Source: **Nortel Networks**

Title: **Node B Angle Spread**

Document for: **Discussion**

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1. Introduction

In 3GPP there have been a number of submissions [1][2][3] proposing various values and methods for modelling the angle spread as seen at the Node B. These are aimed at addressing the per path angle spread, section 2.5.2 of [4], the per path Node B Angle of Arrival (AoA[1]), section 2.5.3 of [4] and the per path Node B Power Azimuth Spectrum (PAS), section 2.5.4 of [4], issues identified in the Spatial Channel Model Text document [4].

This document considers the method of including Node B angle spread, as proposed by Qualcomm in [1]. In [1] Qualcomm proposed that each resolvable tap, within the transmission bandwidth, should have either a 2° or 5° RMS angle spread[2] and all taps are assumed to be at the mean AoA.

The assumption of all taps arriving/departing from the same angle is non-physical since this infers that the scatterers for the different taps are co-located and hence an increase in the number of resolvable components as seen at the Node B does not increase the angle spread as seen at Node B. This is not consistent with observations based on measurements.

2. Node B Angle Spread Example Measurement

Figure 3-1 and Table 3-1 present results derived from an example urban measurement of both the temporal and angular dispersion of a UE transmitted signal when observed at the Node B. The top left hand plot of Figure 3-1 shows how the power, which is denoted by colour, is spread both in angle, as given on the y-axis, and in delay, as given on the x-axis. The bottom right hand plot of Figure 3-1 shows all the chip resolvable components, i.e. taps when assuming a 5MHz transmission bandwidth, above a -10dB threshold, that are present in the delay/angle/power measurement plotted in the top left hand plot of Figure 3-1. The top right hand plot of Figure 3-1 shows the PAS for the discrete tap resolvable components identified above the -10dB threshold and the bottom right hand plot of Figure 3-1 the Channel Impulse Response (CIR).

To determine the change in RMS angle spread with the inclusion of an increased number of taps, the cumulative RMS angle spread was determined using taps 1 to 20, which were identified previously above the specified -10dB power threshold. The results obtained are presented in Table 3-1 which shows clearly that the RMS angle spread at the Node B increases as a function of the number of taps considered.

3. Cumulative Angle Spread at the Node B and Laplacian PASs per tap

The increase of RMS angle spread with the increase in the number of taps considered shows that the taps cannot be assumed to have the same mean AoA and spread as proposed in [1]. A realistic model must assign different mean AoAs to each tap. When allocating these AoAs to taps it should be remembered that each tap as well as the envelope PAS as observed at the Node B are assumed to all have a Laplacian PAS. The taps are assumed to have Laplacian PAS with either σ = 2° or 5° and the cumulative effect as seen at the Node B is assumed to be a Laplacian PAS with σ = 12°. To maintain these two stipulations it is

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[1] which is the same as Angle of Departure (AoD) and so AoA and AoD can be used interchangably

[2] σ_{rms}=2° when the mean AoA at the Node B is 50° and σ_{rms}=5° when the mean AoA at the Node B is 20°

necessary to determine angles for the Laplacian PASs associated with the taps to angles which yield an envelope PAS that is a Laplacian with σ=12°.

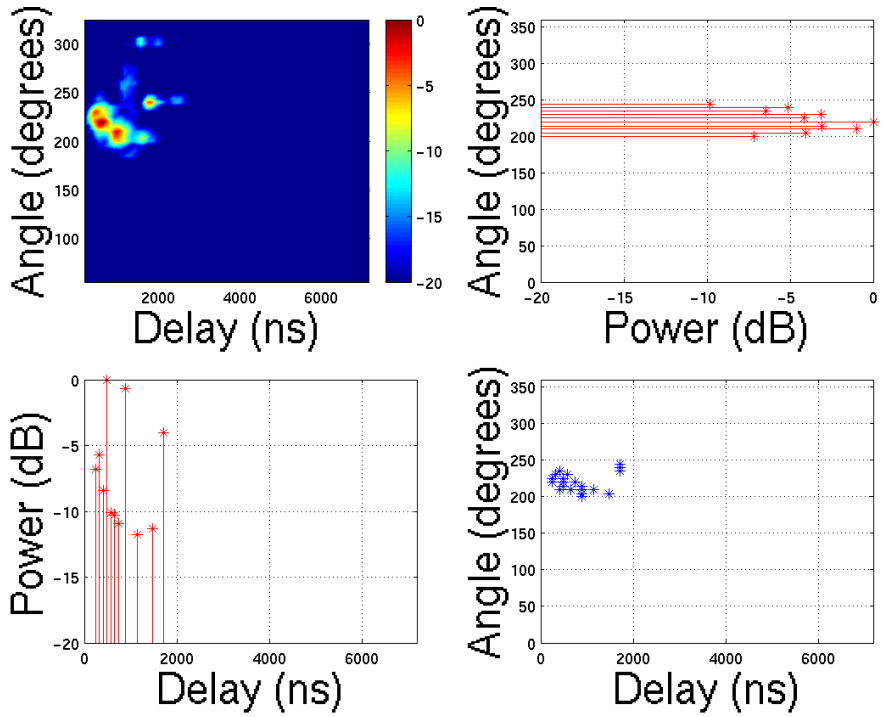

Figure 3-1 Example delay/angle power measurement as seen at the Node B

Tap Number	Cummulative RMS angle spread
1	0.0
2	1.5
3	2.5
4	5.6
5	6.1
6	7.0
7	5.5
8	5.3
9	5.4
10	5.9
11	5.8
12	7.8
13	8.7
14	8.5
15	8.4
16	8.3
17	8.5
18	8.9
19	10.2
20	10.8

Table 3-1 The increase in RMS angle spread (degrees) with the number of taps

To investigate what AoAs could be attributed to the typical 6 taps that are employed in the ITU models, Matlab™ code was written that would position equal powered, 2° Laplacian PASs associated with the taps at specified angles, calculate the envelope PAS of these, and then compare this to a 12° Laplacian PAS. The integral of power contained in the 12° Laplacian was set to be the same as the total power contained in the six 2° Laplacian PASs to enable a fair comparison.

Whilst it is appreciated that the ITU channel models do have taps with different powers, the conclusions reached by considering the equal powered tap case are still applicable. Introducing relative powers between the taps may provide a match to a specific angle of the envelope 12° Laplacian, but the delta function form of power decay means that it is still not possible using 6 taps to provide a reasonable representation of a 12° Laplacian PAS. In fact the low powers attributed to a number of the taps in the ITU channel models means that the effective number of 2° Laplacian PASs is reduced and hence so is the ability to construct a 12° Laplacian PAS.

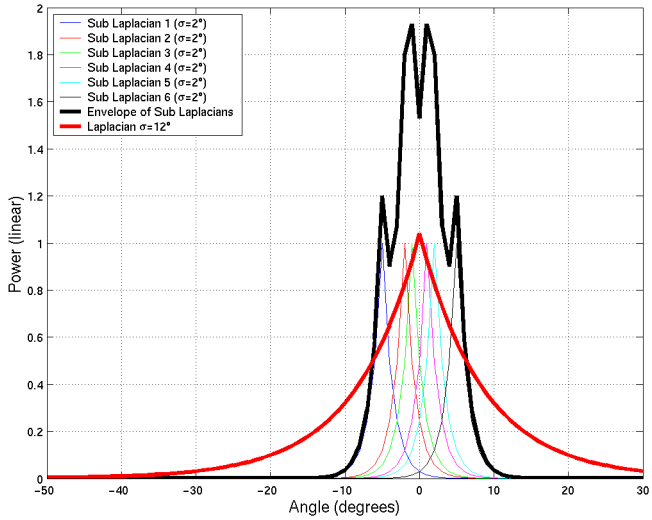

Figure 3-2 Cumulative PAS as seen at the Node B when assuming 6 sub-Laplacians of σ=2° are centred at -5°, -2°, -1°, 1°, 2° and 5°.

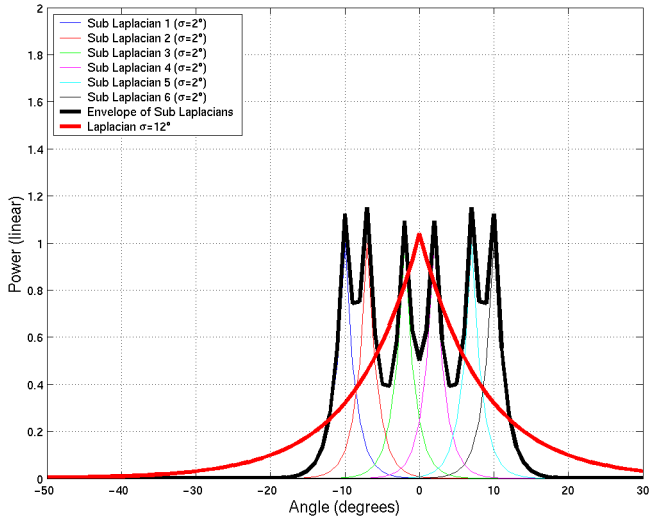

Figure 3-3 Cumulative PAS as seen at the Node B when assuming 6 sub-Laplacians of σ=2° are centred at -10°, -7°, -2°, 2°, 7° and 10°.

The results of two example tap AoA cases are shown in Figure 3-2 and Figure 3-3. They both highlight the problem that due to the delta like form of the 2° Laplacian PASs associated with the taps it is not possible, through the use of different AoAs (as seen at the Node B) to generate a reasonable approximation to a 12° Laplacian PAS. This suggests that either the assumption of Laplacian PAS for each tap, the assumption of a Laplacian envelope PAS or the use of 6 taps, is not appropriate when modelling the angle spread at the Node B since the assumptions are not self consistent.

Taking a more simplified view of what we want to achieve, we wish to attribute AoAs to the taps of the ITU model in such a way, that they yield a 12° RMS angle spread as seen at the Node B for cases where Rayleigh fading on each tap is assumed. For the Outdoor to Indoor and Pedestrian Channel A case which has been modified to have a K=6dB Ricean component for the first arriving tap, as proposed in [4], then the cumulative PAS of the non-Ricean components should still have a 12° RMS angle spread, but the inclusion of a dominant component should reduce the overall RMS angle spread, providing a parallel to the comparable effect observed in measurements[3]. This means that in the Ricean Outdoor to Indoor and Pedestrian Channel A environment the AoAs attributed to all the Rayleigh fading taps should be the same as those attributed to the non-Ricean Outdoor to Indoor and Pedestrian Channel A case. The only difference in will be the inclusion of an extra, Ricean component, at 0ns delay, and hence it will be attributed the mean AoA, which is either 20° or 50°.

4. Attributing AoAs to taps of the ITU models to provide 12° RMS Angle Spread

To determine what AoAs attributed to each of the tapped delay line representations of the ITU models would provide a 12° RMS angle spread a Matlab™ script was written that would randomly attribute angles about either the 20° or 50° mean AoA (as seen at the Node B) to each tap. For each channel type of the two ITU environments the routine was run for 1000 different AoA combinations and those that yielded RMS angle spreads between 11.5° and 12.5° were recorded. It should be noted that random combinations of angles within ±30° about the mean AoA were used for all ITU tapped-delay lines except for the Outdoor-to-Indoor & Pedestrian Channel A case, which due to only having four low powered taps, required a wider angle window of ± 50° to be explored to achieve the required 12° RMS angle spread value.

The proposed (A) and (B) channel definitions extracted from [5] for the two ITU specified test environments relevant to the outdoor environment are given in Table 4-1 and Table 4-3 and the Outdoor to Indoor and Pedestrian environment which was modified to include a Ricean component on the first arriving tap in Table 4-2. These ITU channel definitions have had AoA information attributed to each tap, for both the AoA = 20° and AoA =50° cases, by using one of the AoA combinations determined by the Matlab™ code that has been shown to yield an RMS angle spread close to 12°. It should be noted that there are many combinations of AoAs that can yield the same RMS angle spread (for a given set of tap powers) although the variability of them is dependent upon the powers of the taps with which they are associated. For example, the AoA of a strong powered tap is more constrained in possible values that it can take to provide the specified RMS angle spread, whereas the lower powered taps, contriubute less to the RMS angle spread and hence can take a much wider range of possible values. The AoAs attributed to ITU tap powers to yield a 12° RMS angle spread given in Table 4-1 and Table 4-3 have been arbitrarily chosen, but with the criteria that they should typically have an equal number of taps with AoAs (at the Node B) that have angles greater and less than the mean AoA or either 20° or 50°. Also the angle for the first arriving tap is always set to be the same as the mean AoA.

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3 i.e clear routes that enable strong powered Ricean components suppress the relative significance of the weaker powered components causing the RMS angle spread to decrease

Tap No.	Channel A (non-Ricean first tap case)				Channel B			
	Rel. Delay (ns)	Avg. Power (dB)	Tap AoAs for 20°	Tap AoAs for 50°	Rel. Delay (ns)	Avg. Power (dB)	Tap AoAs for 20°	Tap AoAs for 50°
1	0	0	20	50	0	0	20	50
2	110	-9.7	-19	10	200	-0.9	10	66
3	190	-19.2	32	16	800	-4.9	37	48
4	410	-22.8	-22	41	1200	-8.0	-4	20
5	-	-	-	-	2300	-7.8	45	68
6	-	-	-	-	3700	-23.9	15	37

Table 4-1 Outdoor to indoor and pedestrian test environment tapped delay line parameters

Tap No.	Channel A (Ricean first tap case K=6dB)			
	Rel. Delay (ns)	Avg. Power (dB)	Tap AoAs for 20°	Tap AoAs for 50°
1	0	0	20	50
2	0	-6.51	20	50
3	110	-16.21	-19	10
4	190	-25.71	32	16
`5	410	-29.31	-22	41
6	-	-	-	-

Table 4-2 Modified Outdoor to indoor and pedestrian test environment (K=6dB for first tap)

Tap No.	Channel A				Channel B			
	Rel. Delay (ns)	Avg. Power (dB)	Tap AoAs for 20°	Tap AoAs for 50°	Rel. Delay (ns)	Avg. Power (dB)	Tap AoAs for 20°	Tap AoAs for 50°
1	0	0.0	20	50	0	-2.5	20	50
2	310	-1.0	-1	31	300	0	3	28
3	710	-9.0	4	73	8900	-12.8	37	44
4	1090	-10.0	38	29	12900	-10.0	43	63
5	1730	-15.0	44	41	17100	-25.2	2	56
6	2510	-20.0	32	52	20000	-16.0	32	59

Table 4-3 Vehicular test environment tapped delay line parameters

The RMS angle spread values for the 20° and 50° mean AoA cases for the different ITU channel models are presented in Table 4-4. The first RMS angle spread values, i.e. the ones not in brackets, were derived when simply multiplying tap powers by tap angles, thereby implicitly assuming a delta function PAS. The second RMS angle spread values, i.e. the ones enclosed by brackets, are the RMS angle spreads obtained when assuming that each Rayleigh fading tap has a Laplacian PAS centred on the tap AoAs. It should be remembered that the standard deviation of the Laplacian is 5° when assuming a 20° mean AoA and 2° when assuming a 50° mean AoA.

	Channel A		Channel B	
	AoA = 20°	AoA=50°	AoA = 20°	AoA=50°
Outdoor-to-Indoor & Pedestrian	11.8° (12.8°)	12.1° (12.3°)	12.2° (13.2°)	12.1° (12.3°)
Outdoor-to-Indoor & Pedestrian (Ricean first arriving tap K=6dB)	5.5° (5.7°)	5.7° (5.8°)	-	-
Vehicular	12.3° (13.2°)	12° (12.0°)	12.1° (13.1°)	12.2° (12.3°)

Table 4-4 RMS Angle Spreads for ITU channel Models using attributed tap AoAs

The results in Table 4-4 show that the tap AoAs derived for the ITU models when simply assuming a delta function PAS are in all cases within 1° of the comparable solutions when assuming Laplacian PASs. As expected the largest differences are observed for the mean AoA =20° case where the standard deviation of the Laplacian is 5° and hence provides a poorer approximation to a delta function than a Laplacian with a 2° standard deviation.

It should be noted that the AoAs chosen and presented in this document can be optimised further to provide a better match to the required 12° RMS angle spread if this method of allocating AoAs to the taps of the ITU channel models is accepted by the SCM Group. The aim of this document is merely to present the method and some example results, these are not necessarily intended to be the optimal figures integrated into the SCM Text document [4]. Also the technique of attributing AoAs to the ITU taps to achieve a specified RMS angle spread is generic and can be used for RMS angle spreads other than 12° if required. It is recognised that tap AoAs can be derived directly for the Laplacian PAS case, however since the difference between the assumptions of a Laplacian and delta function PAS appear so small, and to simulate the Laplacian case is more processor intensive and requires changing the σ of the Laplacian depending upon the mean AoA, i.e. 20° or 50°, then it appears reasonable to use the tap AoAs derived for the delta function PAS case.

5. Summary

This contribution has shown that taps have different AoAs (as seen at the Node B) and this is critical in defining the RMS angle spread as seen at the Node B.

The attributing of AoAs to the Laplacian PASs associated with each tap was considered with a view to yielding an envelope Laplacian PAS with a σ = 12° and was shown to provide a poor match given the delta function form of a 2° or 5° Laplacian and the limited number of them, i.e. 6. The inability of 6, 2° Laplacians to form a 12° Laplacian envelope as seen at the Node B, suggests that these assumptions are not self consistent and hence should be reconsidered.

Finally this contribution considered a simplified view of the problem of providing each of the outdoor ITU models with an overall RMS angle spread of 12° for the Rayleigh fading taps. It was assumed that fundamentally, the Rayliegh fading taps of the ITU models must be allocated AoAs such that the RMS angle spread is 12°. A simple Matlab™ script was used to determine a number of possible sets of AoAs for each ITU channel, that would fulfil these criteria. One of these AoA sets was arbitrarily chosen for each ITU channel model and is presented in Table 4-1 and Table 4-3. The special Ricean Outdoor to Indoor and Pedestrian Channel A case was considered a method of attributing AoAs that is consistent with empirically observed trends was proposed and implemented, and a set of AoAs for the both the 20° and 50° mean AoA cases provided (see Table 4-2). It is recognised that attributing AoAs via this technique does mean that the envelope PAS is not going to be Laplacian in form. However as mentioned previously this assumption is not necessarily consistent with the assumed Laplacian form of each tap within a channel.

6. References

[1] Qualcomm, 'Spatial Channel Model Evaluation Methodology for Link Level Analysis', 3GPP, SCM-017_Qcom_revision_LL, Paris, France, April 9th 2002.

[2] Telia AB, 'Scenarios and requirements for MIMO evaluation', R1-02-0246, TSG-RAN WG1#24, Orlando, USA, February 18th - 22nd 2002

[3] France Telecom, 'MIMO Channel Modelling', R1-02-0634, TSG-RAN WG1#25, Paris, France, April 9th-12th 2002

[4] Spatial Channel Model AHG (combined ad-hoc from 3GPP & 3GPP2), 'Spatial Channel Model Text Description', document in progress, last updated May 2nd 2002

[5] 'Universal Mobile Telecommunications System (UMTS); Selection procedures for the choice of radio transmission technologies of the UMTS (UMTS 30.03 version 3.2.0)', ETSI, TR 101 112 V3.2.0, 1998-04.