Design of Dual-band Bandpass Filter for GSM 950 MHz and GSM 1850 MHz Applications using Lumped Component

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Abstract. Filter is an electrical circuit that designed to pass the signal generated at certain frequencies and block the signal generated by all other frequencies. Dual-band filter is a filter designed to work on two frequency bands simultaneously. This research aims to design a dual-band bandpass filter for GSM applications, to pass signals on two frequency bands simultaneously, namely GSM900 with 950 MHz center frequency and bandwidth of 25 MHz and GSM1800 with 1850 MHz center frequency and bandwidth of 75 MHz. The steps taken to design a bandpass filter dual-band is starting to make a normalized lowpass filter Butterworth, then transform the lowpass filter into a bandpass filter with a center frequency of 950 MHz and 1850 MHz, then combining the two bandpass filters are to be filter dual-band with center frequency 950 MHz and 1850 MHz, and finally analyze the performance of the dual-band bandpass filter. Performance filter parameters to be analyzed is the return loss ($S_{11}$), insertion loss ($S_{21}$) and Voltage Standing Wave Ratio (VSWR). From the analysis and discussion for dual-band bandpass filter is obtained that: center frequency of the filter is at 950 MHz and 1850 MHz. Filter bandwidth at center frequency of 950 MHz is 25 MHz (962.5 MHz - 937.5 MHz) and filter bandwidth at center frequency of 1850 MHz is 75 MHz (1812.5 MHz - 1887.5 MHz). Return loss ($S_{11}$) filter at frequency of 950 MHz and 1850 MHz < -10 dB. Insertion loss ($S_{21}$) filter at frequency of 950 MHz and 1850 MHz > -3 dB. VSWR at frequency of 950 MHz and 1850 MHz < 2.

1. Introduction
The current development trend of wireless communications technology that attracts many researchers is the development of RF transceivers capable of working on multiple frequencies (multiband) simultaneously. Multiband technology is needed as more and more new technologies are developed, but work on different frequency bands. GSM (Global System for Mobile Communication) is a standard second-generation mobile communication system (2G), operating in the 900 MHz and 1800 MHz frequency bands [1].

Dual-band technology is a technology that can meet the need for a multi-frequency device in an application. One example of application of dual-band technology is the filter. Bandpass filter is a circuit designed to pass or pass signals on a particular frequency band and block or weaken signals outside the band of the frequency band. A dual-band filter is a filter designed to work on two frequency bands at once. Research that discusses the design of dual-band filters using lumped components (capacitors, and inductors) [2] and microstrip [3].

This study aims to design dual-band bandpass filters for GSM applications, which can pass signals on two frequency bands at once i.e. GSM900 with 950 MHz middle frequency and 25 MHz bandwidth and GSM1800 with 1850 MHz middle frequency and 75 MHz bandwidth. The design of this filter is simulated using Advanced Design System (ADS) software. The software is used to analyze filter parameters consisting of return loss ($S_{11}$), insertion loss ($S_{21}$) and VSWR.

2. Literature Review
2.1. Principles of Dual-band Filter Design
The principle of dual band filter design that has been developed is using multi-resonant circuit technique, through several steps [4] i.e.: (i) one designs the individual passband filters, for which one starts from a low-pass filter and by applying the lowpass to bandpass filter transformation, one obtains the bandpass filters. Next, (ii) one combines the two filters into just one, by means of multi-resonant circuits. Figure 1 is normalized lowpass filter Butterworth circuit with \( L = 2 \, \text{H}, \, C = 1 \, \text{F}, \, Z_0 = 1 \, \Omega \) and \( \omega_0 = 1 \, \text{rad/s} \). Figure 2 is transformed bandpass filter for first centre frequency dan figure 3 is transformed bandpass filter for second centre frequency. Figure 4 is dualband bandpass filter result of merging. The equation used for transforming lowpass filter into bandpass filter is [5], [6]:

\[
L_g = \frac{K_{i,n}}{2\pi B} \\
C_s = \frac{B}{2\pi F_u F_l K_i} \\
L_p = \frac{BK_i}{2\pi F_u F_l C_n} \\
C_p = \frac{C_n}{2\pi B K_i}
\]

with : \( \omega_0 \) is centre frequency, \( B \) is bandwidth, \( k_i \) is denormalization constant = \( 1/Z_0 \).
2.2 Return Loss
Return loss (RL) is the loss of some power that is reflected back to the source due to transmission interruption or unmatched circuit. The usual return loss is expressed as the ratio in decibels. This ratio is a logarithmic form of the ratio of reflected power \(P_R\) to the power transmitted from the source \(P_T\). The value of the Return Loss should be as small as possible, if in dB it means to have as much negative value as possible for maximum transfer power.

2.3 Insertion Loss
Insertion loss (IL) is the loss of power generated due to device insertion between the source and the load. The power delivered from the source to the load will be reflected back to the source and some are transferred to the load, but the power transferred to this load will be partially lost due to the components in the circuit, this loss of power is called insertion loss. This insertion loss is a comparison between the power transmitted to the load \(P_T\) and the load received power \(P_R\) in decibel logarithmic.

2.4 VSWR
VSWR is the ratio between the maximum voltage amplitudes to the minimum voltage amplitudes of standing wave. The maximum and minimum voltage occur due to the superposition between the incident wave and the reflected wave. If both of these waves in phase will occur the maximum voltage and when the opposite phase will happen minimum voltage.

3. Method

3.1 Research stages
These stages that have been grouped into 4 phases. Each stage can be known as below:

- The first phase is to create a normalized third-order lowpass filter Butterworth.
- The second phase is to transform the lowpass filter into a bandpass filter with 950 MHz center frequency and 25 MHz bandwidth.
- The third phase is to transform the lowpass filter into a bandpass filter with 1850 MHz center frequency and 75 MHz bandwidth.
- The fourth phase is to combine both bandpass filters into dual-band filters with the center frequency of 950 MHz and 1850 MHz.

3.2 Measurement and Observation
The measured dan observed of parameters of dualband bandpass filter in this study is frequency response return loss \(S_{11}\), insertion loss \(S_{21}\) and VSWR.

3.3 Design Research
Dual-band bandpass filter used in this study can be seen in figure 5. Value of lumped component used in this dual-band bandpass filter is: \(C_1 = 0.049112\ \text{pF}, L_1 = 440.93\ \text{nH}, C_2 = 0.11163\ \text{pF}, L_2 = 85.935\ \text{nH}, C_3 = 45.438\ \text{pF}, L_3 = 0.61769\ \text{nH}, C_4 = 94.506\ \text{pF}, L_4 = 78.314\ \text{pH},\)
3.4. Data Collection and Analysis Technique
Data collection and analysis technique performed using ADS. ADS are used to analyze filter parameters i.e. return loss ($S_{11}$), Insertion loss ($S_{21}$) dan VSWR.

4. Result and Discussion
Frequency response simulation results of dual-band bandpass filter shown in figure 6. From the picture shows that the center frequency of the filter is at the frequency of 950 MHz and 1850 MHz.

Return loss ($S_{11}$) simulation results of dualband bandpass filter shown in figure 7. Return loss value at frequency of 937.5 MHz is -4.239 dB, at frequency of 962.5 MHz is -4.270 dB, and at frequency of 950 MHz is -71.720 dB. Return loss value at frequency of 1812.5 MHz is -0.0014 dB, at frequency of 1887.5 MHz is -0.0058 dB, dan at frequency of 1850 MHz is -44.333 dB. Seen that return loss ($S_{11}$) value at frequency 950 MHz dan at frequency 1850 MHz are smaller than -10 dB.
Insertion loss ($S_{21}$) simulation results of dualband bandpass filter shown in figure 8. Insertion loss value at frequency of 937.5 MHz is -2.054 dB, at frequency of 962.5 MHz is -2.035 dB, and at frequency of 950 MHz is close to 0 dB. Insertion loss value at frequency of 1812.5 MHz adalah -34.9399 dB, at frequency of 1887.5 MHz is -28.7632 dB, and at frequency of 1850 MHz is -0.576 dB. Seen that insertion loss ($S_{21}$) value at frequency 950 MHz and 1850 MHz are greater than -3 dB.

VSWR simulation results of dualband bandpass filter shown in figure 9. VSWR value at frequency of 937.5 MHz is 4.179, at frequency of 962.5 MHz is 4.150, and at frequency of 950 MHz is 1.001. VSWR at frequency of 1812.5 MHz is 12473, at frequency of 1887.5 MHz is 3006, and at frequency of 1850 MHz is 1.012. Seen that VSWR value at frequency 950 MHz dan 1850 MHz are smaller than 2.
5. Conclusion

- Center frequency of designed dual band filter is at 950 MHz and 1850 MHz. Filter Bandwidth at center frequency 950 MHz is 25 MHz (962.5 MHz – 937.5 MHz) and at center frequency 1850 MHz is 75 MHz (1812.5 MHz – 1887.5 MHz).
- Return loss (S_{11}) value of dual-band filter at frequency 950 MHz and 1850 MHz are smaller than -10 dB.
- Insertion loss (S_{21}) value of dual-band filter at frequency 950 MHz and 1850 MHz are greater than -3 dB.
- VSWR value at frequency 950 MHz dan 1850 MHz are smaller than 2.

Acknowledgment
The authors gratefully acknowledge the financial support provided by Politeknik Negeri Medan, Medan, Indonesia, under the Research and Community Service Unit (UPPM-Polmed) and Telecommunication Engineering study program majoring in Electrical Engineering.

References
[1] Nuraksa M and Lingga W 2010 Teknologi Wireless Communication dan Wireless Broadband (Yogyakarta: Andi Publisher)
[2] Gunawan W, Daniel S, Teguh F, Taufiq A K, Toto S and Hsiao C C 2012 Design Of Concurrent Quadband Bandpass Filter Using Lumped Components For m-BWA The 5th Indonesia-Japan Joint Scientific Symposium
[3] Mohammad R S, Ebrahim A and Leila N 2014 Design of a Microstrip Dual-band Bandpass Filter with Compact Size and Tunable Resonance Frequencies for WLAN Applications International Journal of Computer and Electrical Engineering 6 248
[4] Thiago P R G and Robson N L 2012 A Design Technique for Dual-band RF bandpass Filter 2th Workshop on Circuits and System Design
[5] Arthur B W 2006 Electronic Filter Design Handbook Fourth Edition (USA: McGraw-Hill Companies)
[6] Steve W 2002 Analog and Digital Filter Design Second Edition (USA: Elsevier Science)