EEE22025 – 5G Millimeter wave Bandpass Filter

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Background

Network communication is a significant technological advancement in modern society, and the latest development in this area is the fifth-generation cellular network, known as 5G. This new network aims to improve the quality of service by providing higher data rates and lower latency than the current 4G network. With faster data computation and transmission, 5G is highly versatile and can be used in IoT, mobile communication, and military systems. Therefore, it has become a popular area of research.

item	4G	5G
max data rate	100Mbps	10Gbps
latency	50ms	1ms
capacity	smaller	larger

Figure: comparison between 4G and 5G

Introduction

The fifth-generation (5G) cellular network relies on millimeter wave (mmW) spectrum, a range of frequencies between 30 and 300 GHz used in wireless communication systems. This spectrum enables 5G systems to transmit data quickly over long distances, especially for point-to-point communication. However, using mmW technology for 5G has some challenges. For instance, the antennas require high power and directivity, which can result in significant radiation gain and the production of unwanted signals outside the target frequency band. A band-pass filter with sharp roll-off is necessary to mitigate these issues and reduce radiation.

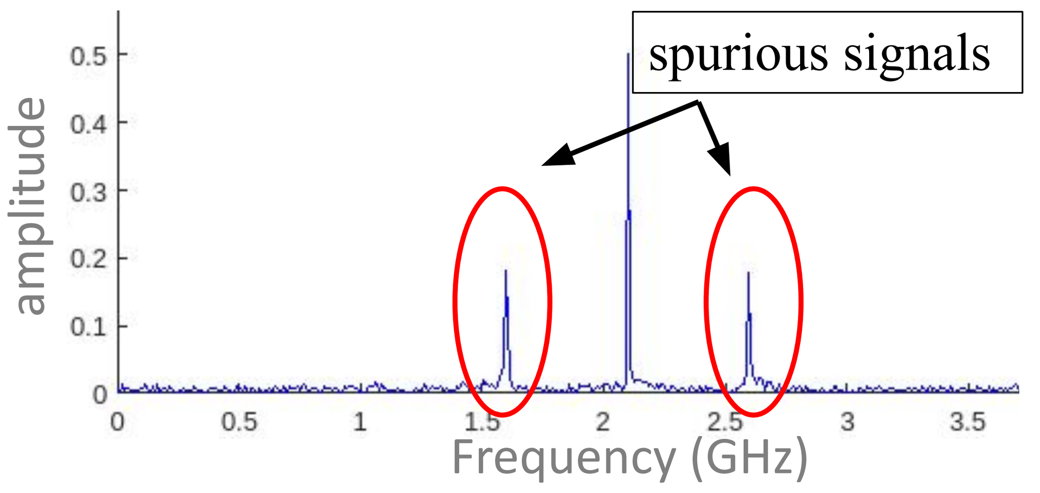

Figure: Demonstration of spurious signals as making signals in 2.1GHz

Experimental Methods

Purpose: Determine which type of the bandpass filter has a better effect on mitigate the spurious signals

Method: Use **MATLAB** to make a simulation of the signals system with 3 types of the bandpass filter design, which is Butterworth, Chebyshev I and II, and doing comparison and analysis on the result.

Results & Analysis

In the simulation, I have implemented three types of bandpass filters with same orders (Butterworth Chebyshev I and II) to filters a 5G wave signal with center frequency 2.1 GHz. The simulation also included spurious signals outside the band of frequency to test the effectiveness of the filters in removing unwanted signals.

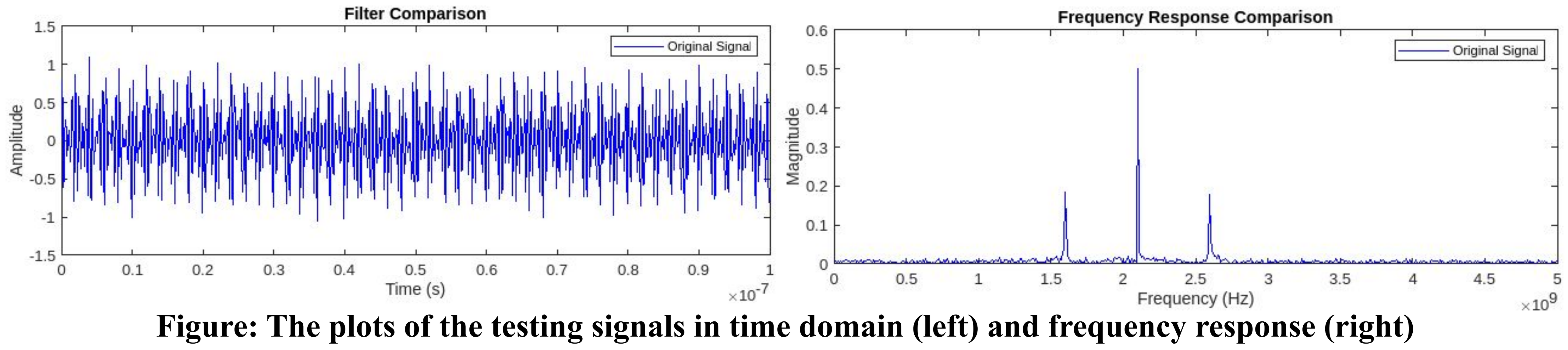

Figure: The plots of the testing signals in time domain (left) and frequency response (right)

In the previous picture, the testing signal features in center frequency of 2.1 GHz. And there are also two spurious signals in the system, which is o 1.6 GHz and 2.6 GHz. Additionally, the system also included the noise to simulate as a real signal.

The following pictures are the demonstration of the results of the simulation on the different bandpass filters:

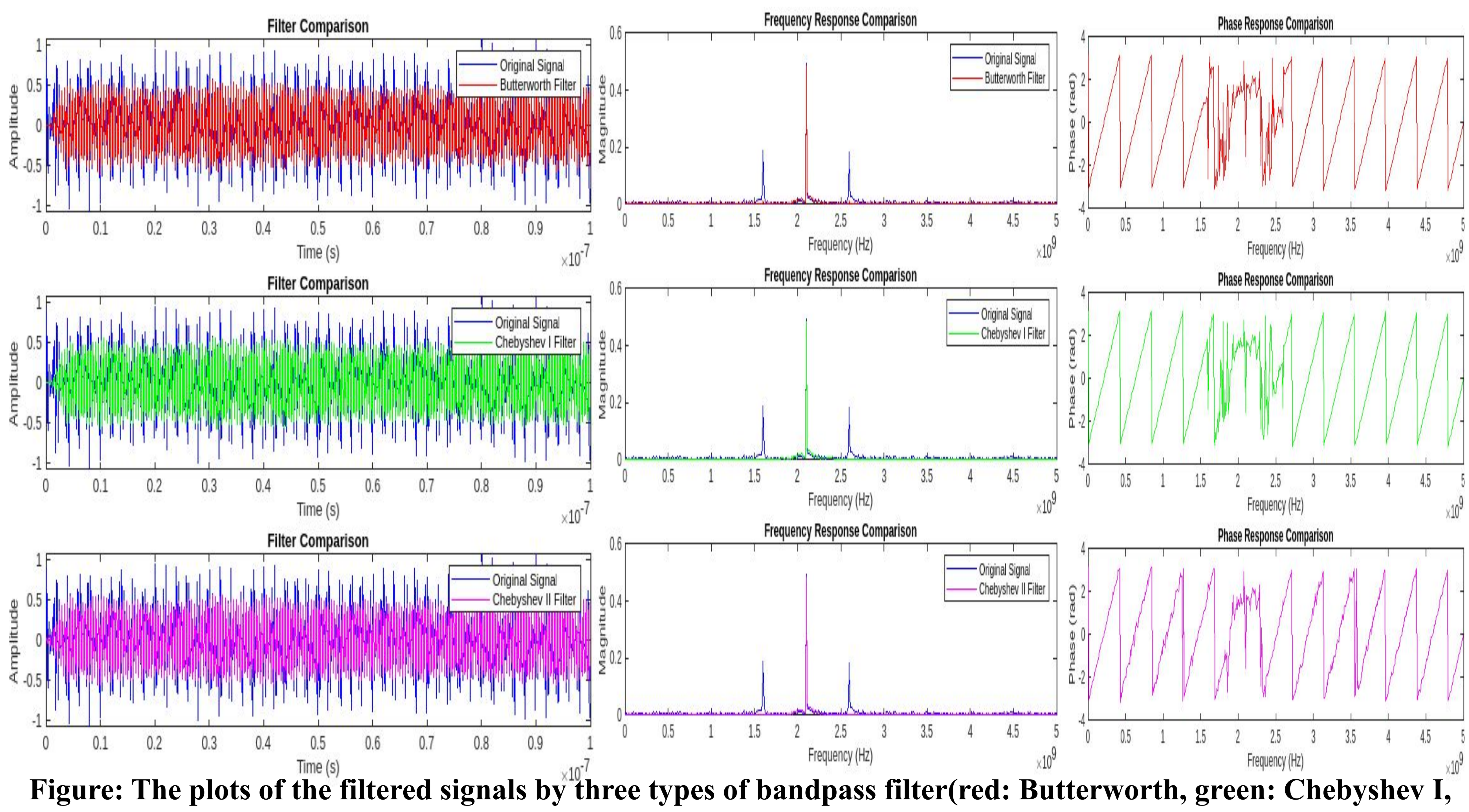

Figure: The plots of the filtered signals by three types of bandpass filter(red: Butterworth, green: Chebyshev I, magenta: Chebyshev II) in three different domains (time domain, frequency response and phase response)

The orders of the filters are 5 and the bandwidth are set at 600MHz. Based on the simulation of filtered signals, all three types of filter have a good effect on filtering spurious signals. However, according to the phase response, the Butterworth filter has a wider transition band compared with the Chebyshev filters, which may result in a slower roll-off in the stopband. On the other hand, both Chebyshev filters have a steeper roll-off transition band when filtering the signals. Therefore, the Chebyshev filters have better attenuation in the stopband compared with the Butterworth filter. When a sharper drop-off and more effective attenuation in the stopband are necessary, the Chebyshev type II filter is the most suitable option, even though it has a wider transition band and stopband ripple than other filters.

Conclusion

When it comes to eliminating spurious signals, three types of filters - Butterworth, Chebyshev type I, and Chebyshev type II - are effective. However, the latter two provide better attenuation in the stopband than the Butterworth filter. This means that if a high degree of spurious signal rejection is needed for the 5G millimeter wave system, using the Chebyshev type I or Chebyshev type II filter may be more suitable than the Butterworth filter.

In conclusion, the choice of the best filter type of for the 5G wave signals depends on the specific requirements of the application. However. in this project, our purpose is to find out which type of the bandpass filter has the best effect on filtering the spurious signals. Therefore, based on the results on the simulation, the Chebyshev type I and Chebyshev type II filters provide better attenuation in the stopband compared to the Butterworth filter. In other words, the Chebyshev type I or Chebyshev type II filter would be a better choice if a high-level spurious signal rejection is required.