

# Index

## A

AC coupling effect  
frequency responses of, 33  
impact on BER performance, 36, 39

Additive White Gaussian noise (AWGN)  
channel, 28

Advanced BiCMOS processes  
at mm-wave frequencies, 127, 195  
HBT transistors, 127, 186  
high-speed HBTs, 127

Agilent 8510XF Network analyzer, 205, 236

Alternating Current (AC), 203

AM/AM distortion, 181

Amplitude Modulation (AM), 183, 191, 216

AM-PM distortion, 194

Analog filters  
external baseband analog filters, 30  
sampling frequency, 30  
Wiener filter, 30  
without Rx equalizer, 30  
with Rx equalizer, 30

Analog Intermediate Frequency (AIF), 26, 27

Analog-to-Digital Converter (ADC), 20, 27, 30, 92, 94, 101

Automatic Cruise Control (ACC), 5

Automatic Gain Control (AGC) loops, 197

Automatic Level Control (ALC) systems, 214

## B

Back End Of Line (BEOL), 117

Backhaul networks  
common public radio interface (CPRI)  
data, 7

conventional baseband unit (BBU) structures, 7

remote radio head (RRH), 7

Bandpass Filter (BPF), 64, 92, 100

Bandwidth of the signal (BW), 30, 81, 82, 85, 92, 94, 96

Baseband (BB), 135

Baseband filters effect  
simulation model for, 30

Baseband Unit (BBU), 7

Baseline BER performance, 30

BiCMOS integrated circuits  
IF and mmW front-end blocks, 25

BiCMOS mmW PAs, 186

BiCMOS 55-nm process, 117, 119

Bipolar CMOS (BiCMOS), 2, 3, 6, 9, 22, 25, 117, 118, 124, 127, 129, 132, 135, 141, 145, 147, 163, 164, 171, 185, 186, 188, 190, 195, 202, 207, 218, 231, 235, 246, 247

Bipolar Junction Transistor (BJT), 177, 180

BISC circuitry for UWB, 92

BISC I/Q imbalance compensation method, 100

BISC Pre-dist. tones, 105

Bit Error Rate (BER), 15, 25

Block RX-DUP, 27

Block TX DUP, 25, 27

Breakdown Voltage (BV), 128, 130, 184, 185, 195, 197

Breakdown voltage of HBTs, 128

Built-in-Self-Calibration (BiSC), 90–94, 97, 100, 105, 107, 109, 112

Built-in-Self-Test (BIST) techniques, 90

**C**

Capacitors, 55, 117, 119, 122–124, 132, 146, 155, 165, 168, 202, 232, 235  
 Centralized or Cloud Radio Access Network (C-RAN), 8  
 CG versus LO voltage swing  
     different base bias voltages, 168  
 Channel distribution, The, 15  
 Channel Separation (CS), 16, 40, 163, 245  
 Chip layout, 154, 203, 223, 235  
 CMOS and BiCMOS mixers, 145, 171  
 CMOS and BiCMOS up-converters, 145, 163  
 Common Base (CB) topology, 168  
 Common BiSC circuitry  
     for I/Q imbalance estimation, 90, 92  
 Common Public Radio Interface (CPRI), 7  
 Common-Collector (CC) configuration, 217  
 Common-Emitter (CE) configuration, 128, 168, 186, 187  
 Common-Source (CS), 178  
 Complementary metal-oxide-semiconductor (CMOS), 1, 3, 5, 6, 117, 141, 145, 163, 171, 185, 194, 198, 207  
 Continuous Wave (CW), 160, 215, 219, 220, 223, 226–228  
 Conversion Gain (CG), 138, 167, 236  
 Coupling capacitor, 222  
 C-RAN approach  
     CPRI interconnect backhaul in, 8  
 Custom BiCMOS integrated circuits, 22

**D**

DAC<sub>1</sub> and DAC<sub>2</sub>, 77  
 DAC delay imbalance  
     compensation, 81, 83, 89, 94, 97, 101, 107  
     correction of, 98, 101  
     estimation of, 94, 95  
 Data Clock Input (DCI), 77  
 Data Clock Output (DCO), 77  
 1-dB compression point, 180, 238, 245  
 DC-decoupling, 122  
 DC power consumption, 145, 154, 155, 188, 191, 192, 195, 205, 227, 236  
 Delay estimation flowchart, 96  
 Design considerations for the detector core, 219  
 Design Rule Check (DRC), 123, 124  
 Detection frequency range, 215  
 Device Under Test (DUT), 215, 231  
 Digital Baseband (DBB), 26, 28

**Digital compensation, 69**

Digital pre-distortion, 69, 194, 214  
 Digital Signal Processing (DSP), 19, 194  
 Digital-to-Analog Converter (DAC), 20, 21, 61–63, 76–81, 83–85, 143, 147, 162, 198  
 Direct Current (DC), 33, 37, 179, 182, 242  
 Doherty PA, the, 191, 192  
 Doherty power amplifier, 191, 192  
 Double-balanced semi-passive mixer topology, 165  
 Double Side-Band (DSB), 152  
 Drain efficiency, 179, 182, 183  
 DS0 Digital sub-band centered at -500 MHz, 37  
 DS1 Digital sub-band centered at -500 MHz, 37  
 4DSP FMC230 board, 22, 76, 242  
 Dynamic range, 216, 244

**E**

E-band multi-gigabit transmitters, 247  
 Effect of the nonlinearity, 40  
 Efficiency enhancement techniques, 191  
 Electromagnetic (EM) simulator, 119  
 Electrostatic Discharge (ESD), 155  
 Elimination and restoration (EER) systems, 192  
 Envelope Detector (ED), 90  
 Envelope elimination and restoration (EER), 192, 193  
 Error Vector Magnitude (EVM), 109, 112, 163, 245  
 European Communications Committee (ECC), 15, 236  
 European Telecommunications Standards Institute (ETSI), 6, 16, 18, 40, 163, 245, 247  
 EVM and MER measurement, 109

**F**

Federal Communications Commission (FCC), 6  
 FET or bipolar transistors, 141  
 Field-effect transistor (FET), 141  
 Field-programmable gate array (FPGA), 22, 25, 76, 77, 162, 214, 242, 245  
 Figures of merit, 127, 135, 138, 177, 209, 213, 214, 228  
 Finite impulse response (FIR), 96–99, 101, 105  
 First In, First Out (FIFO), 77

- For wideband mm-wave power amplifiers, 185  
Forward error correction (FEC) codification, 29  
Fourier transform of a signals, 49  
FPGA board, 76  
Frequency response  
    Maximum oscillation frequency ( $f_{MAX}$ ), 127  
    transition frequency ( $f_T$ ), 127  
Frequency selective I/Q imbalance compensation, 20, 58, 81, 89, 94, 97, 244  
Frequency-division duplex (FDD), 15  
Frequency-selective (FS), 55
- G**  
Gain and phase imbalance, 27, 45, 46, 48, 50, 52, 53, 64, 68, 74–76, 95, 96, 98, 101, 104, 105, 107, 111, 112, 242  
10-Gbps transmission system, 10, 160, 161, 241  
5G Cellular Networks, 7  
General-Purpose Interface Bus (GPIB), 98  
Gilbert cell, 142, 145, 149, 155, 165  
GPIB connection, 98  
Ground-Signal-Ground (GSG), 154, 155, 203, 223, 235
- H**  
HBT transistor, 119, 127, 129, 132, 165, 186  
Henri Chireix, 192  
Heterojunction Bipolar Transistors (HBT), 117, 165, 167, 168, 188, 197, 198, 217  
Hierarchical QAM modulation, 242  
High Definition (HD), 5  
High-Definition Multimedia Interface (HDMI), 5  
High-Electron-Mobility Transistor (HEMT), 2  
High-ohmic polycrystalline (HIPO) resistors, 117  
High-performance Xilinx VC707 FPGA, 22, 242  
1-Hz resolution bandwidth, 245
- I**  
I/Q gain and phase imbalance  
    digital compensation and mitigation of, 61  
I/Q imbalance compensation  
    BiSC comp., 107  
    PSA comp., 107  
I/Q imbalance correction, 68, 69, 89  
I/Q imbalance estimation, 59, 71, 83, 89, 90, 92, 95, 98–100, 104, 111, 112, 147  
I/Q imbalance mitigation methods, 97  
I/Q modulation of the signal, 42  
I/Q modulator and demodulators, 45  
I/Q up-conversion, 19  
IF feedthrough, 139  
IF LO buffer, 150  
IF up-converter mixture, 149  
Image Rejection Ratio (IRR), 66, 145  
    function of amplitude and phase imbalance, 50, 97  
Impact on BER performance, 33, 39, 42, 43, 45, 47, 50, 52, 53, 57  
In-phase / Quadrature (I/Q), 76, 143, 145  
Input 1-dB compression point, 40, 180  
Insertion Loss (IL), 199  
Institute of Electrical and Electronics Engineers (IEEE), 5, 7  
Integrated Circuit (IC), 22, 25  
Intermediate Frequency (IF), 135  
Intermodulation products (IM3), 39, 181  
International Telecommunication Union (ITU), 15, 236  
Internet Protocol (IP), 7, 8  
IRR measurement, 105  
IRR sensor, 94
- K**  
Keysight E4440A spectrum analyzer, 98
- L**  
Lab synthesizers (HP 83712B and Keysight E8257D), 244  
Line of Sight (LoS), 3, 28  
Linearization circuit, 150, 151  
Link budget  
    atmospheric absorption, 17  
    Boltzmann constant, 18  
    parameters and values for, 19  
LmCm baseband filter, 56  
LO feedthrough, 19, 139, 164, 169, 232  
LO signal power, 37  
Local Oscillator (LO), 42–44, 64, 142  
Long-range radar (LRR), 5  
Long-Term Evolution (LTE), 7, 8  
LOs in TX-FSYN, 44, 45  
LOs of the transmitter and receiver analog chain, 25, 30, 43

Lower Side-Band (LSB), 157  
 Low-Noise Amplifier (LNA), 20  
 Low-Pass Filter (LPF), 242  
 LpCp baseband filter, 56

**M**

Matching Network (MN), 122, 124, 130, 139, 168, 177, 178, 184, 186, 189, 195, 201, 202, 232  
 MATLAB program, 98, 101  
 Maximum Available Gain (MAG), 186  
 Maximum oscillation frequency, 136  
 Maxwell equations, 121  
 Measuring Device (MD), 71  
 Medium Range Radar (MRR), 5  
 Metal–insulator–metal (MIM) capacitors, 117  
 Metal-Oxide-Metal (MOM), 122, 123, 132, 165, 168, 222  
 Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET), 2, 180  
 Meyer detector, 217  
 Millimeter-Wave (mmW), 1  
 MIM capacitors, 122, 123  
 MIMO and beamforming technologies, 7  
 Minimum Mean Square Error (MMSE), 85  
 MmW communication system, 61, 164, 241  
 MMW imaging mm  
     CMOS and BiCMOS technologies, 6  
 MmW up-converter, 22, 164, 166, 169, 173  
 Modelling DAC delay imbalance, 78  
 Modulation Error Ratio (MER), 109, 112  
 Monolithic Microwave Integrated Circuit (MMIC), 9, 98, 141  
 MOSFET transistors, 117, 165, 178  
 M-QAM modulation schemes, 21  
 Multiple-Input Multiple-Output (MIMO), 7

**N**

Near-Field Communication (NFC), 1  
 N-MOS transistors, 149, 218, 222  
 Noise Figure (NF), 140  
 Non-frequency-selective I/Q imbalance, 68, 111  
 Non-Frequency-Selective (NFS), 55

**O**

On-wafer performance, 155  
 Output bandwidth, 92, 94, 139, 157, 165, 216, 218, 228  
 Output buffer, 44, 222, 227, 229

Output 1-dB compression point (OP 1-dB), 238  
 Output transformer, 198, 200

**P**

Peak to Average Power Ratio (PAPR), 21, 38, 39, 42, 244  
 Personal Area Network (PAN), 4  
 Phase-Locked Loop (PLL), 43  
 Phase Modulation (PM), 181, 193, 194  
 Phase noise, 27, 28, 42–45  
 Picoprobe, 203  
 PolyPhase Filters (PPF), 146  
 Post-Layout Simulation (PLS), 164, 169, 171–173  
 Pout–pin and gain–pin curves, 205  
 Power-Added Efficiency (PAE), 179, 192, 205  
 Power Amplifier (PA), 20  
 Power combining techniques, 190  
 Power Spectrum Analyzer (PSA), 97–101, 105, 107, 109, 112  
 Power Spectrum Density (PSD), 28  
 Printed Circuit Board (PCB), 155, 160, 162, 223, 235, 241  
 Process Design Kit (PDK), 119, 123, 124  
 Process, Voltage and Temperature (PVT), 197, 213  
 Proportional To Absolute Temperature (PTAT), 198  
 Prototype Controller (PrC), 98, 99, 101  
 PSA Pre-dist. tones, 105  
 PSA- based I/Q imbalance compensation, 97, 98

**Q**

Quadrature Amplitude Modulation (QAM), 30, 33, 37, 38, 40, 44, 46, 58, 109, 232  
 Quadrature LO generation, 154  
 Quadrature modulation, 143, 144  
 Quadrature Phase-Shift Keying (QPSK), 33, 144, 193, 242

**R**

Radio Access Network (RAN), 8  
 Radio-Frequency Identification (RFID), 1  
 Radio Frequency (RF), 1, 19, 20, 25, 28, 39, 58, 59, 69, 90, 121, 122, 135, 137–142, 155, 162, 165, 177–179, 188, 203, 213–217, 222, 223, 235, 241

- Random-Access Memory (RAM), 122  
RC network, 200–202, 216, 218, 221, 229  
Receiver baseband controller, 28, 30  
Receiver I/Q imbalance analysis, 52  
Receiver (RX), 25  
Reed–Solomon (RS), 29  
Remaining I/Q imbalance compensation, 104, 107, 109  
Remaining I/Q imbalance estimation, 95  
Remote Radio Head (RRH), 7  
Resolution Bandwidth (RBW), 245  
RF impairments, 25, 28, 58  
Root-Raised-Cosine (RRC), 16, 21, 242
- S**  
Saturation power ( $P_{sat}$ ), 180, 238  
Short-Range Radar (SRR), 5  
SiGe BiCMOS process, 2, 117, 147, 195  
Signal-Ground-Signal (SGS), 155  
Signal-to-Noise Ratio (SNR), 18, 19, 28–30, 45, 50, 52, 58, 139  
Silicon-based technologies, 2, 9  
Silicon on Insulator (SOI), 2  
Simulated stability factors of the power amplifier, 201  
Simulation model  
    BER COMP, 26  
    Block BIT sources, 25  
    Block TX-DBB, 26  
        for the I/Q imbalance effect, 46  
        for the nonlinearity effect, 40  
    I/Q symbols, 26  
Single Side-Band (SSB) tone, 145  
SNR curves, 19  
SNR degradation, 52, 139  
SNR of the I/Q symbols, 29  
Spectral mask  
    E-band point-to-point communication links, 16  
Spectrum Analyzer (SA), 71, 112  
Stability, 126, 182, 186, 188, 195, 198–202, 232, 235  
STMicroelectronics, 117, 147, 164, 195, 218, 231  
Sub-Miniature version A (SMA), 160, 241  
Surface-Mount Technology (SMT), 160  
Symmetric and the asymmetric models, 67
- T**  
The noise factor (F), 139
- The Wilkinson combiner, 190  
Third-order Intercept Point (IP3), 181  
Transceiver architecture  
    E-band transceiver, 19  
    Superheterodyne transceiver, 19, 231  
Transistor cell implementation, 131  
Transistor placement and connections in a PA stage, 132  
Transmission Line (TL), 3, 117, 119, 124, 125, 131, 132, 145, 146, 165, 190, 195, 202, 214, 232, 241  
Transmitter design, 231  
Transmitter Digital Baseband processor (TX-DBB), 26, 77, 90, 92, 98, 100, 107  
Transmitter frequency-selective I/Q imbalance, 61, 62, 67, 68, 78, 90, 111  
Transmitter I/Q imbalance analysis, 47, 59, 67  
Transmitter part that comprises baseband and IF (TxBB2IF), 61, 62, 65, 69–74, 78, 90–92  
Transmitter requirements, 21  
Transmitter (TX), 64, 66, 68, 89, 92, 94  
TX-FSYN, 27, 44, 45  
TX-MMW, 27, 39
- U**  
Ultra-Wideband (UWB), 58, 76, 81, 82, 92, 112  
Upper Side-Band (USB), 157–159  
UWB transmitters, 90, 111, 112
- V**  
Variable-Gain Amplifier (VGA), 20  
Vector Network Analyzer (VNA), 236  
Very-Large-Scale Integration (VLSI), 122, 124, 131  
Voltage Controlled Oscillator (VCO), 43
- W**  
Waveguide (WG), 241  
Wideband Code Division Multiple Access (WCDMA), 8  
Wideband millimeter-wave signals  
    effect of front-end imperfections TX-AIF, 26