PERFORMANCE ANALYSIS OF SDR-BASED DIGITAL-IF CHANNELIZATION FOR DUAL-BAND CDMA SYSTEM IN WIDEBAND MULTIPATH CHANNEL

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Abstract - In this paper, we analyzed the performance of SDR-based dual-band CDMA system in wideband multipath channel employing RAKE receiver with MRC diversity. For the simulation of SDR-based dual-band CDMA system, we used digital IF techniques, polyphase analysis filter bank as channelizer, where Remez exchange algorithm is employed in the realization of the digital filter.

1. Introduction

Software-Definded Radio (SDR) is believed to be one of key design concepts for the advanced communication systems on the 21st century which are requested provide a variety of multi-media transmissions and services through many communication environments under the conditions of limited frequency spectrum, limited equipment size and limited power supply. The reconfigurability of SDR opens new possibilities and flexibility to multi-band, multi-band and multi-service communication system's operation[1].

Recent advances in high speed analog-to-digital converter (ADC) and digital-to-analog converter (DAC) of sampling rate close to 100Msps has invoked possibilities of realizing direct digital conversion between intermediate frequency (IF) and baseband signals. Moreover, high performace digital signal processing devices such as general purpose digital signal processor (DSP) and field programmable gated array (FPGA) make it feasible to implement software-reconfigurable baseband modems and advanced signal processing modules. This technological progress allows efficient implementation of SDR modems into practice[2].

The SDR is a radio interface technology that generally consists of a software-reconfigurable hardware platform, and software modules that flexibly changes this hardware platform for a specific radio system application[3].

2. Channel Extraction

2.1 Digital IF

The ideal receiver hardware for the SDR consists of a combination of analog-to-digital converter (ADC) connected directly to the antenna and digital signal processor (DSP)[4], which has to deal with wide bandwidth. However, the development of wideband RF components, RF modules, and high-speed digital parts to realize common hardware platform based on SDR is not mature. Thus, in this paper, considering above problem, we use digital IF techniques which use commercial RF components in RF stage and bandpass sampling theory for digitalization in IF stage.

2.2 Channelizer using polyphase analysis filter bank

In this paper, we consider polyphase analysis filter bank as Digital-IF channelizer for Dual-band CDMA system. Compared to the conventional channelizer which is composed of a bank of multiple analog bandpass filters, this technique employs polyphase analysis filter bank so that band extraction as channelizer could be processed with low processing delay and small amount of computations. For this reason system which employs polyphase analysis filter bank is suitable for real-time processing using cost-effective, general-purpose digital signal processing devices.

The polyphase analysis filter banks considered is equivalent to the conventional K-band DFT banks. Here a set of the complex coefficients associated with analysis filter banks can be obtained from the decimation of the coefficients of the prototype FIR lowpass filter with the help of certain frequency shift factor.

Considering the frequency down-conversion fron the IF to the baseband, the complex exponentials are involved which make the filter coefficients complex. The decimation factor should be determined subject to avoiding the spectral cross-talk. If the decimation factor M is equivalent to the total number K of subbands, and the order of prototype lowpass FIR filter whose coefficients are denoted as h(n) (n=0, ...,L-1)is chosen to be L, the coefficients $p_i(m)$ of i-th polyphase filter in the analysis part con be expressd as the following[5]:

$$P_i(m) = j^m h(mK - i) \quad (i = 0, \dots, K-1) \qquad (1)$$

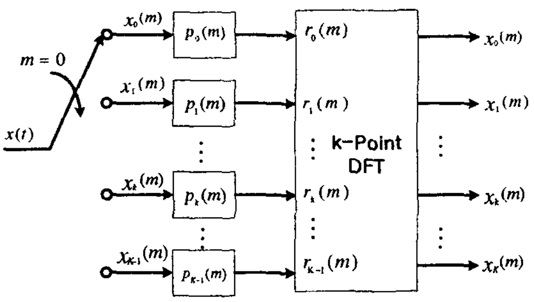

fig. 1 channelizer using polyphase filter bank

3. W-CDMA over Wideband Channel

The wideband multipath channel is generally modeled as a tapped delay linear filter, which is shown in eq. (2) and Fig. 2.

$$h(t) = \sum_{l=0}^{L-1} \sqrt{p_l}\alpha_l \delta(t - \tau_l) e^{j\theta_l} \qquad (2)$$

Here, p_l is the average power of the l-th component of the ITU-R M.1225 delay power profile, α_l is a Rayleigh distributed random variable representing the envelope of a zero-mean complex Gaussian time-invariant process, τ_l is the time delay, and θ_l is the phase of the process. We assume that the $\{\theta_l\}$of the various paths are mutually independent random variables, and are uniformly distributed over (0,2π). The time delay, τ_l, and the path strength component, $\sqrt{p_l}$, are obtained from the ITU-R delay profile.

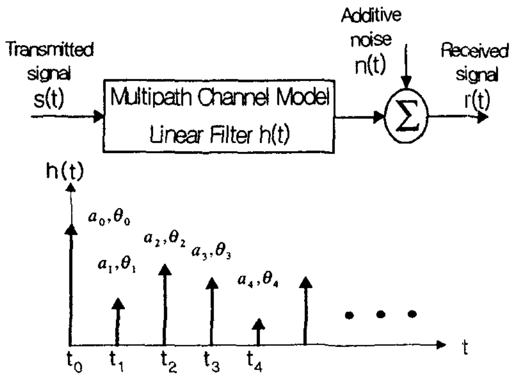

Fig. 2 Linear filter model

In this paper, we apply the ITU-R channel model which can resolve time by a 100 ns time bin, so we assume the channel bandwidth is 10 MHz, which is typical in many measurements.

Let's assume the general situation for the analysis of W-CDMA signals. Total received signal is composed of K -DS waveforms(users), all of which are asynchronous one another. And coherent BPSK, perfect power control, and synchronization are assumed. Then k-th transmitted signal is given by eq. (3).

$$s_k(t) = m_k(t)c_k(t)\exp(j\omega_o t) \qquad (3)$$

Where $m_k(t)$ and $c_k(t)$ are the data and the spreading sequence of k-th user. Then total received signal $r(t)$ can be represented by eq. (4),

$$r(t)=\sum_{k=0}^{K-1}\sum_{l=0}^{L-1}\sqrt{p_l}\alpha_{k,l}m_k(t-\tau_{k,l})c_k(t-\tau_{k,l})\exp[j\{\omega_o(t-\tau_{k,l})+\theta_{k,l}\}]+n(t) \qquad (4)$$

where K is total number of users, L is total number of multipaths, and $n(t)$ is additive Gaussian noise .

The index $k = 0$ represents the signal from a desired user whereas k = 1, 2,---, K-1 stands for signals from undesired users. The index l = 0 represents the first arrived signal while l = 1, 2,---, L-1 stands for second, third, ---,L-1-th multipath signal. And $\tau_{k,l}$ represents the delay time of k-th & l-th indexed signal, while $\theta_{k,l}$ represents the phase shift of k-th & l-th indexed signal caused by impulse response.

The output of a standard correlation receiver at $t = T$ is given by eq.(5).

$$Z = \mathrm{Re}\left[\int_0^T 2r(t)c_0(t)\exp(-(\omega_o t + \theta_o))dt\right]$$
$$= \mathrm{Re}\left[\int_0^T 2\{s_0(t)+s_i(t)+n(t)\}c_0(t)\exp(-(\omega_o t+\theta_o))dt\right]$$
$$\equiv S + I + N \qquad (5)$$

To find out the statistical properties of $Z(T)$, we need to analyze the statistics of each component S, I, and N, which comprise $Z(T)$, respectively.

Let's look through the statistics of wanted user signal S. Then, we can write the equation of S as follow.

$$S = \left| \sum_{l=0}^{L-1} \sqrt{p_l}\, \tilde{\alpha}_{0,l} \exp(j\tilde{\phi}_{0,l}) R_c(\tau_{0,l}) \right| \qquad (6)$$

In eq.(6), ~ stands for the notation of random variable. For further details the references deal with the equation of S [6].

We employ a RAKE receiver with maximal ratio combining (MRC) diversity to use all multipath components. Then, after employing MRC diversity, the output of a receiver can be represented by eq. (7).

$$Z_T = S_T + I_T + N_T \qquad (7)$$

And, the statistics of S_T should be modified as follows,

$$S_T = \sum_{i=1}^{M} G_i S_i \ , \qquad (8)$$

where G_i is the gain of i-th branch. The gain G_i is the ratio of signal voltage to noise and interference power and it is given by eq. (9) [7][8].

$$G_i = K \frac{S_i}{N} \qquad (9)$$

Usually, despread multiple access interference (MAI) is modeled as Gaussion, and noise is additive Gaussion noise [9][10].

In eq.(6) , if L is large, S becomes the absolute value of complex addition of many complicated random variables. Instead of theoretical derivation of the pdf of S, *p(S)*, we find *p(S)* by generating *S* numerically with a random number generator.

4. Simulations

In the simulation, digital IF techniques are applied to dual-band CDMA systems (W-CDMA and IS-95). Also, bandpass sampling in IF stage (Table 1) for digital IF techniques, polyphase analysis filter bank for channelization and blocker rejection are considered, and Remez exchange algorithm is used in the realization of the digital filter in the polyphase analysis filter bank. From above mentioned condition, the performance for realistic channel environments (Table 2, Table 3) and different sampling rates is evaluated.

Sampling frequency (MHz)	IF frequency (MHz)	
	W-CDMA	IS-95
40	15	5
First IF frequency : W-CDMA= 175MHz, IS-95 = 85MHz		

Table 1 sampling frequency and IF frequency for simulation

Also, In order to analyze the performance in wideband multipath channel, we consider indoor office test environment and outdoor to indoor and pedestrian test environment. The ITU-R M.1225 channel parameters are given in the Table 2 and Table 3[11].

Tap	Channel B	
	Relative delay (ns)	Average Power (dB)
1	0	0
2	100	-3.6
3	200	-7.2
4	300	-10.8
5	500	-18.0
6	700	-25.2

Table 2 Indoor office test environment tapped-delay-line parameters

Tap	Channel B	
	Relative delay (ns)	Average Power (dB)
1	0	0
2	200	-0.9
3	800	-4.9
4	1200	-8.0
5	2300	-7.8
6	3700	-23.9

Table 3 Outdoor to indoor and pedestrian test environment tapped-delay-line parameters

In the performance analysis for the different channels (Fig. 3, Fig. 4) and different sampling frequencies, power loss of the signal due to the use of the digital IF techniques is accounted. For better accurate analysis of the performance, power loss of IF signal after passing through channel and the filter, which is consisted of polyphase analysis filter bank, is applied to the rake receiver.

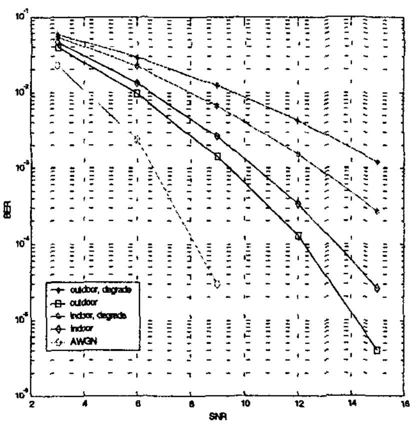

Fig.3. BER in different channel environments

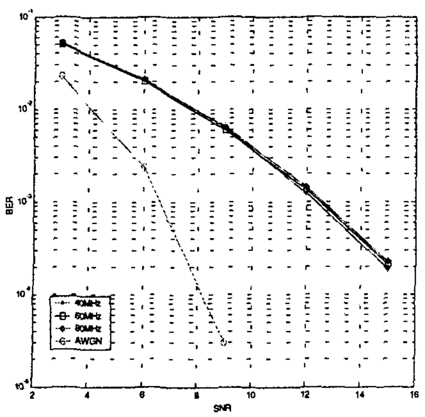

Fig.4. BER over different sampling rates in indoor office test environment

Fig. 3 and Fig. 4 show the performance over different channel environments and sampling rates. In Fig. 3, 'indoor' and 'outdoor' mean the channel environment without power loss. On the other hand, 'indoor degrade' and 'outdoor degrade' mean the channel environment with power loss due to the channel and filter.

5. Conclusions

In this paper, we analyzed the performance of SDR-based dual-band CDMA system in wideband multipath channel employing RAKE receiver with MRC diversity through the simulations. For simulation of SDR-based dual-band CDMA system, we used digital IF techniques, polyphase analysis filter bank as channelizer, and Remez exchange algorithm is employed in the realization of the digital filter in the polyphase analysis filter bank.

As the results of the simulations, we can see that the performance in outdoor to indoor and pedestrian test environment is better than that in indoor office test environment. Also, 'indoor, degrade' and 'outdoor, degrade' have about 1.2dB and 5.8dB worse performance than 'indoor' and 'outdoor' at the BER of 10^{-3}, respectively, because of power loss (Fig. 3). From Fig. 4, the performance for different sampling rates is almost the same. It means that sampling rates doesn't have an effect on the performance of the SDR-based system.

In conclusion, we analyzed the performance of system based on SDR-based Digital IF techniques through the simulation. So, we expect that these results can be useful as basic data to design and implement SDR system.

6. References

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Acknowledgement

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