THERMAL NOISE CURRENT ENHANCEMENT OF INGAN HEMTS DEVICE USING BIHARMONIC COMPARED WITH CUBIC OPTIMIZATION FOR DIFFERENT ASPECT DIMENSION BY LIMITING THE CUT-OFF FREQUENCY

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Abstract

Aim: This work describes InGaN based High Electron Mobility Transistors (HEMTs) which includes Biharmonic and Cubic optimization for microwave applications.
Materials and Methods: The Biharmonic and Cubic optimization methods are implemented to improve the thermal noise current by varying the cut-off frequency of HEMTs. Two groups are considered where, group 1 is biharmonic and group 2 is cubic optimization. Each group has 7 samples and a total of 14 sample sizes. The G power calculation of 0.8.
Result: The thermal noise current will be improved by the variation of the cut-off frequency in HEMTs. SPSS analysis is carried out and has a significance of 0.685 ($p>0.05$, statistically insignificant). The thermal noise value of 1.7 db compared with 1.3 db at cutoff frequency 0.16G Hz by using Biharmonic and cubic optimisation respectively for dimension of L=1µm and W=200µm.
Conclusion: The Biharmonic optimization would get a higher improvement of thermal noise current than Cubic optimization by using Novel Artificial Intelligence Optimization.

Keywords: High Electron Mobility Transistors (HEMTs), Biharmonic optimization, Cubic Optimization, Cut-off frequency, Thermal Noise, Novel Artificial Intelligence Optimization, Power Electronics.

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1. Introduction

Currently the most common power amplifiers for telecommunication application are based on high electron mobility transistors (HEMTs) which exhibit excellent high-power density in the field of Power Electronics. The InGaN based High Electron Mobility Transistors (HEMTs) have demonstrated improved thermal noise current with increased cut-off frequency and intensity (Jena 2008). Hence the incorporation of indium in GaN is expected to improve frequency performance in a similar way that indium gallium arsenide (InGaAs) (Zahari et al. 2015). The observed optimization techniques of AIGaN /GaN HEMT technology suffers from gain compression, as well as significant non-linearity at high frequency (Ture 2018).

Recently, a lot of research has been done on InGaN based High Electron Mobility Transistors and about 90 articles were published in IEEE Xplore. Few best cited articles one by author giving insight on the numerical modeling of electronic and electrical characteristics of InGaN/GaN multiple quantum well solar cells (Yahyazadeh 2020). Another author presents the High breakdown voltage and low-current dispersion in AlGaN/GaN HEMTs high-quality AlN buffer layer (Yahyazadeh 2020; Kim et al. 2021). One of significant works of the author on Numerical modeling of InGaN/GaN pin solar cells under temperature and hydrostatic pressure effects was highlighted (Yahyazadeh 2020; Kim et al. 2021; Chouchen et al. 2019).relative work of author explains the parametric model of GaN based device for high frequency and power application in the field of Power Electronics for high-temperature electrical performances and physics-based analysis of p-GaN HENT device (S. Li et al. 2020).

Our institution is passionate about high quality evidence based research and has excelled in various domains (Vickram et al. 2022; Bharathiraja et al. 2022; Kale et al. 2022; Sumathy et al. 2022; Thanigaivel et al. 2022; Ram et al. 2022; Jothi et al. 2022; Anupong et al. 2022; Yaashikaa, Keerthana Devi, and Senthil Kumar 2022; Palanisamy et al. 2022).The major purpose is to look at the performance of HEMTs devices utilising existing analytical and numerical studies. The proposed work examines how the thermal noise current can be enhanced by changing the HEMTs' temperature by including Biharmonic optimisation and Cubic Optimization by varying temperature the range between 300K-1200K of the InGaN HEMT. The resultant will enhance thermal noise current improvement by using Novel Artificial Intelligence Optimization.

2. Materials and Methods

The research was done in the Power Electronics Simulation lab in the Department of Electrical and Electronics and Engineering at Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences. Two algorithms were chosen for comparison, and the sample size was estimated using G Power software. It was determined that each algorithm contains 7 samples each in 2 group , group 1 Biharmonic optimisation and group 2 Cubic Optimization, resulting in a total of 14 sample tests (Carpintero et al. 2015).With a G power parameter calculation of 0.80 and a maximum error of 0.5, the mean group values were 697.2857 and 558.4286, respectively for both optimization data groups and along with standard deviations of 259.47 and 190.374 are employed for device metric. MATLAB code is used to simulate the device.

Biharmonic Optimisation

Biharmonic B-splines are a beautiful generalisation of univariate B-splines for planar and curved domains with completely irregular knot configurations (Feng and Warren 2012). Despite the theoretical breakthrough, certain technical challenges remain, such as the need for Voronoi tessellation, the lack of an analytical formulation of bases on general manifolds, expensive basis re-computation during knot refinement/removal, and the fact that the method is only applicable to simple domains Novel Artificial Intelligence Optimization. To address this, study presents a basic formulation for biharmonic B-spline computing paradigm. It shows that biharmonic B-splines have an analogous representation based merely on a linear combination of the bi-Laplacian operator's Green's functions (Hou, Qin, and Hao 2015). As a result, biharmonic B-splines can skip Voronoi partitioning and bi-Laplacian discretization without explicitly computing their bases, Power Electronics enabling computational utilities on any compact 2-manifold. The new representation also makes it easier to generate biharmonic B-splines on manifold triangle meshes using optimization-driven knot selection (Hou et al. 2017).

Cubic Optimization

Cubic optimization is a piecewise method based on cubic polynomials that creates a smooth line from a succession of interpolation points. These optimizations are smoother when fitted with cubic spline interpolation, which offers it superior dynamic characteristics in an emergency stop or emergency steering, giving it significant advantages over a path made up of straight lines and arcs. The definition of cubic spline interpolation and the path generating method that goes with it for numerical modelling (W. Li et al. 2020).

Statistical Analysis

SPSS software was used to perform statistical analysis on the biharmonic and cubic optimizations. The cut-off frequency is an independent variable, whereas the current of the dependent value of thermal noise current is improving. The analytical T-tests are carried out in order to increase the device's effectiveness.

3. Results

Table 1 shows how raising the temperature from 0.04 to 0.16 improves the thermal noise current improvement of conventional and proposed systems. The range of thermal noise current accessible in both ways can be seen as a result of this.

A T-test comparison of traditional and proposed techniques reveals a substantial difference between the recommended and traditional procedures in an independent sample test. Table 2 shows a T-test comparison of traditional and proposed techniques when the cutoff frequency was increased from 0.04 to 0.16. The recommended approach's mean value is 0.5743, which is lower than the old approach's mean value of 0.4757.

Table 3 reveals a substantial difference between the recommended and traditional approaches based on an Independent sample test. significance value is observed as 0.685 ($p>0.05$, statistically insignificant).

Figure 1 shows the Comparison of thermal noise drain current with respect to the cut-off frequency in InGaN HEMT. The thermal noise value of 1.7 db compared with 1.3 db at cutoff frequency 0.16G Hz by using Biharmonic and cubic optimisation respectively for dimension of L=1µm and W=200µm.

Figure 2 shows that Comparison of thermal noise drain current Id with respect to the cut of frequency InGaN based high electron mobility transistor (HEMTs). The thermal noise value of 1.3 db compared with 1.1 db using Biharmonic and cubic optimisation respectively for dimension of L=0.7µm and W=150µm.

Figure 3 depicts the mean thermal noise current improvement of the normal system versus the suggested way, the result of the two groups is shown, for thermal noise current with a standard deviation range.

4. Discussions

The Biharmonic and Cubic optimization methods are implemented to improve the thermal noise current by varying the cut-off frequency of HEMTs The work of low-frequency noise (LFN) measurement discussed by the author in a valuable approach analysing device performance, material defects, and device dependability in AlGaN/GaN HEMTs were significantly stated parameter analysis. (Vertiatchikh and Eastman 2003). Many research groups have looked at the effects of in situ/ex situ passivation layers and its uses (Oktyabrsky and Ye 2010). The gate-to-drain distance restoring effects buffer are denoted by author (van Raay et al. 2005). The types of GaN buffer layer given author under of ((*Study of the Effects of GaN Buffer Layer Quality on the Dc Characteristics of AlGaN/GaN High Electron Mobility Transistors* 2015) on the LFN of AlGaN/GaN HEMTs. (Kühn 2011). In this article, the noise level of an AlGaN/GaN metal-oxide-semiconductor (MOS)-HEMTs with a 20% Al concentration was shown to be lower than that of a device with a 35% Al content.

Some of the opposing papers are also there is high electron mobility transistors (HEMTs) improvement of thermal noise and its impact on the enhancement-Mode A1GaN Channel High Electron Mobility Transistor Enabled by pAlGaN Gate (Zhang and van Roosmalen 2010). The author gives the analyses of 2-DEG characteristics in GaN HEMTs with AlN/GaN superlattice as barrier layer grown by MOCVD merits (Zhang and van Roosmalen 2010; Alamgir and Rahman 2014).

Noise performance limitation of modern communication circuits is defined by a set of parameters. It reduces the system's selectivity and increases inaccuracy. Their low frequency noise could be a limiting factor in signal mixing and local signal generating applications.

Hence the future scope due limited voltage rating of current in GaN devices are overcomed by addressing complicated gate driver design and control complexity. Thermal management in GaN-based IC development with regard to area-specific thermal resistance, and packaging concerns to provide robust housing and ensure long-term reliability of these devices are all factors to consider. Each of these factors is explored above in order to determine based device GaN's mere future applications.

5. Conclusion

Comparison analysis between the Biharmonic optimization and cubic optimization was done. From the result obtained,it is observed that the Biharmonic optimization would get a higher improvement of thermal noise current than cubic optimization.The thermal noise value of 1.6 db compared with 1.4 db using Biharmonic and cubic optimisation respectively for dimension of L=1µm and W=200µm. Independent T-test analysis reveals that the significance value is 0.685 (p>0.05) which is statistically insignificant within the limit of study.

Declarations

Conflict of Interests

No conflict of Interest in this Manuscript.

Author Contributions

Author VK was involved in data collection, data analysis, and manuscript writing. Author AN was involved in data validation and review of manuscripts.

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Tables and Figures

Table 1. Simulated results of Simulated Biharmonic Optimisation and Cubic Optimisation for InGaN high electron mobility transistors (HEMTs) for Thermal noise current enhancement.

Cut off frequency (GHz)	**Distortion Factor**	
	Biharmonic Optimisation	**Cubic Optimisation**
0.04	0.12	0.09
0.06	0.18	0.12
0.08	0.32	0.26
0.10	0.47	0.38
0.12	0.72	0.53
0.14	0.93	0.87
0.16	1.28	1.08

Table 2: Group Statistical analysis of comparison Biharmonic Optimisation and Cubic Optimisation

Group statistics					
	GROUP	**N**	**Mean**	**Std.deviation**	**Std.error Mean**
Thermal Noise Current (TNC)	**Biharmonic Optimization**	7	0.5743	0.42489	0.16059
Thermal Noise Current(TNC)	**Cubic Optimization**	7	0.4757	0.37740	0.14264

Table 3. The independent sample T-test is performed for the two groups f of Thermal noise current enhancement between Biharmonic Optimisation and Cubic Optimisation. Significance value is obtained as 0.685 (p>0.05) which is considered to be statistically insignificant.

Independent Samples Test										
		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
Distortion factor	**Equal variances assumed**	**0.173**	0.685	0.0459	12	0.04025	0.21479	121.6357	-0.36943	0.56657
	Equal variances not assumed			0.0459	11.835	0.04025	0.9857	0.21479	-0.37015	0.56729

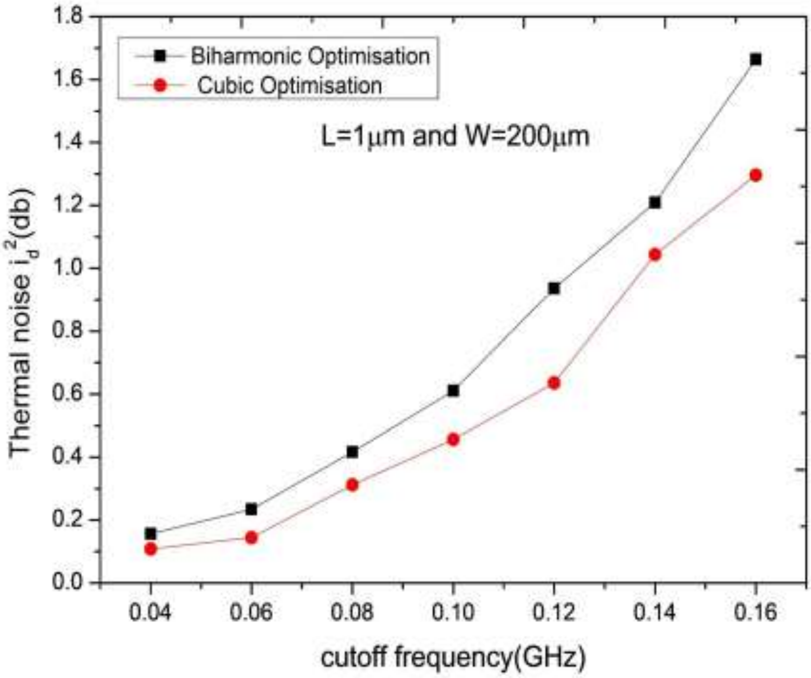

Fig. 1. Comparison of thermal noise drain current with respect to the cut-off frequency in InGaN based high electron mobility transistor (HEMTs)

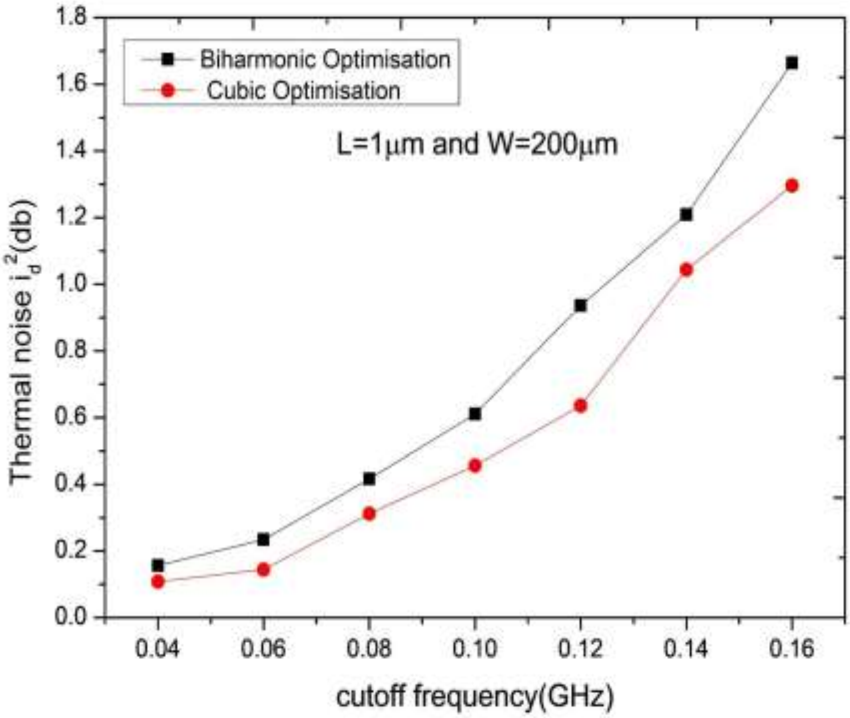

Fig. 2. Comparison of thermal noise drain current Id with respect to the cut of frequency InGaN based high electron mobility transistor (HEMTs)

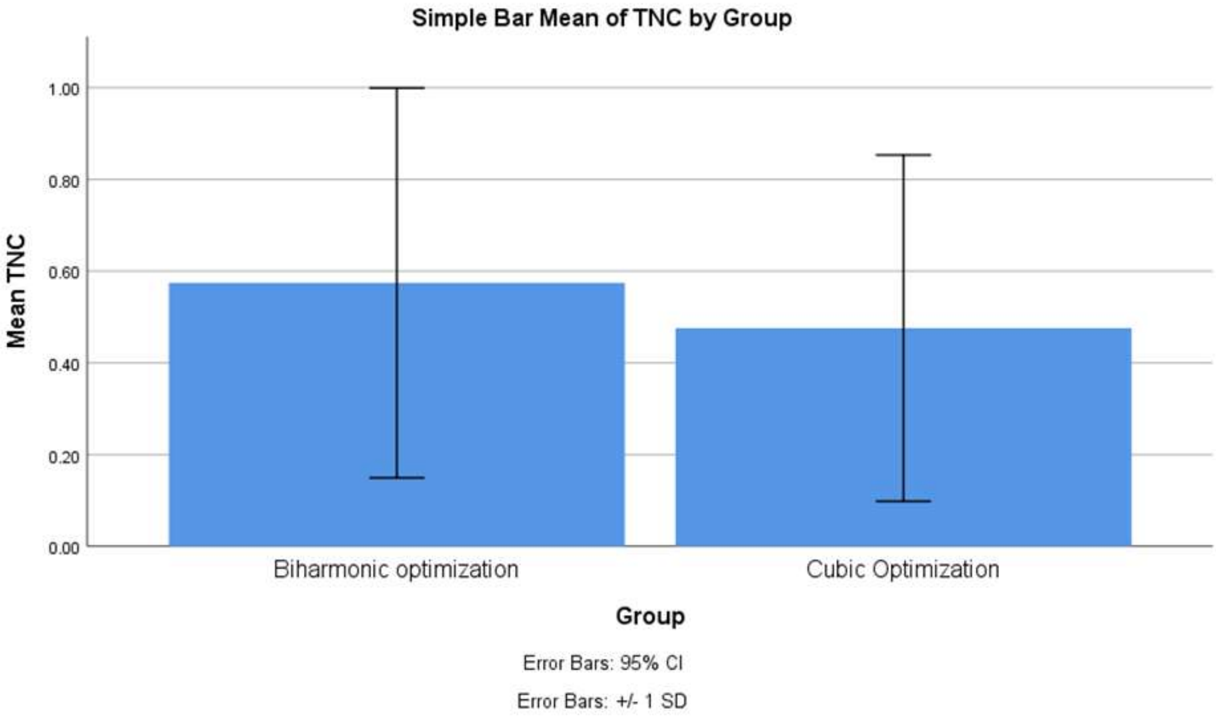

Fig. 3. depicts the mean thermal noise current improvement of the two groups thermal noise current with a standard deviation range. X axis: Biharmonic optimization vs Cubic Optimization Y axis: Mean thermal noise current ± 1SD.