NOISE MODELING OF SIGE HBT BASED ON THE CHARACTERIZATION OF EXTRACTED Y- AND Z-PARAMETERS FOR HF APPLICATIONS

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ABSTRACT

In last several decades silicon-germanium (SiGe) technology has come into the global electronics marketplace. Commercial SiGe HBT facilitates transceiver designs and recommends transistor-level performance metrics which are competitive with the best III-V technologies (InP or GaAs), while sustaining strict fabrication compatibility with high yielding, low-cost, Si CMOS foundry processes on large wafers. This work depicts the complete an ample process to model the noise characteristics of a high frequency 0.1 µm SiGe HBT based on a direct parameter extraction technique. A modeling and characterization of noise parameters of Silicon-Germanium Hetrojunction Bipolar transistor is examined in this issue. Initially, Noise in SiGe Hetrojunction Bipolar Transistors is conferred in detail. Later, a linear noisy two-port network and its equivalent circuit model are presented for extracting and characterizing the noise parameters, for example, noise resistance (R_n), optimum source admittance (G_{Sopt}, B_{Sopt}) and minimum noise figure (NF_{min}) along with its modeling significance. In next step, a novel idea that explains the impact of Ge concentration on these noise parameters is also portrayed. The noise characteristics of the SiGe HBTs are advanced to those of III–V semiconductor devices. A corroboration of objective validity of the noise modeling scheme and the extraction noise parameter is accomplished in the form of Y-, and Z-parameters. These results have been validated using a viable numerical device simulator ATLAS from Silvaco International

KEYWORDS: *SiGe HBT, R_n, NF_{min}, B_{Sopt}, G_{Sopt}.*

I. INTRODUCTION

The multibillion semiconductor industry is rapidly using devices/transistors working in several GHz regions and is pushing to demonstrate useful solid-state transistors, and resultant circuits built from them, capable of operating near the THz regime. There are two major driving forces for SiGe solid-state devices: 1) high frequency communications and radars and 2) various niche THz applications. Recent research has focused on expanding THz options from two-terminal devices (e.g., Schottky diodes) to three-terminal devices (transistors) for both application areas. In high-frequency communications and radars, higher bandwidth transistors are desirable in a number of applications. Optical fiber communications require active amplifiers in decision circuits, multiplexers, and phase-lock loops operating at 100-GHz clock frequency and above. High current-gain and power-gain cutoff frequencies (f_T and f_{max}) are also demanded in microwave, millimeter-wave, and submillimeter wave transceiver designs, where progressive improvements in transistor bandwidth enable the evolution of communications and radars ICs operating to higher frequencies. One of the key concerns in high frequency applications is their noise behavior. Therefore, accurate noise modeling of SiGe HBT is required [1]. SiGe HBTs were first demonstrated in the late 1980s [2]. It quickly became accepted in the field of wireless communication applications, in the form of wireless transceiver circuits because the higher performance than the Si bipolar devices and superior integration level than the III–V devices [3][4][5]. The low noise capability is one of the chief reasons for the success of the SiGe HBT in the field of wireless, RF and optical applications [6][7][8][9].

In past few years, various small-signal SiGe HBT models have been developed using numerous parameter extraction methods with the intention of optimizing their frequency response [10]. Since these SiGe devices reach the cut-off and maximum oscillation frequencies (f_T, f_{max}) beyond 500 GHz (half THz) due to the technology characteristics that's why they are suitable for RF, microwave and optical applications. Over and above, SiGe HBTs are competent devices at low-cost due to their simple coupling with Si technology, in contrast with other technologies (III-V) that offer higher velocities but at higher costs. This is the most important reason why these devices are widely used in electronic industries [9][11].

The defects and non-idealities in semiconductor devices can be computed perceptively by Low-frequency electrical noise. This directly or indirectly impacts the device performance and reliability. Thus, it is of major importance to be able to characterize the noise in semiconductor devices. The interest in low-frequency noise in electronic devices has been motivated by at least two factors. First the theoretical and experimental studies of the noise itself are of major interest. The low-frequency noise has a tremendous impact on devices and circuits. It sets the lower limit of detectable signals, and it converts to phase noise and thereby reduces the achievable spectral purity in communications systems. It is therefore of prime importance to be able to characterize the noise from electronic devices. Equally important is the information the noise carries about the microscopically physical processes taking place. In electronic devices, noise is caused by the random movement of discrete charge carriers, and their interaction with the environment in which they move. Hence, they carry useful information about that environment, e.g., the interior of a resistor or other semiconductor device [12].

Accurate transistor models which describe the high frequency noise behavior of the device are of great importance for the low noise circuit design and moreover, a physics-based equivalent circuit model on the noise behavior of the device. To determine the large number of unknowns of a HBT including the intrinsic elements and the extrinsic capacitances, extraction method based on small-signal π topology is used. Conventional procedures or methods based on simple bias measurements work very well if the extrinsic elements of the HBT have been previously determined. This approach may be used through different procedures—DC, cut-off measurements, or optimization. However, it is often very difficult to accurately determine the values of parasitic elements of the HBT, since the usual DC and cut-off techniques offer poor performance for SiGe HBT devices. In order to avoid this drawback, a new technique has been developed which does not require any additional measurements except for the scattering (S)-parameters at different biases. Linear models with a π topology have been tested to fit the measured S parameters properly. The base resistance, which has a significant impact on the high frequency noise characteristics of the transistor, can be obtained in a consistent way, as an accurate determination of the outer elements simplifies the equivalent circuit to a conventional model [13].

In this paper, an accurate noise model of SiGe HBT is presented by estimating the behavior of its noise parameters. The noise parameters for instance minimum noise figure (NF_{min}) noise resistance (R_n) and optimum source admittance $Y_{S,opt}$ are calculated for this device having 0.1 µm base width. The effect of Ge concentration on these noise parameters is also investigated. Following this motivation, in second section, we discuss various low frequency noise-sources in SiGe HBT. In the next section we introduce a noise model to extract the various noise parameters such as $R_{n,}$ G_{Sopt}, B_{Sopt} and NF_{min} for analyzing the performance of SiGe HBT in high frequency regime. In the fourth section, we discuss the simulation results based on ATLAS. Finally, in section fifth, we concluded with general observations as well as protrusions of this work.

II. SEMICONDUCTOR LOW-FREQUENCY NOISE SOURCES

2.1 Thermal Noise

Inside ohmic device, the charge carriers at temperature T collide with phonons which in turn cause Browninan random motion with a kinetic energy proportional to T. This yields open circuit voltage fluctuations with zero average value and nonzero rms value. This value is given by [12],

$$v_n = \sqrt{\frac{4hfBR}{e^{hf/kT} - 1}} \quad (1)$$

where vn is the rms value in Volts, h = 6.63× 10^{-34} Js is Planck's constant, k = 1.38×10^{-23} JK−1 is Boltzmann's constant, B is the bandwidth of the system in Hz, f is the center frequency of the band in Hz and R is the resistance in Ohms. Here we consider only the first two terms of a series expansion of the exponential, $e^{hf/kT}$-1 ≈ hf/kT. By using the approximation and converting to voltage spectral density v^{2n} /B, we get [12],

$$S_v = 4kTR \quad (2)$$

Hence, the thermal noise is a white noise. In other words, this is a noise with a frequency independent spectrum for frequencies up to the validity of the approximation, f < kT/h ≈ 6250 GHz at 300 K, or f ≈ 1/(2πRC), or f ≈ 1/ τ_{coll} ≈ 10^{12} Hz. Here C is the parasitic capacitance parallel to R and τ_{coll} the mean time between collisions of free charge carriers. Thermal noise is also identified as Nyquist noise or Johnson noise. Thermal noise is usually the white noise floor studied at high frequencies for the MOSFETs and resistors [12].

2.2 Shot Noise

The corpuscular nature of charge transport causes the shot noise. Walter Schottky discovered shot noise in radio tubes in 1918. He developed what has been recognized as Schottky's theorem. Under steady-state conditions, the time-averaged current is constant, while the arrival times of the electrons are not equally spaced in a tube. This is due to the electrons when they leave the cathode at random times. This leads to fluctuations in the measured current, and, it can be described by simple Poisson statistics. It is mandatory that there is a DC current present or there is no shot noise, and thermal noise would dominate. Shot noise can be observed in for example Schottky-barriers and in PN-junctions. In these places the current results from the random emission of charged particles that are independent and discrete. The short circuit current spectral density is given by [12],

$$S_I = 2qI \quad (3)$$

Where q = 1.6 × 10^{-19} C and I is the DC-current in Ampere. In PN junctions, the shot noise is white up to a frequency given by the reciprocal of the transit time, i.e., as long as the fluctuations are slower than the rate of recombination. Shot noise is normally the white noise floor. This is observed for the bipolar devices, for example, the HBTs and the lasers [12].

2.3 Generation-Recombination Noise

The fluctuations in the number of free carriers associated with random transitions of charge carriers between energy states cause Generation-Recombination (GR) noise. These random transitions of charge carriers occur mostly between an energy band and a discrete energy level (trap) in the bandgap. For a two terminal sample with resistance R, the spectral densities are depicted as [12],

$$\frac{S_R}{R^2} = \frac{S_V}{V^2} = \frac{S_N}{N^2} = \frac{\langle \Delta N^2 \rangle}{N_0^2} \frac{4\tau_N}{1 + (2\pi f \tau_N)^2} \quad (4)$$

Where, SV, SR and SN are spectral densities of voltage, resistance and number of carriers, respectively. N0 = hNi is the average number of free carriers. While τ_N is the trapping time. The resultant is of. The Lorentzian type spectrum is approximately constant below a frequency given by f = 1/(2 τ_N), and rolls off like 1/ f^2 at the higher frequencies. These noise signatures are found in all the device types [12].

III. NOISE MODELING

The analytical expression for R_n, NF_{min}, B_{Sopt}, G_{Sopt} are advantageous for gaining additional intuitive insight into device optimization for noise. This can be accomplished using analytical Y-parameter equations. For this purpose a linear noisy two-port network is demonstrated in figure1 [10]. In order to make such analytical expression practical, the accuracy must be balanced against simplicity of functional form. The power spectral densities of the input noise current (S_{i_n}), the input noise voltage (S_{v_n}) and their cross-correlation ($S_{i_n \cdot v_n^*}$) are given by [6],

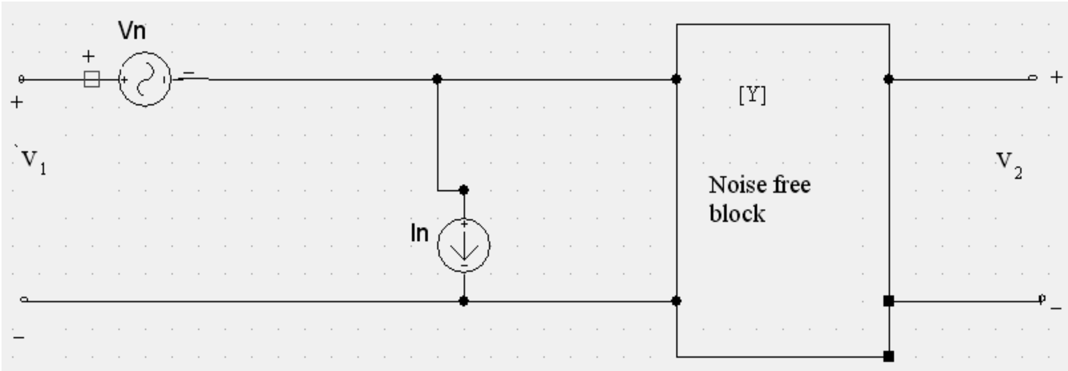


Figure 1: a linear noisy two-port network.

$$S_{v_n} = \frac{V_{na}V_{na}^*}{\Delta f} = \frac{S_{ic}}{|y_{21}|^2} = \frac{2qI_c}{|y_{21}|^2} \tag{5}$$

$$S_{i_n} = \frac{I_{na}I_{na}^*}{\Delta f} = S_{ib} + \frac{S_{ic}}{|H21|^2} = 2qI_B + \frac{2qI_c}{|H21|^2} \tag{6}$$

$$S_{i_n v_n^*} = \frac{2qI_c y_{11}}{|y_{21}|^2} \tag{7}$$

In further step, we state the Y-parameters in terms of fundamental device parameters, for example β, g_m etc. For the purpose of designing the Niu's method is followed. The small-signal equivalent circuit in simplified is shown in figure 2 [6]. The base resistance is not important for the input impedance at frequencies smaller than f_T. Thus it can be ignored for simplicity, even though it is noteworthy as a noise voltage generator.

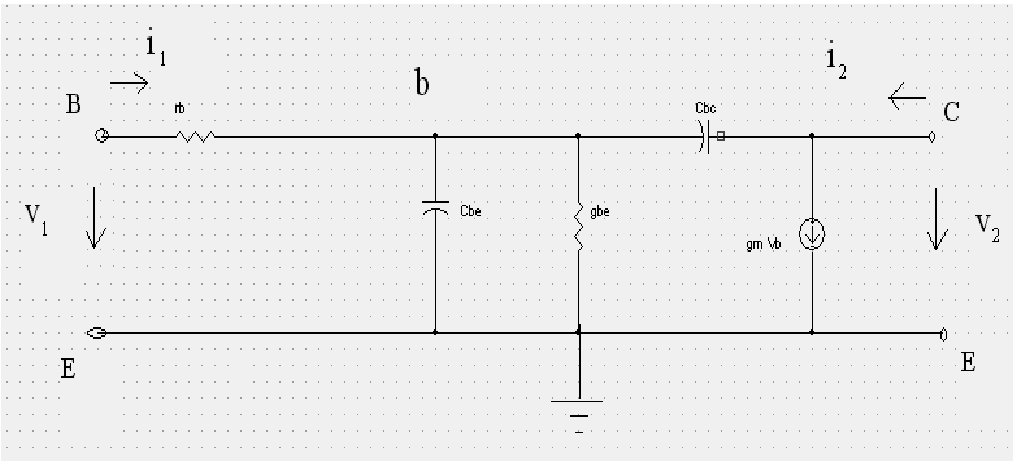


Figure 2: Equivalent circuit for the y-parameter derivation used in analytical noise modeling.

The Y-parameters can be obtained as [6],

$$y_{11} = \frac{g_{,m}}{\beta} + j\omega C_i \tag{8}$$

$$y_{12} = -j\omega C_{bc} \tag{9}$$

$$y_{21} = g_m \tag{10}$$

$$y_{12} = j\omega C_{bc} \tag{11}$$

Where $g_m = qkT/I_C$, and $C_i = C_{be} + C_{bc}$. The C_{be} consists of the EB diffusion capacitance $Si_{1-x}Ge_x$, and $C_{be} = C_{te} + g_m\tau$ with τ being the transit time, and any other EB parasitic capacitances. The C_i is related to f_T and C_{bc} is the total CB junction capacitance, through [6],

$$f_T = \frac{g_m}{2\pi C_i} \tag{12}$$

The oscillation frequency is expressed as [12],

$$f_{\max} = \sqrt{\frac{f_T}{8\pi C_{CB} R_B}} \tag{13}$$

The noise resistance can be determined as [6],

$$R_n = \frac{S_{vn}}{4kT} = r_b + \frac{1}{2g_m} \tag{14}$$

This equation indicates that R_n is directly proportional to the base resistance. R_n also declines with I_C at lower I_C, and then stays constant.

The optimum source admittance can be expressed as [6],

$$G_{s,opt} = \sqrt{\left[\frac{g_m}{2R_n}\frac{1}{\beta} + \frac{(\omega C_i)^2}{2g_m R_n}(1 - \frac{1}{2g_m R_n})\right]} \tag{15}$$

$$B_{s,opt} = \frac{-I\left(S_{i_n v_n^*}\right)}{S_{v_n}} = -\frac{\omega C_i}{2g_m R_n} \tag{16}$$

In general, the admittance increases with collector current and frequency. In the case when diffusion capacitance leads the C_i, then $B_{S,opt}$ becomes independent of I_C, as C_i is proportional to g_m. The absolute value of $B_{S,opt}$ enhances with frequency.

The minimum noise figure is obtained as [6],

$$NF_{\min} = 1 + \frac{1}{\beta} + \sqrt{\left[\frac{2g_m R_n}{\beta} + \frac{2R_n(\omega C_i)^2}{g_m}(1 - \frac{1}{2g_m R_n})\right]} \tag{17}$$

$$NF_{\min} = 1 + \frac{1}{\beta} + \sqrt{2g_m r_b}\sqrt{\left[\frac{1}{\beta} + \left(\frac{f}{f_T}\right)^2\right]} \tag{18}$$

Thus the noise figure NF for two port amplifier with input admittance of Y_S can be given as [14],

$$NF = NF_{\min} + \frac{R_n}{G_s}\left|Y_s - Y_{s,opt}\right|^2 \qquad (19)$$

Where Y_S is the source admittance and G_S is the real part of Y_S.

IV. Simulation Results & Discussion

Based on the above physics based model, the values of various noise parameters are calculated for n-p-n SiGe HBT (figure 3) and investigated for various different Ge concentrations in this paper. Simulation is carried out using ATLAS from SILVACO International. Average Ge concentration in the base region considered in our calculations is varied from 8%-25%. Higher to this are not supported by present epitaxial technologies and beyond it the improvement associated with Ge seizes may be due to lattice constant mismatch [15]. This paper is a next step to our last paper on SiGe HBT [15] for high frequency applications. With the intention of getting excellent accord between analytical and simulated characteristics, all the important physical effects, for example impact ionization (II) is appropriately modeled and accounted for the simulation as well [15].

With the purpose of depicting the complete image of the noise performance, a study of the variation of the noise parameters depending on frequency is employed in figure 4 and 5. The figure 4 describes the dependency and variations of noise parameters (R_n, NF_{min}, B_{Sopt}, G_{Sopt}) as a function of frequency. Figure 4(a) shows the variation of minimum noise figure NF_{min} as a function of frequency and it can be concluded that NF_{min} of SiGe HBT increases with the increase in frequency. This result matches with the analytical expression of NF_{min} as in equation (14) which predicts that the NF_{min} increases monotonically with frequency. It was found that at 65 GHz, simulated NF_{min} is only 2.70 dB at 65 GHz. This is an admirable result. While at cutoff frequency its valve is calculated about 9.82 dB. The variation of optimum source admittance $Y_{S,opt}$ as a function of increasing frequencies are described in figures 4 (b) and (d). The figure 4(b) depicts that behavior of it real part ($G_{S,opt}$) with frequency. It is found that $G_{S,opt}$ increases with the frequency and its calculated value at cut-off frequency is 0.09 mS. Its imaginary part $\left|B_{S,opt}\right|$ as a function of frequency is plotted in the figure 4(d) which concluded that the imaginary part is also monotonically increases with frequency. At cut-off frequency, its value is calculated as 0.012 mS. These results are also matched with the analytical expression of $G_{S,opt}$ and $B_{S,opt}$ as in equations (15) and (16). The negative value of imaginary part signifies the requirement of an inductor for reactive noise matching.

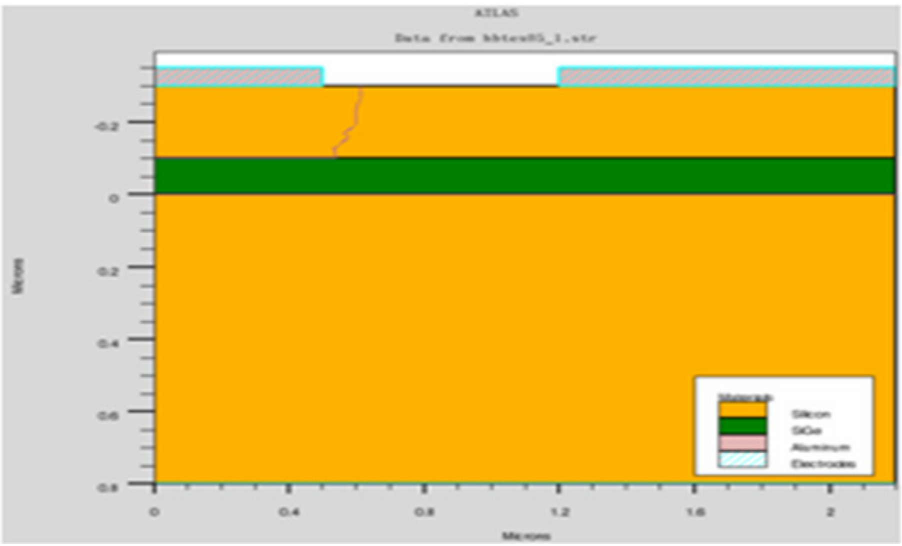
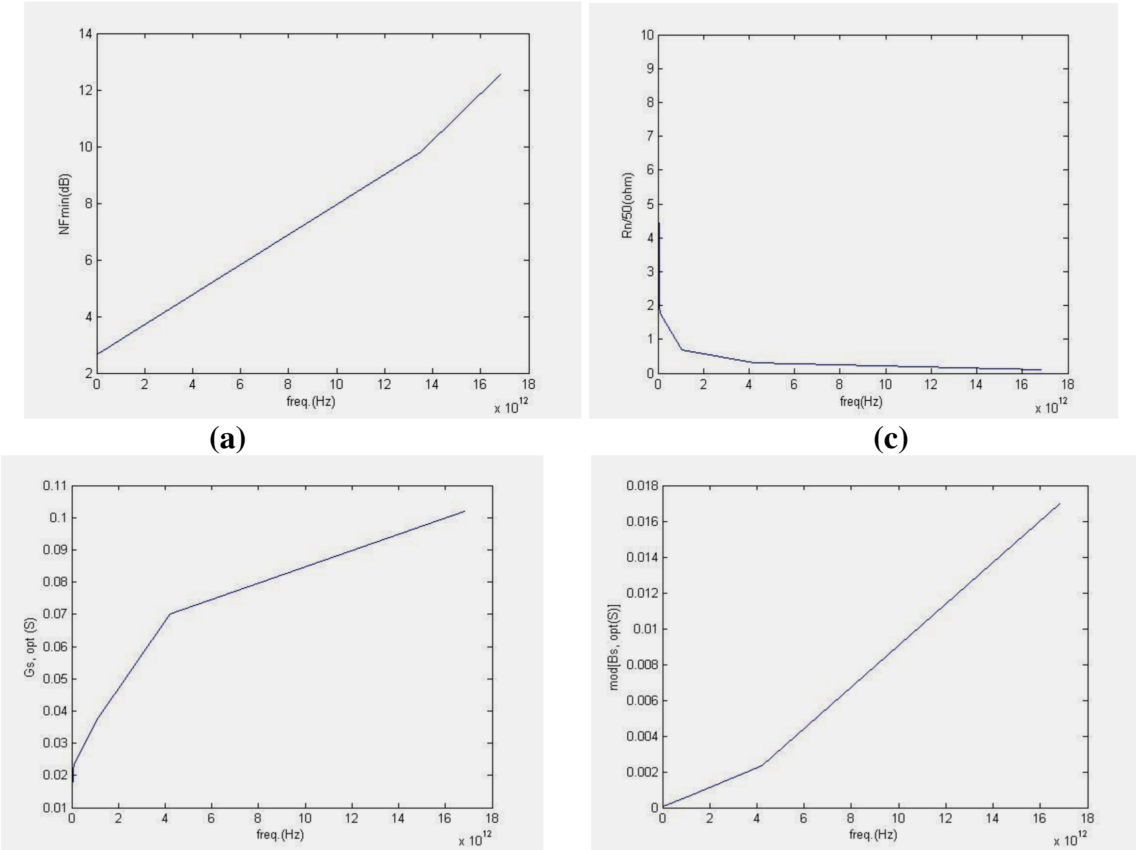


Figure3. The cross-section of the simulated SiGe HBT.

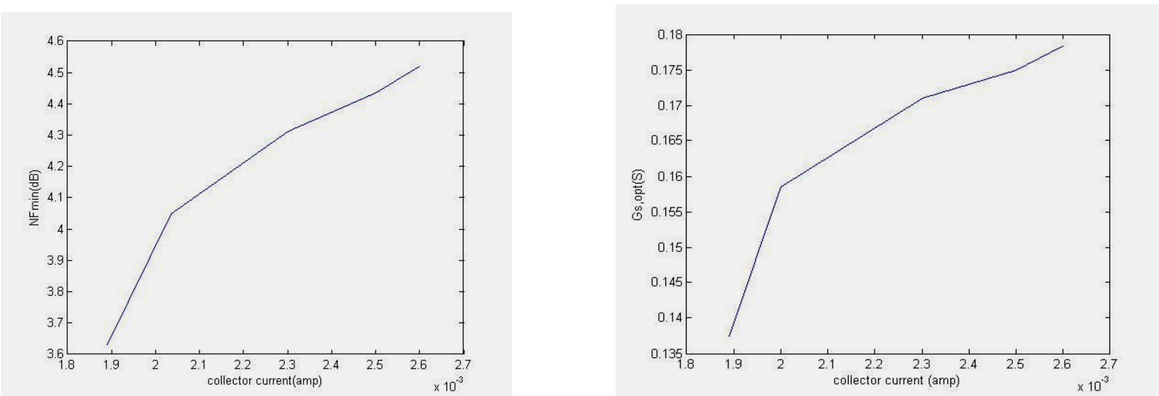
The figure 4(c) demonstrates that the behavior of noise resistance for a frequency range. From the equation (14) it is clear that R_n is directly proportional to base resistance (r_b). From figure 4 (c), it is concluded that noise resistance R_n is weakly depended on frequency. At cut-off frequency, value of R_n is calculated 0.2Ω. This behavior almost fits with its analytical predictions. The following results are demonstrated for maximum oscillation frequency 16.8 THz and corresponding cut-off frequency 13.5 THz [15].



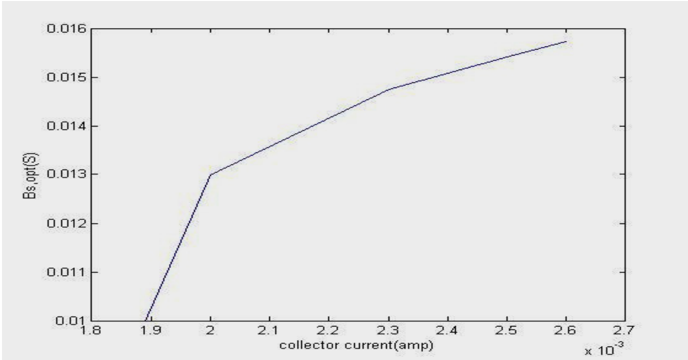
(a) (c)

(b) (d)

Figure 4. Noise parameters versus frequency for SiGe HBT. (a) NF_{min} vs. Frequency Plot (b) G_{Sopt} vs. frequency plot (c) Noise Resistance vs. frequency plot (d) mod of B_{Sopt} vs. frequency plot.



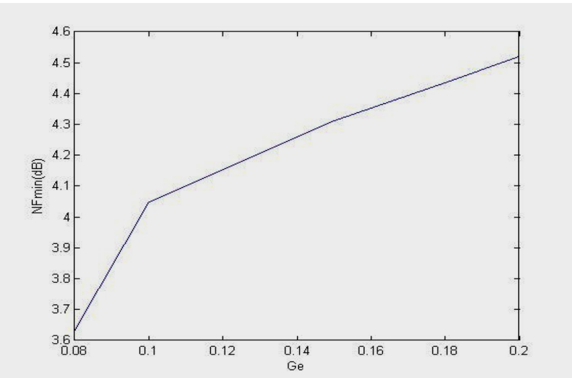
(a) (b)



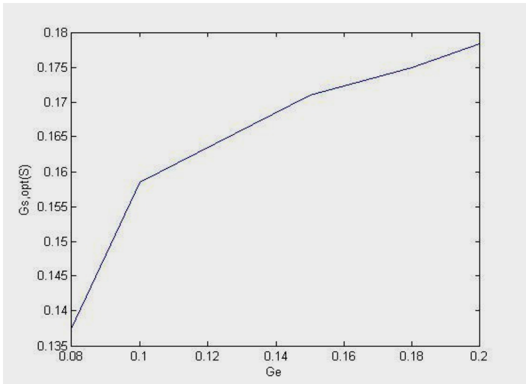
(c)

Figure 5. Noise parameters versus collector current (amp.) for SiGe HBT. (a) NF_{min} vs. collector current plot (b) G_{Sopt} vs collector current plot (c) B_{Sopt} vs collector current

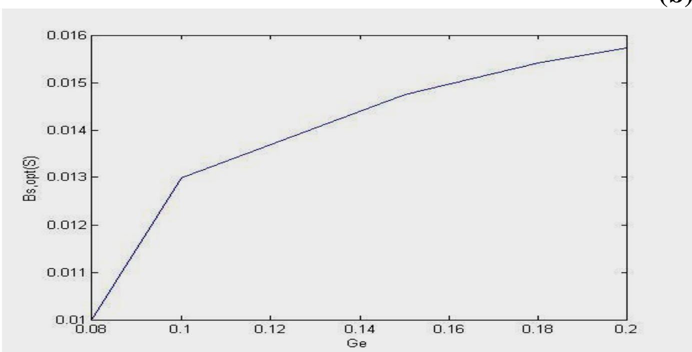
The figure 5 exhibits the variations of above noise parameters as a function of collector current. NF_{min} vs. collector current plot is shown in figure 5(a) and it is concluded that the NF_{min} increases monotonically with collector current of SiGe HBT. While the admittance parameters $G_{S,opt}$ and absolute value of $B_{S,opt}$ are also increases with the increment in the collector current of device as shown in figure 5 (b) and 5 (c). These plots of noise parameters vs. frequency and noise parameters vs. collector current are figured with the help extracted Y-, Z- parameters from ATLAS [16].



(a)



(b)



(c)

Figure 6. Noise parameters versus Ge concentrations (a) Effect of Ge conc. on NF_{min} (b) Effect of Ge conc. on G_{Sopt} (c) Effect of Ge conc. on B_{Sopt}

The effect of germanium concentration over these noise parameters is also investigated in this work. Some observations can be made on the basis of the figure 6 which reveals the impact of Ge concentration on above noise parameters (R_n, NF_{min}, B_{Sopt}, G_{Sopt}). With this analysis it can be proved the values of noise figure NF_{min} is increased with the increment in Ge concentrations as in figure 6(a). At 0.2 Ge concentration, admirable NF_{min} with fine value of 4.52 dB is achieved. While figure 6(b) and 6(c) display the impact of Ge on optimum source admittance $G_{S,opt}$ and $|B_{S,opt}|$. It is concluded with the help of these two figures that these optimum source admittance parameters are increased with the increment in Ge concentrations. At cut-off frequency the calculated Noise parameters are summarized in the Table-1 for the noise model of high frequency SiGe HBT.

Table-1: Summary of Noise parameters of SiGe HBT at cut-off frequency

Noise Parameters	Value
NF_{min}(dB)	9.82
Rn/50 (Ω)	0.2
$G_{S,opt}$(mS)	0.09
Absolute $B_{S,opt}$(mS)	0.012

Now we will discuss some practical issues of employing this noise model. This model is used for observing the noise behavior of transceiver circuits for mobile wireless communication links because these applications demand highly sensitive circuits and in these applications, the dynamic range and sensitivity of high frequency wireless link depends on HF noise of transistors used in low noise amplifiers [17]. Further, this model can be helpful for estimating the noise performance of millimeter wave- band pass mass market applications, for instance, wireless HDMI and USB, several GHz WLAN and automotive radars [18]. In addition, this proposed model can be useful for approximating the noise characterization that cover the realm of 160 Gb/s fiber optic transmission and MMW imaging [19]. Overall, these noise parameters are extremely valuable for designing the low-signal RF amplifier which results in the high power gain and stable function of the amplifier as well as low noise level in wide frequency range.

V. CONCLUSION

In this work, physics based model and its impact on circuit for low-frequency noise in SiGe HBT has been discussed. In this paper a comprehensive analysis has been done and noise parameters based on equivalent noise model are extracted. It is concluded on the basis of above noise analysis that $NF_{\min}$ increases with frequency. An excellent value of simulated $NF_{\min}$ i.e. 2.70 dB at 65 GHz is achieved. While the Noise Resistance R_n is weakly depend on frequency. On the other hand, G_{Sopt} and $|B_{Sopt}|$ increase with frequency and collector current. A novel analysis is also presented which states that the noise figure NF_{min} as well as the optimum source admittance i.e. G_{Sopt} and $|B_{Sopt}|$ of SiGe HBT increases with the Ge contents. At 0.2 Ge concentration, admirable NF_{min} with fine value of 4.52 dB is attained. This model is used for building the low-signal high frequency amplifier. Such viable noise model can estimate the noise behavior of several GHz WLAN and automotive radars as well as millimeter wave imaging.

REFERENCES

[1] K. Kumar, and A. Chakravorty, "Physics based modeling of RF noise in SiGe HBTs", IEEE proceedings of International workshop on Electron Devices and Semiconductor Technology IEDST'09', pp. 1-4, 2009.

[2] G. L.Patton, D. L. Harame, M. C. J. Stork, B. S. Meyerson, G. J. Scilla and E. Ganin, "SiGe-base, poly-emitter heterojunction bipolar transistors" VLSI Symposium. Technical Digest. pp. 35–36, 1989.

[3] Han-Yu Chen, Kun-Ming Chen, Guo-Wei Huang and Chun-Yen Chang, "Small-Signal Modeling of SiGe HBTs Using Direct Parameter-Extraction Method", IEEE Transactions on Electron Devices, vol. 53, no. 9, 2006.

[4] Ankit Kashyap and R.K. Chauhan, "Effect of the Ge profile design on the performance of an n-p-n SiGe HBT-based analog circuit", Microelectronics journal, MEJ: 2554, 2008.

[5] Pradeep Kumar and R. K. Chauhan, "Electrical parameter characterization of bandgap engineered Silicon Germainium HBT for HF applications", proceedings of International conference on Emerging trends in signal processing and VLSI design, GNEC Hyderabad, Jun. 11-13, pp. 1157-1163, 2010.

[6] Guofu Niu, "Noise in SiGe HBT RF Technology: Physics, Modeling, and Circuit Implications" Proceedings of IEEE*,* vol. 93, no. 9, 2005.

[7] J. D. Cressler, "SiGe HBT technology: a new contender for Si-based RF and microwave circuit applications", IEEE Trans. Microw. Theory Tech*.*, vol. 46, issue 5, 572, 1998.

[8] Guofu Niu, Zhenrong Jin, John D. Cressler, Rao Rapeta, Alvin J. Joseph, and David Harame, "Transistor Noise in SiGe HBT RF Technology" IEEE Journal of Solid-state circuits, vol. 36, no. 9, 2001.

[9] A. Pacheco-Sanchez, M. Enciso-Aguilar and L. Rodriguez-Mendez, "Full comparison between analytical results, electrical modeling and measurements for the noise behavior of a SiGe HBT", IEEE proceedings of ANDESCON-2010, pp. 1 – 5, 2010.

[10] F. Jun, "Small-signal model parameter extraction for microwave SiGe HBTs based on Y- and Z-parameter characterization", Journal of Semiconductors, vol. 30, no. 8, pp.1-4, 2009.

[11] N. Zerounian, E. Ramrez-Garca, F. Aniel, P. Chevallier, B. Geynet and A. Chantre, "SiGe HBT featuring f_T 600 GHz at cryogenic temperature", International SiGe & Ge: materials, processing, and device symposium of the joint international meeting of the 214th meeting of ECS, 2008.

[12] Jarle Andre Johansen, "Low-frequency Noise Characterization of Silicon-Germanium Resistors and Devices", thesis University of Tromsø, NO-9037 Tromsø, Norway.

[13] Kenneth H. K. Yau, and Sorin P. Voinigescu, "Modeling and extraction of SiGe HBT noise parameters from measured Y-parameters and accounting for noise correlation", SiRF, p.p.226-229, 2006.

[14] Neelanjan Sarmah, Klaus Schmalz and Christoph Scheytt, "Validation of a theoretical model for NF_{min} estimation of SiGe HBTs", German Microwave Conference, pp. 265-267, 2010.

[15] Pradeep Kumar and R. K. Chauhan, "Device Parameter Optimization of Silicon Germanium HBT for THz Applications", International Journal on Electrical Engineering and Informatics*,* vol. 2, no. 4, pp.343-355, 2010.

[16] ATLAS User's Manual Device Simulation Software, SILVACO International, 2004.

[17] M. S. Selim, "Accurate high-frequency noise modeling in SiGe HBTs ", Design Tools/Sftware, pp.24-32, 2006.

[18] Y. Tagro, D. Gloria, S. Boret, S. Lepillet and G. Dambrine, "SiGe HBT Noise Parameters Extraction using In-Situ Silicon Integrated Tuner in MMW Range 60 - 110GHz", IEEE BCTM 6.1, pp. 83-86, 2008.

[19] P. Sakalas, J. Herricht, M. Ramonas$, and M. Schroter, "Noise modeling of advanced technology high speed SiGe HBTs", IEEE proceedings, pp. 169-172, 2010.

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