Chapter 1

Introduction

1.1 What is Chaos ?

In our day to day life we encounter the term "Nonlinearity" in many ways. The electronic devices, circuits and systems are not an exception. Nonlinearity in the electronic devices is giving many surprising and fabulous results to the researchers from the past two decades.

Chaos is a nonlinear signal which made us to look back and change our perception. Many simulations and experiments have been done by many researchers to discover the way to generate chaos. Most of them are successful in generating chaos over Giga Hertz frequency band by using certain experimental set up of the circuits.

Chaotic signal are characterized well by using certain properties such as Lyapunov exponent (LLE), Kolmogorov Entropy (K2) and Fractal dimension (D2). Lyapunov exponents tell us the rate of divergence of nearby trajectories which is a key component of Chaotic dynamics. The Kolmogorov complexity of an object, such as a piece of text, is a measure of the computability resources needed to specify the object. Fractal dimension is a ratio providing a statistical index of complexity comparing how detail in a pattern changes with the scale at which it is measured.

In our experiment we have generated a Chaotic signal in microwave frequency band by using single microwave transistor namely BFU725F/N1 with essential experimental set up in order to excite with microwave source. BFU725F/N1 is a NPN silicon germanium microwave transistor which has a noise figure of 0.7dB at 5.8 GHz. It has a maximum stable gain of 27dB at 1.8 GHz. By exciting with microwave source and operating the transistor in its nonlinear region giving rise to the generation of chaos in microwave frequency band.

1.2 Application of Chaos

A promising application of Chaos is mainly as a provider for carrier signals in secure communications. The main reason to do so is its extreme sensitivity. The importance of chaos in secure communications has been explained by Chua and other people in the past and they have been successful in implementing it.

1.3 Objectives of this Work

The specific objectives of this work can be summarized as:

- To generate a chaotic signal using simple microwave circuitry.
- To ensure the circuit simplicity, reliability and tunability.

1.4 Thesis Outline

- Introducing the basic principles of chaos and relevant analysis tools and techniques namely iterative map, cobweb plot, Largest Lyapunov Exponent(LLE), Fractal Dimension (D2), Kolmogorov entropy (K2), Phase Portrait and Distance Plot which are used as standard parameters for characterization.
- An iterative map representing chaos with a signal dependence is formulated.
- This iterative map is characterized using cobweb plots for different **'r'** values.
- A hardware based implementation of Chaos generation is performed and standard characterization is done.
- In order to evaluate the tunability of the proposed chaos, waveforms for different **'r'** values are obtained and evaluated.
- The variation of the **'r'** values gives rise to an interesting phenomenon called **"Chirping"** which is studied using Microwind in 180nm CMOS technology.

Chapter 4

Chirping

Chaos Performance of a single Transistor

4.1 Methodology

The experimental results obtained in hardware have motivated us to try out different values of control parameter ‘r’.This is done using Microwind simulation software for our convenience.

The layout of the MOSFET in 180nm CMOS technology is as shown in Fig 4.1.

The output is taken from the collector terminal using the oscilloscope ‘s1’.‘sinus1’ and ‘sinus2’ are the input signal which vary the control parameter ‘r’.

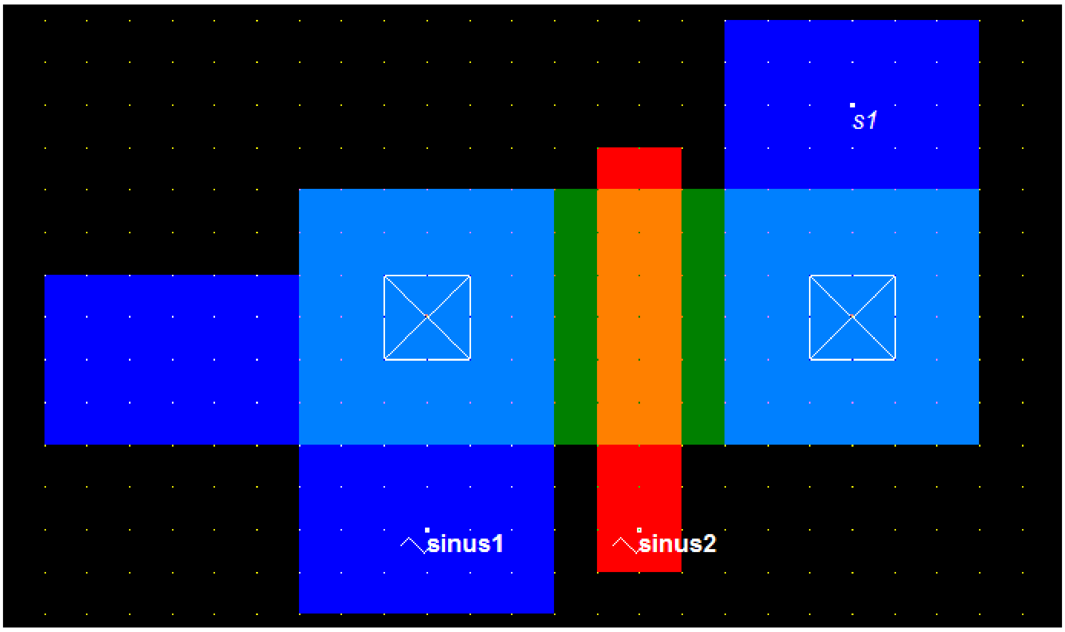

Figure 4.1: Layout of Chaos Generating Single Transistor

For different values of 'r' we get varying LLE,K2,D2.The results are tabulated as follows.

Table 4.1: Characterization of Chaotic Nature of Output for different 'r'

Control Parameter	LLE	K2 (Nats/s)	D2
1.1	9.16	8.9815	0.661
1.2	10.405	8.9813	0.661
1.3	9.84	8.9946	0.661
1.4	9.43	8.9547	0.661
1.5	9.12	8.8827	0.661
1.6	9.2	9.0087	0.661
1.7	10.35	9.0077	0.661
1.8	9.87	8.9685	0.661
1.9	9.03	9.0123	0.661

The next stage of this process is to couple two transistors and try to observe their results. The coupling done for our case is "Cascading" for its simplicity.It is as shown in Fig 4.2.

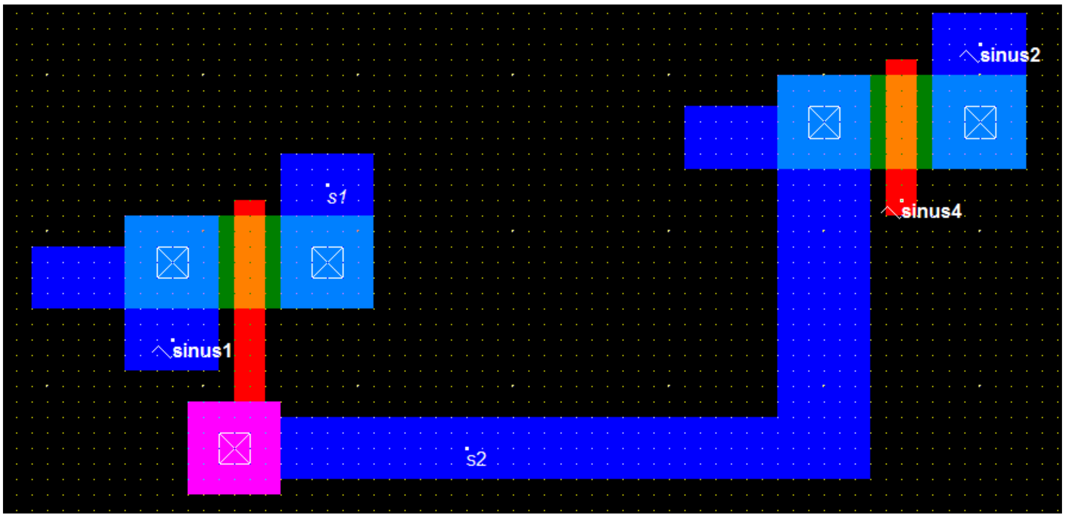

Figure 4.2: Layout of Transistors in Cascade

The inputs are sinusoidal signals of which 'sinus1' is in Microwave frequency. The 'sinus4' and 'sinus2' are used to drive the first transistor which in turn drives the second transistor in cascade.

This gave rise to an interesting phenomena called **"Chirping"**. Chirping means consistent variation of frequency of signals in a given time period.

The waveform obtained at the the value of 1.9503 which is shown in Fig 4.3 which clearly shows the chirping phenomenon.

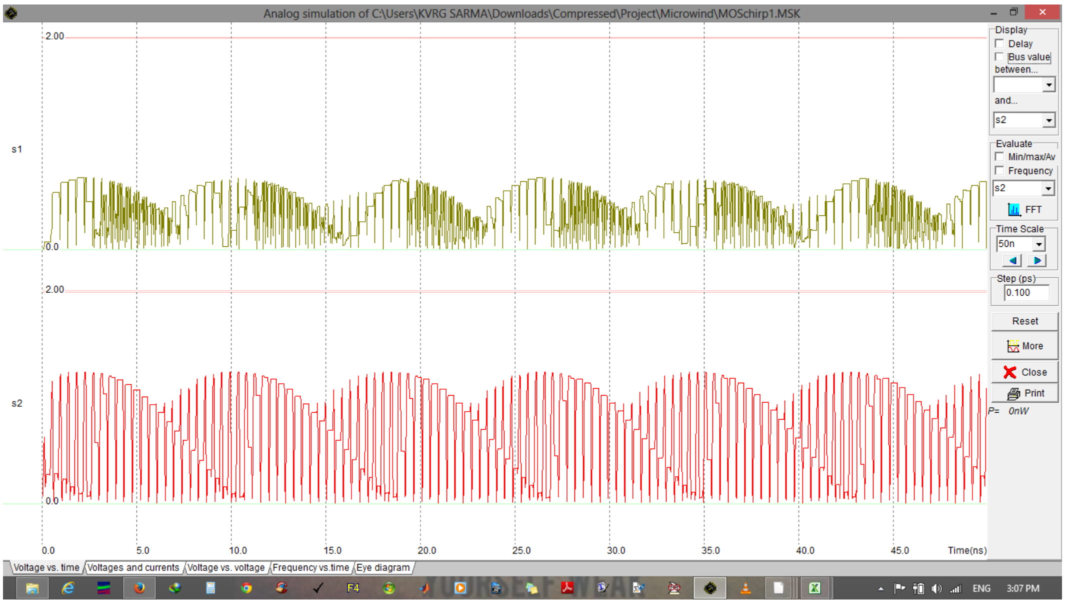

Figure 4.3: Obtained chirp waveform showing variation in Frequency

The obtained waveform is characterized using Polar plot, Phase Portrait, Distance plot and FFT spectrum.

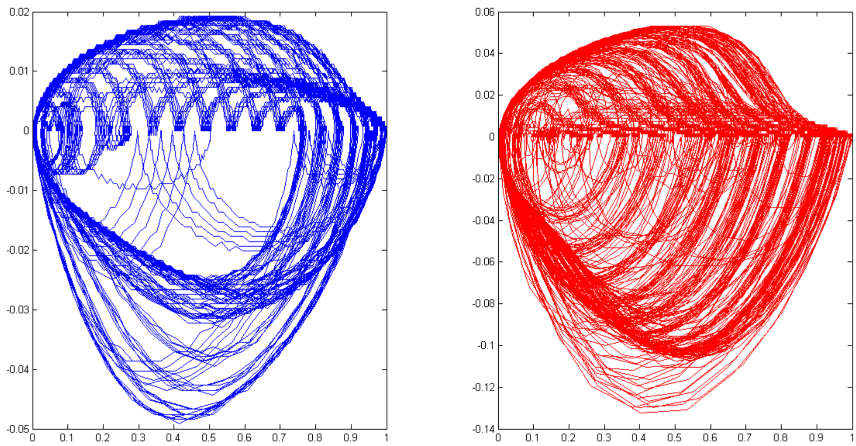

Figure 4.4: Phase portraits Blue - s2 Red - s1

4.2 Inferences

Inferences from the figures are as follows.

- In polar plot, bright and dark pulses are clustered after chirping.

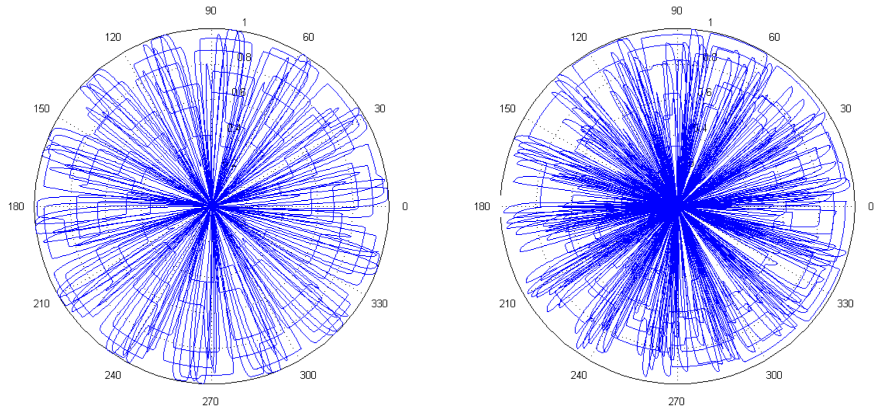

Figure 4.5: Polar Plots Left - s2 Right - s1

- In distance plot, two red blobs have converted into four blobs because of addition of new axis which is the off-diagonal.
- In FFT spectra sidebands have split after chirping.

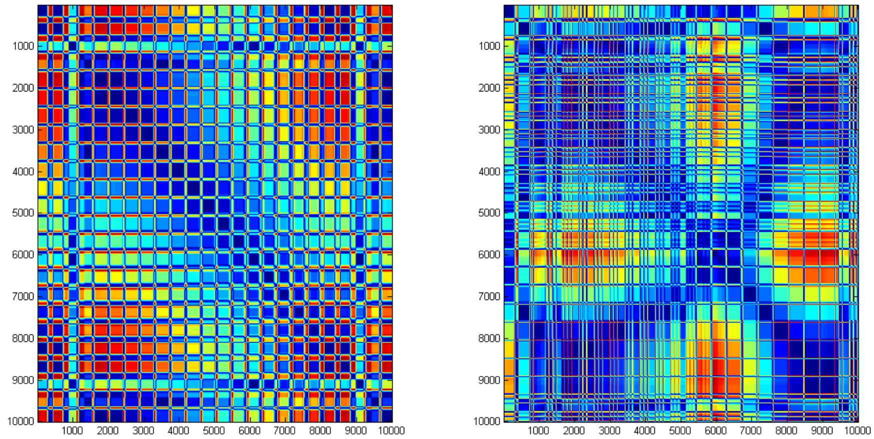

Figure 4.6: Distance plots Left - s2 Right - s1

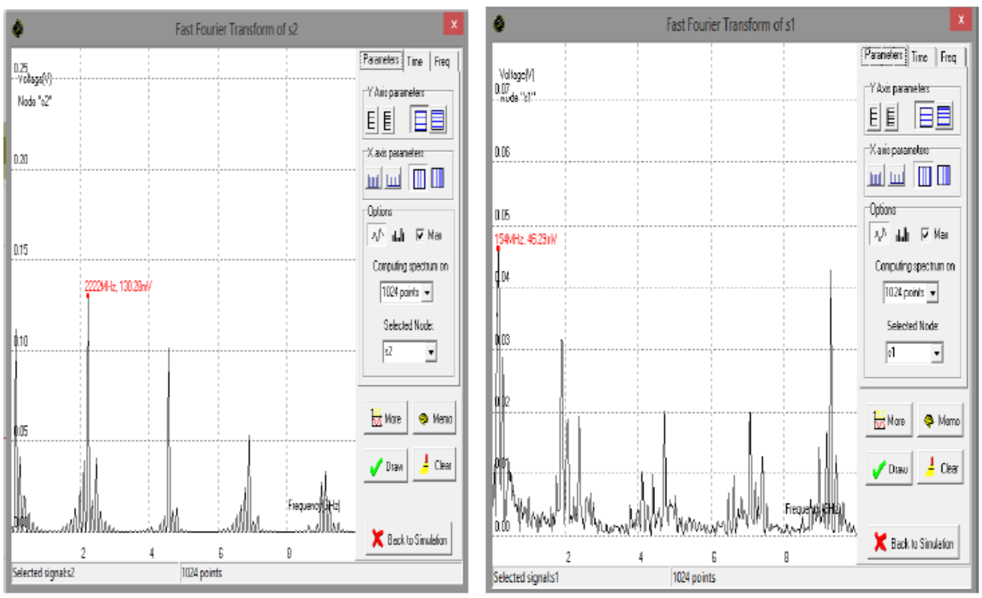

Figure 4.7: FFT spectra Left - s2 Right - s1

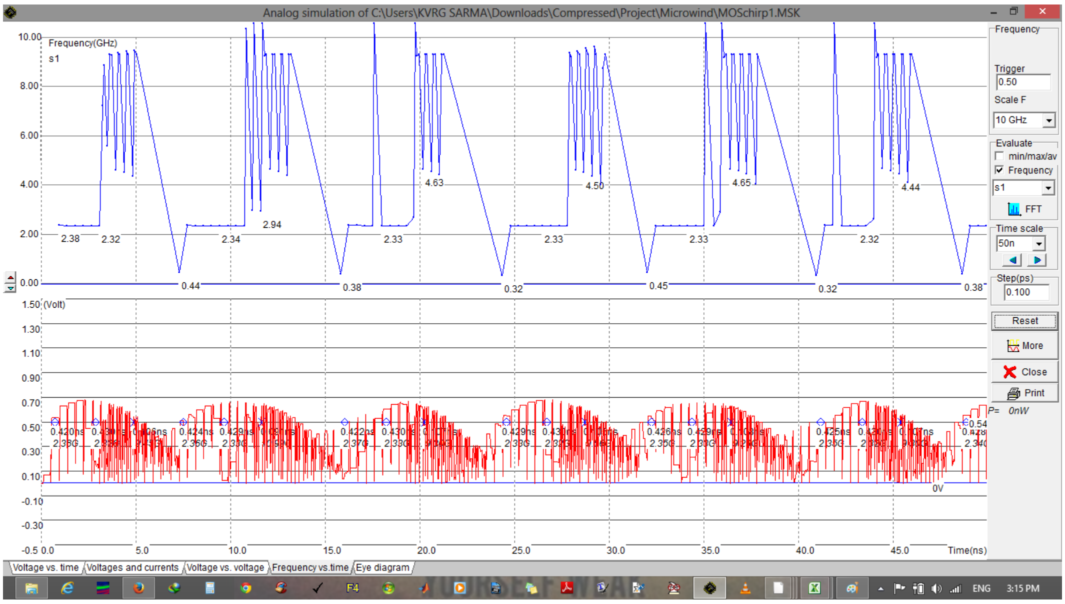

Figure 4.8: Frequency vs Time Diagram of Chirped waveform

Chapter 5

Conclusion

The following section reiterates the key thoughts and results derived from the work explained in earlier chapters.

5.1 Inferences

- Two fundamental concepts of Chaos - Nonlinearity and Sensitivity are elaborated.
- The proposed chaos has been illustrated as an iterative map.
- The three key parameters of the iterative map namely "y", "r", "K" are studied.
- Standard parameters for characterization of a system's chaotic behavior are introduced and studied.
- An implementation of the methodology to generate chaos using simple microwave circuitry is done using a single transistor.
- Microwave characteristic is retained in implementation by identifying the Negative Resistance Region in which the Bias current decreases when Bias Voltage increases.
- The system is made to operate in this Negative Resistance Region for generating chaos in X-Band.
- The tunability and sensitivity are tested by using the variation of the bias voltage of the Gunn source.
- The simplicicty is retained by the use a single transistor in the system and observing its natural reponse to the given inputs.

- The waveforms are analyzed using MATLAB tool for calculation of LLE, K2 and D2 for characterization of observed chaotic behavior of the system.
- The system is developed for CMOS technology in software simulation and results were compared.
- An exciting phenomenon called **"Chirping"** is observed, which is well characterized and the results are documented.

5.2 Future Work and Use

This work helps to promote more cutting edge technology which helps us to explore an unknown territory which shows what can be achieved using simple circuits which give results that are previously thought to be possible only with complex systemms. This also reduces lot of problems genrated by complex systems such as self heating, system degradation and high cost.

Another important avenue that is opened up by this work is the **Chirping** phenomenon which was previously possible by highly expensive and sophisticated systems like "Chaotic Lasers" etc. There is a possibility that if this work is pursued further many more exciting possibilities open up in the areas such as **Secure Communication** as a provider for "Signal Carriers" and "Chirplets" which are being used in **Signal Processing and Analysis**.

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