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Agenda item 7.5 and 7.6

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Title: Guidelines for TX Tests

Document for: Decision

Guidelines for TX Tests

Introduction:

TX-testing in the 2nd generation mobile radio was partly unprincipled. Different measurement principles, even within one standard, occured by chance. Giving top level guidelines for TX-tests should avoid to repeat 2nd generation disorder for 3rd generation. Starting from simple statements this paper rises some points to be decided principally. Some recommendation for decision are given already.

Initial Statements and Content

0.1) In-Channel Testing is conducted by comparing the TX-Signal from the DUT with the reference signal, constructed according to the specifications.

0.2) Adjacent Channel Testing is a selective power-measurement. The filter for channel-selection is derived from the system's requirements (not from existing test-equipment)

0.3) Measurements Outside the System's Band are designed such that standard test-equipment can be used.

1 In Channel Test
1.1 Test Strategy
1.2 Parameter Variation
1.3 Two Methods to achieve best fit
1.3.1 Orthogonal and non Orthogonal Codes
1.4 Measurement result representation
1.4.1 Normalised and not Normalised CDP
1.5 TX-Testing at the Air Interface or as Receiver Perception
2 Adjacent Channel Testing
3 Out of Band Testing
4 Standard Test Signal
5 Operating the Test
6 Freedom of implementation in the test-equipment

1) In-Channel Test

1.1Test Strategy:

a: The DUT-signal is recorded
b: The reference signal is constructed according to the specifications
c: For comparison the reference signal is varied according to a certain set of parameters in order to achieve "best fit" with the DUT-signal.

The underlined terms are discussed in the following:

1.2 Parameter variation

The following parameters are under discussion for variation to achieve best fit with the measured signal:
Note, all parameters can be traced back to an analogue functionality

Name of the modification (a)	**Definition**	**Expected result**
Initial Phase	Rotation in the I/Q diagram	No result. It is a prerequisite for Best Fit
Time alignment (b)	Shift on the time axis	Timing error
Chiptiming (c)	Compression/decompression on the time axis	Chip-Rate-error
Global amplitude (d)	Homogenous compression/decompression of the I/Q plane	Global power error. (needs no discussion about the type of power measurement like PEP, thermal, decision points.... but shifts this discussion into the core specs: Definition of the reference power)
Code-individual I/Q amplitude (d)		Code power error Definition of reference code power in the core specs required.
Frequency	Torsion of the IQ cylinders	Frequency error
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IQ offset (e)	Offset of the I/ Q center	I/Q Offset
IQ imbalance (e)	Excentricity by compression along a (sloping) axis and decompression along the corresponding orthogonal axis	I/Q Imbalance
A lot of additional parameters for tuning are possible (f): non-linearities, errors with memory....		

a) In case of a code multiplexed signals the parameters can be tuned independently for each code channel. It depends on the implementation of the DUT whether this most general case is really meaningful. However, if the code multiplexing is done in the digital domain, the mentioned parameters (analogue origin) are commonly detuned. (Exception I/Q amplitude). Apparently, the latter alternative is "a must" from the practical point of view.

b) distinguish:

- b.a) independent TX Test
- b.b) Transmitter, deriving its timing from the receiver
  - b.a) No result. It is a prerequisite for best fit
  - b.b) Timing error of the transmitter

c) This measurement is only meaningful, if the reference frequency for the synthesisers and for the data clock are independent. Even if independent, it can be expected, due to precise crystal references, that the error is small. Dependent on the chip timing are: Symbol rate, bit rate, slot rate, frame rate and higher timings. It is not necessary to measure them individually.

d) Global amplitude and code individual I/Q amplitude are not independent, of course.

Code power is a exceptional parameter among the other parameters. The reference code power is not constant during the measurement period, it is piecewise constant (4 pieces within a timeslot). Each piece is an independent parameter for variation.

e) Using those parameters within the best fit process give hints on some typical design errors. Nevertheless those hints are doubtful. (E.g.: 2nd order nonlinearity causes offset.) Only if <u>all deterministic error sources, including (f)</u> are varied in this process, the results are unambiguous. I propose not to vary those parameters within the best fit process.

f) Should not be included into the measurement principle

Recommendation:

Time alignment: Matter of in-channel-testing

Chip timing: avoidable: The core specifications should state: RF and chiptiming are derived from the same reference.

Physical power and/or code power: Matter of in-channel-testing. Physical power and Code-Power versus time shall be considered.

Frequency: Matter of in-channel-testing

IQ offset, IQ imbalance, non-linearities, errors with memory, ...: Do not extract! Those contributions remain part of the error-vector or code-domain-power-offset.

Common parameter-variation for all code channels, except they are separated on I and Q

1.3) Two methods to achieve best fit

There are two methods to compare and achieve best fit:
a) Maximise the correlation value (traditionally used for CDP and RHO)
b) Minimise the mean square difference value (traditionally used for EVM)

Correlation: The reference signal is the signal of 1 code. We need N correlations to cover the N-dimensional code space for a complete test.

Difference Value: The reference signal is an entire signal.

The correlation method contains some difficulties which the difference value method seems not to contain. They are discussed in the following paragraph.

1.3.1) Orthogonal and non orthogonal Codes

Signals built from orthogonal codes are independent in any case. Among the non orthogonal codes you can distinguish:

- Orthogonal constructed codes, which become non-orthogonal due to impairments.
- Non-orthogonal constructed codes. (e.g. SCH and TCH)

Using non-orthogonal codes, fractions of the wanted signal get lost and appear in the adjacent codes.

- If the non-orthogonal codes are well scrambled, and
- if the data content is of maximum entropy and
- if the period of observation is long enough,

the crosstalking signals in the adjacent codes are of the white-noise-type. This mechanism is reciprocal.

1.3.1.1)A CDMA signal with non-orthogonal codes, one being of small power, the others of large power crosstalks this way:
The large codes crosstalk an (absolutely) large amount of power into the small code. Vice versa the small code crosstalks an (absolutely) small amount of power into the large codes.
→Error, correlating for the low power code

1.3.1.2) Even the nature of non-orthogonality must be discussed:
Let us assume an N dimensional code-space with N orthogonal codes in it plus one non-orthogonal code (No. N+1) in the same code space (SCH in between TCHs).
In this case N codes together crosstalk an (absolutely) large power into the No. N+1 code.
Vice versa the No. N+1code crosstalks a (relatively) small power into each of the N codes.
→ Error, correlating for the nonorthogonal code

Recommendation
Minimise the mean square difference value

Note1: Any algorithm, which gives results which are, within the measurement accuracy, equivalent to the above mentioned method, is allowed. Practical implementations will seek to replace one N-dimensional optimisation problem by N one-dimensional problems.

Note 2: a possible way to do so, is excluding the portion of time, where the non-orthogonal Synch Channel is present. However if the non-orthogonal Synch Channel is the item under test, maintaining the presence of the other codes, the mean square minimisation process seems unavoidable.

1.4 Measurement result representation: EVM and/or CDP

With the above mentioned test strategy (1.1) and after the best fit process (1.3) it is possible to calculate any of the following measurement representations. This is independent from the previous best fit process.

- Physical Error Vector versus Time
- Code Selective Error Vector versus Time
- Code Power Offsets
- RMS of EVM of entire signal
- RMS of code-selective EMV

a) Both methods return the same results connected with the parameter variation (above)
b) Correlation returns directly CDP
c) Mean Square Difference Value returns the CDP-offset from the reference value as a result from the parameter variation process.

Insofar both are equivalent.

Concerning the residual result they are not equivalent:

a) Each correlation process returns a code domain power. With the knowledge of the correct code power it is possible to derive the code power offset (time averaged deviation from the reference value).

b) During the Best Fit process EMV returns all code power offsets. (The correct code power is an input into the process)
From Error Vector versus Time, RMS value of EMV can be derived. That represents the standard deviation from the current Code Power.

For decision (and/or)	Entire sginal	Code selective signal
Error Function of time	Physical Error Vector versus Time	Code selective Error Vector versus Time
Mean offset value	(all) code power offset coefficients	(one) code power offset coefficient
Standard deviation	RMS of EVM of entire signal	RMS of code-selective EMV

1.4.2) Normalized and not normalized CDP

Code domain power is traditionally normalised. (IS95). The denominator, responsible for normalisation, contain the entire power. The recorded DUT-signal is processed in the DUT by a power control process and the numerous code channels can have their

slot boarders at different instances (BS). The power control has its effect at these slot boarders.
As a consequence the normalized CDP versus time can vary during a slot, whereas the not normalized CDP does not.

Recommendation
apply absolute CDP.

1.5 TX-Testing at the Air Interface or as Receiver Perception

Refer to 2) Adjacent channel, where this item can be discussed more easily.

Recommendation
It is recommended to run In-Channel TX-Test through an ideal matched filter
(TX Test, describing the perception of an ideal receiver, belonging to the system)

Don't apply In-Channel Test without bandlimiting filter (e.g. BW >5MHz)
(TX testing, describing the properties at the air interface.)

Reasons for this recommendation: Much easier measurement algorithms
Code selective measurements are not possible otherwise
Consistency with ACP

2) Adjacent Channel Power Testing

ACP is a band-limited power measurement
The nominal adjacent channel is measured
Thermal power is measured

Bandwidth and type of the measurement filter is discussed in the following.

	Select adjacent channel with one filter	Cover adjacent channel serial in time with a narrow band filter
rectangular	Static ACP at the air interface. (nominal adjacent channel) Dynamic measurement is not possible.	meaningless
Ideal receiver filter (matched filter) (Root cosine rolloff 0.22)	Static and dynamic measurement possible. The perception of an ideal receiver belonging to the system is measured .	meaningless
Gaussian (SA)	Used in GSM, but not according to the high level guideline.	Used in PDC, but not according to the high level guideline.

Recommendation

Measure Adjacent Channel Power through a receiver filter!
(TX test as perception of an ideal receiver belonging to the system.)

3) Out Band Testing

Not discussed here

4) Standard Test Signal

Do we need a Standard Test Signal?

For digital TX testing it is principally not necessary (in contrast to analogue TX-testing), but it can be advantageous to have one ore more of such signals in order to control parameters for testing which are difficult to control in operational mode:

+ in order to avoid trivial tests
  (e.g. trivial data content)
+ for worst case testing
  (e.g. power steps within measurement time)
+ for repeatability
- not to ease measurement technology (e.g. avoid power steps during measurement period)

Recommendation

Standard Test Signals are meaningful in order to control parameters for testing which are not controllable in operation mode, but not to create a special (easy) test situation.
It should be a signal which is, nevertheless, typical for an operational case.

5)Operating the test:

Some papers mix up the core measurement strategy with operational problems related to the test.
The following list (not complete) contains headword which are related to the user interface and test-operation and not to the core test strategy:

The following parameters can be estimated by the test equipment (dangerous, if the test signal is corrupted too much)
or can be input parameters by the operator:

Data content is gained by
(error-free) demodulation of the recorded signal or by
input from the operator

Reference code powers are gained by
Power-discrimination of the recorded signal or by
input from the operator

Carrier frequency is normally an input parameter from the operator, but not necessarily

Used spreading codes / unused spreading codes

Orthogonal variable spreading factor

Scrambling code

Scrambling code phase

6) Freedom of implementation in the test-equipment

The test-strategies above shall be understood as methodology and not as algorithms. During further specification work measurement uncertainties must be defined. Different computationally implementations are allowed, if the results are within the measurement accuracy , taking into account the above mentioned strategy together with realistic worst-case transmitter impairments.