Machine Learning Based Source Reconstruction for RF Desensitization Analysis

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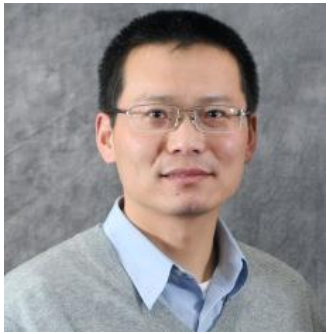
SPEAKER



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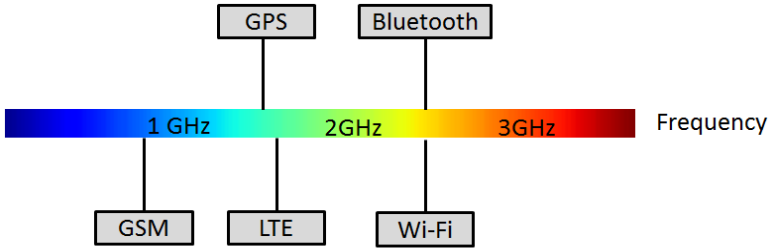
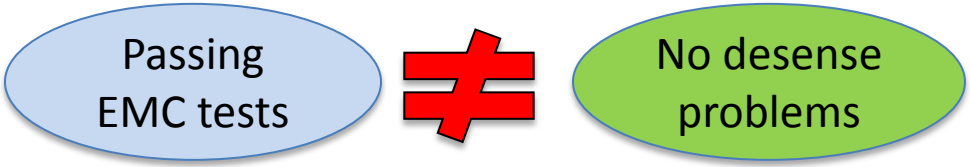
Problem

- RF desense problems are emerging rapidly with various wireless technologies.

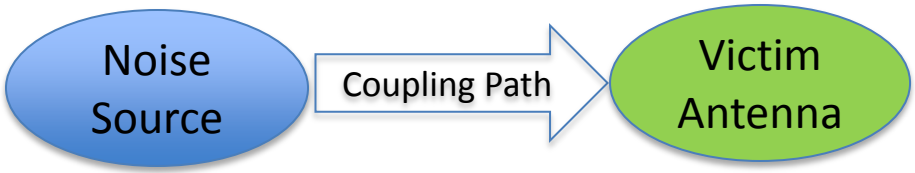


- Passing EMC tests doesn't not guarantee no desense problems.

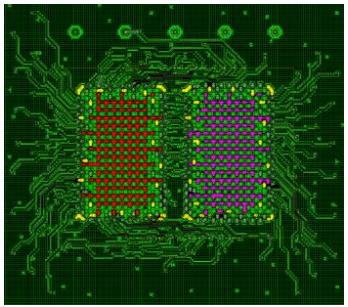


Noise Source Modeling

- An accurate modelling of noise source is the 1st step and to fully understand RF desense problem.



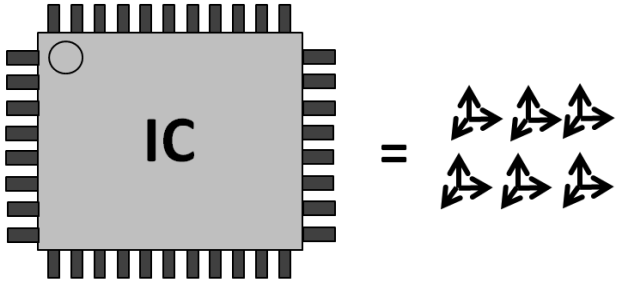
- Direct modeling of noise source, for example an IC, if often time-consuming and sometimes impossible.



Too complex !

Equivalent Dipole Moment Sources

- Dipole moments are widely used to model IC radiated emissions, equivalently.



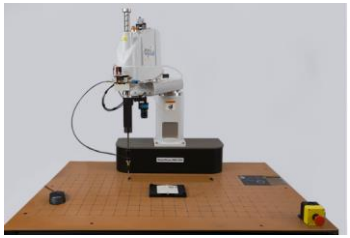
- Dipole moments are infinitesimal current segments(Electric dipoles), infinitesimal current loops (Magnetic dipoles)

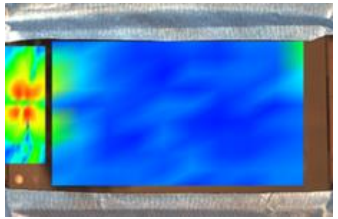
Electric dipole P_z

Current loop in XY plane, facing Z
Magnetic dipole M_z

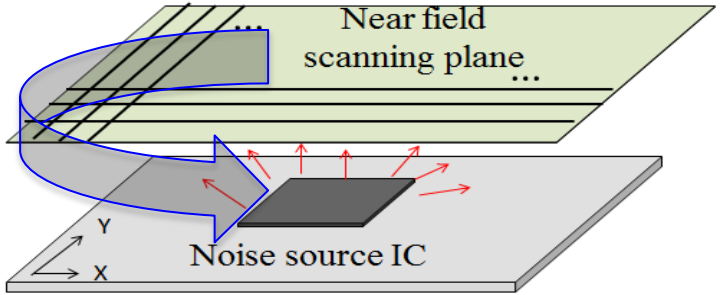
Near Field Scanning

- Near field scanning measurement is often performed to obtain the near field of the noise source.





- Based on the measured near field, the problem is solved backwards to obtain the equivalent dipole moments



Previous Methods

- Previous methods, like Least Square (LSQ) or optimization, are affected by parameter selections (such as number and locations of dipoles), choices of initial values, etc.
- Noise effect in practical measurements is another challenge to traditional method
- A more reliable method is needed.

$$\begin{bmatrix} f_1 \\ f_2 \\ \vdots \\ f_n \end{bmatrix} = \begin{bmatrix} T_{11} & T_{12} & \cdots & T_{1k} \\ T_{21} & & & \\ \vdots & & \ddots & \vdots \\ T_{n1} & & \cdots & T_{nk} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_k \end{bmatrix}$$

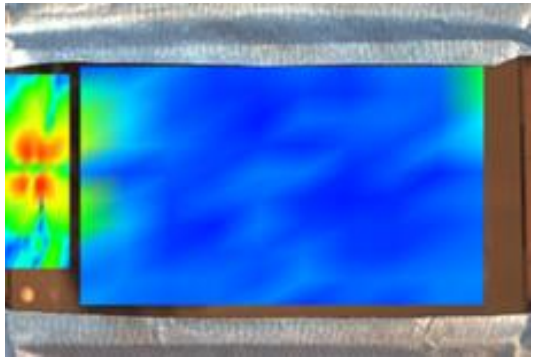
$$H = [B_n - F_n][B_n - F_n]^* = \left\| T_{nk}\hat{X}_k - F_n \right\|^2$$

$$\hat{X}_k = \left[T_{nk}^* T_{nk} \right]^{-1} T_{nk}^* F_n$$

LSQ

A New Perspective

- Our problem: Given the near field picture, what's the radiation source ? Can we "recognize" dipole moments ?
- A typical pattern recognition problem: what's inside the picture?
- Two problems are similar: extract accurate information from a picture.



Near field picture

A table with a chair

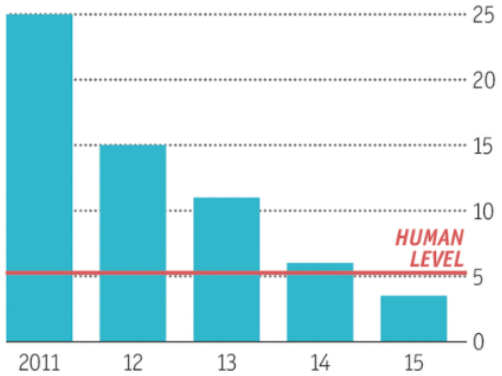
Recent Progress in Pattern Recognition

- Recent machine learning algorithms can achieve a very small error rate for computer vision or pattern recognition in a large dataset.

ImageNet Dataset

Ever cleverer

Error rates on ImageNet Visual Recognition Challenge, %



Sources: ImageNet; Stanford Vision Lab

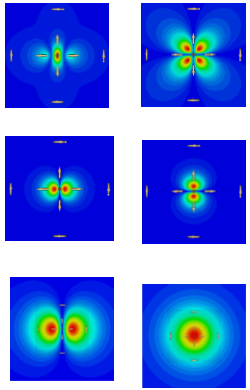
Our Objective

- Develop a machine learning algorithm with the training set from a few simple dipole moment s. After the training, the algorithm can extract primary dipole moments from a new and more complex field pattern.

Px

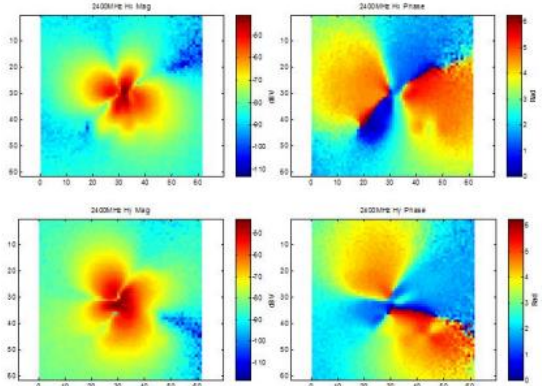
Pz

Mx



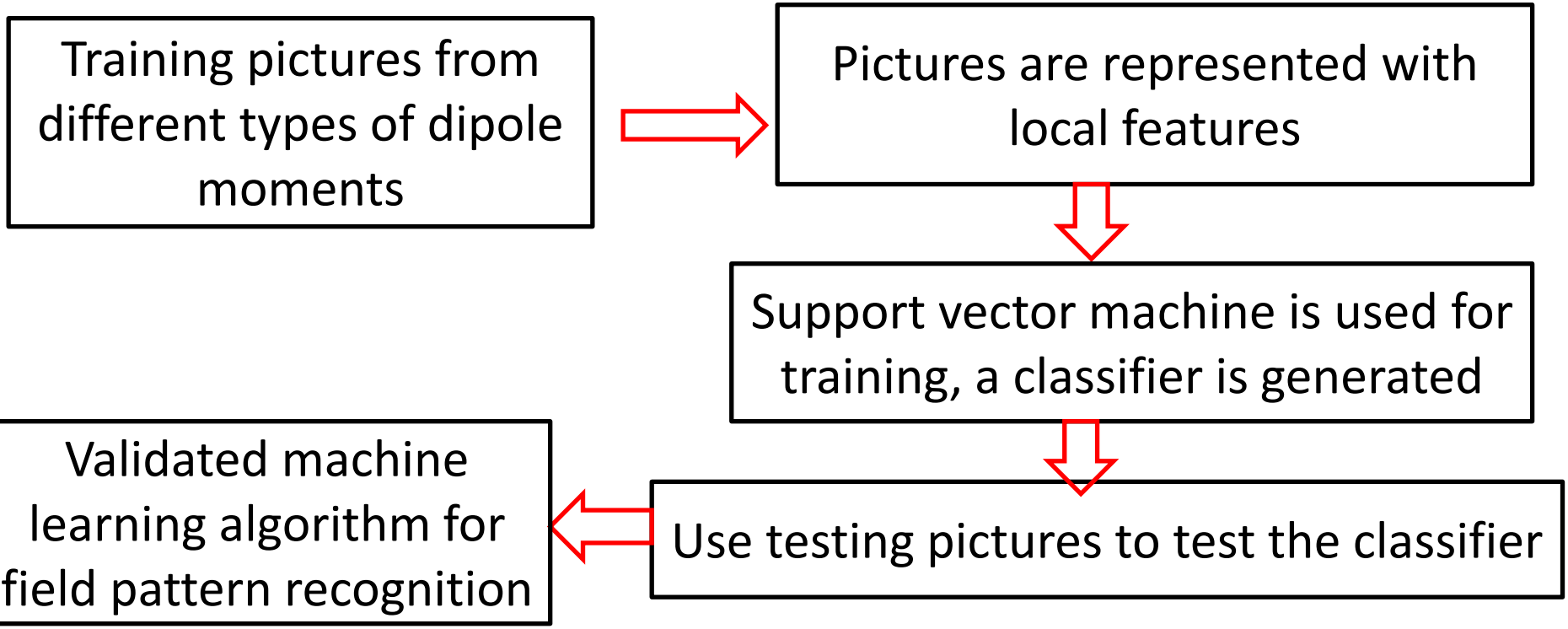
and a lot more

machine learning



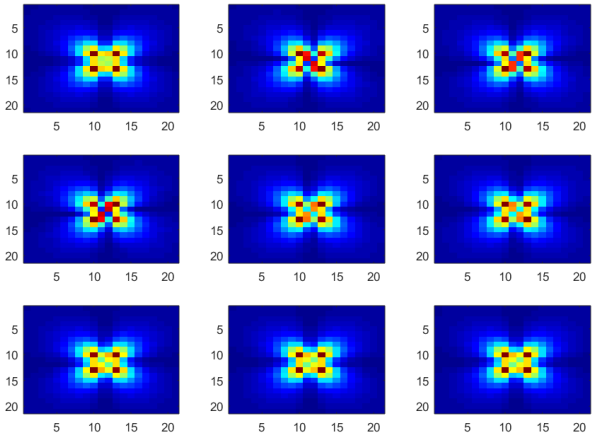
Field patterns of a real IC

High-Level Flow of Machine Learning Algorithm



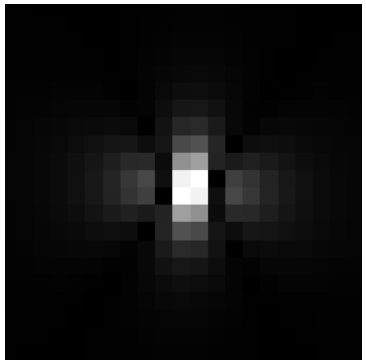
Training Pictures

- The training set is 600 field patterns from 6 basic dipole moments.
- They are generated from analytical formulas.
- Random noise is added to generate pictures with small variations.

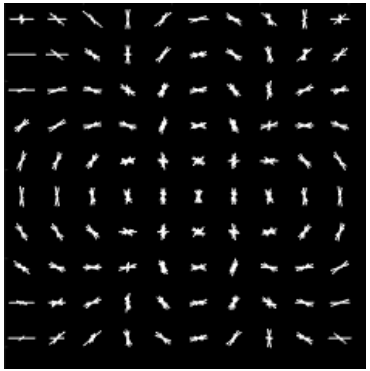


Local Feature Detection and Extraction

- Local features are the building blocks of many computer vision algorithms. In this study, HOG is used.
- HOG features are used to classify different types of dipole moments

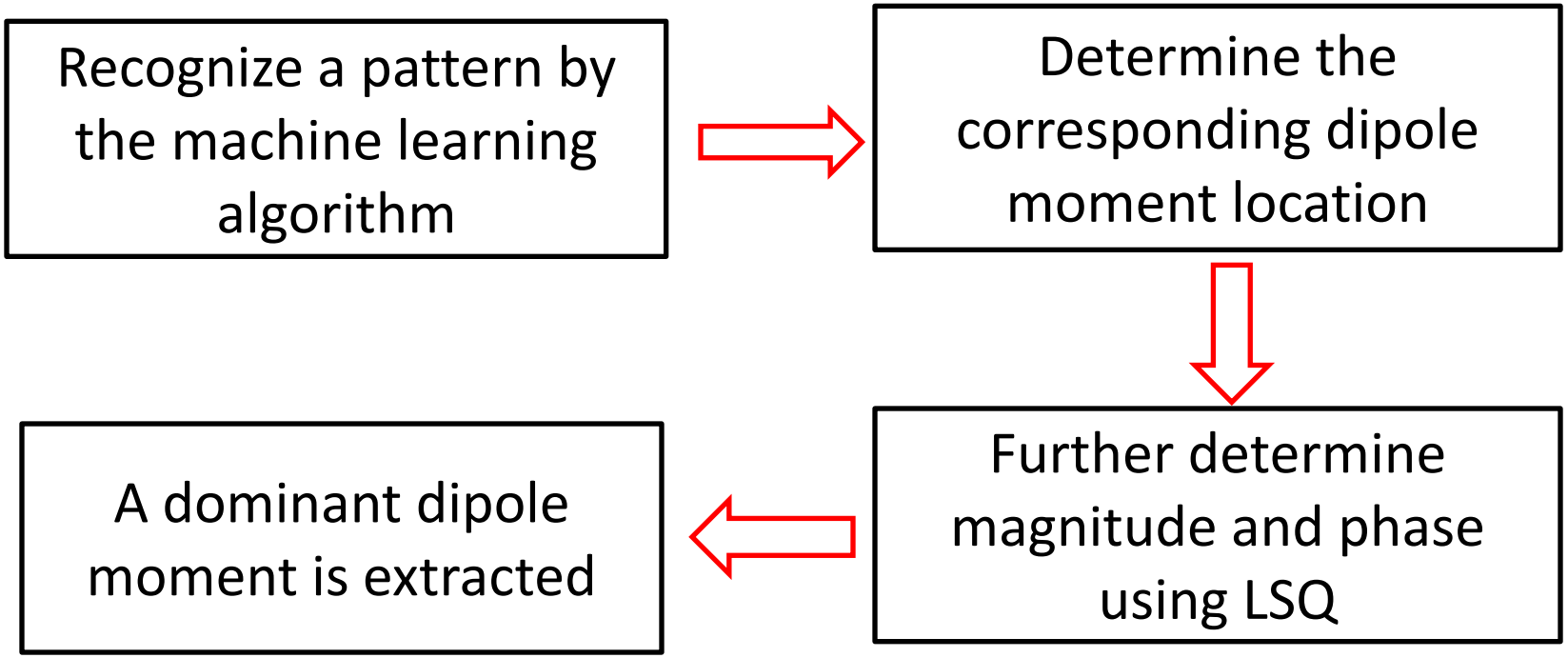


Original picture



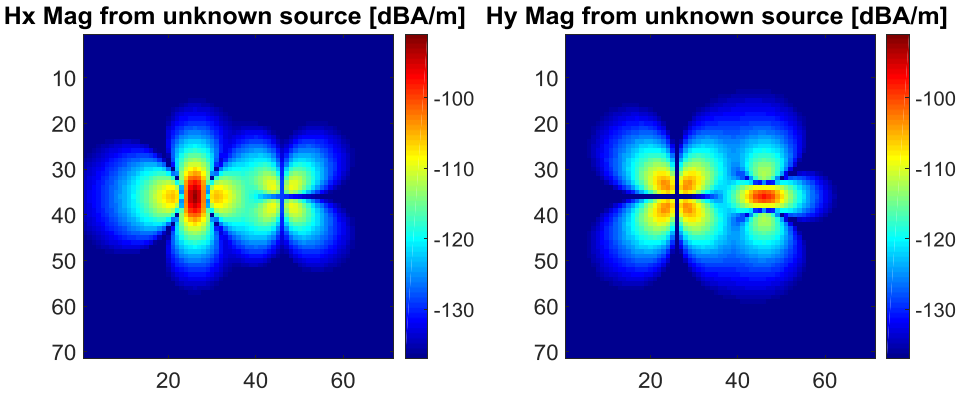
HOG features

Flow Chart of Remaining Steps

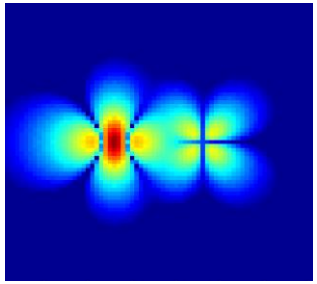


Case Study 1

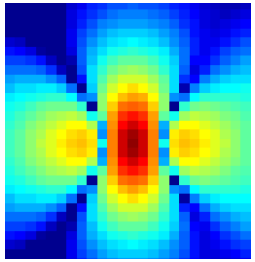
- Hx and Hy are shown below for an unknown source.
- If counting hot spots, there are at least 7-8 radiation sources.
- The proposed machine learning method generates the minimum number of dipole moments.



Workflow of Source Reconstruction

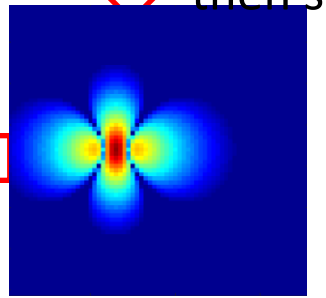


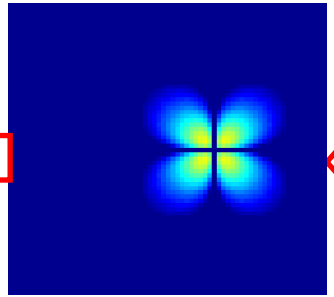
Pick out first pattern



Through machine learning, the main dipole type is obtained

Determine location and then solve LSQ





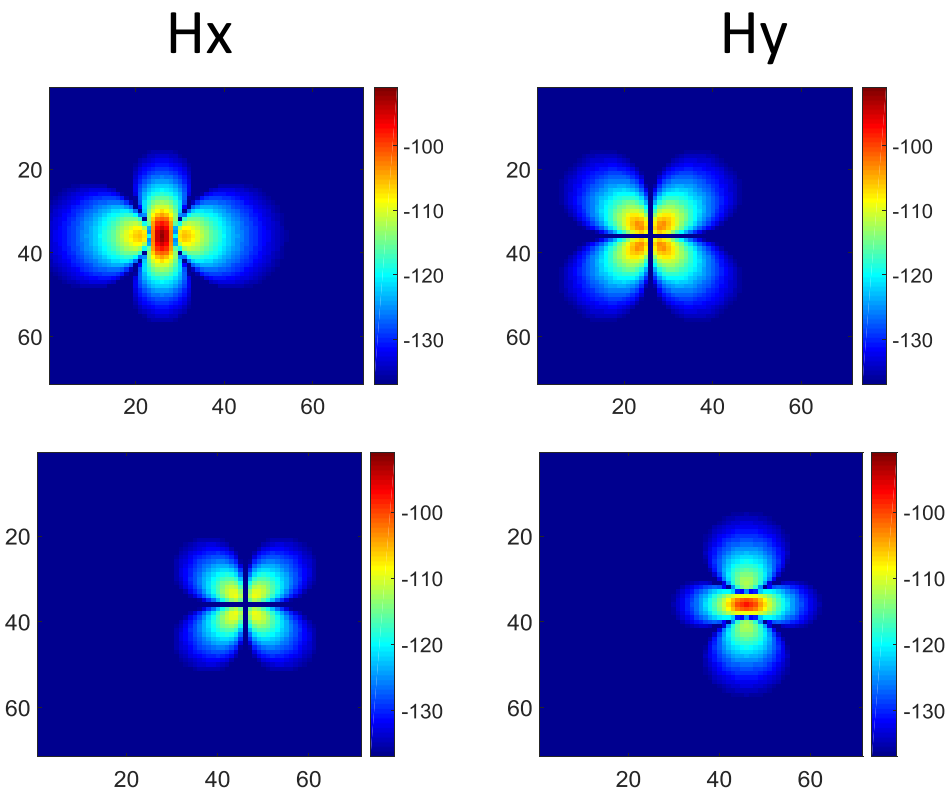
New picture =Original – first dipole

Through machine learning, another dominant dipole type is obtained

Second dipole

Reach error limit, stop

Extracted Dipole Moments

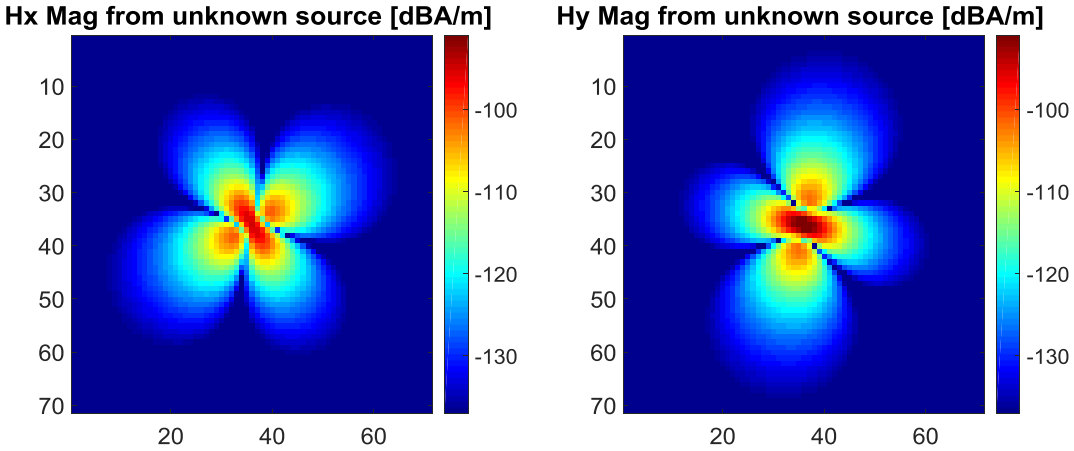


Fields of the most dominant dipole moment - Mx.

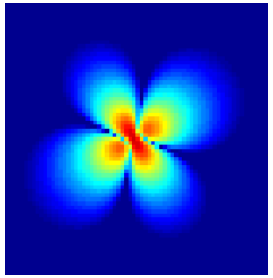
Fields of the 2nd most dominant dipole moment - My.

Case Study 2

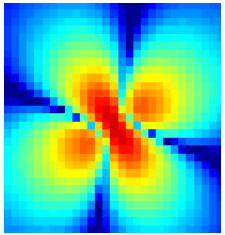
- Hx and Hy are shown below for an unknown source.
- The pattern below can not be easily recognized.
- Our method can still work.



Workflow of Source Reconstruction

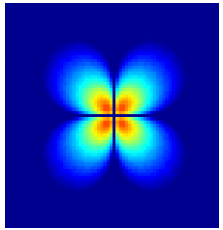


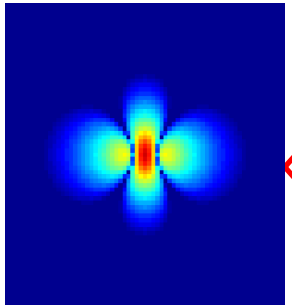
Pick out first pattern



Through machine learning, the main dipole type is obtained

Determine location and then solve LSQ





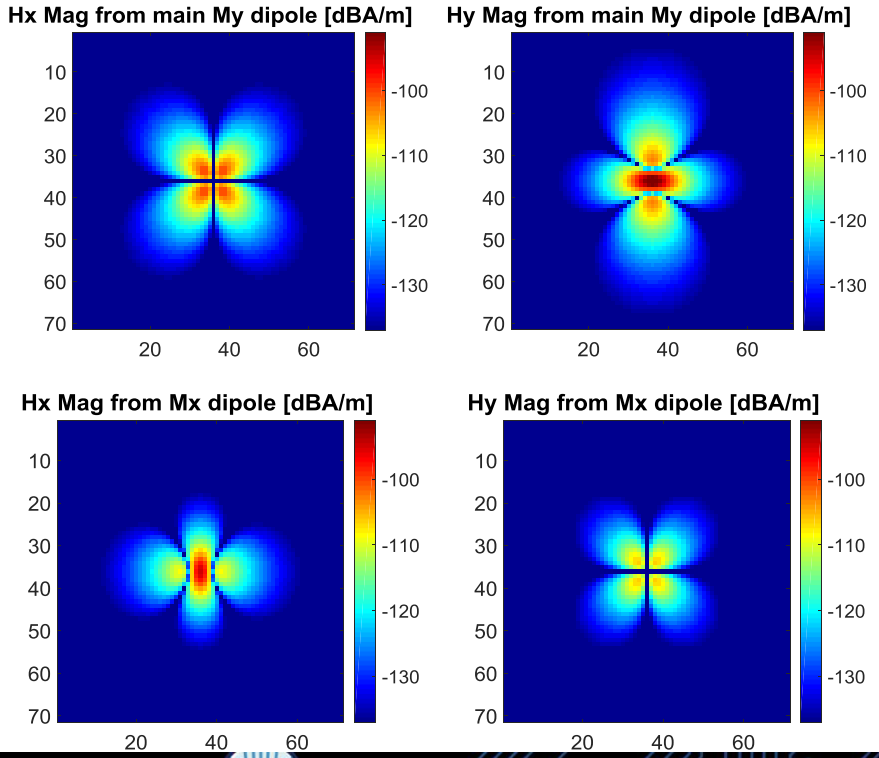
New picture =Original – first dipole

Through machine learning, another dominant dipole type is obtained

Second dipole

Reach error limit, stop

Source is a My dipole + a Mx dipole

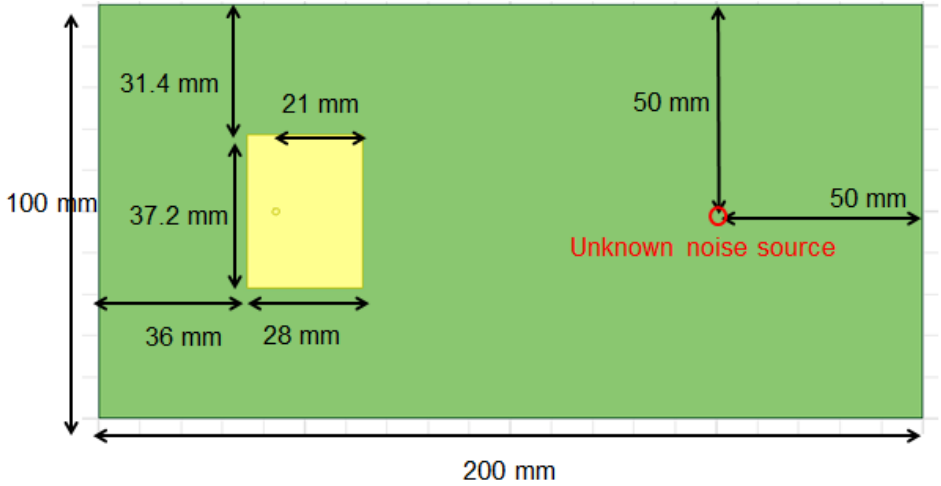


Fields of the most dominant dipole moment - My.

Fields of the 2nd most dominant dipole moment - Mx.

RFI from Unknown Source

- Assume the previous unknown source(case study 2) generates RFI noise in a victim antenna in the following example.
- The victim antenna is a 2.45 GHz WiFi patch antenna

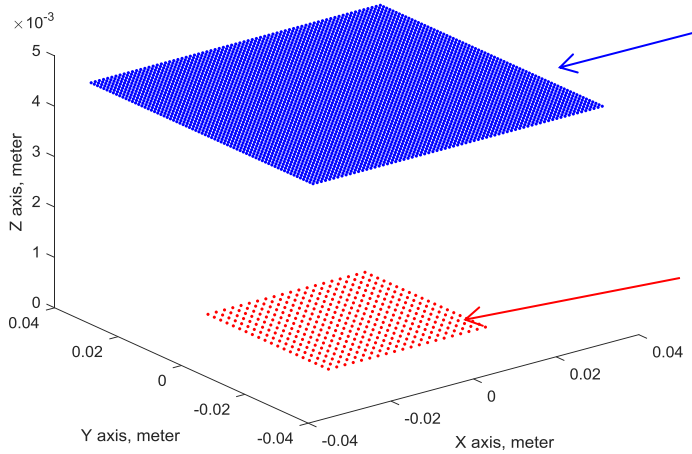


RFI Noise Estimation Using Reciprocity

- Based on previous work, forward problem and reverse problem are needed to predict the RFI noise from the unknown source to the victim antenna
- The unknown source is modeled using dipole moments based on near-field scanning
- The proposed dipole moment reconstruction method based on machine learning is compared to the conventional dipole moment reconstruction methods

Conventional Dipole Moment Reconstruction

- The unknown source is modeled with a dipole moment array that are extracted using the least square method. The total number of dipoles is chosen to be 20×20×3.

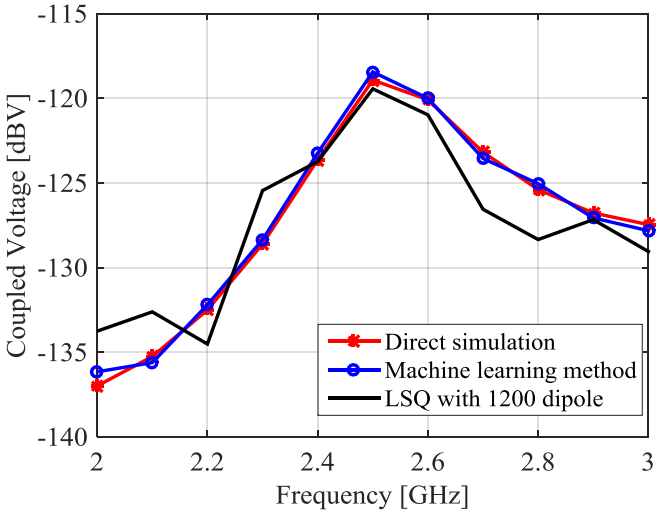


Scanned points

Locations of dipole moments. Each location has 3 types of dipoles:Pz, Mx,My

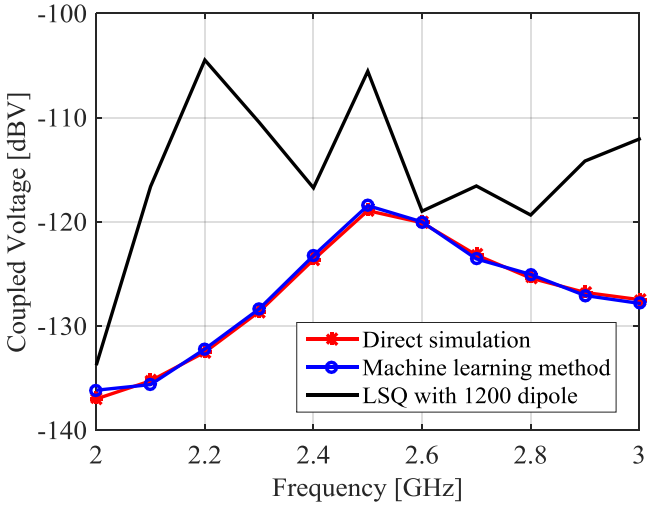
RFI Noise at Victim Antenna

- In this very ideal case, the proposed machine learning method agrees with the direct simulation very well.
- The conventional LSQ method is worse than the machine learning method.



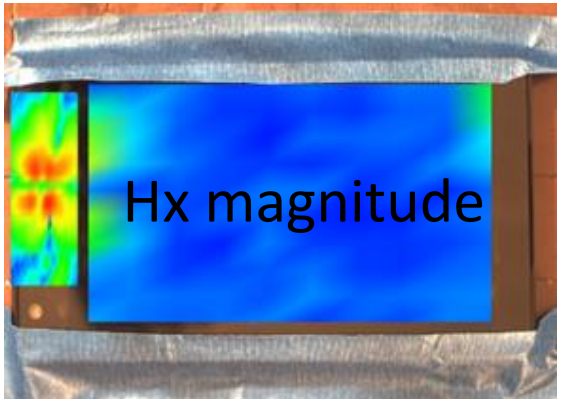
With Random Noise Added to Scanned Fields

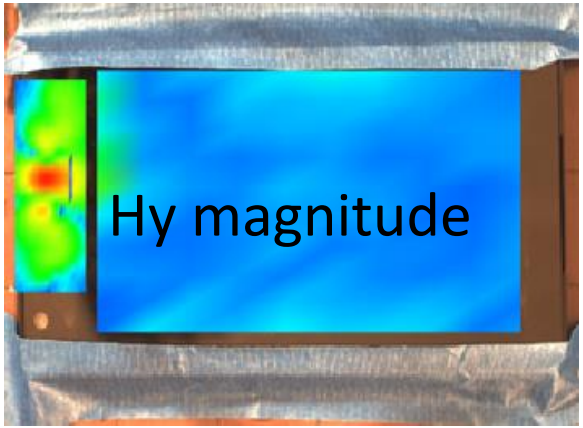
- The proposed machine learning method still works fine.
- The conventional LSQ method fails, as it is sensitive to noise especially when number of unknowns is large.



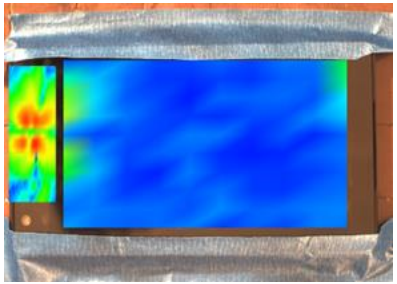
Case Study 3: A Measurement Example

- Near field of a cell phone LCD assembly is shown below.
- Use the proposed machine learning method, the dominant dipole moment is recognized as an My dipole.
- Knowing the source type provides a lot of insights.

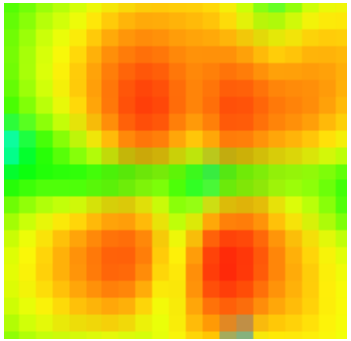




Workflow of Source Reconstruction

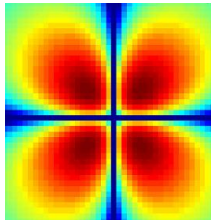


Pick out first pattern



Through machine learning, the main dipole type is obtained

Determine location and then solve LSQ

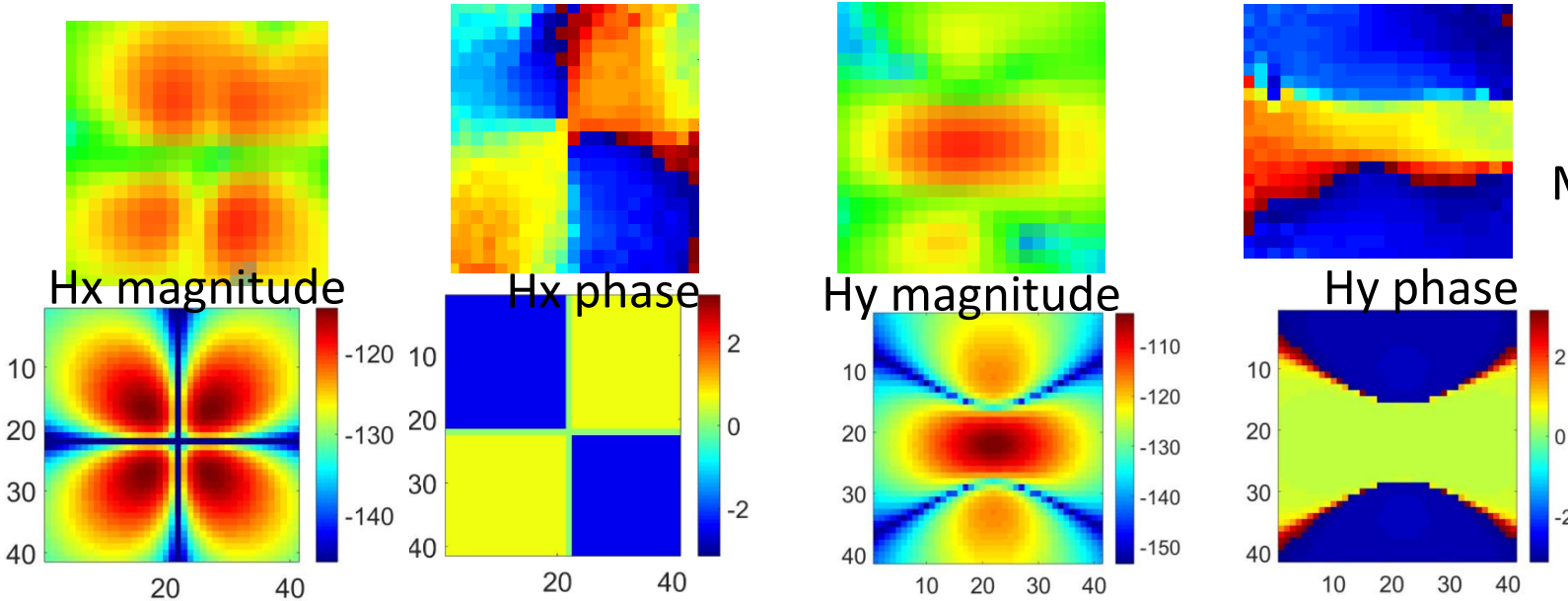


First dipole

Reach error limit, stop

Fields From Measurement and Proposed Method

- Using proposed method, magnitude and phase of H field can match between measurement and dipole moment.



Summary

- Machine learning is used to extract equivalent dipole moments for IC radiated emissions.
- Even for very complex sources, the method may be able to obtain the dominant dipole moments one by one.
- The proposed method has better accuracy and may be more reliable than traditional methods, like LSQ, in handling noise in practical cases.

Thank you!

QUESTIONS?