Radio astronomy Hydrogen line front end on a budget

(Cascading two remote LNA by Adam Alicajic– 9A4QV)

One of most popular radio astronomy projects is radio telescope for receiving electromagnetic radiation from neutral Hydrogen atoms around 1420.405 MHz, usually called a 21cm band. Technical requirements for such a receiving system were quite complicated 10 years ago but today with the introduction of the SDR technology the things are much simpler. The system for receiving the Hydrogen line transmission is made of the antenna, LNA (low noise amplifier), filter and receiver. The antenna requirements are the same as 10 years back, the bigger the better. We can still rely on the old saying where the best LNA is a good antenna. Various antennas have been used with good success, parabolic dish reflectors, big horn antennas, single yagi, yagi arrays. On the other end of the receiving system there is a receiver. There was a requirement for the receiver frequency stability and sensitivity where output should be plotted on the graph so the hydrogen emission can be presented visually. Today we are blessed with the SDR technology where all the requirements can be covered with a small box connected to the PC through the USB port. SDR technology made radio astronomy affordable to everybody. Even a cheap 8-bit TV dongle, with some limitations, can be successfully used for the radio astronomy if driven with powerful software. Antennas can be made and cheap receivers can be purchased. What remains to design is the LNA and the filter. So far we did have both, the LNAs and the filters designed and available through some radio astronomy oriented web pages. Looking back, the cost of such amplifiers and filters was not small. Even today you will have to pay a decent amount for the cavity bandpass filters designed for 1420 MHz. Is there any other way to overcome such a high prices as we have solved the problems with the receivers using the cheap TV dongles? Let see if the low budget front end can be assembled using cheap components.

1. Simple start-up setup

The very simple setup that most of us were using instantly out of the box was the SDR dongle connected to the antenna using an SAT-TV grade coaxial cable as per Fig.1

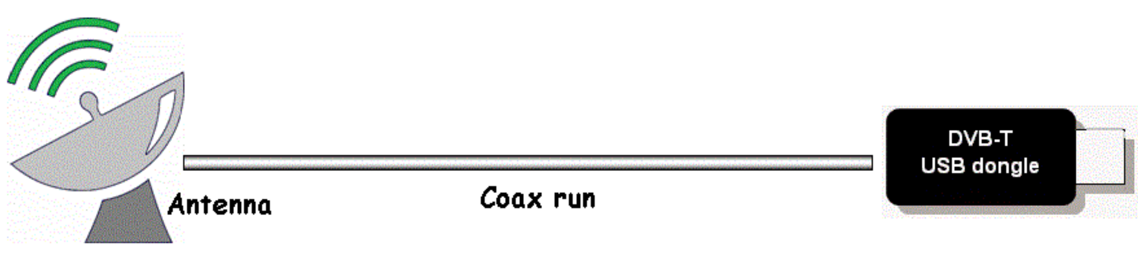


Fig.1 Simple antenna-radio setup

Let's review the simple setup that we are using. For the receiver, we have the DVB-T dongle with NF (Noise Figure) of 6dB. Various declared NF can be found, but this is the value very close to real tests performed, with a maximum gain set on the dongle. 15 meters of RG-6U cable is used to connect the outdoor antenna. Such a long run of the cable introduce extra 3.88dB of loss at 1420 MHz resulting the system NF of 9.88dB. Such a simple setup will not allow receiving the signals lower than -104dBm in 1MHz BW (Bandwith). The AppCAD application can help us with the math around NF and related temperatures.

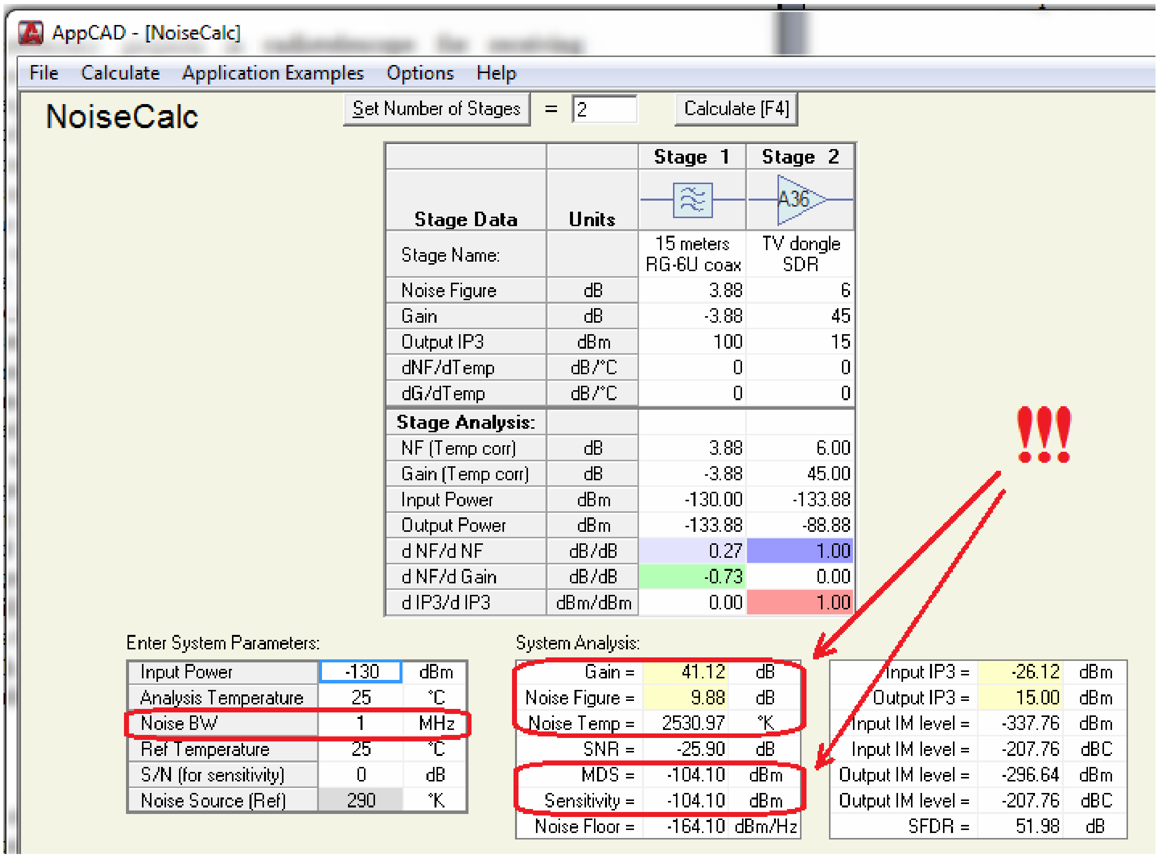


Fig.2 NoiseCalc

As we can see from the results, this setup will deliver poor results other than receiving strong local transmissions. Noise figure is very high and MDS is very poor. But hey, you heard that guys are using the LNA (Low Noise Amplifier) and this can improve the reception (but also create a lot of problems). Let's try the LNA.

2. LNA + SDR dongle setup

So you heard that introducing the LNA in the system the reception can be improved mainly due to the fact that overall system NF will be lower and S/n (Signal to noise ratio) will be higher or better. You also have heard another part of the story where LNA can not improve the S/n as the LNA itself has own noise figure that will add to already high NF of the receiver. Once the signal has been lost in the noise, there is no analog „magic“ LNA that can pull out that signal from the noise. You may ask now, where is the truth?

Both statements are true but you have to know when you will use each of the statements. Let's insert the LNA into our system and calculate the benefits if any. For the next setup, I will place the LNA close to the SDR dongle receiver and run the same 15 meters of RG-6U cable up to the antenna.

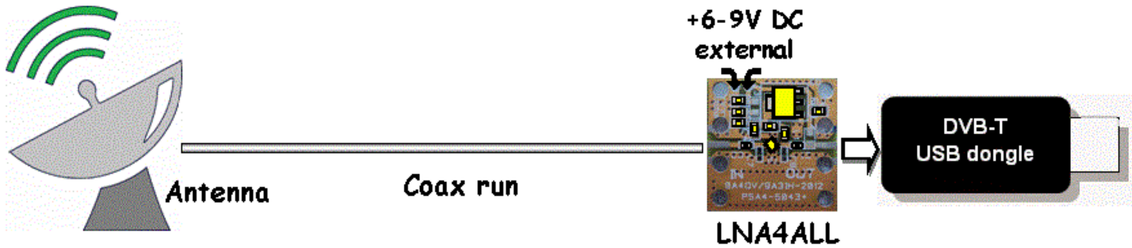


Fig.3 LNA + SDR dongle setup

The LNA used is the wideband LNA4ALL (http://lna4all.blogspot.com/) that cover all the frequencies from 28 MHz up to 3 GHz. LNA4ALL can deliver more than 24dB of the gain on the 100 MHz going down 11.5dB on 3GHz. At the same time, TOI/IP3 is +35dBm and the noise floor is quite low going from 0.65dB at 144 MHz up to 1.4 dB at 2.4 GHz. All S-parameters covering the range 28 MHz up to 3 GHz can be seen in Fig.4

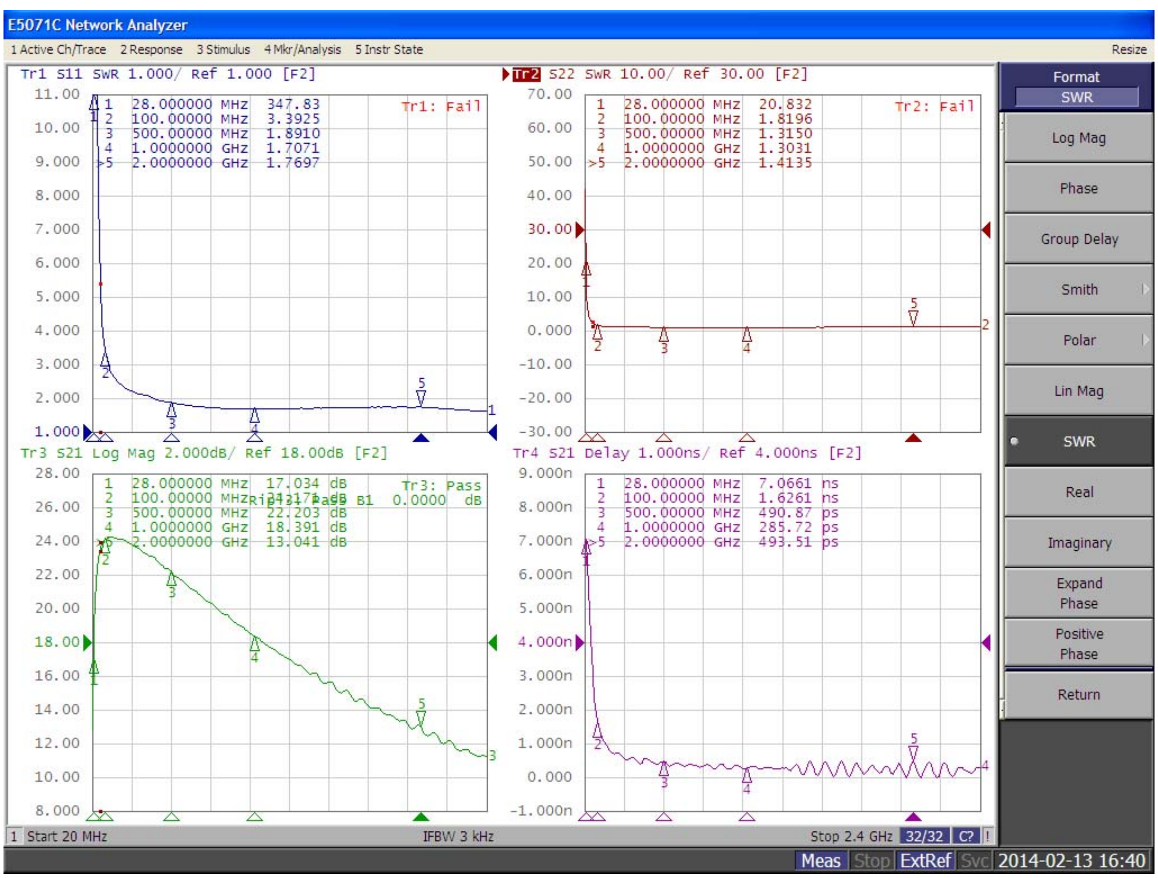


Fig.4 LNA4ALL S-parameters

From the graphs, we can see that LNA4ALL does cover the low frequencies starting from 28 MHz but the best performance can be obtained over 100 MHz. LNA4ALL cover the Hydrogen line center frequency 1420.4 MHz delivering 16.5dB of the gain and 0.9db NF. If we do the basic math from the Simple start-up setup where adding a 15 meters of RG-6U coaxial cable degrade the system NF for 3.88 dB, exactly for the cable losses, one may expect that adding the 0.9 dB NF amplifier will degrade the system noise even more. Well, it does not work that way. At least the *Friis* formula says differently. Besides the low noise figure of the LNA, the gain is very important part of mentioned Friis formula. Not complicate the things the AppCAD application was used to calculate all parameters of our system to find out if there is any benefit adding the LNA. The moment of truth, will LNA improve the sensitivity and system NF? Look for the answer in Fig.5.

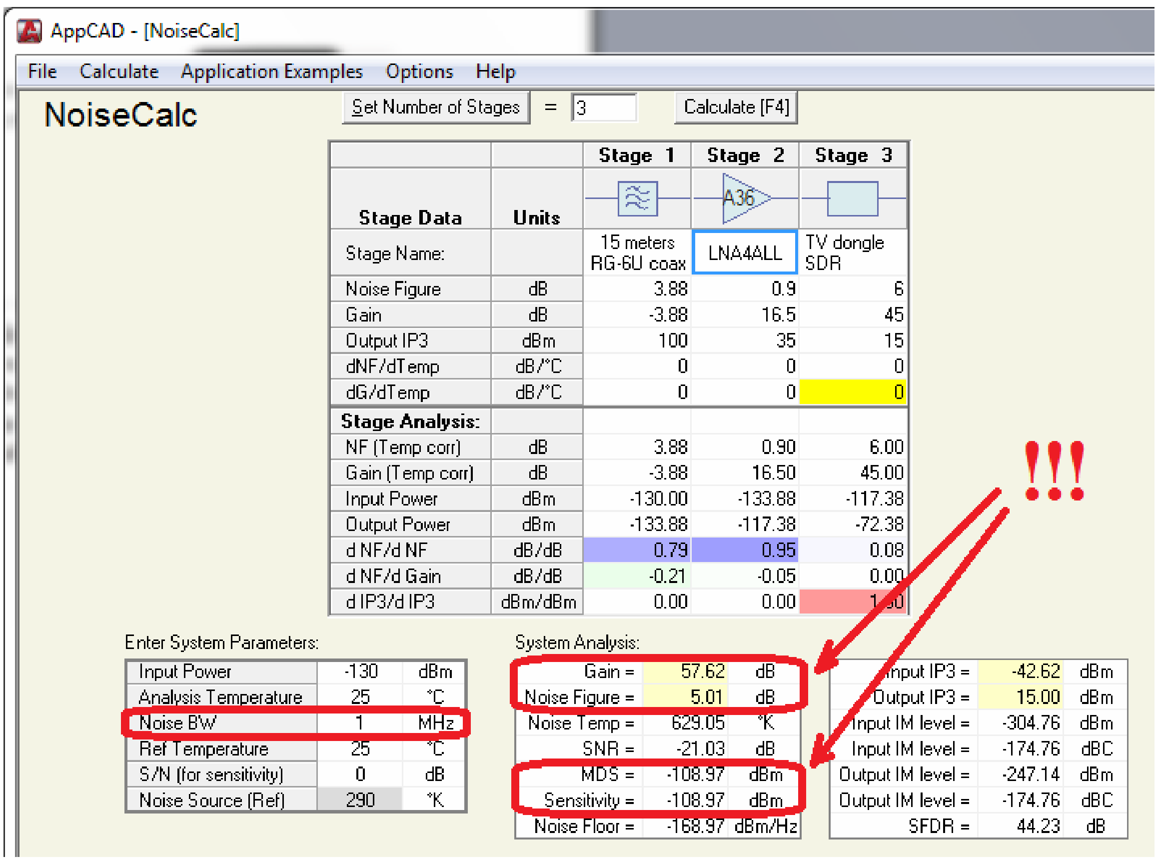


Fig.5 NoiseCalc LNA4ALL + SDR dongle

Comparing the results from the Simple startup setup and the one running the LNA4ALL we can notice the improvements in lower system NF (9.88 dB vs. 5.01 dB) and increased sensitivity (-104.10 dBm vs. -108.97 dBm). Both, the NF and sensitivity are better for exactly 4.87 dB. And yes, it does mean that we can receive now the signal that was buried in the noise a few dBs earlier without LNA.

The rule of the thumb point to the fact that the LNA should be placed near the antenna and not close to the receiver. What about that? Is that also true?

3. Remote LNA + SDR dongle setup

Let's try the following setup then. The LNA should be placed as close as possible to the antenna, preferably directly on the antenna feed or radiator. I will use the same 15 meters of the RG-6U coaxial cable and our TV SDR dongle at the end. The setup is the same as in the previous setup just the position of the LNA has been changed as per Fig.6.

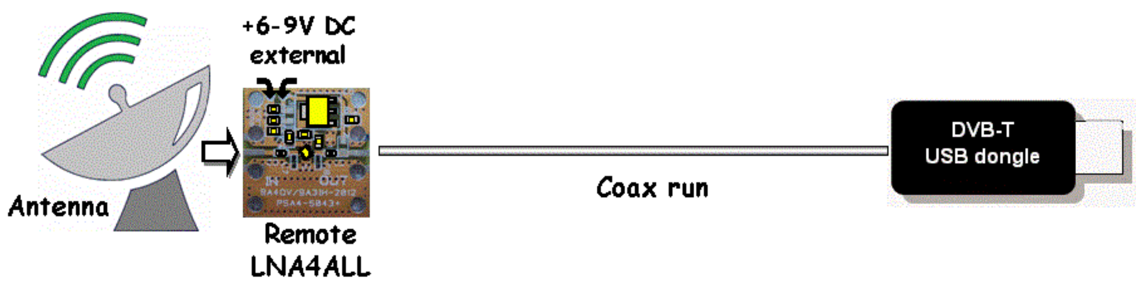


Fig.6 Remote LNA + SDR dongle setup

Installing the LNA on the antenna require a proper weather protection/shielding. It does mean more connectors and more potential humidity and contacts oxidation hence the proper installation is required. You do not want the water in your coaxial cable. Visually it may look in order but water in the cable is always a big problem. Let's see if the remote LNA installation is worth all the trouble. Here are the results, Fig.7.

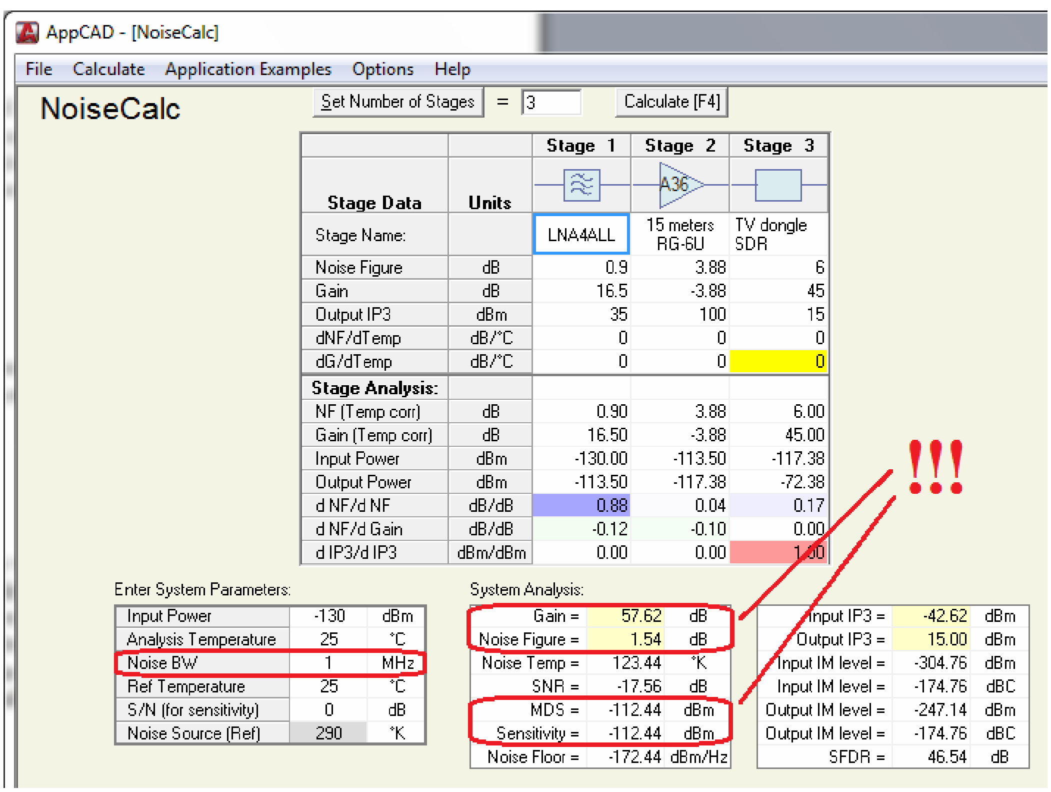


Fig.7 NoiseCalc Remote LNA + SDR dongle

The same AppCAD application was used and the same parameters. I just swap the coaxial cable and the LNA4ALL places in the calculator. Comparing the same figures, the NF is lowered to 1.54 dB and sensitivity increased to -112.44 dBm. Just repositioning the LNA close to the antenna NF and sensitivity improved for 3.47 dB. It seems that the results are worth the trouble by weather protecting the remote LNA. Unfortunately, this is not the only problem, there is also the power supply question. When the LNA was installed close to the receiver it was easy to power it from the external power supply with a short connecting wire. When the LNA is close to the antenna then the power supply cable should have the same length as the coaxial cable, in our example 15 meters. Another cable around the house. Welcome to the club!
This problem can be solved using the Bias-T. You probably heard about that trick too. Briefly, the Bias-T is a three port device, a standard diplexer. A diplexer is a device where you have a sum port with two filters, high pass filter on one port and the lowpass filter on the other port. Low pass filter should only pass the DC component and the high pass filter should block the DC and pass only the RF component. Both DC and RF will be present on the sum port. You guess already, the coaxial cable can carry both, the DC and the RF. This is something you can not do with the waveguide ☺ If you have the same Bias-T on both sides (receiver and the LNA) you can power supply your LNA through the coaxial cable. The Bias-T is not a perfect duplexer and there are some losses but they are minor and they are not affecting significantly the receiving chain.
The standard DVB-T dongles are not supporting the Bias-T on board and you should use the external Bias-T unit. You can find such a devices within the SAT-TV accessories called Power inserter. SDR dedicated dongles usually support the Bias-T (RTL-SDR, AirSPY, HackRF, RSP) Their Bias-T deliver 4-5V DC and currents up to 50mA. The receiver Bias-T can be usually switched on through the software application but there are some receivers requiring simple hardware modification.
To have the complete setup working properly the LNA should also support the Bias-T operation mode. The LNA4ALL with Bias-T 5V modification support the Bias-T operation. When ordering you need to specify that you need such an option, or you can do it by yourself. You can clearly see the modifications done on the Fig.8. marked green.

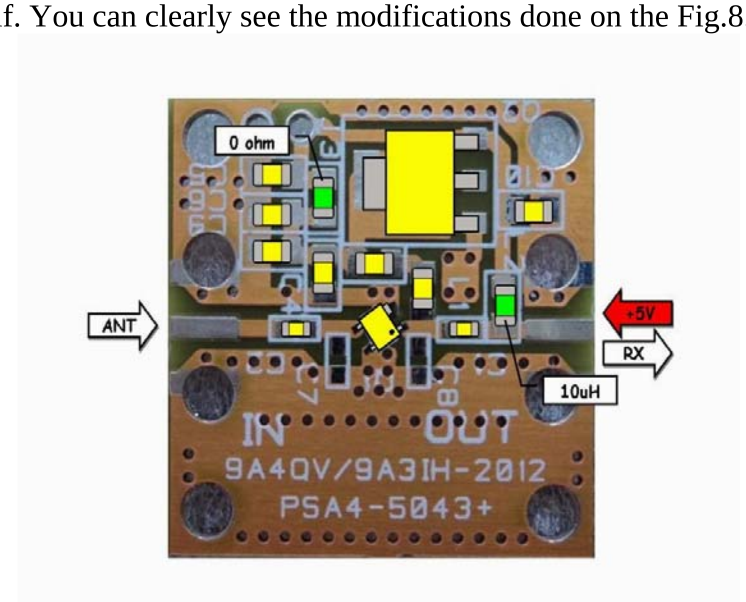


Fig.8 LNA4ALL with Bias-T 5V mod

The standard nonmodified LNA4ALL should be powered using the side pads and the 6-9V DC power supply. There is on board low noise 5V voltage regulator required for the safe operation. SDR dongles are powered through the USB port where the maximum DC voltage is 5V. The same voltage from the USB port is used then for the receiver bias-T voltage. In practice, this voltage is always lower than 5V but this is not a problem as LNA4ALL does work from 3.3 V up to maximum 5V.
The first modification includes the Bias-t LNA4ALL modification. The only thing that should be installed is the inductor L2 close to the OUT SMA connector. I use the 0805 size SMD wire wound 8.2uH or 10uH inductor. The rest of the parts are already installed. This modification will route the DC power from the coaxial cable to the voltage regulator input. You can apply any voltage from 6 to 9 volts on the receiver side Bias-T. The dongle can only deliver 5 volts or less to the Bias-t hence the second 5V modification is required too.
The second modification that should be done on the LNA4ALL is 5V mod. This is done by adding the 0 (zero) ohm 0805 SMD resistor in the place marked J3 (green SMD). You can use also a piece of wire. With this modification, we will bridge the 5V voltage regulator and any voltage applied to the side pads will be present on the MMIC amplifier. As mentioned, this voltage can be anything from 3.3V up to 5V DC.
The same modification can be used if you want to have your LNA close to the receiver as per the previous setup and not using the external 6-9V DC power supply. This can be handy, you just need to insert the LNA4ALL in the coaxial line and you are ready for the reception.

3. Two cascaded remote LNAs + SDR dongle setup

One is good, two is better? Not always, but we can do that and cascade two remote LNA4ALL amplifiers. This is not recommended unless you have the devices that are unconditionally stable over the wide range of the frequencies with *Rollet* factor >1 and where the S-parameters allow cascading the same devices without unwanted results like self-oscillations. This can lead to disaster, not only damaged LNA but damage to the receiver as well. Let's try to cascade two remote LNA4ALL as per Fig.9.

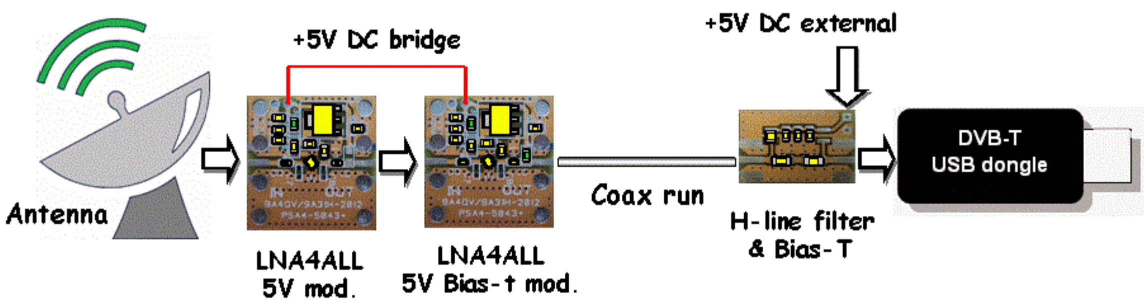


Fig.9 Remote cascaded LNA4ALL + Bias-T

Consumption of the LNA4ALL is 56mA @ 5V. To supply two units 5V 112mA source is required. Most of the widely used cheap SDR devices can deliver maximum 50mA at the antenna port through the onboard Bias-T. Dongle can handle one LNA4ALL as the consumption is lower than 56mA due to a lower voltage, usually 4.6V. To supply two remote LNA4ALL the external Bias-T unit with 5V is required. Another problem is high signal level reaching the DVB-T dongle SDR receiver. The same dongle has no any front end selectivity, it is wide open to all signals coming through the antenna connector. Two LNA4ALL will deliver more than 32dB of gain on 1420 MHz but they will also amplify all the other signals present on the antenna like strong BC radio and TV signals, as well as nearby cell tower signals. DVB-T dongle will run into saturation due to strong out of the band of interest signals present on the antenna port and this will lead to desensitization where the weak signals will be lost. We can solve this problem by reducing the receiver gain, which may help a bit but a proper way should be increasing selectivity. The filter should be installed to increase the selectivity and to reduce the strong out of the band signals of interest.

H-line filter (http://adsbfilter.blogspot.hr/2015/06/hydrogen-line-1420-mhz-filter.html) can do both, increase selectivity and inject the 5V from the external power supply into the coaxial line. All my latest filters (http://adsbfilter.blogspot.hr/) H-line, L-band, ADS-B filter have the Bias-T on board and the filter for the appropriate frequency as per Fig.10.

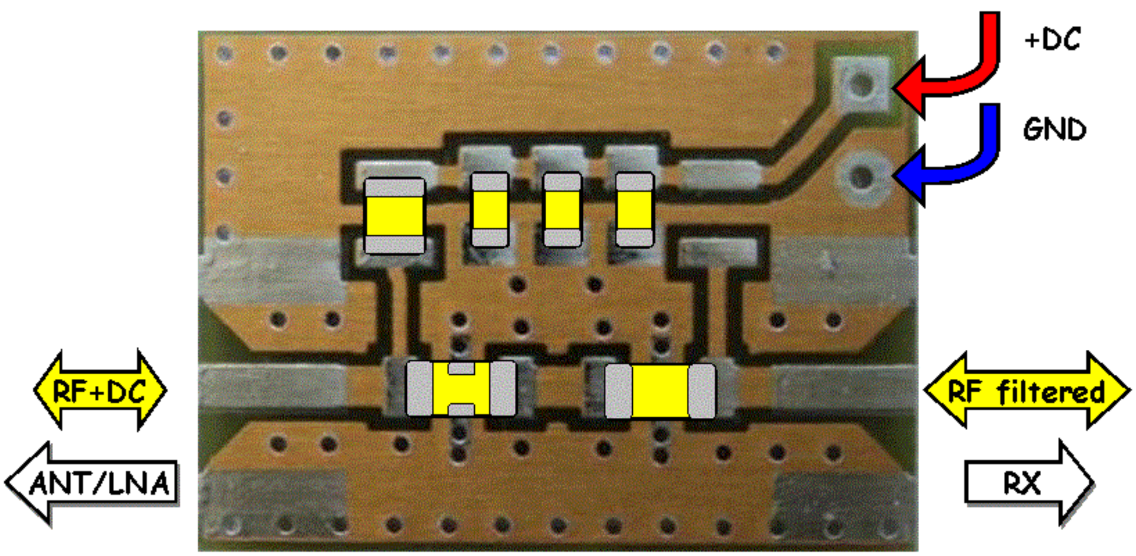


Fig.10 H-line filter with Bias-T

As there is „No free lunch“, the catch is in the filter insertion loss 2.5dB. If you insert this filter straight after the antenna, the system noise figure will be increased for the same value, sensitivity will be degraded too. This is why this kind of the filters should be installed in the receiving chain where they will not affect the noise figure a lot, at least this is what *Friis* formula says. Not to mess with the math, again i will use the AppCAD to do the job for us. All items are included, two LNA4ALL, 15 meters of the RG-6U coaxial cable, H-line filter with Bias-T and the SDR dongle receiver. Before we look at the AppCAD results Fig.11 there is one important thing to explain. How to power both LNA4ALL through the same coaxial cable? The LNA4ALL can not pass through the DC power. DC power present on the OUT SMA connector will not reach the IN SMA connector on the same LNA. LNA4ALL is a DC block device too, it can pass (amplify) just the RF signal in one direction. The proper DC power route follows Fig.9. External 5V DC power is applied to the H-line filter & Bias-T side pads. Bias-T injects the 5V into the coaxial cable that reaches the first LNA4ALL with 5V and Bias-T modification. The same 5V is present on the first LNA side pads. This is where we should solder the red wire and bridge the first and the second LNA4ALL. The second LNA4ALL does require just the 5V modification and not the Bias-T modification. This way we can power supply both cascaded LNA4ALL units.

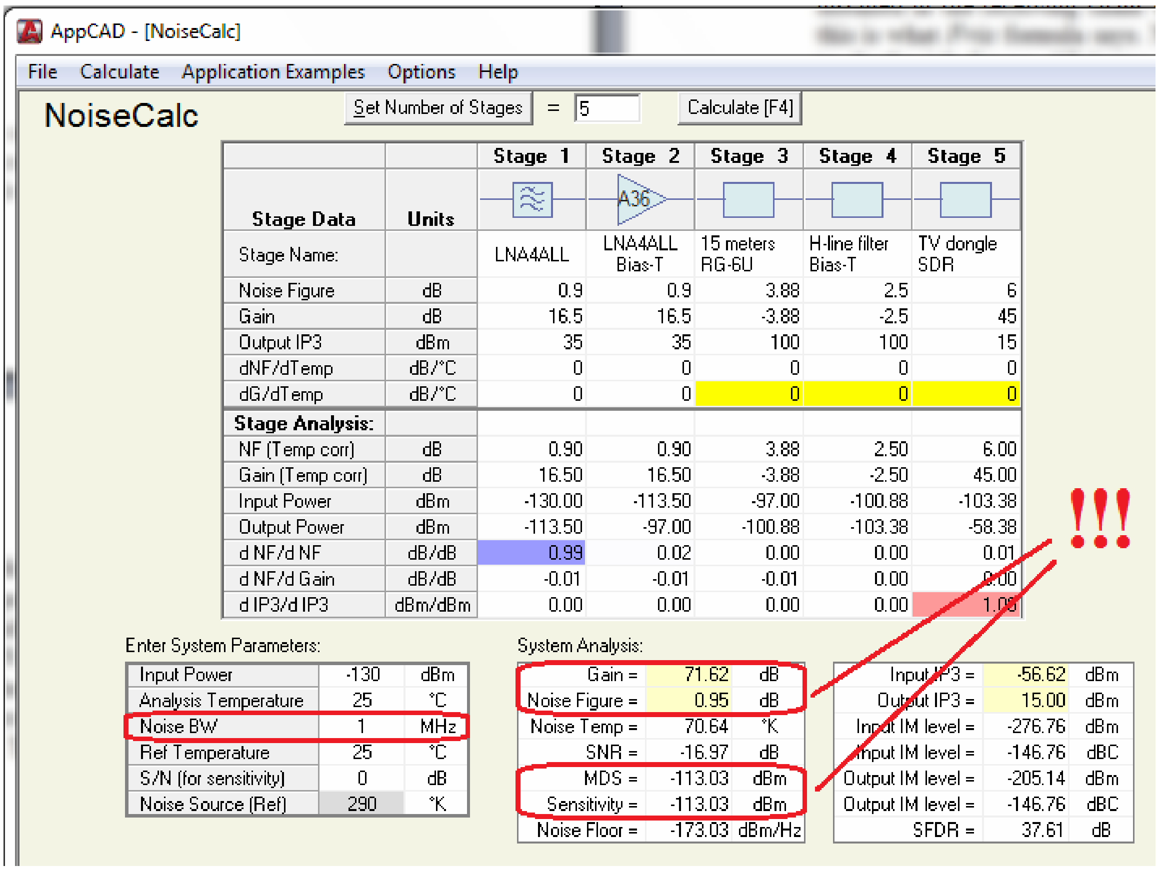


Fig.11 NoiseCalc Cascaded LNA4ALL + H-line filter Bias-T

This setup will bring our system NF below 1dB. If you compare the noise figure against the only one LNA4ALL you may note the improvement of „only“ 0.59dB. It may not look a lot but if you compare this two setup through the Noise temperature (line below the Noise Figure) you may note the improvements for 52.8 Kelvin. If you ask any radio astronomer how much is this, he will be happy with lowering the noise temperature for that value. Can we improve further the Noise figure and how? Where are the limits? The answer is yes, we can go even lower than 0.95dB and the serious radio telescopes are reaching 0.2dB or lower NF. If the NF is going down the cost of the system is going up. The rule of the thumb says that the most important is the first device (LNA) in the receiver chain. It should have the lowest possible noise figure and the highest gain possible. To improve further present setup you need to replace the first LNA4ALL (the one close to the antenna) with another one with NF lower than 0.9dB and the gain higher than 16dB. You may ask, OK but when we should be happy with the NF, when to stop? The lower – the better but you may stop when your system noise temperature is lower than the noise temperature of a typical directive antenna. If you live in the urban area your spectrum will be crowded and the noise temperature will be high. This is why the best radio telescopes are located far in the remote areas and the special regime is on force regarding the usage of all radio, electric and electronic devices. We can estimate (using some graphs) that this temperature is 60 Kelvin at 1420 MHz for the beam elevation angle of 90 degrees (antenna pointed up to the sky). 60 Kelvin corresponds to NF of 0.8dB, so you should be OK with the system NF of 0.8dB at this point. Going further down will not give you the better results as your antenna will pick up the surrounding noise that is higher than your system noise. Two cascaded LNA4ALL can deliver better NF than declared 0.9dB but I prefer to keep more conservative figures. Here are the cascaded LNA4ALL measurements Fig.12 performed by the third party with idea to use them for the same purpose, Hydrogen line radio telescope.

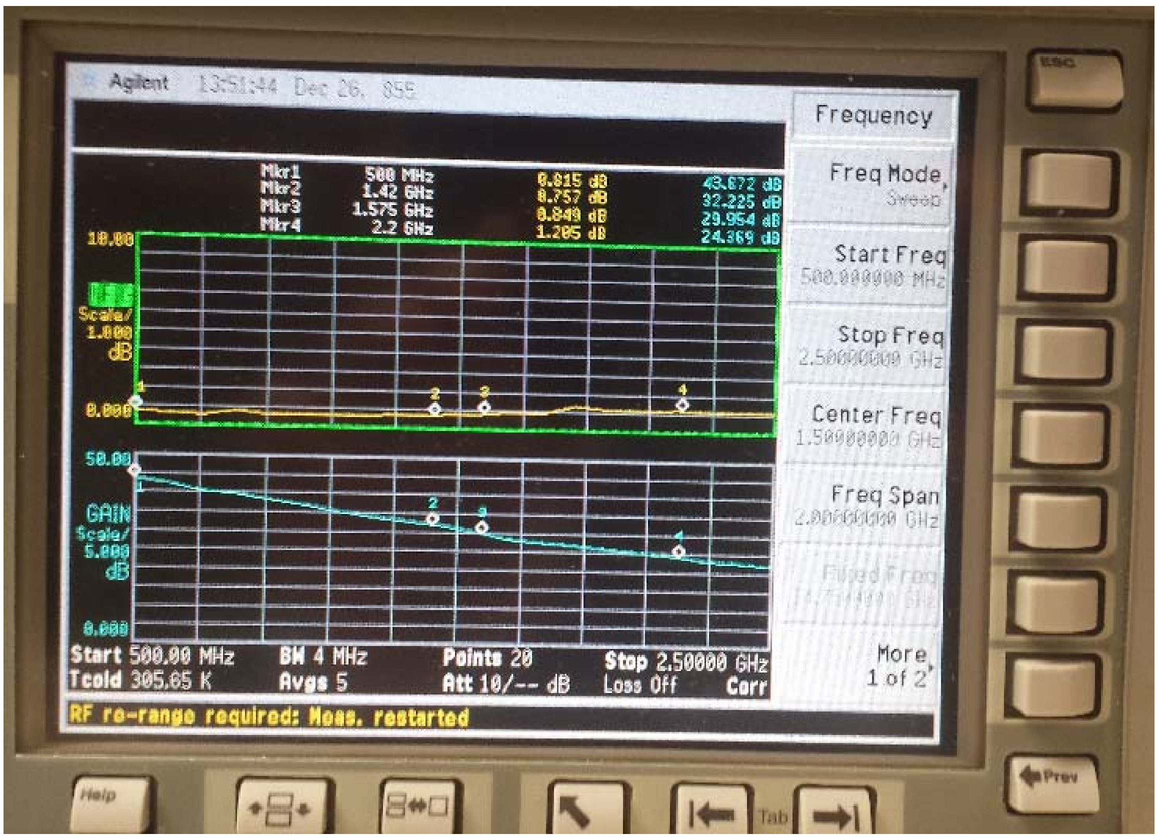


Fig.12 Cascaded LNA4ALL NF and Gain test

The NF and gain measurements gave a bit better results. 0.757dB NF and 32.2dB gain are more than I expected from this setup at 1420 MHz. The measurements were performed using two calibrated noise heads with ENR 4.5dB and ENR 15dB to verify the results. As presented on the graphs we may notice the stable operation all over the range from 500MHz up to 2.5GHz. There are no signs of self-oscillations what should be expected from the two cascaded unconditionally stable amplifiers. To meet this conditions, the output of the first LNA should be well matched to the input of the second LNA. This means that S1,1 is approximately equal to S2,2 all over the wide range. If these criteria are not satisfied most likely your system will be prone to oscillations. This problem can be cured by inserting interstage, like the attenuator between the stages. The 10dB attenuator will increase the match for 20dB. Of course, you have to count on extra 10dB attenuation in your signal chain. Another trick is to use an isolator to isolate the LNA stages. The isolator will introduce not more than a 1db loss in the receiving chain which is acceptable. The only drawback is that the isolator is not a wideband device and it will introduce a higher I.L. (Insertion loss) which should not be a problem if you are designing the system for the narrow frequency range. The next possibility is installing the filter as the interstage. This is my favorite option, cheap and effective. Let's upgrade our front end system even more.

4. Two cascaded remote LNAs + two H-line filters

Upgrading the system with another H-line filter as per Fig.13 will result with some benefits. The LNA4ALL is the high IP3/TOI amplifier but at some point, the intermodulation products will degrade the reception. In cascaded LNAs, the second one in the chain will receive much stronger signal than the first one, equal to the gain of the first stage. As the LNAs are wideband all the signals will be amplified together with the strong out of the band signals of the interest. This signals may create a lot of problems to the second stage. If not the second but then to all other stages following in the chain.

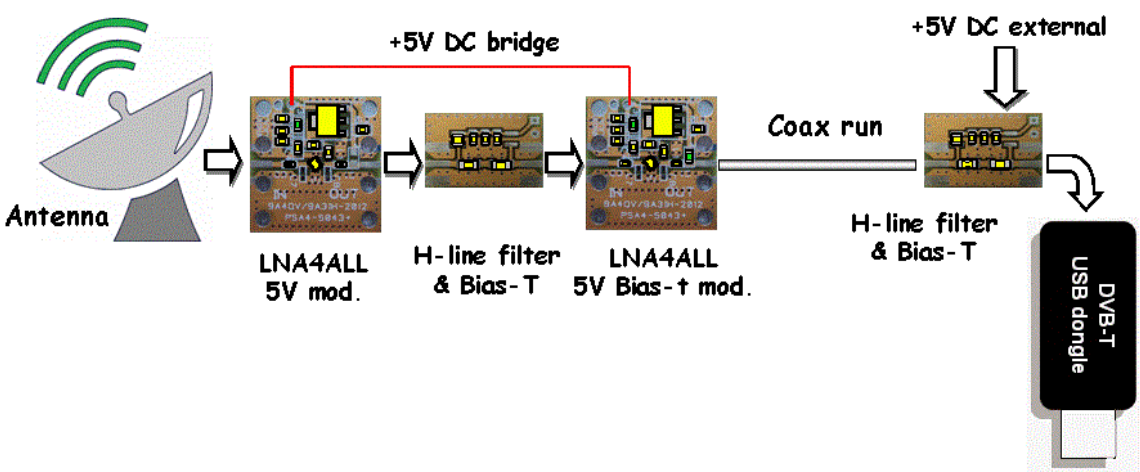
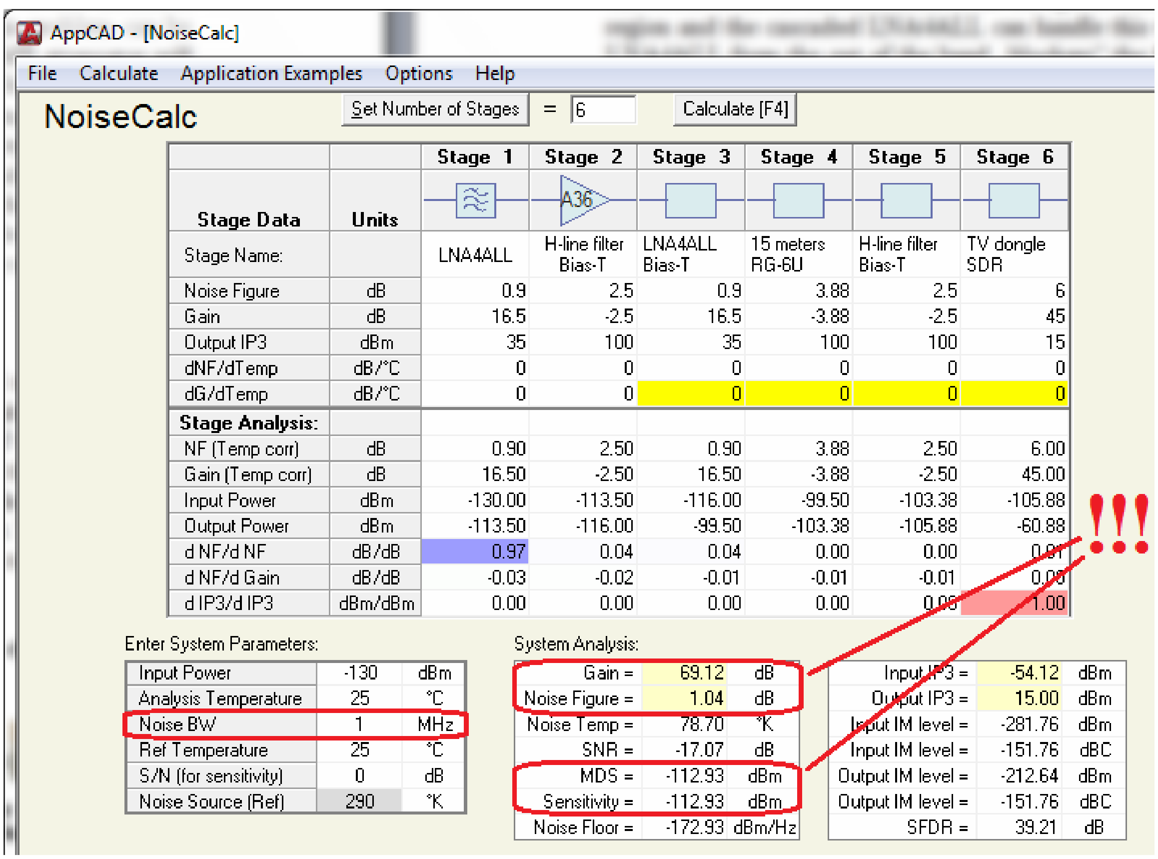


Fig.13 Two LNA4ALL + two H-line filters

The IP3 chain works quite opposite to the NF signal chain. In the NF (Noise figure) chain the first component should have the lowest NF and the highest gain. The first component has the biggest influence to the system NF. With IP3 the last component in the chain is the limiting factor and it should have the highest IP3. This is logical, as every stage is amplifying the signal the next should handle the much stronger signal than the previous stage. We can see that also in all previous NoiseCalc calculations. Pay the attention to the System analysis output IP3 window. In all calculations that figure is equal to 15dBm, the same value as the last component in the chain (DVB-T dongle). No matter the LNA or filter IP3 figure, the resulting IP3 was always 15dB. Radioastronomy frequency 1420 MHz is in protected band where other transmissions are not allowed so the astronomers can observe the H-line radiation from the space. Basically, this is a clear radio frequency region and the cascaded LNA4ALL can handle this weak signals. To protect the second LNA4ALL from the out of the band „blockers“ the filter is used between the stages, the very same H-line filter used before. The second benefit is better filtering. You remember, one is good – two is better. Here we have two LNA4al cascaded stages isolated with two H-line filters. The same is valid also for the filters, where the two filters are isolated with one LNA4ALL. We saw that cascading the LNAs oscillations can occur if specific criteria are not satisfied. What about the filters, they are the passive devices, they can not oscillate? The filters are generally the reflective device, they have a very good match on the passband frequency but very bad match out of the passband frequency. A bad match means high reflection affecting the first filter in the cascaded chain. This may result in extra attenuation and strange bandpass shape of the filter. Unless you do not have the reflectionless filters do not cascade them without interstage, as we have done with the LNA4ALL in our example. The last benefit is extra attenuation of unwanted signals. If one filter attenuates the BC WFM signals for 40dB, two filters will attenuate the same signal for 80dB. The main drawback of using the second filter is the extra attenuation introduced. The influence is small not only to the overall system gain but also to the NF as the filter is not the first component in the chain (remember the *Friis* formula).



Stage Data	Units	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Stage Name:		LNA4ALL	H-line filter Bias-T	LNA4ALL Bias-T	15 meters RG-6U	H-line filter Bias-T	TV dongle SDR
Noise Figure	dB	0.9	2.5	0.9	3.88	2.5	6
Gain	dB	16.5	-2.5	16.5	-3.88	-2.5	45
Output IP3	dBm	35	100	35	100	100	15
dNF/dTemp	dB/°C	0	0	0	0	0	0
dG/dTemp	dB/°C	0	0	0	0	0	0
Stage Analysis:							
NF (Temp corr)	dB	0.90	2.50	0.90	3.88	2.50	6.00
Gain (Temp corr)	dB	16.50	-2.50	16.50	-3.88	-2.50	45.00
Input Power	dBm	-130.00	-113.50	-116.00	-99.50	-103.38	-105.88
Output Power	dBm	-113.50	-116.00	-99.50	-103.38	-105.88	-60.88
d NF/d NF	dB/dB	0.97	0.04	0.04	0.00	0.00	0.01
d NF/d Gain	dB/dB	-0.03	-0.02	-0.01	-0.01	-0.01	0.00
d IP3/d IP3	dBm/dBm	0.00	0.00	0.00	0.00	0.00	1.00

Enter System Parameters:

Input Power	-130	dBm
Analysis Temperature	25	°C
Noise BW	1	MHz
Ref Temperature	25	°C
S/N (for sensitivity)	0	dB
Noise Source (Ref)	290	°K

System Analysis:

Gain =	69.12	dB	Input IP3 =	-54.12	dBm
Noise Figure =	1.04	dB	Output IP3 =	15.00	dBm
Noise Temp =	78.70	°K	Input IM level =	-281.76	dBm
SNR =	-17.07	dB	Input IM level =	-151.76	dBC
MDS =	-112.93	dBm	Output IM level =	-212.64	dBm
Sensitivity =	-112.93	dBm	Output IM level =	-151.76	dBC
Noise Floor =	-172.93	dBm/Hz	SFDR =	39.21	dB

Fig.14 NoiseCalc two LNA4ALL + two H-line filters

Let's review our new improved system. LNA4ALL followed by H-line filter and another LNA4ALL, all on the antenna feed or radiator. The same power bridge to feed the power to the first LNA. 15 meters of the same cable going to the second H-line filter that is also used as a Bias-T to inject the DC power required for the LNA4ALL amplifiers. At the end is the same DVB-T dongle.
Comparing the results computed using the NoiseCalc, Fig.14 with the results from the Fig.11 one can notice the difference in NF of 0.09db in favor of the system using only one H-line filter or difference in noise temperature of 8.06 K. As predicted, the second filter will not degrade significantly the system NF. What can not be seen in the NoiseCalc is how much the selectivity is improved. To get the picture how much the selectivity can be improved we have to build and measure or simulate the system using the proper S-parameters. On the Fig.15 we can see the transmission characteristic or S2,1. The red line indicates the reflection characteristic or S1,1 for the same system (2x LNA4ALL & 2x H-line filter).

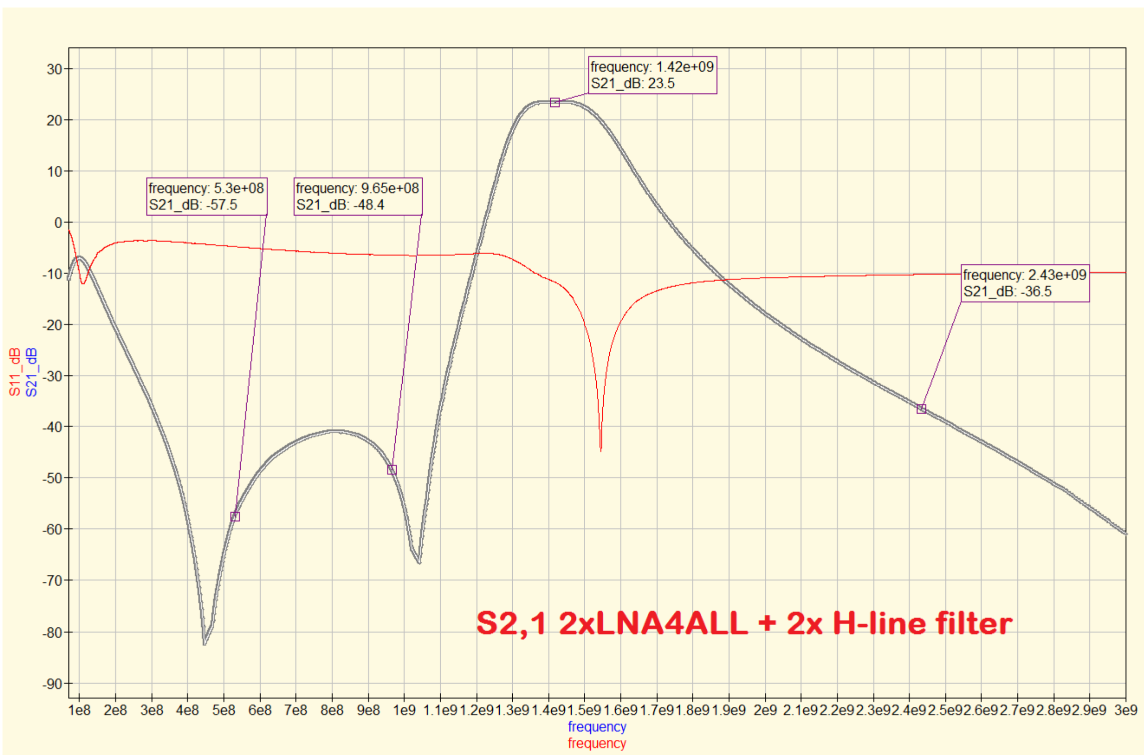


Fig.15 Transmission S2,1 and Reflection S1,1 characteristics

This is what you should expect from the system where 2x LNA4ALL and 2x H-line filters were used. We can notice the gain on the 1420 MHz and the attenuation elsewhere. This the simulation was done using the S-parameters for all components in the system. Now we can compare the simulation with the real situation.
Going back to the Fig.12, the measured gain of the cascaded two LNA4ALL was 32.22dB. If we deduct the I.L. of both H-line filters (2x2.5dB) and the loss in the 15m of the cable (3.88dB) the result is 23.34dB. Now we can compare the S2,1 reading at 1420 MHz from the Fig.15 where the marker is indicating the S2,1 = 23.5dB. This is quite

close to simulations done and we can be sure that the rest of the markers on the graph are also showing the numbers close to the real ones. The rest of the markers on the S2,1 curve are positioned on the potential „blockers“ or the sources of the strong RF signals. The first marker is on 530 MHz. This is kind of the center of the DVB-T broadcasting band and the attenuation is 57.5dB or 81dB below the H-line signal. Next marker is centered on the 965 MHz, the GSM band. Attenuation there is 48.4dB. Marker on 1420 MHz is shoving useful gain at the 1420 MHz of 23.5 MHz and the last marker on the 2.43 GHz is showing 36.5dB of Wi-Fi signal attenuation. The attenuation on the WBFM frequency of 100 MHz is not so big, only 8dB or 41.5dB below the 1420 MHz and if there is a problem, extra notch filter should be used to attenuate that signal even more. Considering the size and the cost of the filters the obtained results are quite good. Of course, performance can be improved by using the proper cavity filters but this is where the price and the size of the filters can make the system not affordable anymore.

5. Tweaking the system even more

As mentioned, if your receiver is positioned close to some strong WBFM transmitters you can improve your system adding the band-stop filter for the range of frequencies. If this is the WBFM signal you will center your band-stop filter around 100 MHz. If you suffer from the strong DAB or DAB+ signals you will center the band-stop filter on the center of the MUX or around 200 MHz if you want to cover complete DAB band. A common practice is making the bandstop filter using the open end quarter wavelength coaxial cable creating a notch filter. Pay attention to the frequency response of a such made notch filters. The frequency response is harmonically related where the notches will be present on all odd multiplier frequencies (x3, x5, x7 etc.). It means that the coaxial notch designed to notch the 100 MHz will notch also the 300 Mhz, 500 MHz, 700 MHz etc. Make sure not to notch your frequency of interest, 1420Mhz in this case. You want to place your notch filter just after antenna, before the first LNA in the system. This filter should not affect the NF of your system.

Another important issue is the front-end ESD protection. The ESD can build on the antenna and the first component is your receiver is the front-end LNA. It may be damaged if there is no ESD protection. The best way to do that is to use the DC shorted antenna. If the antenna is properly installed and grounded all ESD will be routed to ground protecting this way your electronics. If your antenna is not DC short then there is a neat trick that you can apply to do that. The same way we made the quarter wavelength notch filter, now we can make the shorted end instead of the open end, This will create a kind of bandpass filter and will not influence on the reception but will DC short the antenna. Of course, the antenna mount should be properly grounded.

The last option is installing the ESD protection diode or another kind of ESD protections. The LNA4ALL may be protected this way but this option is prone to some IMD problems if there are strong nearby signals present.

6. How much it can cost – the budget H-line system

The last question that should be addressed first is how much this can cost? If you ever try to build the radio telescope than you already know what you can expect. Some surplus parts can be purchased through the e-bay but hardly or in rear occasions they are good for 1420 MHz. The system proposed can be made from the following parts:

1x LNA4ALL with SMA and 5V mod. = 21 Euro
1x LNA4ALL with SMA and Bias-T 5V mod. = 23 Euro
2x H-line filter with Bias-T = 40 Euro

Total front-end parts cost is 84 Euro.

Of course, we need the receiver. The RTL.SDR dongle in the aluminum housing V.3 is quite handy as it does support the bias-T 5V and it has the SMA connector. The price is 20 Euro for one unit. This can be done cheaper using some DVB-T dongles based on R820T tuners and RTL2832 chipsets but you may get stuck with the temperature drift problems and higher noise using these cheap dongles. It can be done but it does require some extra engineering and fine soldering.

A few jumper SMA male/male jumpers will be required. This where the e-bay is handy. For 3 Euro a decent 50 ohms jumper coaxial cable can be found. Four pieces should be enough, so another 12 Euro.

You should consider buying also a power supply. As mentioned, the dongles and other receivers are limited to the maximum current power supply on 50mA. Our fron tend requirement is 120mA and the external 5V power supply is required. Another 20 Euro for a decent power supply. Avoid the cheap switching supply if possible. If they are not filtered properly they will just cause you problems introducing the extra hum and noise in your system. For the same reason avoid the USB port 5V source. This may be quite noisy and on the other hand, if something goes wrong with your system you do not want to kill your PC. Using a small rechargeable pack may be a smart option for noise-less supply. You should consider also that. The price should be the same as the external power supply.

At the end, we need some coaxial cable to connect our antenna with the front-end with our receiver. SAT-TV cable can do the job. 20 Euro should be more than enough for the 15 meters run of coax. There are much more expensive options offering better quality but the RG-6U can do the job also.

All together we can build the cheap 1420 MHz radio telescope for not more than 156 Euro or USD 180. Besides that. we need some software that is free and the antenna. Antennas are usually homebrew and this is the topic that should be discussed in some future paper.

Notes
AppCAD v.4 - http://www.hp.woodshot.com/
QucsStudio - http://dd6um.darc.de/QucsStudio/qucsstudio.html
LNA4ALL - http://lna4all.blogspot.hr/
H-line, L-band, ADS-B filters - http://adsbfilter.blogspot.hr/