International Journal of Multimedia and Ubiquitous Engineering
Vol.10, No.11 (2015), pp.397-406
http://dx.doi.org/10.14257/ijmue.2015.10.11.38

A Frequency-Shift Keying Modulation Technique Using a Fractal Ring-Oscillator

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Abstract

A novel way of achieving the well-known FSK(Frequency-Shift Keying) modulation was introduced and verified. A simple form of CMOS ring-oscillator, that is generating a GHz level of frequency, was used as a base frequency generator. With its fractal structure, a local change in the oscillator will yield a global frequency change, which is to serve for the FSK. A local change is done with different number of inverting amplifiers in the ring oscillator with a multiplexer. Depending on how many cell changes, the frequency shifts are controlled and can be selected. The measured frequency difference between the shifts was from 9.2% up to 22.5%, in GHz range in CMOS SPICE simulations. Layout for CMOS implementation is also included.

Keywords: *Fractal, Multiplexers, CMOS Ring Oscillator, Frequency Shift Keying*

1. Introduction

A novel type of FSK (Frequency-Shift Keying) modulation technique that uses a CMOS oscillator with multiplexers is introduced. The CMOS oscillator in its fractal structure generates and distributes a gigahertz (GHz)-level oscillation signal [1-4]. This fractal oscillator supplies clock signals for today's widely used high-speed digital circuits, and has steady oscillation property with minimum clock skew. The fractal oscillator circuit is much simpler and easier to implement than the well-known Phase Locked Loop circuit [2-6].

The FSK modulation is achieved by multiplexers, by choosing a different path in the CMOS fractal oscillator. One of the two different frequencies, f1 and f2, is selected by the multiplexer switch, that is composed of three two-input NAND gates and one inverter.

Different number of fractal cells was chosen using these multiplexers to yield a global frequency change, yielding a shift of $f1+\Delta f = f2$ for the FSK [3-5 and 7-8].

2. GHz-level Clock Distribution Technique with a CMOS Fractal Oscillator

2.1. CMOS Fractal Oscillator Structure

Figure 1 shows the structure of the fractal Oscillator Network [1 and 10-13].

ISSN: 1975-0080 IJMUE

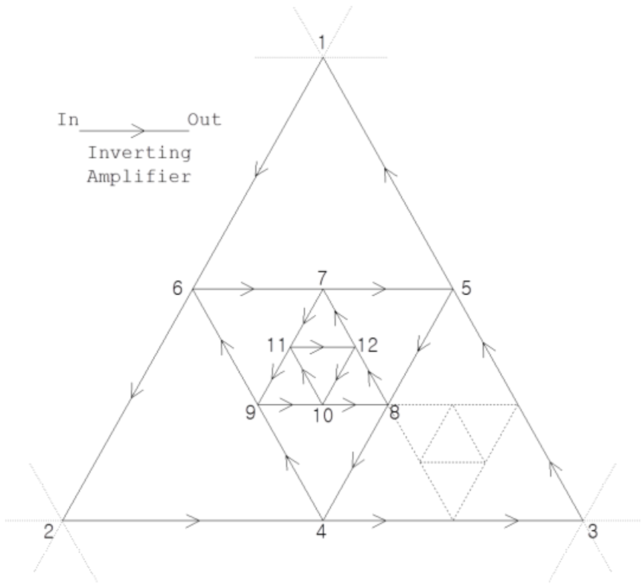

Figure 1. Structure of Fractal Oscillator Network

Figure 1 shows the structure of the CMOS fractal oscillator. 108 inverters are shown. As shown in the figure, each fractal oscillator cell consists of three inverting elements, which configure a ring oscillator. Each inverting element is shared with its three adjacent cells. Thus, this oscillator can spread out infinitely in the fractal mode [14-16]. Each inverting element, which in this paper is a simple CMOS inverter, has a $\frac{2}{3}\pi$ phase difference because three inverters will consume a complete cycle (2π) [1 and 3-5].

A way of implementing the CON is hereby suggested and displayed in Figure 2 using today's multilayer integrated circuit process and package technique. Digital and analog planes are break up for minimum interference between two different planes, and in center the proposed CON can be installed as shown [3-5].

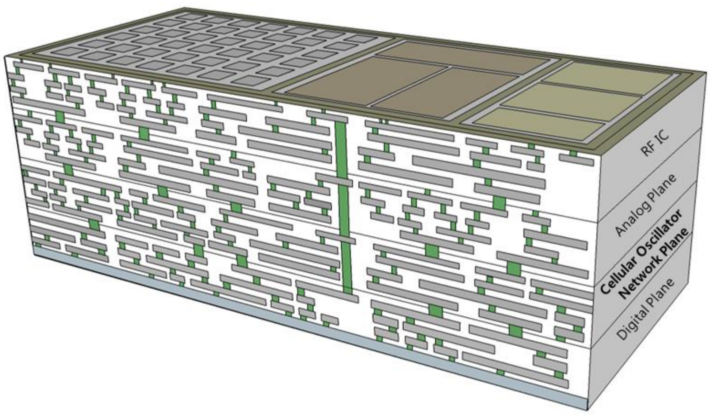

Figure 2. The CON Silicon Implementation in Multilayer CMOS Multi-Chip Module Package Technique

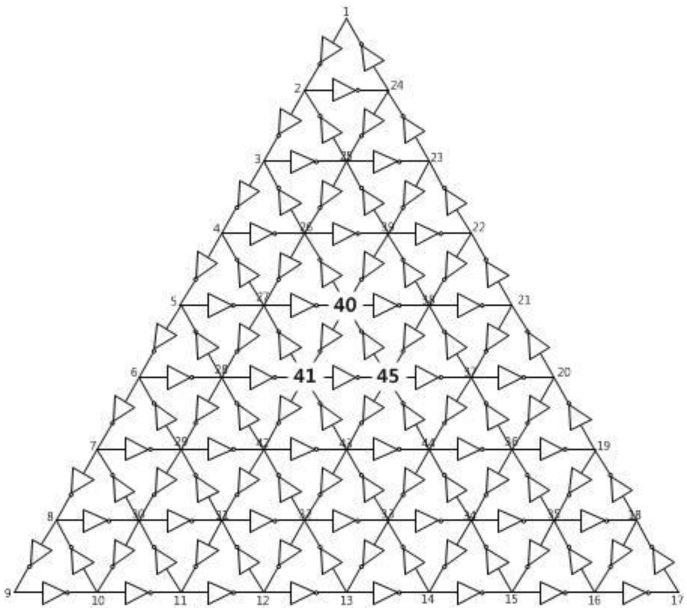

Figure 3. CMOS Fractal Oscillator with 108 Inverters

Figure 3 shows a CMOS fractal oscillator with 108 inverters. Given external power (3V in this study), each fractal cell will oscillate; and due to its structure, each node in Figure 3 will generate the same frequency oscillating signal. Note that even with a local change in a few nodes, the change will be instantly ‘averaged’ through the fractal networks, and the frequency of each node will stay the same, within a minimum clock skew [1 and 3-5].

2.2. Fractal oscillator for FSK(Frequency-Shift Keying) modulation

Figure 4 shows baseband binary signal along with a corresponding the well-known Frequency Shift Keying (FSK) signal. As shown, two binary states are modulated into two different frequencies, f1 and f2.

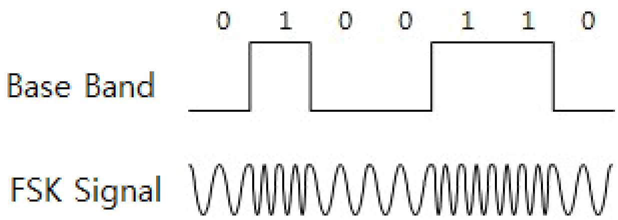

Figure 4. Frequency Shift Keying Modulation Scheme

Figure 5 shows a modified structure of the fractal oscillator for the FSK modulation. As seen, one center cell (nodes 40, 41, and 45) is changed to have nine inverters (three inverters on each side) in the cell, instead of three inverters, for frequency change. Then the frequency in the center cell will generate a different frequency (lower than in the original three-inverter case), and this local change will spread through the entire network and change the global oscillating frequency from f1 to f2. If we have a control for selecting a mode between that in Figure 3, and that in Figure 5, using multiplexers, the FSK modulation could be simply achieved [4 and 6-9].

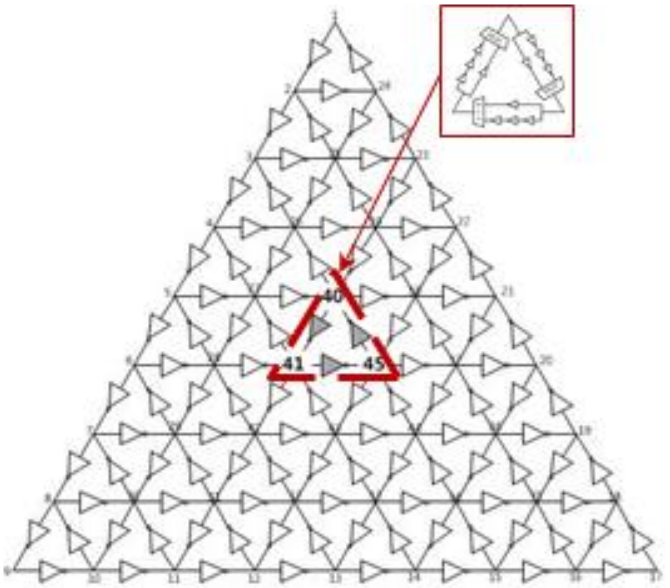

Figure 5. FSK Modulation CMOS Oscillator with a Local Change at the Center Cell

Figure 6 shows a diagram of the FSK modulation scheme with a multiplexer. The SEL control signal selects one of the two different paths with two different frequencies, f1 (upper) and f2 (lower), which will serve as the two FSK modulation signals.

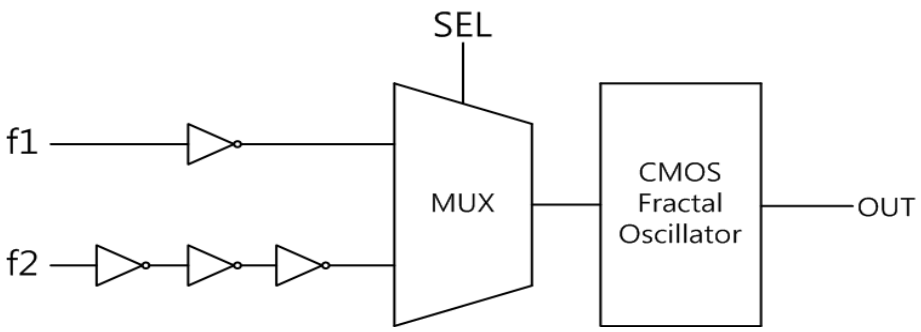

Figure 6. Diagram of the FSK Modulation Scheme with a Multiplexer

Figure 7 shows a logic diagram for a 2-to-1 multiplexer.

Using three NAND gates and one inverter, one of the frequencies will be selected: f1 when SEL = 0, or f2 when SEL = 1.

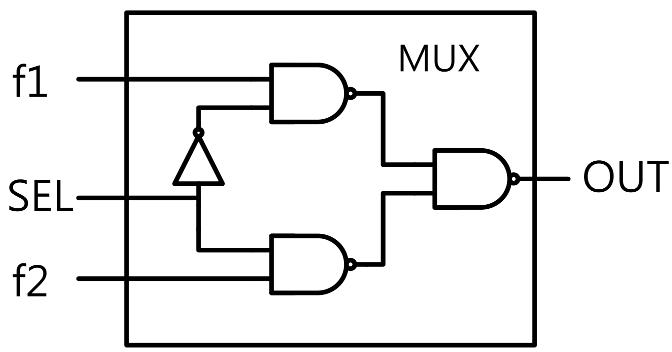

Figure 7. 2-to-1 Multiplexer Logic Diagram

2.3. Fractal Oscillator FSK Modulation with different Number of Cells

Figure 8 shows a diagram for the FSK modulation with different number of cell change; from a one center cell to outer 15 cells change. Here, we stepped these changes in three cases; 1-9-15 cell changes, from the center cell to the outer cells.

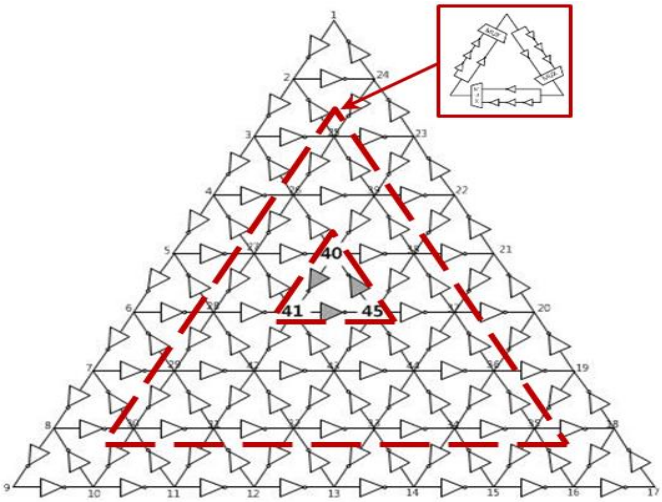

Figure 8. M A Diagram For the FSK Odulation With different Number of Cell Changes

3. SPICE Simulation Results for the FSK Modulation

Combining Figure 7 and 8, SPICE simulations were performed. The results are shown in Figure 9. The FSK frequency change is clearly shown in the bottom graph with the corresponding SEL (FSK0 and FSK1) changes. A power supply of 3 volts, a 0.5um minimum feature size, and N-well CMOS technology process parameters were used for the simulation at room temperature (300 K).

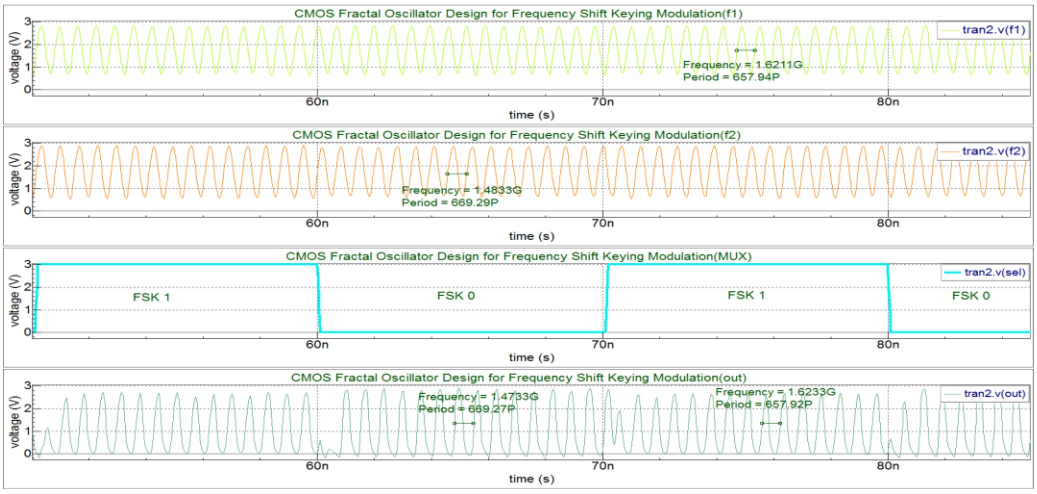

Figure 9. SPICE Simulation Results for the FSK Modulation: (Top to Bottom) f1, f2, SEL, and FSK Modulation

Figure 9 shows a center cell change case. The frequency of the oscillator shown in Figure 3 was measured as 1.6211 GHz (at top), and the modulated case with a center cell change was measured as 1.4733 GHz (at second from top). The frequency gap between two is 137.8MHz, from binary 1 to binary 0. With a given FSK selection (3^{rd} from top), the FSK modulation is achieved as expected (at bottom). Notice here a transient between shifts is due to the multiplexer delay, which seems negligible.

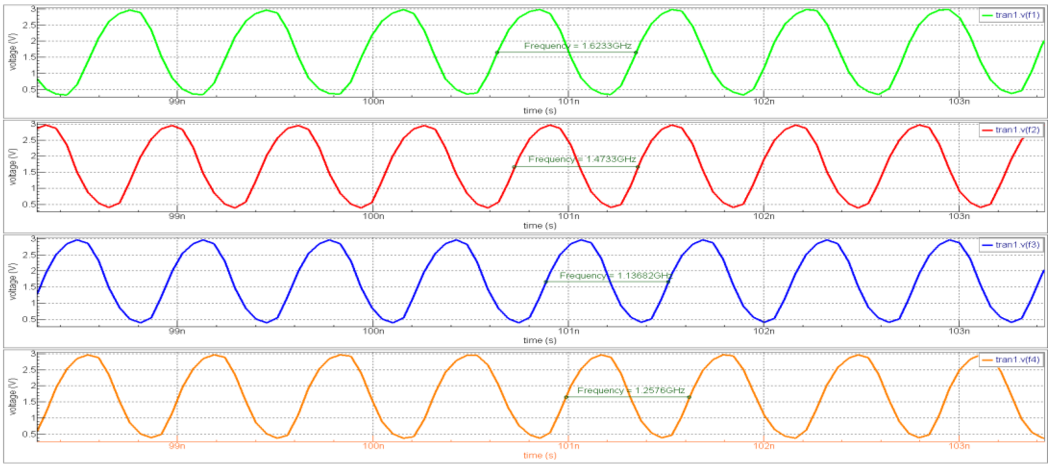

Figure 10. SPICE Simulation Results for the FSK Modulation with different Number of Cells (Top to Bottom); f1, f2 (1-Cell), f3 (9-Cells) and f4 (15-Cells)

Table 1. Frequency Changes for FSK with different Cell Changes in Figure 10

	f1	f2(1-Cell)	f3(9-Cells)	f4(15-Cells)
Frequency	1.6233GHz	1.4733GHz	1.3682GHz	1.2576GHz
Δf		0.15GHz	0.2551GHz	0.3657GHz
%		9.24	15.7	22.5

Figure 10 shows SPICE simulation results for the FSK modulation with different number of cells (top to bottom); f1, f2(1-cell), f3(9-cells) and f4(15-cells). Table 1. summerizes the frequency change results. As seen, with a different number of cell changes (a local change), a different frequency shift was measured from 9.2% to 22.5%, shown in Figure 11.

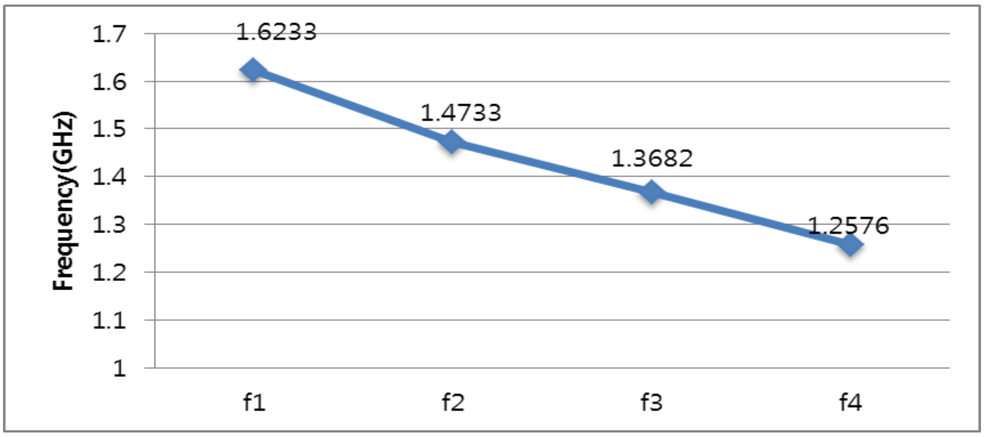

Figure 11. Frequency Shifts in a CMOS Fractal Oscillator with different Cell Changes

Figure 11 shows frequency shifts in a CMOS fractal oscillator with different cell changes. Each frequency change seems approximately 100MHz, and depending on how many cells we select with multiplexers control, we can easily choose the frequency gap between two binary state shifts.

Finally, Figure 12 shows the Layout of a CMOS fractal oscillator.

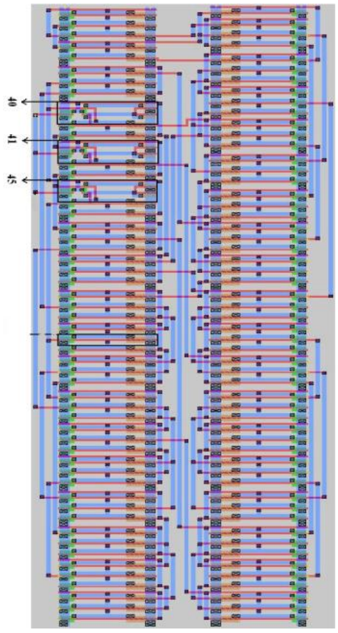

Figure 12. Layout of a CMOS Fractal Oscillator

4. Conclusions and Future Studies

A novel way of achieving FSK modulation was introduced.

Using a CMOS fractal oscillator along with simple 2-to-1 multiplexers to select a different fractal cell, the FSK was realized in the GHz frequency range. Three NAND gates were used for the multiplexer. The measured frequency difference between the shifts was from 9.2% up to 22.5%, which can be controlled either by the number of inverters in one cell or by the number of different fractal cells. This is possible only because a local change in a fractal cell will spread throughout the entire oscillator and yield an instant global change.

A layout is in progress for chip fabrication and actual measurements in the future.

Acknowledgments

This research was supported by Hallym University Research Fund, 2015(HRF-201507-012). This work was also supported by IDEC (EDA Tool) in Korea.

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