New Approach to Optimize a Sigma Delta Modulator

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Summary
In this paper, a new approach to optimize a sigma-delta modulator has been presented. This last became the most popular tools in analog-to-digital conversion application. Sigma delta modulator will be the most suitable choice for multistandard system reception. We proposed to add dither before the quantizer of sigma-delta modulator in order to eliminate any distortions introduced by the quantization stage.
Simulation of second-order sigma-delta modulator for the GSM receiver has proved that this adapted method is very efficient term of linearity as well as of gain in Signal to Noise Ratio (SNR).
Key words:
Dither,GSM,sigma-delta modulator.

1. Introduction

The design of a software radio is based on two simple design goals. First, the analog-to-digital and digital-to-analog converters should be placed as near the antenna as possible, in the chain of RF Front-end components. Second, the resulting samples should be processed on a reconfigurable digital domain with digital signal processors or field programmable gate arrays.Finally, the analog-to-digital converter that is based on the technique of the sigma-delta modulation is a good alternative to reduce a quantization error.
In this work, we thoroughly provide a new approach to optimize a sigma-delta modulator based on the addition of a dither before the quantizer of the second-order sigma-delta modulator for the GSM receiver. The paper is organized as following. Section II presents the ideal sigma-delta modulator, the main element of the analog-to-digital converter for the GSM system. Performances given by adding a dither for the second-order sigma-delta modulator in GSM system are described in Section III. Finally, some conclusions are drawn in section IV.

2. Standard sigma-delta modulator for GSM receiver.

2.1 Choice of the sigma-delta modulator

Several architectures of ADC conversion are served for the GSM system. In this work a sigma-delta modulator, principal element of the sigma-delta analog-to-digital converters, is chosen to respect many reason. First, based on the principle of the noise formatting, this last is going to shape the spectral distribution of the quantization noise, so that most of this noise is going to be outside of the bandwidth of the useful signal. Second, the sigma-delta modulator is also based on oversampling. By sampling at a frequency that is much greater than the signal bandwidth, it is possible for the feedback loops to shape the quantization noise. Consequently, most of the noise power is shifted out of the signal band (it operate at frequency F_S higher than Nyquist frequency F_N = 2*B*. Oversampling ratio (*OSR*) *k* is defined as the ratio between sampling frequency F_S and Nyquist sampling frequency F_N) [1]. Another characteristic of the sigma-delta modulator, the combination of high order loop filter (>2nd order) and high lever nonlinear quantizer may lead to a system instability: modulator internal signal grows out of bounds or oscillate violently. In this paper, we strive to analyze the adoption of second-order sigma delta modulator so as to overcome the lack of system stability while ensuring high linearity .The Oversampling frequency is fixed to 70 MHz. Table 1 summarizes ADC specification for GSM receiver.

Table 4: ADC specification for GSM system

parameters	GSM
B (bandewidth)	200KHz
Fs (sampling frequency)	70 MHz
OSR (OverSampling Ratio)	175
SNR/Bits (Signal to Noise Ratio)/resolution	96dB/15

2.2 Simulation results

The Simulink model of the second-order sigma-delta modulator structure is shown in Fig.1. Note that both

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integrators in the second-order loop have a delay. We simulated the model of figure 1 with MATLAB/SIMULINK.

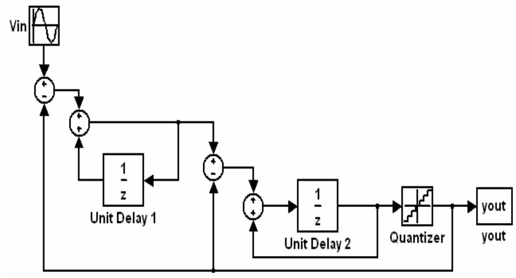

Fig. 1 Model Simulink of the ideal sigma-delta modulator

Figure 2 shows power density spectrum for second-order sigma-delta modulator for the GSM. We conclude that the noise is rejected toward the high frequencies.

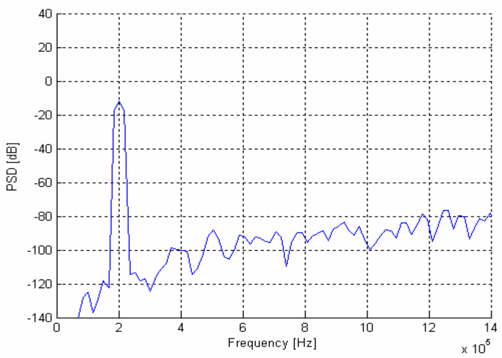

Fig. 2 Power density spectrum of the ideal Sigma-Delta modulator

Figure 3 is a zoom of figure 2 for a frequency between 0 and 0.8 MHz. Figure 3 shows that some distortions exist around the bandwidth of the useful signal caused by the presence of the mistakes introduced at the time of the quantization.

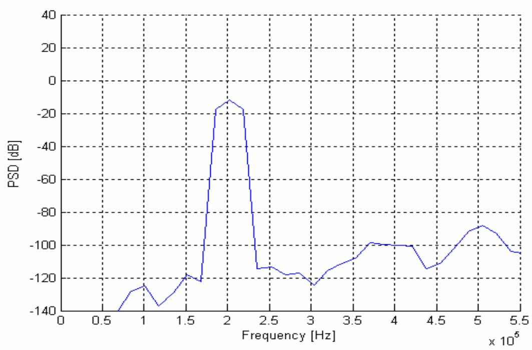

Fig. 3 Zoom of figure 2 witch frequency between 0 and 0.55 MHz

3. Optimization of the sigma-delta modulator

In order to optimize performances of the previously studied sigma-delta modulator, we suggested to add a dither before the quantizer of the modulator.

3.1 Dithered quatization

Dithering techniques are now common place in applications where it is necessary to reduce the precision of data prior to storage or transmission. Dither can render the total error signal statistically independent of the input signal as well as the error samples separated in time statistically independent of one another. There exist two types of dither: subtractively dithered (SD) and non-subtractively dithered (NSD) systems [2]. First, the dither signal must be available for subtraction at playback in SD systems, and so must the dither sequence or information be sufficient to be reconstructed, stored or transmitted with the signal.
Second, the NSD systems do not require this added information at playback .It is their primary advantage over SD systems. Practically speaking, it is difficult to use the first technique. One, therefore, will proceed in our application with the technique of non subtractive dither.

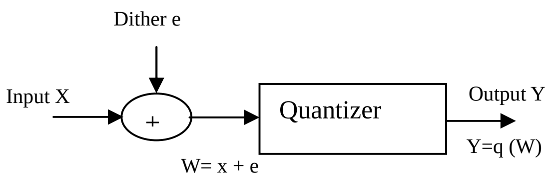

Fig. 4 Dither added to the quantizer input

3.2 Dithered Sigma-Delta modulator

We will only consider quantizer which is uniform. quantization can introduce an error signal which is simply the difference between the output of the quantizer, $q(x)$ and its input, *x:*

$$\varepsilon = x - q(x) \qquad (1)$$

The signal *x* is supposed to be a stochastic variable with density of Probability $p_x(x)$ and a function characteristic P_x . Error will be uniformly distributed for arbitrary input distributions if and only if:

$$P_x\left(\frac{k}{q}\right) = 0 \qquad (2)$$

where *k* is an integer except zero. The idea consists then in adding to the signal a non subtractive dither e with probability density p_e independent of the signal input *x* [4] before the entry of the quantizer of the sigma-delta modulator. The quantizer output in a non-subtractively dithered quantizing system is given by :

$$w = q(x + e) \qquad (3)$$

so that the total error is :

$$\varepsilon = x - q(x + e) \qquad (4)$$

If the two uniformly distributed dither signals e_1 and e_2 are independent of the input signal x and of each other, adding them together creates a new dither signal whose PDF (Probability Density Function) is the convolution of two rectangles. This kind of dither is of very great practical interest. It meets the condition (2).Therefore, we will choose a triangular dither for our application. The triangular PDF distributed p_e is given by convolution of p_{e_1} and p_{e_2} witch p_{e_1} and p_{e_2} are respectively the rectangular PDF distributed of e_1 and e_2 . These references [3][4] show that only with a triangular distribution dither, the average and the variance of the quantification total error are independent of the input signal of the quantizer using a non subtractive dither[4].

3.2 Simulation and result

To the model simulink already simulated we propose to add a non subtractively dither *e* of triangular distribution (addition of 2 RPDF dither) of hopeless average and weak variance (of the order of 0:06). The model of figure 1 will be replaced by the one of figure 5.

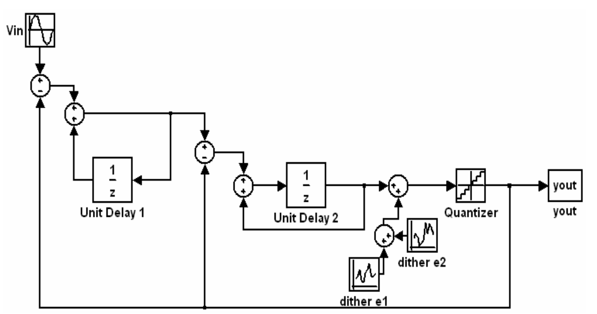

Fig. 5 Model Simulink with dither

The curves representing the power density spectrum of sigma-delta modulator before and after the addition of a dither are given by figure 6.

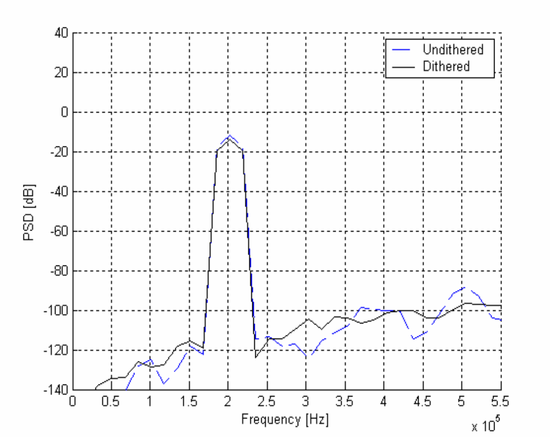

Fig. 6 Power density spectrum of sigma-delta modulator output with dither quantization.

figure 6 shows that there is an improvement of the specter reconstituted after the addition of dither. There is also reduction of Differential Non Linear error (DNL) and Integrals Non Linear error (INL) [5]. Dither is used in nonlinear feedback control systems to achieve linearization or approximate linearization. One also notices that the introduction of non subtractively dithered permits a light reduction of signal to noise ratio (SNR). This last is the price to pay to get the elimination of the nonlinearity of ADC converters. In our application the SNR is decreased by 3 dB by adding a non subtractive dither before the quantizer [6] [7] [8].

4. Conclusion

In this paper, a new approach to optimize a sigma-delta modulator has been proposed. The theoretical ideas about adding dither before a quantizer of the sigma-delta modulator that has been developed in this work. Simulation results for the GSM system indicate that the use of this technique is very efficient to decrease the distortions introduced by the quantizer .Frequently, the used dither will achieve linearization or approximate linearization of sigma-delta modulator. However, this technique can provoke a less reduction of Signal to Noise Ratio (SNR) for the GSM system. This last is the price to pay in order to increase the linearity of the sigma-delta modulator.

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