Investigation into Non-Recursive Digital Filter in Correlated Jamming Environment

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Abstract - **The author presents results of investigation into non-recursive digital filter. Kinds of window proceeding have been considered. A simulated model of jamming correlated interference is used to obtain results.**

Keywords - **non-recursive digital filter, jamming correlated environment**

I. Introduction

In many publications, connected with digital communication theory, the most frequently assumed model for a transmission channel is the additive white Gaussian noise (AWGN) channel [1-3]. However, for some communication systems the AWGN channel is a not good model [1]. For instance, if a useful signal and correlated noise are summed in a communication channel, the received signal is badly distorted. That will lead to wrong decision by the receiver. On the one hand it might be decided that of the input of the receiver there is a useful signal but, in fact there is not; on the other hand, a useful signal might be missed. One of the basic methods to reduce the correlated jamming environment in communication channel is an implementation of digital band pass filter (BPF). In [1] it is investigated a non-correlated . Rician fading channel and Rayleigh fading cannel. At the end of that article it is given that the developed channel model can be extended with minor additions to a model of other types of fading channel. A correlated Rucian fading channel is given as an example. The other articles [2-4] consider correlated Rayleigh distributed fading samples by using the modified sum of sinusoids method

The paper is organized as follows. Section II gives a brief introduction of possible method of synthesis of BPF. A frequency method of obtaining ideal amplitude frequency characteristic (AFC) is examined. This method is used for achieving pulse characteristic of non-recursive PBF. At this examination a different kind of window proceeding is used. At solving that task, AFC is referred to spectral components of interference. The jamming correlated noise is modeled and his characteristic of power spectral density (PSD) is intently located on low frequency domain. A transversal structure of BPF is obtained on the base of received pulse characteristic. The results from investigation into BPF that is not conjugated with spectral components of jamming environment are presented in section III. There are other results obtained by using a window proceeding not only on frequency samples, but also on correlated noise. In addition, there are tables which contain information about a variety of filter elements and extension of frequency transient filter area.

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In Figures 5 and 6 is shown the effect of amplitude frequency characteristic lobes upon proceeding signal. In section IV there are some commentaries on received results. At the end of the article there are some references.

II. Pulse Characteristic of Transversal BPF

It is possible for us to use method for synthesis of BPF with procedure, which minimizes a mean quadratic error in frequency domain. In addition, it is necessary the required AFC $H_d(e^{iw})$, to be determined by discrete raw of spectral components $\{\omega_j\}$, $j = 1,2,\ldots,M$. Mean quadratic error for these components is determined by equation (1) [5]:

$$\varepsilon = \sum_{j=1}^{M}\left[\left|H(e^{iw_j})\right| - \left|H_d(e^{iw_j})\right|\right]^2 . \qquad (1)$$

In that case is supposed that the transmission function of filter is determined by equation (2)

$$H(z) = A\prod_{n=1}^{N}\frac{1 + a_n z^{-1} + b_n z^{-2}}{1 + c_n z^{-1} + d_n z^{-2}} = AG(z) . \qquad (2)$$

A cascade form of realization has been chosen. In this way, it is achieved a low sensitiveness of accuracy of coefficients as well as convenience at calculating the derivatives. These derivatives are necessary for optimizing the filter.

This article investigates the non-recursive BPF with transversal structure, built by frequency sample methods. It is assumed that correlated jamming noise is located on low frequency domain, showed on Fig. 1 and marked as (1). The low frequency domain range is from 0 to $f_{up}/2$, where f_{up} is the assumed upper passing frequency of channel. The uncorrelated white noise is spread in high frequency domain. Two useful signals are situated in the communication channel. They are harmonics that are placed in different domains. The first is located under $f_{up}/2$, and the second harmonic signal is located above $f_{up}/2$. These signals are chosen to determine influence of BPF on wideband useful frequency signal.

The main parameters are frequency of discrete sample, marked with *F*, upper frequency of non-passing band, marked with f_s, and lower frequency of passing band, marked with f_p. Width of transmission band is determined by equation (3):

$$\Delta\omega = \frac{2\pi}{F}(f_p - f_s) , \qquad (3)$$

and for investigated model $\Delta\omega = 0.039\pi$.

In this investigation it is used transversal filter with different number of elements, which are marked with N. When a window function is used, the order of transversal filter is N=32. On frequency channel band a known ideal AFC $\tilde{H}(k)$ of BPF is defined, and frequency samples are estimated. These samples then are converted by Discrete Fourier Transform (DFT) (4):

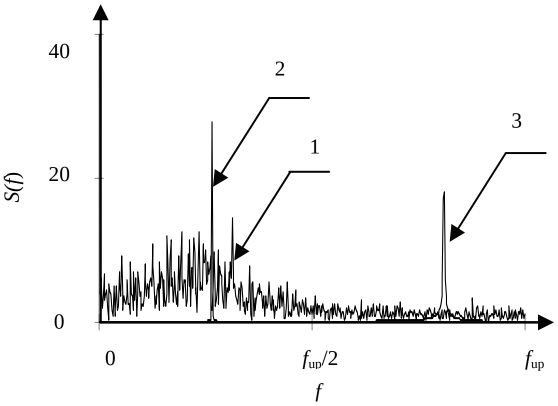

Fig. 1. Channel with correlated noise (1) and useful signals (2 and 3)

$$H(e^{-i\omega n}) = \sum_{n=0}^{N-1} h(n) e^{-i\omega n} . \qquad (4)$$

Any sequence with limited length is completely determined from N sample of DFT. Consequently, synthesis of BPF may be achieved by finding N sample of pulse characteristic. The results obtained from of DFT of $\tilde{H}(k)$ are the pulse characteristic of band digital filter (DF). The received signal will be treated with this filter to reduce the jamming low frequency clutter. The obtained pulse characteristic is plotted in Fig.2.

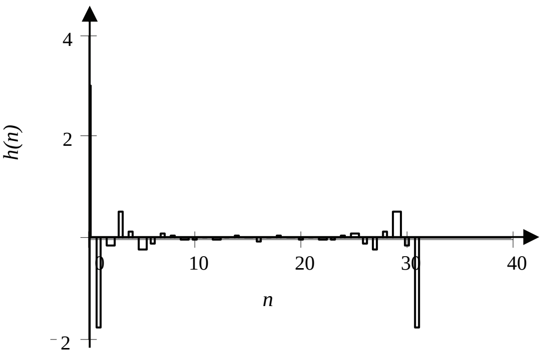

Fig. 2. Pulse characteristic of digital filter

The discrete samples of $\tilde{H}(k)$, marked as $H_d(e^{iw})$ have to be given with simple functions, which are possible to be integrated. If that is impossible, representation of transmission function is $h_d(n)$ and is obtained by analogue-to-digital conversion of AFC marked as $H_d(e^{iw})$ and by using Inverse DFT Eq. (5):

$$\tilde{h}_d(n) = \frac{1}{M} \sum_{k=0}^{M-1} H_d(e^{i\frac{2\pi}{M}k}) e^{i\frac{2\pi}{N}kn} . \qquad (5)$$

On Fig. 3 is given obtained transmission function of BPF with Hemming window.The same frequency characteristic, as in Fig. 2 is used.

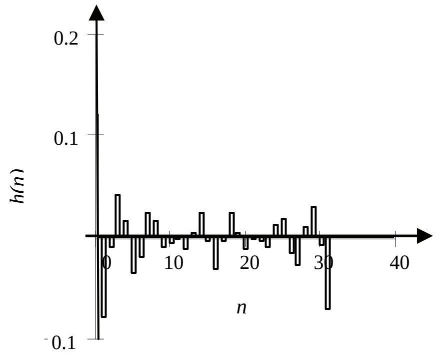

Fig. 3. Transmission characteristic of filter proceeded with Hamming window

III. Results from Investigation of BPF

The coefficients of band pass transversal filter are determined by pulse response characteristic. Thus it is possible to estimate suppression of filter over received jamming signal. In the process of investigation the levels of different spectral components before and after proceeding are valued. For that purpose jamming spectral components are divided into some groups. At first division, the spectrum components of noise are grouped in two equal parts.

The first group is S_L and it consists of components, which are covered by frequency band from 0 to $f_{up}/2$, and the second group is S_H, which consists of components, covered by band from $f_{up}/2$ to f_{up}. The point of this division is to estimate the relative share of these groups applied to whole interfere signal and to evaluate the influence of various BPF on frequency components of treated signals. The result of this grouping is shown in Table I. The first column of Table I shows different kind of known treating windows.

TABLE I

Relative share of two groups applied to whole signal

Kind window treating	S_L	S_H
	%	
Before filtering	80	20
Derichlet	65,4	34,6
Han	65,6	34,4
Hamming	64,2	35,8
Exact Blakcman	69	31
Blackman-Harris	68,9	31.1
Flat-Top	67,2	32,8

The same kind of dividing of spectral components, but this time in three equal groups, is shown in Table II. The first group is P_L and it consists of components, which are covered by frequency band from 0 to $f_{up}/3$, the second group is P_M, which is consists of components covered by band from $f_{up}/3$ to $f_{up}.2/3$ and the third group - P_H, $f_{up}.2/3$ to f_{up}.

The results in two tables give information about suppression of digital transversal filter over channel interfered signals. They are obtained with different window processing, and without it.

Table III shows the results which are obtained with high pass DF which is not conjugated with interfered correlated noise and has two, three and four branches and the value of coefficients is always one.

TABLE II
RELATIVE PART OF THREE GROUPS APPLIED TO WHOLE SIGNAL

Kind window treating	P_L	P_M	P_H
	%		
Before filtering	65	23	12
Derichlet	43,9	34,5	21,6
Hann	44,3	34,2	21,7
Hamming	37,3	43,3	19,5
Exact Blakcman	46,3	32,9	21
Blackman-Harris	46,2	32,9	21.1
Flat-Top	45,8	32,8	21,5

TABLE III
NO CONJUGATED FILTER PROCEEDING

Kind Filter	P_L	P_M	P_H	S_L	S_H
	%				
Two branches	*43,9*	*34,5*	*21,6*	*65,4*	*34,6*
Three branches	*57,8*	*30,7*	*11,5*	*77,8*	*22,2*
Four branches	*69,6*	*22*	*8,4*	*86,2*	*13,8*

In Table IV are shown results, obtained with window proceeding over received signals.

Table V shows the results obtained with window proceeding over received signals with non-recursive filter. In the process of receiving of the results, BPF with various numbers of elements, marked as *N*, are used. The window proceeding used is Flat top – Flat top.

TABLE IV
BEFORE FILTERING RECEIVED SIGNALS ARE PROCEEDED WITH DIFFERENT WINDOW TREATMENT. KINDS OF WINDOWS: D – DERICHLET, HM – HAMMING, HN – HANN, F – FLAT TOP

Kind Windows	P_L	P_M	P_H	S_L	S_H
	%				
D-D	*43,9*	*34,5*	*21,6*	*65,4*	*34,6*
Hm-Hn	*37,1*	*43,3*	*19,7*	*63,7*	*36,3*
Hm-F	*37,7*	*43,4*	*19,1*	*63,9*	*36,1*
Hm-Hm	*37*	*43,4*	*19,7*	*63,7*	*36,3*
F-F	*46,3*	*33*	*21*	*67,7*	*32,3*

TABLE V
RESULTS OBTAINED WITH DIFFERENT NUMBER OF FILTER ELEMENTS. N – NUMBER OF ELEMENTS

N	P_L	P_M	P_H	S_L	S_H
	%				
0	*65*	*23*	*12*	*80*	*20*
16	*54,9*	*27,5*	*18,1*	*73,4*	*26,6*
32	*45*	*34,6*	*20,7*	*67*	*33*
64	*44,4*	*35*	*20,9*	*64,7*	*35,3*
128	*44,7*	*34,5*	*21*	*64,3*	*35,7*

Figure 4 and Figure 5 show the influence of non-recursive BPF upon proceeding jamming signal. In low band domain the effect of AFC diagram lobes is visible. The number of these lobes depends on the number of filter elements. In Figure 4, the number of elements is 16 and in Figure 5 – 64. That effect is not visible in high pass frequency domain.

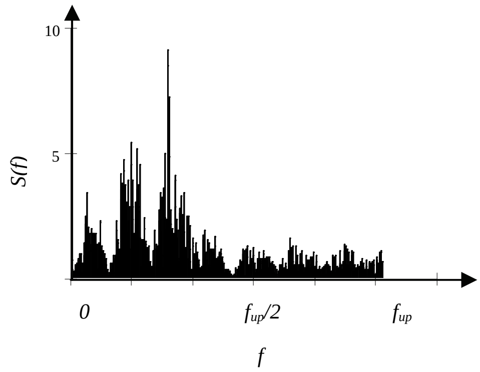

Fig. 4. Filtered jamming signal, *N*=16

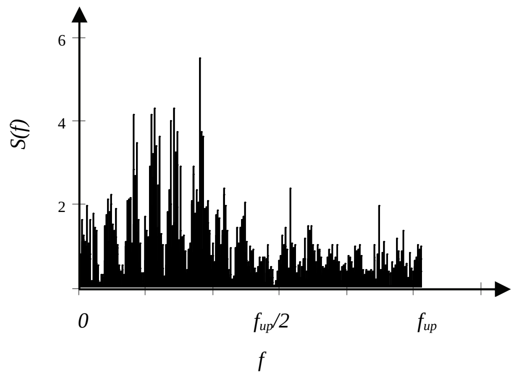

Fig. 5. Filtered jamming signal, *N*=64

Table VI shows the results connected with the investigation of width of the frequency transient filter area according to the number of elements and with regard to suppressing possibilities of BPF (3).

TABLE VI
RESULTS OBTAINED TO VARIOUS WIDTH OF FREQUENCY TRANSIENT FILTER AREA

N	$\Delta\omega$	P_L	P_M	P_H	S_L	S_H
		%				
32	$\Delta\omega = \pi/8$	*45*	*33,3*	*22,1*	*66,7*	*33,3*
	$\Delta\omega = \pi/16$	*45*	*34,6*	*20,7*	*67*	*33*
64	$\Delta\omega = \pi/11$	*44,4*	*35*	*20,9*	*64,7*	*35,3*
	$\Delta\omega = \pi/32$	*44,9*	*34,2*	*21,2*	*65,2*	*34,8*

IV. COMMENTS ON RECEIVED RESULTS

From the results shown in Tables I, II and IV it is possible to make a conclusion that proceeding with Hamming window gives the best results. The suppression of correlated is better than of other window proceedings. When this Hamming window is used, a rising of PSD in middle of spectral domain is observed.

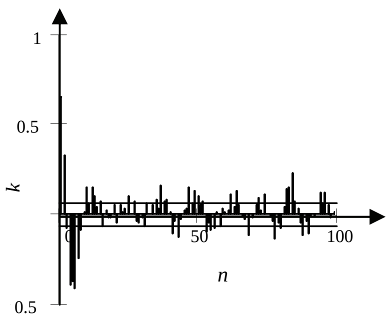

Fig. 6. Correlation coefficients exceed limits

The signal 2 from Fig. 3 is suppressed when a 128-element filter is used. This can be explained with the fact that the signal 2 is canceled by AFC filter lobes.

After BPF proceeding of jamming environment, the output signal remains correlated. This result is shown in Fig. 6. In this figure the correlation coefficients exceed the 5% admissible limits.

This can be explained with the fact that BPF parameters are not in compliance with the correlation characteristics of the jamming environment.

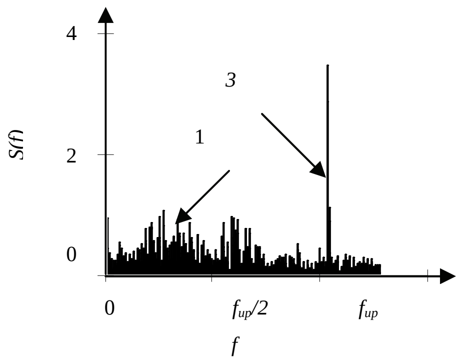

Fig. 7. Signals 1 and 2 are received after proceeding with BPF, and they are shown also in Fig. 1 before proceeding. The useful signal 2 is suppressed.

After filter proceeding, the useful signal 2 is suppressed – Fig.1. This signal is located in non-pass frequency area of BPF. The amplitude of other useful signal 3 rises above the interfere noise and it is shown in Fig.7.

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