Real-Time Tracking Based on Recursive Unitary ESPRIT

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ฝ่ายวิจัยและพัฒนาสาขาโทรคมนาคม

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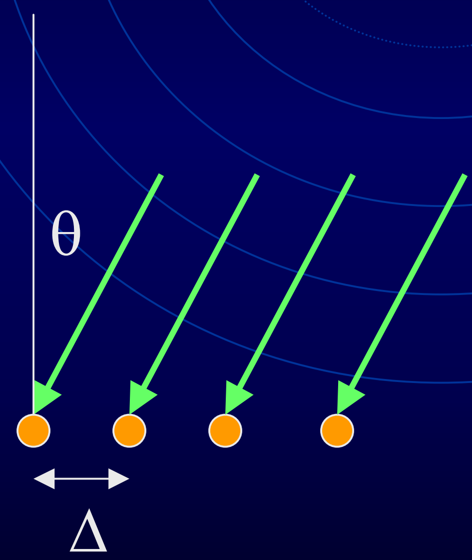
Outline

- Algorithm
  - ESPRIT
  - Recursive ESPRIT
  - Recursive Unitary ESPRIT
- FPGA implementation
- Simulation
- Problems & Discussions
- Conclusion

ESPRIT

Estimation of Signal Parameter via Rotational Invariance Techniques



Signal Model

$$\nu(\theta) = 2\pi\Delta\sin(\theta)/\lambda$$

$$x(m)=\Sigma s_i e^{j\nu(\theta)m}$$

$$x(m+1)=x(m)e^{j\nu(\theta)}$$

↓

$$A_2=A_1\Phi$$

Data matrix

$$R_x = XX^T$$

$$=[U_s\ U_n]^T\Lambda U^T$$

Us ↓

$$U_2=U_1\Psi$$

↓

$$\Psi=T\Phi T^{-1}$$

Recursive ESPRIT

Orthogonal → $Q(n)$; Upper Triangular → $R(n)$

$$Q(n)R(n) = R_x(n)Q(n-1)$$

$$R_x(n) = \alpha R_x(n) + (1-\alpha)x(n)x(n)^T$$

$$Q(n)R(n) = Q(n-1)G^T G[..R(n-1)..]$$

$$\begin{bmatrix} x_1' \\ 0 \end{bmatrix} = \begin{bmatrix} \cos\varphi & \sin\varphi \\ -\sin\varphi & \cos\varphi \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

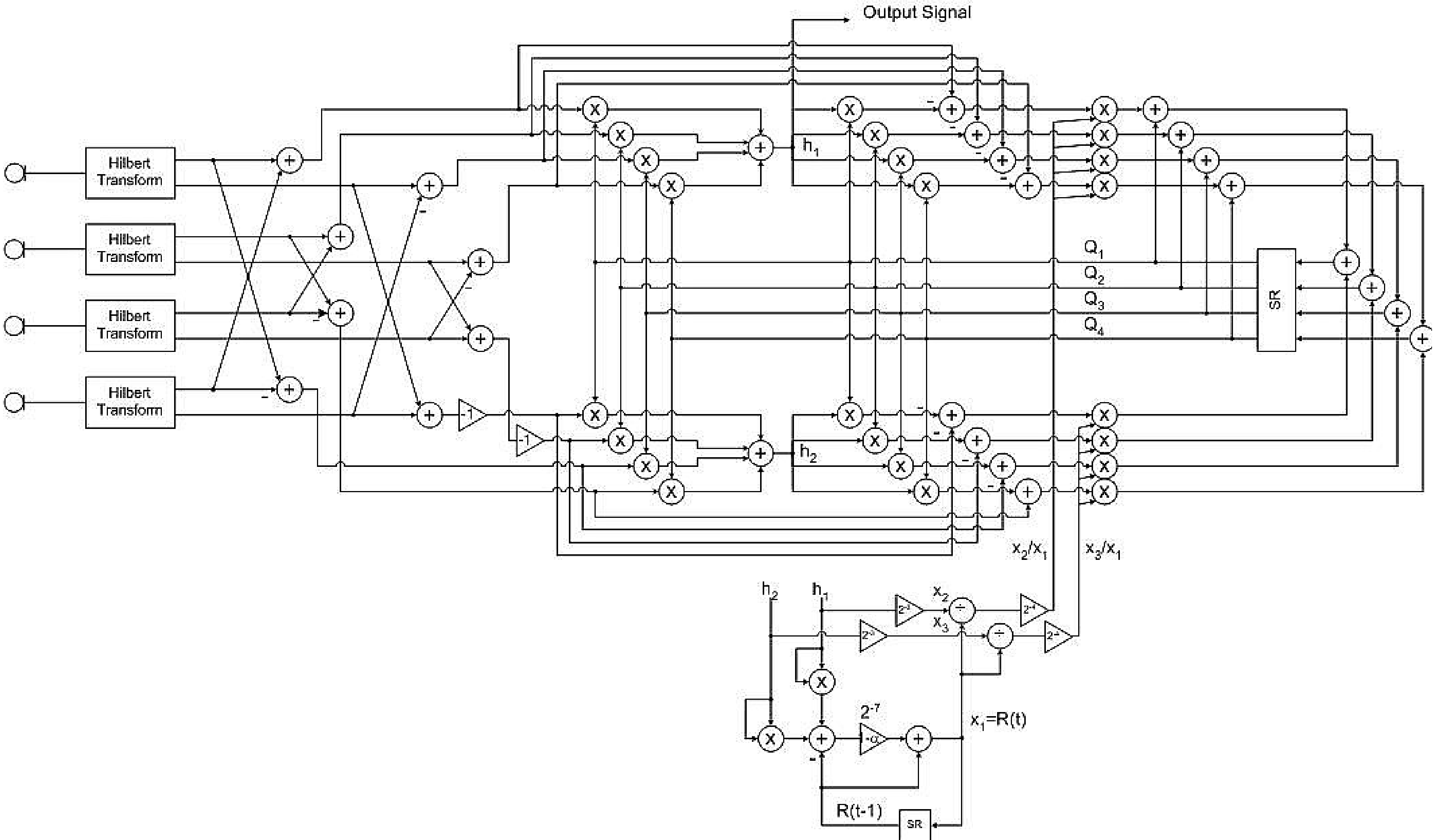
Recursive Unitary ESPRIT

Complex Number Comutation → Real Number Computation

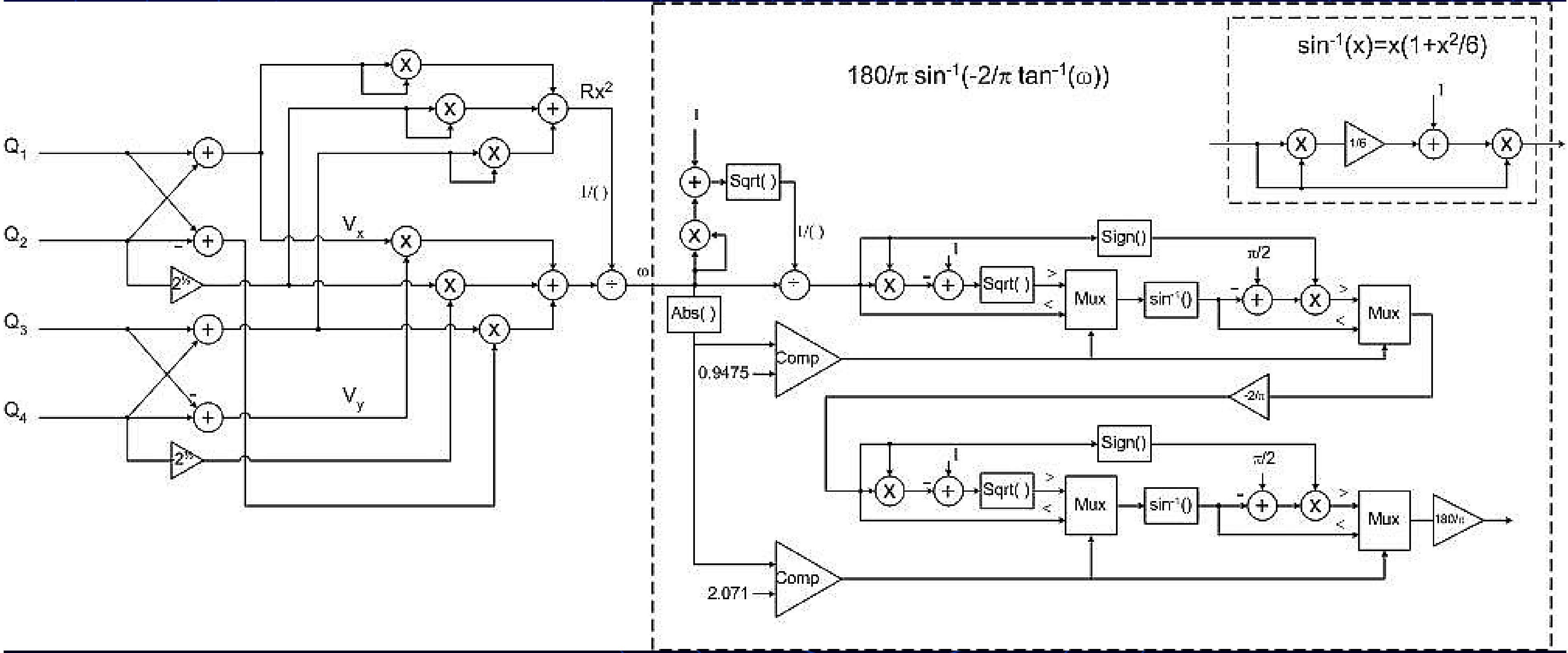
$$Q = \frac{1}{\sqrt{2}} \begin{bmatrix} \mathbf{I} & j\mathbf{I} \\ \mathbf{J} & -j\mathbf{J} \end{bmatrix}$$

$$Q = \frac{1}{\sqrt{2}} \begin{bmatrix} \mathbf{I} & \mathbf{0} & j\mathbf{I} \\ \mathbf{0}^T & \sqrt{2} & \mathbf{0}^T \\ \mathbf{J} & \mathbf{0} & j\mathbf{J} \end{bmatrix}$$

Implementation



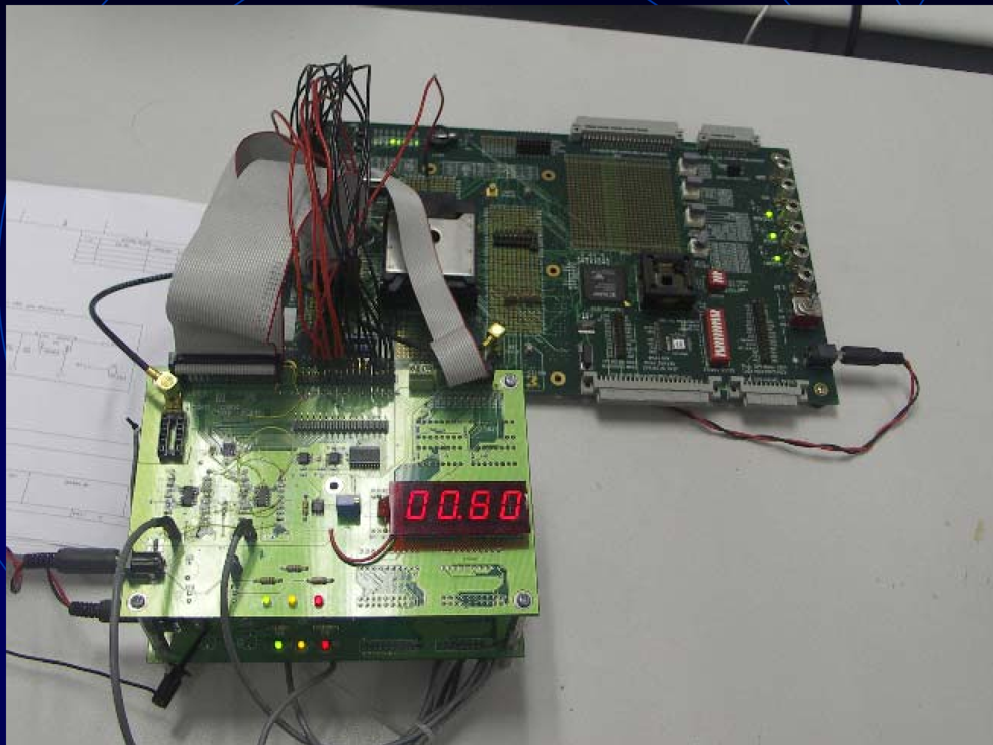
Implementation

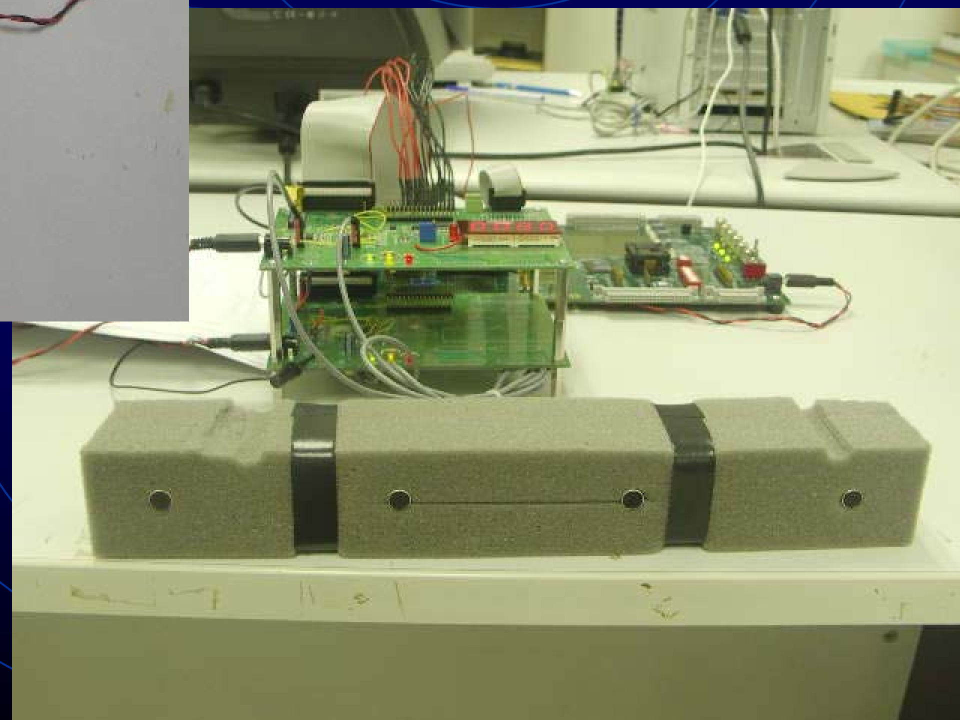


Implementation

- FPGA XC2V3000 (Xilinx)
  - Fixed-point arithmetic
- I/O Board
  - 4 microphone uniform linear array
  - 4 channel 12-bit A/D, 11 kSamples/s
  - 7-segment display

Implementation



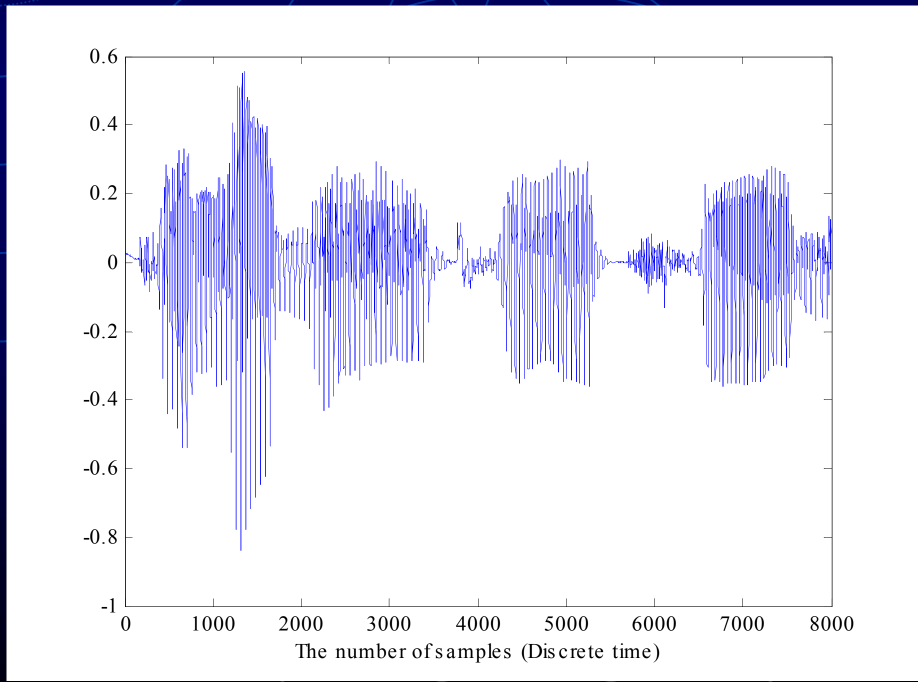


Simulation Result

- **Assign Parameters and conditions for Simulation**

  1. The tested signal for simulation is the only one speech signal plus a complex white Gaussian noise (with SNR = 10 dB)

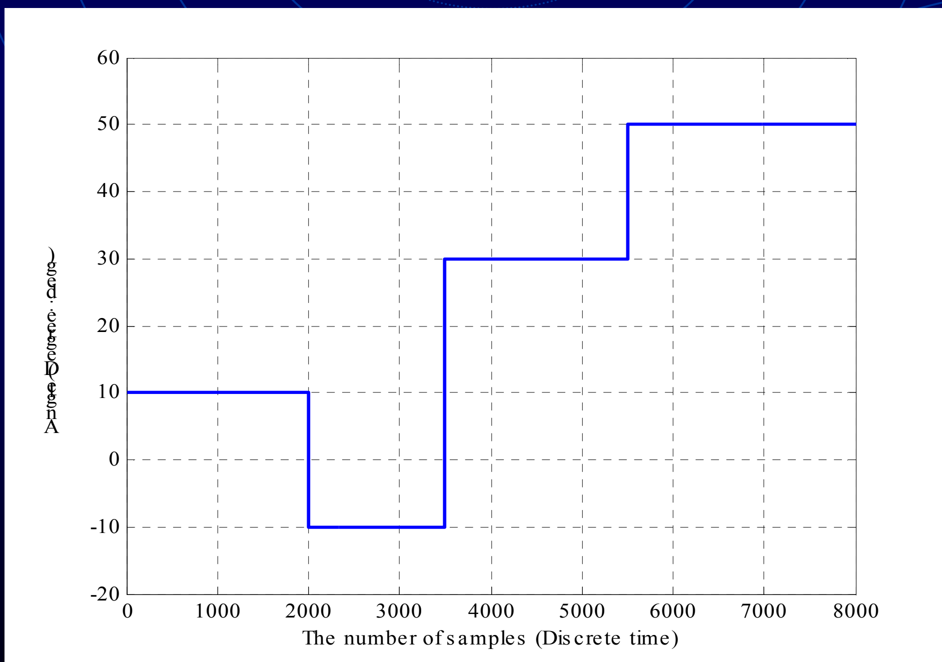
  2. A speech signal is sampled at 250 Ksample/s



Simulation Result (Cont.)

- **Assign Parameters and conditions for Simulation (Cont.)**

  3. The values of DOA of speech signal abruptly change at different time instants, between which they remain constant.



- **Assign the variation of DOA's:**
  - 1 - 2000 samples => 10 deg
  - 2001 – 3500 samples => -10 deg
  - 3501 – 5500 samples => 30 deg
  - 5501 – 8000 samples => 50 deg

Simulation Result (Cont.)

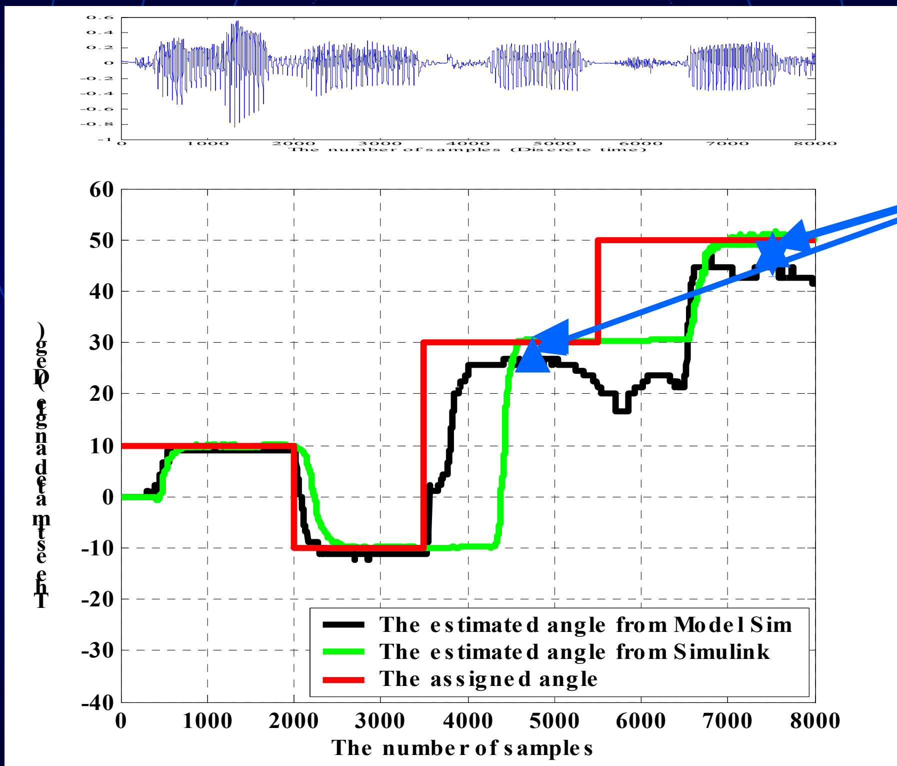
- **Assign Parameters and conditions for Simulation (Cont.)**

  4. Choose Model Sim 5.6 SE in Xilinx ISE 5.1 and Simulink. in Matlab Program for Comparing Simulation results of. the designed circuit.

  5. Specification of FPGA chip of Xilinx.

  Device family: Virtex 2.
  Device type : XC2V3000.
  Packet type : FF1152.
  Speed : -6.

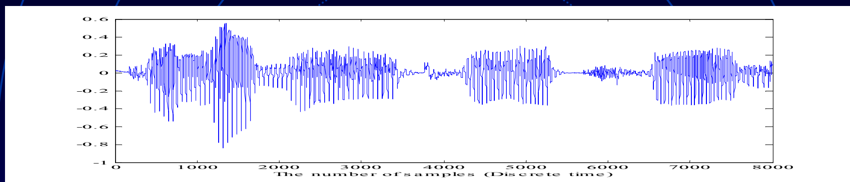
Simulation Result (Cont.)

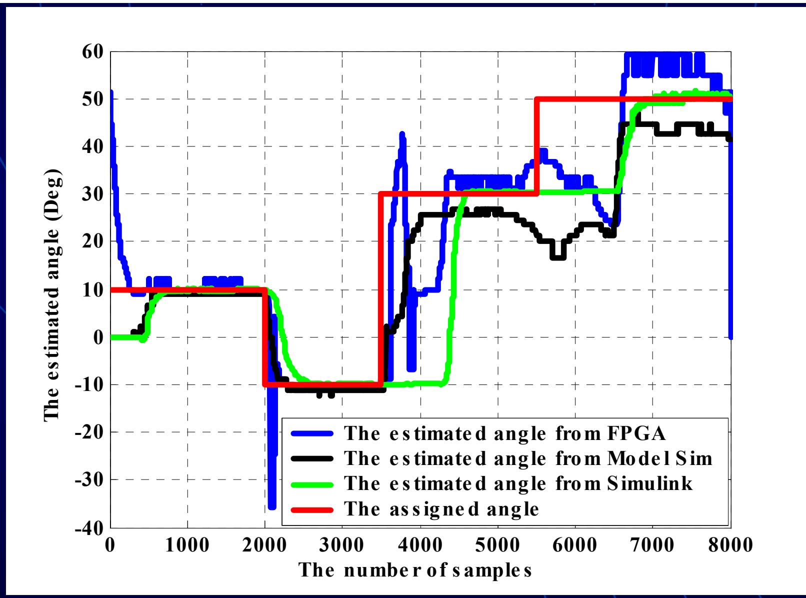


Steady state error

- The simulation result from Model shows a faster tracking speed but higher steady state error.
- The high error occurs during no speech signal or silence signal.

Simulation Result (Cont.)





- The simulation result from FPGA
  - A fast tracking speed and high steady state error as same as Model Sim.
  - More accurate than the result from Model Sim
  - The high error occurs at the edge of changing of DOA's and during no speech signal

Simulation Result (Cont.)

- **After Synthesize process**, we obtain the maximum system speed is 16.7 MHz
- **After Implementation design process,** we obtain

# of Slices:	7,779 out of 14,336	54%
# of Slice Flip Flops:	4,974 out of 28,672	17%
# of 4 input LUTs:	12,092 out of 28,672	42%
# of bonded IOBs:	342 out of 720	20%
# of MULT 18x18s:	70 out of 96	72%
# of GCLKs:	3 out of 16	12%
Total equivalent gate count		432,470

Problems and Discussions

- Speech signal is wideband (200-3000 Hz).
- Very low amplitude signal received from 2m distance.
  - High SNR.
- Near-field ←→ far-field?

Conclusion

- A FPGA Implementation of subspace tracking is presented.
  - a fast recursive ESPRIT algorithm.
  - real-valued computations using unitary transform.
  - The system of 4-sensors ULA is simulated for a speech with 10 dB SNR.
- ESPRIT is not suitable for a non-stationary and wideband signal such as speech.
  - Use RF front-end to evaluate the subspace tracker.
  - Change algorithm for speech signal.