RF POWER CONSUMPTION EMULATION OPTIMIZED WITH INTERVAL VALUED HOMOTOPIES

ABSTRACT

This work presents the approaches and methods towards the power consumption emulation of the analog part of the transceiver chain (RF device). Status quo emulation methodologies are only compatible with digital designs as the emulated power is extracted from the RTL designs

MOTIVATION

The rapidly growing wireless telecommunication technology demands high data rates at low costs and low power consumption. Sophisticated modulation and access schemes such as the *Orthogonal Frequency Division Multiplex (OFDM)* in *Long Term Evolution (LTE)* have been introduced to meet the high data rates demand, but the low cost and power consumption criteria are much influenced by the *Base Band (BB)* and *RF (Radio Frequency)* devices.

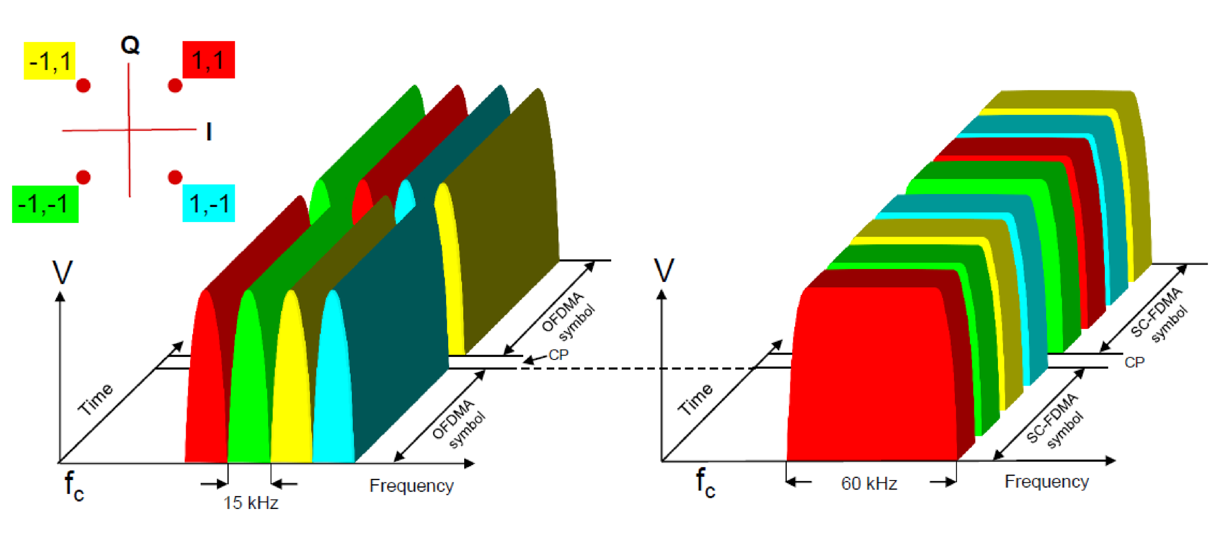
The focal point of this work is the definition of a power emulation model to be used for the analysis of the dissipated electrical power (with the intent of optimization) of the RF devices before the production of the handsets.

LTE TECHNOLOGY

- Fundamentals
  - Orthogonal Frequency Division Multiple Access (OFDMA)
  - The single carrier- Frequency Multiple Access (SC-FDMA)
  - The Multiple Input Multiple Output

OFDMA VS SC-FDMA
QPSK EXAMPLE USING M=4 SUBCARRIERS

The fundamental technologies, OFDMA for downlink and SC-FDMA for uplink, of the LTE and their main differences are illustrated below. The OFDMA is a multi-carrier technology utilizing orthogonal subcarriers separated by 15KHz whereas SC-FDMA is a single carrier spectrum inefficient technology. Though the OFDMA technology is the most spectrum efficient, it is only used in the downlink direction due to its high PAPR demand (12dB) compared to the 3 dB PAPR of the signals generated using the SC-FDMA methodology.

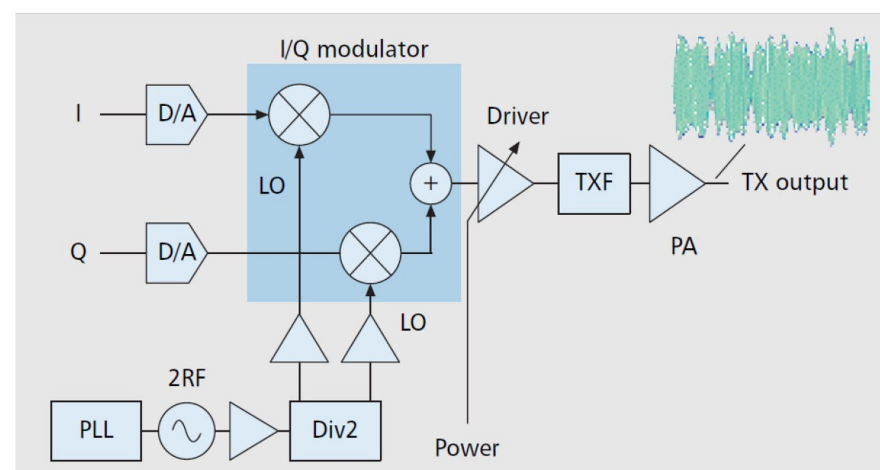


OFDMA
Data symbols occupy 15 kHz for one OFDMA symbol period

SC-FDMA
Data symbols occupy M*15 kHz for 1/M SC-FDMA symbol periods

THE RF DIRECT UP-CONVERSION ARCHITECTURE

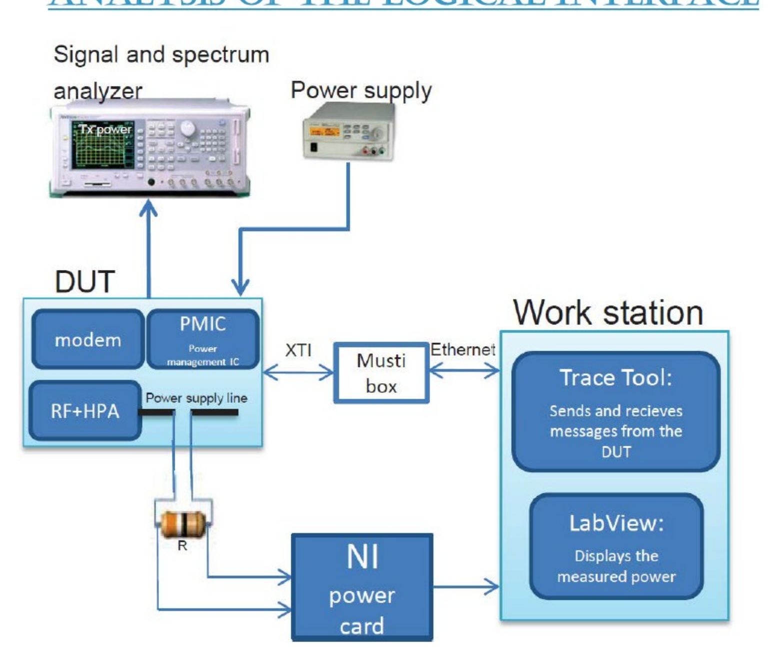
The power consumption of the RF device of the architecture below is emulated in this work



POWER INFLUENCING PARAMETERS

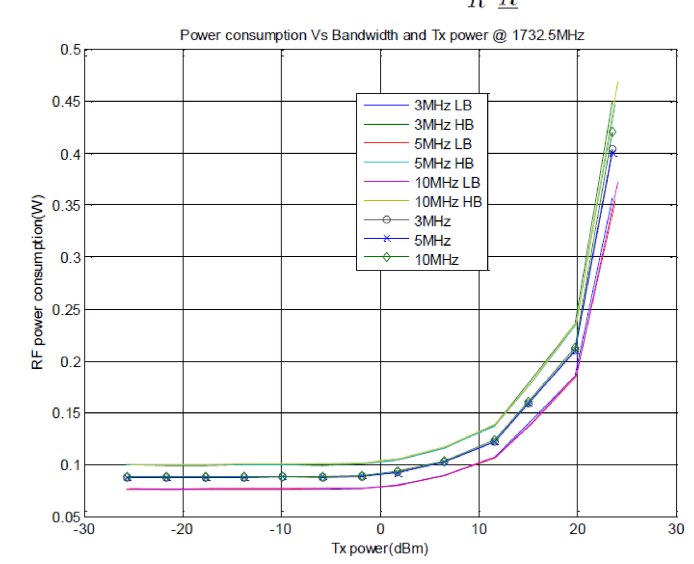
- RF-BaseBand logical interface parameters
  - Uplink bandwidth
    - 1.4 3 5 10 15 20 MHz
  - Carrier frequencies (Asia and Europe)
    - Band1: 1920 – 1980MHz
    - Band3: 1710 – 1785MHz
    - Band7: 2500 – 2570MHz
    - Band8: 880 – 915MHz
  - TX signal power
    - -40 – 23 dBm
- Baseband hal parameters
  - Modulation
    - QPSK, 16QAM and 64 QAM
- Physical environmental parameters
  - Temperature
  - Humidity

ANALYSIS OF THE LOGICAL INTERFACE



RESULTS OF THE LOGICAL INTERFACE ANALYSIS

$$[\underline{P}\ \overline{P}] = [\underline{V}\ \overline{V}] \times ([\underline{Vd}\ \overline{Vd}] \times [\frac{1}{\underline{R}}\ \frac{1}{\overline{R}}]$$



The power consumption of the wireless device, with the RF device of interest, was analyzed using the setup in the previous column.

It is only the RF— BaseBand logical interface parameters that are analyzed in this work. In this work, it is assumed that the measurements are conducted in a constant room temperature with constant humidity.

The work with continuous temperatures and humidity is pending. And it is planned to model the power consumption as a function of these continuous variables as convex homotopies.

By utilizing interval analysis, the precisions in the measurement tools (power supply, resistor and NI power card) are implicated in the computation of the power consumption. The power consumption is thus provided in terms of low and high bounds as a function of the measurement tools uncertainties.

Here the power consumption of the RF device while operating at 3, 5 and 10 MHz is plotted.

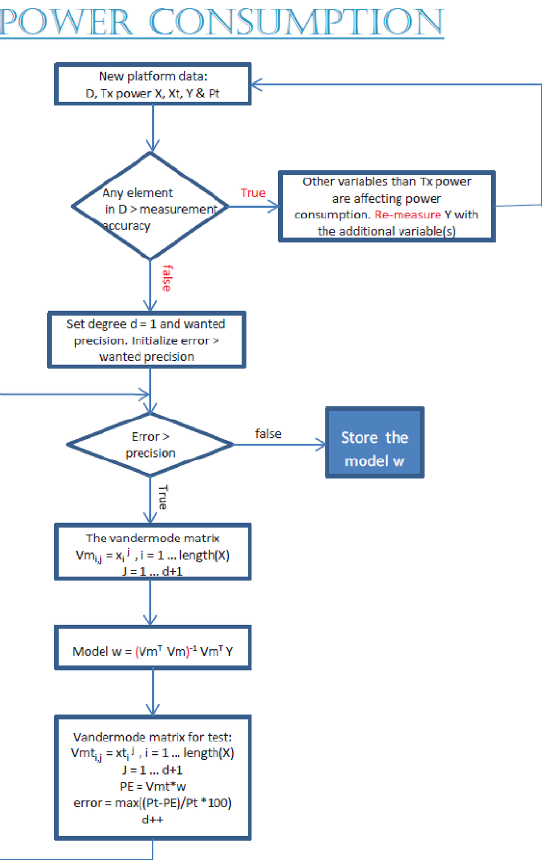
MODELING OF THE RF POWER CONSUMPTION

New platform data:

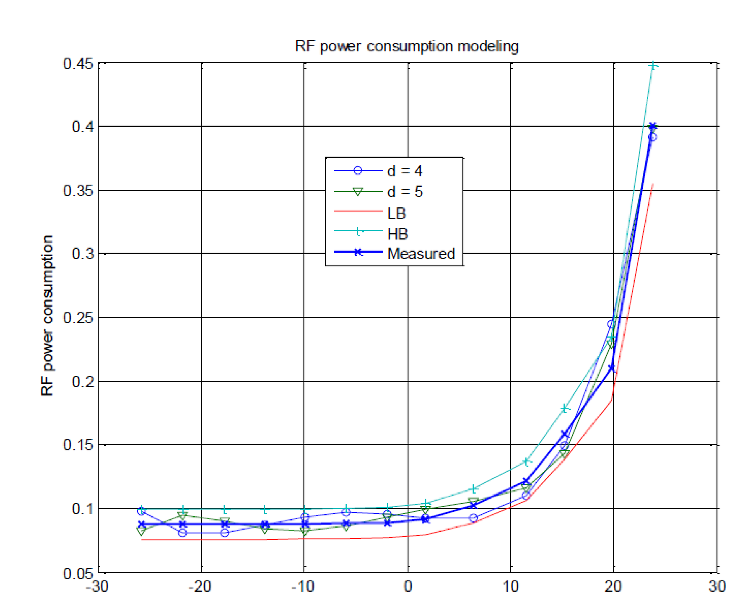
- $P_1 = P(BW = 1.4MHz, f = 2570MHz, TxP = 23dBm, 64QAM)$,
- $P_2 = P(BW = 20MHz, f = 2570MHz, TxP = 23dBm, 64QAM)$,
- $P_3 = P(BW = 20MHz, f = 704MHz, TxP = 23dBm, 64QAM)$,
- $P_4 = P_2$,
- $P_5 = P(BW = 20MHz, f = 2570MHz, TxP = 23dBm, QPSK)$,
- $P_6 = P_4$.

Vector $D = [P_2 - P1, P_4 - P3, P_6 - P_5]$
Tx power $X = [-10, -5, 0, 3, 8, 11, 16, 20, 23]dBm$
$Y = P(x_i, 20MHz, 2570MHz, 64QAM)$

Test inputs:
$V = [\mathcal{N}(0,1), \mathcal{N}(0,1), ..., \mathcal{N}(0,1)]$ A vector of length(X) whose elements are computed from a normal distribution with mean 0 and variance 1.
$Xt = X + V$
$Pt = P(x_{ti}, 20MHz, 2570MHz, 64QAM)$
Pt should be independently measured from Y.



THE LEARNING OF THE MODEL

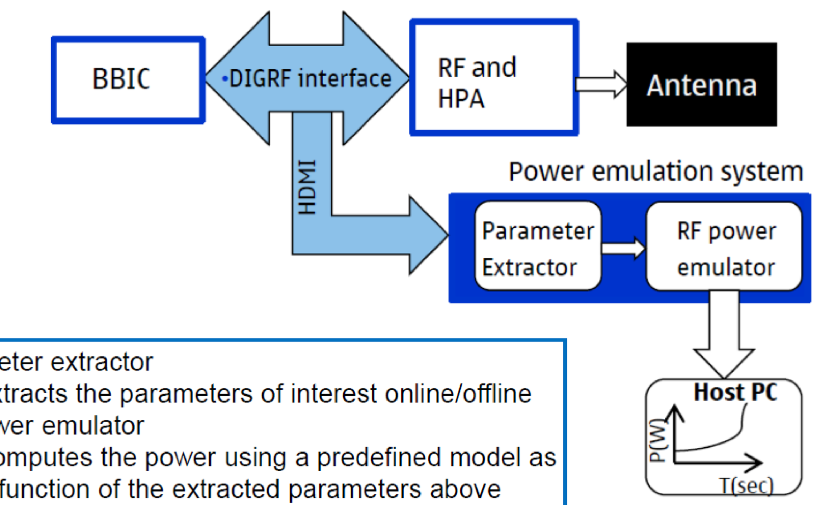


The state diagram takes the data from a new wireless platform to produce a model to be used by the power emulator for the computation of the emulated power.

In the state diagram, the degree of the vandermonde matrix is iteratively incremented until the test error is less than the measurement uncertainties.

In the graph on the left, it can be observed that the emulated power from a vandermonde matrix of degree 5 has a test error less than the measurement uncertainties .

RF power emulation system



- Parameter extractor
  - Extracts the parameters of interest online/offline
- RF power emulator
  - Computes the power using a predefined model as a function of the extracted parameters above

CONCLUSION AND FURTHER WORK

This work has developed an approach for the emulation of the power consumption of the RF device. We have analyzed the parameters influencing the power consumption from the theoretical and physical perspectives. The physical perspective has been supported by the physical power measurements and these measurements form the basis of the RF power emulation system.

The emulation of the RF power consumption is conducted as a function of the logical interface parameters extracted by the parameter extractor and the pre-defined model (see the state diagram).

Thus during runtime of a wireless device, logical interface parameters are extracted and forwarded to the RF power emulator which computes the emulated power and displays it on the host PC.

The feasibility of emulating the power consumption of the RF device from the early phase of the design (1st or 2rd build of the proto type), enables us to have an accurate estimate of the power consumption of the wireless devices while performing high level scenarios (as Voice over IP, video transfer, etc.) . In this way, hot spots can be identified at this stage where approaches towards their minimization can be taken. Moreover, as the methodologies for emulating the power consumption of the digital part of the transceiver have proven to be viable, we can have a full picture of the power consumption of the whole transceiver chain at the early stages of the design.

The corresponding challenge is to define an emulation model for the radiant energy emitted out of the antenna. And in this case, the logical interface and physical environmental variables are to be analyzed towards their influence on the radiant energy.

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