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Frequency Conversion using Phase Locked Loop scheme for Medical Implantable Devices.

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ABSTRACT

The objective of this anticipated work is to examine various techniques to up-convert a base band signal into radio frequency signals, and to explore the sensible tribulations encounter in an offset phase locked loop design by realization. Phase locked loops are commonly used in radio transmitters and receivers to generate accurate RF signals from a low-frequency reference signal. This will emphasize some of the tribulations and strength of various up-conversion schemes, and suggest offset-PLL architecture to gratis from many of those tribulations. An offset-PLL is often used in mobile communication systems where the required level of out of band transmission is tough and the use of super heterodyne up-conversion cannot be used due to spectrum or bandwidth requirements. However a drawback of an offset-PLL is the high locking time; this can render the offset PLL useless in TDMA communication systems. This problem among others has been studied theoretically as well as practically on an actual implementation of an offset-PLL for mobile communications.

Keywords: frequency conversion, locked loop, offselt-PLL

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INTRODUCTION TO UP-CONVERSION

Up-conversion is the process of transforming base band signal to pass band signal at a higher frequency. This can be described as a transfer of the signal in the frequency province as shown in figure.1. In a digital transmission system[1], the binary sequence of information available in the digital system is transmitted and converted to an analog representation. The resultant output waveform is called a baseband signal. The baseband signal is typically produced by a signal processor or analogous digital circuit is designed to encode the data and to add error correction information. In a classic contemporary radio system, the signal is transmitted and is usually created digitally in baseband form. A baseband signal is a signal which carries the desired information centered on zero in the frequency domain. Transforming baseband signals over air is difficult and hence the baseband signal is converted to a higher frequency signal by up-conversion process[2].

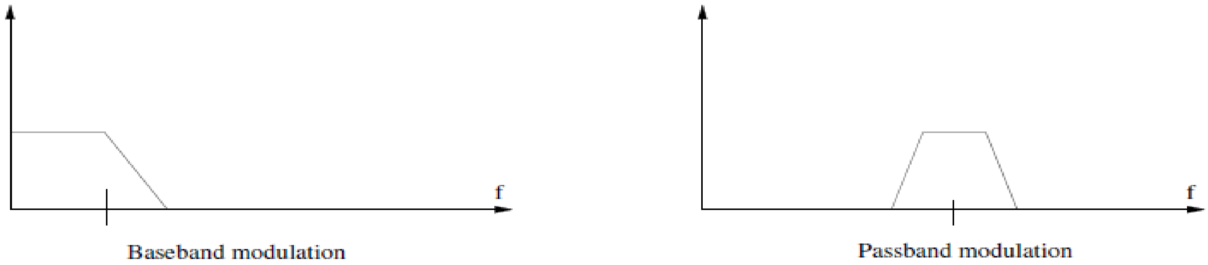

Figure 1: Baseband vs. Pass band signal

Mathematically, up-conversion is is considered as the process of amplifying baseband signal by a carrier frequency, which is considered as local oscillator (LO).

Nonlinearities

The main problem in all up-conversion technique using amplification process causes nonlinearities in the component which disturbs the entire stability of the system[3]. Hence if a sinusoidal signal is passed through a nonlinear component, harmonics will be created and the harmonics generated is as given in the below equation.

$$RF_{in} = Sin(wt)$$

One widespread technique to nullify the presence of even harmonics is to use a double balanced mixer. After eliminating the harmonics the RF signal present in the system will then become as

$$RF_{out} = \alpha_1 \sin(wt) + \alpha_3 \sin(3wt) + ...$$

Up-conversion schemes

To attain a sparkling transmission of baseband signals there are two types of up-conversion process. They are[4]

Homogenous up-conversion

Homogenous up-conversion is the process of converting the baseband signal directly to the desired frequency without any intermediate frequency.

Heterogeneous up-conversion

Heterogeneous up-conversion is the process of converting the base band signal directly to the desired frequency by using one or many intermediate frequencies during the up-conversion process.

Direct digital synthesis (DDS)

Direct digital synthesis is a totally digital elucidation which creates the most wanted output signal without analog baseband signals or intermediate frequency signal.

Even though each method aim is to achieve perfect up-conversion and the weaknesses of different architecture cannot be ignored. In the following chapters, the different architectures will be described and analyzed.

Transmitter architectures

Selecting the precise transmitter architecture is very imperative, and can be the difference between product success and failure. There are numerous types of up-conversion methods and it is required to optimize and utilize the available spectrum restricts the designers choice between different architectures. This section will emphasize several features and the functions of the most common up-conversion methods.

Homodyne up-conversion

Homodyne up-conversion implies that the baseband signal is directly transformed to the preferred frequency without any intermediate frequency. In order to stay away from signal corruption by aliasing, the baseband signal must be represented as an intricate valued signa[5]. The true value is referred to as the in-phase in direct phase, I component whereas the imaginary value is referred to as the quadrature-phase, *Q* component. The output signal is described by:

$$RF = I.Cos\omega_{LO} + Q.Sin\omega_{LO}$$

The baseband signal can either be directly converted to the desired frequency by a complex Mixer (IQ-mixer), or by two separate mixers and a combiner, as seen in Fig.2.

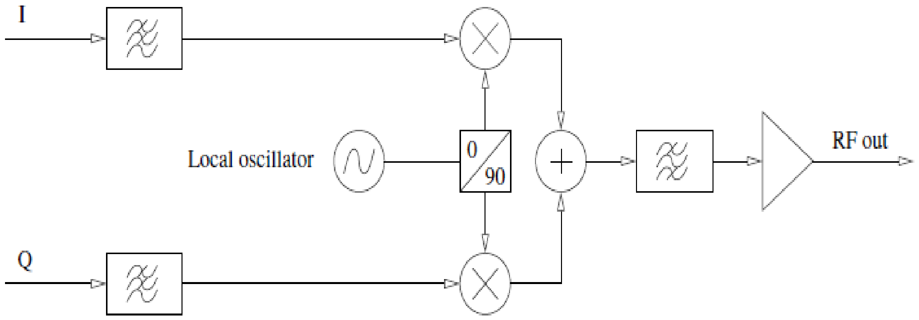

Figure 2: Homodyne transmitter

The baseband signals are frequently considered to be as a digital low-pass filter in the signal processor or as a DAC incorporating a digital noise shaping filter[6]. This ensures that the range of the baseband signal inward bound to the mixer has a clean spectrum, free from unwanted harmonics.

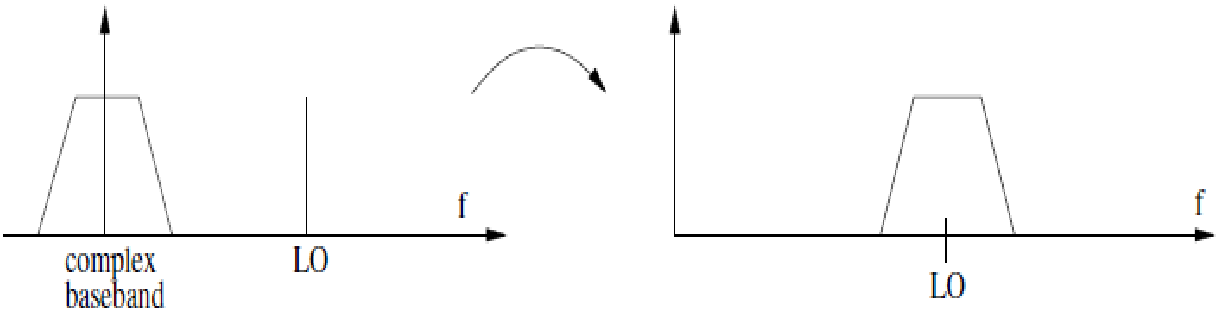

Figure 3: Homodyne up-conversion

Heterodyne up-conversion

Unlike homodyne up-conversion, heterodyne up-conversion uses an Intermediate Frequency during up-conversion. The baseband signal is first transformed to an intermediate frequency by modulating the frequency of the tunable oscillator circuit, or the intermediate signal is formed directly by a digital signal processor. The intermediate frequency is then filtered by a special band-pass IF-filter, often a very narrow crystal or ceramic filter. This procedure ensures that the intermediate frequency has a clean spectrum before it is fed into the mixer. Usually the intermediate frequency has a low frequency compared to the radio frequency[7]. The resulting RF signal is described by:

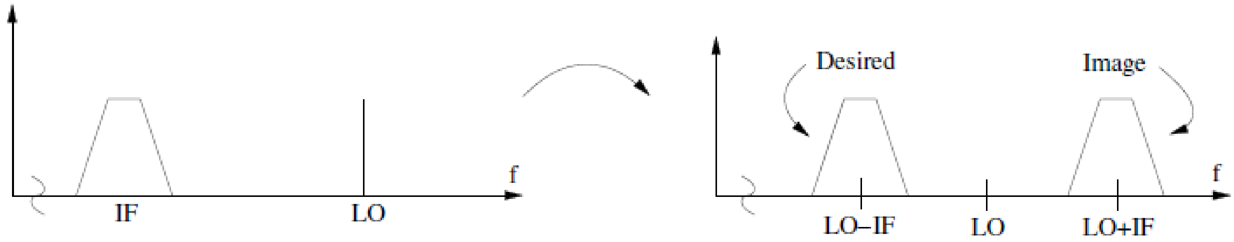

Figure 4: Heterodyne up-conversion

Due to signal intonation to the intermediate frequency, the intermediate frequency has to be filtered to get a clean spectrum by using narrow band pass filter before it is fed to the mixer. The ensuing architecture is realized as follows:

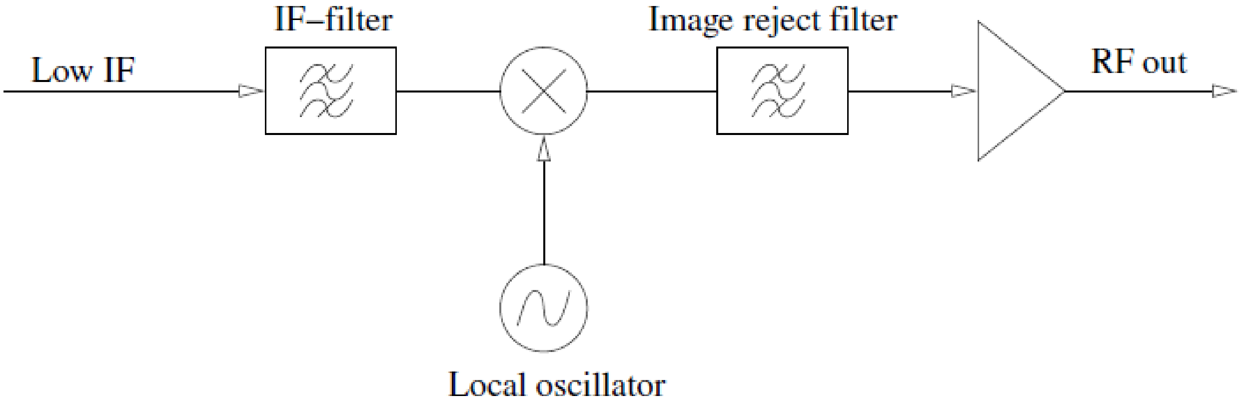

Figure 5 Heterodyne transmitter

The intermediate frequency and corresponding filter are frequently in the range of frequency from 10.7 MHz to 71 MHz depending on the existing design. The assortment of the intermediate frequency is decisive and is discussed later in this section. The intermediate frequency is real-valued, in distinction to the complex valued baseband signal used in homogenous up-conversion. This allows the use of a standard mixer instead of an IQ-mixer[8], and will thus reduce the unit cost and intricacy.

Heterodyne up-conversion is the most used method of converting the baseband signal. The intermediate frequency is typically formed by modulating a fixed frequency modulator, or by accumulating the desired baseband signal in the PLL feedback loop. Engineers have continued to improve the method and as a effect a customized architecture has been developed.

This architecture is called superheterodyne up-conversion and is a sub class of heterodyne up-conversion and is even more popular than regular heterodyne up-conversion. The main difference between super heterodyne up-conversion and heterodyne up-conversion is the use of two or more intermediate frequencies during the up-conversion process. The structure is presented in figure 6. This allows the designer to use a higher frequency on the final intermediate frequency and thus position any image out of a large band.

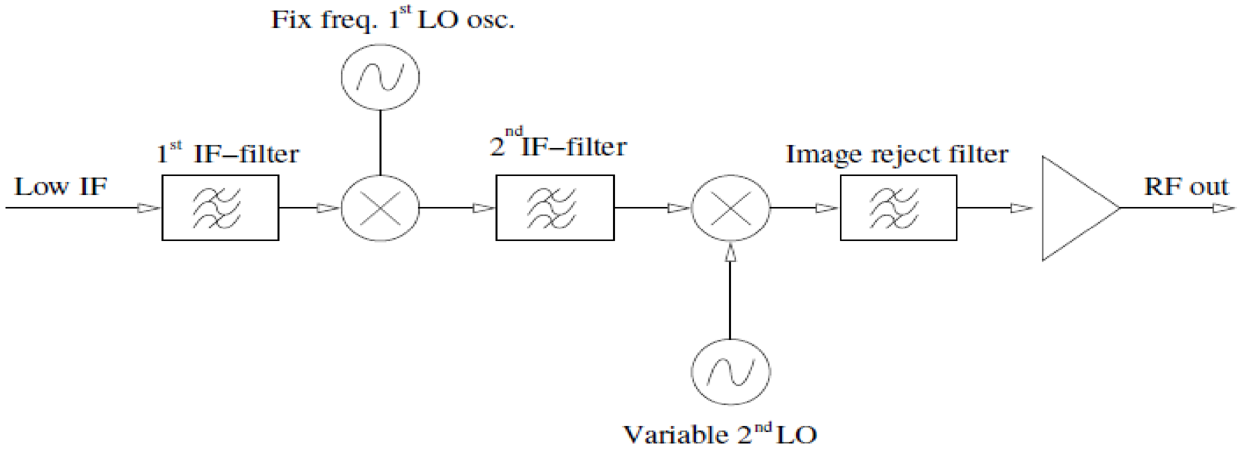

Figure 6: Superheterodyne transmitter

Heterodyne and super heterodyne up-conversion is the mostly used up-conversion technique and has certain drawbacks[9]. The drawback of heterodyne up-conversion is that it is hard to know precisely the variation of the transmitted signal, unless the low intermediate frequency is produced by a signal processor or its equivalent. The frequency components in the different stages of up-conversion are presented in figure 6. The first intermediate frequency gw3FN is created by a signal processor and then multiplied by the carrier frequency of the first fx-frequency local oscillator. The result of the multiplication is the desired product consisting of the difference term. Here the desired frequency component is selected by a narrow band pass filter. The method is then repeated and finally the desired frequency component is selected by an image reject band filter at the output of the modulator. This filter can both be of a band-pass or a low-pass type.

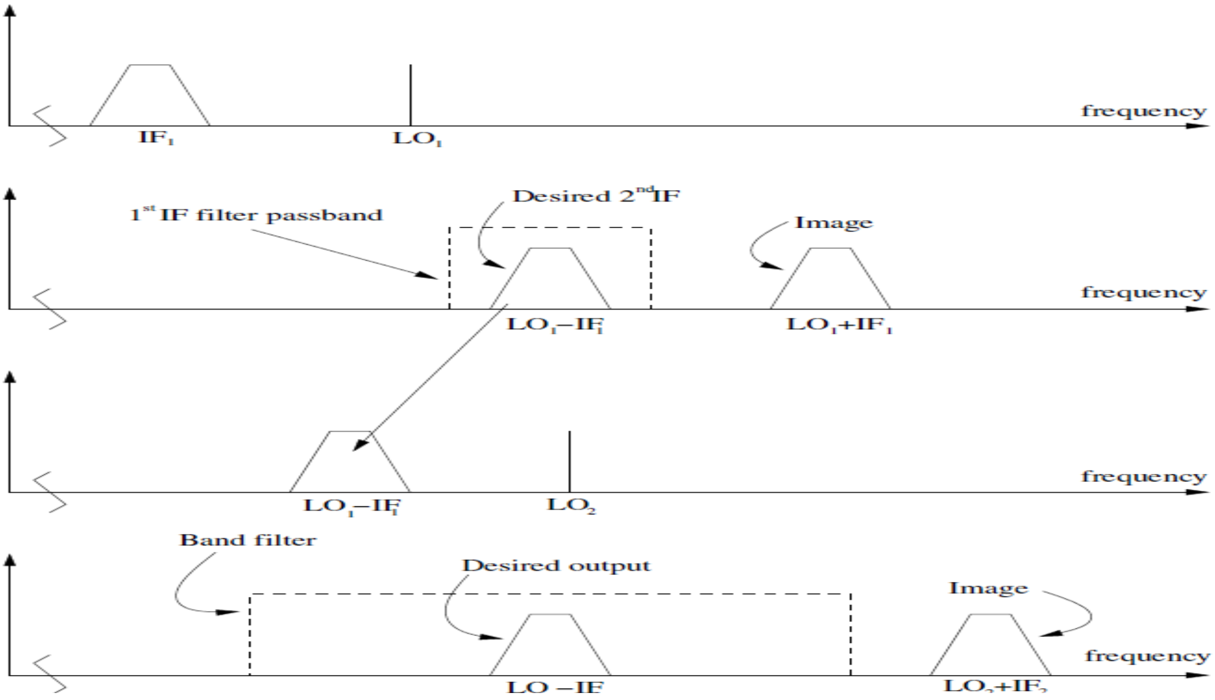

Figure 7: Spectrum in the different stages in super heterodyne up-conversion

Direct Digital Synthesis

Direct Digital Synthesis, *DDS*, is a totally unusual approach to generate a modulated carrier at radio frequencies. Unlike both homodyne and heterodyne up-conversion methods, it generates the radio frequency signal directly from digital modulation information. Besides a digital to analog converter and a modernization filter, the DDS is absolutely digital component.

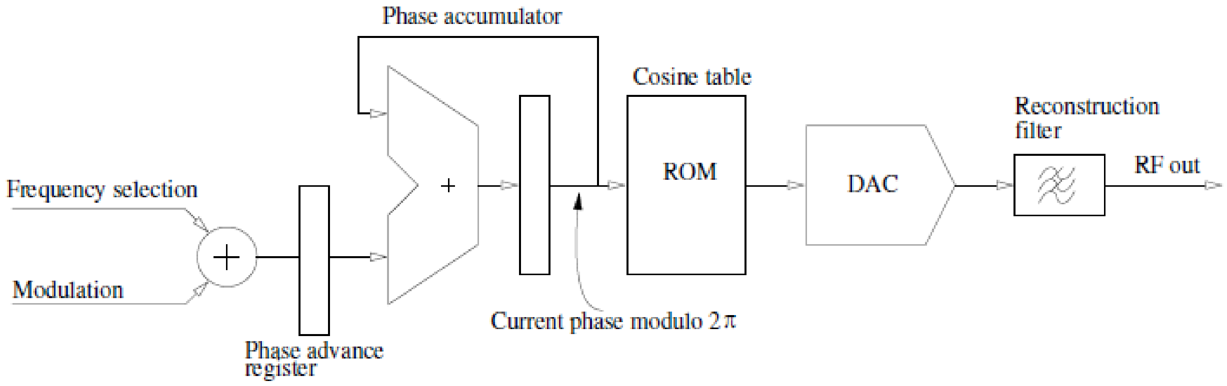

Figure 8: Schematic view of a DDS

The basic theory of direct digital synthesis is to employ a phase accumulator concept to make a directory for sine or cosine table and is stored in a memory. The sine or cosine table stored in the memory device is then fed to a digital to analog converter and later to a reconstruction filter to smoothen the radio frequency signal. The computation of the contents of both the frequency register and the modulation register is called phase advance. The desired output frequency is derived from the clock frequency and the phase advance every clock cycle. Figure 9 illustrates the main waveforms of direct digital synthesizer. The upper waveform illustrates a modulated output signal. The carrier frequency is selected by changing the stationary phase advance. In this example the stationary phase advances. Then modulation with a deviation is added to the stationary phase advance. This modulation is shown as the ripple of the line in the lower figure.

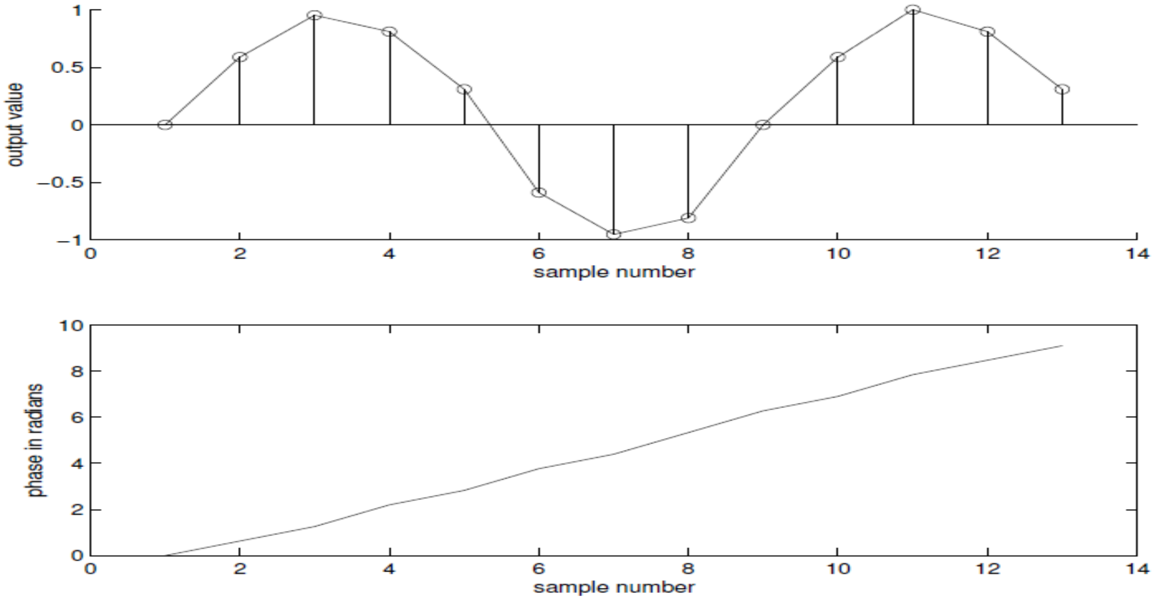

Figure 9: Waveforms in a DDS

As described in the previous section the frequency assortment is done by amplifying the phase by a steady state value for each clock cycle and the resultant signal is then added or subtracted with the desired phase modulation to obtain the desired output frequency range. In this manner, the resultant output frequency can be tuned and modulated without changing the clock frequency of the DDS.

Architecture analysis

As mentioned earlier the architecture described in the previous section has its own drawbacks. In the following pages the most occurring drawbacks of the three up-conversion methods will be raised and discussed.

Homodyne up-conversion

Homodyne architectures will endure from nonlinearities in the mixer which affects the stability of the system. Due to the nonlinearity present in local oscillator and the base band signal harmonics exists and the same is illustrated in figure 10. Harmonics of the local oscillator can easily be filtered out by an external low-pass filter because they have at least one octave higher frequency. On the other hand, baseband harmonics are a greater problem since they cannot easily be filtered out. They can however be abridged by careful mixer design or mixer selection. But generally it is firm to create a high performance mixer covering a large band, i.e., the avionics band1 or a military VHF band.

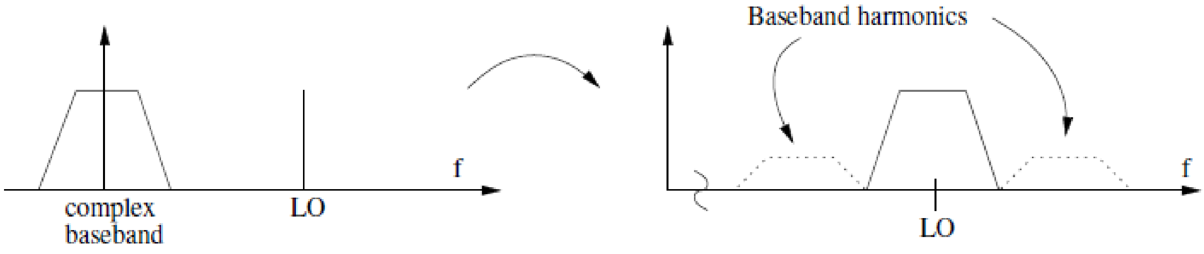

Figure 10: Nonlinearities in a homodyne up-converter

Homodyne up-conversion requires larger amplitude and phase accuracy over a larger frequency band of frequencies. The mixer imperfections can roughly be corrected totally by a digital correction filter in the DSP

Heterodyne up-conversion

Due to the non-linear behavior of a real mixer, harmonics at intermediate frequency range and the harmonics in local oscillator persist. All of the intermediate frequencies will mix with the local oscillator harmonics and produce a larger amount of amalgamation products called spurs. The ensuing radio frequency signal will contain both sums and difference frequencies as shown above. The frequency components generated consists of summation of a local oscillator harmonic and an intermediate frequency harmonic which can easily be filtered out by a low-pass filter due to its high frequency range. The frequency components which arise from difference products will however create signals which lie in the band of interest.

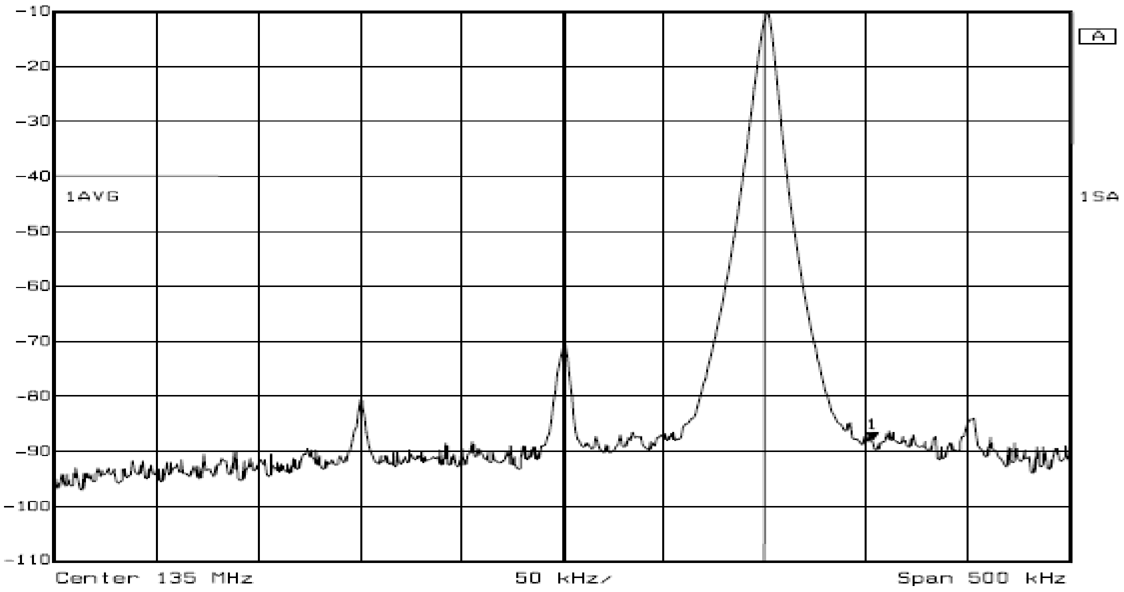

Figure 11: Measured output spectrum

In figure 11 shows the superfluous frequency components and are clearly visible. The superfluous frequency components that appear in the spectrum are referred to as spurs or spurious frequency components. This spurs are raised from the nonlinearities in the mixer as mentioned before.

A pragmatic model of any real mixer is shown in figure 12 and is distinctive for heterodyne up-conversion and is hard to avoid if the system is designed to cover a large frequency band. The subsequent outcome was created by Matlab simulations for the previous example using the mixer model in figure 12. The precise amplitude of the spurs are as shown in figure 13 which cannot be determined as they are dependent on the bandwidth of the mixer and the attenuation of high frequency harmonics in the mixer. In figure 13 the amplitude of the harmonics is inversely proportional to their order.

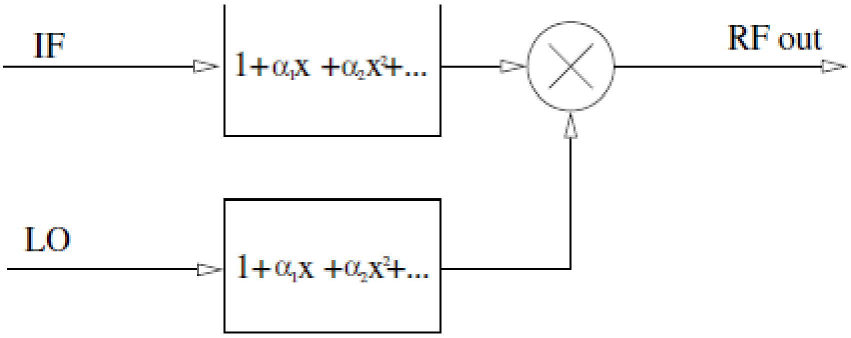

Figure 12: A realistic model of a mixer

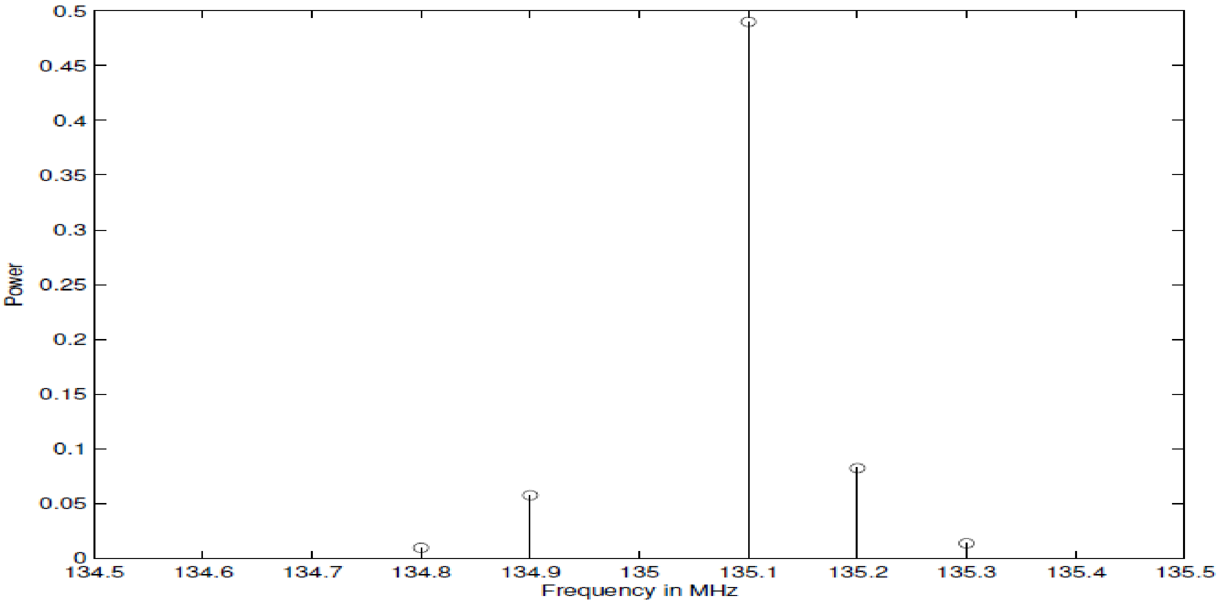

Figure 13: Calculated output spectrum

Every spur created by harmonics are up to the 11th order and are calculated using Matlab/SIMULINK. In order to conclude the spectrum of frequency for the occurrence of the number of spurs for a certain range of frequency can be estimated from the desired frequency. The desired frequency can be estimated by calculating the presence of all harmonics of both the local oscillator and the intermediate frequency, and their sum and difference. In the following example, the number of spurs within 10 MHz from the desired frequency is calculated for different local oscillator values between 100MHz to 200 MHz frequency and is set to 45 MHz

CONCLUSIONS

As affirmed before, choosing the right transmitter architecture is incredibly significant and the choice of exact architecture is a tricky one in the design of transreceiver. If the invention is to operate within a small band of frequency spectrum, the heterodyne architecture is preferred since it can be realized quite proficiently and cost effectively. By opting a suitable intermediate frequency the problem of spurs can be ease, if not eliminated. However, this is not possible if the band of frequency spectrum is extensive. If a huge band of frequency spectrum is to be covered, then the homogenous architecture is preferred since it will not suffer from spurs in the same sense as a heterogeneous architecture. Instead the homogenous architecture will necessitate a highly linear complex-valued mixer in order to curb baseband harmonics. Also, more processing power is obligatory to make the digital equalizer a most promising concept in compensating the imperfections incurred in mixer and baseband filters. This will make the invention to be more multifaceted and boost in their unit price. Offset PLL is another promising technique which reduces the multifaceted design and boost in their unit price. This elucidation is gratis from many of the tribulations linked with the up-conversion technique which has been discussed earlier methods. The offset PLL is able to operate in a broad band without image or spur problems.

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