Automatic Loss Adjustment for CDMA2000 and 1xEV-DO Standard for Downlink and Uplink

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Abstract. *The functional and thermal testing of the mobile phone is always performed under various conditions that vary in terms of the connection between the DUT (Device Under Test) and the measuring instrument. To achieve repeatable measurements under such conditions, it is necessary to adjust uplink and downlink loss using the instrument's external attenuation. While for GSM, WCDMA and LTE this is a relatively easy task, CDMA2000 and 1×EV-DO make automation of the adjustment process somewhat challenging due to the nature of the CDMA standard. An especially forward link is more complicated as those tests are run in signaling mode and not all instruments provide an FER value measured by an MS. This paper describes the algorithm for forward link loss adjustment and its implementation using Rohde-Schwarz CMW500.*

Keywords

DUT, GSM, LTE, QoS, WCDMA.

1. Introduction

In CDMA2000 networks, control of the Mobile Station (MS) transmit power is essential to ensure stable transmission and an efficient radio resource management within the system. Generally speaking, the output power of the MS transmitter that is too low decreases the coverage area while an excess output power may cause interference to other channels or systems. Both effects decrease the system capacity [1], [2], [3].

CDMA2000 standard defines three methods for controlling the power of the MS, but when some power measurements need to be performed it is necessary to properly deal with the automatic power control to achieve repeatable and reliable measurement results under various conditions. This issue is described in the chapter entitled "CDMA2000 and Its Evolution" in [4].

During the initial connection setup, the open loop power control is active. It is crucial to estimate the output power from the measuring instrument so that a connection will be established. If the output power is too high, the DUT will lower its transmit signal because from a strong BS (Base Station) signal it assumes that the DUT is very close to the BS and thus it does not need to transmit with high power [5].

Thanks to the built-in functionality of some measuring instruments (Rohde & Schwarz CMW in this case, CMW is a wideband radio communication tester) it is possible to implement the automatic adjustment of the forward link signal with the help of FER (Frame Error Rate) measurement in signaling mode, which is sufficient for R&D tests. However, because the FER measurement is not particularly fast, the method depicted here is not suitable for EOL (End of Line) or production testing.

2. State of the Art

Three main methods of power control will be described in the following subchapters in order to give an overview of their built-in automatism. A description of the discovered solution will be presented via a concrete example based on the Rohde & Schwarz CMW500 instrument with the help of an attribute based instrument driver for the remote control of the instrument from LabVIEW [6], [7].

2.1. Open Loop Power Control

In an open loop, the reverse link transmission power is set based upon the received power on the forward link. The transmitter attempts to minimize the transmit power using the average received signal strength as an indication of path loss. This mechanism inverses the slow fading effect (path loss, shadowing) and acts as a safety fuse when the fast power control fails [8].

When the forward link is lost, the closed loop reverse link power control freewheels and the terminal disruptively interferes with neighboring cells. In such case, the open loop reduces the terminal output power as it gets closer to any cell and therefore limits the impact to the system.

When a mobile first attempts to access the CDMA network, it uses Open Loop Power Control to assure that it achieves a good trade-off between the interference caused to the system and the access time. The interference caused to other users is inversely proportional to the mobile transmit power while the probability of network access for a given attempt is directly proportional to the transmit power.

In Open Loop Power Control, the mobile measures the pilot strength which is related to path loss. The transmit power is then set inversely to the measured pilot strength. If the pilot is weak, which means that there's a large path loss, the mobile station transmits on high power and vice versa.

2.2. Fast Closed Loop Power Control

Unlike CDMA, where Fast Closed Loop Power Control was applied only to the reverse link, both CDMA2000 channels can be power controlled at up to 800 Hz in both reverse and forward directions. The main goal of fast closed loop power control is to dynamically adjust the allocated power for each user in a manner that meets the required quality of service (e.g. FER) of these users, and as a consequence maximizes system capacity.

Unlike open loop or slow closed loop power control, fast closed loop power control is sufficient for keeping track of multipath induced fading. The receiver measures the received signal's strength every 1.25 ms (800 Hz) and sends a power control command to the transmitter by means of power control bits. Power Control Bits (PCB) are used to request an increase or reduction in transmit power. A series of these power control bits is sent on the traffic channel instead of the scrambled data bits. The transmitter receives the PCB commands and adjusts its transmit power by a predetermined step size (e.g. 1 dB). One to four data bits (depending on the data rate) are replaced by the corresponding number of PCBs ("0...0" or "1...1").

The finer steps allow tighter power control for the low mobility or stationary phones. Tighter control (less power ripple) lowers the average power and thus raises the capacity of the system. If the statistical multiplexing of the forward link channels is sufficient, the gain in the link margin translates directly into an equivalent system capacity gain.

However, if statistical averaging is not sufficient - for example when the base station only transmits to one user with a very high data rate, the high dynamic range of the forward link signal may result in power amplifier inefficiencies and system instabilities due to the coupling with neighboring cells. In order to avoid any instability, the network may then limit the power dynamic range of the high rate channels by means of EIB (Erasure Indicator Bit) or QIB (Quality Indicator Bit) as described in patent [9].

2.3. Outer Loop Power Control

This loop is slow compared to other power control loops (typically 50 Hz). Outer Loop Power Control is driven by QoS requirements and drives the closed loop power control to the desired set point based on the error statistics it collects from the supervised link (forward or reverse). Due to the expanded data rate range and various QoS requirements, different users will have different outer loop thresholds, i.e. different users will be received with different power at the base station. One difficulty associated with such a broad rate range appears in variable configurations when switching between rates. The required signal to the interference ratio value is not necessarily proportional to the data rate ratio, and changing rates may imply changing the QoS if the channel gain is not adapted accordingly. In the forward link, this issue is left for the manufacturer to solve. The remaining differences (depending on the radio environment) will be corrected by the outer loop itself. To deal with other differences the base station requires feedback about the QoS from the mobile station for a more accurate power control. The fastest feedback information is a frame error indication, which is transmitted once per frame. If the complete FER measurement is taken, outer loop power control is even slower.

Some measuring instruments, especially mobile station radio communication testers, do not implement forward link power control, yet such instruments are used for testing mobile stations. Power control can be simulated on the controlling PC using RX measurements to ensure repeatable measurements and to behave in a similar way as with outer loop power control. It is required by laboratories performing special measurements which are not conformant to the standard, such as temperature tests.

3. Frame and Bit Error Rate

The Bit Error Rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission, and its determination is quite simple. The radio communication tester sends a data stream to the mobile, which then sends it back to the tester (loop). The tester compares the sent and received data streams to determine the number of bit errors.

The Frame Error Rate (FER) measures the percentage of frame errors over the total number of frames received. The instrument Rhode&Schwarz CMW monitors the Fundamental Channel (FCH) and Supplemental Channel 0 (SCH0). The frame error rate is a variant of the bit error rate [10].

FER measurement has to be carried out over an active connection in the signaling mode. The CMW generates data that are transmitted to the DUT and back from the DUT to the measuring instrument. For this, a special service option with loopback functionality has to be selected during connection setup. As data, it is possible to use internally generated data, which are represented as a pseudo-random bit sequence, or real data using the instrument's special hardware option called DAU (Data Application Unit). As is usual when remote operation of measuring instruments, FER measurement was taken in single shot measurement mode.

4. Method

The selected method automatically sets the instrument's external attenuation in order to keep the signal power on the value set as a reference for the concrete type of DUT. Using the FER measurement during the established connection while lowering output power by means of external attenuation, the instrument can find a breaking point at which the connection drops, or the confidence level of the BER drops below 95 percent. By subtracting the last working output power value from the reference level an algorithm establishes the external attenuation (EA) value to provide the same output power level for various DUTs of the same type and various connections (conducted or wireless).

It is important to define the reference either by calculating the theoretical optimal value (as the middle of the interval of allowed power values for cellular connection type) or by conducting an experiment if the reference connection is less than perfect. In using experiment, it is important to have the best connection available to ensure minimum loss (the conducted test with proper cabling should be sufficient).

We have found that with a proper connection the theoretically established reference is the same as the reference made by experiment. The CDMA power offset of the access probe for the cellular connection is -73 dBm and the allowed range of corrections is ± 32 dBm. If the CDMA output power was set on the instrument to a value -70 dBm and the external attenuation was left at 0 dB, the DUT showed a 50 percent signal strength and the established connection was stable over the whole testing period of circa 3 hours.

Initial power cannot be set to the maximum level just to avoid establishing a reference, because the initial connection is always done using open loop power control. Thus, if the DUT receives maximum power, it assumes that it is located a minimum distance from the base station according to the values in the preamble. Then it significantly lowers reverse link output power, and a connection cannot be established. Therefore, a reasonable initial reference power is important.

Algorithm 1 Individual steps of the algorithm.

```
FIND a reference using either calculation or experiment with the conducted test
CONNECT the DUT
CONFIGURE startup parameters. SET EA
ESTABLISH call
MEASURE BER
while confidence_level>0.95 BER do
    EA=EA−0.1
end while
SUBTRACT the last correct value from the reference and use the resulting value as the external attenuation value
```

To find the proper value of external attenuation, the following algorithm including 7 steps can be used. The individual steps are depicted in Alg. 1.

Tab. 1: CMW signal configuration.

Parameter	Value
CDMA Power	-70 dBm
Channel	200
Band Class	BC0:US Cellular
Service Option	SO2 (Loopback)
Radio configuration	1.I
Expected Power Mode	Open Loop
Number of measured frames	600
Sweep mode	Single
Confidence level	95 %
Power control bits	All Up

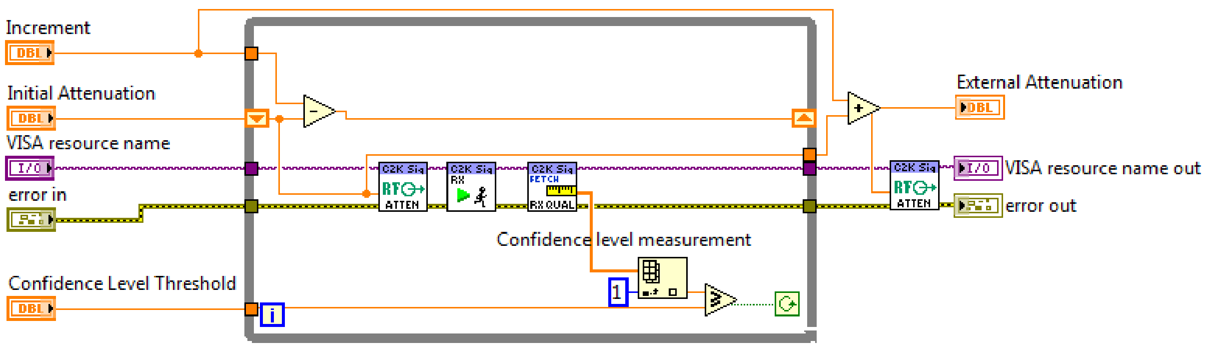

Fig. 1: Individual steps of the algorithm.

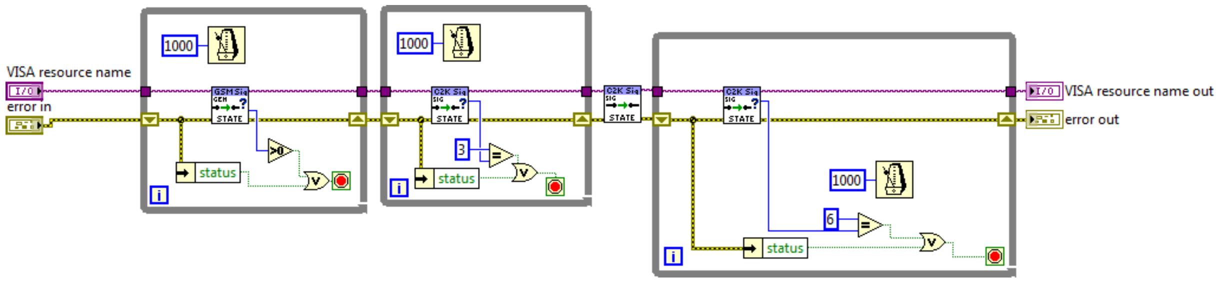

Fig. 2: Individual steps of the algorithm.

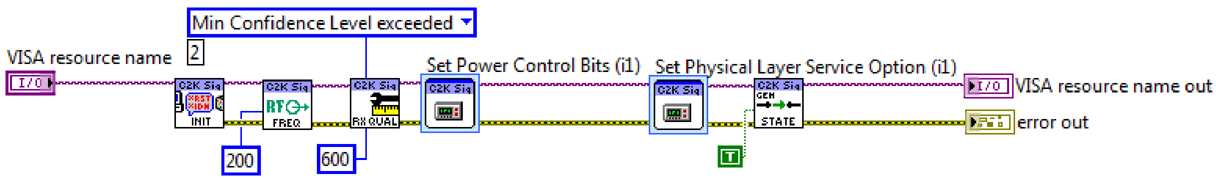

Fig. 3: Individual steps of the algorithm.

5. Implementation

To prove the above-described algorithm, the radio communication tester CMW500 from Rohde & Schwarz and HTC EVO 4G was used as the DUT. The algorithm was implemented in LabVIEW using the downloaded attribute instrument driver.

The implementation of the experiment consists of three parts. First it is necessary to setup the instrument with the values listed in Tab. 1. The implementation of SubVI for instrument setup is in Fig. 1.

Establishing a call with previously set parameters is done in four steps, see Fig. 2. First it is necessary to turn on the signal generator and wait until it is settled.

The second step is simple while loop is waiting for the DUT to register in the network simulated by the instrument. Then it is possible to establish a call by sending the proper command to the instrument and performing a manual answer of the incoming call on the DUT. Waiting for the call establish is realized by the last while loop. The implementation of SubVI for establishing a call is shown in Fig. 2.

Measurement itself is a simple loop used to find the breaking point, which means the attenuation causing the connection drop or the confidence level falling under the threshold. The breaking point value can be added to the reference value, which is described in previous the chapter, to calculate the external attenuation needed to have a repeatable measurement. The implementation of measuring SubVI is shown in Fig. 3.

6. Results

The setup described above was able to reliably detect the lowest power, below which the confidence level dropped under the acceptable 95 % threshold or the connection dropped completely. The value that was found, when used as external attenuation value, was suitable for compensation of the imperfections in the testing environment. When using standard production testing cables, the compensation was very small, with just 3.15 dB amplification of the signal. When a laboratory shielded chamber was used, the compensation was higher with a value of 11.5 dB. In both cases, the connection was stable for the duration of the testing period of 3 hours each.

7. Conclusion

CDMA2000 includes three methods for controlling the power of the MS, which are described in [4]. It brings serious problem in CDMA2000 during thermal testing when conditions change, and it is necessary to adjust uplink and downlink loss in order to achieve repeatable and reliable measurement results.

The contribution of this paper is a new approach for CDMA2000 which automatically sets the instrument's external attenuation under thermal testing in order to keep the signal power on the value set as reference for the concrete type of DUT. Speed of this is suitable for the purpose it was intended for and it is much better than manual periodic adjustment which presents current practice.

The solution, implemented using the standard commands in the .NET environment, is used for temperature testing in Nokia together with the Rohde & Schwarz CMW500 instrument. From the overall network perspective, it does not make much sense to compensate for downlink. The base station as part of the whole cellular network is set up to work with maximum efficiency of spectrum in mind and its cellular network operator task to do the setup. However, when testing new equipment, such as smartphones, it might be useful to have the comparison either between various types of DUT and also between different production batches of the same DUT type. The described method provides easy software-based compensation for the missing feature of the measuring instrument.

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