Application Note 69: 3GPP TR 25.943 Deployment Channel Models for UMTS W-CDMA

Document 3GPP TR25.943 consists of generic fading models for testing devices operating in the cellular radio channel environment. 3GPP TR 25.943 is based on both the COST[1] 259 radio propagation studies and on the GSM test specifications derived from COST 207. Recent enhancements have been made to 3GPP TR25.943 describing how to tailor the generic channel models for specific applications, in this case UMTS W-CDMA[2]. This document describes the 3GPP TR 25.943 UMTS W-CDMA channel models and illustrates how they are implemented using a TAS4500 FLEX5 RF Channel Emulator. An example derivation of the UMTS W-CDMA channel model translations is also included in the Appendix.

UMTS W-CDMA test specifications such as 3GPP TS 25.141, TS 34.121, TS 25.142, and TS 34.122 isolate particular receiver functions to facilitate conformance testing of both UE's and Node B's. These conformance test specifications contain static and dynamic radio propagation channel models used to evaluate an UMTS W-CDMA receiver. Static channel models define up to six path Wide Sense Stationary Uncorrelated Scattering (WSSUS) models. Dynamic channel models consist of non-stationary (delay profiles varying with time) Moving Propagation and Birth-Death conditions and are intended to evaluate the ability of a UMTS W-CDMA RAKE receiver to track dynamic channel conditions.

3GPP TR 25.943 shifts the focus from product conformance testing to product deployment testing. For example, a Node-B or UE manufacturer/designer is now able to use 3GPP TR 25.943 to evaluate the performance of their design under deployment-like conditions. The deployment models defined by 3GPP TR 25.943 include conditions that emulate Rural, Urban, and Hilly Terrain environments.

The TAS4500 FLEX5 from Spirent Communications exceeds the 3GPP radio channel modeling requirements defined by 3GPP TS 25.141, TS 34.121, TS 25.142, and TS 34.122 and the requirements specified in 3GPP TR 25.943. The end-user can easily recall pre-defined standard files that map 3GPP channel models to FLEX5 instrument settings. The end user can also modify and save standard files to create an unlimited combination of user-defined scenarios.

3GPP TR 25.943 Channel Models for UMTS W-CDMA

[1] COST (COperation européenne dans le domaine de la recherche Scientifique et Technique) is a European Union Forum for cooperative scientific research. For example, the COST 259 project on Wireless Flexible Personalized Communications ran from 1996 to 2000 and dealt with different aspect of mobile radio communications.

[2] Enhancements to 3GPP TR 25.943 were approved by the 3GPP RAN (Radio Access Network) working group in December 2001 and are incorporated into version 4.1 of the document.

This section outlines the UMTS W-CDMA Deployment Channel Models defined by 3GPP TR 25.943. A detailed explanation for the derivation of the UMTS W-CDMA channel models is found in the appendix of this document. The channel models are presented for all three (3) cases specified in 3GPP TR 25.943: Rural Area (RAx), Typical Urban (TUx), and Hilly Terrain (HTx). All channel models are presented with a sampling resolution of Δt=½ chip rate as recognized by the industry as the best chip rate for UMTS W-CDMA. The chip rate for UMTS W-CDMA applications is 3.84 Mchips/s.

When tailored to the UMTS W-CDMA application, the number of taps required, the relative time of each tap, and the total average relative power of the tap change relative to the generic channel model. However, the velocity of each channel model specified in Table 5.1 of 3GPP TR 25.943 remains the same.

Table 1 shows how the Rural Area (RAx) Channel Model found in Table 5.3 of 3GPP TR 25.943 is modified based on the calculations discussed in this document.

Tap Number	Tap Relative Quantized Time (nsec)	Average Relative Power (dB)
1	0.0	-5.2dB direct, -6.4dB faded[3]
2	130.2	-4.4dB
3	260.4	-11.1dB
4	390.6	-18.5dB
5	520.8	-18.3dB

Table 1. Rural Area (RAx) Channel Model for UMTS W-CDMA

[3] In the case of tap # 1 in Table 1 the total average relative power is expressed in two components, -5.2dB direct path, and a -6.4dB faded path, because the tap includes both a direct path along with a faded path. This is also equivalent to a Rician faded path of -2.7dB with a k factor of -1.2dB.

Table 2 shows how the Typical Urban (TUx) channel model found in Table 5.2 of 3GPP TR 25.943 is modified based on the calculations discussed in this document.

Tap Number	Tap Relative Quantized Time (nsec)	Average Relative Power (dB)
1	0.0	-5.7dB
2	260.4	-7.6dB
3	520.8	-5.4dB
4	651.0	-11.5dB
5	781.2	-13.4dB
6	1171.8	-16.3dB
7	1302.0	-12.4dB
8	1562.4	-14.5dB
9	1822.8	-16.9dB
10	1953.0	-22.6dB
11	2083.2	-20.1dB

Table 2. Typical Urban (TUx) Urban Channel Model for UMTS W-CDMA

Table 3 shows how the Hilly Terrain (HTx) channel model found in Table 5.4 of 3GPP TR 25.943 is modified based on the calculations discussed in this document.

Tap Number	Tap Relative Quantized Time (nsec)	Average Relative Power (dB)
1	0.0	-3.6dB
2	390.6	-6.5dB
3	520.8	-8.6dB
4	651.0	-9.8dB
5	781.3	-16.2dB
6	911.4	-14.5B
7	14973.8	-17.6dB
8	16015.5	-22.7dB
9	16536.3	-24.1dB
10	16926.9	-23.9 dB
11	17838.4	-24.6 dB

Table 3. Hilly Terrain (HTx) Channel Model for UMTS W-CDMA

TAS4500 FLEX5 Addresses UMTS W-CDMA Deployment Channel Models

The TAS4500 FLEX5 from Spirent Communications addresses all the requirements for emulating the UMTS W-CDMA channels specified in 3GPP TR 25.943 as well as other static and dynamic 3GPP channel models. The FLEX5 contains more than the minimum number of paths specified by the 3GPP TR 25.943 for testing UE and Node B equipment in representative UMTS W-CDMA environments. The figure below shows the high-level functional diagram of the 4500 FLEX5 product.

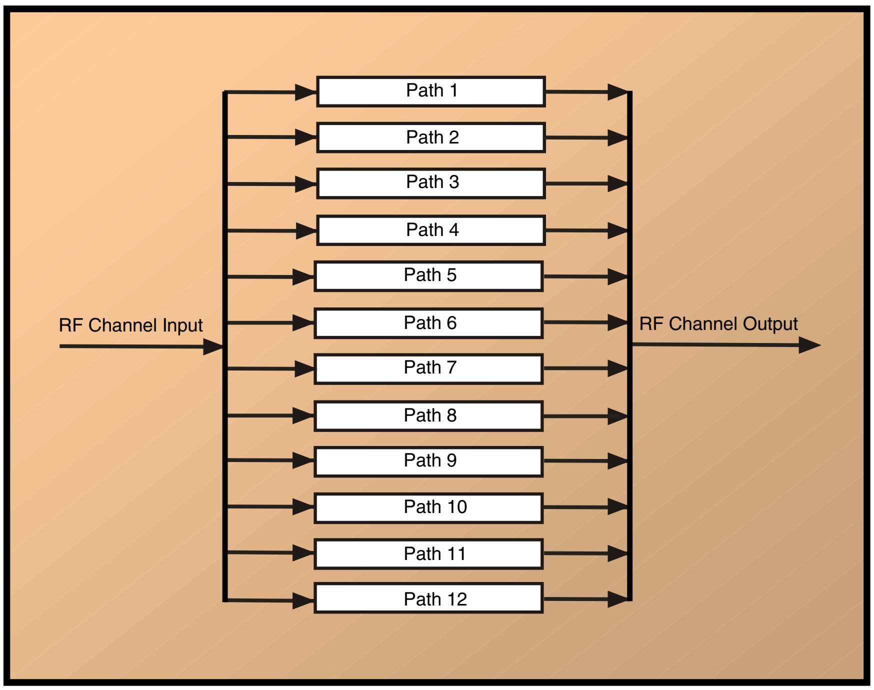

Figure 1. TAS4500 FLEX5 Functional Diagram

The TAS4500 FLEX5 simplifies the testing specified in 3GPP TR 25.943 by allowing the user to recall predefined parameter configuration files for each of the UMTS W-CDMA channel models via the TASKIT/4500 control software. Table 4 below maps the different channel models in 3GPP TR 25.943 to a zip download file that contains parameter configuration files for the TASKIT/4500 software.

UMTS W-CDMA Deployment Channel Model	Download files for TASKIT/4500
Rural Area - RAx (Δt/2)	RAx_25943.zip
Typical Urban – TUx (Δt/2)	TUx_25943.zip
Hilly Terrain – HTx (Δt/2)	HTx_25943.zip

Table 4. TASKIT/4500 Files for 3GPP TR 25.943 UMTS W-CDMA Channel Models

Spirent Communications regularly updates these files to reflect the evolving standards. Pre-defined 3GPP channel models for the FLEX5 are available on the Spirent Communications, TAS Division web site at the following URL:
http://tas.spirentcom.com/customer_software_download.htm

Summary

The enhancements to 3GPP TR 25.943 approved by the 3GPP RAN working group define UMTS W-CDMA specific channel models. This document has provided the channel models for UMTS W-CDMA associated with 3GPP TR 25.943, along with an explanation of how the channel models are derived (see Appendix).

To address the channel model requirements defined by 3GPP TR25.943, the TAS4500 FLEX5 provides full control of RF channel characteristics for UMTS W-CDMA such as:

- Multi-Path Fading
- Relative Path Loss
- Relative Delay Spread

In addition to exceeding the requirements of 3GPP TR 25.943, the TAS4500 FLEX5 exceeds the requirements of 3GPP static and dynamic conformance channel models found in 3GPP TS 25.141, TS 34.121, TS 25.142, and TS 34.122. Furthermore, the TAS4500 FLEX5 product provides pre-defined configuration files that implement the full range of 3GPP channel models. The end user can customize and enhance these files to create an unlimited number of user-defined test scenarios.

Works Cited

3GPP TR 25.943: 3rd Generation Partnership Project Technical Report 25.943; Technical Specification Group Radio Access Networks; Deployment Aspects. http://www.3gpp.org.

3GPP TS 25.141: 3rd Generation Partnership Project Technical Specification Working Group. RAN Working Group 4; Radio Access Networks; Base Station conformance testing (FDD). http://www.3gpp.org.

3GPP TS 34.121: 3rd Generation Partnership Project Technical Specification Working Group. RAN Working Group 4; Radio Access Networks; Mobile Station conformance testing (FDD). http://www.3gpp.org.

3GPP TS 25.142: 3rd Generation Partnership Project Technical Specification Working Group. RAN Working Group 4; Radio Access Networks; Base Station conformance testing (TDD). http://www.3gpp.org.

3GPP TS 34.121: 3rd Generation Partnership Project Technical Specification Working Group. RAN Working Group 4; Radio Access Networks; Mobile Station conformance testing (TDD). http://www.3gpp.org.

COST 259: L.M. Correia, ed., Wireless flexible personalized communications – COST 259: European cooperation in mobile radio research, John Wiley & Sons 2001.

COST 207: "Digital Land Mobile Radio Communications – COST 207," Commission of the European Communities, Final Report, 14 March 1984 – 13 September, 1988, Office for Official Publications of the European Communities, Luxembourg, 1989.

Appendix – Derivation of the 3GPP TR 25.943 Channel Models for UMTS W-CDMA

Document 3GPP TR25.943 consists of generic fading models for testing devices operating in the cellular radio channel environment. Recent enhancements have been made to 3GPP TR25.943 describing how to tailor the generic channel models for specific applications, in this case UMTS W-CDMA. The two items taken into consideration when mapping the generic channel models into application specific channel models are the receiver bandwidth and the receiver sensitivity. The application specific channel models will be less complex then the generic models, allowing for more efficient simulation and testing. This appendix explains in detail the derivation of the UMTS W-CDMA channel model from the generic channel model.

The receiver bandwidth, or chip rate, helps determine the time resolution for which individual taps of a fading model may be discerned by the receiver. If individual taps are very close together in time, the receiver will see them as just one tap. As found in 3GPP TR 25.943, if taps are within a time equal to half of the chip rate of each other then the receiver will see just one tap resulting in the assignment of a single finger for the signals in this delay bin. For UMTS W-CDMA the chip rate is 3.84 Mchips/s, leading to a tap resolution of 130.2nsec. Any taps in the generic channels models that are within this time will be seen as just one tap, and thus can be modeled as just one tap.

The receiver sensitivity determines the lowest power at which a tap will be seen by the receiver. This power is relative to the total power in the fading model. As stated in 3GPP TR 25.943, only taps where the power is within 25 dB of the total power need to be retained in the channel models.

The generic Rural Area Channel Model with ten (10) taps is shown in Table A.1. Figure A-1 below takes the information in Table A-1 above and provides a graphical representation of the power delay profile. Each tap is shown with its average relative power, and delay spread. As shown in Figure A-1, some of the multi-path taps are very close to each other along the temporal time delay axis (the x-axis).

Tap Number	Relative Time (nsec)	Average Relative Power (dB)	Doppler Spectrum
1	0	-5.2	direct path, $f_s = 0.7 * f_d$
2	42	-6.4	classical
3	101	-8.4	classical
4	129	-9.3	classical
5	149	-10.0	classical
6	245	-13.1	classical
7	312	-15.3	classical
8	410	-18.5	classical
9	463	-20.4	classical
10	528	-22.4	classical

Table A-1. Generic Rural Area channel model from Table 5.3 of 3GPP TR 25.943

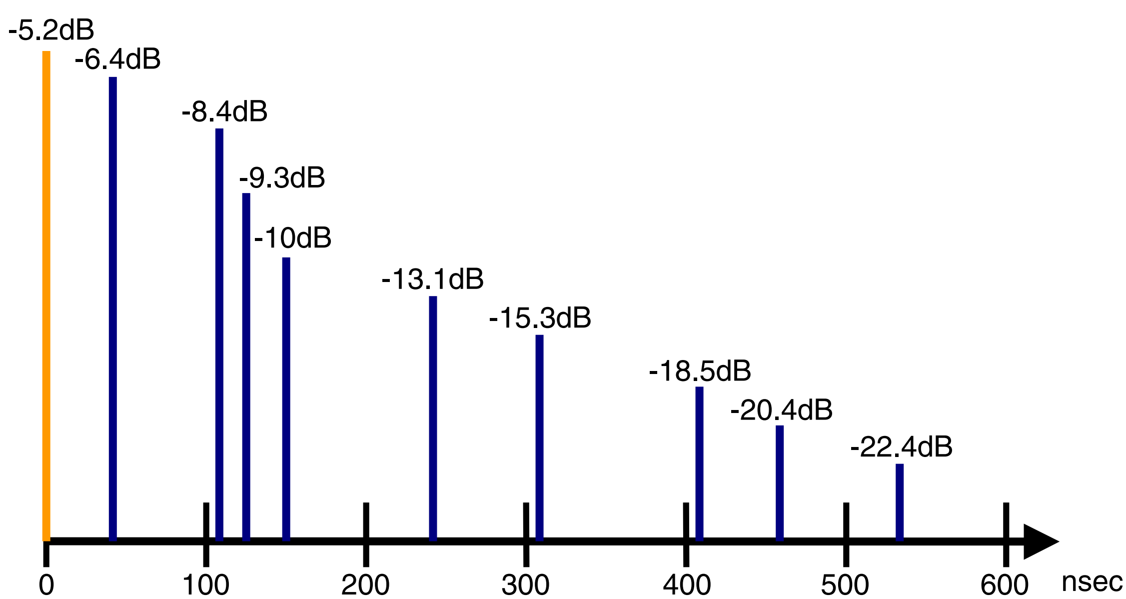

Figure A-1. Generic Power Delay Profile for Rural Area from 3GPP TR 25.943

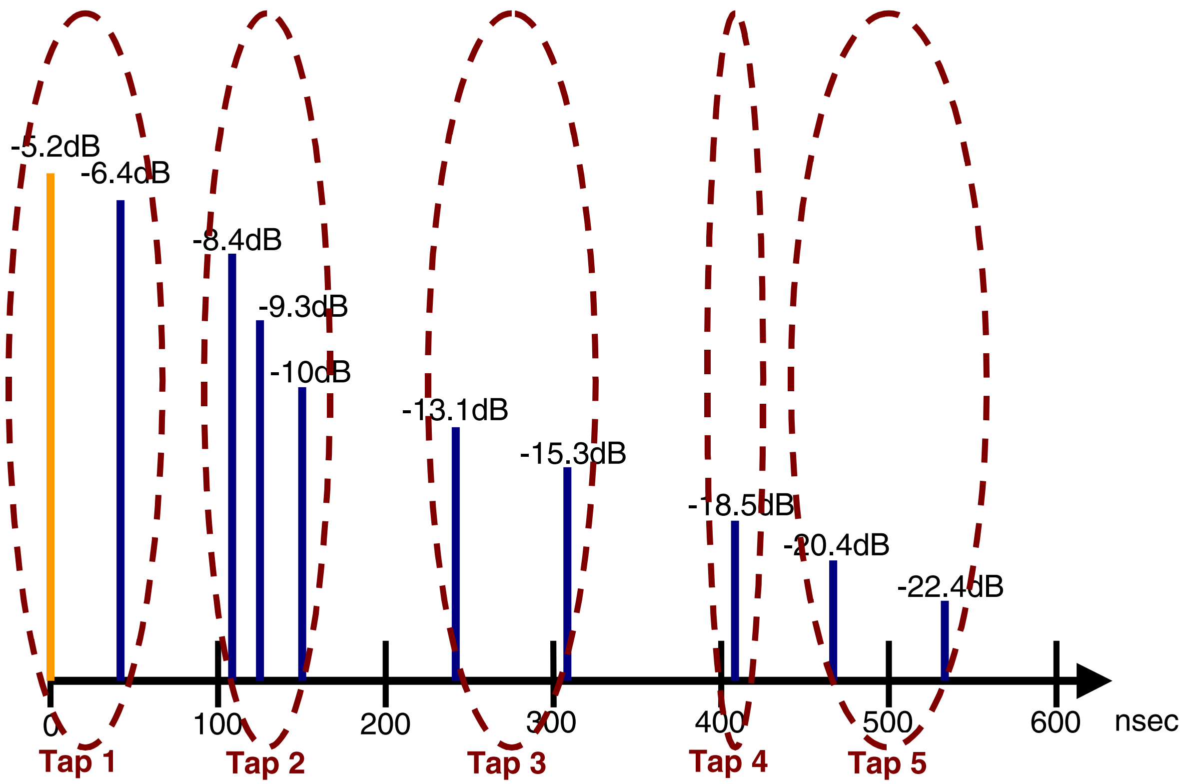

Figure A-2. Quantized Power Delay Profile for Rural Area from 3GPP TR 25.943

Figure A-2 above illustrates the power delay profile of the generic Rural Channel Model where taps within ½ chip rate of each other are grouped together. This may be referred to as a profile that has been quantized at Δt=½ chip rate. Taps that are close together in time will be seen as just one tap by the receiver. Notice that the number of taps necessary to perform the channel model for the Rural Area decreased from ten (10) taps as shown in the original Figure A-1 to five (5) taps in Figure A-2 after the quantization.

Tap Number	Relative Time (nsec)	Average Relative Power (dB)	Doppler Spectrum
1	0	-5.2	direct path, $f_s = 0.7 * f_d$
2	42	-6.4	classical
3	101	-8.4	classical
4	129	-9.3	classical
5	149	-10.0	classical
6	245	-13.1	classical
7	312	-15.3	classical
8	410	-18.5	classical
9	463	-20.4	classical
10	528	-22.4	classical

New Tap Nmbr.	Tap Relative Quantized time (nsec)	Relative sampling range (nsec)	Tap # from Table 5.3 TR 25.943 v.4.0.0	Tap powers from Table 5.3 sampled into this delay bin (dB)	Total avg. rel. pwr. sampled into this delay bin (dB)
1	0.0	0.0 – 65.1	1, 2	-5.2 dB (direct), -6.4 dB (classical)	
2	130.2	65.1 – 195.3	3, 4, 5	-8.4 dB, -9.3 dB, -10.0 dB	-4.4 dB
3	260.4	195.3 – 325.5	6, 7	-13.1 dB, -15.3 dB	-11.1 dB
4	390.6	325.5 – 455.7	8	-18.5 dB	-18.5 dB
5	520.8	455.7 – 585.9	9,10	-20.4 dB, -22.4 dB	-18.3 dB

Figure A-3. Mapping Generic Rural Area (RAx) Model to UMTS W-CDMA RAx Model

Figure A-3 shows how the generic Rural Area model maps over into a UMTS W-CDMA model. The quantization is in increments of Δt=½ chip rate for Figure A-3. The chip rate for UMTS W-CDMA is 3.84 Mchips/s which equates to 260.4 nanoseconds. Therefore, ½ chip rate is 130.2nsec (260.4nsecs/2). Thus every new tap is in n * 130.2nsec increments: 0.0nsec, 130.2nsec, 260.4nsec, 390.6nsec, etc where n is a series of positive integer numbers starting at 0. The sampling range, also referred to as a delay bin, is +/- ½ the quantization factor, which in the case of Δt=½ chip rate is 130.2 nsec/2 = 65.1 nsec. For example, Tap # 2 is at the position of 130.2nsec. Tap # 2's sampling range is calculated as follows: 130.2nsec – 65.1nsec = 65.1nsec and 130.2nsec + 65.1nsec = 195.3nsec. So the sampling range on Tap # 2 is from 65.1 nsec to 195.3 nsec as shown in the lower table in Figure A-3.

Each of the original taps moves into the corresponding rows for the new model, as depicted by the arrows, based on the relative sampling time. For example, original taps 3, 4, and 5 move into new tap # 2 because the their relative time offset, 101 nsec, 129 nsec, and 149 nsec, fall within the 65.1 nsec to 195.3 nsec associated with the new tap # 2.

Since multiple taps are quantized and sampled together, the power level associated with each original tap gets summed to determine the new total relative average power based on the following equation.

$$P_{av} = 10\log_{10}(10^{(P1/10)} + 10^{(P2/10)} + \ldots + 10^{(Pn/10)})$$

So in the case of the example of new tap # 2, the power associated with old taps 3, 4, and 5 are used in the equation above to determine total average relative power as follows:

$$P_{av} = 10\log_{10}(10^{(-8.4/10)} + 10^{(-9.3/10)} + 10^{(-10/10)})$$

$$P_{av} = -4.4\text{dB}$$

Thus the right most column for new tap # 2, indicates the value of the total average relative power above, -4.4dB.

Based on the techniques outlined in this appendix, the UMTS W-CDMA deployment channel models were calculated and presented in this document.