A BAND PASS FILTER FOR THE 436 MHZ BAND

Adrian DONE
Stefan cel Mare University of Suceava,Suceava
Str. Universitatii 13, 720229 Suceava, Romania,
Tel: +40 230 216 147, Fax: +40 0230 520 080, Email: rectorat@usv.ro

Abstract: To reduce interference, on the satellite receivers input, in the signal band the intercalation of a filter with the smallest possible insertion loss (less than 1 dB) is necessary , but with an attenuation out of useful band as high as possible. In designing, a series of data was obtained through simulation that allowed the practical execution of some filters. The filter series is composed of a filter with one λ/4 coaxial segment, with 3 λ/4 coaxial cells capacitive coupled, a 5 cell interdigital filter inductively coupled, with fixed input and output, and a capacitive coupled interdigital filter adjustable both at the input and output.

Keywords: *filter 435 MHz, coaxial filter, interdigital filter.*

I. INTRODUCTION

For very weak signals captured from satellites it is required a very low noise and high gain preamplifier. In the current use of the adjacent frequency bands, the preamplifier must ensure a selectivity that enables operation in all conditions, in the linear area, without inter-modulations.

The IARU (International Amateur Radio Union) became responsible for the management of the frequency bands for satellite communications, namely those located inside the amateur bands. Almost all the amateur or educational satellites use the frequency band between 435 and 438 MHz. If a few years ago the adjacent frequency bands were scarcely used, currently these are under ever growing pressure. Unfortunately for us, in the Suceava area, a commercial digital communications band has already been allocated, between 421 and 425 MHz. The common preamplifiers, as well as the antennas used, separate the two bands of signals to a very small extent (of the order of decibels, only through the antenna). Thus, interference are produced, this leading to increased noise in the reception, which often covers the signals.

A filter of at least 15 or 20 dB is required for the mitigation of the undesirable band, but with the lowest possible insertion loss. One must also consider that this mitigation is added to the NF (Noise Figure) factor of the first floor of the receiver.

II. EXISTING SOLUTIONS

In practice, on the receiver input wider band filters are used for two reasons: to tune on a given frequency without the retuning of the input and to eliminate interference by using directive antennas. Recent years have led to the development of ever more SDR (Software Defined Radio) receivers which often have very large filters. If for these the operating principle is very promising for space communications (especially through the ability to see a larger band and to easily compensate frequency variations due to the Doppler effect), the use of some preamplifiers and filters is necessary on the input.

The filters' theory is well established, but their practical realization often involves major efforts to find practical solutions for their construction.

The parameters of the filters that can be bought from the market do not meet some specific needs or their cost becomes dominant in the total price of the receiver**.**

The usual method of designing a filter uses formula that enables the calculation of the physical dimensions of the mechanical elements from the filter structure. Thus, for the l/4 "notch" filters, the physical length depends on the shortening coefficient, according to the dielectric material used in the coaxial cable. For the interdigital filters, the mechanical dimensions are intricate to choose, so that the usual method is that of tables or online calculators.

III. SOME THEORETICAL ISSUES

For a two-port, the ideal band pass filter provides a total energy transfer between two ports in its passing band and a null energy transfer outside the pass band. In reality, such a filter does not exist.

To define the actual filters, the definition of the S parameters is used, that are utilized in the microwave systems. If we designate as a_i and b_i the power that enters, respectively the one that exits:

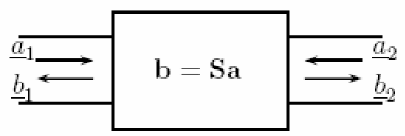

Figure 1. The S [10] type parameters.

The two-port (according to figure 1), the

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following relation can be defined:

$$\begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{vmatrix} s_{11} \; s_{12} \\ s_{21} \; s_{22} \end{vmatrix} \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} \quad (1)$$

The s_{ij} coefficients are complex numbers and are defined by the condition of adapting to the two ports. For the passive two-port, as the RLC filters, the module of each S parameter, are subunit, as shown in [10]. The physical characterization of the two-port can be obtained under certain imposed conditions. Thus, when appropriate impedance adjustment on the output exists, then $a_2 = 0$ and thus it is obtained a relation like:

$$s_{11} = \frac{b_1}{a_1} \quad (2)$$

s_{11} being the input reflection coefficient.

Setting for the output the same adaptation condition, namely $a_2 = 0$, the following relation is obtained:

$$s_{21} = \frac{b_2}{a_1} \quad (3)$$

where s_{21} is the transfer characteristic of the output related to the filter's input. This is the most important parameter of a filter. The s_{ij} (with $i,j \in \{1,2\}$) parameters are dependent on the frequency, through projection the filter having to follow that dependency chart.

IV. PROPOSALS AND TESTED VARIANTS

In order to achieve the goals, the analysis and the simulation of the designed solutions were conducted using Ansoft HFSS 12 software that allows the charting of the S parameters variation curves, based on the physical and mechanical parameters. The new filters were tested under laboratory conditions and are being used for the satellites reception systems in the 435 to 438 MHz band. Subsequently, these filters are to be tested practically on more receivers in real operating conditions.

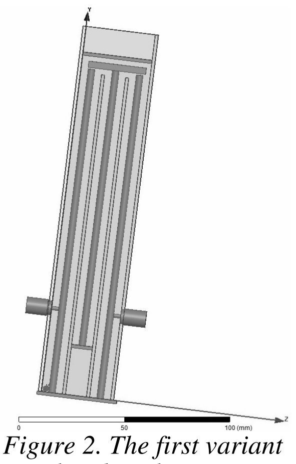

Figure 2. The first variant simulated, with promising results.

IV.1 Filter with one coaxial segment

For the beginning, a notch filter with a λ/4 coaxial cable segment was chosen. It is a solution often used to reject bands or unwanted frequencies. In our case, this solution proved to be entirely inadequate, with a mitigation difference between the two bands (421-425 MHz, 435-438 MHz, respectively) of only 3-4 dB (both in the simulated version, as well as in the practical one).

IV.2 Filter with three λ/4 coaxial cell

Under these circumstances, a combination of three coaxial dielectric air cells with λ/4 length, capacitive coupled in the area of maximum voltage was firstly chosen. As shown in Fig.3, a satisfactory feature was achieved through simulation, but mechanically difficulties arise in the practical realization (the distance between the coupling bar and the two input and output cells, should be low, performed as precisely as possible, ideally with adjustment options). Because in this version, the top of the bar of the middle cell transfers the energy by capacitive means, there is a need to reduce the length of the middle cell in order to obtain the desired resonance. On mechanical grounds, it was chosen to change this capacity especially on the side cells, thus resulting the configuration shown in Fig 4.

The input and output ports are represented by the two N jacks, obtained from an internal cylinder with the diameter of 2 mm and an outer cylinder with the diameter of 7 mm, separated by a teflon type dielectric. Cylinder A is used as a frequency adjustment screw. The B round pieces are teflon cylinders, with a reinforcement role and with a secondary electrical role, as it resulted later, both from the simulation and the practical testing. The 3 coaxial segments are with the round section of the main cable and the interior of the external part in the shape of square. To calculate the impedance of this "coaxial" in order to achieve the three lines, we used data from the tables given in [1].

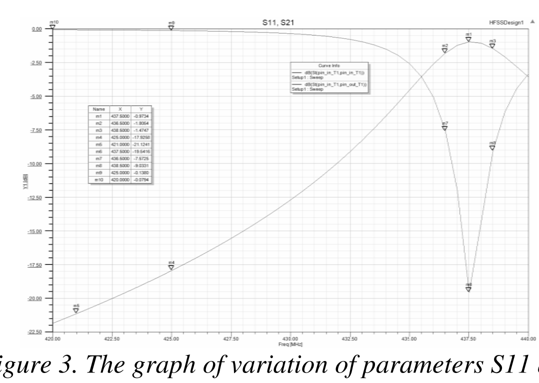

Figure 3. The graph of variation of parameters S11 and S21 of the filter, in the range 420-440 MHz.

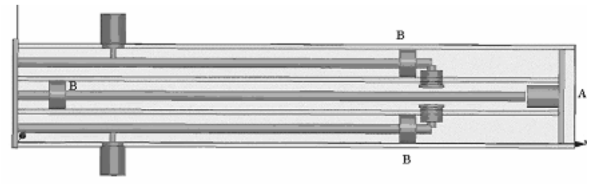

Figure 4. The image of the filter in HFSS.

After the simulation, the following parameters emerged: insertion loss below 1 dB, in the desired band, and an attenuation of 11 to 14.5 dB, for the unwanted band. The SWR (Standing Wave Ratio) was up to 1.4: 1 in the band and over 25: 1 in the unwanted band.

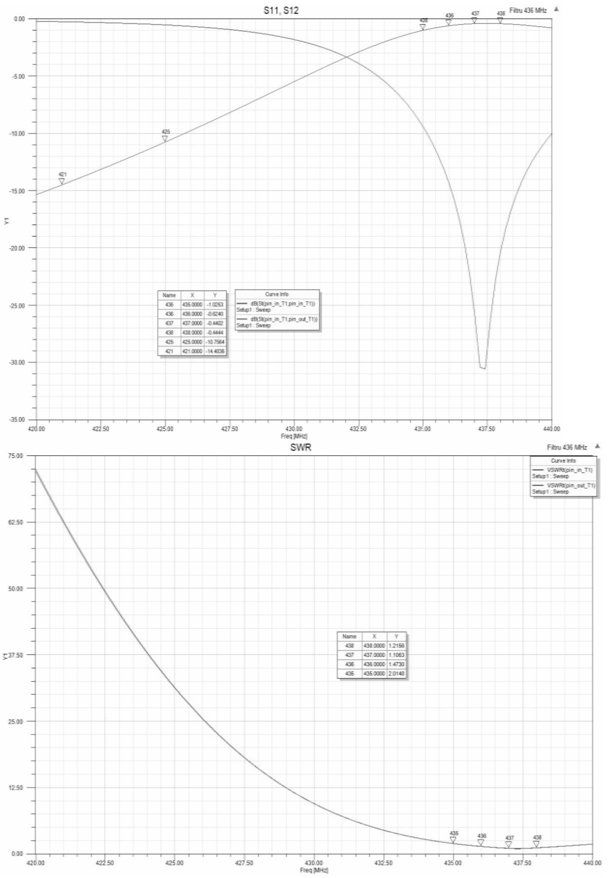

Fig. 5. The s_{11}, s_{21} Simulation and the VSWR of the filter

Fig. 5 represents: the input filter mitigation and losses and the input and output SWR , all depending on the frequency.

Practical Realization
After the Ansoft HFSS 12 simulation, the mechanical achievement, then the testing /practical evaluation followed. *Dimensions*: The Designing was based on the materials available on the market. Thus the "wire" of the coaxial was made of a copper pipe with an outer diameter of 3.5 mm. In order to obtain the highest possible quality factor, the coaxial cavity must have an impedance of approximately 75 ohms. From [1], it follows that for these requirements, the interior space of rectangular section, has to have the edge of about 11 mm. We chose 10 mm, for which the impedance value is approximately 67 ohms. The remaining dimensions were obtained through the HFSS software simulation.

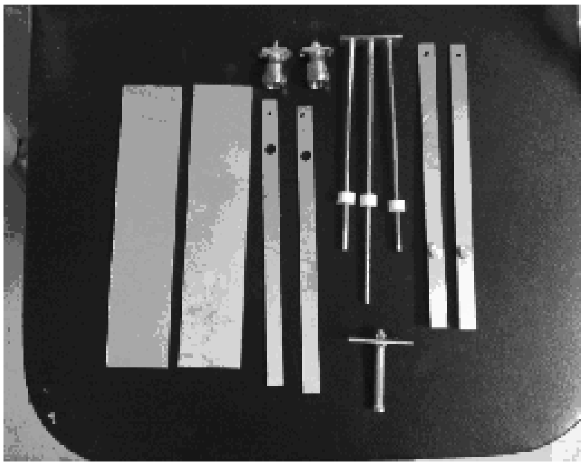

Figure 6. The components of the filter before assembly

Materials: For the entire filter, we used copper as conductor material and air as dielectric . Because the operation frequency is of 435 MHz in [2] it is shown that the radio-frequency penetrates the copper walls only 3.12 micrometers. Thus, we can choose as a material for the walls: double-plated copper glass-reinforced epoxy laminate (FR4) that has a thickness of the copper layer of 35 micrometers and the dielectric of 1.5 mm. Therefore, the material is thus much easier to solder and is cheaper than solid copper, without unwanted electrical effects.

Measurements: To check the achieved filter, a noise generator of about 70dB is used on the input and on the output the Anritsu MS2690A spectrum analyzer.

The measured values indicated a close correspondence with those obtained through simulation. It was noted the need of a screw A for frequency adjustment. The teflon spacers position modified, leading to a variation of up to 2 MHz of the working frequencies. The best position is the one shown in Fig. 4. The final positions of the B spacers were checked, using HFSS in order to highlight if negative influences occur.

In Fig. 7, the picture from the spectrum analyzer screen

Figure 7. The noise signal generator through the three coaxial cells filter.

is presented. In the lower left, it can be observed the disturbing signal that can still penetrate through the unscreened parts of the filter, when it is not adequately screened.

IV.3 Interdigital filter with five fixed inductively coupled cells

To increase the attenuation of the unwanted band, the shifting to a variant of 5 cells interdigital filter version was made. Unfortunately, the mechanical width restriction had to be abandoned because it would have led to an overcoupling regime with large ripple in the desired band.

After several simulations, a more difficult solution to achieve in practice occurred, having input and output couplings fixed to the socket, but with good performance compared to the 3 coaxial cells.

IV.4 Interdigital filter with five cells with adjustable capacitive coupling

Maintaining the dimensions of the previous filter and modifying only the coupling mode on the outside, it was reached the variant of Fig.8. For the software simulation, at the input and at the output two rigid bars were considered.

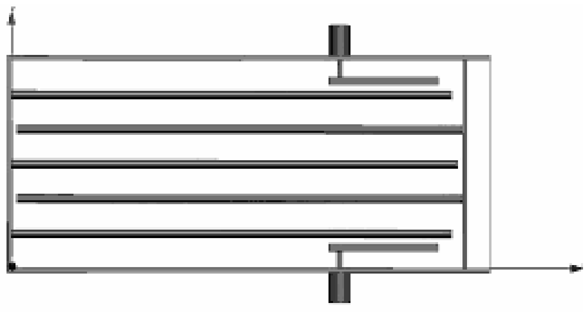

Figure 8. The simulated designs of the interdigital filter with 5 cells with adjustable capacitive coupling.

Actually, having only coupling purposes, these were basically made of two elastic blades, whose distances to the appropriate cells are adjusted by two plastic screws, threaded M4.

The HFSS software simulation was started in order to monitor this filter and the graph in Fig. 9 was obtained. During the simulation minor changes (below 0.5%) of the physical dimensions were noted, that causes major changes to filter parameters. Final adjustments were made in the practical realization, by using the 5 cells of threaded bars, with one blocking jam-nut.

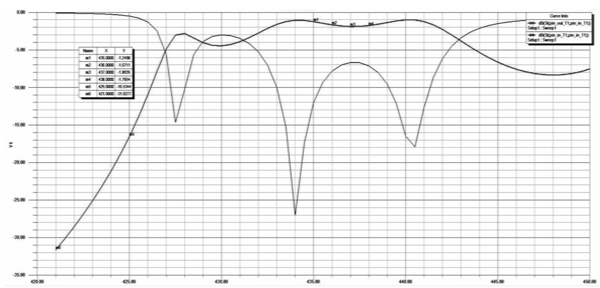

Figure 9. The variation of the s_{11} and s_{21}parameters versus frequency for the interdigital filter with 5 cells.

After building the filter, its performance measurements were done through two methods: using a noise generator or a N5183A Agilent signal generator. In both cases, an Anritsu MS2690A spectrum analyzer was used on the output. In the first case, the voltage/frequency graphic is shown in real time (the analyzer has been set to display averages), thus allowing rapid adjustment of the filter. In the second case, the graphic was displayed in 2-3 minutes but the values are more accurate, see Fig. 10.

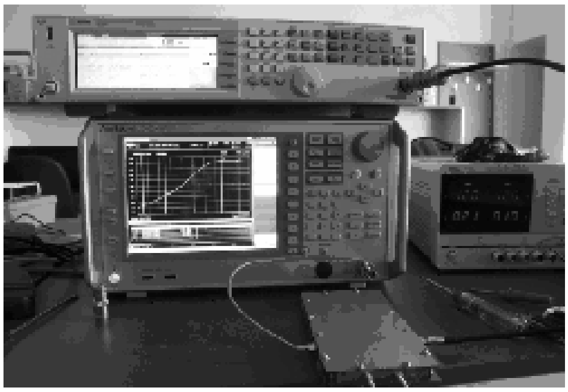

Figure 10. The measurement of the filter (bottom right) using an Agilent N5183A signal generator.

As a result of the simulations and practical tests, three filters with the following parameters were built:

No.	The filter type	Insertion loss [dB]	The loss on 425 MHz [dB]
1	3 coaxial cells	-0,88	-13
2	5 interdigital cells, fixed inductively coupling	-4,38	-27,29
3	5 interdigital cells, variabile coupling	-3,60	-33,85

V. CONCLUSIONS

Practically, three types of bandpass filters were made for frequencies between 435 and 438 MHz for the removal of band interference, usable in a ground stations reception for satellites.

In filters building, it was started from the dimensions defining and materials choice, then filter parameters were simulated using Ansoft HFSS software product 12. The process was iterative, until the achievement of the desired parameters.

All filters have been tested and characterized for an impedance of 50 Ohms, these being used at any point between antenna and receiver that is on receiver input, on preamplifier input or on the pillar, near the antenna. For a facile reconfiguration, these were built using N or SMA jacks.

Further research should confirm the assumption that the best option is the sequence of 3 filter cells (with low insertion loss) and preamplifier, mounted on the pillar of the antenna, then on the feeder and then one of the other filters mounted at the receiver input.

Their testing under actual operation conditions is to be made in the ground station using both a RTL-SDR receiver (which is a very cheap software defined radio that uses the DVB-T TV tuner dongle based on the RTL2832U chipset) and a FT857 transceiver.

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