MIMO progress in DVB-NGH Standardization Process

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Summary & Outline



Summary

- DVB-NGH standardization process is studying the introduction of MIMO techniques for potential increased robustness and/or capacity

Presentation Outline

MIMO rate 1&2 schemes for NGH

Helsinki 2 channel model

MIMO simulation results

Conclusions

MIMO rate 1&2 schemes for NGH

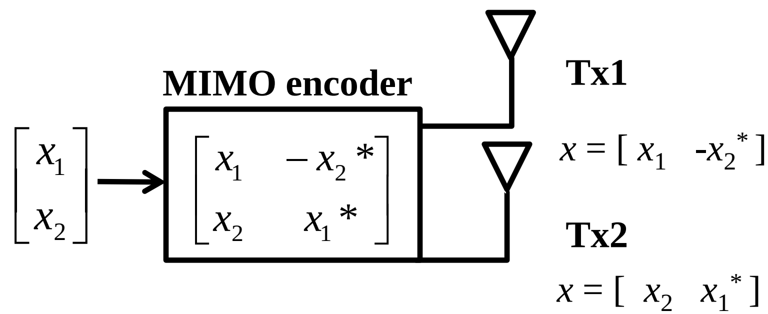
- The standardization group has distinguished between rate 1 and rate 2 MIMO codes.

k:= number of symbols the encoder takes as its input in each encoding operation

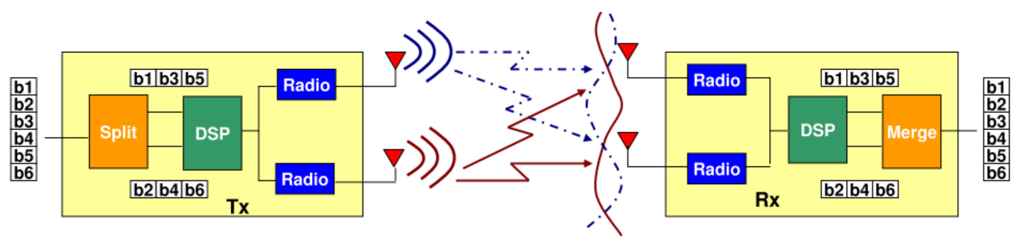
- MIMO rate code: $R = k / p$

p:= number of transmission periods required to transmit the coded symbols through the multiple transmit antennas

- Rate 1
  - Diversity gain
  - Compatibility with single antenna transmitters and receivers



- Rate 2
  - Diversity gain
  - Multiplexing gain
  - But require the implementation of two antennas at the transmitter and the receiver side



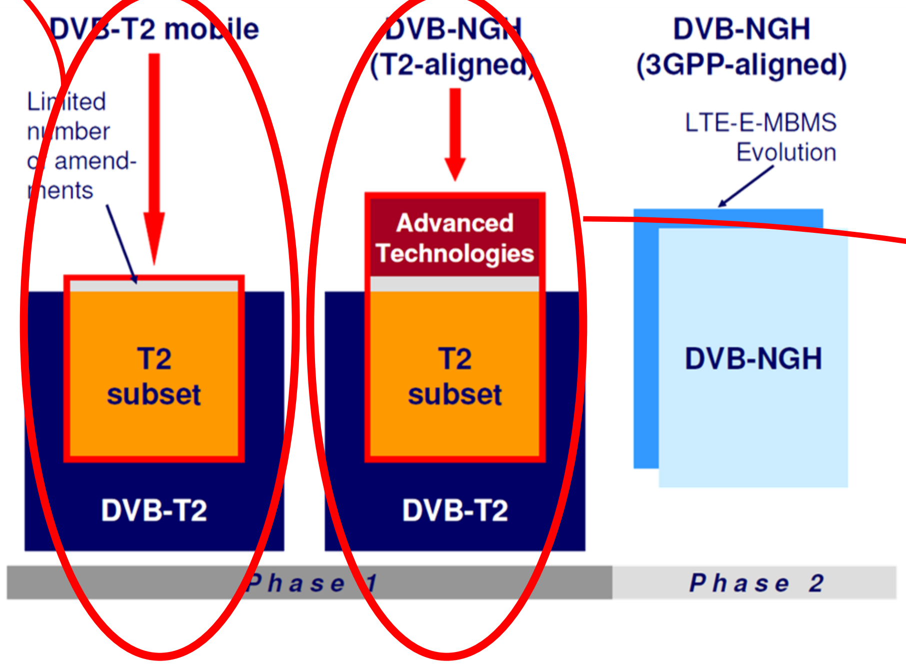
MIMO rate 1&2 schemes for NGH

- DVB-NGH standardization phases & MIMO schemes

Reference: TM-NGH790 *The Next Generation of mobile broadcasting*

SISO/MISO

Maximum compatibility with T2 specification



MIMO rate 1&2

Integration of advanced technologies

MIMO rate 1&2 schemes for NGH

- DVB-NGH rate 1 proposed schemes
  - SISO,SIMO, TxAS, eSFN, MIMO Alamouti
  - Currently rate 1 decision between MIMO Alamouti and eSFN
- DVB-NGH rate 2 proposed schemes
  - SM, eSM, hSM, rSM, SM-PH, eSM-PH, hSM-PH, rSM-PH
  - Proposed MIMO architecture:

$$\begin{bmatrix} 1 & 0 \\ 0 & e^{j\phi(k)} \end{bmatrix} \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}, \theta = TBD, \phi(k) = \frac{2\pi}{N}k,\ k = 1,\ldots,N-1$$

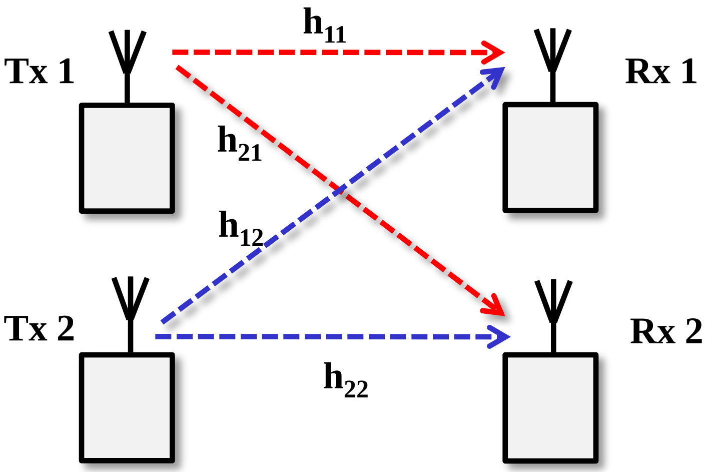
Phase hopping term for increased diversity, aproved

Rotation angle to be defined by simulations eSM (33.3º)or hSM (45º)

Helsinki 2 channel model

- New channel model developed from second Helsinki sounding campaign
  - P. Moss, "*DVB-NGH channel models*", TM-NGH063r5 2010

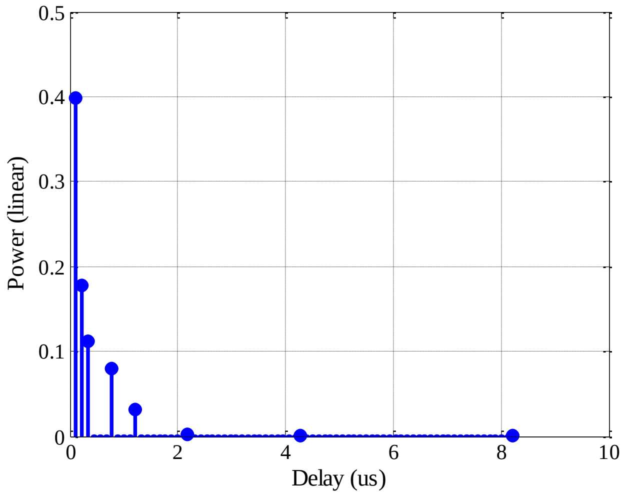
- Channel model scenarios:
  - Portable outdoor (0 Hz and 1.67 Hz)
  - Portable indoor (0 Hz and 1.67 Hz)
  - Mobile vehicular outdoor (33.3 Hz and 194.8 Hz)
  - 4x2 model, 2-tower SFN



Channel model characteristics



- An 8 tap channel model
  - Outdoor model
    - *1st tap LOS*
    - *Remaining taps only NLOS component*
  - Indoor model
    - *1st tap LOS + NLOS*
    - *Remaining taps only NLOS component*



- Intra-tap correlation
  - Correlation between taps of different MIMO channel paths

$$\mathbf{R}_p = \sigma_{11}^2(\tau_p)\begin{pmatrix} 1.00 & 0.06 & 0.06 & 0.05 \\ 0.06 & 0.25 & 0.03 & 0.05 \\ 0.06 & 0.03 & 0.25 & 0.06 \\ 0.05 & 0.05 & 0.06 & 1.00 \end{pmatrix}$$

Covariance matrix

$$\mathbf{V} = \begin{pmatrix} 1.00 & 0 & 0 & 0 \\ 0.06 & 0.4964 & 0 & 0 \\ 0.06 & 0.0532 & 0.4935 & 0 \\ 0.05 & 0.0947 & 0.1053 & 0.9887 \end{pmatrix}$$

Cholesky descomposition

Simulation Practicalities

- Antenna rotation and asymmetry terms have been included
  - Rotation matrix is included to model non-ideal alignment
  - Asymmetry matrix is included to model H/V asymmetries

$$\mathbf{H}(t,\tau)=\mathbf{W}\mathbf{H}(t,\tau)\mathbf{\Gamma}$$

Rotation matrix (W) — Asymmetry matrix (Γ)

- Rotation matrix

$$\mathbf{W}=\begin{pmatrix}\cos\Omega & -\sin\Omega\\ \sin\Omega & \cos\Omega\end{pmatrix} \qquad \mathbf{\Omega}=\{-45^{o},0^{o},45^{o}\}$$

50% power is lost in SISO with -45º and 45º

- Asymmetry matrix

$$\mathbf{\Gamma}=\begin{pmatrix}1.1074 & 0\\ 0 & 0.8796\end{pmatrix} \qquad \mathbf{\Gamma}=\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix} \qquad \mathbf{\Gamma}=\begin{pmatrix}0.8796 & 0\\ 0 & 1.1074\end{pmatrix}$$

23% power is lost in SISO and SIMO

MIMO received power is mostly unaffected by rotation and asymmetry matrixes!

Simulation Practicalities



- Matrixes **W** and Γ pass through all possible combinations in a deterministic manner on a TI block basis
  - SIMO and MIMO simulations pass through 9 states: three possible values of Γ and three possible values of W (Ω = {-45º, 0º, +45º})

  - SISO simulations pass through 6 states: three possible values of Γ and two possible values of W (Ω = {0º, +45º})

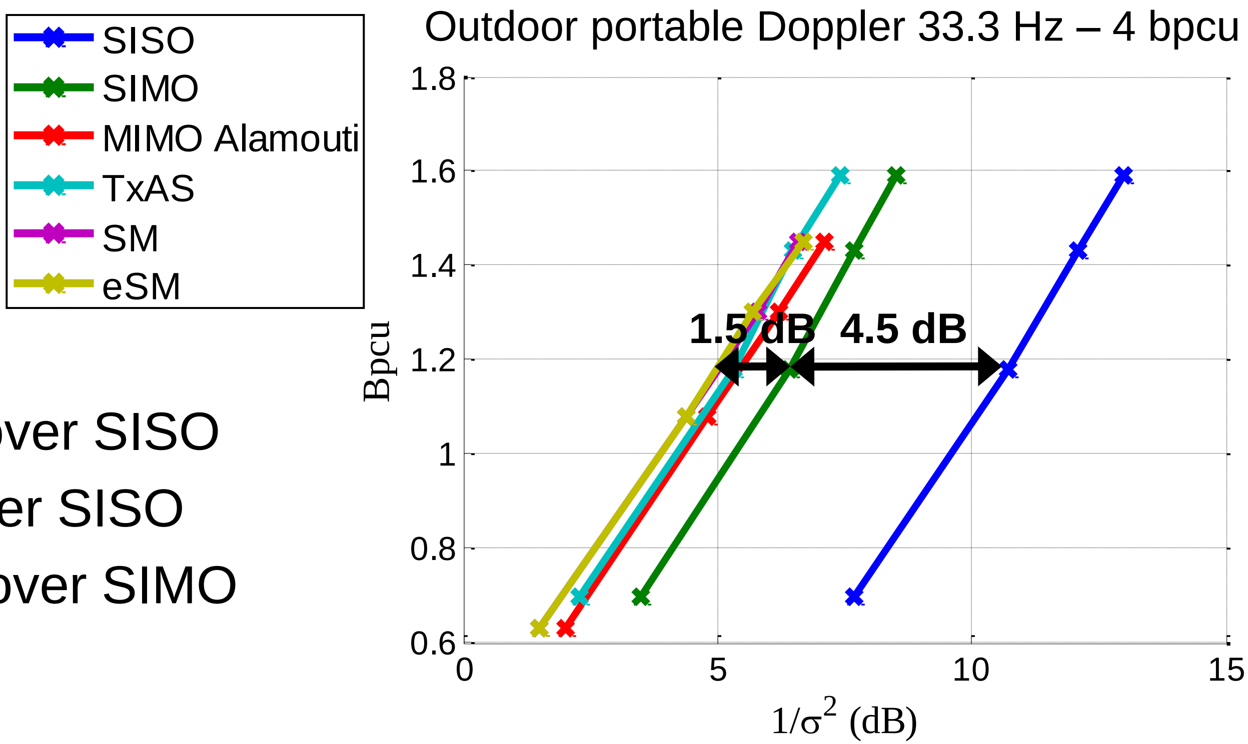
Simulation Parameters

- Simulation parameters agreed in the MIMO group
  - Full TI memory utilization
  - Half TI for non-separable MIMO codes
  - Same amount of memory for all schemes for fairness
  - Pilot overhead is taken into account
    - 1/12 for SISO/SIMO/TxAS/eSFN
    - 1/6 for MIMO schemes

Simulation Parameters	
Bandwidth	8 MHz
FFT size	4K
Guard interval	1/4
LDPC length	16200 bits
Constellation	16QAM (QPSK+QPSK) 256QAM (16QAM+16QAM)
Code rates	1/4 (1/5), 2/5 (2/5), 1/3 (1/3) and 1/2 (4/9)
Channel estimation	Ideal
TI memory	500 Kcells for SISO, SIMO and separable MIMO 500 Kcells for MIMO (250Kcells per antenna path)
Channel Model	Revised NGH MIMO Outdoor channel model 33.3 Hz of Doppler
Simulation length	300 TI blocks/T2 frames
QoS Criteria	BER < 10-5 after LDPC
Stop Criteria	1% BLER

Simulation Results

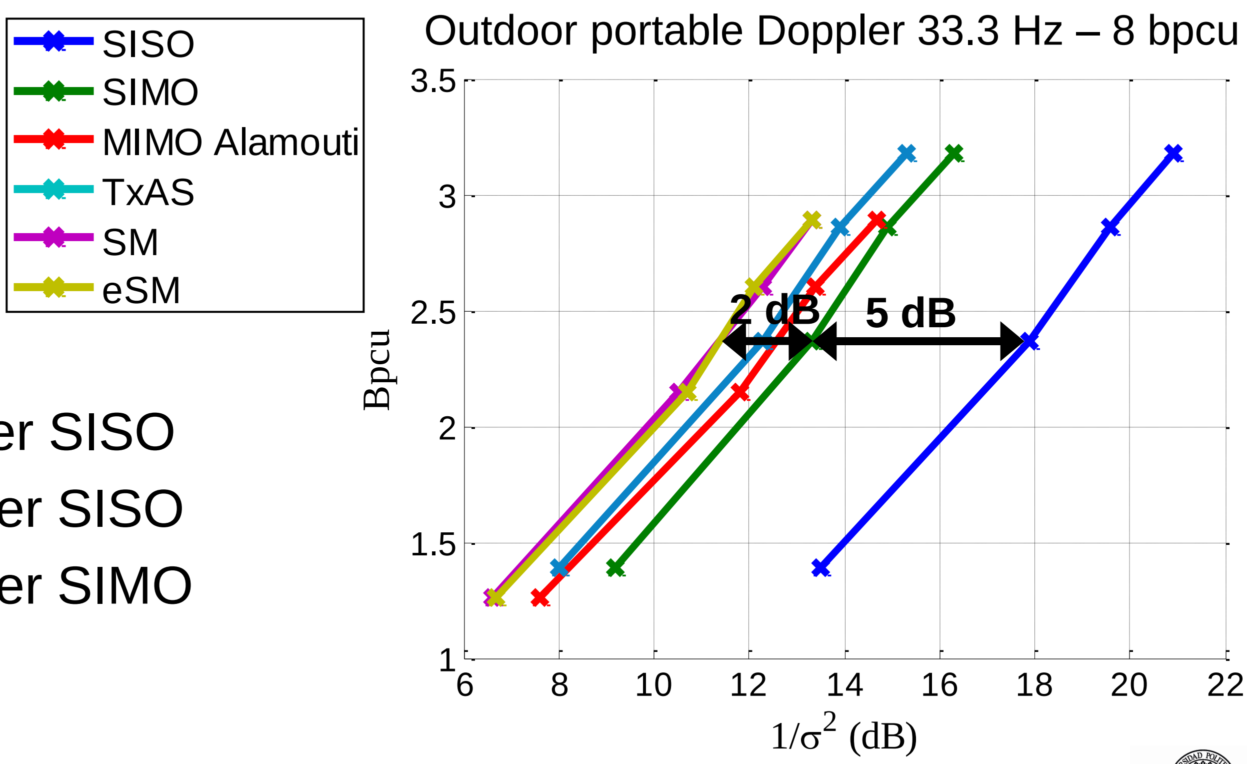
- Ranking between schemes
  - eSM = SM > TxAS > Alamouti > SIMO > SISO



- SIMO gains 4.5 dB over SISO
- MIMO gains 6 dB over SISO
- MIMO gains 1.5 dB over SIMO

Simulation Results

- Ranking between schemes
  - eSM = SM > TxAS > Alamouti > SIMO > SISO



- SIMO gains 5 dB over SISO
- MIMO gains 7 dB over SISO
- MIMO gains 2 dB over SIMO

Conclusions

- The utilization of multiple antennas provides high gains in the new channel model
  - Up to 6 – 7 dB in the mobile vehicular outdoor scenario
  - A cross-polar pair of receive antennas achieve large gains due to alignment issues
- MIMO provides significant gains over SIMO
  - Up to 1.5 – 2.0 dB in the mobile vehicular outdoor scenario
  - Rate 2 codes such as eSM and SM achieve the best performance
- Additional issues must be considered
  - MIMO is more resilient than SIMO against H/V asymmetry issues
  - But requires the implementation of two antennas at the transmitter and the receiver side



Thanks for your attention!

Questions?

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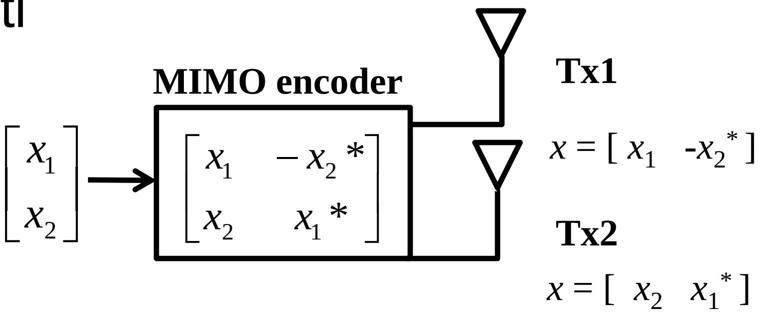
Back-up slides
MIMO rate 1 schemes



- MIMO Alamouti



- Transmit Antenna Switching (TxAS)
  - Divides the set of sub-carriers into two groups, and assigns to each transmit antenna only one group.

H_eff(k) = H_1(k) for k=1,2,…K/2

H_eff(k) = H_2(k) for k=K/2+1,..K

- enhanced SFN (eSFN)
  - Presumes that both transmit antennas are active for all sub-carriers, and then chooses some pre-distortion signal.

H_eff(k) = H_1(k)P_1(k)+H_2(k)P_2(k)

for k=1,2,…,K

Back-up slides
MIMO rate 2 schemes (I)



- General Rate 2 MIMO architecture

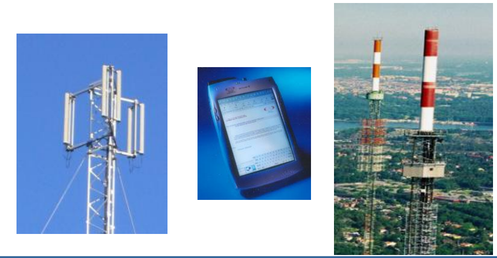
$$\begin{bmatrix} 1 & 0 \\ 0 & e^{j\phi(k)} \end{bmatrix} \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}, \ \phi(k) = \frac{2\pi}{N} k, \ k = 1, \ldots, N-1$$

- Spatial multiplexing (SM)
  - $\phi(k) = 0, \ \ \theta = 0$

- enhanced Spatial multiplexing (eSM)
  - $\phi(k) = 0, \ \ \theta = 33.3^{\text{o}} (16QAM + 16QAM)$

- hadamard Spatial multiplexing (hSM)
  - $\phi(k) = 0, \ \ \theta = 45^{\text{o}}$

Back-up slides
MIMO rate 2 schemes (II)

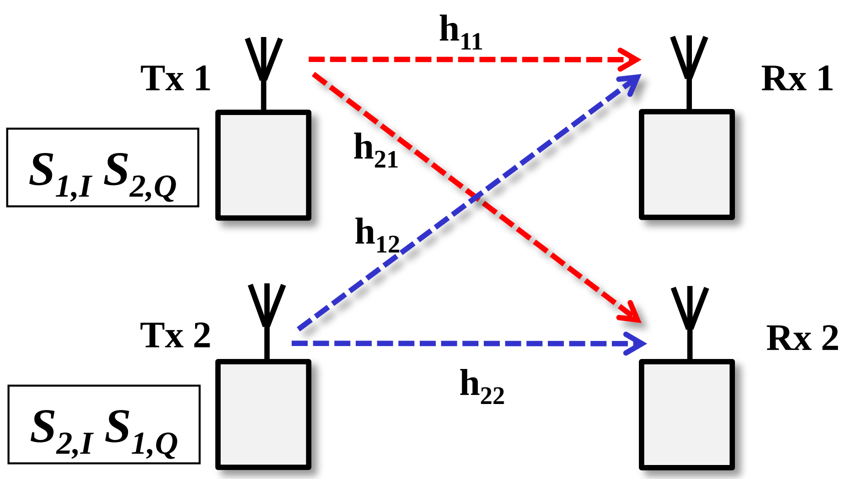


- rotated Spatial Multiplexing (rSM)

$$S_1 = S_{1,I} + S_{1,Q}$$

$$S_2 = S_{2,I} + S_{2,Q}$$

S_1 and S_2 QAM symbols after rotation



- PH (Phase Hopping)
  - Can be applied to all MIMO schemes

$$\phi(k) = \frac{2\pi}{N} k,\ k = 1, \ldots, N-1$$