Narrowband active GaAs MMIC filters in K-band

J. Vindevoghel*, P. Descamps**

* Institut d'Electronique et de Microélectronique du Nord (IEMN) – UMR CNRS 8520
Université des Sciences et Technologies de Lille
Avenue Poincaré
BP 69
F – 59652 Villeneuve d'Ascq Cedex
Ph : +33 (0)3 20 19 79 32
Fax : +33 (0)3 20 19 78 95
E-mail : jean.vindevoghel@iemn.univ-lille1.fr

** Now with : ISMRA – ENSI Caen
6, Boulevard Maréchal Juin, 14050 Caen Cedex, France
Ph : +33 (0)2 31 45 27 95
Fax : +33 (0)2 31 45 27 89
E-mail : descamps@ismra.fr

***Abstract* - Active GaAs MMIC filters in K-band, around 22 GHz, have been designed, realised and characterised. Simulation and measurement results are compared and agree. The best performances measured for a band-pass filter centered at 21.98 GHz are a bandwidth of 0.75 GHz and a noise figure of 1.95 dB.**

I. INTRODUCTION

In Europe, a lot of applications such as digital high definition television and integrated services of digital broadcasting operate in the frequency-band 21.4 to 22 GHz [1] ; so, it appears of interest to develop low cost and low noise filters in this frequency-band ; these filters are to be used as first stage in home receivers.
In order to build high-selectivity filters, GaAs MMIC active inductors have been first conceived in this band [2] ; these inductors exhibit high Q values (about 2500) in a narrow band of frequencies.The design of the inductors is simple and we have got low losses, low noise figures, low power consumptions. Moreover, it is possible to widely tune the inductors.

In this paper, we present and compare simulated and experimental results about MMIC active filters using this technology ; large-signal behaviour and temperature dependence of these components are presented.

II. SIMULATION AND DESIGN OF THE FILTERS

The active inductors and the active filters use HEMTs (process ED02AH from PML foundry [3]) ; we have chosen normally off transistors which have a low consumption, a high transconductance gm and a low noise figure at 22 GHz.
The gate of the transistors has 6 fingers which are 30 µm wide. The optimum biasing voltages of the normally off transistors are V_{gs} = 0.65 V and V_{ds} = 3 V.

The main specifications asked to the band-pass filter that we report about are a central frequency of 22 GHz, a bandwidth of 60 MHz, a rejection of –30 dB outside the bandwidth, a noise factor lower than 5 dB. Moreover, it must be input and output matched, must be linear and unconditionally stable. This can be done using active inductors [2] which can be electrically tuned. This technology allows to electrically adjust the quality factor Q in order to obtain a very narrow resonating frequency-band and to tune the central frequency.

The circuit diagram of a band-pass filter is presented in figure 1.

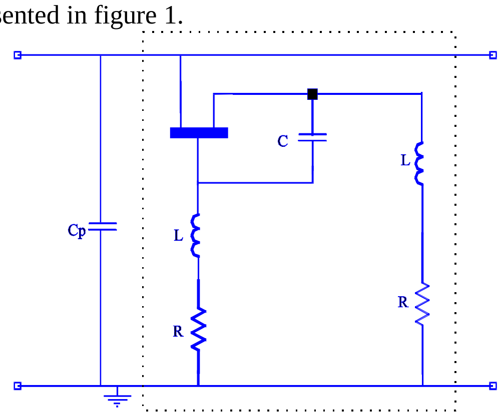

Fig.1 : circuit diagram of a band-pass filter

It can be seen that the band-pass filter works with a MMIC capacitor Cp paralleled with an active inductor ; in the case of a band-stop filter, a MMIC capacitor would be seried with the active inductor.

In order to balance the losses of the active filter, an amplifier is added : it is also made with a normally-off transistor. The whole circuit (filter and amplifier) is input and output matched to a 50 Ω load.

A S-parameter analysis of the circuit has been made between 1 and 30 GHz [5], to make sure of the unconditionally stability of the filter. The theoretical results are shown in figure 2 for the S-parameters and in figure 3 for the K-factor.

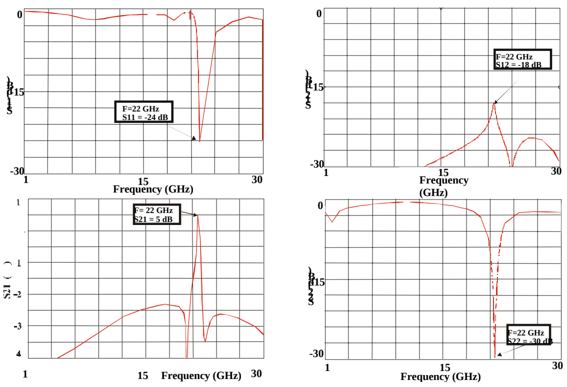

Fig.2 : Simulated $S_{ij}(f)$

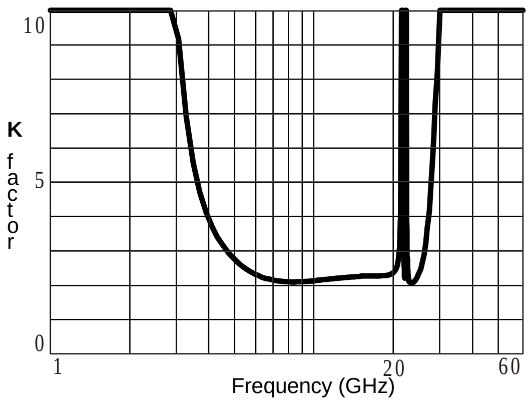

Fig.3 : K(f)

It can be noted that values, obtained at 22 GHz, are S_{11} = -24 dB, S_{22} = -30 dB, S_{12} = -18 dB, S_{21} = 5 dB. The K factor is always higher than 2.

Moreover, a simulation about the noise figure in the bandwidth of the filter gives NF = 3.5 dB.

At last, a non-linear analysis was made and we obtain the 1 dB compression point for P_{out} = 9.5 dBm and P_{in} = 6 dBm.

III. RESULTS

The band-pass active filter (figure 4) has been built in GaAs MMIC technology at PML foundry, within the context of a multi-user project. The dimensions of the integrated circuit are 2000 * 1500 µm.

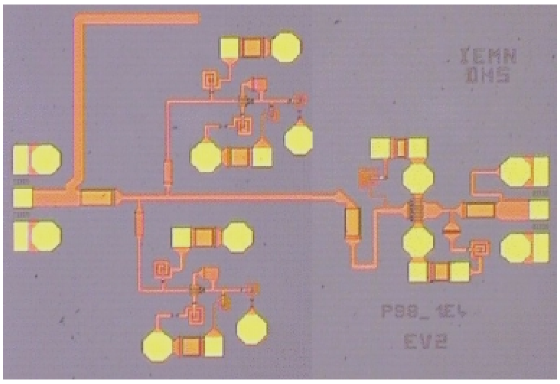

Fig.4 : photograph of the 22 GHz GaAs MMIC active filter

To be characterised, the filter is mounted in a K-cell [4] as shown in figure 5.

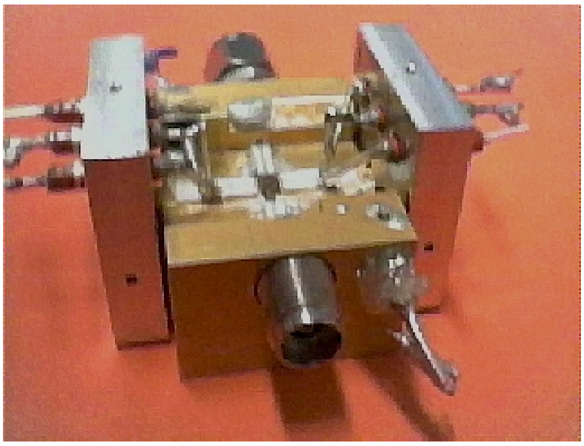

Fig.5 : photograph of the filter in the K-cell

As formerly said, in order to be sure that the circuits are unconditionally stable, the measurements have been made from 1 GHz up to 25 GHz. The measurements have also been made vs the temperature (temperature controlled from –50°C to +50°C) and vs the biasing voltage V_{ds}.

In figures 6 to 8 we present the experimental results about the S-parameters S_{11}, S_{22} and S_{21} vs the frequency, up to 25 GHz , at room temperature and for a biasing V_{ds} = 2 V and V_{gs} = 0.65.

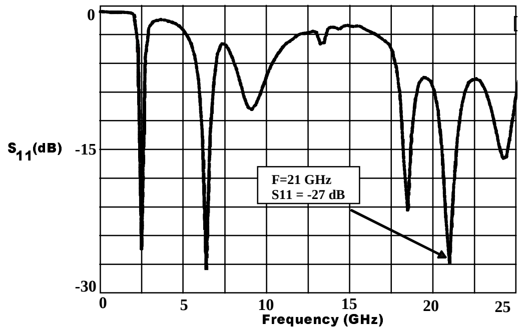

Fig.6 : S_{11} (f) – Experimental

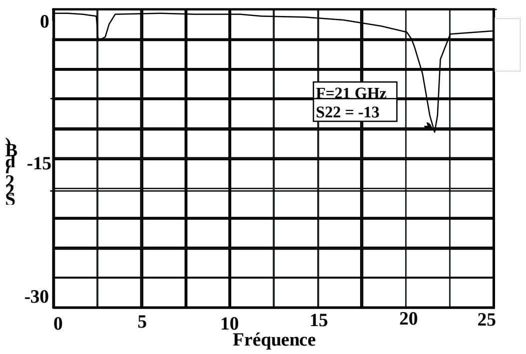

Fig.7 : S_{22} (f) – Experimental

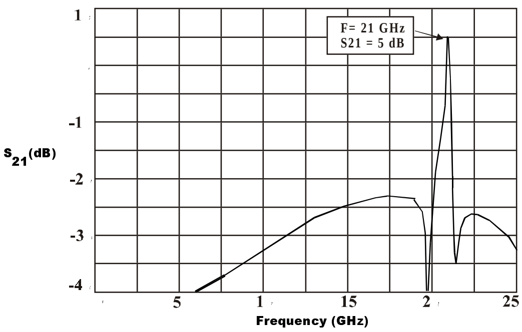

Fig.8 : S_{21} (f) – Experimental

In figure 9 we compare the simulated and measured values of the transmission coefficient S_{21} vs the frequency ; we also compare the simulated transmission coefficient of the active filter to the one obtained using a passive inductor.

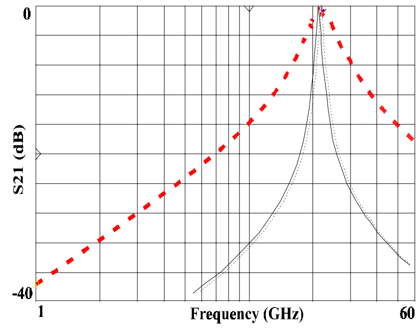

Fig.9 : MMIC active band-pass filter : S_{21} simulated (full line)and measured (points)
Comparison with a passive band-pass filter (dotted line)

These curves clearly show that using an active filter instead of a passive one is of a great interest : the frequency band of the active filter is widely more selective than for the passive one : the 3 dB bandwidth is 6.4 GHz when looking at the simulated passive filter and only 0.75 GHz for the active filter. The resonant frequency is 21.98 GHz. Moreover, the measured values of S_{21} agree very well with the simulated values of the active filter (the two curves superimpose fairly good). We also measured insertion losses of 0 dB at the resonant frequency of 21.98 GHz ; the return losses are -15 dB at 21.98 GHz. As for the noise figure, its better value is 1.95 dB at 21.98 GHz, and its variation vs frequency are shown in figure 10.

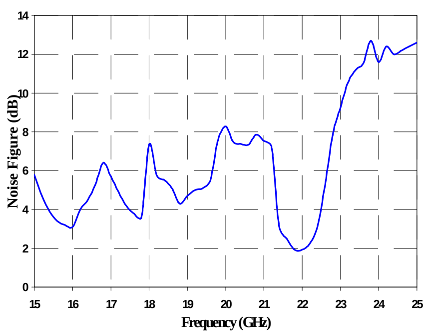

Fig.10 : noise figure of the MMIC active band-pass filter vs frequency

We note that it is also possible to tune the resonant frequency using a voltage adjustment of V_{ds} : when varying V_{ds} from 3.2 to 3.5 Volts, it is possible to shift the central resonant frequency from 21.87 GHz to 22.18 GHz. As an example we have adjusted the central frequency at 22 GHz : then we measured insertion losses of –0.5 dB, but it is possible to reduce them at 0 dB, varying V_{gs}.

As last results, the –1 dB compression point is 12 dBm and the variations of the noise figure vs the temperature between –50°C to +50°C are less than 0.15 dB around the initial value of 1.95 dB at 25°C.

IV. CONCLUSION

Tunable, high quality GaAs integrated active filters in K-band are demonstrated ; 0.2 µm GaAs P-HEMT from PML foundry have been used. The best performances measured for a band-pass filter centered at 21.98 GHz are a bandwidth of 0.75 GHz and a noise figure of 1.95 dB. The dc power consumption is 40 mW and rejection up to –60 dB is obtained.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

[1] M.R. Stiglitz, C. Blanchard, *Frequency allocations accommodate new commercial applications*. Microwave Journal, July 1992, pp 28-34

[2] E. Vanabelle, *Filtres actifs et amplificateur faible bruit monolithiques à 22 GHz en technologie P-HEMT destinés à la télévision haute définition.* Thèse d’Université, Lille, 19/07/1999

[3] Philips Microwave Limeil, GaAs Foundry and ASIC Design Centre, *ED02AH Design Manual –V 1.1-, Document number PML –G-SC-0009-E/V1.1*

[4] G. Dambrine, *Caractérisation des transistors à effet de champ : mesure précise de la matrice de répartition et détermination directe du schéma équivalent*. Thèse d’Etat, Lille, 1989

[5] HP –EESOF, *Microwave Design System – 6.0*