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Design of Adaptive Heterodyne Filters for Digital Receivers

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ABSTRACT

Modern broad-band communication systems as well as complex systems and high-quality audio often require the removal of narrow-band interferences through an adaptive band-stop filter with highly linear phase throughout its pass-band. In this paper we study different techniques of adaptive tunable filters, which use complex heterodyne process to tune the filter fully over the range DC to the Nyquist frequency. All the techniques rely on rotating of poles and zeros in the Z-plane like a simple combination lock: clockwise once, counterclockwise twice, then clockwise once. A simple detection circuit is proposed to identify the interference signal to be attenuated and a numerically controlled oscillator (NCO) is proposed to interface between the detection circuit and tunable complex heterodyne notch filter. The filters are built using blocks of SIMULINK and simulation results are represented in the paper.

KEYWORDS : *Adaptive tunable filter, LMS, MATLAB, NCO, SIMULINK.*

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I. INTRODUCTION

Modern broad-band wireless systems are designed to be co-located with older narrow-band communications so as to share valuable spectrum. This is accomplished by using a pseudorandom number sequence to control the spreading of the spectrum of the modern wireless transmitter so that it appears to be background noise that easily filtered out by narrow band receiver. The five most common techniques for achieving spread-spectrum are (1) Frequency Hopping Spread Spectrum (FHSS, e.g. IEEE 802.11-1997), (2) Direct Sequence Spread Spectrum (DSSS, e.g.: IEEE 802.llb and 802.11g, (3) Time Hopping Spread Spectrum (THSS, e.g.: IEEE 802.15), (4) Chirp Spread Spectrum (CSS, e.g.: IEEE 802.l5.4a-2007), and (5) Ultra Wide Band (UWB, e.g.: IEEE 802.15.3a.

When working properly, the narrow-band transmissions licensed to the frequency spectrum do not affect the broadband systems. They either interfere with a small portion of the broad-band transmission (which may be re-sent or reconstructed). However, in practice the narrow-band transmissions can cause serious problems in the spread spectrum receiver . To alleviate these problems, it is often necessary to include narrow band interference attenuation circuit in the spread spectrum receivers. Adaptive heterodyne are effective approach to eliminate these narrow band interferences.

1.1.THREE –WAY TUNABLE COMPLEX HETERODYNE FILTER TECHNIQUE

The basic structure for Tunable Complex Heterodyne filters is as shown in Figure 1. Three-way Complex Heterodyne circuits consists of three complex heterodyne units and two identical prototype filters. By selecting correct prototype filters, we are able to design tunable band-stop and notch filters, tunable cut-off frequency low-pass and high-pass filters and tunable bandwidth band-pass and band-stop filters. These filters are maximally tunable in that the band-pass and band-stop filters can be tuned from DC to the Nyquist frequency and the other filters can be tuned such that their bandwidth varies from zero to half the Nyquist frequency. There is no distortion in the filters, the prototype design transfers directly except that the pass-band ripple is doubled, thus we must design prototype filters with half the desired pass-band ripple

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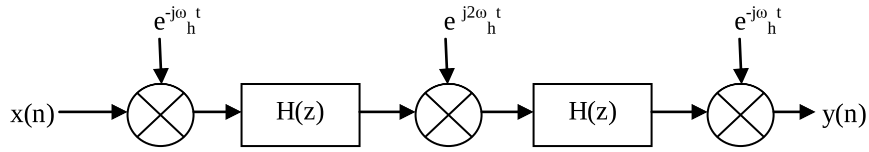

$$T(z) = y(z)/x(z) = H(ze^{+j\omega_h t})H(ze^{-j\omega_h t})$$

Figure 1: Three-way Tunable Complex Heterodyne Filter Using Identical Real Transfer Function H(z)

In the circuit s shown above, the three complex heterodyne operations have the effect of rotating poles and zeros of the fixed coefficient filters H(z), first to the left, then twice to the right, and finally, once to the left much like opening a combination lock. The effect is to generate a new transfer function T(z), which shifts the notch or band-pass frequency to a new location specified by the heterodyne frequency W_h. Usually H(z) is a high-pass filter which is transformed into a tunable notch filter by the heterodyne process. We designed the filter in MatLab: blp=frrpm(64, [O 1/(1 +delta) 1 *(l+delta) 1],[0 0 1 1],[2 5]);

The frequency response of prototype filter H(z) is as shown in Figure: 2

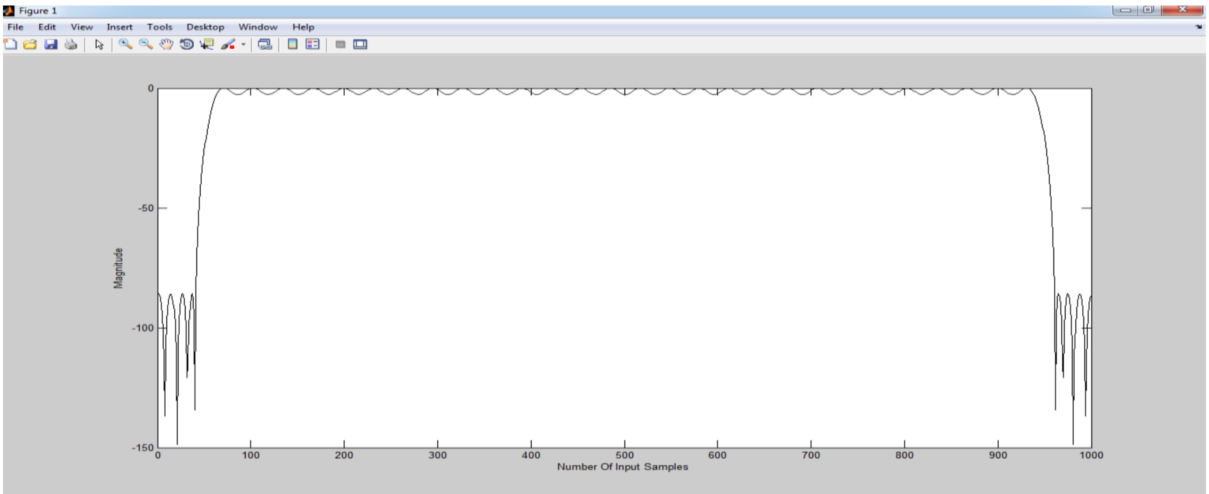

Figure 2: Frequency Response of Prototype Filter H(z)

Figure 3 and 4 shows Frequency Response When Heterodyne Frequency Changes

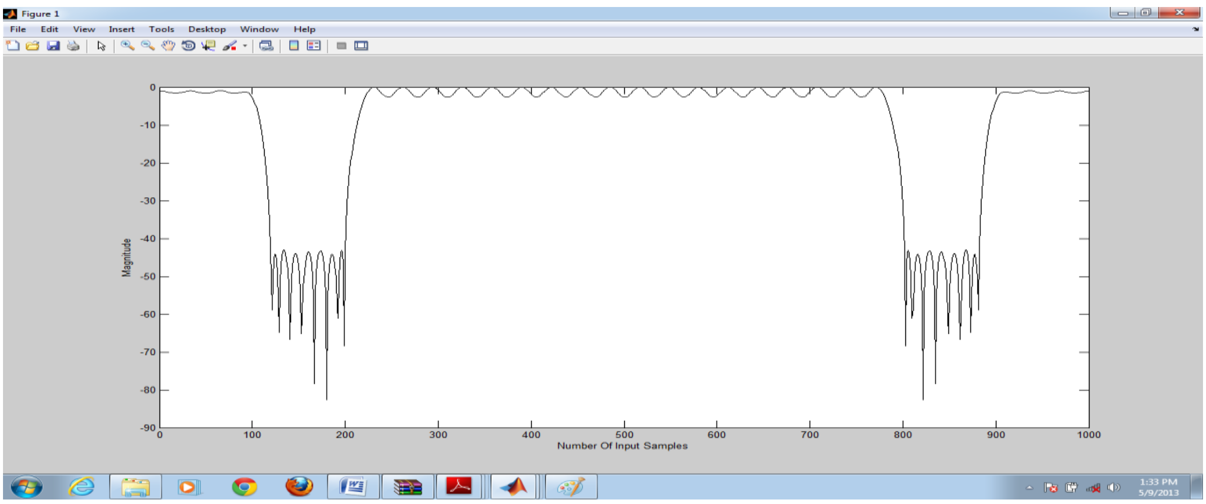

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Figure 3: Frequency Response of Three Way Heterodyne Filter When ω_h=1

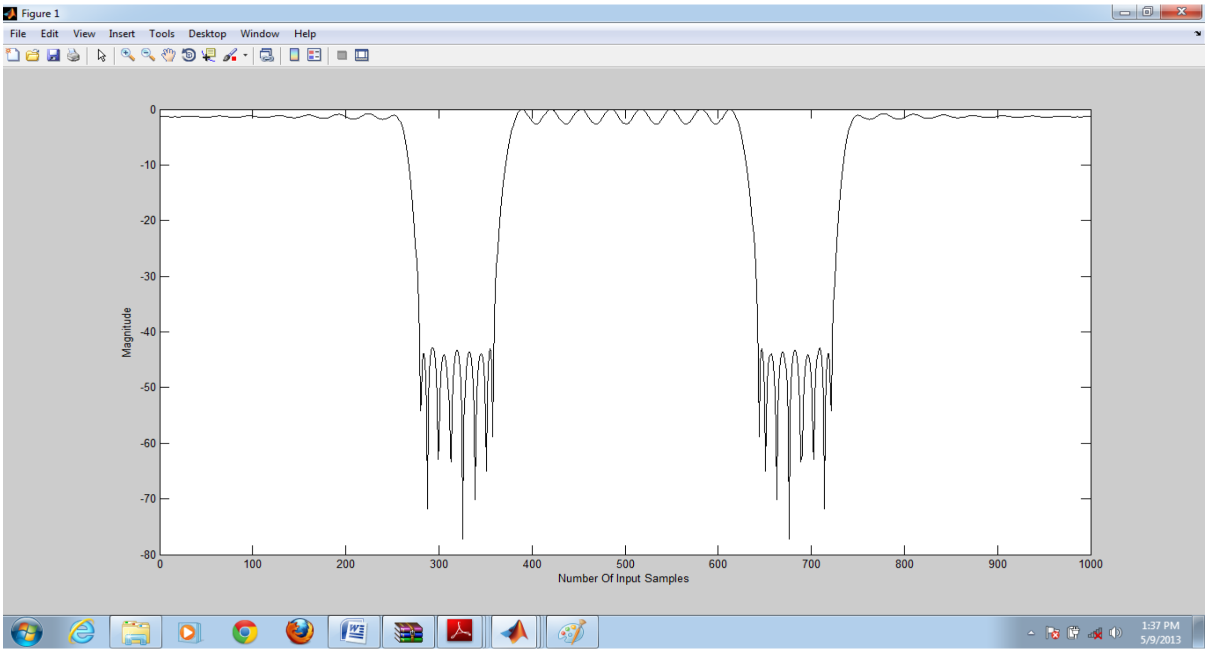


Figure 4: Frequency Response of Three Way Heterodyne Filter When ω_h=2

1.2NYQUIST TUNABLE HETERODYNE FILTER TECHNIQUE

The Figure 5 shows the block diagram Nyquist tunable complex heterodyne filter circuit.

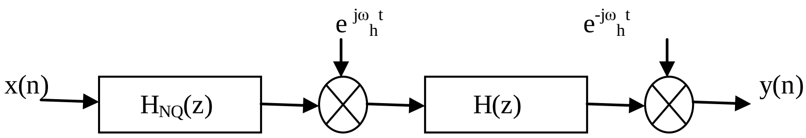


Figure 5: Nyquist tunable complex heterodyne filter circuit

In the circuit of Figure 5 the signal is first passed through $H_{NQ}(z)$, a complex-coefficient digital filter that removes all frequencies from bottom half of the unit circle in z-plane. Thus this filter removes all negative frequencies or equivalently the frequencies above the Nyquist frequency. Such a filter is easily designed in MatLab by designing a low-pass filter with cut-off frequency of π/2 and then rotating it in the z-plane so as to pass positive frequencies and to attenuate negative frequencies.

Figure 6 and 7 shows poles of low-pass filter and Nyquist filter respectively.

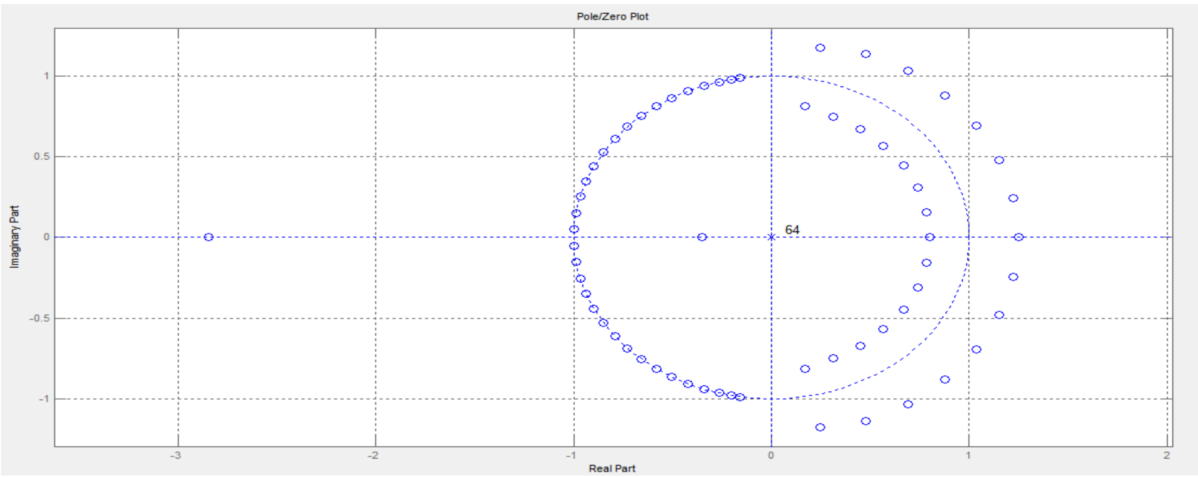


Figure 6: Plot of poles of prototype low-pass filter

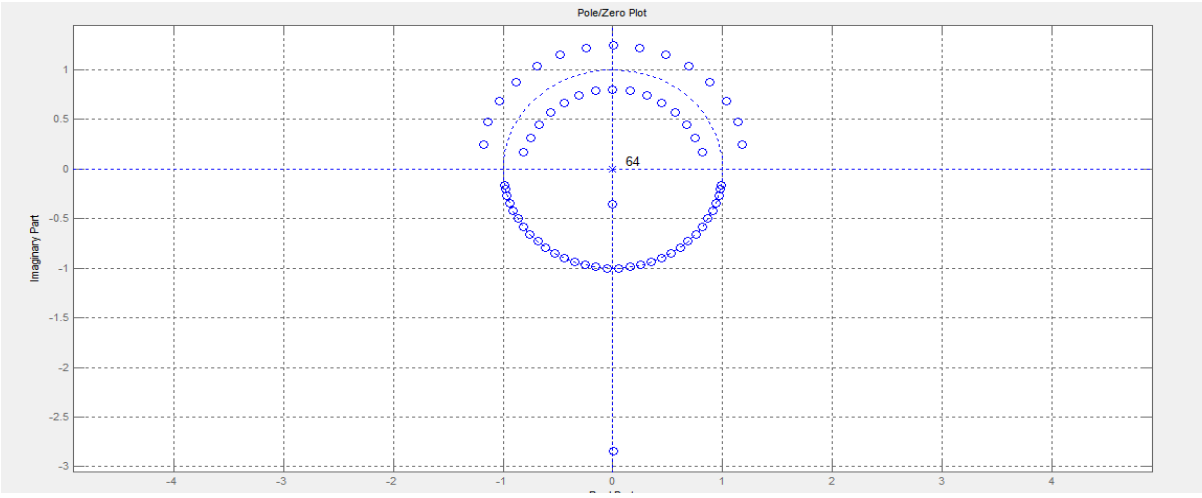


Figure 7: Plot of poles of Nyquist filter

II. FREQUENCY DETECTION CIRCUIT

The proposed frequency detection circuit is based on the well-known second-order FIR adaptive notch filter using the LMS adaptive algorithm. This simple adaptive notch filter is known to provide an unbiased estimate of the narrow-band frequency to be attenuated. In addition, the Least Mean Square (LMS) algorithm is robust and converges quickly to the desired value.

The adaptive filter adapts the single parameter β in a simple second-order FIR notch filter:

$$y(n) = x(n) - \beta x(n-1) + x(n+2) \qquad (1)$$

The LMS adjustment algorithm is based on finding and minimizing the square of the error function ε(n):

$$\varepsilon(n) = y(n) - x(n) = x(n-2) - \beta x(n-1) \qquad (2)$$

Figure 8 shows the circuit to calculate *β(n),* the output of Figure 8 is given by:

$$\beta(n) = 2COS(\theta) \qquad (3)$$

$$\beta(n) = 2COS(2\pi\omega_h/\omega_s) \qquad (4)$$

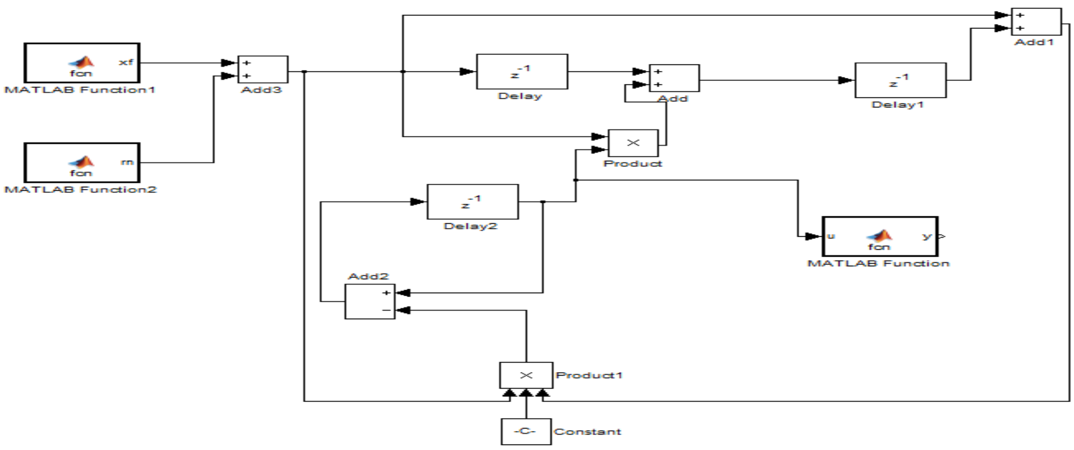


Figure 8: Detection Circuit Generates β(n) Necessary to Identify Frequency to be Attenuated.

III. NUMERICALLY CONTROLLED OSCILLATOR

In order to tune the tunable complex heterodyne filter to the correct frequency to attenuate the narrow-band interference detected by the circuit of Fig. 5, we must convert β into a heterodyne frequency W_h. What is needed is an NCO that takes β as its input and generates:

$$e^{j\omega_h nT} = COS(\omega_h nT) + jSIN(\omega_h nT) \qquad (5)$$

Where $T=2\pi/W_s$

Hence,

$$e^{j2\pi\omega_h n/Ws} = COS(2\pi\omega_h n/\omega_s)+jSIN(2\pi\omega_h n/\omega_s) \qquad (6)$$

From equation (4), we can calculate the heterodyne frequency by using the following formula

$$m=round[256arccos(\beta(n)/2)\ /2\pi] \qquad (7)$$

Figure 9 shows the proposed NCO, to be used as interconnection between the Frequency detection and tunable heterodyne filter.

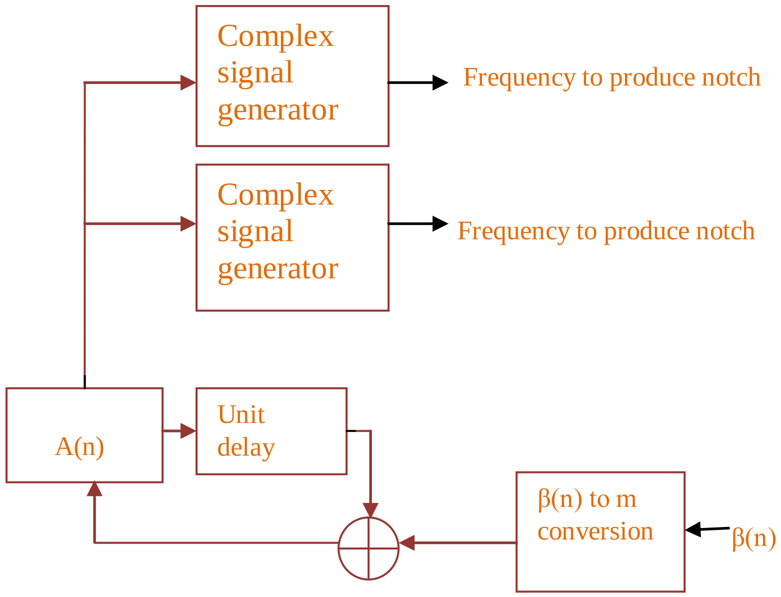
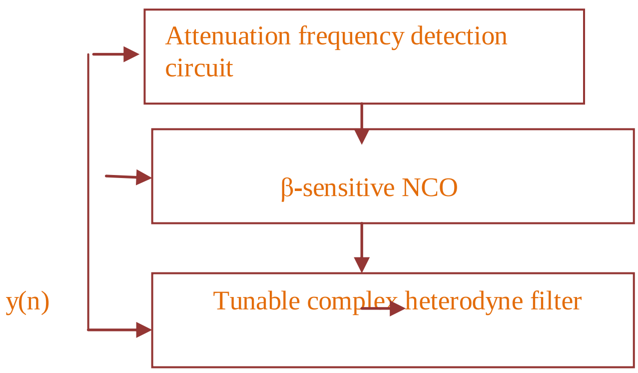


Figure 9: Numerically Controlled Oscillator

Figure 10 shows the complete block diagram of adaptive heterodyne filters



VI. CONCLUSION

This paper mainly describes the two techniques to design tunable heterodyne filters. Then tunable heterodyne filters are converted into adaptive tunable heterodyne filters by adding attenuation frequency detection circuit and β-sensitive NCO. Nyquist tunable filter technique uses less chip area because it has one less heterodyne stage compared to Three-way tunable heterodyne filter.

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BIOGRAPHIES

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