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Research paper

Design of Digital up Converter for Solid-State Transmitters

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Abstract

Digital Up converters (DUC) are used in communication system for the baseband processing and it is implemented in solid-state transmitters. The design of DUC is the most significant block in every digital communication system. The input signal applied that has to be upsampled and mixed with the carrier signal that is generated from Direct Digital Synthesizer (DDS). In this work processing is done using filters like Cascaded Integrator Comb (CIC), Compensator-FIR (CFIR), Pulse-Shaping Finite Impulse Response (PFIR), Half Band Filters (HBF) and Finite Impulse Response (FIR) filters are being used as interpolation filters. It is also explained that HBF's are preferable over CIC filters. This paper focuses on effective implementation of the DUC in order to reduce the resources for the optimisation of the design.

Keywords: *Digital Up Converter (DUC), solid-state transmitters, Direct Digital Synthesizer (DDS), Cascaded Integrator Comb (CIC), Compensator-FIR (CFIR), Pulse-Shaping Finite Impulse Response (PFIR), Half Band Filter (HBF), Finite Impulse Response (FIR).*

1. Introduction

The DUC is used to convert the baseband signal to Radio Frequency (RF) signal. DUC is also called as complex DUC. Since it has two identical paths, one is Inphase input and another path is Quadrature input. The structure of DUC mainly depends on the required conversion ratio. The conversion ratio of WiMAX (Worldwide Interoperability for Microwave Access) system is in the order 8 to 10. DUC will be constructed using FIR filters because of its low conversion rates. But for higher rate conversions other filters are used[2].
In communication system DDS can be implemented in modulator as well as demodulator. DDS is flexible thus, can be used for signal generator in software radio. DUC is implemented in transmitter part. In weather radars solid state transmitters are preferably used. These transmitters operate at much lower voltages. Because of this they are very useful in airborne, spaceborne and phased array applications. They operate in wider bandwidth and also offer better efficiency, lower operating life and higher reliability. In order to transfer data from one ground station to another ground station in a different location through satellite, DUC is preferred as it can be used in the transmission of satellite signals. [1].

2. Digital up Converter

DUC is the one of the essential block for transmission of RF signal. In digital processing DUC is the most well known sample rate conversion process and also an important component of digital front-end circuits of RF system. The block diagram of Digital Up Converter is shown in Fig. 1.

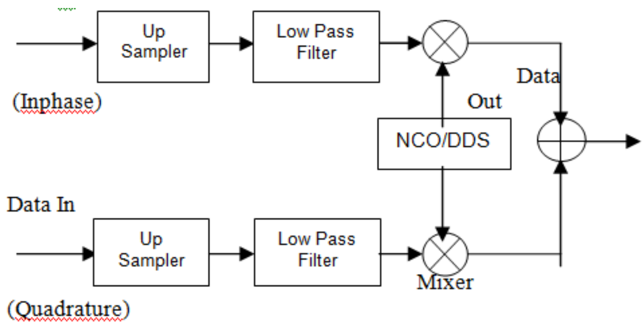

Fig. 1: Block Diagram of Digital up Converter (DUC)

The DUC process mainly comprises up sampler, low pass filter, mixer and NCO/DDS. The main function of DUC is to translate the baseband signal to a passband signal. Low pass filters present performs interpolation in order to increase the sample rate. Along with the increase in the sample rate, filtering is performed to acquire spectral shaping. Mixing is performed by the mixer for the sake of shifting the signal spectrum to the desired frequency level.

2.1. Digital up Converter with PFIR, CFIR and CIC filters

The two baseband signals Inphase and Quadrature phase signals received by DUC are given to the interpolation filters. For matching desired spectral profile, pulse shaping is performed by first filter. The second filter pre-emphasises the passband data to compensate for the passband droop introduced by CIC filter. Finally the output is given to the CIC filter and that is to be mixed with the signal provided by DDS. Other than these operations these filters perform interpolation. Fig. 2 shows the block diagram of DUC with PFIR, CFIR and CIC filters.

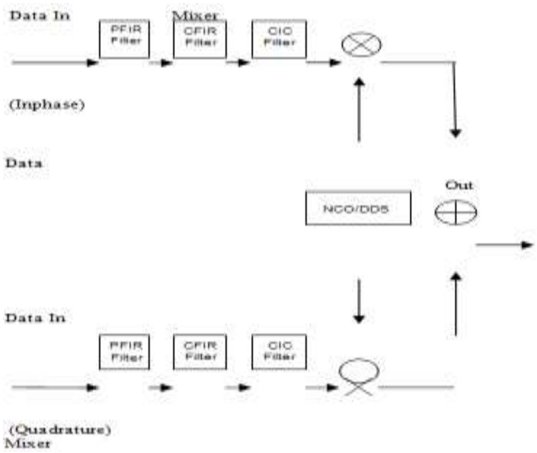

Fig. 2: Block Diagram of DUC with PFIR, CFIR and CIC filters

1) PFIR Interpolation Filter: The number of taps of PFIR filter is determined by number of channels and PFIR interpolation. PFIR interpolation factor is normally 2, 3, 4 or 5. For an interpolation of 1or 2 the PFIR has symmetrical taps. In order to filter and shape the waveform PFIR filters are selected. These filters increase the sample rate by a factor of 2 and also perform transmitter nyquist pulse shaping.

2) CIC and CFIR Interpolation Filters: A CIC filter performs interpolation efficiently. For interpolation these filters cascade several comb filters with an up-sampler and several integrators. In CIC filtering rate change is always involved. The parameters that affect the frequency response of CIC filter is rate change, the number of stages and the differential delay of the comb unit. Since it has disadvantage of passband droop which is not suitable for most applications. So it is essential to cascade it with a FIR filter for the compensation of this droop with an inverse sync like response. Compensation filter includes an interpolation step of two, because of which the number of stages may reduce as required in the CIC filter. The flowchart shows the operation of DUC process using PFIR, CFIR and CIC filter is shown in Fig. 3.

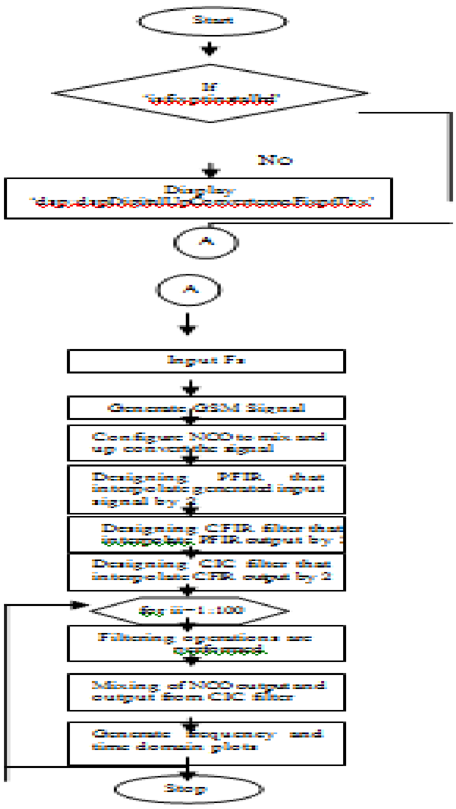

Fig. 3: Flowchart of DUC with PFIR, CFIR and CIC filters

3. Proposed Methodology

3.1. Digital up Converter with Half Band Filters and FIR Filter

The cascade of CIC and FIR interpolation filters eliminate the droop but it increases the resource consumption as well as area occupied. So in order to overcome this drawback HBF's

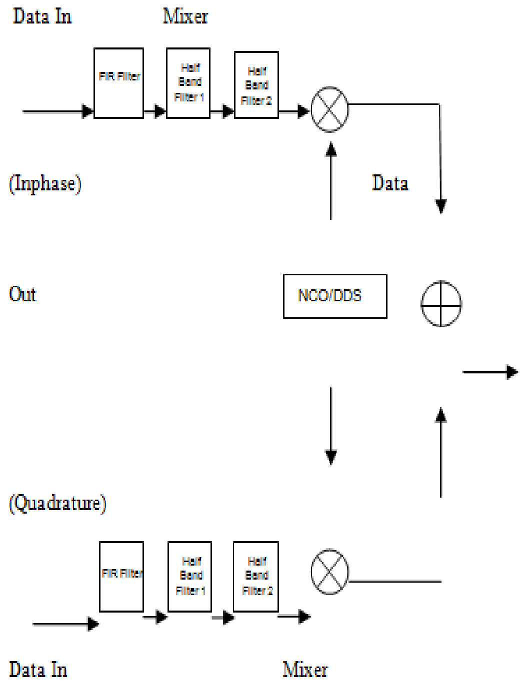

Fig. 4: Block Diagram of DUC with HBF's and FIR filter

Are replaced with cascaded filters. The block diagram of DUC with HBF's and FIR filter is shown in Fig. 4.

1) FIR Interpolator Filter: FIR filters can be defined as a filter having an impulse response of finite period. These filters are normally used in multirate applications. Number of filtering is performed in DUC either separately or in a single filter comprising set of filters. FIR filter used in DUC is to perform some functions like spectral shaping and also it acts as anti-aliasing filter after upsampling.

2) Half Band Filters (HBF): Half Band filters are very efficient type of filters having a special case of Nyquist filter when interpolation factor of the filter is 2. These HBF's reduces the bandwidth of the signal by half. Half of the coefficients of the HBF's are zero. HBF can also be used to efficiently implement synthesis or analysis filter banks. There are two different set of HBF's where, one acts as filter and another acts as interpolator. The first filter reduces the sampling frequency and also improvises the attenuation factor of the low frequency signal whereas second filter carries out interpolation process.

3) Mixer and Direct Digital Synthesizer (DDS): Multiplication of vector of baseband signal with a vector of sinusoid carriers is the basic function of DUC. This function is a vector dot product for channels that is modulated onto carriers. Although the implementation of the dot product normally involves serial operations, up-mixing directly uses a dot-product. In up sampling cosine portion leads the sine portion.

DDS is also known as NCO that generates random signal from a fixed frequency reference signal. DDS consists of a phase accumulator, amplitude converter, Digital to Analog Converter (DAC) and a filter. Under digital signal processor frequency, phase and amplitude of DDS can be varied. This is the main advantage of DDS [3]. The flowchart shows the operation of DUC using HBF's and FIR filter in Fig. 5.

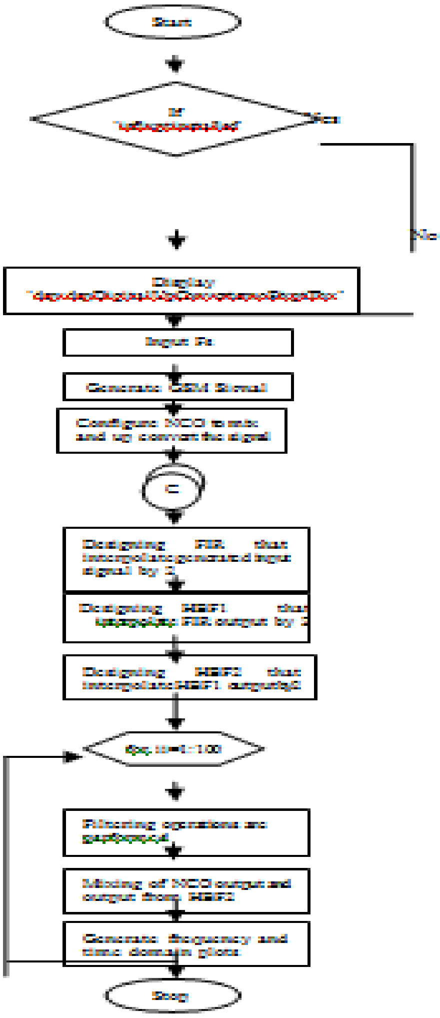

Fig. 5: Flowchart of DUC with HBF's and FIR filter

4. Results and Discussions

4.1. Output of DUC with PFIR, CFIR and CIC Filters

DUC with interpolation filters such as PFIR, CFIR and CIC is designed using MATLAB. The baseband signal frequency used is of 10MHz with sampling frequency of 10.1MHz and interpolation factor is of 8. NCO output obtained is 64MHZ is shown in the Fig. 6. DUC output is 80MHz is shown in the Fig. 7.

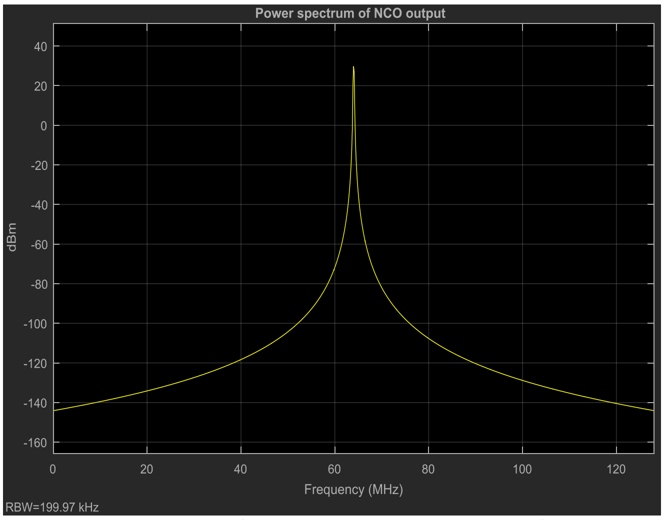

Fig. 6: NCO output of DUC using PFIR, CFIR and CIC filters

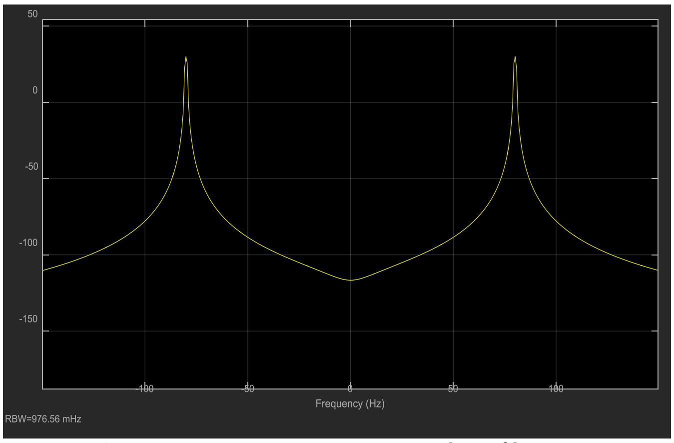

Fig. 7: DUC output using PFIR, CFIR and CIC filters

4.2. Output of DUC with HBF's and FIR Filter

Matlab code for DUC with HBF's and FIR filter is written. Input frequency applied is of 10MHz and sampling frequency is 10.1MHz. An interpolation factor is 8 that is interpolation factor of HBF is 2 and FIR filter is 2. NCO output obtained is 64MHz as shown in Fig.8. DUC output obtained after interpolation and filtering is 80MHz is as shown in Fig.9.

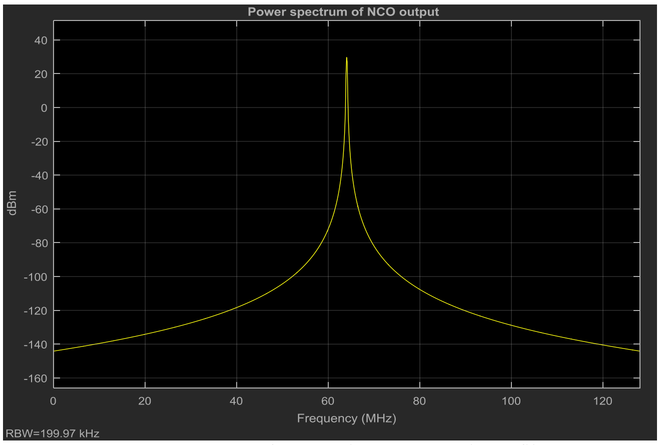

Fig. 8: NCO output of DUC using HBF's and FIR filter

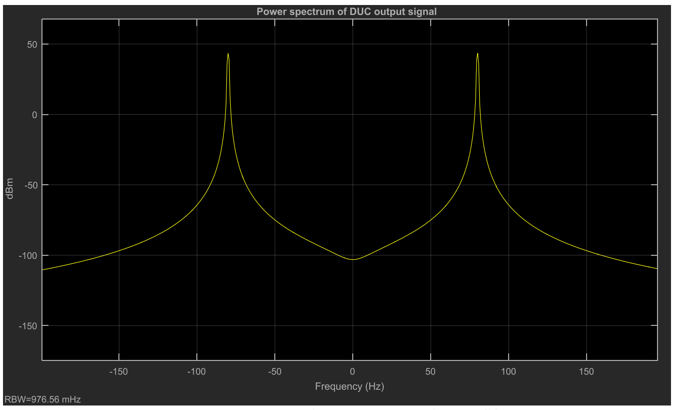

Fig. 9: DUC output using HBF's and FIR filter

5. Conclusion

Implementation of DUC using PFIR, CFIR and CIC interpolation filters is done using MATLAB. In this process there are three subpulses, two H and V polarisation and two I and Q samples are present. Totally it has twelve channels. Because of this CIC filters consumes more resources. In order to overcome this disadvantage HBF's are used and designed using MATLAB. In HBF's since their alternative coefficients are zero and its interpolation factor is two, it consumes less resources. Therefore HBF's are preferable and it significantly saves more logic than CIC filter.

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