More Than You Ever Wanted to Know About Radio, Bandwidth, Modulation and the FCC

or What's Old is New Again

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NYCwireless Presentation

May 25, 2005

http://oldisnew.cuzuco.com/

A Few Trivia Questions

- Who designed the first electronic digital messaging system?
- Who Sent the first digital message over radio?

Answers

- A middle-aged painter named Samuel FB Morse in 1835. The code is named after him, and encodes information using dots and dashes

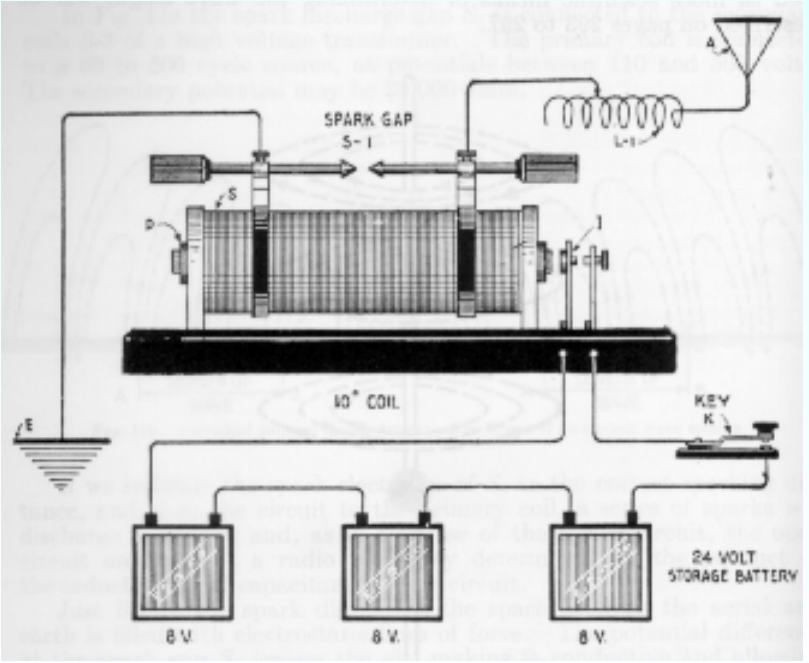
- Guglielmo Marconi succeeded in 1895 using a Hertz spark gap generator to send an “S” (dot dot dot) about a mile and a half.

Early Timeline

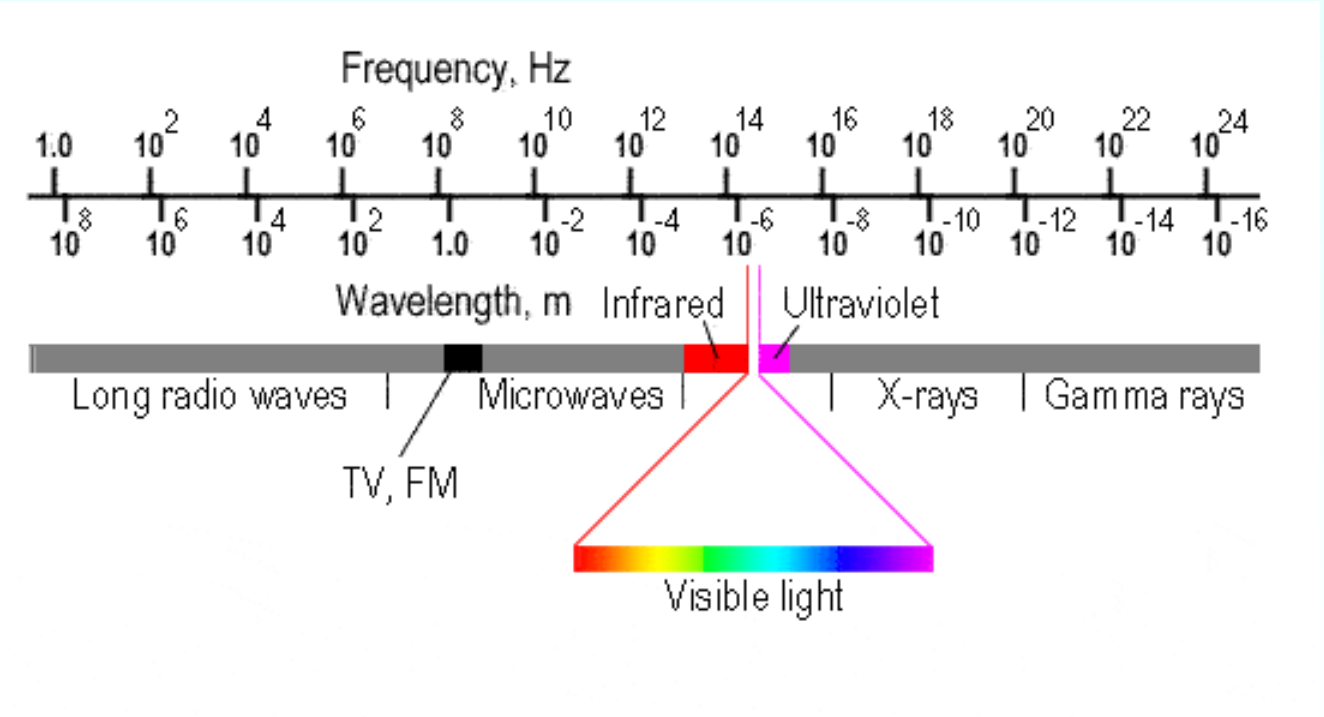
- **1820** Ørsted notes that electric current running in a wire would deflect a compass
- **1826** Henry invents the electromagnet
- **1835-1844** Morse invents the telegraph
- **1855-1868** Maxwell mathematically defines field equations for electromagnetism
- **1876** Bell invents the telephone
- **1887** Hertz notes a rapid variation of current could be projected into space
- **1895** Marconi sends and receives first radio transmission using a Hertz spark gap device
- **1905** Einstein: photons are electromagnetic radiation in discrete units

Spark Gap Transmitter

- The frequency is determined by the length of the antenna wire
- The longer the wire, the lower the frequency, the farther the transmission would travel
- Before amplifiers, so high voltage and current
- 1.9 mile antenna is 100kHz
- 1000 foot antenna is 1MHz
- 100 foot antenna is 10MHz
- 10 foot antenna is 100MHz
- 1 foot antenna is 1GHz



The Electromagnetic Spectrum



Early Radio Timeline

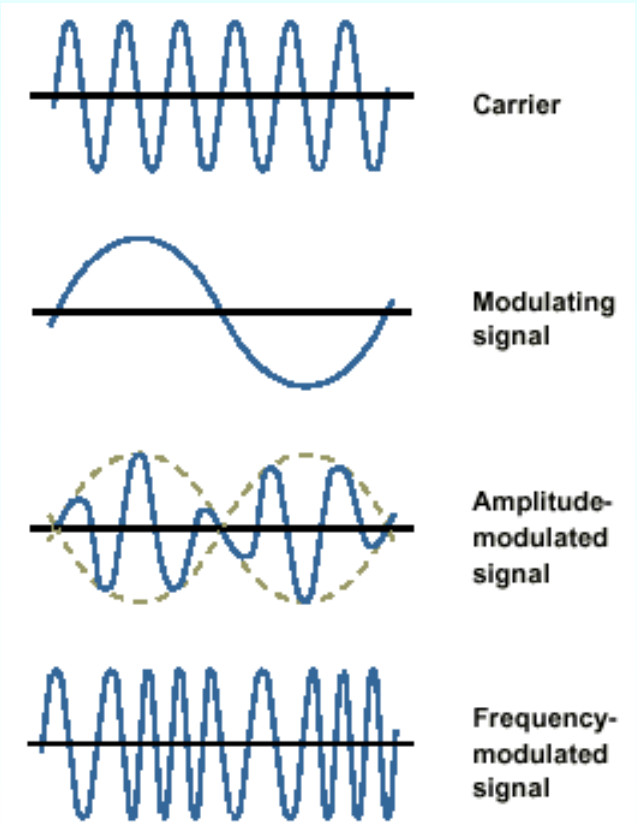
- **1897** Braun invents cathode ray tube
- **1901** Marconi transmits first transatlantic message (“S” or . . . at 850kHz)
- **1906** DeForest invents the vacuum tube amplifier, the audion, later called a triode
- **1906** Voice first transmitted over radio
- **1915** Bell Labs invents first practical radio telephone
- **1920** First commercial AM radio station, KDKA, 980kHz, Pittsburg PA
- **1922** Fransworth invents cathode ray tube for TV
- **1925** First viable load speaker
- **1927** Legislation curtails spark gap transmissions

Radio's Golden Age

- **1927** Farnsworth transmits first TV picture
- **1933** Armstrong patents FM radio
- **1934** FCC formed
- **1934** Telecommunications Act allows broadcasters to use the frequency for free in exchange for certain services, e.g. PSA and EBS
- **1935** RCA demonstrates a fully electronic 343 line television system
- **1935** Bell Labs invents coaxial cable for sending television signals from city to city
- **1938** Valensi patents method of adding color to monochrome TV
- **1941** first commercial FM station
- **1941** NTSC B&W TV Standard approved

AM vs. FM

- **AM: Amplitude Modulation**
  - The height of the signal varies as the frequency remains constant
  - Prone to noise, heard as static
- **FM: Frequency Modulation**
  - The frequency or tone of the signal varies as the amplitude remains constant
  - Highly resistant to noise - no static at all



Commercial Broadcast TV

- The NTSC standard of 525 lines of resolution was a compromise between RCA (441 lines) and Philco, DuMont and Zenith (600-800 lines). Use of AM for video, the amplitude controlled the brightness of the pixel. Use of FM for audio. Video is 30 frames/sec, interlaced 2 to 1, an aspect ratio of 4:3. Each channel is 6MHz wide.
- Only 480 lines could be used for video. And in reality even today you get no more that 336 lines from broadcast TV.
- **1941** First commercial TV stations. WNBT (channel 1, RCA, later WNBC) and WCBW (channel 2, CBS, later WCBS).

What Happened to TV Channel One?

- **1945** RCA's WNBT TV is on channel one (50-56Mhz).
- RCA gets the FCC to move channel one to 44-50MHz, and FM radio from 42-50MHz to 88-108MHz.
- RCA moves it TV operations to channel 4
- Consumers have to buy new FM receivers. RCA successfully delayed FM to protect its AM stations.
- **1948** FCC reallocates channel one frequencies for land mobile use.
- **1954** Armstrong commits suicide, thinking FM radio is a failure

TV is a Success

- **1947** Transistor invented at Bell Labs
- **1948** One million TV sets are in use in the US.
- **1949** First commercial CATV
- **1951** CBS color TV is FCC approved, but is incompatible with existing sets
- **1952** FCC approves UHF-TV broadcasting (channels 14-83, 470MHz – 886MHz)
- **1954** FCC approves compatible NTSC color
- **1954** RCA 12” color TV set retails for $1,000 vs. 20” B&W set for $150
- **1954** Sticker price for a Chevy 150 is $1,696

NTSC Color

- How did more information (the color) get squeezed into the same bandwidth as monochrome?
- Color is added to the existing signal by use of Quadrature Amplitude Modulation (QAM). The signal amplitude is still the brightness (luminance), but the signal is shifted out of phase for the color element (chrominance). This technique was invented 16 years earlier.
- This seems hard to grasp but an easy way to envision this (though not technically correct) is that it is a combination of both AM and FM; or that FM is QAM with a constant amplitude.

NTSC Chrominance

Phase Shift	**Color**
0°	Burst (white)
15°	Yellow
75°	Red
135°	Magenta
195°	Blue
255°	Cyan
315°	Green

NTSC Color Issues

- The need for the hue or tint control on NTSC sets is due to the fact the phase can shift off color due to a number of factors. The control offsets the phase back. This got NTSC to be parodied as Never Twice the Same Color.
- PAL and SECAM color was specifically designed to avoid this problem and do not have a tint control. They also use 8MHz of bandwidth.

Videotape, Modems & FM Stereo

- **1956** 450MHz assigned to radio-telephone
- **1956** Ampex first practical videotape system of broadcast quality
- **1957** FCC grants 23 channels at 27MHz for Class D Citizen Band (CB radio)
- **1958** Bell Labs invents 110 baud modem using FSK
- **1961** FCC approves FM stereo. Some stations go live the same day.
- **1962** Kennedy signs the All Channel Receiver Act into law (UHF tuners are required in all new TVs by 1964)
- **1962** First commercial modem (AT&T Bell 103) full-duplex 300baud FSK
- **1964** CCITT ratifies V.21 (110,150,300baud) modem 4 phase FSK (2x2 QAM)

Bandwidth Crunch, Rise of Cable TV and Home Video Tape

- **1966** NBC goes all color
- **1966** FCC stops assigning new licenses for UHF TV channels 70-83
- **1970** FCC designate those frequencies for land mobile use
- **1972** first premium cable channel starts: Home Box Office (HBO)
- **1972** 50% of US TVs are color
- **1974** Sony Betamax home use videotape
- **1974** FCC reclaims UHF TV channel 37 for radio astronomy use
- **1975** HBO delivered to other cable systems via satellite (10 meter dish)
- **1976** VHS (Video Home System)
- **1976** First hybrid Fibre cable TV system

CATV

- Originally CA was for Community Antenna
- **1948** Mahanoy City, PA. John Walson had a problem selling TVs due to poor reception in the area
- Placed and antenna on a nearby mountain and ran the wire to his shop and home
- He would extend the wire to anyone that bought a TV from him
- **1949** He started charging for it
- It had three channels

Analog Cable Systems

- The first cable systems were limited to 22 channels (nothing over 200MHz)
- It expanded to 36 channels (300 MHz), 62 channels (450MHz), 70 channels (500MHz) and 99 channels (550MHz) over the years as technology advanced
- Coaxial cable has higher attenuation at higher frequencies.
- But amplifiers were the real problems. To over come the cable attenuations and customer splits there were about 30 to 40 amps between the cable head end and the customer.
- Each added noise, and any single failure could take out many neighborhoods at once.

Analog Cable continued

- Their reputation was bad quality and unreliability
- With the advent of hybrid fibre cable (HCF) there are no more than two amps between the head end and the customer
- As cable got more reliable and provided more content than broadcast TV the FCC imposed the must-carry regulation to prevent cable from destroying over the air free TV
- However the broadcaster had to provide a usable signal at the cable head end or pay for lease lines to get it there. The level is -49 dBm for analog VHF-TV and -45 dBm for analog UHF-TV

Attenuation per 100 feet

Freq	RG59	RG6	300 ohm twin lead
100MHz	3.4dB	2.5dB	1.1dB
500MHz	8.0dB	6.7dB	2.6dB
600MHz	8.9dB	7.4dB	2.9dB
700MHz	9.7dB	8.0dB	3.2dB
800MHz	10.5dB	8.7dB	3.4dB

RG stands for “Radio Guide” an old military designation

Cellular and DBS TV Start

- **1977** FCC increases 27MHz CB from 23 to 40 channels
- **1980** V.22 600/1200 baud differential phase shift keying (QDPSK)
- **1981** NHK (Japan) demonstrates HDTV with 1,125 lines of resolution
- **1982** FCC says "market place" would decide AM stereo standard
- **1982** first CD player
- **1982** FCC auctions off UHF TV channels 70-83 for cellular service
- **1983** first commercial cellular service
- **1983** Direct Broadcast Satellite service begins

Bandwidth Crunch and HDTV

- **1984** first stereo TV audio broadcast
- **1984** V.22bis 2400 baud (4x4 QAM)
- **1984** V.32 4800/9600 baud
- **1985** Motorola wants the FCC to reallocate UHF-TV spectrum for 2-way mobile use
- **1985** FCC unlicensed "garbage bands" in 900MHz, 2.4GHz an 5.8GHz if spread spectrum is used
- **1986** FCC decides to reclaim some UHF-TV, broadcasters say they need it for HDTV
- **1987** FCC says it won't reclaim until HDTV is defined and rolled out
- **1987** ATSC starts planning HDTV

HDTV Slow to Start

- **1987** Super VHS (S-VHS)
- **1987** FCC allows cellular to use 800MHz band
- **1988** IEEE 802.11 committee formed
- **1989** General Instruments first stuffed MPEG on 6MHz bandwidth
- **1989** Bellcore develops DSL (for video-on-demand)
- **1990** General Instruments first proposal for all digital TV.
- **1991** V.32bis 7200/12k/14.4k baud
- **1993** FCC sets the AM stereo standard
- **1993** HDTV Grand Alliance formed: AT&T,General Instruments, Zenith, MIT, Sarnoff, Philips and Thompson
- **1994** GA adopts Zenith's 8VSB because GI has problems getting 32QAM to work

HDTV Arrives

- **1995** two-way pagers
- **1996** v.34bis 28.8k/33.6k baud
- **1996** FCC adopts ATSC with 18 formats (later Canada, S Korea, Taiwan & Argentina will use same)
- **1996** First HDTV commercial transmission
- **1996** Worldwide there are 1 billion operational TVs
- **1997** 802.11a/b standards published
- **1997** DVDs commercially available
- **1997** Bob Dole wants to auction spectrum, he wants $70billion for it
- **1997** Commercial DSL
- **1998** Cable modems
- **1998** HDTV sets go on sale for the Holiday Season
- **1998** FCC reserves future use of UHF TV channels 60,61,68,69 for public safety

ATSC Standard

- Fits into existing 6MHz channels
- Has a data rate of 19.39Mbps
- MPEG2 Video
- Dolby AC-3 Audio
- 18 varieties of video size/aspect ratio/frame rates and interlacing
- Carries 1 HDTV or 6 SDTV programs
- Transmitted using 8VSB (8 level Vestigial SideBand)
- Supposedly needs 1/10th the power for the same coverage as NTSC

ATSC Standard

- This modulation make it impossible for moving vehicles to decode the signal.
- In the past with marginal signal you had a snowy picture, but as long as the sound held up it people would tolerate it.
- Now sound gets choppy.
- It performs better in open rural areas, not so good in urban areas where multipath interference is a problem.
- OFDM (EU DTV standard) is better at multipath resistance but overall FCC concluded there was no substantial advantage over 8VSB

ATSC Approved Formats

Designation	Scan lines	Pixels	Refresh	Aspect Ratio	Classification
1080i	1080	1920x1080	60i	16:9	HDTV
	1080	1920x1080	30p	16:9	HDTV
	1080	1920x1080	24p	16:9	HDTV
720p	720	1280x720	60p	16:9	HDTV
	720	1280x720	30p	16:9	HDTV
	720	1280x720	24p	16:9	HDTV
480p	480	704x480	60p	4:3	EDTV
480i	480	704x480	60i	4:3	SDTV
	480	704x480	30p	4:3	SDTV
	480	704x480	24p	4:3	SDTV
	480	704x480	60p	16:9	EDTV
	480	704x480	60i	16:9	SDTV
	480	704x480	30p	16:9	SDTV
	480	704x480	24p	16:9	SDTV
	480	640x480	60p	4:3	SDTV
	480	640x480	60i	4:3	SDTV
	480	640x480	30p	4:3	SDTV
	480	640x480	24p	4:3	SDTV

Consumer Slow on HDTV

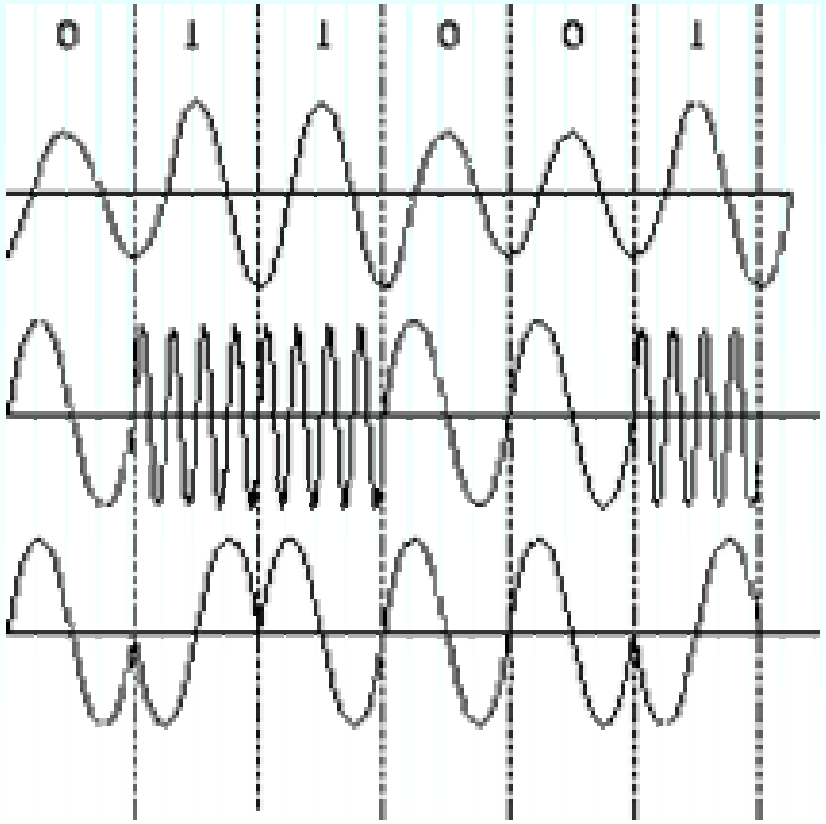
- **1998** V.90 56k baud modem
- **1999** Sinclair petitions FCC to add COFDM to 8VSB.
- **1999** Mitsubishi & Panasonic sponsor broadcasters HDTV programming
- **2000** Manufactures agree on HDTV delivery via cable 64 and 256 QAM
- **2001** FCC rejects COFDM for HDTV
- **2002** Cable & manufactures agree on plug & play
- **2002** Digital VHS (D-VHS)
- **2004** All 1-way digital cable boxes must have over the air ATSC tuners
- **2004** Digital cable operators above 750MHz must supply CableCARDs upon request
- **2004** VeriLAN first commercial 802.16a (WiMAX)

Now and Near Future

- **2005** All digital cable boxes must have DVI or HDMI outputs
- **2005** FCC: digital cable only has to carry the primary DTV channel
- **2005** HDTV equipment must honor the broadcast flag DRM (struck down)
- **2006** Last analog NTSC transmission
- **2006** FCC to reclaim UHF TV channels 52-69 for auction (except 60,61,68,69)
- **2007** All TVs > 13" or devices with tuners only (e.g. VCRs) must have ATSC tuners

Digital Modulation Primer

- Amplitude Shift Keying (ASK) – AM signaling: different amplitude for “0” and “1”
- Frequency Shift Keying (FSK) – FM, different frequencies for “0” & “1”
- Biphase Shift Keying (BPSK) – two phases 0° for “0” and 180° for “1”



Note: the word “keying” is from the telegraph operator key

Digital Modulation Primer

- Quadrature Phase Shift Keying (QPSK) – 4 phases

Phase	Data
45°	00
135°	01
225°	11
315°	10

- Quadrature Differential Phase Shift Keying (QDPSK) – 4 phases but the phase is relative to previous phase (prevents synch problems)

Digital Modulation Primer

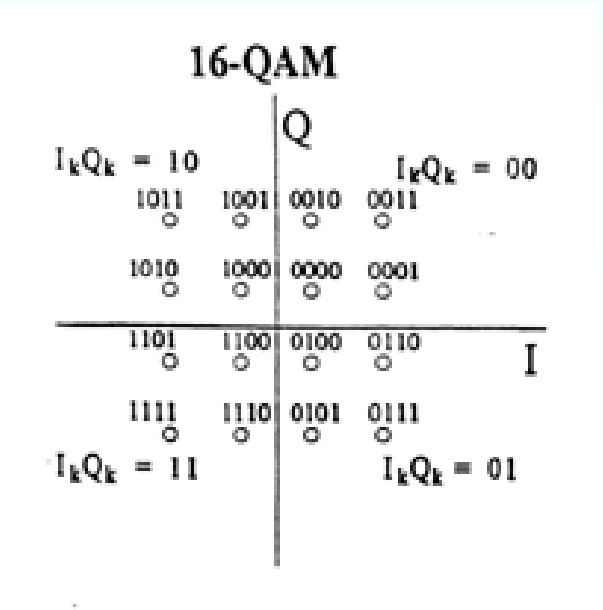
- Eight Phase Shift Key (8PSK)

Phase	**Data**
0°	000
45°	001
90°	011
135°	010
180°	110
225°	111
270°	101
315°	100

Digital Modulation Primer

- Combine 4 levels of Amplitude and QPSK – you get **16QAM**
- Caveat: this needs a better signal to noise ratio than plain QPSK

	0°	**90°**	**180°**	**270°**
+3	0010	0110	1110	1010
+1	0011	0111	1111	1011
-1	0001	0101	1101	1001
-3	0000	0100	1100	1000



Digital Modulation Primer

- Combine 8 level amplitude and 8PSK – you get **64QAM**
- Combine 16 level amplitude and 16PSK – you get **256QAM**
- Combine 32 level amplitude and 32PSK – you get **1024QAM**
- 1024QAM is not commercially is use
- 256QAM can only be used in a close low noise environment (e.g. cable)

Digital Modulation Primer

- FDM = Frequency Division Multiplexing – divides available bandwidth into small subchannels and transmits on them simultaneously.
- OFDM= Orthogonal FDM. Adjacent subchannels are at right angles to each other to prevent interference.
- COFDM = Coded OFDM. OFDM plus Forward Error Correction (FEC) coding

Digital Modulation Primer

- FHSS = Frequency Hopping Spread Spectrum. The radio jumps quickly from one frequency to the next.
- DSSS = Direct Sequence Spread Spectrum. The data stream is XOR'd with a another data sequence (Barker code) that results in the radio modulating across the spectrum. Redundant data is transmitted decreasing the error rate as well as the throughput.
- CCK = Complementary Code Keying. Instead of using the Barker code, a series of codes called Complementary Sequences are used. There are 64 unique code words that can be used. Up to 6 bits can be represented by a particular code word vs. the 1 bit represented by Barker.

How is all this on my 20 year old RG59 coax?

My service from Cablevision:

- 87 analog channels (55-571MHz)
- 255 SDTV digital channels
- 15 HD digital channels
- 9 SDTV on demand digital channels
- 1 HD on demand digital channel
- 45 “CD quality” digital music channels
- Cable modem with 5Mb/s download and 1Mb/s upload speeds

Digital Cable

- All analog signals are still there
- Above analog channels, digital cable channels are allocated and are also 6MHz.
- Current downstream is 50 to 868MHz
- Upstream is 5 to 42MHz
- 8 to 12 SDTV or 2 HDTV channels can be placed in that 6MHz using 256QAM
- Nominal signal level is 0dBmV at 75 ohms

Digital Cable must-carry for DTV

- Minimum signal level for cable to must-carry is -61 dBm for both VHF and UHF DTV signals
- DTV-only TV stations to chose must-carry for retransmission consent on cable systems and allowed them to elect whether their signal was carried in digital or analog format. Stations with both NTSC and DTV channels were not given must-carry rights for their DTV signal, but they may negotiate retransmission consent.
- Cable can remodulate the 8VSB signal into QAM but it must be on a basic tier.
- Cable is not required to carry a broadcast DTV signal at a higher resolution than nonbroadcast digital programs it carries.
- DTV resolution cannot be reduced below that of any nonbroadcast digital program.
- If a DTV broadcaster is transmitting multiple program streams and ancillary or supplemental data, the broadcaster must chose which program stream is the primary, and that is the only one the cable company is required to carry.

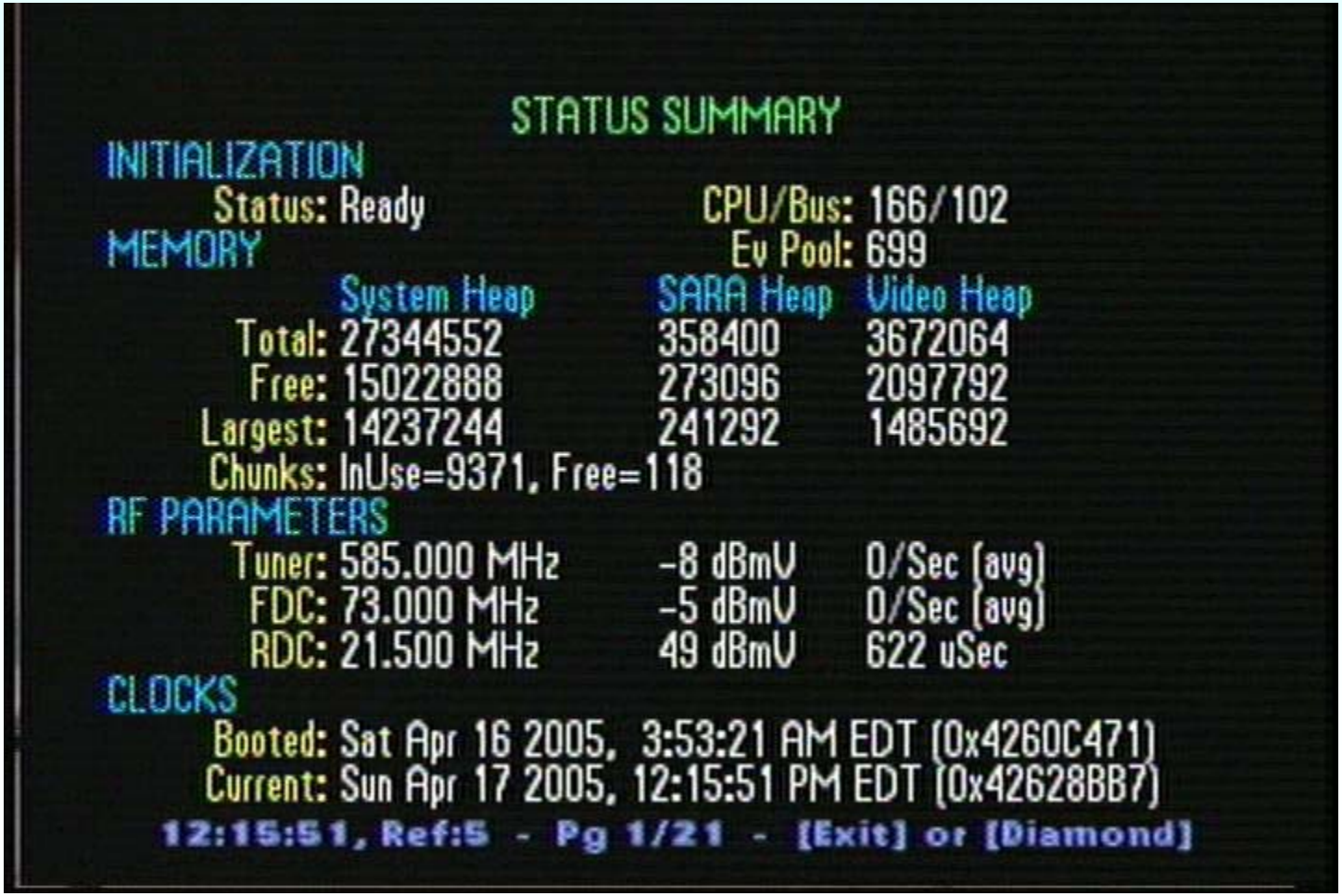
Digital Cable

	US	US	US		US		EU	EU
QAM	64	256	1024		1024		64	256
Bandwidth MHz	6	6	6		12		8	8
Raw Rate Mbps	30.3	42.9	49.2		100.0		41.7	55.6
Information Rate Mbps	27.0	38.8	44.3		90.0		38.2	51.0
SD Streams	7.2	10.3	11.8		24		10.2	13.6
HD Streams	1.4	2.0	2.3		4.6		2.6	3.4

Cable Box Clues

Press Diamond until mailbox flashes, then press INFO.

Cable Box Summary



Cable Box Channel Specific

Found From Cable Box

- All digital content found on 20 channels: 585MHz, 591MHz, 615MHz, 645MHz, 657MHz, 669MHz, 681MHz, 687MHz, 693MHz, 699MHz, 705MHz, 711MHz, 717MHz, 753MHz, 759MHz, 765MHz, 777MHz, 789MHz, 801MHz, 813MHz
- 7 Analog channels found

Freq	Channel Numbers
585MHz	24,25,27,35,41,46,50,51,54,84
591MHz	28,33,34,37,38,39,43,52,53,55,60
753MHz	26,29,36,40,45,47,49,61,12,68

Cable Modems

Download

One 6MHz channel between 50 and 750MHz. Signal level between -15 to +15dBmV, S/N of 30 to 39 dB.

Mod	Chan band width	Raw Mbps	Payload Mbps
64QAM	6MHz	30.34	27
256QAM	6MHz	42.88	38
64QAM	8MHz	40.44	36
256QAM	8MHz	57.2	51

Upload

Channel width of 200kHz, 400kHz, 800 kHz, 1.6MHz or 3.2 MHz between 5 and 42MHz. Transmit power of 30 to 55dBmV.

Mod	Chan band width	Raw Mbps	Payload Mbps
16QAM	1.6MHz	5.12	4.6
16QAM	3.2MHz	10.24	9
QPSK	1.6MHz	2.56	2.3
QPSK	3.2MHz	5.12	4.6

My Cable Modem

- Downstream channel ID = 0
- Downstream channel frequency = 603 MHz
- Downstream channel width = 6 MHz
- Downstream modulation type = QAM64
- Downstream received signal power = -8.5 dBmV
- Upstream channel ID = 4
- Upstream channel frequency = 25.008 MHz
- Upstream channel width = 3.2 MHz
- QoS max upstream bandwidth = 1 Mbps
- QoS max downstream bandwidth = 10 Mbps
- SigQu: Signal to Noise Ratio = 33.9 dB
- Upstream transmit signal power = 53.0 dBmV
- SB Downstream freq 1st trial = 603 MHz
- SB Downstream freq 2nd trial = 645 MHz
- SB QAM16 preamble = True

Convert dBmV to dBm

- Signal and power levels for cable have been listed in dBmV (dB in respect to 1 mV)
- Were more used to seeing dBm (dB in respect to 1 mW)
- Watts = Voltage^2 ÷ Resistance
- R = 75 ohms; V = 1mV = 0.001V
- mW =[(.001) ^{2} ÷75]*1000 = 1/75,000 mW
- dBm = 10log(1/75,000) = -48.75dBm
- So just subtract 48.75 from dBmV to get values in dBm

Direct Broadcast Satellite

- Downlink is Ku-band (12.2 – 12.7 GHz)
- Each satellite as 16 or 32 transponders of 120Watts
- Each transponder has a bandwidth of 24MHz using circular polarization
- Modulation is either
  - QPSK - 27Mbps/transponder = 3 SDTV channels
  - 8PSK - 41Mbps/transponder = 4 SDTV channels
- Video is MPEG2
- Satellite has 12 to 15 year lifespan (current ones all launched between 1993 and 1998)
- LNB converts the signal down to 950 - 1450MHz so it can be sent over coax
- Not required to carry any metro broadcast stations. But must carry them all if they carry any. The satellite provider must offer to install an extra dish for free if needed to pick up any missing channels

DSL

- Early ADSL
  - 18,000 feet distance limitation
  - Carrierless Amplitude and Phase (CAP) (like QAM)
  - Voice 0-4kHz
  - Upstream 25-160kHZ
  - Downstream 240-1.5MHz
- Now it uses Discrete Multitone (DMT) which breaks the entire bandwidth up into multiple 4kHz channels. This is just OFDM. Each channel can be encode with 64QAM if it is “clean” down to QPSK if it is noisy. There can be 256 channels (upto 1GHz) and 32 channels are defined for upload.

DSL chart

Type	Max Send	Max Rec'v	Max Distance	Lines Req'd	Dialtone?
ADSL	800Kbps	8Mbps	18,000 ft	1	Yes
HDSL	1.54Mbps	1.54Mbps	12,000 ft	2	No
IDSL	144Kbps	144Kbps	35,000 ft	1	No
MSDSL	2Mbps	2Mbps	29,000 ft	1	No
RADSL	1Mbps	7Mbps	18,000 ft	1	Yes
SDSL	2.3Mbsp	2.3Mbps	22,000 ft	1	No
VDSL	16Mbps	52Mbps	4,000 ft	1	Yes

What does all of this have to do with WiFi?

- 802.11b has a bandwidth of 22MHz, so I should have more than 11Mbps.
- 802.11g fixes this. It uses OFDM and divides 16.26MHz into 52 channels that are 312.5kHz wide. 48 channels are used to transmit data, 4 are for pilot signals as a reference carrier wave. The channels can be modulated with BPSK, QPSK, 16QAM or 64QAM. It falls back to 802.11b otherwise

Typical 802.11g

Speed	Modulation	Rec'v Sensitivity
54Mbps	64QAM	-73dBm
48Mbps	64QAM	-75dBm
36Mbps	16QAM	-80dBm
24Mbps	16QAM	-84dBm
18Mbps	QPSK	-87dBm
11Mbps	CCK	-88dBm
5.5Mbsp	CCK	-91dBm
1.2Mbs	BPSK	-94dBm

DTV Questions

- Did you realize analog TV broadcasts stop in 19 months?
- Did you know SDTV is DVD quality and HDTV is much much better?
- Did you know DTV stations are broadcast on standard UHF-TV channels in the same 6MHz bandwidth?
- Did you know even if you don't have a HDTV set you can watch broadcast TV in DVD quality that is better than quality than non-HDTV digital cable or DBS satellite?

Video Resolutions

Broadcast TV	336x480
DirecTV	544x480
DISHNet	480x480
Digital Cable	352,412,480,544,640,704 or 720x480 at any given time
VHS SP mode	240x480
VHS EP mode	220x480
BetaMax	250x480
8mm	300x480
Hi8	400x480
S-VHS SP mode	425x480
S-VHS EP mode	400x480
Laserdisc (pre1990)	528x480
Laserdisc (post1990)	544x480
VCD (MPEG1)	352x240
SVCD(MPEG2)	480x480
DVD(MPEG2)	720x480
DV(camcorder)	720x480
SDTV 480i	704x480 (30 fps)
EDTV 480p	704x480 (60 fps) Fox
HDTV 720p	1024x720 (60 fps) ABC, ESPN, Fox
HDTV 1080i	1920x1080 (30 fps) NBC, CBS, PBS, WB, UPN, HBO
ReplayTV (MPEG2 capture)	425x480 (but created file is 720x480)

DTV in the NYC Area

Station	Analog Channel	Analog ERP	Digital Channel	Digital ERP
WCBS	2	45kW	56	349kW
WNBC	4	48kW	28	178kW
WNYW	5	50kW	44	246kW
WABC	7	204kW	45	399kW
WWOR	9	180kW	38	170kW
WPIX	11	123kW	33	160kW
WNET	13	123kW	61	219kW
WLIW	21	2,735kW	22	92kW
WPXN	31	1,800kW	30	100kW
WXTV	41	2,340kW	40	300kW
WNJU	47	1,500kW	36	832kW
WNJN	50	2,090kW	51	200kW
WLNY	55	5,000kW	57	500kW

ERP for TV

Channels	Analog NTSC Max ERP	DTV Min ERP	DTV Max ERP (Zone I)	DTV Max ERP (Zone II)
2-6	100kW	1kW	10kW	45kW
7-15	316kW	2.3kW	30kW	160kW
14-69	5000kW	50kW	1000kW	1000kW

Broadcast Power Reference

Typical outdoor VHF antenna gain for channels 2-6: 4dB; for channels 7-13: 8dB. Typical outdoor UHF antenna gain: 10dB.

Channel	Freq	Raw free space loss	typical antenna	w/antenna in dB	antenna +50ft RG59
2	55MHz	1x	1x	0dB	0dB
6	83MHz	2x	2x	3dB	3dB
7	175MHz	10x	4x	6dB	7dB
10	193MHz	12x	5x	7dB	8dB
13	211MHz	15x	6x	8dB	9dB
14	471MHz	80x	20x	13dB	15dB
28	555MHz	100x	25x	14dB	16dB
42	639MHz	125x	30x	15dB	18dB
56	723MHz	158x	40x	16dB	19dB
69	801MHz	200x	50x	17dB	22dB

Home Made HDTV Antenna

6 inch diameter loop of 12 AWG wire. Pick up all channels except 5 and 13.

HDTV Tuner Outputs

Inside the HDTV Tuner

How Do You Record HDTV?

- Over the air PCI card. No current copy protection cost about $100.
- Standard interface is IEEE 1394 (aka Firewire to Apple or i.Link to Sony). Stick it directly into your PC or D-VHS recorder. (DRM: Digital Transmission Content Production (DTCP) or 5C is built into IEEE 1394).
- Component (Y/Pr/Pb) PCI card cost about $2000

Digital VHS

- Input is IEEE 1394
- Looks just like old VHS tapes
- Device costs $400; Tapes $7 - $20

Rec'd Mode	Quality	Tape Speed	Bandwidth
HS	HD (720p/1080i)	33.35mm/s	28.2Mbps
STD	ED	16.67mm/s	14.1Mbps
LS2	SD/DVD (480i)	8.33mm/s	7.0Mbps
LS3	S-VHS (400i)	5.55mm/s	4.7Mbps
LS5		3.33mm/s	2.8Mbps
LS7	VHS (240i)	2.38mm/s	2.0Mbps

Tape	Length	HS	STD	LS2	LS3	LS5	LS7
DF-480	3,160 ft	4 hrs	8 hrs	16 hrs	24 hrs	40 hrs	56 hrs
DF-420	2,760 ft	3.5hrs	7 hrs	14 hrs	21 hrs	35 hrs	49 hrs
DF-300	1,980 ft	2.5hrs	5 hrs	10 hrs	15 hrs	20 hrs	25 hrs

Digital Video (DV Camcorders)

- DV compression is fixed at 36Mbps
- Interlink is IEEE 1394
- Resolution is 720x480

DVD

- Maximum video bit rate is 9.8Mbps but the average is around 4Mbps.

Compression	Allowable resolutions
MPEG2 (NTSC)	720x480, 704x480, 352x480, 352x240
MPEG1 (NTSC)	352x240

- DVD Video Recorders will be limited by their inputs – composite / s-video

HD-DVD / Blu Ray

Type	Laser	Video and Audio Codecs	Disc capacity Single / Dual	Bandwidth
Window Media Video HD	650nm (Red)	WMV9, WMA9	4.7G / 8.5G (standard DVD)	22Mbps
HD-DVD	405nm (Blue)	MPEG2 SD / HD, H.264, VC-1 PCM, MLP, Dolby Digital+, DTS HD	15G / 30G (ROM) 20G / 40G (recordable)	36Mbps
Blu-ray	405nm (Blue)	MPEG2 HD, H.264, VC-1 PCM, Dolby Digital, DTS	27G / 50G	36Mbps

H.264: MPEG-4 AVC (MPEG4 part-10) video compression and G.722 audio compression

What Video Connection Should I Use?

Ordered from worst to best [copy protection]

- Analog
  - RF F-Connector 336x480 [Macrovision]
  - Composite Video (yellow RCA) 336x480 [Macrovison]
  - S-Video (YC) 500x480 [Macrovision]
  - Component (YPrPb) unlimited resolution
- Digital
  - DVI (Digital Visual Interface) – uncompressed video, no error correction. [High bandwidth Digital Content Protection (HDCP)]
  - HDMI (High-Definition Multimedia Interface) is DVI + digital audio. Uncompressed and no error correction. [High bandwidth Digital Content Protection (HDCP)]

Cable Box Copy Protection Screen