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Analysis of Various Methodologies for Generation of Microwave Chaos Spectrum and improved microwave colpitts oscillator

Babita Saxena, Alok Dubey and Sandeep Shrivastava
Department of Electronics and Communication Engineering,
SIRT, Bhopal, (MP)

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ABSTRACT: This paper describes various methods of generation of microwave chaos signal spectrum origin from certain continuous dynamical systems – that may exhibit dynamics of signals that are highly sensitive to initial conditions. Many side lobes in chaos signal spectrum which makes the unambiguous detection difficult because of the spectrum of the chaotic signal is not very fat and smooth, with pulsation peaks in it, has been reduced and hence spectrum is improved in some extent using optimum algorithm for parameter selection of microwave colpitts oscillator, and adjusting them for getting more flat spectrum. This happens even though these systems are deterministic, meaning that their future dynamics are fully defined by their initial conditions, with no random elements involved. This paper also describe whole scenario of chaotic signals and system generates these signals.

Keywords: Attractor, Bifurcation, Chaos signal, Dynamic Systems, Nonlinearity, Sensitivity, Strange Attractors, Chua's circuit, colpitts oscillator

I. INTRODUCTION

Although there may be some variance, as to the correct definition of chaos, it is generally characterized as a nonlinear, deterministic phenomenon. For a class of common chaotic systems, this paper introduces equivalent analysis of various systems generating chaos . Such models have many advantages as they are much better matched to traditional signal and system theory.

Chaos signals are aperiodic oscillations - that do not repeat values after some period it is known as chaotic oscillations or chaos.

It is a kind of phenomena in deterministic nonlinear continuous dynamical system, which is periodic and sensitively depends on its initial value.

Chaos signal theory attempts to explain the fact that complex and unpredictable results can and will occur in systems that are sensitive to their initial conditions. A common example of this is known as the Butterfly Effect. It states that, in theory, the flutter of a butterfly's wings in any one country could, in fact, actually effect weather patterns in another City, thousands of miles away. In other words, it is possible that a very small occurrence can produce unpredictable and sometimes drastic results by triggering a series of increasingly significant events. In tests, the chaotic signal produced better results than the other approaches. "Chaos theory, is also known as sensitive dependence on initial conditions. Just a small change in the initial conditions can drastically change the long-term behavior of a system. Such a small amount of difference in a measurement might be considered experimental noise, background noise, or an inaccuracy of the equipment. Such things are impossible to avoid in even the most isolated lab. With a starting number of 2, the final result can be entirely different from the same system with a starting value of 2.000001. It is simply impossible to achieve this level of accuracy - From this idea, Lorenz stated that it is impossible to predict the weather accurately. However, this discovery led Lorenz on to other aspects of what eventually came to be known as chaos theory.

II. HISTORY

Edward Lorenz, a meteorologist who first discovered evidence supporting chaos signal theory in 1960.Lorenz's work cultivated with the publishing of the now-famous image, the Lorenz Attractor.

Despite an appearance of randomness, chaotic dynamics are in fact deterministic. The appearance of randomness is caused by a high dependence on initial conditions exhibited in chaotic regimes. The visual appearance of these dynamics, when plotted against the oscillating input voltage, is of a system whose state "hovers" around a limit-cycle, but whose state never quite passes through the same trajectory twice.

Consequently, plots of chaotic dynamics generally display a thick band of activity indicating the multiple trajectories through phase space, rather than a thin line that would suggest a single stable trajectory. The key features are Self-similarity and No characteristic length-scale.

III. APPLICATION AREAS

Examples of these complex systems that Chaos Theory helped fathom are earth's weather system, the behavior of water boiling on a stove, migratory patterns of birds, or the spread of vegetation across a continent. Chaos is everywhere, from nature's most intimate considerations to art of any kind.
RADAR for improving rang ambuiguity amd in SAR. A NEW type of radar which harnesses chaos theory can see clearly through walls and could help find survivors in disasters. The technology could also make on-board radar a practical proposition for cars.
Secure Communication.its wide band property is used and unique synchronization property is very usefull in that area.
Bio-Medical field , its propery of unique independence on initial condition is used for early detection of cancer and tumer in human body . It has even been speculated that the brain itself might be organized somehow according to the laws of chaos. Chaos even has applications outside of science. Computer art has become more realistic through the use of chaos signals and fractals. Now, with a simple formula, a computer can create a beautiful, and realistic tree. Instead of following a regular pattern, the bark of a tree can be created according to a formula that almost, but not quite, repeats itself. Music can be created using fractals as well believe that the variations are very musical and creative.

IV. ORIGIN

Dynamical systems theory deals with the long-term qualitative behavior of continuous dynamical systems, and the studies of the solutions to the equations of continuous dynamical systems that are partial differential equations Here, the focus is not on finding precise solutions to the equations defining the dynamical system (which is often hopeless), but rather to answer questions like "Will the system settle down to a steady state in the long term, and if so, what are the possible steady states?", or "Does the long-term behavior of the system depend on its initial condition?".
An important goal is to describe the fixed points, or steady states of a given dynamical system; these are values of the variable which won't change over time. Some of these fixed points are *attractive*, meaning that if the system starts out in a nearby state, it will converge towards the fixed point.
Similarly, one is interested in *periodic points*, states of the system which repeat themselves after several time steps.

V. AN APPROACH TO CHAOS

1. Derive a state sate equation for a system: At any given time a dynamical system has a *state* given by a set of real numbers (a vector) that can be represented by a point in an appropriate *state space* (a geometrical manifold). Small changes in the state of the system create small changes in the numbers. The *evolution rule* of the dynamical system is a fixed rule that describes what future states follow from the current state. The rule is deterministic; in other words, for a given time interval only one future state follows from the current state

To determine the state for all future times requires iterating the relation many times—each advancing time a small step. The iteration procedure is referred to as *solving the system* or *integrating the system*. Once the system can be solved, given an initial point it is possible to determine all its future positions, a collection of points known as a *trajectory* or *orbit*.”.
The behavior of trajectories as a function of a parameter may be what is needed for an application. As a parameter is varied, the dynamical systems may have bifurcation points where the qualitative behavior of the dynamical system changes.

2. Bifurcation point: Bifurcation theory is the mathematical study of changes in the qualitative or topological structure of a given family, the solutions of a family of differential equations. a bifurcation occurs when a small smooth change made to the parameter values (the bifurcation parameters) of a system causes a sudden 'qualitative' or topological change in its behavior.[1] Bifurcations occur in both continuous systems (described by ODEs, DDEs or PDEs), and discrete systems (described by maps).

It is useful to divide bifurcations into two principal classes:

- Local bifurcations, which can be analyzed entirely through changes in the local stability properties of equilibrium, periodic orbits or other invariant sets as parameters cross through critical thresholds; and
- Global bifurcations, which often occur when larger invariant sets of the system 'collide' with each other, or with equilibrium of the system. They cannot be detected purely by a stability analysis of the equilibrium (fixed points).

A local bifurcation occurs when a parameter change causes the stability of an equilibrium (or fixed point) to change. In continuous systems, this corresponds to the real part of an Eigen value of an equilibrium passing through zero. The equilibrium is *non-hyperbolic* at the bifurcation point. The topological changes in the phase portrait of the system can be confined to arbitrarily small neighborhoods of the bifurcating fixed points by moving the bifurcation parameter close to the bifurcation point (hence 'local').

Global bifurcations occur when 'larger' invariant sets, such as periodic orbits, collide with equilibrium. This causes changes in the topology of the trajectories in the phase space which cannot be confined to a small neighborhood, as is the case with local bifurcations. In fact, the changes in topology extend out to an arbitrarily large distance (hence 'global'). Global bifurcations can also involve more complicated sets such as chaotic attractors (e.g. crises).

3 Attractor: Complex systems often seem to run through some kind of cycle, even though situations are rarely exactly duplicated and repeated. Plotting many systems in simple graphs revealed that often there seems to be some kind of situation that the system tries to achieve, an equilibrium of some sort. That equilibrium is called an attractor. A dynamic kind-of-equilibrium is called a Strange Attractor. The difference between an Attractor and a Strange Attractor is that an Attractor represents a state to which a system finally settles, while a Strange Attractor represents some kind of trajectory upon which a system runs from situation to situation without ever settling down

4. Fractals: A fractal is a geometric shape that is similar to itself at different scales. More clearly, a fractal shape will look almost, or even exactly, the same no matter what size it is viewed at. Fractal objects have several interesting properties. One of the most interesting is self-similarity. The Sierpenski triangle is a good example of this. Sierpenski's is composed of four smaller triangles, each of which are composed of four even smaller triangles, and so on. A fractal t object such as this exhibit self-similarity over many scales of observation. Another property of a fractal object is a lack of well defined scale., and the bronchial tree all show some type of organization the eigen values of a matrix determine the structure of the phase space. From the eigen values and the eigenvectors of *a matrix* it is possible to determine if an initial point will converge or diverge to the equilibrium point at the origin. The distance between two different initial conditions in the case matrix $\neq 0$ will change exponentially in most cases, either converging exponentially fast towards a point, or diverging exponentially fast. Linear systems display sensitive dependence on initial conditions in the case of divergence. For nonlinear systems this is one of the (necessary but not sufficient) conditions for chaotic behavior.

An example:-

A model of three ordinary differential equations proposed by Lorenz now known as the Lorenz equations:

$$\frac{dx}{dt} = \sigma(y - x)$$
$$\frac{dy}{dt} = x(\rho - z) - y$$
$$\frac{dz}{dt} = xy - \beta z$$

Here x, y, and $z$make up the system state, t is time, and σ, ρ, β are the system parameters. The Lorenz equations also arise in simplified models for lasers (Haken 1975) and dynamos (Knobloch 1981).

A trajectory of Lorenz's equations, rendered as a metal wire to show direction and 3D structure.

From a technical standpoint, the Lorenz system is nonlinear, three-dimensional and deterministic

For small values of ρ, the system is stable and evolves to one of two fixed point attractors. When ρ is larger than 24.28, the fixed points become repulses and the trajectory is repelled by them in a very complex way, evolving without ever crossing itself.

VI. VARIOUS METHODS

Chaotic dynamics in electronic systems have been a subject of interest since Linsay's seminal paper in 1981 that demonstrated a simple RLD circuit was capable of producing them . There are many types of chaotic oscillators such as Chua's circuit, Colpitts oscillator [5] and Duffing oscillator [6].

Chaotic carrier generator operating in RF/microwave band and modulate the information directly onto the carrier, resulting in a direct chaotic communication (DCC) system. The heart of the DCC approach is to design a chaotic carrier generator with a sufficiently high fundamental frequency. There are many types of chaotic oscillators such as Chua's circuit, Colpitts oscillator [5] and Duffing oscillator [6]. Chua’s circuit [2] is probably the most well-known and commonly used chaotic oscillator in this field. many generalizations of Chua’s circuit, as complicated attractors have been proposed by Suykens & Vandewalle [3] by introducing additional breakpoints in the nonlinearity of Chua’s circuit, leading to so-called-double n-scroll attractors. The Colpitts oscillator has becomes a hot topic in recent years. Unlike the famous Chua's circuit [7], whose bandwidth was greatly limited by the nonlinear negative resistance commonly built with operational amplifiers [8], The upper limit fundamental frequency of a Colpitts circuit is generally determined by the threshold frequencies of the bipolar junction transistors (BJTs) employed in the circuit [9].

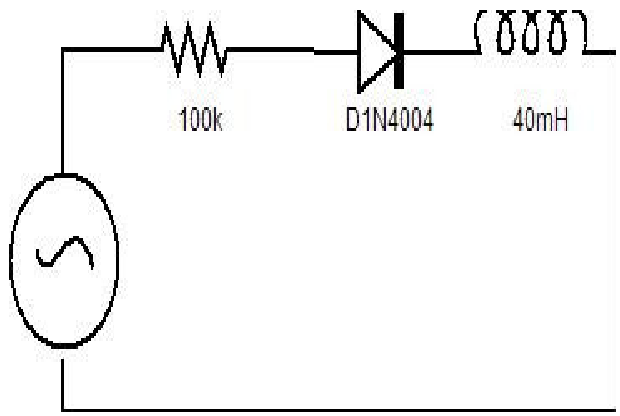

Fig. 1. Simple non linear RLC circuit.

Because microwave BJTs are easily available and the threshold frequencies can be very high, Colpitts oscillator is therefore more suitable for the design and implementation of microwave chaotic carrier generator [10]. In 1995 chaotic oscillation was reported experimentally in the high frequency (HF) range at a fundamental frequency of 25 MHz using a general purpose type BJT 2N2222A with a threshold frequency of 300 MHz [13]. In 2001, chaos was predicted by PSpice simulation in the Colpitts oscillator at fundamental frequency of 950 MHz, employing the simulation parameters of Philips' broadband type BJT BFG520 with a threshold frequency of 9 GHz [12]. In the latest report in year 2004, G. Mykolaitis et al. [13] verified the simulation results in [14], where the highest fundamental frequency is about 1 GHz.

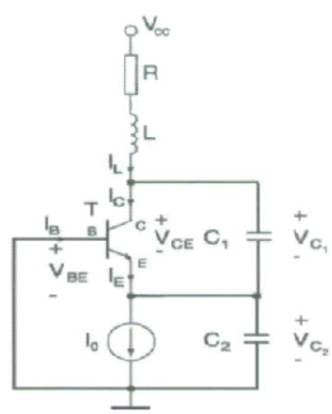

Fig. 2. Schematic of the Colpitts oscillator.

VII. PROPOSED WORK

The highest fundamental frequency of the chaotic oscillator using BFG425W reaches 1.6 GHz. Based on the experimental work, we package the oscillator into a simple module, which could be used directly as a "plug and play" device on a motherboard, for convenient uses in applications. chaotic circuits with fundamental frequency more than 1 GHz were implemented [14–15], where the Colpitts oscillator is the major candidate due to its simple circuit structure. The transistor is modelled with a voltage-controlled nonlinear resistor *RE* and a linear current-controlled current source, neglecting the base current. The driving-point characteristics of the nonlinear resistor *RE* can be expressed as:

$$I_E = f(V_{BE}) = I_s\left(\exp\left(\frac{V_{BE}}{V_T} - 1\right)\right)$$

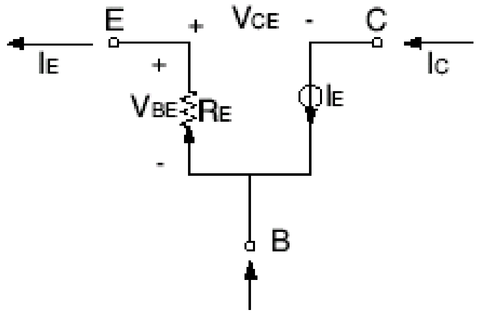

Fig. 2(a). Equivalent circuit model of fig 2.

where *Is* is the inverse saturation current and *VT* _ 26mV at room temperature. The state equations for the Colpitts oscillator shown in Fig. are:

$$C_1 \frac{dV_{C_1}}{dt} = -f(-V_{C_2}) + I_L$$
$$C_2 \frac{dV_{C_2}}{dt} = I_L - \frac{V_{C_1} + Vee}{Re}$$

$$L \frac{dI_L}{dt} = -V_{C_1} - V_{C_2} - I_L R + V_{CC}$$

The inductance *L*, the capacitance *C*1, *C*2, the voltage source *V cc* and *V ee*, are critical because they determine whether the chaotic oscillation can be achieved and the fundamental frequency of the oscillation. These parameters can be selected using geneting alorithms for optimum parameters selection which give fundamental frequency about 2 Ghz. In our simulations, the circuit parameters are listed as follows: *V cc* = 12 V, *V ee* = -12V, *R* = 23 Ohm, *Re* = 1.*2* kOhm, *L* = 5.5 nH, *C*1 = 8 pF, *C*2 = 8 pF. Simulations of circuit by using MATLAB are plotted.

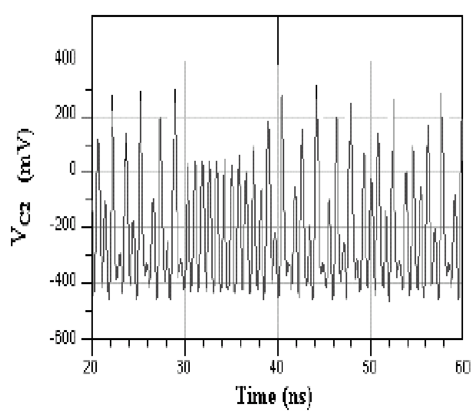

Fig. 3. (a)

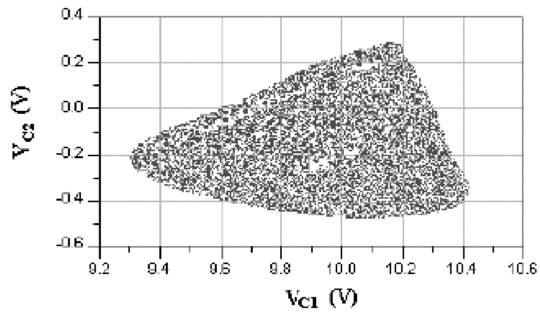

Fig. 3. (b)

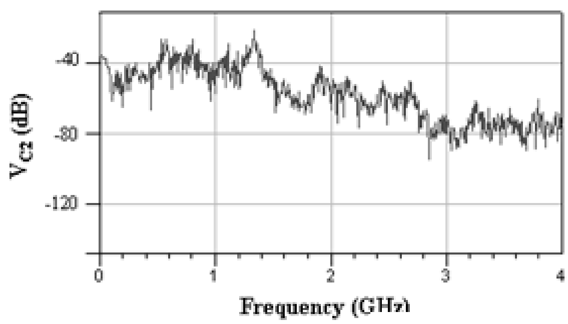

Fig. 3. (c)

Fig. 3(a) shows the time-domain waveform of one of the voltage node *VC*2 , which is a noise-like signal. Fig. 3(b) plots the projection of the attractor in the phase space into the *VC*2 -*VC*1 plane. This is a typical chaotic attractor of Colpitts oscillator. Fig. 3(c) shows the broadband continuous spectrum of the signal *VC*2. Now we adjust the circuit parameters of the microwave Colpitts oscillator. In the different parts of the bifurcation diagram, using genetic algorithm of optimum selection of parameters, the dynamic characteristics are deferent, especially when they belong to difrent types of chaos region, namely the Feigenbaum chaos or the Shilnikov chaos region [11]. Finding operating condition with more abound dynamic characteristics can help improve the signal spectrum.

VIII. CONCLUSIONS AND DISCUSSIONS

It can be seen from the waveforms that only very small ripples appear on the surfaces are no discernible peaks. It indicate that the chaotic signals generated by same circuits with parameters selected from genetic algorithm for optimum performance of the circuit in terms of large bandwidth by optimizing SNR and autocorrelation function for given waveform. The waveform has non-repetitive random features. Since they are not repetitive, they scarcely correlated with each other . In previous work [13] signal from the Colpitts oscillator shows many sidelobes which is undesirable for many applications. It is because that the spectrum of the chaotic signals was not very flat and smooth, with pulsation peaks in it. From the time-domain view, the chaotic signals with time distance of $\tau 0$, $2\tau 0$, ..., $n\tau 0$ (n is small) have similarities which result in the side lobes. Using genetic algorithm for parameter selection of Colpitts oscillator introduced in this paper improves the spectrum, The spectrum of chaotic signal from the microwave Colpitts oscillator is optimized, that is, the randomness characteristics of the microwave chaotic signal is improved.

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