Narrow-Band Interference Removing Filter for Mobile Communication Systems

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***Abstract*—In wireless communication systems, the received signal is often distorted by narrow-band interference (NBI). Notch filter is commonly used for removing NBI. In this paper, we propose NBI removing filter, which is composed of two mixers and one high pass filter (HPF) to enhance the receiver performance in high NBI environment. Using two mixers and one high pass filter, the NBI can be removed by down-converting the received signal wherever the NBI is located.**

I. Introduction

Mobile communication systems such as synthetic aperture radar (SAR), 4G mobile broadband, and wireless local area network (WLAN) standards (IEEE 802.11a/g/n/ac) have significant performance degradation when there are high narrow-band interference (NBI) [1]–[3]. Main reason of the NBI is utilization of the unlicensed bands in many wireless communication standards. These systems are located in the same frequency band with other systems. Much research has been done to remove unwanted NBI [4]–[7].

A simplified system model of a wireless communication system is illustrated in Fig. 1. In this paper, we will analyze the performance of the single carrier system, because the orthogonal frequency division multiplexing (OFDM) based system can easily remove the NBI problem by simply erasing the corresponding subcarrier symbol of FFT output. The modulated data passes through the SRRC filter and the digital-to-analog converter (DAC) to produce band-limited analog signals. The converted analog signal is transmitted in a wireless mobile communication system through a narrow-band channel, which is generally a multipath fading channel. On the receiver, NBI and additive white Gaussian noise (AWGN) are added to the received signal. After converting the received analog signal into a digital signal by an analog-to-digital converter (ADC), the digitized received signal is filtered and demodulated by an SRRC filter. In this paper, we propose the NBI removing filter by applying the notch filter which is one of the most commonly used scheme for removing the interference. When using the notch filter, once the design is completed, it is impossible to change the frequency to be filtered. To avoid this disadvantage, frequency changeable notch filter can be used. However, in this case, the design complexity of the filter is increased highly. By using the proposed NBI removing filter, it is possible to change the frequency to any frequency to be filtered through a low complexity mixer.

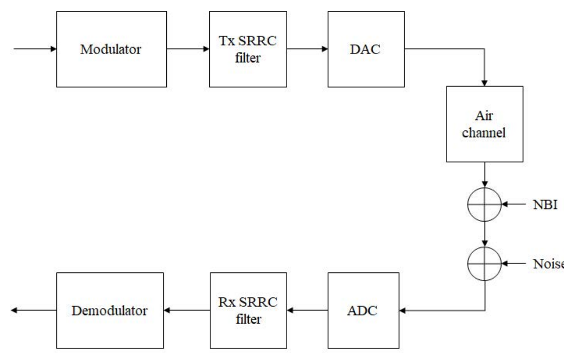


Fig. 1. A simplified system model of wireless communication system.

The rest of the paper is organized as follows. In Section II, system performance degradation due to NBI is introduced. In Section III, NBI removing filter is proposed and a performance assessment of the proposed NBI removing in various environments is provided through a numerical analysis. Finally, conclusions are given in Section IV.

II. The Analysis of the Performance in Narrow-Band Interference

To analysis the performance degradation due to NBI, we divide the NBI into three categories which are NBI at the in-band, NBI at the band edge, and NBI at the out-of-band as shown in Fig. 2.

Bit error rate (BER) performances for the NBI located at the in-band, band edge, and out-of-band are depicted in Fig. 3, Fig.4, and Fig. 5, respectively. To evaluate the impact of the NBI, we evaluate BER performance with QPSK, 16QAM and 64QAM when the NBI is presented in units of 10dB from 0dB to 100dB. NBI power in the figure is the relative signal power which is compared to the desired signal. NBI power 0dB means that the power of NBI is same as the average in-band power in the frequency domain of the desired signal. In fig. 3, BER performance degradation is observed from NBI power 20dB for QPSK and 16QAM, 10dB for 64QAM when

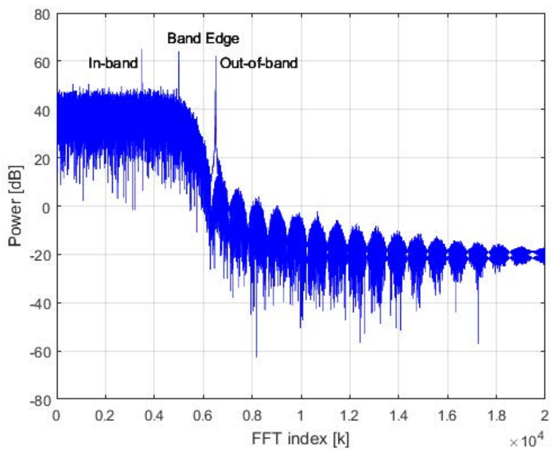


Fig. 2. Received signal with 20dB higher NBI.

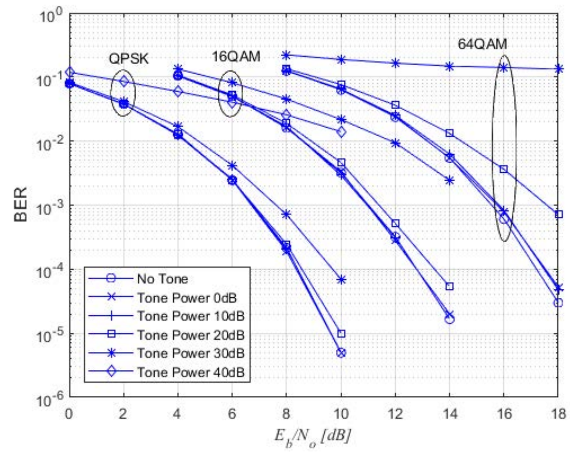


Fig. 4. BER performance when the NBI is located at the band edge in AWGN channel.

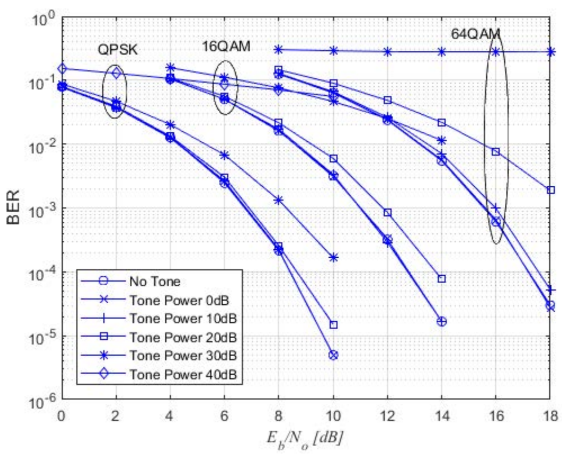


Fig. 3. BER performance when the NBI is located at the in-band in AWGN channel.

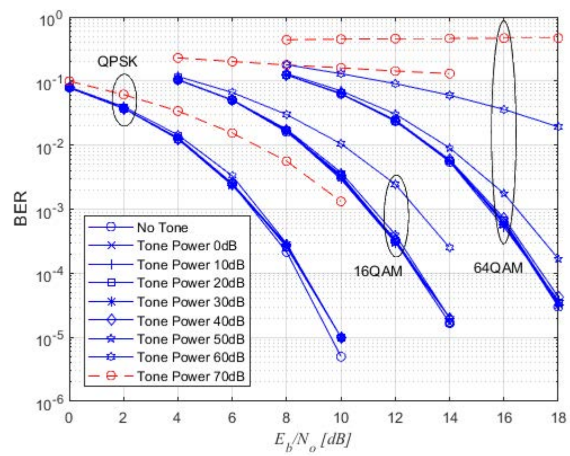


Fig. 5. BER performance when the NBI is located at the out-of-band in AWGN channel.

the NBI is located at the in-band. In fig. 4, BER performance degradation is observed from NBI power 20dB for QPSK and 16QAM, 0dB for 64QAM when the NBI is located at the band edge. In fig. 5, BER performance degradation is observed from NBI power 70dB for QPSK, 60dB for 16QAM, and 50dB for 64QAM when the NBI is located at the out-of-band. Because even though the NBI is located at the out-of-band, this NBI is folded into in-band during the demodulation process.

III. The Proposed Narrow-Band Interference Removing Filter

The proposed filter consists of two mixers and one high pass filter (HPF) as illustrated in fig. 6. The first mixer is used to place the NBI in 0Hz, and the second mixer is used to return to the original spectrum after filtering. After down-converting the received signal by the amount of the center frequency of the NBI, the NBI can be removed by the HPF and then the received signal is up-converted back. In the conventional notch filter, once the filter is design, it is impossible to change the frequency to be filtered. To avoid this disadvantage, frequency changeable notch filter can be used which has very high implementation complexity.

The overall process of the NBI filter is illustrated in fig. 7. The NBI filter input signal in (a) of this figure is frequency shifted by the first mixer so that NBI is located at 0 Hz which is depicted in (b). As shown in (c), the frequency shifted signal passes through the HPF and NBI is removed in this process. NBI removed signal is returned to the original frequency by the second mixer as shown in (d).

To reduce the hardware size mixer can be implemented by coordinate rotation digital computer (CORDIC). HPF is designed with stop band frequency 0.001MHz, pass band frequency 0.02MHz, stop band attenuation 50dB, pass band ripple 0.01dB with Chebyshev type 2 which has 5th order

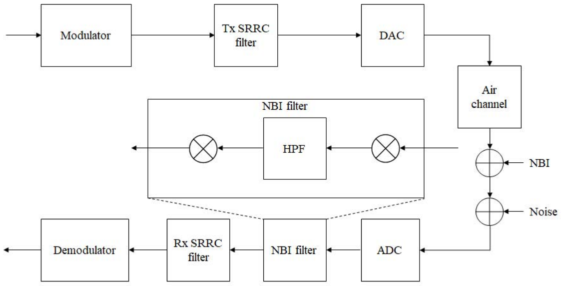
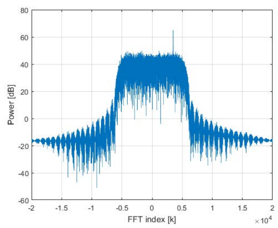
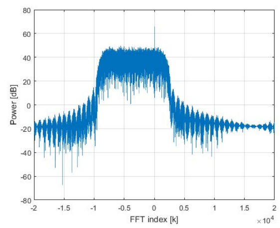


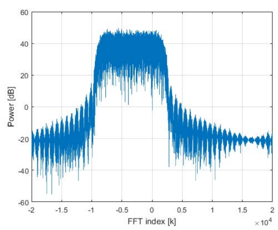
Fig. 6. A simplified system model of the receiver with proposed NBI removing filter.



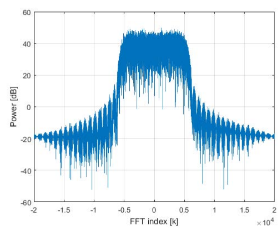
(a) NBI filter input signal



(b) First mixer output signal



(c) HPF output signal



(d) Second mixer output signal

Fig. 7. BER performance of the proposed and the conventional SRRC receiver filters with QPSK, 16QAM, and 64QAM in AWGN channel.

filter coefficient {1, -1.99999987450149, 1, 1, -1} for feed forward, and {1, -1.99826656741428, 0.998269689373816, 1, -0.998269688023325} for feedback[8].

BER performances for the proposed NBI removing filter with the NBI located at the in-band, band edge, and out-of-band are depicted in Fig. 8, Fig.9, and Fig. 10, respectively. In fig. 8, BER performance is enhanced when the NBI power is larger than 40dB for QPSK and 16QAM, 30dB for 64QAM when the NBI is located at the in-band. However, if the NBI power is smaller than those mentioned value, BER performance is degraded, because HPF erases the meaningful data. In fig. 9, BER performance is enhanced when the NBI power is larger than 40dB for QPSK and 16QAM, 30dB for 64QAM when the NBI is located at the band edge. However, if the NBI power is smaller than those mentioned value, BER performance is degraded, because HPF erases the meaningful data, which is the same as the NBI is located at the in-band. In fig. 10, BER performance degradation is observed from NBI power 80dB for QPSK and 16QAM, and 60dB for 64QAM when the NBI is located at the out-of-band. The

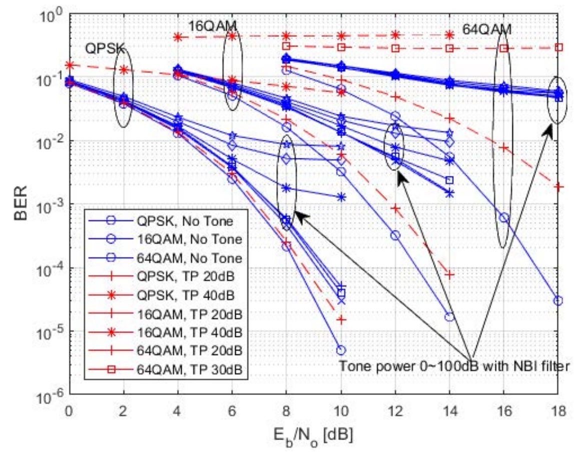


Fig. 8. BER performance of the proposed AGC algorithm when the NBI is located at the in-band in AWGN channel.

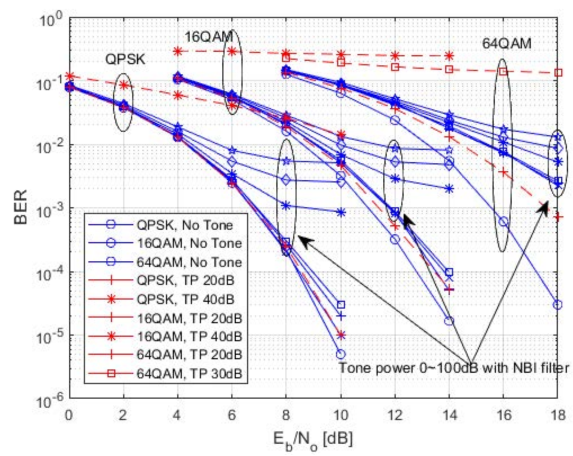


Fig. 9. BER performance of the proposed AGC algorithm when the NBI is located at the band edge in AWGN channel.

BER performance is enhance obviously in this case, because the filtering is done at the out-of-band. From the results, the overall BER performance will be enhanced by switching on the proposed NBI removing filter for following two cases. The first is when the NBI is located at the in-band or at the band edge with 20dB larger power than the desired signal. The second is when the NBI is located at the out-of-band with any power.

IV. Conclusion

In this paper, we proposed a new NBI removing filter by adopting two mixers and one HPF. The proposed NBI removing filter can enhance the BER performance in high NBI environment. In low NBI environment when the NBI is located at the in-band or at the band edge, BER performance is worse than no filtering, because HPF erases the meaningful data. In order to enhance the overall performance, the proposed NBI

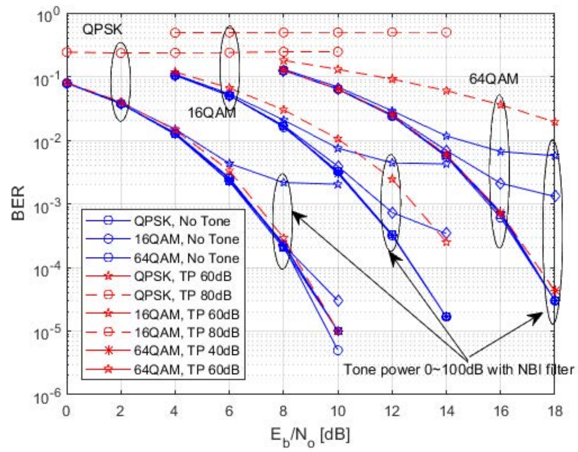


Fig. 10. BER performance of the proposed AGC algorithm when the NBI is located at the out-of-band in AWGN channel.

removing filter is adaptively used according to the power level of the NBI.

Our future work will develop the overall scenario for NBI detection, investigating better HPF coefficient and NBI removing filter switching mechanism.

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