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IMPULSE NOISE CANCELLATION IN AN OFDM SYSTEM TRANSMITTING MEDICAL IMAGES USING DUAL TRANSFORM AND GEOMETRIC ADAPTIVE FILTER

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ABSTRACT

A new Geometric adaptive filtering (GAF) algorithm is developed for the removal of impulse noise particularly in the images transmitted in the OFDM system. Impulse noise commonly called, Salt and pepper noise can be commonly found in the transmission channel during acquisition and transmission of digital images [4]. From the input image the CVT (curvelet transform) is applied with different coefficients to the compression process, A progressive restoration mechanism is devised using multipass nonlinear operations which adapt to the intensity and the types of the noise. Simulation results from Matlab show that this method can eliminate the salt and pepper noise in OFDM transmitted images efficiently and preserves the edges and detail information of the image. Also the Geometric adaptive filter algorithm method can remove noise from low-noise contaminated image with noise level of the order of 30%,Since medical images has to be restored with greater visual image clarity.

Keywords–*Orthogonal Frequency division multiplexing (OFDM), Curvelet transform(CVT), Bit Error Rate (BER), Phase shift keying(PSK), additive white Gaussian noise (AWGN), Fast fourier transform(FFT), Geometric adaptive filter(GAF).*

I. INTRODUCTION

Presently OFDM has emerged as the standard of choice in a number of important high data applications [2]. The basic principle of the OFDM system is to decompose the high rate data stream (bandwidth W) into N number of parallel lower rate data streams or channels, one for each subcarrier [3]. Hence the total channel bandwidth is converted into multiple smaller bandwidths (slow rate channels) to avoid the effects of inter symbol interference (ISI) at the receiver side [4]. Fourier transformation and Discrete Fourier Transformation (DFT) are used to realize modulation and demodulation, respectively [6].

Advancements in medicine and wireless data transmission has allowed medical experts from anywhere in the world to send, interpret and manipulate any digital information..Wireless networks have gained popularity as a result of advancements that has solved security issues that have confined with the use of wireless technology in low-cost applications. In this paper, we discuss an approach for transmission of medical images and its remote transmission through OFDM ,since it is one of the most promising methods of wireless transmission. High data rate transmission, impulse noise suppression, Orthogonality elimimating ICI, cyclic prefix eliminating ISI makes OFDM best suited method for medical image transmission[8]. Since applying curvelet transform provides better noise rejection, we dev eloped a new multicarrier scheme which combines the two transforms namely CVT and FFT resulting in reduced impulse noise.

II. METHODOLOGY

OFDM transmission is considered over different channel SNR values with the transformation process and modulation. OFDM transmitter input images to apply the curvelet Transform (CVT) to transform the spatial domain to frequency domain process. Fig1 shows the block diagram of the novel OFDM transmitter and receiver.

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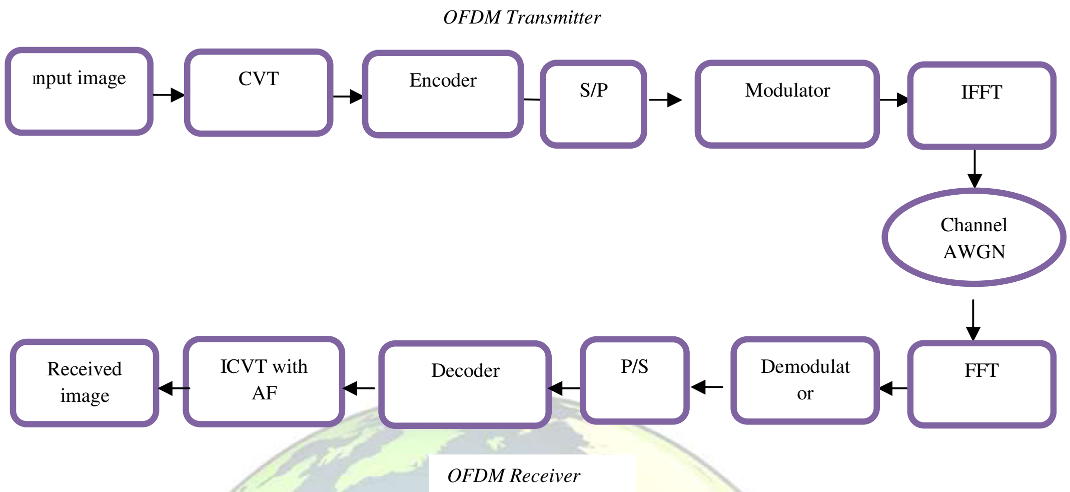

Fig 1. Block diagram of the proposed OFDM transmitter and receiver

This paper presents a simple, yet efficient way to remove impulse noise from digital medical images in OFDM. This novel method comprises two stages. The first stage is to detect the impulse noise in the image. The pixels can be roughly divided into two categories based on only the intensity values, namely the "noise-free pixel" and "noisy pixel". Eliminating the impulse noise from the image is the second stage, where only the "noisy-pixels" are processed. The output image consists of directly copied "noise-free pixels"

This adaptive method as the name indicates adaptively changes the size of the adaptive filter based on the number of the "noise-free pixels" in the neighborhood. For the filtering, the finding of the median value of only the "noise-free pixels" are considered. The results from 2 test medical images showed that this proposed method surpasses some of the state-of-art methods, and can remove the noise from low-noise corrupted images, up to noise percentage of 30%.

An interesting feature of the Geometric Adaptive filter (GAF) technique is that based on the 2-D geometric information of the corrupted pixels, the impulse detection is achieved .First, the 3-D medical images are converted into 2-D gray-scale images. The curvelet transform is appiied to the image whose dimension is altered to power of two pixels in both horizontal and vertical dimensions .to this image following which the second transform, namely IFFT is applied. The dual transformed image is passed through the OFDM system. The data is differentially encoded before transmitting.

At the OFDM receiver, inorder to distinguish the sharp step edges from other types of edges during the image extraction, we define the edge feature-identification threshold, T_e , which represents the value of a derivative [6]. In addition to this ,the length of a line is used as another important feature to distinguish a noisy line from a fine image line. According to the noise ratio, a length threshold T_l is also defined.

Second, in terms of the pixel coordinates of the gray-scale image, B ,a set of corrupted pixels is defined as

$$\begin{aligned} S_1 = \{c| &\left((\mathbf{G}^a < (-T_e)) \wedge (\mathbf{G}^d < (-T_e))\right) \\ &\vee \left((\mathbf{G}^a > T_e) \wedge (\mathbf{G}^d > T_e)\right), \mathbf{n}_k^d \in N_d, \mathbf{n}_k^a = 1 \\ &\text{for } 1 \le k \le 4, N_d = \{1, 2, 3, \ldots T_m\} \\ &T_m = (T_l + 1)/2\} \end{aligned}$$

where T_m is used to define corrupted pixel-sizes in and whose default value is 2. According to above equation, if the two partial derivatives G^a and G^d of a pixel have the same sign while their magnitudes are greater than a preset threshold T_e , when n_k^a is 1 and n_k^d is 1 or 2 or 3, or T_m (its components may have different values), then the pixel belongs to S_1 . Set S_1 includes individual impulse pixels, slant noise lines with one-pixel width and the pixels of the lines only adjacent to each other in diagonal direction within the defined length of T_l.

Third, a set of corrupted pixels, which include individual impulse pixels, straight noise lines with one-pixel width and the pixels of the lines being only 4- neighbours to each other within the defined length of T_l, is defined as

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$$S_2 = \{c \ ((G^a < (-T_e)) \wedge (G^d < (-T_e))) \\ \vee ((G^a > T_e) \wedge (G^d > T_e)) ; n_k^a \subset N_a ; n_k^d = 1 \\ \text{for } 1 \leq k \leq 4, N_a = \{1, 2, 3, \ldots T_m\} \\ T_m = (T_t + 1)/2\}$$

Where T_m is used to define corrupted pixel-sizes in this set and its default value is 2. According to the above equation, if the two partial derivatives G^a and G^d of a pixel have the same sign while their magnitudes are greater than a preset threshold T_e , when n_k^a is 1 and $n_k^d$is 1 or 2 or 3, or (its k components may have different values), then the pixel belongs to S_1. Next, a set of corrupted pixels is defined as S_3,which include noisy pixels/regions within 3-pixel width in any direction except the noisy pixels already in $S_1$and/or S_2 , i.e., c ϵ S_1 $_U S_2$

$$\text{If } S = \{c| ((G^a < (-T_e)) \wedge (G^d < (-T_e))) \\ \vee ((G^a > T_e) \wedge (G^d > T_e)) ; n_k^d = n_k^a = L\}$$

Where 1≤ k≤4, , L is 2 or 3, and the default value for and $\mathbf{n}^d$ and $\mathbf{n}^a$ is 2. Thus,S_3 can be represented as

$$S_3 = S - (S_1 \cup S_2)$$

Where T_m =2 for S_1 and S_2 . According to the above equation, if the two partial derivatives of a pixel have the same sign while their magnitudes are greater than a preset threshold T_e ,when n_k^a and n_k^d are 2 or 3 and the pixel is not in S_1 or S_2 ,then the pixel belongs to S_3.

According to observations made on a variety of natural images corrupted with the impulse noise, a protrusive point in a border area with high possibility of being a corrupted pixel is defined as,

$$S_4 = \{c| ((G_k^a < (-T_e)) \wedge (G_v^d < (-T_e))) \\ \vee ((G_k^a > T_e) \wedge (G_v^d > T_e)) , \\ n_k^d = n_k^a = n_v^d = n_v^a = 1, \\ \forall k \in \{y \ y \in N_n \wedge y \neq c\}, c \in N_n, \\ N_n = \{1, 2, 3, 4\}, (v = k) \\ \wedge (v \in \{2, 3\} \vee v \in \{3, 4\} \vee v \in \{4, 1\} \\ \vee v \in \{1, 2\})\}.$$

According to the above equation, the two partial derivatives G^a and G^d of a pixel have the same sign while their magnitudes are greater than a preset threshold T_e, with the partial derivatives indexed by k containing only three out of the four distance settings, and the partial derivatives indexed by being either {2, 3} or {3, 4} or {4, 1} or {1, 2} and equal to k , whenn_k^d ,n_k^a ,n_v^a , andn_v^a are 1, then the pixel belongs to S_4 .

At each coordinate c ϵ B , a square filter processing window is defined, which centers at the coordinate c and contains N pixels, where N is an odd number. The width of the window is represented as √ N and must be a positive integer, i.e., 3, 5, 7, and so on, in the recommended implementation. The operations for removing impulses in S_1,S_2,S_4 , and are implemented by a 3x 3 processing window, and the operation for removal of impulses in S_3 is implemented by a 5x5 processing window.

In detecting and removing impulse noise, a filter may make three main types of mistakes. When the filter does not detect a corrupted pixel, Type I error [7] (*miss*) occurs. When the filter detects an impulse noise pixel which is actually clean Type II error (*false alarm*) happens When the filter removes an impulse noise and replaces it with a value determined by a certain restoration strategy, Type III error[7](*over-* or *under-correcting error*) is defined as the difference between the true pixel value as the noise-free pixel was and the resultantvalue after the restoration process. The restoration technique used in this work is based on the modified median and with the increase of the processing window size the destruction of noise-free pixels (i.e., Type II error) becomes increasingly severe[7]. In order to achieve the best performance of the proposed filter, in terms of both visual quality of the image and their objective measurements, the design of the processing windows has to depend on the sizes and shapes of the corrupted pixels. In order to discriminate the corrupted pixel and its neighborhood , the threshold is usually set to less than 20 in magnitude for the filter. This helps to improve perceptual image quality (i.e.,reducing Type I error); However, with the threshold reduction , the filter removes more and more

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uncorrupted details of the image during the operation. It is important that Type II error is also under good control in order to preserve the uncorrupted details, structures and features of the image as much as possible. A balance between the noise removal and detail preservation must be made based on optimization of objective measurements.

In the following implementation, the threshold is chosen from the range of [1],[2] adapted to the size of processing window. Implementation of the principles of the GAF is described as follows. At each coordinate , a square filter processing window is defined, which centers at the coordinate and contains pixels, where is an odd number. [5] discussed about Improved Particle Swarm Optimization. The fuzzy filter based on particle swarm optimization is used to remove the high density image impulse noise, which occur during the transmission, data acquisition and processing. The proposed system has a fuzzy filter which has the parallel fuzzy inference mechanism, fuzzy mean process, and a fuzzy composition process. In particular, by using no-reference Q metric, the particle swarm optimization learning is sufficient to optimize the parameter necessitated by the particle swarm optimization based fuzzy filter, therefore the proposed fuzzy filter can cope with particle situation where the assumption of existence of "ground-truth" reference does not hold. The merging of the particle swarm optimization with the fuzzy filter helps to build an auto tuning mechanism for the fuzzy filter without any prior knowledge regarding the noise and the true image. Thus the reference measures are not need for removing the noise and in restoring the image. The final output image (Restored image) confirm that the fuzzy filter based on particle swarm optimization attain the excellent quality of restored images in term of peak signal-to-noise ratio, mean absolute error and mean square error even when the noise rate is above 0.5 and without having any reference measures.

The width of the window and must be a positive odd integer,i.e., 3, 5, 7, and so on, in the recommended implementation. The operations for removing impulses in S_1, S_2 and S_4 are implemented by a 3x3 processing window, and the operation for removal of impulses in is implemented by a 5x5 processing window. Each processed pixel in an image is at the center of the symmetric window. The restoration technique used in this work is based on the modified median as described previously. With the increase of the processing window size the destruction of noise-free pixels (i.e., Type II error) becomes increasingly severe but less likely with the increase of the edge feature threshold . The design of the processing windows has to depend on the shapes and sizes of corrupted pixels/ pixel regions in order to achieve the best performance of the proposed filter, in terms of both visual quality of the image and the parameters measured . The threshold to discriminate the corrupted pixel and its neighborhood is usually set to less than 20 in magnitude for the filter, in order to improve perceptual image quality (i.e.,reducing Type I error; However, with the decrease of the threshold , the filter removes more and more uncorrupted details of the image during the operation. It is important that Type II error is also under good control in order to preserve the uncorrupted details, structures and features of the image as much as possible.

A balance of removing noise and preservation of the details must be made based on optimization of objective measurements. The threshold for detecting the sharp step edge type for color images can be determined by a greedy algorithm searching for the least MSE (mean square error) [6] using a set of test color images with different impulse noise ratios and types in an off-line experiment.

A design principle for the following operations, which are adapted to different noise ratios and types, is to use as small a size of the window and as less a number of the passes as possible, as long as the impulse noise can be removed (to ensure preserving image details as much as possible). The number of passes was determined for removal of a noise region based on the worst case scenario within the estimated maximal size of the noise region.

The median filters produce the best result only for low noise densities up to 30% and the filter fails to perform well at higher density levels but the new adaptive weighted algorithm [4] can be used for highly corrupted images.

Peak Signal to Noise Ratio (PSNR) and BER of the output image are computed to analyze the performance of the given algorithm as a removal of impulse noise from OFDM images[6].

The table indicates the comparison of received images using FFT OFDM and Geometric adaptive filter compared to dual transform OFDM with Geometric adaptive median filter.

On the other hand, the Geometric adaptive filter was found to be best-suited for removing such signal-independent noise, while at the same time preserving the edges of the image[6]. If the noise is not completely independent of the signal content, for example, in the case of additive or multiplicative noise corrupting an OFDM transmitted image where the noisy pixels are a mixture of of original pixel intensities and noise levels, then adaptive median filters are the solution.

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TABLE 1 IMPULSE NOISE SUPPRESSION PERFORMANCE OF THE GAF FOR DIFFERENT MODULATION TECHNIQUES, WHERE THE TEST IMAGE *BRAIN* AND *SCAN* CORRUPTED WITH DIFFERENT RANDOM IMPULSE NOISE LEVELS

Modulation	**SNR In dB**	**Average phase error**		**% pixel error**		**BER**	
		Without G AF	***With GAF***	***Without G AF***	***With GAF***	***Without GAF***	***With GAF***
BPSK	0	51.77	51.6	78.15	78.06	17.42	17.28
BPSK	6	23.7	23.6	5.96	5.57	0.78	0.72
QPSK	12	11.48	11.39	1.13	0.86	0.32	0.24
16-PSK	12	11.63	11.46	67.60	66.83	43.1	42.62
16-PSK	24	3.34	2.21	1.59	0.10	0.80	0.054
256-PSK	12	11.70	1.5	96.10	61.58	96.1	61.5

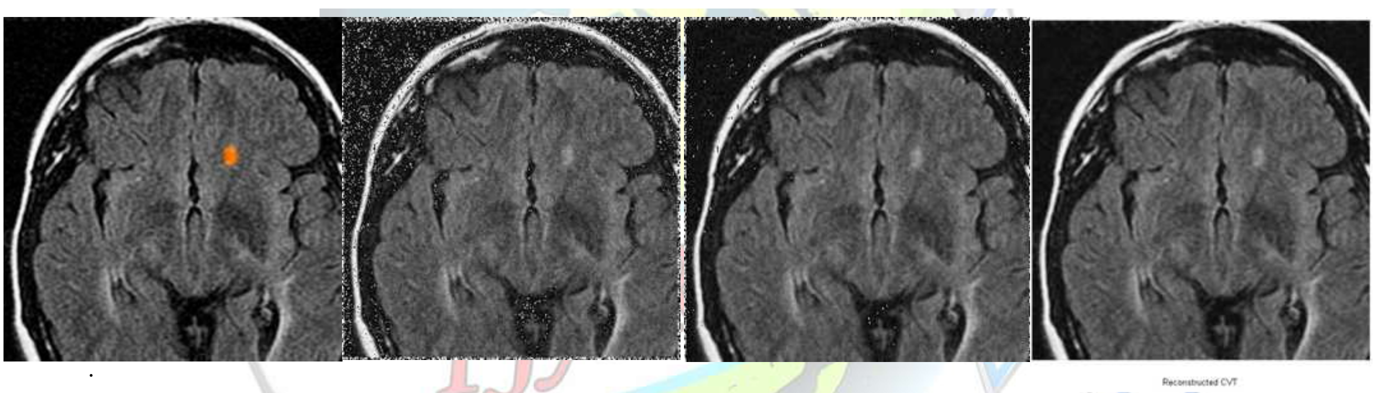

Fig. 2a)The transmitted brain image b) Input image to OFDM receiver for SNR = 12dB c) Image after adaptive filtering d) Output image of receiver after Reconstructed CVT using 256-PSK modulation.

Fig. 3a) The transmitted scan imageb) Input image to OFDM receiver for SNR = 24dBc) Image after adaptive filtering d)Output image of receiver after Reconstructed CVT using 16-PSK modulation

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The simulation was done for an IFFT size of 1024 and with the number of subcarriers as 500 for an OFDM system with differential encoding and decoding. The simulation was performed as follows:

(i) OFDM system mentioned above with CVT along with FFT and Geometric adaptive filter at the receiver. ii)The same is repeated for various modulation techniques.

The Table I above indicates the % phase error and % pixel error rate and BER for the different modulation schemes in OFDM for four values of SNR namely 0dB, 12dB for BPSK modulation 12dB and 24dB for QPSK, 16-PSK and 256-PSK.

Amplitude clipping of 6dB is also done in addition to GAF suppress the impulse noise. The GAF provides best performance in terms of medical image quality for SNR>6dB in case of BPSK modulation , SNR >12dB for QPSK and for SNR >24 dB for 16-PSK and 256-PSK. in OFDM. Compared to wavelet filters, the GAF provides better performance in terms of edge preservation and de-blurring.

The concept behind Geometric adaptive median image filtering is that by varying the filtering method as the kernel slides across the image , they are able to adapt themselves to the local properties and structures of an image[6]. In other words, the Geometric adaptive weighted median filters can be thought of as self-adjusting digital filters. Adaptive median filters perform better than median filters at removing impulse noise especially at high noise levels and they are generally used for denoising non-stationary images, which tend to exhibit abrupt intensity changes. As the filtering operation is no longer purely uniform, instead modulated based on the local characteristics of the image, these filters can be employed effectively when there is little a priori knowledge of the signal being processed.They are described for a) OFDM system without GAF b) OFDM system with GAF.

Higher order PSK modulation schemes have high data rate but also high BER and phase error. They have to use Error correcting codes for long distance communication. Lower order modulation schemes have lower BER and lower but lesser data rate. There is always a trade-off between error rate and data rate.

CONCLUSION

OFDM, being a gifted method for wireless image transmission, its features and advantages are fully made use of in transmission of medical images. OFDM can survive severe channel conditions like frequency selective fading. The enormous bandwidth and high data rates of OFDM makes it an excellent technology for transmission of medical images. Also the noise rejection capability of the combined effect of dual transform and Geometric adaptive median filter provides low BER, Pixel error rate and phase error The Geometric adaptive weighted median filter which are edge preserving smoothing filters are best suited for impulse noise removal. Since the CVT(curvelet transform) is very efficient in representing curve-like edges, this dual transformation used for images along with impulse-noise removal using Geometric adaptive filter helps in faithful retrieval of medical images transmitted in an OFDM system in less noisy communication channels with less than 30% impulse noise.. For extremely noisy channels, a suitable modification of the geometric adaptive filter could be used to eliminate impulse noise.

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