SIMULATION TOOL AND RAPID PROTOTYPING FOR CDMA2000

M. De Nobili, R. W. Stewart
Electronic & Electrical Engineering Dept.
University of Strathclyde
204 George St., Glasgow, G1 1XW, UK
Tel: +44 (0) 141 548 2684; Fax +44 (0) 141 552 2487
e-mail: mdenobili@eee.strath.ac.uk

G. Freeland
EnTegra Ltd.
2 Waltham Road, Maidenhead,
Berkshire, SL6 3NH, UK
Tel: +44 (0) 1628 829061; Fax: +44 (0) 1628 824790
e-mail: g.freeland@ieee.org

ABSTRACT

This paper describes the features of a cdma2000 physical layer compliant library for rapid prototyping and system modelling. References to the standard specifications and to particular CDMA signal transmission scenarios are used to describe the CDMA2000*Lib* library's functionality and benefits. Single-pilot signals and signals with multiple code channels are generated, and relative constellation diagrams are shown. A non linear system model, represented by a tube wave travelling amplifier (TWTA), is implemented and used to study the CDMA signal degradation (in time domain) and to estimate the error vector magnitude (EVM) parameter. A signal transmission on a multipath channel enviroment is considered, implemented and studied.

1. INTRODUCTION

cdma2000 is the American third-generation (3G) mobile wireless technology proposal submitted to the International Telecommunication Union (ITU), [1], based on the second-generation (2G) IS-95, or cdmaOne, standard.

cdma2000 can support mobile data communications at speeds ranging from 144 kbps to 2Mbps, doubling the voice capacity of cdmaOne networks. It can deliver peak packet data speeds of 307 kbps in mobile environments.

The recent cdma2000 evolution is represented by the cdma2000 1xEV standard, which includes the cdma2000 1xEV-DV (Data and Voice), [2], and the cdma2000 1xEV-DO (Data Only), [3], specifications. Improving the data throughput and simultaneously providing coexisting voice services within the same radio frequency (RF) carrier have been the goals of the cdma2000 1xEV-DV, also known as cdma2000 Release C. The cdma2000 1xEV-DO is optimized for packet data services only; it delivers peak data rates of 2.4Mbps and supports applications such as MP3 transfers and video conferences. 1xEV-DO and 1xEV-DV are both backward compatible with cdma2000 and cdmaOne.

The CDMA2000*Lib* provides all the functionality required for complete cdma2000 (Release B), [1], compliant physical layer transmitter and receiver design, building and testing. This library has been developed to run within the SystemView simulation tool, which is a useful platform for rapid prototyping, test custom processing and receiver designs. The CDMA2000*Lib* offers a suite of functional blocks (or tokens) that can be integrated with any other library's model included in SystemView simulation environment. The main characteristics of the CDMA2000*Lib* are: hierarchical structure (it can provide discrete single function tokens or individual tokens capable of implementing full forward and reverse systems), and efficient and intuitive graphical user interface (GUI).

This paper presents typical cdma2000 structures built with the CDMA2000*Lib* tokens in order to emphasize the aforementioned characteristics, and to show its adaptability to different environments and system analysis.

This paper is organised as follows: code channels and CDMA channels are discussed in Section 2, where two different CDMA signals are generated and their respective constellation diagrams are shown. Section 3 discusses a non linear system using a TWTA, and the signal degradation is analyzed together with an estimation of the EVM parameter. Section 4 investigates a Rayleigh fading channel model, and a 2 finger Rake receiver is used to recover the signal. Finally, Section 5 presents the conclusions.

2. CDMA CHANNELS

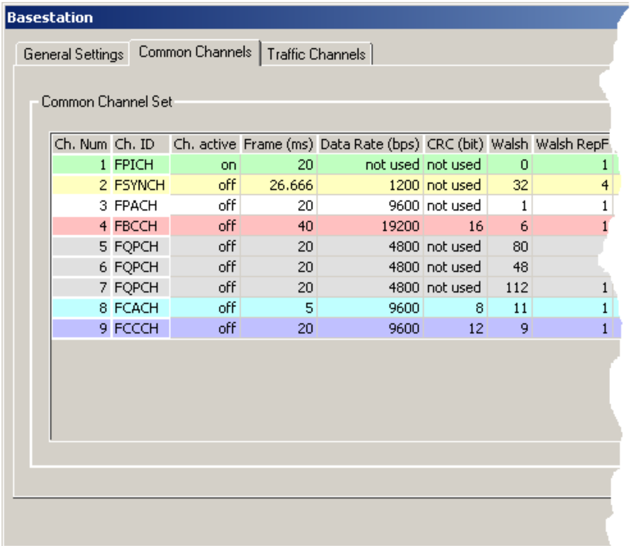
As specified in [1], a CDMA channel is a set of code channels transmitted between the base station and mobile stations on a given CDMA frequency assignment. Code channels include forward or reverse, common or traffic channels, like the Forward Broadcast Channel (F-BCCH), the Forward Paging Channel (F-PACH), the Reverse Access Channel (R-ACH), or the Reverse Fundamental Channel (R-FCH), etc.

Each code channel is spread by an orthogonal Walsh function or quasi orthogonal function. In the forward link each CDMA channel is also specified by a particular pilot Pseudo Noise (PN) offset (i.e. unique for each base station).

Due to the hierarchical design of the CDMA2000*Lib*, the user can create a forward CDMA channel characterised by one or more code channels simply using the BaseStation token, which generates a complete forward link system including channel coding, spreading/channelisation, scrambling, RRC filtering and final I/Q modulation onto a carrier.

Figure 1 shows the graphical user interface of the BaseStation token. The GUI consists of three property pages, one for the general setting (Radio Configuration, Spreading Factor, Transmission Mode parameters, etc.), the other two for the Common and the Traffic Channel list, respectively.

The user can activate a code channel, set its channel coding and spreading/scrambling parameters, in order to create a particular configuration which is defined according to the standard specification. It is also possible to add or remove code channels from the selected list, in order to have a different set of code channels or to simulate a multi-user environment.



Ch. Num	Ch. ID	Ch. active	Frame (ms)	Data Rate (bps)	CRC (bit)	Walsh	Walsh RepF
1	FPICH	on	20	not used	not used	0	1
2	FSYNCH	off	26.666	1200	not used	32	4
3	FPACH	off	20	9600	not used	1	1
4	FBCCH	off	40	19200	16	6	1
5	FQPCH	off	20	4800	not used	80	
6	FQPCH	off	20	4800	not used	48	
7	FQPCH	off	20	4800	not used	112	1
8	FCACH	off	5	9600	8	11	1
9	FCCCH	off	20	9600	12	9	1

Figure 1: CDMA2000*Lib* BaseStation's GUI

The constellation diagrams of a single-pilot signal and of a signal with multiple code channels (pilot, synchronization and traffic channel), respectively, are shown in Figure 2.

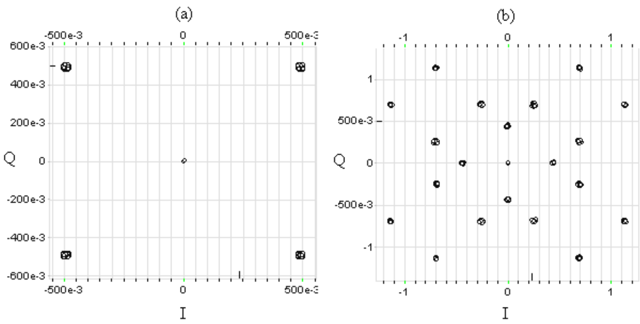


Figure 2: Constellation diagrams: (a) single-pilot signal, (b) signal with multiple code channels.

3. RF PERFORMANCES ANALYSIS

The CDMA2000*Lib*'s tokens can be use to build system models in order to study and verify the Radio Frequency (RF) performances of a base station or a mobile station standard-compliance, as specified in [4] and [5]. Parameters like Channel Power, Occupied Bandwidth, Error Vector Magnitude (EVM), Code-Domain Power, Out-of-Channel Spurious and Adjacent Channel Power Ratio (ACPR), or Out-of-Band Spurious, can be estimated under particular conditions, and compared to the minimum standard requirements.
One of the most important modulation quality metrics of a cdma2000 base station transmitter is the EVM. The EVM is a measure of the difference between the ideal signal and the measured signal. This difference is called error vector. EVM is defined as the square root of the ratio of the mean error vector power to the mean reference power expressed as a percentage. Figure 3 shows the error vector and its components.

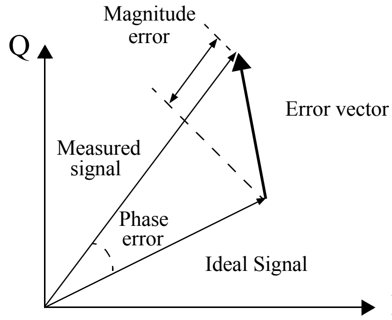


Figure 3: Error Vector and related parameters

The single-pilot CDMA signal, presented in Section 2, is now used as the input signal of a non-linear channel model, represented by a travelling wave tube amplifier (TWTA). The TWTA model is simulated using a token from the SystemView RF/Analog Library.
The TWTA input/output non-linearity is described by the following equations:

$$A(r) = \frac{\alpha_r r}{1+\beta_r r^2}, \Phi(r) = \frac{\alpha_\phi r^2}{1+\beta_\phi r^2} \qquad (1)$$

where $A(r)$ is the output magnitude, $\Phi(r)$ is the output phase, and r is the input magnitude. The TWTA model depends on the 4 parameters α_r, β_r, α_ϕ and β_ϕ. For this example, the following values for the TWTA coefficients have been chosen: $\alpha_r = 1.9638$, $b_r = 0.9945$, $\alpha_\phi = 2.5293$, and $\beta_\phi = 2.8168$. Figure 4 shows the transfer function of the TWT non-linear amplifier, [6].

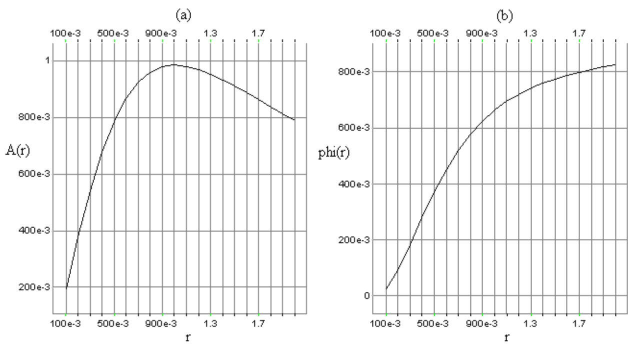


Figure 4: TWTA transfer function: (a) input/output amplitude, (b) input/output phase

The high level of signal degradation, due to the TWTA parameter choice, can be observed in the time domain analyzing the signal constellation diagram. Figure 5 shows the

constellation diagram of the single-pilot CDMA signal, as the output of the token performing active gain control and carrier phase compensation. Comparing this diagram with the one depicted in Figure 2 (a), the constellation results distorted because of the AM/AM and AM/PM properties of the non-linear amplifier.
The system model depicted in Figure 6 can be used to estimate the EVM parameter, when the non linearity source of the system is a TWTA. A value equal to 10.3% has been found for the TWTA with the parameters defined above.

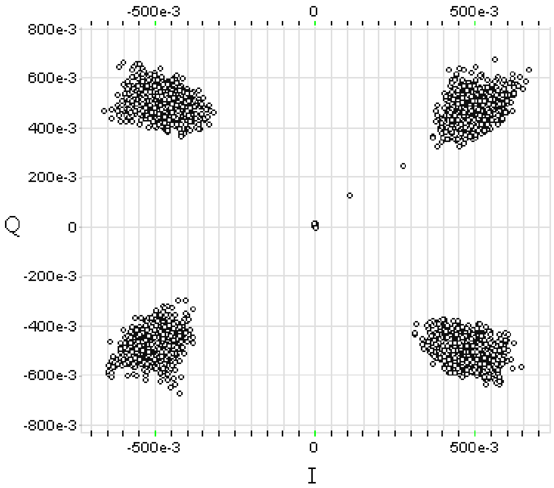


Figure 5: TWTA output signal constellation

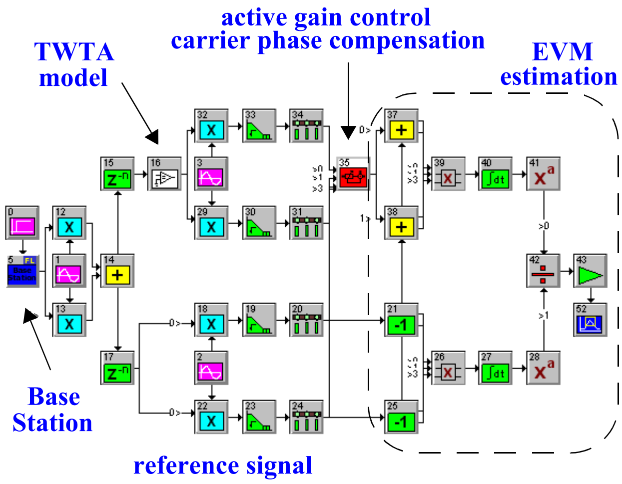


Figure 6: System View model for EVM calculation

4. MULTIPATH RAYLEIGH FADING CHANNEL

In this section a multipath Rayleigh fading channel model is used to analyse and study the behaviour of a traditional rake receiver demodulating a CDMA signal.
The SystemView Communications Library provides the user with a functional block to implement a general baseband (complex) fading channel model, whose input/output relation is described by the following equation:

$$y(t) = y_I(t) + jy_Q(t) = \sum_{i=0}^{N-1} G_i w_i(t) x(t - \delta_i) \qquad (2)$$

where $w_i(t)$ are the complex filter weights, whose envelope has a Rayleigh distribution and is generated using the modified Jakes fading model described in [6], while δ_i and G_i for $0 \le i < N$ are the time delay and the instantaneous amplitude of the i-th path, respectively.
Figure 9 shows the SystemView block diagram simulating the transmission on the Rayleigh fading channel and a 2-finger Rake receiver.
The Rayleigh fading channel has two independent paths with a relative delay between them of 5 chips.
Before entering the channel, the input signal is spread by a Walsh code and scrambled by a PN sequence as specified in [1]. The spreading and the despreading operations, as well as the scrambling and the descrambling operations, are performed by the same CDMA2000*Lib* tokens, the Walsh Code Generator and the Quadrature Spreading blocks, respectively. Figure 7 shows the GUI of the Walsh Code Generator token.

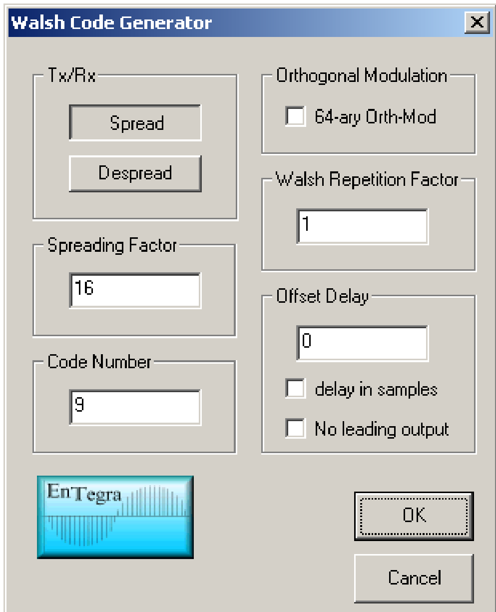


Figure 7: Walsh Code Generator GUI

At the channel output, the first and the second finger of the Rake receiver descrambles and despreads the signal received respectively through the first and the second path.
A phase correction is implemented for each finger to compensate the phase rotation introduced in the channel. Finally, the output of the two fingers are combined to produce an estimate of the transmitted signal. There are various combining techniques, in this example the equal gain combining criterium has been used in which equal importance is given to the output of each finger. As shown in Figure 8, the transmitted signal is recovered correctly.

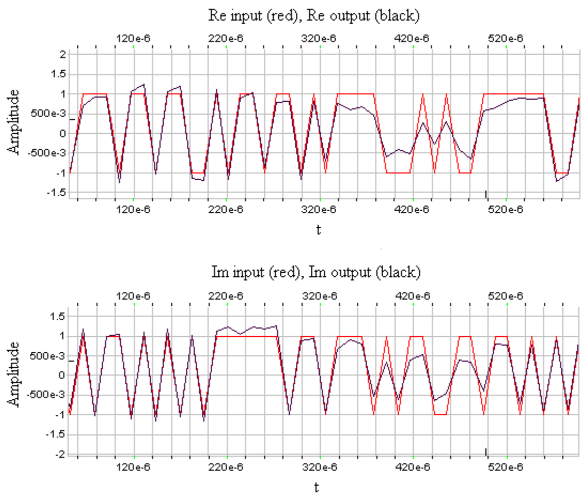


Figure 8: Comparison between the input signal and the 2-finger Rake receiver output signal

5. CONCLUSIONS

This paper has focused on the CDMA2000*Lib* features and on its use for rapid prototyping and system modelling. Code channels and CDMA channels have been defined and generated using the library base station token. A non linear TWT amplifier model has been implemented and the CDMA output signal degradation has been analyzed in the time domain. The CDMA2000*Lib* was demonstrated using a multipath Rayleigh fading channel model, and a 2-fingers Rake receiver has been used to recover the signal.

REFERENCES

[1]3GPP2 C.S0002-B v1.0 "Physical Layer Standard for cdma2000 Spread Spectrum Systems", April 2002.

[2]3GPP2 C.S0002-C v1.0 "Physical Layer Standard for cdma2000 Spread Spectrum Systems", May 2002.

[3]3GPP2 C.S0024-C v4.0 "cdma2000 High Rate Packet Data Air Interface Specification", October 2002.

[4]3GPP2 C.S0010-B v1.0 "Recommended Minimum Performance Standards for CDMA2000 Spread Spectrum Base Stations", December 2002.

[5]3GPP2 C.S0011-B v1.0 "Recommended Minimum Performance Standards for CDMA2000 Spread Spectrum Mobile Stations", December 2002.

[6]Dent, G.E. Bottomley, G. Croft, "Jakes Fading Model revisited", Electronics Letters,June 1993, Vol. 29, No 13.

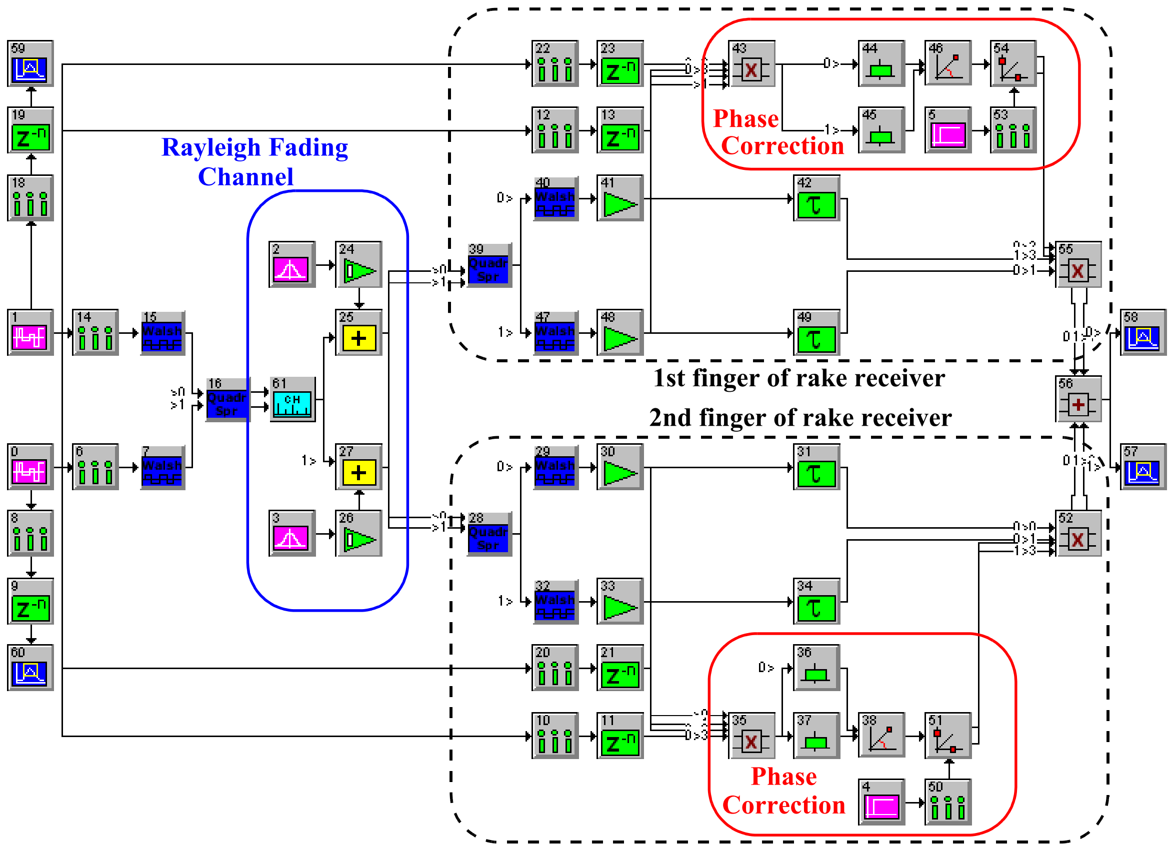


Figure 9: 2-finger Rake receiver block diagram