INDEX

λ/4 transmission line, see quarter-wave transmission line

1-dB compression point, definition, 132

ACLR, see adjacent-channel leakage ratio
ACPR, see Adjacent channel power ratio
ACPR1, see adjacent-channel power ratio
ACPR2, see alternate-channel leakage ratio
active area adjustment, see device periphery adjustment
active load-pull measurement, see load-pull
active load-pulling effect, 181
additive white Gaussian noise, 134
adjacent channel
    definition, 134–135
    interference, 5, 10, 133
    offset for IS-95, 163
    offset for WCDMA, 193
adjacent-channel leakage ratio, see adjacent-channel power ratio
adjacent-channel power ratio, definition, 133

AlGaAs/GaAs HBT, see GaAs HBT,
    also bipolar device models
alternate channel
    definition, 134
    offset for IS-95, 163
    offset for WCDMA, 193
alternate-channel leakage ratio,
    definition, 134
AM-AM, 10, 132, 188, 196
amplitude modulation, see modulation
    also spectral regrowth
amplitude-shift keying, see digital modulation schemes
AM-PM, 10, 133, 174, 175, 178
ASK, see amplitude-shift keying
avalanche current, 25, 26, 29, 31, 33, 77–78
AWGN, see additive white Gaussian noise

backoff region, 159, 177, 179–181, 183–184, 190, 193–194
ballast resistance, see ballasting
ballasting, 136, 146
    base, 137–138
    emitter, 136–137, 147–148
    split base, 137–138
base ballasting, see ballasting
base pushout, see also base widening, 24, 27, 28, 31, 32
base resistance, 3, 17–18, 23, 54, 155
effect of current crowding, 23
extraction, 60–61, 63, 73
Gummel–Poon model, 23
HICUM model, 33
MEXTRAM model, 32
VBIC model, 28
base widening, see base pushout
base width modulation, 18, 22, 29, see also Early effect
base–collector capacitance
extraction, 58–59, 73
Gummel–Poon model, 23
HICUM, 32–33
MEXTRAM, 31
behavioral modeling, 1, 10
Berkeley short-channel IGFET model, see BSIM
bias adaptation, see efficiency enhancement techniques
binary phase shift keying, see digital modulation schemes
binned model, 40, 43, 44
bipolar device models
Ebers–Moll model, 18–20
empirical GaAs HBT model, 63–70
Empirical model formulation, 70–80
empirical Si BJT model, 71–76
empirical SiGe HBT model, 77–83
Gummel–Poon model, 20–25
29, 31, 33, 53–55, 79
HICUM, 32–34, 49, 51
hybrid $\pi$ topology, 53–54
hybrid T topology, 53
MEXTRAM, 29–32, 49, 51, 53
SGP model, 29, 25–29, 34, 49, 51, 53
VBIC model, 25–29, 31–32, 49–51, 53
bipolar intrinsic capacitance extraction, 58–59
bipolar junction transistor, 2, 16–18, 49–51, 53, 54, 71–76
BJT, see bipolar junction transistor
bond wire, 125, 144, 145, 155
inductance, 145
mutual inductance, 145
resistance, 145
BPSK, see binary phase shift keying
breakdown voltage, 2, 17, 33, 77, 129, 141, 143, 157
BSIM, see MOSFET models
BSIM2, see MOSFET models
BSIM3, see MOSFET models
BSIM3v3, 44–45
modified scalable model, 91–119
NQS effect modeling, 88
shortcomings, 87, 88
BSIM4, see MOSFET models
carrier amplifier, 179, 181–183, 186, 188–190
carrier velocity saturation, 32, 36, 37, 40–42
CCDF, see complementary cumulative distribution function
CDMA, see code-division multiple access
channel length modulation, 37, 39, 40
Chireix’s outphasing amplifier, see efficiency enhancement techniques
Class A operation, 125–127, 129, 153, 173–175, 179, 188–190, 196
overdriven, 127, 129
Class AB operation, 125–127, 129, 153, 159, 163, 167, 173, 175, 179, 188, 190, 193, 196
Class B operation, 125–129, 131, 187–189, 193
push–pull, 149
Class C operation, 125, 127, 128, 179, 188, 190, 193
Class D operation, 128, 129
push–pull, 128
switching, 128, 129
Class E operation, 129–131
Class F operation, 129–131
odd, 131
even, 131
classes of operation, see RF power amplifier
classical Doherty amplifier, 179–180, see also Doherty amplifier
CMOS power amplifiers, see Si MOSFET power amplifiers
CMOS power amplifiers, see Si MOSFET power amplifiers
code-division multiple access, 6, 7, 123, 125, 126, 134, 142, 153, 162, 163
power amplifier for, 162–166
cold FET method, see model parameter extraction
cold S-parameter measurement, see model parameter extraction
collector epitaxial model, 31–32
complementary cumulative distribution function, 134
conduction angle, 125–127, 189, 191
constant-envelope modulation, 5, 7, 123
constellation diagrams, 6, 8
correlator, 8
current crowding, 23, 32, 33, 136
current distribution, nonuniform, 136
current gain, 16–17, 22, 54, 77, 141, 188
at high bias current, 55, 78–79
BJT versus HBT, 17, 50
collapse, 3, 136
effect of bandgap difference, 3
temperature dependence, 136
cutoff frequency, 18, 24, 27, 61, 77, 141, 144, 155

dBm, definition, 132
dECoT, see digital enhanced cordless telecommunications
describing parasitics, see model parameter extraction
deployment capacitance, 23, 26, 30, 31, 33, 36, 39, 41, 42, 53, 90
derivative superposition, 153
device models
compact, 4, 53
empirical, 15, 16
numerical, 4, 15
physics-based, 15
device periphery adjustment, 153–169
DiBiL, see drain-induced barrier lowering diffusion capacitance, 18, 23, 27, 30, 31, 33
digital enhanced cordless telecommunications, 123, 142
digital modulation schemes, 5–8
amplitude-shift keying, 6
binary phase shift keying, 6, 8
frequency-shift keying, 6, 7
Gaussian minimum shift keying, 7
minimum shift keying, 7
on-off keying, 6
phase-shift keying, 6
quadrature phase shift keying, 6–8
quadrature amplitude modulation, 7, 8
direct parameter extraction, see model parameter extraction
direct sequence spread spectrum, see spread spectrum
distributed capacitance,
base–collector, 23, 52, 54
partition model, 23
Doherty amplifier, see efficiency enhancement techniques
drain efficiency, 125, 127, 175, 179, 180, 186–189
drain-induced barrier lowering, 37, 43
DSSS, see direct sequence spread spectrum

Early effect, modeling of, 21, 25, 29, 33, 71, 77, 78
Early voltage, see Early effect
Ebers–Moll model, see also bipolar device models
injection version, 18
transport version, 18
EIR, see envelope elimination and restoration
efficiency, see drain efficiency
efficiency enhancement techniques, 5, 142, 153, 173–198
bias adaptation, 175
Chireix's outphasing amplifier, 176–178
Doherty amplifier, 175–176, see also classical Doherty amplifier, multistage
Doherty amplifier
envelope elimination and restoration, 174–175
electron mobility, see mobility
embedded passives, 125
emission coefficients, 21, 22, 54–56, 71, 79
envelope elimination and restoration, see efficiency enhancement techniques

gate-source capacitance, 36, 91, 100, 101

Gaussian minimum shift keying, see digital modulation schemes

generalized integral charge-control relation, 32–33
global system for mobile communications, 7, 123, 142

GMSK, see Gaussian minimum shift keying

GSM, see global system for mobile communications

Gummel plot, 50, 73

Gummel–Poon model, see bipolar device models

harmonic balance, 9–10, 69

harmonic distortion, 5, 133

harmonic suppression filters, 142, 143, 148–149

open-stub, 142–143

snake-type, 143

stepped-impedance, 142–143

harmonic termination, 11, 129–131

harmonic tuners, see load-pull

HEMT, 2

heterojunction bipolar transistor, 2, 16–18, 33, 49–53, see also GaAs HBT, SiGe HBT
double heterojunction bipolar transistor, 17

single heterojunction bipolar transistor, 17

HICUM, see also bipolar device models

level 0, 34

level 2, 34

high-current model, see HICUM

high-injection effects, see high-level injection

high-level injection, 17, 20, 22, 29

hot-carrier degradation, 38

hotspot, 136

HSPICE level 28 model, see MOSFET models

hybrid π bipolar model topology, see bipolar device models

hybrid T bipolar model topology, see bipolar device models

emitter ballasting, see ballasting

FCC, see Federal Communications Commission

FCC, Federal Communications Commission, 123

Fermi potential, 35

FHSS, see frequency-hopping spread spectrum

fifth-order intermodulation distortion, see intermodulation distortion

first-generation MOSFET models, see MOSFET models

flatband voltage, 35

$f_{\text{MAX}}$, see maximum frequency of oscillation

forward transit time, see transit time frequency-hopping spread spectrum, see spread spectrum

frequency modulation, see modulation frequency-shift keying, see digital modulation schemes

FSK, see frequency-shift keying

$f_t$, see cutoff frequency

GaAs HBT, 2–3, see also bipolar device models

AlGaAs/GaAs HBT, 3

InGaP/GaAs HBT, 3, 51

GaAs MESFET, 2, 3

gain compression, see AM-AM
gain expansion, see AM-AM
gallium nitride, 2

GaN, see gallium nitride
gate-induced drain leakage, 38, 45
gate leakage, 38, 45
gate resistance, 45, 87, 88, 94, 96, 116, 117, 120, 155
distributed, model for, 89
gate-drain capacitance, 36, 91, 100, 101, 155
ideality factor, see emission coefficients
InGaP/GaAs HBT, see GaAs HBT
integral charge-control relation, see
generalized integral charge-control relation
interconnect parasitics, 95–99, 124, 156
intermodulation distortion, 5, 10,
132–134, 161, 167–169
asymmetry, 158
fifth-order, 133,
in-band, 134
nonlinear term cancellation, 166–169
out-of-band, see spectral regrowth
third-order, 132, 133, 167
intrinsic capacitances, 36, 54, 58–59, 68,
73, 98
extraction, 58–59
inverse Class F, 131

junction capacitance, see depletion capacitance

Kirk effect, 55, 77, 78, 144
knee current, 21, 31, 33, 55, 79
knee voltage, 71, 141, 144
Kuif model, 27, 29, 32

large-signal model, see bipolar device models, also MOSFET models
LDMOS FET, 2
least-squares error minimization, 51
level 1 SPICE model, see MOSFET models
level 2 SPICE model, see MOSFET models
level 3 SPICE model, see MOSFET models
limiter, 174, 175
LINC, see linear amplification using nonlinear components
linear amplification using nonlinear components, see Chireix’s outphasing amplifier
linearity metrics, see RF power amplifier linearization, power amplifier, 153
load-line, 4, 124, 144, 179
load-pull, 4, 10–13, 116, 118, 120, 124,
155, 157, 181, 184, 185
active, 12, 13
contours, 4, 10–12
harmonic tuners, 11, 124
passive, 10, 11
prematching tuners, 11
low-level injection, 22
low-temperature cofired ceramic, 142–145, 148–151
LTCC, see low-temperature cofired ceramic

main channel, 133, 134
maximally flat waveforms, 131
maximum frequency of oscillation, 17,
18, 61, 155–156
metal–insulator–metal capacitor, 162
MEXTRAM, see bipolar device models
Meyer model, 39
minimum shift keying, see digital modulation schemes
mobility, 35–37, 40, 41, 43, 44
model parameter extraction, 50–51,
see also bipolar device models, also MOSFET models
deembedding parasitics, 61–62
cold FET method, 98
open-collector and cold S-parameter method, 62, 63,
79
direct extraction, 50–52, 54, 90
intrinsic parameters, 68, 91, 96,
100, 116, see also intrinsic capacitances
test structures for,
GSG probes, 95, 99
open structure, 79, 97, 99
short structure, 97, 99
modified BSIM3v3 model, see BSIM3v3
modulated DC supply, 174–176
modulation, see also modulation schemes
amplitude, 1, 6, 7, 124, 127, 173
analog, 5
digital, 6, see also digital modulation schemes
frequency, 6, 7, 9
phase, 6, 7
modulation schemes, 1, 5-8, see also modulation, also digital modulation schemes
MOS model 9, see MOSFET models
MOS model 11, see MOSFET models
MOSFET
device physics, 35-38
long-channel, 36, 37, 88
saturation voltage, 35, 37, 38, 41, 45
short-channel effects, 36-38, 40-42, 88
subthreshold current, 35, 43
threshold voltage, 35, 37, 38, 166
MOSFET charge model
deployment charge, 29, 30, 31, 36, 39, 41-43
gate charge, 39, 42, 43
inversion charge, 35, 36, 39, 41, 42
Yang model, 42
MOSFET linear region current, 38, 41
MOSFET models
BSIM, 40-43
BSIM2, 43-44
BSIM3, 44-45, 87, see also BSIM3v3
BSIM4, 45-46
first-generation, 40, 41
HSPICE level 28, 43-44
level 1, 38-39
level 2, 40, 41
level 3, 40
MOS model 9, 45
MOS model 11, 45
second-generation, 40, 41, 44
third-generation, 44, 45
MOSFET saturation region current, 39, 41-42
most exquisite transistor model, see MEXTRAM
MSK, see minimum shift keying
multicarrier signals, 7, 134, see also OFDM
multistage Doherty amplifier, 181-197
device periphery ratio, 189, 193
dynamic biasing, 193, 196
efficiency, 186-188
N-stage, 181, 188
practical considerations, 188-190
principle of operation, 181-186
three-stage, 181-186, 188, 190-197
noise power ratio, 134
nonquasistatic effects, 33, 88
nonconstant-envelope modulation, 5, 6, 9, 123, 126, see also amplitude modulation, spectral regrowth
nonexponential CMOS process, 89
nonideality factor, see emission coefficients
nonlinear term cancellation, see intermodulation distortion
NPR, see noise power ratio
NQS effects, see nonquasistatic effects
Nyquist bandwidth, 6, 133, 134
OFDM, see orthogonal frequency-division multiplexing
on-off keying, see digital modulation schemes
OOK, see on-off keying
open-collector method, see deembedding parasitics
orthogonal frequency-division multiplexing, 7
outphasing amplifier, see Chireix’s outphasing amplifier
output power backoff, see backoff region overlap capacitance, 29, 31, 45
package parasitics, 125, 145
pad parasitics, see model parameter extraction
PAE, see power-added efficiency, definition
PAPR, see peak-to-average power ratio
parameter extraction, see model parameter extraction
PCB, see printed circuit board
peak amplifier, 179-191, 193, 196, 197
peak-to-average power, 7, 134, 173
peak-to-average power ratio, see peak-to-average power
poly-poly capacitor, 157
power-added efficiency, definition, 132
power amplifier, see RF power amplifier
power amplifier classes, see RF power amplifier
INDEX

power amplifier linearity, see RF power amplifier
power control, see RF power amplifier
power match, 4
power spectral density, 5, 8, 10, 123, 123, 134, 142, 168, 169
power spectrum, see power spectral density
printed circuit board, 125, 157, 159, 164, 190

quadrature amplitude modulation, see digital modulation schemes
quadrature phase shift keying, see digital modulation schemes
quarter-wave transformer, see quarter-wave transmission line
quarter-wave transmission line, 130, 175, 179, 181, 193
quasi-Fermi level, 41
quasi-saturation, 24, 27, 31, 33

rake receiver, 8
recombination, 17, 18, 22, 27, 31, 50
residual error, 64
RF-blocking inductor, 138
RF carrier, 5, 133
RF power amplifier
bias network, 137, 138, 143, 145, 158, 162
classes of operation, 125–131
design methodology, 124–125
linearity, 5
linearity metrics, 132–135
matching, 124–125, 144, 153–155, 157–159, 162–163, 186, 190
performance metrics, 132–135
power control, 132, 157, 173
ring-shaped substrate contact, see substrate contact topologies

Schichman–Hodges model, see MOSFET models, level 1
second breakdown, 136
second-generation MOSFET models, see MOSFET models
self-heating, 3, 4, 25, 29, 33, 49–56, 77, 78, 124, 136, 141
SGP model, see bipolar device models
shooting methods, 9, 10
short-channel effects, see MOSFET
SiGe HBT, 2, 3, 17, 51, 53, 54, 77–83, 136, 137
SiGe HBT power amplifiers, see silicon-based power amplifiers
silicided gate, 89, 155
silicon-based power amplifiers, 4, 141–169
SiGe HBT power amplifiers, 142–152, 162–166
Si MOSFET power amplifiers, 157–161, 166–169
Si MOSFET power amplifiers, see silicon-based power amplifiers
small-signal model, 53, 54, 57, 61, 64, 91, 93, 94, 96
source-pull, 10–12, 69, 73
space charge capacitance, see depletion capacitance
spectral regrowth, 5, 10, 123–135, 173
spectrum, see power spectral density
spectrum mask, 123, 134
SPICE, 9, 10, 15, see also bipolar device models, also MOSFET models
SPICE: Gummel–Poon model, see SGP model
spread spectrum, 7–8
stage bypassing, 153–154
substrate capacitance, 103, 107, 109, 110
substrate contact topologies
ring-shaped, 91–94, 101, 120
side substrate contact, 91, 92, 101, 103, 104
substrate resistance, 29, 45, 46, 87, 88
bias dependence, 109
distributed model, 89–91
scalability, 101–115
switching amplifier, 128–129

Taylor series, 132, 166
thermal conductivity, 2, 52, 141, 146–147
thermal instability, 136–138, 146
thermal management, 1, 125
thermal resistance, 50, 55, 56, 71, 147
thermal runaway, see thermal instability
thick-gate oxide MOSFETs, 101, 106, 112–114, 157
third-generation MOSFET models, see MOSFET models
third-order intermodulation distortion, see intermodulation distortion
threshold voltage, see MOSFET transconductance, 16, 17, 64, 91, 101, 126, 155, 167
transit time, 20, 24, 27, 29, 31, 33, 88
transmission line, 10, 89, 125, 130, 148, 158, 162. see also quarter-wave transmission line

ultra-wideband, 7
UWB, see ultra-wideband

Variable-envelope modulation, see nonconstant-envelope modulation
VBIC model, see bipolar device models
vector network analyzer, 94
velocity saturation, see carrier velocity saturation
vertical bipolar intercompany model, see VBIC model
VNA, see vector network analyzer

WCDMA, see wideband code-division multiple access
wideband code-division multiple access, 123, 153, 190–197