International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in

Vol.3., Issue.3, 2015

RESEARCH ARTICLE

ISSN: 2321-7758

ACTIVE INTERFERENCE CANCELLATION TECHNIQUE FOR 'MB-OFDM' SYSTEM USING 'AIC' TONES

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Article Received:06/05/2015 | Article Revised on:10/05/2015 | Article Accepted on:14/05/2015

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ABSTRACT

Active interference cancellation (AIC) is an effective technique to shape the OFDM spectrum, providing deep notches over protected bands without affecting receiver design. In OFDM interference is considered as major problem. In this paper, wepresent interference reduction in OFDM system. In OFDM turning off the interfering tones has been studied as alternative solution, but the inter-carrier interference may limit the notch depth to 10-15dB. Further we approach with AIC technique using AIC tones that enables the accurate notch bandwidth and depth control for the general OFDM transmitter, reduces interference up to 101dB.

Keywords – MB-OFDM, Active Interference Cancellation, Cognitive radio, AIC tones

I INTRODUCTION

Spectrum is the most valuable resources in wireless systems but not unlimited. Static spectrum allocation policies results in underutilization of the spectrum due to the fact that most of the permanently allocated spectrum is not utilized all the time hence results in spectrum holes in time domain[1]. There comes a new technology named Cognitive radio [2], which works on the principle of detect-and-avoid (DAA) and utilizes the spectrum in an intelligent and opportunistic manner. OFDM proved to be a suitable candidate for cognitive radios[2] but high spectral side lobe of OFDM have tendency to interfere out-of-band as well as in-band services. In today's we are surrounded by many wireless services, so there is very high probability that two services have to share the same spectrum. The same congestion can be seen in ultra wideband (UWB) and OFDM[3] is a recognized approach for implementing UWB systems. It promises to delivery very high data rates up to 480 Mbps. The easiest way[8] of creating notch is turning off the OFDM tones.

In OFDM, tones are placed at a regular frequency interval to avoid the inter-carrier interference [4][5] (orthogonality). The inter-carrier interference becomes large in-between the tones and is generated by all the non-zero tones following the sine function interpolation. Due to this property, turning off a single tone does not create a spectral null within its band, and its residual in-band power is determined by the neighbouring non zero tones. For a single tone, the notch bottom level (the inter-carrier interference power) is typically10-15dB below the average signal power. This may be insufficient (subject to the conditions of bandwidth, distance and sensitivity of the victim system). In OFDM, a deeper notch is achieved by turning off a large number of tones.

The paper is organized as follow: In Section II, we review the AIC technique. In Section III, performance of AIC is discussed. In section IV, results are mentioned. Conclusions are drawn in Section V.

II ACTIVE INTERFERENCE CANCELLATION

In 2004, Yamaguchi proposed an Active Interference Cancellation (AIC) technique [6][7], which creates a deep notch by as compared to that of nulling technique. In AIC technique, two additional tones are introduced at the edges of victim band to nullify the effect of sidelobe within the victim band

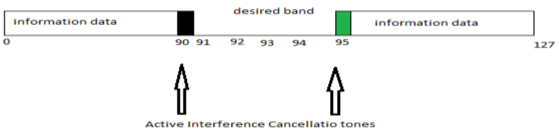


Figure 1

The whole process of AIC can be viewed in two steps. In the first step nulling of tones corresponding to the desired band is to done and then calculate the interference within the desired(victim) band due to the sidelobe of the others active subcarriers. In second step, AIC tones are calculated to produce nullifying effect. Mathematical formulation of AIC technique is given as follows: : When the information data is denoted by X(k) ,k=0,1,…,127, the transmitted OFDM signal is given by:

$x(n)=\sum_{k=0}^{127} X(k)\, e^{j2\pi nk/128}$ (1)

In order to evaluate the interference in-between the tone frequencies, we up-sample (we apply four-times up-sampling here) the corresponding spectrum, which is given by$Y(l)$ (l=0,1,…4*128-1),

$Y(l) = \frac{1}{128}\sum_{n=0}^{127} x(n)\, e^{-j2\pi n\frac{l}{128}*1/4}$ (2)

On calculating the IDFT and DFT of x(n) and from above equation ,we come to the conclusion that is

Y(0) =X(0)

Y(4) =X(1)

Y(8) =X(2) by using up sampling four times.

Combining eqn.(1) and eqn. (2) to obtain relation between X and Y

$Y(l) = \frac{1}{128}\sum_{n=0}^{127}\left(\sum_{k=0}^{127} X(k)\, e^{\frac{j2\pi n}{128}*(k-\frac{l}{4})}\right)$

$Y(l)=\frac{1}{128}\sum_{k=0}^{127} X(k) P(l,k)$ (3)

Where $P(l,k) = \sum_{n=0}^{127}\left(e^{\frac{j2\pi n}{128}*(k-\frac{l}{4})}\right)$ and is called the kernel transform.

Instead of turning off a large number of tones, we define two special tones at the edges of the interference band as shown in figure 1, and would prove that these two tones can sufficiently cancel the interference in the band. The tone values can be arbitrarily determined without affecting the information tones due to the orthogonality relationship. We call these special tones Active Interference Cancellation (AIC) tones. We discuss below how to compute the AIC tones, and how to create the notch using minimum number of tones, or equivalently, how maxime the spectrum efficiency.

The tones #91,92,93, and 94 (values of k) of the MB-OFDM Band #1co-locate with this band . The MB-OFDM interference to this band is evaluated at four times (or higher) finer frequencies denoted vector d_1.$d_1(1)$,$d_1(4)$,$d_1(8)$, $d_1(12)$ corresponds to the MB-OFDM tones #91,92,93 and94. We then add two tones on the edge outside these four tones, and try to cancel the interference inside the interference band using the total of six tones. It will be shown later that the AIC tones plat the dominant role and four 'in-band' tones can be simply 'turned off'. It has been found that increasing the number of the AIC tones does not significantly improve the cancellation performance, thus the current solution seems to be near optimum.

The vector d_1 is given by

$d_1 = P\,g$ (4)

Where P is the kernel defined by (3) and g is the column vector of the information data tones with subcarriers of the desired band X(90) to X(95)turned off (carrying zeros by all six subcarriers of the desired band).

Now the product of kernel transform and column vector (P*g) or d_1 can be viewed as the interference within the band. In order to cancel the interference within the band, we need to generate the negative of interference signal using the tones X(90) to X(95). Again using the relation (4) above, setting all elements of X to zero except for X(90) to X(95), the equation to be solved is given by :

$P_1*h=-d_1=-(P*g)$ (5)

Where h is the column vector with all elements equal to zero except elements from X(90),….X(95) and here it must be noticed that the major difference between nulling in which we transmit zeros to subcarriers of the desired band and in AIC here we transmit an arbitrary elements to the subcarriers of the desired band and rest all the elements equal to the zero which is reverse of the nulling effect.P_1 is the small sub matrix of the kernel P by limiting the index according to h and d_1. Thus P_1 is a 13 x 6 matrix.

Here, h is our desired tone values (like h_1 at 90, h2 at 91…h_6 at 95).

$$h=(P_1)^{-1}[-d_1] \qquad (6)$$

However, (5) cannot be solved in the straightforward way because the matrix $P_1$is not invertible. Hence, instead we seek the minimization which leads to

$$h=-(P_1^T P_1)^{-1} P_1^T d_1 = -W_1 d_1 \qquad (7)$$

This minimum mean square solution is also known as the Moore-Penrose generalized inverse. It is noted that the resultant inverse 6 x 13 matrix W_1 is precomputable because the interference band location is pre-defined (by the regulator rules. Also it can be broadcast by means of the inter-device communication).

Now combining (4) and (7), h is given by

$$h= -W_1P\, g = -W_2\, g$$

Where W_2 is also a pre-computable 6 x 128 matrix.

III. AIC PERFORMANCE

For the targeted band (subcarrier 90-95) we compare two approaches, firstly we use nulling of subcarriers by transmitting zeros (turned off) and interference is reduced by an amount -19dB as shown below

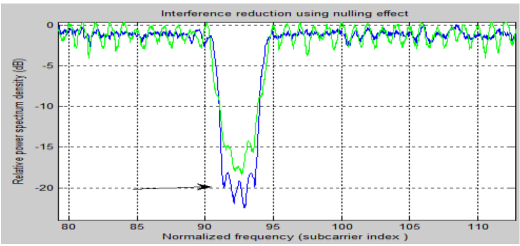
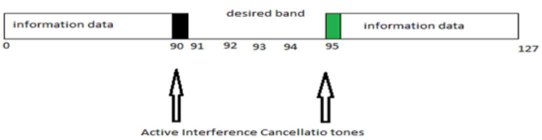


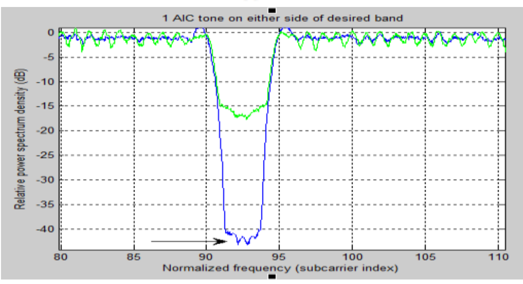
Figure 2

Secondly we use AIC tones at different position of the desired band likewise and interference is suppressed accordingly as shown below:

Case study I

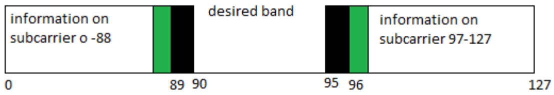
One AIC tones at #90 and #95, interference suppressed by amount of -42 dB as shown below:

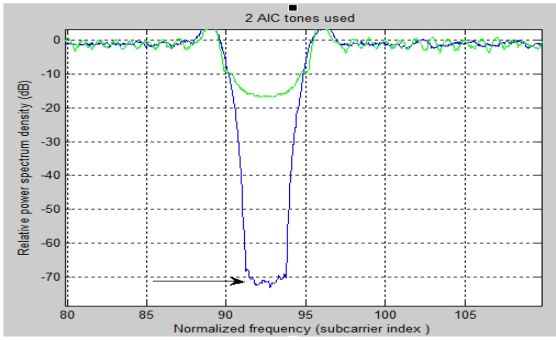




Case study II

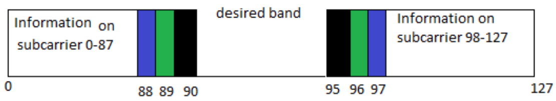
Two AIC tones on either sides of desired band #90,#89 and #95,#96, interference suppressed by an amount of -70dB as shown below:

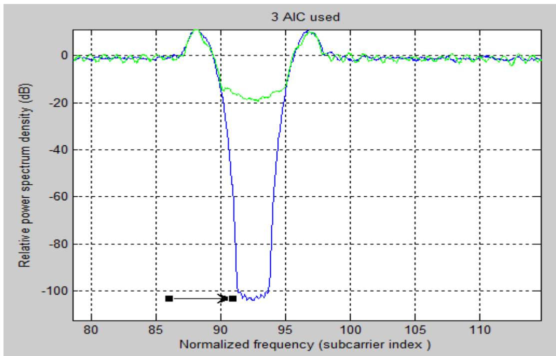




Case study III

Three AIC tones on either side of the desired band #90,#89,#88 and #95,#96,#97 , interference is suppressed by an amount of -101dB as shown below:





IV. RESULTS

The overall result of the above whole scenario are listed below in table with the system efficiency

S. NO.	Number of AIC tones used In desired band	Interference Reduction in the desired band (90-95)	Efficiency
1	No AIC tone used (nulling)	Up to -19dB	100%

2	1 on either side, total=2	Up to -42dB	98.43%
3	2 on either side, total=4	Up to -70dB	96.88%
4	3on either side, total=6	Up to -101dB	95.31%

V. CONCLUSION

The AIC technique presented here is based on the benefits of the frequency –domain signal processing, proposed as MB-OFDM as the worldwide UWB standard. The results show that there is suppression in the interference in the desired band with a trade-off in system efficiency.

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