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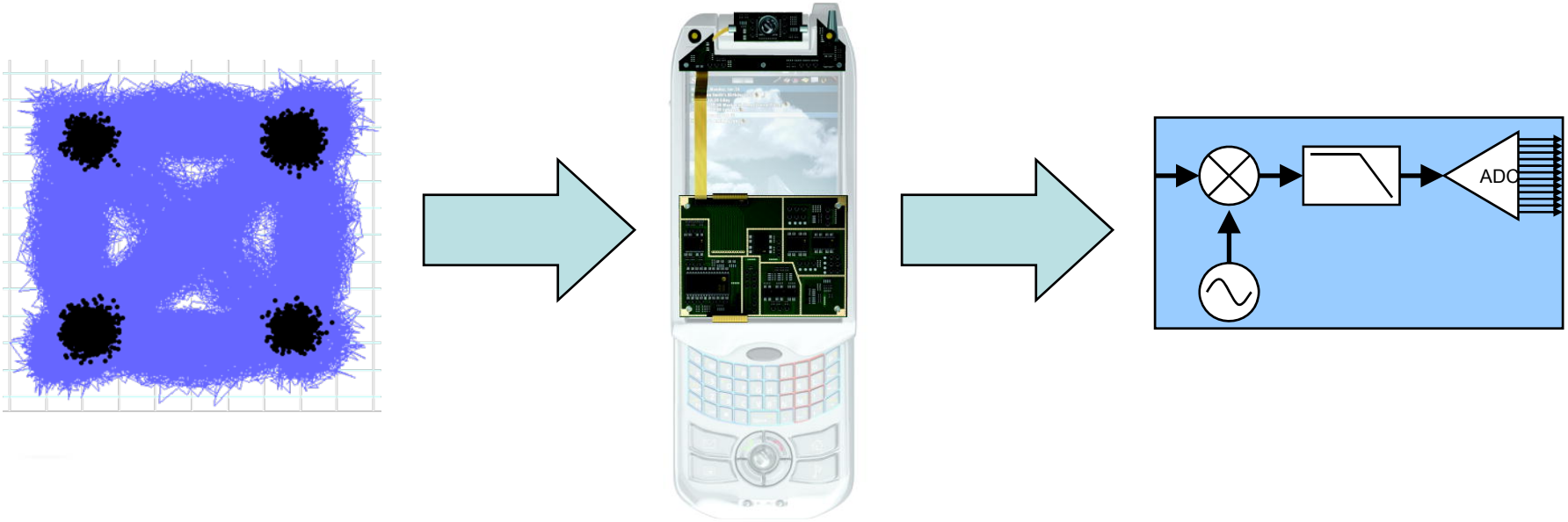
NATIONAL INSTRUMENTS

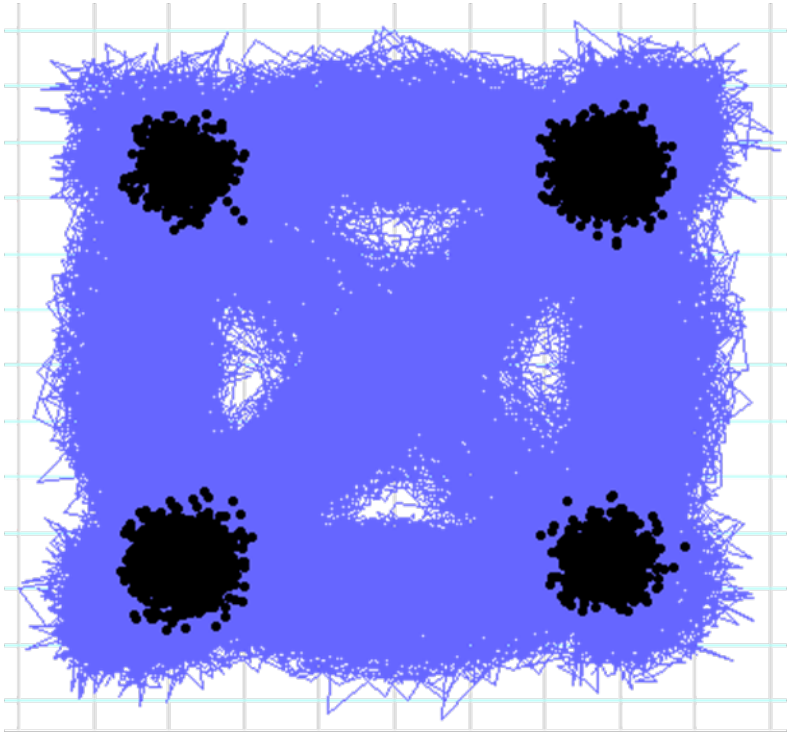
INTRODUCTION TO RF AND COMMUNICATIONS: CHALLENGES IN THE RF ENVIRONMENT

Agenda

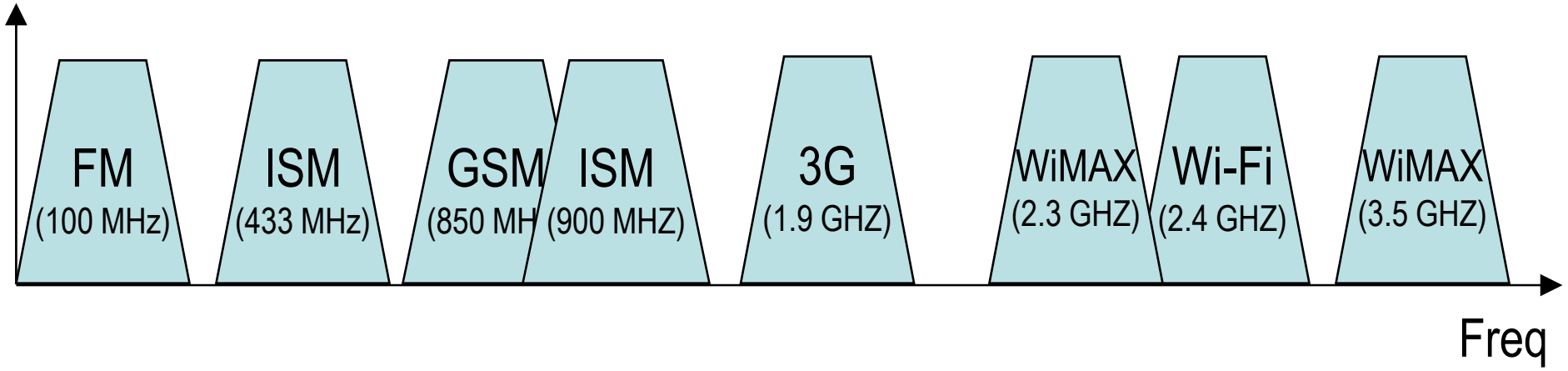
- Part 1: Basics of RF and Communications
- Part 2: Challenges of Wireless Systems
- Part 3: Receiver Validation and Verification



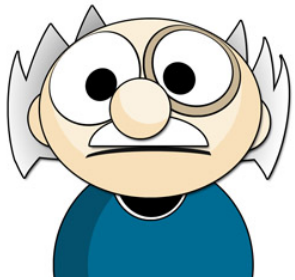
Part 1: Basics of RF and Communications



What Are RF and Microwaves?

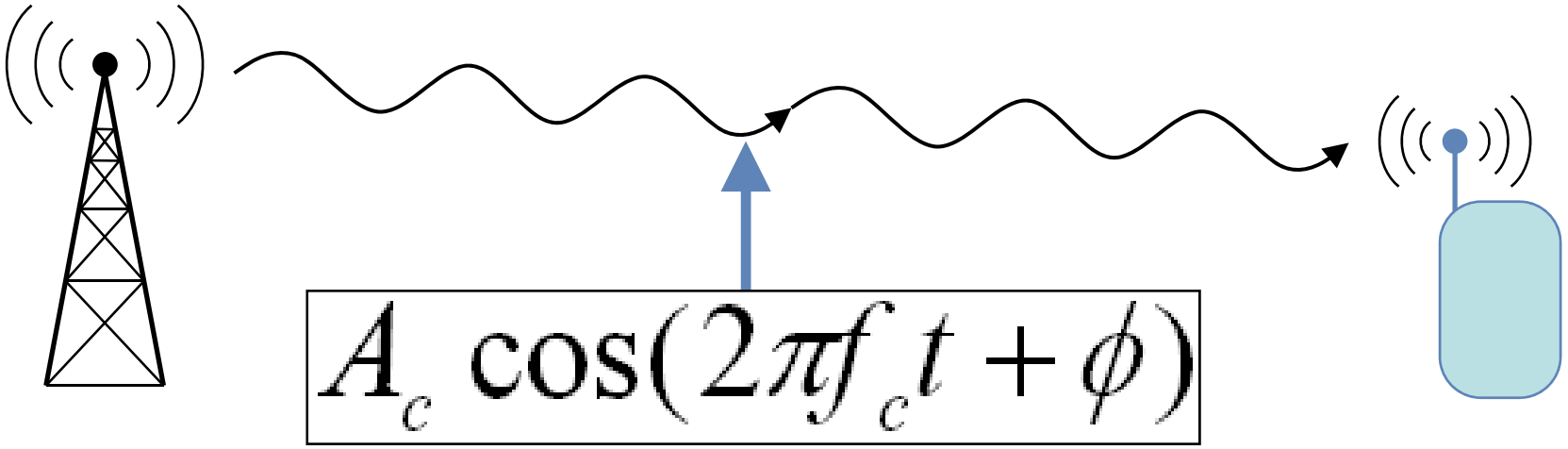


- One day, an old guy decided that "**RF**" starts at 1 MHz
- Frequencies $>$ 1 GHz are considered "**microwave**"
- RF/microwave signals are ideal for communications



Why Use RF Signals for Communications?

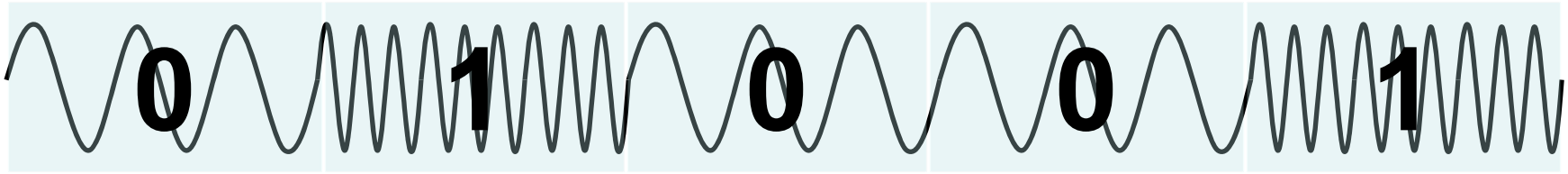
- High frequency ⟶ smaller antennae
- Support many communications links



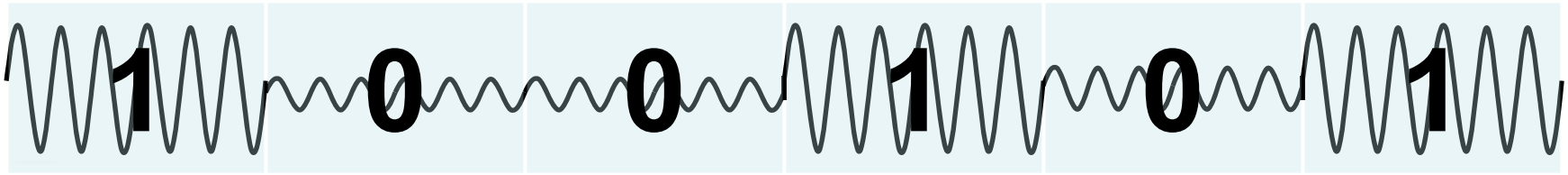
Using Modulation for Digital Communications

$$A_c \cos(2\pi f_c t + \phi)$$

FSK: **F**requency **S**hift **K**eying

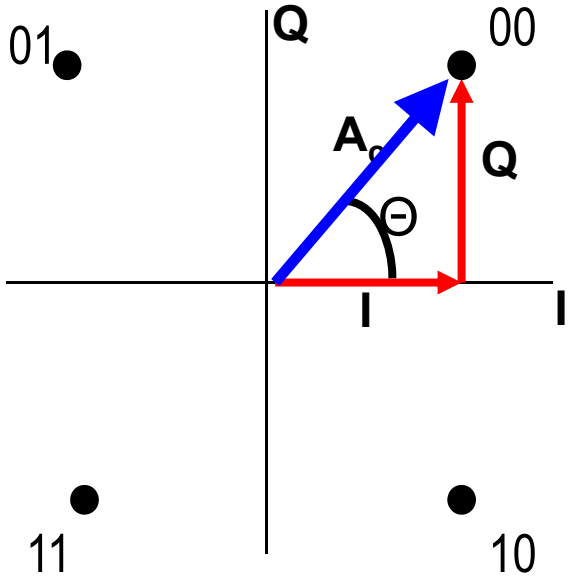


ASK: **A**mplitude **S**hift **K**eying



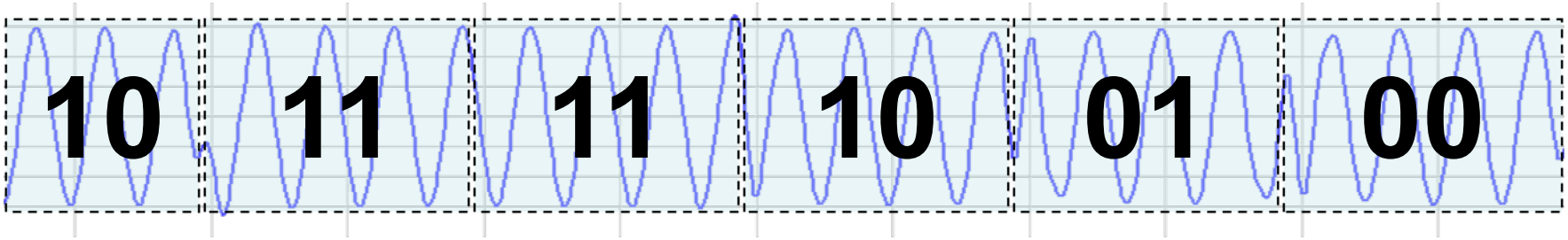
Quadrature Modulation → Phase/Amplitude

$$A_c \cos(2\pi f_c t + \phi)$$



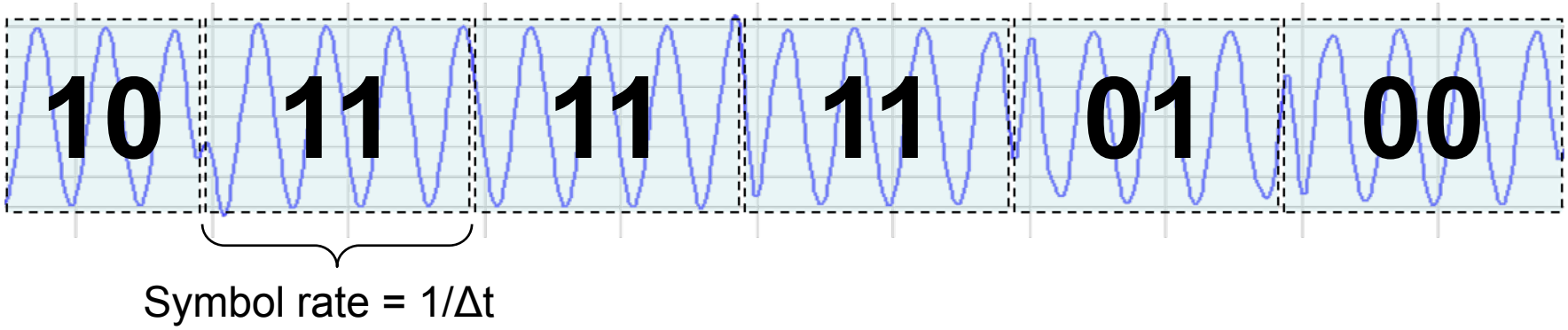
- QAM = Quadrature amplitude modulation
- 4 symbols = 2 bits per symbol

QAM: Time Domain



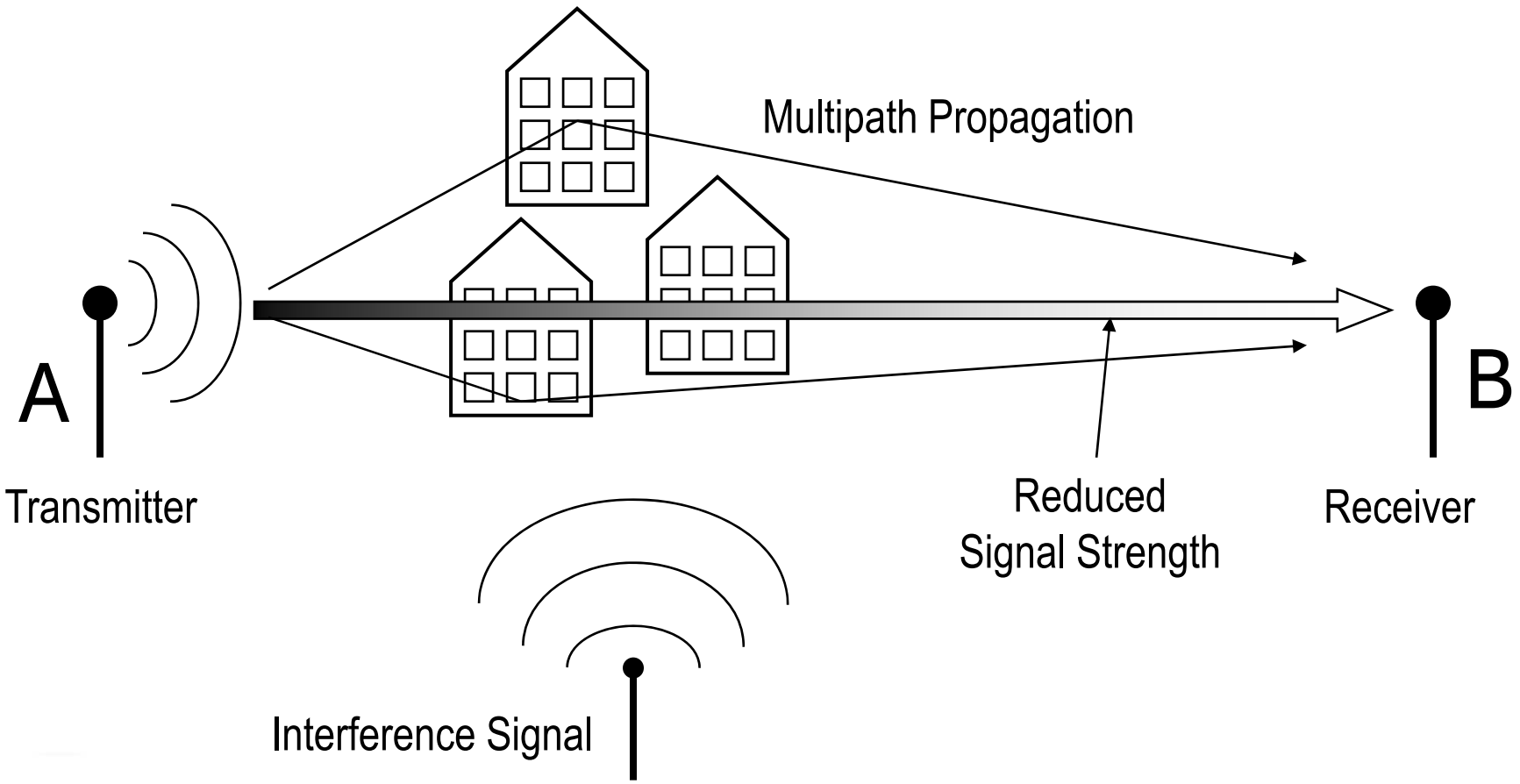
Calculating QAM Bit Rate

- 4-QAM = 2 bits per symbol
- 16-QAM = 4 bits per symbol
- Bit rate = symbol rate x bits per symbol
- Greater symbol rate → wider channel width



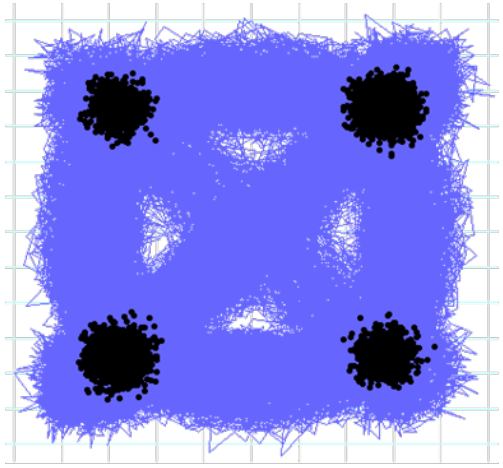
Part 2: The Wireless Environment

Challenges in a Wireless Environment

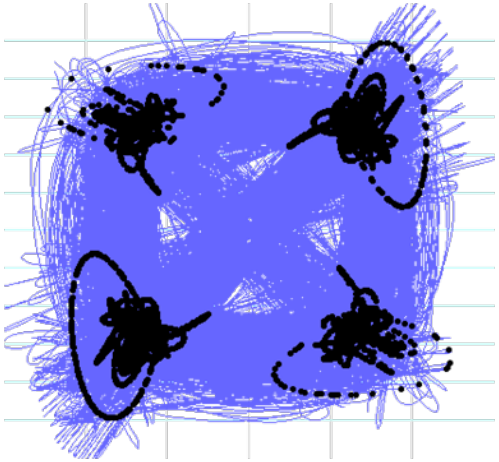


Modeling a Wireless Environment

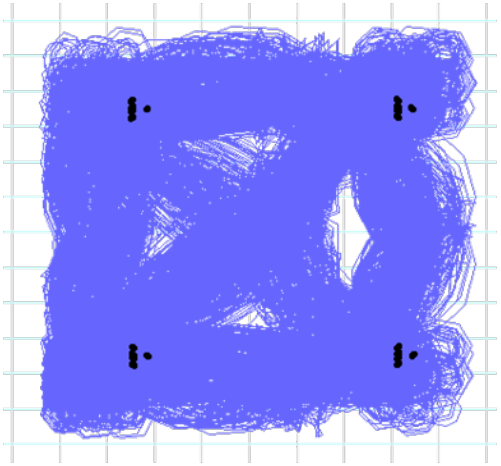
- Low-signal strength → AWGN
- Multipath interference → Rician fading
- Carrier interference → multitone blockers



AWGN



Multipath Fading

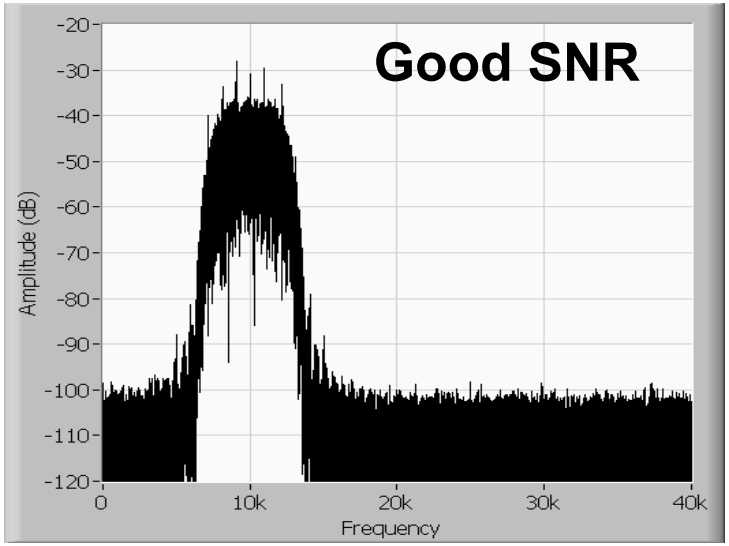


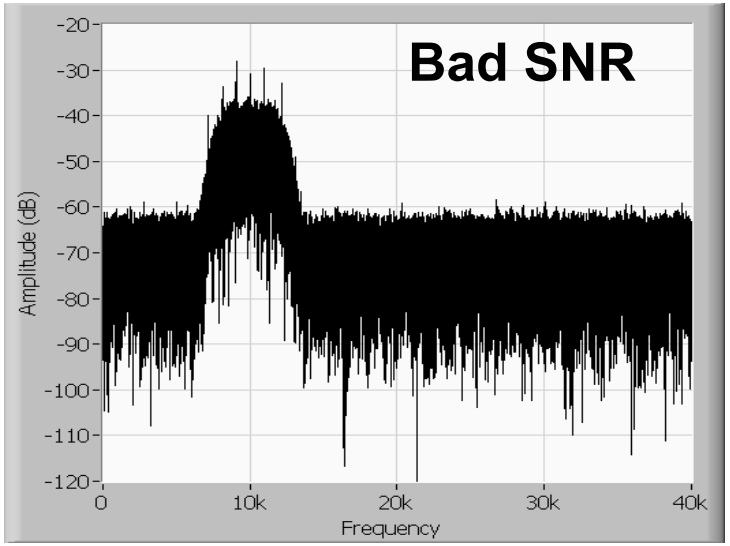
Interference

The Challenge of Signal Strength

- Signal-to-noise ratio (SNR) decreases with distance
- Effective radiated power (ERP) is dependent on signal strength and antenna characteristics
- Protocols such as Wi-Fi (802.11g) use adaptive modulation schemes to deal with this challenge

$$E = \frac{7.07\sqrt{ERP}}{d}$$

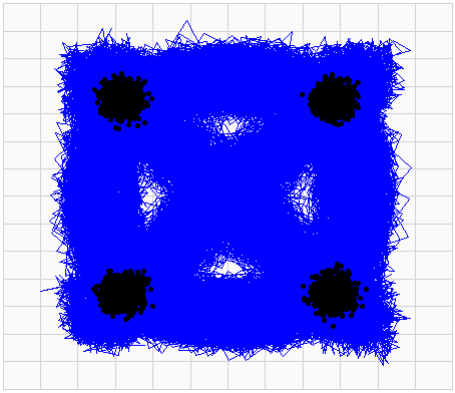




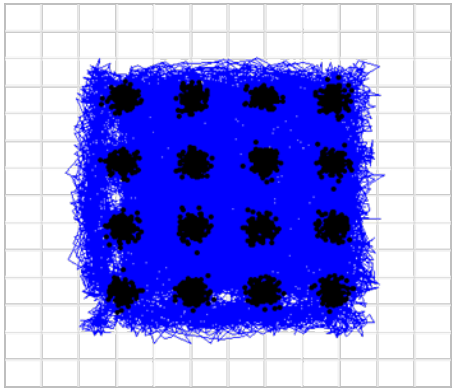
Noise in Modulated Signals

- Signal-to-noise ratio (SNR) reduces EVM
- Higher-order modulation schemes are most affected
- SNR can be modeled with additive white Gaussian noise (AWGN)

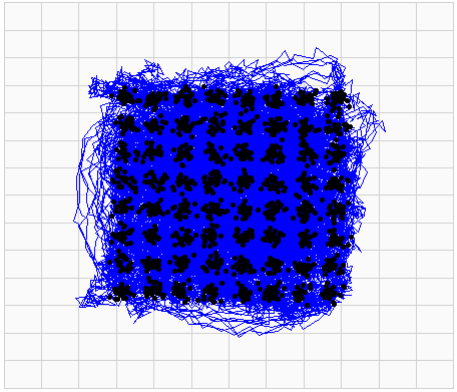
QAM (Quadrature Amplitude Modulation): SNR = 30



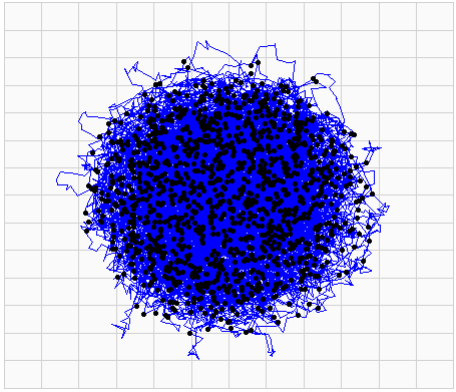
4-QAM



16-QAM



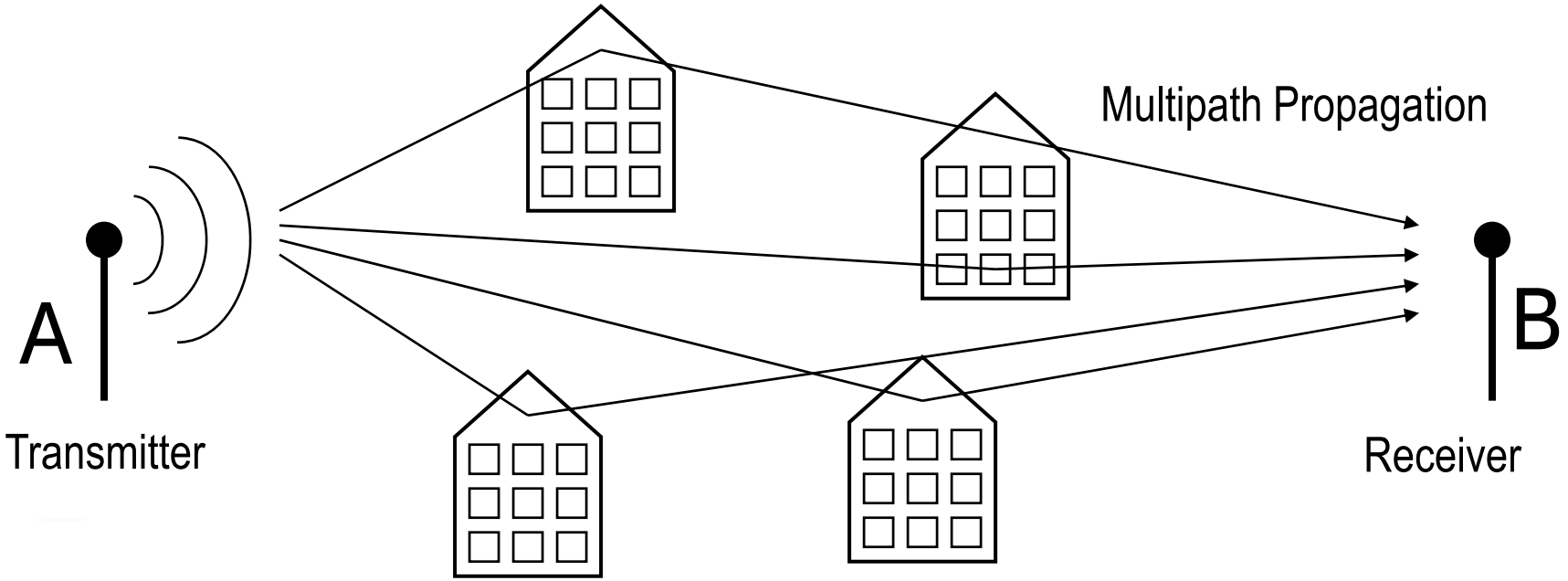
64-QAM



256-QAM

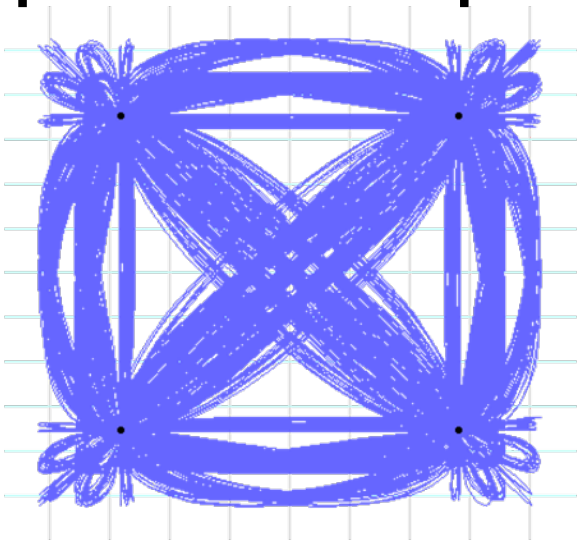
The Problem of Multipath Reflections

- Physical structures cause signal reflection/diffraction
- Reflections cause instantaneous phase/amplitude fluctuations
- Reflections cause intersymbol interference (ISI)



Types Fading Models

- Rician fading profile – emulates line of sight
- Raleigh fading profile – emulates no line of sight
- Doppler shift – represents a mobile receiver

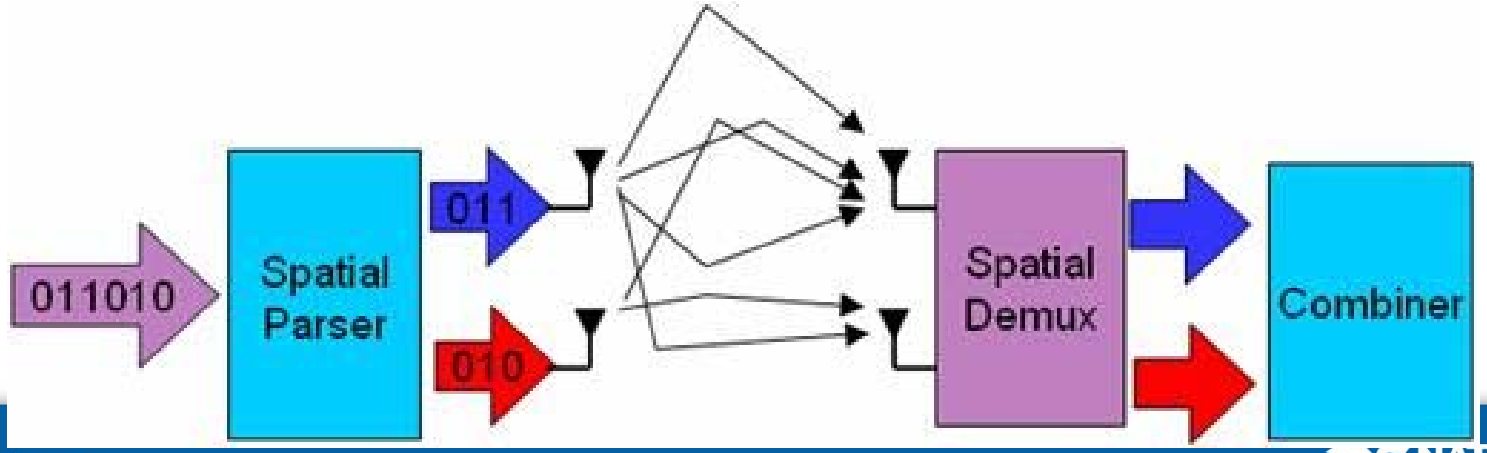


"Ideal" Symbol Recovery

Symbol Recovery with Fading

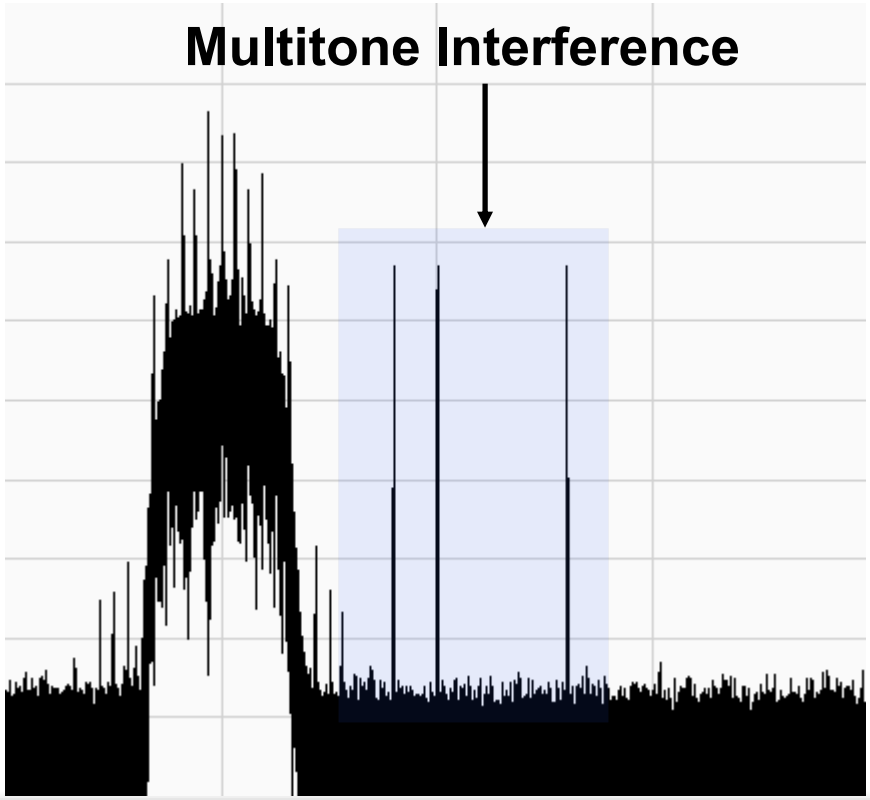
One Exception to Multipath: MIMO

- MIMO = multiple input multiple output antennae
- Uses multipath reflections to determine channel characteristics
- Used in 802.11g/n and WiMAX



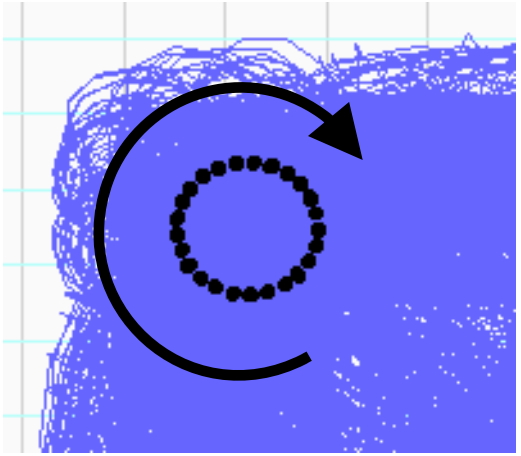
The Problem of Interference (Blockers)

- Communications protocols are allocated to specific bandwidths
- Causes of interference
  - Misdirected antennae
  - Illegal broadcasting
  - Noncompliant hardware



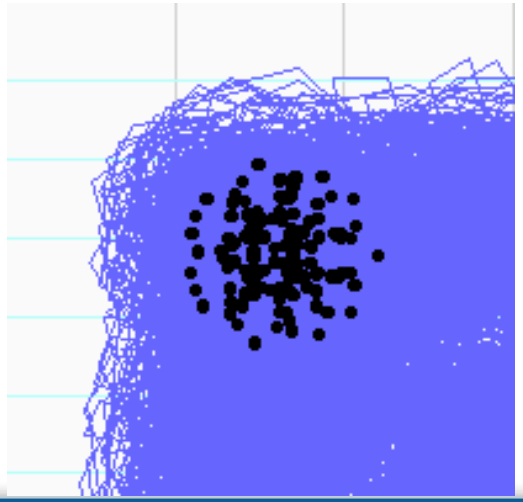
Symbol Recovery with Interference

- Single-tone blocker causes symbols to rotate at a “beat frequency”



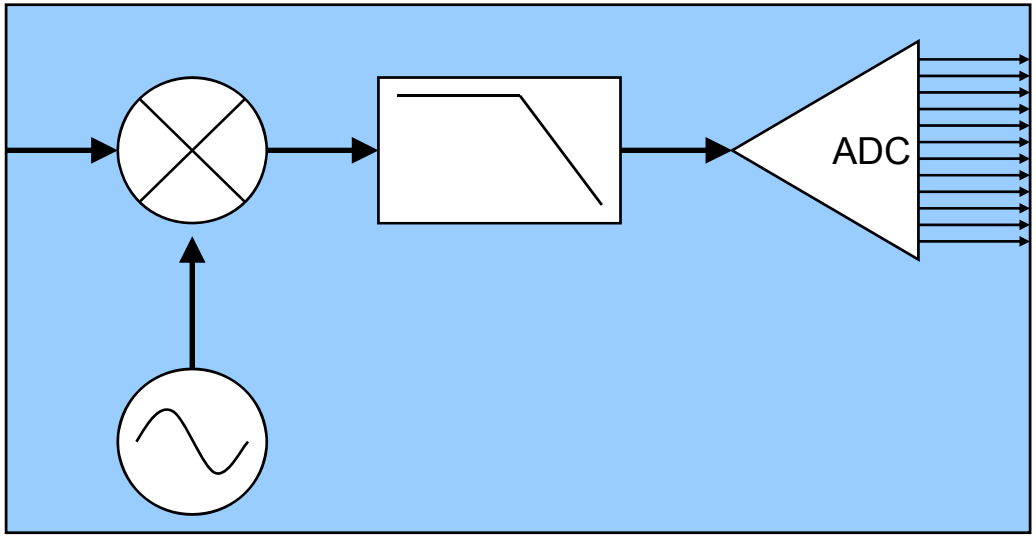
Symbol Rotation

- Multitone blockers create appearance of noise



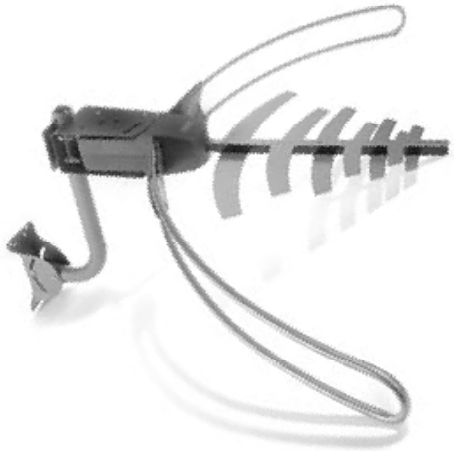
Symbol Spread

Part 3: Wireless Receivers Test Strategies



Application: High-Definition Television (HDTV)

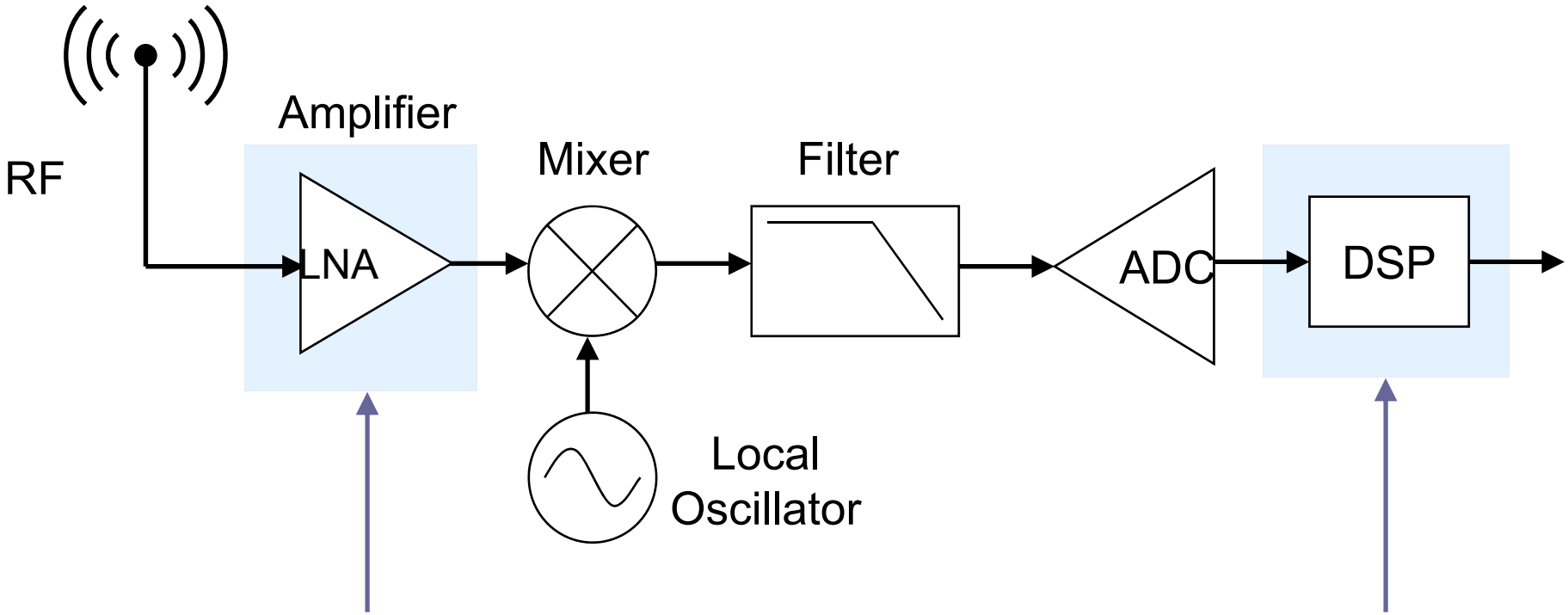
- Uses RF carriers from 54 to 806 MHz
- Uses channel bandwidths of 6, 7, and 8 MHz
- Common standards include: ATSC, DVB, ISDBT



Compliments of Terk, Inc.

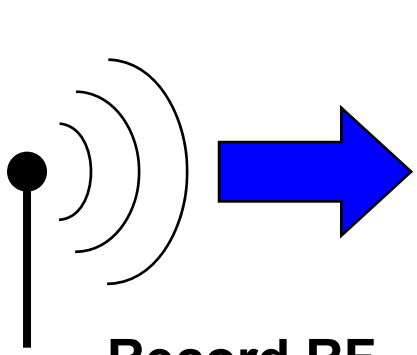
Compliments of Sony, Inc.

Architecture of a Wireless Tuner

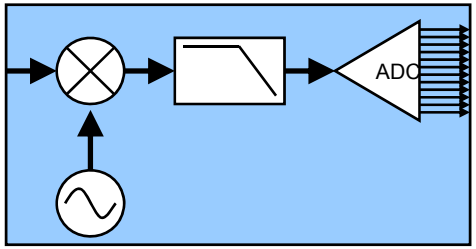


Creating “Ideal” Simulation Environments

- Use for RF record and playback systems in PXI
- Acquire 20 MHz of bandwidth for more than five hours
- Generate recorded signals with a vector signal generator

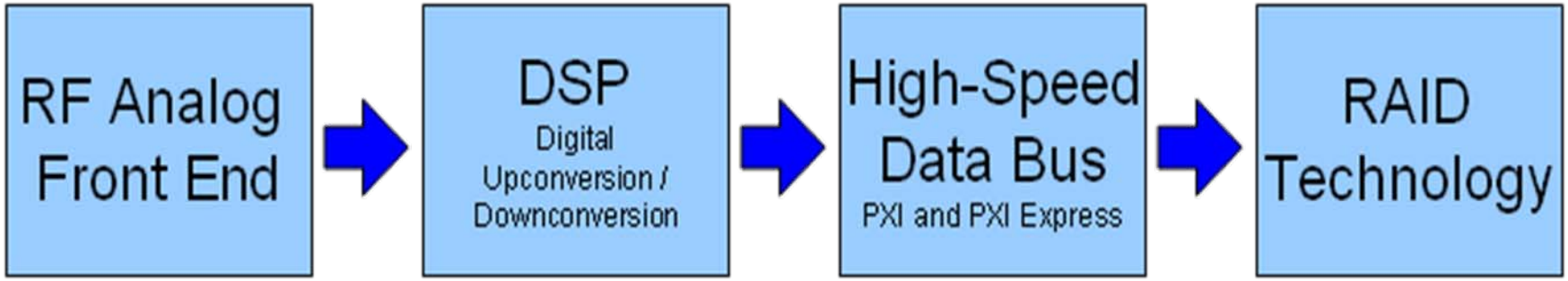


Record RF Environment



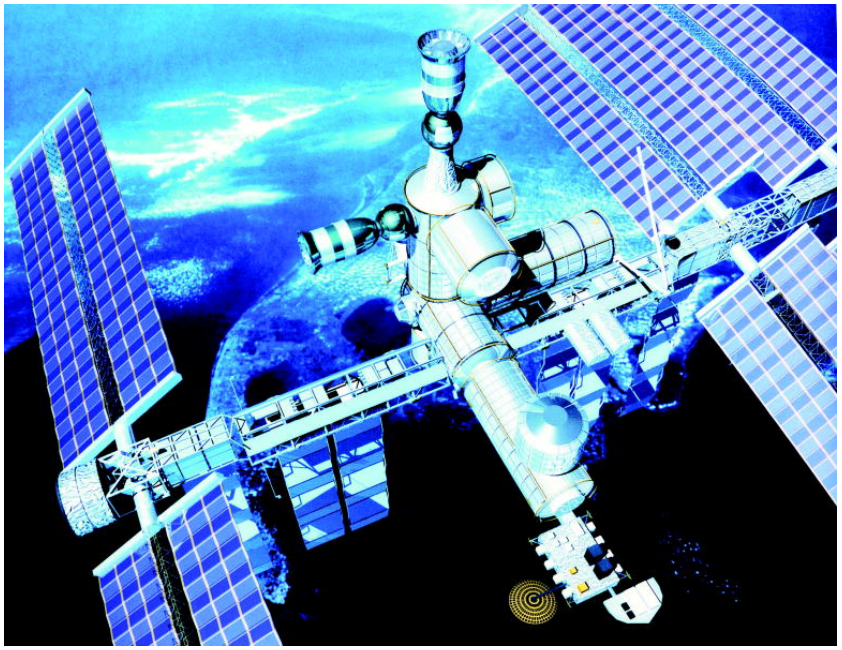
Wireless Receiver Verification/Validation

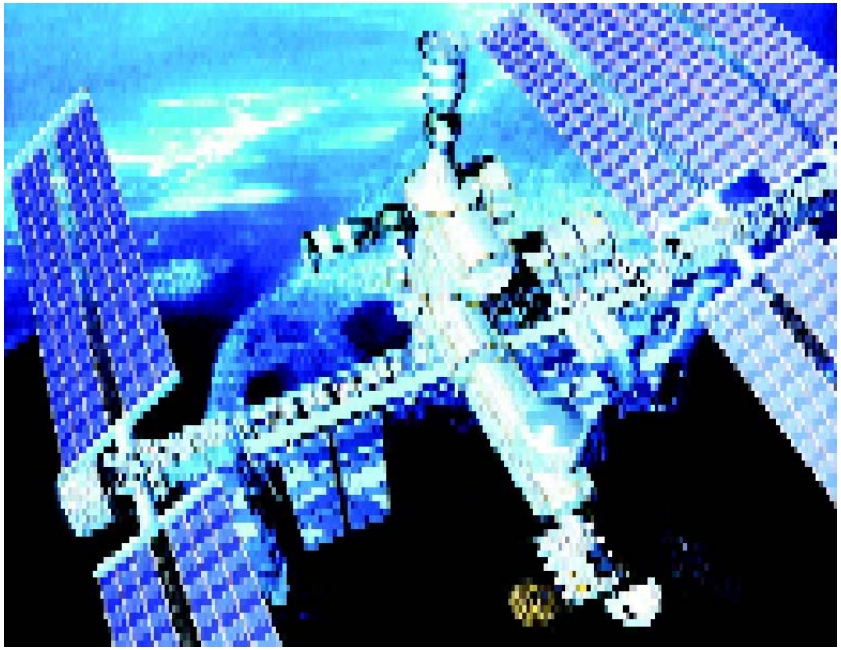
RF Continuous Acquisition with a VSA



- High-Speed Data Bus
  - PXI (PCI) bus provides 132 MB/s (120 MB/s sustained) throughput
  - PXI Express (PCI Express) provides 1 GB/s (400 MB/s to each instrument)
- RAID Technology
  - Stands for redundant array of inexpensive disks
  - Write data in parallel to multiple disks
  - Achieve data read and write rates at up to 650 MB/s

Demo: HDTV Interference Test





Conclusions and Further Information

- Wireless environments are inherently “nonideal”
- LabVIEW provides tools to model wireless signal behavior
- RF record and playback systems enable “perfect” simulations

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