High frequency crystal monolithic filter with high power level in airborne application

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ABSTRACT

Radar and communications systems require frequency references with ultimate noise performance with the aim of improving the sensitivity of the advanced devices.

In order to achieve a very low noise floor combined with a high level output, *AR-Electronique* has studied and developed a new filter generation.

In this paper, we present a specific filter design using monolithic crystal resonators technology with a special cut angle and innovative metallization, allowing high input power. Combined with an oscillator, a very low phase noise floor is achieved at the output.

INTRODUCTION

Following our paper of 2007, we have continued our investigations about the behaviour of a crystal filter operated at a high input level.

The objective is also to minimize the filter volume in order to integrate it in the oscillator case and to obtain, directly at the oscillator output, an ultimate phase noise floor.

AR-Electronique has studied in particular this phenomenon in airborne applications to improve the new systems, i.e. in the range of 100 to 200 MHz.

STATE OF THE ART

Standard quartz filters actually accept only low drive levels lower than 0.1 mW, i.e. –10 dBm.

In our paper of 2007, we had investigated different cut angles and different materials.

In order to deliver a constant input signal level in the full temperature range, we have chosen a special double rotation cut enabling us to obtain the relevant useful bandwidth.

In accordance to the customer requirements, we have made all our tests at a commonly used frequency : 120 MHz.

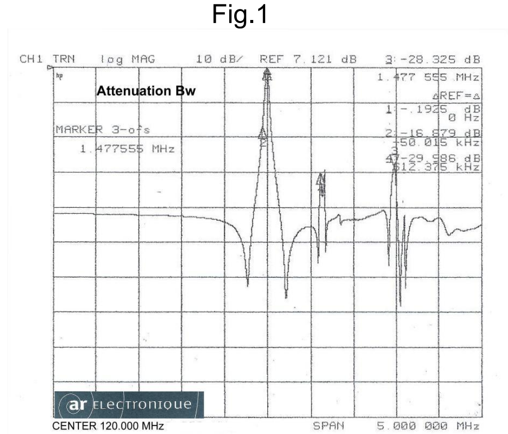
This filter is designed using a 2 poles structure integrated on a single monolithic wafer. This enables to optimize the miniaturisation of the filter, compatible with the oscillator hardened structure.

DOUBLE ROTATION CUT FUNDAMENTAL MODE

Special computations and design has allowed us to obtain and reproduce the useful bandwidth to be very flat : < 0.5 dB over 10 kHz.

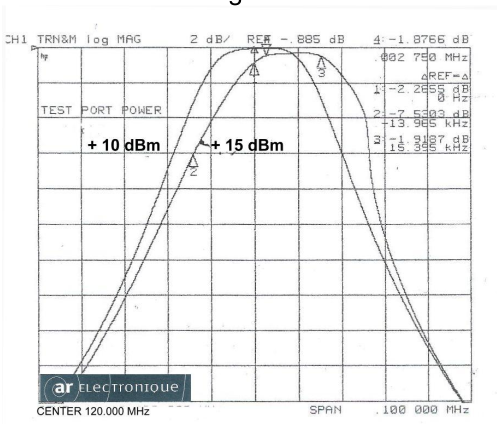
Typical out of band attenuation is given hereunder :

Fig.1



On the next figure, we can see the pass bandwidth for 2 input levels : + 10 and +15 dBm.

Fig.2



We can observe that after +13 dBm, for + 15 dBm, the curve is very distorted. Higher levels often cause the destruction of the crystal resonator.

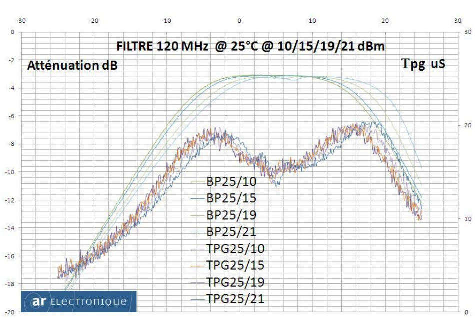
DOUBLE ROTATION CUT
3 rd OVERTONE

We have recalculated special metallization mask with a relevant metal coating in order to use the monolithic resonator in third overtone.

The power tests have been very satisfactory, a very low distortion enables to accept levels up to +17 dBm (50 mW).

Results for different levels are given hereunder :

Fig.3



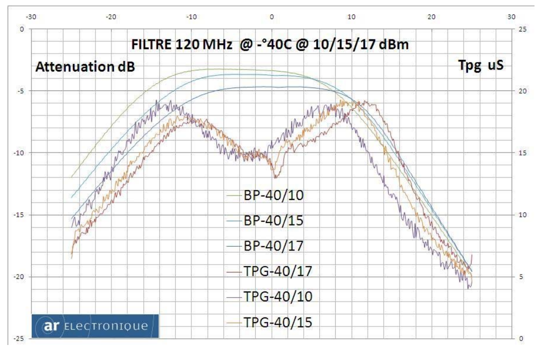
We have optimised the cut angle and the metallisation of the blanks in order to obtain a filter working correctly in an airborne standard temperature range.

Following curves allow us to observe the bandwidth drift in the temperature range -40 to + 85°C combined with input levels from 0 up to + 17 dBm.

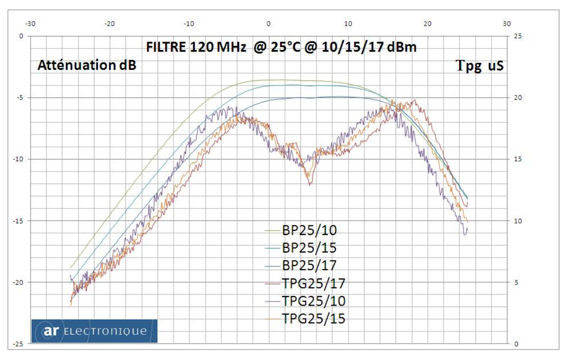
We can see that the filter behaviour is stable and keeps it characteristics with an Insertion Loss of only 4 dB ± 0.5 dB.

The 3 following curves show the pass bandwidth variations in attenuation and group delay with 3 input levels : +10, +15 and + 17 dBm, at 3 temperatures : -40,+ 25 and +85°C.

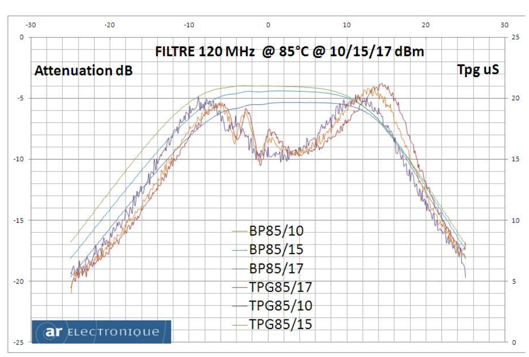
- 40°C Fig.4



+ 25°C Fig.5

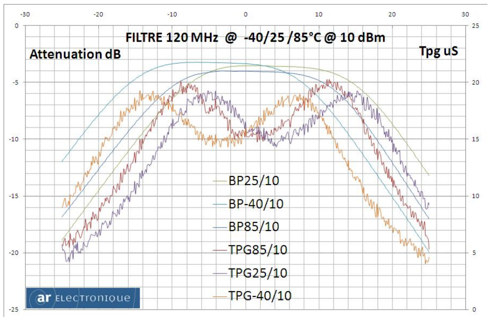


+ 85°C Fig.6

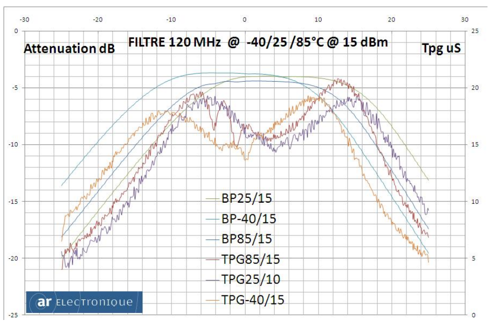


The 3 other following curves show the pass bandwidth variations in attenuation and group delay with these 3 temperatures at these 3 input levels : +10, +15 and + 17 dBm (50 mW).

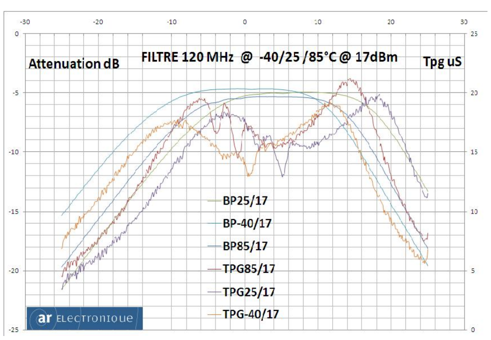
+10 dBm Fig.7



+ 15 dBm Fig.8



+ 17 dBm Fig.9



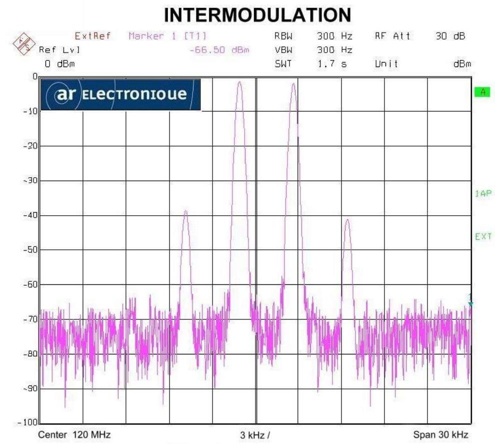
INTERMODULATION MEASUREMENTS COMPARISON

High power level sensitivity of a device can be as well characterized by 3rd order intermodulation measurements.

Following curves compare, with equal levels of 2 input frequencies, the 3 rd. order intermodulation tones level for filter designed with single rotation AT cut crystal and filter designed with our special double rotation cut crystal.

Fig.10 shows Intermodulation with standard AT cut at level of 0 dBm:

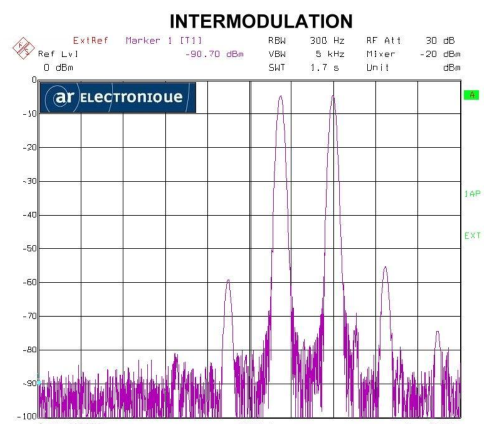
Fig.10



Input tons level 0 dBm Standard AT Cut O3.

Fig.11 shows Intermodulation with 3rd.overtone special double rotation cut at level of 0 dBm :

Fig.11



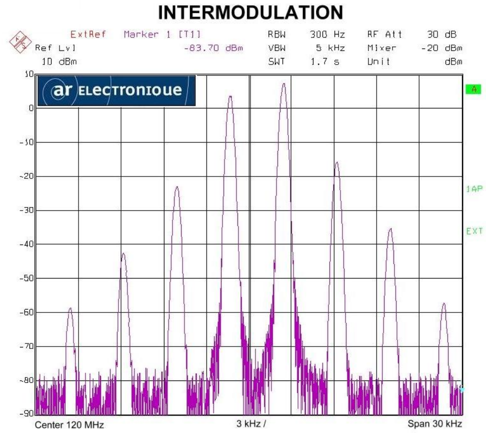
Input tons level 0 dBm double rotation Cut

We can observe that the intermodulation of the filter designed with special double rotation cut is improved with a ratio of about 15 dB.

We have then increased the input level at + 10 dBm. Results are given hereafter.

Fig.12 shows the Intermodulation with standard AT cut at level of + 10 dBm:

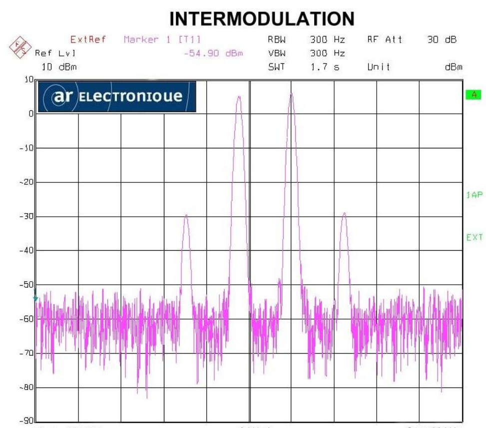
Fig.12



Input tons level + 10 dBm Standard AT Cut O3.

Fig.13 shows Intermoduation with 3 rd. overtone special double rotation cut at level of + 10 dBm :

Fig.13



Input tons level + 10 dBm double rotation Cut

We conclude that the filter performance designed with special double rotation cut has improved by a ratio of 8 and 10 dB.

INTEGRATION INTO THE OSCILLATOR

The filter has then be integrated in cascade with the oscillator in order to obtain directly the output signal.

We can compare on the following curves the phase noise reduction due to the effect of the filter with an input level of + 17 dBm (50 mW).

Fig 14

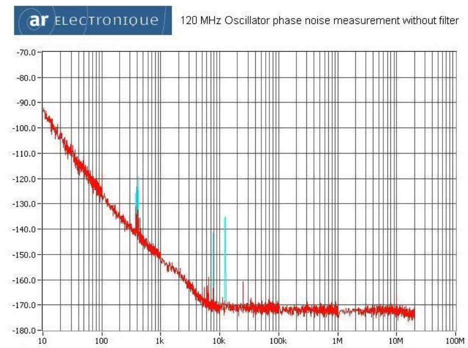


Figure 14 shows the phase noise of the unfiltered oscillator. Noise floor is at -170 dBc / Hz.

Fig 15

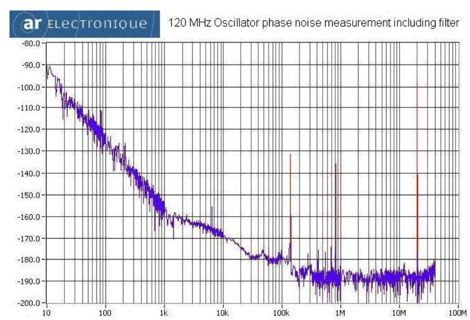


Figure 15 shows the phase noise of the oscillator with the filter in cascade. We can observe that the noise floor is now around - 190 dBc / Hz (limit of the measurement system).

Fig 16

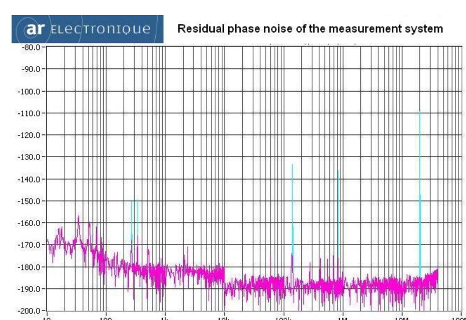


Figure 16 shows the residual phase noise of the measurement system which is lower than -190 dBc / Hz.

We can guarantee that the noise floor of the oscillator is lower than - 190 dBc / Hz.

In order to characterize this ultimate noise floor, the measurements have been performed by the use of cross correlation phase noise setup from *Aeroflex.*

SEVERE ENVIROMENTAL CONDITIONS

We have tested the filtered oscillator In extreme mechanical and thermal environmental conditions.
No damage and no degradation of behaviour have been noticed during and after the tests.

The monolithic resonator is mounted in a small 3 fixation points case. This type of case offers a very good behaviour under severe environmental conditions.

Such complete oscillators have been tested with this high power for more than 3000 hours in order to evaluate the liability and the ageing. We do not have observed any significant variation.

CONCLUSION

Currently *AR-Electronique* has clearly confirmed that it was possible to produce high frequency filters at 120 MHz working with high input power drive level under hard environmental conditions.

Such types of filters will be specially appreciated in airborne application.

This type of filter associated with a very low phase noise oscillator has enabled us to reach ultimate noise floor of the system.

AR-Electronique is now in the industrial phase of manufacturing oscillators delivering high output power up to + 14 dBm specifying very low phase noise floor lower than - 190 dBc / Hz.