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Fifteen Pole Superconducting Filter for Radio Astronomy

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Abstract: Application of High Temperature Superconducting (HTS) materials in the communication industry has become attractive in recent years. Mobile communications, radar, radio telescope and satellite communication links, are some of the many applications, which use microwave filters made from HTS materials. Most of HTS microwave filters reported in the literature were designed for narrow band applications; this is due to the recent commercial requirements. However, some astronomy laboratories need to employ a fairly wide band filter for their radio telescope receivers. An HTS filter is ideal for this application because of the low intrinsic insertion loss and steep filter skirts. A Fifteenth Order Chebyshev HTS band pass filter, designed for Jodrell Bank Observatory, is presented for astronomy applications. Sonnet EM Simulation results are provided for this 15-order filter with fractional bandwidth of 26.4%. Good agreement between theoretical results and simulations is obtained. Size miniaturization has also been carried out. Comparisons of simulation results between original and minimized design are also provided.

1. INTRODUCTION

Since the discovery of high temperature superconductor (HTS) [1] in 1986, there has been a trend in implementing HTS materials into microwave components. HTS microwave filter started to emerge during the early 1990s, and much effort has been put into filter designs for narrow band applications. However, there are not still many wide band HTS filters reported. Here we are interested in a wide band filter for radio astronomy applications.

With the increasing radio communications activities of recent years, the radio spectrum is becoming intensely crowded and is set to increase at an extraordinary rate. Radio astronomy is particularly sensitive to interference of this type and such interference is effectively converted to noise in the receiver. A high temperature superconducting (HTS) filter at the front-end of the receiver has the potential to effectively eliminate the interference from adjacent bands. Such a filter will have negligible loss, have extremely sharp filter skirts and be small enough to fit into the current low temperature systems.

This work reports on the design of a Chebyshev HTS band pass filter for Jodrell Bank Observatory. The filter structure consists of 15 parallel half-wavelength stubs. Coupling between the stubs is determined by the different admittance of the stubs and $\frac{1}{4}$ wavelength interconnection lines. Sonnet EM [2] simulation results are provided for this 15-order filter

with fractional bandwidth of 26.14%. This paper also provides description for different stages of circuit size reduction.

2. THEORY BACKGROUND

Conventional parallel-coupled strip line filter has been reported in many papers [3]. Such a filter is shown in Fig. 1. It includes half-wavelength strip-line resonators paralleling each other along half of their length. This parallel arrangement gives relatively large coupling for a given spacing between resonator strips. However, this construction can be only applied for the filters with less than 15 percent bandwidth filter. For larger bandwidths, it has been found that unreasonably small gaps are required between resonator elements [3].

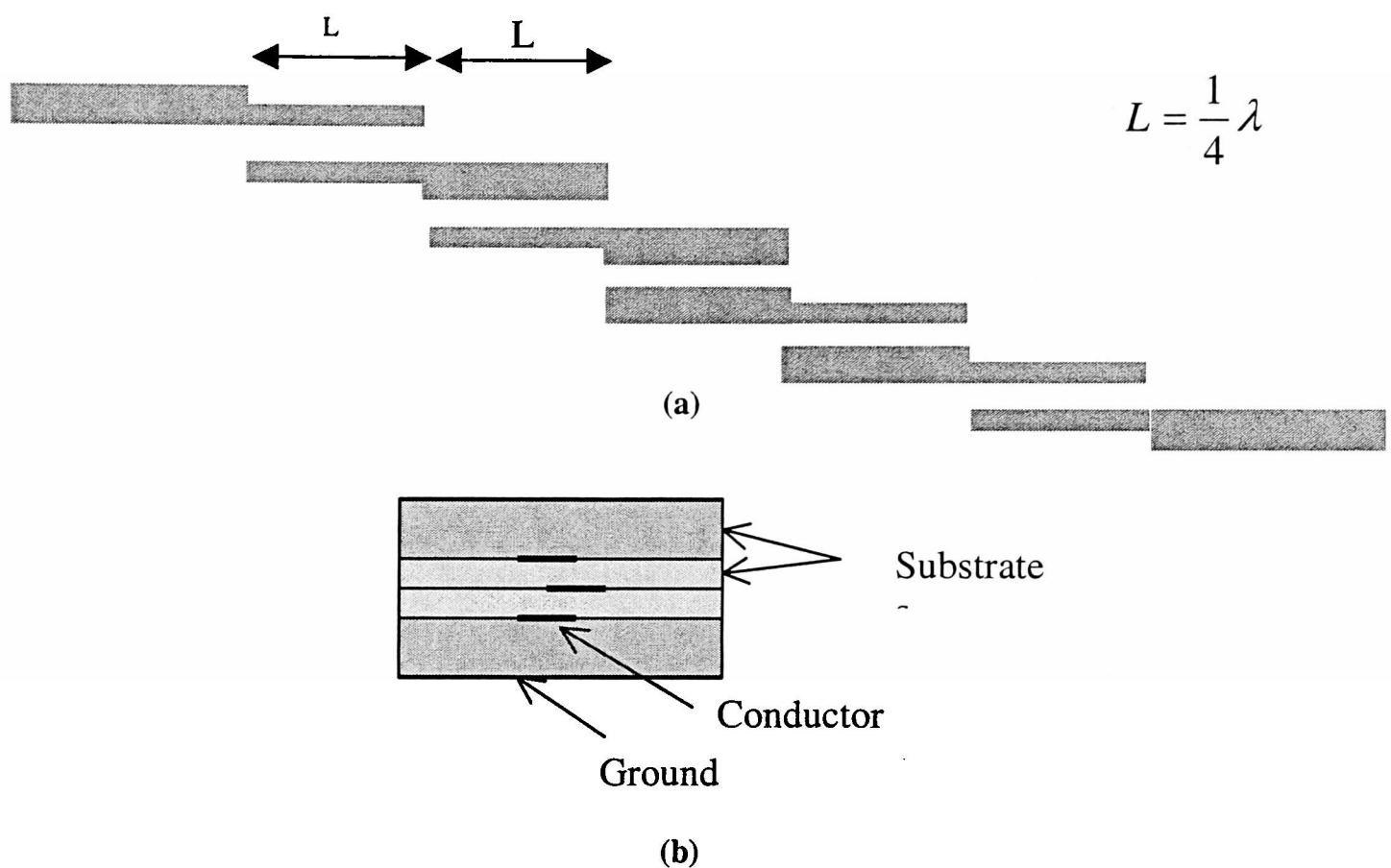


Figure 1: Parallel-coupled Line filter (a) Conventional Layout (top view) (b) Interleave Layout (cross view)

One way to avoid this problem is to use the interleaved construction shown in Fig. 1(b) [4]. In this construction, alternate resonators are printed on two different parallel layers of dielectric, hence achieving tight coupling. However, this kind of construction is not feasible for High Temperature Superconducting (HTS) filter, which is normally fabricated on single substrate layer.

A filter, which uses open half wavelength stubs, can be made to have pass-band characteristics similar to the parallel-coupled filter. The circuit derivation procedure can be found in Matthaei's [4], a small sector of such a filter is shown in Fig. 2.

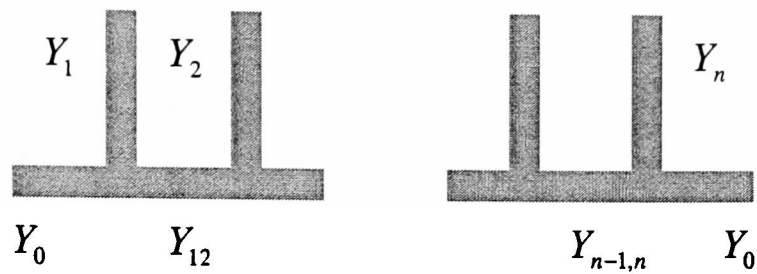


Figure 1: Modelling of Stub Filter

The simplified equations to determine the admittance of the stub and the connection lines can be written as follows:

$$Y_1 = Y_0 \left(N_{1,2} - \frac{J_{1,2}}{Y_0} \right) \quad (1)$$

$$Y_k = Y_0 \left(N_{k-1,k} + N_{k,k+1} - \frac{J_{k-1,k}}{Y_0} - \frac{J_{k,k+1}}{Y_0} \right) \quad (2)$$

$$Y_n = [Y_0 (g_n g_{n+1} - g_0 g_1) \tan(\theta)] + Y_0 \left(N_{n-1,n} - \frac{J_{n-1,n}}{Y_0} \right) \quad (3)$$

$$Y_{c_{k,k+1}} = J_{k,k+1} \quad (4)$$

where Y_1 , Y_k , Y_n and $Y_{c_{k,k+1}}$ are the characteristic admittance of the first stub, the middle stubs, the end stub and the connection lines, respectively. Y_0 is the input port admittance of $1/50 \Omega^{-1}$. Due to the limited space, we will not show the definition of other parameters in the equations here. However, they can be found in [4].

3 CIRCUIT DESIGN & GRAPHIC RESULTS

Fig. 3 shows the layout of the designed 15-pole HTS band pass filter, which comprises of stub resonators and meandered $\frac{\lambda}{4}$ connection lines. The filter has a dimension of $(0.5\text{mm} \times 25.2\text{mm} \times 110.2\text{mm})$ on the Lanthanum Aluminates with dielectric constant of 23.4.

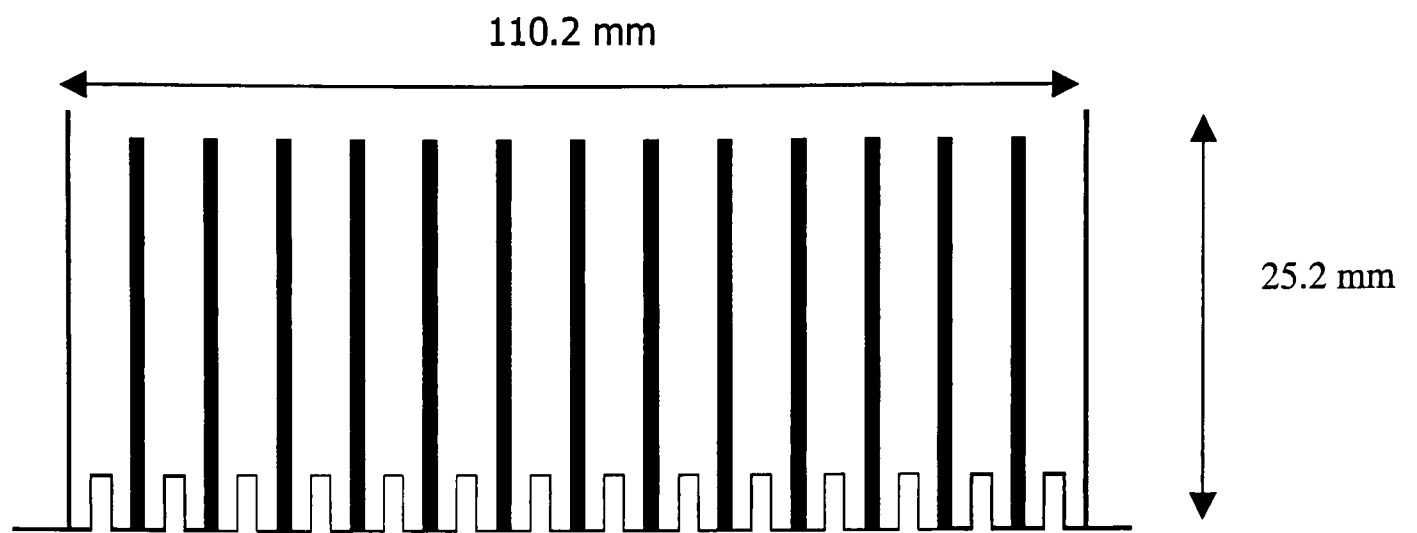


Figure 2: 15 Pole Meandered Line Filter

The simulation results are obtained through full-wave electromagnetic simulator [2]. They have a good agreement with the theoretical results. The increase in the insertion loss at the higher pass band frequencies is probably due to the unwanted cross coupling between stub resonators.

15-Order Chebyshev Band-Pass Filter Response

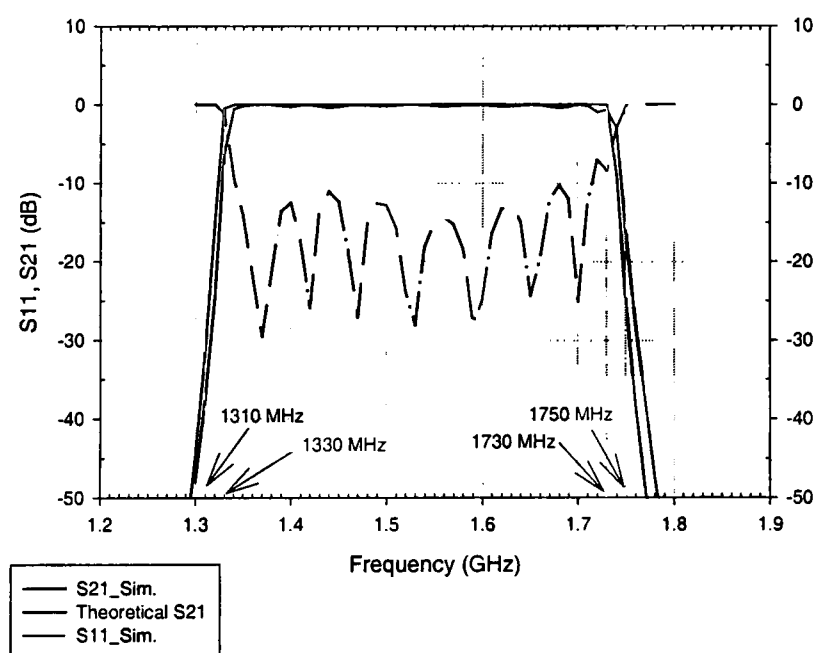


Figure 3: Comparison between Theoretical and Simulation Results

The circuit layout shown in Fig. 2 is obviously not able to fit in the available maximum substrate of 3inch in diameter. The filter layout shown in Fig. 4 has been modified to fit in the limited space.

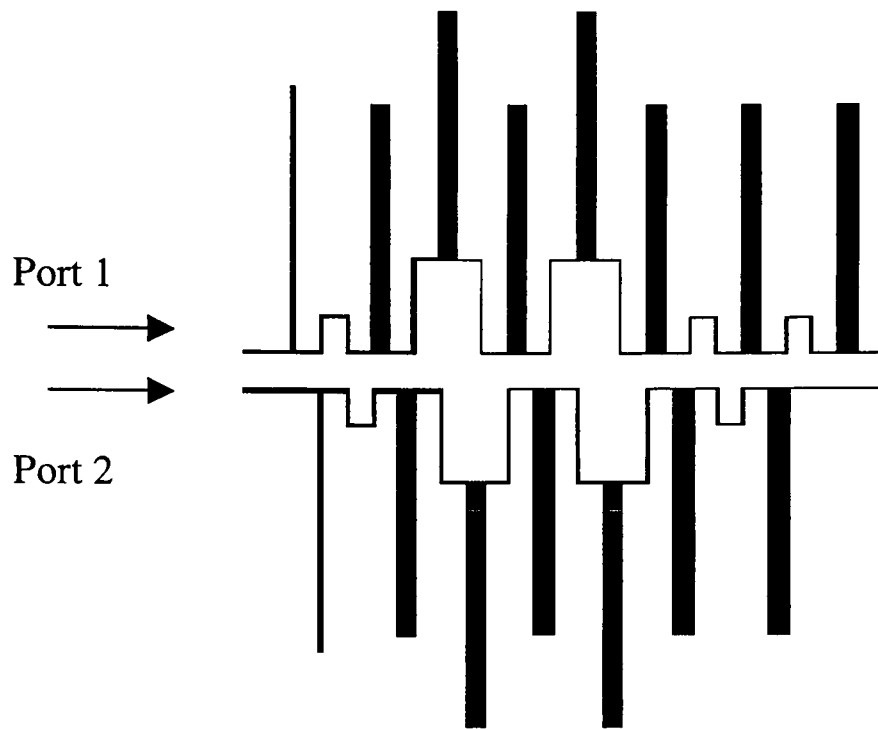


Figure 4: Further Size Reduction of 15 Pole Filter

However, from the EM simulation results it appears that the responses deteriorate with this size reduction, as the unwanted non-adjacent coupling increases. Work is in progress on the tuning of the responses.

15-Order Chebyshev Band-Pass Filter Response

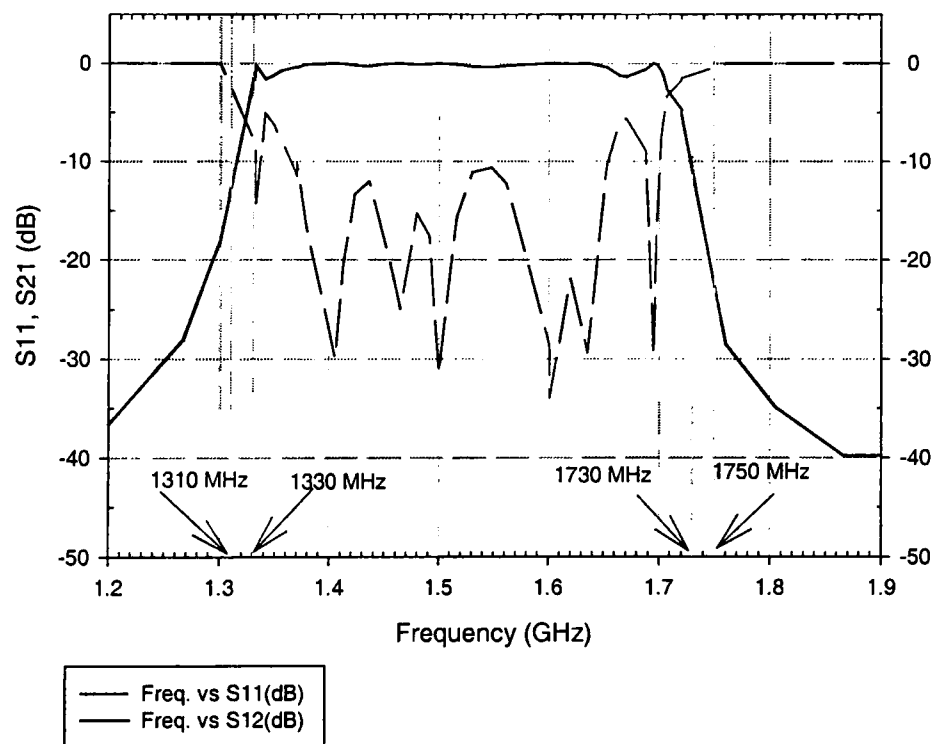


Figure 5: Simulation Responses of the Filter

3. CONCLUSION

We have shown a new HTS fifteen-pole band pass filter on a LaAlO₃ substrate. We have described the filter design, and the simulation results. The first meandered line stub filter shows a promising results for radio astronomy applications at 1.55 GHz. However, as it is going to be fabricated on superconductor, it is important to bring down the whole size whilst still maintaining the performance. Hence, we need to further optimise the circuit before production.

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