Studies on a Super-Regenerative Detector Using Harmonics of an Oscillator

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Abstract

This paper proposes a novel super-regenerative detector which is able to operate in multi-frequency bands. It operates in the same frequency as the fundamental oscillation and its harmonics of the oscillator in it, while conventional one operates in a single frequency band. An FET oscillator was used in the super-regenerative detection, whose fundamental frequency was 2.4 GHz*. The detection of an on-off keying signal has been confirmed over a carrier frequency of* 4.8 GHz *which corresponds to the second harmonics as well as over a carrier frequency of* 2.4 GHz *(fundamental one). The dependency of the demodulated signal voltage on the input power is shown together with the time domain waveform.*

1. Introduction

Recently, communication systems in microwave and millimeter wave region have rapidly developed. Among them, short range communication systems are used much wider than before, and transceivers in small size cards have also appeared. Applications for such short range communications require their devices to be low-cost and low-power consumption.

A super-regenerative detector is suggested in 1922 by E. H. Armstrong [1]. The circuit is essentially composed of a single active device. Recently, because of its simplicity and high-sensitivity, some applications to short-range digital communications in microwave region have been performed [2], [3]. An application to the spread spectrum communication in the 2.4 GHz ISM band [4], and a wide-band tunable super-regenerative detector [5] are also utilized. Since a super regenerative detector is composed of an oscillator, it can operate as a transceiver applying a modulator [6]. Moreover, applications to a radar are also proposed [7], [8].

In this work, a novel super-regenerative detector which operates in multi-frequency bands is proposed and its characteristics are shown.

2. Fundamental Operation of a Super-Regenerative Detector

First of all, a fundamental operation of a super-regeneraive detector is briefly explained showing some figures. A super-regenerative detector is composed of an oscillator which operates at the same frequency as that of the signal to

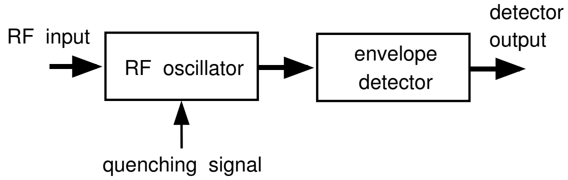

Fig. 1: Configuration of a super-regenerative detector.

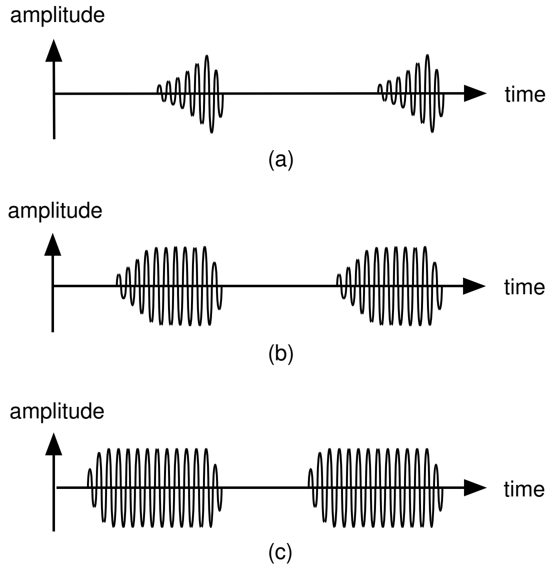

Fig. 2: Changes of the oscillation-starting by the input signal; Oscillation waveform (a) with no input signal, (b) with an input signal, (c) with a large input signal.

detect and an envelope detector as shown in Fig. 1. In the super-regenerative detection, an oscillation waveform in the oscillator is changed to a burst signal by applying a quenching signal. The quenching signal is used to modify the close-loop gain of the oscillator periodically.

At the instant of the oscillation start with no input signal to the oscillator, the transient of the waveform growth depends on various conditions such as thermal noise and a gain of an active components in the oscillator as shown in Fig. 2(a). On the other hand, when a signal of the same frequency as

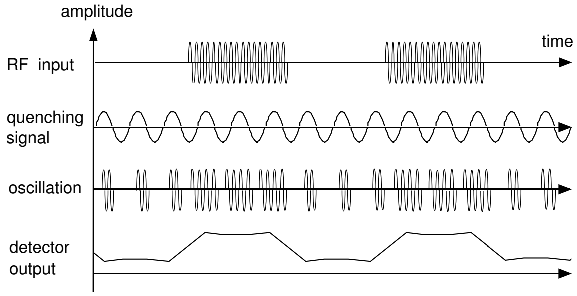

Fig. 3: Waveforms of the signals in a super-regenerative detector.

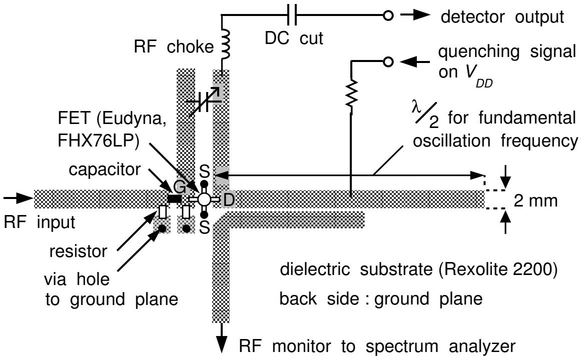

Fig. 4: Layout of the super-regenerative detector circuit.

the oscillation is applied to the oscillator, the oscillation is triggered. As shown in Fig. 2(b), this phenomenon leads to a reduction of the rise-up time of the oscillation. If the amplitude of the appled signal is larger than the case in Fig. 2(b), the rise-up time is much shorter as shown in Fig. 2(c). As the result of the response to the amplitude of the input RF signal, the oscillation waveform is modulated in pulse-width by the input signal as shown in Fig. 3. Finally, detecting the envelope of the oscillation waveform provides an output signal from the super-regenerative detector. Here, Fig. 3 shows the time domain waveforms of the input RF signal, the quenching signal, the oscillation in the oscillator and the output signal from the envelope detector [2], [9], [10], [11].

We have tried the capability of detecting a signal over a harmonic frequency of the oscillation and verified it. Namely, the proposed super-regenerative detector is able to operate not only in the fundamental oscillation frequency but also in a harmonic frequency.

3. Configuration of Circuit

Figure 4 shows a schematic of a prototype super-regenerative detector. The circuit is composed on a dielectric substrate, Rexolite 2200 using microstrip lines. The oscillator is composed of an FET(Eudyna, FHX76LP) and a feed back line from drain terminal of the FET to the gate terminal. Here, an estimated equivalent circuit of this oscillator is shown in Fig. 5. In this figure, a transmission line which consists of an inductor and capasitors corresponds to the feesback transmission line from the drain terminal of the FET to the gate terminal. As shown in Fig. 5, the FET and the feedback transmission line establish the Colpitts circuit. Hence, we can decide the oscillation frequency by aligning the length of the transmission line.

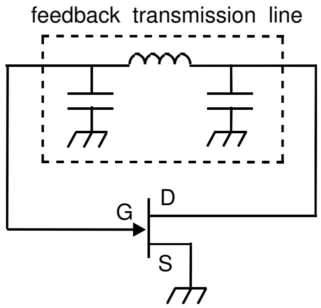

Fig. 5: Estimated equivalent circuit of the super-regenerative detector as the oscillator.

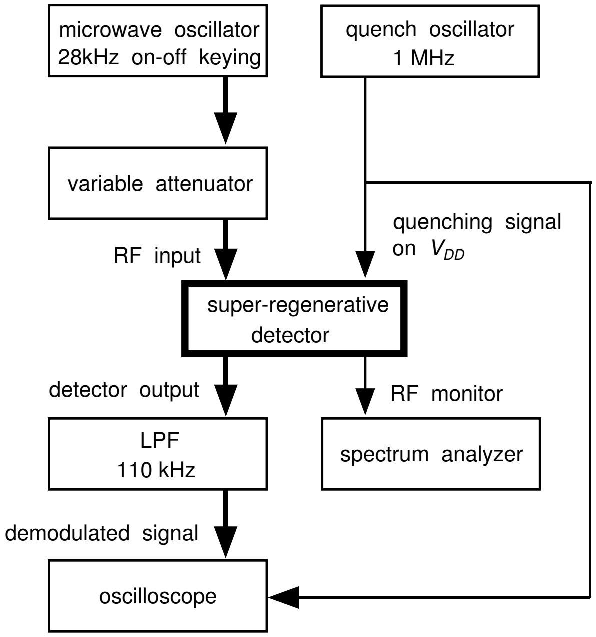

Fig. 6: Experimental setup for the super-regenerative detector.

An open ended stub whose length is half of the wave length of the oscillation signal is connected to the drain terminal. The central position of the stub is the feeding point of a quenching signal. The quenching signal is super-positioned on voltage source V_{DD}. A coupling line to the stub is used to observe a spectrum of the oscillation.

An input signal is applied to the gate terminal, and the output signal is obtained from the drain terminal through an RF choke and a capacitor to eliminate V_{DD}. In this circuit, the FET also operates as an envelope detector utilizing its non-linearity.

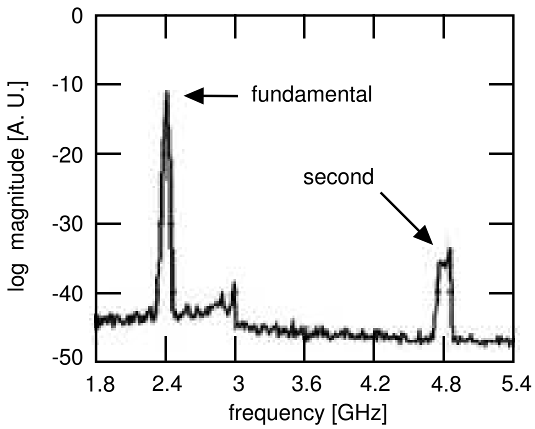

Fig. 7: Spectrum of the fundamental and the second orders of the quenching oscillation in the super-regenerative detector.

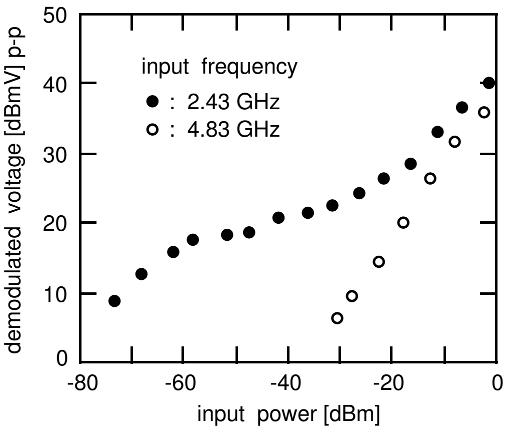

Fig. 10: Demodelated signal voltage vs. input signal power.

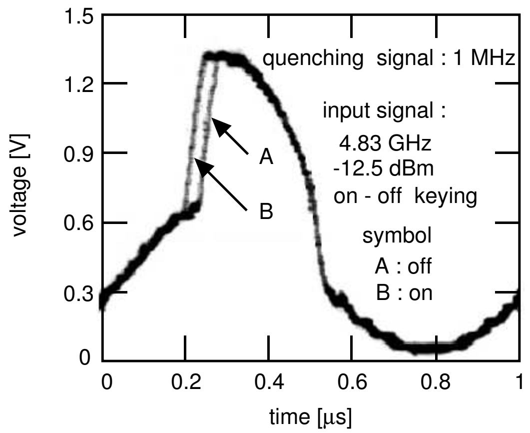

Fig. 8: Changes of the envelopes of the quenching oscillation as a response to the input signal.

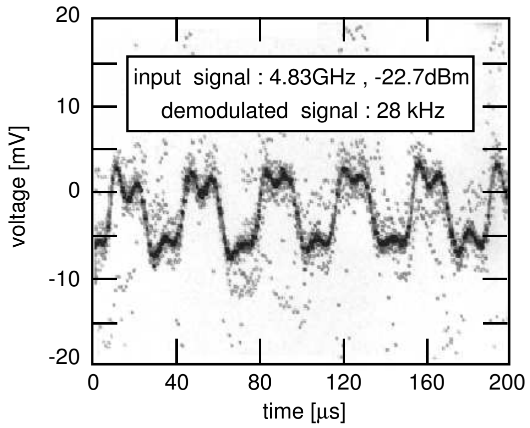

Fig. 9: Time domain waveform of the demodelated signal.

4. Experimental Results

Figure 6 shows an experimental setup for the super-regenerative detector. A quenching signal which is superpositioned on voltage source V_{DD} has a sinusoidal waveform of $1\,\mathrm{MHz}$. An input carrier frequency is $2.4\,\mathrm{GHz}$ or $4.8\,\mathrm{GHz}$. These frequencies correspond to the fundamental and second orders of the oscillation frequency of the super-regenerative detector, respectively. And the input signal is modulated in $28\,\mathrm{kHz}$ on-off keying. A variable attenuator is used to change the input power to measure the demodulated signal voltages as a response to the input signal powers. The demodulated signals of $28\,\mathrm{kHz}$ are observed by an oscilloscope through a low pass filter with $110\,\mathrm{kHz}$ cutoff to eliminate the quenching signal of $1\,\mathrm{MHz}$.

Next, Fig. 7 shows a spectrum of the quenching oscillation of the super-regenerative detector. In this figure, there exist the fundamental order of $2.4\,\mathrm{GHz}$ and the second order of $4.8\,\mathrm{GHz}$. In this paper, super-regenerative detections have been performed in these frequency bands.

Next, Fig. 8 shows envelopes of the quenching oscillation. These waveforms are input voltages of the quenching signal on V_{DD}. They respond to the evolution of the oscillation through the change in the input impedance. The RF input signal is $4.83\,\mathrm{GHz}$, $-12.5\,\mathrm{dBm}$ with $28\,\mathrm{kHz}$ on-off keying. In this figure, waveform A is rising up of the quenching oscillation when the symbol of the modulation is "off", and waveform B is rising up when the symbol is "on". Earlier rising-up can be seen in waveform B, so the changes in the oscillation evolutions are clearly observed.

Figure 9 shows a time domain waveform of the demodulated signal obtained through the low pass filter. The waveform of $28\,\mathrm{kHz}$ is clearly observed. In this measurement, the input signal is $4.83\,\mathrm{GHz}$ of $-22.7\,\mathrm{dBm}$ with $28\,\mathrm{kHz}$ on-off keying. Finally, the demodulated signal voltage as a response to the input siganl power are shown in Fig. 10. The super-regenerative detector shows a high sensitivity as the response to the input signal of $2.43\,\mathrm{GHz}$ which corresponds to the fundamental oscillation frequency of the super-regenerative detector. Besides it, the demodulated signal is also obtained as a response to the input signal of $4.83\,\mathrm{GHz}$ which corresponds to the second order of the oscillation frequency of the super-regenerative detector.

5. CONCLUSION

This paper proposes a novel super-regenerative detector which is able to operate in multi-frequency bands including a higher band than the oscillation frequency band of the oscillator. We have confirmed the detection of a base band signal on carrier frequencies of 2.4 and $4.8\,\mathrm{GHz}$; the former is the same frequency as the fundamental oscillation of the super-regenerative detector and the latter is its harmonic frequency.

Simple structure, low-power consumption and high-sensitivity are salient features of super-regenerative detectors. The multi-frequency operation will open a new possibility of microwave communication and measurement devices with simple architectures. In addition, utilizing a tunable super-regenerative detector [5] in the proposed structure may achieve a detector which operates in a very wide frequency band.

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