Design of DDSM Modulator without Unwanted Tones with Effective Random Dither

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ABSTRACT:
The output of a Digital Delta-Sigma Modulator (DDSM) is always a periodic signal and the input is constant. The frequency synthesizer is commonly used due to its flexibility and convenient frequency adjustment. This paper presents a new method to implement random dither in MASH 1-1-1 modulator. There are two different methods to remove unwanted tones from the MASH modulator output, which are deterministic and random. Deterministic methods include setting the initial conditions of the internal registers, using the first-module quantizer, and the HK-MASH structure. On the other hand, the random method involves applying a random dither signal to the circuit in different ways to eliminate the periodic behavior of the output string. Deterministic methods are not useful for most practical applications. In most practical applications, dither signal is a suitable method. In this article, the disadvantages of different dither methods will be investigated and a new vibration method for MASH sigma-delta modulators for use in fractional frequency synthesizers will be presented.

KEYWORDS: Fractional frequency synthesizers, Digital sigma delta modulator, dither signal, undesirable tones.

1. INTRODUCTION

In digital PLL circuits, fractional synthesizers, and data converters, the technique of quantization noise shaping via sigma-delta modulation is widely used. In the digital sigma delta modulator, the discrete time input is oversampled and quantized to produce an output signal with lower accuracy and reduce the quantization noise power in the desired frequency band.

The block diagram of a first-order digital sigma-delta modulator is shown in Fig. 1. The functions F(z), G(z) are the forward and feedback path filter functions, respectively, and Q(.) is the quantizer. The signal and noise conversion functions of this modulator STF(z), NTF(z) are expressed by the following relationship.

$$STF(z) = \frac{F(z)}{1+F(z)G(z)}, NTF(z) = \frac{1}{1+F(z)G(z)} \qquad (1)$$

Therefore, the z domain model of the modulator output is expressed by equation (2).

$$Y(z) = STF(z)X(z) + NTF(z)E(z) \qquad (2)$$

where E(z) is the quantization noise which is modeled as white noise.

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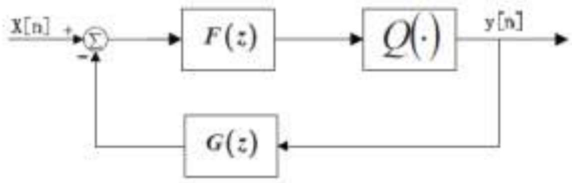

Fig. 1. Block diagram of first order DDSM modulator.

Fig. 2 shows a block diagram of a third-order MASH digital sigma-delta modulator, which is constructed from the cascade connection of three first-order blocks and a noise shaping network. In this structure, the output of each stage is entered into the noise shaping network, where the quantizer noise will be modulated and removed with the D(z) filter. The modulator output relationship is as follows.

$$Y(z) = STF_{out}(z)X(z) + NTF_{out}(z)E_3(z) \quad (3)$$

where $STF_{out}(z)$ and $NTF_{out}(z)$ are general signal and noise transformation functions expressed by the following relation.

$$STF_{out}(z) = STF_1(z)D_1(z), NTF_{out}(z) = \prod_{i=1}^{3} NTF_i(z) \quad (4)$$

where 〖$STF_i(z)$ and $NTF_i(z)$ are the i-th stage signal and noise transformation functions. In this article, the MASH 1-1-1 modulator signal and noise conversion functions are considered as follows.

$$F_1(z) = F_2(z) = F_3(z) = \frac{1}{1-z^{-1}}, G_1(z) = G_2(z) = G_3(z) = z^{-1}, D_1(z) = 1, D_2(z) = D_3(z) = -(1-z^{-1}) \quad (5)$$

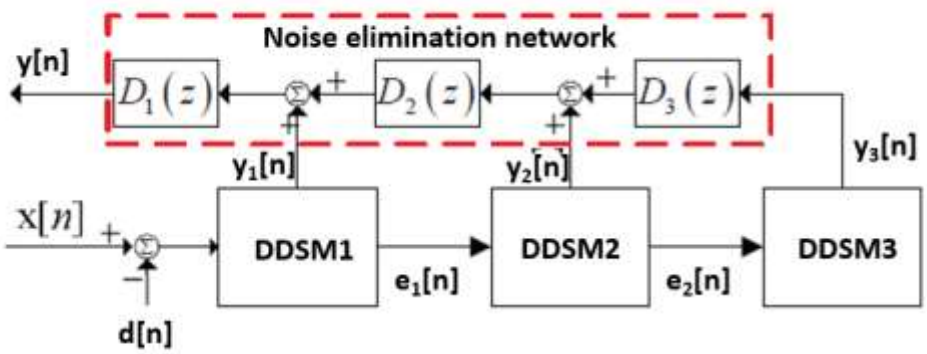

Fig. 2. MASH 1-1-1 block diagram.

2. REDUCTION OF UNDESIRABLE TONES IN MASH MODULATORS

Some important methods that have been proposed to reduce unwanted tones in MASH modulators are:

- Prime Modulo Quantizer: In these MASH modulators, the initial conditions of the internal registers must be chosen correctly. Hosseini and Kennedy showed that the length of the output string is equal to the quantization level M, if the value of the modulus of M is prime. This design reduces the range of undesirable tones. But quantizers with prime number modulus are more complicated than power-2 quantizers. Also, the initial condition of the quantization error in the modulator must be zero. [1,2]
- -Output feedback: Lie provides a new method for randomizing the output string of a digital sigma-delta modulator. In this method, the output of the MASH modulator is entered into a digital processor and processed. The output of this accumulator storage provides transportation to the next stage. [3,4]
- -Modified feedback error modulator (HK): Hosseini and Kennedy presented a new method to increase the string length of the MASH modulator, which uses a feedback loop. In this MEFM MASH each hardware has an additional accumulator. Therefore, MASH modulator hardware will increase. [5,6]
- -Shaped accumulated dither: In this method, a one-bit dither signal will be added to the input of the modulator

to reduce unwanted tones. This problem can be solved by using filtered vibration. In this article, it is proposed to add dither to the other stages of the MASH modulator to obtain the shaped dither. [7,8,9]

3. PROPOSED METHOD FOR APPLYING DITHER

If a dither signal from a pseudo-random source is added to the input of the third stage to reduce low-frequency quantization noise, the amplitude of the unwanted tones will not be reduced unless the dither string length is very large. But if the dither signal is applied to another path, it can greatly reduce the range of unwanted tones. There are a few different ways to apply dither. In these paths, a compromise must be considered between the loss of the alternating mode of the string and the increase of low frequency noise. In this article, the best way to add dither in MASH 1-1-1 modulator is shown in Fig. 3. This dither can be applied to the input of the last two stages of the modulator. This will not increase the circuit hardware. In this circuit, the three-bit output has the following relationship.

$$Y(z) = X(z) + \frac{1}{M} D(z)((1 - z^{-1})^1 + (1 - z^{-1})^2) + (1 - z^{-1})^3 E_3(z) \quad (6)$$

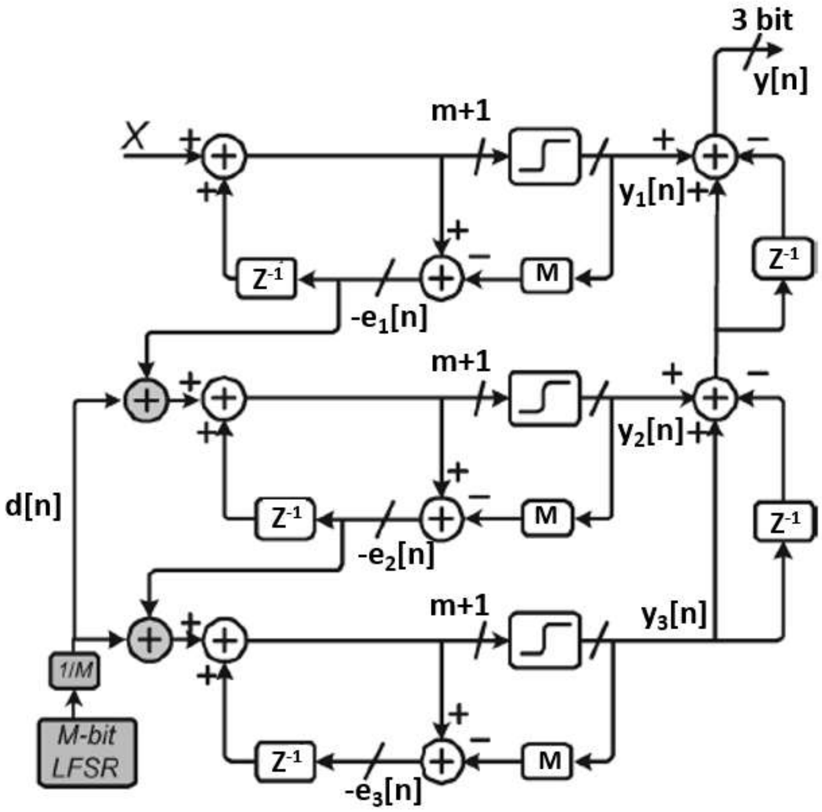

Fig. 3. MASH 1-1-1 sigma-delta modulator with recommended effective dither signal.

In this section, an optimal method of applying dither to MASH digital sigma-delta modulators is presented in order to reduce the undesirable tones of the output spectrum. In this method, the digital dither signal is applied according to Fig. 4.

In this structure, high frequency noise shaping is done and undesirable tones are reduced. The output spectrum of MASH 1-1-1 modulator with dither signal is shown in Fig. 5. The vibration signal is shaped and the low frequency noise is reduced.

4. CONCLUSION

An optimal dither structure is proposed for MASH 1-1-1 sigma-delta modulator in fractional frequency synthesizers. In this method, a simple pseudo-random string generator is used to randomize the output spectrum without increasing the power and occupied area. The dither is not dependent on the sigma-delta modulator input and its shaping is done properly. The synthesizer output phase noise at high frequency does not have undesirable tones; Therefore, the loop filter can be designed with fewer restrictions.

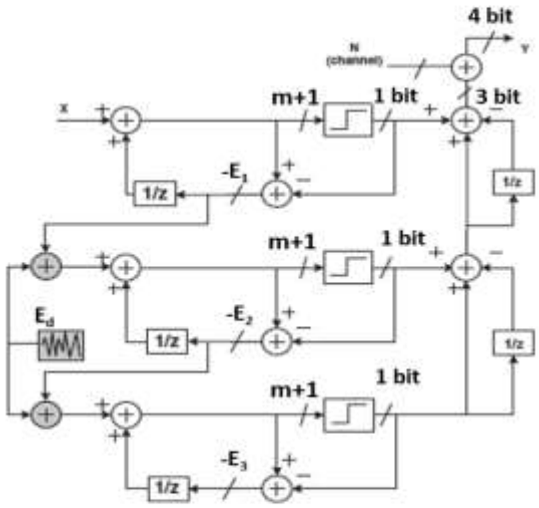

Fig. 4. Proposed dither method to MASH 1-1-1 sigma-delta modulator

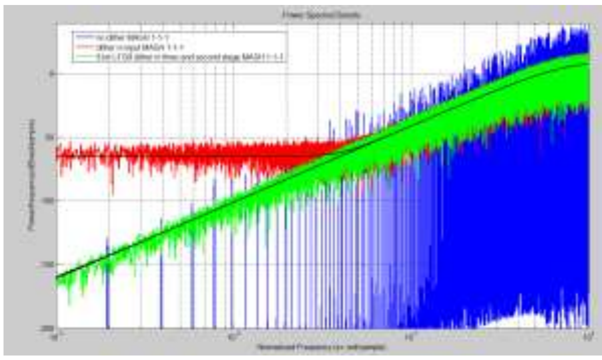

Fig.5. MASH modulator output spectrum 1-1-1 without dither, with dither at the input and 8-bit dither at the input of the second and third stage.

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