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Implementation of Bi-polar Pulse SR Receiver using Schmitt Trigger and evaluation of its performance

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Abstract—We consider application of Stochastic Resonance to a wireless communication system. Stochastic Resonance(SR) is well known as a phenomenon in which the weak signal in a nonlinear system can be detected by added noise. The receiver using Stochastic Resonance(SR Receiver) can detect the weak signal which is not detectable in the conventional receiver. In this paper, we consider implementation of Bi-Polar Pulse SR Receiver using Schmitt Trigger and evaluate its performance in Signal to Noise Ratio(SNR) and Bit Error Rate(BER).

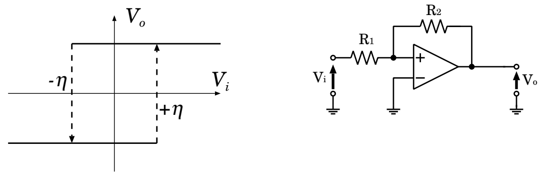
1. Introduction

Let us consider an extremely weak signal with the amplitude below receiver sensitivity. In such a situation, the signal is undetectable with a receiver. However, it may be detected by SR receiver.

Stochastic Resonance (SR) is a phenomenon, which enhances the response by additive noise. The response is usually measured by the signal to noise ratio (SNR). In SR system, the output SNR increases rapidly with increasing noise, passes through a peak and decrease gradually. By the addition of suitable noise, SR system can detect an extremely weak signal [1].

Some applications of SR in a communication system have been discussed. In the bistable system, enhancement of the bi-polar pulse and the BPSK signal is reported by simulation [2]. The bistable system designed by simple Schmitt Trigger circuit using SPICE simulator is considered [3]. In this paper, increasing of output SNR with increasing noise is reported. However a receiver using SR is not implemented.

In this paper, we evaluate experimentally the performance of the Stochastic Resonance receiver. First, at the receiver, the received signal passes through the Stochastic Resonance circuit. Then, output of SR circuit is fed to the demodulator. As the result, the extremely weak signal is converted to a detectable signal with SR circuit. We consider the implementation of the Bi-polar Pulse Stochastic Resonance receiver and evaluate its performance.



(a) (b)

Figure 1: The characteristic of Schmitt Trigger (a) and its circuit schematic (b).

2. Schmitt Trigger

For implementation of the SR receiver, we build a SR circuit using Schmitt Trigger. Schmitt Trigger is one of the circuit models of SR system. Figure.1 shows its input-output characteristic and the circuit schematic using an operational amplifier. In Fig.1, V_i and V_o are its input and output voltage respectively. Schmitt Trigger is known as a comparator which has hysteresis. It is the circuit model of the bistable system. In ideal conditions, the output of Schmitt Trigger $r_s(t)$ is represented as follows.

$$r_s(t) = V_m \mathrm{sgn}\left(r(t) - \frac{R_1}{R_2} r_s\right), \tag{1}$$

where V_m is the maximum voltage of its output and $s(t)$ is the input of the Schmitt Trigger. In more practical Op-amp model, the output given by

$$\dot{r}_s(t) = -\beta \left\{ r_s - \tanh\left[B \left(r(t) - \frac{R_1}{R_2} r_s \right) \right] \right\}, \tag{2}$$

where, β and B are constants which decide its transition characteristics. If $\beta, B \to \infty$, circuit characteristics become ideal. Then, the threshold of Schmitt Trigger η is given by

$$\eta = \frac{R_1}{R_2} V_m. \tag{3}$$

3. System overview

In this section, we introduce our proposed SR receiver using Schmitt Trigger. Figure.2 shows the block diagram of our system. The receiver consists of the SR system and the demodulator. The received signal is detected by the SR system composed of the internal noise source and Schmitt Trigger. The internal noise source can control its intensity to improve the received signal.

A bi-polar pulse waveform $s(t)$ is represented as

$$s(t) = A \sum_{i} d_i \psi(t - iT_b), \tag{4}$$

where $d_i \in \{\pm 1\}$ is the transmitted data sequences, A is the amplitude of the signal, and $\psi(t)$ is defined as

$$\psi(t) = \begin{cases} 1 & 0 \leq t < T_b \\ 0 & (othewise). \end{cases} \tag{5}$$

At the channel, the channel noise $n_c(t)$ assumed to be zero-mean white Gaussian noise with variance σ^2 is added to the transmitted signal $s(t)$ and the composed signal is fed into the receiver. Then the received signal $r(t)$ represented as

$$r(t) = s(t) + n_c(t). \tag{6}$$

The model of the receiver with sensitivity $\pm\eta$ is shown in Fig.3. The output of the receiver $y(t)$ can be modeled as follows.

$$y(t) = \begin{cases} r(t) & (|r(t)| \geq \eta) \\ 0 & \text{(otherwise)}. \end{cases} \tag{7}$$

We assume that the received signal $r(t)$ is extremely weak and the conventional receiver can not detect it. Here, we consider the detection of the weak received signal by SR. Our SR receiver is composed of Schmitt Trigger and the demodulator.

The input of Schmitt Trigger $r_{ST}(t)$ is composed of the received signal $r(t)$ and the internal noise $n_{SR}(t)$ and represented as follows.

$$r_{ST}(t) = r(t) + n_{SR}(t), \tag{8}$$

where the internal noise $n_{SR}(t)$ is zero-mean Gaussian noise with variance σ^2_{SR}. The output of Schmitt Trigger $r_s(t)$ is demodulated and decided at the subsequient stage.

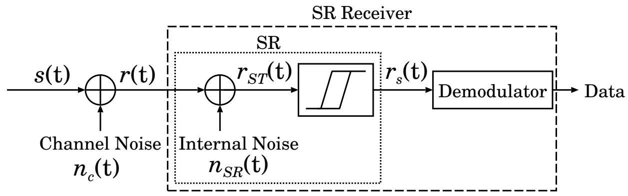


Figure 2: Block diagram of the proposed system.

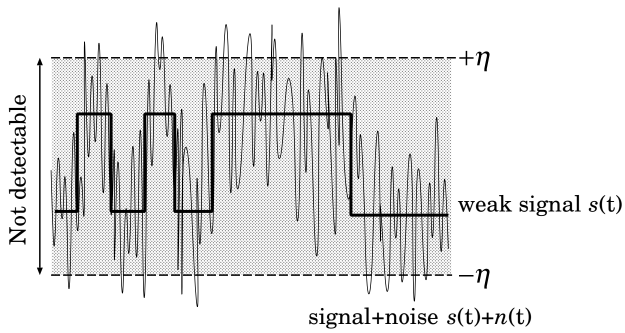


Figure 3: Model of the sensitivity of the receiver.

4. Experiments

In this section, we evaluate experimentally the output SNR and BER of the Stochastic Resonance receiver. The purpose of output SNR evaluation and measurement of BER are check of SR effect and performance evaluation of the receiver, respectively.

Figure.4 shows the implemented SR circuit. The weak signal and the noise pass through the Schmitt Trigger and the Impedance Conversion Circuit(ICC). The ICC prevents the fluctuation of the threshold.

4.1. SNR measurement

The system diagram for the output SNR measurement is shown in Fig.5. Here, we consider that the channel noise $n_c(t)$ and the internal noise $n_{SR}(t)$ are the equivalent noise $n(t) = n_c(t) + n_{SR}(t)$. The attenuated signal $s(t)$ and bandlimited zero-mean Gaussian noise $n(t) = n_c(t) + n_{SR}(t)$ are fed into the implimented circuit. The signal amplitude is 50mV and the threshold of Schmitt Trigger is ±80mV. Therefore, the output without input noise has no signal component. In SNR measurement, $s(t)$ is the square wave with its frequency 600Hz and the output SNR γ is given by

$$\gamma = 10 \log \frac{S(\omega_s)}{S_N} \ \text{[dB]}, \tag{9}$$

where $S(\omega_s)$ is Power Spectrum Density(PSD) at the signal frequency and S_N is the noise PSD around the signal frequency.

The results for the SNR measurement are shown in Fig.6. It is clear from this figure that the output SNR has the peak at PSD=0.001V^2/Hz. Hence, the implemented circuit has SR characteristic.

4.2. BER measurement

The system diagram for BER measurement is shown in Fig.7. In the BER measurement, $s(t)$ is the bi-polar pulse signal with bit rate 1.2kbps and BER between $s(t)$ and $r'(t)$ is measured with Error Rate Tester. The signal amplitude and the threshold of Schmitt Trigger are same as the SNR measurement.

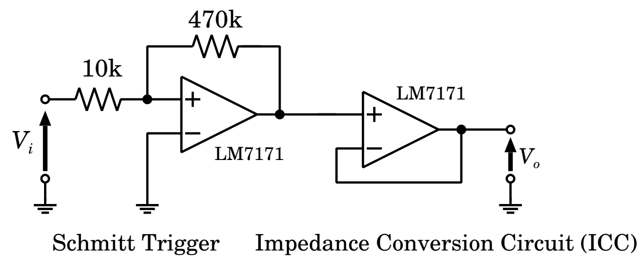


Figure 4: Implemented circuit.

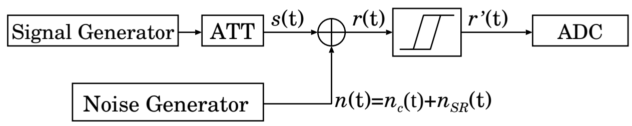


Figure 5: The system diagram for output SNR measurement.

The results for the BER measurement is shown in Fin.8. This figure shows the implovement of BER at PSD=0.001V^2/Hz. Since the peak of SNR and BER have the same noise PSD, the improvement of BER is due to SR.

5. Conclusions

In this paper, we have evaluated the performance of the bi-polar pulse stochastic resonance receiver using Schmitt Trigger. For the bi-polar pulse receiver, we have shown that the SR can improve the output SNR and BER performance by experimental evaluation. By addition of the noise which has appropriate power, SR receiver can detect the weak signal. The experimental result shows that we can detect the weak signal with the Stochastic Resonance Receiver.

References

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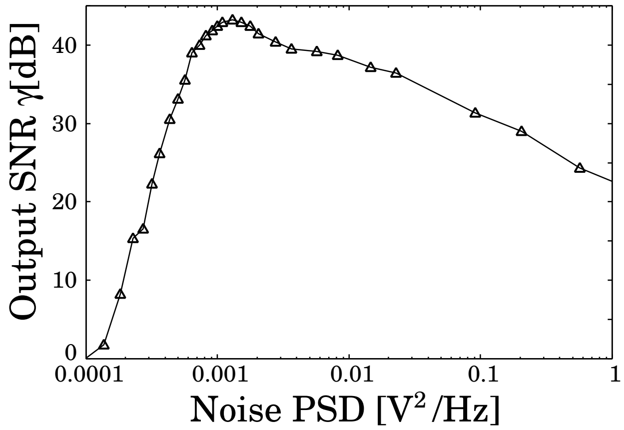

Figure 6: Output SNR of the SR receiver using Schmitt Trigger, where the signal amplitude is 50mV and the threshold is ±80mV

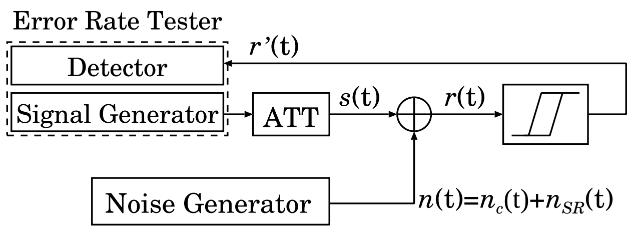

Figure 7: The system diagram for BER measurement.

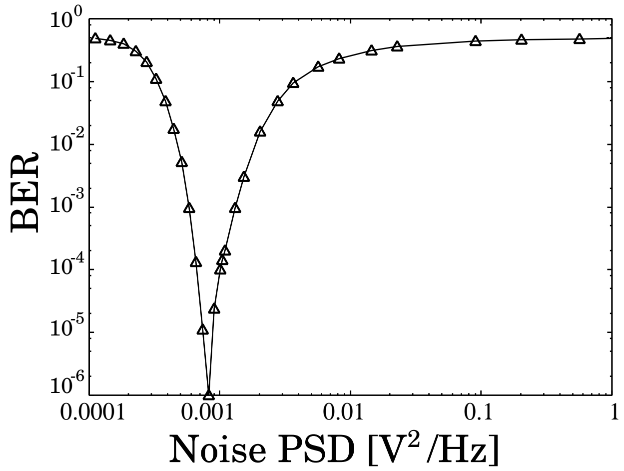

Figure 8: Bit Error Rate performance of the SR receiver using Schmitt Trigger, where the signal amplitude is 50mV and the threshold is ±80mV