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## TGac Channel Model Addendum

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***Note:***

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***explicit contributions and review comments.***

Abstract

This document provides the addendum to the TGn channel model document to be used for the Very High Throughput Task Group (TGac).

## Revision History

|  |  |  |
| --- | --- | --- |
| **Date** | **Version** | **Description of changes** |
| 03/09/09 | 1.0 | First Draft of TGac Channel Modem Addendum Document |
| 04/22/09 | 2.0 | Updates to Sections 2, 3 and 5. |
| 05/??/09 | 3.0 | Updates to all sections for May 2009 TGac meeting. Supporting material extracted to [3] |
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# Introduction

The TGn task group has developed a comprehensive MIMO broadband channel model, with support for 40 MHz channelization and 4 antennas [1]. The TGac task group is targeting >1 Gbps MAC SAP throughput using one or more of the following technologies:

* Higher order MIMO (> 4x4)
* Higher Bandwidth (> 40 MHz)
* Multi-User MIMO with > 4 AP antennas
* OFDMA

This document describes modifications to TGn channel models to enable their use for TGac. The reader is referred to [3] for supporting data and justification.

The scope of this document is limited to extensions of the existing TGn channel model definitions (*i.e.,* Models A-F). The introduction of a new model definition covering indoor corridor propagation is TBD.

# Modifications for Larger System Bandwidth

The TGn channel models assume minimum tap spacing of 10 ns and were employed for system bandwidth of up to 40 MHz. TGac systems may have much larger bandwidth. For TGac systems with larger overall system bandwidth, the channel sampling rate shall be increased by reducing the power delay profile (PDP) tap spacing by a factor of , where W is the new system bandwidth in MHz. These scaling factors are summarized in Table 1, for up to 1.28 GHz system bandwidth

Table : Channel sampling rate expansion (tap spacing reduction) factors

|  |  |  |
| --- | --- | --- |
| **System Bandwidth W** | **Channel Sampling Rate Expansion Factor** | **PDP Tap Spacing** |
| **W ≤ 40 MHz** | 1 | 10 ns |
| **40 MHz < W ≤ 80 MHz** | 2 | 5 ns |
| **80 MHz < W ≤ 160 MHz** | 4 | 2.5 ns |
| **160 MHz < W ≤ 320 MHz** | 8 | 1.25 ns |
| **320 MHz < W ≤ 640 MHz** | 16 | 0.625ns |
| **640 MHz < W ≤ 1.28 GHz** | 32 | 0.3125 ns |

The PDP tap spacing shall be reduced by generating new PDP taps based on linear interpolation of the TGn-defined PDP tap powers on a cluster-by-cluster basis using the following approach:

For each cluster in the TGn-defined model, and assuming a channel sampling rate expansion factor *k* (new sampling rate = *k*\*100MHz), a sequence of *k*-1 new PDP taps, spaced 10/*k* ns apart, shall be appended after each TGn-defined PDP tap. The first PDP tap in the sequence shall occur 10/*k* ns after the TGn-defined PDP tap. The power (in dB) assigned to each new tap shall be determined by linear interpolation of the TGn-defined PDP tap powers (in dB) immediately before and after the new PDP tap, in proportion to its position in time relative to the two TGn PDP taps. No new PDP taps shall be added after the final TGn PDP tap for each cluster.

Figure 1 illustrates this procedure for the example of *k*=4 (new channel sampling rate = 400MHz), for a hypothetical pair of TGn-defined PDP taps spaced 20ns apart. The TGn PDP taps are denoted by the thick grey arrows, and the new interpolated PDP taps are denoted by the thin black arrows. In this case, 3 new taps are added 2.5ns, 5.0ns, and 7.5ns after TGn Tap *i*. Power for each of the new PDP taps is derived from the line connecting the power of the TGn PDP Taps *i* and *i*+1, which accomplishes the dB-proportional power interpolation described above. This procedure is performed for all TGn PDP Taps *i* for *i*=1 to (*n\_taps*-1), where *n\_taps* is the number of PDP taps in the cluster being interpolated.



Figure : Illustration of PDP tap interpolation scheme for channel bandwidth expansion

Tap interpolation must be performed on the TGn cluster definitions themselves in order to allow for appropriate normalization of the NLOS PDP and ensure conservation of energy in the final modeled channel. This process is validated in [3], which shows that Ricean K is preserved after interpolation.

Note that since the interpolated PDP taps result in independent channel tap realizations, the newly generated TGac channel, post-interpolation, is a fundamentally different channel compared to TGn base channels. Such a TGac channel will have larger frequency diversity compared to TGn base channel. Hence, for development work going forward, it is recommended to state explicitly whether simulations are based on TGn or TGac versions of the channel models.

# Higher Order MIMO

The TGn channel models were originally conceived for systems with 4x4 MIMO, and are based on the Kronecker channel correlation model assumption [2].

The TGac channel models shall use the identical Kronecker correlation model for simulation of higher-order MIMO channels. See [3] for supporting measurements.

# Modifications to AoA and AoD for Multi-User MIMO with up to 16 AP Antennas

TGac requires specification of channels to multiple users as simultaneous communication will take place to multiple STAs in technologies like multi-user MIMO. The TGn channel model document specifies the cluster AoAs and AoDs for point-to-point single user transmissions. Extensions of these AoDs and AoAs to the multi-user case are needed.

Multi-user channels shall be modeled with the following modifications to the AoA and AoD for each client:

* Assume TGn-defined cluster AoDs and AoAs as baseline.
* For each client in the DL:
	+ Apply single random offset of ±180° to the LOS tap AoD and AoA.
	+ Apply single random offset of ±180° to the NLOS cluster AoA
	+ Apply single random offset of ±TBD° to the NLOS cluster AoD
* For each client in the UL:
	+ Apply single random offset of ±180° to the LOS tap AoD and AoA.
	+ Apply single random offset of ±TBD° to the NLOS cluster AoA.
	+ Apply single random offset of ±180° to the NLOS cluster AoD

Note: The random offsets mentioned above shall be generated using a well-known random number generator algorithm. [To be specified in the Appendix]

# Modifications to Doppler Components

Recent indoor channel measurements [4] indicate that the magnitude of Doppler assumed in the TGn channel model is too high. TGac shall use the Doppler model specified in the TGn channel model document, with the following modifications:

In Section 4.7.1 of TGn channel model document, the environmental speed, *v*o, may be reduced to TBD km/h.

See [4] for supporting data.

# Incorporating Dual-Polarized Antennas

By exploiting polarization diversity in the channel, dual-polarized antennas may provide significant improvement in MIMO channel capacity, especially in LOS scenarios. Furthermore, co-located dual-polarized antennas can minimize real estate in devices with large number of antennas, making them likely to be employed in TGac devices.

The TGac channel model may (TBD) use the TGn defined polarization model with the following parameters:

* XPD value of 10 dB for channel elements representing transmission between orthogonally-polarized antennas in the steering matrix *HF*
* XPD value of 3 dB for for channel elements representing transmission between orthogonally-polarized antennas in the variable matrix *Hv*
* Correlation of 0.2 for co-located orthogonally-polarized antenna elements
* Correlation of zero for non-colocated orthogonally-polarized antenna elements

The channels incorporating XPD shall be normalized only to the norm of the co-polarized elements of the channel matrix. This is because normalization to the Frobenius norm of the entire channel matrix will fail to account for the additional path loss due to transmitting and receiving on orthogonal polarizations.

# References

1. Erceg, V. et al. “TGn Channel Models.” Doc. IEEE802.11-03/940r4.
2. Schumacher, L.; Pedersen, K.I.; Mogensen, P.E., "From antenna spacings to theoretical capacities - guidelines for simulating MIMO systems," *Personal, Indoor and Mobile Radio Communications, 2002. The 13th IEEE International Symposium on*, vol.2, no., pp. 587-592 vol.2, 15-18 Sept. 2002.
3. Breit, G. et al., “TGac Channel Model Addendum Supporting Material,” Doc. IEEE802.11-09/0569r0
4. Yasushi, T. et al., “Measured Doppler Frequency in Indoor Office Environment,” Doc. IEEE802.11-09/537r0