A Computationally Efficient ASIC Implementation for the decoding of Space-Time Block Codes

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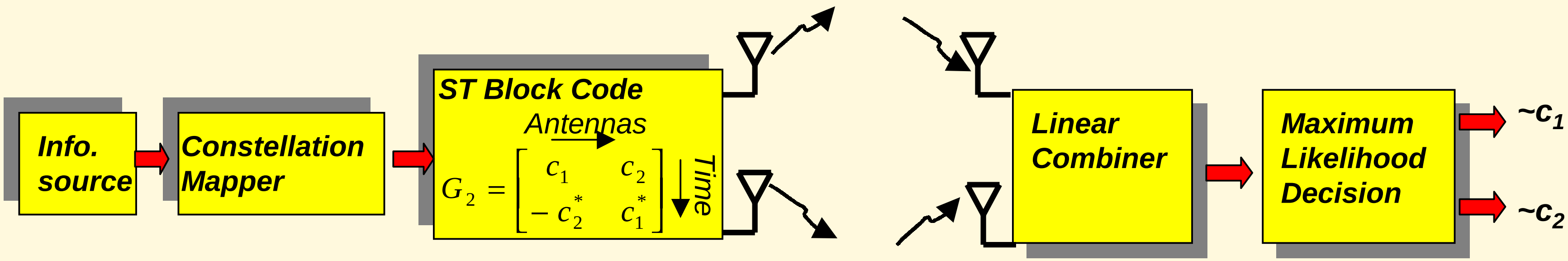
ST BLOCK CODES

- ***A transmit diversity scheme with simple decoding complexity at the receiver***
  - *Orthogonal structure of provides de-coupling of signals from different antennas*
  - *Decoding complexity is linearly dependent on the constellation size*



r_1^j : Received signal at antenna j at time slot l

p_k : Symbol from the constellation signal set

$\alpha_{i,j}$: Channel coeff. from Tx ant. i to Rx ant. j

c_l : Transmitted symbol

$$M_{G2}(c_1, p_k) = \left| \left[\sum_{j=1}^{m} (r_1^j \alpha_{1,j}^* + (r_2^j)^* \alpha_{2,j}) \right] - p_k \right|^2 + \left(-1 + \sum_{j=1}^{m} \sum_{i=1}^{2} \left| \alpha_{i,j} \right|^2 \right) \left| p_k \right|^2$$

$$M_{G2}(c_2, p_k) = \left| \left[\sum_{j=1}^{m} (r_1^j \alpha_{2,j}^* - (r_2^j)^* \alpha_{1,j}) \right] - p_k \right|^2 + \left(-1 + \sum_{j=1}^{m} \sum_{i=1}^{2} \left| \alpha_{i,j} \right|^2 \right) \left| p_k \right|^2$$

Sign Approach for BPSK and QPSK

$$M(c_m, p_k) = \min_{p_k} \left\{ \left| (a + jb) - p_k \right|^2 + \beta \left| p_k \right|^2 \right\}$$

$$M(c_m, p_k) = \min_{p_k} \left\{ a^2 + b^2 + p_{kx}^2 + p_{ky}^2 - 2\left(a\,p_{kx} + b p_{ky}\right) + \beta\left(p_{kx}^2 + p_{ky}^2\right) \right\}$$

p_k^2 is same for BPSK & QPSK

$a^2 + b^2$ is common for all comparisons

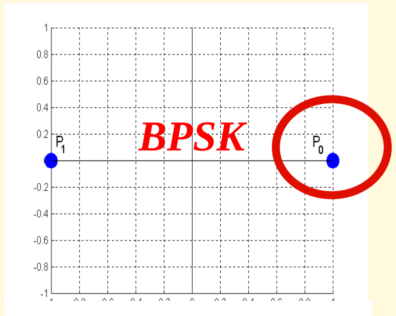
$$M(c_m, p_k) = \min_{p_k} -2\left(a\,p_{kx} + b p_{ky}\right)$$

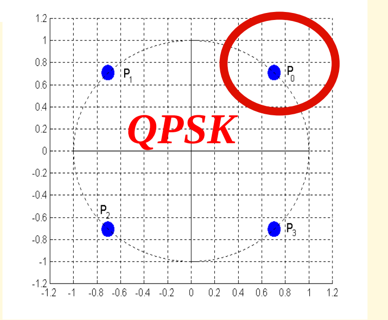
$$\max_{p_k} \left(a\,p_{kx} + b p_{ky}\right)$$

$$sign(a) \equiv sign(p_{kx})$$

and

$$sign(b) \equiv sign(p_{ky})$$





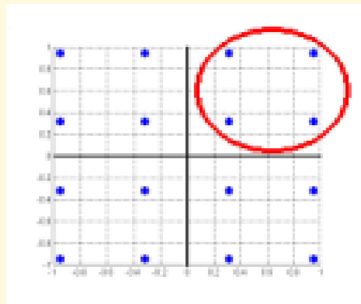
48 Mult & 47 Add → sign(a) ,sign (b)

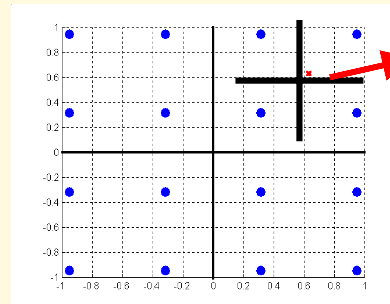
16-QAM-Variable Bias Point Approach

$$M(c_m, p_k) = \left|(a+jb) - p_k\right|^2 + \beta \left|p_k\right|^2 \qquad \beta = -1 + 2\sum_{j=1}^{m}\sum_{i=1}^{2}\left|\alpha_{i,j}\right|^2$$

$sign(a)$

$sign(b)$





(0.6325, 0.6325) for $E_{ave} = 1$

$bias = 0.6325(\beta + 1)$

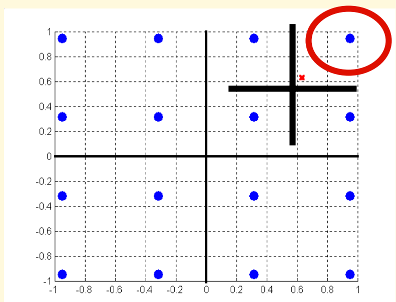
$bias = 1.265\left(\sum_{j=1}^{m}\sum_{i=1}^{2}\left|\alpha_{i,j}\right|^2\right)$

$a' = a - bias$

$b' = b - bias$

$sign(a')$

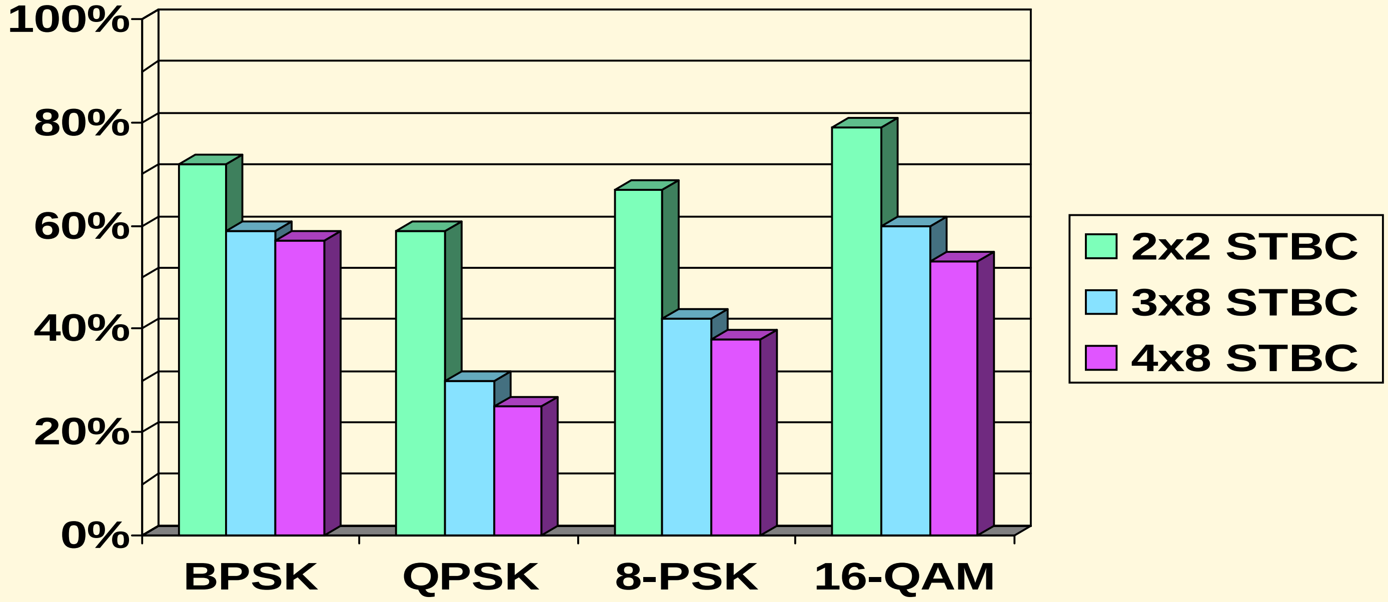
$sign(b')$



96 Mult & 76 Add → 1 Mult & 2 Subt

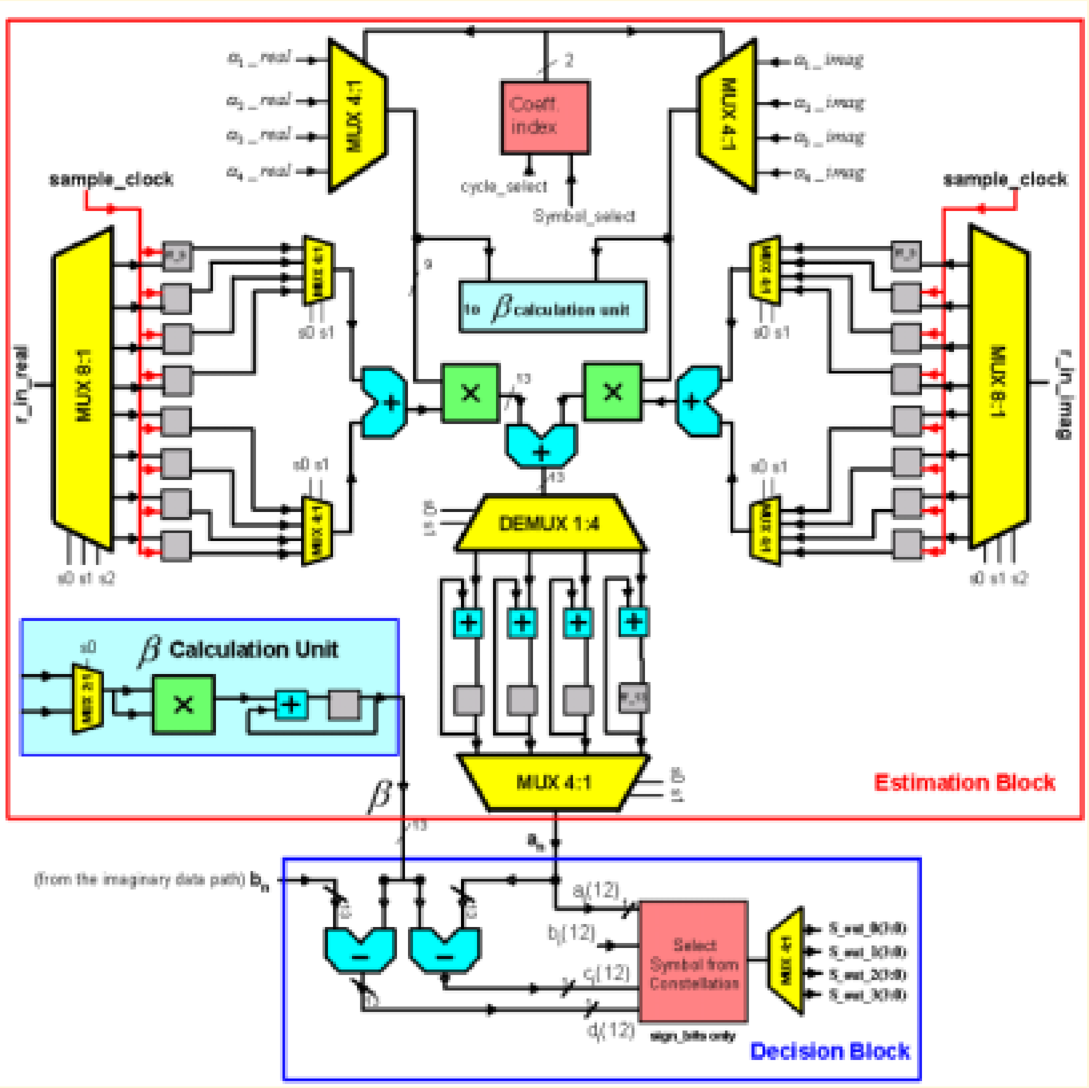
Computation Reductions

Percentages of the computation reductions using New Algorithm



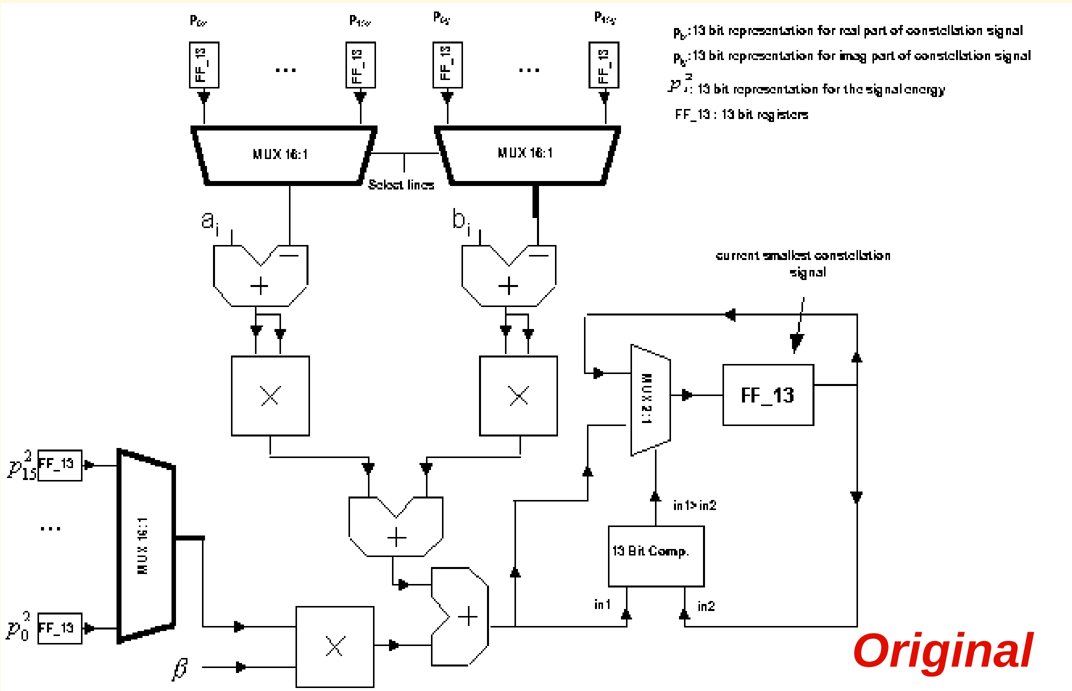
- ***Same performance*** **with up to 80% computation reduction**
- **In most cases more than 50% reduction in computation complexity**

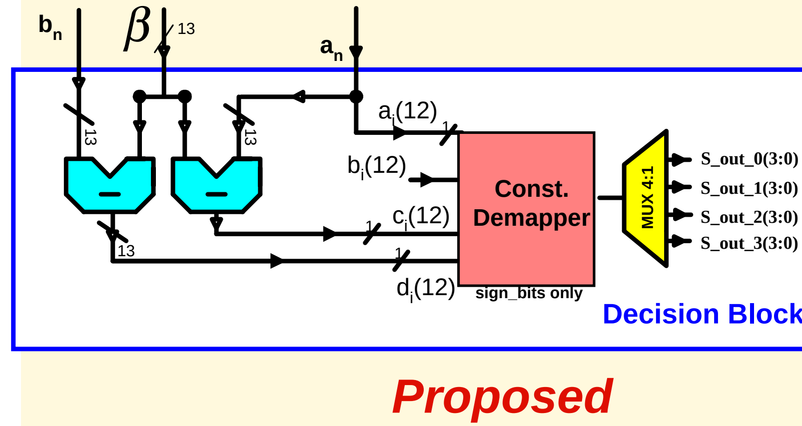
Proposed Estimator Block for a & b variables



- *Benefits from the symmetry and common terms in decision metrics*
- *Halves the total number of operations for estimation of a & b variables*
- *Two sides are symmetric*
- *Same control signals*
- *Store @ f_{symbol}*
- *Wait till the arrival of r_8*
- *Process @ fclk >4 x f_{symbol}*

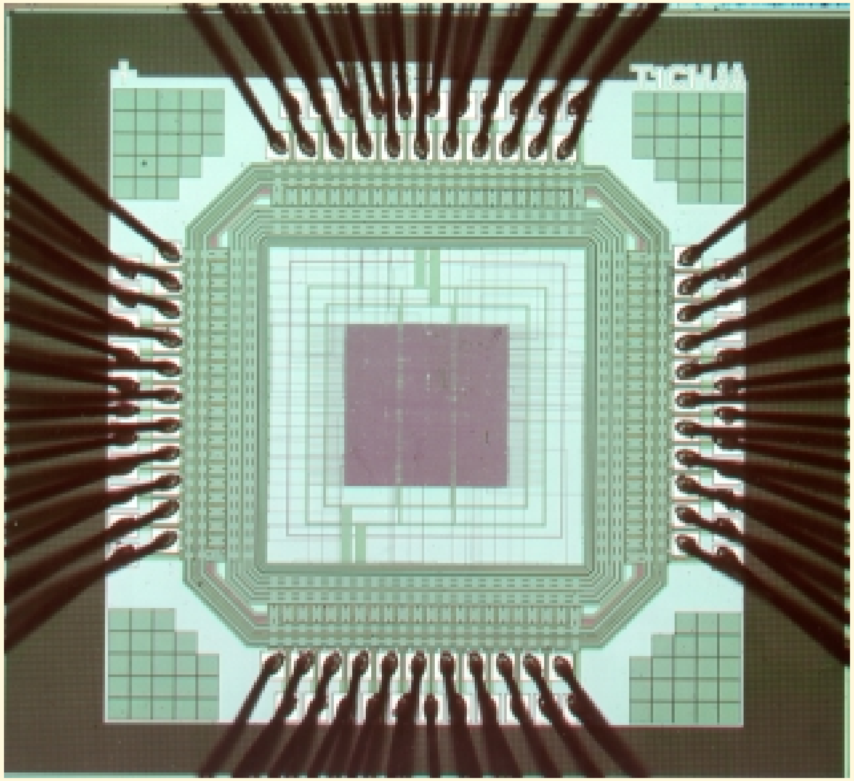
Hardware Complexity of Decision Blocks





- ***Direct implementation of original block needs additional:***
  - *49 (13-bit) registers*
  - *3 Multipliers + 4 Adders + 3 (16:1) Muxes + 1 (2:1) Mux + 1 comparator*
  - *4 parallel instances of the above figure !!!*

STBD ASIC



- **Features**
  - ***Variable symbol rates with up to 75 MBaud***
  - ***Variable modulation***
    - ***BPSK, QPSK, 8-PSK, 16-QAM***
  - ***3.3/1.8V TSMC 0.18 μ process***
  - ***5.5 mW core power***
  - ***Core area: 0.5 mm x 0.5 mm***
  - ***Chip area: 1.7 mm x 1.7 mm***
  - ***5208 Gates***

	Power	Cell Area	# of Cell
Proposed	5.5 mW	0.16 mm^2	5208
Original	20.33 mW	0.82 mm^2	28018

- ***Up to 80% computation reductions***
- ***A symmetrical low computation approach for estimation of a & b variables***
- ***Substantially simplified decision block architecture***
- ***%75 area & power savings compared to a direct implementation of original algorithm***