Base Station Performance Model

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Abstract -- **At present the testing of power amplifiers within base station transmitters is limited to testing at component level as opposed to testing at the system level. While the detection of catastrophic failure is possible, that of performance degradation is not. This paper proposes a base station model with respect to transmitter output power with the aim of introducing system level monitoring of the power amplifier behaviour within the base station. Our model reflects the expected output levels of second or third generation CDMA base stations conforming to the Open Base Station Architecture Initiative (OBSAI) open base station reference architecture. The simulated base station output power is verified by comparison to field data using such metrics as power complementary cumulative distribution function (CCDF), volatility, absolute deviation, mean absolute deviation and rate of change.**

Keywords – **Put your keywords here, if you wish.**

I INTRODUCTION

In recent years many base station manufacturers have begun to integrate other company's components into their base stations. As a result power amplifiers in base station transmitters tend to be tested at the component level by the third party vendor and not at the system level. Hence components supplied by different manufacturers have different test capabilities and even a elaborate alarm capabilities may not be suitable for the test of the full range of operational modes of the system. It is, therefore, possible that certain failure mechanisms and performance degradation may not be detected or false alarms may be reported. A desirable improvement on this state of affairs would be to develop a system level test where the expected output power level would be compared to a predicted output power level, the value of which would vary with the user context. As the first step in providing a context aware base station power alarm a base station model with respect to output power has been developed based on the Open Base Station Architecture Initiative open base station reference architecture for CDMA. Section II gives a brief overview of the OBSAI reference architecture. In section III the difficulties encountered in modelling the base station output power are discussed. The software implementation of the base station model is outlined in section IV. The metrics used to verify the results and the simulated results are presented in section VI. The conclusions are drawn in section V.

II OPEN BASE STATION MODEL

The OBSAI reference architecture consists of four functional blocks and three internal interfaces between the functional blocks as shown in **Figure 1** to describe the base transciever station (BTS). Each block represents a logical separation of the base station transceiver functions and each block consists of one or more modules, which perform a subset of block functions. The open base station reference consists of the following functional blocks:

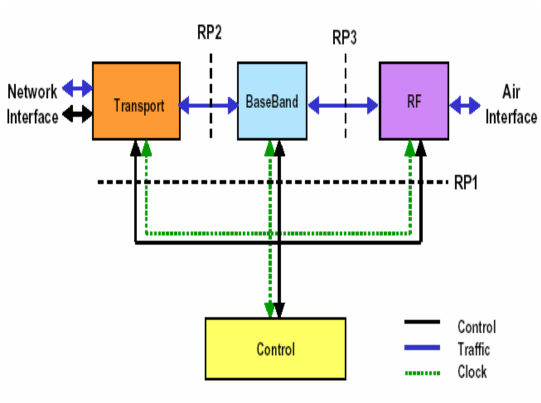

Figure 1: Base Transceiver Station Reference Architecture

a) Transport Block (TB)

The transport block performs the functions of internal and external network interface via RP1 and RP2. It also provides quality of service, synchronization, security and operations, administration, maintenance and provisioning functions [1].

b) Control and Clock Block (CCB)

The clock and control block is the primary control processor of the BTS. It controls BTS resources, supervises BTS activities, monitors and reports BTS status. It provides concurrent operation for 2 or more air interface standards. Its performs congestion control to determine and report on the occurrence of resource overload and corrective action needed. Admission control is also the responsibility of the CCB and either admits or denies new radio links and performs the radio resource management for the BTS radio resources. The CCB provides high-level interface to other BTS modules from various vendors as well as RF scheduling and system clock generation and distribution [1].

c) Baseband Block (BB)

The baseband block consists of one or more modules that perform processing for the air interfaces that include but are not limited to: 800 cellular, 900 GSM, 1800 GSM Europe, 1900 CDMA Korea, 1900 US PCS and 2100 WCDMA. The BB shall provide the capability for concurrent operation of two or more air interfaces. When configured to support CDMA2000 it provides the following functions: scrambling, channel encoding or decoding, interleaving or de-interleaving etc [1].

d) RF Block (RFB)

The RF block shall consist of one or more modules that perform the RF functions of the previously mentioned air interfaces. The RF block provides the capability for the concurrent operation of two or more air interfaces. The following functions are carried out by the RF block: modulation, A/D and D/A conversion, up/down conversion, carrier selection, linear power amplification, antenna interface, transmit/receive filtering, RF combining etc[1].

e) Internal Interfaces

The reference points (RP) are interfaces for the transport of signaling and user data between modules. RP1 is the internal interface between the CCB and the other blocks and includes control data and clock signals. RP2 is the interface for the transport of user data between the TB and the BB. Neither of these interfaces have an effect on the output power levels of the RF module. RP3 provides transport for air interface data between the BB and RFB. Hence, RP3 has a significant effect on the output of the RF block. Several topologies for the interface between the baseband block and the RF block are allowed including mesh as shown in **Figure 2**, centralized combiner and distributor shown in **Figure 3** as well as bridge modules connecting several module of the same type together. Each of these topologies have an effect on the final output power [1, 7].

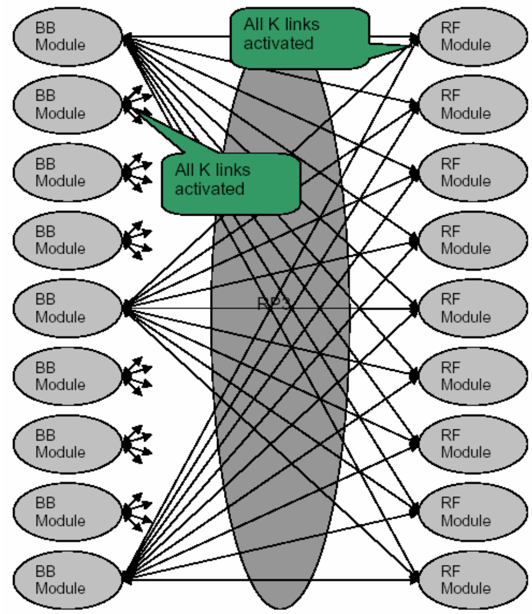

Figure 2: Full Mesh RF Interface

III MODELLING ISSUES

There were many difficulties involved in modeling a base station with respect to power. These difficulties involved the fact that the user load was in no way constant, varying with the number of users, with the mobility of these users, with the type of traffic (either voice or data), with the data rate of signal transmision, with the RF interface topology being used and with the distance of the user from the base station distance from the base station.

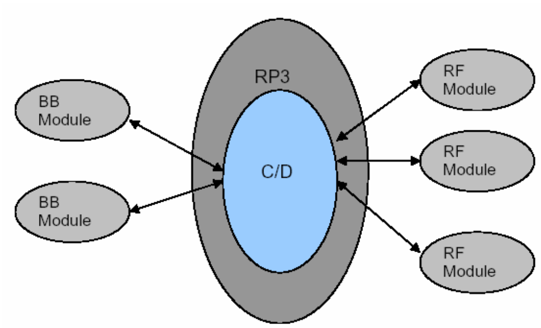

Figure 3: Centralised Combiner and Distributor RF Interface

a) User Statistics

As call statistics were unavailable certain assumptions were made regarding transmitter usage. It is clear however that the average number of users would vary depending on whether it was day or night and what the time was. For example there would be a far greater number of users during business hours than at 2a.m. on a school night but it would be expected that number of users would increase significantly at night during the weekend. It was also assumed that the amount of voice traffic transmitted would be far greater than that of data traffic being transmitted.

b) Markov Chains

Speech is encoded to a variable output data rate based on speech activity by a vocoder. The signal is then transmitted at a power level which is dependent on the data rate and this data rate can change from frame to frame of transmitted data [3]. This data rate and output power variation is modeled using Markov transition matricces. Let P be a k X k with elements

$$\{P_{i,j} : i,j = 1, \ldots\ldots\ldots\ldots k\}$$

A random process (X_0, X_1,...) with finite state space

$$S = \{s_{1,} \ldots\ldots\ldots\ldots\ldots, k\}$$

is said to be a Markov chain with transition matrix P, if for all

$$i,j \in \{1, \ldots\ldots\ldots, k\}$$

and all

$$i_{0,} \ldots, i_{n-1} \in \{1, \ldots, k\}$$

we have

$$P(X_{n+1} = s_j | X_0\, s_{i_0}, \ldots, X_n = s_i)$$

$$P(X_{n+x1} | X_n = s_i)$$

$$P_{i,j}$$

The elements of the matrix P are called transition probabilities. The transition probability $P_{i,j}$ is the conditional probability of being in state s_j next given that the current state is s_i [4].

c)RF Interface

Each RF module shall have a maximum of K pairs of unidirectional links i.e. 2*K links in total. A pair constitutes one incoming and out going signal. Each RF module shall implement K_{RFIN} incoming links and K_{RFOUT} out going links with unused links disabled for power conservation purposes where

$$0 \le K_{RFIN} \le K,\ \ 0 \le K_{RFOUT} \le K$$

Similarly the base band module shall have a maximum of K pairs or unidirectional links with

$$0 \le K_{BBIN} \le K,\ \ 0 \le K_{BBOUT} \le K$$

Assuming N baseband and M RF modules in a base station there exist in total N*M pairs of unidirectional links with differential signalling between baseband and RF modules in full mesh. Each baseband module is connected to M RF modules while every RF module is connected tp N basband modules. Therefore

$$P_{RFIN} = X$$

Assuming N baseband and M RF modules in a base station. All links of both baseband and RF modules are connected to a centralized combiner and distributor that is located in RP3. Inputs that are targeted for the same antenna and carrier at the same instant are added together so that a single output stream is formed. At a maximum K*(N + M) pairs of unidirectional links are connected to the combiner and distributor but any number of links below this maximum may be connected [7].

d) Power Variation With User Distance

When considering the power variation with distance two cases should be taken into consideration: that of the nearby mobile unit and that of the mobile unit at the boundary of the cell. For the mobile close to the BTS the transmitted power at the cell site for the jth mobile unit is P_j, which is proportional to r^n_j.

$$P_j \propto r_j^n \tag{1}$$

where r_j is the distance between the cell site and the jth mobile unit and n is a number. It was found that the power control scheme with n = 2 provides the optimum capacity and also meets the requirements that the forward link signal still reach the mobile near the boundary of the cell with reduced power to reduce interference with adjacent cells.

$$P_j = P_R * \left(\frac{r_j}{R} \right)^2 \quad (2)$$

where P_R is the power required to reach those mobile units at the boundary at the cell boundary. [2]

e) Modelling Speech Input Signal

The speech input signal is modelled as a signal which varies in amplitude for the duration of the call. The variation of the speech signal follows a poisson distribution. The input signal for one user is shown in **Figure 4**.

IV SOFTWARE IMPLMENTATION

The BTS was modelled using MATLAB. Initially the model was designed to reflect a 2G IS-95 based system and was then extended to include 3G CDMA2000. First of all the system parameters such as user type, context, distance of user from BTS, number of users, call duration etc. are initialised. Values for these parameters were selected at random from a certain interval and in the case of certain variables a poisson distribution was assumed. The output power for each call was then calculated depending on whether the user was stationary or non-stationary. These calculations take into consideration distance, data rate, number of power amplifiers in the transmitter, interface topology and the mobility of the user. The combined output power is given by:

$$outputpower = \sum_{i=1}^{n} useroutputpower$$

For mobile users the possibility of handover and the changing distance from the BTS must also be considered must also be considered. The changing distance of the user from the cell site is calculated by:

$$distance_{t+1} = distance_t \pm (speed * \Delta tim$$

For users moving away from the BTS the duration to handover is given by:

$$t_{HANDOVER} = \frac{d_{MAX} - d_{INITIAL}}{s_{USER}}$$

For users moving towards the BTS it is given by:

$$t_{HANDOVER} = \frac{(2 * d_{INITIAL}) + (d_{MAX} - d_{INITI\!A}}{s_{USER}}$$

Where d_{MAX} is the maximum distance from BTS before handover occurs, $d_{INITIAL}$ is the initial distance of the user from the BTS, s_{USER} is speed of user and $t_{HANDOVER}$ the time that will ellapse before handover occurs.System overhead in the form of control channels such as the pilot, paging and synchronization channel should also be simulated. The output power of these channels does not vary much and can be modelled as follows:

$$P_{OVERHEAD} = P_{PILOT} + P_{SYNCH} + P_{PAGE}$$

The transport and clock and control blocks are not considered in this model as they do not affect the output power of the RF module. The overall simulation procedure is shown in the flowchart in **Figure 5** below.

V RESULTS

The metrics chosen to run a comparsion between the simulated data and the field were the complementary cumulative distribution function, volatility, absolute deviation and rate of change.

a) Rate of Change

The rate of change of output power with respect to time is calculated as follows:

$$\Delta P_{out} = \frac{P_2 - P_1}{\Delta t}$$

and is then avereaged over the simulation length.

b) CCDF

The RF output power signal such as that shown in **Figure 6** is difficult to quantify because of its inherent randomness. In order to extract useful information from the noise like signal a statistical description of the power levels is needed. The CCDF curves specify completely and without ambiguity the power characteristics of signals that are mixed, amplified and decoded by communications systems. The CCDF was obtained by obtaining the PDF of the RF envelope and then computing its CDF. The CCDF is the complement of the CDF.[5]

$$CCDF = 1 - \int PDF (RFEnvelope)$$

c) Volatility

Volatility is a measure of the random variations of the RF envelope. Let

$$\ldots {}^{t-2}Q, {}^{t-1}Q, {}^{t}Q, {}^{t+1}Q \ldots$$

be a stochastic process. The volatility of the process at time t-1 is defined as the standard deviation of the time t return.

$$\log return = \ln\left(\frac{{}^{t}Q}{{}^{t-1}Q}\right)$$

Volatiltiy is hence:

$$volatility = std\left(\ln\left(\frac{{}^{t}Q}{{}^{t-1}Q}\right)\right)$$

d) Absolute Deviation

Let u denote the mean of a set of quantities u_i. The absolute deviation is defined by:

$$\square u_i \equiv |u_i - \bar{u}|$$

The mean absolute deviation of a set $\{x_0, x_1, \ldots., x_{n-1}\}$ is:

$$\text{mean}\square u_i = \frac{\sum_{i=0}^{n-1} |u_i - \bar{u}|}{n}$$

A comparison between the simulated and measured data for each of these metric can be seen in **Figures 7 – 10** below.

VI CONCLUSIONS

In this paper a base station model with respect to output power is presented. This model is compared to field data in terms of CCDF, volatility, absolute deviation and rate of change. It has been shown that the model reflects similar CCDF functions as the measured data. The rates of change, absolute deviation and volitility also lie within the same range as that of the field data.

REFERENCES

[1] OBSAI. "Open Base Station Architecture Initiative BTS System Reference Document Version 1.0". *OBSAI*, 2002.

[2] W.C.Y. Lee. "Overview of Cellular CDMA". *IEEE Transactions on Vehicular Technology*, 40:291-302, 1991.

[3]K. Wesolowski. "Mobile Communication Systems". *John Wiley & Sons*, 2002.

[4] O. Häggström. "Finite Markov Chains and Algorithmic Applications". *Cambridge University Press*, 2002.

[5] _. "Characterizing Digitally Modulated Signals with CCDF Curves". *Agilent Application Note*, 2000.

[6]__. "Volatiltiy", "Return", http//www.riskglossary.com

[7] OBSAI. "Reference Point 3 Specification Version 1.0". *OBSAI*, 2004.

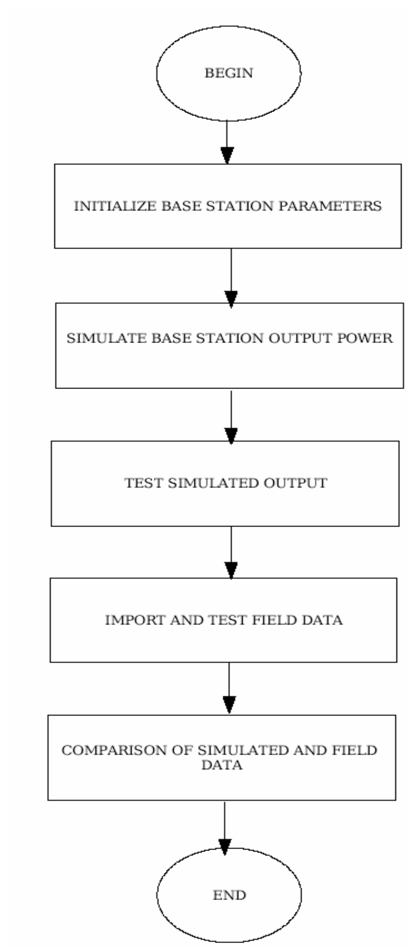

Figure 5: Model flowchart

Figure 6: Speech Signal

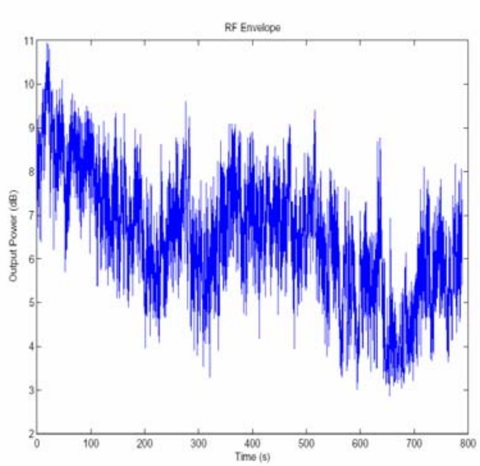

Figure 6: RF Envelope

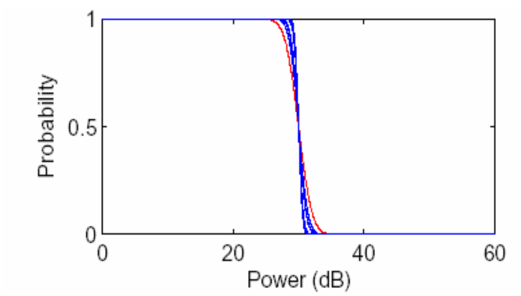

Figure 7: CCDF Curves

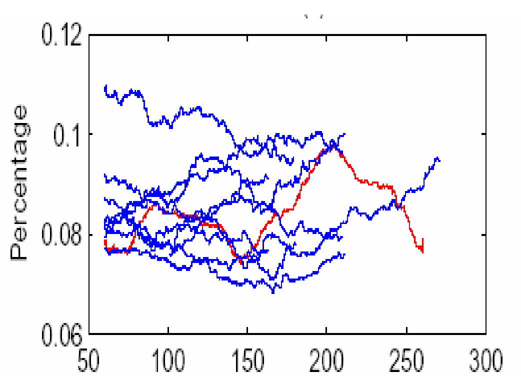

Figure 8: Volatility Curves

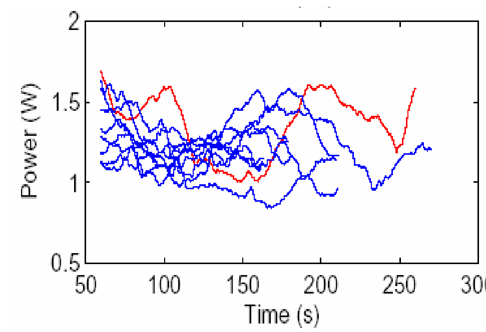

Figure 9: Absolute Deviation Curves

Figure 10: Rate of Change Curves