RF Environment behavior modeling based on 3-D Ray-Tracing and Neural Networks to mitigate multipath in indoor position estimation

Fermin Esparza Alfaro, Meenakshi Rawat, Ramzi Darraji, Karun Rawat, S. Aidin Bassam, Fadhel M. Ghannouchi ,
Victor Torres and Francisco Falcone

University of Calgary

iRadio Laboratory, Electrical Engineering Department,

University of Calgary, Canada

Washington, DC, November 30, 2010

Outlines

Part I: Problem Definition

Part II: Proposed methodology for high accuracy position estimation

2.1 Position Estimation Methods.

2.2 3-D Ray Tracing and Neural Networks Channel Model.

2.3 Integration of the position estimation solution for error minimization in TDoA.

Part III: Implementation and experimental results

3.1 Measurement set-up.

3.2 Experimental Results.

Part IV: 4. CONCLUSION

Problem Definition

- Highly accurate position estimation is very desirable in many applications.
- RF environment for communication are often characterized with strong multipath behavior.
- There is a need for characterizing the multipath behavior of the channel to mitigate this multipath effect.
- The empirical techniques offer low computational cost, but also low accuracy.
- Deterministic techniques, which are based on the calculation of electromagnetic field, offer high accuracy at the expense of very high computational complexity.

Position Estimation Methods

Location Estimation

Relative Signal Strength (RSS)

- Distance is calculated based on relative signal strength of each antenna

+ No synchronization between Tx & Rx required

- Highly prone to environment effects

Time of Arrival (TOA)

- Position is calculated based on time of arrival from transmitter to receiver

+ Less number of BSs required as compared to TDOA

- Synchronization between Tx & Rx required

Time Difference of Arrival (TDOA)

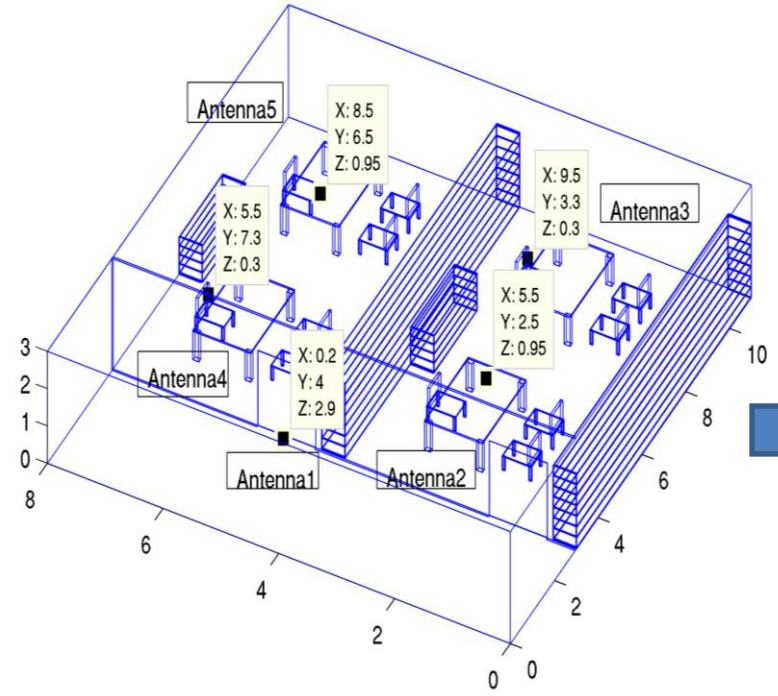
- Position is calculated based on time difference of arrival from different transmitters to 1 receiver

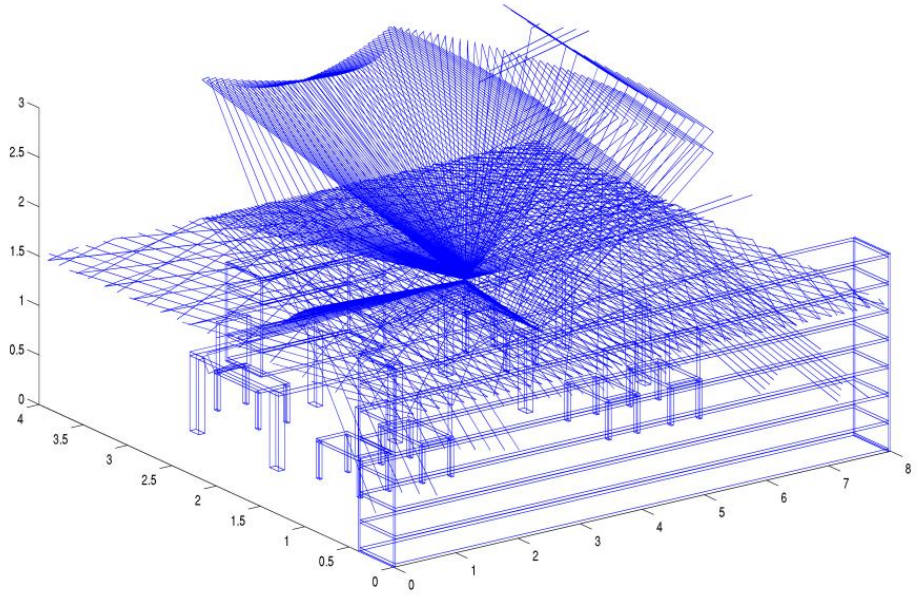
+ No synchronization between Tx & Rx required

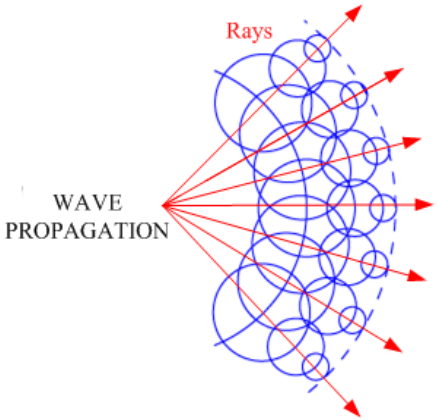
- Synchronization between transmitters is needed

- As compared to TOA, requires more no. BSs

3-D Ray Tracing (1/2)







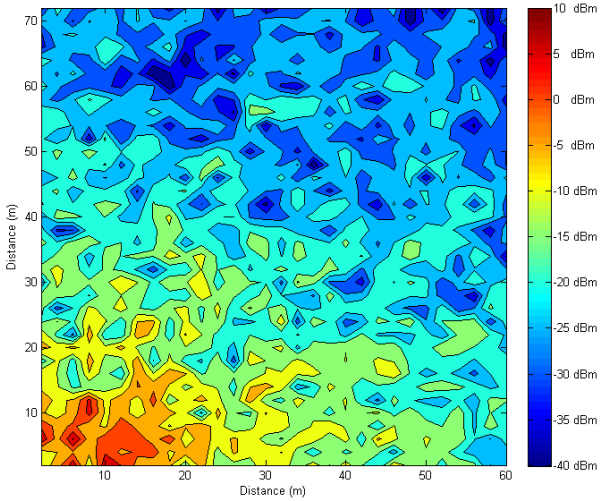
Information Extraction

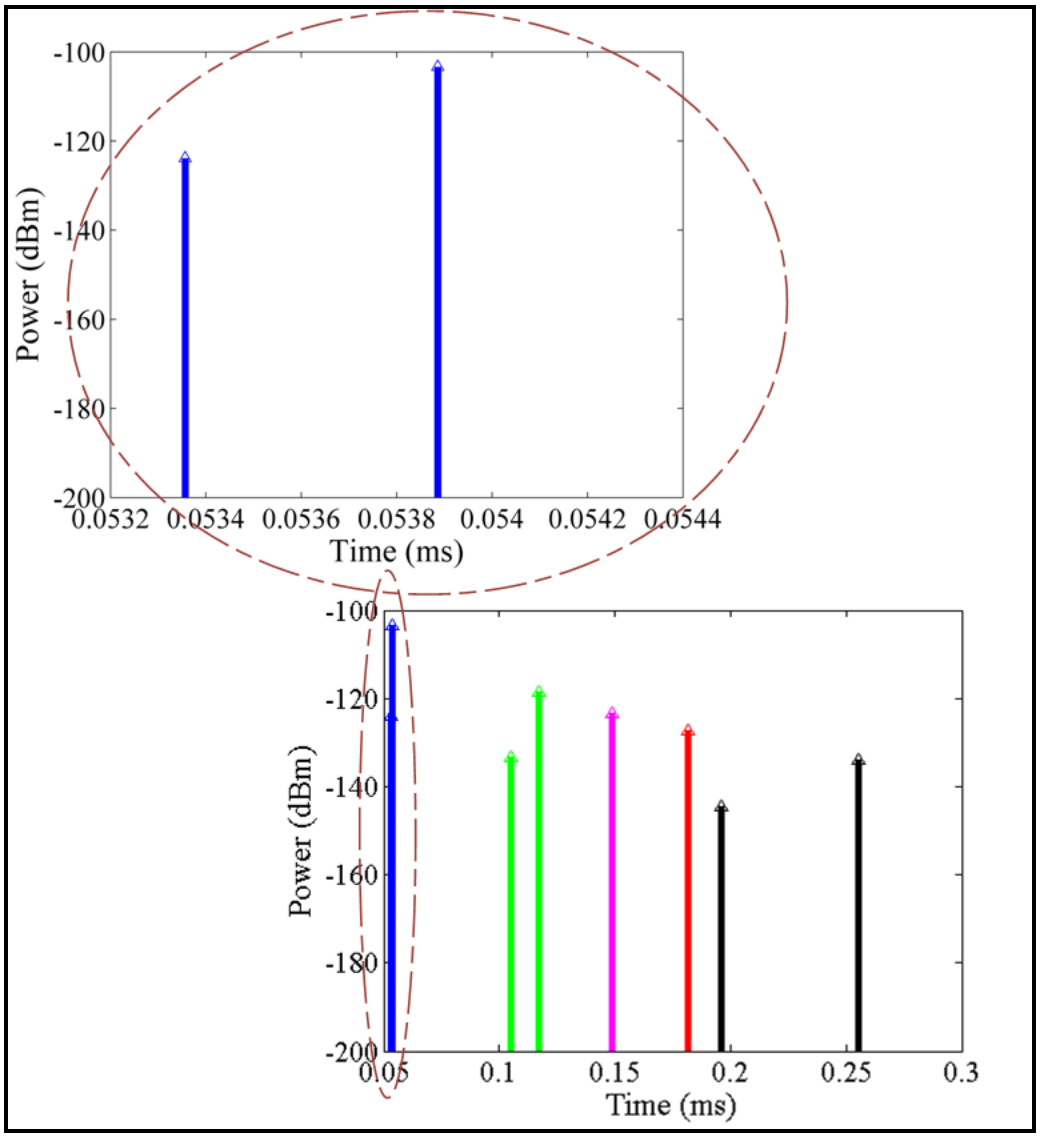
- Electric field created by transmitter
- Electric field at receiver antenna
- Received power
- Power Delay Profile
- Medium Delay
- Dispersion

3-D Ray Tracing (2/2)

Power Delay Profiles

Power Maps





Neural networks

Why?

- To lessen the burden of storing the data and computation for 3-D Ray–Tracing.
- To predict for the positions not visited by rays in Ray-Tracing.
- To adapt to the change in environment while learning from Ray-Tracing simulations.

Neural Network Architecture

*Two Hidden layer feedforward Neural network.

*First Layer :

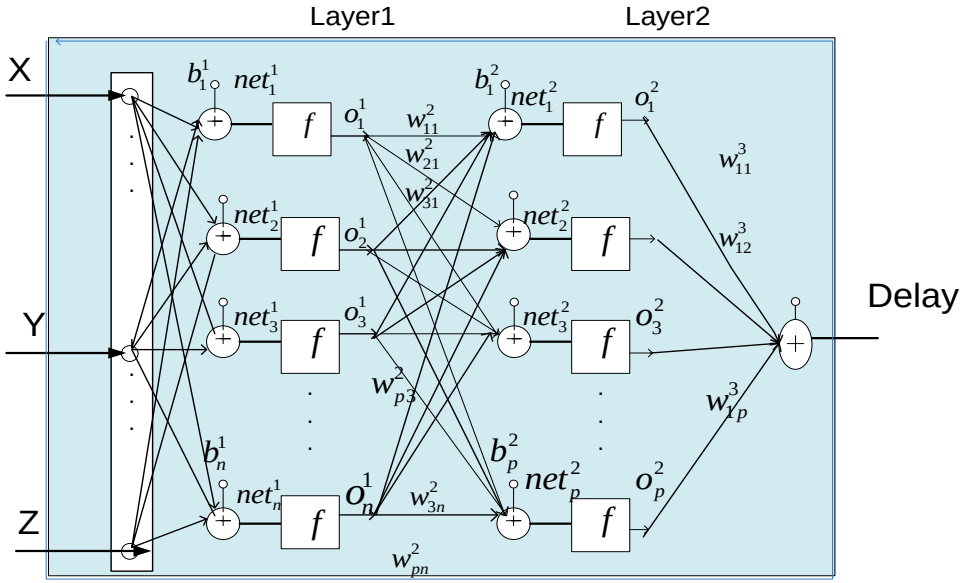
Activation function: $\frac{1}{1-e^{-x}}$

No. Of neurons: 4

*Second Layer:

Activation function: $\frac{e^{x}-e^{-x}}{e^{x}+e^{-x}}$

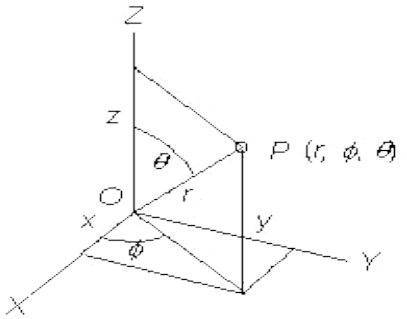
No. Of neurons: 17



*Inputs: Co-ordinates of point in the space.

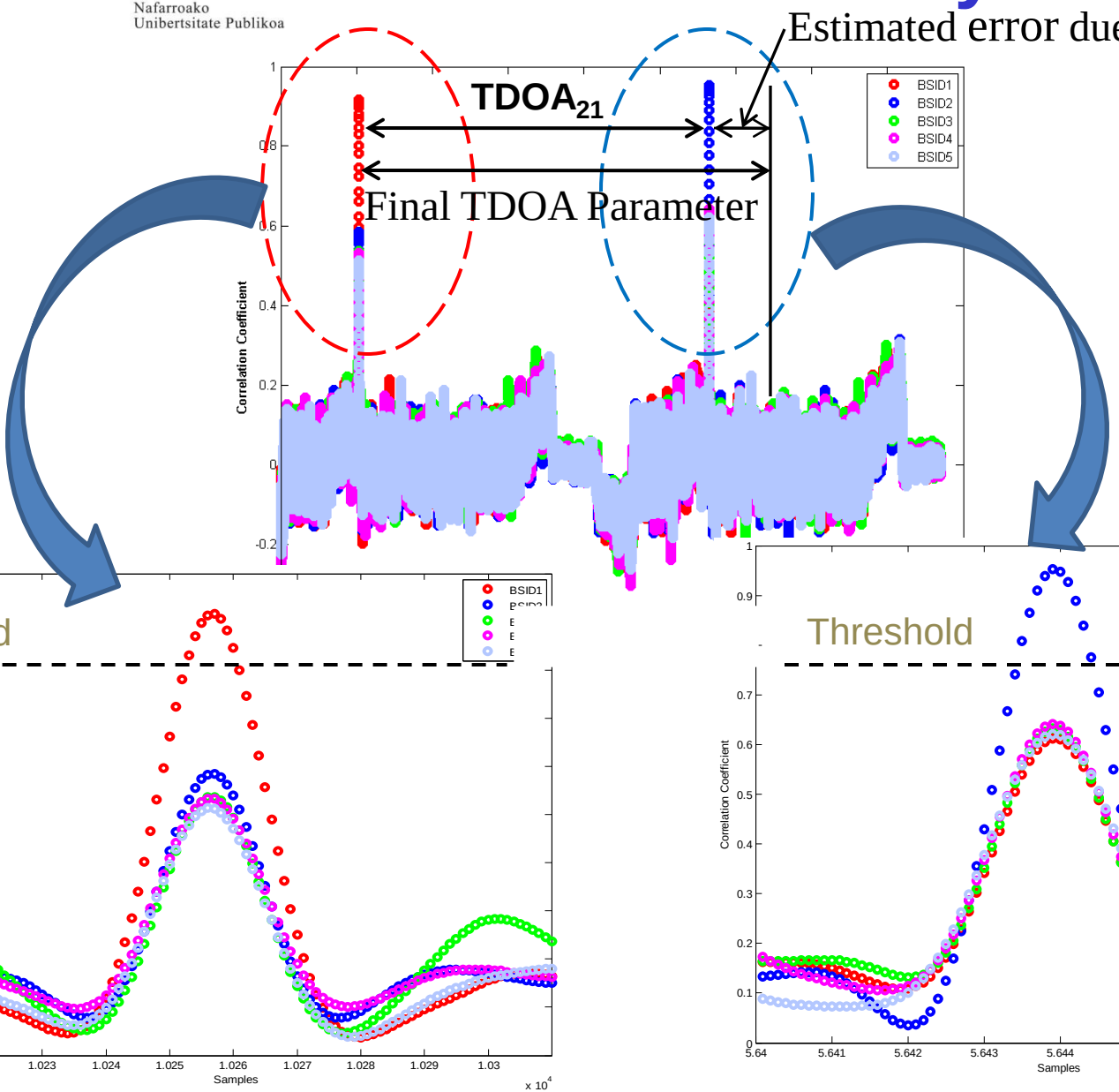
*Output: Delay error due to multipath.

*NN training uses Levenberg Marquardt Back Propagation algorithm for mean square error minimization.

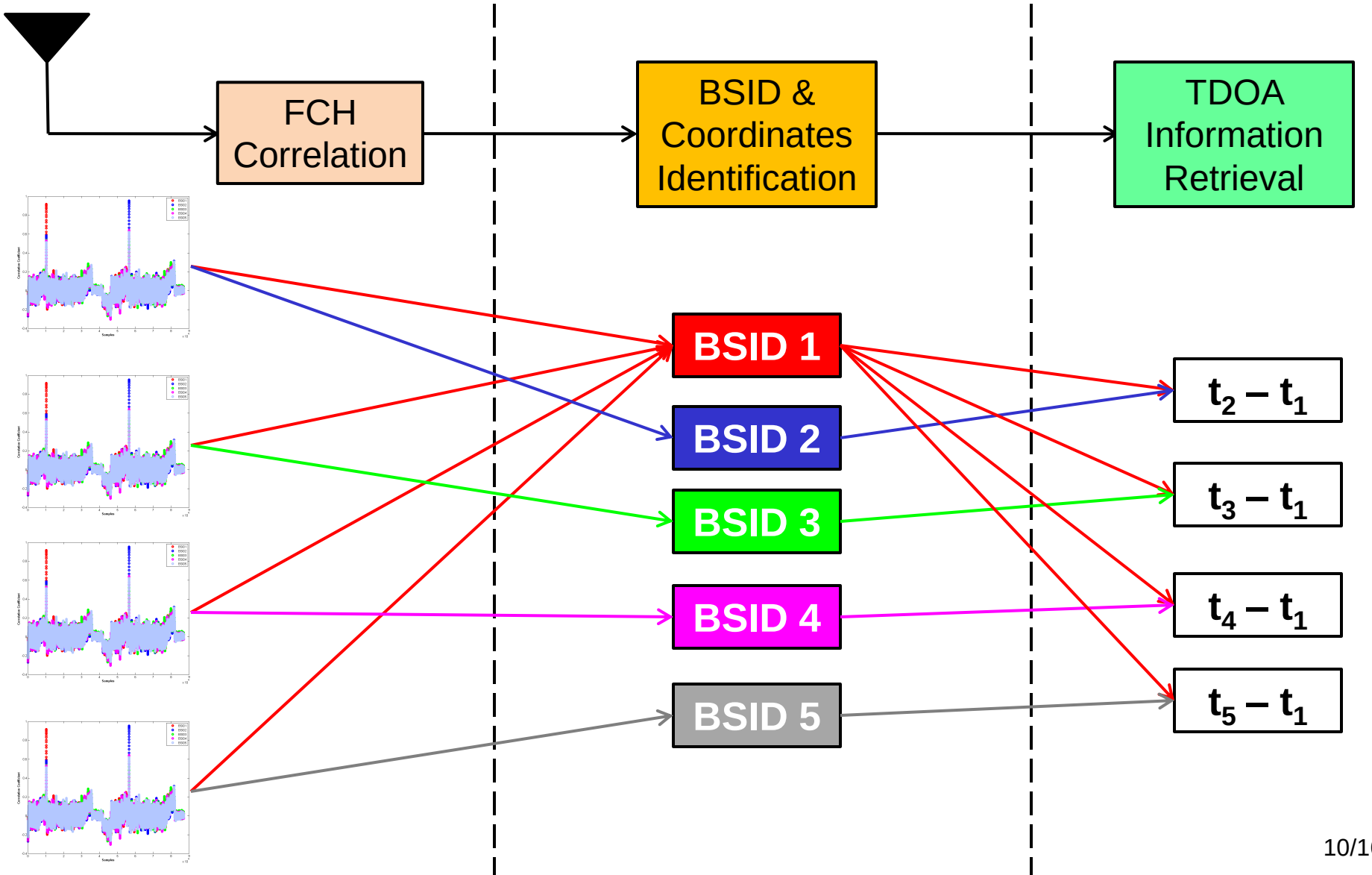


*Normalized mean square error (NMSE) of 0.018nS is achieved while trained network is used with another set of data from the same scenario, where maximum error is of 0.02nS.

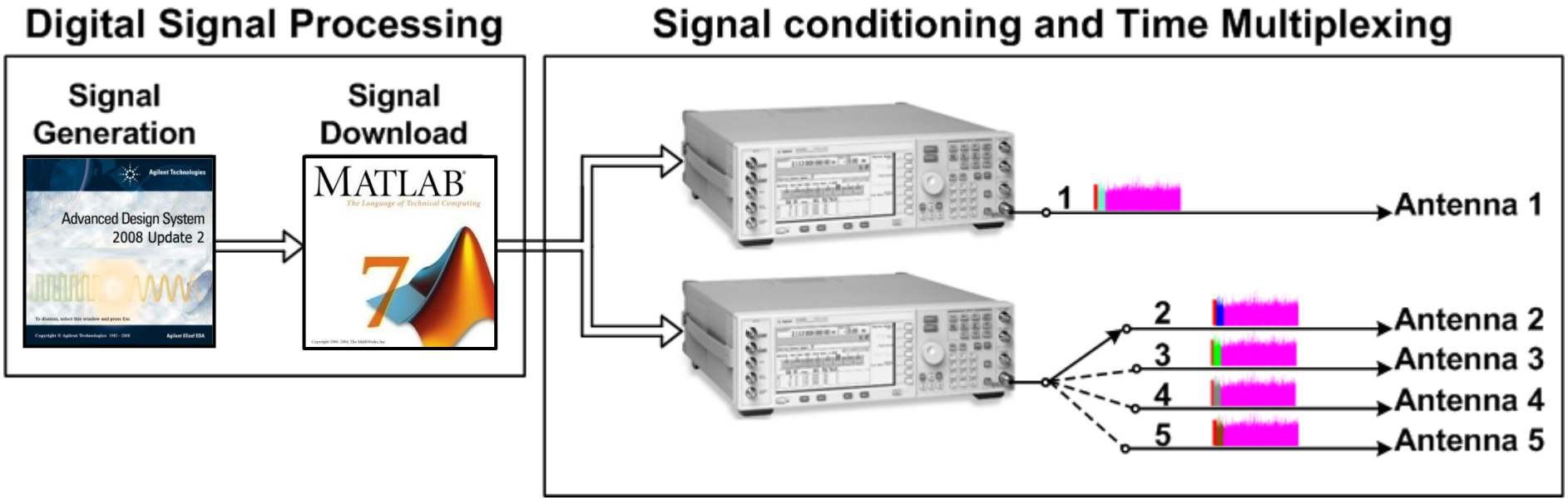
Waveform Analysis

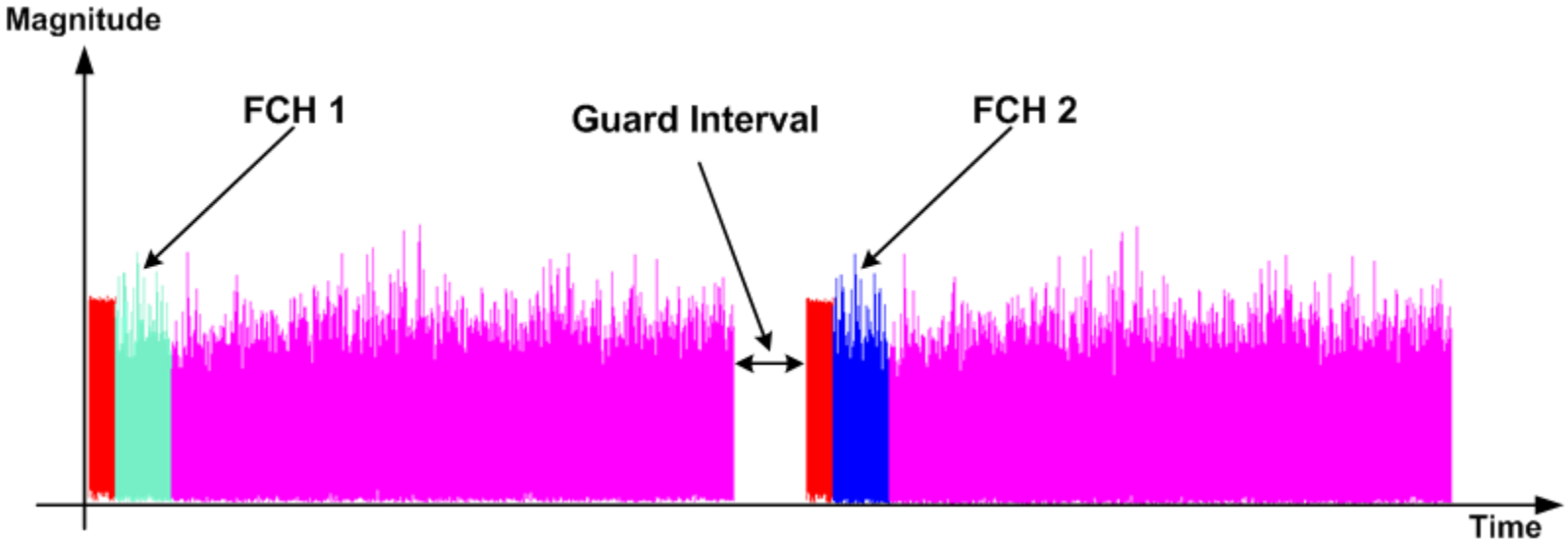


Waveform Analysis



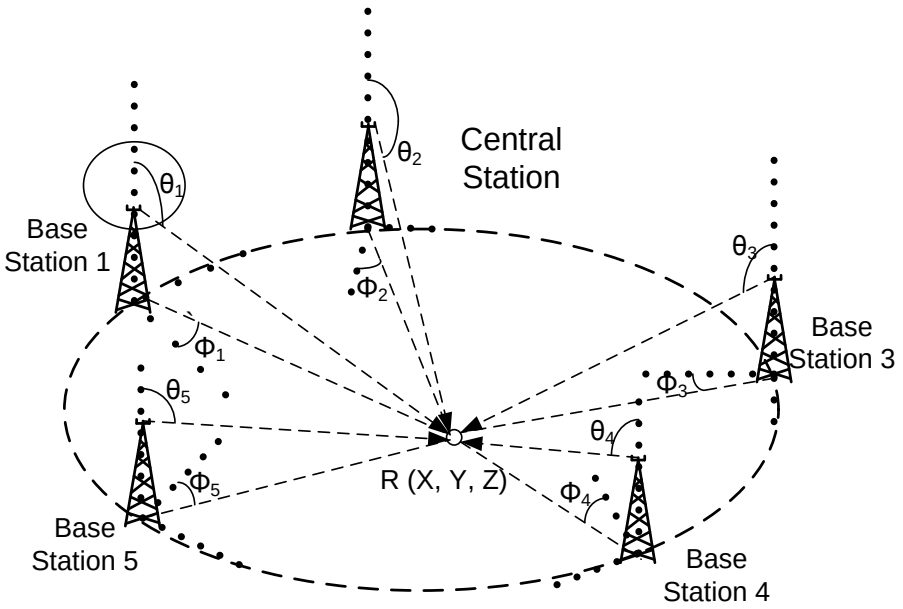
Waveform Synthesis





Proposed Location Estimation Improvement

1. Initial TDOA Based Position Estimation
2. Multipath Characterization :
   - Ray Tracing
   - Neural Network
3. Broadcasting of error due to multipath to receiver.
4. Final TDOA Based Position Estimation with multipath correction at receiver.



Experimental Setup

BS # 1

BS # 2

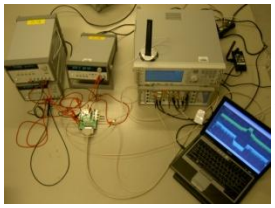
BS # 3

Hawking Antennas
- 2.4 – 2.5 GHz
- 7 dBi gain

Mobile Node

MAX2830 RF Transceiver
- 2.4 – 2.5 GHz zero-IF
- OFDM compatible
- -75 dBm Rx Sensitivity
- Gain control interface

Agilent 89600 VSA
- 2 MHz -78 MHz



MAXIM

Agilent Technologies

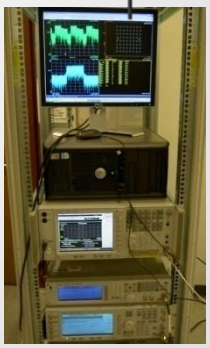
Receiver's Position

Central Node

Agilent E4440A VSA
- Up to 26.5 GHz
- 75 dB dynamic range

Agilent VSA Software
- 1 ms capturing window

Agilent E4438C ESG
- Up to 15 dBm 6 GHz



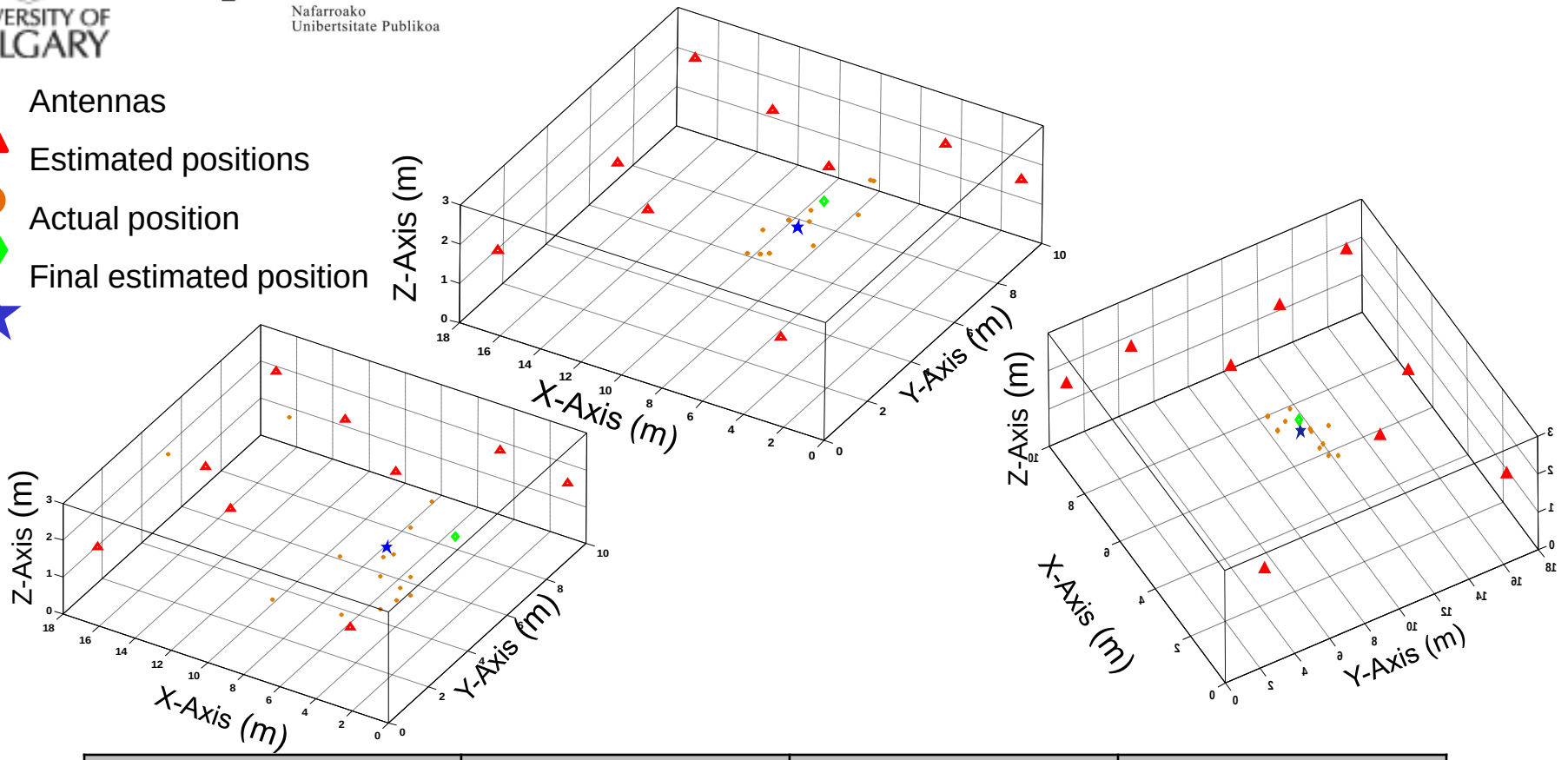
Agilent Technologies

BS # 5

BS # 4

Measurements' Results

- Antennas
- Estimated positions
- Actual position
- Final estimated position



Receiver Position	Error before multipath correction (m)	Error after multipath correction (m)	Error reduction
Position 3	0.8201	0.6017	26.63%
Position 2	2.6416	2.6063	1.34%
Position 1	2.5846	1.444	44.13%

Conclusions

- A method to improve the accuracy and performance of a ray-tracing algorithm using feed forward neural networks has been developed.
- The proposed algorithm is used to improve the position estimation using TDOA.
- The proposed method only needs a software upgrade in the device.
- It has been shown that with this method an error reduction up to 44.14% is achieved.
- We propose this method as an inexpensive solution to improve the location estimation of TDOA based algorithms for environments characterized such as emergency scenes and indoor environment.

University of Calgary
Public University of Navarre

Thank you for your attention