac{W}{h} = \frac{8e^A}{e^{2A} - 2}$$
$$A = \frac{Z_0}{60}\left[\frac{\varepsilon_r + 1}{2}\right]^{0.5} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left[0.23 + \frac{0.11}{\varepsilon_r}\right] \quad (1)$$

2. Effective Dielectric Material Permittivity ($\varepsilon_{r,eff}$) (2)

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$$\varepsilon_{r,eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{0.5}$$

3. Wavelength (λ_g)

$$\lambda_g = \frac{300}{freq\sqrt{\varepsilon_{r,eff}}} \quad (3)$$

4. Groundplane

$$L_s = 5 + Total\ Lebar\ Patch \quad (4)$$

$$W_s = 5 + W$$

F. BPF Microstrip Parameters

In determining the performance or effectiveness of a bandpass filter, it is necessary to define various parameters. These parameters are interrelated with each other (Orifansyah et al., 2020).

1. Frequency; is the number of wave vibrations per second, ranging from 30 KHz to 300 GHz, commonly referred to as radio frequency (RF). The unit of frequency is Hertz (Hz), where one Hz is defined as one cycle per second.
2. Return Loss (S11); also known as the reflection coefficient, is the amount of power reflected back towards the source from an improperly terminated point. The minimum value of return loss commonly used is < -10 dB to determine the bandwidth width.
3. Insertion Loss (S21); commonly referred to as the insertion loss, is the power sent from the source to the load, some of which is reflected back to the source and some is transmitted to the load. The commonly used minimum value is > -3 dB.
4. Bandwidth; commonly referred to as the frequency range in the middle of a bandpass filter. Bandwidth can be calculated based on the return loss characteristics.

2. RESEARCH METHOD

The method used in this research is the PPE (Planning, Production, Evaluation) model developed by Richey and Klein (Sugiyono, 2020). The focus of this method is a comprehensive analysis from the beginning to the end, covering Design, Production, and Evaluation stages.

Fig 1. PPE Model



Planning is the process of creating a product plan with specific objectives. Planning begins with needs analysis through research and literature study. Production involves the process of creating a product based on the established design. Evaluation is the testing and assessment of the quality and performance of the product against predetermined specifications. Here are the steps involved.

A. Planning

Planning is the stage of designing a microstrip bandpass filter. Literature study and analysis of the required materials, specifications, and dimensions are conducted.

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Table 2. Dielectric Materials

Materials	ε_r	h
RO4350	3.77	1.44
FR-4	4.3	1.6
RT5880	2.2	1.58

Table 3. Bandpass Filter Spesifications

Parameters	Values
Center Frequency	113 MHz
Return Loss	≤ -10 dB
Insertion Loss	≥ -3 dB
Bandwidth	± 10 MHz

B. Production

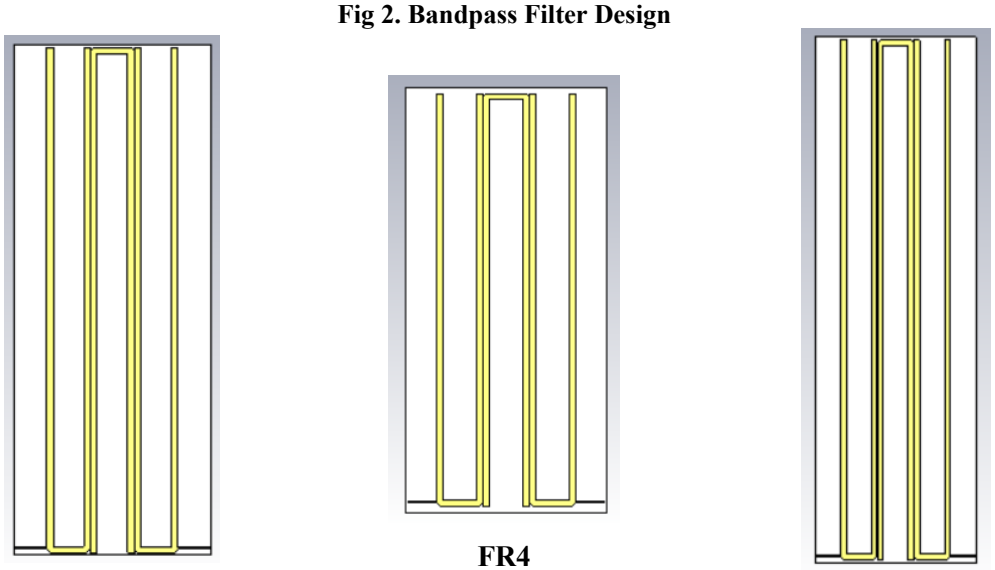
This is the design stage of the microstrip bandpass filter. Calculation of dimensions using microstrip bandpass filter formulas is performed, followed by the initial design of the bandpass filter based on these calculations.

Table 4. Bandpass Filter Dimension

Description	RO4350	FR4	RT5880
Resonator Length (W)	544.5 mm	738 mm	625.5 mm
Resonator Width (L)	10 mm	10 mm	10 mm
Groundplane Length (W_s)	549.5 mm	743 mm	630.5 mm
Groundplane Width (L_s)	410 mm	410 mm	410 mm
Feedline Length (F_i)	45 mm	45 mm	45 mm
Feedline Width (L_f)	3 mm	3 mm	3 mm

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Fig 2. Bandpass Filter Design



RO4350 **FR4** **RT5880**

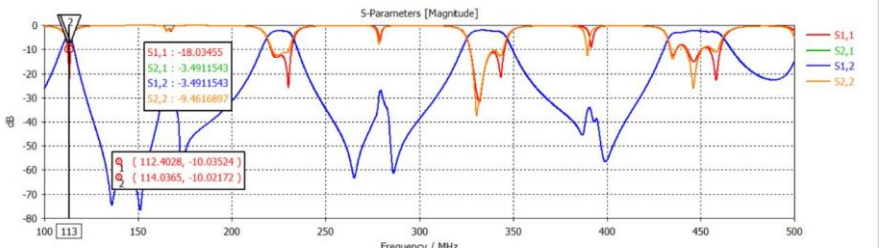
C. Evaluation

This is the stage of optimizing the dimensions of the microstrip bandpass filter, followed by simulating the design results of the optimization. The parameters simulated include center frequency, return loss, insertion loss, and bandwidth.

Table 5. Bandpass Filter Dimension After Optimation

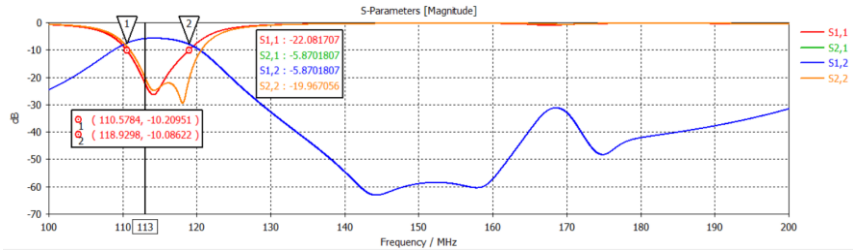
Description	RO4350	FR4	RT5880
Resonator Length (W)	745.12 mm	669.55 mm	933.93 mm
Resonator Width (L)	9.38 mm	9.825 mm	9.38 mm
Groundplane Length (W_s)	751.97 mm	689.39 mm	943.73 mm
Groundplane Width (L_s)	288 mm	325.55 mm	288 mm
Feedline Length (F_i)	45 mm	45 mm	45 mm
Feedline Width (L_f)	3 mm	3 mm	3 mm

Fig 3. Simulation of Bandpass Filter.

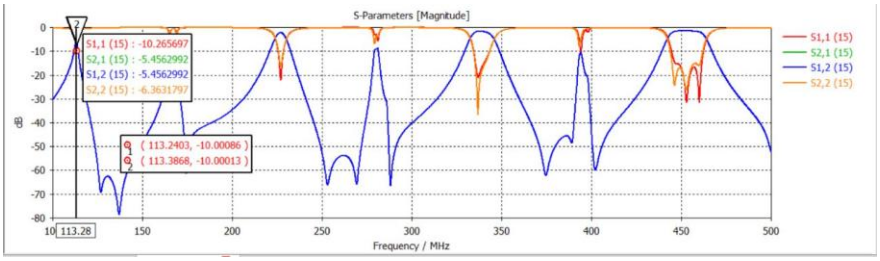


RO4350

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FR4



RT5880

3. RESULTS AND DISCUSSION

After conducting the final simulation based on the optimized dimensions, differences in simulation parameters were discovered among the materials used. Subsequently, these differences were further analyzed to examine the resulting parameters and their comparisons.

A. Return Loss (S11)

Table 6. Return Loss Comparison

Materials	Spesification	Simulations	Explanations
RO4350	≤ -10 dB	-18.03 dB	V
FR4		-22.08 dB	
RT5880		-10.26 dB	

V = Satisfied

X = Unsatisfied

The table above indicates that the bandpass filter made from the three different materials has met the specified return loss requirement of being less than or equal to -10 dB. For RO4350, the value is -18.03 dB, for FR4 it is -22.08 dB, and for RT5880 it is -10.26 dB.

B. Insertion Loss (S21)

Table 7. Return Loss Comparison

Materials	Spesification	Simulations	Explanations
RO4350	≥ -3 dB	-3.49 dB	X
FR4		-5.87 dB	
RT5880		-5.45 dB	

V = Satisfied

X = Unsatisfied

The table above indicates that the bandpass filter made from the three different materials has not yet met the specified insertion loss requirement of being greater than or equal to -3 dB. For RO4350, the value is -3.49 dB, for FR4 it is -5.87 dB, and for RT5880 it is -5.45 dB.

C. Bandwidth

Table 8. Return Loss Comparison

Materials	Spesification	Simulations	Explanations
RO4350	± 10 MHz	2 MHz	X
FR4		8 MHz	
RT5880		0.1 MHz	

V = Satisfied

X = Unsatisfied

The table above indicates that the bandpass filter made from the three different materials has not yet met the specified bandwidth requirement, which is approximately -10 MHz. For RO4350, the value is 2 MHz, for FR4 it is 8 MHz, and for RT5880 it is 0.1 MHz.

4. CONCLUSION

The conclusions that can be drawn based on the results obtained from the research are as follows as can be drawn.

1. This research has been conducted regarding the simulation of a 113 MHz frequency bandpass filter using a hairpin structure with three different materials: RO4350, FR4, and RT5880.
2. There are differences in simulation results among these three materials. In terms of return loss, RO4350 has a value of -18.03 dB, FR4 has a value of -22.08 dB, and RT5880 has a value of -10.26 dB. For insertion loss, RO4350 has a value of -3.49 dB, FR4 has a value of -5.87 dB, and RT5880 has a value of -5.45 dB. Regarding bandwidth, RO4350 has a value of 2 MHz, FR4 has a value of 8 MHz, and RT5880 has a value of 0.1 MHz.
3. The factors determining the differences in the obtained parameters are the material specifications based on permittivity (ε_r) and thickness (h). For RO4350, ε_r= 3.77 and h = 1.44. For FR4, ε_r = 4.3 and h = 1.6. For RT5880, ε_r = 2.2 and h = 1.58.

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