Spectrum Policy

Technology Leading to New Directions?

national spectrum managers association

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Objectives

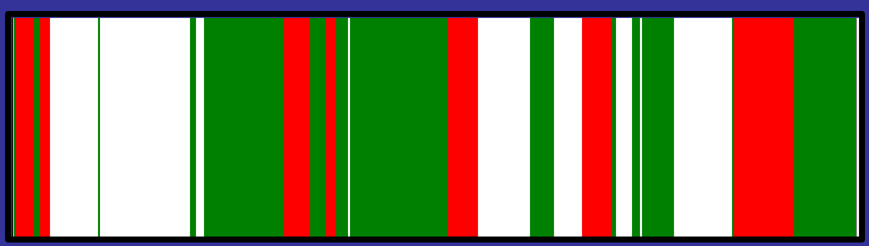
Looking for Better Ideas on Spectrum Policy

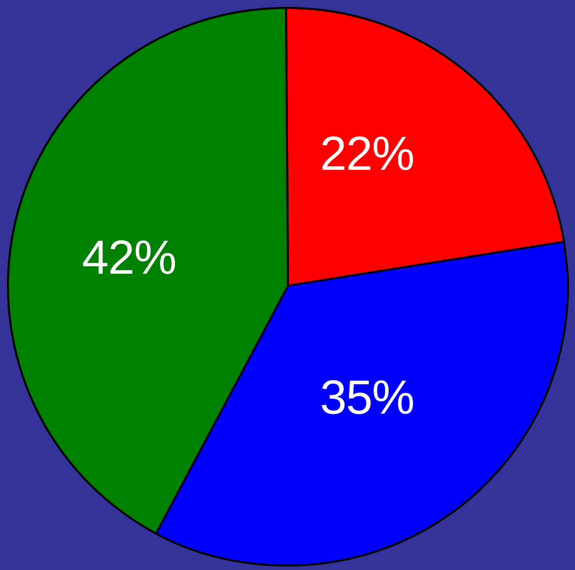
- Looking for an *integrated approach* across the wide "spectrum" of wireless applications
- Policy should not be the limiter to technology and product development

US Spectrum Allocations
(Government, Non-Government, Shared)

Spectrum Policy Task Force

	G	NG	Shared
MHz	621.6	985	1171
%	22%	35%	42%
Total	2778		

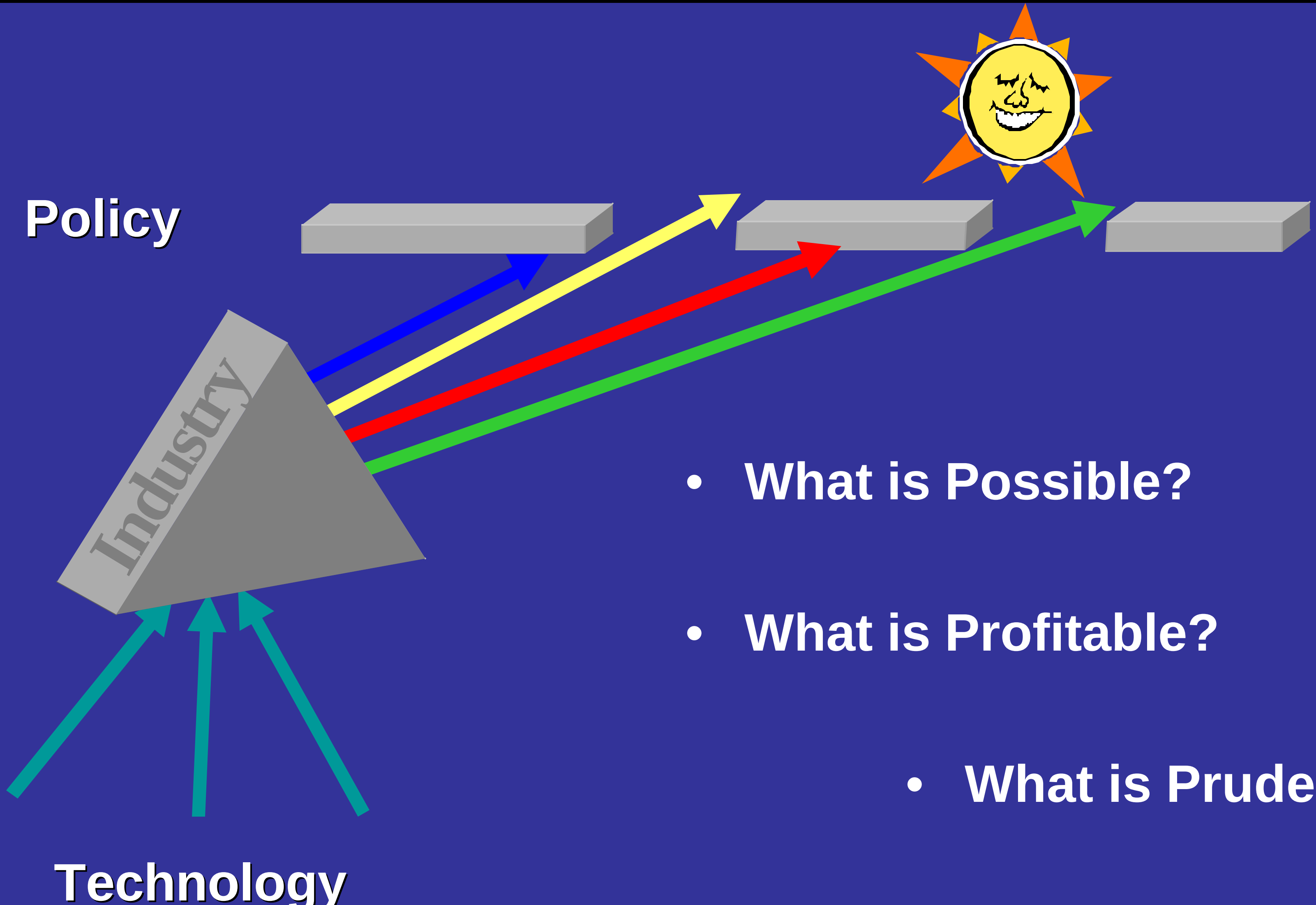




Spectrum from 322-3,100 MHz:
NTIA regulates 22%
FCC regulates 35%
Shared NTIA/FCC regulates 42%

Frequency Agility and Wideband and Ultra-Wideband Devices, creates Challenges at the Interfaces between the Different Allocations

Critical Roles

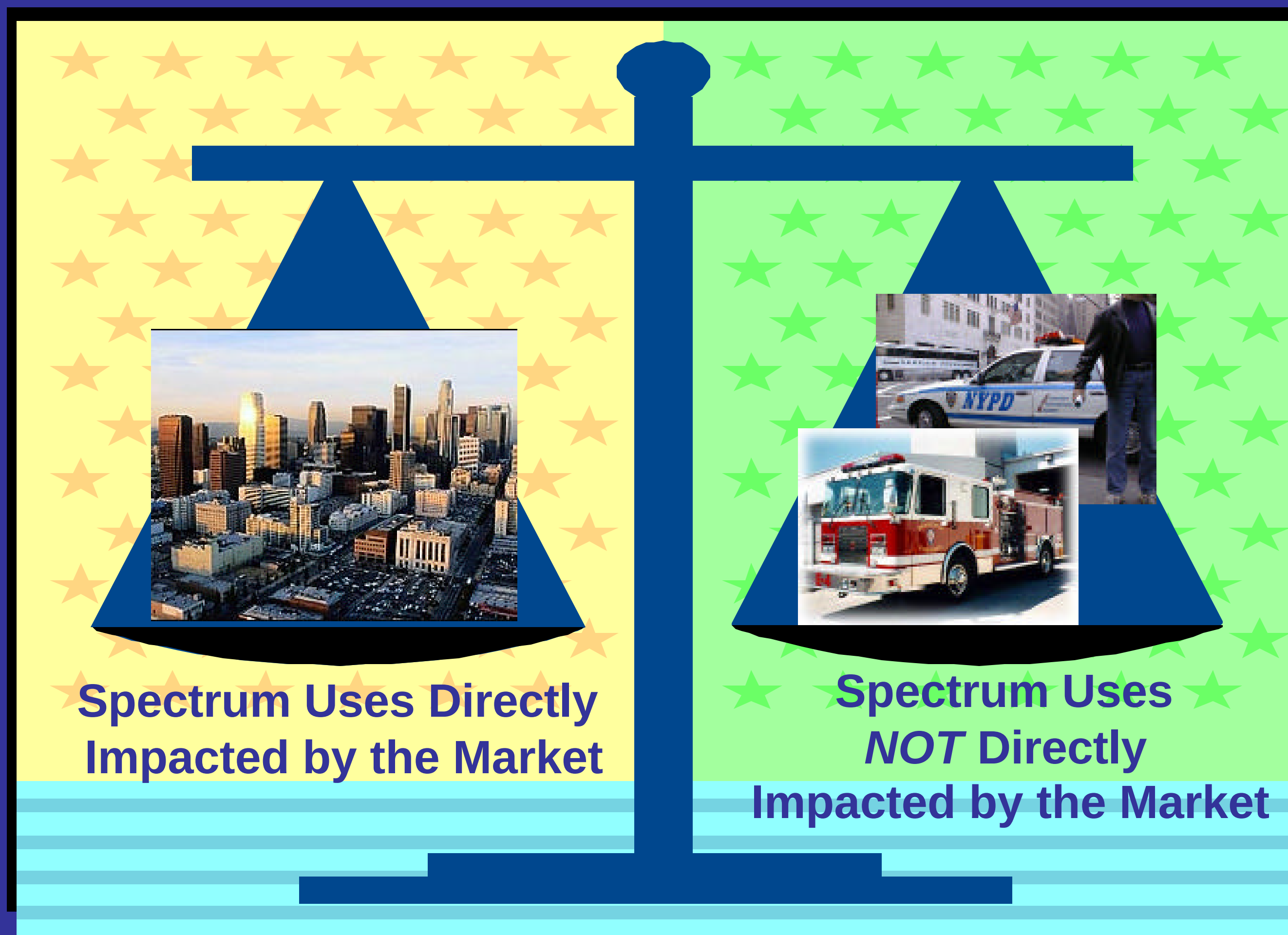


- What is Possible?
- What is Profitable?
- What is Prudent?

Spectrum Policy Task Force

- FCC Chairman formed Spectrum Policy Task Force
  - Will address what can be done to move current "command and control" system for spectrum allocation to more market-driven policy
  - Will examine how to improve system to promote innovation
  - Will consider structural/organizational improvements (FCC/NTIA coordination)

Finding the Right Balance



Adapting to Change

The Landscape for Spectrum Policy

Spectrum Policy Task Force

Device Mobility Continues to Rise

Mobility

Transceiver Density is Also Increasing

1-10 Devices per Building

1-10 Devices per Home

1-10 Devices per Person

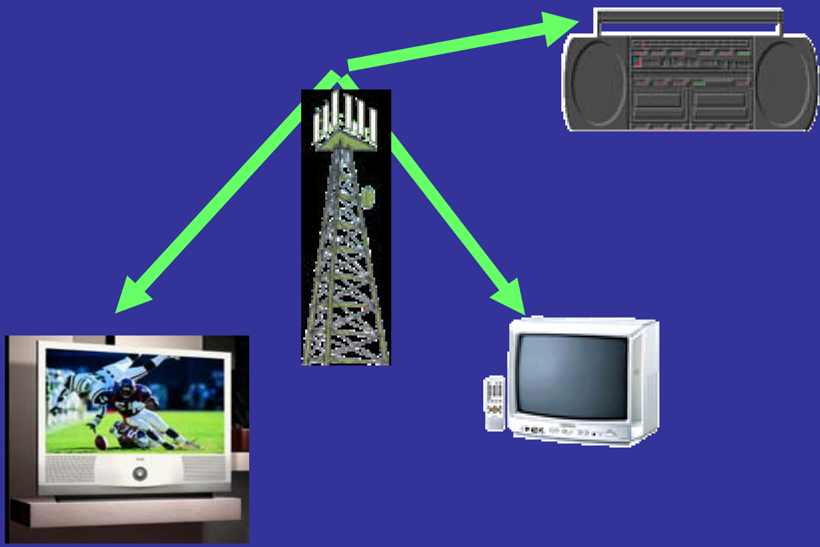
- **Is the tendency to follow a similar trend that the computer industry exhibited?:**
  - **A few devices that the user interacts with directly such as a mainframe or personal computer (television, cell phones, amateur radio) ; to**
  - **A few devices that the user interacts with directly and many more devices that are in the background performing functions such as optimizing performance of automobiles, refrigerators, toys, televisions, etc (bluetooth, 802.1x, UWB)**

Spectrum Use Impacts Spectrum Management and Policy

- **No more <<1 Transmitter per Family, now it is >1 Transmitter per person!**
  – Cell Phone, Pager, RIM, 802.11x, ITV, SATCom, Robotics, Cordless Phones, Device Monitoring, etc
  – Device ranges can be *extremely short*

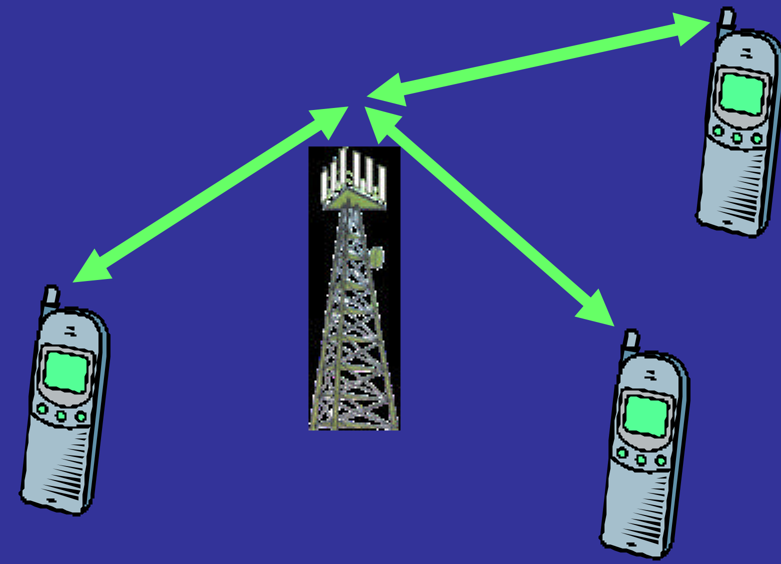
- **Most of the new devices are for mobile applications (to be worn by people or in vehicles)**
  – ***Interference ranges are NOT predetermined***
  – **Worst case analysis is not applicable**

Transmitter to Receiver Ratio



Past

- One Transmitter
- Many Receivers

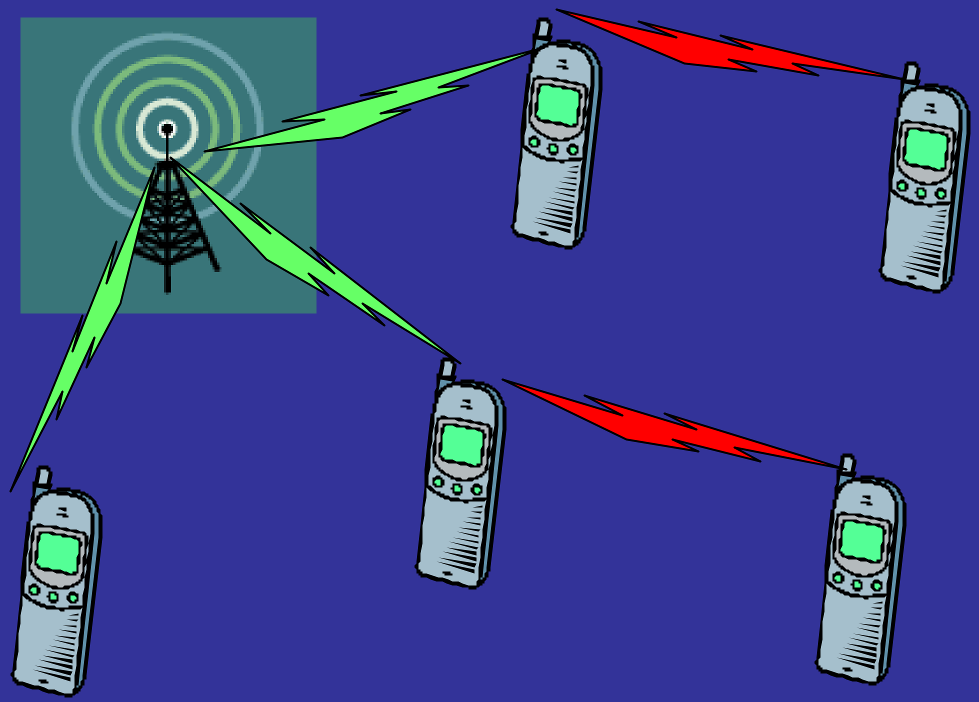


Current

- Many Transmitters
- Many Receivers

Before, the Best Design Economically was to Push the Cost to the Transmitter, That is Now Changing

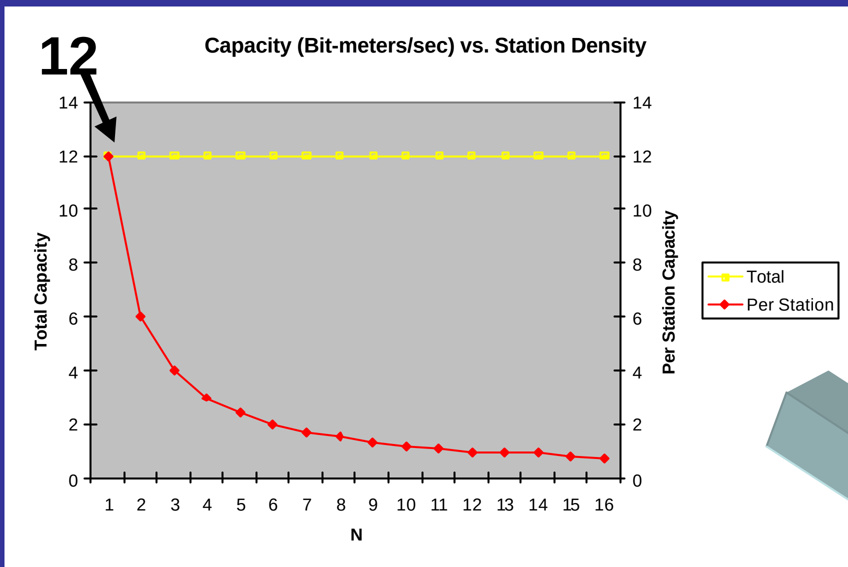
Higher Density can Translate into Higher Capacity

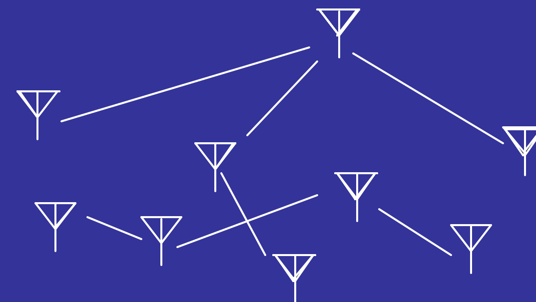


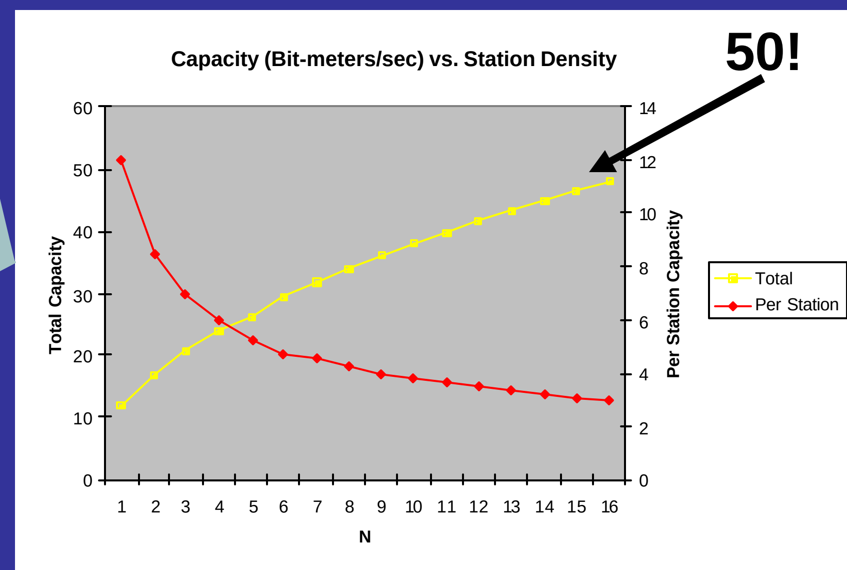
- Pros
  - Lower Power
  - Frequency/Code Reuse
- Cons
  - Complexity
  - Latency

Peer-to-Peer Mobile Ad Hoc Networks Increase the Capacity of the Network at the Cost of Complexity

Impact of Networking on Capacity





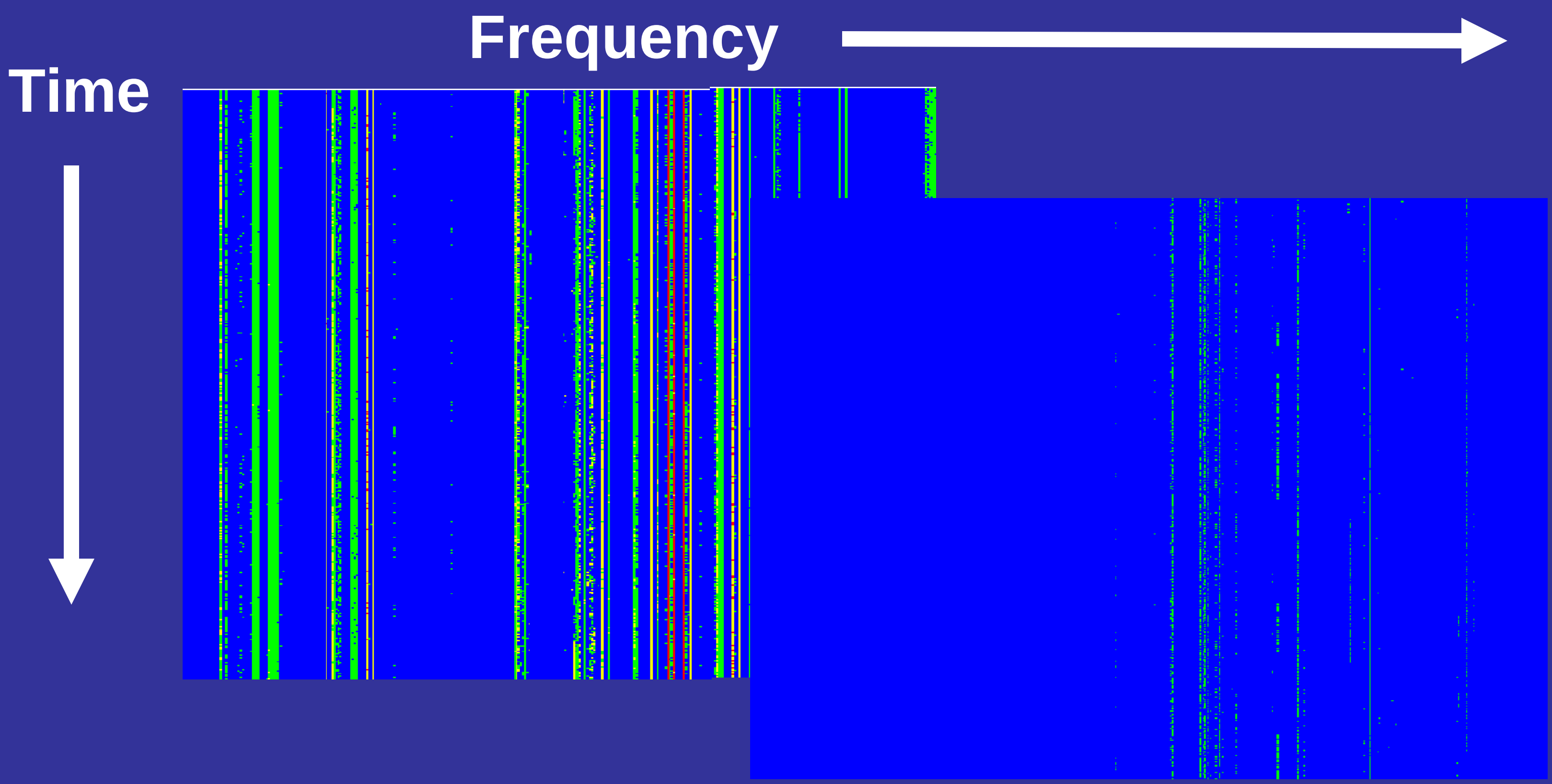


Spectrum Reuse can potentially scale with the number of transceivers – “Every radio is a basestation!”

Where are we Now?

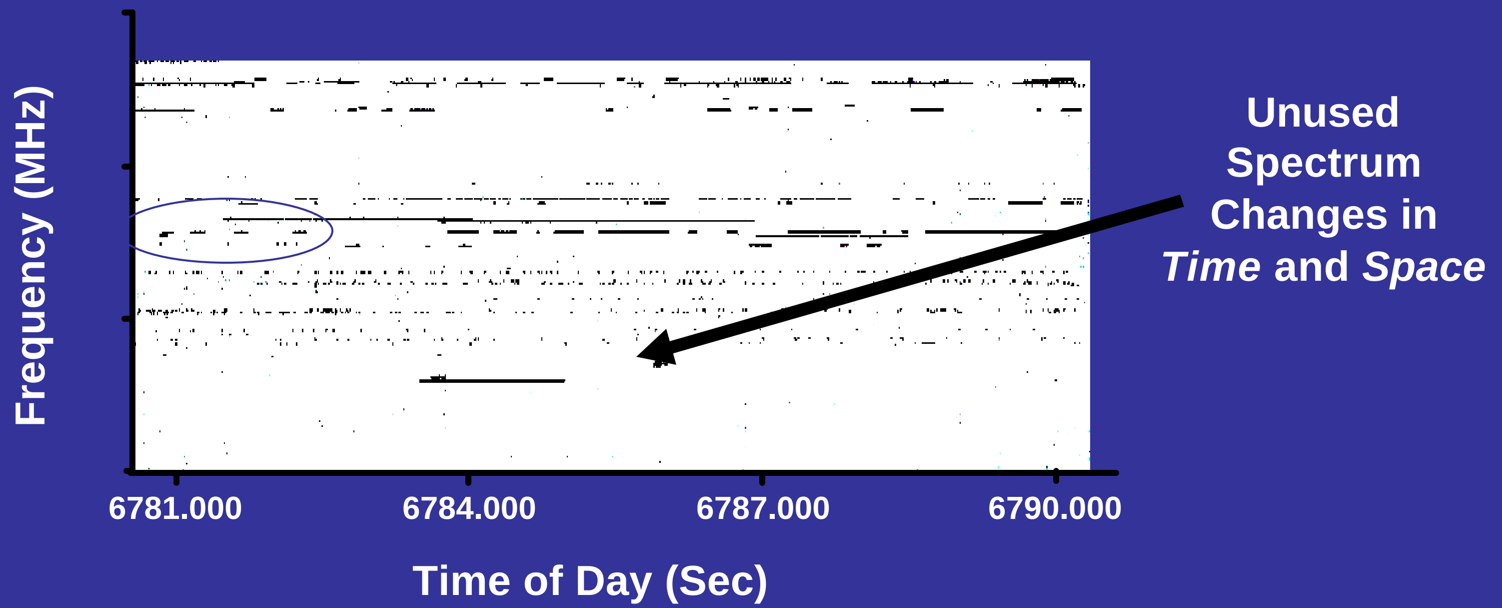
What is State of the Spectrum?

State of the Spectrum?



- **Is spectrum oversubscribed or overused?**
- **Can technology provide a window of opportunity?**

State of the Spectrum?



Spectrum Availability Observations

1. Differs by location and frequency
2. Differs by medium duration priority interrupts (10’s of seconds)
3. Differs by short duration spectral holes (100 ms)

Possible Directions for Improving the Use of the Spectrum

Flexible … "capable of responding or conforming to changing or new situations"

Agile … "marked by ready ability to move with quick easy grace"

Dynamics

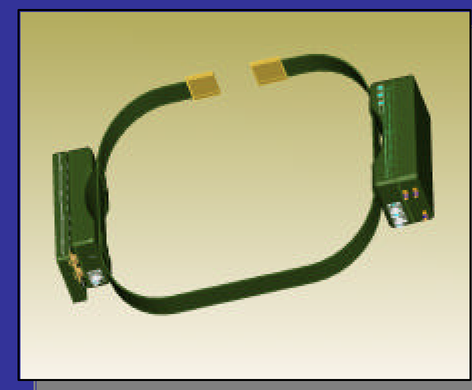
Flexible Allocations and Use of Frequency Agility Fundamentally Changes the Manner in Which Spectrum is Managed

Webster's New Collegiate Dictionary

Where are we Now?

What is State of Technology?

Technology for Flexibility



Software and Software Definable Radios are available from multimode cell phones to hardware with programmable waveforms

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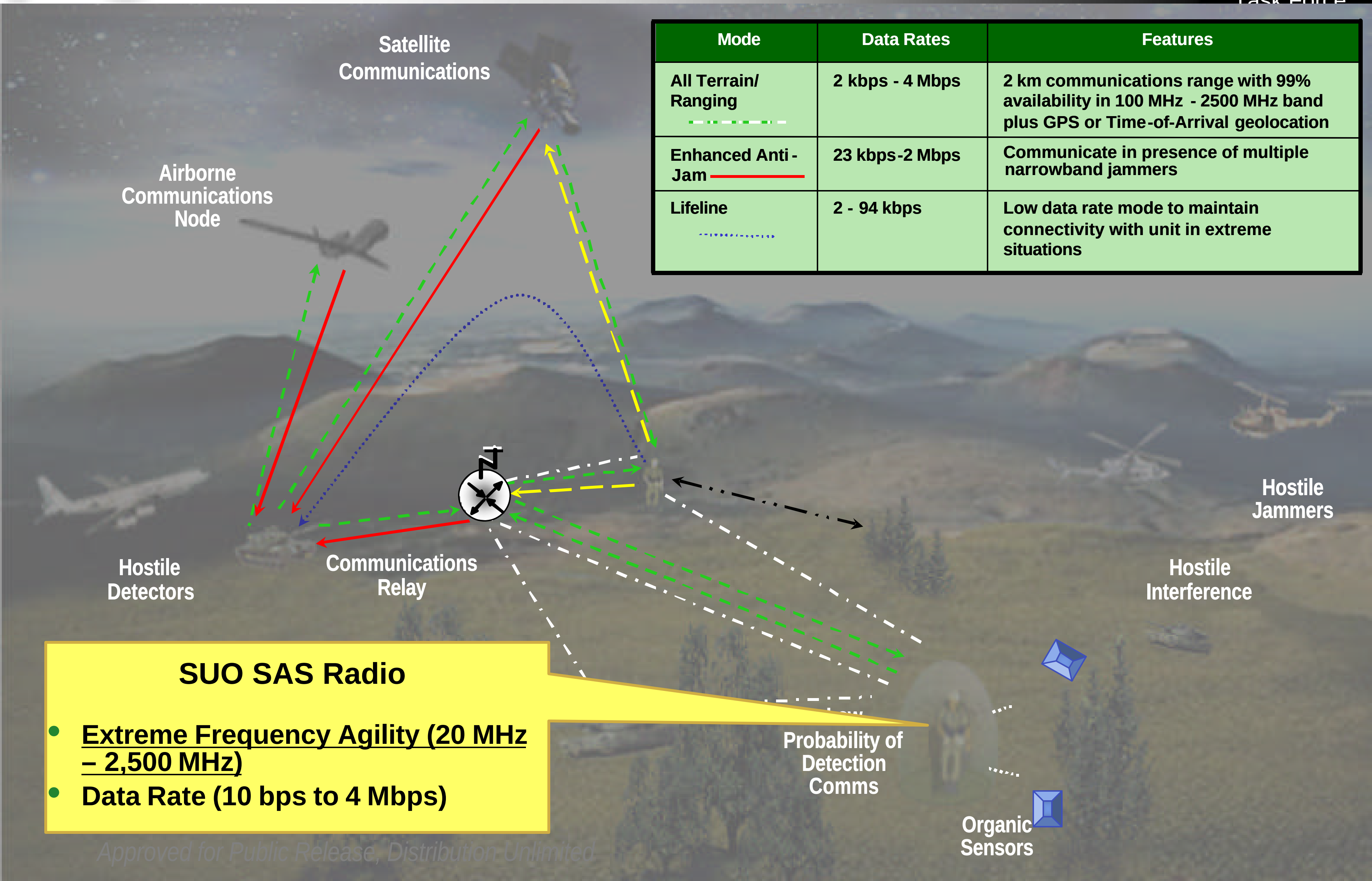
DARPA SDR using Flexible RF Links

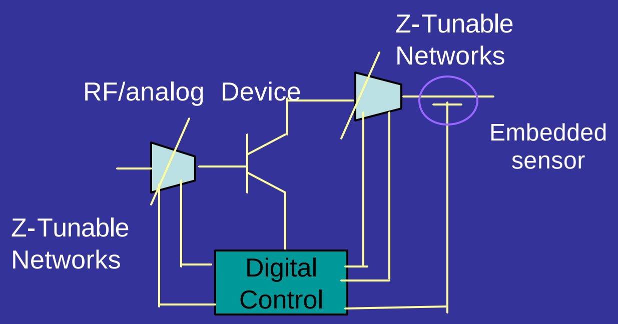
Mode	Data Rates	Features
All Terrain/ Ranging	2 kbps - 4 Mbps	2 km communications range with 99% availability in 100 MHz - 2500 MHz band plus GPS or Time-of-Arrival geolocation
Enhanced Anti-Jam	23 kbps-2 Mbps	Communicate in presence of multiple narrowband jammers
Lifeline	2 - 94 kbps	Low data rate mode to maintain connectivity with unit in extreme situations



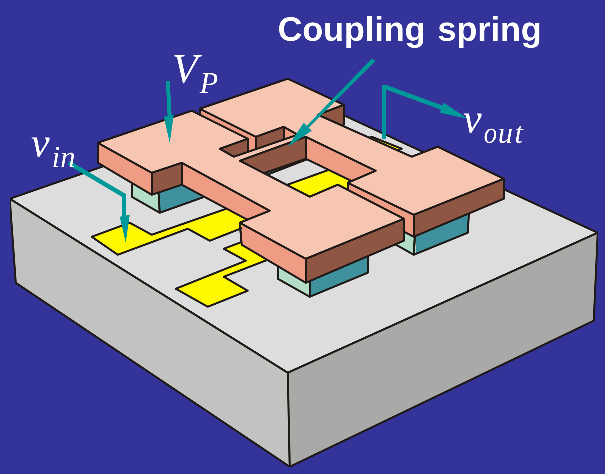
SUO SAS Radio

- Extreme Frequency Agility (20 MHz – 2,500 MHz)
- Data Rate (10 bps to 4 Mbps)

Technology for Agility



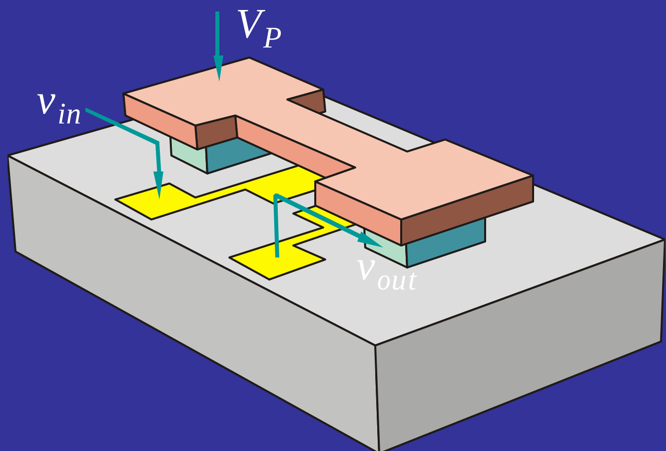
Power Amplifiers

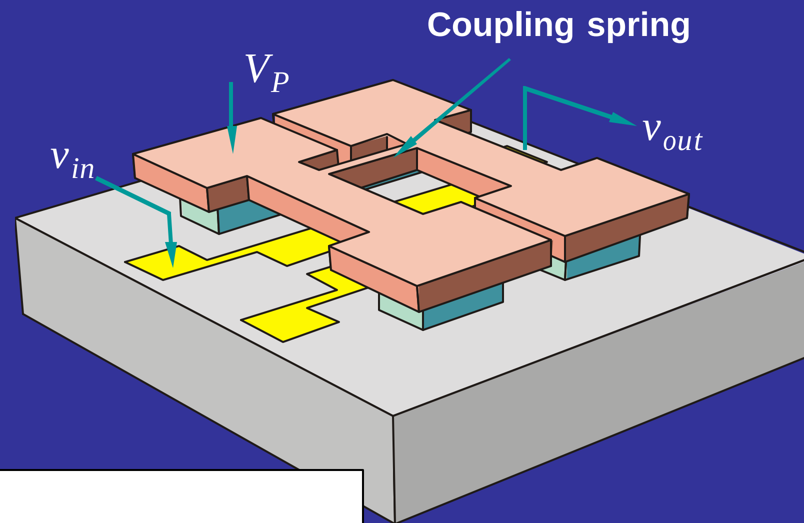


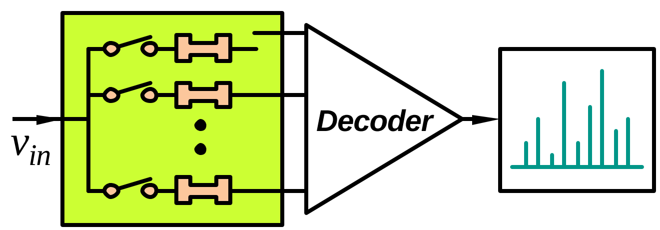
Filters

- **Adaptive RF Components**
  - Wideband Power Amplifiers
  - Broadband Antennas
  - Adaptive Filters

Nano-Mechanical Array Signal Processing (NMASP)







Spectrum Analyzer /Fourier Signal Transformer

Better Filters allow for Better Interference Rejection which Provides Better Use of the Spectrum

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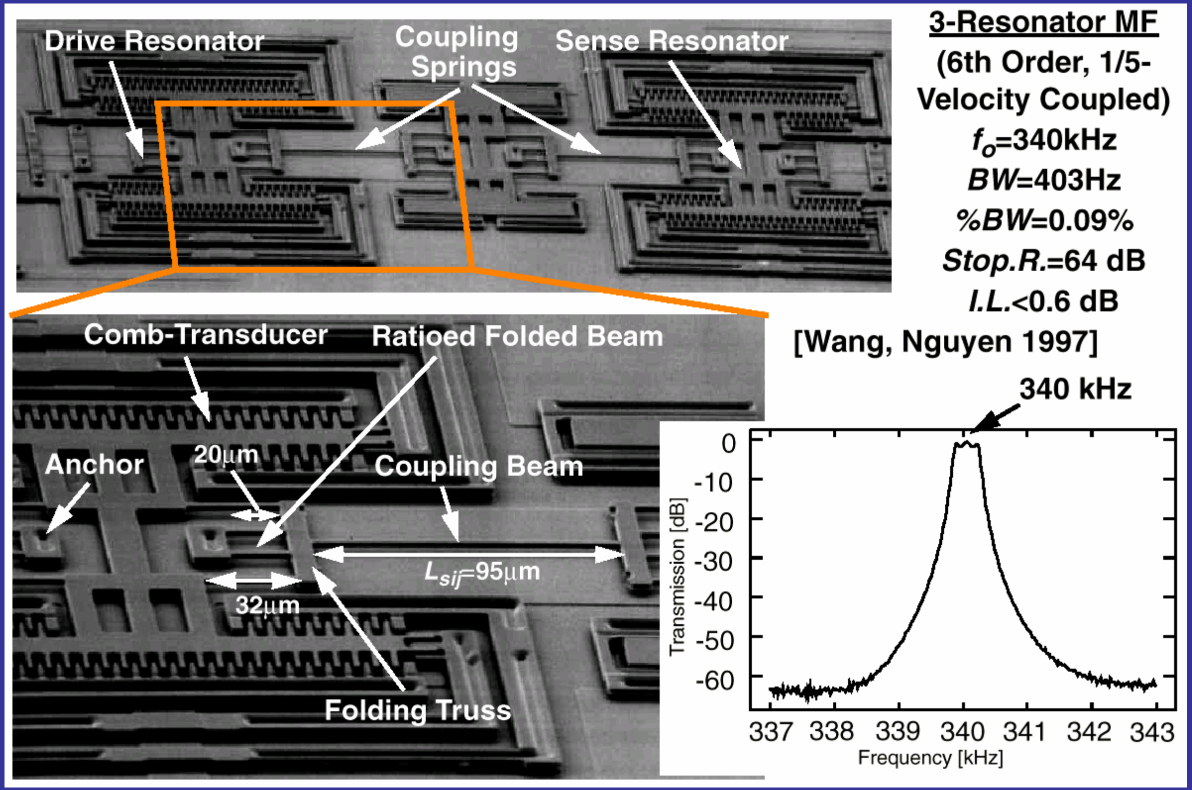
High-Order Filter



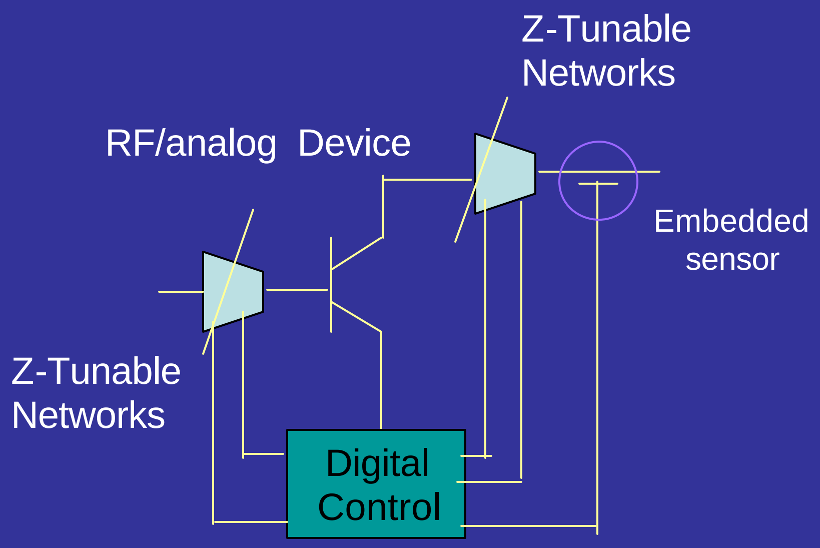
MichiganEngineering

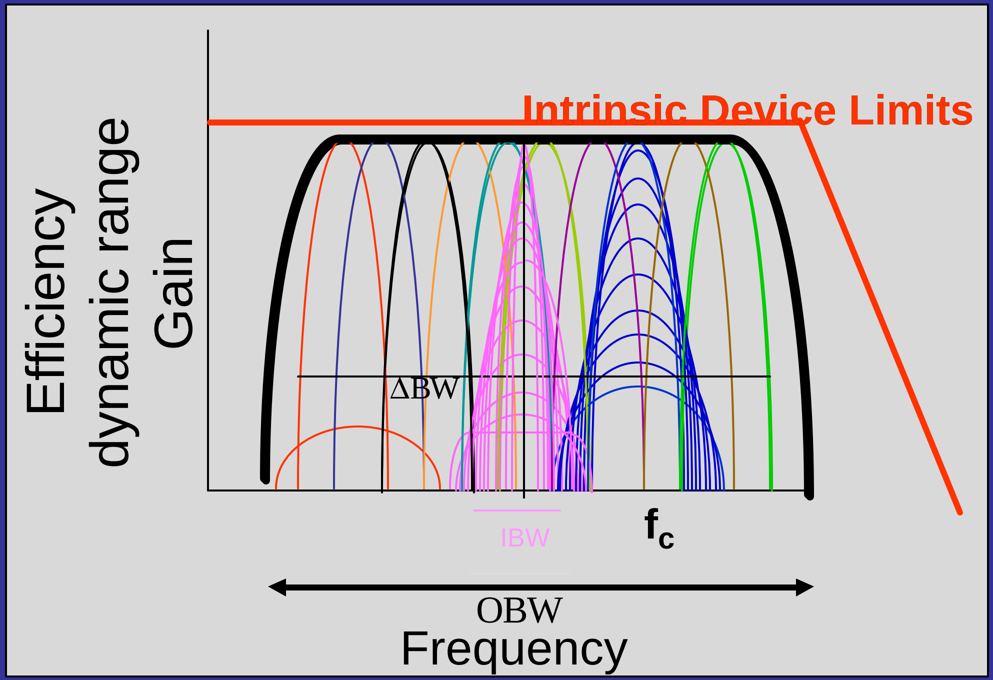
Boundary Conditions	Resonator Dimensions (L ´ w ´ t , in µm)			
	100 × 3 × 0.1	10 × 0.2 × 0.1	1 × 0.05 × 0.05	0.1 × 0.01 × 0.01
Both Ends Clamped or Free	77 kHz (42)	7.7 MHz (4.2)	380 MHz (205)	7.7 GHz (4.2)
Both Ends Pinned	34 kHz (18)	3.4 MHz (1.8)	170 MHz (92)	3.4 GHz (1.8)
Cantilever	12 kHz (6.5)	1.2 MHz (0.65)	60 MHz (32)	1.2 GHz (0.65)

Intelligent RF Front End

"Adaptation for Efficiency"

Adaptation of operational BW is achieved by active control and real time tuning of impedance networks (Z)





Tunable Power Amplifiers so a Radio can Operate Efficiently across a Wide Frequency Range

Summary

- The future use of spectrum will be very different than it is today
  - Density, Ubiquity, Selectivity, Flexibility, Agility
- The rapid change in technology and the ingenious use of spectrum is hastening
  - Command and Control Schemes are Inhibitory
  - Policy needs to be made less reactive
- The understanding of how dynamics in geometries, transmitters, receivers, and RF environment will lead to new methods for spectrum management