



Contents

1	Introduction	1
1.1	Large-Signal Model Types	2
1.2	GaN HEMT Modeling Challenges	3
1.3	Outline of the Thesis	5
2	GaN HEMT Modeling Strategy	7
2.1	AlGaIn/GaN HEMT	8
2.1.1	AlGaIn/GaN HEMT Structure	8
2.1.2	Basic AlGaIn/GaN HEMT Operation	9
2.2	GaN HEMT Small-Signal Modeling	10
2.2.1	Extrinsic Parameter Extraction	11
2.2.2	Intrinsic Parameters Extraction	18
2.3	GaN HEMT Large-Signal Modeling	21
2.3.1	Nonlinear Circuit Modeling	22
2.3.2	Large-signal Capacitances Modeling	25
2.4	Trapping Effects in GaN HEMTs	32
2.4.1	Physical Mechanisms of Trapping Effects	32
2.4.2	Gate-Lag Effects	34
2.4.3	Drain-Lag Effects	36
2.4.4	Overview of the Published Models	39
3	Pulsed S-Parameter Measurements	45
3.1	Principle of Pulsed Measurements	46
3.2	Pulsed S-Parameter Measurement Test Bench	48
3.3	Pulsed Measurement Characteristics	49
3.3.1	Device Self-Heating Reduction	49



3.3.2	Traps Isolation	52
4	GaN HEMT Modeling Based on Pulsed S-Parameter Measurements	55
4.1	Small-Signal Modeling	56
4.1.1	Extrinsic Parameters	56
4.1.2	Intrinsic Parameters	60
4.1.3	Small-Signal Model Verification	63
4.2	Large-Signal Modeling	65
4.2.1	Drain-Source Current Model Parameters	66
4.2.2	Capacitance Model Parameters	68
4.3	Large Signal Model Verification	70
4.3.1	I/V Characteristics	70
4.3.2	S-Parameters	72
4.3.3	Load-Pull Performance	74
4.4	Conclusions	76
5	Parameter-Scaling Drain-Lag Model	77
5.1	Large-signal Model Extending	78
5.1.1	Extending the Large-signal Model	78
5.1.2	Models with Scaled Parameters Verification	80
5.2	Drain-lag Model based on Scaled Parameters	84
5.2.1	Model Description	84
5.2.2	Model Parameter Extraction	88
5.2.3	Model Verification	88
5.3	Discussion of Model Limitations	93
5.4	Conclusions	95
6	Combined Drain-Lag Model	97
6.1	Model Development	97
6.1.1	Developed Large-Signal Model Topology	98
6.1.2	Output Conductance Match	100
6.2	Model Parameter Extraction	101
6.3	Model Verification	104
6.3.1	Pulsed I/V Characteristics	104
6.3.2	Pulsed S-Parameters	106



6.3.3	Load-Pull Performance	107
6.3.4	Low-Frequency Large-Signal Behavior	109
6.4	Conclusion	111
7	General Conclusions and Future Work	113
7.1	Key Research Results	113
7.2	Future Works	116
A	i_{ds}-Related Parameters	117
B	Classical Capacitances and Transcapacitances	119
C	List of Symbols	121
D	List of Abbreviations and Acronyms	123