EECS 1

Introduction to Electrical Engineering And Computer Science

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Course Schedule

April 1	Intro (Profs. Ender Ayanoglu and Rainer Doemer)
8	Electronic Circuit Design (Prof. Payam Heydari)
15	RF, Antennas, Microwaves (Prof. Filippo Capolino)
22	Semiconductors and Optoelectronics (Prof. Ozdal Boyraz)
29	Programming (Prof. Rainer Doemer)
May 6	Hardware Systems (Prof. Nader Bagherzadeh)
13	Software Systems (Prof. Brian Demsky)
20	Chip Design (Prof. Fadi Kurdahi)
27	DSP & Communications (Prof. Ender Ayanoglu)
June 3	TBD

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EE Specializations

- Electronic Circuit Design
- RF, Antennas and Microwaves
- Semiconductors and Optoelectronics
- Digital Signal Processing
- Communications

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What is DSP & Comm?

- Higher level, more abstract view of signals and systems
  - Signal: acoustic, electromagnetic, vibrational, financial, etc.
  - System: anything with an input and output
- Focus on mathematical and statistical models, theory, algorithms
- Common tasks: remove noise, extract one signal from a mixture of many, find patterns in data, compress/quantize data, detect the presence of a signal, locate a target, predict a future output, etc.
- Applications: wireless networks, satellite systems, speech or image recognition, radar/sonar, GPS, image and video coding and compression, biosignals (EEG, MRI), remote sensing
- The brains behind what the hardware and software does …

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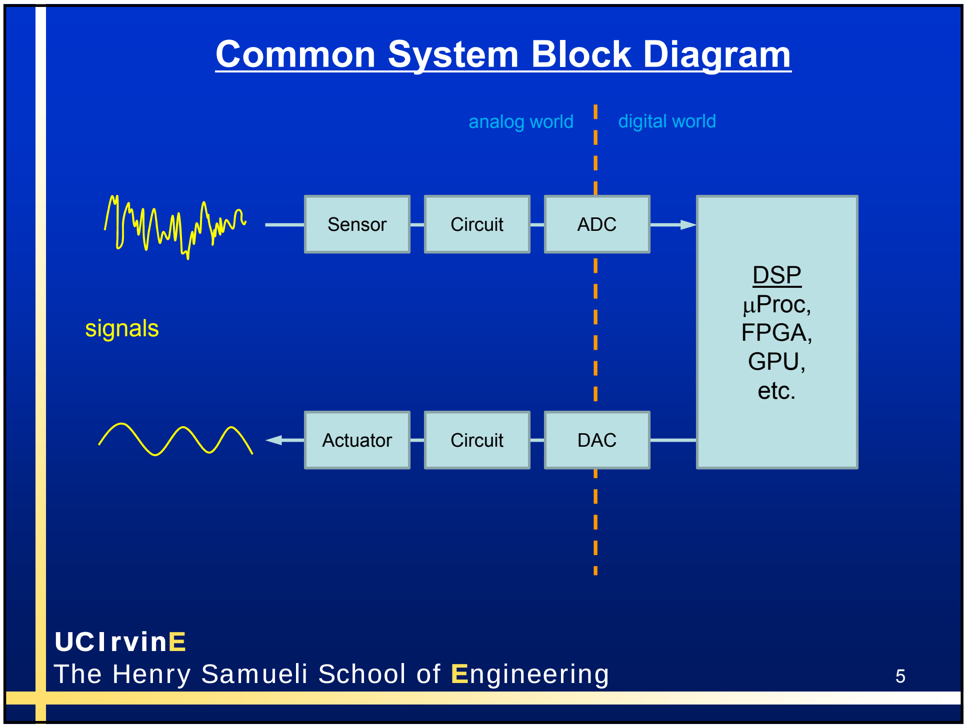
Common System Block Diagram
analog world
digital world
Sensor
Circuit
ADC
signals
DSP
µProc,
FPGA,
GPU,
etc.
Actuator
Circuit
DAC
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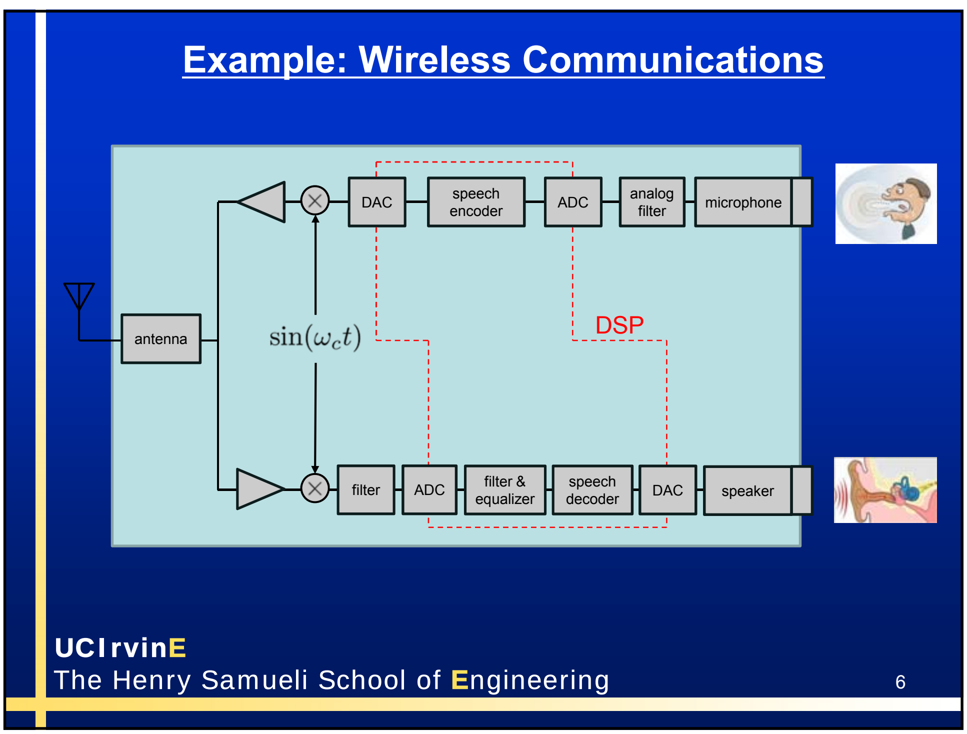
Example: Wireless Communications
DAC
speech encoder
ADC
analog filter
microphone
antenna
sin(ωct)
DSP
filter
ADC
filter & equalizer
speech decoder
DAC
speaker
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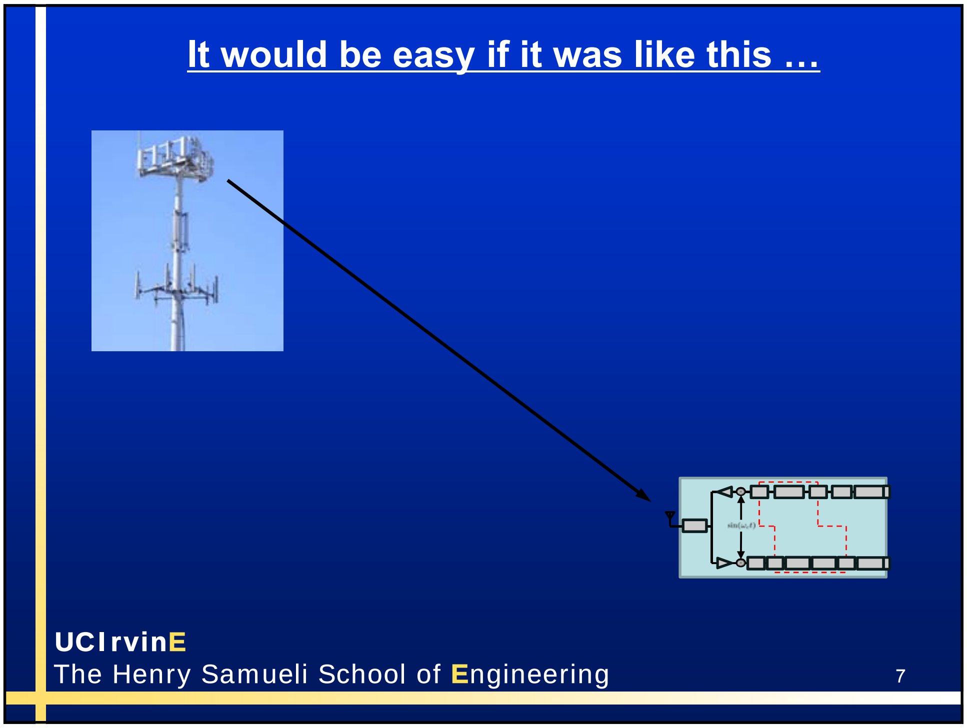
It would be easy if it was like this …
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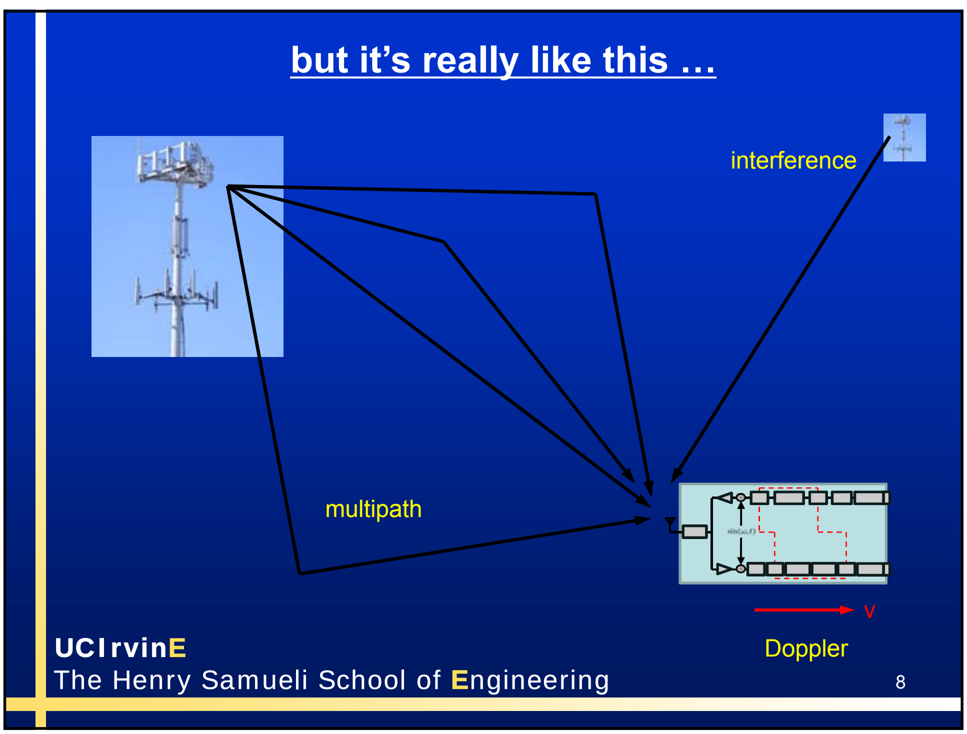
but it's really like this …
interference
multipath
v
Doppler
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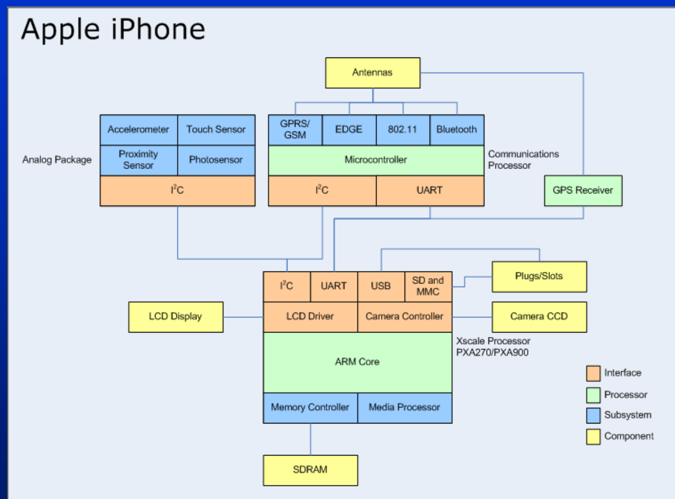
More Realistic Block Diagram



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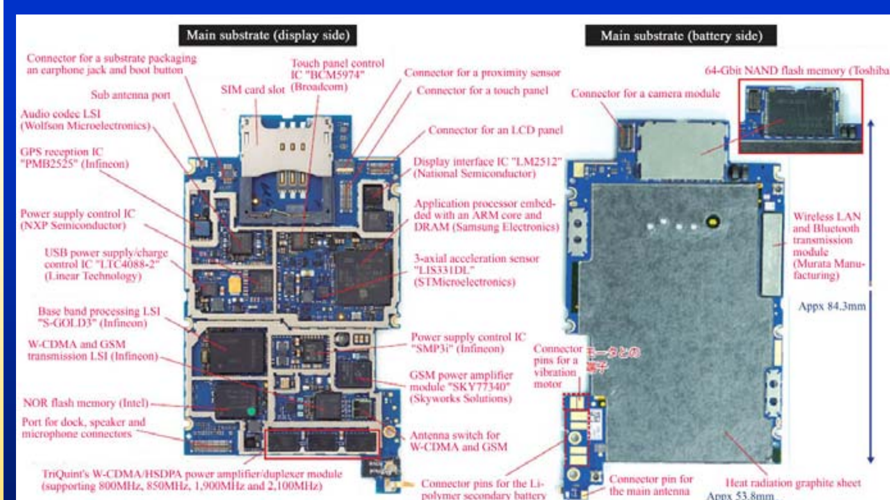
Under the Hood



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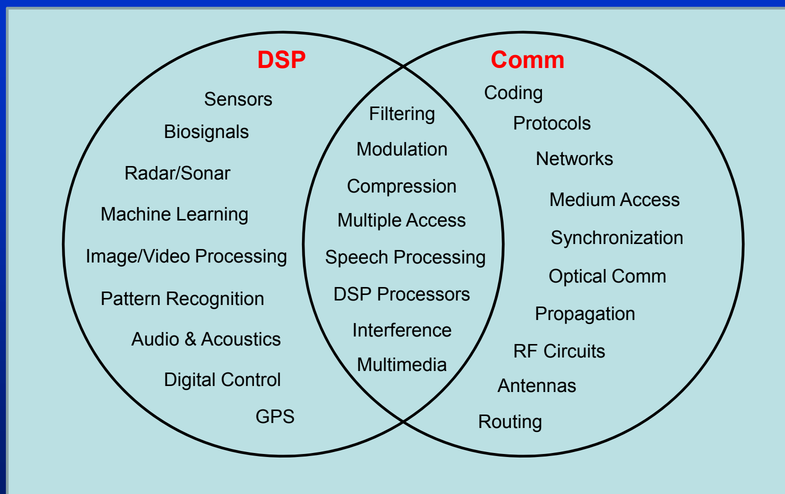
DSP/Comm Venn Diagram



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Samples of My Research

- Diversity coding
- 56K modems
- Wavelength division multiplexing
- Wireless packet transmission
- MIMO beamforming
- Energy efficiency for wireless cellular
- Modulation techniques for 5G cellular

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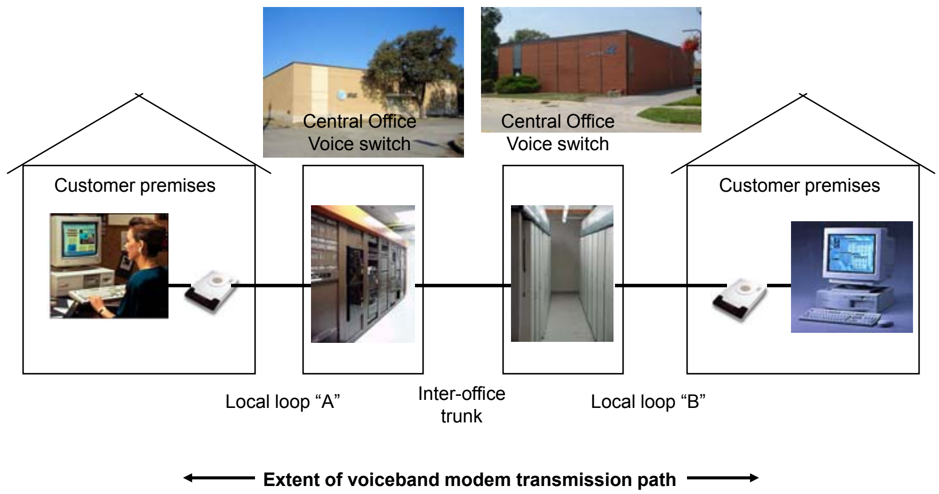
56K Modems: Voiceband Modem Network Architecture



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Voiceband Modems

Year	ITU-T Standard	Modulation	Bit Rate b/s	Signal Processing
1964	V.21	Binary FSK	300	
	V.22bis	QPSK	1200	
1968	V.26	QPSK	2.4K	Adaptive eq, Echo cancellation (V.26ter)
1984	V.32	16QAM	9.6K	TCM, Echo cancellation
1994	V.34	1024QAM	22.8K	Precoding, Multidimensional TCM
1996	V.34fast	Nested 4x960	33.6	Shell mapping, warping
1998	V.90	Downstream: Digital 56K		
		Upstream: V.34fast 33.6K		
	V.92	Downstream: Digital 56K		
		Upstream: Digital 56K		

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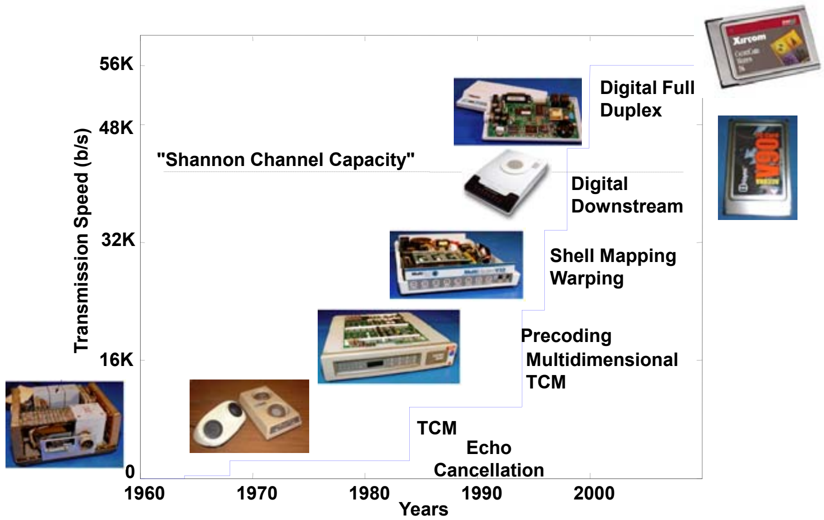
Transmission Rates of Voiceband Modems



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Patented Technology

United States Patent [19]
Ayanoglu et al.

US005394437A
[11] **Patent Number: 5,394,437**
[45] **Date of Patent: Feb. 28, 1995**

[54] **HIGH-SPEED MODEM SYNCHRONIZED TO A REMOTE CODEC**

[75] Inventors: **Ender Ayanoglu,** Atlantic Highlands; **Nuri R. Dagdeviren,** Red Bank; **James E. Mazo,** Fair Haven; **Burton R. Saltzberg,** Middletown, all of N.J.

[73] Assignee: **AT&T Corp.,** Murray Hill, N.J.

[21] Appl. No.: **963,539**

[22] Filed: **Oct. 20, 1992**

[51] **Int. Cl.**[6] **H04B 1/38**
[52] **U.S. Cl.** **375/222;** 370/103; 341/144; 341/145; 375/350; 375/354; 375/356
[58] **Field of Search** 375/8, 13, 107, 108, 375/106, 99, 11, 18, 7, 111, 101, 103; 341/61, 126, 144, 155; 370/32, 103

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,890,303	12/1989	Bader	375/107
5,184,347	2/1993	Farwell et al.	375/107
5,214,637	5/1993	Sridhar et al.	375/8
5,261,118	11/1993	Vanderspool, II et al.	375/107
5,268,929	12/1993	Hashimoto et al.	375/13

Primary Examiner—Stephen Chin
Assistant Examiner—Amanda T. Le
Attorney, Agent, or Firm—Henry T. Brendzel

[57] **ABSTRACT**

A modem that operates reliably at a symbol rate that corresponds to twice its bandwidth even when it is coupled to a receiving A/D converter that operates under control of a clock is realized by synchronizing the modem's operation to the A/D's clock. The superior operation of this modem advantageously extends to A/D clock frequencies beyond the frequency of twice the modem's bandwidth. To minimize quantization noise, the modem's output is conditioned to minimize intersymbol interference by adjusting the modem's output to the A/D converter's sampling times and slicing levels. When the A/D's clock is higher than twice the bandwidth of the modem's output signal, some intersymbol interference cannot be avoided. In accordance with this invention, the position and value of this interference is computed at the receiver and subtracted from the received signal.

16 Claims, 4 Drawing Sheets

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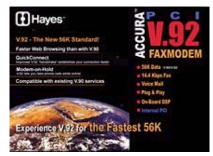
State of Voiceband Modems



V.92 achieves the limit in voiceband modems!

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Fixed Broadband Wireless: 4G Technology in 2000

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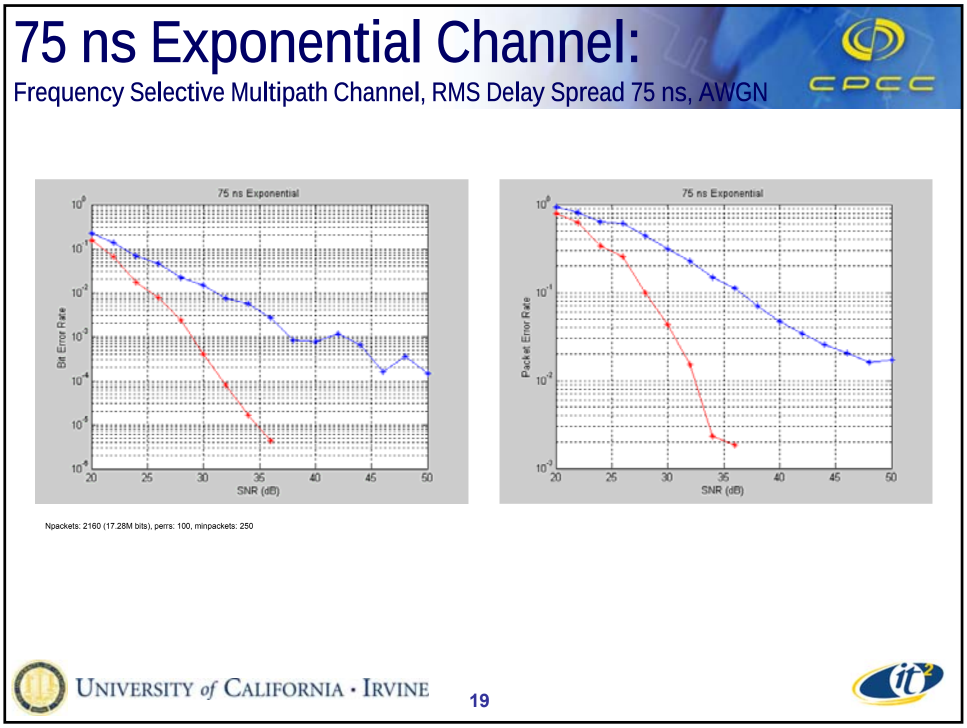
75 ns Exponential Channel:
Frequency Selective Multipath Channel, RMS Delay Spread 75 ns, AWGN
75 ns Exponential
Bit Error Rate
SNR (dB)
75 ns Exponential
Packet Error Rate
SNR (dB)
Npackets: 2160 (17.28M bits), perrs: 100, minpackets: 250
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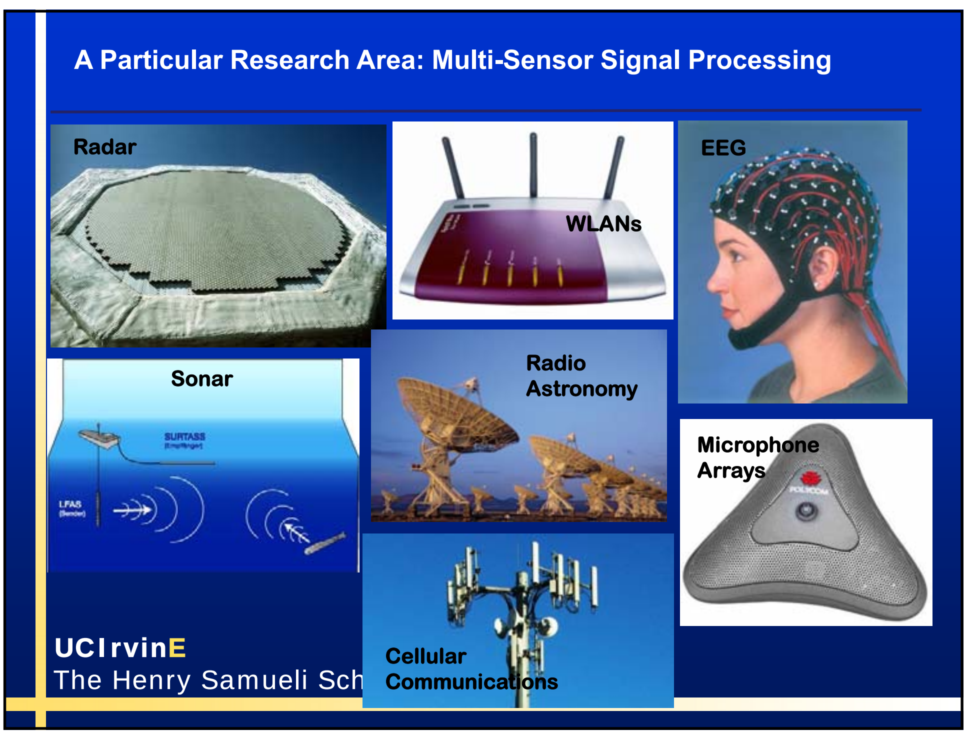
A Particular Research Area: Multi-Sensor Signal Processing
Radar
WLANs
EEG
Sonar
Radio Astronomy
Microphone Arrays
Cellular Communications
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Multiple Antennas for Communications

You've seen multiple antennas on cell towers

But you can get similar benefits with them on your cell phone

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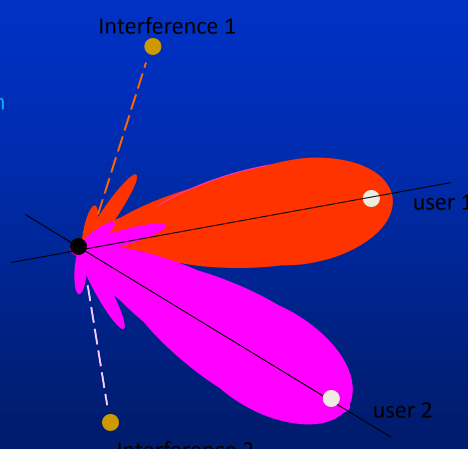
Benefits of MSSP for Communications

- interference reduction
- multiplexing users in space
- at high SNR, *M* antennas can yield *M*-fold gain in rate w/out bandwidth expansion
- antenna degrees of freedom also used for nulling
- in general, to increase rate by *R* and null *J* jammers, need *M=R+J* antennas
- another alternative: reduce transmit power (increase battery life) for same QoS
- user 1 and user 2 can be different antennas for the same user: MIMO



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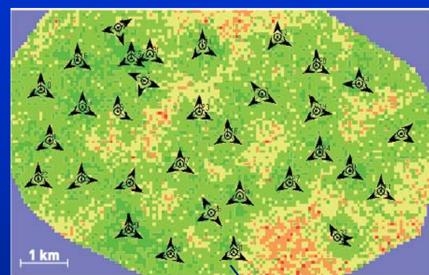
MIMO Coverage Benefits

With MIMO
(On Client Device Only)

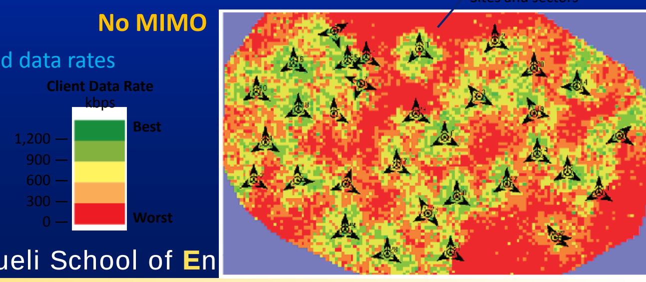
Higher data rates at handset *and* improved coverage throughout cell

- Better data rates even in poor coverage areas
- Fewer dead spots



No MIMO

Very poor coverage and data rates across cell



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Diversity Coding for Network Restoration

CPCC

- Failures in networks are common
- Existing restoration techniques incur delay
- Can we design a *hitless* scheme using erasure codes?

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Major Network Failures in 1980s

- May 8, 1988
  - Fire in unmanned central office in Hinsdale, Illinois
  - Loss of service and isolation to 35K residential telephones, 37K trunks, 13.5K special circuits, 118 long-distance fiber optic circuits, and 50% of the cellular telephones in Chicago
  - 500K residential and business customers who made 3.5M telephone calls per day were impacted.
  - Full service was not restored until June 5, 1988
- November 1988
  - Construction crew accidentally severed a major fiber optic cable in New Jersey
  - Much of the long distance service along the East Coast was disrupted
  - 3.5M call attempts were blocked

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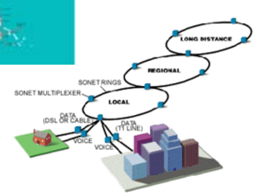
Most Carriers Employ SONET Rings for Protection or Restoration



- Guarantees <50 ms restoration time
- Requires >100% extra capacity
- UPSR: Unidirectional Path-Switched Ring
- BLSR: Bidirectional Line-Switched Ring
- Sprint's OC-192 backbone has more than 400 SONET rings (AT&T, together with 22-state legacy SBC and BellSouth, 6700)

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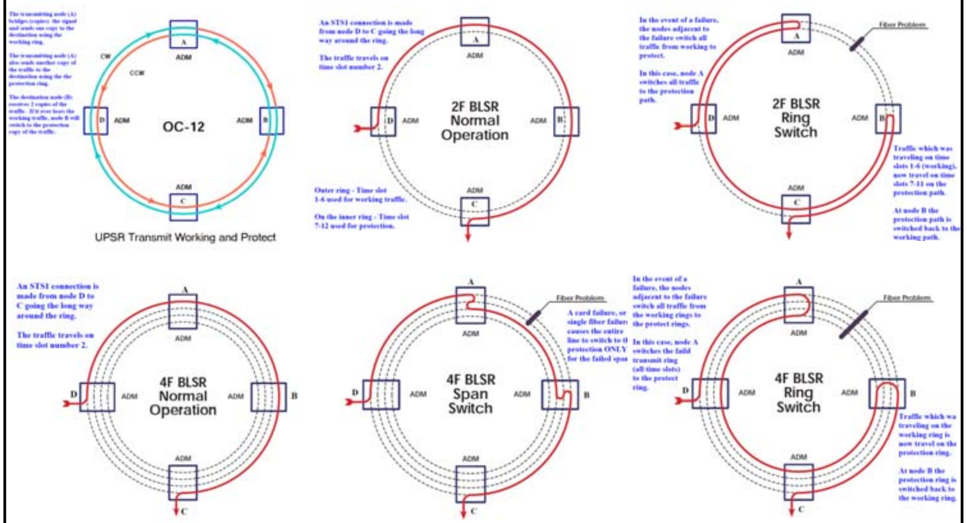
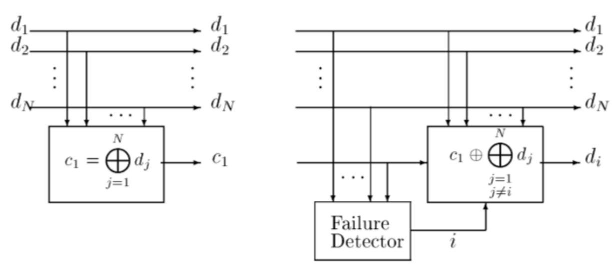
UPSR: Unidirectional Path-Switched Ring
BLSR: Bidirectional Line-Switched Ring

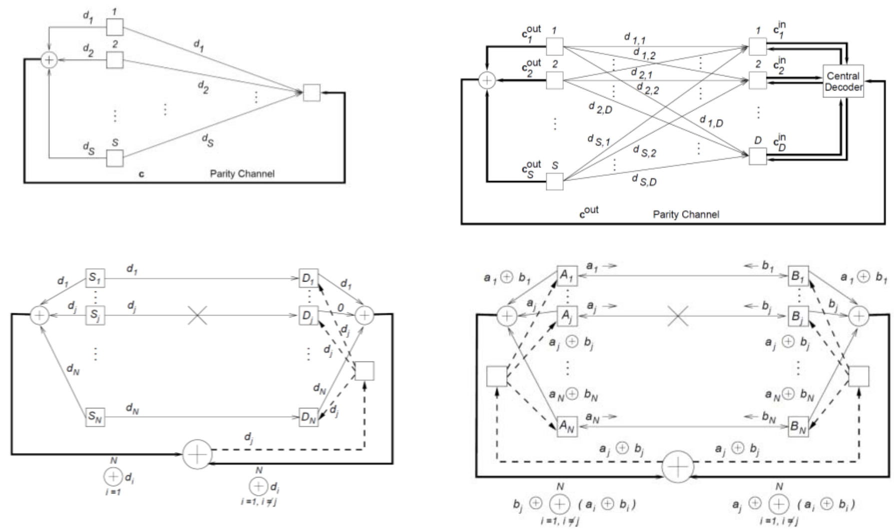


Frequency-Diversity Coding



- Links d_1, d_2, ..., d_N carry actual data
- Parity link c_1 carries parity data
- When link *i* fails, its data can be reconstructed by c_1 and d_1, d_2, ..., d_{i-1}, d_{i+1}, ..., d_N *without feedback*, in a *hitless* manner
- Observation due to Falconer and Gitlin in unpublished Bell Labs Memorandum (1975)
- Suggested for Bell System microwave radio links (Data Under Voice)

Diversity Coding Structures



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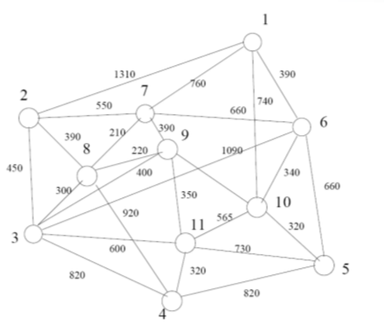
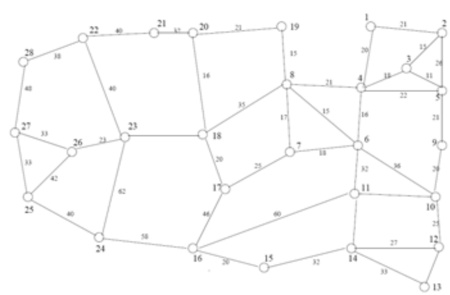
Our Technique Restores in 30 µs, Others in Seconds





COST 239 Network, 11 nodes, 26 spans	
Protection Scheme	Spare Capacity Percentage
Diversity Coding	98%
Source Rerouting	90%
p-cycles	64%

US Long Distance Network, 28 nodes, 45 spans	
Protection Scheme	Spare Capacity Percentage
Diversity Coding	106%
Source Rerouting	91%
p-cycles	107%

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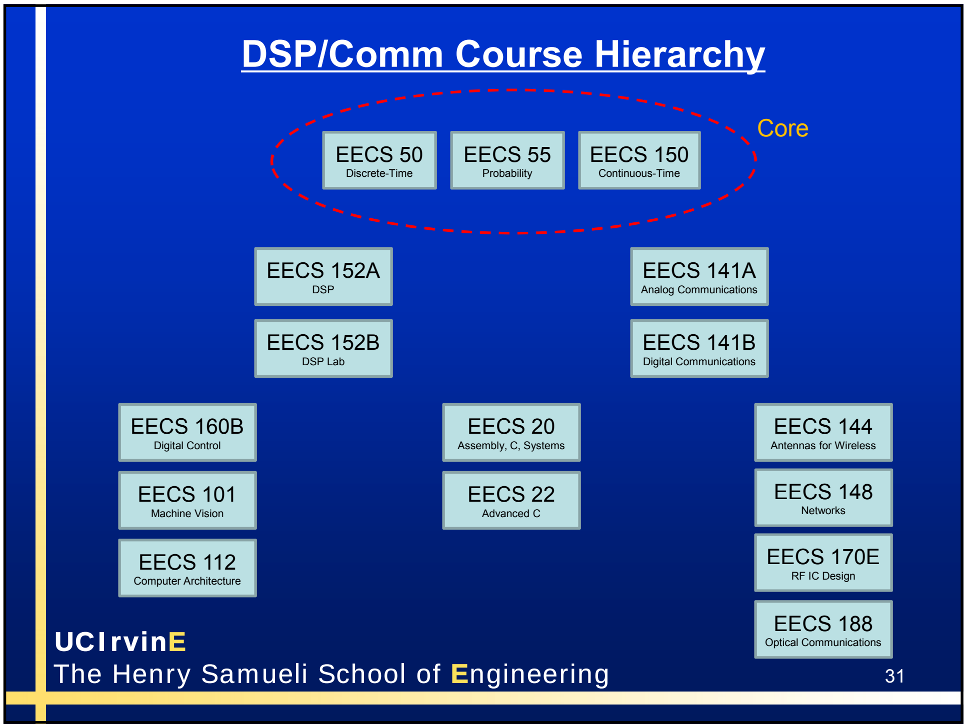
DSP/Comm Course Hierarchy
Core
EECS 50
Discrete-Time
EECS 55
Probability
EECS 150
Continuous-Time
EECS 152A
DSP
EECS 152B
DSP Lab
EECS 141A
Analog Communications
EECS 141B
Digital Communications
EECS 160B
Digital Control
EECS 101
Machine Vision
EECS 112
Computer Architecture
EECS 20
Assembly, C, Systems
EECS 22
Advanced C
EECS 144
Antennas for Wireless
EECS 148
Networks
EECS 170E
RF IC Design
EECS 188
Optical Communications
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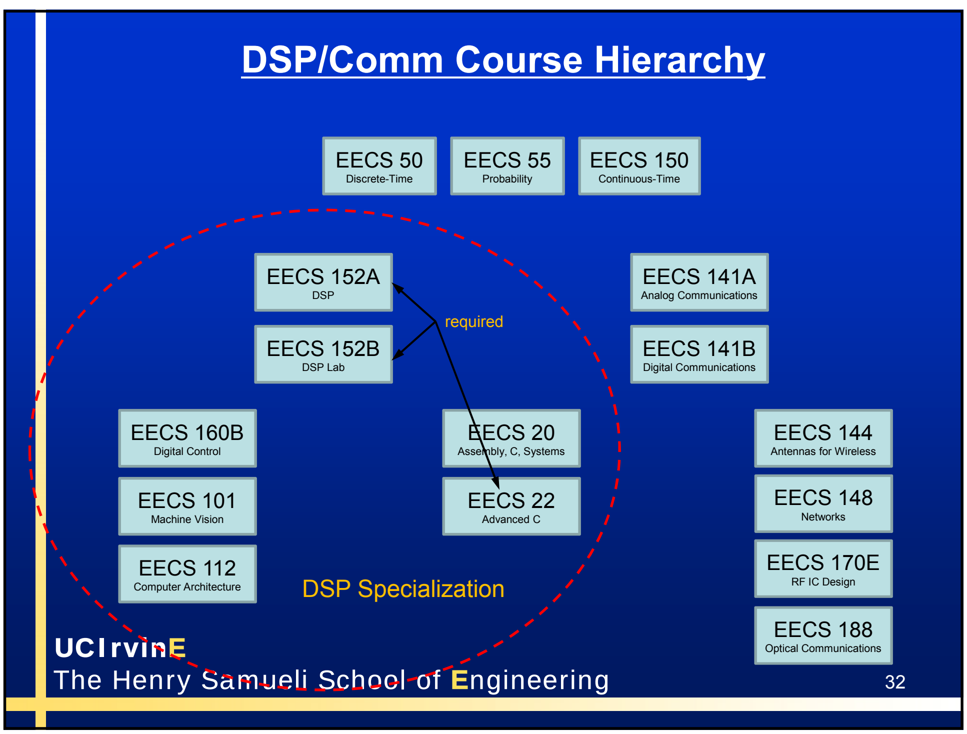
DSP/Comm Course Hierarchy
EECS 50
Discrete-Time
EECS 55
Probability
EECS 150
Continuous-Time
EECS 152A
DSP
required
EECS 152B
DSP Lab
EECS 141A
Analog Communications
EECS 141B
Digital Communications
EECS 160B
Digital Control
EECS 101
Machine Vision
EECS 112
Computer Architecture
EECS 20
Assembly, C, Systems
EECS 22
Advanced C
DSP Specialization
EECS 144
Antennas for Wireless
EECS 148
Networks
EECS 170E
RF IC Design
EECS 188
Optical Communications
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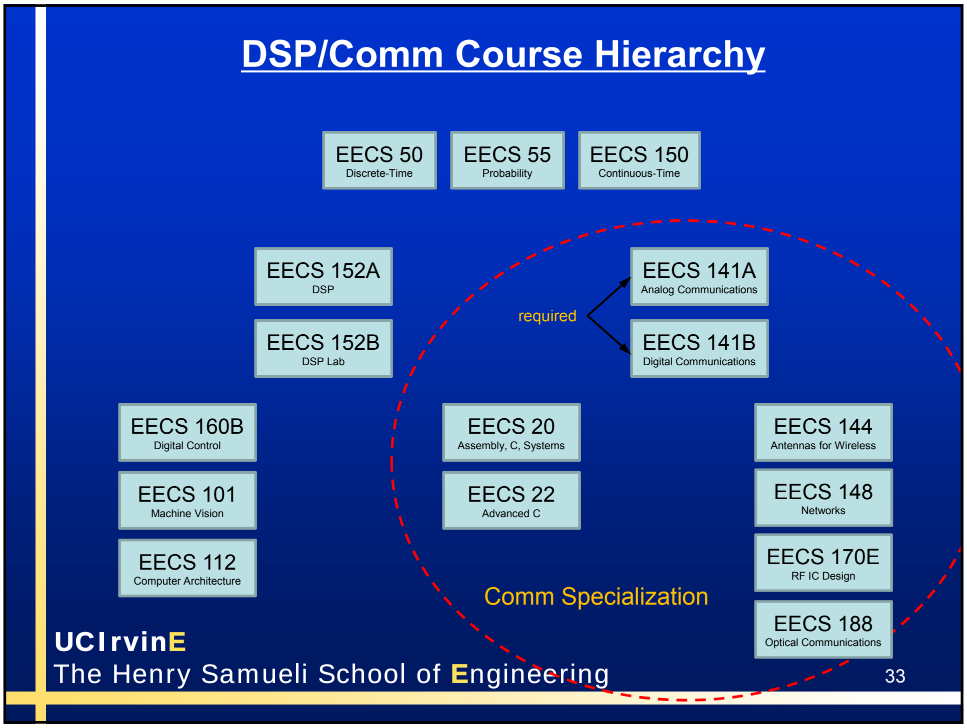

Digital Signal Processing

EECS 152A*	Digital Signal Processing	EECS 101	Machine Vision
EECS 152B*	DSP Lab	EECS 112	Computer Architecture
EECS 20*	Computer Systems & C	EECS 141A	Comm Systems I
EECS 22	Adv. C Programming	EECS 141B	Comm Systems II
		EECS 160B	Digital Control

Specialized Electives 3 courses

*Required for Specialization


Anima Anandkumar
Machine Learning, Graphical Models


Hamid Jafarkhani
Communication and Coding Theory


Lee Swindlehurst
Wireless, Radar, Sensor Networks


Syed Jafar
Information Theory, Wireless Communications


Glenn Healey
Machine Vision, Image Processing


Ender Ayanoglu
Wireless Communications and Networks

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Communications

EECS 141A*	Comm Systems I	EECS 144	Wireless Antennas
EECS 141B*	Comm Systems II	EECS 148	Computer Networks
EECS 20	Computer Systems & C	EECS 152A	Digital Signal Processing
EECS 22	Adv. C Programming	EECS 152B	DSP Lab
		EECS 170E	Analog/Comm IC Design
Specialized Electives	4 courses	EECS 188	Optical Electronics

*Required for Specialization

Anima Anandkumar
Machine Learning, Graphical Models

Lee Swindlehurst
Wireless, Radar, Sensor Networks

Athina Markopoulou
Network Coding and Measurements

Hamid Jafarkhani
Communication and Coding Theory

Syed Jafar
Information Theory, Wireless Communications

Ender Ayanoglu
Wireless Communications and Networks

Ahmed Eltawil
VLSI Architectures for Wireless

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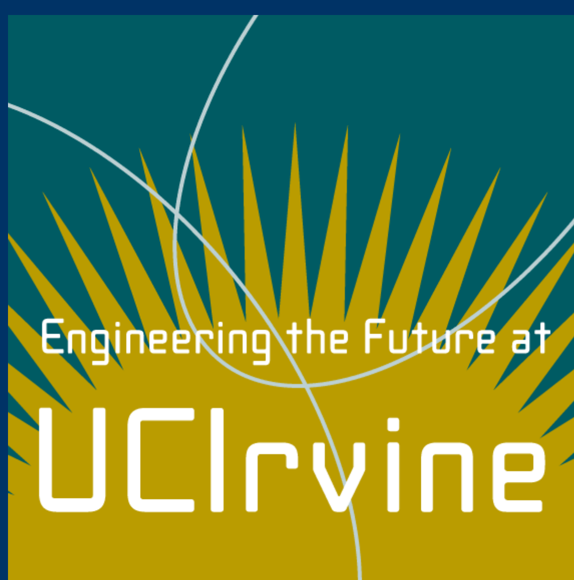

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