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Title	**Channel models for long range deployments**
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Re:	
Abstract	This document suggests an additional model for TG3, for long range deployments
Purpose	Add a long-range channel model to the existing SUI models.
Notice	
Release	
Patent Policy and Procedures	

Channel models for long range deployment

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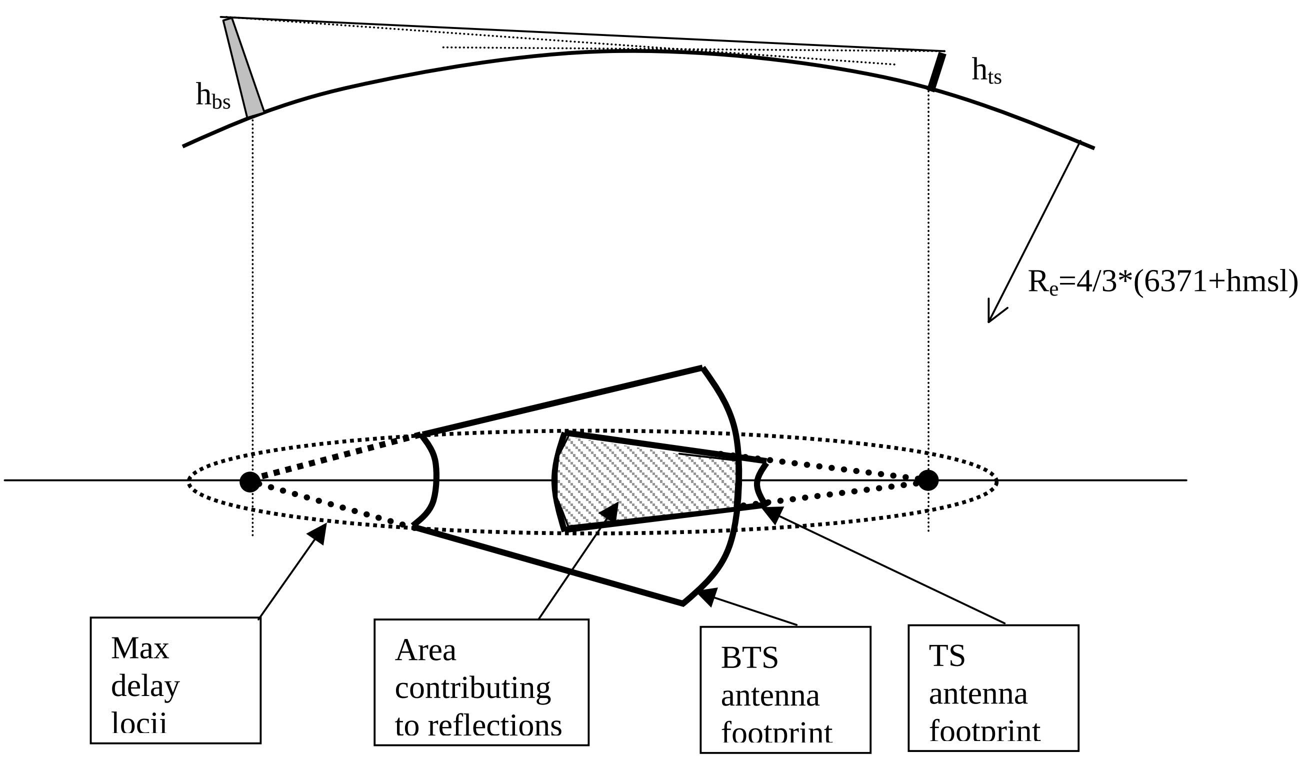
Introduction

The scenarios for which TG3 channel models, described in [1], were developed refer to cells of 7km size, which are considered to be typical for those types of applications. However, as mentioned in [2] and [3], super-cell configurations are also possible, especially in the initial phase of deployment. For those cases there is a need to define channel models for 30km size cells. In this document such models, based on an extrapolation of the SUI models, are suggested.

Conditions for extrapolation

The basic geometry of the problem is depicted in figure 1 below. The area contributing to reflections is the intersection of the BTS antenna footprint, TS antenna footprint, and the horizon radii of the BTS and TS for a given object height.

The antenna heights defined for the SUI models in [1] were 30m (base station) and 6m (terminal station). The horizon distance for those antenna heights is 23km (for the base station) and 10km for the terminal station, giving together a possible cell size of 33km. The cell size used in [1] was only 7 km, however, it is possible to use such antenna heights for super-cell configurations of 30km cells. Obviously, the gain of the antennas, their tilt, their transmission power and receiver sensitivity should be adjusted for operation in the super-cell's 30km range.



Figures 2,3 and 4 describe the behavior of the maximal delay and the total illuminated area as a function of cell size (with a possible reflecting object height as a parameter). Figure 2 describes that for the case where both base station and terminal station antennas have omni-directional pattern. In this case it is the horizon radii, which affects the result. In this case the illuminated area geometry, which is determined mainly by the terminal station antenna height, does not change with cell size until a certain breakpoint is reached. Following that point, both the maximal delay and the total illuminated area decreases linearly. Figure 3 depicts the case of an omni-directional base station, and a terminal station, which uses a directional antenna. In this case, mainly the terminal station footprint determines the illuminated area geometry. The maximal delay decreases as the range increases, while the illuminated area remains constant until a certain break point is reached. Figure 4 describes the case where both terminal station and base station use directional antenna. In this case the intersection of the footprints determines the geometry. The maximal delay increases linearly with cell size, and the total illuminated area increases linearly with the square of the cell size.

Assuming the SUI models, and the equations in [1], describe the dependency of the delay spread and the K factor reliably, up to a range of 10km, and assuming most reflections are generated by objects 6m and higher, we can safely use the values for the delay spread and K-factor formulation of [1] up to cell sizes of 30km, for the directional- directional antenna case. For the other cases, it might be advisable to use a lower value of the range power, ε, in the delay spread equation, and a lower (more negative) value for the range dependency power, γ, in the K-factor formula, to reflect the fact that the maximal delay is reduced in higher ranges, and the illuminated area is reduced as well.

Extrapolation of the Values

Using the formulas, and methods suggested in [1], the following values for the delay spread, Doppler spread and K – factors should be expected:

$$\tau_{rms}(30km) = \tau_{rms}(7km)\left(\frac{30}{7}\right)^{\varepsilon}$$

$$K(30km) = K(7km)\left(\frac{30}{7}\right)^{\gamma}$$

With ε between 0.5 and 1, and $\gamma = -0.5$.
Thus the values for the long range super-cells are summarized in table 1, taking $\varepsilon = 0.75$.

Table 1: Values for τ_{rms} and K for super-cells

Extrapolated model	τ_{rms} (μs)	K		
		90%	75%	50%
SUI-1, Omni antenna	0.307	1.6	5.02	
SUI-1, 30^o antenna	0.122	6.8	21.4	
SUI-2, Omni antenna	0.596	0.77	2.46	
SUI-2, 30^o antenna	0.226	3.33	10.5	
SUI-3, Omni antenna	0.908	0.24	0.77	
SUI-3, 30^o antenna	0.444	1.06	3.38	
SUI-4, Omni antenna	4.006	0.1	0.29	
SUI-4, 30^o antenna	2.017	0.48	1.55	
SUI-5, Omni antenna	9.094	0.05	0.14	0.46
SUI-5, 30^o antenna	4.447	0.19	0.63	2.0
SUI-6, Omni antenna	15.608	0.05	0.14	0.46
SUI-6, 30^o antenna	7.059	0.19	0.63	2.0

Using those numbers for the models themselves:

Extrapolated SUI-1 Channel Model				
	Tap 1	Tap 2	Tap 3	Units
Delay	0	1.19	2.68	µs
Power - Omni Antenna	0	-15	-20	dB
90% K-Factor (omni)	2	0	0	
75% K-Factor (omni)	7	0	0	
Power - 30 Antenna	0	-21	-32	dB
90% K-Factor (30 deg)	7	0	0	
75% K-Factor (30 deg)	26	0	0	

Extrapolated SUI-2 Channel Model				
	Tap 1	Tap 2	Tap 3	Units
Delay	0	1.2	3.3	µs
Power - Omni Antenna	0	-12	-15	dB
90% K-Factor (omni)	1	0	0	
75% K-Factor (omni)	4	0	0	
Power - 30 Antenna	0	-18	-27	dB
90% K-Factor (30 deg)	4	0	0	
75% K-Factor (30 deg)	13	0	0	

Extrapolated SUI-3 Channel Model				
	Tap 1	Tap 2	Tap 3	Units
Delay	0	1.2	2.7	µs
Power - Omni Antenna	0	-5	-10	dB
90% K-Factor (omni)	0	0	0	
75% K-Factor (omni)	2	0	0	
Power - 30 Antenna	0	-11	-22	dB
90% K-Factor (30 deg)	1	0	0	
75% K-Factor (30 deg)	5	0	0	

Extrapolated SUI-4 Channel Model				
	Tap 1	Tap 2	Tap 3	Units
Delay	0	4.5	11.9	µs
Power - Omni Antenna	0	-4	-8	dB
90% K-Factor (omni)	0	0	0	
75% K-Factor (omni)	1	0	0	
Power - 30 Antenna	0	-10	-20	dB
90% K-Factor (30 deg)	1	0	0	
75% K-Factor (30 deg)	2	0	0	

Extrapolated SUI-5 Channel Model				
	Tap 1	Tap 2	Tap 3	Units
Delay	0	11.9	29.8	µs
Power - Omni Antenna	0	-5	-10	dB
90% K-Factor (omni)	0	0	0	
75% K-Factor (omni)	0	0	0	
50% K-Factor (omni)	1	0	0	
Power - 30 Antenna	0	-11	-22	dB
90% K-Factor (30 deg)	0	0	0	
75% K-Factor (30 deg)	1	0	0	
50% K-Factor (30 deg)	3	0	0	

Extrapolated SUI-6 Channel Model				
	Tap 1	Tap 2	Tap 3	Units
Delay	0	41.7	59.6	ms
Power - Omni Antenna	0	-10	-24	dB
90% K-Factor (omni)	0	0	0	
75% K-Factor (omni)	0	0	0	
50% K-Factor (omni)	1	0	0	
Power - 30 Antenna	0	-16	-36	dB
90% K-Factor (30 deg)	0	0	0	
75% K-Factor (30 deg)	1	0	0	
50% K-Factor (30 deg)	2	0	0	

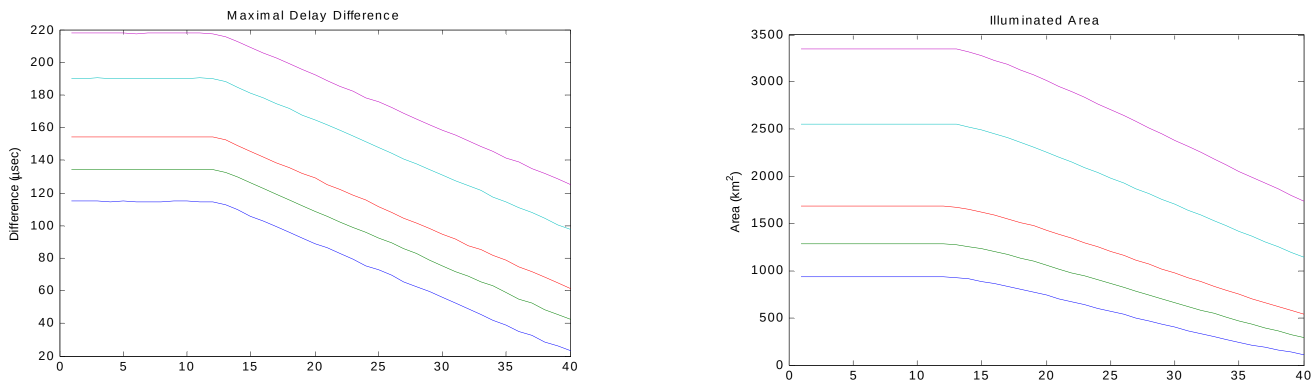


Figure 2: Maximal Delay and illuminated area for omni-directional antennas, for various obstacle heights (3, 6, 10, 20, 30 m)

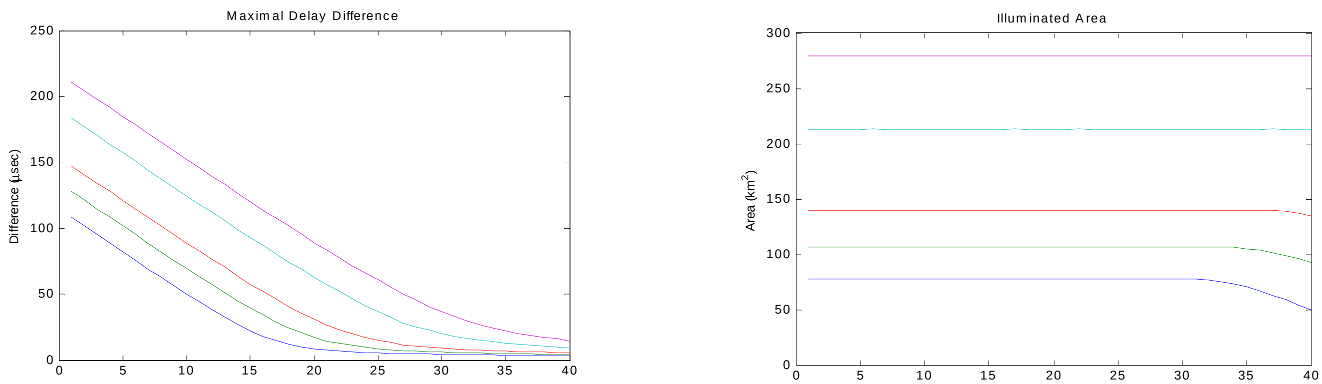


Figure 3: Maximal Delay and illuminated area for an omni-directional at the for base station and a directional antenna at the terminal station, for various obstacle heights (3, 6, 10, 20, 30 m)

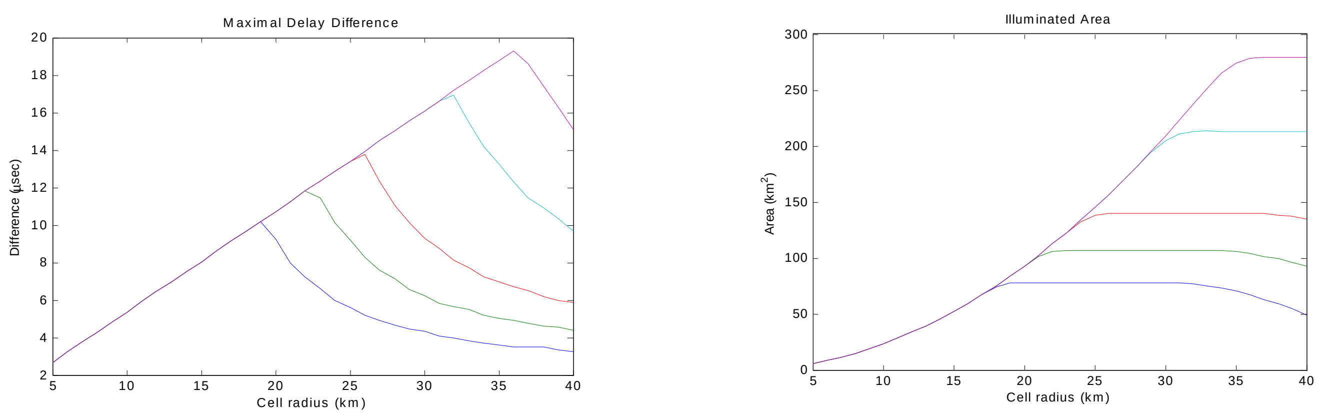


Figure 4: Maximal Delay and illuminated area for an omni-directional at the for base station and a directional antenna at the terminal station, for various obstacle heights (3, 6, 10, 20, 30 m)

References

[1] IEEE 802.16.3c-01/29r2: Channel Models for Fixed Wireless Applications
[2] IEEE 802.16.3-00/02r4: Functional Requirements for the 802.16.3 Interoperability Standard
[3] IEEE 802.16.3c-01/50: An Operator's perspective