SLANTLET TRANSFORM-BASED OFDM SCHEME

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الخلاصة

إن الاتصالات الرقمية اللاسلكية في توسع مستمر مما يستدعي الحاجة إلى أنظمة موثوقة وذات كفاءة طيفية عالية و لتحقيق هذه الحاجة فأن تقنية مزج الترددات المتعامدة (OFDM) استحوذت على الكثير من الاهتمام. في هذا البحث اقترحت طريقة جديدة لتحسين اداء ال(OFDM). ان الطريقة الجديدة في هذا البحث هو تقليل مستوى التداخل وازالة الحاجة الى استعمال الفترة الفاصلة وبهذا تم تحسين كفاءة النطاق (Bandwidth) في منضومة ال(OFDM) ،هذا يتم عن طريق تبديل تحويل الفورييربطريقة الأنحدارالمائل(Slantlet). وان ال (Slantlet) هو تطويرحصل في المويجات (Wavelet) فقد لوحظ ان (SLT-OFDM) افضل من (WP-OFDM) في حالة القناة الوهن الانتقائي للتردد و كذلك ان خوارزمية (Slantlet) اسرع بكثير من خوارزمية (Wavelet). في هذا البحث تم التركيز على المقارنة بين (FFT-OFDM) و (SLT-OFDM) من اهم النتائج التي تم الحصول عليها هو ان اداء (SLT-OFDM) يكون افضل بحدود18 dBعن اداء (FFT-OFDM) في قناة الوهن المستوي. بينما اداء نظام(SLT-OFDM) يكون افضل فقط في منطقة SNR الواطئة وسوف ينعكس الاداء مع زيادة SNR في حالة القناة الوهن الانتقائي للتردد.

ABSTRACT

Wireless digital communication is rapidly expanding resulting in a demand for systems that are reliable and have a high spectral efficiency. To fulfill these demands OFDM technology has drawn a lot of attention.

In this paper a new technique is proposed to improve the performance of OFDM. The new technique is use the slantlet transform (SLT) instead Fast Fourier transform (FFT) in order to reduce the level of interference. This also will remove the need for Guard interval (GI) in the case of the FFT-OFDM and therefore improve the bandwidth efficiency of the OFDM. The SLT-OFDM is also better than wavelet packet (WP)-OFDM in the selective channel because the slantlet filter bank is less frequency selective than the traditional DWT filter bank, due to the shorter length of the filters and SLT algorithm is faster than WP algorithm. The main results obtained indicate that the performance of SLT-OFDM is better on average by 18dB in comparison with that of FFT-OFDM flat fading channels. For frequency selective fading channel the SLT-OFDM performs is better than the FFT-OFDM on the lower SNR region, while the situation will reverse with increase SNR values.

WORD KEY

slant let transform - OFDM- Guard interval

INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is very similar to the well known and used technique of Frequency Division Multiplexing (FDM). OFDM uses the principles of FDM to allow multiple messages to be sent over a single radio channel. It is however in a much more controlled manner, allowing an improved spectral efficiency.

The Fourier transform (or other transform) data communication system is a realization of FDM in which discrete Fourier transform are computed as part of modulation and demodulation process. In addition to eliminating the banks of subcarrier oscillators and coherent demodulators usually required in FDM system, a completely digital implementation can be built around a special-purpose computer performing the fast Fourier transform [1]. OFDM has recently been applied widely in wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency and its robustness to multi-path delay. It has been used in wireless LAN standards such as American IEEE802.11a and the European equivalent HIPERLAN/2 and in multimedia wireless services such as Japanese Multimedia Mobile Access Communications. A dynamic estimation of channel is necessary before the demodulation of OFDM signals since the radio channel is frequency selective and time-varying for wideband mobile communication systems [2].

Recently, Selesnick has constructed the new orthogonal discrete wavelet transform, called the slantlet wavelet, with two zero moments and with improved time localization [3]. This Transform method have played an important role in signal and image processing applications. The slantlet has been successfully applied in compression and denoising. It also retains the basic characteristic of the usual filterbank such as octave band characteristic, a scale dilation factor of two and efficient implementation. However, the SLT is based on the principle of designing different filters for different scales unlike iterated filterbank approaches for the DWT [4].

SLANT LET FILTER BANK [5]

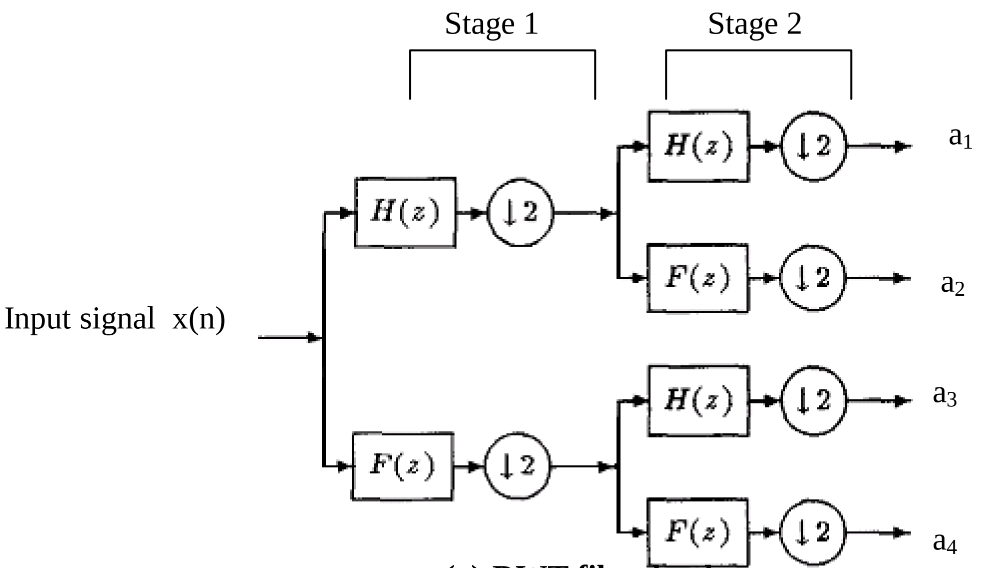
It is useful to consider first the usual iterated DWT filter bank and an equivalent form, shown in Figure 1. The symbol a_1 is the symbol with the highest frequency, while symbol a_4 is the symbol with the lowest frequency. The 'slantlet' filter bank described here is based on the second structure in figure (1.b), but it will be occupied by different filters, that are not products. With the extra degrees of freedom obtained by giving up the product form, it is possible to design filters of shorter length, while satisfying orthogonality and zero moment conditions, as will be shown. For the two-channel case, the shortest filters for which the filter bank is orthogonal and having K zero moments, are the well known filters described by Daubechies [6]. For K = 2 zero moments, those filters H (z) and F (z) are of length 4. For this system, designated D2,the iterated filters in Figure 1 are of length 10 and 4. Without the constraint that the filters are products, an orthogonal filter bank with K = 2 zero moments can be obtained where the filter lengths are 8 and 4, as shown in Figure 2, side by side with the iterated D2 system. That reduction of two samples grows with the number of stages, as in Figure 3. We make several comments regarding Figures 2 and 3.

- Each filter bank (equivalently, discrete-time basis) is orthogonal. The filters in the synthesis filter bank are obtained by time-reversal of the analysis filters.
- Each filter bank has 2 zero moments. The filters (except for the lowpass ones) annihilate discrete-time polynomials of degree less than 2.
- Each filter bank has an octave-band characteristic.
- The scale-dilation factor is 2 for each filter bank. Between scales, the filters dilate by roughly a factor of 2. (In the slantlet filter banks, by exactly a factor of 2.)
- Each filter bank provides a multiresolution decomposition. By discarding the highpass channels, and passing only the lowpass channel outputs through the synthesis filter bank, a lower resolution version of the original signal is obtained.

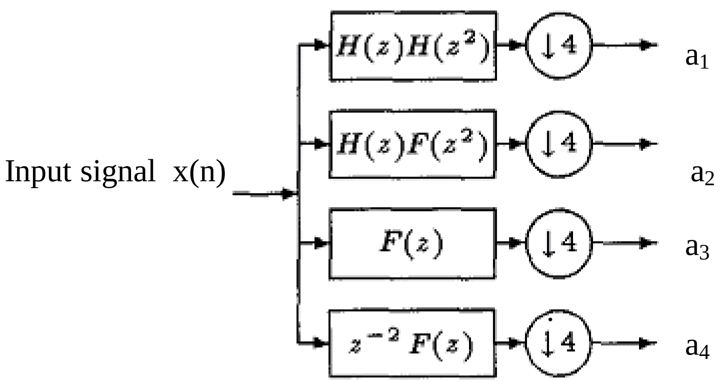
- The slantlet filter bank is less frequency selective than the traditional DWT filter bank, due to the shorter length of the filters. The time-localization is improved with a degradation of frequency selectivity.
- The slantlet filters are piecewise linear.
- In figure 1 it is clear that DWT needs two stages while Slantlet needs one stage only.

It must be admitted that, although both types of filter banks posses the same number of zero moments, the smoothness properties of the filters are somewhat different. In Figures 2 and 3, the slantlet filters have greater "jumps" than do the iterated D2 filters.
However, the Haar basis, with its discontinuities, is suitable for analyzing piecewise constant functions that have jumps. Likewise, the slantlet filter bank appears appropriate for the analysis of piecewise linear functions, as illustrated in the denoising example below.

The ability to model jumps is also relevant for other applications, like edge detection and change point analysis, in which the detection of abrupt changes in an otherwise relatively smooth but unknown function is considered [7]. In figure(2) the S1 is frequency response of F(z) and S2 is frequency response of $H(z)F(z^2)$ and S3 is frequency response of $H(z)H(z^2)$ and V1 is frequency response of $G_1(z)$ and V2 is frequency response of $F_2(Z)$ and V3 is frequency response of $H_2(Z)$ and also in figure(3) the S1 is frequency response of F(z) and S2 is frequency response of $H(z)F(z^2)$ and S3 is frequency response of $H(z)H(z^2)F(z^4)$ and S4 is frequency response of $H(z)H(z^2)H(z^4)$ and V1 is frequency response of $G_1(z)$ and V2 is frequency response of $G_2(z)$ and V3 is frequency response of $F_3(z)$ and V4 is frequency response of $H_3(z)$.

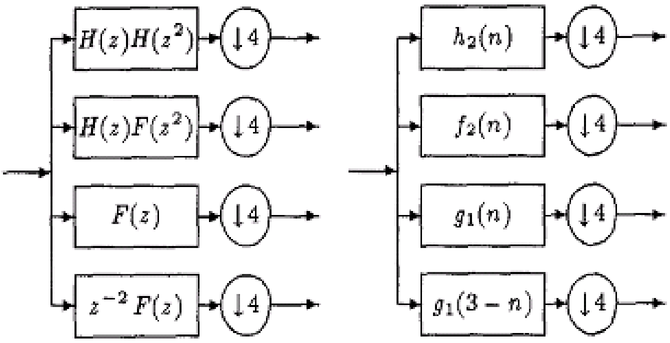


(a) DWT filter bank

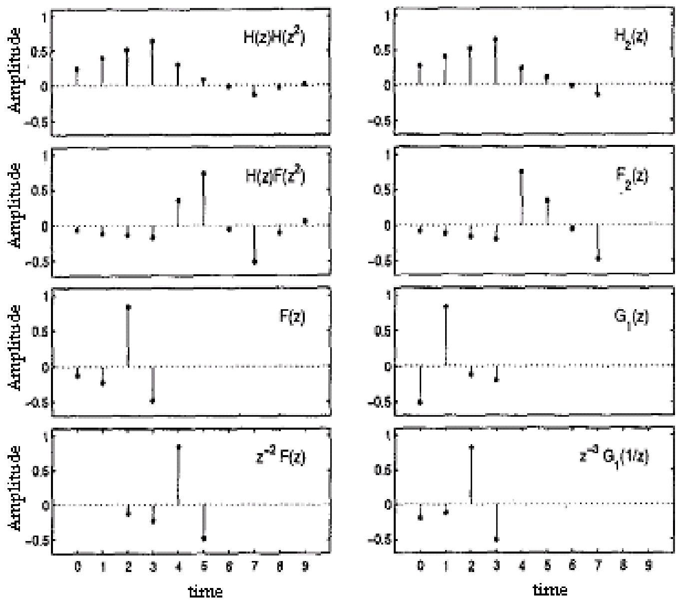


(b) slantlet filter bank

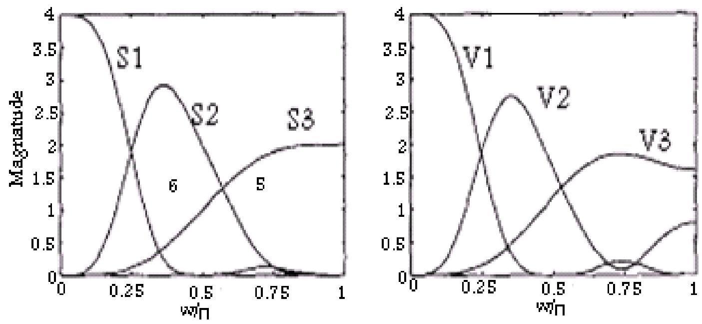
Fig. 1: Iterated filter bank and an equivalent structure.



(a) Block diagram

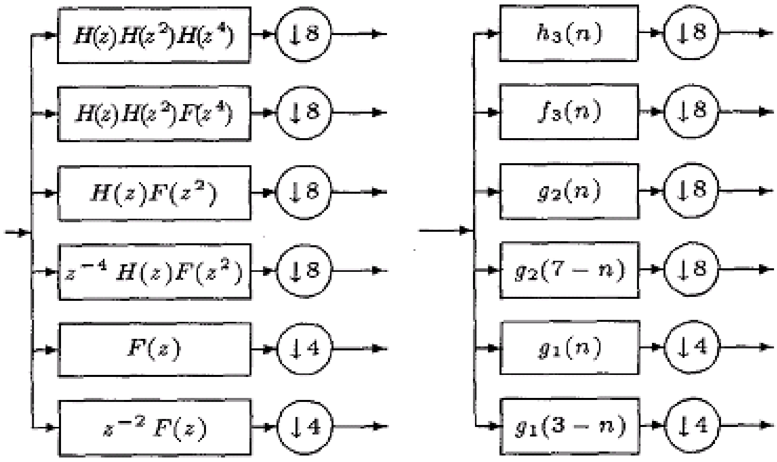


(b) Impulse response of filter bank.

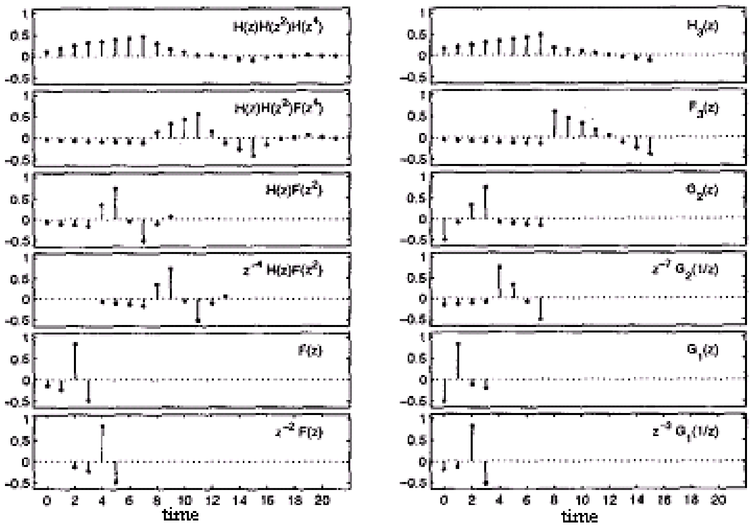


(c) Frequency response.

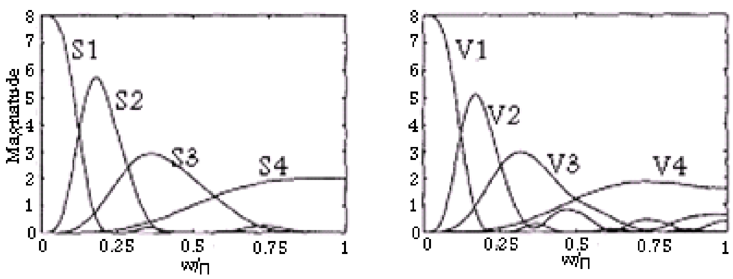
Fig. 2: Comparison of iterated D2 filter bank (left-hand side) and slantlet filter bank (right-hand side).



(a) Block diagram



(b) Impulse response of filter bank .



(c) Frequency response.

Fig. 3: Comparison of iterated D2 filter bank (left-hand side) and slantlet filter bank (right-hand side).

A SYSTEM FOR FFT-BASED OFDM

The block diagram of the system for OFDM is depicted in figure (4).

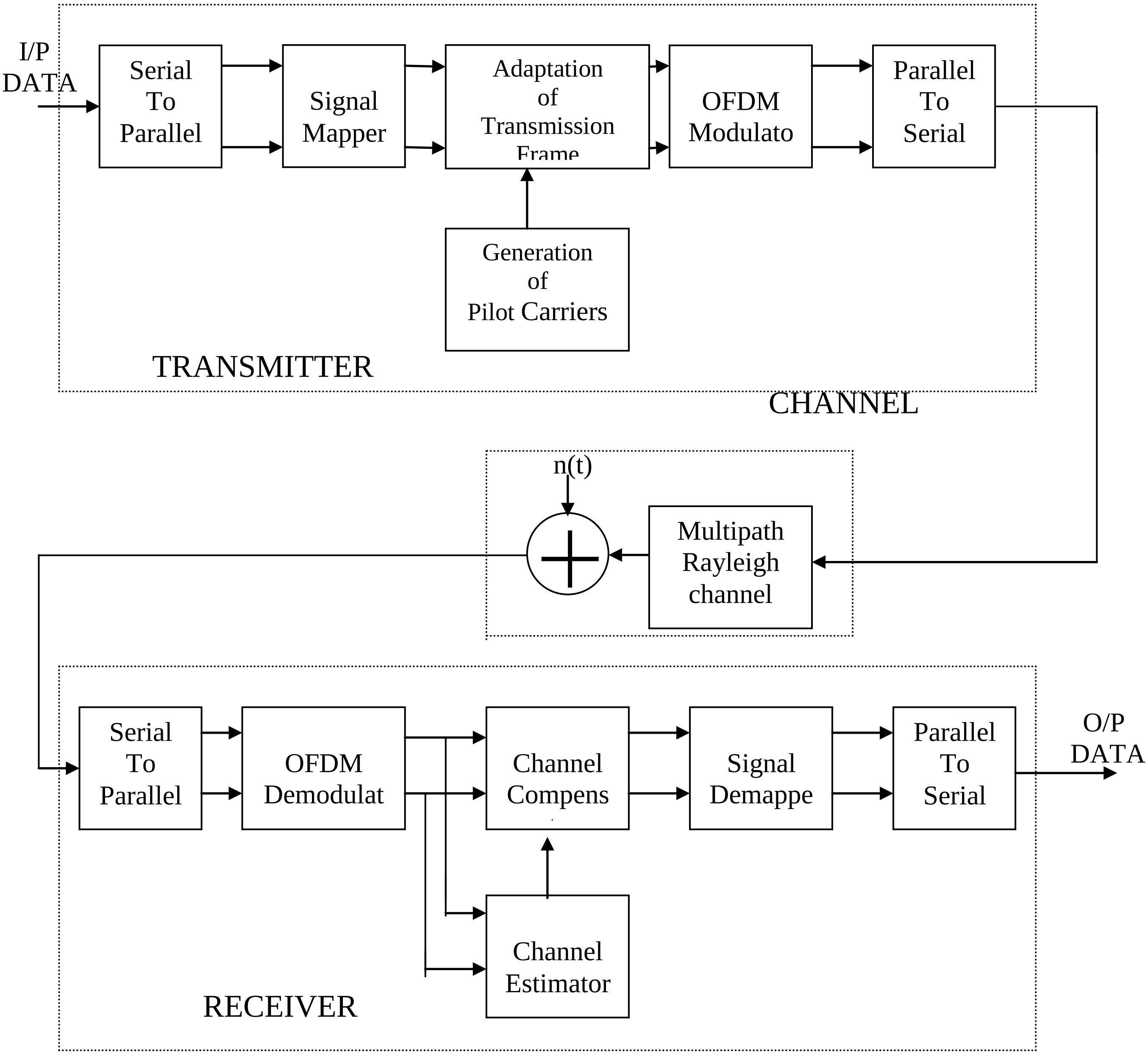
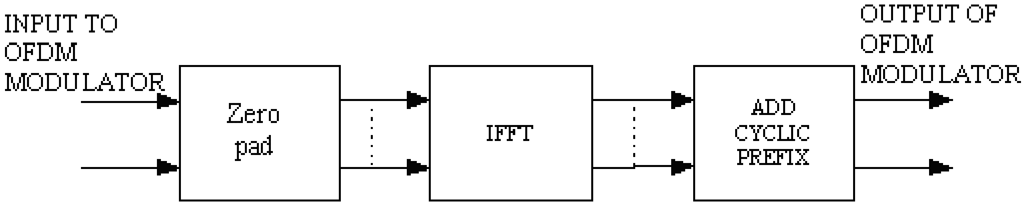
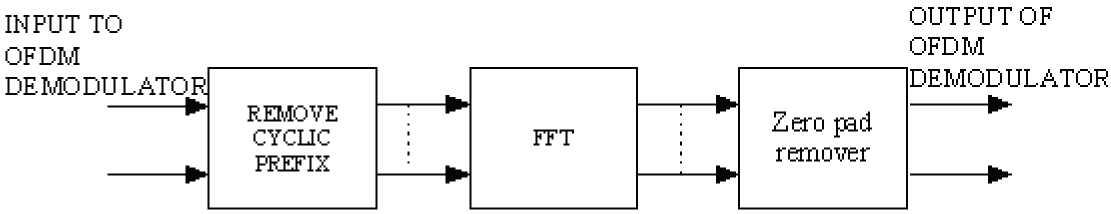


Fig. 4: Block Diagram of OFDM System.

The OFDM modulator and demodulator of FFT-based OFDM is shown in figure (5).



(a) OFDM Modulator.



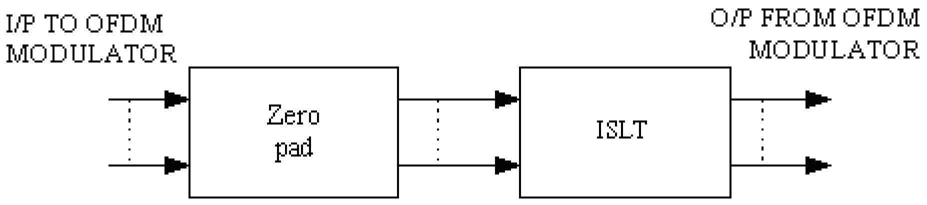
(b) OFDM Demodulator.

Fig. 5: The OFDM modem system.

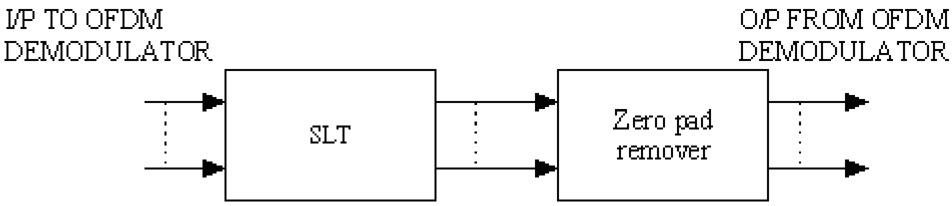
First of all, the input serial data stream is formatted into the word size required for transmission e.g. 2 bit/word for QPSK and 4 bit/word for 16-QAM, and shift into a parallel format. The data is then transmitted in parallel by assigning each word to one sub-carrier in the transmission. After that, the data to be transmitted on each sub-carrier is then mapped into QPSK or 16-QAM constellation format. This process will convert data to corresponding value of M-ary constellation which is complex word, i.e. real and imaginary part. The training frame (pilot sub-carriers frame) will be inserted and sent prior to information frame. This pilot frame will be used for channel estimation that's used to compensate the channel effects on the signal. After that, the complex words frame and pilots frame will pass to IFFT to generate an OFDM symbol. Zeros will be inserted in some bins of the IFFT in order to make the transmitted spectrum compacts and reduce the adjacent carriers interference.

PROPOSED SYSTEM FOR SLANTLET TRANSFORM -OFDM

The overall system of OFDM is the same as in figure (4). The only difference is the OFDM modulator and demodulator. The slantlet transform SLT-OFDM modulator and demodulator that used are shown in the figure below:



(a) SLT-OFDM modulator.



(b)ISLT-OFDM demodulator.

Fig. 6: SLT-OFDM modem system

The processes of the S/P converter, the signal demapper and the insertion of training sequence are the same as in the system of FFT-OFDM. Also the zeros will be added as in the FFT based case and for the same reasons. After that the inverse slantlet transform (ISLT) will be applied to the signal.

The main and important difference between FFT based OFDM and SLT based OFDM is that the SLT based OFDM will not add a cyclic prefix to OFDM symbol. Therefore the data rates in SLT based OFDM can surpass those of the FFT implementation. After that the P/S converter will convert the OFDM symbol to its serial version and will be sent through the channel.

At the receiver, also assuming synchronization conditions are satisfied, first S/P converts the OFDM symbol to parallel version. After that the SLT will be done. Also the zero pad will remove and the other operations of the channel estimation, channel compensation, signal demapper and P/S will be performed in a similar manner to that of the FFT based OFDM.

PERFORMANCE OF THE OFDM SYSTEMS IN THE FLAT FADING CHANNEL:

In this type of channel, the signal will be affected by the flat fading with addition to AWGN (Additive White Gaussian Noise), in this case all the frequency components in the signal will be affected by a constant attenuation and linear phase distortion of the channel, which has been chosen to have a Rayleigh's distribution. A Doppler frequency (Doppler Shift) of 50 & 100 Hz is used in this simulation and the table (1) explains the simulation parameters. Figure (7) show the BER performance of SLT-OFDM and FFT-OFDM in flat fading channel for QPSK modulation type.

Table (1): Simulation Parameters.

Number of sub-carriers	64
Number of SLT points	64
Number of FFT points	64
Channel model	Flat fading+AWGN
	Frequency selective fading+AWGN

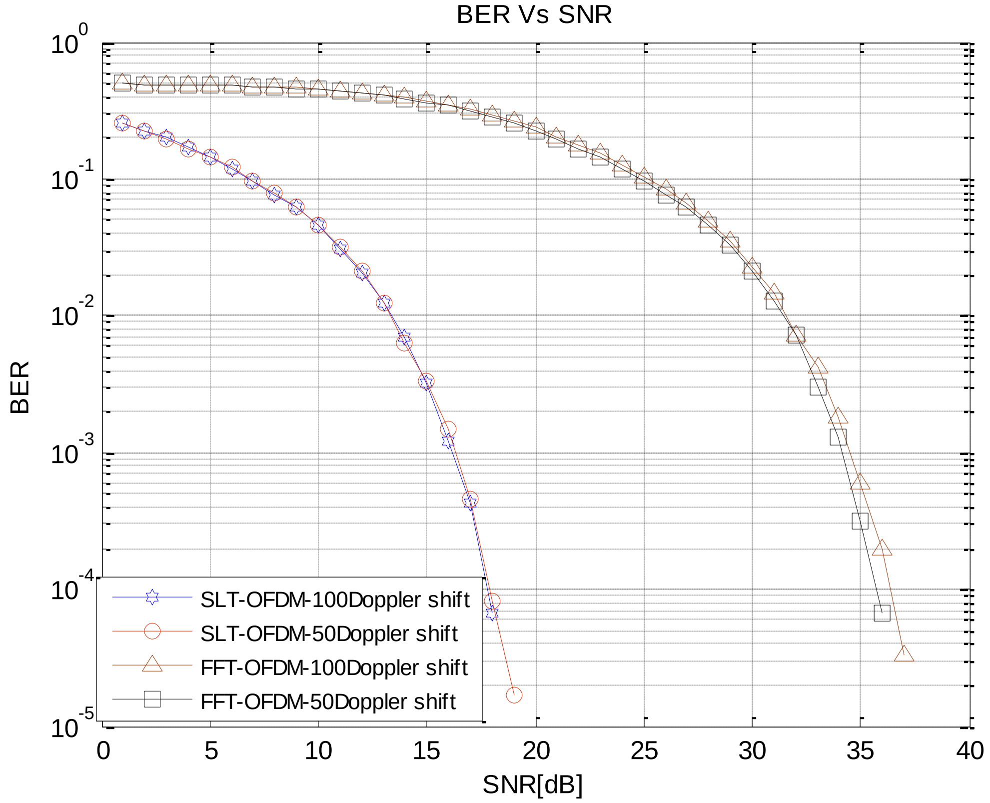


Fig. 7: BER performance of SLT and FFT- OFDM for QPSK modulation in flat fading channel.

The Performance of OFDM Systems in Frequency Selective Fading Channel (multipart's-channel).

The BER performance of SLT and FFT-OFDM systems in frequency selective fading channel are shown in figure (8). This case corresponding to multipaths where two paths are chosen and the attenuation and delay of the second path are -8dB and 8 samples respectively. From the figure (8), it is clear that the BER performance of SLT-OFDM will become constant after a certain SNR. From the same figure, one can see that the BER curves of FFT-OFDM will decrease with the increase of the SNR. In the frequency selective fading the SLT-OFDM is not better than the FFT-OFDM for all the SNR.

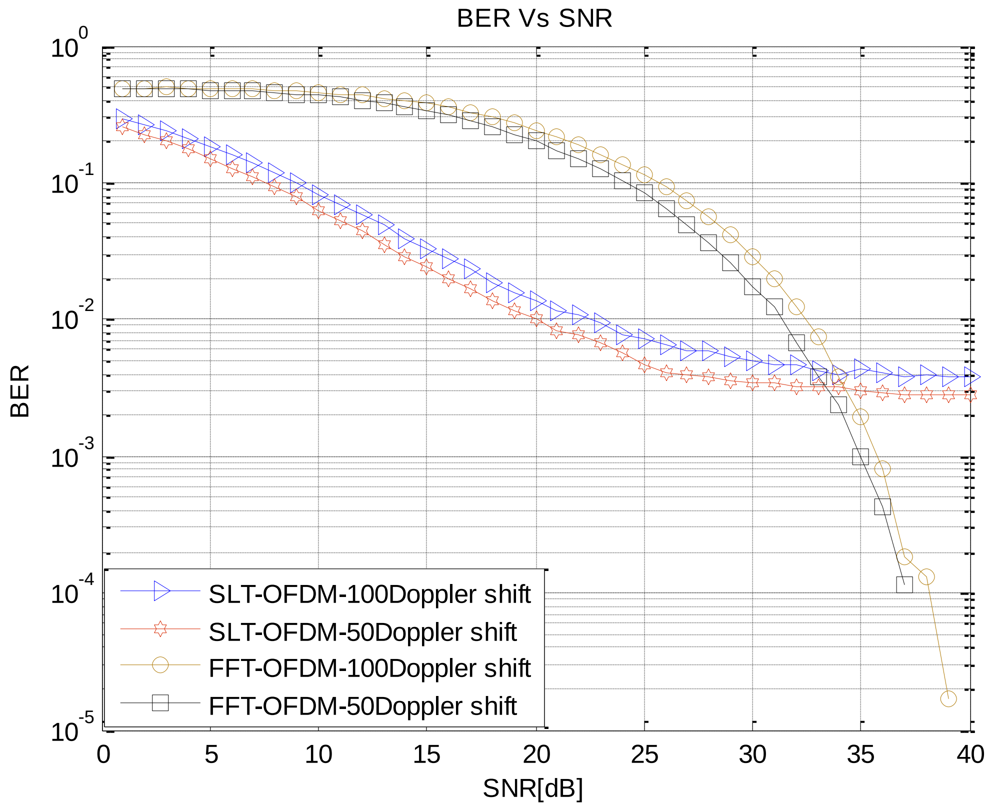


Fig. 8: BER performance of SLT and FFT-OFDM for QPSK modulation in selective fading channel.

The above results can be interpret as follows. The FFT-OFDM has a guard interval(cyclic prefix) of 25% this mean that a cyclic prefix is equivalent to 16-samples, therefore no ISI will effect on the FFT-OFDM until the delay of the second path exceed 16 samples. Since the delay of the second path is equal to 8-samples as assumed above, no ISI will effect on it, while in SLT-OFDM there's no cyclic prefix this mean that ISI will occur in SLT-OFDM. Also due to high spectral containment between the sub-channels in SLT,SLT-OFDM will robust again ISI and ICI until a certain SNR value, after this value , the SLT-OFDM performance will be constant approximately with the increasing of SNR and the FFT-OFDM performance will become better than it.

CONCLUSION

In flat fading channel, it was found that the SLT-OFDM performance was better than that of the FFT-OFDM. A gain of about 18dB was obtained in SLT-OFDM over that for the FFT-OFDM and also the effect of Doppler Shift is very slightly in SLT-OFDM. But in frequency selective fading channel (multipaths case), the situation will be changed. Since the Cyclic Prefix (CP) which is already exists in the FFT-OFDM will eliminate the ISI, therefore no ISI will occurred in FFT-OFDM if the CP is greater than the delay spread of multipaths (in this case we considered that this condition is satisfied). In the case of WP-OFDM there's no CP therefore ISI will occurred. Therefore the BER performance of SLT-OFDM was better than the FFT-OFDM case until a certain value of SNR. After this value the FFT-OFDM was better than SLT-OFDM. It was noticed that the BER curves of SLT-OFDM will become flat (constant with the increase of SNR).

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