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A Modified DVB-T System Architecture with Multi-carrier Multi-code Transmission and MPIC Based Reception

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Abstract-- **In this paper, we propose a modified DVB-T system architecture with a multi-carrier multi-code transmission format. The main techniques we use in the system include the orthogonal Walsh code spreading and soft multipath interference cancellation (soft MPIC). Both techniques are used to combat the system degradation caused by the multipath effect. With the spreading gain and the path diversity gain achievable from the used techniques, the proposed system architecture shows much better performance compared with the original DVB-T system.**

Index Terms-- **DVB-T, spreading code, orthogonal code, Walsh code, MPIC, soft PEQ, multicarrier, OFDM, soft information.**

Ⅰ. INTRODUCTION

The DVB-T is the digital video broadcasting standard [1] proposed by the ETSI in the Europe. Many countries now set the DVB-T standard as their domestic digital TV broadcasting standard. With the help of the digital signal processing, the DVB-T system transmits both video and audio data in digital form and uses the channel bandwidth efficiently by compressing video data with the MPEG-Ⅱ standard. As a result, the transmission signal quality of DVB-T is much better than the old analog TV standard.

The DVB-T standard uses the orthogonal frequency division multiplexing (OFDM) technique to transmit data. The independent message data are carried by different subcarriers which are orthogonal to each other. When the data carried by the OFDM signal are transmitted through the channel, they will be affected by the multipath phenomenon. Because all the subcarriers are orthogonal to each other, when one particular subcarrier is highly attenuated by the channel, the data signal on this subcarrier may disappear at the receiver side. Therefore, the receiver might completely lose the data information on some subcarriers and this causes a serious problem in a conventional OFDM system. When one subcarrier fades, no other subcarriers are able to help with the situation if channel coding and interleaving are not used.

In this paper, we propose a modified DVB-T system architecture which uses both the spread spectrum technique [2][3] and the multipath interference cancellation technique. Here, we use the Walsh code as the spreading code, and distribute the energy of each data symbol to all the subcarriers in a predefined group. By this way, even when some subcarriers within the group are seriously affected by the channel and highly attenuated, other subcarriers will still have good signal quality and carry information contained in different Walsh code chip elements. This method will solve the serious attenuation problem and improve the system performance.

Another important technique we apply in the modified DVB-T system is the MPIC technique. The MPIC technique [4][5][6] is used here to solve the problem of multipath interference. When the Walsh coded OFDM signal is transmitted through a multipath channel, the orthogonal property of the Walsh codes will be destroyed. In order to recover the orthogonality of the Walsh code and fully utilize the spreading gain, we use the MPIC technique as a channel equalization method. The MPIC technique is executed in two phases. In the initial phase, we use a partial equalizer to restore the channel distortion effect. For different channel characteristics, we choose the suitable parameters to design the coefficients of partial equalizer. After initial equalizing, the soft data will be used to reconstruct the multipath interference. The reconstructed multipath interference will be sent to the next phase for more precise data detection and interference reconstruction. This procedure can be done iteratively. Each time we repeat the procedure in the second phase, the system performance will be improved gradually.

The organization of this paper is as follows. In section 2, the DVB-T system is reviewed. In section 3, we describe the details of the multi-code multi-carrier and MPIC based DVB-T system architecture. The mathematic analysis is included in section 4. In section 5, we show our simulation results and compare the performance of the modified DVB-T system with the original DVB-T system. Finally, some conclusions are given in section 6.

Ⅱ. DVB-T SYSTEM ARCHITECTURE

The block diagram of a DVB-T transmitter is shown in Fig.1. First, the video and audio data is compressed by the

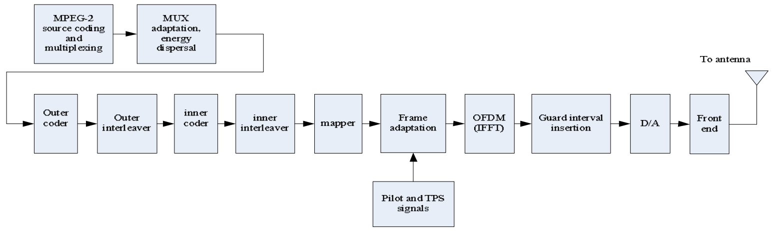


Fig.1 The transmitter architecture of the DVB-T system

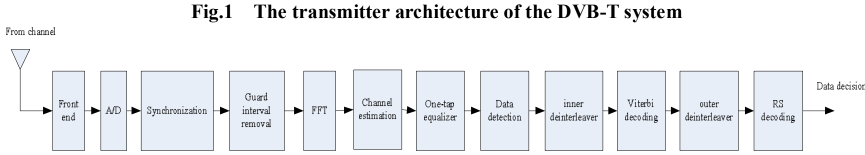


Fig.2 The receiver architecture of the DVB-T system

MPEG-2 coder and multiplexed. Then the data are processed for the uniform energy distribution purpose. Afterward, the data are coded by a RS coder as the outer coding and by a convolutional coder as the inner coding. The interleaver is placed after each coder to decorrelated the data transmitting through the fading channel and enhance the decoder performance. After coding and interleaving, the binary data together with both pilot and TPS (transmission parameter signaling) signals are mapped into the transmitted symbols. The pilot signals are used for the synchronization purpose and the TPS signals are used for transmitting system parameters. Then the symbols are processed by the IFFT for OFDM modulation. The length of IFFT depends on the mode the system uses. After the IFFT, a guard interval is inserted in front of every OFDM symbol for both synchronization and the ISI protection purposes. Finally, the data are transformed from digital to analog form by the D/A and is sent into RF front end.

The block diagram of a DVB-T receiver is shown in Fig.2. The data received from the RF front end are first processed by A/D and transformed into the digital form. Then the signals are sent to the synchronization block where both timing synchronization and frequency synchronization are achieved. After synchronization, the guard interval in front of each symbol is removed and the symbol is processed by FFT for OFDM demodulation. After the signal is transformed into frequency domain, the channel state information is estimated first and then used to compensate for the distortion caused by the multipath channel through using an one-tap equalizer. The transmitted data are then recovered by the data detection block which is also known as the data demapping block. The demapped bit data are then processed by both the inner and the outer channel decoder. For this channel decoding operation, the data are first deinterleaved by the inner deinterleaver and decoded by the Viterbi decoder. Then the data are deinterleaved by the outer deinterleaver and decoded by the RS decoder. Afterward, the decoded data are sent to the MPEG-2 decoder.

Ⅲ. THE PROPOSED MULTI-CODE MULTI-CARRIER AND MPIC BASED DVB-T SYSTEM ARCHITECTURE

The block diagrams of the modified DVB-T system are shown in Fig.4 for the transmitter and in Fig.5 for the receiver. The main change we make in the transmitter is to use the multi-carrier and multi-code technique, and that in the receiver is to use multipath interference cancellation (MPIC) technique with soft information processing.

In the transmitter, the signal is processed in the same way as the original DVB-T system before the mapping step. After the mapping step, the data symbols are spread with the Walsh code. The main motivation for using Walsh code spreading is to distribute the energy of all the information bits evenly to all the subcarriers. In this way, when some subcarriers fade, other subcarriers still have the energy such that data information can be recovered more robustly. We note that the subcarriers used in the DVB-T system are only part of an OFDM symbol. For example, in the 2k mode of DVB-T, the total number of subcarriers in each OFDM symbol is 2048. Excluding the pilot subcarriers, the guard band and the zero padding subcarriers, the actual number of data subcarriers is 1512 only. In order to fully utilize these 1512 data subcarriers, we group the 1512 subcarriers into the set of {1024, 256, 128, 64, 32, 8}. Within each subgroup, the data symbols are spread by corresponding length Walsh codes, as Fig.3 shows.

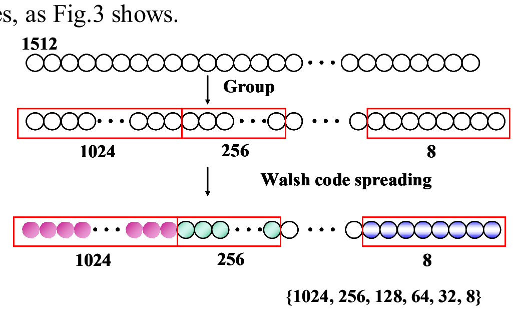


Fig.3 The subgroups of 1512 data subcarriers

$$\mathbf{X}_{\mathbf{spread}} = \left[(\mathbf{C}_{\mathbf{1024}}\mathbf{X}_A)^T, (\mathbf{C}_{256}\mathbf{X}_B)^T, (\mathbf{C}_{128}\mathbf{X}_C)^T, (\mathbf{C}_{64}\mathbf{X}_D)^T, (\mathbf{C}_{32}\mathbf{X}_E)^T, (\mathbf{C}_8\mathbf{X}_F)^T \right]^T \quad (1)$$

After Walsh code spreading, we sum them together within the same subgroup and concatenate all the subgroups. The spread signal can be represented as(1). The $\mathbf{X}_{\mathbf{spread}}$ represents the final data vector after the spreading. The C_i represents the Walsh code matrix (i × i) with each codeword length of i, and the $\mathbf{X}_{A-F}$ are the data vectors grouped according to the set of {1024, 256, 128, 64, 32, 8}. The original pilot signals remain unchanged and the whole frequency domain signal $\mathbf{X}_{spread+pilot}$ is processed by the IFFT which is known as the OFDM modulation. After the data are transformed from the frequency domain to the time domain, we add the guard interval in front of every OFDM symbol to combat the ISI (inter-symbol interference) effect. As a result, the signal transmitted to the channel is represented as in (2).

$$\mathbf{x}_{\mathbf{tx}} = \left[GI \;\; | (\mathbf{IFFT} \cdot \mathbf{X}_{(spread+pilot)})^T \right]^T \quad (2)$$

where $\mathbf{x}_{\mathbf{tx}}$ is the transmitted data vector in time domain, **IFFT** is the inverse Fourier transform matrix, $\mathbf{X}_{(spread+pilot)}$ is the spread data plus the pilot signals, and GI is the added guard interval. Finally, the data are converted from digital form to analog form by D/A converter and transmitted into the channel.

In the receiver, we use the multi-code dispreading and the MPIC techniques to recover the data. The received data signal can be represented in the frequency domain as follows:

$$\mathbf{R}_{\mathbf{re}} = \mathbf{H}\mathbf{X}_{\mathbf{tx}} + \mathbf{N} \quad (3)$$

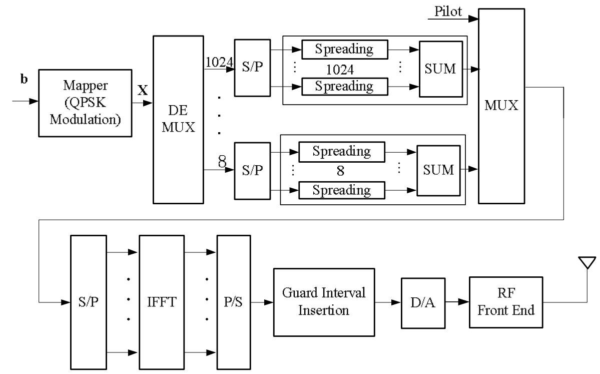
$$\mathbf{R}_{\mathbf{re}} = [R_0, R_1, R_2, \cdots, R_{N-1}]^T$$

$$\mathbf{X}_{\mathbf{tx}} = [X_{tx,0}, X_{tx,1}, X_{tx,2}, \cdots, X_{tx,N-1}]^T$$

$$\mathbf{H} = diag(H_0, H_1, H_2, \cdots, H_{N-1})$$

$$\mathbf{N} = [N_0, N_1, N_2, \cdots, N_{N-1}]^T$$

The symbols $\mathbf{R}_{\mathbf{re}}$ and $\mathbf{X}_{\mathbf{tx}}$ represent the received data vector and the transmitted data vector in the frequency domain. **H** is the channel state information (CSI) matrix in the frequency domain and we assume each subcarrier encounters flat fading. **N** is the noise vector in which each component N_i is i.i.d. AWGN with zero mean and the variance is σ_n^2. For this modified DVB-T system, we do not change the original synchronization or system control related subcarriers. We assume time synchronization, frequency synchronization and channel estimation are perfect. After the FFT, we separate the pilot subcarriers and the data subcarriers apart. The pilot subcarriers are used for synchronization, channel estimation and for deriving the system parameters. The data subcarriers are sent to the "Soft PEQ / Soft MPIC" subsystem which is the main signal processing block in our design. The "Soft PEQ" means soft partial equalization and the "Soft MPIC" stands for soft multipath interference cancellation.



$b = [b_0, b_1, b_2, \cdots, b_{2N'-1}]^T$ is the coded binary data vector.

$X = [X_0, X_1, X_2, \cdots, X_{N'-1}]^T$ is the QPSK modulated signal vector.

$X_i = P_i + jQ_i \qquad P_i, Q_i \in \{1/\sqrt{2}, -1/\sqrt{2}\}$

Fig.4 The transmitter block diagram of the proposed multi-carrier multi-code based DVB-T system

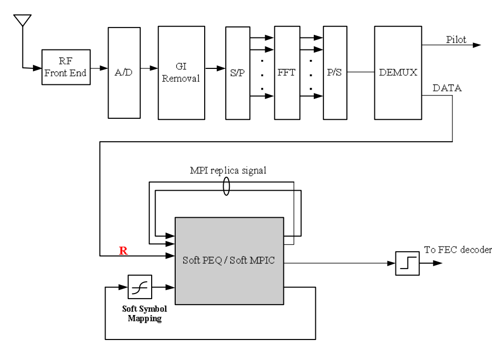


Fig.5 The receiver architecture for the proposed multi-carrier multi-code DVB-T system

In the "Soft PEQ / Soft MPIC" subsystem, there are two sub-blocks which are shown in the Fig. 6 and Fig. 7 in more details. In the beginning, the received signals after FFT processing are sent to the soft PEQ sub-block. In this sub-block, we execute partial data equalization [12], data dispreading, and soft data detection to coarsely estimate the data signals and use coarsely estimated data to reconstruct the interference signals from each path. Then in the soft MPIC sub-block, we use the reconstructed interference to separate the multipath signals. With the separated path data and the estimated channel state information, we use maximum ratio combining (MRC) to obtain more reliable data that could be used for despreading and soft data detection. We can improve the system performance by

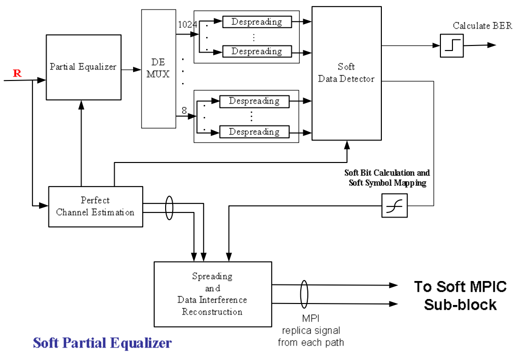


Fig.6 The "Soft PEQ" sub-block of the receiver system

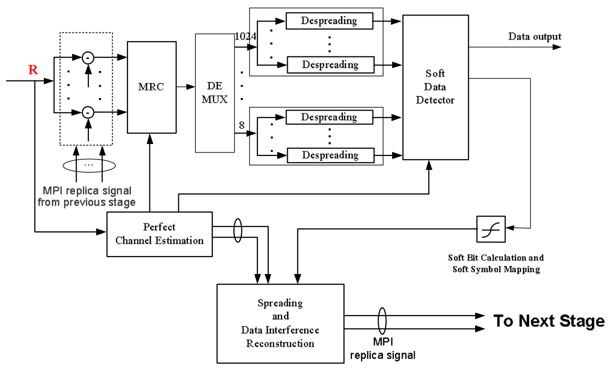


Fig.7 The "Soft MPIC" sub-block of the receiver system.

executing this reconstruction and re-detection process within the soft MPIC sub-block iteratively [7] [10]. In the next section, we will describe the mathematic algorithms and the detail signal processing of each sub-block.

IV. THE MATHEMATIC ALGORITHMS OF THE RECEIVER

In the soft partial equalization sub-block, we first send the data signal after FFT to a partial equalizer. The purpose of this partial equalization is to make a tradeoff between the residual channel distortion and the enhanced noise. We adjust the partial equalizer through a single parameter β and the coefficients of the partial equalizer for each subcarrier are calculated in (4).

$$G_i = H_i^* / |H_i|^{1+\beta}, \qquad 0 \le \mathrm{i} \le (\mathrm{N}-1),\ -1 \le \beta \le 1 \qquad (4)$$

where H_i is the estimated channel state information for the i-th subcarrier, G_i is the corresponding equalizer coefficient, and β is the parameter of the partial equalizer which could be adjusted according to the channel characteristic. Here, we assume that channel estimation is perfect.

Afterward, we despread the equalized data symbols. Because the OFDM subcarriers are separated into different subgroups in the transmitter side, we despread the data subcarriers also in subgroups to recover the transmitted data symbols in the receiver side. The despread data symbols can be expressed in (5).

$$\begin{aligned} z_{l,k} &= \mathbf{c}_{l,k}^T \mathbf{G}_l \mathbf{r}_l \\ &= \mathbf{c}_{l,k}^T \mathbf{G}_l \left(\mathbf{H}_l \left(\sum_{j=1}^{l} x_j \mathbf{c}_{l,j} \right) + \mathbf{N} \right) \\ &= \sum_{i=1}^{l} \left(g_i h_i \sum_{j=1}^{l} x_j c_{l,k,i} c_{l,j,i} \right) + \mathbf{c}_{l,k}^T \mathbf{G}_l \mathbf{N} \\ &= \underbrace{x_k \sum_{i=1}^{l} g_i h_i}_{DS} + \underbrace{\sum_{\substack{j=1 \\ j \ne k}}^{l} \sum_{i=1}^{l} g_i h_i x_j c_{l,k,i} c_{l,j,i}}_{IS} + \underbrace{\sum_{i=1}^{l} c_{l,k,i} g_i n_i}_{NS} \end{aligned} \qquad (5)$$

where l represents the subgroup length as defined by the set {1024, 256, 128, 64, 32, 8}, $\mathbf{r}_l$ is the received signal vector of length l, $\mathbf{G}_l$ is a ($l \times l$) diagonal coefficient matrix of the equalizer, $\mathbf{c}_{l,k}$ is the k-th Walsh code with length l, $\mathbf{z}_{l,k}$ is the signal after the equalizing and despreading process, $\mathbf{N}$ is the AWGN in the frequency domain, and $\mathbf{H}_l$ is the ($l \times l$) channel gain matrix. From (5), we can separate the dispread data symbol into three parts. The "DS" part is the desired signal, the "IS" part is the multipath interference signal after equalizing, and the "NS" part is the enhanced noise.

Through some detailed mathematic calculation, we can derive the mean and variance of $\mathbf{z}_{l,k}$. The mean and the variance of the real part (image part can be calculated in the same way) of $\mathbf{z}_{l,k}$ can be expressed as follows [9]:

$$m_{\mathrm{Re}\{z\}} = \mathrm{Re}\{x_k\} \sum_{i=1}^{l} g_i h_i \qquad (6)$$

$$\sigma_{\mathrm{Re}\{z\}}^2 = \frac{(l-1)}{2} \sum_{i=1}^{l} \psi_i^2 + \frac{\sigma_n^2}{2} \sum_{i=1}^{l} |g_i|^2 \qquad (7)$$

$$\psi_i = g_i h_i - \frac{1}{l} \left(\sum_{j=1}^{l} g_j h_j \right) \qquad (7\text{-}1)$$

Because the DC component of $g_i h_i$ has no effect on the variance, we subtract it first in (7-1) before calculating (7). From the central limit theorem, the signal $\mathrm{Re}\{z_{l,k}\}$ can be modeled as a Gaussian random variable with mean $m_{\mathrm{Re}\{z\}}$ and variance $\sigma_{\mathrm{Re}\{z\}}^2$.

We choose the parameter β of the partial equalizer in terms of the channel model. We can reach near optimal BER performance when using the suitable β value in certain channel. The optimal value of β_{opt} according to the criterion of minimum BER can be derived as (7-2).

$$\begin{aligned}\beta_{opt} &= \arg\min_{\beta} BER(\beta) \\ &= \arg\min_{\beta} Q\left(E_z(\beta)/\sqrt{\sigma^2_{\mathrm{Re}\{z\}}(\beta)}\right) \\ &\equiv \arg\max_{\beta}\left\{E_z(\beta)/\sqrt{\sigma^2_{\mathrm{Re}\{z\}}(\beta)}\right\}\end{aligned} \tag{7-2}$$

where $Q(\cdot)$ is the Q-function, $E_z(\beta)=\sum_{i=1}^{l}|h_i|^{1-\beta}$, and $\sigma^2_{\mathrm{Re}\{z\}}(\beta)=\frac{(l-1)}{2}\sum_{i=1}^{l}\psi_i^2+\frac{\sigma_n^2}{2}\sum_{i=1}^{l}|g_i|^2$. It is hard to solve the close form of (7-2). But, as $E_z(\beta)/\sqrt{\sigma^2_{\mathrm{Re}\{z\}}(\beta)}$ is a convex function, we can obtain the optimal value β_{opt} by using a bisection algorithm. We first define a slope function as in (7-3).

$$\begin{aligned}\Omega(\beta) &= \frac{\partial}{\partial\beta}\left\{\ln\left(\frac{E_z(\beta)}{\sqrt{\sigma^2_{\mathrm{Re}\{z\}}(\beta)}}\right)\right\} \\ &= \frac{\sum_{i=1}^{l}(l-1)\psi_i\left(Q_i-\frac{1}{l}\sum_{j=1}^{l}Q_j\right)+\sigma_n^2|h_i|^{-2\beta}\ln|h_i|}{(l-1)\sum_{i=1}^{l}\psi_i^2+\sigma_n^2\sum_{i=1}^{l}|h_i|^{-2\beta}}-\frac{\sum_{i=1}^{l}Q_i}{\sum_{i=1}^{l}|h_i|^{1-\beta}}\end{aligned} \tag{7-3}$$

where $\partial/\partial\beta(\cdot)$ is defined as a partial derivative with respect to β, $Q_i=|h_i|^{1-\beta}\ln|h_i|$, and $\ln(\cdot)$ is the natural logarithm operation. The bisection algorithm is summarized in the following:

i. Initially, let $l=0$. We can set $\beta_+^{(0)}=-1$ and $\beta_-^{(0)}=+1$.

ii. At the $(l+1)th$ iteration, let $\beta^{(l+1)}=\left(\beta_+^{(l)}+\beta_-^{(l)}\right)/2$.

iii. If $\Omega\left(\beta^{(l+1)}\right)\geq 0$, let $\beta_+^{(l+1)}=\beta^{(l+1)}$ and $\beta_-^{(l+1)}=\beta_-^{(l)}$. Else if $\Omega\left(\beta^{(l+1)}\right)<0$, let $\beta_-^{(l+1)}=\beta^{(l+1)}$ and $\beta_+^{(l+1)}=\beta_+^{(l)}$.

iv. Let $l=l+1$. Reprocess the procedure ii. After some iterations, we can approach the optimal value β.

In the receiver, we use soft decision to enhance the system performance. We derive the soft information from the log-likelihood ratio (LLR) of the posterior probability of each symbol. Assume the channel is symmetric and each data bit has equal a prior probability, i.e. $P(\mathrm{Re}\{x_k\}=+1/\sqrt{2})=P(\mathrm{Re}\{x_k\}=-1/\sqrt{2})=1/2$.

Then the LLR of the posterior probability of each data bit is derived from (8). And The numerator and denominator part of (8) can be obtained from (9) and (10).

$$\begin{aligned}\Gamma_{k,\mathrm{Re}} &= \ln\frac{P\left(\mathrm{Re}\{x_k\}=+1/\sqrt{2}\mid \mathrm{Re}\{z_{l,k}\}\right)}{P\left(\mathrm{Re}\{x_k\}=-1/\sqrt{2}\mid \mathrm{Re}\{z_{l,k}\}\right)} \\ &= \ln\frac{P\left(\mathrm{Re}\{z_{l,k}\}\mid \mathrm{Re}\{x_k\}=+1/\sqrt{2}\right)}{P\left(\mathrm{Re}\{z_{l,k}\}\mid \mathrm{Re}\{x_k\}=-1/\sqrt{2}\right)}\end{aligned} \tag{8}$$

$$P\left(\mathrm{Re}\{z_{l,k}\}\mid \mathrm{Re}\{x_k\}=+\frac{1}{\sqrt{2}}\right)=\frac{1}{\sqrt{2\pi\sigma^2_{\mathrm{Re}\{z\}}}}\exp\left(-\frac{\left(\mathrm{Re}\{z_{l,k}\}-m_{\mathrm{Re}\{z\}}\right)^2}{2\sigma^2_{\mathrm{Re}\{z\}}}\right) \tag{9}$$

$$P\left(\mathrm{Re}\{z_{l,k}\}\mid \mathrm{Re}\{x_k\}=-\frac{1}{\sqrt{2}}\right)=\frac{1}{\sqrt{2\pi\sigma^2_{\mathrm{Re}\{z\}}}}\exp\left(-\frac{\left(\mathrm{Re}\{z_{l,k}\}+m_{\mathrm{Re}\{z\}}\right)^2}{2\sigma^2_{\mathrm{Re}\{z\}}}\right) \tag{10}$$

where $m_{\mathrm{Re}\{z\}}$ is calculated from equation (6) and $\sigma^2_{\mathrm{Re}\{z\}}$ is calculated from (7). From above, the LLR of the real part of k-th symbol can be represented in (11).

$$\Gamma_{k,\mathrm{Re}}=\frac{1}{2\sigma^2_{\mathrm{Re}\{z\}}}\left\{\left(\mathrm{Re}\{z_{l,k}\}+m_{\mathrm{Re}\{z\}}\right)^2-\left(\mathrm{Re}\{z_{l,k}\}-m_{\mathrm{Re}\{z\}}\right)^2\right\} \tag{11}$$

And the soft bit $\hat{x}_k$ can be calculated from the LLR with the following formulas [9]:

$$\mathrm{Re}\{\hat{x}_k\}=1/\sqrt{2}\tanh(\Gamma_{k,\mathrm{Re}}/2) \tag{12.a}$$

$$\mathrm{Im}\{\hat{x}_k\}=1/\sqrt{2}\tanh(\Gamma_{k,\mathrm{Im}}/2) \tag{12.b}$$

$$\hat{x}_k=\mathrm{Re}\{\hat{x}_k\}+j\,\mathrm{Im}\{\hat{x}_k\} \tag{12.c}$$

With the soft information of each symbol, we can reconstruct the transmitted data by spreading the soft symbol with Walsh code. And we can continue to reconstruct the received data of each path by using the estimated channel state information. Finally, we send the reconstructed multipath signals to the "Soft MPIC" stage.

In the "Soft MPIC" stage, we first calculate the received signal of each path by subtracting multipath interference signals from the received signal. Each path signal provides more reliable information for data detection and it can be represented as follows [12]:

$$\mathbf{r}_d=\mathbf{R}-\left(\sum_{\substack{i=1\\i\neq d}}^{P}\mathbf{H}_i\right)\left(\sum_{k=1}^{l}\hat{x}_k\mathbf{c}_k\right),\qquad 1\leq \mathrm{d}\leq \mathrm{P} \tag{13}$$

where $\mathbf{r}_d$ is the dth path signal, $\mathbf{H}_i$ is the transfer function matrix of the i-th path, and P is the total number of paths. This subtraction is also known as multipath interference cancellation (MPIC). After we separate all the paths, we can use maximum ratio combining to coherently combine the signals together. In this way, we can achieve the path diversity gain. Afterward, we despread the data and calculate the soft information in this "Soft MPIC" stage. The LLR and the soft bit can be represented as follows:

$$\Gamma_k=(2/N_s\sigma_n^2)\cdot\mathbf{c}_k^T\sum_{d=1}^{P}\mathbf{H}_d^*\mathbf{r}_d \tag{14}$$

$$\hat{x}_k=1/\sqrt{2}\tanh\left(\mathrm{Re}\{\Gamma_k\}/2\right)+j(1/\sqrt{2})\tanh\left(\mathrm{Im}\{\Gamma_k\}/2\right) \tag{15}$$

where $\mathbf{H}_d^*$ is the complex conjugate of the channel transfer function matrix of the d-th path, N_s is the normal factor that equals the length of the Walsh code used, and $\hat{x}_k$ is the estimated soft symbol. We can use the estimated soft bits to reconstruct the data and the received signal of each path again. The signal processing as described above can be done in an iterative manner [11][12]. By repeating the above soft MPIC process several times, we can achieve more reliable data detection and the performance of this system will become much better than the original DVB-T system.

V. SIMULATION RESULTS

In this section, we show our simulation results of the modified DVB-T system as compared with the original DVB-T system. The channel environment simulated include a fixed channel and a multipath fading channel. The parameters of our simulation are shown in Table1. For simplicity, we did not consider channel coding for both systems. The fading channels are generated from the Jake's model at vehicle speed 30km/hr and 120km/hr which correspond to Doppler frequency 16.66 Hz and 66.66 Hz.

Fig. 8 shows the bit error rate performance of the modified DVB-T system in a two-path equal power fixed channel. At stage 0, the receiver executes "Soft PEQ" and at stage 1, 2, 3, the receiver executes the "Soft MPIC" process. From Fig.8, we observe that the receiver performance converges after 2-3 iterations of the "Soft MPIC" process.

Fig. 9 shows the bit error rate performance of the modified DVB-T system in a two-path fixed channel with a different path power ratio. If we use only the "Soft PEQ" process, there will be more than 2dB power gain at the BER 10^{-3} level compared with original DVB-T system. When both "Soft PEQ" and "Soft MPIC" are used, the power gain will be approximately 4dB. Fig. 10 and Fig. 11 are the simulation results of a two-path fading channel at the vehicle speed of 30km/hr and 120 km/hr. We again observe a significant performance improvement from the modified DVB-T system. The SNR gain in the 30km/hr channel is about 4.5dB at the BER 10^{-3} level when only "Soft PEQ" is used and about 7dB when both "Soft PEQ" and "Soft MPIC" are used. The main reason for poor performance of the original DVB-T system is that when the channel fades, some subcarriers may be seriously affected, and that will seriously degrade the BER performance. The code spreading and the MPIC technique used in our design help to eliminate the multipath influence, and effectively improve the overall system performance.

Table 1 The Simulation Parameters of The Modified DVB-T System

	Parameter
DVB-T System Mode	2k mode
Modulation	QPSK
Carrier frequency	600MHz
PEC parameter	β=0.5, 0.7 (derived from (7-3))
Number of subcarriers	2048
Useful symbol time	224 μs
Guard interval	56 μs
Overall symbol time	280 μs
Vehicle speed	30 km/hr, 120 km/hr
Doppler frequency	16.66Hz, 66.66Hz
Path number	2
Max delay spread	13.89 μs (127 samples)

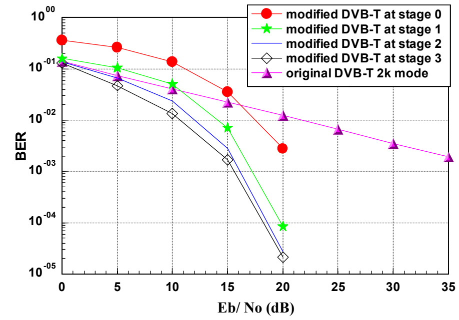


Fig.8 The bit error rate performance of the modified DVB-T system in a 2-path equal-power fixed channel (PEQ β= 0.7).

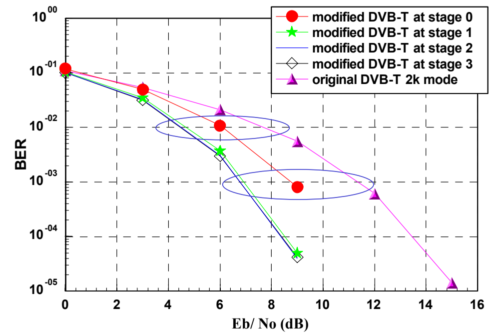


Fig.9 The simulation result for the proposed system in a 2-path (power ratio 4:1) fixed channel (PEQ β= 0.7).

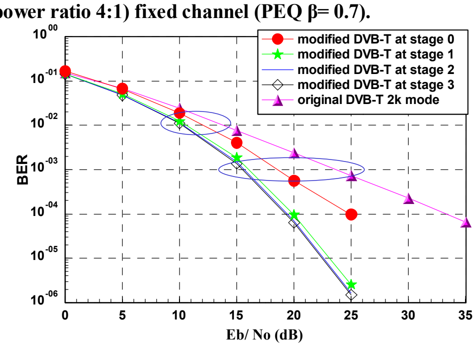


Fig.10 The bit error rate performance of the proposed system in a 2-path equal power fading channel with vehicle speed 30km/hr and PEQ parameter β= 0.5.

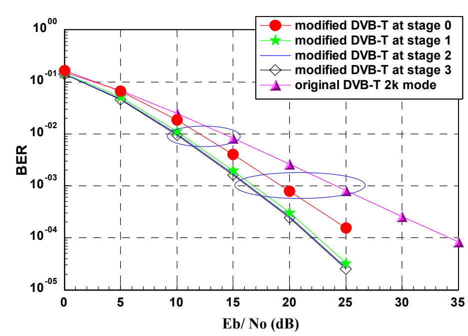


Fig.11 The simulation result for the proposed system in a 2-path equal power (1:1) fading channel with vehicle speed 120km/hr and PEQ parameter β= 0.5.

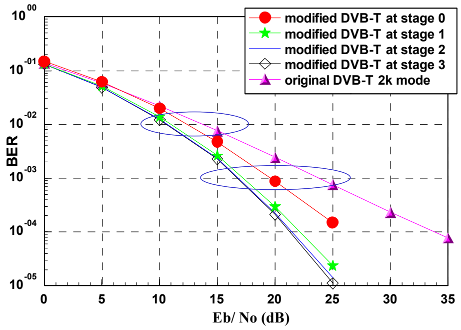


Fig. 12 The simulation result for the proposed system in a 2-path (power ratio 4:1) fading channel with vehicle speed 30km/hr and PEQ parameter β= 0.5.

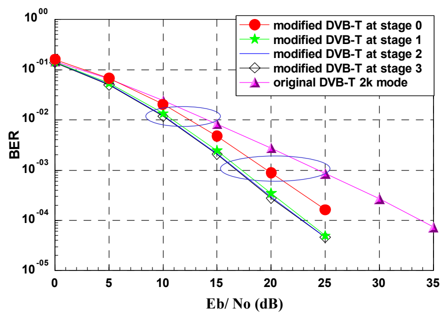


Fig.13 The simulation result for the proposed system in a 2-path (power ratio 4:1) fading channel with vehicle speed 120km/hr and PEQ parameter β= 0.5.

Fig. 12 and Fig. 13 show the system performances in a two-path fading channel at vehicle speed of 30km/hr and 120km/hr with a different path power ratio. The performance improvement trend of the modified DVB-T system is also very clear.

VI. CONCLUSION

In this paper, we describe a modified DVB-T system and compare its performance with the original DVB-T system. The modified system utilizes both the multi-code spreading technique and the MPIC technique to eliminate the degradation from the multipath effect. In the receiver, we execute both the "Soft PEQ" and the "Soft MPIC" algorithms and use soft information to improve the system performance. An iterative data detection process provides clear system performance improvement.

We use the 2k mode of the DVB-T standard as an example to demonstrate our system design, and the method can be generalized to the 8k mode. From our computer simulation, we conclude that the modified DVB-T system provides much better performance than the original DVB-T system and this modified system architecture can be one promising candidate for establishing the next generation digital video broadcasting standard.

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