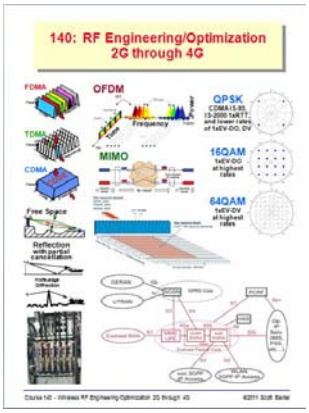
Course 140: RF Engineering/Optimization 2G through 4G

Day One: Wireless Technologies, RF Signals, Capacity, Propagation



I. Survey of Wireless Technologies and Operators
   a. CDMA/1xRTT/1xEV-DO
   b. The GERAN: GSM, HSCSD, GPRS, EDGE
   c. 3G: WCDMA, UMTS, the UTRAN, and HSPA
   d. 4G: LTE and WiMAX

II. Wireless Signals: Types and Characteristics
   a. What is Modulation?
   b. Types of Modulation: analog AM, FM, PM
   c. Digital Modulation: ASK, FSK, PSK and their special characteristics
   d. How many bits will fit in a 10 pound bag? Why we like Claude Shannon
      i. How modulation rate determines signal bandwidth
      ii. How complexity of modulation determines data throughput
      iii. Looking at the "constellations" of popular modulation types
      iv. What's the capacity of BPSK? QPSK? 8PSK? 16QAM? 64QAM?
      v. The Capacity of GSM, CDMA, GPRS, EDGE, HSPA, LTE, more
   e. How 3G+4G systems adaptively, instantaneously exploit modulation type

III. The RF Spectrum and how RF signals propagate through space
   a. Spreading out and weakening in free-space
   b. What happens if there are reflecting objects or surfaces nearby?
   c. What happens if the signal must "diffract" over or around objects?
   d. What if the user is inside a building? How much signal will they get?
   e. Are there simple formulas to predict what happens in these situations?

IV. Wireless System RF Design Methods to Obtain Desired Coverage
   a. Propagation Prediction Models for different environments
   b. Types of Models: Area, Point-to-point, Terrain and clutter-based
   c. Model Hands-On playground with web and server-based examples
   d. Wavelength vs. Frequency – how signals penetrate obstacles and openings
   e. Why signals of widely different frequencies propagate differently
   f. Reliability Statistics: 50% good enough? 75%? 90%? How many extra db?
   g. Whether, when and how to do trial measurements with test transmitters
   h. How to collect and analyze propagation measurement data

V. Wireless System RF Design Methods to Obtain Desired Capacity
   a. The inherent capacity vs. spectrum relationship for popular technologies
   b. Traffic Density dictates Cell Density
   c. User Traffic Profiles and User Density estimation
   d. Principles of Traffic Engineering
   e. How to predict and manage special situations – traffic jams, sports events

VI. Special Techniques: DAS, Cell Enhancers/Boosters/Reradiators/Repeaters
   a. Bidirectional amplifiers, on-frequency repeaters: gain and link budgets
   b. Distributed Antenna Systems: Neutral Host, 1-Operator, hardware/design

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Day Two: Wireless Antennas

I. Thinking in Decibels: A commanding skill for your entire wireless career
   a. Decibels are a logarithmic number system that eases complex calculations
   b. Matching power ratios with easier-to-manipulate dB (formula to and from)
   c. Forget formulas: A visual "ladder" of ratios vs. db – do it in your head!
   d. Some special uses of db: To express real powers, to express antenna gains

II. Antennas for Wireless Systems
   a. What is an antenna? How does radiation happen? In what directions?
   b. What *is* antenna gain? How can a lifeless piece of metal have "gain"?!
   c. How is antenna gain measured? Standard antennas/nomenclature
   d. Two main techniques for getting directionality: reflectors, phased arrays
   e. Choosing where you need to deliver RF, and picking a pattern to do it
   f. Electrical and Mechanical Downtilt – do you need it? If so, how much?

III. Other parts of Antenna Systems
   a. Transmission Lines: Coaxial Cables, Striplines,Waveguides, other types
   b. The important characteristics of a transmission line
      i. Most important: how much loss. Check the catalog or measure it
      ii. Characteristic Impedance: What is it, why do we care?
      iii. Velocity Factor? When is it important, and when not?
      iv. Power handling capability – should I ever be worried?
   c. Important Accessories: connectors, directional couplers, duplexers, bandpass/notch/band reject filters, combiners, transient arrestors, stubs
   d. Grounding: a frightening look at Ohm's law during a stroke of lightning
   e. Installing transmission lines: be delicate! handling techniques and why

IV. Antenna and Transmission Line Tests
   a. Load Matching, reflected power, and standing waves
   b. How much reflection is detrimental? 4 ways to express it, how they relate
   c. Devices and techniques for measuring reflections
   d. Line sweeping techniques, equipment, and pitfalls
      i. VSWR/%refl/Return loss/refl. coefficient vs. frequency
      ii. VSWR/%refl/Return loss/refl. coefficient vs. distance (TDR)
      iii. Interference during sweep tests: a two-way street
      iv. Proper calibration and good connections for accurate sweeps
   e. Passive Intermod Testing – What is it?
      i. Is it needed? Is it reliable? What's at stake?

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Day Three: Inner Workings of 2G and 3G Technologies

I. Interference and Receiving Problems: C/I, S/N, Eb/No
   a. The thermal noise floor: the hostile background that's always there
   b. Cochannel interference, Adjacent channel interference, image frequencies
   c. Interference detection tools: Spectrum analyzers, modern DSP receivers

II. The "Curse" of Intermodulation ('IM')
   a. Nonlinearity in amplifiers, devices, cables and connections
   b. IM Products: unwanted sum and difference signal comb: 3^{rd}, 5^{th} order, etc.
   c. Third order intercept, 1 db gain compression, and intermod sources
   d. Finding Intermod: a "witch trial" unless using detective tools and tricks
      i. It's everywhere – (even in your test equipment!) Who to believe?
      ii. Using filters, pads, or the latest DSP receivers to see what's real
      iii. Intermod prediction software, antenna isolation, IM forensics

III. Traffic Engineering Basics
   a. Transmission paths, traffic units, grade of service, and their relationships
   b. Probability of blocking and the principle of trunking efficiency
   c. Understanding sector/air interface capacity; cell splitting
   d. Estimating offered traffic in wireless systems, identifying traffic sources
   e. How bad can it get? Some techniques for worst-case estimation

IV. Multiple Access Techniques
   a. A separate frequency for you: simple Frequency Division Multiple Access
   b. Time Division Multiple Access, Code Division Multiple Access

V. CDMA: Code Division Multiple Access
   a. Coding and Spreading Gain – spread spectrum signals – hopping and dsss
   b. Forward Link: Walsh codes for users, Short PN code offset for sectors
      i. Magic with different-length walsh codes, some family tree taboos
   c. Reverse Link: Long PN Code offsets for individual mobiles
   d. PN Planning, mobile PN offsets; search windows; nbr. lists, false handoffs
   e. Special handoff triggers: RTD, pilot beacons

VI. 1xEV-DO: Advanced Modulation & Using TDMA in CDMA signal
   a. Slots, Frames, Control Channel Cycles; Hybrid ARQ; burst pilot, MAC
   b. Adaptive modulation in motion: how C/I determines speed
   c. Logical channels and call processing

VII. GSM, GPRS, EDGE
   a. TDMA structure; logical channels; EDGE and 8PSK

VIII. WCDMA: UMTS, UTRA, HSPA
   a. A different take on CDMA: code similarities and differences
   b. TDMA inside CDMA; slots, frames
   c. HSPA advanced modulation

IX. Key Performance Indicators (KPIs)

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Day Four: 4G Technologies: LTE and WiMax

I. Introduction to 4G – What's Different from 3G and 2G?
   a. Speeds, Latencies, Throughput; All-IP SAE "Flat" Network
II. The battle of the heavyweights: WiMAX vs. LTE
   a. Ingredients OFDMA, MIMO
   b. WiMAX: out first (+2 yrs); TDD, inter-RAT HOs not fully developed
      i. Sprint chose early, but capital pinch slowed down rollout
   c. LTE: out second; FDD, inter-RAT HOs and other features already in
      i. Verizon early adopter; majority of other existing carriers
   d. Today: Both technologies have TDD, FDD; LTE has wider acceptance
III. Spectrum for 4G and 4G Players
   a. 850, 1900, 2650, 700, AWS and the operators in each band
IV. The LTE Air Interface
   a. A more dense signal: Fwd. OFDM, OFDMA, Rev. SC-FDMA
   b. Thin-carrier spacing, modulation, capacity: QPSK, 16QAM, 64QAM
   c. Signal Generation and Detection in DSP, not discrete hardware
   d. Downlink and Uplink Structure, modulation, scheduling, Slots, Frames
   e. Resource elements, Resource Blocks, and capacity
   f. The great capacity multiplier: MIMO
V. The Protocol Stacks and Layers
   a. Physical, MAC, RLC, PDCP, RRC, NAS
VI. LTE Network Architecture and Elements
   a. Evolved Packet System (EPS) and Evolved Packet Core (EPC)
   b. Functional Elements (eNB, MME, SGW, PGW, PCRF, HSS)
   c. Standard Interfaces and Key Protocol Stacks
VII. Radio System Identifiers, Tunnels, Connections, and Bearers
   a. UE identifiers (IMSI, TMSI, GUTI…..); UTRAN and EPC identifiers
   b. Dedicated and Default Bearers; Tunnels, Parameters, Proxy Mobile IP
   c. What is a Session? A Connection?
VIII. System Operation: Modes and procedures
   a. Cell Search Procedures, Initial Acquisition and Synchronization
   b. Idle Mode and Paging
   c. Tracking Area Identification and updating
   d. Cell Reselection (idle mode handover)
IX. Paging Operations

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Day Five (Half Day): LTE Event Processing

X. UE Attach to the network
   a. Cell Search
   b. Selecting suitable MME, SGW, and PGW
   c. Authentication, Ciphering, IP address allocation
   d. Default Bearer Setup
   e. Connected Mode and UE States
   f. RRC connection setup
   g. Service Establishment
   h. QoS parameters and TFT

XI. Message Flow: Incoming and outgoing calls
   a. eNB to eNB Handover flow: (same MME, SGW and PGW)
   b. eNB to eNB Handover flow: (different MME, same SGW and PGW)
   c. eNB to eNB Handover flow: (different MME and SGW, same PGW)
   d. eNB to eNB Handover flow: (different MME, SGW, and PGW)

XII. LTE Inter-RAT Handoffs and Interoperability

XIII. LTE Network Performance Evaluation and Optimization Issues
   a. Channel Quality Reporting
   b. ARQ, H-ARQ and Scheduling
   c. Another look at QoS
   d. Throughput Calculations and Optimization
   e. Voice-over-IP support and voice quality projections (VOLGA)