TECHNION Israel Institute of Technology

THE ANDREW & ERNA VITERBI FACULTY OF ELECTRICAL ENGINEERING

COMMUNICATION LABORATORY
DEPARTMENT OF ELECTRICAL ENGINEERING
המעבדה לתקשורת

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Ultra Narrow Bandwidth Microwave Filters

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Goal: Designing a microwave Filter for high frequencies with an ultra narrow bandwidth

Introduction

- While designing wideband communication systems at cm and mm waves (5G), we need to take into account the noise of the frequency oscillator. This noise consists of phase noise, a "skirt" around the targeted frequency, and "white" noise that spreads far from the oscillator frequency (Figures 1,2).
- In wide-band communication systems, the power of this "white" noise impacts the quality of the communication system because the white noise is integrated over the signal bandwidth.
- To improve communication quality we will remove "white" oscillator noise with narrow-bandpass filter, where it's characteristic is represented by Figure 3.
- A band-pass filter is a device which passes signal in some frequency range and stops all other frequencies.
- To characterize microwave filter response we use S-parameters which are defined by ratios between incident, reflected and transmitted Waves (Figure 4).
- For analyzing and designing filters we used two computer simulation softwares: CST and Microwave Office (AWR).
- Quality of a filter can be described by the Q factor, which is defined by a ratio between stored and dissipated energy in the filter. The Q factor also defines how narrow a bandwidth the filter can have. The higher the Q factor, the better the filter response will be.
- **Our project aims to create an ultra-narrow bandwidth bandpass filter at a frequency of 8.25GHz. We will try to use multiple technologies to achieve the desired result.**

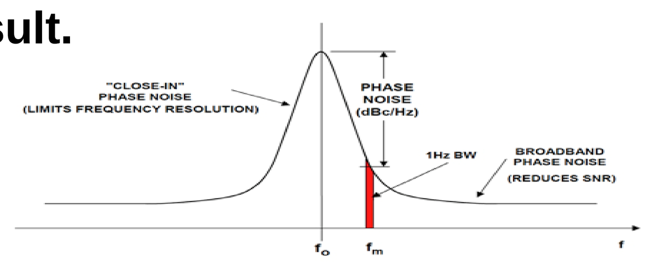
Figure 1: Signal oscillator spectrum

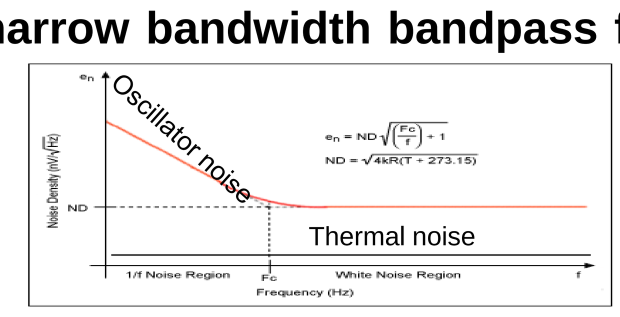

Figure 2: Oscillator noise

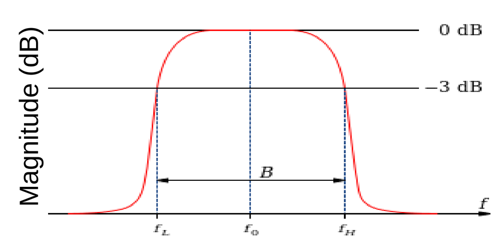

Figure 3: Bandpass filter frequency response

$$S_{11} = \frac{Reflected\ Voltage}{Transmitted\ Voltage}$$

$$S_{21} = \frac{Passed\ Voltage}{Transmitted\ Voltage}$$

Figure 4: S Parameters Equations

Microstrip Technology Based Filter

A microstrip is a type of electrical transmission line made of a conducting strip separated from the ground by a dielectric layer (Figure 5). This technology is commonly used in printed circuit boards.

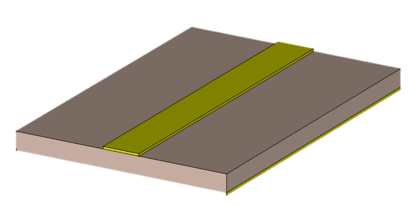
Figure 5: an example of a basic microstrip transmission line

Ring Resonator Filter

The first design we tested was microstrip ring resonator filter (Fig. 6) [1]. This design had two major problems - it was technologically challenging to print this circuit and it's bandwidth was too wide (Fig. 7).

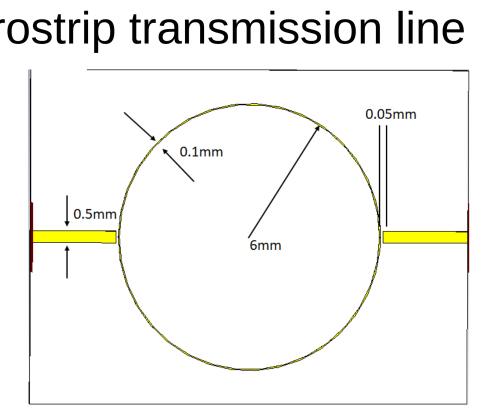
Figure 6: Microstrip filter. The ring resonator placed between two microstrip lines

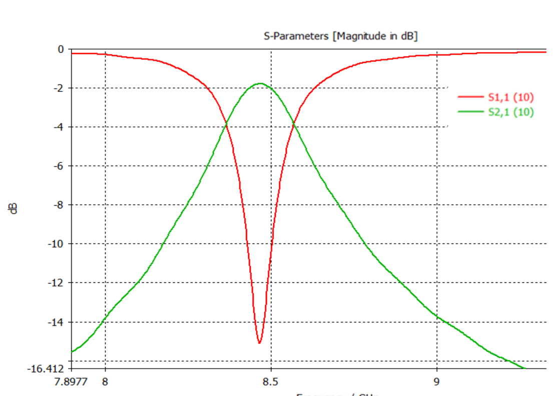
Figure 7: S-parameters of the filter above.

1D Line Resonator Filter

The second design was line resonator filter (Fig. 8). This design had high insertion loss meaning that most energy was lost to heat and microwave radiation (Fig. 9).

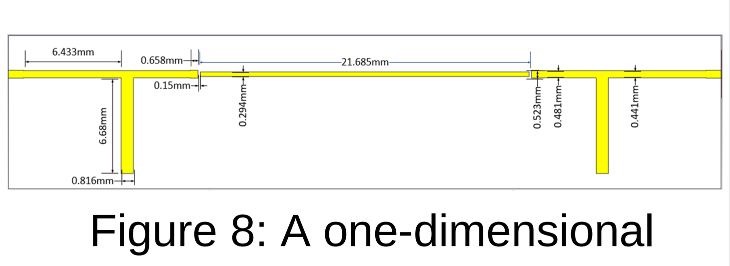
Figure 8: A one-dimensional line resonator

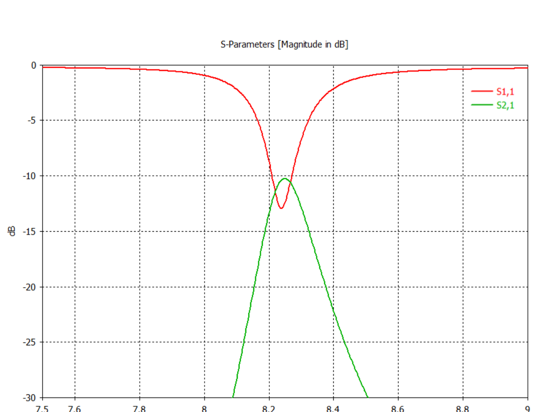
Figure 9: S-parameters of microstrip 1D line resonator filter

Suspended Stripline 1D Line Resonator Filter

To prevent radiation and heat losses we changed from microstrip to suspended stripline design (Fig. 10). As one can see (Fig.11) there is a huge improvement in insertion loss and bandwidth of the filter.

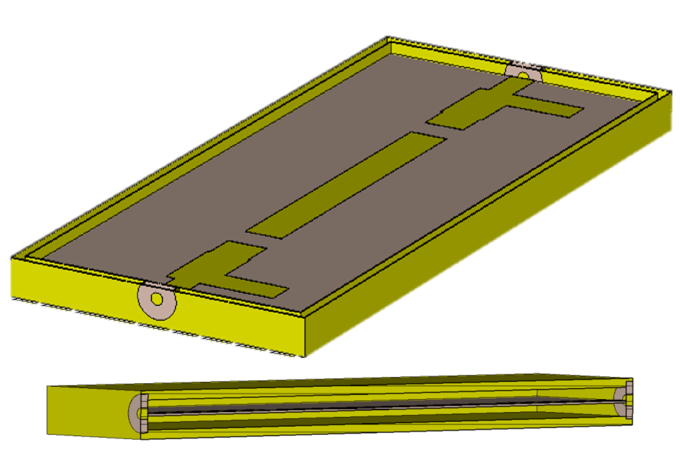
Figure 10: A perspective view and cross section of a suspended stripline filter

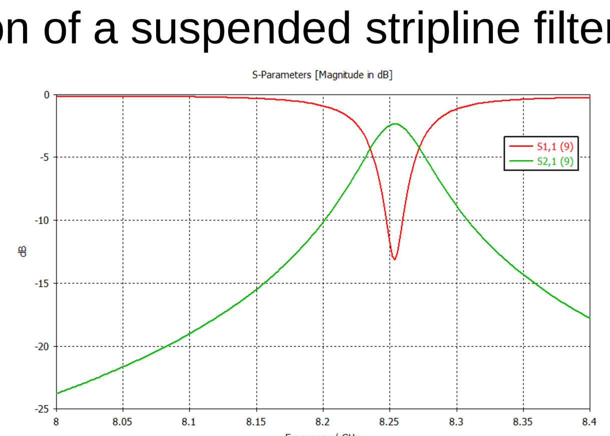
Figure 11: S-parameters of suspended stripline1D line resonator filter

Dielectric Resonator on Microstrip Based Filter

This type of filter uses a high epsilon dielectric material in a ring shape to create sharp frequency response which means less noise affecting communication signal. Here we recreated the design shown in article [2] (Fig. 12) to check if the technology works and if our simulation is properly running. At Figure 13 we can see that the frequency response we achieved corroborates the results of article [2]. It shows a resonance at 5.6 GHz but the bandwidth is too wide due to radiation losses.

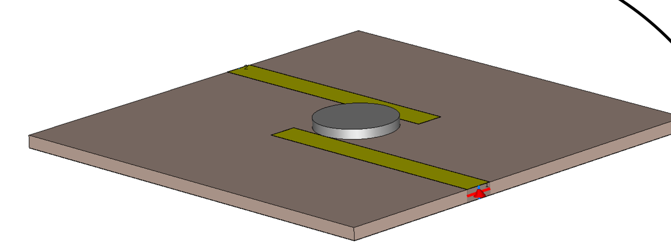
Figure 12: Dielectric Resonator Microstrip Filter

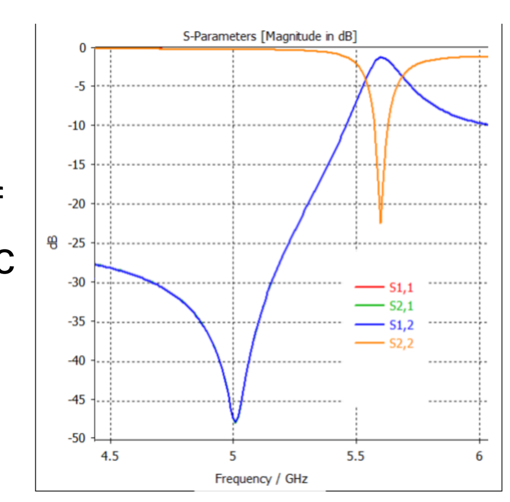
Figure 13: Frequency response of the Dielectric Resonator Filter.

Dielectric Resonator Loaded Cavity Based Filter

To prevent radiation losses we are trying to enclose dielectric resonator filter inside a metal box (Figs.14 and 15). This type of filter also uses a dielectric material to create resonance. We will design it instead of the dielectric resonator ring we have at the lab. The catch is that instead of just the dimensions of the strip and the gap between the strip being adjusted to optimize, with this filter you need to adjust all of the internal dimensions of the box, the amount of the coaxial pin exposed, and the overall length of the coaxial pin which makes this filter much harder to optimize. The S parameters in Figure 16 are extremely good. They show a resonance at about 7.2 GHz (which is close to the specs for the resonator) and a small bandwidth of a little less than 100MHz at the -10dB level.

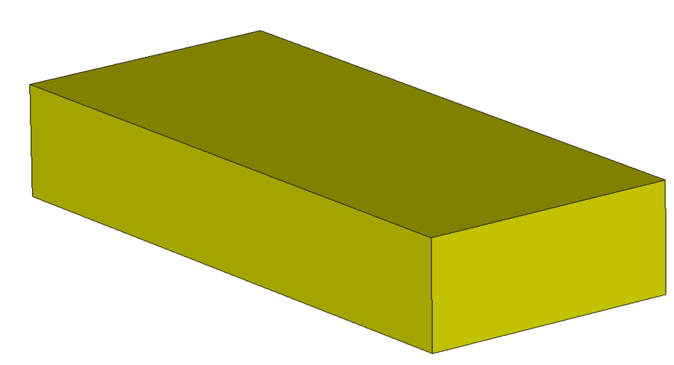
Figure 14:Dielectric Resonator Loaded Cavity Filter

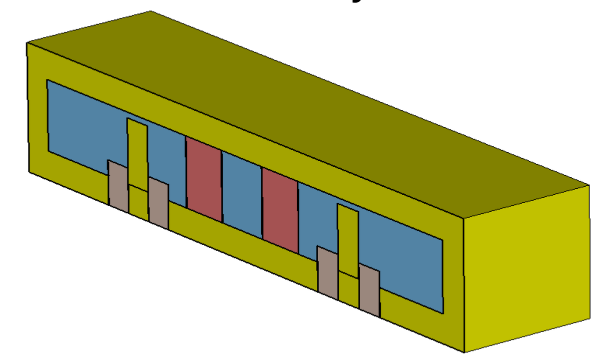
Figure 15: Dielectric Resonator Loaded Cavity Filter Cross Section

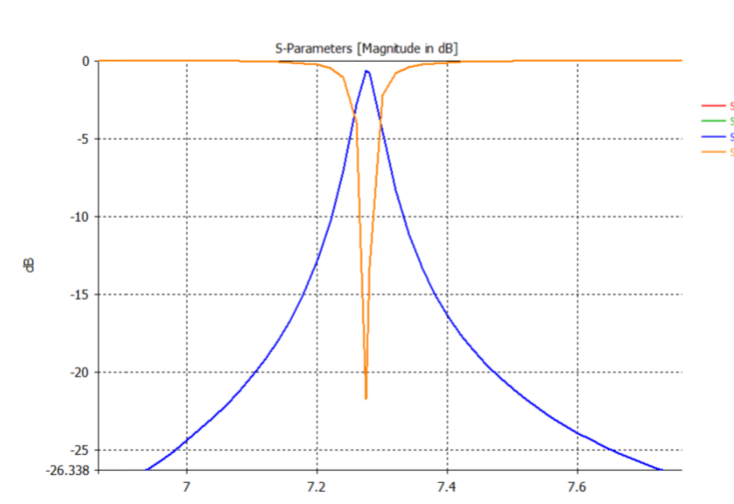
Figure 16: S parameters for the Dielectric Cavity. Top line is S1,1 and S2,1, and the bottom line is S1,2 and S2,2

Conclusions

In this research we tested four different technologies for filter design, starting from the less expensive and simple and finishing with cavity based design. The conclusions are:

- Microstrip technology gives us wide bandwidth and high insertion loss because of dielectric and radiation losses.
- Dielectric resonator microstrip technology gives us lower insertion loss, but still has wide bandwidth due to radiation losses.
- The cavity based design remove radiation losses and increases the quality factor of the filter and significantly narrows the bandwidth (Fig. 16).

As a conclusion, for our purposes the only usable filter are cavity based ones.

References

1. Hong, J. (2011). Microstrip Filters for RF / Microwave Applications (2nd ed.). Hoboken, NJ: John Wiley & Sons.
2. Massoni, E., Bozzi, M., Perregrini, L., Tamburini, U. A., & Tomassoni, C. (2017). A Novel Class of High Dielectric Resonator Filters in Microstrip Line Technology. 2017 IEEE MTT-S International Microwave Workshop Series on Advanced Materials and Processes for RF and THz Applications (IMWS-AMP). doi:10.1109/imws-amp.2017.8247397

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