Testing The Effective Performance Of Ofdm On Digital Video Broadcasting

Ali Mohammed Hassan Al-Bermani
College of Information Engineering, Al-Nahrain University
email: alicom1980@yahoo.com

Ali Abdullatif Mohammed Ali Al-Bayati
College of Engineering, Al-Nahrain University
email :ali.albayati@gmail.com

Abstract

One of the most exciting areas in telecommunications and networking is wireless technology. The rapid growth of mobile telephone uses various satellite services. So, the present work deals with high data stream applications of Digital Video Broadcasting (DVB), which takes an important place in the studies and development researches due to its direct contacts on the human daily life. In this design the focusing is on the modern types of DVB where modified module of the Terrestrial DVB for Handheld terminals (DVB-H) is used and it was simulated to perform the physical layer of the designed system. Different modes of DVB-H with high bit rate of Orthogonal Frequency Division multiplexing (OFDM) and high number of sub-carriers are considered to show the effect of Coded Orthogonal Frequency Division multiplexing (COFDM) on the system SNR using the convolutional encoding. The modes are tested to show the characteristics of each type involving BER calculation. The obtained results show the effect of OFDM in the designed system by evaluating it using AWGN and mobile multipath channels. These demonstrate the effective of OFDM over single carrier systems where the complexity and cost of implementation are both increaseed by increasing number of carrier. The elimination of ISI is achieved using efficient coding techniques with small guard time. The 4k mode shows good performance in mobile reception, providing satisfactory and reasonable receiver cost/complexity. The Peak Signal to Noise Ratio (PSNR) measurement of the reconstructed received image pixels provides more mentality and good comparing method than the BER measuring. The obtained results are compared between the PSNR of each reconstructed images for different modes with the corresponding transmitting SNR.

Keywords: *OFDM, COFDM, DVB-T, DVB-H, MPEG-2, Multicarrier, Mobile Communication, Multipath Channel.*

1. Introduction

Wireless technology has become convenient and often less expensive to deploy than fixed service, It is known that the frequency and time selectivity of radio channel due to multipath propagation and Doppler shift are the main aspects to affect the mobile communication system. A popular approach to combat the channel frequency selectivity is Orthogonal Frequency Division Multiplexing (OFDM) [E. Lawrey , 2001]. There are many applications that use Frequency Division Multiplexing, Digital Video Broadcasting is one of the important systems of these applications. The challenge is to create a cocktail of technical ingredients to offer new services to handheld terminals, DVB-H standard reaches successfully this exciting challenge. DVB-H re-uses basically the well-known DVB-T transmission parameters.

2. Digital Video Broadcasting (DVB)

The DVB standards specify the delivery mechanism for a wide range of applications, including satellite TV (DVB-S), cable systems (DVB-C), terrestrial transmissions (DVB-T) and handheld terminals (DVB-H). The physical layer of each of these standards is optimized for the transmission channel being used. The DVB-T specification was initially created for the purpose of providing digital television over the air, mostly for fixed reception as it was done with analog television. The main issue to solve was to provide a robust modulation scheme against echoes created by reflections against buildings, hills, and other terrestrial obstacles. (OFDM) was proposed as the optimal scheme against these problems. DVB is a transmission scheme based on the Moving Picture Expert Group (MPEG-2) standard, as a method for point to multipoint delivery of high quality compressed digital audio and video. It is an enhanced replacement of the analogue television broadcast standard. The single carrier transmission method is, however, unsuitable for terrestrial transmissions as multipath severely degrades the performance of high-speed single carrier transmissions. For this reason, OFDM was used for the terrestrial transmission standard for DVB. The use of higher modulation schemes will achieve a higher data throughput.

3. DVB-H Trransmission Modes

DVB-H includes a new transmission mode in the DVB-T Physical layer using a 4096 FFT size: the 4k mode. In addition to the 2k and 8k transmission modes provided originally by the DVB-T standard, the 4k mode brings additional flexibility in network design by trading off mobile reception performance and size of Single Frequency Networks (SFN) [DVB-H Implementation, 2005]. The DVB-H 4k mode can be used both for single transmitter operation and for small and medium SFN. It provides a Doppler tolerance allowing very high speed reception ["Digital Video Broadcasting, 2004]. The 4k mode modulation mode is available only in dedicated DVB-H networks because it is not included in DVB-T. The DVB-T has only two modulation modes, 2k and 8k. The 2k mode is four times more robust to terminal speed than 8k, but with that mode, the realization of SFNs is difficult due to interference. In the 8k mode, multi frequency networks are used instead but the terminal speed that can be achieved is considerably lower [A. Arjona, 2005]. With the 4k mode, advantages from both 2k and 8k modes are obtained. It can use a wide area SFN and also reach considerable high terminal speed. The proposed 4K mode is also architecturally / hardware compatible with existing DVB-T infrastructure, requiring only minor changes in the modulator and the demodulator [Transmission System for Handheld].

4. IN-DEPTH Interleaver of 2K & 4K Modes

The longer the symbol duration of the 8k transmission mode makes it more resilient to impulsive interference. For a given amount of noise power occurring in a single impulsive noise event, the noise power is averaged over 8192 sub-carriers by the FFT in the demodulator. 8k interleaver can be used with 4k or 2k but, if the 8k interleaver is used with 2k or 4k, impulse interference tolerance will increase [P. Talmola , 2005]. In the 4k and 2k transmission modes, the same amount of impulse noise power is averaged only over 4096 and 2048 carriers, respectively. The noise power per sub-carrier is therefore doubled for 4k and quadrupled for 2k when compared with 8k.

5. System Simulation and Evaluation by Matlab

The DVB-H is simulated and evaluated using with AWGN and mobile channels, where the three modes are presented to describe and test the specification of each mode. As mentioned previously the DVB-H mainly consists of link and physical layer. Here physical layer was simulated. Also we deal with channel coding, block interleaving, mobile channel and, OFDM modulation. The OFDM modulation is important, by achieving high data rate transmission with high performance in wireless channel. An OFDM system is designed and, simulated using MATLAB m-file, also this OFDM system is basically used to perform the DVB-H system. This system is tested in multipath and mobile channel. To achieve more mentality to the results a transmission and receiving colored image is performed instead of movie sample for simplicity. The system was designed and simulated for DVB-H physical layer which consist of Reed Solomon block coding, convolutional interleaver and, convolutional coding, 16-QAM modulation, and, OFDM modulation. Some of the characteristics of the OFDM used in the DVB-Hare also investigated. The behavior of each of the three DVB-H modes are studied and compared using the multipath channel, the focusing is on the new 4K mode by testing its behavior in mobile receiving using Jakes module of Rayliegh multipath channel (Jakes presented a realization for the simulation of fading channel model which generates real and imaginary parts of the channel taps coefficients as weighted sum of sinusoids). Transmitting and receiving an image, using the DVB-H system is tested by simulation showing the different results of reconstructed images and computing the PSNR of each with different OFDM parameters.

5.1 OFDM Modulation

The OFDM modulation took important role in the communication world specially, after the DSP development revolution. The OFDM system is configured and simulated as shown in fig.1. Hence OFDM modulation system with 16-QAM is designed to fit the DVB-H 2K mode standard, as listed in table 1.

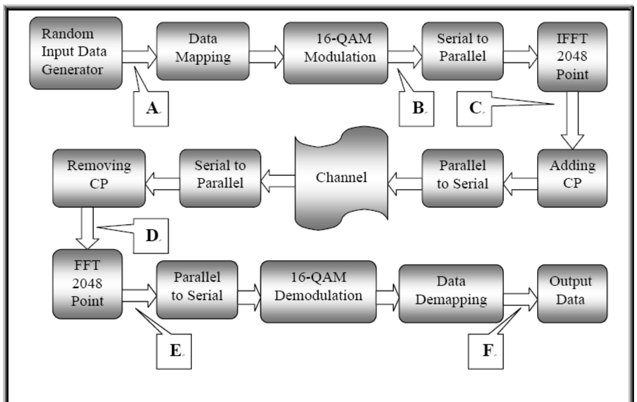

Figure (1) OFDM modulation block diagram.

Table (1) DVB-T 2K mode OFDM parameters

Parameter	Description	Value
FFT	Number of FFT points	2048
K	Number of carrier	1706
K_{min}	Value of carrier number Kmin	0
K_{max}	Value of carrier number Kmax	1705
Tg	Guard time	1/4 Tu = 56 µs
Ts = Tu+Tg	OFDM symbol period	224+56=280 µs
Tu	OFDM useful period	224 µs
1/Tu	Carrier spacing	4,464 Hz

The first block with an output at (A) is the random input digital data generated with equal (0 , 1) Probability.The input data is mapped to inter the digital modulation stage at (B), uniform16-QAM modulation is used since it has high data rate with acceptable SNR. Since the number of sub-carriers is 1706 in 2k DVB-H therefore a zero padding is done in the IFFT block to complete the 2048 IFFT points to generate the OFDM signal. The output at (C) is shown in fig. 2. Guard time insertion selected is a cyclic prefix with 1/4 of the OFDM symbol interval is used which equal 56 µs , At this step it can be said that the OFDM transmitting part is finished.

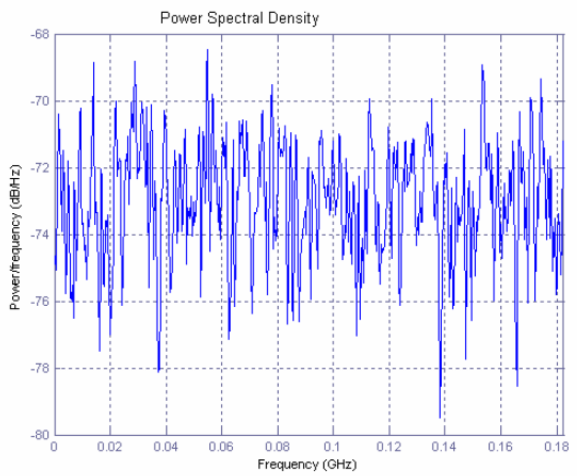

Fig. 2 Transmitter OFDM power spectral density (C).

The channel used in this simulation is the AWGN channel, SNR=5 dB is used. The receiving part of process will reverse. So figs. 3 and 4 shows output block of (D), (E) respectively.

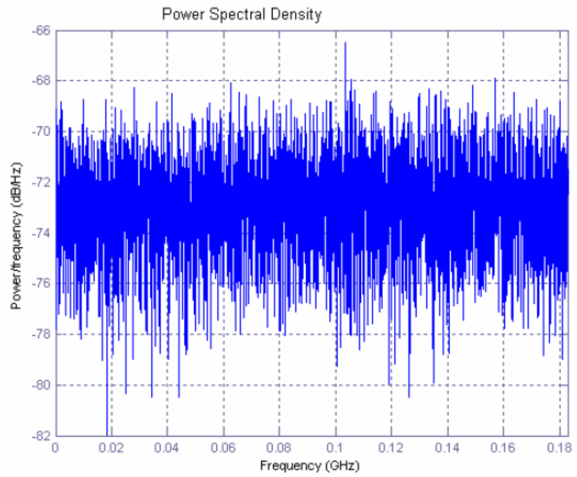

Fig.3 Receiver OFDM power spectral density (D).

The theoretical bit error rate simulation for single carrier 16-QAM modulation is calculated. The advantage on the SNR of the OFDM modulation over single carrier modulation through AWGN could be clearly noticed at fig.5. The improvement in SNR of the OFDM system is about 3.8 dB at bit error rate of 1*10-5.

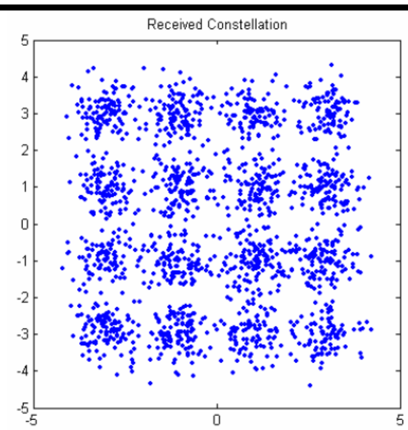

Fig. 4 Received 16-QAM constellation (E).

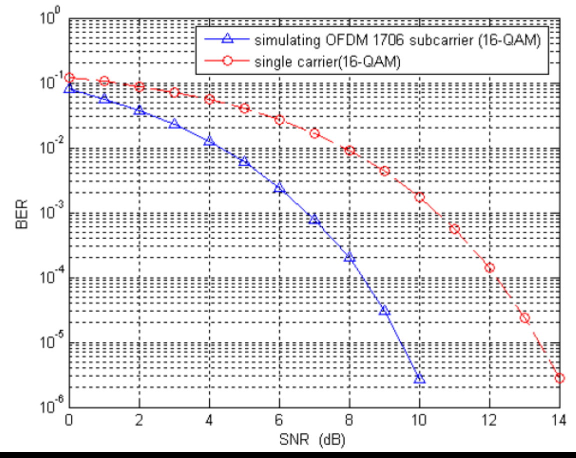

Fig. 5 A 16-QAM modulation for OFDM and single carrier obtained on AWGN channel.

5.2 The DVB-H 2k, 4k, and 8k OFDM Modes

To illustrate the effect number of sub-carrier and to show the three OFDM modes (2k, 4k and, 8k) of the DVB-H performance for the system in fig.1 which is simulated over multi path Rayleigh fading channel as shown in Fig.6. Cyclic prefix =1/4 of the OFDM symbol, number of frames =68 and, number of sample per frame =20 are used, numbers of FFT are (2048, 4092 and 8184 for 2k, 4k and 8k, respectively) as shown in table 2.

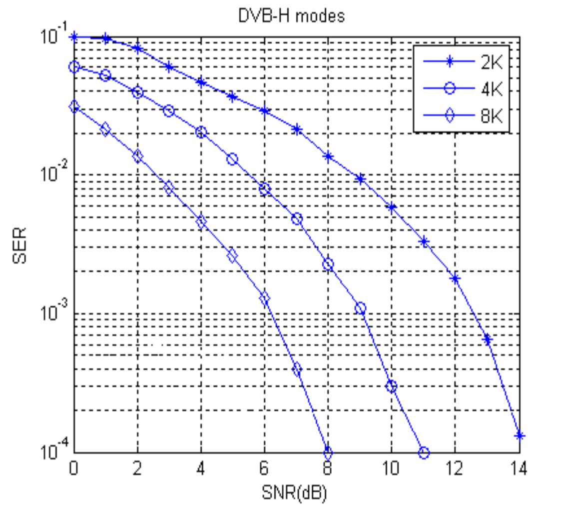

Fig. 6 The three OFDM modes of DVB-H performance in mobile channel.

Table 2 OFDM parameters for 2k, 4k and, 8k

	2k	4k	8k
No. of FFT points	2048	4092	8184
No. of subcarrier	1706	3408	6816
Tu	224 µ s	448 µ s	896 µ s
Tg (1/4)	56 µ s	112 µ s	224 µ s
Ts	280 µ s	560 µ s	1120 µ s
Bit rate (CR=1)	24.2 Mbps	24.2 Mbps	24.2 Mbps

5.3 DVB-H Coded OFDM and interleaving

In mobile and portable reception the most usable modulation scheme is 16-QAM with code rate of 1/2 or 2/3, which require moderate SNR and, provide sufficient transmission capacity for DVB-H services [DVB-H, 2005].

Fig. 7 shows the DVB-H physical layer block diagram. The convolutional byte-wise interleaving with depth I = 12 was applied to the error protected packets. For the coding system a convolutional encoder was used with code rates 1/2, 2/3. The OFDM modulation parameter was set to the values shown in Table 2 with 16-QAM modulation, through multipath Rayleigh channel. The evaluation results shown in fig. 8, which it could be seen the effect of the channel coding and interleaving over the uncoded OFDM system. The DVBH uses the Reed-Solomon RS (204,188, t = 8) shortened code, derived from the original systematic RS (255,239, t = 8) code, the Reed-Solomon code has length 204 bytes, dimension 188 bytes and allows to correct up to 8 random erroneous bytes in a received word of 204 bytes. And, the RS block is simulated to show the ability of high error correction between the input SER (Symbol Error Ratio) and the out SER is as shown in Fig. 9.

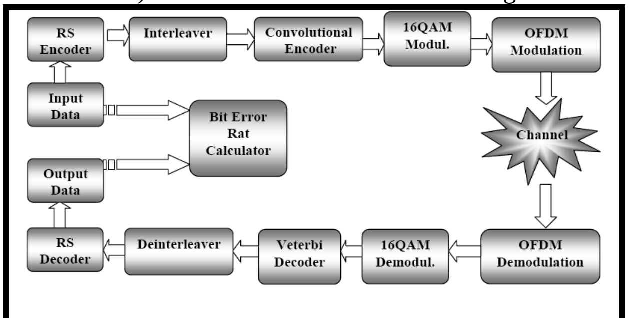

Fig. 7 Designed DVB-H physical layer block diagram.

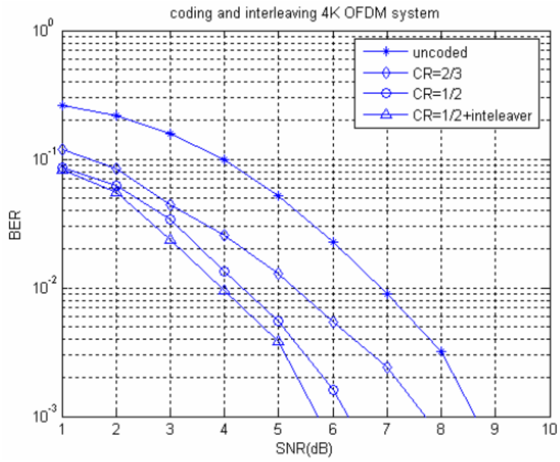

Fig. 8 OFDM convolutional coding and interleaving.

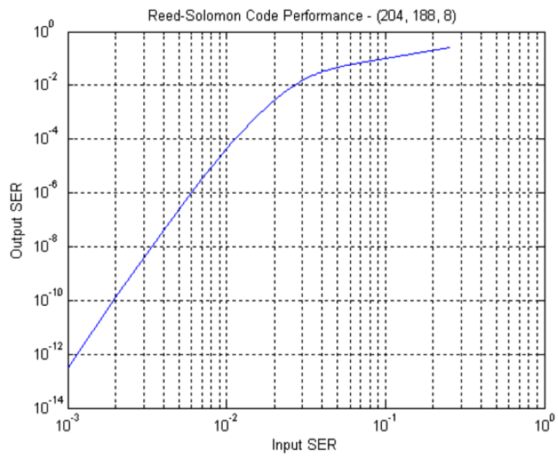

Fig. 9 Reed Solomon block coding.

5.4 Mobile DVB-H Receiving

The real target of the new 4k mode is the performance enhancement in mobile reception. The current DVB-H standard provides excellent mobile performance with 2k modes, but with 8k modes the performance is unsatisfactory, especially with reasonable receiver cost/complexity. On the network planning side, the short guard interval the 2k mode implements effectively prevents its usage in the allotment type of planning, where rather large geographical areas are covered with one frequency. For these reasons, a compromise mode between the 2k and 8k, would allow acceptable mobile performance on the receiver side whilst allowing more economical and flexible network architectures [DVB-H, 2005]. The new 4k mode which is concerned with DVB-H makes its special from other modes (i.e. 2k and 8k), because the last two mode are previously used in the DVB-T standard. Here we illustrate the effect of the receiver mobility on the bit error rate (BER) versus the signal to noise ratio (SNR) for the 4k DVB-H mode. The system shown in Fig.10 which configure the DVB-H simulates the physical layer that performs the Quasi Error Free (QEF) threshold 2*10-4 after Viterbi decoder. The system blocks are set to the values in the table 3. The Jakes module for Rayleigh channel is used to show the effect of the handheld terminals mobility on the system BER versus the SNR increasing.

Table 3 OFDM parameter for DVB-H 4K mode

Parameter	Description	Value
FFT	Number of FFT points	4092
K	Number of carrier	3409
K_{min}	Value of carrier number K_{min}	0
K_{max}	Value of carrier number K_{max}	3408
Tg	Guard time	1/4 Tu = 112 µs
Ts = Tu+Tg	OFDM symbol period	448+112=560 µs
Tu	OFDM useful period	448 Tu
1/Tu	Carrier spacing	2,232Hz
T=Tu/4092	Elementary period	7/64 µ s
Bet rate	See Appendix B	12.1 Mbps

Fig. 10 shows the receiver mobility effect on the system performance through Rayleigh multipath Jakes module channel.

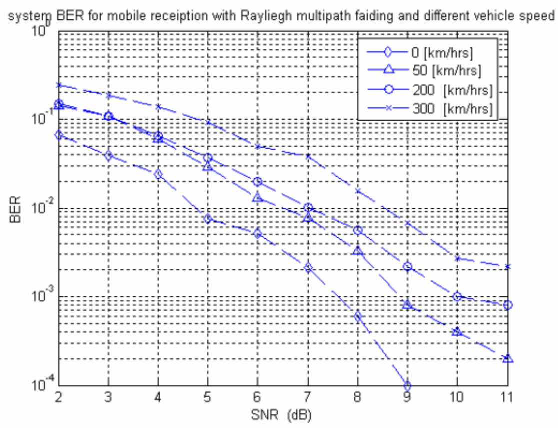

Fig. 10 Receiver mobility with different speeds.

6. TESTING THE SYSTEM BY TRANSMITTING AN IMAGE

In order to test and investigate the system validity to transfer an image then, receiving it properly and, showing the channel verity affects as well as the mode of transmission used, on the image vision to enable the smart comparison among different cases, a Joint Photographic Experts Group (JPEG) format image is transmitted using the block diagram shown in Fig.11. A colored image first acquired then read it into its luminance components range between (0) and (255) level, then reshaping the resultant arrays was performed and converting them into binary values. Taking in mind that number of bit have to be fit the digital transceiver system requirement, so the zero padding is necessary. 16-QAM modulation, 4k DVB-H and, 1/2 convolutional encoding and convolutional interleaver was used in this MATLAB simulation. The actual metric we will compute is the peak signal-to-reconstructed image measure which is called PSNR. Assume we are given a source image f(i,j) that contains N by N pixels and a reconstructed image F(i,j) where F is reconstructed by receiveing the transmitted version of f(i,j). Error metrics are computed on the luminance signal only so the values f(i,j) range between black (0) and white (255). First the mean squared error (MSE) is computed of the reconstructed image as follows:

$$MSE = \frac{\sum [f(i,j) - F(i,j)]^2}{N1 * N2} \qquad (1)$$

The summation is over all pixels. The root mean squared error (RMSE) is the square root of MSE. PSNR in decibels (dB) is computed by using the following equation.

$$PSNR = 20\log_{10}\left(\frac{255}{RMSE}\right) \qquad (2)$$

Typical PSNR values range between 20 and 40 dB. Two main cases were chosen to describe the channel effects the on received image.

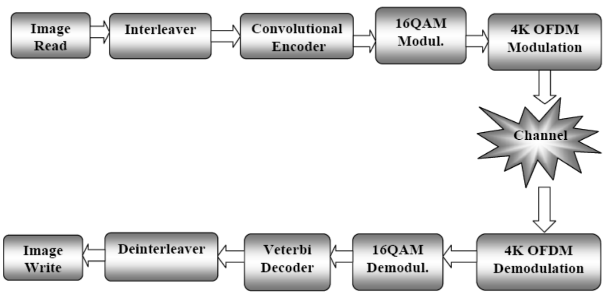

Fig. 11 JPEG image transmitting and receiving.

6.1 Through AWGN Channel

JPEG image is transmitted and received through AWGN channel by simulation with different values of SNR using 16-QAM modulation, and 4k DVB-H. The obtained images from this module of simulating are shown in Fig.12. It is easy to notice that the first image is look noisy when the value of the SNR is 2dB, and when the SNR increased the noise of the image is decreased, so at the SNR =8 dB the difference between the transmitted and the original image is null. The PSNR was calculated for each image, as shown in Table 4. The image with PSNR = ∞ means that the reconstructed image is exactly the original image (i.e. no errors) according to equation 2.

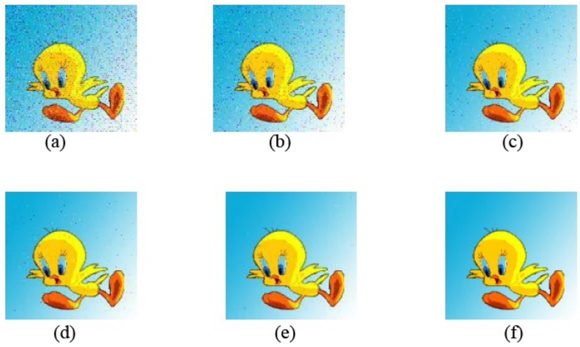

Fig. 12 Reconstructed Received images using AWGN.

Table 4 Transmitted SNR with the Corresponding PSNR (AWGN)

Image	(a)	(b)	(c)	(d)	(e)	(f)
SNR(dB)	0	2	4	6	8	10
PSNR(dB)	29.12	32.07	36.87	43.64	53.45	∞

6.2 Transmission Through Rayleigh Channel for Fix Terminal

The effect of the Rayleigh multipath channel is different from the AWGN. The distortion effects on the image pixels is not Gaussian distribution, but the effect will show Rayleigh distribution. The three DVB-H modes were used to show a good comparison between each mode according to each reconstructed image. The channel which was used is Rayleigh multipath channel module with fixed receiver terminal (i.e. no doppler effect is present). Figs. 13 to 15 shows the reconstructed images for the 2k, 4k, and 8k modes respectively. The calculated PSNR for each image are shown in table 5.

Table 5 Transmitted SNR with the Corresponding PSNR (Rayleigh)

	Image	(a)	(b)	(c)	(d)	(e)	(f)
	SNR(dB)	2	6	8	12	16	20
2k	PSNR(dB)	22.36	23.19	26.60	31.41	37.45	55.58
4k	PSNR(dB)	22.86	23.32	27.29	33.45	41.22	59.07
8k	PSNR(dB)	23.03	23.71	29.58	36.44	45.12	62.20

6.3 Transmission Through Rayleigh Channel for Mobile Terminal

Another evaluation includes different value of receiver mobility speed with SNR of 10 dB. The channel used is Jakes module that represent the Rayleigh multipath channel. The obtained reconstructed images are shown in figs. 19 to 21 for the 2k, 4k, and 8k modes respectively according to the corresponding terminal speed values of table 6 as well as the calculated PSNR. The 2k mode is more robust to terminal speed than 4k, and 8k. Also it has short symbol duration so the realization of SFNs is difficult due to interference, then the 8k is more robust to interference than other modes. But the 8k mode adds more complexity to practical implementation so the 4k is the moderate case between other two modes which take the advantages from both 2k and 8k modes.

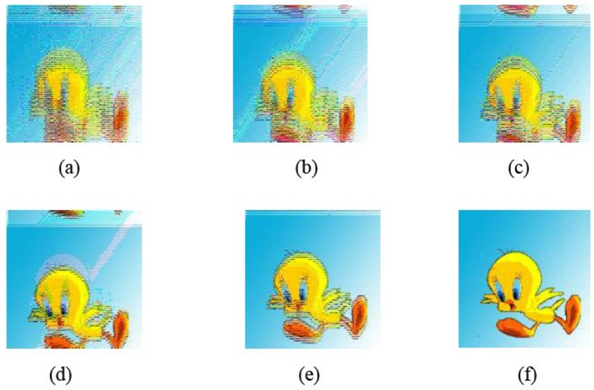

Fig. 13 Reconstructed Received images using Rayleigh channel for fix terminal with 2k mode transmission.

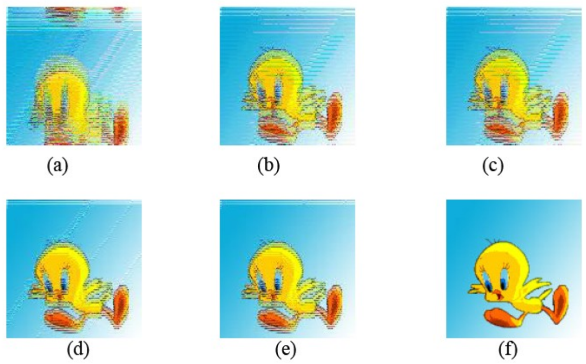

Fig. 14 Reconstructed Received images using Rayleigh channel for fix terminal with 4k mode transmission.

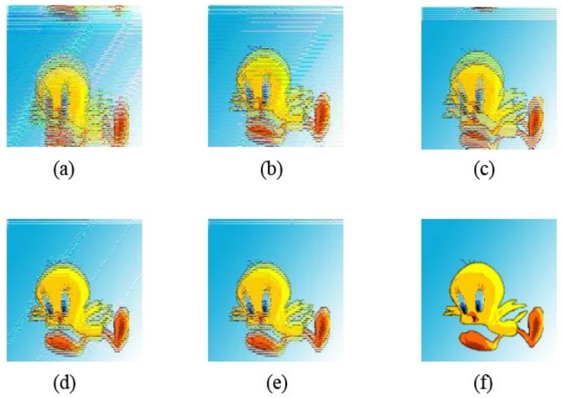

Fig. 15 Reconstructed Received images using Rayleigh channel for fix terminal with 8k mode transmission.

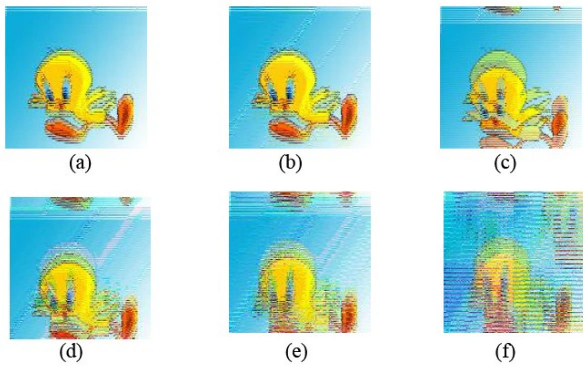

Fig. 16 Reconstructed Received images using Rayleigh channel for mobile terminal with 2k mode transmission.

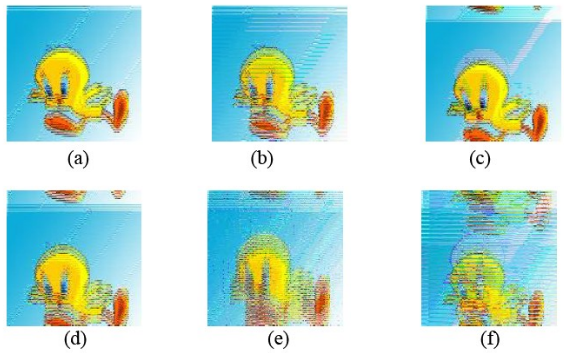

Fig. 17 Reconstructed Received images using Rayleigh channel for mobile terminal with 4k mode transmission.

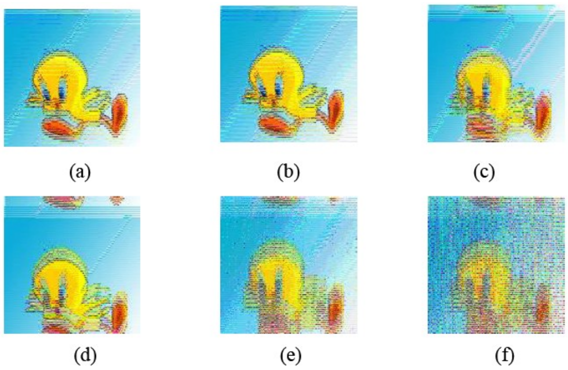

Fig. 18 Reconstructed Received images using Rayleigh channel for mobile terminal with 8k mode transmission.

Table 6 Receiver mobility speed with the Corresponding PSNR (Rayleigh)

	Image	(a)	(b)	(c)	(d)	(e)	(f)
	Receiver speed(Km/h)	0	20	50	80	100	300
2k	PSNR(dB)	29.92	28.51	27.61	26.74	25.32	23.39
4k	PSNR(dB)	30.82	28.61	27.43	26.47	24.86	22.69
8k	PSNR(dB)	31.32	28.75	27.39	26.21	24.43	22.1

7. CONCLUSIONS

Our study demonstrates the effectiveness of Orthogonal Frequency Division Multiplexing, over single carrier systems. The simulation shows that, when the number of sub-carrier increased, the BER performance is improved, so the 8k mode provides higher bit rate as well as better SNR than 4k mode, than 2k mode. However, the complexity and the cost of implementation both are increased by increasing number of carrier. Using efficient coding techniques with small guard time is enough to eliminate ISI perfectly. The 4k mode shows good performance in mobile reception, providing satisfactory and reasonable receiver cost/complexity. The PSNR measurement of the reconstructed received image pixels provides more mentality and good comparison method than the BER measuring. The 4k mode achieves many advantages then other 2k and 8k modes. It can use a wide area SFN and also reach considerable high terminal speed.

REFERENCES

[1] E. Lawrey "Adaptive Techniques for Multiuser OFDM", James Cook University, 2001.

[2] "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television", ETSI EN 300 744 V1.5.1, 2004.

[3] V. C. Ramasami "Orthogonal Frequency Division Multiplexing" KUID report No. 698659, 2001.

[4] "Digital Video Broadcasting (DVB); Transmission System for Handheld Terminals (DVB-H)", ETSI EN 302 304 V1.1.1, 2004.

[5] DVB-H Implementation Guidelines, DVB Blue Book organization, Document No. A092, 2005.

[6] A. Arjona, Internet Protocol Data casting," Transparent Interactivity Using Different Communication Channels", Helsinki University of Technology, 2005.

[7] Transmission System for Handheld Terminals, DVB Blue Book, document No A081.

[8] P. Talmola, "DVB-H Standard Overview", Nokia Ventures Organisation, 2005.

الخلاصة

يتناول هذا البحث دراسة موسومة للبث الفديوي الرقمي (DVB) الذي احتل مكانة مهمة في الدراسات والابحاث التطويرية لاتصاله بحياة الانسان اليومية. هذه الدراسة تعرض الانواع المعيارية للبث الفيديوي الرقمي مع التركيز على احدث هذه الانواع الا وهو البث الفيديوي الرقمي المخصص للاجهزة المحمولة باليد(DVB-H). هذا النوع هو النموذج المطور لطريقة البث الفيديوي الرقمي الارضي (DVB-T) لكي يتناسب مع الاجهزة النقالة المحمولة باليد. تم تصميم منظومة للمحاكاات بالحاسبة لتمثيل الطبقة الفيزياوية لـ (DVB-H). وقد استخدمت المنظومة نظام عن التقسيم الترددي المتعدد و المتعامد (OFDM)

التحري يعرض تاثيرات الـ(OFDM) من خلال تطبيق المنظومة المصممة عبر قناة متنقلة ومتعددة الاتجاهات. ان الاصناف الثلاثة لـ (DVB-H) اخذت بعين الاعتبار وهي (2k, 4k ,8k) بحسب استخدامها عدد الحاملات المعوضة لـ (OFDM) وهي (2048, 4092, 8184) بالتتابع. تم اظهار بعض خصائص هذه الاصناف بتجربتها ومحاكاتها بالحاسبة وحساب معدل خطا الكسرة الرقمية. تم اختيار الصنف (4k) لتطبيق ظروف الاستقبال المتنقل من خلال ارسال و استلام صورة معينة باستخدام نوعين من القنوات محاكتان بالحاسبة وتضمنت التجربة حساب ومقارنة نسبة الضوضاء العظمى للصورة المسترجعة (PSNR) لكل صورة مستلمة لنسبة الاشارة الى الضوضاء المرسلة(SNR) لها.