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# Performance Analysis of Various Nonlinear Elements in Frequency Multiplying Circuits for Wireless Applications

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**ABSTRACT-** This paper presents the performance comparison of various nonlinear elements in frequency multiplying circuits for low power wireless applications. An analysis and design are derived. Passive frequency multipliers take advantage of the nonlinear behavior of passive circuit components. Passive frequency multipliers take advantage of the nonlinearity of passive circuit components. In this category, Schottky diodes and varactor diodes are used for frequency multiplication. We analyzed passive devices like resistive diodes (Schottky-barrier diodes) and nonlinear capacitors (varactors). The performance between frequency doubling System using Schottky diode and frequency doubling System using varactor diode is compared. Performance was evaluated in terms of output Voltage (mV), output frequency (MHz) and Output power (dBm). Frequency doubling System using Schottky diode is fast switching and more output voltage and power provides to the load side as compare to frequency doubling System using varactor diode. Input power -4.66 dBm given to frequency doubler using Schottky diode as well as varactor diode system. Output power -13.932 dBm for frequency doubling System using Schottky diode and -28.545 dBm for frequency doubling System using varactor diode is observed. We can use passive frequency doubler using Schottky diode for low power sensing application in wireless communication.

**Keywords:** Frequency Doubling Reflectenna (FDR), Frequency Multiplier Circuit (FMC), Frequency Multiplier Refelectenna (FMR).

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## 1. INTRODUCTION

The frequency multiplier technique is an excellent way to identify sensor signals from environment noise without using an RFID chip [4],[5],[13]. A frequency multiplier device has three components: a receiving antenna with resonance frequency *F*, a transmitting antenna with resonance frequency mF, and a frequency multiplication circuit (FMC) [10], [12], [14]. *Figure 1* describes the functioning mechanism of a frequency multiplier reflectenna with interrogator for wireless applications. During operation, the reader emits a wireless interrogation signal using an *F* antenna. *F* antenna will transmit *F* frequency to FMC [18]. The diode's nonlinearity results in a greater output signal at harmonics of the incident frequency. This application measures the incident frequency's second (2F) and third (3F) harmonics [7], [8]. The output signal at mF is backscattered to the reader using a patch antenna with mF resonance frequency [9],[11]. Finally, a reader measures the backscattered signal on the interrogator side. The backscattered sensor signal has a frequency of mF, whereas undesirable ambient reflections on the reader interrogation signal maintain the same frequency. As a result, the reader can distinguish between backscattered sensor signals and undesirable reflections. Frequency multipliers are devices that employ semiconductors' nonlinear characteristics to do frequency multiplication.

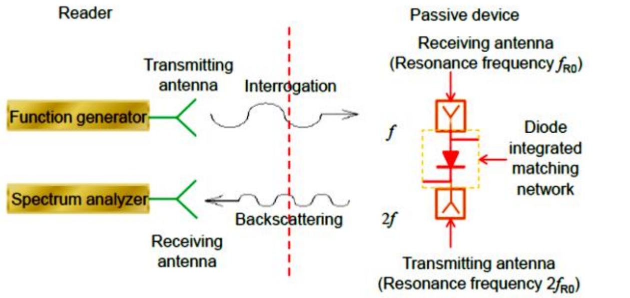


**Figure 1.** Frequency doubling reflectenna with function generator and spectrum analyzer for Wireless application

The purpose of frequency multipliers is to extract the desired harmonic from the fundamental and send it to the output while

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suppressing all other frequencies. The purpose of frequency multipliers is to extract the desired harmonic from the fundamental and send it to the output while suppressing all other frequencies. We can utilize a passive frequency multiplier with a diode for low-power sensing applications in wireless communication [1],[2],[3]. We can also use passive frequency multiplier as sensing device in IOT application [6].

## 2. PROPOSED SYSTEM

A frequency doubler circuit should comprise a nonlinear device and filters that allow you to choose the required component at the output while isolating the source from the generated harmonics. The nonlinear device will generate higher order voltages from the first harmonic current. One of these voltages is in the proper order and will pass through the band-pass filter. Low-pass and band-pass filters will be very resistant to unwanted harmonic voltages [15], [16], and [17]. Allowing the other harmonics' currents to run indicates that their intermodulation products contribute to the desired harmonic of the output frequency. This means try to short the currents of the undesirable harmonics. To deliver as much power as possible to the load, the frequency doubler should be matched at both the input *F* and the output *2F*. *Figure 2* illustrates block diagram of frequency doubling System. *Equation 1* represents resonant frequency. *Equation 2* represents lower cutoff frequency. *Equation 3* represents higher cutoff frequency. *Equation 4* represents $\alpha$ value for parallel LC.

$$\omega_0^2 = \frac{1}{LC} \tag{1}$$

$$\omega_{c1} = -\alpha + \sqrt{\alpha^2 + \omega_0^2} \tag{2}$$

$$\omega_{c2} = \alpha + \sqrt{\alpha^2 + \omega_0^2} \tag{3}$$

$$\alpha = \frac{1}{2RC} \tag{4}$$

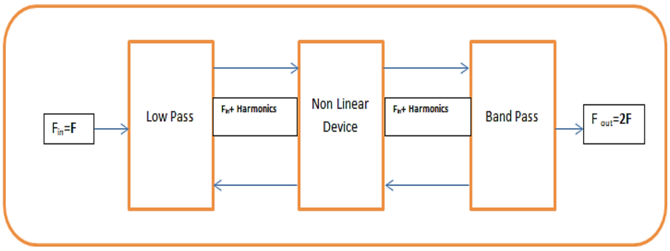


**Figure 2.** Block diagram of frequency doubling System

## 3. IMPLIMENTATION TECHNIQUES

The diode in igures 3 and 4 is flanked by two LC tanks tuned to the appropriate frequencies. The first LC tank near the input is tuned to the fundamental frequency (F), and the second is tuned to double the fundamental frequency (2F). The LC tanks are short for any other frequency they are set to. This ensures that no more harmonics of the fundamental frequency enter the diode or emerge at the output. The frequency doubling system employing the Schottky diode has a lower conversion loss than the frequency doubling system using the varactor diode.

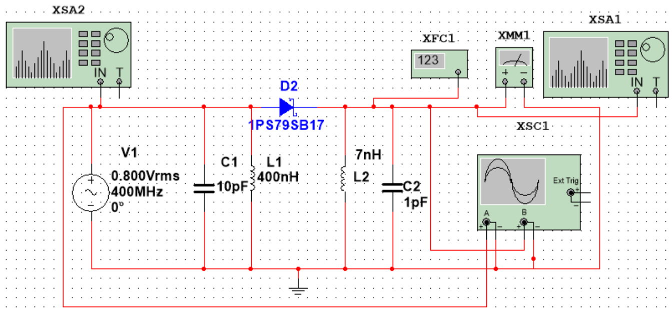


**Figure 3.** Simulation circuit diagram of frequency doubling System using Schottky diode

The best possible efficiency of a passive multiplier is around 1/n2, where n is the harmonic number. Resistive diodes have more bandwidth than capacitive diodes. *Figure 3* represents a simulation circuit schematic of a frequency doubling device based on a Schottky diode. *Figure 4* represents a simulation circuit diagram for a frequency doubling device using a varactor diode. *Figures 3* and 4 are implemented in NI Multisim.

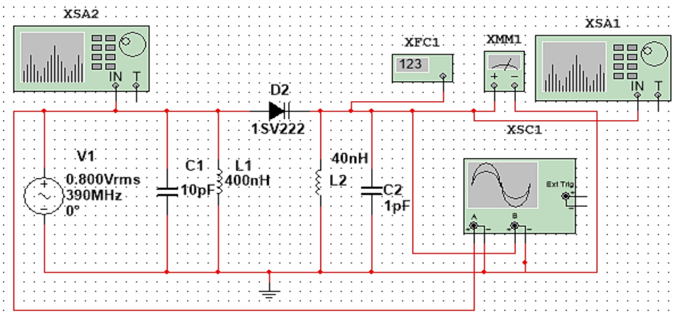


**Figure 4.** Simulation circuit diagram of frequency doubling system using varactor diode

## 4. RESULT AND ANALYSIS

Performance comparison of different nonlinear elements in frequency multiplying circuit for IoT applications is implemented. *Figure 5* represent simulated output waveform of frequency Doubler system using Schottky diode in NI Multisim.

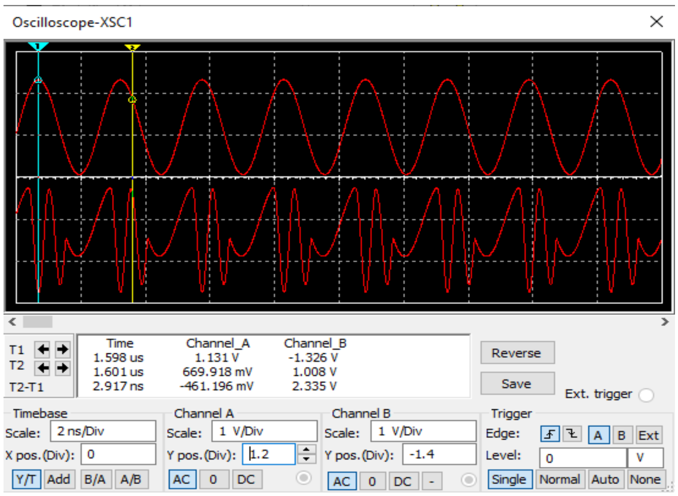


**Figure 5.** Output waveform of frequency Doubler system using Schottky diode

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*Figure 6* represents simulated output waveform of frequency Doubler system using varactor diode in NI Multisim. *Figure 7* shows input power -4.66 dBm to frequency Doubler System using Schottky diode and varactor diode. *Figure 8* shows simulated output power -13.932 dBm of frequency Doubler System using Schottky diode. *Figure 9* shows output power -28.545 dBm of frequency doubler system using varactor diode.

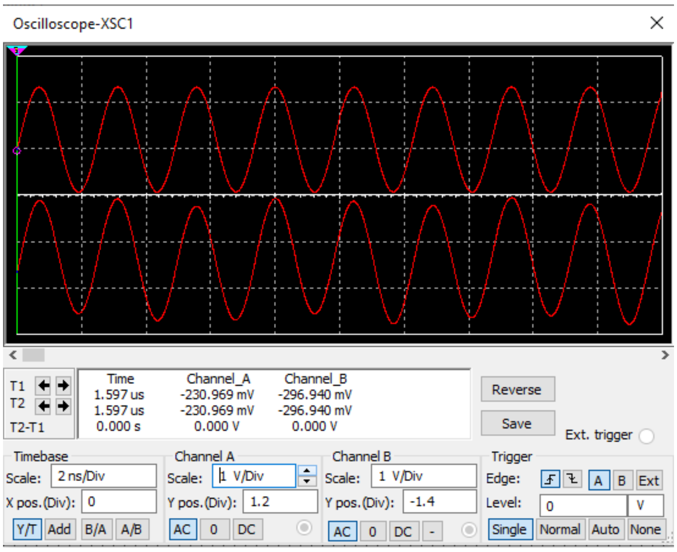


**Figure 6.** Output waveform of frequency Doubler system using varactor diode

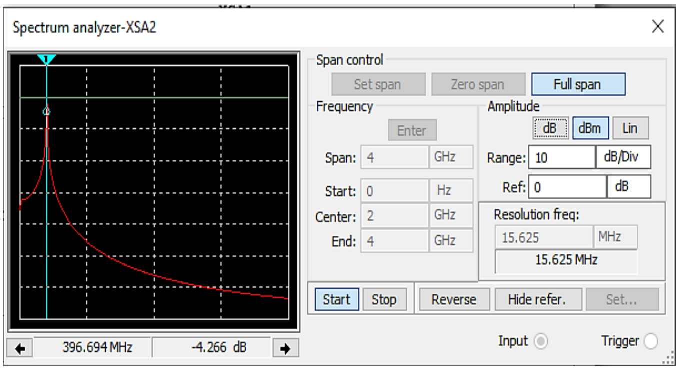


**Figure7.** Input power (dBm) to frequency doubler system using Schottky diode and varactor diode

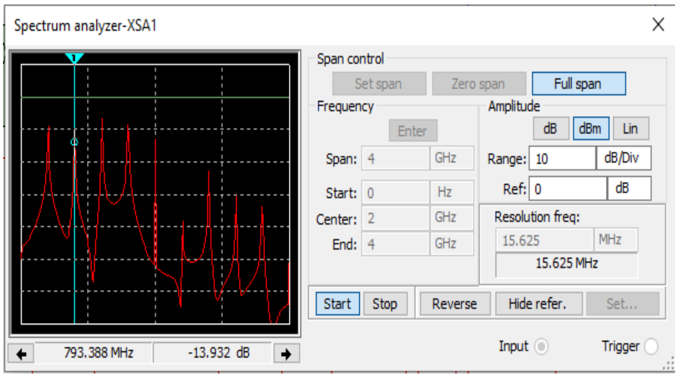


**Figure 8.** Output power (dBm) of frequency doubler system using Schottky diode

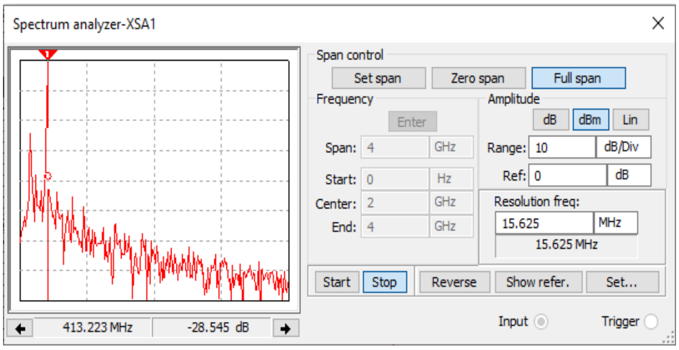


**Figure 9.** Output power (dBm) of frequency doubler system using varactor diode

Based on comparison of simulated results of frequency doubler systems in NI Multisim, we obtained better result for frequency doubler system using Schottky diode. Hence, we implemented hardware of frequency doubler using Schottky diode which is shown in *figure 10*. *Table III* represent hardware output frequency and output voltage for frequency doubling System using Schottky diode at different input frequency with 800mV input voltage. *Figure 11* hardware fabrication of frequency multiplying Reflectenna.

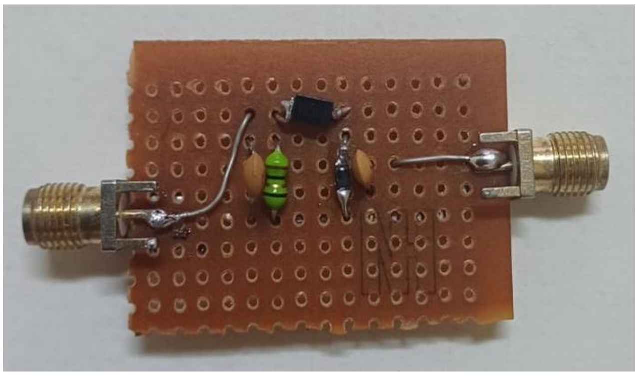

**Figure 10.** Hardware implementation of frequency doubler using Schottky diode

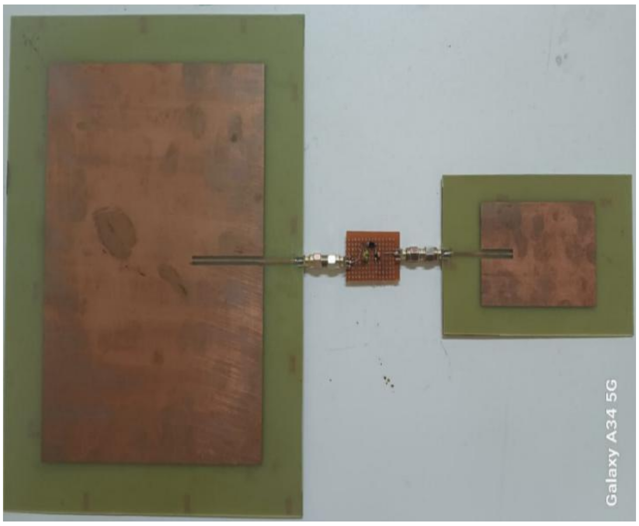


**Figure 11.** Hardware fabrication of frequency multiplying Reflectenna

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**Table I. Simulation output frequency and output voltage for frequency doubling system using Schottky diode**

| Input Frequency | Input voltage | Output frequency | Output voltage |
|---|---|---|---|
| 390Mhz | 800mV | 757Mhz | 711mV |
| 392Mhz | 800mV | 763Mhz | 711mV |
| 394Mhz | 800mV | 767Mhz | 712mV |
| 396Mhz | 800mV | 769Mhz | 713mV |
| 398Mhz | 800mV | 775Mhz | 715mV |
| 400Mhz | 800mV | 778Mhz | 717mV |
| 402Mhz | 800mV | 784Mhz | 716mV |
| 404Mhz | 800mV | 787Mhz | 716mV |
| 406Mhz | 800mV | 791Mhz | 715mV |
| 408Mhz | 800mV | 795Mhz | 715mV |
| 410Mhz | 800mV | 799Mhz | 715mV |

**Table II. Simulation output frequency and output voltage for frequency doubling System using varactor diode**

| Input Frequency | Input voltage | Output frequency | Output voltage |
|---|---|---|---|
| 390Mhz | 800mV | 396Mhz | 901mV |
| 392Mhz | 800mV | 303Mhz | 931mV |
| 394Mhz | 800mV | 410Mhz | 955mV |
| 396Mhz | 800mV | 412Mhz | 965mV |
| 398Mhz | 800mV | 396Mhz | 957mV |
| 400Mhz | 800mV | 414Mhz | 951 mV |
| 402Mhz | 800mV | 405Mhz | 925mV |
| 404Mhz | 800mV | 403Mhz | 890mV |
| 406Mhz | 800mV | 405Mhz | 900mV |
| 408Mhz | 800mV | 410Mhz | 911mV |
| 410Mhz | 800mV | 411Mhz | 924mV |

*Table I* represent simulated output frequency and output voltage for frequency doubling system using Schottky diode at different input frequency and 800mv input voltage. *Table II* represent simulated output frequency and output voltage for frequency doubling system using varactor diode at different input frequency and 800mv input voltage.

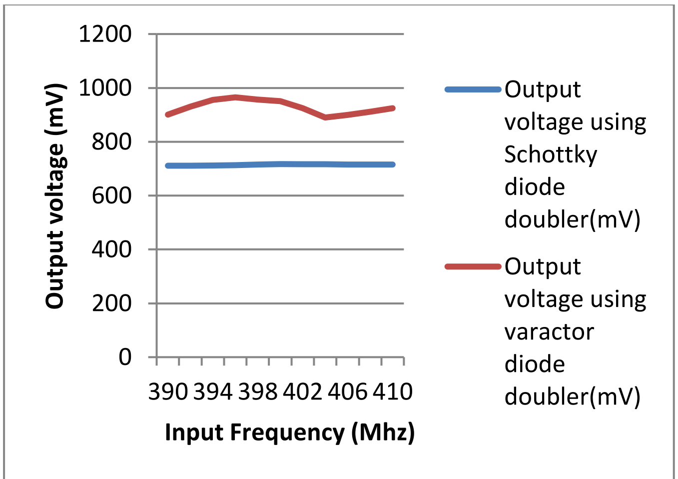


**Figure 12.** Comparison of output Voltage (mV) vs input frequency (MHz) for doubler system using Schottky diode and varactor diode

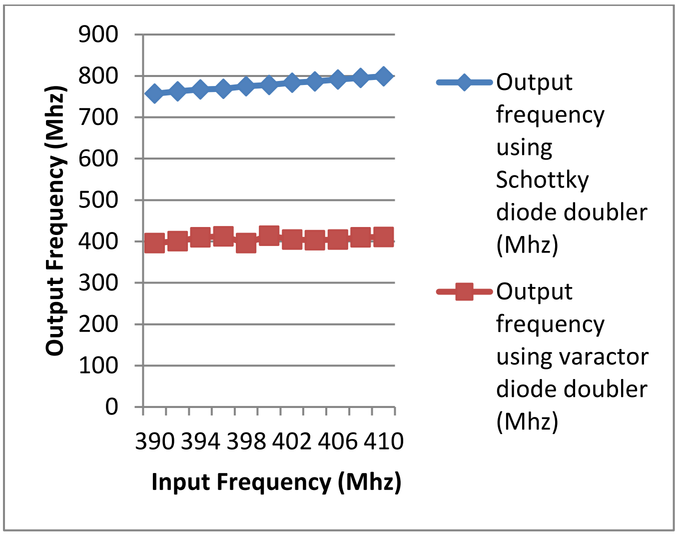


**Figure 13.** Comparison of output frequency (Mhz) vs input frequency (Mhz) for doubler System using Schottky diode and varactor diode

*Figure 12* represents comparison of output Voltage (mV) vs input frequency (MHz) for doubler system using Schottky diode and varactor diode. *Figure 13* represents comparison of output frequency (MHz) vs input frequency (MHz) for doubler system using Schottky diode and varactor diode.

**Table III. Hardware output frequency and output voltage for frequency doubling system using Schottky diode**

| Hnbn Input Frequency | Input voltage | Output frequency | Output voltage |
|---|---|---|---|
| 390Mhz | 800mV | 782Mhz | 701mV |
| 392Mhz | 800mV | 786Mhz | 702mV |
| 394Mhz | 800mV | 786Mhz | 702mV |
| 396Mhz | 800mV | 794Mhz | 703mV |
| 398Mhz | 800mV | 794Mhz | 705mV |
| 400Mhz | 800mV | 802Mhz | 706mV |
| 402Mhz | 800mV | 806Mhz | 706mV |
| 404Mhz | 800mV | 810Mhz | 706mV |
| 406Mhz | 800mV | 814Mhz | 705mV |
| 408Mhz | 800mV | 814Mhz | 705mV |
| 410Mhz | 800mV | 816Mhz | 705mV |

## 5. CONCLUSION

A performance comparison of different nonlinear elements in frequency multiplying circuit for IoT applications is proposed in this paper. This paper compared the performance between frequency doubling System using Schottky diode and frequency doubling System using varactor diode. Performance was evaluated in terms of output Voltage (mV), output frequency (MHz) and output power (dBm). The advantage of frequency doubling system m using Schottky diode is fast switching and more output voltage and power provides to the load side as compare to frequency doubling system using varactor diode. Output power -13.932 dBm for frequency doubling system using Schottky diode and -28.545 dBm for frequency doubling system using varactor diode is observed.

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Future work will be to test frequency multiplying reflectenna for low power application in wireless communication. We will also test passive frequency multiplying reflectenna as sensing device in IOT Application.

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