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UMTS FDD power measurements:

Improved power estimator and measurement equipment validation

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Management summary

The Swiss decree on non-ionized radiation also requires the measurement of UMTS FDD power in order to prove the compliance to the installation limit value. Some unexpected differences between the measurement results of different laboratories triggered METAS to start a deeper analysis of the UMTS FDD power measurement equipment.

We found significant improvements when an integrating receiver and a brick wall filter are applied instead of a RAKE receiver and a root raised cosine receiver filter.

We derived a set of tests that allow validating the properties of the UMTS receivers with respect to the application for code-selective measurements according to the measurement recommendation [2]. The result of the validation measurements with eight different UMTS receivers is shown.

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1   Introduction

1.1   Motivation

The Ordinance relating to Protection from Non-Ionising Radiation (ONIR) aims at protecting the Swiss population from too high radiation powers for frequencies below 300 GHz. There is a theoretical procedure with which the received powers can be roughly computed prior to building base station and antenna. For critical cases, these values have to be verified by measurements.

For the Global System of Mobile Communication (GSM), this measurement procedure is rather simple and precise. For the Universal Mobile Communication System (UMTS) – we consider only the Frequency Division Duplex (FDD) variant that is currently being rolled out - it becomes more difficult. We had concerns about the ability of commercial receivers to cope correctly in case of multipath reflections, and therefore it was very important to test them under well defined conditions.

1.2   The Ordinance relating to Protection from Non-Ionising Radiation (ONIR)

On 1 February 2000 the Swiss government has put into force an ordinance on the protection of the general population from non-ionizing radiation (NIR) in the frequency range from 0 Hz to 300 GHz. The ordinance enforces the reference levels for the general population as recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). These exposure limit values must be respected at all places accessible to the general public. In addition, precautionary installation limit values for a variety of radiation sources help reduce long-term exposure in residential areas. The installation limit values are much lower than the exposure limit values (100 times less power) and they must be complied with wherever people regularly spend lengthy periods of time (e.g. apartments, schools, hospitals, offices and playgrounds).

There is a procedure [1] that allows determining theoretically the received electromagnetic power radiated by an antenna at a specific place. This procedure needs to be practically verified at critical locations. These locations are rather close to the transmitting antenna, such that there is either only a single propagation path received, or multiple propagation paths are received within rather short time instants.

1.3   GSM vs. UMTS FDD power measurements

The Global System of Mobile Communication (GSM) applies a Time Division Multiple Access (TDMA) scheme. It transmits one broadcasting carrier from each base station sector. This carrier keeps transmitting all time slots at maximum power, independent of the specific traffic situation, in order that, in adjacent cells, mobiles are able to detect the power of the cell in question. This allows for a very simple measurement procedure to estimate the maximum possible received power of this base station at a given location: With a spectrum analyzer, the received power of this broadcasting channel is measured; this power is then multiplied by the number of carriers of this base station sector (as specified by the operator), resulting in the maximum possible received power at the given location.

On the other hand, the Universal Mobile Communication System (UMTS) applies the Code Division Multiple Access (CDMA) scheme. The UMTS system under consideration here is UMTS Frequency Division Duplex (FDD), also referred to as Wideband Code Division Multiple Access (WCDMA), as opposed to UMTS Time Division Duplex (TDD), also referred to as Time Division / Code Division Multiple Access (TD / CDMA). In CDMA, all control and traffic channels are transmitted at the same time and at the same frequency, modulated by different channelization codes. The Common Pilot Channel (CPICH) is always transmitted at the same power. The power measurement equipment has to dispread the CPICH in order to separate it from the other channels. Then, this estimated CPICH power must be multiplied with the ratio of the maximum base station power divided by the CPICH power (as specified by the operator).

2   Theoretical considerations

2.1   The base station transmitter of UMTS FDD

The simplified block diagram of a UMTS FDD base station transmitter is depicted in Figure 1. It illustrates how different data channels are combined and filtered before they are directed to the root raised cosine filter (with a roll-off factor of $r = 0.22$) and the modulator. In principle, there are two classes of signals that are processed in a different manner:

The complex symbols of the Primary- and Secondary-Synchronization Channels (P-SCH and S-SCH) are fed directly to the combiner, whereas the CPICH and all other channels are first orthogonalized by multiplication with a so-called channelization code and then spread by the Primary Scrambling Code (PSC).

The CPICH is transmitted continuously at a constant power and is therefore well suited to serve as basis for power estimation. Its input data sequence is the complex sequence with repeated complex symbols (1+j) and its channelization code is the all one sequence. This unique property means that the pilot signals are hidden as the Primary Scrambling Code (PSC) sequence in the spread signal composition. Detecting the PSC in the received signal is used commonly in receivers for channel estimation purposes.
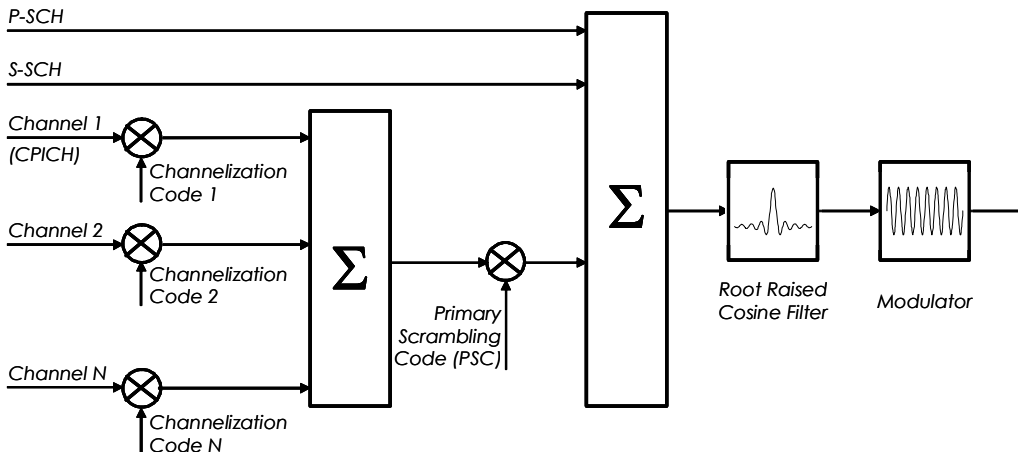
Figure 1: Simplified block diagram of an UMTS FDD base station transmitter.

2.2 Traditional UMTS FDD power estimator: RAKE receiver and root raised cosine filter

Figure 2 shows the situation of a UMTS FDD power measurement. After the digital signal generation (cf. Figure 1), the signal is filtered by a root raised cosine (RRC) filter with a roll-off factor of r = 0.22, modulated and propagated through the mobile radio channel to the receiver. The power of interest is then at the receiver antenna. After this antenna, the signal is demodulated. It is common engineering practice to implement the same RF filter at the input of the receiver as at the output of the transmitter. Therefore all UMTS FDD power measurement receivers are commonly equipped with an RRC filter with a roll-off factor of r = 0.22 as RF input filter. The fact that transmitter and receiver filters are the same is commonly referred to as matched filter technique; it provides the best noise suppression [3] for all propagation situations.
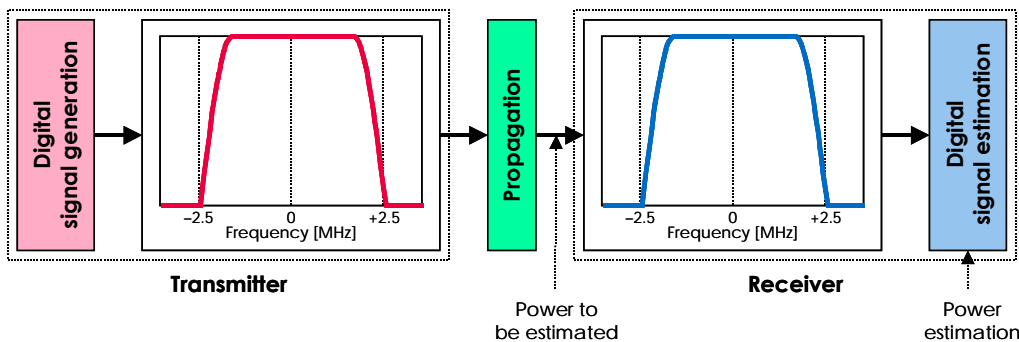
Figure 2: Conventional UMTS FDD power measurement receiver.

In order to save resources in the receiver or to increase the measurement speed, it is also common engineering practice to implement a RAKE receiver instead of a full integrating receiver:

- The full integrating receiver correlates with the PSC at all chip times (or even sub chip times). All these correlation results are then weighted according to their received power and phase, and added.

- The RAKE receiver correlates only at the time instants, where there are significant received powers of the propagation channel. These individual receivers are called fingers. There are fingers that receive the signal of a specific propagation path at given positions. Other fingers are used as searchers that periodically search for new propagation paths to eventually pop up, i.e., new peaks in the received propagation channel impulse response. With this information, the receiving fingers may be reallocated if needed.
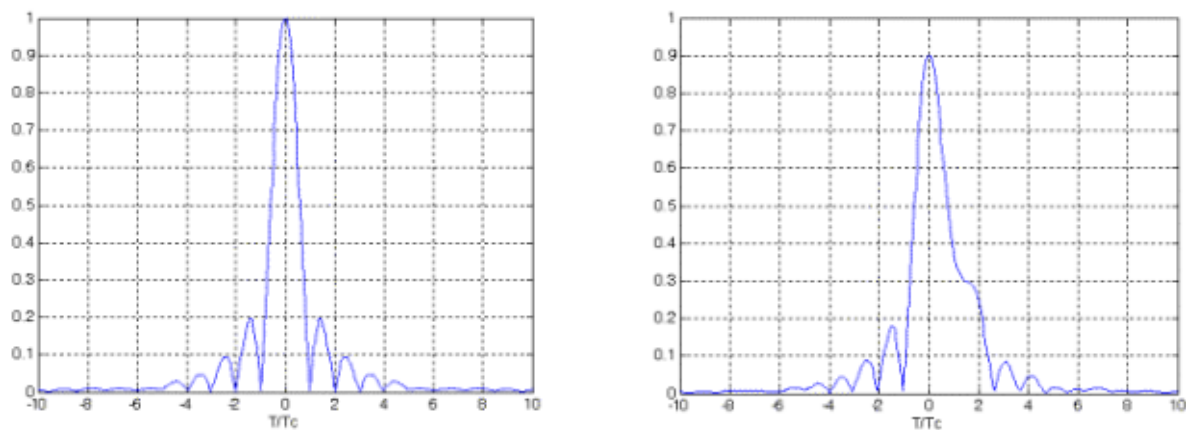
Figure 3: Impulse response of a root raised cosine (RRC) transmit and receive filter combination with roll-off factor of r = 0.22 (left) and response of the same filter combinations, when 2 paths are entered, where the first path has amplitude 1 at time 0 and the second path has amplitude 0.5 at time 1.4 chips.

If there is only one propagation path, or if the propagation paths are separated by at least 2 chip durations, then a RAKE receiver detects the peaks of all propagation paths and therefore correctly estimates the overall received power (cf. the plot on the left of Figure 3). If, on the other hand, two propagation paths are separated by less than 2 chip durations, we may observe a situation as depicted on the right in Figure 3: A conventional RAKE receiver would only detect and receive the main propagation path at chip time instant zero, but not the one at 1.4 chip times, since this latter one does not correspond to a local maximum.

We therefore conclude that, in situations where different propagation paths arrive within less than 2 chip durations, a conventional RAKE receiver may not yield a good estimate of the received power. Such a situation is visualized in Figure 4 that shows the estimated CPICH signal after the receiver RRC filter with two propagation paths of power 0dB and –3dB, respectively, where the latter is delayed 0.5 chips with respect to the first path. The received paths are both marked with black lines; the first path with a blue dot on top, the second path with a yellow one. The first path always arrives with phase 0°, while the second path arrives with phases 0°, 90°, 180° and 270° in the different plots. On the top right of each plot, the green line shows the correct power measurement and the purple line indicates the estimated power by the RAKE receiver. The error   is also indicated.

2.3   Novel UMTS FDD power estimator: Integrating receiver and brick wall filter

Next, we are going to explore the performance of a UMTS FDD power estimator with an integrating receiver together with a different kind of RF receiver filter, as depicted in Figure 5:

- Instead of a RAKE receiver, we propose to use an integrating receiver that overcomes the problem depicted in Figure 3.

- Instead of a RRC filter, we propose to use a brick wall (BW) filter with a square or "brick wall" in the frequency domain, i.e., with a sin (x) / (x) shape in the time domain, or, since this is only a theoretic device, a close approximation thereof.

  The reason for this is explained as follows: No receiver filter would leave the shape of the received signal unchanged, but it would have an inferior noise suppression performance and would even more receive interfering UMTS FDD signals from adjacent bands. The first negative effect can be easily overcome by a longer correlation time in the CDMA receiver. The second negative effect is persistent. It can however be overcome by using the proposed brick-wall filter. With respect to its performance regarding the transmitted signal, there is no difference since, outside the passing range of the brick wall filter, no signal component was sent in the transmitter.

  We strongly believe that this proposed brick-wall method is maximum likelihood, without providing a mathematical proof for this statement. But we argue that, in the absence of noise and intracell interference from other CDMA signals, the estimate is precise without any error.
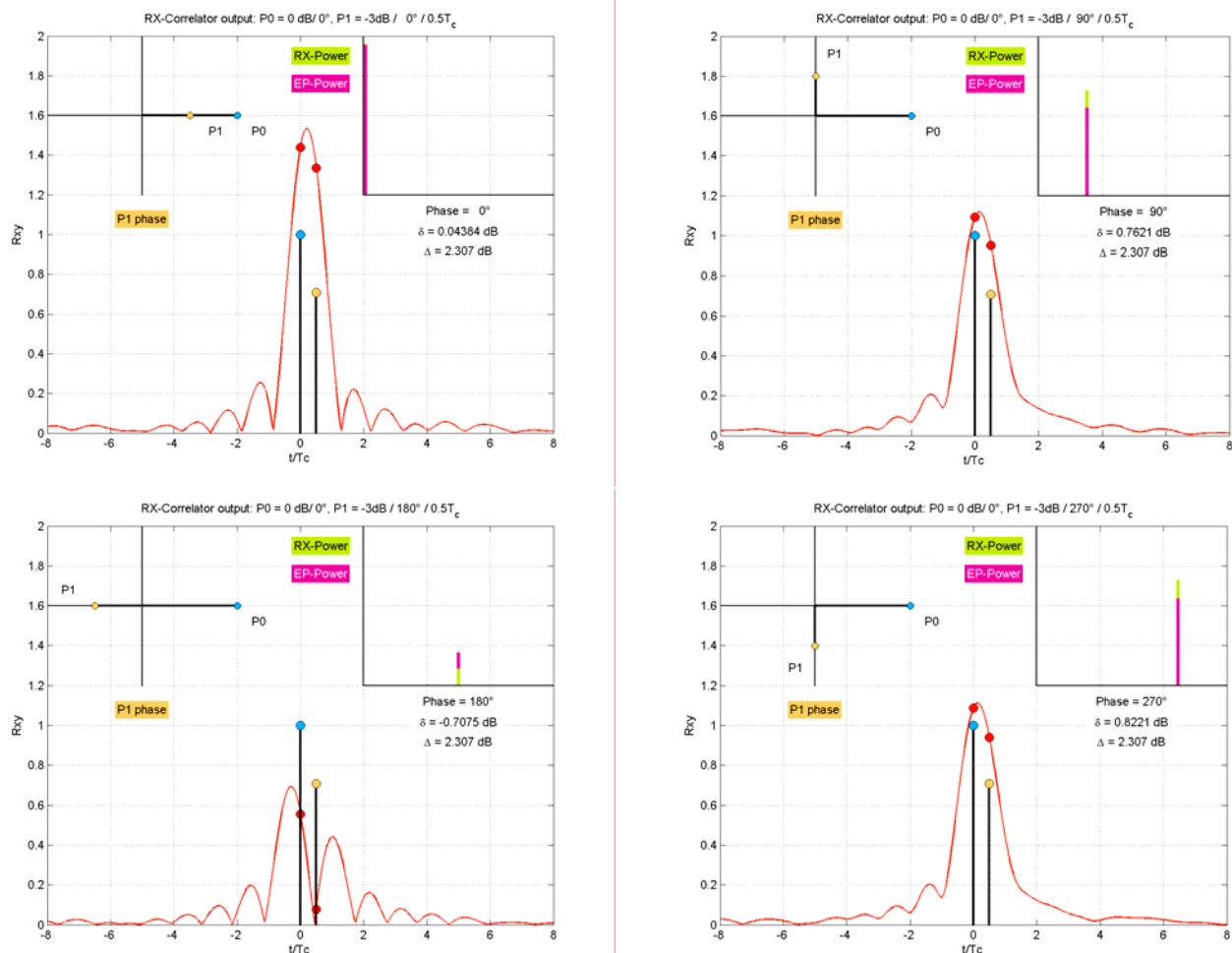
Figure 4: Estimated CPICH signal of a UMTS FDD power estimator with a receiver root raised cosine (RRC) filter and a conventional RAKE receiver with two propagation paths of power 0dB and –3dB, respectively, where the latter is delayed 0.5 Chips with respect to the first path. The phase of the first path is always 0°, the one of second path is 0°, 90°, 180° and 270° (from the top left to the bottom right). See Annex A and Figure 10 for assumptions and explanations.
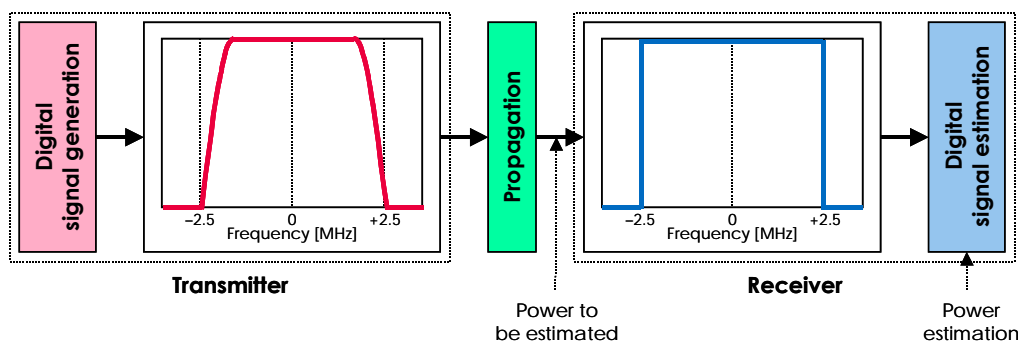
Figure 5: Novel UMTS FDD power measurement receiver.

The plots in Figure 6 show a superior performance as compared with Figure 4, where a RAKE receiver together with an RRC filter was applied. Table 1 compares the performance of all combinations of RRC and BW filter as well as RAKE and integrating receiver. We see that, as expected, the BW filter / integrating receiver performs best, but that the combination of the usually preferred RRC filter with the integrating receiver yield also acceptable results.

Second path		Pilot power estimation error δ – Range / deviation Δ in dB			
		Root raised cosine (RRC) filter		Brick wall (BW) filter	
Gain	Delay τ	RAKE	Integrator	RAKE	Integrator
−3dB	0.5 T_c	−0.71 to 1.60 / 2.31	−0.10 to 0.40 / 0.50	−1.10 to 1.48 / 2.58	−0.07 to 0.06 / 0.13
−3dB	T_c	−0.89 to 1.84 / 2.73	−0.23 to 0.24 / 0.47	−0.83 to 1.78 / 2.61	−0.04 to 0.04 / 0.08

Table 1: Pilot power estimation error δ (ranges and deviation Δ) for the two path reception scenario with a first path gain of 0dB and a second path delay τ over phase shifts between 0° and 270° of the second path.

In fact, some of the UMTS FDD power measurement equipment applies an integrating receiver; but we are not aware of any that apply a brick wall filter.
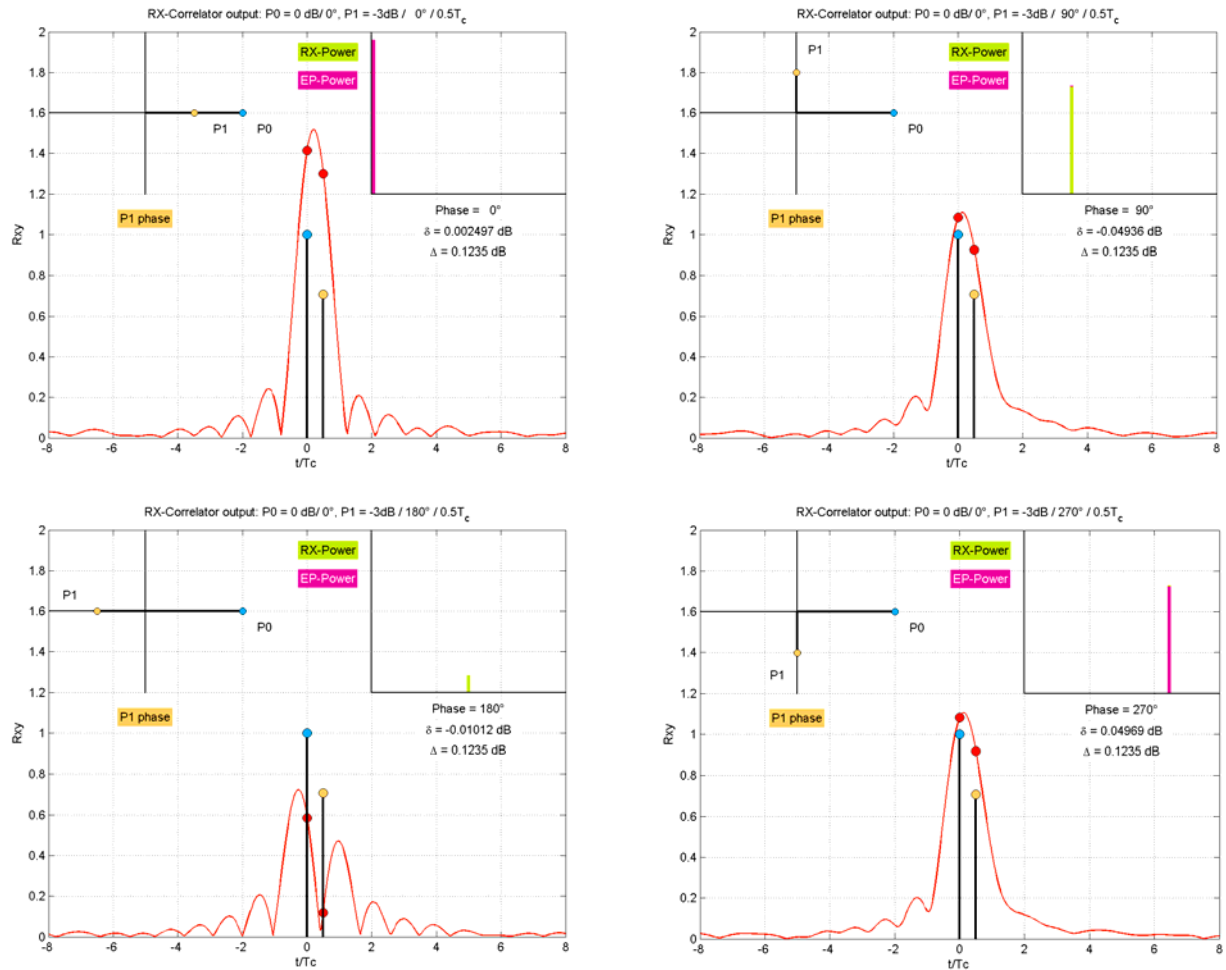
Figure 6: Estimated CPICH signal of a UMTS FDD power estimator with a receiver Brick Wall (BW) Filter and an integrator with two propagation paths of power 0dB and −3dB, respectively, where the latter is delayed 0.5 Chips with respect to the first path. The phase of the first path is always 0°, the one of second path is 0°, 90°, 180° and 270° (from the top left to the bottom right). See Annex A and Figure 10 for assumptions and explanations.

3   Test scenarios

3.1   Test scenario 1: Reference situation with 1 propagation path

The purpose of this scenario is to be used as the reference for the following scenarios. Each result of the following scenarios will be quantified relatively to this first reference scenario.

3.2   Test scenario 2: Static situations with 2 propagation paths

The purpose of this scenario is as follows: two-path measurement capability under different propagation and phase conditions (4 combinations of phase shift). The following combinations are considered here:

- Scenario 2a: Path delay of 3 chips

- Scenario 2b: Path delay of 1 chip

- Scenario 2c: Path delay of 0.5 chip

Each of these scenarios is performed with phase shift of 90º, 180º, 270º, and also 0º.

In Scenario 2a, the superposed paths are nearly uncorrelated; thus their sum power should always be the sum of the powers of the individual components independent of their phase difference. In Scenario 2c, this is no longer the case; therefore the received power becomes a function of the phase variation of the two paths. Figure 7 illustrates the scenario on the basis of the estimated CPICH signal.
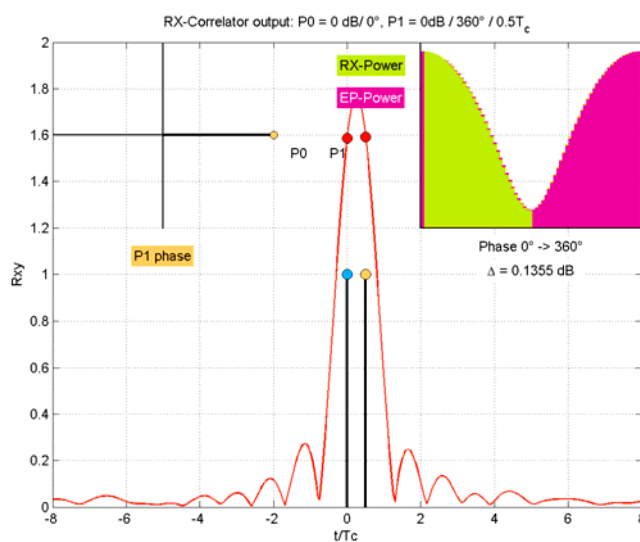
Figure 7: Estimated CPICH signal after the brick wall filter of the novel receiver with two propagation paths of equal power 0dB with propagation delay of the second path of 0.5 chips. See Annex A and Figure 10 for assumptions and explanations.

3.3   Test scenario 3: Static situations with 3 to 6 propagation paths

The purpose of these scenarios is to check the number of paths that the receiver can handle. Four scenarios (3a, 3b, 3c, and 3d) have been defined with number of path ranging from 3 to 6, and path delay of the order of 1 to 6 Chips.

Figure 8 illustrates the scenario 3a on the basis of the estimated CPICH signal. Note that the total signal power remains constant, independent of the phase change of path 2.

3.4   Test scenario 4: Single propagation path with time dependent power

The purpose of this scenario is to test the response time of the receivers. We therefore define 7 scenarios (4a to 4g) with one single propagation path. The power changes abruptly from -6 dB to 0 dB and goes back to -6 dB. The duration of the increased level (0 dB) varies from 5 s (scenario 4a) to 125 ms (scenario 4g).

3.5   Summary of the test scenarios

Table 2 summarizes the different test scenarios. For each scenario, we calculated the power of the addition of all paths together. Scenario 1 has a value of 0 dB since it is the reference. In the case of scenario 4, we only considered the power during the increased level.
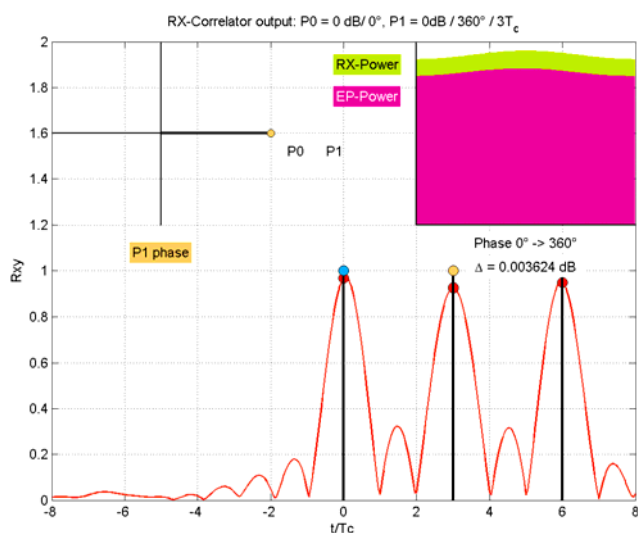
Figure 8: Estimated CPICH signal after the brick wall filter of the novel receiver with 3 propagation paths of equal power 0dB with propagation delay between each other of 3 chips. See Annex A and Figure 10 for assumptions and explanations.

| Scenario | Description | Propagation paths with | | | Doppler (Hz) | Duration (s) | # of traffic channels (ETSI models) | Calculated Power[1] (dB) |
		Power (dB)	delay (Chips)	phase relative to 1st path (°)				
1a	Static with 1 path	0	0	–	–	10	32	0
2a	Static with 2 paths and	0, 0	0, 3.0	0 90 180 270	–	10	32	2.98 3.03 3.04 2.99
2b	4 phases	0, 0	0, 1.0	0 90 180 270	–	10	32	3.00 3.01 3.02 3.01
2c		0, 0	0, 0.5	0 90 180 270	–	10	32	5.12 3.01 −1.28 3.01
3a	Static with 3 – 6 paths	0, 0, 0	0, 2, 4	all 0	–	10	32	4.82
3b		0, 0, 0, 0	0, 2, 4, 6	all 0	–	10	32	6.08
3c		0, 0, 0, 0, 0	0, 2, 4, 6, 8	all 0	–	10	32	7.06
3d		0, 0, 0, 0, 0, 0	0, 2, 4, 6, 8, 10	all 0	–	10	32	7.86
4a	Dynamic with single power steps	−6 → 0 → −6	0	–	–	10→5.000→10	32	0
4b		−6 → 0 → −6	0	–	–	10→2.000→10	32	0
4c		−6 → 0 → −6	0	–	–	10→1.000→10	32	0
4d		−6 → 0 → −6	0	–	–	10→0.750→10	32	0
4e		−6 → 0 → −6	0	–	–	10→0.500→10	32	0
4f		−6 → 0 → −6	0	–	–	10→0.250→10	32	0
4g		−6 → 0 → −6	0	–	–	10→0.125→10	32	0

Table 2: Overview on the validation scenarios with the ETSI model [4] as listed in Table 9 and Table 10 of Annex C.

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[1] Derived from simulations, applying the simulation parameters defined in Annex C

4 Simulation of different receiver types

Before doing the measurements, we tried to simulate the behavior of different types of receivers with the test scenarios defined in Section 3:

- **One path receiver:** This receiver type is able to track only one path, and therefore measures the power of only one path.

- **RAKE receiver:** This receiver is able to track several paths together (up to a given maximum) under the assumption that the delay between the paths is more than 2 chips (cf. Section 2.2). Here, the receiver was modeled with up to 3 fingers.

- **Integration receiver:** This receiver is able to perform a full integration of the correlated signals as described in Section 2.3. It is able to measure the power correctly even in the case of sub chip delays. The difference between the true calculated power and the power estimate of the integration receiver can be explained by the limitation of the integration interval to 40 chip periods and the interference of traffic and synchronization channels.

SUMMARY OF SIMULATED RESULTS

Scenario	Step	Description	Delay (chips)	Phase shift (degrees)	Simulated Power Estimation Error in dB		
					One path receiver	RAKE receiver	Integration receiver
2a	1	Static 2 paths	0;3	0	-3.3	-0.1	0.0
	2	Static 2 paths	0;3	90	-2.8	0.1	0.1
	3	Static 2 paths	0;3	180	-2.7	0.3	0.0
	4	Static 2 paths	0;3	270	-3.0	-0.1	-0.1
2b	1	Static 2 paths	0;1	0	-1.6	-1.6	0.0
	2	Static 2 paths	0;1	90	-2.9	0.0	0.0
	3	Static 2 paths	0;1	180	-2.0	1.1	0.0
	4	Static 2 paths	0;1	270	-2.9	0.0	0.0
2c	1	Static 2 paths	0;0.5	0	-0.2	-0.2	0.0
	2	Static 2 paths	0;0.5	90	-1.1	-1.1	0.0
	3	Static 2 paths	0;0.5	180	-2.0	1.2	0.0
	4	Static 2 paths	0;0.5	270	-1.1	-1.1	0.0
3a	1	Static 3 paths	0;2;4	0	-3.7	0.9	0.2
3b	1	Static 4 paths	0;2;4;6	0	-4.7	-0.1	0.2
3c	1	Static 5 paths	0;2;4;6;8	0	-5.5	-1.0	0.2
3d	1	Static 6 paths	0;2;4;6;8;10	0	-6.3	-1.6	0.2
4a	run	5000ms; 6dB			0.0	0.0	0.0
4b	run (10)	2000ms; 6dB			0.0	0.0	0.0
4c	run (10)	1000ms; 6dB			0.0	0.0	0.0
4d	run (40)	750ms; 6dB			0.0	0.0	0.0
4e	run (20)	500ms; 6dB			0.0	0.0	0.0
4f	run (40)	250ms; 6dB			0.0	0.0	0.0
4g	run (80)	125ms; 6dB			0.0	0.0	0.0

Table 3: Simulated results of theoretic MRUs relatively to the calculated power in Table 2.

5 Measurements

5.1 Description of the test setup

Figure 9 depicts the measurement setup that was used to validate the various MRUs: The RF-Generator SMIQ produced an UMTS signal at a center frequency of 2.15 GHz. The used pilot and traffic channels were according to the ETSI test model with 32 codes (cf. Annex C). The air interface emulator generated the different signals described in the test scenarios 1 to 4. The total output level of the air interface emulator was between −20 dBm and −30 dBm depending on the scenarios. The total power was measured with the FSMR spectrum analyzer with RMS detector and a 5 MHz channel filter. The level of the pilot channel CPICH was −10 dB of the total power according to the ETSI test model (see Table 9and Table 10 in Annex C). The RF generator SML03 was only used to produce the local oscillator frequency for the emulator. All equipments were synchronized with the METAS 10 MHz frequency standard.
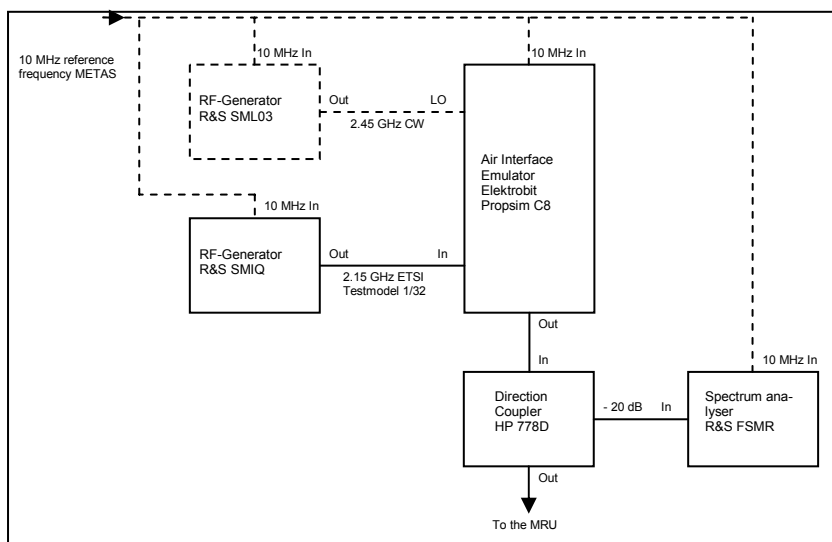
Figure 9: Measurement setup to validate the MRUs.

The measured power at the spectrum analyzer was used as reference level for the test. The RF input of the MRU was connected to the output of the direction coupler HP 778D.

5.2 Tested Equipment

In July 2006 METAS made a round robin test with all the accredited labs in Switzerland. For this test, we also invited interested labs from Germany. We used this occasion to test their different equipment with regard to the ability of multipath propagation. The equipment was operated by the lab staff.

Manufacturer	Type	Software version	Comment
Anritsu	MT8220A	WCDMA 1.10; Package 1.68	Handheld; Base Station Analyzer
Tektronix	Y400 NetTek Analyzer	YBT250 Version 1.422	Handheld; Base Station Transmitter and Interference Analyzer
Rohde & Schwarz	FSQ	3GPP Option K76	Signal Analyzer
Rohde & Schwarz	ESPI	RFEX 4.1.10 (external PC)	Test Receiver
Rohde & Schwarz	FSP	RFEX 4.1.10 (external PC)	Spectrum Analyzer
Narda	SRM 3000	1.4.10	Handheld; Selective Radiation Meter
Rohde & Schwarz	TSMU	RFEX 4.0.2 (external PC)	Radio Network Analyzer (Version with Rake receiver)
Rohde & Schwarz	TSMU	RFEX 4.1.10 (external PC)	Radio Network Analyzer (modified version with integration receiver)

Table 4: Tested equipment.

5.3 Results

In Table 2, columns "Simulated", the difference between the simulated receivers (one path receiver, 3 finger RAKE receiver and integration receiver) and the calculated power were listed. In Table 2, the columns "Measured", the difference between the measured values from the MRU's and the reference level measured with the spectrum analyzer FSMR were listed.

The fact that the reference measurement includes the 5 MHz (3dB) channel filter and the properties of the Propsim air interface emulator results in a small difference of maximum 0.2 dB between the measured reference values and the calculated power values. This difference was considered as negligible.

SUMMARY OF SIMULATED AND MEASURED RESULTS

Scenario	Step	Description	Delay [chips]	Phase shift [degrees]	Simulated			Measured							
								One path receivers			RAKE receivers				Integration
					One path receiver	RAKE receiver	Integration receiver	Anritsu	Tektronix	R&S FSQ (interne SW)	R&S ESPI (RFEX)	R&S FSP (RFEX)	Narda SRM	R&S TSMU (old Version)	R&S TSMU (new Version)
2a	1	Static 2 path	0;3	0	-3.3	-0.1	0.0	(1	-2.7	-2.6	(2	-0.2	0.2	0.4	0.1
	2	Static 2 path	0;3	90	-2.8	0.1	0.1	(1	-2.6	-3.2	-0.8	(2	0.2	0.3	-0.2
	3	Static 2 path	0;3	180	-2.7	0.3	0.0	-2.7	-2.7	-2.8	-1.3	(2	0.0	0.1	-0.2
	4	Static 2 path	0;3	270	-3.0	-0.1	-0.1	-0.7	-2.6	-2.4	(2	(2	0.1	0.0	0.1
2b	1	Static 2 path	0;1	0	-1.6	-1.6	0.0	-3.9	-1.0	-1.3	-1.0	-0.8	-1.1	-0.4	0.1
	2	Static 2 path	0;1	90	-2.9	0.0	0.0	(1	-2.8	-3.1	(2	(2	0.0	-0.3	-0.5
	3	Static 2 path	0;1	180	-2.0	1.1	0.0	-1.0	-2.0	-1.9	(2	0.2	0.9	0.6	-0.2
	4	Static 2 path	0;1	270	-2.9	0.0	0.0	-1.1	-3.0	-2.2	(2	(2	0.1	-0.2	0.3
2c	1	Static 2 path	0;0.5	0	-0.2	-0.2	0.0	-0.3	-0.1	0.0	-0.3	-0.1	-0.2	0.1	-0.1
	2	Static 2 path	0;0.5	90	-1.1	-1.1	0.0	(1	-0.9	-1.1	(2	-0.9	-0.9	-0.4	-0.1
	3	Static 2 path	0;0.5	180	-2.0	1.2	0.0	-1.1	-2.0	-1.9	(2	0.2	0.9	0.5	-0.3
	4	Static 2 path	0;0.5	270	-1.1	-1.1	0.0	-0.2	-0.9	-0.7	-0.8	-0.5	-1.0	-0.8	0.0
3a	1	Static 3 path	0;2;4	0	-3.7	1.0	0.2	(1	-3.7	-3.5	0.2	0.5	0.6	1.3	0.1
3b	1	Static 4 path	0;2;4;6	0	-4.7	-0.1	0.2	(1	-5.0	-4.5	-0.6	0.3	0.0	-1.6	0.0
3c	1	Static 5 path	0;2;4;6;8	0	-5.5	-1.0	0.2	(1	-5.9	-6.0	(2	0.2	0.2	-1.9	-1.2
3d	1	Static 6 path	0;2;4;6;8;10	0	6.3	-1.6	0.2	(1	-6.9	-6.3	(2	-0.1	-1.3	(2	(2
4a	run	5000ms; 6dB			0.0	0.0	0.0	0.0	-0.1	0.0	-0.2	0.3	0.0	0.0	0.0
4b	run (10)	2000ms; 6dB			0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.3	0.0	0.0	0.0
4c	run (10)	1000ms; 6dB			0.0	0.0	0.0	0.0	-0.1	0.0	0.4	0.4	0.0	-0.1	0.0
4d	run (40)	750ms; 6dB			0.0	0.0	0.0	-6.0	-6.1	0.0	-0.5	-0.1	0.0	-0.1	0.0
4e	run (20)	500ms; 6dB			0.0	0.0	0.0	-6.0	-6.1	-6.0	0.0	-0.4	-0.2	-2.8	-0.1
4f	run (40)	250ms; 6dB			0.0	0.0	0.0	-6.0	-6.1	-6.0	-0.6	-0.5	-0.3	-2.5	0.0
4g	run (80)	125ms; 6dB			0.0	0.0	0.0	-6.0	-6.1	-6.0	-0.6	-0.5	-6.0	-5.7	-0.2

Deviation: ▭ < 0.4 dB   ▭ 0.4 dB ≤ ... < 1.0 dB   ▭ 1.0 dB ≤ ... < 2.0 dB   ▭ ≥ 2.0 dB

Table 5: Difference in dB of the simulated results of theoretic MRUs and calculated power (Table 2) as well as difference of the measured MRU's and the measured reference level.

Remarks: (1 The displayed value was not stable

(2 The MRU was not able to synchronize

A significant deviation of the expected indicated value can be interpreted as follows, depending on the respective scenario:

- Scenario 2a: The MRU is not capable of estimating the total received power when a second path is superposed. Note that this is the scenario with lowest requirements

- Scenario 2b: The MRU has probably difficulties to recognize two paths in certain phase conditions. Note that, although the received signals are almost orthogonal, a distance of 1 chip can cause problems for the channel estimator to resolve the two paths under all phase conditions.

- Scenario 2c: The same as for scenario 2b. Note that this is the most challenging situation for the MRU, since the received power changes significantly under different phase situations.

- Scenario 3a to 3d: This scenario indicates how many paths can be processed simultaneously by the MRU.

- Scenario 4a to 4g: Typical reasons for insufficient performance are among others

    * a too large averaging window size,

    * the implementation of an averaging procedure,

    * a too low processing rate, or

    * a too low processing speed.

    Note that, if an MRU failed this validation scenario due to the first two reasons, it would pass a new validation scenario with periodically repeated power steps. This additional validation scenario showed that all equipment had an averaging window size of 10ms, i.e., one UMTS FDD frame.

6 Summary

By means of simulations we have shown that the performance of a UMTS FDD power measurement receiver can be significantly improved when, instead of a root raised cosine receiver filter and a RAKE receiver, a brick wall filter and an integrating receiver are applied instead.

Moreover we have compared commercial UMTS power measurement receivers using a set of scenarios. Significant differences have been observed depending on the type of receiver implemented.

In the scope of NISV measurements, it is very probable that the field to be measured is the sum of a direct path with several reflected paths. The path difference between direct ray and reflected rays may typically be shorter than 78 m (that corresponds to 1 Chip delay). Therefore it is important that the receivers have the ability to measure correctly UMTS CPICH power in this kind of situations.

Annex A: Simulation parameters and plot diagram explanation

The following parameters were used in the simulations and plot diagrams above:

- Scrambling Code: Code 0.
- Transmitted channels:
    * The Common Pilot Channel (CPICH) is set to a relative amplitude of 0dB.
    * The Primary and Secondary Synchronization Channels (P-SCH and S-SCH) are set to relative amplitudes of −1.8dB and −3.5dB, respectively.
    * 12 Physical Channels (PCH) are set to relative amplitudes of −3.1dB, −4.0dB, −0.5dB, −7.0dB, +1.8dB, +1.5dB, −6.4dB, −6.4dB, −6.4dB, −6.4dB, −6.4dB, and −6.4dB.
- Correlation length: The correlation length of the matched Scrambling Code Sequence is 10ms or 38'400 chips.

Figure 10 depicts a typical plot diagram together with some explanations.
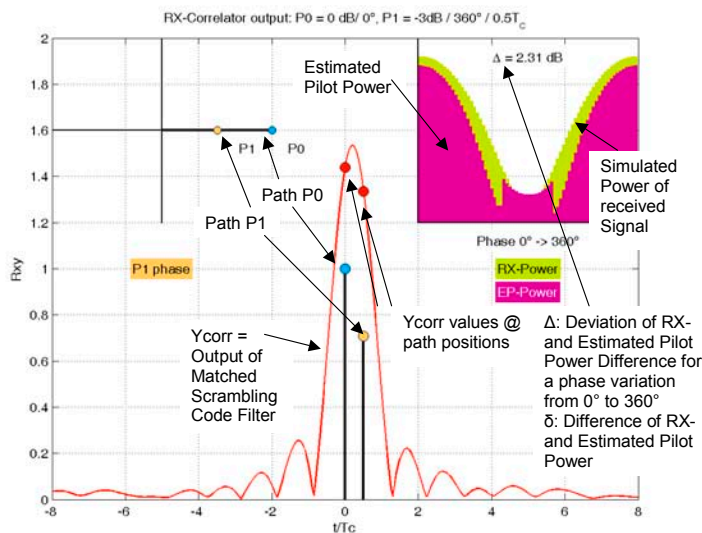
Figure 10: Typical diagram together with explanations.

Annex B: Results of the simulated receiver

Table 6 to Table 8 list the full results of simulated one-path, the three finger RAKE and the ideal integrating receiver.

Simulated one path receiver

Scenario	Step	Description	Delay (chips)	Phase shift (degrees)	Calculated Power (dB)	MRU (dB)	Delta MRU - Calculated Power (dB)
2a	0	Reference	0	0	0.00	0.00	
	1	Static 2 paths, 4 phases	0;3	0	2.98	-0.35	-3.33
	2	Static 2 paths, 4 phases	0;3	90	3.03	0.22	-2.81
	3	Static 2 paths, 4 phases	0;3	180	3.04	0.37	-2.67
	4	Static 2 paths, 4 phases	0;3	270	2.99	-0.05	-3.04
2b	0	Reference	0	0	0.00	0.00	
	1	Static 2 paths, 4 phases	0;1	0	3.00	1.36	-1.64
	2	Static 2 paths, 4 phases	0;1	90	3.01	0.09	-2.92
	3	Static 2 paths, 4 phases	0;1	180	3.02	1.00	-2.02
	4	Static 2 paths, 4 phases	0;1	270	3.01	0.07	-2.94
2c	0	Reference	0	0	0.00	0.00	
	1	Static 2 paths, 4 phases	0;0.5	0	5.12	4.95	-0.17
	2	Static 2 paths, 4 phases	0;0.5	90	3.01	1.95	-1.06
	3	Static 2 paths, 4 phases	0;0.5	180	-1.28	-3.26	-1.98
	4	Static 2 paths, 4 phases	0;0.5	270	3.01	1.92	-1.09
3a	0	Reference	0	0	0.00	0.00	
	1	Static 3 paths	0;2;4	0	4.82	1.13	-3.69
3b	0	Reference	0	0	0.00	0.00	
	1	Static 4 paths	0;2;4;6	0	6.08	1.36	-4.72
3c	0	Reference	0	0	0.00	0.00	
	1	Static 5 paths	0;2;4;6;8	0	7.06	1.59	-5.47
3d	0	Reference	0	0	0.00	0.00	
	1	Static 6 paths	0;2;4;6;8;10	0	7.86	1.60	-6.26
4	0	Reference 0dB		0	0.00	0.00	
	10	Reference 6dB		0	6.00	6.00	
4a	run	5000ms; 6dB				6.00	0.00
4b	run (10)	2000ms; 6dB				6.00	0.00
4c	run (10)	1000ms; 6dB				6.00	0.00
4d	run (40)	750ms; 6dB				6.00	0.00
4e	run (20)	500ms; 6dB				6.00	0.00
4f	run (40)	250ms; 6dB				6.00	0.00
4g	run (80)	125ms; 6dB				6.00	0.00

Table 6: Simulated measurement sheet of the theoretical one-path receiver.

Simulated 3 finger RAKE receiver

Scenario	Step	Description	Delay (chips)	Phase shift (degrees)	Calculated Power (dB)	MRU (dB)	Delta MRU - Calculated Power (dB)
2a	0	Reference	0	0	0.00	0.00	
	1	Static 2 paths, 4 phases	0;3	0	2.98	2.90	-0.08
	2	Static 2 paths, 4 phases	0;3	90	3.03	3.16	0.13
	3	Static 2 paths, 4 phases	0;3	180	3.04	3.38	0.34
	4	Static 2 paths, 4 phases	0;3	270	2.99	2.88	-0.11
2b	0	Reference	0	0	0.00	0.00	
	1	Static 2 paths, 4 phases	0;1	0	3.00	1.36	-1.64
	2	Static 2 paths, 4 phases	0;1	90	3.01	3.04	0.03
	3	Static 2 paths, 4 phases	0;1	180	3.02	4.11	1.09
	4	Static 2 paths, 4 phases	0;1	270	3.01	3.02	0.01
2c	0	Reference	0	0	0.00	0.00	
	1	Static 2 paths, 4 phases	0;0.5	0	5.12	4.95	-0.17
	2	Static 2 paths, 4 phases	0;0.5	90	3.01	1.95	-1.06
	3	Static 2 paths, 4 phases	0;0.5	180	-1.28	-0.06	1.22
	4	Static 2 paths, 4 phases	0;0.5	270	3.01	1.93	-1.08
3a	0	Reference	0	0	0.00	0.00	
	1	Static 3 paths	0;2;4	0	4.82	5.70	0.88
3b	0	Reference	0	0	0.00	0.00	
	1	Static 4 paths	0;2;4;6	0	6.08	5.94	-0.14
3c	0	Reference	0	0	0.00	0.00	
	1	Static 5 paths	0;2;4;6;8	0	7.06	6.09	-0.97
3d	0	Reference	0	0	0.00	0.00	
	1	Static 6 paths	0;2;4;6;8;10	0	7.86	6.23	-1.63
4	0	Reference 0dB		0	0.00	0.00	
	10	Reference 6dB		0	6.00	6.00	
4a	run	5000ms; 6dB				6.00	0.00
4b	run (10)	2000ms; 6dB				6.00	0.00
4c	run (10)	1000ms; 6dB				6.00	0.00
4d	run (40)	750ms; 6dB				6.00	0.00
4e	run (20)	500ms; 6dB				6.00	0.00
4f	run (40)	250ms; 6dB				6.00	0.00
4g	run (80)	125ms; 6dB				6.00	0.00

Table 7: Simulated measurement sheet of the theoretical three finger RAKE receiver

Simulated integration receiver

Scenario	Step	Description	Delay (chips)	Phase shift (degrees)	Calculated Power (dB)	MRU (dB)	Delta MRU - Calculated Power (dB)
2a	0	Reference	0	0	0.00	0.00	
	1	Static 2 paths, 4 phases	0;3	0	2.98	2.95	-0.03
	2	Static 2 paths, 4 phases	0;3	90	3.03	3.15	0.12
	3	Static 2 paths, 4 phases	0;3	180	3.04	3.07	0.03
	4	Static 2 paths, 4 phases	0;3	270	2.99	2.87	-0.12
2b	0	Reference	0	0	0.00	0.00	
	1	Static 2 paths, 4 phases	0;1	0	3.00	2.99	-0.01
	2	Static 2 paths, 4 phases	0;1	90	3.01	3.01	0.00
	3	Static 2 paths, 4 phases	0;1	180	3.02	3.03	0.01
	4	Static 2 paths, 4 phases	0;1	270	3.01	3.01	0.00
2c	0	Reference	0	0	0.00	0.00	
	1	Static 2 paths, 4 phases	0;0.5	0	5.12	5.12	0.00
	2	Static 2 paths, 4 phases	0;0.5	90	3.01	3.04	0.03
	3	Static 2 paths, 4 phases	0;0.5	180	-1.28	-1.24	0.04
	4	Static 2 paths, 4 phases	0;0.5	270	3.01	2.98	-0.03
3a	0	Reference	0	0	0.00	0.00	
	1	Static 3 paths	0;2;4	0	4.82	4.98	0.16
3b	0	Reference	0	0	0.00	0.00	
	1	Static 4 paths	0;2;4;6	0	6.08	6.25	0.17
3c	0	Reference	0	0	0.00	0.00	
	1	Static 5 paths	0;2;4;6;8	0	7.06	7.24	0.18
3d	0	Reference	0	0	0.00	0.00	
	1	Static 6 paths	0;2;4;6;8;10	0	7.86	8.03	0.17
4	0	Reference 0dB		0	0.00	0.00	
	10	Reference 6dB		0	6.00	6.00	
4a	run	5000ms; 6dB				6.00	0.00
4b	run (10)	2000ms; 6dB				6.00	0.00
4c	run (10)	1000ms; 6dB				6.00	0.00
4d	run (40)	750ms; 6dB				6.00	0.00
4e	run (20)	500ms; 6dB				6.00	0.00
4f	run (40)	250ms; 6dB				6.00	0.00
4g	run (80)	125ms; 6dB				6.00	0.00

Table 8: Simulated measurement sheet of the theoretical integration receiver.

Annex C: ETSI model

The European Telecommunication Standards Institute (ETSI) has defined a model [4] that specifies the power distributions of the UMTS FDD DPCH spreading codes that are applied in all test scenarios (cf. Table 9) and their timing offsets and level settings (cf. Table 10).

Type	Number of Channels	Fraction of Power [%]	Level setting [dB]	Channelization Code	Timing offset (x 256 chip times)
P-CCPCH+SCH	1	10	-10	1	0
Primary CPICH	1	10	-10	0	0
PICH	1	1.6	-18	16	120
S-CCPCH containing PCH (SF=256)	1	1.6	-18	3	150
DPCH(SF=128)	16/32/64	76.8 in total	see Table 6.2	see Table 6.2	see Table 6.2

Table 9: Power distribution of the UMTS FDD control channels according to the ETSI model [4], with a reference to a Table 6.2 in [4].

Code	Timing offset (x 256 T_{CHIP})	Level settings [dB] 16 codes	Level settings [dB] 32 codes	Level settings [dB] 64 codes	Code	Timing offset (x 256 T_{CHIP})	Level settings [dB] 16 codes	Level settings [dB] 32 codes	Level settings [dB] 64 codes
2	86	-10	-13	-16	4	91	–	–	-17
11	134	-12	-13	-16	9	7	–	–	-18
17	52	-12	-14	-16	12	32	–	–	-20
23	45	-14	-15	-17	14	21	–	–	-17
31	143	-11	-17	-18	19	29	–	–	-19
38	112	-13	-14	-20	22	59	–	–	-21
47	59	-17	-16	-16	26	22	–	–	-19
55	23	-16	-18	-17	28	138	–	–	-23
62	1	-13	-16	-16	34	31	–	–	-22
69	88	-15	-19	-19	36	17	–	–	-19
78	30	-14	-17	-22	40	9	–	–	-24
85	18	-18	-15	-20	44	69	–	–	-23
94	30	-19	-17	-16	49	49	–	–	-22
102	61	-17	-22	-17	53	20	–	–	-19
113	128	-15	-20	-19	56	57	–	–	-22
119	143	-9	-24	-21	61	121	–	–	-21
7	83	–	-20	-19	63	127	–	–	-18
13	25	–	-18	-21	66	114	–	–	-19
20	103	–	-14	-18	71	100	–	–	-22
27	97	–	-14	-20	76	76	–	–	-21
35	56	–	-16	-24	80	141	–	–	-19
41	104	–	-19	-24	84	82	–	–	-21
51	51	–	-18	-22	87	64	–	–	-19
58	26	–	-17	-21	91	149	–	–	-21
64	137	–	-22	-18	95	87	–	–	-20
74	65	–	-19	-20	99	98	–	–	-25
82	37	–	-19	-17	105	46	–	–	-25
88	125	–	-16	-18	110	37	–	–	-25
97	149	–	-18	-19	116	87	–	–	-24
108	123	–	-15	-23	4	91	–	–	-17
117	83	–	-17	-22	9	7	–	–	-18
125	5	–	-12	-21	12	32	–	–	-20

Table 10: DPCH spreading code, timing offsets and level settings of the traffic channels according to the ETSI model [4].

Glossary of terms

BW	Brick Wall filter
CDMA	Code Division Multiple Access
CPICH	Common Pilot Channel
DPCH	Dedicated Physical Channel
ETSI	European Telecommunication Standards Institute
FDD	Frequency Division Duplex
FOEN	Swiss Federal Office for the Environment
GSM	Global System of Mobile communication
ICNIRP	International Commission on Non-Ionizing Radiation Protection
MRU	Measurement Receiver Unit (under test)
NISV	Nicht ionisierende Strahlungsverordnung – in English: Decree on Non-Ionized Radiation
OMEN	Orte mit empfindlicher Nutzung – in English: Locations of sensitive usage
P-CCPCH	Primary Common Control Physical Channel
PCH	Physical Channels
PICH	Pilot Channel
PSC	Primary Scrambling Code
P-SCH	Primary-Synchronization Channels
RF	Radio Frequency
RRC	Root Raised Cosine filter
S-CCPCH	Secondary Common Control Physical Channel
SCH	Synchronization Channel
SF	Spreading factor
S-SCH	Secondary-Synchronization Channels
TCH	Traffic Channel
TD / CDMA	Time Division / Code Division Multiple Access
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Communications System
WCDMA	Wideband Code Division Multiple Access
WHO	World Health Organization

References

[1]   "Decree on Non-Ionized Radiation", Swiss Federal Office for the Environment (FOEN) http://www.bafu.admin.ch/elektrosmog/.

[2]   "Messempfehlung Mobilfunk-Basisstationen (UMTS-FDD), Entwurf vom 17.9.2003", Swiss Federal Office for the Environment (FOEN) http://www.bafu.admin.ch/elektrosmog/.

[3]   John G. Proakis, "Digital Communications", McGraw-Hill, 1983.

[4]   ETSI Standard TS 125 141 V4.1.0