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Original Article

Study of the Dual Resonant Frame Parametric Generator

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Abstract: We have built the research model of the dual resonant frame parameter generator based on the actual circuit diagram implemented in the laboratory to evaluate the mechanism of the dual resonant frame, two-frequency generator. The dual resonant frame parameter oscillator produces the desired frequency w_2 which depends on the pump frequency and frequency w_1. On the basis of the research model, we have successfully tested the mechanism of the dual-frequency transmitter, which makes it possible to manufacture RF oscillators with low phase noise, thereby improving stability. The output frequency stability w_2 depends on the stability of the pump frequency and the frequency w_1.

Keywords: dual resonant frame, parametric generator system, pump frequency.

1. Introduction

The dual resonant frame parametric generator system is a two degrees of freedom system. The block diagram of the system is shown in Figure 1.

In dual resonant frame parametric amplification, if we choose $f_P = f_{10} + f_{20}$ (with an energy compensation) we can have a signal amplification either in frame I or frame II, where f_{10} and f_{20} is the resonant frequency of frame I and frame II, respectively. Output power is taken from two frames, input power is from a pump source. In this case the output power depends not only on the frequency relationship f_2/f_1 but also on the energy compensation level [1].

When $m \geq m_{th}$ the parametric modulation factor is greater than or equal to the critical value, the system can be self-excited to become a dual resonant frame parametric generator. When fb is low ($f_P = f_{20} + f_{10}$) according to the Manley-Rowe's ratio the system is with no energy compensation, and the system becomes a frequency conversion. Output power of frame II (high frequency frame) is taken from

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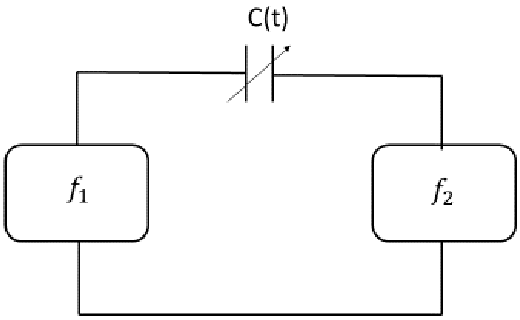
the pump power source and the signal source (f_{th} is the signal frequency). In this case the system cannot be self-excited, the power gain depends on the frequency relation f_1/f_2 ($f_2 \approx f_{20}$, $f_1 \approx f_{10}$).



C(t) element with variable parameter;
$C(t) = C_0(1 + m\cos\omega_0 t)$;
m: parameter variation coefficient;
f_1 natural frequency of frame I;
f_2 natural frequency of frame II;
f_P the pump frequency, $\omega_0 = 2\pi f_P$.

Figure 1. Block diagram of a dual resonant frame parametric generator system.

In case f_P is low and $f_P \approx 2f_{10}$, the condition of self-excitation matches $m > m_{th}$, the system will transmit the I frame parameter which is a low frequency resonant frame with $f_1 = f_P/2$.

In case f_P is high and $f_P \approx 2f_{20}$, the condition of self-excitation matches $m > m_{th}$, the system will transmit the II frame parameter which is a high frequency resonant frame with $f_2 = f_P/2$.

In case $f_P = f_{10} + f_{20}$ and the condition of self-excitation matches $m > m_{th}$ then the system will transmit double frame parameter.

One main property of the dual frame parametric generator is that it can generate two oscillators simultaneously (with frequencies that are multiples or not multiples). When the frequencies are multiples of each other, there may be self-synchronization between the two frequencies or frequency division. We study the generator diagram with two frames (Figure 1). In the parametric regenerative amplifiers with dual resonant frames there may be a modulated signal. If the regeneration factor is greater than one, the system becomes self-excited and switches to a generator mode. We survey the transmitter, with the law of capacitance change in the frame [2]:

$$C(t) = C_0(1+m\cos\omega_P t).$$

Where ω_P is the angular frequency of the pump signal, we also denote "1" and "2" as the resonant angular frequency of frame I and frame II, respectively.

The specified rule is similar to that of the generator case with a two-diode symmetrical scheme, or with a capacitance variation in amplification modes with small pump source that is larger than the multiples of the signal. In the expression of C(t) includes the DC component and the AC component: $C_0 + mC_0\cos\omega_P t$.

Frame II is an open circuit for the frequency ω1 (current $j_{\omega 1}$) and frame I is an open circuit for the frequency ω2 (current $j_{\omega 2}$). During the calculation, we consider connecting C_0 in parallel with C_1 and C_2, the residual between the two frames is the variable capacitive component ΔC. In this case, in order to satisfy the self-excitation condition, it is still necessary to:

$$\frac{\Delta C}{C_1}\cdot\frac{\Delta C}{C_2}\rangle\frac{1}{Q_1}\cdot\frac{1}{Q_2}$$

With Q1, Q2 is the quality factors of the frame I and frame II. The higher the quality level is, the easier it is to satisfy the self-stimulation condition. To achieve the maximum gain, the system is put to operate in the near self-excited mode (super regenerative amplification), so the pump amplitude must be stable.

The use in a transmitter mode is very beneficial: a pump frequency is very stable, changing ω_1 we can vary the frequency ω_2 exactly (because $\omega_2 = \omega_b - \omega_1$), with a high stability of the frequency ω_2. This means previously, we had a stability at only one frequency, now we can tune the frequency mechanically and still get a stable frequency. It is a combinatorial excitation effect with the frequencies that are not multiples of each other. It is special that when ω_1 and ω_2 are close in a multiple, there can be self-synchronous, in frame I or frame II there can be a periodic oscillation exactly equal to ω_1 or ω_2. When changing the ratio $n=\omega_2/\omega_1$ the parametric transmission area of the dual frame parameter generator system will change accordingly, this will be studied experimentally [2].

2. Experimental Results

We have built a research model of the dual resonant frame parametric generator based on the principle diagram for the investigation in laboratory (Figure 2).

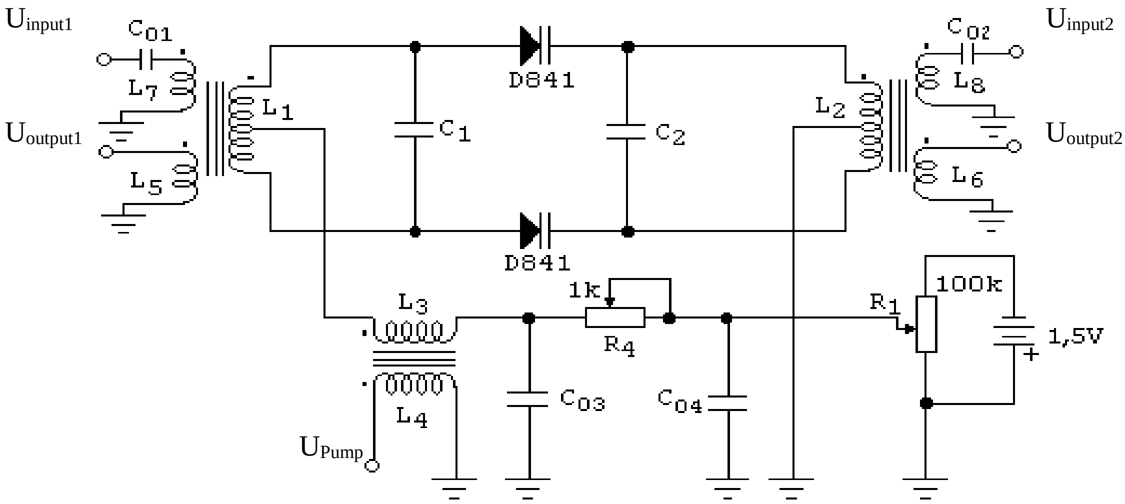
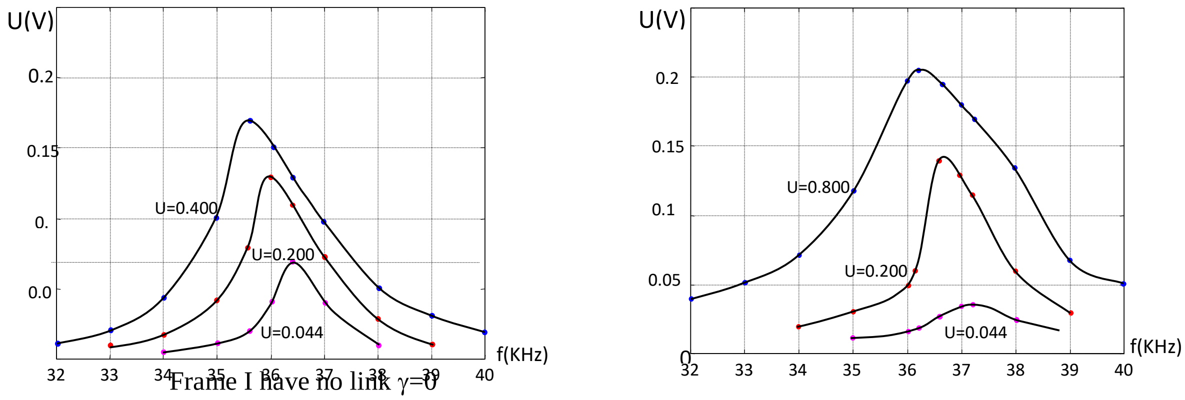


Figure 2. The principle diagram of a dual resonant frame parametric generator.

The set-up is used for measuring resonance characteristics of frames when they possess no link $\gamma = 0$ (completely isolating frames) and when two frames are linked $\gamma \neq 0$.

Experimental results show that: when linking two frames together, frame II (high frequency resonant frame) appears to shift the resonant frequency of frame I (low frequency resonant frame) towards the low frequency. This change is not very large, about 7 KHz. In contrast, frame I significantly affects the resonant frequency of frame II, the resonant frequency increases to about 196 KHz. Thus, when two frames are linked, due to mutual influence, the resonant frequencies of the two frames are separated apart, the resonant frequency of the high frequency frame will shift further than the resonant frequency of the low frequency frame.

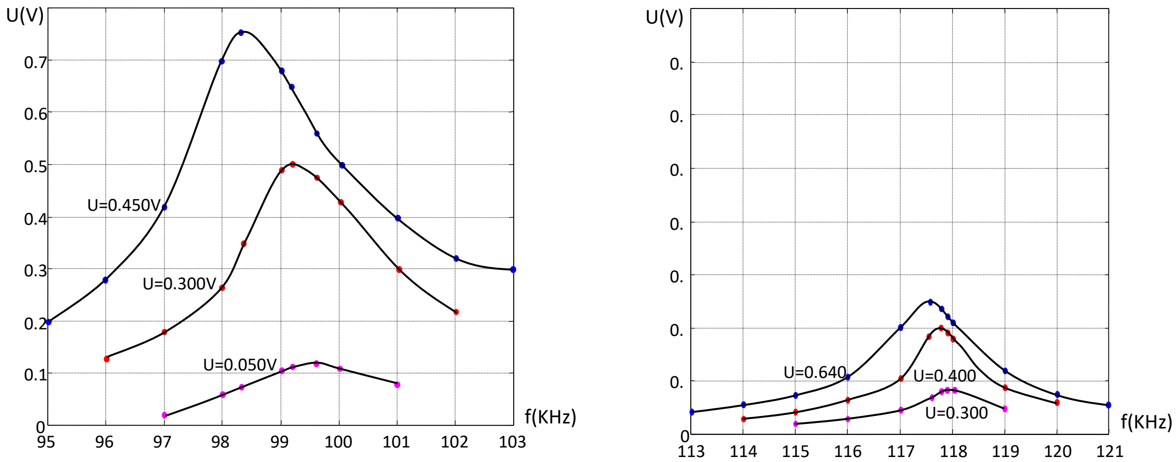
The structure of the dual frame generator system consists of two resonant frames, these two frames are linked together by a variable capacitance, which is essentially a pairing of two single frame generators. When interrupting frame II, putting pump on satisfying self-excitation condition, the system will output single frame parameter with a resonant frame as frame I. Similarly, by interrupting frame I, putting a pump in the satisfying self-excitation condition, the system will transmit a single frame parameter with a resonant frame as frame II. In the above two cases, the system transmits parameters with each frame independently and unaffected by the other frame.



Frame I have no link γ=0

Frame I have link γ≠0

Figure 3. Resonance characteristics of the frame I.

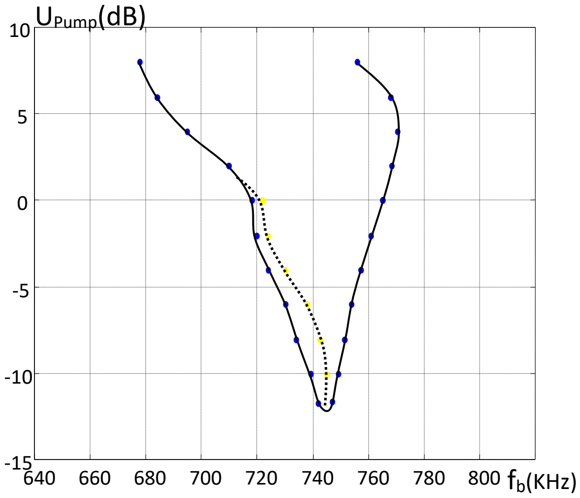


Frame II have no link γ=0

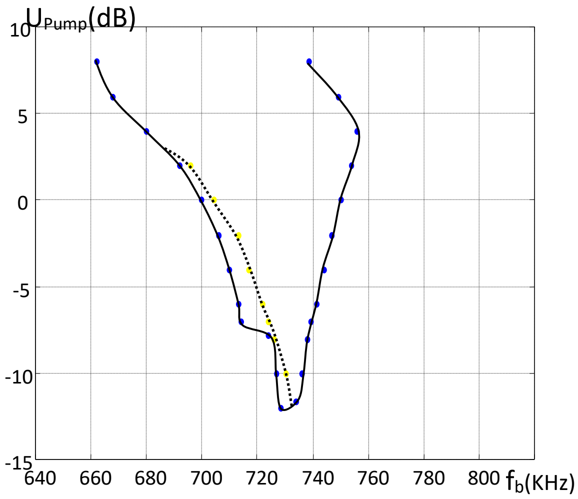
Frame II have link γ≠0

Figure 4. Resonance characteristics of the frame II.

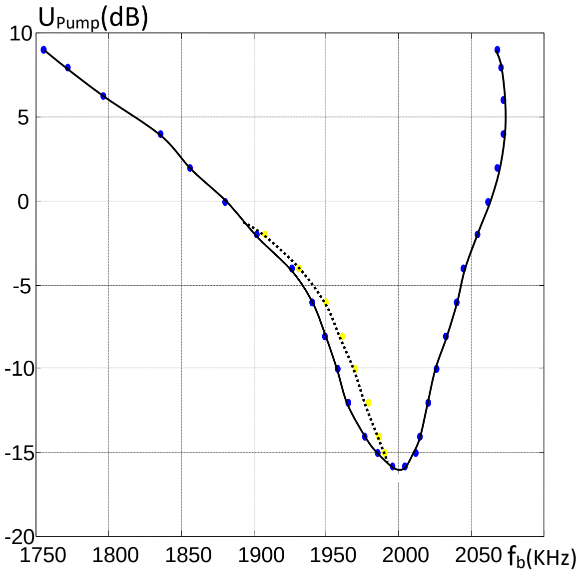
The problem becomes complicated when we put the two frames in a link through the average capacitance (C_0) of the diode. The system can still transmit parameters of every single frame when we give the pump frequency twice of the resonant frequency of that frame, but now the transmitter frequency region will change and the change with each frame is different (Figure 5).



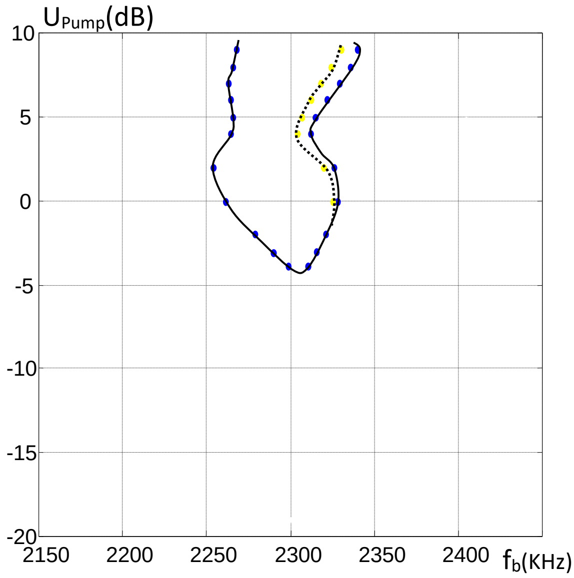
Transmitter frequency region of frame I have no link γ=0



Transmitter frequency region of frame II have link γ≠0



Transmitter frequency region of frame II have no link γ=0



Transmitter frequency region of frame II have link γ≠0

Figure 5. Transmit frequency regions.

From the survey results, frame II has a little effect on the parametric transmission frequency area of frame I: the transmission frequency of frame I is only slightly reduced, the pumping threshold U_{Pump}≈-11dB (about 0.2V) and the transmit region does not change in width except for a small region near the threshold value.

But the effect of frame I on frame II is very strong. When two frames are linked together, the form of the transmitting area of frame II changes a lot, the pumping threshold U_{Pump}≈-4dB (about 0.8V) is much higher than the transmitting threshold when the two frames are not linked U_{Pump}≈-16dB (about

0.08V). In particular, when the resonant frequency ratio of the two frames approaches the multiple frequency ratio, the frame parameter II transmission area narrows and may be distorted, broken or completely disappeared (Figure 6).

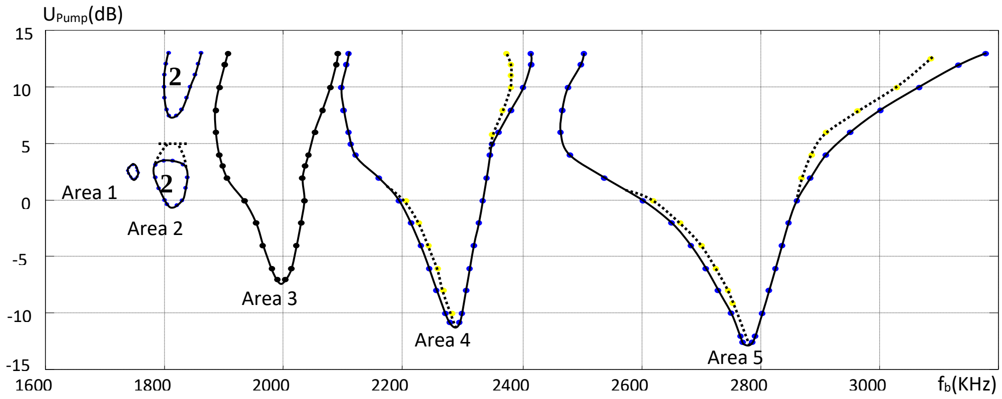
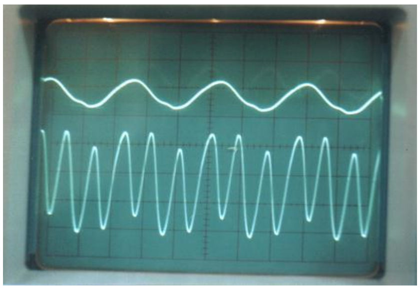


Figure 6. Transmit frequency regions of frame II when changing multiples between two frames (γ≠0).

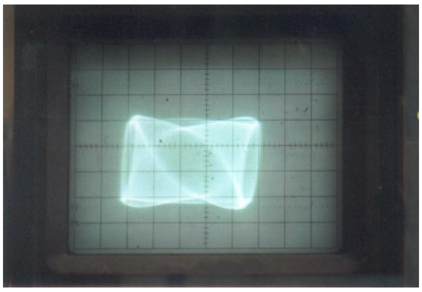
The interaction between the two frames is the binding interaction of the system of two degrees of freedom. Due to the flexible link (capacitive link), the transmit frequency of frame I shifts to the low frequency, the transmit frequency of frame II shifts to the high frequency. On the other hand, the coils in the two frames have an influence on each other, especially when the two resonant frequencies of the two frames are near to each other. Experimental data show that frame I is not significantly affected, while frame II is really strongly affected, the degree of impact will change according to the ratio of the resonant frequencies of the two frames.

Setting the pumping frequency $f_{Pump} \approx f_{10}+f_{20}$, when the self-excitation condition is satisfied ($m>m_{th}$), the system will generate the dual parameters.

With a dual frame parametric generator, if the resonant frequency ratio of the two frames is appropriate, then by changing f_P: $f_P \approx 2f_{10}$, $f_P \approx f_{10}+f_2$, $f_P \approx 2f_{20}$ the system will possess three transmitter regions, and if offsets are inappropriate multiples there will remain only one or two transmitting regions (Figure 8). With the investigation of the transmission regions of the dual resonant frame parametric system, the results allow us to select a required transmission frequency according to the different transmission modes, which is very convenient.



Pump signal and output signal



Self-modulating generation represented by the Lissajous

Figure 7. Signal images from a dual resonant frame parametric generator.

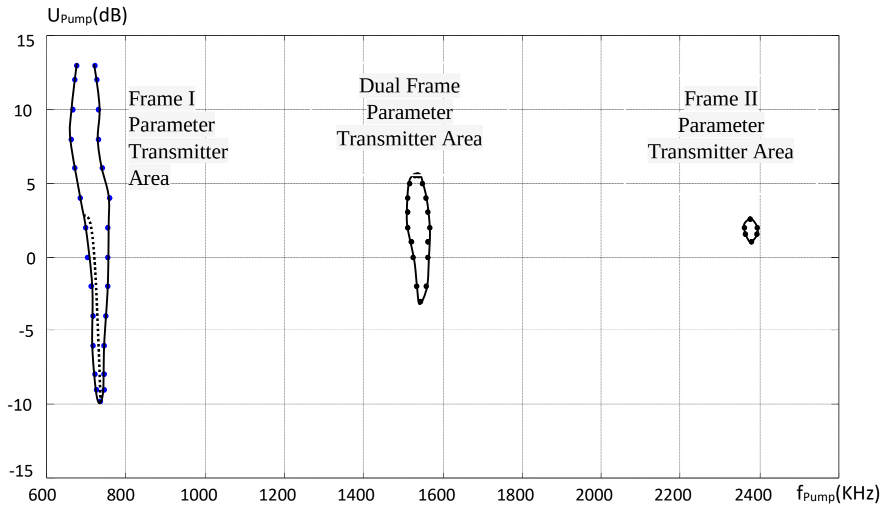


Figure 8. Transmitter zones of a dual resonant frame parameter generator

4. Conclusion

The survey results of the transmitter regions of the dual frame parametric generator show that the experimental results are completely consistent with the theory. When changing the pump frequency, it is possible to obtain the desired transmit frequency, the transmitter signal has a much better stability than using transistors, which is important in electronic engineering. With the surveys and obtained results, it is possible to fabricate a two-frequency oscillator with high frequency stability as well as minimize the oscillator's phase noise due to the pumping mechanism.

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