Microwave Update 2002
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New Receive Section Design for 1296 MHz. Transverters

With increasing out of band interference problems generated from public communication systems and the continued exploitation of the surrounding ISM bands, state of the art 23 centimeter amateur band receiver designs of only a few years ago are becoming inadequate. Most LNA and transverter front end designs that are designed for noise figure and gain performance begin to show their short comings in high RF environments. Simply using higher IP3 output GaAs-FETs or PHEMTs in low noise designs are not enough . Adding band pass filters to the output s of LNA gain stages will not always solve the problems and may indeed mask other problems if the input of the LNA is overloaded. This short paper will review a LNA design that will not win a noise figure contest for 1296 MHz. LNAs but will be an excellent choice for a small compact "Tropo Quality" transverter or receive converter with out using a externa l band pass filter or cavity input circuit. This paper will demonstrate the different stages of development of this LNA design showing the circuits schematically and presenting data to verify the improvements . The presentation of this paper at the Microwave Update 2002 conference will discuss all of the above mentioned aspects and include this LNA design in a complete transverter receive section reviewing some methods of circuit analysis and proper adjustment required to achieve the best performance.

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The LNA Design:

At Microwave Update 2000, I presented our current 903 transverter design. The LNA had a shunt L, series C, then shunt C and L input circuit using a Agilent ATF21186 GaAs FET. This FET is now out of production but the design is quite universal for the low microwave and UHF region. The concept of the design was to eliminate lower frequency gain while maintaining an acceptable noise figure and gain at the frequency of interest. The design featured surface mount low loss trimmer capacitors produced by Voltronics in the .3 -3 pF range and pre-wound fixed value inductors produced by Delvan in the low nano-henry region. This circuit provided adequate high pass frequency filtering while maintaining a good noise figure and gain at 33 cm. What would a similar circuit do at 23 cm.? If the circuit loss increased by tenths of a dB it will contribute to the noise figure. Could a slightly different design provide attenuation of frequencies from the 33 cm ISM band and below (high pass filtering) yet provide adequate gain and noise figure at 1296 MHz in particular?

The following graphs and schematics will be in the order of development to demonstrate the improvements made as the 23 cm. LNA design progressed. All gain and band pass data was measured point by point from 5 samples of each of the 4 circuits. (20 LNAs total) The data from the 5 samples of each circuit type was averaged and entered into a spread sheet as one set of data. Independently, all noise figures and gains of the 20 units were measured at 1296 MHz. on a HP 8970A noise figure meter. This data was also averaged and recorded per circuit type. The first three graphs were then plotted from the spread sheet data to show a circuit to circuit comparison. They start with the base line WB5LUA (now W5LUA) ATF10136 LNA design using a standard "Series L" input circuit with a resistor loaded output circuit.[1] Then the three new design "Tuned Input" circuits utilizing Agilent's ATF-34143 PHEMT are shown one by one to highlight their improvements in performance. For the purpose of simplicity of this paper, the output circuits of the baseline and new designs are not shown schematically. The baseline design is a simple resistor wide band match. All of the "Tuned Input" designs have identical output circuits and have been optimized through computer simulation and tested for performance. There are no adjustments required in the output section and is simply stated as a high pass matching network suited for the ATF34143 PHEMT to utilize it's gain and High IP3 performance .

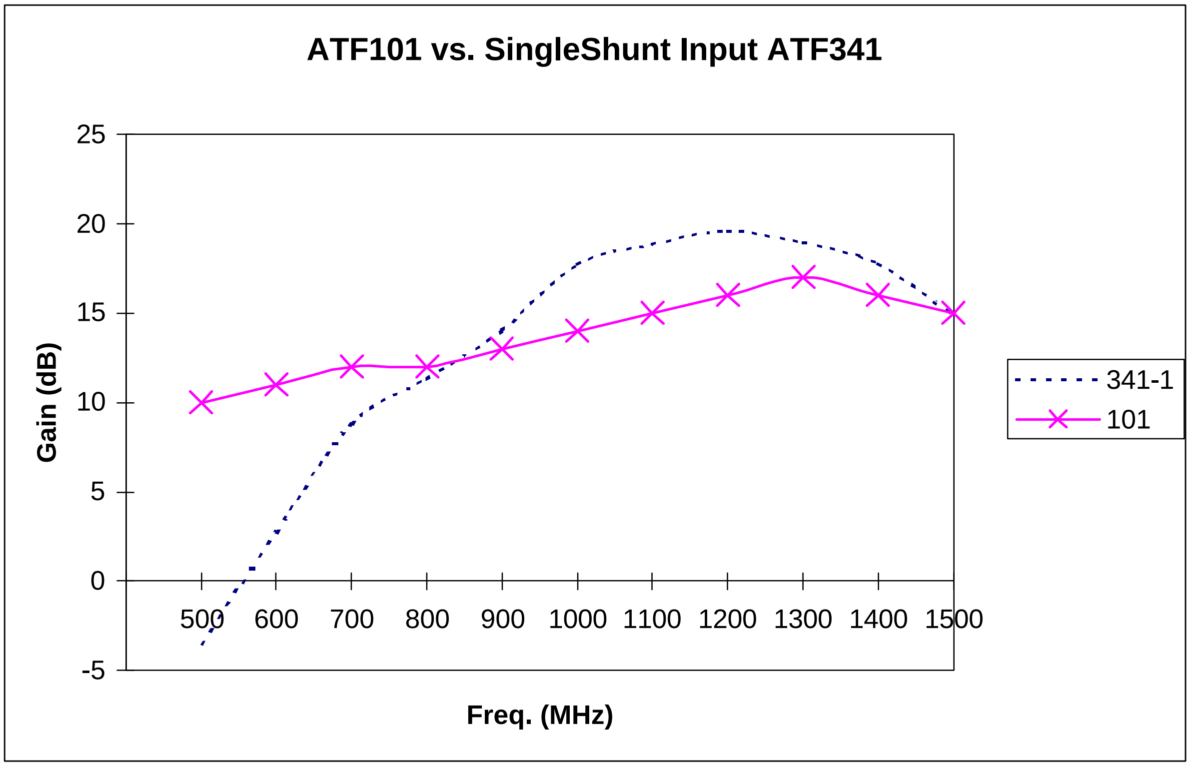
The 4^{th} graph shows the final design LNA by itself compared to the same LNA with a 3 pole band pass filter on the output. The 5^{th} graph is a narrow band pass look at the output of the 4^{th} graph with and with out the band pass filter. The 6^{th} graph is a compilation of the 4 separate circuits with the band pass filter circuit shown for comparison and depicts the circuit improvements as the shunt inductors were added and values changed. Please understand the every circuit was optimized for noise figure and gain at 1296 MHz. before the pass band data was recorded.

Comments:

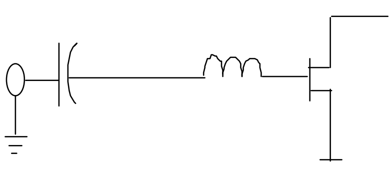
Though this is a short paper, it demonstrates the first development stage of a new 1296 transverter receive section. Other aids such as AppCAD[2] provided data for cascade gain analysis, system noise figure and IP3 input / output analysis resulting in the line up of components used in the complete transverter design. The final LNA design was again computer simulated and "Tweaked" to further improve stability and matching into the band pass filter without degrading it's performance.

I hope the information provided in this paper will help many understand one of the development process of a transverter and to show what is required in a receiver design concerning RF density problems. I also hope it provided some inspiration of getting on and operating in these "noisy bands". It has become difficult and it will not get any easier to operate on these bands in the future. For now all we can do is use the same components that the commercial industry uses but in a way that suite our needs as amateur radio operators. It is a challenge. All future amateur radio designs in the microwave bands need to take this challenge seriously. If we cannot prove to ourselves that we can use these bands effectively, we will stop using them. If we stop using them we will loose them permanently.

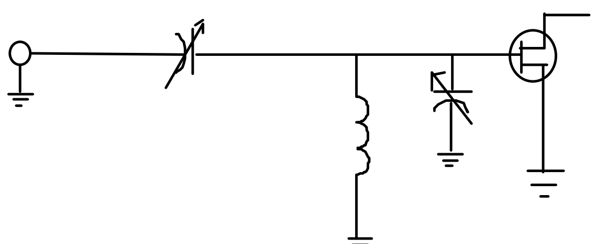
Standard series L input circuit with ATF10136 compared to a single shunt of 2.5 ηh with ATF34143 PHEMT. Both circuits optimized for noise figure.



Baseline WB5LUA design using ATF101



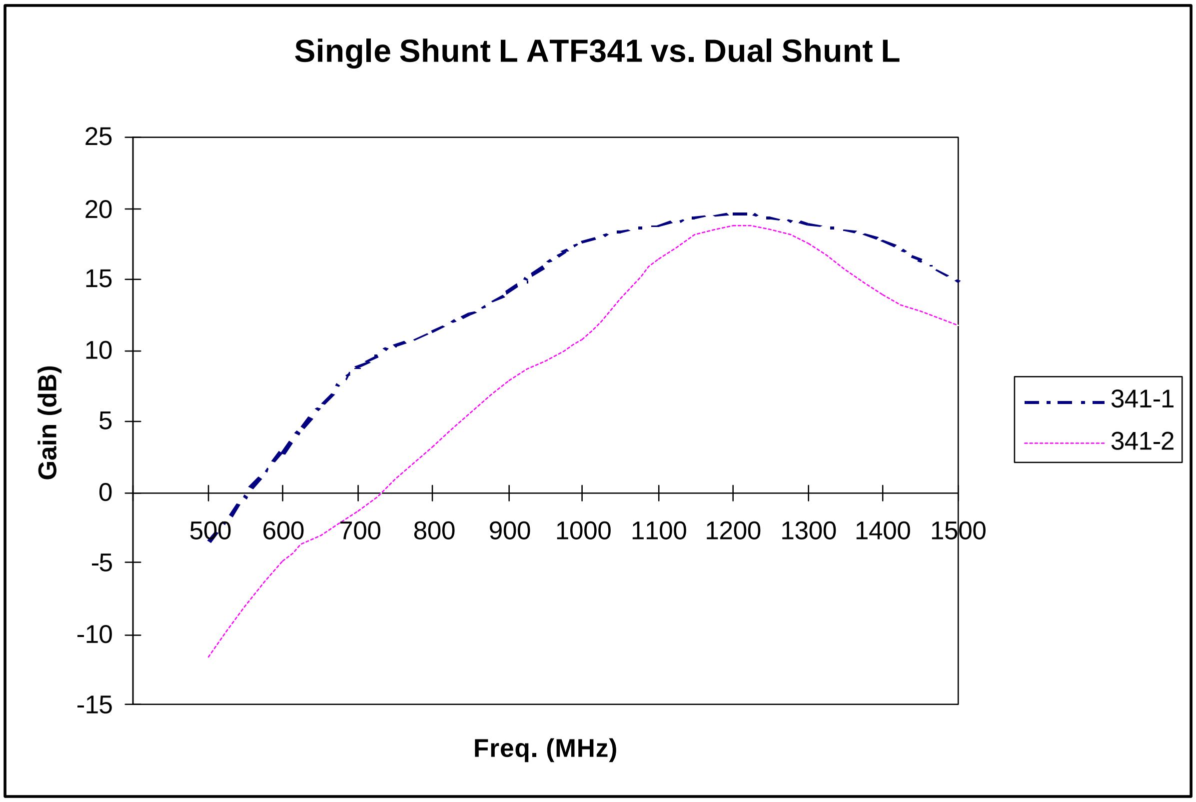
Single Shunt L ATF341



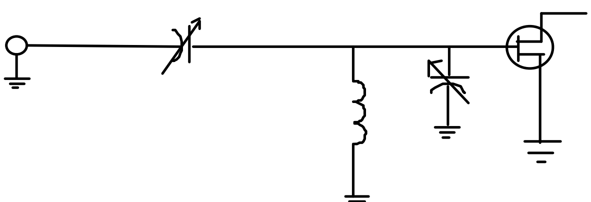
16.05 dBG , 0.57dBNF@ 1296 MHz.

17.91dBG, 0.74dBNF@ 1296 MHz.

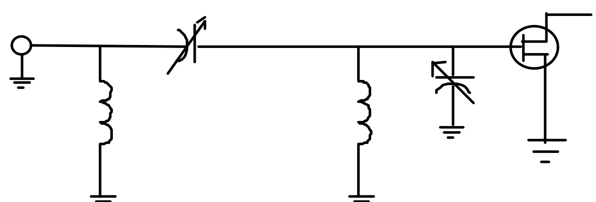
Single shunt LNA compared to dual shunt. Added input shunt inductor value is 10 ηh. LNA noise figure was re-optimized before data was recorded.



Single Shunt L ATF341



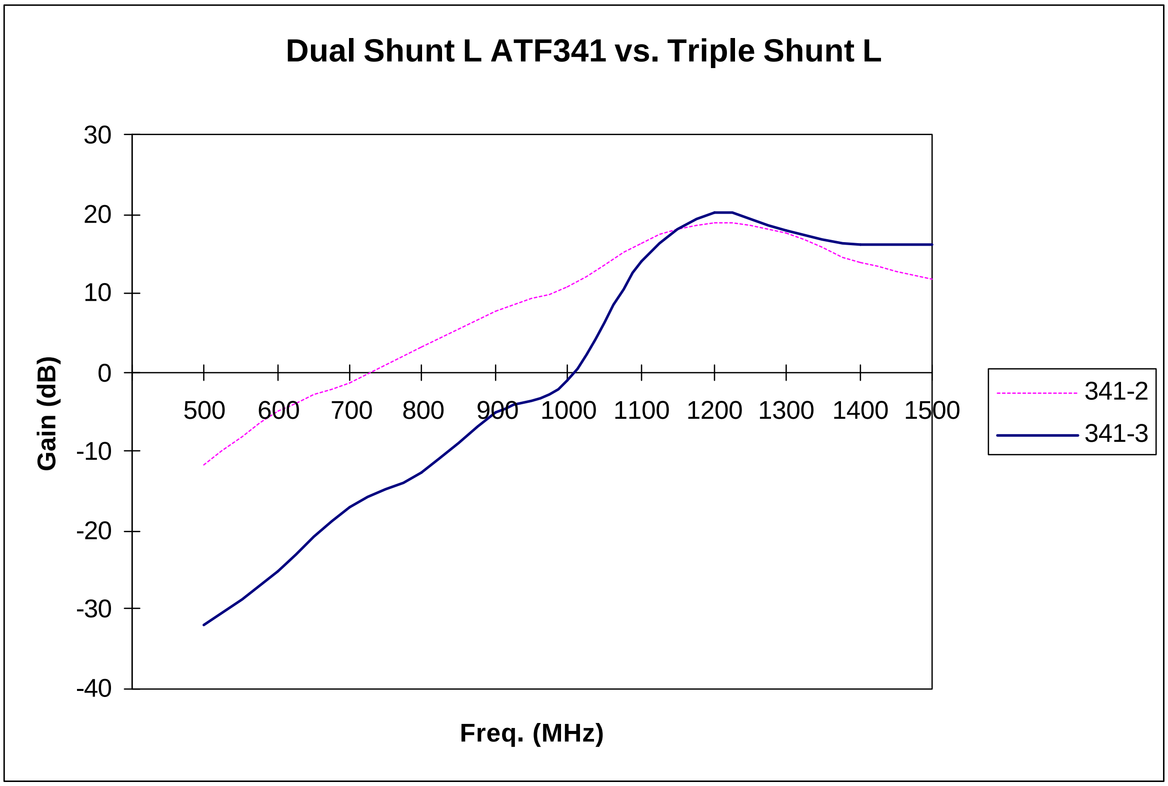
Dual Shunt L ATF341



17.91dBG, 0.74dBNF

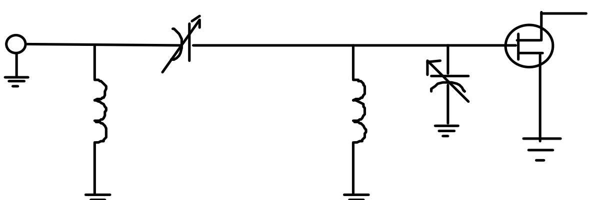
17.55dBG, 0.70dBNF

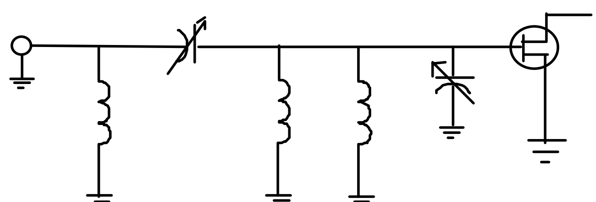
Triple shunt circuit uses 10ηh input and parallel 1.5 and 5 ηh. The 2.5 ηh was removed from the dual shunt circuit. Triple shunt circuit noise figure was re-optimized before data was recorded.



Triple Shunt L ATF341

Dual Shunt L ATF341

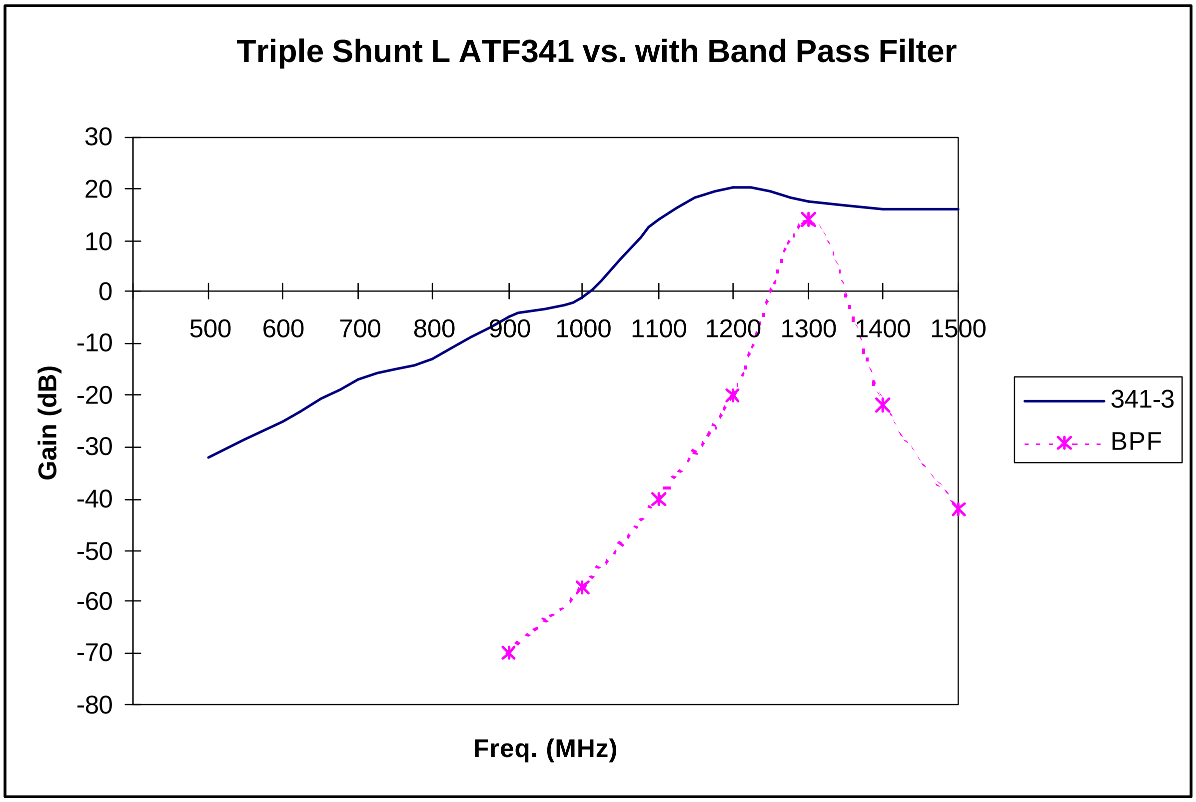




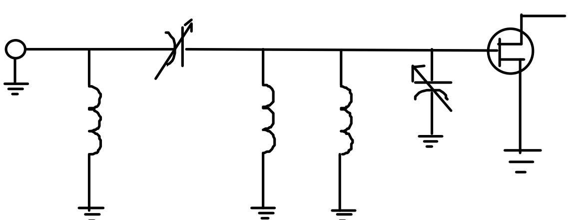
17.54dBG, 0.87dBNF

17.55dBG, 0.70dBNF

Optimized 3 pole band pass filter added to output circuit at 50 ohm point. Re-optimization of LNA for noise figure showed little or no improvement to circuit performance.

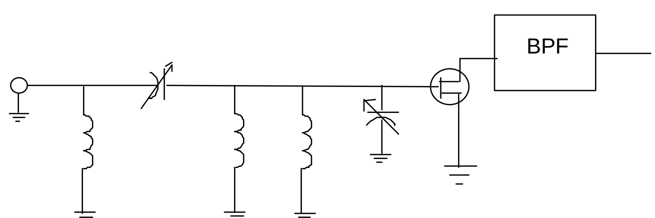


Triple Shunt L ATF341



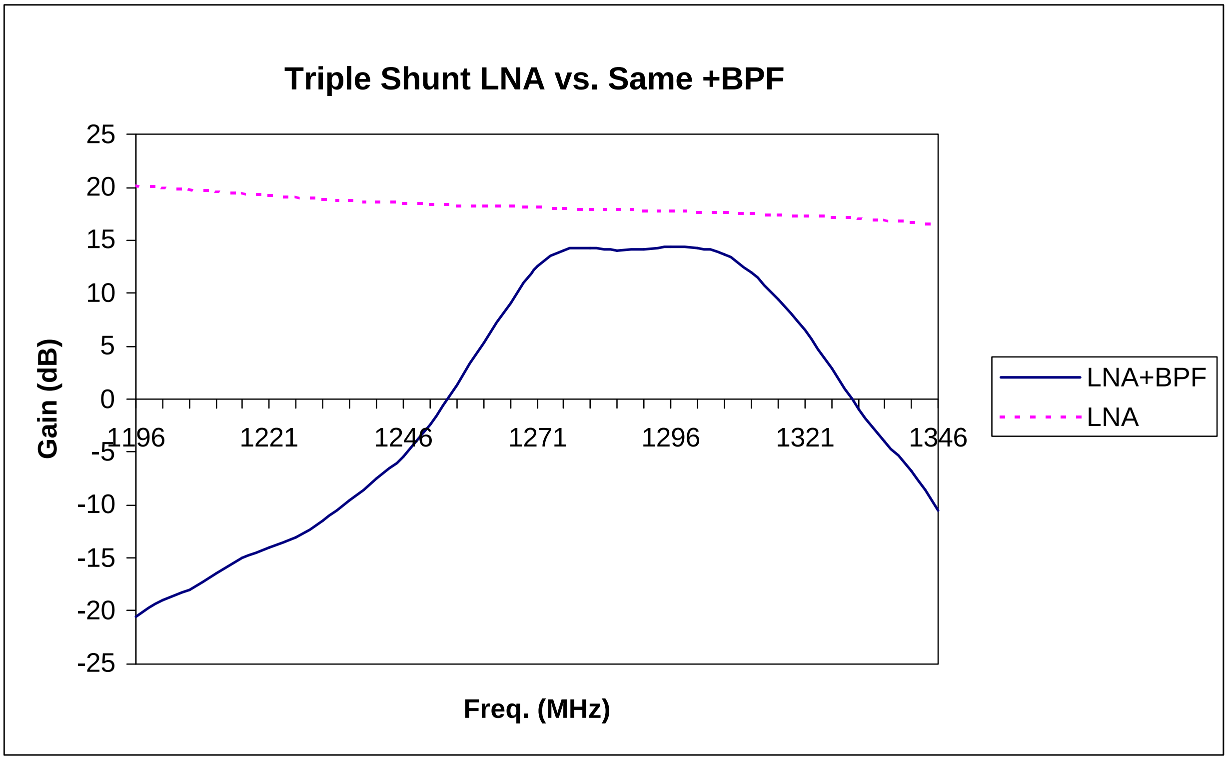
17.54dBG, 0.87dBNF

Triple Shunt L with Band Pass Filter Output

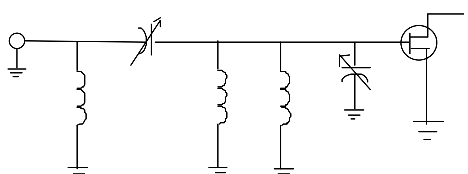


14.83dBG, 0.90dBNF

Narrow band graph showing the effectiveness of a 3 pole helical filter on the output of a triple shunt inductor input circuit LNA. The top graph is without the filter.

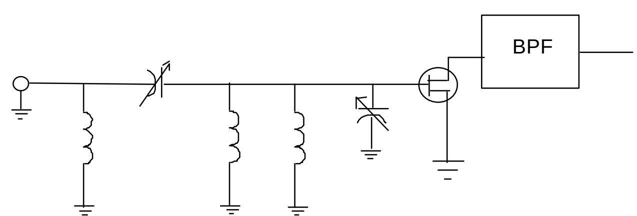


Top Graph is the
Triple Shunt L ATF341



17.54dBG, 0.87dBNF @1296 MHz.

Bottom Graph is the



14.83dBG, 0.90dBNF@ 1296 MHz

Triple Shunt L ATF341 with Band Pass filter

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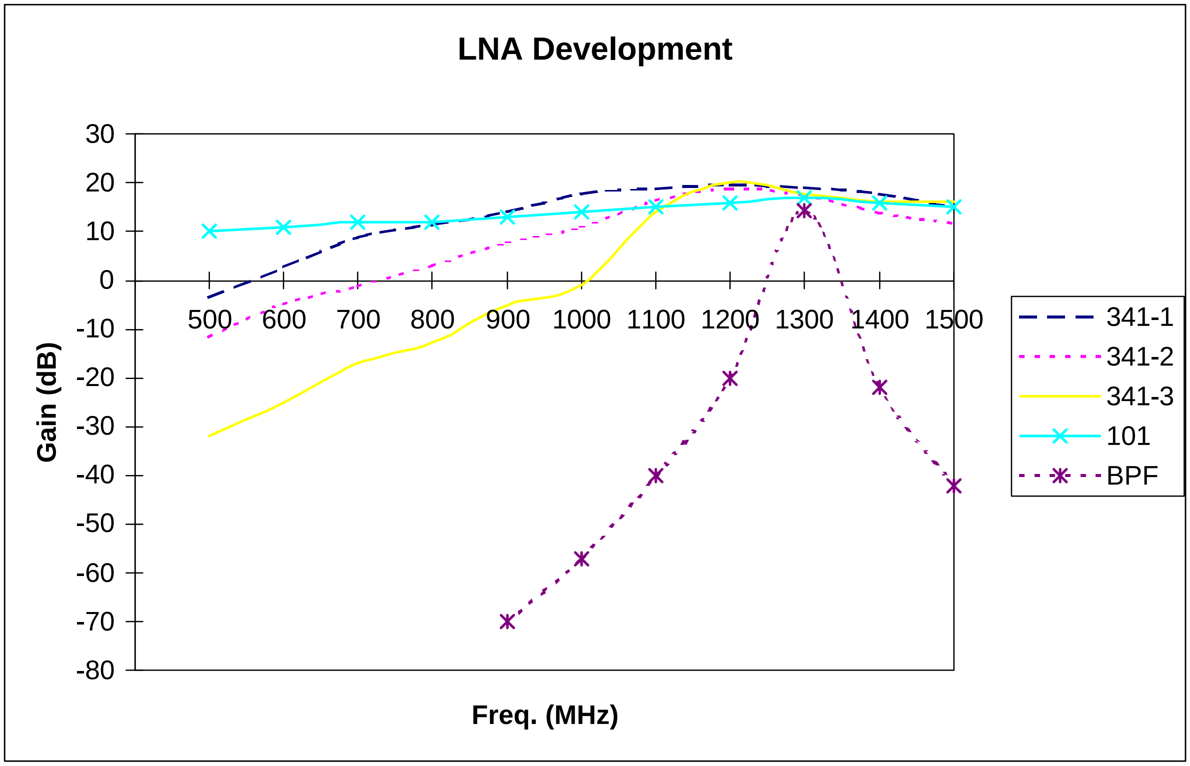
Base line circuit (101) compared to the 3 different circuits (341-1,-2, -3) and triple shunt with band pass filter output. (BPF) This graph is a compilation of the 4 previous graphs and depicts the development of the LNA circuit .



Final Notes:

It is important to understand that all of the data shown are after the circuits have been optimized for noise figure. If further selectivity was desired or required it could be obtained at the sacrifice of gain and noise figure. This may be desirable in some transverter systems that utilize a very low noise preamplifier that can be switched out of line during overload conditions. In a final transverter design, additional filtering is employed to further reduce unwanted signals and noise before entering the mixer. The presentation of this paper will cover designing the complete receive section of the transverter.

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[1] Al Ward , RF Design, Feb, 1989

[2] AppCAD for Windows is provided free of charge by Agilent Technologies as a service for RF and Microwave customers.