ECE Interview 2021

fred harris

21-January 2021

I Teach 161C which is an excellent course
(my assessment)
It is an Introduction to real system application
what can we do with DSP,
examples of what has been done,
and what kinds of things are
waiting to be done with DSP.

UC San Diego
Jacobs School of Engineering

Signal and Image Processing (seventy-two units)

- Breadth Courses: ECE 100, 101, 107, 109
- Depth Courses: ECE 153, 161A-B-C

Breadth

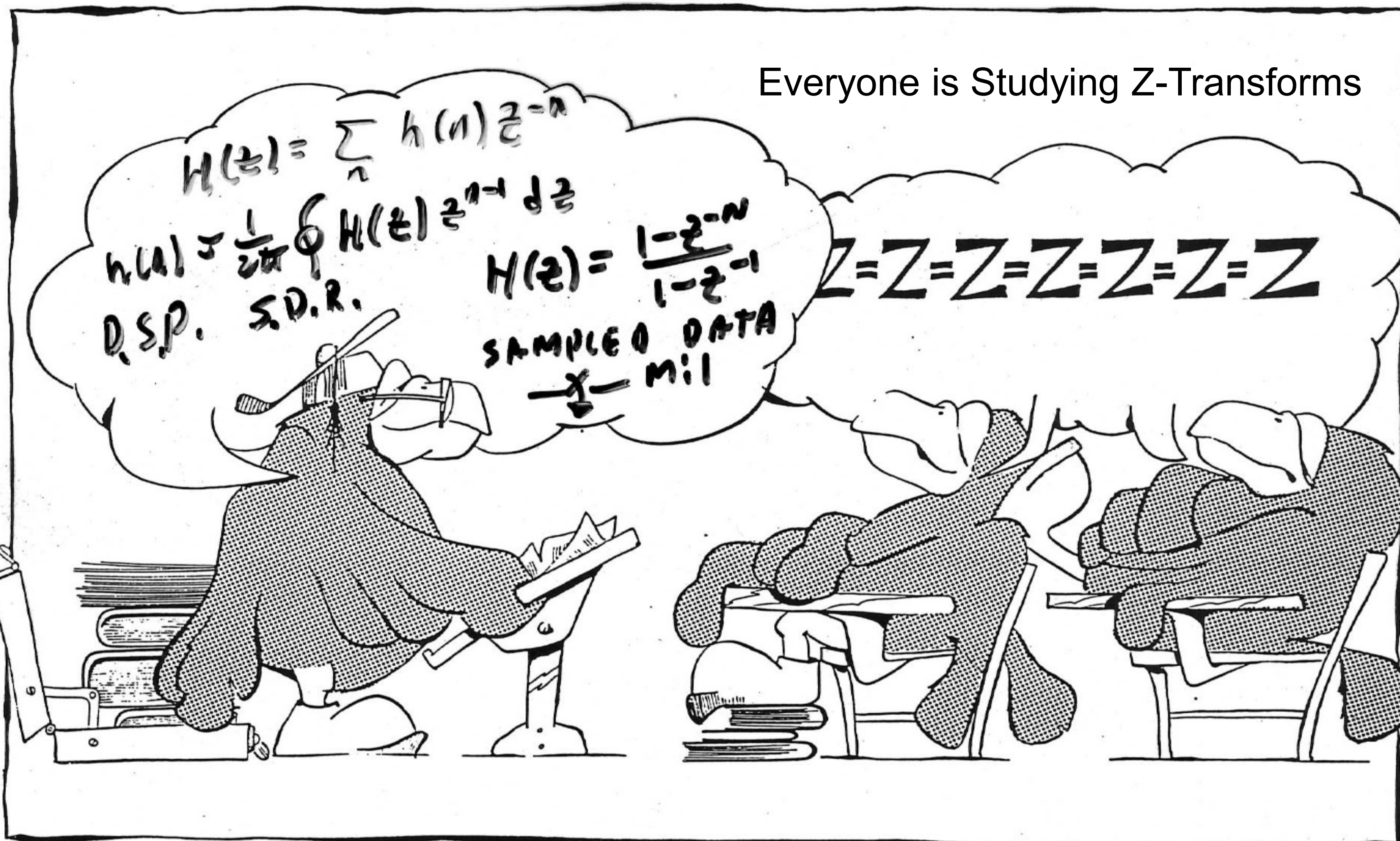
ECE 100 Linear Electronic Systems
ECE 101 Linear Systems Fundamentals
ECE 107 Electromagnetism
ECE 109 Engineering Probability and Statistics

Depth

ECE 153 Probability and Random Processes for Engineers
ECE 161A Introduction to Digital Signal Processing
ECE 161B Digital Signal Processing
ECE 161C Applications of Digital Signal Processing

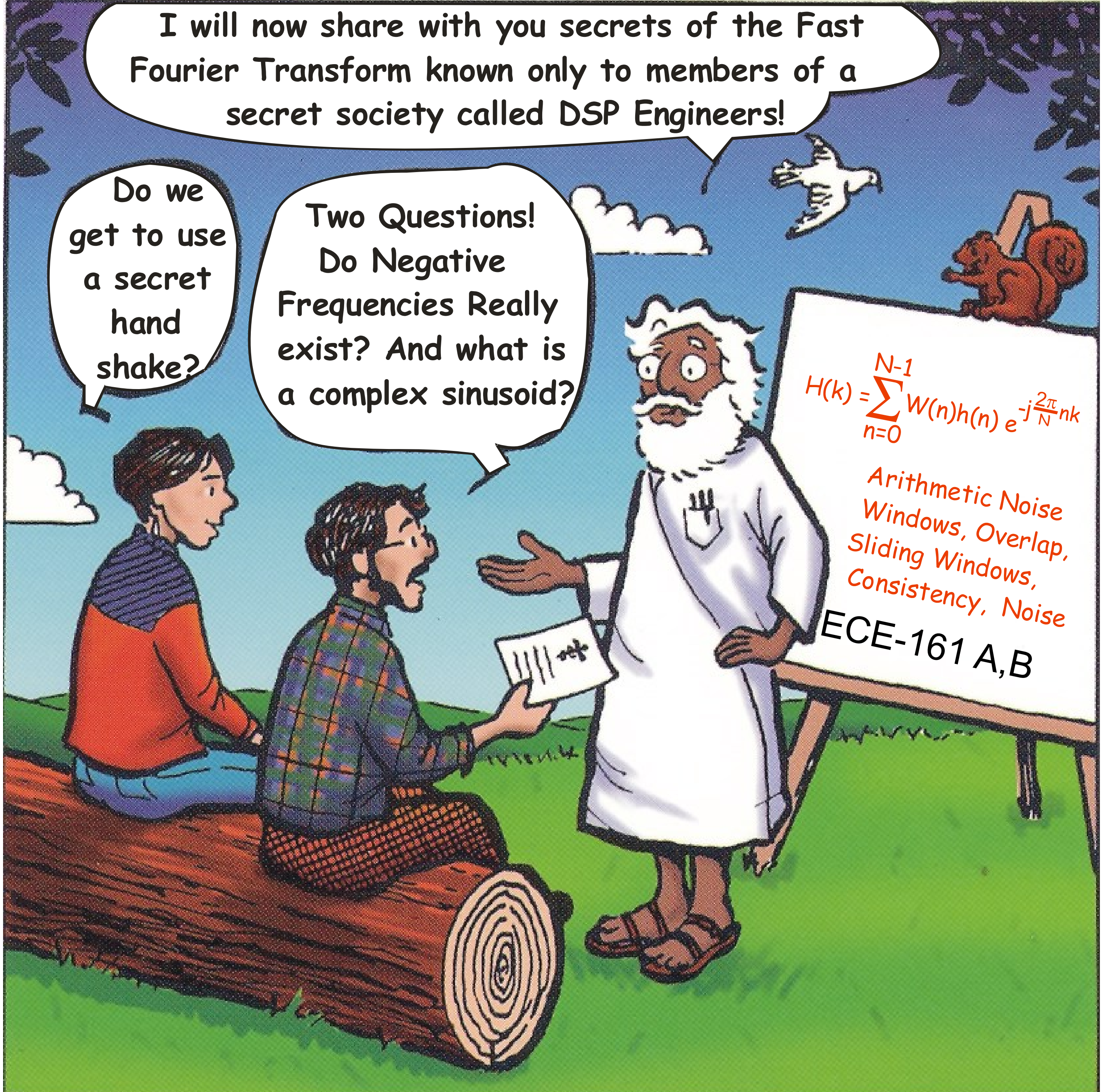
Very Marketable Combo: DSP,
Communication Systems,
Embedded System Programming
FPGA

Everyone is Studying Z-Transforms



PROFESSOR harris DELIVERS ANOTHER OF HIS STIMULATING PRESENTATIONS

Interesting DFT Trivia from the FFT Guru



- Alan V. Oppenheim the Massachusetts Institute of Technology
- Fred Harris, University of California at San Diego
- Anthony Constantinides, Imperial College, London, United Kingdom
- Athina Petropulu, Rutgers University
- Scott C. Douglas, Southern Methodist University
- Waheed Bajwa, Rutgers University.

We extend our thanks to our pioneers Anthony Constantinides, fred harris, and Alan V. Oppenheim for being the pillars of our ICASSP 2019 education panel and for their roles in educating generations of researchers who are carrying the torch of our discipline well into the 21st century.

Transforms of Deterministic Signals
ECE-161A

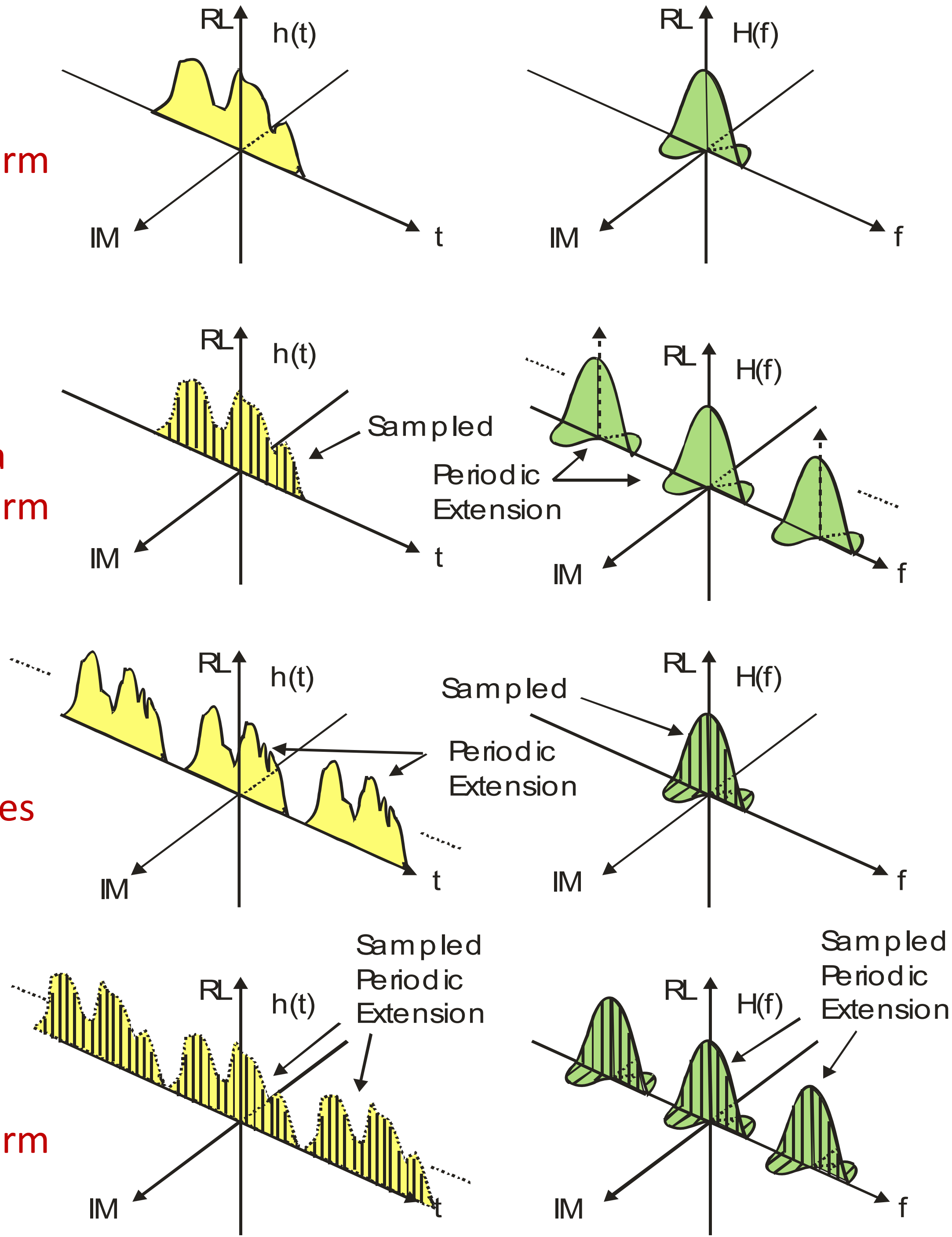
Sampling in Time and Frequency Domains

Fourier Transform

Sampled Data Fourier Transform

Fourier Series

Discrete Fourier Transform



Transforms of Random Process ECE 153

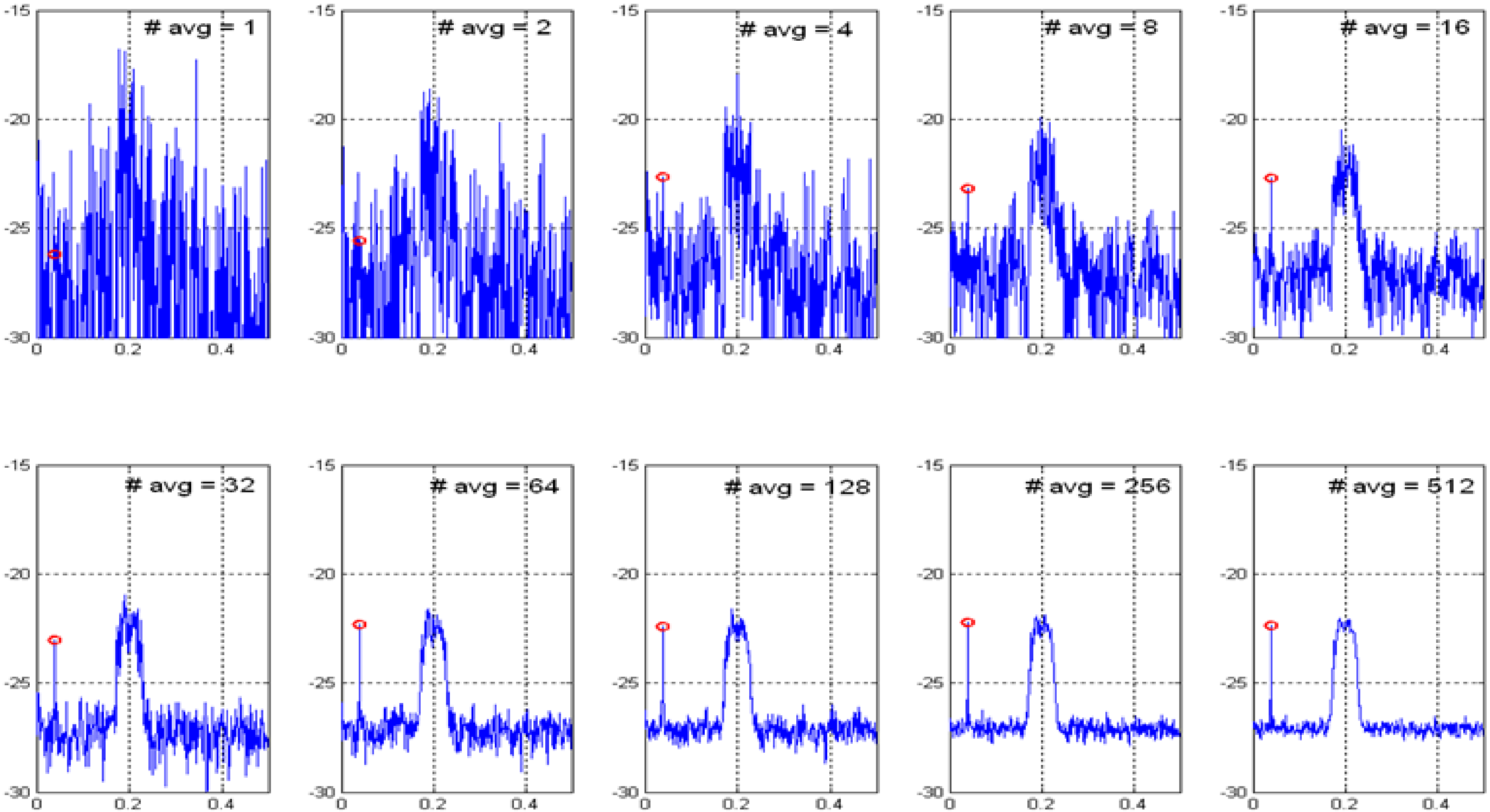
Spectral Estimation of Random Process in Noise (Need for Ensemble Averaging)

Noise is your friend.
If there were no noise, anyone could solve the problem. Noise makes the problem interesting and offers us job security!

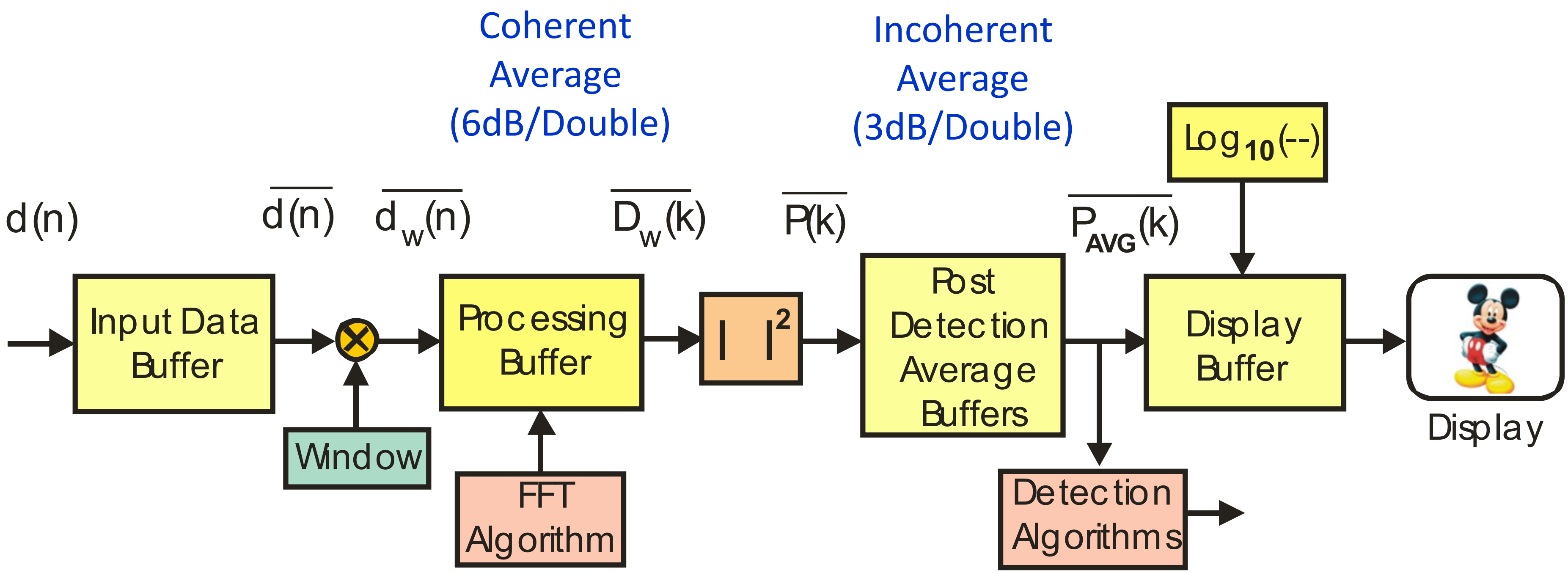
A Consistent Estimator:

It would be nice if when you feed more data to an estimator, the quality of the estimate doesn't get worse! FFT is Inconsistent estimator!

Spectra: Ensemble Averaged FFTs of Sinewave and QAM Signal in White Noise



Power Spectrum Estimation of Random Signals with FFT



- I taught my first DSP course in 1967 from Hand written Mimeograph Notes.
- I was a graduate Student here in 1967.
- I had to Tell People How to Spell DSP and explain what it was!
- The first DSP text book!
  - Digital Processing of Signals (1969)
  - Lincoln Labs, Bernard Gold
- It was a graduate course
- There was no place to publish in this area.
- Technology Limited DSP to Processing Audio
    - (8-kHz ADC, Processed off-line in main Frame Computer)
- Publication Evolution:
  - IEEE Audio (1964)
  - IEEE Audio and Electro-Acoustics (1965)
  - IEEE Acoustics, Speech, & Signal Processing (1974)
  - IEEE Signal Processing (1989)

    (Classic example of the Camel's Head in the Tent)

If the camel once gets his nose in the tent, his body will soon follow.

I started doing DSP in 1963. A mentor took me aside and asked why was I doing DSP. He said, "All you can do is process audio and why would you want to do that?" I am so glad I Ignored his advice not to do it!

I started teaching my DSP Radio course in 1985. I presented one-week courses at MI-5 and at NSA. Recently did one at DSTL (Defence Science Technology Lab)

For many years now, students come into my office and share with me;
"My dad had you as a professor when he was a student here!"

Two related Stories:
In 1968, Tony Constantinides, wrote first PhD thesis on DSP. “Design of Digital Filters from prescribed Amplitude Characteristics”. He had to convince his thesis Committee that algorithms were in fact filters. While writing a difference equation on board, one of his committee members asked, “Where is the filter?” (IEEE Oral History) He graduated and went to work for the British Post Office. He wrote an internal memo suggesting the post office would find great benefit using digital filters in communication systems. He was called before the deputy director of the research lab. The dialogue went like this: “I've read your paper. It's very interesting. Really fascinating. But I would like you to know something very important. Digital techniques have no place in telephony and if you persist in supporting your position I will have to let you go.” Soon after the meeting Tony went to Imperial Collage and took a position there. A number of times I have heard him say, “I wish I knew where his body rests. I would like to leave a cell phone on his tombstone!”

In 2003, I was invited to write a paper on *DSP in Microwave Receivers* for the 50-th Anniversary publication of the IEEE MTT Journal (Microwave Theory & Transactions). I wrote the paper: one of my reviewers asked “Why would a microwave designer care about DSP?” I bit my tongue and did not respond with my first thought “Because Gordon Moore is Coming to Eat Your Lunch!”, Instead I explained how, in a number of ways, DSP techniques corrected analog circuit imperfections (Dirty RF) and thus Improve performance and reduce cost of microwave receivers.

A Sad but True Story!

- In 1983 I designed a 65536 channelizer for GTE in San Jose in response to a Request for Proposal (RFP) for Multi channel receiver for US Navy.
- My Design aliased all 65 k channels to baseband by down sampling prior to any signal processing. I then used the phase rotators of the IFFT to extract (un-alias) the separate channels.
- I was sure we would be famous. We were revolutionizing channelizers! And GTE was assured to be awarded the contract!
- The proposal was returned to us by the reviewer

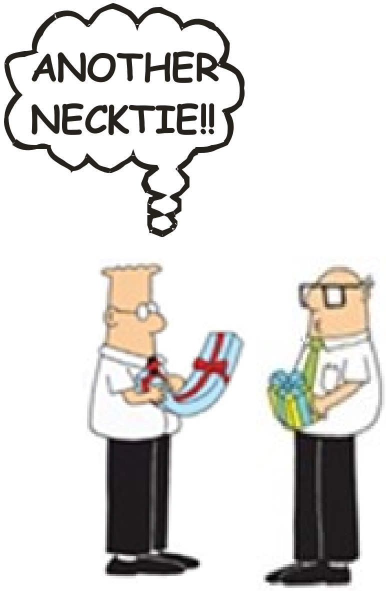
  with **big red** letters across the face of the proposal saying…

- "Those Who Don't Understand The Nyquist Theorem Shouldn't be Doing Signal Processing"

What I Learned is that if you are smarter than your reviewer, you are both in trouble.

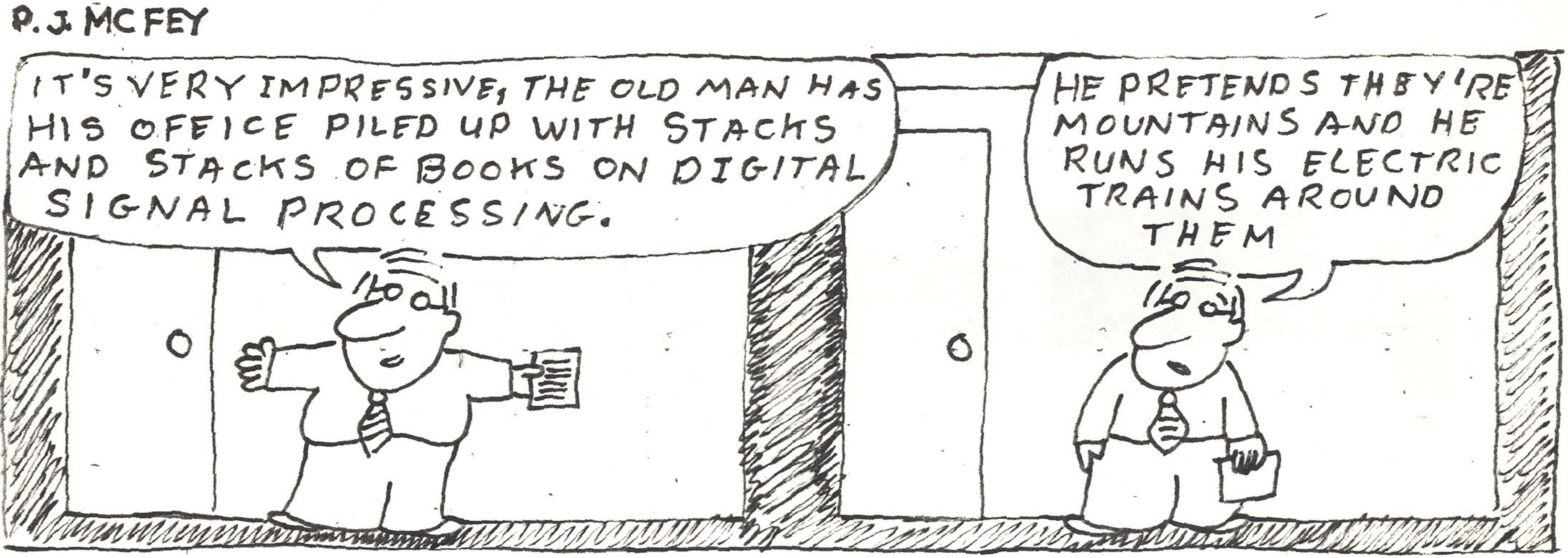
Going to work on my trusty steed, Trigger

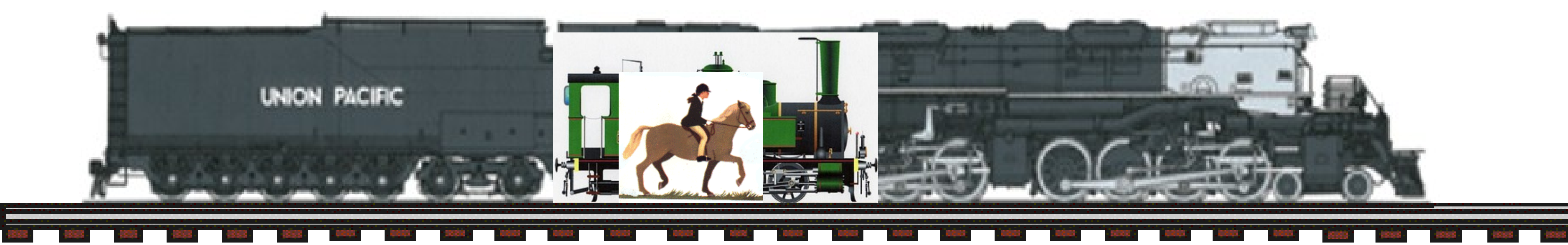
Going to work on my other trusty steed Big Girl



300 Cartoon Neckties

Recognize Any of the Characters?


P. J. MCFEY
IT'S VERY IMPRESSIVE, THE OLD MAN HAS HIS OFFICE PILED UP WITH STACKS AND STACKS OF BOOKS ON DIGITAL SIGNAL PROCESSING.
HE PRETENDS THEY'RE MOUNTAINS AND HE RUNS HIS ELECTRIC TRAINS AROUND THEM


UNION PACIFIC

Why do we do DSP?

Because it is in our Blood!

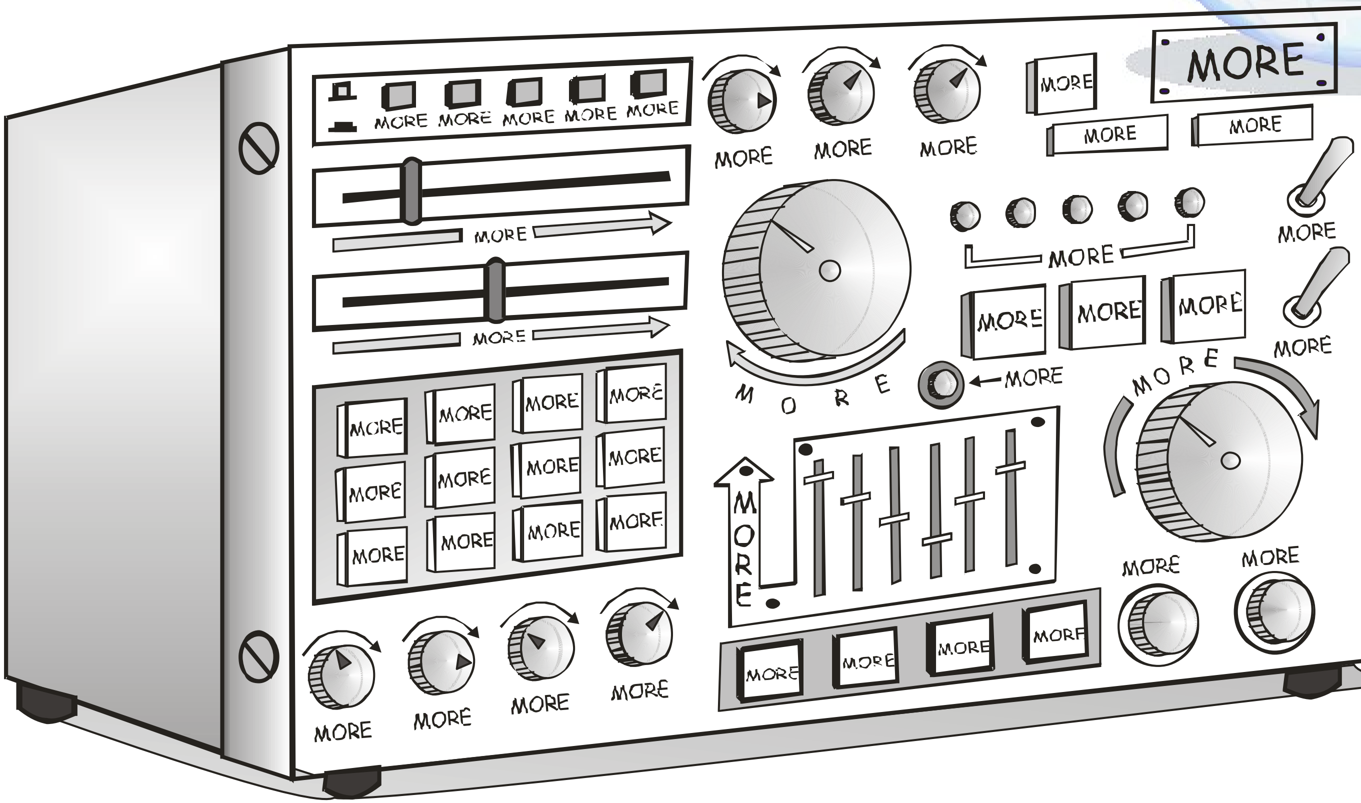
Who uses DSP?

Everyone!

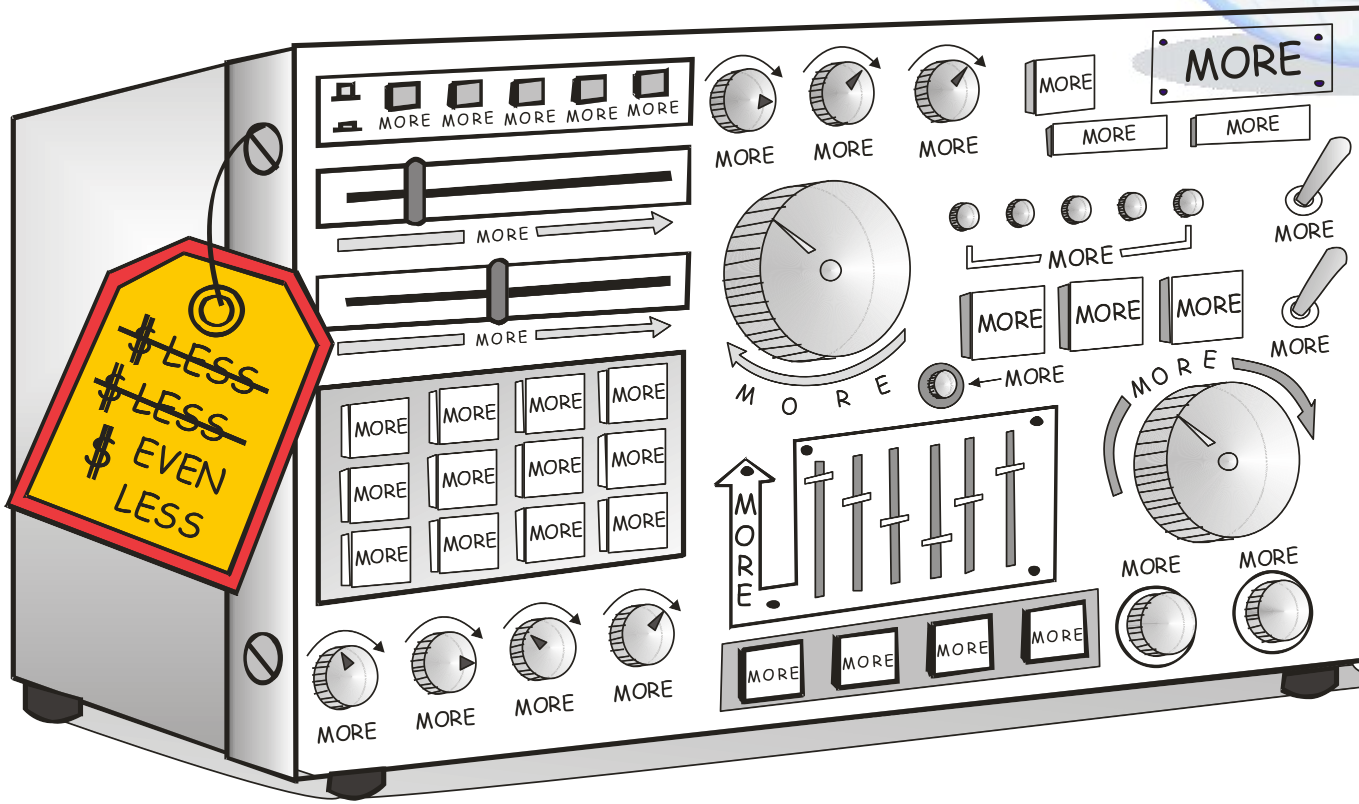
Why do they Use DSP?

See next 4-Slides!

What the Customer Wants

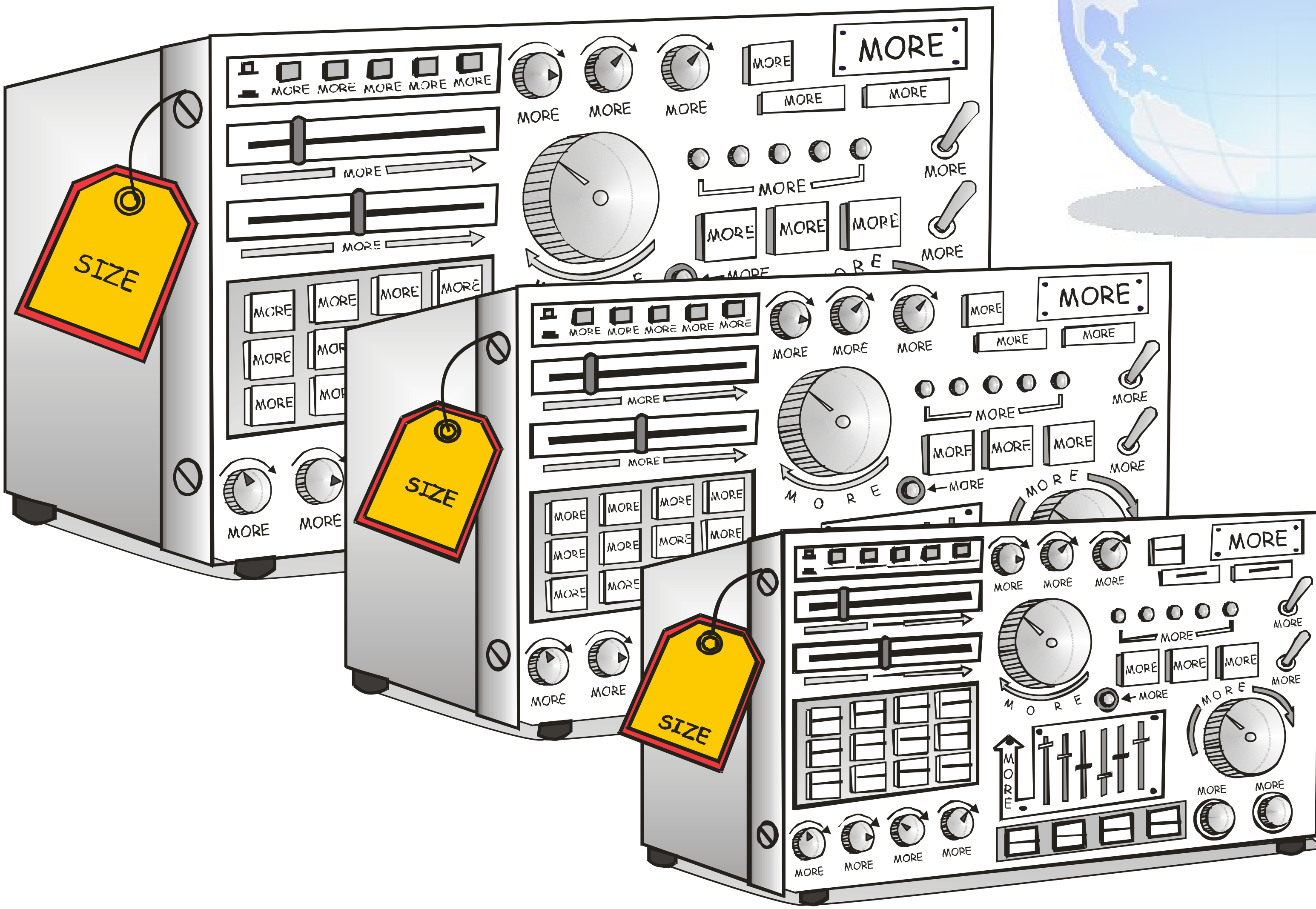


What the Customer Expects to Pay



When the Customer Wants it.

Size the Customer Wants.



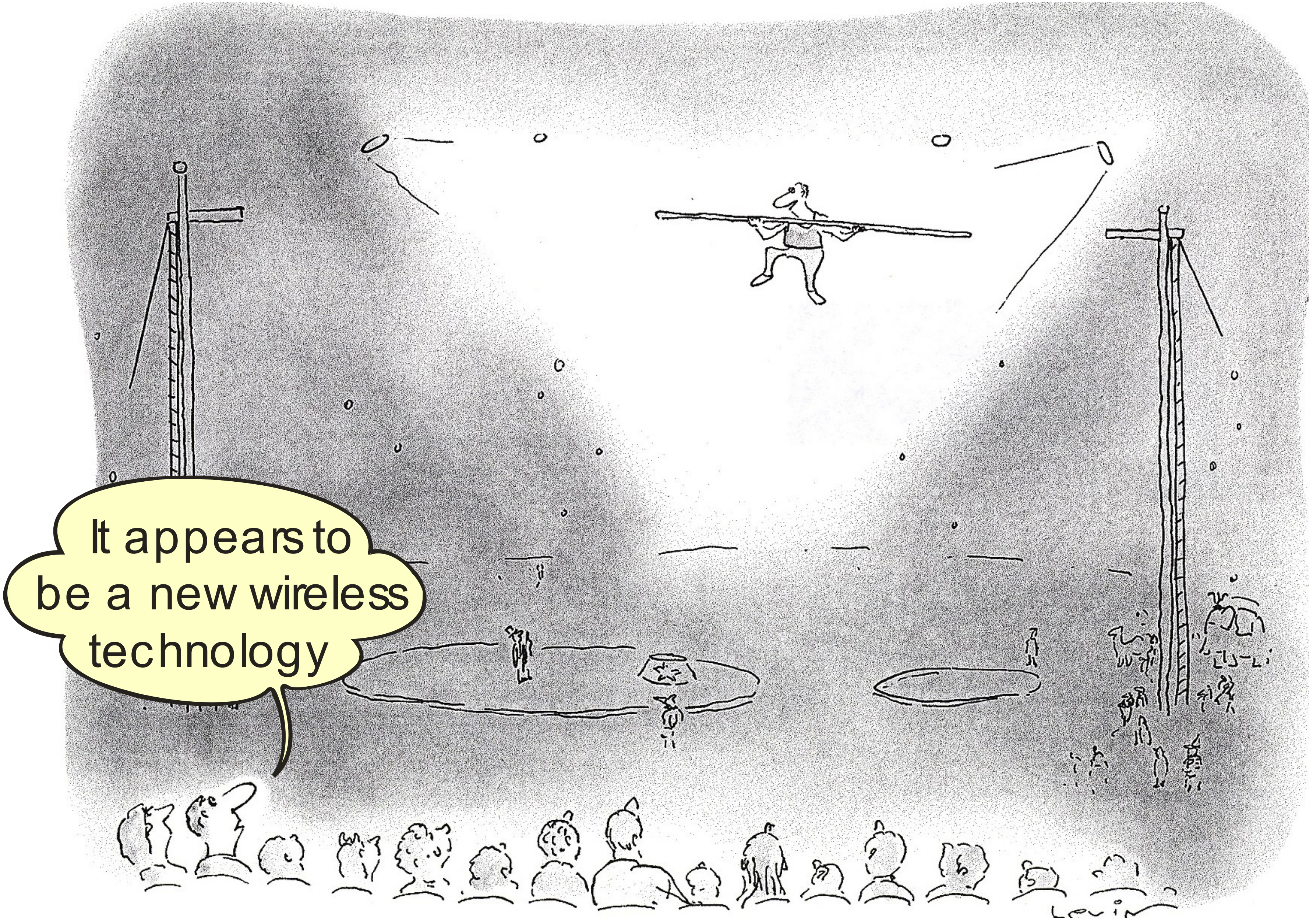
Why Digital Signal Processing?

- New and Enhanced Capabilities!
- Reduced Cost!
- Shorter Time to Market!
- Reduced SWAP (Size, Weight, and Power)

DSP Everywhere

- Audio Entertainment
  - Separation, Enhancement, Effects, Compression
- Video Entertainment
  - Compression, Enhancement, Special Effects, Games
- Radio Communications
  - Cell Phones, Internet Access, Software Defined radio
- Sonar
  - Oil Exploration, Collision Avoidance, Disaster Recovery
- Radar
  - Air Traffic Control, Automotive Collision Avoidance
- Satellites
  - Weather, Resource Monitoring, Exploration, Navigation
- Medical Instrumentation

  CAT Scans, Magnetic Resonance Imaging, Fetal Imaging
- Human Interface
  - Voice Recognition, Facial Recognition, Visual Inspection
- Remote Control
  - Robotics, Minimum Intrusive Surgery, Manufacturing


It appears to be a new wireless technology
Levin

Synthetic Aperture Radar (SAR) Image of San Diego

Radar image comparable to eye resolution of image: Antenna aperture about 4000 wavelengths

Automotive Applications

- Communication and Information
  - ***Car Navigation Systems***
  - ***Toll Collection***
  - ***Traffic and Road Condition***
  - ***Mobile Phone, Multiple Standards***
  - ***Internet, Wide Area Network***
- Entertainment
  - ***Television, Multiple Standards***
  - ***Digital Audio Broadcasting (DAB)***
  - ***In-Band On Carrier (IBOC)***
  - ***AM/FM Radio***
  - ***Satellite Radio***
  - ***Bluetooth***

The cost of Electronics in Modern Automobile Exceeds the Cost of Metal in the Car

Today, microelectronics enable advanced safety features, new information and entertainment services, and greater energy efficiency. The electric/electronic share of value added to a state-of-the-art vehicle is already at 40 percent for traditional, internal combustion engine cars and jumps as high as 75 percent for electric or hybrid electric vehicles. This trend will accelerate as advances in semiconductor technology continue to drive down the cost of various electronic modules and subsystems.

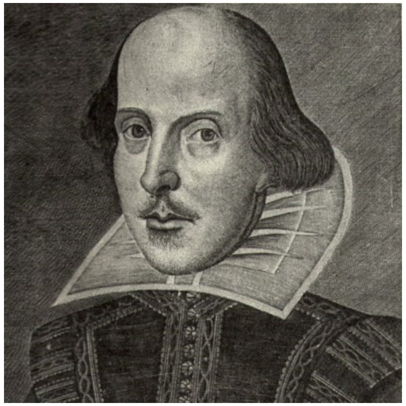
Why Digital Communications?

But Let Your Communications Be
Yea, Yea: Nay, Nay:

For What So Ever is More Than
These Cometh of Evil.

Sermon on the Mount,
Matthew, Ch. 5, verse. 37

To Paraphrase the Great Bard



The World is an Analog Stage

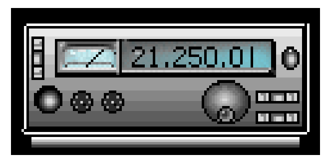
In Which Digital

Plays A Bit Part

We do Digital Signal Processing

We are Pretty Good at it!

In Particular, we apply DSP to Communication Systems



To Physical Layer of Radios

To Software Defined Radios

To Cognitive Radios

A Nice Gift

Peggy and Eric Johnson

Peggy is CEO of Magic Leap,
a wearable spatial computers
Company, and a former
Executive at Microsoft and
at Qualcomm.
Business Insider named her
The most powerful Female
Engineer of 2017.
Eric was founder and CEO
Of the successful startup
Tourmaline Networks and is
Now an angel investor in
tech start-ups.

The gift: **$3.1 Million Cash 2020, $0.40 Million 2010**

The donors:
Peggy Johnson (’85, B.S. electrical and computer engineering, SDSU) and
Eric Johnson (’86, M.S. electrical and computer engineering, SDSU)

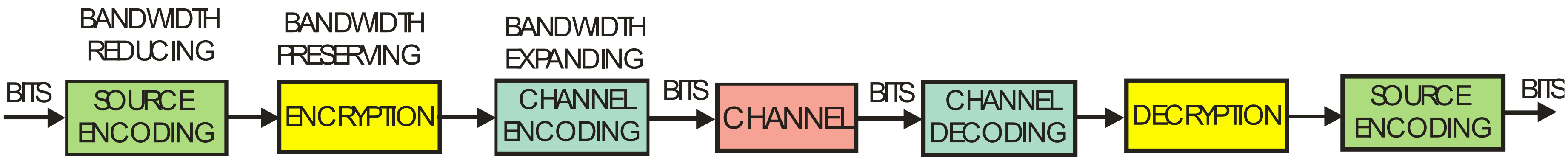
To Support Faculty:
Creates the **fred harris Chair in Digital Signal Processing**, named after fred harris, professor emeritus who taught electrical and computer engineering at San Diego State University for 50 years

Why they wanted to give back:
Most of us — if we were lucky — had a professor who profoundly influenced us. For Eric, that professor was harris. “He was very good at making very difficult concepts understandable,” Eric says. Tasked with designing an aspect of satellite communications at his first job, Eric was able to take theory harris taught him and easily apply it. “Within six months we had a satellite communication system up and running,” he says. Peggy never had harris in class. “But Eric never stopped talking about him,” she says. “He still talks about how something fred taught him has stuck in his head. Those are the teachers that we need to celebrate.”

Shannon's Model Of A Communication System

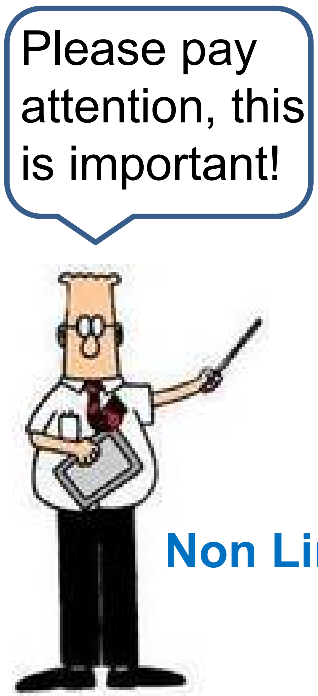
Transformations of Bit Sequences

Shannon Channel: Bits in, Bits Transformed, Bits Everywhere



Shannon Model of the Channel:

Linear, Time Invariant, with Additive White, Gaussian, Noise



harris Model of the Channel:

(Include Transmitter and Receiver in the Channel Model)

Non Linear, Time Varying, with Additive Non White, Non Gaussian, Noise

Difference Between Working in Analog Land and Digital Land

I recently had dinner with Minnesota’s Senator Amy Klobuchar

I held my tongue and did not share this slide with her!

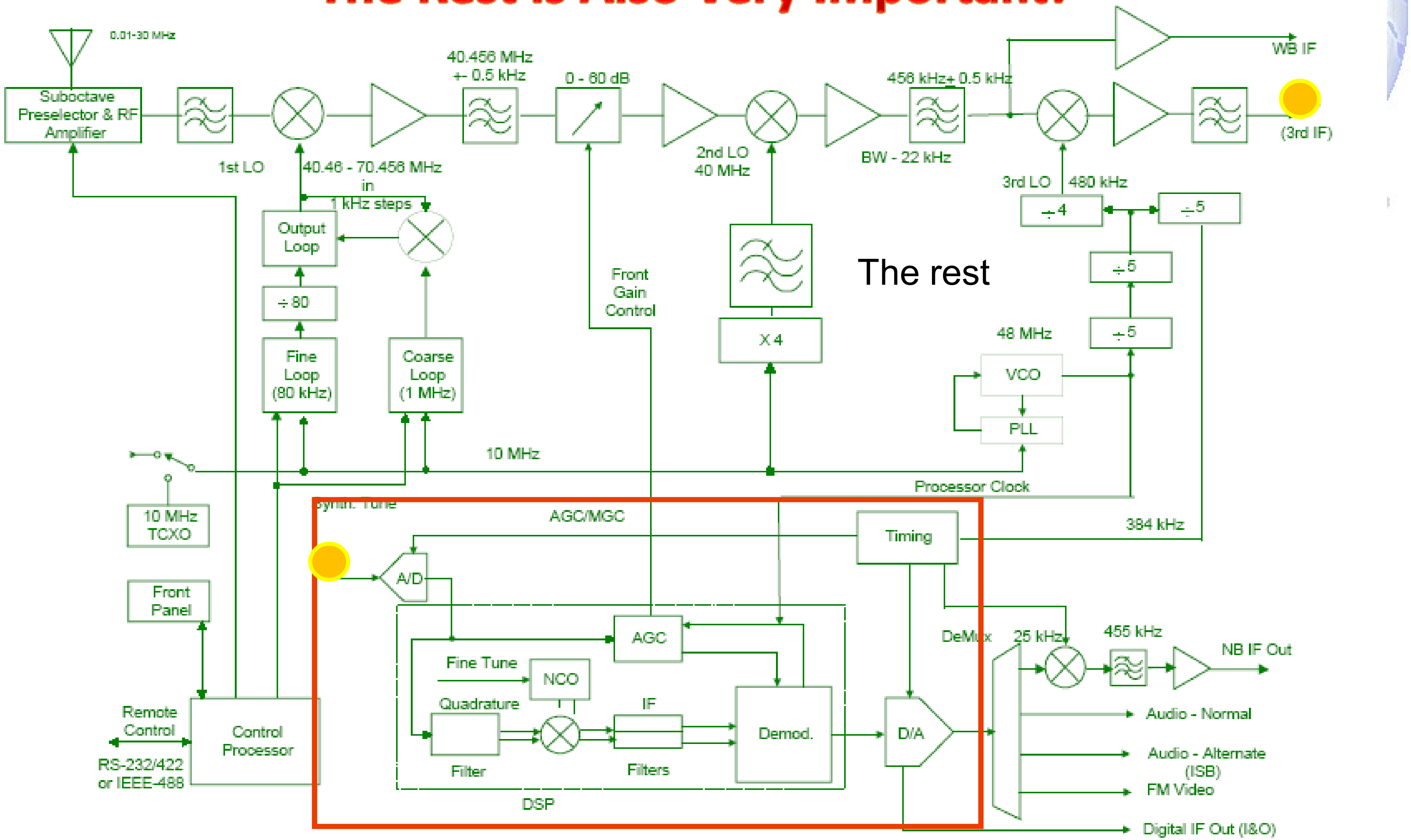
Analog Land is like working in
Minnesota in High Winter.
Snowing, Cold Air,
Harsh Biting Wind, no Sunshine.

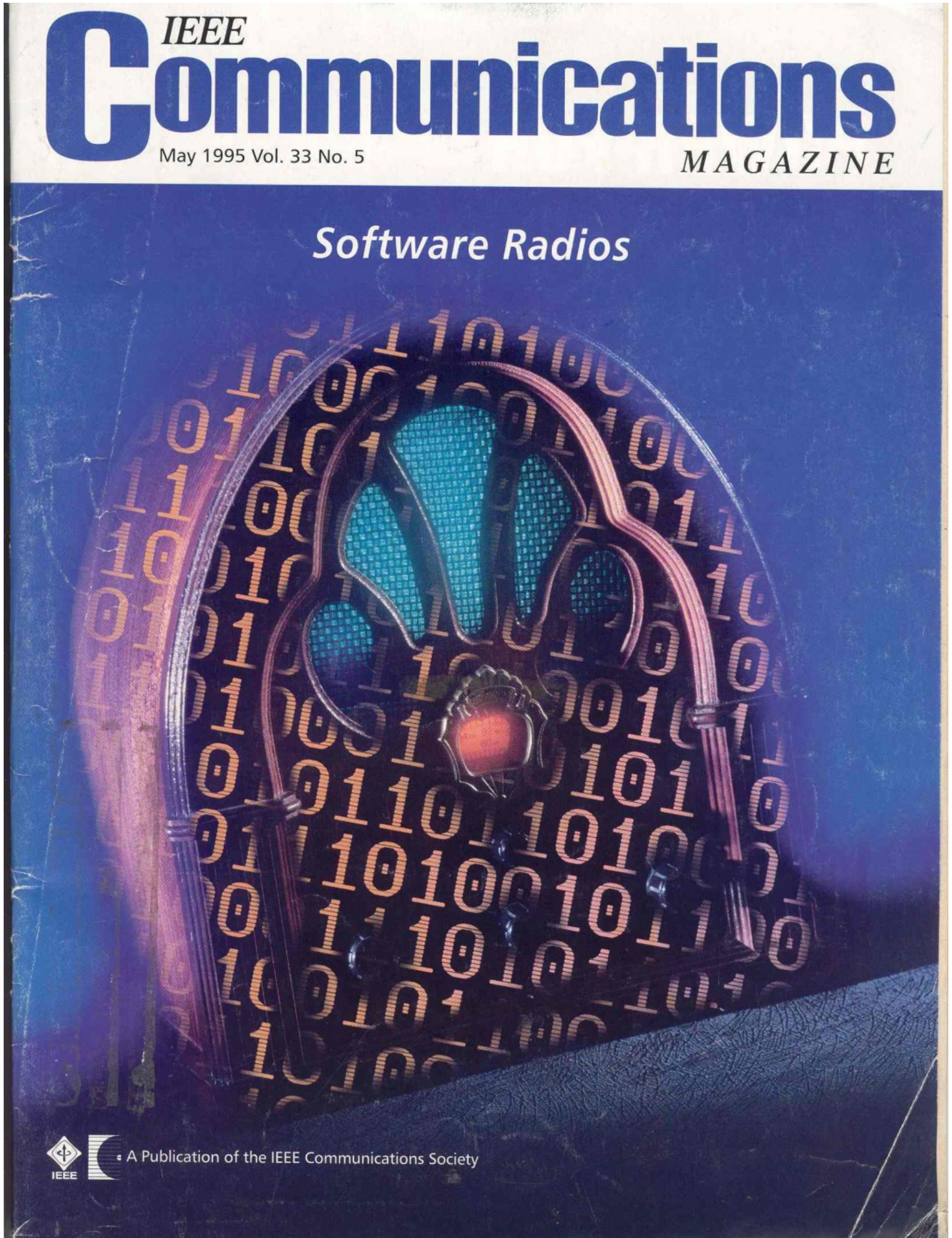
Digital Land is like working in
San Diego in High Summer.
Gentle Breeze,
Surf’s up, Warm Sweet Air, Sunshine.

I once presented this slide at a seminar where an attendee protested:
“I’m offended by that slide! I love working in Minnesota”.

Now when I show the slide I add the comment:
“This is meant to be humorous and not offensive!”

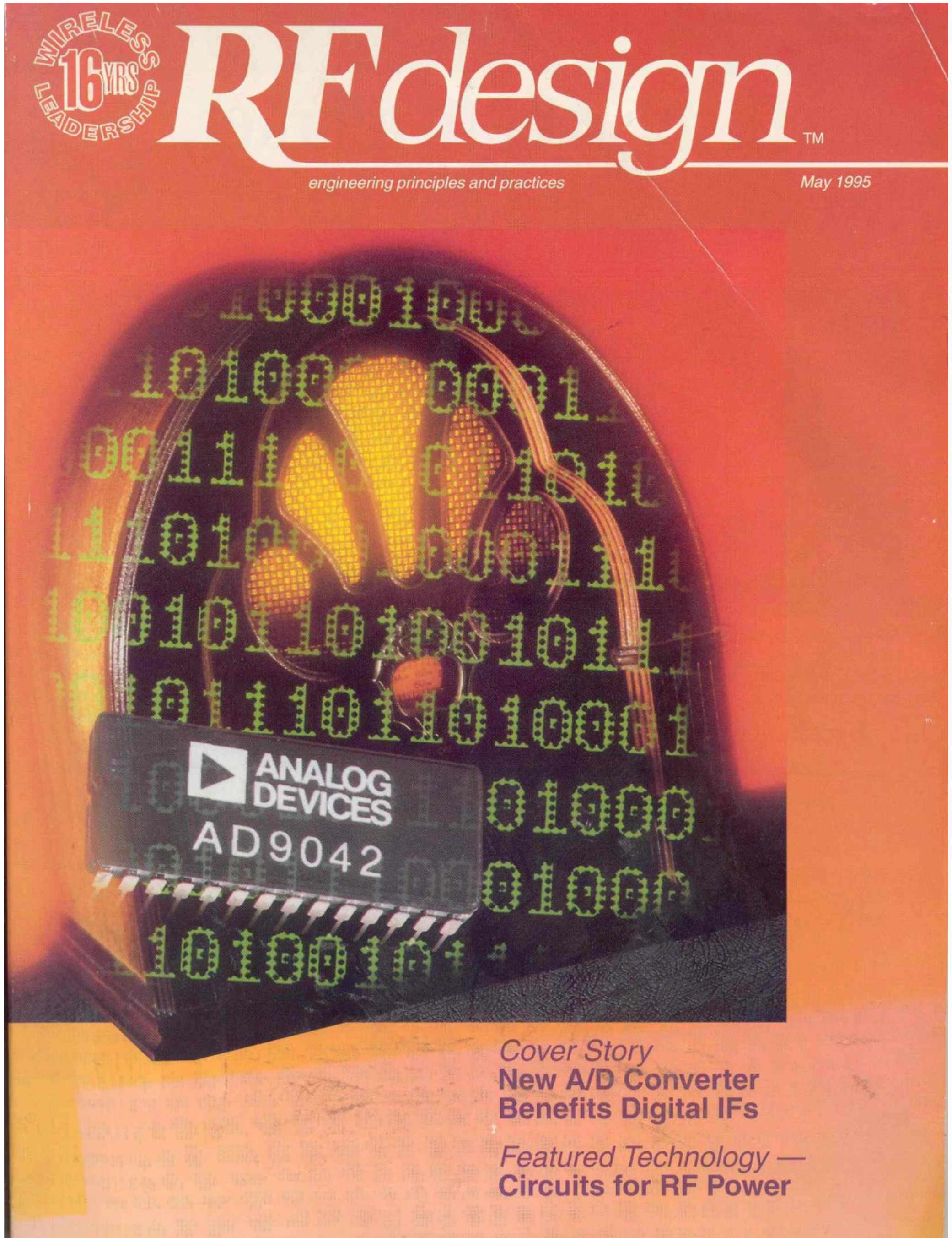
A Digital Radio:
DSP, A Small (But Very Important) Segment
The Rest is Also Very Important!





Joe Mitola
Editor and
Father of SDR

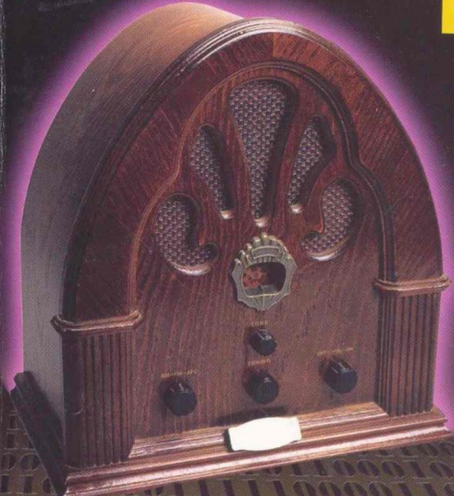
Notice Month



Notice Month

PROCEEDINGS OF THE IEEE
VOLUME 90, NUMBER 8 AUGUST 2002

TECHNICAL ADVANCES IN DIGITAL AUDIO RADIO BROADCASTING



JPEG 2000: Standard for Interactive Imaging

Sensorless Control of Induction Motor Drives

Multiresolution Markov Models for Signal & Image Processing

Classic Paper Reprint: Synchronous Communications by J.P. Costas

Plus

Scanning Our Past from The IEEE History Center: In His Own Words, John R. Pierce

PROCEEDINGS OF THE IEEE 90 ANNIVERSARY YEAR

IEEE

software-defined radio

A **software-defined radio** (SDR) system is a radio communication system which uses software for the modulation and demodulation of radio signals.

An **SDR** performs significant amounts of signal processing in a general purpose computer, or a reconfigurable piece of digital electronics. The goal of this design is to produce a radio that can receive and transmit a new form of radio protocol just by running new software.

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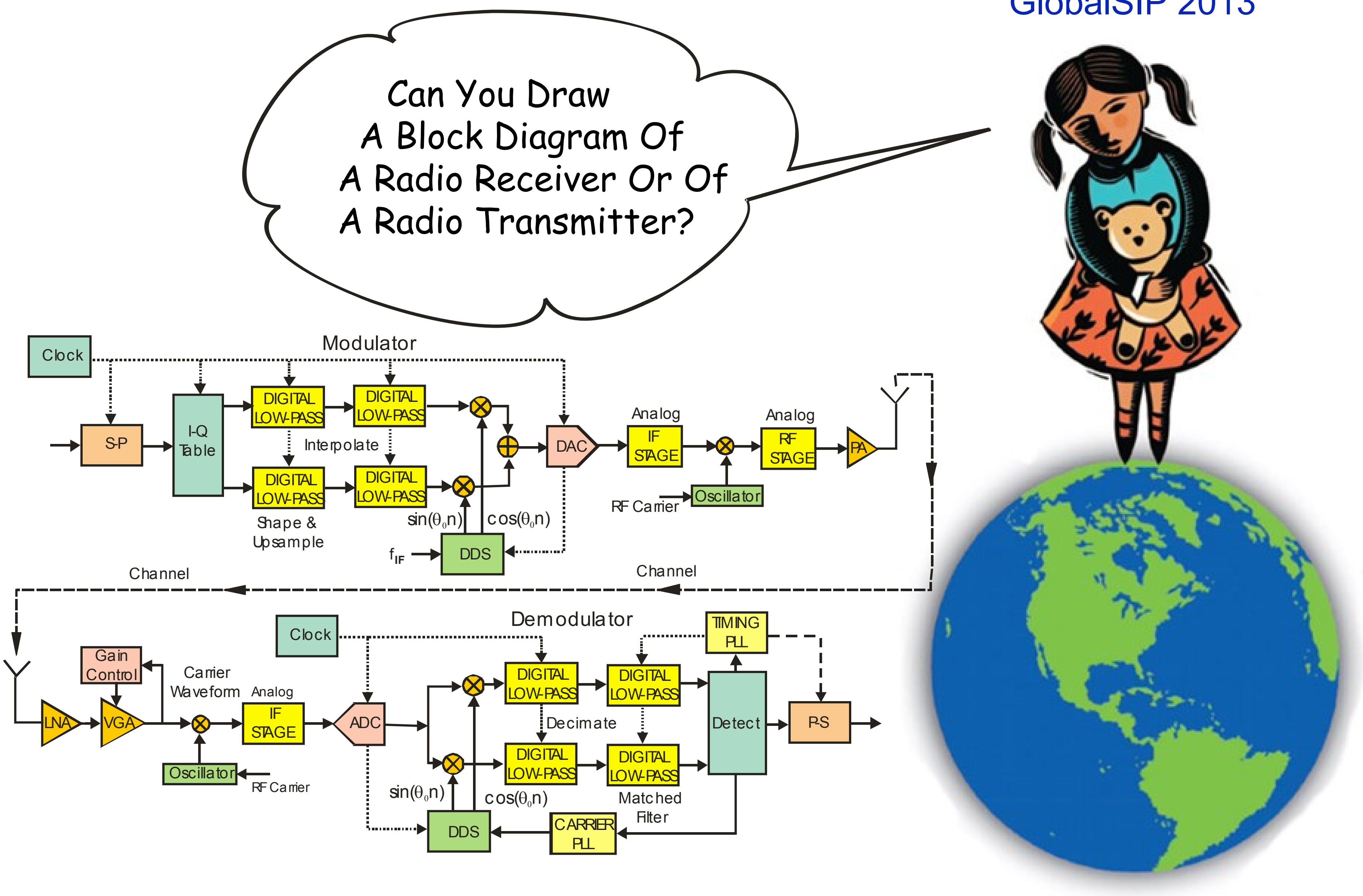
From Physical Layer, The Neglected Stepchild of Communication Systems

GlobalSIP 2013



From Physical Layer, The Neglected Stepchild of Communication Systems

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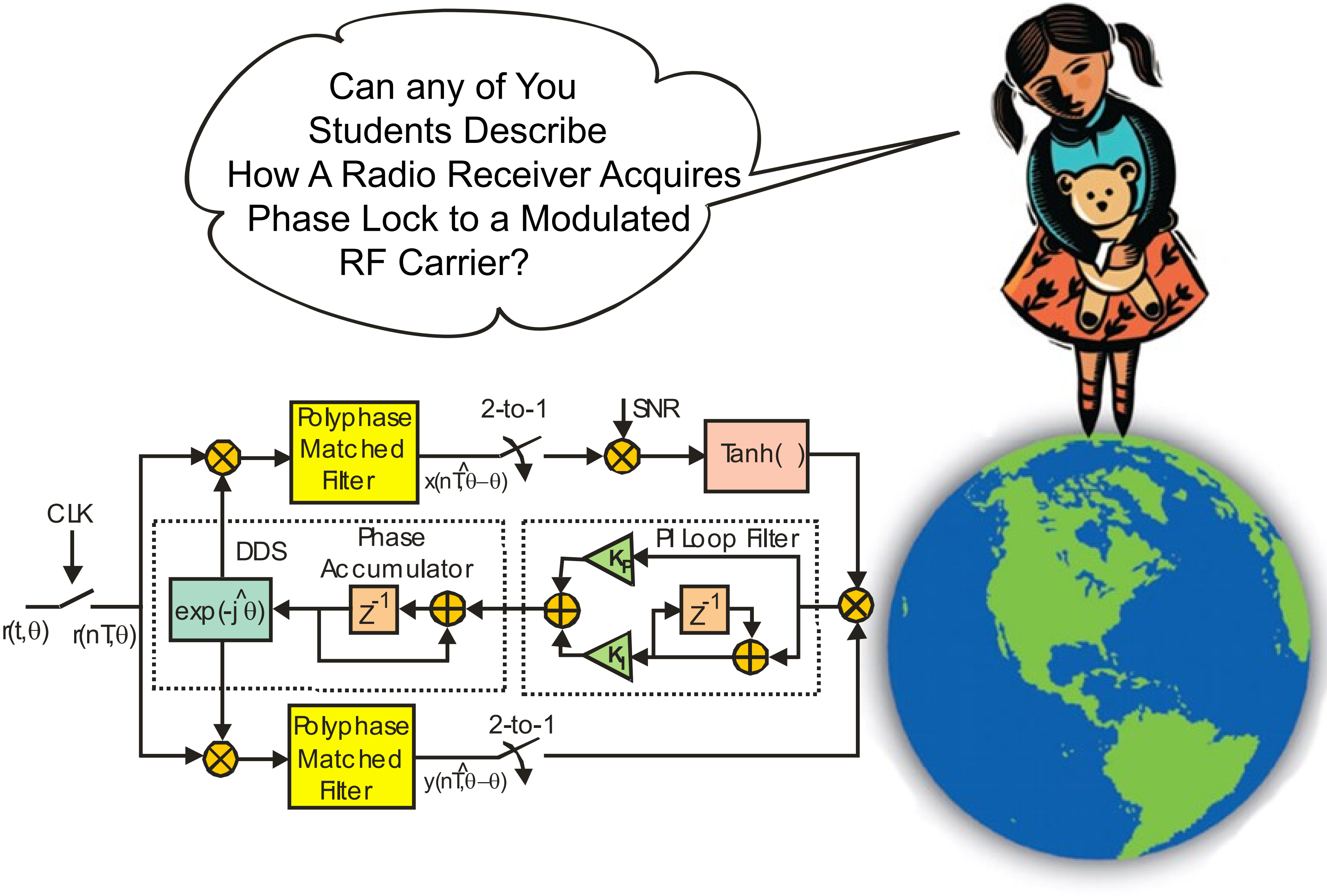
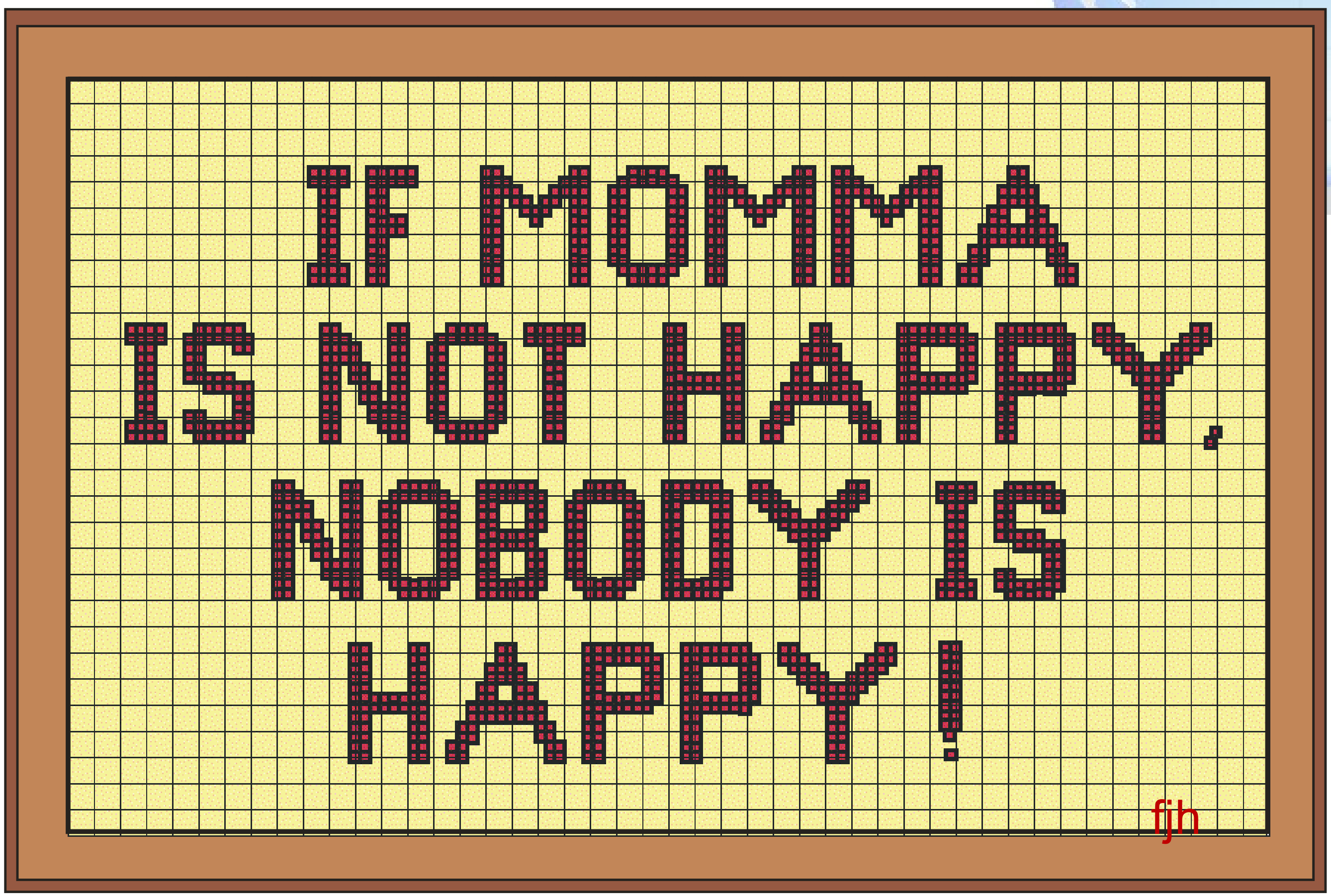
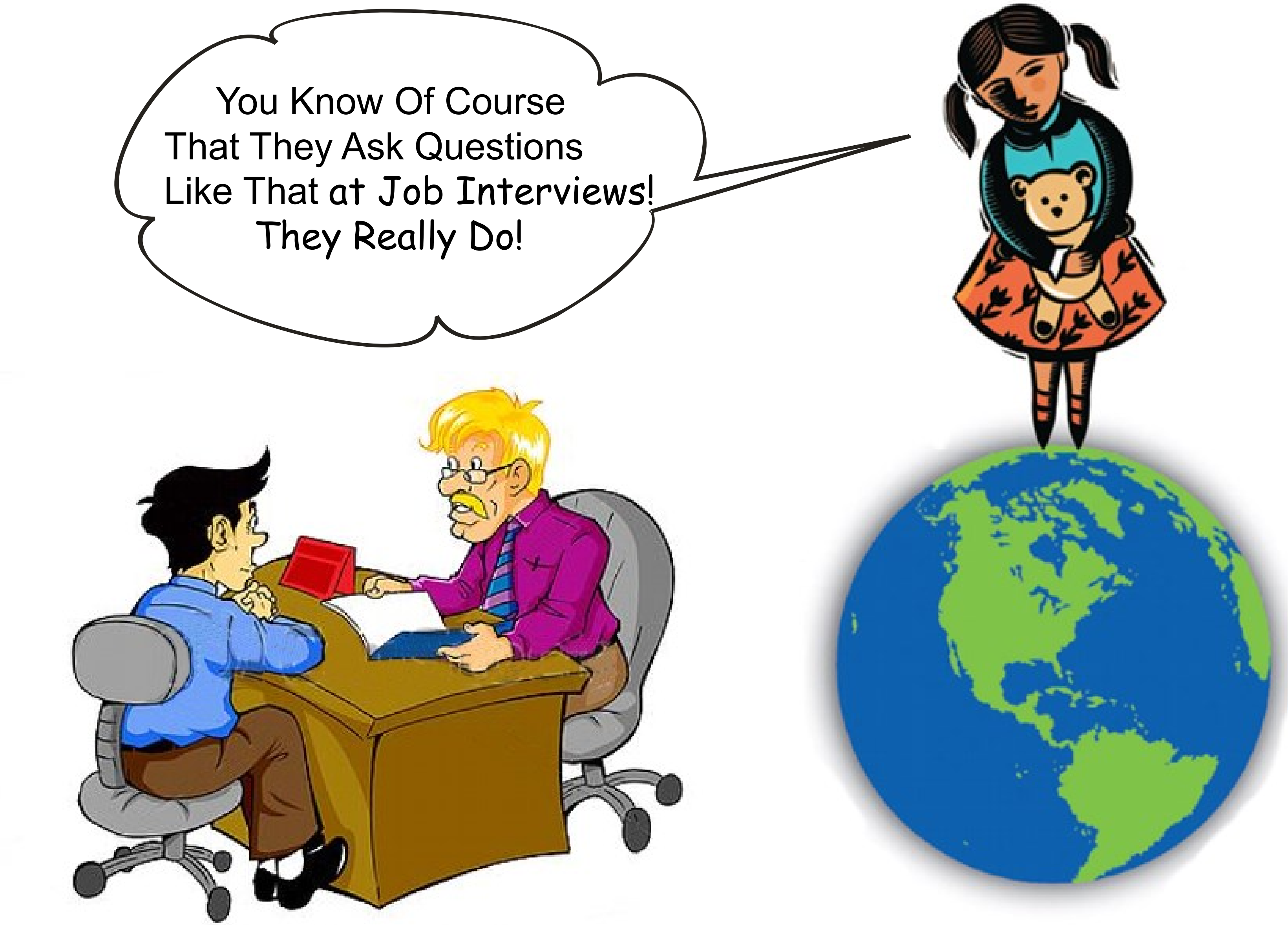


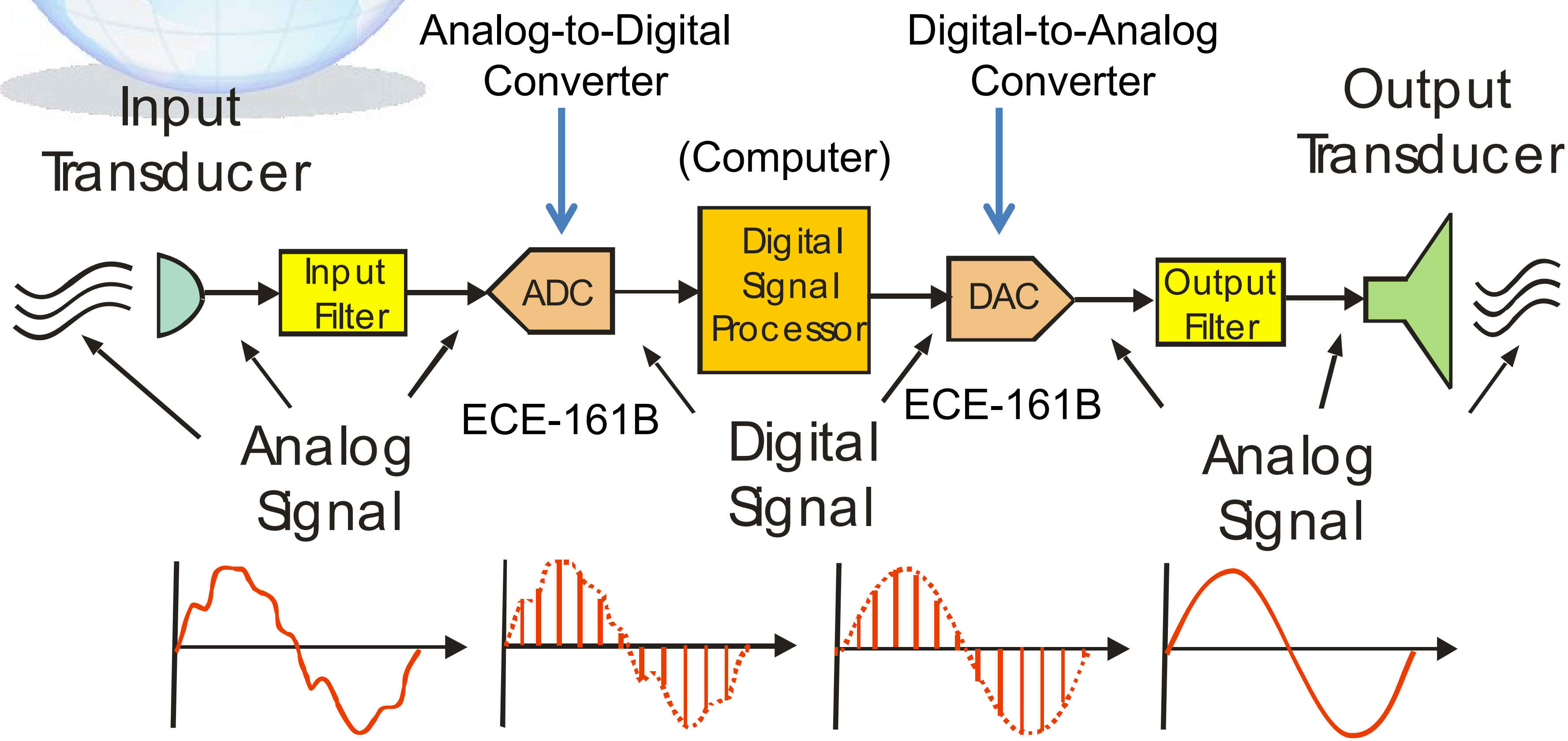
A Needle Point Hanging in the Physical Layer Kitchen



Momma's Middle Name is Synchronizer


You Know Of Course That They Ask Questions Like That at Job Interviews! They Really Do!

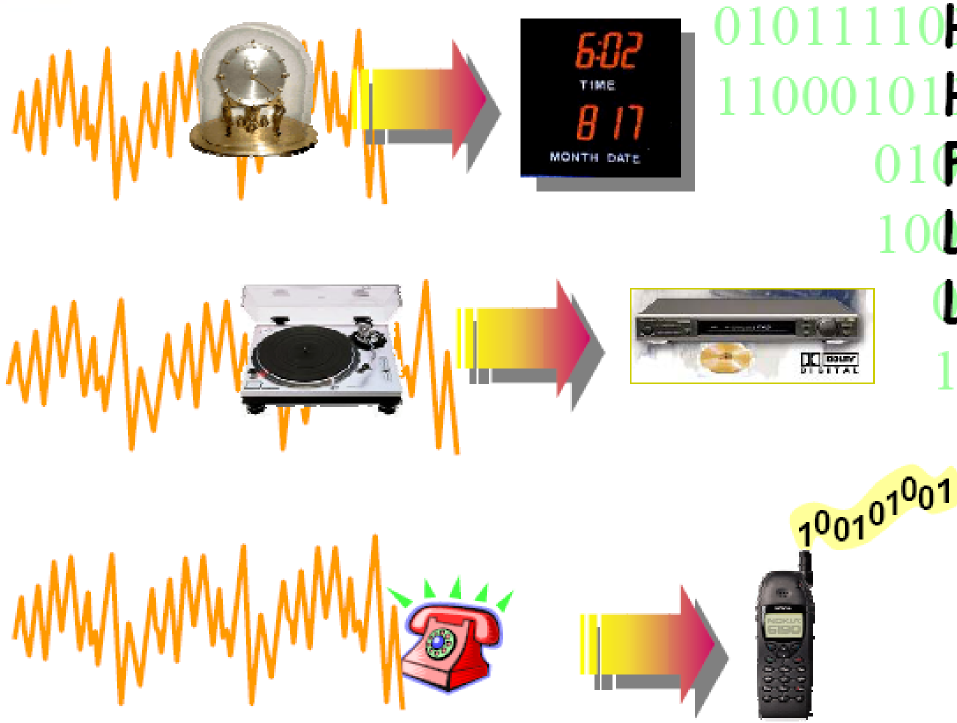
A DSP Based System Looks Something Like This:



The Digital Age of Consumer Electronics

Digital technology brings

- Higher accuracy
- Higher reliability
- Faster speed
- Lower power
- Lower cost



More things smarter than I am! I have to ask my grandson to program them!

Digital Signal Processing (DSP)

- Signal: Waveform related to some physical quantity that varies amplitude as a function of time or space.

Example 1. Sound pressure level from vibrating strings of a piano.

Example 2.

Light Intensity reflected from an illuminated scene.

Example 3. Radio Waves propagating in free space or in a cable.

- Signals are intercepted or captured by a transducer or sensor that converts the signal to an electrical representation of the original signal.

Example 1. Microphone converts Sound Pressure to Electrical waveform with voltage levels proportional to time varying sound pressure leve

Example 2. Focal-Plane Array of photo sensors convert image intensity at each pixel to an electrical signal proportional to image intensity.

Example 3. Antenna intercepts radio waves and generates voltages proportional to radio wave signal strength.

Digital Signal Processing (DSP)

- Processing: Modify signal by enhancing and improving desired components, suppressing undesired components, apply transformations to signal to estimate or detect parameters of signal, alter representation of signal for compact storage or transport of signal.

Example 1. Bass and treble control of audio signal.
Example 2. Color or contrast correction of captured image.
Example 3. Steer antenna to collect weak radio signal from specific direction.
Example 4. Stereo Separation of Composite FM waveform.
Example 5. Feedback signal in power steering servomechanism.
Example 6. Automatic gain control and automatic frequency control signals in radio receiver.

Digital Signal Processing (DSP)

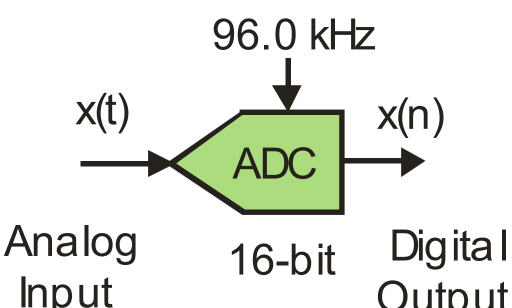
Use a Computer to Process the Signal

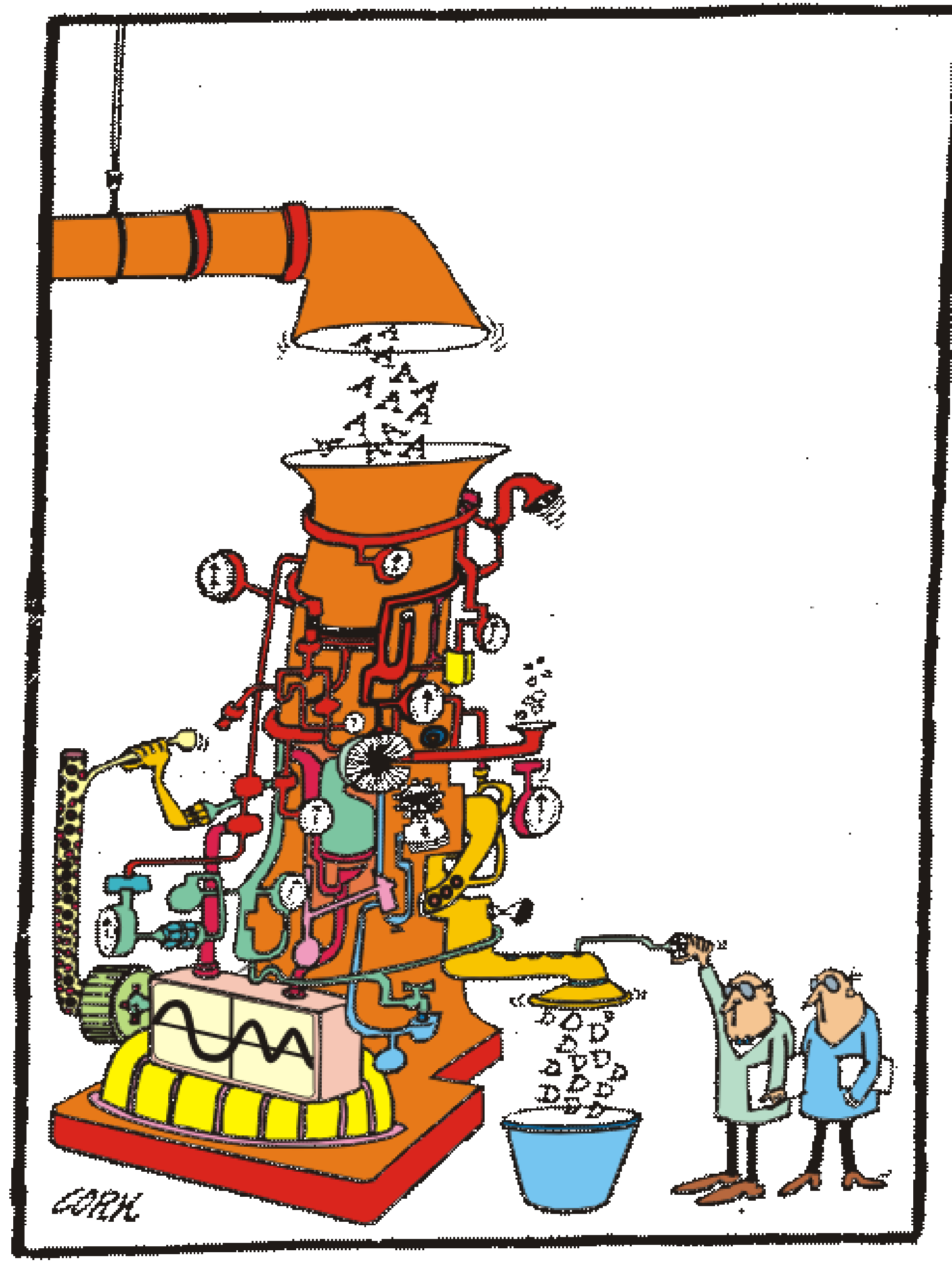
We can Move Back and Forth Between
Analog (A) and Digital (D)
Representations of the Signal

Sample time varying voltage level waveform at equally spaced intervals and convert the sample values to a sequence of numbers representing the same signal by a process called ADC (Analog to Digital Converter).

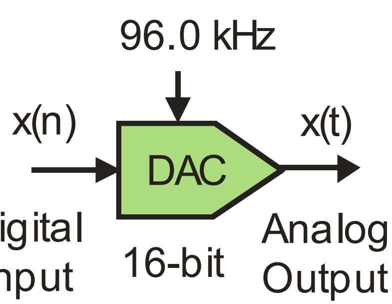
In the reverse process, a sequence of numbers output from a digital system is converted back to a time varying waveform by a DAC (Digital to Analog Converter).

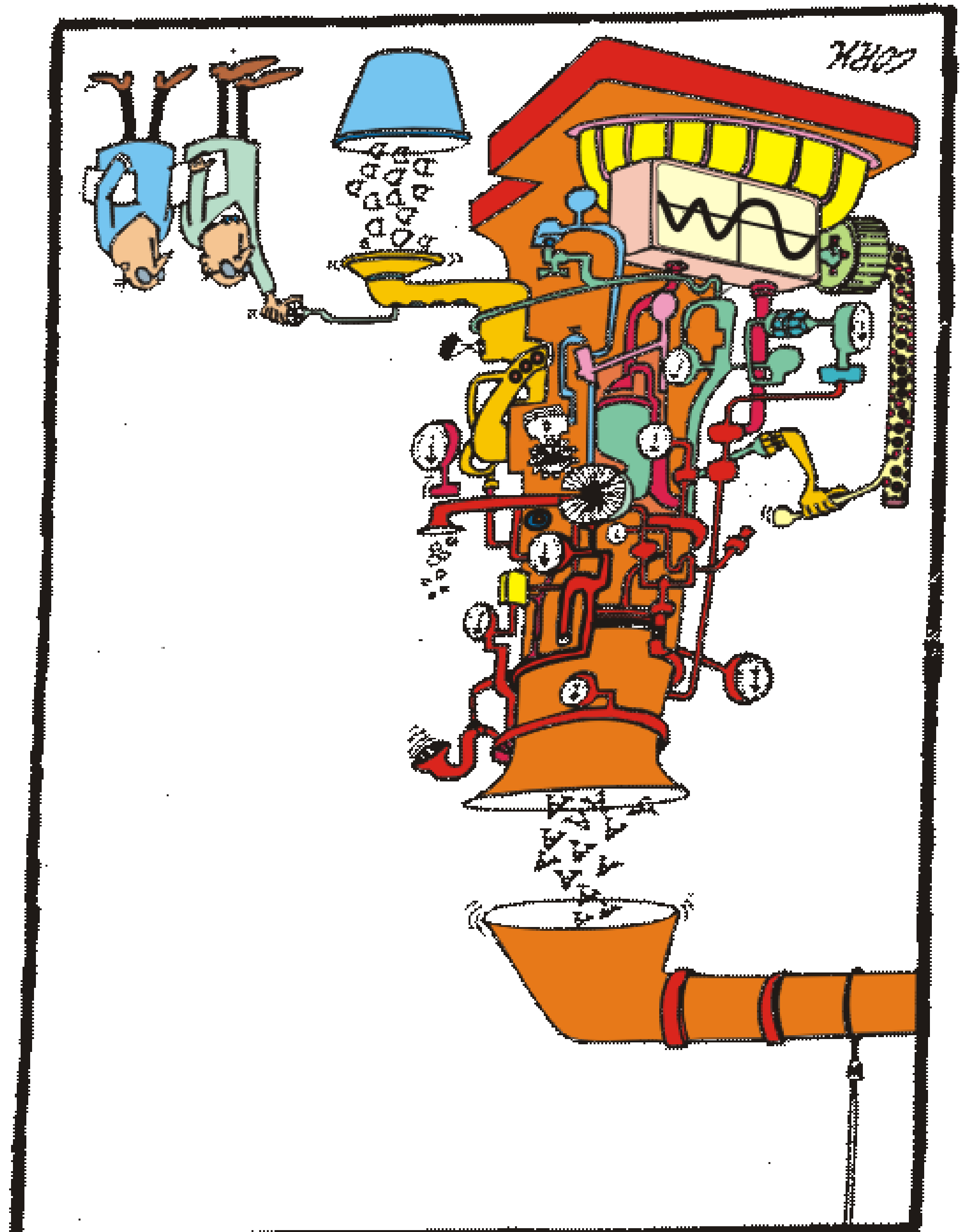
Analog-to-Digital Converter (ADC)



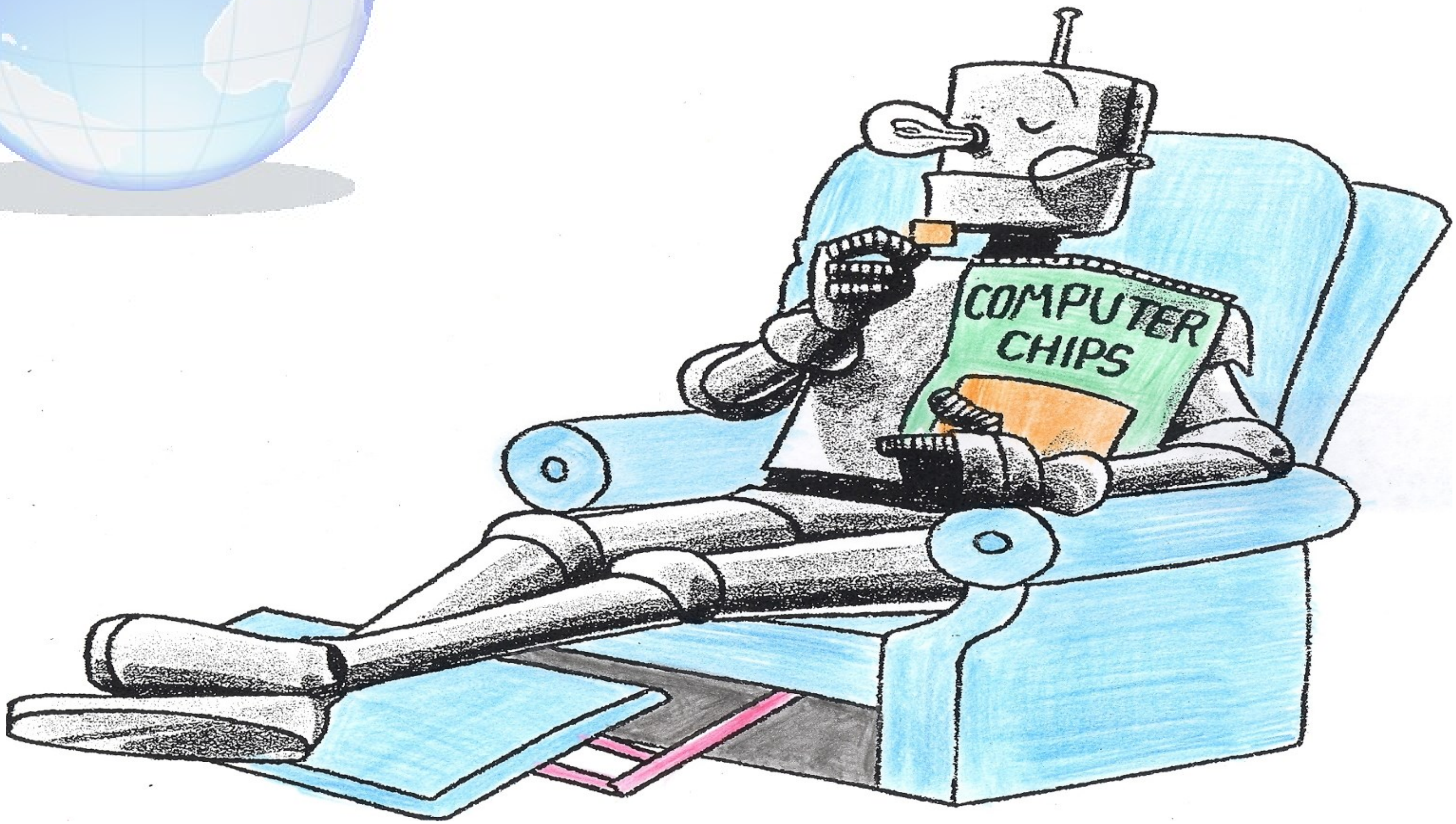


Digital-to-Analog Converter (DAC)





It’s All Done with Computer Chips



We all own a Billion Transistors

We have an amazing wealth of resources at our disposal!

What can you do with a Billion Transistors? Wait a moment,

Just how big is a Billion?

A stack of a billion bank notes is 76.2 kilometers High.

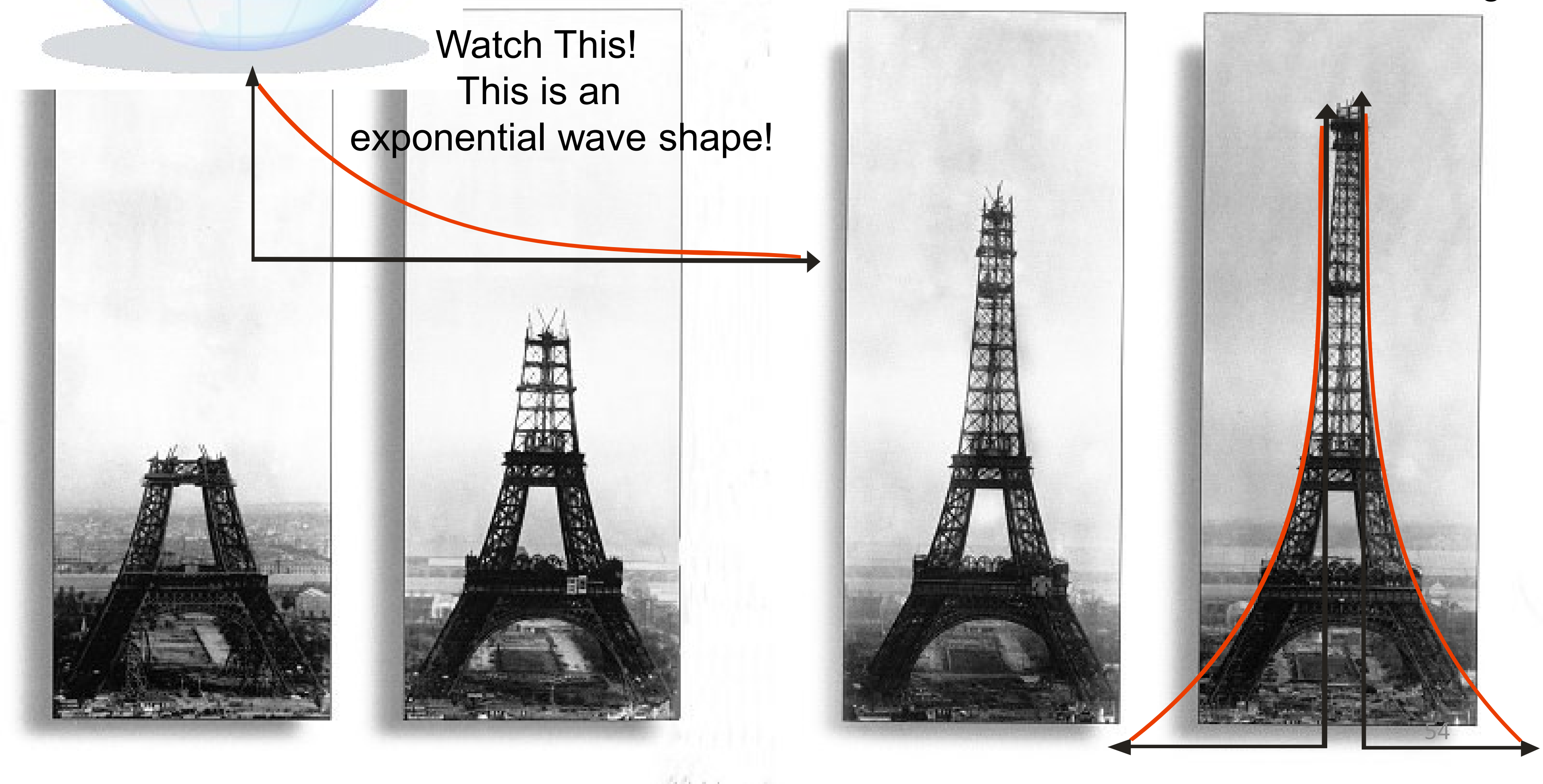
A billion seconds from now you will be 32.5 years Older!

For Comparison, the Eiffel Tower Contains 18,084 Parts. It is Fastened Together by 2.5 Million Rivets

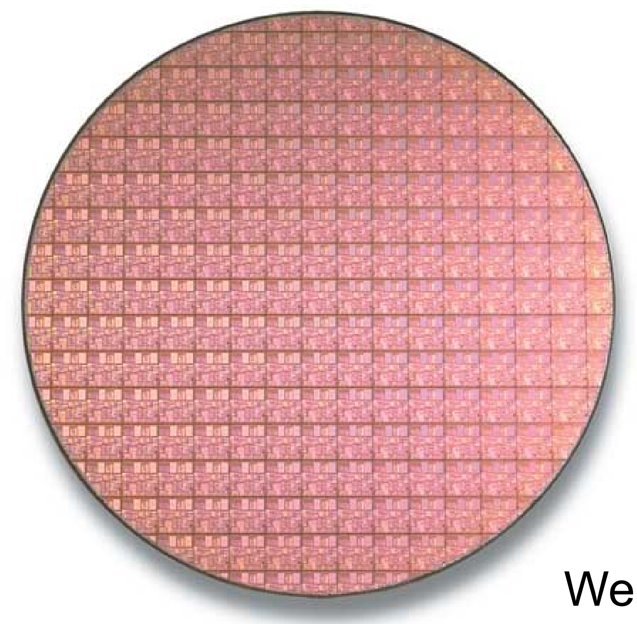
Washington Monument

Woolworth Building

Isn't that Interesting?



The world manufactures more transistors than it grows grains of rice.



Wow!

We all own a billion Transistors

0.13-micron, Intel Pentium 4
300-mm silicon wafer

Long grain Jasmine rice

What we can do with a Billion Transistors.

Satellite Broadcasts 384 MP3 Channels to Earth Stations

Demodulate all MP3 Channels
Remodulate as FM Channels

Task: Replace Legacy Transceiver

What size room is required to house new DSP based Transceiver?

Equipment Bay: 192-Stereo FM Modulators

Conversation with Client!

- How big a room will we need to house the DSP version of this Transceiver?
- My Answer: I think it will fit on one chip.
- Response:

  Don't be Absurd: Can't Pack a Room onto a Single Chip!
- Results: 48-Analog Devices Blackfin Processors to Demodulate 192 MP3 Stereo Channels.
- 1 Virtex V-4 for 192 Digital Stereo FM Modulators and 256 Channel Channelizer @ 293 kHz Bandwidth per Channel. (60% of Chip)

A Smaller Package

X-Digital Systems

2-U High, Full Rack Width

H 3.5 in, 8.89 cm
W 17.0 in, 43.18 cm
D 9.4 in, 23.88 cm

ow to Pack Room of Analog M Modulators nto a Xilinx FPGA

by Fred Harris
Professor
San Diego State University
fred.harris@sdsu.edu

Dragan Vuletic
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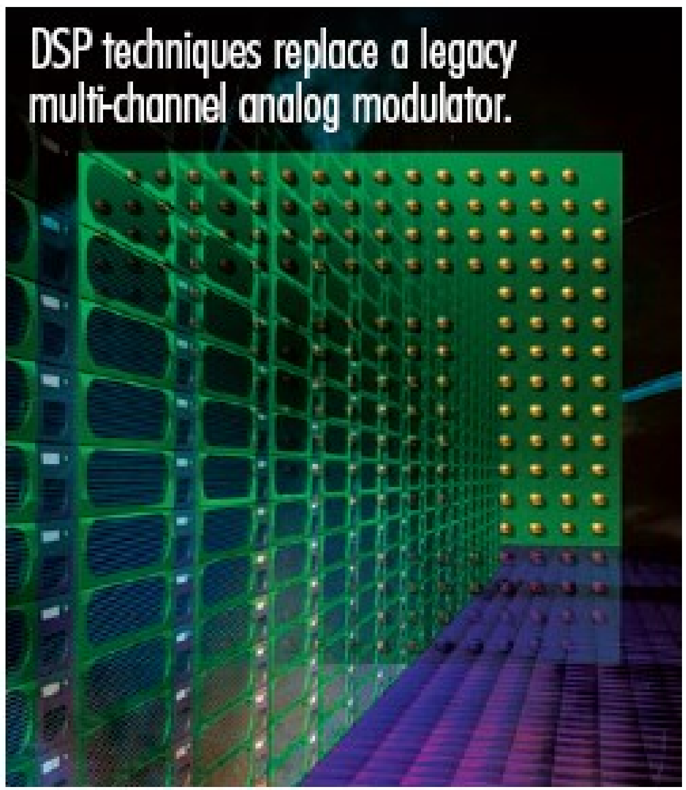
wade.lowdermilk@signumconcepts.com



You are likely familiar with the way that digital television is transmitted from satellites as multi-channel MPEG (Motion Picture Experts Group) compressed video to a cable head end where the multiple channels are demodulated. The MPEG streams are decoded and then remodulated as channelized analog NTSC (National Television Standards Committee) or PAL (Phase Alternating Lines) television signals for insertion in a cable distribution plant.

Similarly, high-quality stereo audio is transmitted from a satellite as multi-channel MP3 (MPEG Layer-3) compressed audio to a cable head end where the multiple channels are demodulated. The MP3 streams are decoded and then remodulated as channelized analog FM signals for insertion in a cable distribution plant.

Figure 1 – Equipment bay containing legacy transceiver equipment

如何将一大堆模拟 M 调制器纳入一个Xilinx FPGA 中

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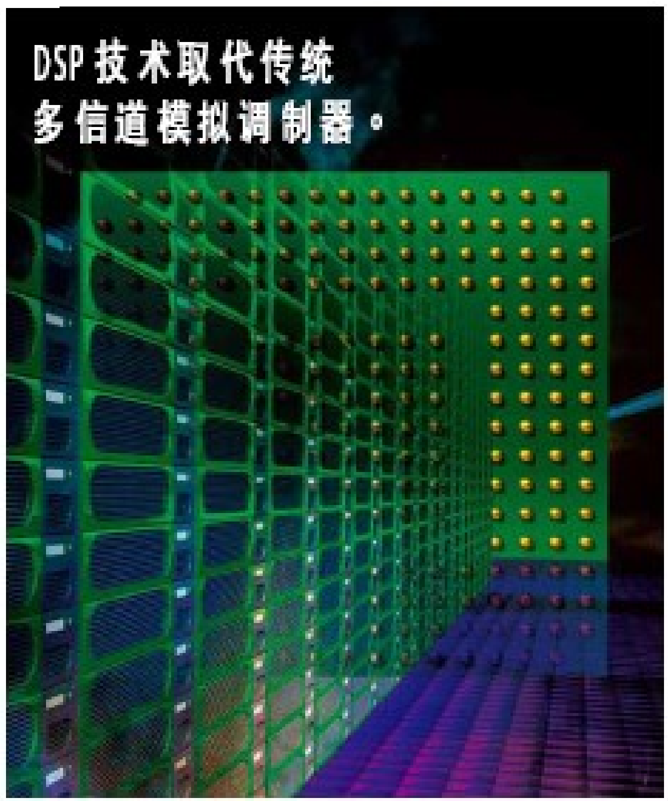


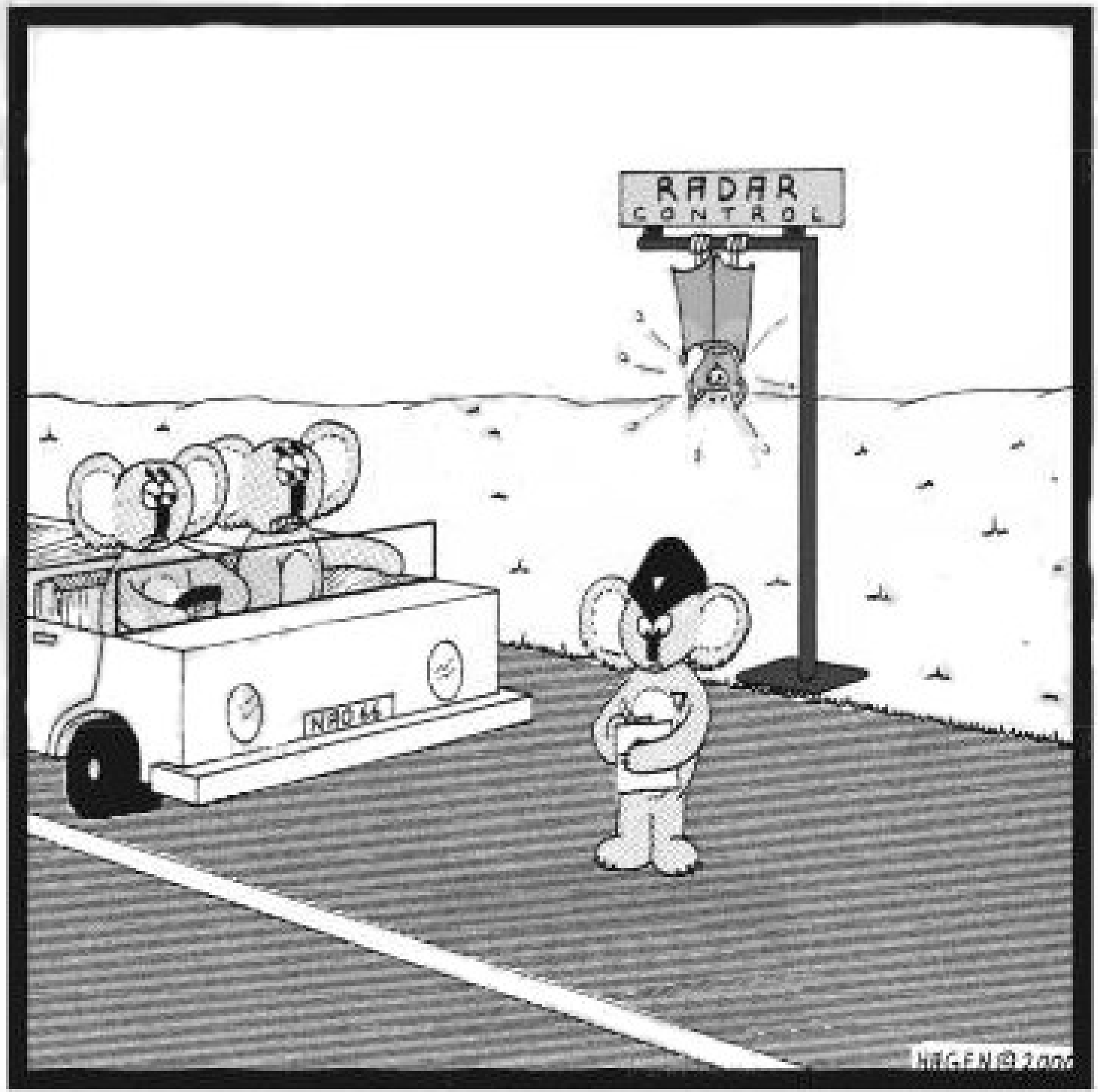
您可能熟悉数字电视的传播方式。信号以多信道 MPEG（移动图像专家组）压缩视频格式从卫星传送到电缆头端器。然后对多个信道进行解调。MPEG 流经解码后被重新调制为信道化模拟 NTSC（国家电视标准委员会）或 PAL（逐行倒相）电视信号并插入到电缆分配设备中。

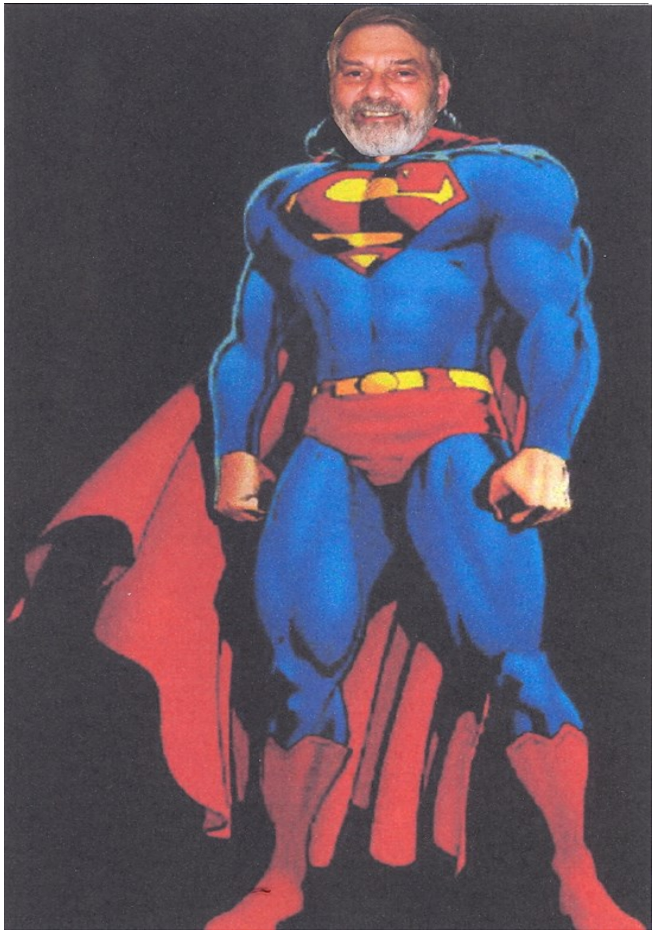
与此相似，高品质的立体声音频信号以多信道 MP3 (MPEG Layer-3)压缩音频格式从卫星传送到电缆头端器。然后对多个信道进行解调。MP3 流经过解码后被重新调制为信道化模拟 FM 信号并插入到电缆分配设备中。

图 1 - 包含传统收发器设备的设备架


Just_constel_550

Presentation at Radio Telescope Group in Sydney
Found Cartoon on Line with Australian scheme, Koala Bears and Bat Radar.
I used Cartoon at end of presentation (without permission from author)
When presented, I was told the cartoonist was in the adjacent room.





SOFTWARE DEFINED RADIO MAN

Is Open For Questions