



Spectrum Management and Technology Innovation in Broadcasting

A Technologist's Perspective

Glenn Reitmeier

NABA Annual General Meeting - March 6, 2007

Outline

- The Big Picture - Existing products & services
- Spectrum & Innovation
 - Traditional Approach
 - De-Regulatory Approach
- Future of Over-The-Air (DTV) Broadcasting
 - Technology Catalysts
 - New Service Opportunities
 - ATSC Strategic Plan
- Spectrum Protection
 - Current issues – “white spaces”
- Final Thoughts



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...and a Difficult Job



“Thank You!” to our Regulators

Broadcasting Spectrum Investment (in the U.S.)



Radio

AM	1.065 MHz	[535 kHz - 1.6 MHz]
FM	20 MHz	[88 – 108 MHz]
Satellite	25 MHz	[2.320 – 2.345 GHz]

Television

VHF (Ch 2-13)	72 MHz	[54 - 72; 76 – 88; 174 – 216 MHz]
UHF (Ch 14-69)	336 MHz	[470 – 806 MHz]
Satellite	500 MHz	[12.2 – 12.7 GHz]



Radio & TV Contribution to the U.S. Economy (2005)

TV Ad revenue	\$ 67.9 B
Radio Ad revenue	\$ 20.0 B
TV receiver sales (analog & DTV)	\$ 20.1 B

TOTAL	\$ 110 B

Sources: GDP, bea.doc.gov; Television Bureau of Advertising, Radio Advertising Bureau, CEA

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TV Revenue Growth (in the U.S.)

	TV Receiver Sales		Broadcast TV Ad Revenue	
	Unit sales	\$	HH%	\$
1965	11.0	1.84	78% mono 5% color	2.47
1975	11.3	2.63	75% mono 68% color	5.2
1985	20.4	5.80	91%	19.7
1995	23.7	6.80	97%	30.7
2005	30+	20+	98%	40+

Traditional TV is a huge economic engine

source: Television Bureau of Advertising, Consumer Electronics Assoc.

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Spectrum Protection Is

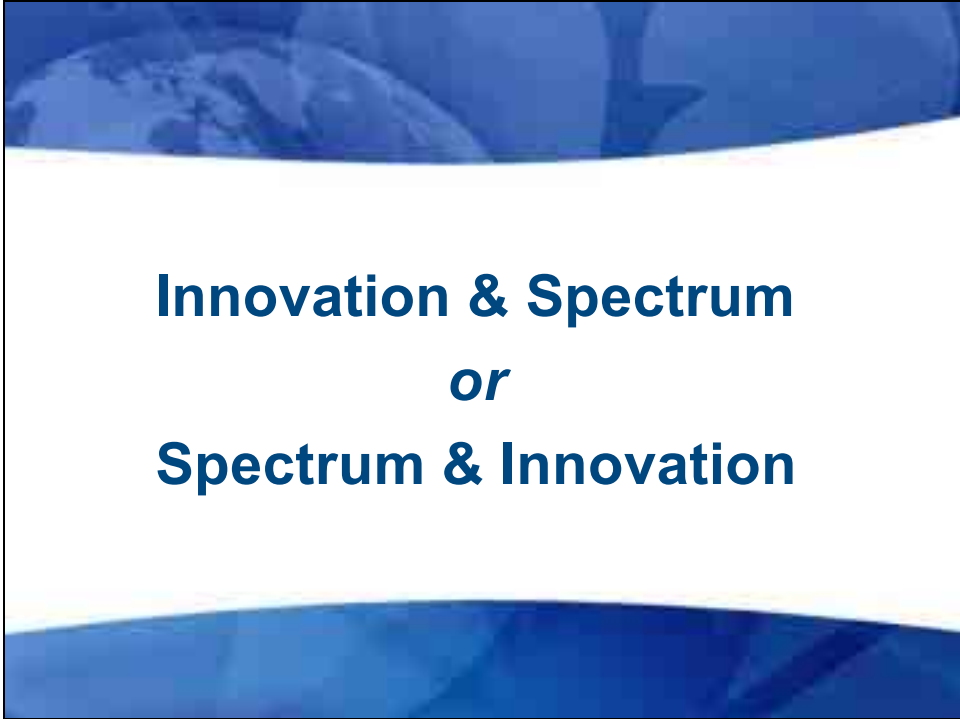


*Protecting the economic base of
traditional products & services*

Smart Thinking

*Preserving the opportunity for
innovation & economic growth*

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The background of the slide features a blue-tinted image of a globe on the left and a hand holding a pen on the right, set against a white background with blue curved borders at the top and bottom.

**Innovation & Spectrum
or
Spectrum & Innovation**

“Traditional” Regulatory Approach



- Develop enabling technology
- Establish technical standards
- Allocate Spectrum
- Launch Products & Services
- Innovation continues “in the box”



Technology Innovation Catalyzes Applications that Require Spectrum...

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Radio

AM

1920



Home Radios

1950 –
 > 1,309 M units
 > \$21 B
 > 98% HH

FM Stereo

1960s



1978 – FM listeners exceed AM



HD Radio

2002



HD Radio

> 1,200 stations
 > 515 multicast
 > ~\$149 radios

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Television



Monochrome
Television

1946 –
> 245 M units
> \$27 B
> 80% HH



Color
Television



1954 –
> 624 M units
> \$184 B
> 98% HH



CTV / Stereo
1984 –
> 180 M units
> \$72 B
> 98% HH



H/DTV

1998 –
> 69 M units
> \$66 B
> 33% HH

HD TV

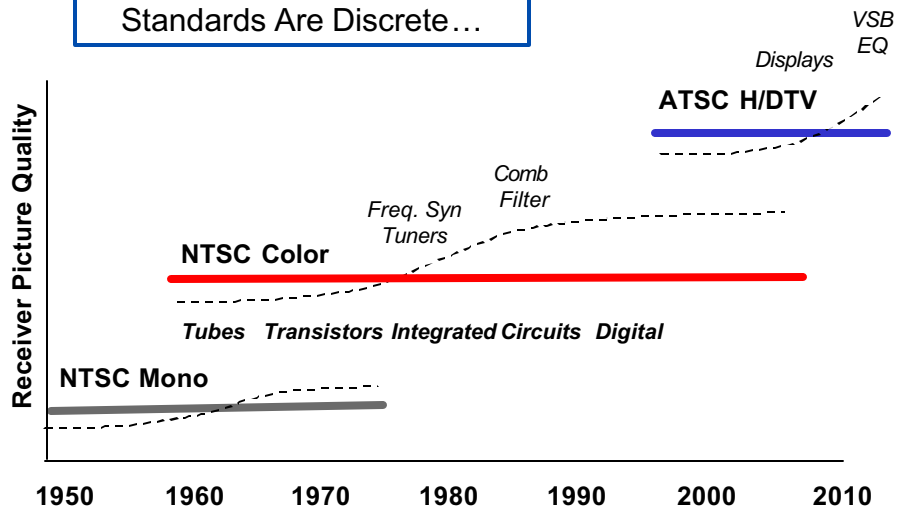


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Technology Innovation in TV



Standards Are Discrete...



Technology Innovation Is Continuous...

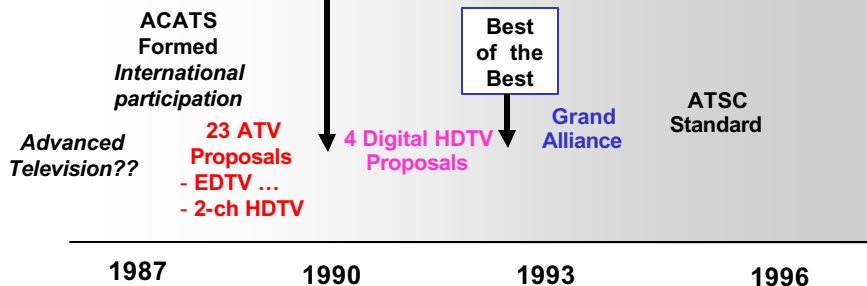
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ATSC Timeline



Policy
 1. Full HDTV
 2. One 6 MHz channel
 3. No new Spectrum

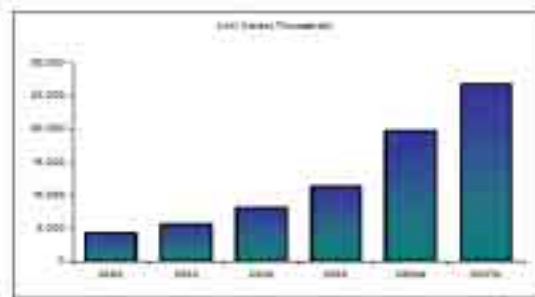
FCC Approval



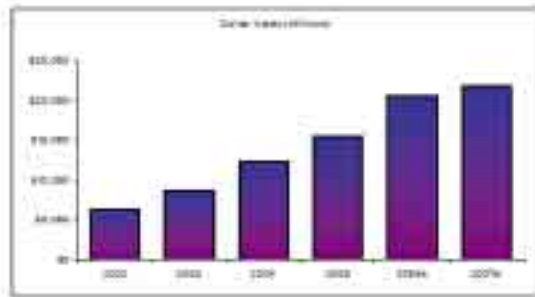
Standards Focus Innovation
 Subsequent Policies Influence Adoption

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High-Definition Digital Television



2006 sales ~19M units
 2007 est. ~21M units
 cum. sales > 69 M units



2006 sales > \$20 B
 2007 est. > \$22 B
 cum. sales > \$85 B



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New “Deregulatory” Approach

- Allocate Spectrum
 - > increased use of unlicensed spectrum approach
- Avoid technical standards (as a regulatory matter)
- Competing Groups Develop their own enabling technology
- Launch Products & Services
- Technology innovation continues



Spectrum Availability Catalyzes Technology Innovation



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ATSC Formats – Not An FCC Requirement

	Format	Aspect Ratio			Frame Rate		
	1920 x 1080 (square pixels)	16:9			60 I	30 P	24 P
	1280 x 720 (square pixels)	16:9		60 P		30 P	24 P
TV	704 x 480 (CCIR 601)	16:9	4:3	60 P	60 I	30 P	24 P
	640 x 480 (square pixels)		4:3	60 P	60 I	30 P	24 P
		Film	TV		TV		Film
	Computer			Computer		Computer	



Supported frame rates include both 60.0 and 59.94 Hz related rates Glenn Reilmeier

Licensed Spectrum, No Standards

		
<i>License acquired / applied</i>	1981	1987 / 1992
<i>Technology</i>	Geosync . constellation MPEG-2 compression proprietary transport unique modulation, CA	Geosync . constellation MPEG-2 compression MPEG-2 transport unique modulation, CA
<i>Service Launched</i>	1994	1996
<i># Subs Total / New 2006</i>	15.1M / .82M	13.1M / 1.0M
<i>2006 Revenue / Income</i>	\$14.76B / \$1.42B	\$ 9.8B / \$608M

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Licensed Spectrum, No Standards

		
<i>License acquired</i>	1997 (\$83M)	1997 (\$89M)
<i>Technology</i>	3 Elliptical /few terrestrial PAC/AAC compression	2 Geosync /many terrestrial CT-aacPLUS compression
<i>Service Launched</i>	2002	2001
<i># Subs Total / New 2006</i>	6M / 2.7M	7.6M / 1.7M
<i>2006 Revenue / Income</i>	\$ 637M / - \$1,17B	\$ 933M / - \$718M

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Unlicensed Spectrum

Unlicensed spectrum at 2.4 GHz was made available in 1986
 915 MHz (902-928 MHz), 2.4 GHz (2400-2483.5 MHz), and 5.7 GHz (5725-5850 MHz) bands



Annual worldwide WLAN equipment sales are forecast to reach \$3.82 billion in 2009

WiFi market revenues reached \$1B in 2006

- > 230M notebook PCs
- > Enterprise products made up 48% of WLAN equipment revenue, residential products 44%, and service provider products 8%



Cisco is the leader in enterprise WLAN equipment; Aruba, Symbol, and Trapeze follow

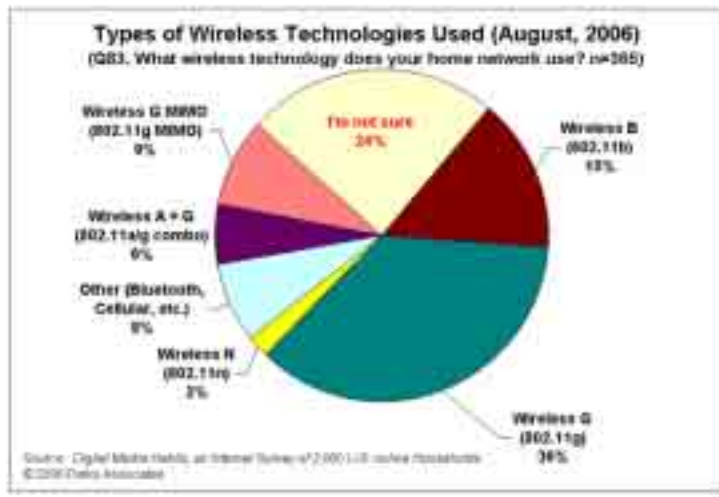
Linksys is the leader in residential WLAN equipment sales, followed by NETGEAR and D-Link

North America accounts for 46% of all WLAN equipment revenue, EMEA for 29%, Asia Pacific 20%, and CALA 5%
 Source: Infonetics Research

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Wi-Fi Standards

There are networks in more than 22M U.S. Households
 source: Parks Associates

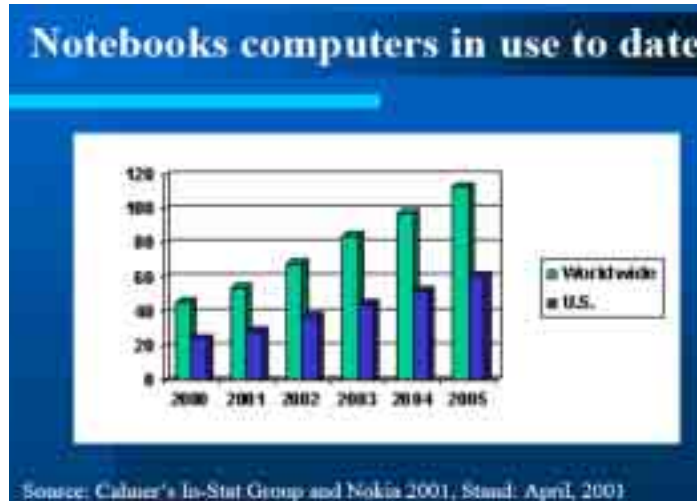


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Notebook Computers

Shipments of notebook computers exceeded desktop computers in 2005 source: CEA

90% notebook PCs Wi-Fi enabled as of Nov. 2005 source: Wi-Fi.org



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One Spectrum Value Assessment...

Source: "The Economic value of licence exempt spectrum" – a report to Ofcom

Figure 6.2 Spectrum value per MHz – licenced versus licence exempt

Licensed spectrum

Application	% of 0.7 to 3 GHz used	Value (£/m of 2004 prices and without licence)	Value per MHz (£/m)
Mobile telephony	56%	21750	68
Broadcast	17%	12250	27
Fixed links	8%	3883	28
Maritime	5%	1.2	8,008

Source: Ofcom (2005) p. 10; Ofcom (2005) p. 10; Ofcom (2005) p. 10; Ofcom (2005) p. 10

Unlicensed spectrum

Application	Value (£/m of 2004 prices)	Beneficial users (MPCs)	Frequency used (GHz)	Value (£/m per MHz)
1. Road user charging	55	28	5.6	2.65
2. Submarine short range radars	1778	6882	78	8.36
3. Active medical implants (2)	0	5	0.4	8
4. RFID in retail	2478	4	0.8	428
5. WiFi public access	3270	83	2.8	68
6. Home WiFi networking	396	83	2.8	18
7. Wireless building automation	96	83	2.8	18
8. Fixed	50	9500	70-80	0.805
9. Telephony	800	2	0.4	308
10. Home alarms	140	5	0.9-0.4	28

1) +3dB for medium density scenario
 2) Benefit to no access until 20 or 40 years after implementation
 Source: Inteligo, Agg and Ocom

Public Access WiFi is projected to be a high value application


<http://www.ofcom.org.uk/research/technology/overview/ese/econassess/value.pdf>

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Some Innovation & Spectrum Conclusions...

- Technology innovation will always occur
 - > Regulation doesn't cause innovation, but it can intensely focus it
 - > Standards don't inhibit innovation, they just bound it
- Perhaps the real Innovation Catalysts are:
 - > Mass Market Opportunity – national/global scale
 - > Technical Standardization – creates interoperability and market certainty (consumer confusion impedes adoption)
- Licensed Spectrum is necessary for Services and applications that demand strict reliability
 - > associated standards could reduce non-productive investment
- Unlicensed spectrum fine for products and applications that are not fragile to occasional and intermittent disruption

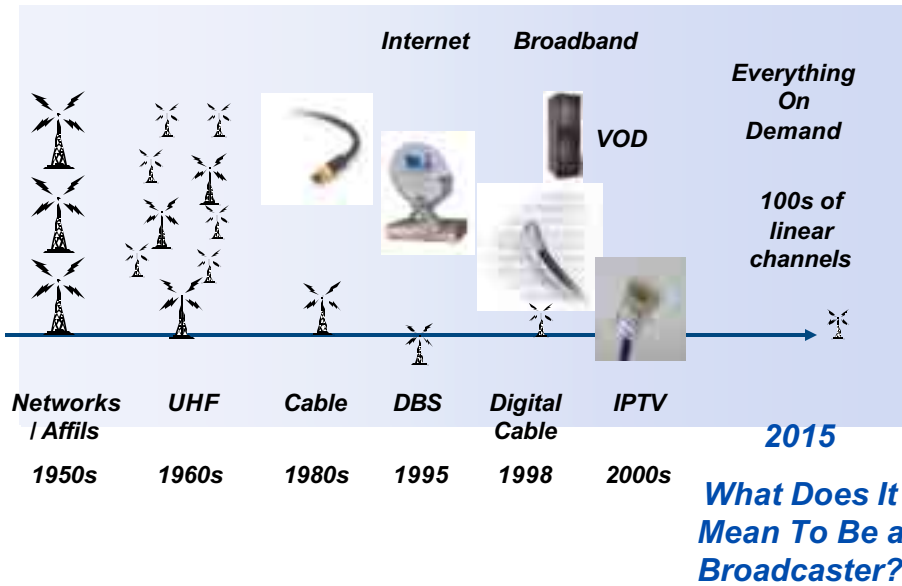
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The Future of Over-The-Air Digital TV Broadcasting

Demise or Renaissance?

Technology – Multichannel Delivery



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OTA Delivery – Key Attributes



Can We Re-establish Value in OTA Delivery?
...maybe, if we leverage unique attributes...

Wireless (the original!)

Wide-Area coverage (DMA)

National / Local

- > Network / national content access
- > Local content
- > Established business relationships



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Hmmm...

TV Rabbit Ears Are Back: In High-Def

The antenna, that relic of the pre-cable age, gets an afterlife thanks to high-definition TV.

By Johnnie L. Roberts

Newsweek

Feb. 19, 2007 issue - When cable TV arrived in the '70s, rabbit ears seemed destined to go the way of the polyester pantsuit. So, too, the clunky outdoor antenna, a rooftop fixture that once upon a time signaled the rise of television in American life. But a funny thing happened on the way to the analog dust heap: it turns out that a new generation of rabbit ears and antennas can receive high-definition television broadcasts. And it's free.

The irony is marvelous. Pushed into obsolescence by the technological advances of cable and satellite, antennas are re-emerging thanks to one of the most promising high-tech services of the digital age. High-def channels can be plucked out of thin air by antennas just like regular broadcast signals —no cable, no satellite dish, no monthly bill, no waiting for the cable man. It's like the old days, except this time antennas (which cost between \$18 and \$150) may offer the clearest picture. "More than 90 percent of our customers say they want the antennas for high-def," says Jerry Chapman, owner of online dealer SolidSignal.com, which ships "thousands of antennas." The downside—and it's a big one—is that antennas can only pick up the broadcast networks, not cable channels like ESPN or HBO.

Still, antenna makers are enjoying a warm reception. Companies like Terrestrial Digital of St. Louis, Winegard of Burlington, Iowa, and Audiovox of Hauppauge, N.Y., are watching sales soar. Terrestrial Digital's sales have doubled annually since its launch in 2003, to \$1.4 million last year, says founder Richard Schneider. The company is "a hobby spiraled out of control," he says, noting that he got his start essentially selling homemade antennas out of the back of his truck. "People thought I was selling drugs," Schneider says. "Nerds were showing up in my driveway." Winegard believes more consumers would embrace antennas if they only knew high-def can be delivered via the anachronism. "Our biggest focus right now is on consumer



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OTA Receivers

The primary HDTV – 42" and up

- < 15% and shrinking
- Nobody wants a rooftop antenna
- HD adopters care about TV - Cable/Satellite provides additional programming

Secondary TVs – 14" – 27"

- >300M screens, but are they really used for OTA TV?
- Nobody wants "rabbit ears"

Portable TVs

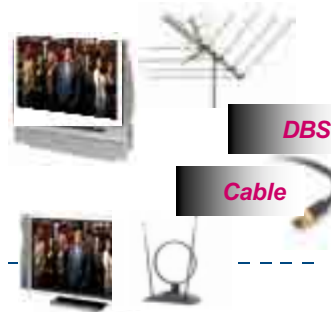
- New CE products likely to emerge as costs decline

Notebook PCs

- DTV tuner dongles now available...
- Integrated tuners?

Cellphones

- Require higher power, lower bit rate transmission
- Require special "time slicing" for power management / battery life
- Platform controlled by service provider



*Opportunity
but Indoor / Portable
Reception is a key
issue*

*Opportunity
but Mobile Reception
and power are key
issues*

Uniquely Wireless

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Technology Catalyst – Notebook PCs



In 2005, both unit sales and dollar volume of notebooks exceeded desktops for the first time! (HP alone ships about 4M / year in the US)

Generally have an almost-HD-resolution LCD screen

Enough processing power to decode HDTV

notebooks becoming more appliance-like, more portable...

Higher resolution, lower power consumption, better batteries coming...



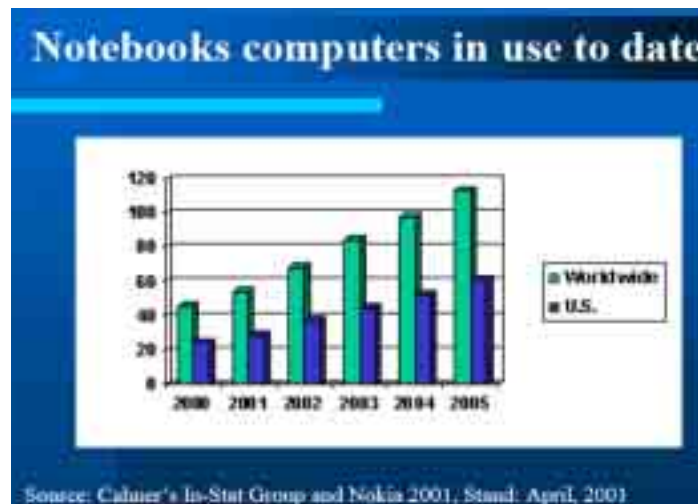
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Notebook Computers



Shipments of notebook computers exceeded desktop computers in 2005 source: CEA

90% notebook PCs Wi-Fi enabled as of Nov. 2005 source: Wi-Fi.org



Source: Caliper's In-Stat Group and Nokia 2001, Stand: April, 2001




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Technology Catalyst - Storage

Processing – Moore’s law

Communications – increasing fast, but still the bottleneck

Storage – faster than Moore’s law...

	 Flash Memory	 Portable HDD	 Standard HDD
2006	4 GB = 1 DVD = 4 PVs	20 GB = 4 DVDs = 16 PVs	300 GB = 60 DVDs
2008	16 GB = 4 DVDs = 16 PVs	80 GB = 16 DVDs = 64 PVs	1 TB = 180 DVDs = 36 HD
2012 est.	256 GB = 50 DVDs = 200 PVs	1 TB = 180 DVDs = 36 HD	16 TB = 2880 DVDs = 576 HD

•Compression will also continue to advance, magnifying effective storage capacity

>DVD can hold up to 9 GB, using MPEG-2 compression. Advanced video compression (MPEG-4 AVC or WM9) can achieve comparable quality at about half of the MPEG-2 file size

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Technology Catalyst – ATSC Tuners

Pre- 2005



Feb. 2005

Microtune Shrinks TV Tuners
MT2131 - higher performance at 65% the size of everyday tuners
 “three-in-one” - handles NTSC, ATSC and digital cable-ready (DCR) standards.
 All this for \$3 apiece...



Jan. 2006 – Thomson & Others

JENSEN MPC4000 (MSRP \$299) available in spring
 Any notebook becomes an HDTV:
 • integrated antenna
 • USB connects the receiver to the PC
 • downloads PSIP program guides
 • DVR functionality



The Future...

(Canopus concept)



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Overall Impact

“Enhanced Linear TV” - internet-like, on-demand experience enhances linear programming

- > Readily available to the audience that wants it
- > Invisible to traditional linear viewers



“...not your father’s rabbit ears...”

OTA DTV can reach a unique audience (where it makes sense)



The ATSC is an international, non-profit organization developing voluntary standards for digital television

Over 140 member organizations, across many industries

- > broadcasting
- > broadcast equipment
- > motion picture
- > consumer electronics
- > computer
- > cable
- > satellite





Some Key ATSC Standards

- > A/53 ATSC Digital Television Standard
- > A/65C Program and System Information Protocol (PSIP)
- > A/90 Data Broadcast Standard
- > A/97 Software Data Download Service
- > A/101 Advanced Common Application Platform (ACAP)
- > A/110A Synchronization Standard for Distributed Transmission



ATSC Strategic Plan

In mid-late 2006, the ATSC Board of Directors developed a strategic plan to serve as a guideline for the future work of the organization.

- > The plan takes into account both the likely progression of technology and the importance of backwards compatibility with existing DTV consumer receivers
- > The Board believes that ATSC should focus on comprehensive solutions that enable compelling services and products

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Broadcast Environment Findings



Media landscape is widening with the use of new technologies

- > Broadcasters should respond competitively

A confluence of transmission, reception, storage and display technologies will enable new wireless and personalized services

Broadcasters may wish to use DTV to expand and enhance a direct-to-viewer wireless service

- > Leverages wireless and local service



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Executive Summary

Major Recommendations



Documentation of service levels that group standards together to form a logical bundling of features and functions

- > ATSC 2.0
 - New services for the conventional fixed DTV receiver
- > ATSC-H
 - Delivery to handheld and portable devices
- > ATSC-M
 - Delivery to mobile devices

Develop a standard for Non-Real-Time delivery of services

- > Leverages the low cost of storage
- > Provides consumers with content they want, when and where they want it
- > May be an element of each of the above service levels



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ATSC-M/H (Draft) Requirements



Highly desirable that providing service to pedestrian and handheld (ATSC-H) devices be accomplished within the same broadcast service stream that is intended to reach mobile receivers (ATSC-M)

Exact relationship between mobile, handheld and pedestrian services may vary depending on technologies...

ATSC standard might specify

- > Physical Layer (Modulation and FEC)
- > Transport, signaling and announcement
- > Advanced codecs for video and audio to provide for scalable quality and quantity of mobile and handheld services
- > Picture formats optimized for target displays
- > Non-real-time mode (by reference to NRT Standard to be developed)
- > Data broadcasting
- > Middleware layer optimized for handheld and mobile devices

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NRT Requirements ...in Progress



- Target applications likely include
 - > Video clip delivery: news, weather, traffic, sports...
 - > Targeted Ads
 - > Telescoping ads
 - > Entertainment content downloads (video, music, web)
 - > Game downloads
- An ATSC NRT Standard might specify
 - > Data broadcasting protocol
 - > File specifications including video formats, advanced video and audio CODECS
 - > File and storage management (multiple providers)
 - > Announcement, signaling & program guide
 - > DRM
 - > Targeted ad insertion triggers

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The 2007 ATSC Annual Meeting

May 17, 2007

ATSC
The Next Generation

**...Back to Spectrum
Management**

The “Best” Spectrum?



- 1969 – VHF, especially the “low Vs”
- > High economic value - TV Broadcasting
 - > Over-the-horizon propagation;



2009 - UHF

- > High economic value - mobile & portable devices
- > Small antenna size, reasonable indoor penetration...



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Current Issue - TV “White Spaces”



- After DTV transition and spectrum repacking... “white spaces” (unused DTV channels) are still “available” in the spectrum plan
- Best Use?
 - Low-Power DTV?
 - Extended DTV coverage area?
 - Enhanced DTV transmission robustness?
 - Rural internet access?
 - Localized mesh network?
 - other???

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Some “White Space” Considerations

Signal types, power levels, fixed/mobile use and practical receiver characteristic all come into consideration

- Nature of interference – occasional? ... intermittent?
 - > Fixed vs. mobile interferers
- Tuner characteristics of typical receivers
 - > Low-cost, portable, mobile receivers should not be expected to have great tuners/RF circuits
 - > Multiple adjacent channel interferers are dangerous
- Significance of interference
 - > Public Safety vs. Broadcasting vs. Wireless Data
 - > Slowdown in data services vs. impairments in DTV
 - > Level of impairment (loss of service vs. slowdown of service vs. occasional artifacts)

Wishful thinking is no substitute for good engineering

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Did You Know?

Not all digital signals are the same...

	<u>Data rate</u>	<u>Threshold CNR</u>	<u>peak-to-avg pwr</u>
802.11b Direct Seq. SS	11 Mbps	~15 db	~2 db
802.11g 64-OFDM/64-QAM	54 Mbps	~25 db	~8.2 db
802.11g 64-OFDM/BPSK	6 Mbps	~4 db	~7.8 db

...and in 6 MHz...

*4 db = a 2.5x
power difference*

	<u>Data rate</u>	<u>Threshold CNR</u>	<u>peak-to-avg pwr</u>
8-VSB	19.39 Mbps	15 db	~7 db
COFDM (DVB-T)	13.6 Mbps	19 db	~9-15 db
DVB-H 4kCOFDM	7.5 Mbps	~17 db	~9-15 db
MediaFLO 4kCOFDM/dual	6 Mbps	~16 db	~15 db

source ATSC Forum

MEASURING THE PEAK-TO-AVERAGE POWER OF
DIGITALLY MODULATED SIGNALS
Charles J. Meyer, Senior Applications Engineer, Boonton Electronics

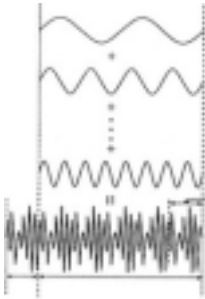
Power Measurements of OFDM Signals
Mark Briggs, Juan Martinez, David Bare
Elliott Laboratories Sunnyvale, CA USA

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The Technical Details Matter

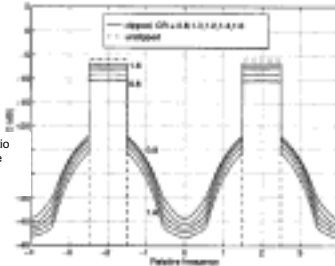
Peak-to-Average Power in OFDM

Peak-to-Average Power
Reduction in OFDM
Communications
ETH



Reducing The Peak-to-Average Power
Ratio in OFDM
Kevin Huang, Stanford Univ

CR = clipping ratio and is defined by the ratio
of the clipping level to the rms power of the
OFDM signal
The spectral spreading effect is also
plotted for N = 128.
This graph shows significant spectral
splattering due to clipping.



OFDM → DTV
interference

Higher peak power
potentially increases
co-channel interference

Peak level clipping
introduces substantial
adjacent-band
“splatter”

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Some “White Space” Conclusions

- Don't preclude an over-the-air broadcast DTV renaissance by prematurely loading up the UHF spectrum with interferers
 - > Preserve ability for enhanced DTV signals to reach mobile and handheld devices with small, low-cost tuners
- Consider innovative use of DTV / 8-VSB signals for
 - > Low-Power DTV service
 - > Extended DTV coverage area
 - > Enhanced DTV transmission robustness
 - > DTV signal delivery of downstream data; possibly with the return channel on another frequency (like cable modems!)
- Consider use of low-VHF for fixed internet access services and other data applications

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Final Thoughts

Final Thoughts



- Preserve the economic contribution of broadcasting
- Recognize the benefits of:
 - > Licensed Spectrum
 - > Good engineering-based spectrum management
 - Nature and Significance of interference
 - Tuner characteristics of typical receivers
 - > Technical Standards
- Encourage and stimulate the technology innovation and standards development needed to create a renaissance in:
 - > Use of over-the-air DTV broadcast signals to reach portable, handheld and mobile devices
 - > New DTV services and applications

Benefits the public, receiver manufacturers, retailers, and broadcasters

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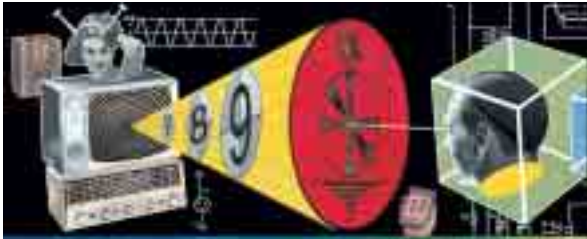
Fun Reading



The New York Times

Confounding Machines: How the Future Looked

By PETER EDIDIN
Published: August 28, 2005



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