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Deep Memory Waveform Generation: Applications & Methods

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presented by:

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Deep Memory Waveform Generation

Applications & Methods

This presentation reviews the utility of generating waveforms from long and unique data sets. At the end of the presentation you should have a clear understanding of how this may be applied to your project and how to approach the issue in order to increase your test coverage while minimizing the cost and time investment.

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Deep Memory Waveform Generation

Agenda

- Deep memory waveforms
- Applications & generation methods
  - Radar Target Simulation
  - Radar Emitter Simulation
  - GPS Simulation
  - Software Defined & Cognitive Radio Test Cases
  - Air Interface Simulation for Communication Systems
- Waveform streaming demonstration
- Questions & answers

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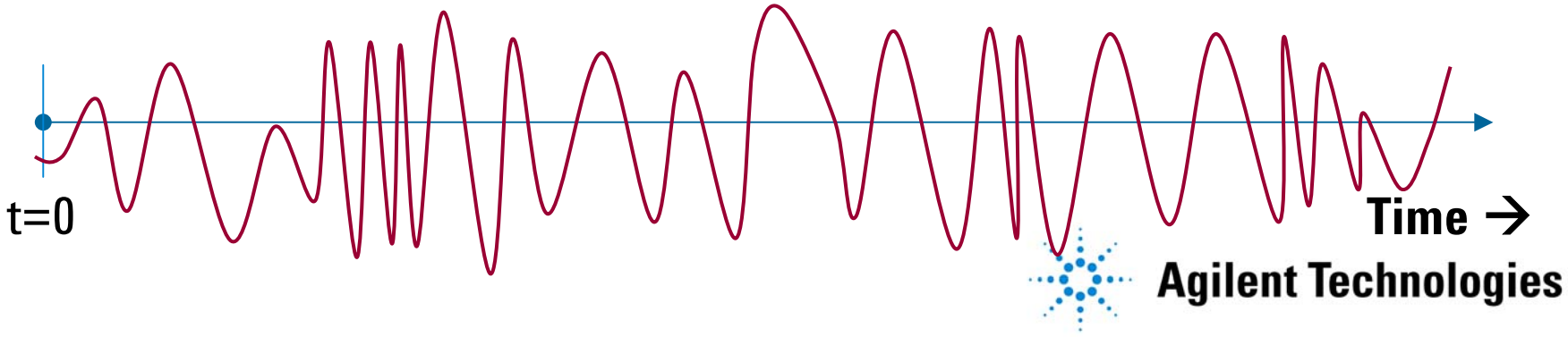
What are Deep Memory Waveforms?

- **Regenerate waveforms directly from I/Q samples stored in a virtually unlimited memory source (e.g. hard disk drive)**
- **Some signal generation applications require long, unique, non-repetitive waveforms**
  - Field testing
  - Air interface physical layer simulation
  - Test and evaluation of software defined radios
- **The cost of characterizing and testing systems in the field has increased while budgets test & characterization have decreased**

  Example: The cost of a radar flight test involving two aircraft at Edwards AFB in 1980 was ~$40K/hour, now the cost is in excess of $100K/hour



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How Much Memory is Enough?

- **Current off the shelf baseband generators contain some amount of playback memory and some have long term waveform storage**
- **Agilent ESG and PSG vector signal generators have up to 64 Megasamples of waveform memory with the internal baseband generator**
  - At 100 MSa/s this is 640ms of playback time
  - At 40 MSa/s this is 1.6s of playback time
- **Sequencing: solution for waveforms with repetitive segments**
  - Pulsed signals with long periods of “off” time
  - Communications signals with repetitive frames of data
- **Data generated in “real-time” internal to the baseband generator**
  - PN sequences

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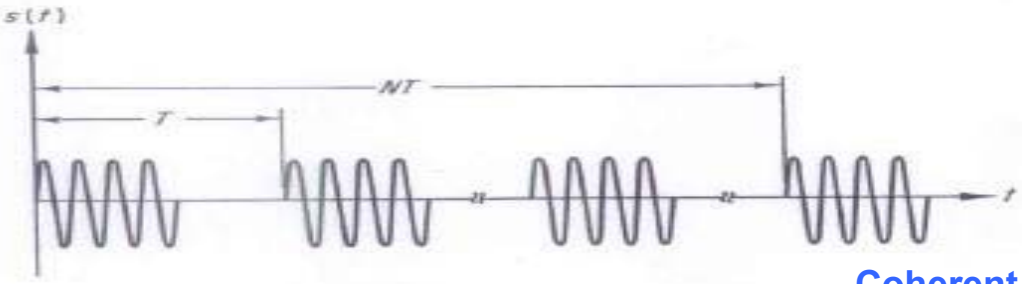
Radar Return Signal Simulation



Coherent pulse train

- **Simulating multiple and realistic targets is essential in the development and verification of radar receivers**
- **Simulation systems for use with active and coherent radar systems are currently almost always based on digital RF memories (DRFM)**
- **Passive or bistatic/multistatic radars, and those active systems that use incoherent detection methods, can benefit from simulation tools based on COTS vector (I/Q) arbitrary waveform generators (ARB)**
  - **Lower cost**
  - **Greater flexibility**
  - **Deep memory waveform playback**

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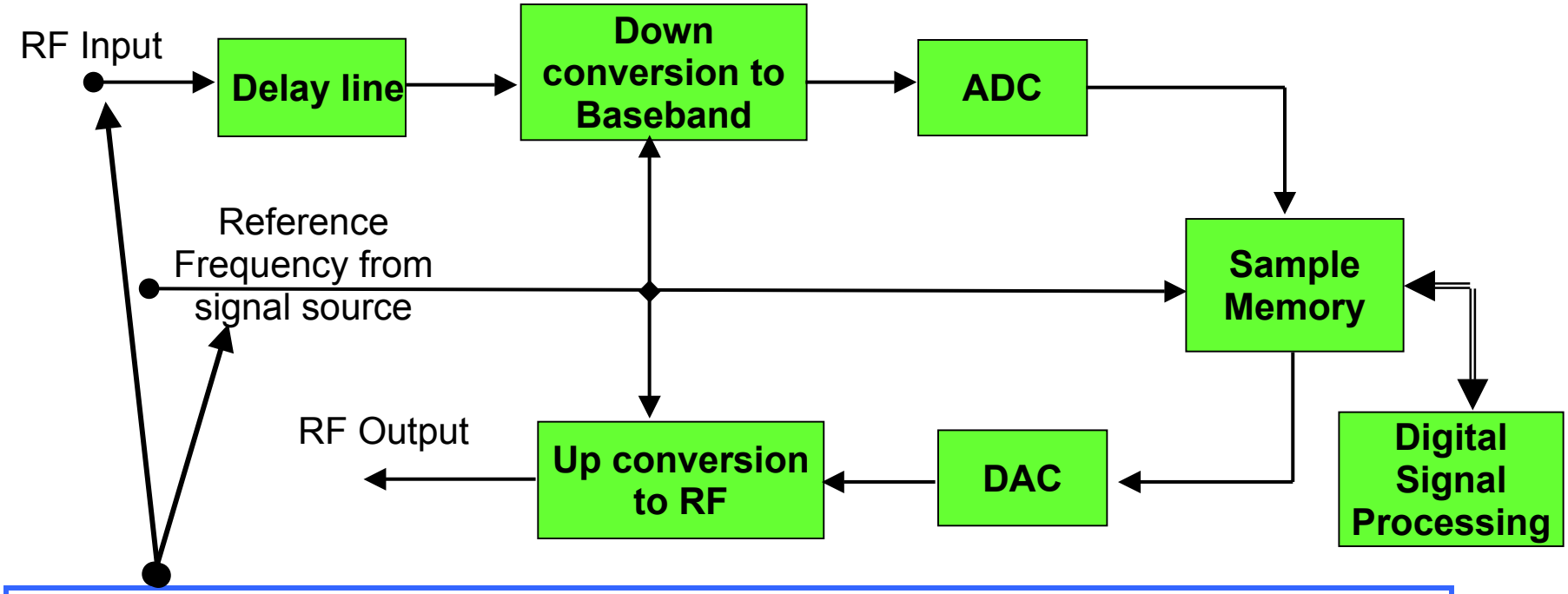
Digital RF Memories (DRFM)

Developed for EW applications,
also used for coherent target simulation



Intrinsically phase coherent with the signal source

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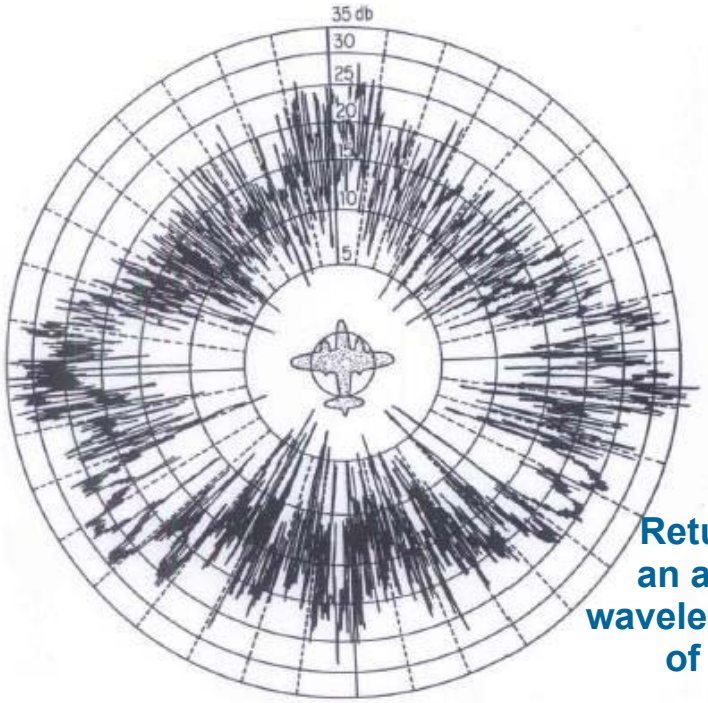
Radar Cross Section (RCS)

- The amplitude and phase of the radar return signal changes as the aspect angle of the target changes
- RCS is very dependent of the target size, shape and construction material
- Radar return RCS simulated using Swerling models (I – IV)



Return power from an aircraft at 10 cm wavelength as a function of azimuth angle

In order to evaluate the radar performance in terms of ability to find and track various target types as they maneuver, many different long scenarios are required.

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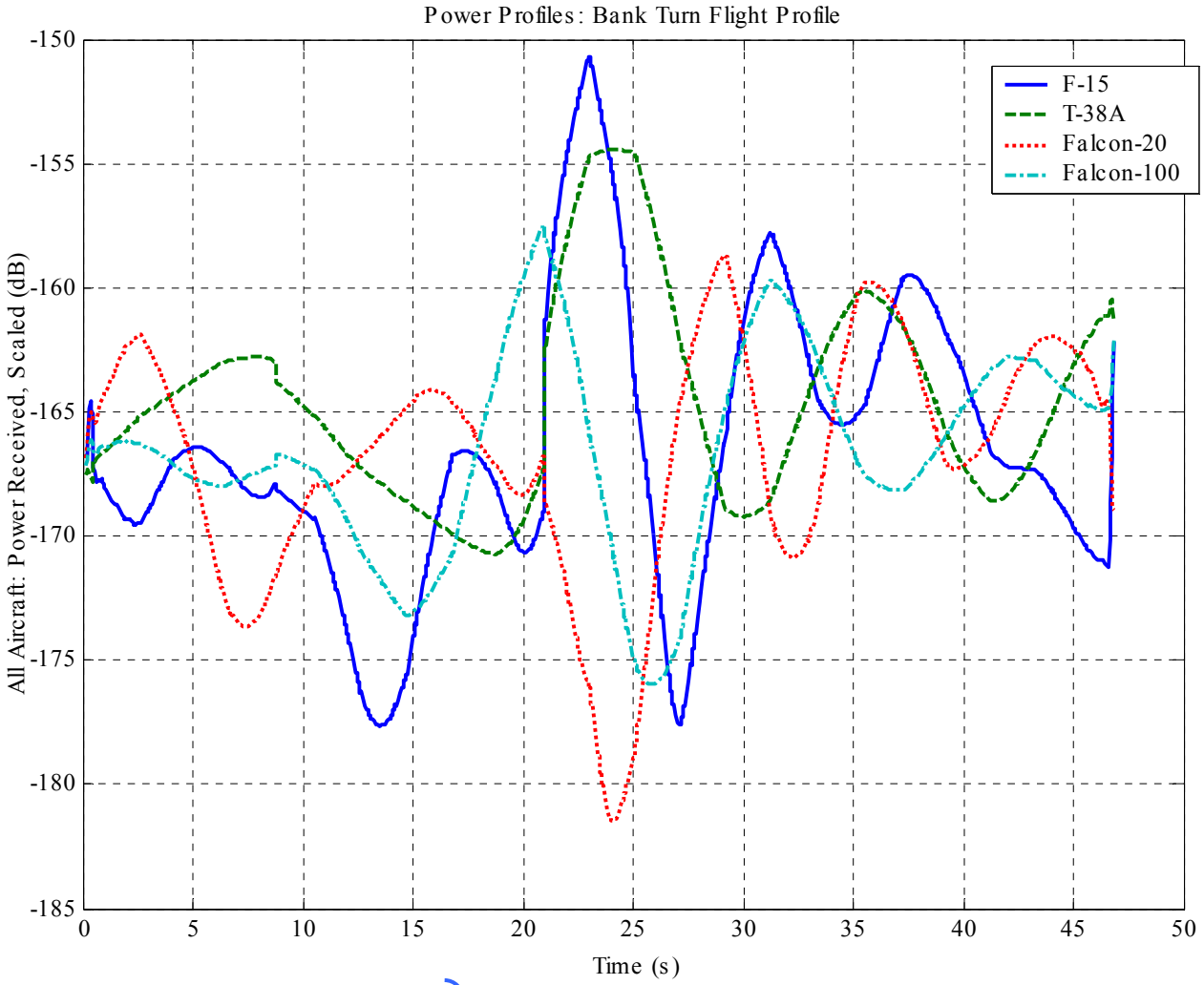
Radar Target Characterization



Lisa Ehrman, Georgia Tech
Automated Target Recognition Using
Passive Radar and Coordinated Flight Models

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Radar Emitter Simulation & ELINT Receiver Test

- Radar emitter simulation can also be characterized as “Radar Threat Simulation”
- Most current systems are combinations of off the shelf equipment and custom hardware
- Electronic and signal intelligence systems must be evaluated with signals that match the complexity of current operational communication systems
- Testing human interaction with electronic threats requires a realistic simulation environment

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GPS Signal Simulation

- **Current system verification test methods require an expensive specialized GPS simulator**
- **Creating verification waveforms and using an off-the-shelf signal generator to stream 12 or more channels of data provides a cost effective alternative**
- **As new systems (Galileo) come on line and new capabilities are added to the the GPS system such as new bands (L5) and addition coding schemes to the L2 band (CM, CL), flexibility will be critical.**

Civil Signal	Carrier Frequency (MHz)	Code Length (chips)	Code Clock (MHz)	Phases	Bit Rate (BPS)	Forward Error Correction
L1	1,575.42	1,023	1.023	Bi-Phase	50	No
L2	1,227.60	10,230 (CM) 767,250 (CL)	1.023	Bi-Phase	25	Yes
L5	1,176.45	10,230 10,230	10.23	Quad-Phase	50	Yes

[GPS World]

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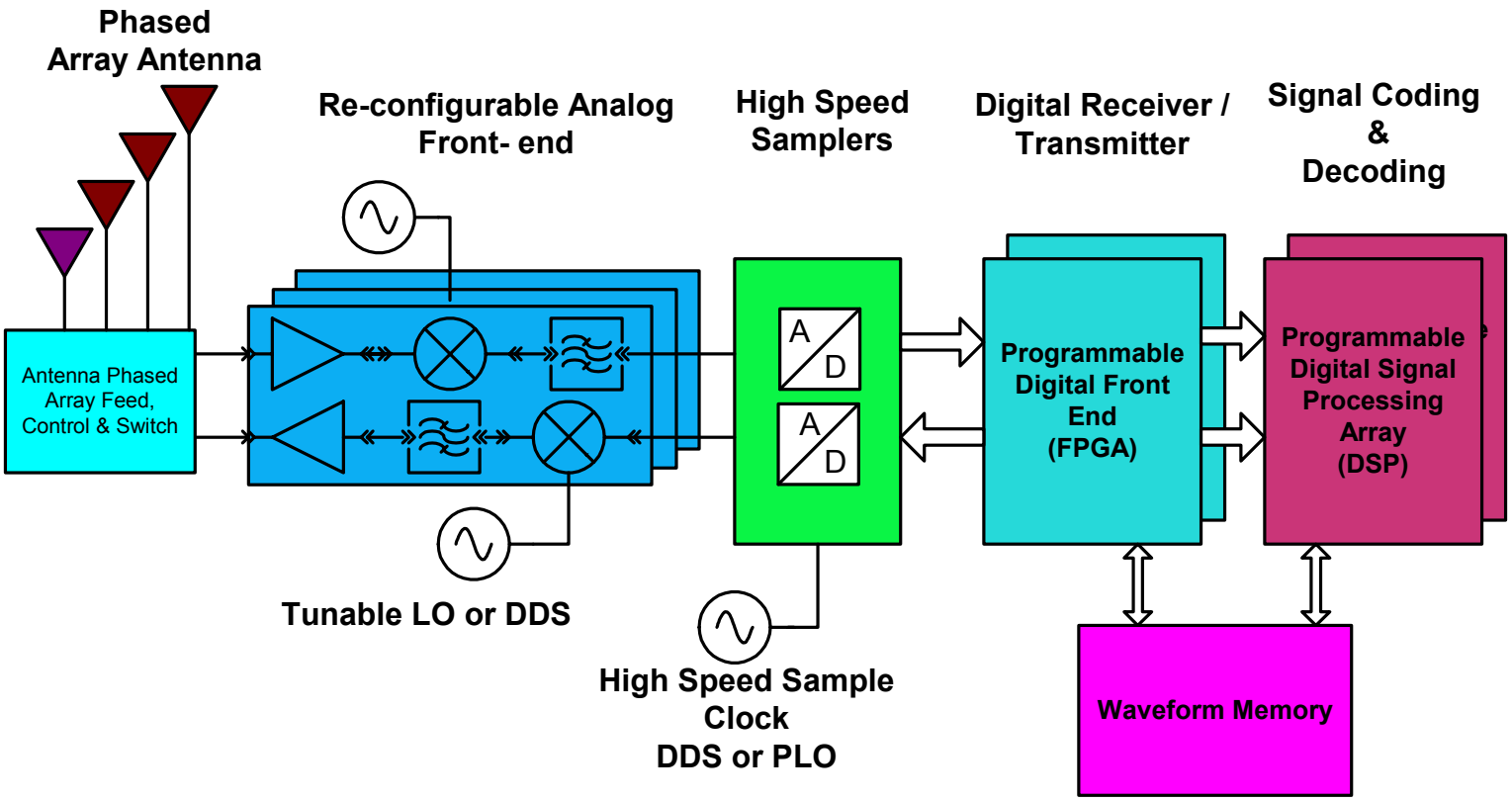
Software Defined & Cognitive Radios

A software defined radio is a radio receiver that is reconfigurable. A cognitive radio is one that can reconfigure itself dynamically.



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Software Defined & Cognitive Radios

System verification test case examples

- Hand off not only between base stations on the same system
- Reconfiguration between dissimilar systems
  - Different transmission techniques (e.g. OFDM, CDMA, TDMA)
  - Different modulation methods (e.g. BPSK, QPSK, QAM)
  - Widely differing operating bands (2.4GHz ISM & 5GHz UNII bands)
- High rate closed loop/open loop power control
- Test cases for the control interface for operational control and reconfiguration
- Security features: encryption and authentication
- High data rate applications: video streams

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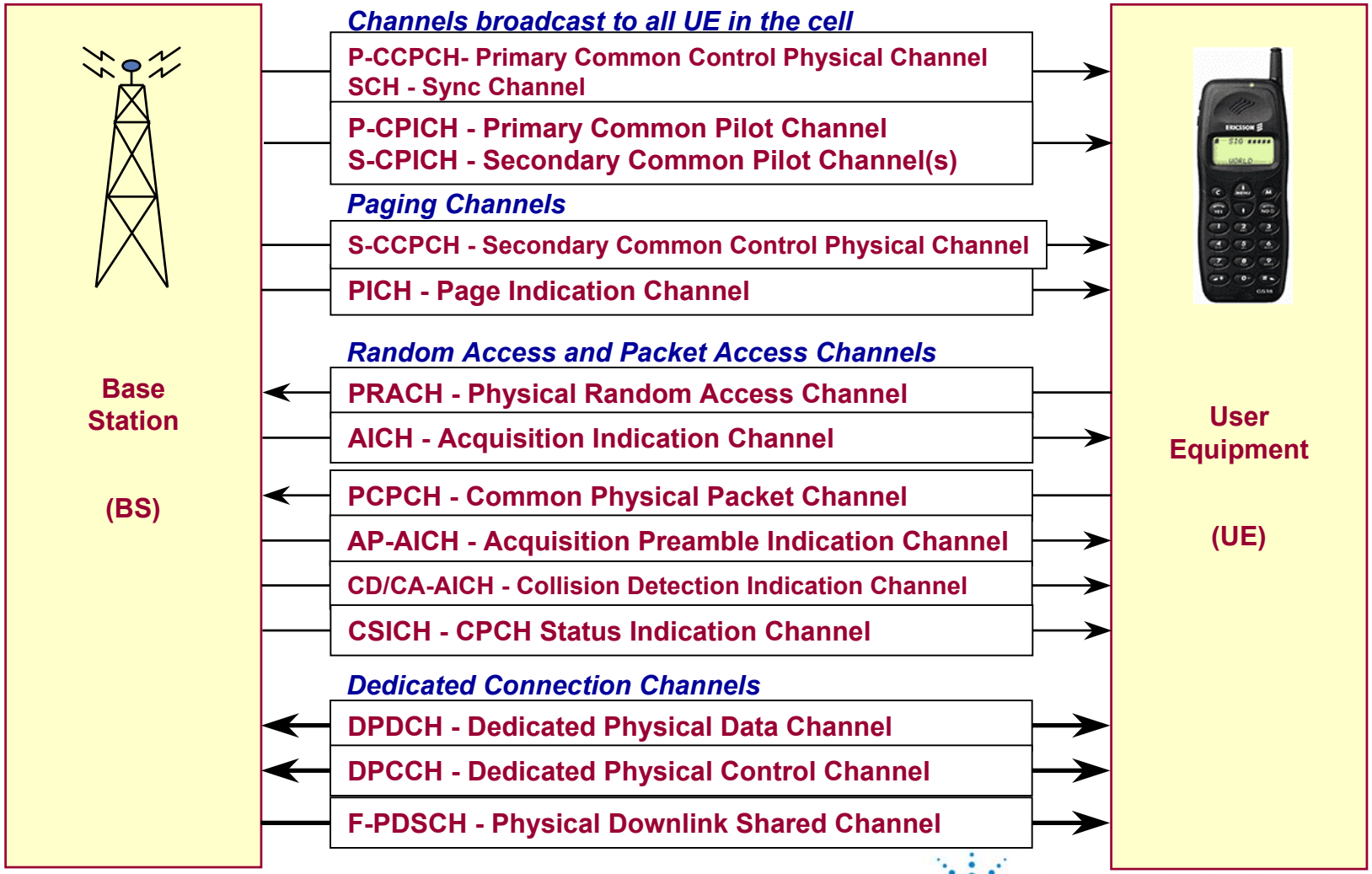
Air Interface Characterization

W-CDMA Example



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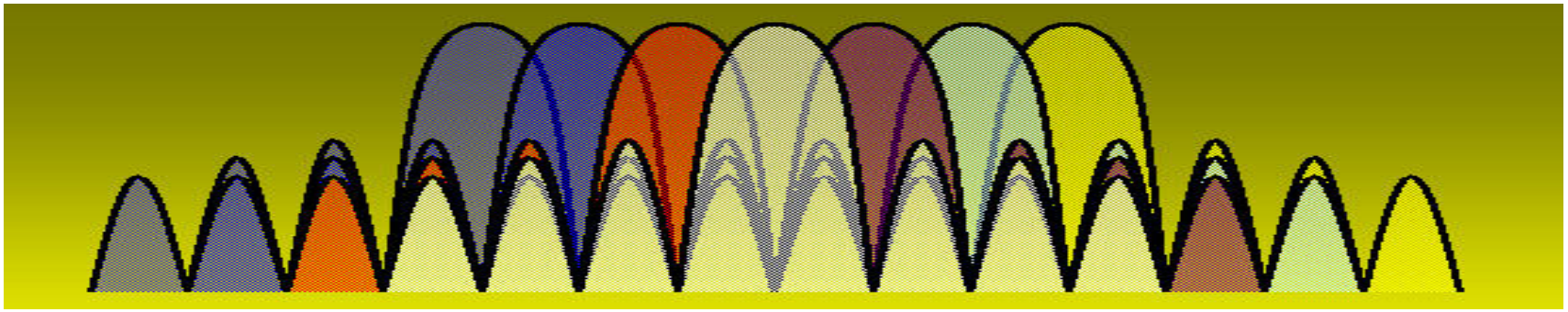
Video Test Signal Generation

- Video test patterns
  - Easier implementation of subjective test techniques: Mean Opinion Score (MOS Testing)
- Surveillance system test: Unmanned Aerial Vehicles (UAVs)
- Digital Video Broadcast (DVB) formats



Very simplified spectral representation of an OFDM signal

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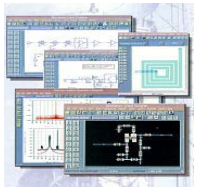
Baseband Studio for Waveform Streaming

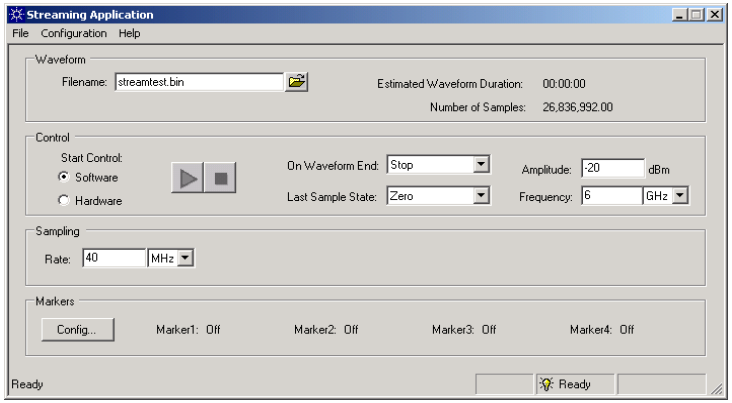


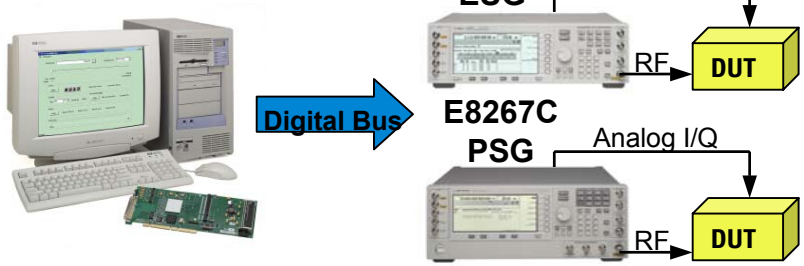
ADS

MATLAB
C++
VB

User Created Waveform

Baseband Studio for waveform streaming





Key Features

- **Continuous I/Q waveform streaming** (direct from PC HDD to ESG/PSG)
- **Eliminates waveform download time**
- **Virtually unlimited waveform length** (scaleable with disk drive technology)
- **Up to 40 MSa/s & 32 MHz RF modulation BW** (scaleable with disk drive & PC technology)
- **Up to 25 ns resolution for pulse shaping**
- **Set playback characteristics**
  - Playback once, N times, or infinitely
  - Playback when triggered
- **Selectable waveform format**
  - 16-bit I/Q
  - 15-bit I/Q w/ 2 markers
  - 14-bit I/Q w/ 4 markers
- **Supports external HW and SW triggering**
- **Automation using the Microsoft .NET API**

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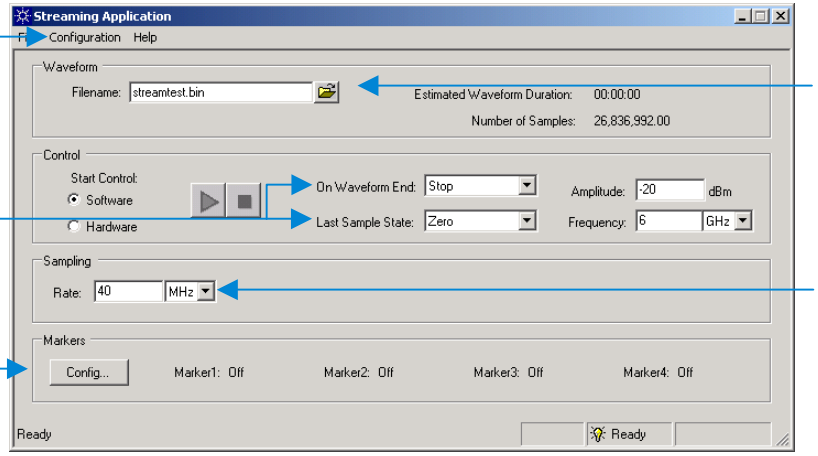
How it works

Step 1
Configure hardware

Step 3
Set playback parameters

Step 5
Configure markers



Step 2
Select waveform from PC

Step 4
Set sample rate

Step 6
Stream waveform

Baseband Studio for waveform streaming

Digital Bus

E8267C PSG/ E4438C ESG

Analog I/Q

DUT

RF

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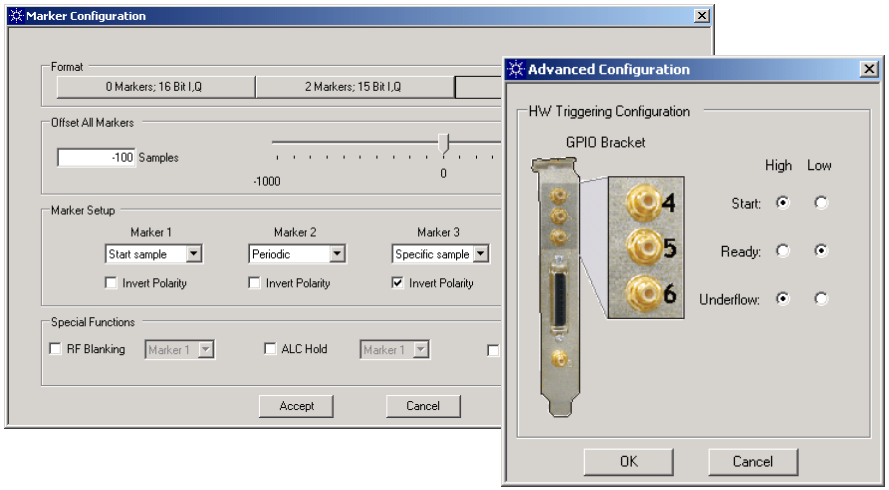
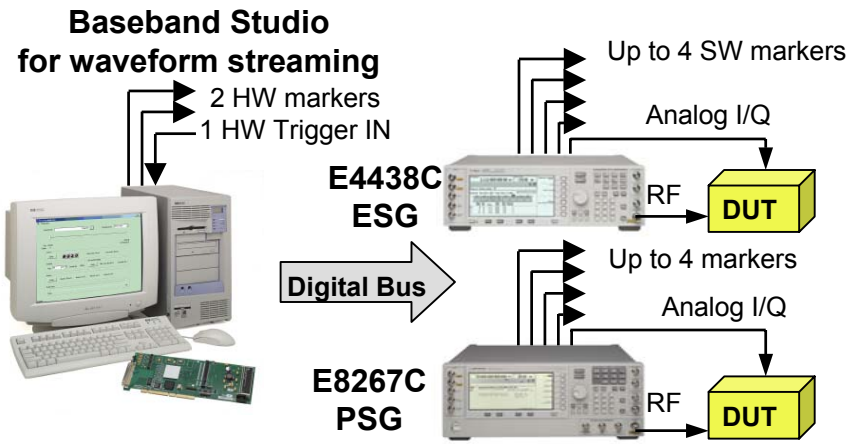
How it works

Hardware and software markers and triggers





Marker/Trigger Features

- Select 0, 2, or 4 SW markers
  - Start, stop, or specific sample
  - Periodic
  - Zero or range detect
  - Special functions: RF Burst, ALC Hold, ALT Power
- Independently configure SW markers
  - Time resolution = 1/fs
  - Set marker duration
  - Delay up to ±1000 samples
- HW markers and input trigger
  - Markers: HW Ready, Underflow, Trigger: Start Stream

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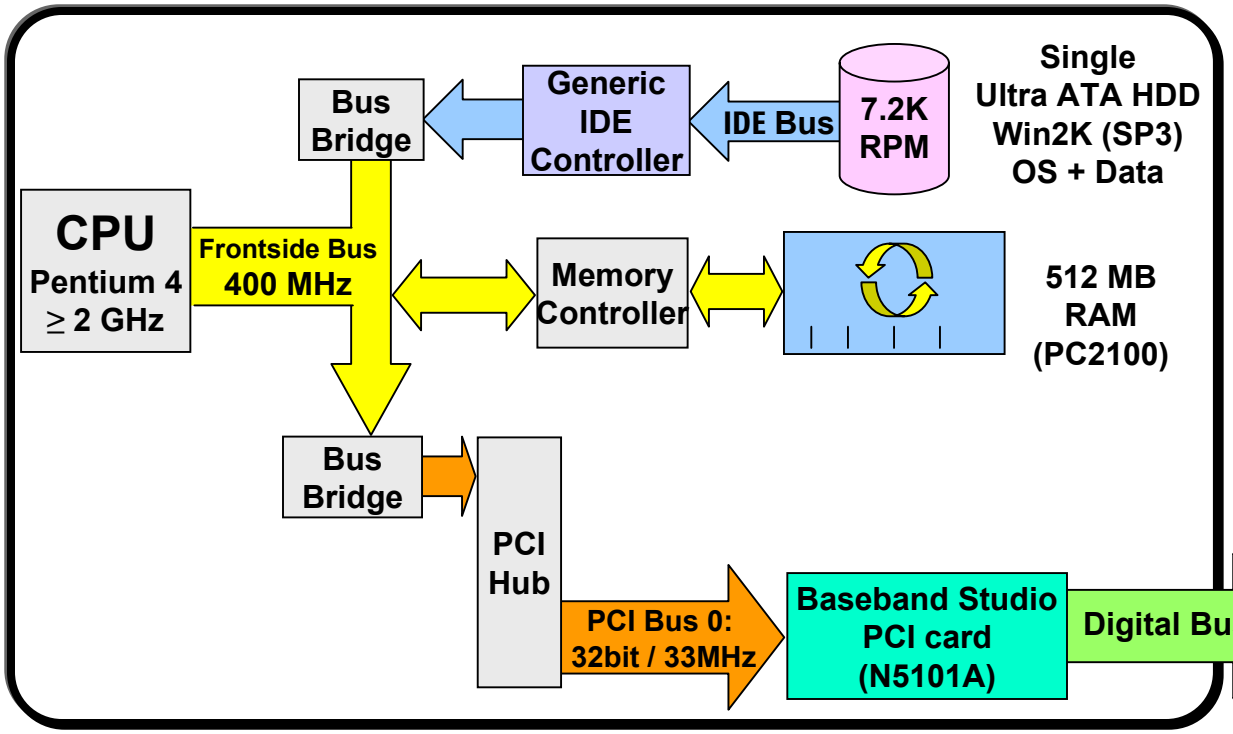
What about speed?

Slow rate waveform streaming



Streaming rate

- Up to 5 MSa/s

E4438C ESG or E8267C PSG
Vector Signal Generator

Important PC Characteristics

- Processor & clock speed
- Front side bus speed
- Hard Disk
- Memory size & speed

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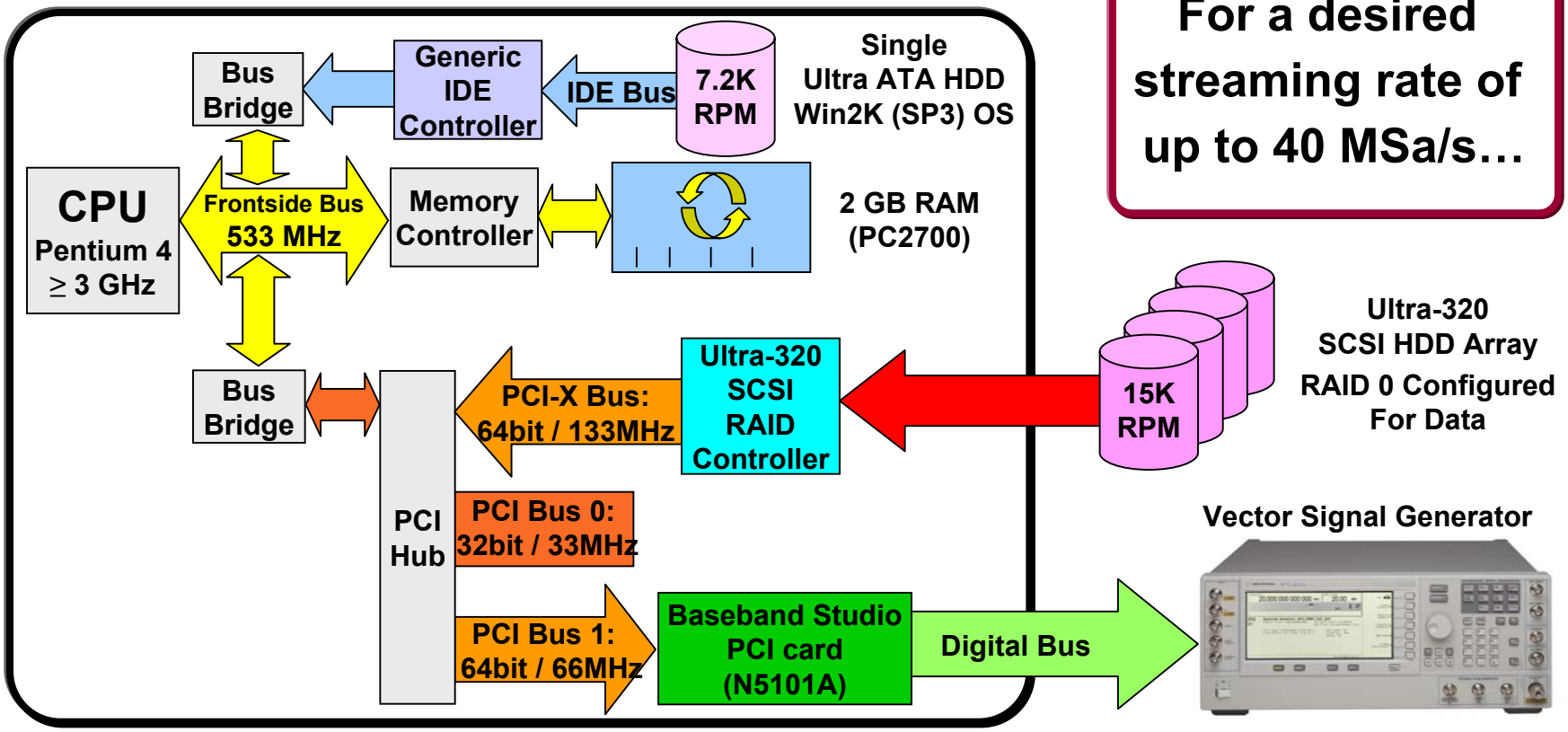
What about speed?

High Rate Streaming



For a desired streaming rate of up to 40 MSa/s…

Important PC Characteristics

- Processor & clock speed
- Front side bus speed
- Memory size & speed
- PCI bus configuration
- HDD Controller
- Hard Disks & configuration

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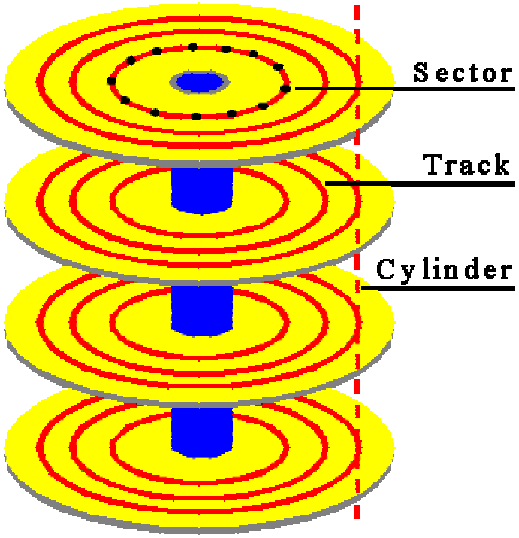
Optimizing HDD Access Speed

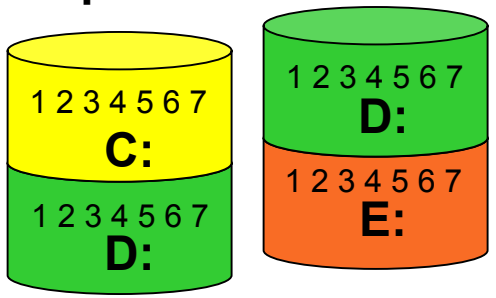
Recommended HDD structure

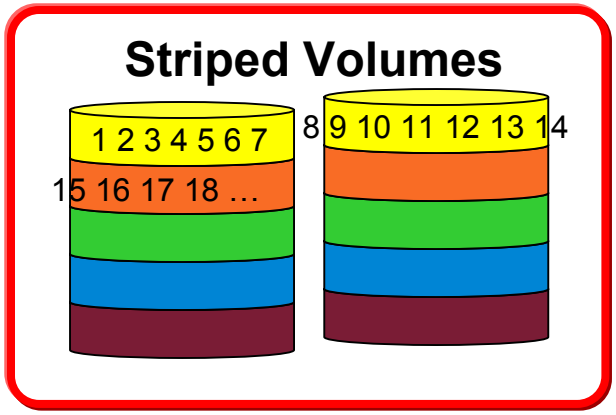
- **Disk partitioning** - take advantage of physical attributes of drive to minimize seek time
- **Striped volumes** – multiple HDDs are accessed simultaneously to maximize throughput (RAID 0)

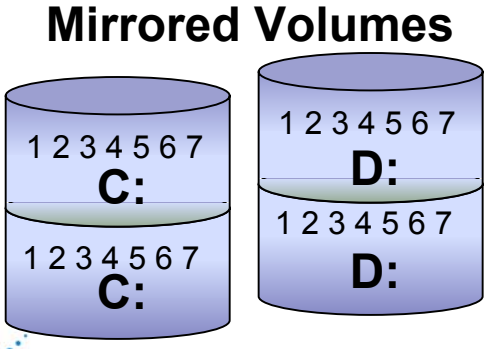
Recommended HDD maintenance

- **De-fragmentation** – re-orders data in a sequential order to minimize seek time
- **Clean Up** – remove temporary files left by many programs to minimize seek time and fragmentation









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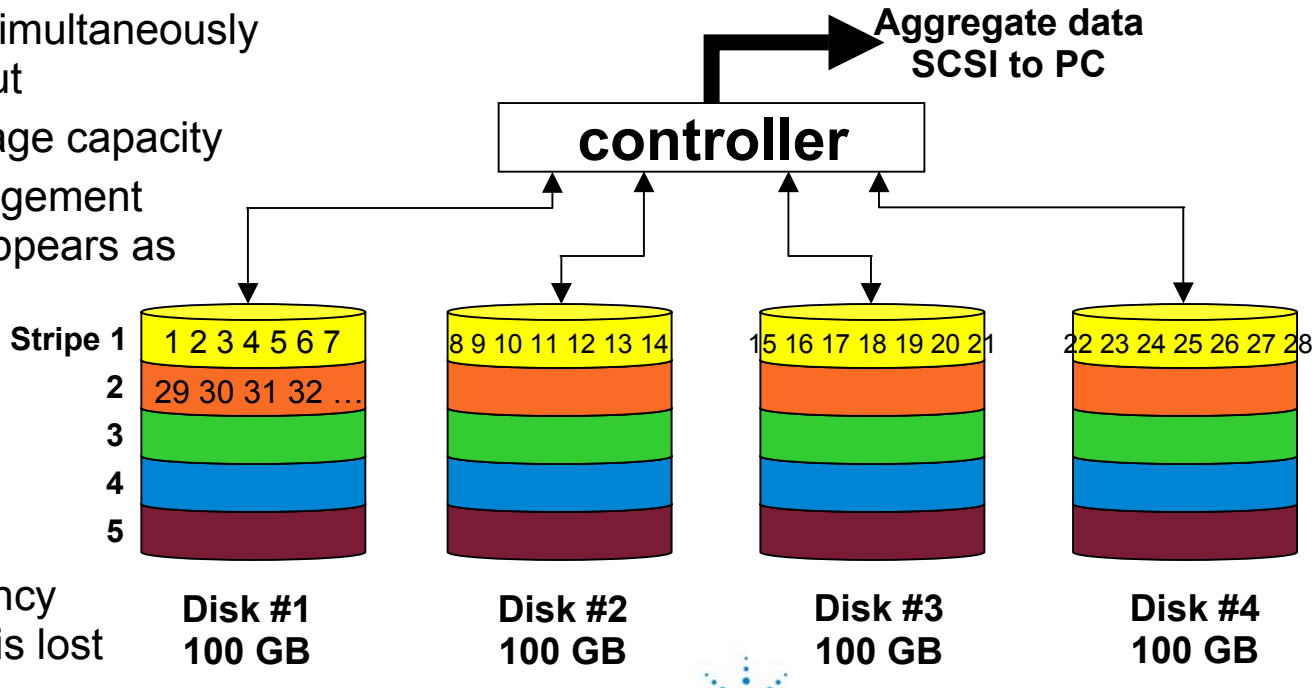
Optimizing HDD Access Speed

Redundant Array of Inexpensive Disks (RAID)

RAID 0 Architecture

- Simplest form of RAID architecture
- “Stripes” data evenly over multiple HDDs
- Optimized for data access speed (2x, 3x, 4x data rate)
- Access all four disks simultaneously to maximize throughput
- Enables scalable storage capacity
- Convenient disk management because file system appears as single 400 GB volume

RAID
is simply a method of creating one or more pools of data storage space from several hard drives…



WARNING
- No data redundancy
- If disks crash, data is lost

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Record and Playback Long Waveforms

Take your waveform simulation to the next level...

- **Record signals off the air with the 89600 VSA**
- **Transfer files to a PC equipped with Baseband Studio and re-format**
- **Stream them into the PSG or ESG signal generator for playback**

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Summary

- Deep memory waveform generation has high utility in a variety of applications including:
  - Radar target and emitter simulation
  - GPS signal simulation
  - Development of test case for software defined or cognitive radios
  - Air interface simulation
- COTS vector arbitrary waveform generators with deep memory or waveform streaming can offer a lower cost and often more capable alternative to conventional testing methods for many applications

Thank You for your Attendance!!!

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Waveform Streaming Demonstration

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Q & A

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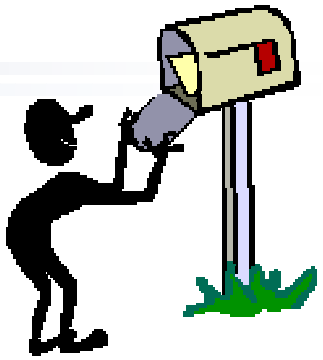

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