ATSC 방식 DTV 방송의 RF 수신 성능

2001. 6. 1.

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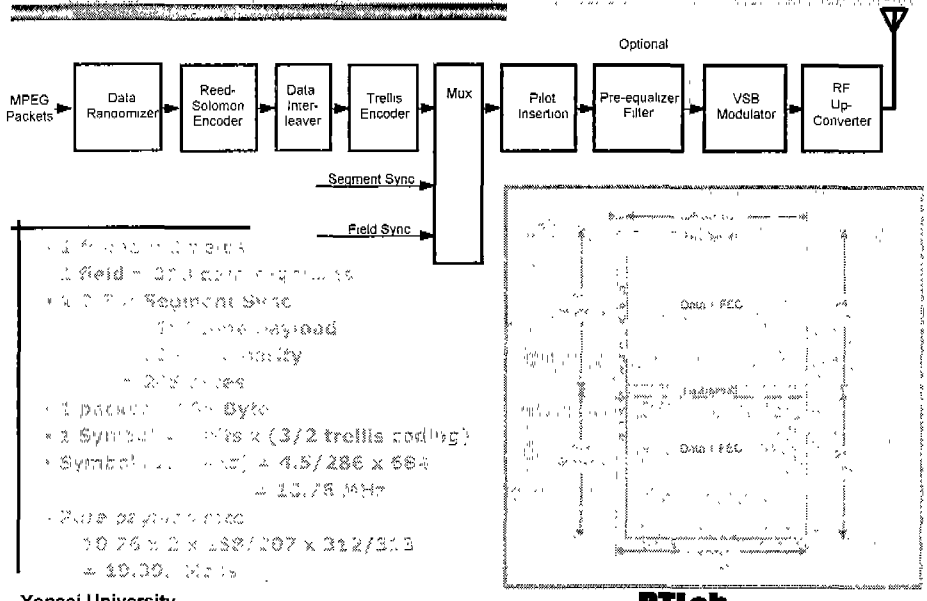
Contents

ATSC DTV Standard

- **Video Formats(18 formats)**
  - 1920x1080;16:9; 24p,30p,30i (3 formats) / 1280x720; 16:9 ; 24p,30p,60p (3 formats)
  - 704x480; 4:3/16:9; 24p,30p,60p,30i (8 formats) / 640x480; 4:3; 24p,30p,60p,30i (4 formats)
- **Video /Audio Compression : MPEG-2 /Dolby AC-3 (CD grade, 5.1 channel)**
-

Parameter	Terrestrial Mode	High Data Rate Mode
Channel Bandwidth	6 Mhz	6 Mhz
Excess Bandwidth	11.5%	11.5%
Symbol Rate	10.76 Msymbols/s	10.76 Msymbols/s
Bits/Symbol(Modulation)	3(8-VSB)	4(16-VSB)
Trellis FEC	2/3	None
Reed-Solomon FEC	T=10(207,187)	T=10(207,187)
Segment Length	832 symbols	832 symbols
Segment Sync	4 symbols/segment	4 symbols/segment
Frame Sync Payload data rate	1/313 segments 19.28 Mbps	1/313 segments 38.57 Mbps
NTSC Co-channel Rejection	NTSC rejection filter in receiver	N/A
Pilot Power Contribution	0.3 dB	0.3 dB
C/N Threshold	14.9 dB	28.3 dB

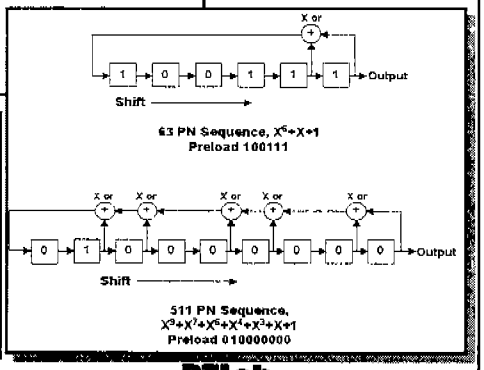
ATSC 8VSB Transmitter - A/53



Data Field Sync in A/53

A : 4 symbols segments sync.
B : 511 symbols of the PN511 training signal
C : 63 symbols of PN63 training signal
D : 63 symbols of PN63 training signal(Alternatively Polarity)
E : 63 symbols of PN63 training signal
F : 24 symbols VSB mode
G : 92 unused symbols
H : 12 symbols for trellis coding

- **PN63 :**
  $X^6 + X + 1$
  Pre-load value of 100111
- **PN511 :**
  $X^9 + X^7 + X^6 + X^4 + X^3 + X + 1$
  Pre-load value of 010000000

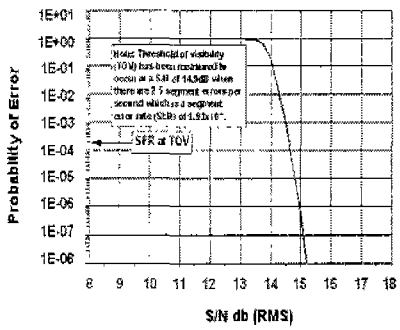


ATSC Transmitter Requirements

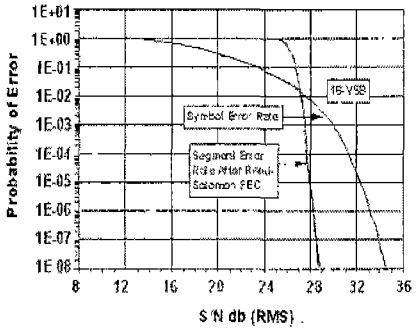
- A Broadcasters Requirements drafted document the Broadcaster Requirements ad hoc group in july 2000
  : specify a DTV Transmission systems, easier to receive than the present analog system
- Assuming adequate signal level, excellent reliability for fixed, portable, pedestrian(5km/h),and mobile(>5km/h) receivers
- Multimode service :
  Robust lower/Normal data rate mode(19.39Mbps)
- On-channel repeater to extend coverage
- No antenna re-positioning
- Suitable antenna, which delivers sufficient power to the receiver
- Minimum field strength
  - For Longley-Rice LR(50,90) service contour
  - Assuming a receiver antenna height 30 foot AGL
  - An incident field strength : 41dBuV/m (41dBu)

ATSC DTV Performance

Terrestrial Mode



High Data Rate Mode



- C/N threshod in Reference SER : $3x10^{-6}$
  - 8-VSB : 14.9dB
  - 16-VSB : 28.3dB

DTV Activity in Korea

- **Digital TV for Terrestrial**
  - **Adopted ATSC DTV standard(8-VSB) for use in Terrestrial Broadcasting ('97.11)**
  - **Exp. : KBS('99.6), SBS('99.9), MBC('99.10)**
  - **Test shooting : SBS('00.8.31), KBS•MBC('00.9.3)**
  - **DTV Beginning expected : 2001**
  - **Organized a committee for Performance Enhancements of Terrestrial DTV ('00.12~)**
    - **Continually to improve 8-VSB performance**
    - **To address market requirements and broadcaster requirements**
    - **To document appropriately the methodology into DTV standard**
    - **To introduce results of field test and ATSC activities**

DTV Activity in U.S.A

- *FCC Goals for DTV*
  - Replace analog service, using existing TV spectrum
  - Replicate existing analog service, including during the transition
  - Minimize interference to DTV and analog service
- *FCC DTV Order* (January 18, 2001)
  - Affirmed exclusive use of ATSC/8-VSB modulation system in the U.S.
    - Found no reason to revisit previous denial of Sinclair's request to allow alternative use of COFDM
  - Found significant improvements being made in DTV receivers
  - Found 8-VSB sufficiently flexible to accommodate improvements
  - Did not impose performance standards on DTV receivers
  - Sought further comment on whether to require DTV reception capability in certain TVs, and how to phase in any such requirements, if adopted

DTV Activity in U.S.A

- Issues driven by broadcasters, not consumers
  - *Adequacy of indoor reception*
  - *Receiver implementation shortcomings vs. modulation standard problems*
  - *Increasing interest in mobile services*
- FCC rejected proposal to add COFDM as an option (Feb., 2000)
  - VSB receiver improvements will resolve problems
  - Adding COFDM would create incompatibility, customer confusion, delay
  - Testing VSB receiver improvements in Washington & Baltimore
- ATSC Task Force assessing RF System Performance (March, 2000)
  - Led to formal activity to standardize VSB enhancements
- Broadcaster industry organizations conducting tests, soliciting and funding VSB improvements (NAB/MSTV tests completed December, 2000)
- Newer VSB receivers show substantial improvements

Performance Assessment – MSTV/NAB

- **MSTV/NAB Tests(8VSB/COFDM test project)**

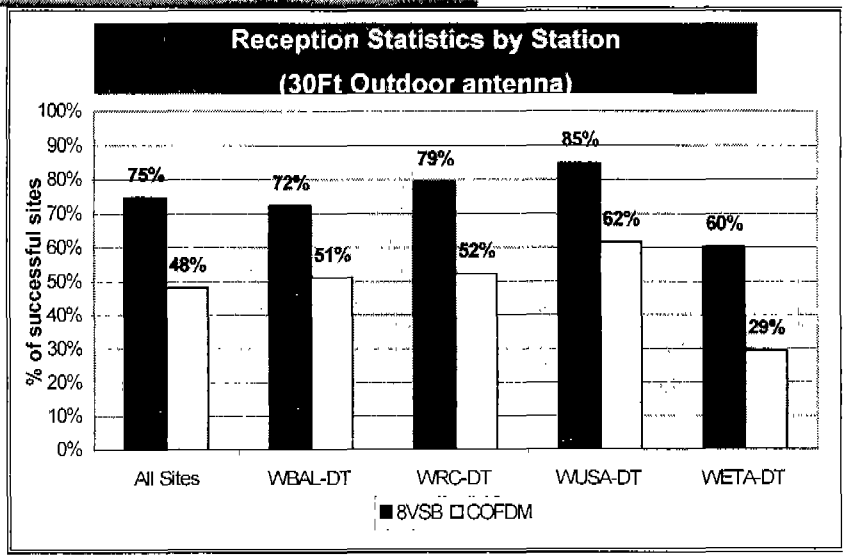
  Designed to evaluate the difference between 8VSB and COFDM systems operating *at the same average power levels*, not to predict performance or coverage

- **Purpose**
  - **Examine and compare performance of early and current models of DTV receivers with respect to predicted coverage; *also collect data on analog TV reception***
- **Description**
  - **Five 8-VSB DTV receivers: 1 first generation, 1 late first generation, 1 prototype second generation, 2 third generation**
  - **Signals of local stations in Washington, D.C. and Baltimore, Maryland**
  - ***Test sites throughout stations' service areas: close-in,* suburban, and rural (near edge of predicted service)**

Performance Assessment – MSTV/NAB

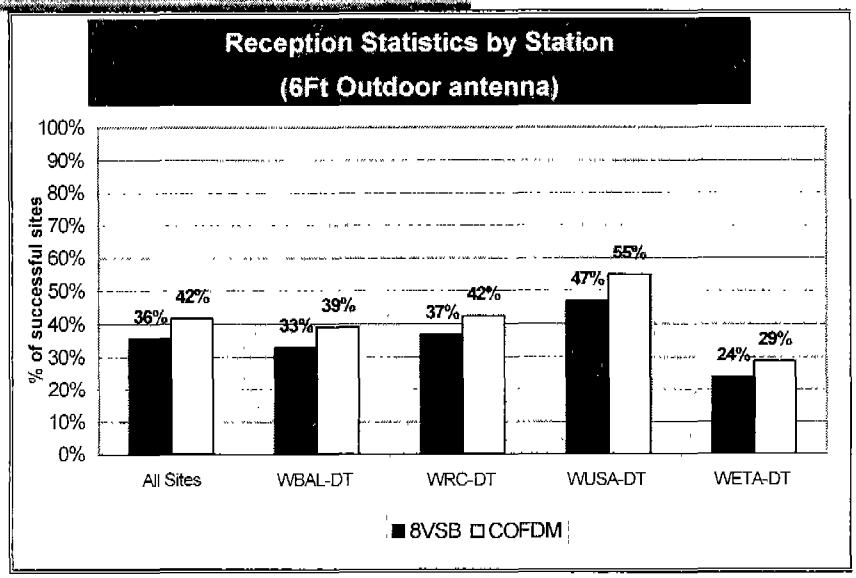
- 8-VSB outperformed COFDM in Washington 30 ft. tests (UHF)
  - 8-VSB 75%; COFDM 48%
- COFDM outperformed 8-VSB in Washington 6 ft. tests
  - 8-VSB 36%; COFDM 42%
- 8-VSB outperformed COFDM in Washington indoor tests
  - 8-VSB 32% (Silver Sensor antenna) and 30% (bow tie antenna)
  - COFDM 28% (Silver Sensor antenna) and 27% (bow tie antenna)
- 8-VSB outperformed COFDM in Cleveland 30 ft. tests (VHF)
  - 8-VSB 73%;COFDM 60%
- 8-VSB outperformed COFDM in Cleveland 6 ft tests
  - 8-VSB 28%; COFDM 14%
- 8-VSB outperformed COFDM in Cleveland indoor tests
  - 8-VSB 26%; COFDM 17%
- Carrier-to-noise threshold performance advantage of ~4 dB confirmed for 8-VSB
- COFDM would reduce viewing population 5.9%, service area 13.9%
- 8-VSB showed superior impulse noise performance

Performance Assessment – MSTV/NAB



DTLab Digital Transmission Laboratory

Performance Assessment – MSTV/NAB



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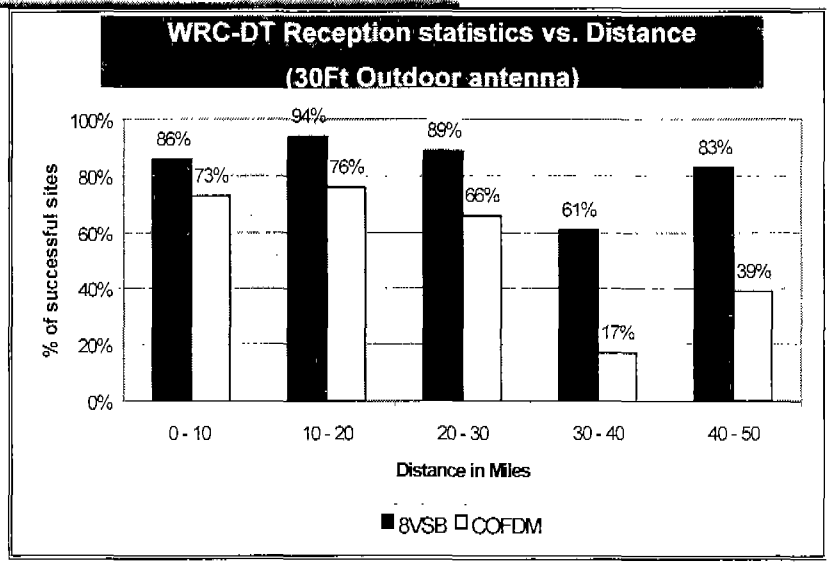
Performance Assessment – MSTV/NAB



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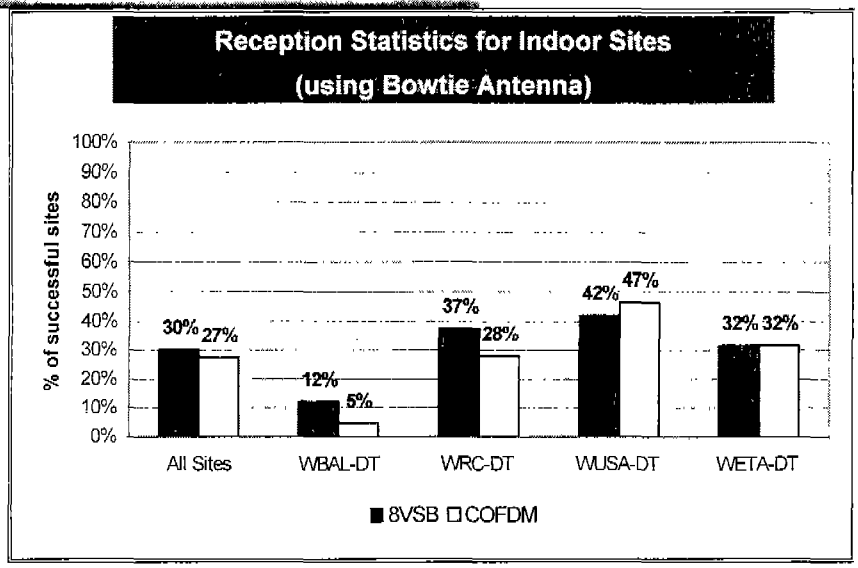
Performance Assessment – MSTV/NAB



DTLab Digital Transmission Laboratory

Performance Assessment – MSTV/NAB

- 8VSB is suitable for a broadcast service when a 30 foot outdoor antenna is used for reception
- Results are less optimistic for outdoor reception at 6 foot for both systems
- Neither systems exhibited the level of reliability required for an indoor broadcast service
- Given the level of failures at moderate and weak signal levels at low VHF, the data suggests the planning factors used by the FCC to predict low VHF service are inadequate

Performance Assessment - FCC

- Goal
  - To evaluate reception using 30 foot and 7 foot outdoor antenna for receiver improvements and to confirm the field strength at 30 foot
- An indication of the true C/N required for real-world reception
  - *In 30 foot coverage measurement*
    - C/N threshold, 15~16dBto 25dB(Newer generation, 2~3dB improvements)
  - *In 7 foot coverage measurement*
    - C/N threshold of the best receiver is under 20dB for 85%
  - *In high multipath, high signal strength site*
    - In 30 foot, under 25dB for the best 85% (6~7dB reduction to 1st generation)

Station	Antenna	# of Sites	TxHAAT	SA	SPI
WUSA (34)	Log Periodic on Mast	51	254	98%	100%
WUSA (34)	Bowtie on Tripod	40	254	98%	90%
WUSA (34)	Silver Sensor on Tripod	14	254	93%*	57%*
WUSA (34)	Total for BT &SS onTripod	50	254	98%	86%
WRC(48)	Log Periodic on Mast	51	242	98%	98%
WRC(48)	Bowtie on Tripod	42	242	98%	86%
WRC(48)	Silver Sensor on Tripod	13	242	92%*	46%*
WRC(48)	Total for BT &SS onTripod	50	242	98%	84%

Performance Assessment - CRC

- Communication Research Center(CRC)
  - Laboratory and field tests to evaluate the performance of ATSC 8VSB receivers(from different manufactures/generations)
- The latest test(Aug. 2000) :
  - less sensitive to the phase of echoes, and a wider equalizer window(-2 ~ 40uS)
- Performance test(with average ERP, 30kW)
  - Outdoor : successful 91%(of test sites)
    67%(of successful 91%) NTSC quality grade 3 or higher
  - Indoor(tripod antenna of about 5 feet) :
    - 58% reliable (active ant) /53% (passive ant)

DTV Outdoor Reception vs. NTSC Quality

No. of Sites	NTSC grade	DTV Margin
22	4-4.5	>15dB
9	3-3.5	>9dB
10	1-2.5	<9dB
1	2.5	16dB
4	1-1.5	No DTV

DTV Indoor Reception vs. NTSC Quality

	Active	Passive	NTSC grade
Reliable DTV	25/43 (58%)	23/43 (53%)	1.5~4.5
Sensitive DTV	5/43 (12%)	2/43 (5%)	0.5~3
No DTV	13/43 (30%)	18/43 (42%)	0.5~3

VSB Enhancement Proposals

T3/S9 Ad hoc group

1. Study proposals submitted to T3/S9 on Dual stream systems

2. Study proposals submitted to T3/S9 related to training signal(TrS) improvement and modifications

VSB Enhancements

- In response to emerging broadcaster requirements, in June 2000 the ATSC began formal activity to standardize enhancements to VSB *in parallel with ongoing DTV implementation*
- Goal is to provide broadcasters with further flexibility to offer different types of service, such as reception by mobile receivers
- Work Plan (T3/S9-Specialist Group on RF Transmission)
  - Define market and technical requirements
  - Issue a formal Request for Proposals (RFP) – (Issued 1/25/01)
  - Analyze proposals
  - Select technical approaches and refine details

VSB Enhancements Project Schedule

- Issue RFP: January 25, 2001
- Respondents Q&A session: February 15
- Letters of intent to propose: March 2
- Written responses to RFP: April 2
- Proponent presentations: June 6-7
- Proof of concept(s): August 6
- Selection of technology for field tests: September 14
- Field tests begin: November 14
- Review of field tests: January 15, 2002
- Adoption of standard or revision to A/53 by T3/S9: 1/31/2002

VSB Enhancements RFP

- *Compatible, partially compatible, and non-compatible* enhancements can be proposed
  - Highest priority placed on *compatible* 8-VSB enhancements
  - "Compatible" means no adverse effect on existing receiving devices
  - Non-VSB approaches are outside the scope of this project
- Top priority is compatible improvement of fixed and indoor 8VSB terrestrial DTV service
- Other areas of focus include improving portable reception and pedestrian service, plus techniques to provide mobile service applications

VSB Performance Enhancement

- Priorities of Performance Enhancement
  - Receiver-only Improvements(No changes to transmitted signal)
  - Compatible Changes or "Enhancements" to Transmitted Signal
    - New receivers have higher performance
    - Existing receivers are unaffected
  - Non-compatible Changes to VSB Signal(Existing receivers affected)
- Technologies for Performance Enhancement
  - Improved Equalization
  - Training Signal Improvements
  - Diversity Reception
  - 2- or 4-VSB
  - Scalable Approaches(New receivers adopting robust or hierarchical mode)

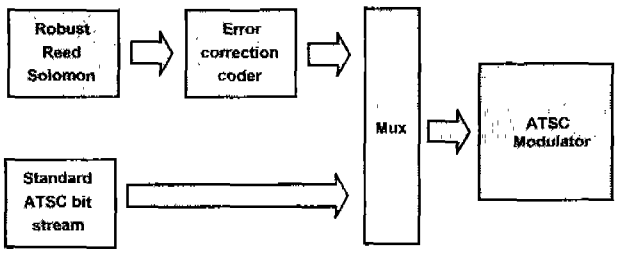
Proposals on Dual Streams System

- Common Elements of Proposals
  - Replace some of standard data with more robust data stream at lower payload rate and improved CNR threshold
  - Robust stream contains data instead of merely training signals
  - Standard and robust streams are multiplexed at the packet level
  - All claim backward compatibility

- Nxtwave : Robust packets(rate 3/1 coding(1bit/symbol) ⇨ 8-VSB mapping)
  Null packet header for backward compatibility
- Philips : Robust packets(1bit/symbol, 2VSB, 4VSB, or hierarchical-VSB mapping)
  Non-systematic RS encoder for backward compatibility
- Zenith : Robust packets(8-level signal,
  Enhanced coding with reduced payload)
  Packet PIDs(identify robust packet for backwards compatibility)

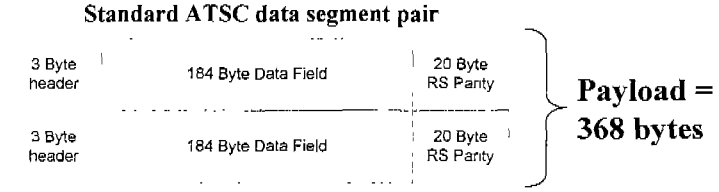
Zenith-scalable mode

- R-VSB is fully compatible with and transparent to ATSC 8-VSB Standard
  - Data frame appears identical to the ATSC 8-VSB data frame
  - Standard existing receivers can read R-VSB packets and per the standard, gracefully discard those packets
  - New receivers with additional decoder layer can decode enhanced data segments
- Broadcasters can have a choice in data rates
- Significant performance improvements
- Full scale public demonstrations will be given in the near future

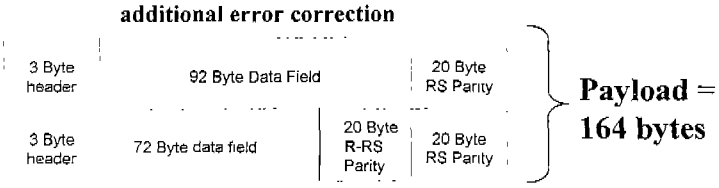


Zenith-Configuration

Standard ATSC data segment pair



Enhanced data segment pair containing additional error correction



Zenith-Performance/Benefits

- In 1/2 Rate Code

No. of R-VSB Segments/ Frame	ATSC Rate (Mbps)	R-VSB Rate (Mbps)	Total Rate (Mbps)
0	19.39	0	19.39
8	18.88	0.21	19.11
40	16.9	1.08	17.99
80	14.42	2.16	16.58
152	9.94	4.12	14.06
200	6.96	5.42	12.38
240	4.47	6.5	10.98
280	1.98	7.58	9.57
312	0	8.45	8.45

- Adding enhanced data does not degrade performance in ATSC segments
- For MPEG video applications, the enhanced segments have a white noise TOV performance < 11.5 dB
- Bit error rate performance for enhanced segments substantially exceeds that of 2-VSB for data-casting applications

Proposals on Training signal(TrS)

- Usage of Training Signal
  - System synchronization
  - Channel estimation
  - Help adaptive equalizer converge etc.

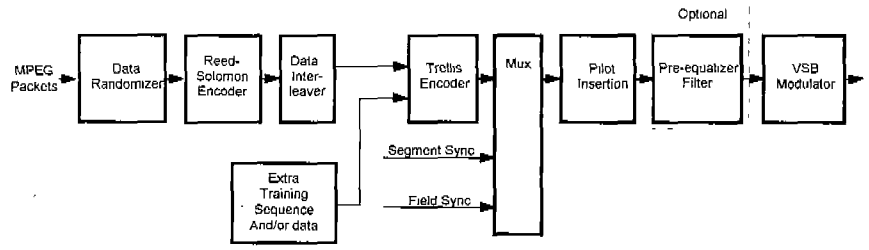
Proposals received

- Broadcom (increase the length and frequency of TrS)
- Conexant (use water marker for channel estimation)
- Nxtwave (increase the frequency of the TrS)
- Oren (modify TrS)
- PLM (change TrS to PN1023, increase length & frequency)
- Sarnoff (increase the frequency of TrS)

Problems on Training Signal

- If the TrS is not long enough:
  - It can not detect long delay ghost
  - The adaptive equalizer might not converge under long and severe ghost conditions
  - There might be strong and long delay ghosts under SFN
- If the TrS is not frequent enough:
  - It is difficult to handle the moving ghosts
  - It is difficult to handle severe multipath distortion
- If the training signal is not good enough:
  - It might have spectrum "blind sports"
  - Adaptive equalizer might not converge well

Broadcom



Proposal Is ...	▪ Increase the length and frequency of the TrS ▪ Increase the channel estimation range

Based on performance trade-off between payload and TOV levels
414 8VSB symbols is replaced by Extra training sequence
(414 Symbols) in every A/53 field

Conexant

Proposal Is ...	▪ Use water marker for channel estimation to increase the length and frequency of the TrS ▪ Increase channel estimation range

Concept

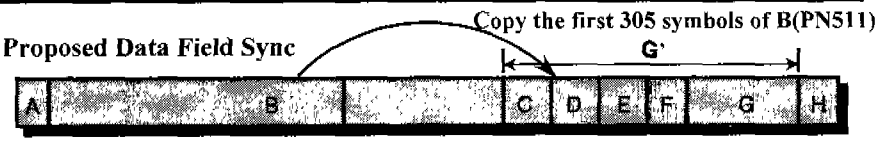
The DTT(Digital Terrestrial TV) down-link be made significantly more robust by Transmission of additional helper signal in-band with the existing VSB signal
The helper signal - " " or " ":
the independent signal which is synchronized to the VSB symbol, appears as additional noise to the receiver
Typically, the power is 30dB below the main VSB signal
One bit of the PRBS per VSB symbol is carried in the field

Oren

Proposal Is ...

- Modify the TrS for fast adaptive equalizer converge

Direct calculation of the channel model with no distortion by using cyclic repetition symbols(305 symbols long)
Using FFT and IFFT for equalizer coefficient calculation : optimal splitting of the channel correction between Feedforward and Feedback equalizer section, the best filter structure



A : 4 symbols segments sync.
B : 511 symbols of the PN511 training signal
G' : 305 symbols, which equals the first 305 symbols of B (Cyclic repetition symbols)
H : 12 symbols for trellis coding

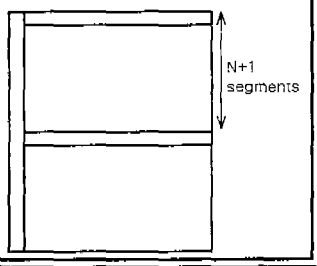
Sarnoff

Proposal Is ...

- Increase the frequency of the TrS
- Trade off between data rate and system performance

Concept

- Change to the ATSC frame structure to provide more robust performance in the face of dynamic multipath
- To modify the field structure
  - additional modes will provide varing time periods between frame sync segments
- Default mode (mode 0, N=312)
- Additional modes (mode 1~5, N=156, 104, 52, 24,12)



Nxtwave & PLM

Nxtwave

Increase the frequency of the TrS
Improve moving ghost and severe ghost performances
Impact : trade off between data rate and system performance

PLM

Change TrS to PN1023, increase length & frequency
Improve moving ghost, severe ghost, and long delay ghost performances
Impact : all existing Rx will not work
* PLM(Patel, Limberg, McDonald)

Conclusions

- **Issues**
  - *Adequacy of indoor reception*
  - *Receiver implementation shortcomings vs. modulation standard problems*
  - *Increasing interest in mobile services*
- **Performance Assessment**
  - In COFDM/VSB Comparison test,
    : less optimistic for outdoor reception at 6 foot antenna
    : Neither systems, the level of reliability required for an indoor service
  - In recent of FCC test,
    - *Service availability with 30 foot antenna, 98%*
    - *System Performance Index, 98~100%*
    - *Newer generation receivers, 2~3dB improvements In 30 foot coverage measurement*
    - *In high multipath, high signal strength site,*
    - *C/N required, 6~7dB reduction to 1st generation*

Conclusions

- **VSB Enhancement**

  : formal activity to standardize enhancements to VSB

  : Top priority is compatible improvement of fixed and indoor 8VSB terrestrial DTV service

  - **Technologies for Performance Enhancement**
    - Improved Equalization
    - Training Signal Improvements
    - Diversity Reception
    - 2- or 4-VSB
    - Scalable Approaches(R-VSB or Hierarchical Mode...)
  - **Proposals submitted to T3/S9**

    - On Dual stream systems

    : Nxtwave, Philips, Zenith

    - On training signal improvement and modifications

    : Broadcom, Conexant, Nxtwave, Oren, PLM, Sarnoff

Thank you!