

# Cryogenic Filters for RFI Mitigation in Radioastronomy

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**Abstract.** RFI mitigation in Radioastronomy can be achieved adopting cryogenic filters in appropriate typologies. A study has been conducted in L, C and X band with the evaluation of the filter architecture in copper, with theoretical estimation, computer simulations, prototypes realization, laboratory measurements. Such work has been preliminary to the realization of HTS samples with the purpose of a similar complete characterization approach.

## 1. Introduction

Interferometric observations in radioastronomy and in particular in VLBI are less sensitive to the RFI presence with respect to a single dish total power system. Indeed an interferometer primarily responds to correlated signals, then radio interference present at only one telescope produces reduced effects, that are strongly attenuated as long as the integration time increases. Nevertheless strong signals can affect the general interferometer performance because of the inter-modulation products. An other effect the interferometer is affected by is the de-correlation of the bandwidth in case of wide band interference as fringe rate at opposite edges of the observed band is in general much different. Moreover any additive contribution to the receiver noise acts as decreasing factor for the correlation coefficient.

A good approach to properly take into account the RFI effects this is adopting general rules to set as high as possible the spurious free dynamic range increasing the receiver OIP3 factor and accurately studying the nature of the observed band in order to better adapt the receiver with the environment where it has to operate. While the first is in some way straightforward to implement, the second requires an accurate determination of the interfering signals in the band and outside, because harmonics could introduce products in the observed band. Different solutions are possible and the filtering option is the most obvious, while it is not too obvious where to insert a filter and which type is to be selected: the choice indeed depends on the specific RFI spectrum occupancy. A band-pass filter can be inserted in the LNA amplification either as an inter-stage filter or as front-end. Such filter insertion can be realized inside the LNA enclosure and depending on the position the realization technology has to be chosen between Cu and superconducting materials.

The different solutions have as common factor the need to take into account that the LNA operates, for adding a reduced noise contribution, at cryogenic temperatures. A filter inserted in the cryogenic path should then behave noise performance minimal enough to keep its insertion still valuable. While this

contribution could be important in an intermediate stage, it is an essential element when the filter is the first component of the chain. A trade-off evaluation has to be performed determining the conditions when the increased noise temperature due to the filter insertion is worth with respect to the reduced noise contribution due to the interfering signal.

## 2. Filters performance

An analysis has then been undertaken to determine the filter typologies that better fits with their insertion in a LNA enclosure, then considering linear dimension and area occupancy. Pass-band filters have been examined as inter-stage elements planning their realization with the same substrates and adopting materials and technologies used for the low noise amplifier realization. In the case of front-end filters, HTS (High Temperature Super-conducting) materials have been taken into consideration. For the sake of simplicity and practical realization, lumped element filters have not been examined, but only microstrip typologies. More software packages have been used and compared to simulate the performance and in some cases the filter realization has been performed to verify the simulation goodness and actual filter performance. Such prototypes have even been measured at cryogenic temperature to evaluate their effective impact on the overall performance. Few architectures have been proved particularly valuable for the goal to achieve. In some cases a design for the HTS version has been produced and the methods to implement such kind of filters are under an advanced detailed study; the first prototype will be shortly measured in L band.

Studies have been done in C band in the range 4.70-5.05, band commonly adopted in VLBI radioastronomy, taking into consideration square open-loop typology in quasi-elliptic structures. Simulations have been realized with some practical realization for comparison. Adopting Cu on RT/Duroid6010LM, at 300 K temperature behaving  $er=10.2$ , with 1.7dB typical attenuation in band and a minimum rejection of -32.4 dB for frequency values in the lower side, while -20.4 in the upper side, with a typical selectivity of 115 dB/GHz. The same filter at 77 K, having an  $er=11.75$ ,

presents a mean attenuation in band of 1.2 dB with similar minimum rejection values while a selectivity of 128 dB/GHz. This project has been transferred to an HTS material YBCO on LaAlO<sub>3</sub>, with  $\epsilon_r=23.6$  operating at 77 K, and showing an attenuation of 0.1 dB in band, minimal rejection of -32.5 dB and -25.2 dB, with the interesting selectivity values of 215 dB/GHz and 362 dB/GHz in the lower and upper side of the filter frequency pass-band.

In the X band for the frequency range 8.18 - 8.58 GHz, still widely adopted in VLBI, similar studies reported at 300 K for Cu on Duroid a typical attenuation in band of 2.5 dB with minimal rejection of 37.1 dB and 22.8 dB for lower and upper band sides respectively. Similar rejection values have been found for the HTS material, with a much reduced attenuation in band of 0.06 dB.

Linear phase filter have even been analyzed trying to optimize the phase linearity in the range of the L band 1.40 - 1.72 GHz, adopting Cu on Duroid at 300 K. Attenuation of 0.4-1.2 dB in band is obtained for a group delay of 1.4 - 1.9 ns. This kind of project showed particular difficulties for taking under reasonable values all the fundamental parameters.

Finally an HTS filter in L band range 1.40 - 1.72 GHz has extensively studied to produce a real sample to be adopted for a radar emission mitigation. Typology considered was Hairpin with YBCO on LaAlO<sub>3</sub>. Simulated performance show still pretty good attenuation values in band, less than 0.1 dB, return loss better than -20 dB, minimal rejection better than -40 dB and -30 dB respectively for lower and upper sides of the pass-band, while slopes are 165 dB/GHz and 160 dB/GHz. The realization of the filter prototype is at time of writing in advanced phase and it will be reported.

### 3. Conclusions

Integrating filters inside LNA structures is an interesting option in order to mitigate effects of severe RFI. A good method is to determine the spectrum to observe inserting pass-band filters at a stage where the best compromise is found between benefits and drawbacks. Cryogenic temperature brings moderate benefits on Cu lines, while much better performance are obtained with superconducting materials at the expenses of increased cost and more difficult implementation. It's anyway valuable in some cases adopt Cu structures in intermediate stages. The trend we think useful to follow is to gain experience components so to adopt them when the RFI situation suggest their use. So much effort is worth to be spent on this subject for an careful costs versus benefits evaluation.

### References

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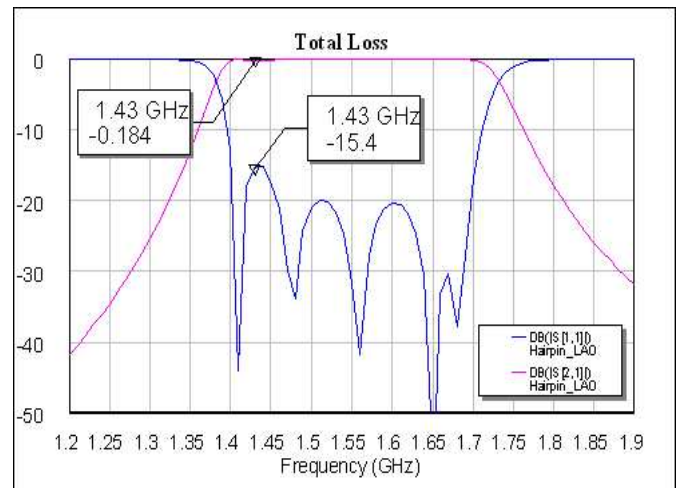


Fig. 1. HTS filter response simulation in L band.