LNA – Active Bandpass Filter for Receiver-Indicator of Glonass+GPS

V.M. Vladimirov, S.N. Kulinich, Yu.G. Shikhov

Abstract - **For the receiver-indicator of GLONASS+GPS a Low Noise Amplifier (LNA) with an integrated active bandpass filter has been developed. The LNA has the structure and characteristics of an active bandpass filter: NF = 1.2 dB in the frequency band from 1572 to 1612 MHz with the gain coefficient not less than 16 dB and off–band rejection at the frequencies of 1.4 GHz and 1.8 GHz of not less that 55 dB. The upper linearity boundary of IICP is equal to 7 dBm. The LNA has been produced by the hybrid - integral technology. It has bulk dimensions of 22x 10x3 mm^3 and is united with the receiving antenna into one functional module. Application of the LNA – active bandpass filter – allows one to increase considerably the interference immunity of the receiver-indicator of GLONASS+GPS.**

Keywords – **LNA, active filter, NF, IICP.**

I. Introduction

In exploitation process of receiving equipment of the navigation systems GLONASS+GPS the problem of receiving a stable signal from the satellite occurs still more often. Frequently, this problem is due to arising of intermodulation interferences, which result in distortion or quenching of signal.

Frequency range, beginning from decimeter one, is loaded to the limit with powerful radiosignals, which are the sources of intermodulation distortions in the input modules of receiver-indicator devices. There are traditional methods of minimizing of intermodulation distortions, which are widely used in designing of radio receivers. Mainly, the designers of such an equipment try to use, if possible, a minimum of nonlinear LNA cascades. Amplifiers are being designed with a broadened dynamic range of both in the direction of noise decreasing of low-noise FIT transistors and in the direction of increasing of upper linearity boundary of the input transfer characteristic – the input compression point (IICP) - and the input intermodulation interception point of the third order (IIP3) associated with it [1,2].

Recently great progress has been done in this direction. PHEMT transistors with very low noise factor and sufficiently high input compression point have been produced. But in a number of cases the decreasing of intermodulation distortions to permissible level remains impossible. It is known that the noise factor (NF) and the level of IIP3 depend considerably on drain current of the FIT transistor; in addition, with current increasing, the level of IIP3 increases, and the noise factor grows, which is not always permissible for the LNA, because in many cases the increasing of interference immunity at the cost of loosing of receiver sensitivity is unacceptable.

There is a certain drain current, at which the transistor has an optimal dynamic range.

Also, there is another method of decreasing of intermodulation distortions, i.e. the insertion of bandpass filter (BPF) – preselector - at the LNA input. In ideal case, the BPF should pass a signal without loss only in the operating band and reject all off-band signals as much as possible. In this case, for relatively narrow-band signal, intermodulation distortions do not arise practically; only non-linear distortions of ICP type remain, which are not so essential. Real bandpass filters with acceptable selective parameters have loss of 2.5÷3 dB in the bandpass; insertion of such a filter at the LNA input will result in increasing of NF by 2.5÷3 dB. The increasing of the noise factor up to unacceptable values is the main limitation of using of LNA preselectors, especially in cases, when the power of transmitted signal is limited, in particular, signals from the GLONASS and GPS navigation satellites.

There is a perspective compromise solution, i.e. BPF is not installed at the LNA input but is integrated into the scheme and replaces its input and output matching circuits. In a particular case the LNA has the structure and characteristics of active bandpass filter with NF=1.2 dB in frequency band from 1572 to 1612 MHz, gain factor G_A of not less than 16 dB, off–band rejection of not less that 55 dB at the frequencies of 14000 MHz and 1800 MHz. The upper linearity boundary of input transfer characteristic IICP is equal to 7 dBm.

II. Designing of LNA – the Active Bandpass Filter

It follows from analysis of the LNA scheme solutions that the scheme with the common source has been mostly spread in microwave range. It is the only scheme with an invariant stability factor value (more than 1) in broad frequency band [3]. To provide temperature stability in a wide range of temperature change, the scheme with common source and negative feedback by direct current is also preferable.

Let us accept a scheme with the common source, automatic current drift and resonance matching circuits at the transistor input and output as the base electric LNA scheme. The amplifying element has been selected to obtain the acceptable price/quality ratio. The GaAs field transistor with Schottky-barrier gate ATF 10136 of the "HEWLETT PACKARD" company has relatively low price at sufficiently good electric parameters. Thus, at the frequency of 1.6 GHZ and optimal drain current of 20 - 22 mA, the noise factor does not exceed 0.55 dB, the gain factor of G_A is not less that 16 dB. Besides, it possesses an increased linearity of output transfer characteristic: OICP=20 dBm. It should be noted that the ATF

An earlier version of this paper was presented at the 37th International Conference on Information, Communication and Energy Systems and Technologies, ICEST 2002, October 1-4, 2002, Niš, Yugoslavia

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10136 transistor does not possess record parameters but fits well for solving the problem.

Principal equivalent electric LNA scheme is given in Fig.1, where Z_1 and Z_2 are the resonance contours connected via

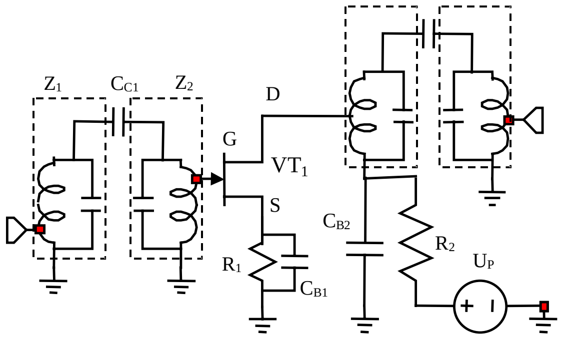

Fig.1 Schematic Diagram of the LNA.

coupling capacitor C_{C1}, forming the input narrow-band filter; Z_3 and Z_4 are the resonance contours connected via coupling capacitor C_{C2}, forming the output narrow-band filter. VT_1 is the GaAs field transistor ATF 10136, whose modes are determined by the resistors R_1 and R_2. C_{B1}, C_{B2} are the bypass capacitors. The drain potential value V_P in the absence of signal is selected such that the value U_{GS} at the limit value of the input signal should not exceed the value $U_{GS} - U_P$. Thereby non-linear distortions are minimized, arising at drifting of operating point into the area of initial part of the output characteristic. One of the main requirements dictated by technology of mass production is the condition of the device productability by integral or hybrid-integral technologies. Among all types of filters, the integral microstrip electrodynamics filters meet these requirements most fully [4]. The production technology of microstrip filters is sufficiently developed. Besides, the adjustment and tuning of these filters are much simpler in contrast to other types of electrodynamics filters.

Typical topology of a microstrip filter with the parameters satisfying the requirements, claimed to the input LNA filters, is given in the insertion of Fig.2. Microstrip filter consists of dielectric substrate with high dielectric permeability ε=80, whose lower part is metallized. On the outer side the microstrips are located, which form regular quarter-wave resonators coupled electromagnetically with one another. The input LNA filter should possess minimal loss in pass band and ensure maximal selectivity at minimum dimensions. To fulfill these conditions simultaneously is impossible; therefore, it is necessary to optimize compromise requirements.

III. LNA SIMULATION

The optimization was carried out with virtual models in the program package “Microwave office 2002” and “Serenade 8.5”. The simulation was made using both electrodynamic and quasi-static calculations. The dependencies of transfer constant and return loss (in term of S-parameters) of the input two–mesh microstrip filter on frequency are shown in Fig.2.

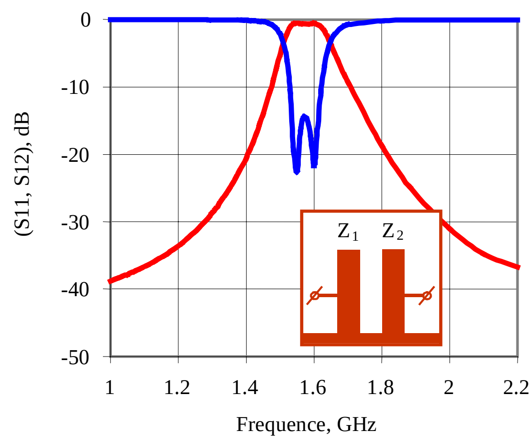

Fig.2. Layout and theoretical results of the input microstrip filter.

Minimal loss in the pass band does not exceed 0.8 dB. It is evident that such microstrip filters can be used as LNA input matching circuits.

A microstrip two-mesh filter given in the insertion of Fig. 3 is used as LNA output matching circuits. The main task of the output filter is to match a sufficiently low drain impedance of field transistor with the subsequent LNA cascades and to ensure normalized impedance at the output. Besides, it is expedient to use elements of the output filter not only as matching links, providing selective characteristics, but also as LNA feed filter. The transistor drain is powered via the resonator Z_3 serving as an impedance transformer. The dependencies of the transfer constant and return loss on the output microstrip filter frequency are shown in Fig. 3. Loss in frequency pass band does not exceed 1.2 dB.

Further in simulation process the matching of the input/output filters with the gate and drain of the field transistor is made. The optimization problem of filters matching with transistor is a problem with the set of variable parameters. It is solved by the method of sequential approximations. After that a topology correction of the input/output filter is carried out.

To complete the simulation, the full LNA computer model has been obtained with optimized input and output filters calculated in electrodynamics. As a result of the simulation and studying of electrodynamics models a final amplifier plate topology correction has been made and the most important electrical parameters have been optimized, as well as its construction.

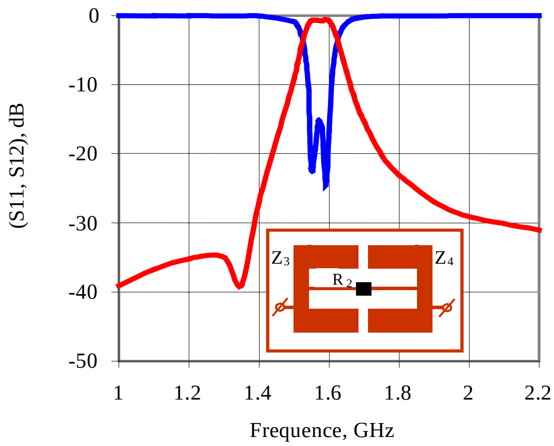

Fig.3. Layout and theoretical results of the output microstrip filter.

IV. MEASUREMENTS

In Fig.4 LNA the topology scheme on ceramic substrate with ε=80 and thickness of 1 mm is given. The substrate is metallized with electrotechnical copper with thickness of 15 μm. Topology of the output microstrip filter is developed so that the resistor R_2 produced on a ceramic substrate by the thin film technology provides transistor feed via the output port. According to the simulation data, the LNA-active filter with overall dimensions of 22x10x3 mm^3 has been produced. Electrical parameters have been measured at Up=5V and drain current of 22 mA. The impedance of the input and output ports is 50 Ohm and they are loaded for appropriate external loads.

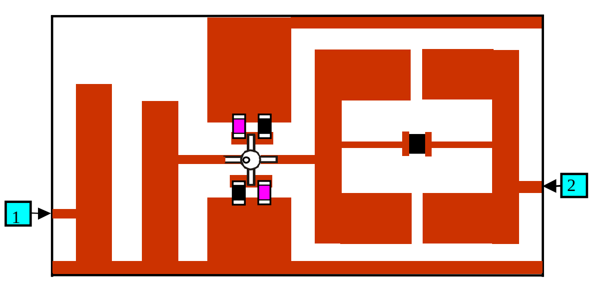

Fig.4. Optimised topology of the LNA

In Fig. 5 the calculated and experimental curves of microwave power transfer constants in the frequency range from 1 GHz to 2.2GHz are given. Good agreement of the measured parameters of real amplifier with the calculated parameters of the LNA computer model is observed. The difference of the calculated gain factor G_A from the measured one does not exceed a permissible measurement error and is 16 ± 0.3 dB. The operating frequency range of the real amplifier is drifted into the high frequency area ~ 10 MHz. It may be associated with inaccurate measurement of ε=80±2 of used ceramics. Signal rejection beyond the pass band at the transmission frequency of 1.4 GHz and 1.8GHz relative to a maximal gain in both cases is 55 dB. The absence of attenuation pole at frequency of 1.39 GHz of real gain-frequency characteristic seems to be associated with some discrepancy of the computer model and the real amplifier. The model has been made so that the electrodynamic problem is solved not for whole LNA structure. Input/output structures calculated in electrodynamics, are linked in a quasi- static approximation. In this Figure the dependence of the noise factor on frequency is given. The NF calculated in the operating frequency band, does not exceed 1.1 dB, and the one measured in the real amplifier – 1.2 dB.

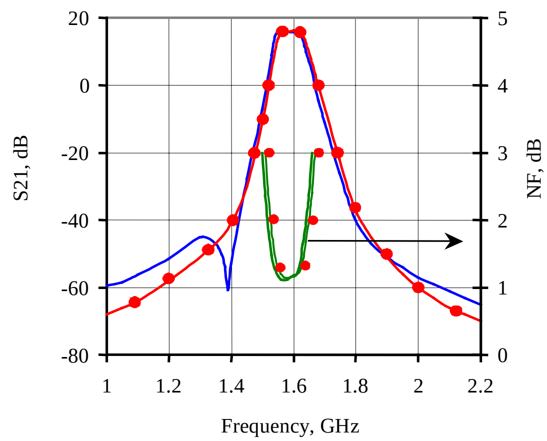

Fig. 5. Comparison of measured(symbol) and simulated (line) S 21 and noise figures.

In Fig. 6 the graphs of input and output dependencies on the return loss frequency of a real amplifier are shown. It should be noted that input return loss in such types of amplifiers at relatively low frequencies, both calculated and real, have a low level. To exclude distortion of the input signal as a consequence of multiple re-reflections caused by a mismatch of the receiving antenna and LNA, it is necessary to exclude all intermediate links and to match the LNA directly with the antenna, integrating them into a functional module. Return loss at the output of the real LNA, as it is seen in the Figure, is less than 15 dB, which is quite sufficient for an optimal match of the amplifier output with subsequent cascades/modules of the receiving device. The calculated parameter S22 of the amplifier model does not correspond to the measured value for a real LNA and is equal to 3 ÷ 4 dB.

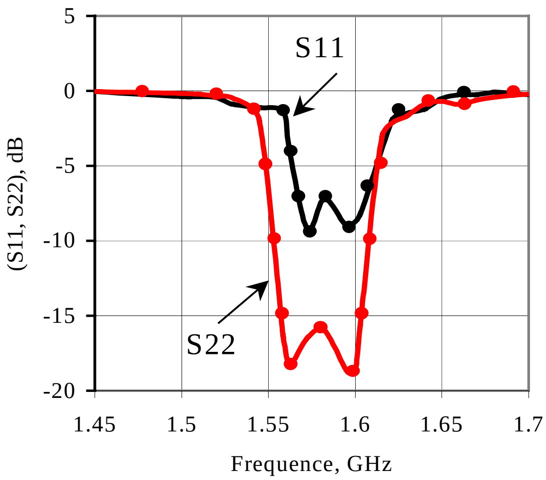

Fig. 6. Measured S11 and S22 of the LNA.

In Fig. 7 we show the curves of calculated dependencies of the upper linearity boundary of the transfer characteristic – the input compression point (IICP) and the output compression point (OICP) associated with it.

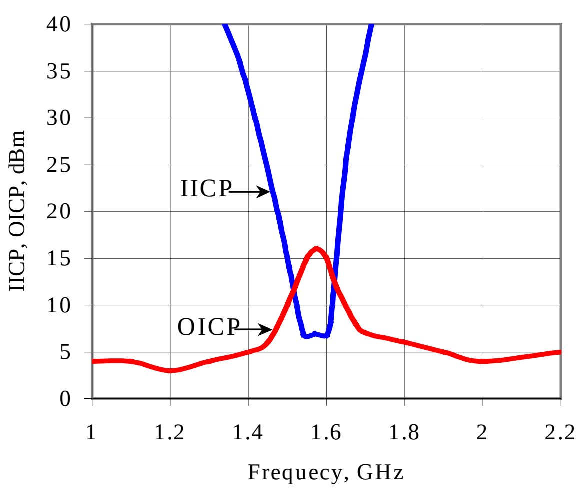

Fig.7.Simulated IICP and OICP of the LNA.

It is seen that the input compression point is minimal in the active filter pass band and is equal to 7 dBm, and at tuning out of the pass band it increases sharply. Thus, already at the frequencies of 1400 MHz and 1700 MHz it reaches 30÷35 dBm. It is evident that beyond the range 1400÷1700 MHz interfering signals with the power higher than 30 dBm do not shift LNA into nonlinear amplification mode. Hence, the probability of arising of intermodulation distortion connected with interfering signals located near the pass band decreases considerably. Dependence of the output compression point on frequency is more complicated. It is maximal in the amplifier pass band and reaches 16 dBm, but at tuning out of the pass band it decreases to 3 ÷ 5 dBm. It is associated with the fact that at frequency tuning out the transistor goes out of optimal matching modes. This fact has to be taken into account in designing of amplifiers of such a type.

V. CONCLUSION

The LNA has been developed having the structure and characteristics of an active bandpass filter. The LNA has been produced by the hybrid-integral technology and has bulk dimensions of 22x10x3mm^3. Selective properties of the LNA are not worse than in filters applied for frequency selection in GLONASS+GPS receiver-indicators [5]. Thus, having the pass band of 1572 ÷ 1612 MHz and off-band rejection at the frequencies of 1400 MHz and 1800 MHz not less than 55 dB, noise factor NF = 1.2 dB, which is comparable with the noise factor of a broad-band LNA in the same frequency range [6]. Combining the properties of a narrow-band filter and a low-noise amplifier with great dynamic range, the developed LNA allows one to solve practically the interference immunity problem of GLONASS + GPS receiver – indicator at the receiving of weak radio signals in the conditions of complicated interference situation.

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