International Journal of Advance Research in Science and Engineering
Volume No.06, Issue No. 10, October 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

Desgin of LNA for IRNSS Receiver using ANN

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ABSTRACT

Paper presents a Neural Network Modeling approach to microwave LNA design. To acknowledge the specifications of the amplifier, Mobile Satellite Systems are analyzed. Scattering parameters of the LNA in the frequency range 0.5 to 18 GHz are calculated using a Multilayer Perceptron Artificial Neural Network model and corresponding Smith charts and Polar charts are plotted as output to the model. This paper describes the design and measurement of a medium power amplifier (MPA) using 0.15µm GaAs PHEMT technology for wireless application. At 2.4 GHz and 3.0 V of VDS, a fabricated MPA exhibits a P1dB of 15.20 dBm, PAE of 12.70% and gain of 9.70 dB. The maximum current, Imax is 84.40mA and the power consumption for this device is 253.20mW. The die size of this amplifier is 1.2mm x 0.7mm.

I. INTRODUCTION

In this research, attention is paid to the modeling of the scattering (S–) parameters of a gallium nitride high electron mobility transistor (GaN HEMT) power amplifier for C band satellites [1]. The S-parameters of a microwave transistor depend on the operating bias condition as well as on the frequency. Modeling of the S-parameters is based on application of artificial neural networks (ANNs). In the last two decades artificial neural networks have found their place as an efficient tool for modeling of microwave devices [2, 3]. ANN models are usually extracted from the measured data directly, without need for detailed knowledge about device physics, allowing them to encounter all effects contributing to the device behavior. ANN model is developed to obtain the microwave characteristics of the device which is further used to develop the ANN model for S-parameter extraction of pseudo orphic HEMT (High Electron Mobility Transistor). The calculated S-parameters, Gain and minimum Noise figure from the ANN model are the parameters which are used to design the low noise pHEMT (Pseudo High Electron Mobility Transistor) power amplifier.

II. LITERATURE SURVEY

Shruti singh et.al (2016) [1] presents an ANN modeling of microwave LNA for the global positioning front end receiver, operating at 1.57542 GHz. To design LNA, multilayer perceptron architecture is used. The scattering parameters of LNA are calculated using Levenberg Marquardt Back propagation Algorithm for the frequency range 100 MHz to 8 GHz. The inputs given to this architecture are drain to source current, drain to source voltage, temperature and frequency and the outputs are maximum available gain, noise figure and scattering parameters (magnitude as well as angle). ANN model is trained using Agilent MGA 72543 GaAs pHEMT Low Noise Amplifier datasheet and this model shows high regression. The smith and polar charts are plotted for frequency range 100 MHz to 8 GHz.

Sang Le Yun et.al, (2001) [2] proposed the designing method of first gallium nitride based high electron mobility transistor (HEMT) power amplifier using an ANN modeling technique. This technique is used in the modeling of small signal behaviour of device having frequency from 1 GHz to 26 GHz. The device having this frequency range should have multiple bias points. These bias points are based on fitting between calculated scattering parameters and measured scattering parameters. A neural, network is trained and used to calculate and model the scattering parameters within the operational range and under bias conditions of the device. One of the advantages of proposed neural networks in device modeling was that only a few measured data are necessary to accurately and quickly model the scattering parameters of the device in the complete operational range The comparison between neural network calculations and measured data has shown an excellent agreement in frequency from 1 GHz to 26 GHz. From this calculated scattering parameters obtained from the modeled neural network, the power amplifier was designed and then tested at the design frequency of 8 GHz.

D. Xiao et.al, (2003) [3] presented an accurate and simple large signal model of GaN field effect transistor (FET) based on modeling of ANN .A lengthy diversion via hundreds of multi-bias scattering parameters measurements is avoided while also modeling the thermal and trapping effects is minimized. This simple method also moderates the device degradation. This device degradation is due to extensive measurement at bias conditions which are required in classical modeling methods. This methodology is well suited for other GaN FET technologies because the thermal heating is less in case of SiC and Si based GaN FETs moreover GaN based FETs have more potential in high power uses than others.

Mark H, Weatherspoon et.al, (2007) [4] presented a method to efficient and exact modeling of microwave devices using ANNs. To model scattering parameters of MESFET, four inputs and eight-outputs ANN is employed. The inputs are bias, frequency and temperature. A three-inputs and eight-outputs ANN is employed to model these circuit parameters of MESFET. The evaluations of modeled data and measured arc presented which show good agreement, The radial basis function training algorithm minimizes the requirement of data storage and amount of the data required to create the models are reduced with little fluctuations in accuracy. These factors can potentially reduce the time and cost to market for microwave circuit applications like amplifier design.

David M. Pozar, [2009] [5] presented the description of microwave engineering and its applications. The theory of transmission line, given by the author contains information of waveguide and smith charts. The influencing parameters like MAG, scattering parameters, stability factor and reflection coefficient arc considered in designing LNA.

M. Faith Caglar et.al, (2009) [6] presented low noise amplifier, matched and stable amplifier at operating frequency 5 GHz. The amplifier is developed utilizing the datasheet of Agilent. As a substitute for impedance matching of proposed LNA, an ANN model is suggested. Yet neural models are uncomplicated and evaluation is very quick. The matching network is formed using outputs of smith chart and MATLAB (Matrix Laboratory) RF Toolbox is used for solutions of simulation for comparison. A smith chart is structured by using ANNs in multilayer perceptron.

Eldon Y. Li et.al, (1994) [7] presented the common and important characteristics of neural network and gave a discussion about the probability of ANN applications in commercial fields. Further presented four actual cases of application and categorizes the drawbacks of current neural network technology. After this, some multilayer and trained ANN models emerged in the early 1980's. ANNs have been increasingly popular since, then despite having some inherent limitations. These networks are practical for commercial applications which need the clarification of recognizing patterns from imperfect inputs, equations of composite system and adjusting decisions to varying situation.

Wei Zhang et.al, (2015) [8] presented ANN modeling approach to analyze NF of the entire circuit. In this technique the effects of matching., networks of circuit are analyzed. The ANN model is exploited to represent the link in NF of circuit and matching networks. Proposed ANN model allows RF amplifier designers to acquire an accurate system conveniently and effectively. The examples of two amplifier circuit are employed to validate the suggested process. In presented paper, the writers proposed a novel method for calculation of NF of entire circuit. The matching networks' effects on the NF of circuit are analyzed. Then neural network model is developed to represent a connection between NF of circuit and matching networks.

Mohamed Rizk et.al, (2007) [9] presented a low voltage and wide band LNA using pHEMT(Pseudo High Electron Mobility Transistor). The designed LNA is single stage with pi type input as well its output matching circuit. The sensitivity exploration sad noise eliminating principle are performed for simulated LNAs. The simulated outcomes are compared with the identical LNA and these results give a major increase in gain by additional 23 % at the same input and output return loss and NF. Another LNA designing is optimized to accomplish the maximum gain with very small NF as well as input and output return loss which gives a 0.65 NF and maximum gain of 16 dB at 3GHz frequency. Thus, four LNAs are designed using pHEMT transistor with two operation condition.

Rafik Zayani et.al, (2008) [10] presented the pre-distortion techniques which is based on feed-forward network. This work is proposed to linearize the power amplifiers which are used in the satellite communication, obviously, the paper presents suitable neural structure which gives the finest performance for considered three satellites down links. A stationary and memory less amplifier is the first connection, a non-stationary and memory-less amplifier is the second and memory-less amplifier tracked through linear filter is the third one. This technique informs points related to the applications of different neural network training algorithms so that the most advancement for this pre-distortions can be determined. The adaptive techniques have fast convergence, low completely and best performance.

Imad Benner et.al, (2014) [11] presented the modeling and simulation of a low voltage pentacenc organic FET. The authors described a model which allows a convenient method of device modeling. without obtaining the knowledge of device physics. Examine various models having one or three hidden layers and two to fifteen neurons in every layer. Top contact organic FET is explored with MATLAB simulation using ANN and a finite component simulation. The comparison between predicted (ANN model) values and experimental data has shown that there are least errors.

Hossein Sahoolizadeh et.al, (2009) [12] presented a new circuit desgin, of LNA. In the leading stage of every microwave receive, LNA is present and this stage shows an essential part in receiver's quality factor. The design of LNA circuits needs balance among NF, gain, stability, consumption of power and complexity. This situation leads designers to create variations in the designs of RF circuits. In this work, the purpose is designing and simulation of the single stage LNA with low noise and high gain utilizing MESFET for the frequency range front 5 to 6 GHz. This simulation procedure is done with developed design system. Thus, this LNA with single stage is effectively designed for frequency of 5.3GHz.

Zhan Su et.al, (2016) [13] presented the design of high-quality linear amplifier which is based on ANN training process. There is no feedback loop and the complete schematic remains as parallel differential pair So the frequency could be pushed to several GHz. No extra component is needed during linearization. Therefore. good input matching performance and NF is achieved. This linearization technique also improves the required gain which shows small power consumption for the same amplifying requirement. As a conclusion, the proposed technique brings a simple amplifier structure with remarkable linear range extension. higher gain. less power, good noise performance and wide bandwidth compared to most of the stare-of-art. This design completely avoids the balance amid linearity improvement and die other performance of amplifier. Therefore. this could be a crucial solution for die increasing requirement of linearity in both industrial applications and wireless communications.

Francesco Piazza et.al. (1998) [14] presented low-power RF front end receiver suitable for small portable GPS applications. The power consumption of receiver is as low as 31.5 mW which is combined with minimal number of external components. The front-end gain is 26.5 dB and the NF is 8.1 dB which are as good as while consuming much less power. The integrated circuit described here is a less power front end receiver for GPS for the Civilian L1 band of frequency I.57512GHz. The important application of this integrated receiver is to provide GPS time reference and GPS positioning which will be helpful to set the correct time zone for small and portable consumer products. Therefore consumption of low power is a primary requirement.

Arduvan Rahimian et.al, (2012) [15] presented the realization, CAD, modelling performmance exploration of microwave LNA which is accurately developed for operation at 3GHz.. The chief objective of research work is to deeply analyze and build up a trustworthy microstrip LNA for the possible service in satellite applications and wireless communication systems. The S-band microwave LNA describes the suitability to expand fixed and high performance device recognition for wireless systems. The selection of appropriate transistor is very importance for microwave system design and comprehension for accurate design of high performance component having low noise and an accurate matching network for the transfer of maximum power and better SNR. Modeling and simulations of LNA for the desired RF operating frequency specified scattering parameters must be considered.

George Fikioris, (2004) [16] presented the certain formulas which include an exceptional set of susceptance of conductance transformation equations and simplified versions helpful for highly mismatched lines where it is occasionally difficult to utilize the smith chart. All the equations are established from familiar facts of transmission line theory. The smith chart interpretations of various analytical results are given. It helps in finding the impedance or admittance at any point next to a transmission line from the impedance or admittance at any different point without manipulating the complex numbers. This potential leads to the numerous applications. Thus the analytical investigations supplement smith chart. For greatly mismatched lines, these formulas bring out certain similarities to resonant series RLC circuit and offer a remarkable connection to the familiar subject of common circuit theory.

M. Habib Ullah et.al, (2012) [17] presented a LNA operated at 1.5GHz. This LNA is applicable in the output stage of a transmitter where a strong signal is needed for the transmission. From the LNA design parameters and simulation result, this is clear that 1.5 GHz LNA is designed for RF or microwave oriented application whose main target is suitable maximum gain and minimum NF. The proposed approach explains the scattering parameters as a design aid using smith chart plots for the identification of largest achievable constant gain circle and preferred constant NF circle. The proposed approach is very precise in the designing of microwave LNA that is used M communication system.

Anthony Zaknich, (1990) [18] presented a realistic and simple to recognize network for processing of signals called as improved probabilistic neural network. This network is a regression technique alike to regression network. The regression neural network is centered on radial function and the bandwidth of this network and is linked with noise statistics. This network has advantages in application to spatial series and time series signal processing problems because the network can be created simply and directly from the features of training signal waveform. The design parameters are simply derived from the noise characteristics and training signal.

M. Isikhan et.al. (2009) [19] presented versions of LNA which are modelled for GPS applications of L1 band (1.575GHz). A complementary metal oxide (CMOS) technology is employed for operation of these versions. These diverse versions are designed for comparing results, analyzing some effects and optimizing few critical performance criteria. On-chip inductors having a minor change in topology and several quality factors are used to achieve this design Several topologies are considered to fulfill the performance objectives. This LNA provides adequate gain for a bandwidth of 20.46MHz for L1 band applications of GPS. An amplifier with a capacitive-inductive load topology can accomplish this condition This is proven through both on-printed circuit board and on-wafer measurements that LNA versions operating at a supply voltage range from 2.1V to 3.6V draws a current of 107mA and achieves gain of 13 dB to 17 dB with NF of LNA effects critically on the overall NF of system. The NF of LNA should be kept below 1.5 dB to make overall NF of less than 2 dB for high precision GPS applications.

Samna Raazavi et.al, (2011) [20] presented a function approximation techniques with feed forward neural network. This is useful to a large variety of problems of various orders. However, ANN is a model which consists of multiple difficulties related to training. This research work firstly analyses the internal behaviour of networks and then employs a described interpretation of geometry of network functions. The geometrical exploration describes that novel variables are proposed for these networks. These variables are geometrically interpretable and more effective alternative for the conventional set of network biases and weights. The proposed work also developed a geometrical interpretation explaining how the feed forward ANNs work in function approximation. This geometrical interpretation enables the network users to gain some clear insight into the behaviour of their neural networks.

Trung-Kien Nguyen et.al, (2004) [21] presented four LNA designing procedures applicable for cascade topology using CMOS technology. These techniques are controlled noise optimization conventional noise matching. simultaneous matching of noise and power controlled noise matching techniques. Very, simple expressions for noise constraint are presented for power-constrained noise optimization, simultaneous noise matching and power controlled noise matching techniques. On the basis of noise related parameter equations, this research work describes obvious perceptive of fundamental limitations, design principles and benefits of the our LNA design methods. By doing this, the designers acquire the overall design perspective of LNA. The folding of transistor supports in the extension of cut-off frequency of transistor. The parasitic capacitances at drain side of transistor are removed through the resonance with inductance at the supply. The reduction of this parasitic capacitance suppresses the noise contribution of common-gate transistor at the output and avoids the signal loss into the substrate.

A. Shamim et.al, (2011) [22] presented the standard smith chart which is nothing but a distinct case of fractional smith chart. Illustrations are given for conventional lumped and fractional components. A novel graphical method carried by the logical manner is offered to plot the impedances on fractional chart. This concept is then utilize in matching networks of impedance, where this novel approach becomes very resourceful and gives a single element notching network for a complex load as equated to the two elements in the conventional approach. A novel concept of this smith chart is initiated in this paper to support the emerging applications of circuit elements. The effect of variation on smith chart is discussed. Graphical and logical schemes are made for plotting and matching of fractional impedance. In distinction with conventional two element L shaped type-matching network, the feasibility of a single fractional element impedance matching network has been verified.

P.K. Chopra et.al (2013) [23] designed a high quality performance, future efficient wireless communication systems require a broadband amplifier in the frequency range under consideration. When such an amplifier is plugged into the measuring path it would enable the system to receive even the weakest of signals. To achieve this, a new Scattering-parameter model that is valid for a wide frequency range has been developed for microwave analysis of a pseudomorphic high electron mobility transistors (pHEMT). The developed neural network model is used for designing a pHEMT power amplifier. The calculated *S*-parameters, gain and minimum noise figure from the artificial neural networks (ANN) model are the parameters used to design the low noise pHEMT power amplifier. The various gains so obtained from the *S*-parameters have been plotted with the frequency and it was found to yield a close fit to the simulated model. Neural network training has been done using Levenberg-Marqaurdt back propagation algorithm implemented in ANN toolbox of MATLAB software. All the results have been compared with the experimental data that showed a close agreement and validated our model. The calculated *S*-parameters, gain and minimum noise figure from the ANN model are the parameters used to design a stabilized and matched LNA.

Metin Sengul, (2013) [24] presented the strategy of broadband matching networks suitable for microwave communication systems. Commercial tools am always preferred for use for the design of broadband matching networks of microwave systems. However. the matching topologies and values of constituents are designated accurately for those tools. Therefore. a real-world method is presented for matching networks having good initial values of constituents. The designed network's performance is boasted using the commercial CAD tools. An example is given to elaborate the employment of proposed method. The suggested method provides good openings for CAD tools. As the design of useful matching networks is the main problems in microwave engineering therefore in this paper. an initialization method is proposed. The suggested method is for the construction of lossless broadband matching networks. In this method, the front end or back end impedance of matching network is determined in terms of the scattering parameters of matching network. Then, one of the termination impedances (ZG or ZL) and this calculated impedance are used to calculate the transducer power gain of the system.

III. CONCLUSION

An approach for the microwave nonlinear device modelling technique based on the combination of the conventional equivalent circuit model and the artificial neural network (ANN) is presented in this paper. The main advantage of the proposed method is that the integration and differential of the ANN can directly be carried out from the original ANN. The proposed technique is very useful for neural based microwave computer-aided-design, and for analytically unified dc, small signal and nonlinear device modelling.

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