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Customer Success Is Our Mission

Applications Drive Progress!

A Perspective on the Past and Future of Signal Processing

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The Perils of Prognostication

- "It's tough to make predictions, especially about the future."
  — Attributed to Yogi Berra

- "No, it's not hard to make predictions. It's just tough to make ones that turn out to be right."
  — Accurately attributed to John Treichler

- Perhaps the best way is to gain historical perspective, and then project forward …

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First, an observation about signal processing —

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- The need for signal processing almost always comes about when a transducer fails to meet the user's needs or desires
- Examples
  - It does not make the measurement you want
  - The quality isn't good enough
  - Resolution is wrong
  - Too much data for transmission or storage
  - It doesn't sound or look right
- Note that this is neither the official, nor the complete, definition of signal processing

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My claim – signal processing is a journey, not a destination …

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More specific claim – Every important signal processing technique was driven by an application and has followed a set of roughly predictable steps

1. An “impossible” application or requirement
2. Theory development
3. Proof-of-concept (The “Hero Experiment”)
4. Technology-enabled cost reduction

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The Rest of the Predictable Steps

5. Upping the ante
6. Encountering and addressing other system limitations, for example –
   - Sensors
   - Human ability to use the product or capability
7. Recycle – using this experience to define the next more outrageous, but related, application – typically an order-of-magnitude, or more, more taxing

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Example – RADAR Signal Processing

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RADAR as the Example – Steps through the cycle

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- Problem – fully exploit returns from pulses radars
- Theory – “sampled data systems” and DSP
- Proof of concept with unfieldable technology
- Cost reduction in a myriad ways
- Operational and then commercial success
- Upping the ante – MTI, antijam, bistatic
- Countering other systems limitations – SAR
- Recycle —

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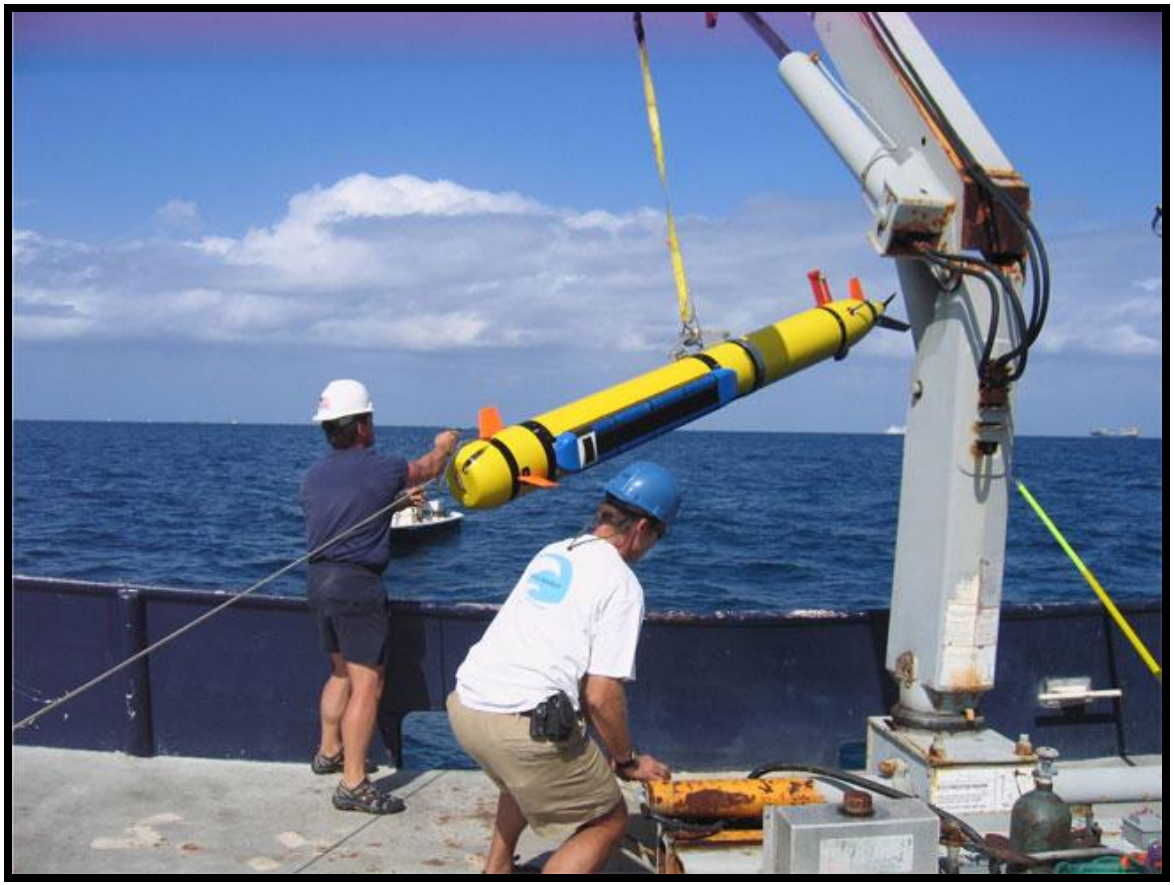
The Next "Impossible Requirement"



Synthetic Aperture Sonar (SAS) carried on an Autonomous Underwater Vehicle (AUV) — DSP throughout ! – sensors, navigation, control, communications

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Observations

- It took more than 20 years per cycle
- A variety of skills were required, including from many people who didn't even know what the big objective was
- There was no single source of developmental funding, and, in fact, there were many competing organizations, labs, and even countries
- Many many derivative products have resulted, including many totally unrelated to radar
- Commercialization of the technology, and hence the value of the IP, lagged military use by 20 years or so

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Another problem – circa 1971: Engine Noise Interfering with a Pilot's Voice

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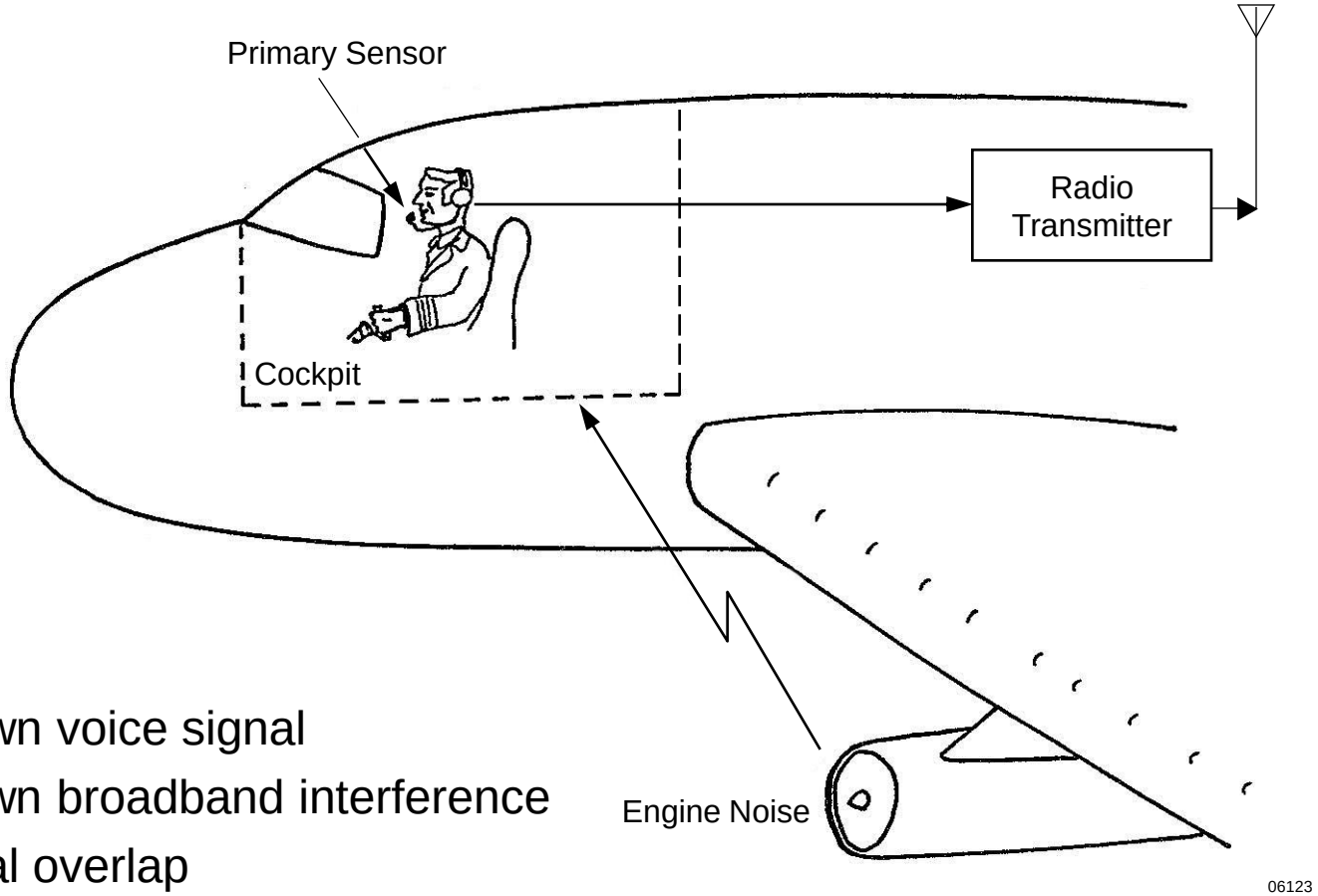

- Issues
  - Unknown voice signal
  - Unknown broadband interference
  - Spectral overlap

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Kaunitz' Solution – the "Adaptive Noise Canceller"

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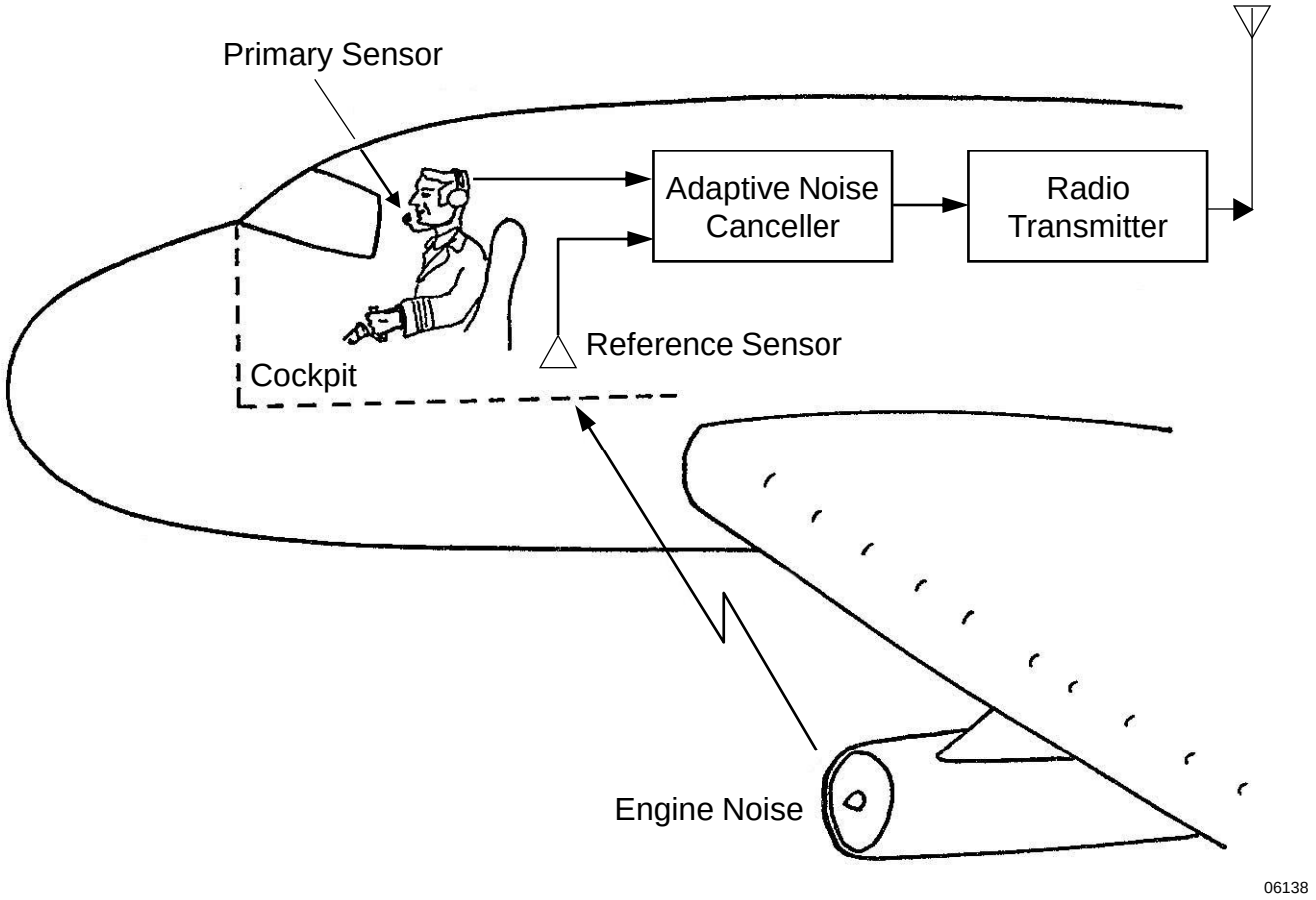

[Kaunitz, 1972]

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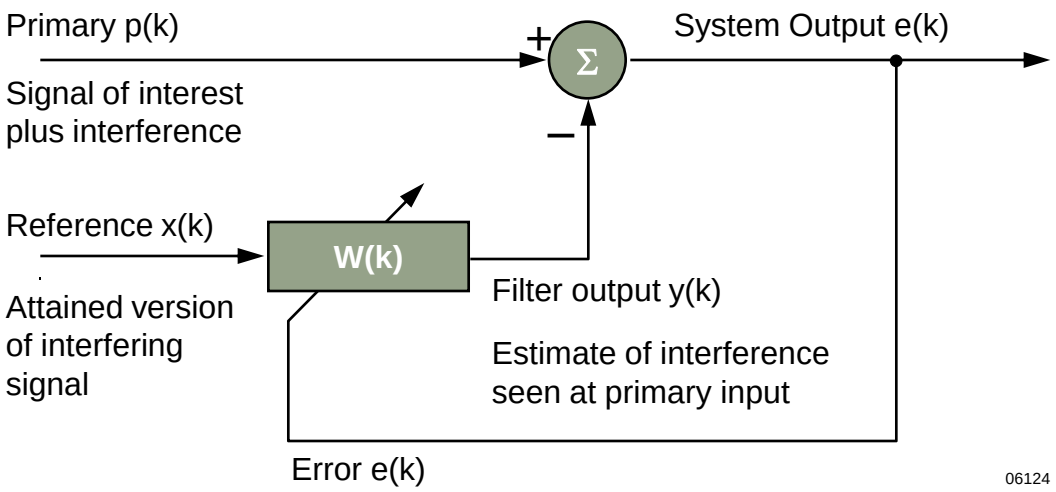
The Adaptive Noise Canceller



[Widrow, 1975]

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The First Operational ANC Application

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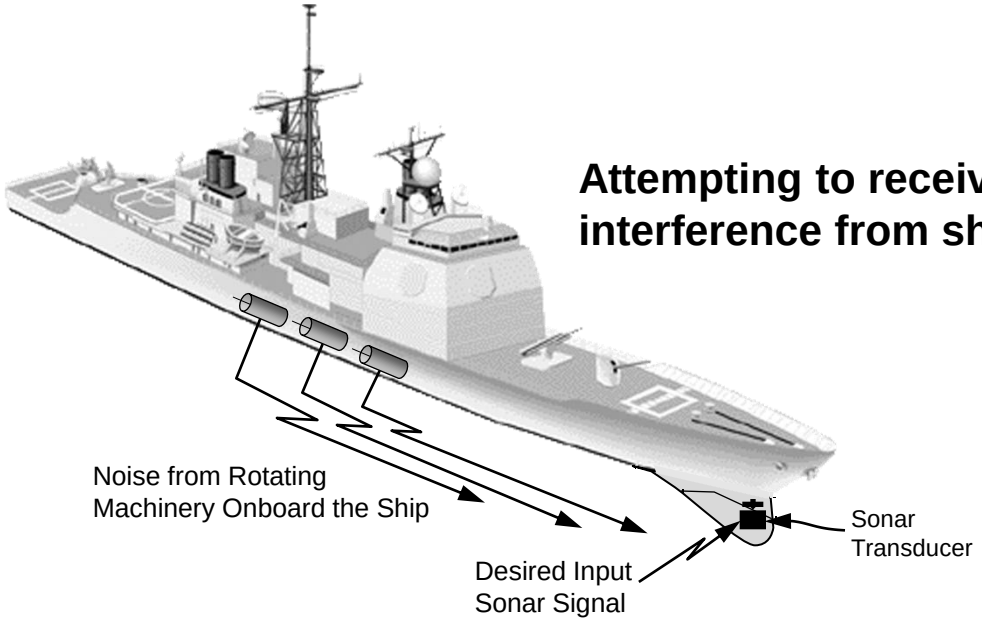
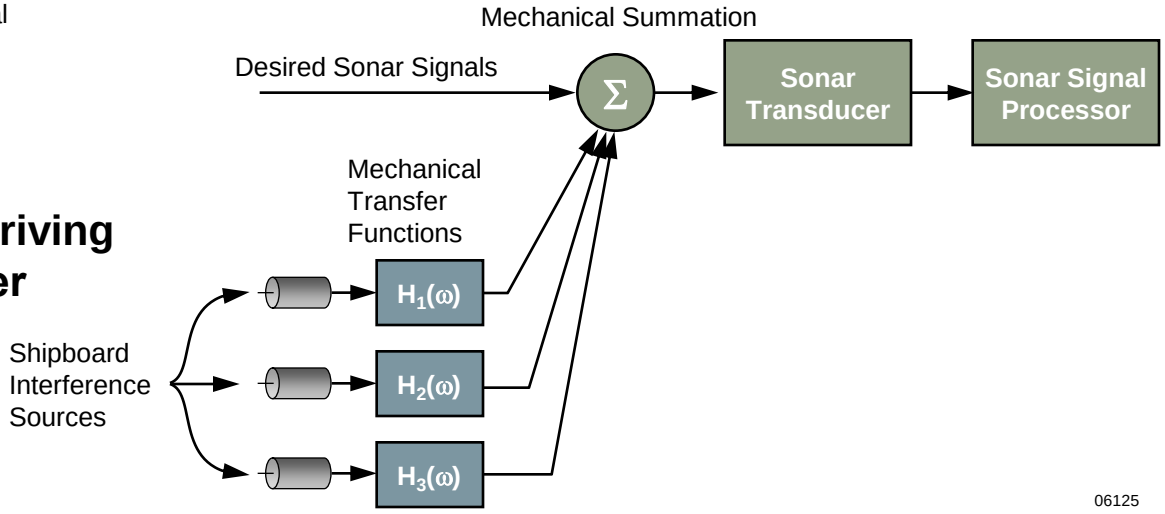


Attempting to receive sonar signals in the presence of interference from shipboard machinery

A model describing the signals arriving at the sonar's receiving transducer



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Extension of the ANC to Multichannel Inputs

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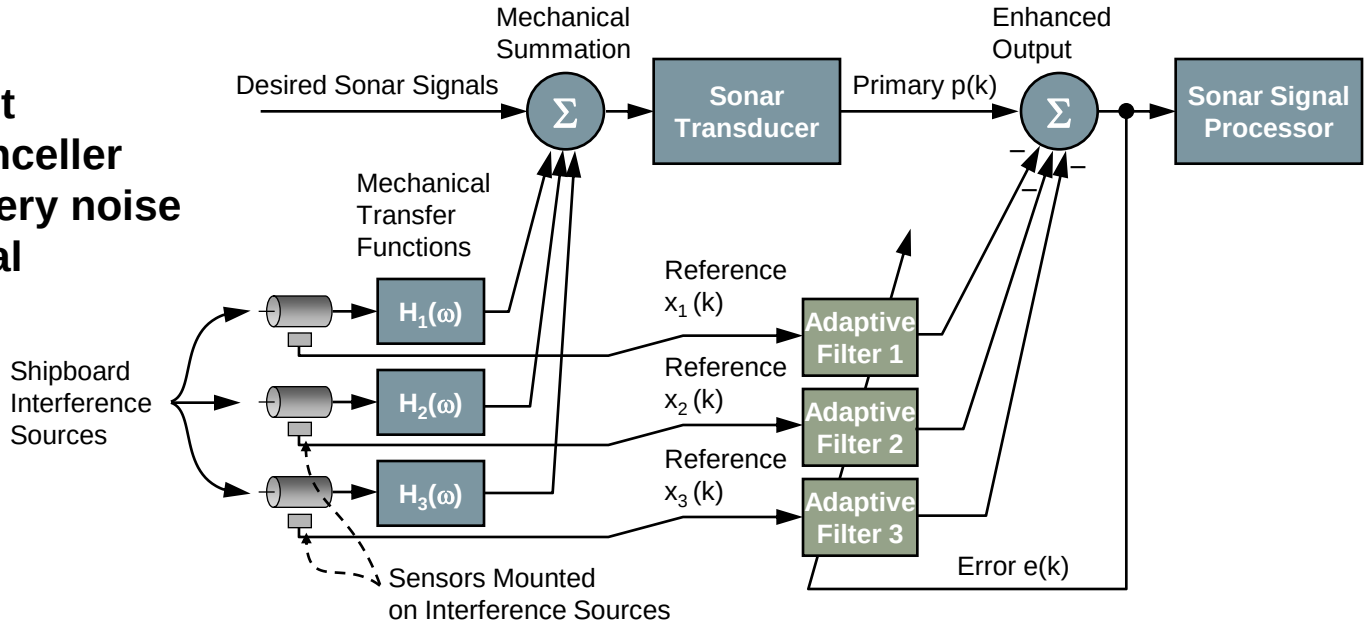
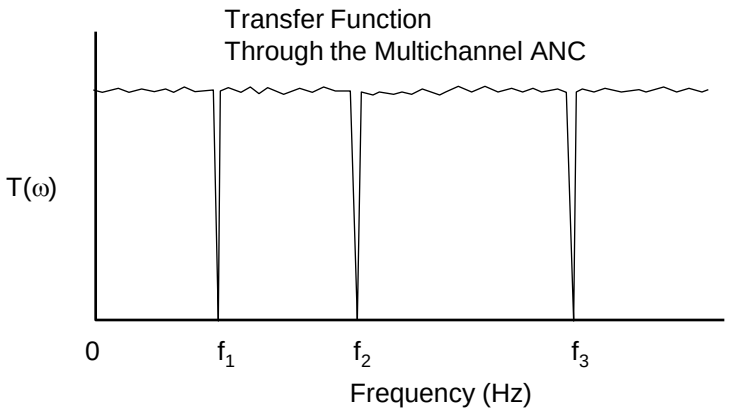
Using a multi-input adaptive noise canceller to remove machinery noise from a sonar signal



- **Physical Implementation**
  - **128 taps**
  - **$f_s \cong 1000$ sps**
  - **Construction: MSI**
  - **Rack mounted**



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Modern Version of the ANC

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My thesis: Most Applications Follow the Same Trajectory

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- Medical imaging: CAT, MRI, and sonography
- Seismic exploration
- The design of A/D convertors
- Wireless telephony
- Global positioning system
- 3D graphics for video games
- Music and video recording and broadcasting
- Modern computer-laden automobiles
- Telepresence
- And on and on

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A Very Important Point –
We Signal Processing Folks Are Very Special!

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- Orders-of magnitude improvement in semiconductor technology has blessed us with dramatic reduction of the size, weight, power consumption, and cost of signal processing

1980

2007

- Both were state-of-the-art processors of 5 MHz-wide signals

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Comparisons!

Boeing 707

Boeing 787

TDC 1010J 16-bit MAC

Xilinx Zynq

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So, if we understand these patterns, where does that take us?

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- The realization that signal processing will be everywhere
- The realization that since other fields need it, they will develop/redevelop signal processing if we don't reach out to those fields and the applications that they serve
- The realization that signal processing education is needed by virtually everyone who enters
  - Any field of engineering
  - Most in science and
  - Many in the arts

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Examples of Future Societal Needs and Wants – All DSP-Enabled

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- Entertainment (up through and including the “holodeck” from StarTrek®)
- Universal language translation (in real time, both spoken and written)
- Better noninvasive (less invasive) medical diagnostics and interventions
- Networks of sensors to provide alerts to the public against spreading diseases, contagion, toxic chemicals, etc.
- Low-cost systems of sensors, processing, and telemetry for daily health monitoring without going to a physician’s office

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More Examples

- Energy efficient personal transport with automated navigation
- Transparent, secure, inexpensive communications with anyone of your choice, with a full range of “telepresence”
- Environmental protection (models of the world’s weather, gaining an understanding of global temperature change, etc.)
- Robotic systems to go places and do things that humans won’t, can’t, or shouldn’t
- And, most importantly, things we can’t even imagine yet!

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And in my world —

- Making the oceans transparent (or opaque!)
- Combating terrorists who are using 4th generation (and beyond) wireless systems
- Finding nuclear proliferators
- Verifying ecotreaties
- …… and more

What, exactly, from a DSP perspective, do we need to solve these problems? And how do we go do it?

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So what limits our progress?

- Demobilization of our efforts based on the false belief that "signal processing is mature"
- Psychological issues to be mentioned shortly
- Permitting signal processing (and electrical engineering in general) to become confused with computer engineering
- Education that
  - Shortcuts building intuition and relies only on design tools
  - Stresses individual excellence over team performance
  - Stresses design skills to the exclusion of producing a quality product
  - Fails to encourage communication and leadership skills
- Having math suited only to linear shift-invariant systems

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Psychological Considerations That Might Limit Future Achievements

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- Are we willing to trust technological trends enough to plan on them?
- Are we willing to think beyond how we currently do things?
- Does “future shock” debilitate us disproportionately since most other high-tech things don’t change as fast as DSP-enabled, silicon-driven technology?
- Do we think too narrowly?

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Observations

- Applications drove the technology, both algorithms and physical implementations
- None met the original theoretical model, but …
- All succeeded and were crucial to meeting the need
- This pattern can be expected to continue —

Strong knowledge of applications will be the key to technical breakthroughs

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The Bottom Line

Far from being exhausted, the applications of “wide-sense signal processing” are just beginning to explode

- **Following the cycle through for the existing applications**
- **Going after the new outrageous ones**
- **Extending the definition of signal processing to applications that didn’t think of themselves that way**
- **Developing the funding and educational systems to support the work, and**
- **Gaining trust in ourselves to go do it!**

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