

行政院國家科學委員會專題研究計畫 期中進度報告

後三代行動通訊處理器設計(2/3)

計畫類別：個別型計畫

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計畫主持人：陳光禎

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後三代行動通訊處理器設計 (2/3)

Beyond 3G Receivers Design

計劃編號: NSC 92-2213-E-002-038-92c9109

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主持人: 陳光禎 臺灣大學電機系 教授

一、中文摘要：

後三代無線通訊系統的目標是支援行動通訊環境下高速多媒體傳輸服務。為了要抵抗衝擊性噪音(impulsive noise)和多通道效應(multipath effect)並且更有效地使用頻寬，我們採用了正交頻域多工(orthogonal frequency division multiplexing)這種多載波調變技術。它已經被廣泛地採用在許多的通訊系統。例如：數位語音廣播(digital audio broadcasting)、數位地面影像廣播(digital video terrestrial broadcasting)也成為了 IEEE 802.11a, IEEE 802.11g 等的調變標準。此外，我們提出一種和正交頻域多工調變技術有著相似概念的多速率多載波(multi-rate multi-carrier)碼分多工(code division multiple access)接收器架構，以滿足多使用者服務及多速率傳輸。

多碼(Multi-Code)及可變展開長度(Variable-Spreading-Length)是兩個在支援多速率分碼多工(Code Division Multiple Access)系統中常使用的觀念。在此將研究這兩種觀念在多調碼分多工(Multi-Tone Code Division Multiple Access)的應用，使得在選頻衰退通道(frequency-selective-fading channel)上得多速率傳輸可以更有效率。此外，我們還研究了以匹配濾波器(matched filter)所建立的接收器最終

的信號特性及傳輸效能，並與選擇適合多速率計畫的多調碼分多工(Multi-Tone Code Division Multiple Access)作比較。既然切片等級的正交性已被多調碼分多工(Multi-Tone Code Division Multiple Access)所改變，我們將分析干擾對多碼(Multi-Code)及可變展開長度(Variable-Spreading-Length)系統的影響，並找出兩者的主要問題。雖然據我們了解，可變展開長度(Variable-Spreading-Length)的觀念應用在直序分碼多工(DS-SS)的效能很好，但多碼(Multi-Code)的觀念在位元錯誤率(BER)及多調碼分多工(Multi-Tone Code Division Multiple Access)上的應用則較適合。

此外，我們也將研究溫納相位噪音(Wiener phase noise)在正交頻域多工系統的效應，並提出修正它的方法。由於溫納相位雜訊(Wiener phase noise)所導致共相位誤差(common phase error)和載波間干擾(inter-carrier interference)會嚴重降低正交分頻多工(OFDM)系統的效能，在 B3G 的系統下，其影響則更為嚴重，所以溫納相位雜訊的修正與分析對正交分頻多工(OFDM)系統是一個很決定性的挑戰。所以在這一年的計劃中，我們藉著最大可能性法則(maximum likelihood criterion)來提出一個有效的

共同相位差估測器 (common phase noise estimator)。有別於常見的最大可能性接近法 (maximum likelihood approach)，其只視由不同之子載波 (subcarrier) 所觀察到的載波間干擾為獨立同一分佈 (independent identically distributed)，而我們則以研究載波間的協方差函數 (covariance function)，載波間干擾權重 (weighting) 的自相關函數 (autocovariance function)，結合導向輔助 (pilot-aided) 和決策導向 (decision-directed) 方法去產生廣義的最大可能性接近方案。透過載波間干擾權重的自相關函數，由載波間干擾所產生的效能下降則準確地分析和利用模擬來驗證。

關鑑詞：多調碼分多工、多載波、碼分多工、可變展開長度、相位雜訊、正交分頻多工、最大可能性估測法

英文摘要：

Beyond Third Generation (B3G) wireless communications systems aim to support high-rate multimedia services in the mobile environment which makes a highly distorted radio channel. In order to combat multipath effects and make better use of the system available bandwidth (i.e. high spectral efficiency), orthogonal frequency division multiplexing (OFDM) multicarrier modulation technique which has been widely used for many communication systems such as digital audio broadcasting (DAB), digital video terrestrial broadcasting (DVB), IEEE 802.11a, IEEE 802.11g, etc. In addition,

we proposed multi-rate multi-carrier CDMA receiver structure which shares the similar concepts with OFDM modulation to meet multi-user service and variable data rate transmission.

Multi-Code (MC) and Variable-Spreading-Length (VSL) are two widely used schemes in CDMA systems to support multiple rates services. In the second year of the project, we investigate the applications of these two concepts to Multi-Tone Code-Division-Multiple-Access (MT-CDMA) for efficient multi-rate transmission over frequency-selective-fading channels. The resulted signal properties and transmission performance with the receiver based on matched filters are studied and compared for selecting the appropriate multi-rate scheme in MT-CDMA. Since the chip-level orthogonality among sub-carriers is inherently altered in MT-CDMA, we analyze the involved interference effect on MC and VSL schemes and identify the key problems. Although VSL concept is known advantageous in DS-CDMA, MC scheme is shown favorable in the concerns of BER and spectrum utilization in MT-CDMA systems.

Besides, we study the Weiner phase noise effect in OFDM system and propose a correction method.

Performance degradation due to Wiener phase noise which causes both common phase error (CPE) and inter-carrier interference (ICI) is a crucial challenge to the implementation of OFDM systems, especially in B3G systems. We propose a common phase error estimator based on maximum likelihood criterion. Different from conventional maximum likelihood approach which assumes the inter-carrier interferences observed on different subcarriers to be independent identically distributed, we investigate the covariance matrix among carriers by autocorrelation function of the ICI weighting and combine pilot-aided and decision-directed approaches to yield a generalized maximum likelihood estimation scheme. The performance degradation caused by ICI is accurately analyzed and justified with simulation.

Index terms: Multi-Tone-CDMA, Multi-carrier, CDMA, OFDM, Variable-Spreading-Length, Phase noise, Maximum likelihood estimation.

二、前言：

In the communications systems beyond the third generation (B3G) mobile communications, the primary concept leads to develop the efficiently utilization of spectrum to provide the higher data rate services than IMT-2000 and to develop the programmable systems adaptive to multiple communications systems, such as the

wide-band CDMA in IMT-2000, OFDM in IEEE 802.11a and IEEE 802.11g, the Bluetooth technologies.

It was in 1993, that three types of new multiple access schemes based on a combination of code division and OFDM techniques were proposed, such as “multi-carrier (MC-) CDMA,” “multi-carrier DS-SS-CDMA,” and “multi-tone (MT-) CDMA.” These signals can be easily transmitted and received using the fast Fourier transform (FFT) device and have attractive feature of high spectral efficiency due to minimally densely sub-carrier spacing. They inherently suit for asynchronous multimedia data transmission. But they suffer from intersymbol interference (ISI), multiple access interference (MAI) and intercarrier interference (ICI) which cause performance degradation.

An important feature of future wireless communication is to accommodate many types of traffic, which require multi-rate transmission and large bandwidth. From viewpoints above, this year we focus on multi-rate multi-tone CDMA and study phase noise in OFDM to enhance system performance.

Although OFDM can combat impulsive noise and robust to frequency selective fading channel, it has several disadvantages such as difficulty of sub-carrier synchronization and performance sensitivity to phase noise and frequency offset.

To know how phase noise affects

system performance, we study it and try to propose a correction scheme. Phase noise effects introduced by local oscillator in any receiver, which can be interpreted as a parasitic phase modulation, can only be ameliorating by improving the performance of the oscillator itself, with associated cost increase. So it must be carefully considered when dealing with any of these communication systems since an accurate prediction of the tolerable phase noise can allow the system and RF designers to relax specifications.

三、研究目的：

Wireless multimedia communications require efficient multi-rate physical-layer transmissions. Lots of research extensively studied the multi-rate transmissions over direct-sequence Code-Division-Multiple-Access (DS-CDMA) systems [1] for multimedia communications, where multi-code (MC) and variable-spreading-length (VSL) are the two most widely applied multi-rate concepts. MC scheme assigns multiple spreading codes for data multiplexing and VSL scheme adjusts the spreading factor respectively to achieve multi-rate transmission. Comparatively, VSL was shown advantageous due to its better interference pattern and lower implementation complexity in DS-CDMA [2]. However, with the increasing demand of wideband high-speed communications, research

attentions have been changed to multi-carrier systems in recent years, which provide efficient transmissions over broadband wireless channels [3]. Hence, it is natural to apply MC concept to MT-CDMA.

In [7], it is shown that the OFDM is in orders of magnitude more sensitive to carrier frequency offset and phase noise than single carrier systems. And it is also proved that the Wiener phase noise is a much more complex phenomenon than carrier frequency offset. The effects of phase noise are the well-known common phase error (CPE) and inter-carrier interference (ICI). The primary source of phase noise in a receiver is the local oscillator in the mixer. Components with ultra-low phase noise specifications are readily available, but are often large and expensive, therefore, meeting the phase noise requirements for an OFDM system may add cost to the mixer especially for systems with a large number of subcarriers. Hence, the significance of phase noise suppression algorithms is to transfer the effort from analog to digital part to simultaneously lower the cost and preserve the required performance.

四、研究方法：

Applying MC concept to MT-CDMA is straightforward as transmitting multiple basic-rate MT-CDMA signals. However, simply assigning codes of variable length to users of different symbol rates cannot

simultaneously keep constant bandwidth and symbol-level orthogonality in MT-CDMA. It is because the sub-carrier separation in MT-CDMA depends on the symbol rate instead of chip rate, although the bandwidth at each sub-carrier is fixed. Hence, in addition to MC scheme, we propose two varieties of VSL schemes to respectively hold constant bandwidth and symbol-level orthogonality. To evaluate the performance of MT-CDMA receptions in different multi-rate schemes, the suffered interferences, including multiple-access interference (MAI) and ICI, are the most important factors to be considered [6]. Besides comparing basic signal properties, we focus on analyzing the characteristics of the three multi-rate schemes about interference immunity in the receiver based on matched filters and identify their challenging problems. Quasi-synchronous reception is considered for fundamental investigations as a necessary precursor to asynchronous uplink. With BER comparison in simulations, application suggestions are given in the conclusion.

Then we present the phase noise corrupted OFDM signal model and the phase noise model respectively. Based on that, first investigate the statistical characteristics of the sufficient statistics, it then proceed to derive the maximum likelihood estimator for CPE. Afterward, the analysis of the effect ICI is given. Performance evaluations via computer simulation are addressed as shown as

follow. Finally, we make some discussions in year's project.

五、結果與討論：

We studied MC and VSL multi-rate transmissions of MT-CDMA, including interference analysis and performance comparison, where the MC scheme is shown more appropriate for applications. Showing constant bandwidth, the major detection challenge of MC scheme is Intra-carrier MAI and can be easily mitigated by orthogonal codes such that users of any rate can achieve the best performance compared to using the other schemes. VSL-O scheme is good for users of higher data rates but it occupies wider bandwidth and the rate-varying bandwidth makes the spectrum utilization a serious concern. VSL-FB scheme shows the best PAPR condition and its constant spectrum profile identical to MC scheme makes their transceiver architectures easier integrated like that in DS-CDMA system [2]. However, the performance of non-basic-rate users in VSL-FB is poor due to severe Self-ICI, even though basic-rate users perform well.

In contrast to MC-CDMA [5] and MC-DS-CDMA [4], where frequency diversity and MAI pattern respectively dominate the transmission performance of a multi-rate scheme, the evaluation of multi-rate schemes in MT-CDMA is dominated by the resistance against ICI and the spectrum utilization. MC scheme is superior in terms of both BER

and spectrum efficiency, although adequate PAPR reduction may be necessary due to amplifier restrictions.

Then we propose a common phase error estimator based on maximum likelihood criterion to effectively remove the complex gain caused by phase noise on the frequency domain transmitted symbols. Different from conventional maximum likelihood approach which assumes the inter-carrier interferences observed on different subcarriers to be independent identically distributed, we combine pilot-aided and decision-directed approaches and investigate their covariances to yield the generalized maximum likelihood estimation scheme. By the autocorrelation function of the ICI weighting function, the effect of ICI is analyzed and verified with numerical results. The effectiveness of the proposed algorithm is manifested by simulations and is shown to outperform the conventional least-squared approach.

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七、圖表：

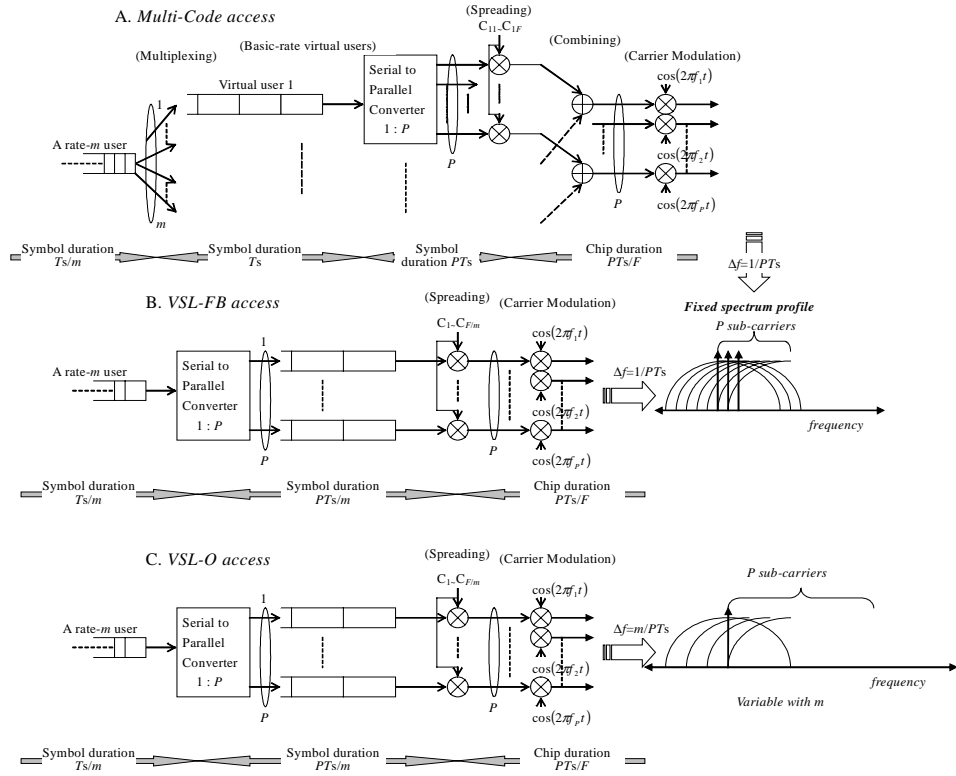


Fig. 1 Three multi-rate MT-CDMA transmission schemes

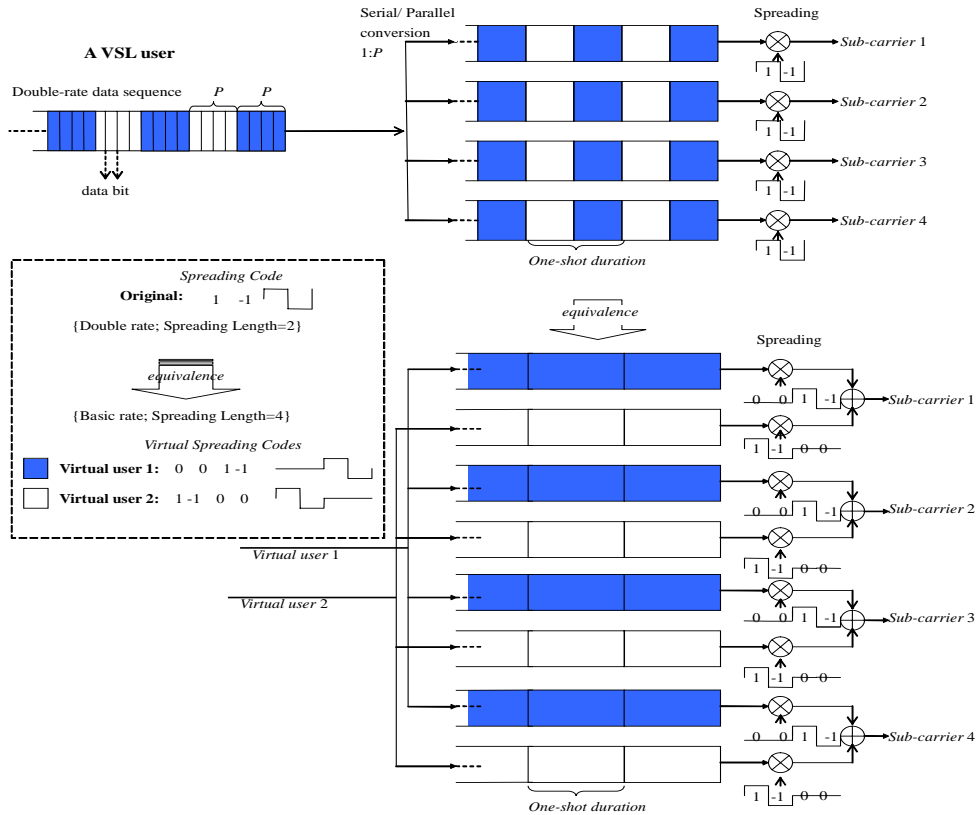


Fig. 2 Virtual users in VSL-FB and VSL-O schemes of MT-CDMA. This is an example of a double-rate user with spreading codes 1 -1; Serial-to-parallel conversion ratio $P=4$. The colored bits belong to the virtual user 1 and white bits belong to the virtual user 2.

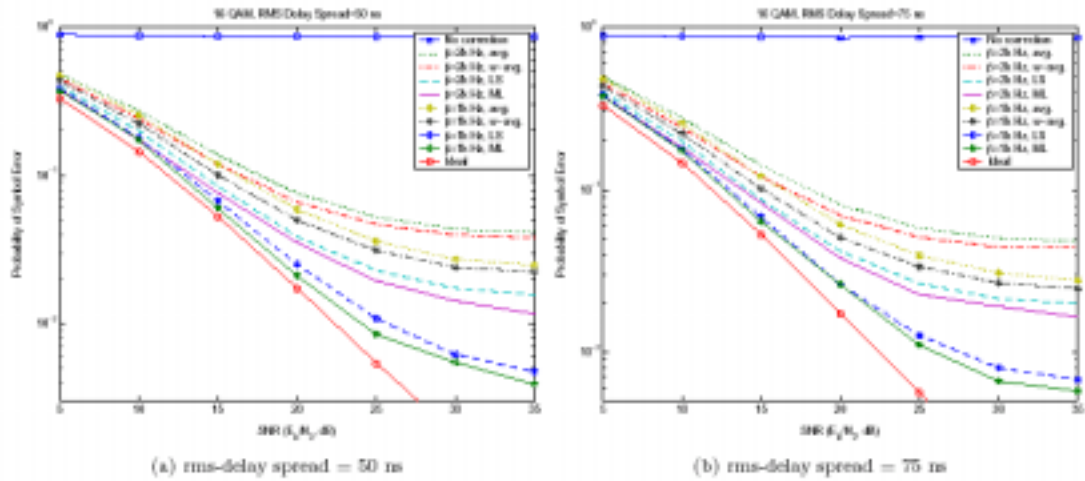


Figure 3: SER Performance of the CPE correction schemes with 16 QAM

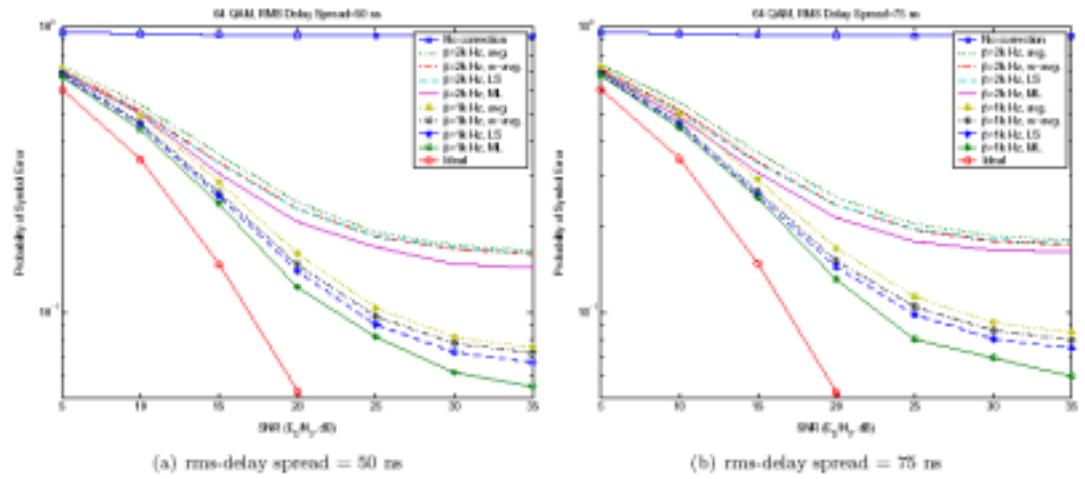


Figure 4: SER Performance of the CPE correction schemes with 64 QAM