Simultaneous Localization of Multiple GNSS Interference Sources via Neural Networks

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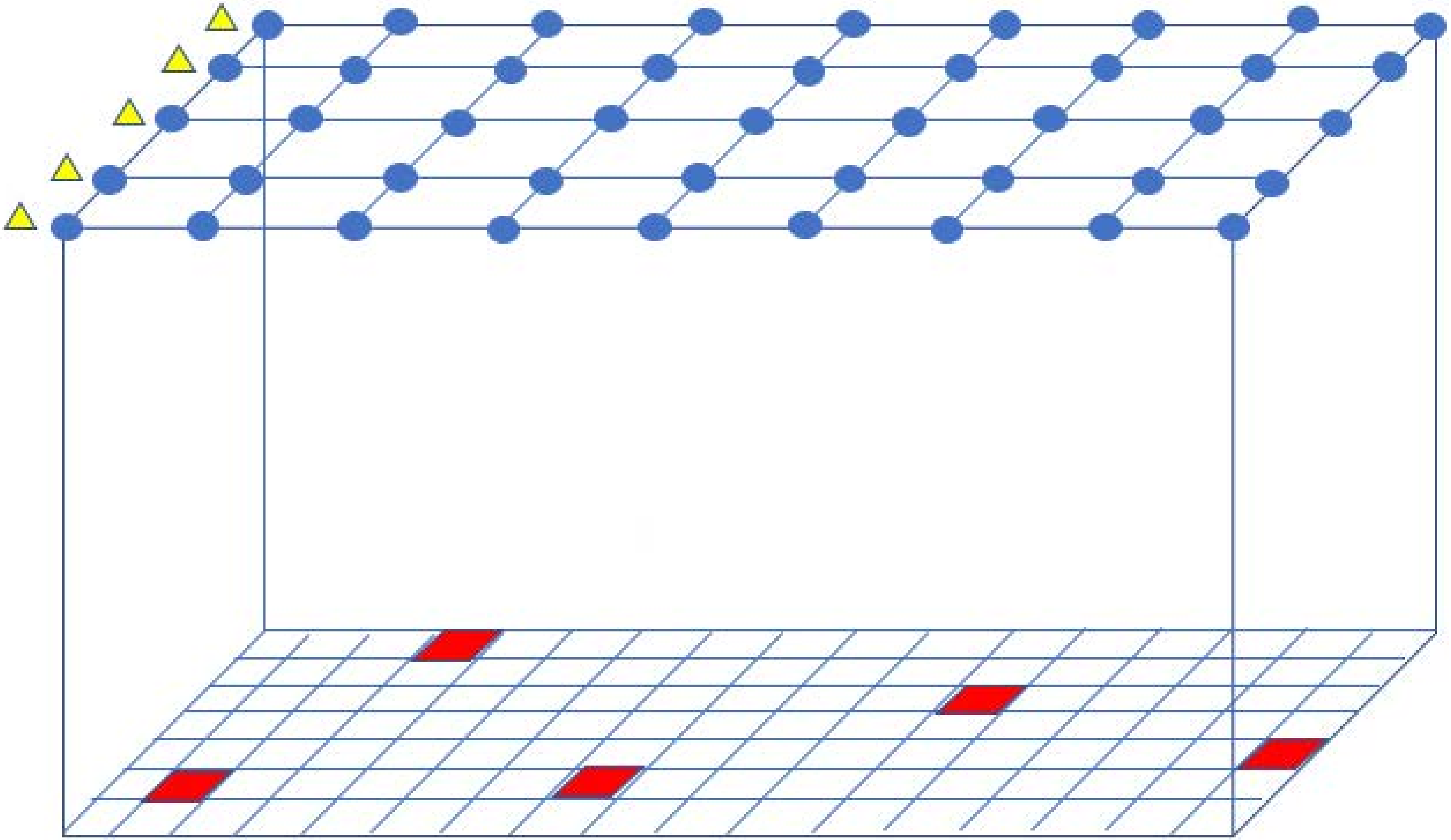
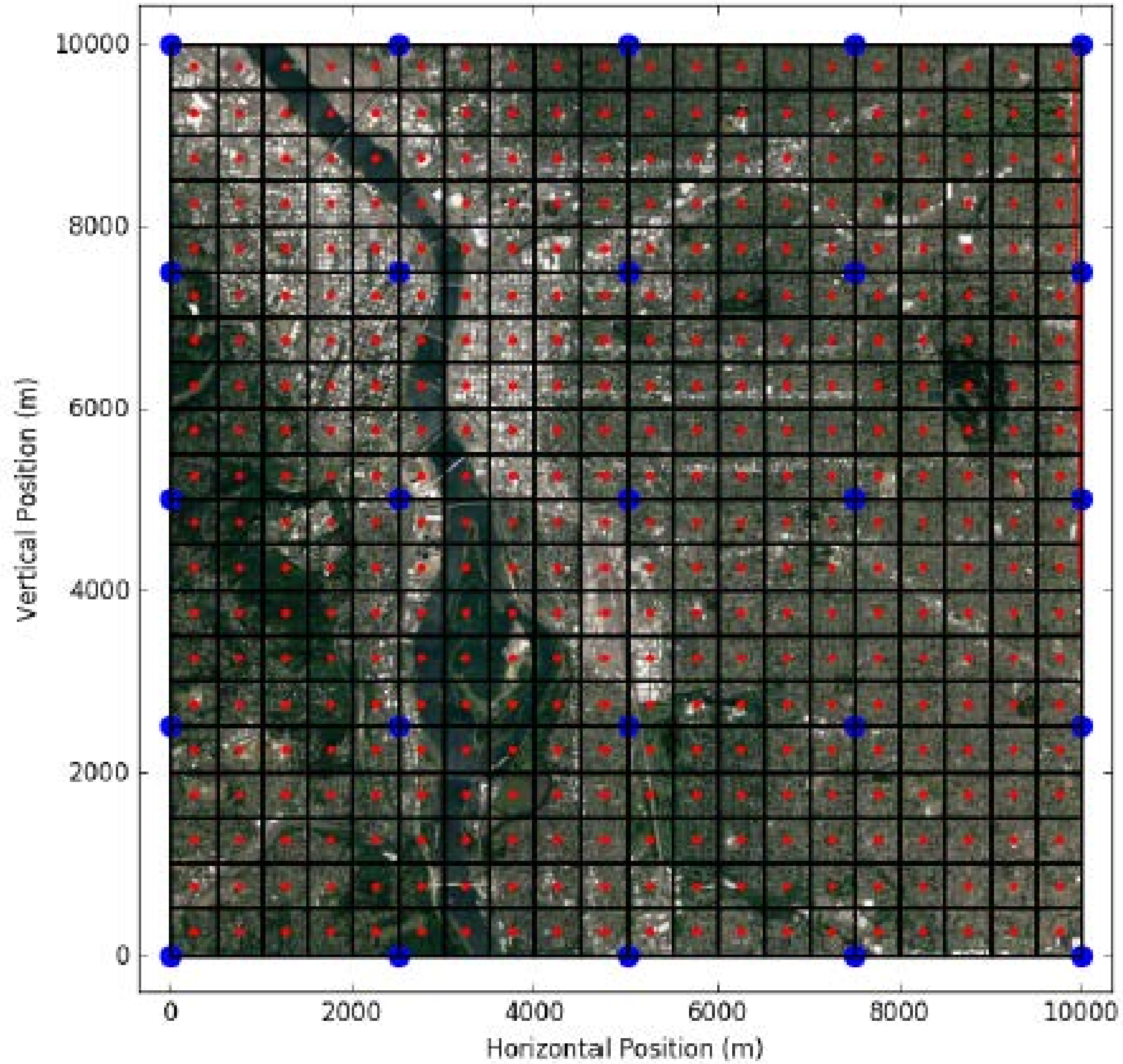
Overview

- Problem statement
- Overview of artificial neural networks and their applications
- Creation of training and test sets
- Performance metrics and analysis
- Inspection of trained neural networks
- Test cases
- Conclusion and Future work

Problem

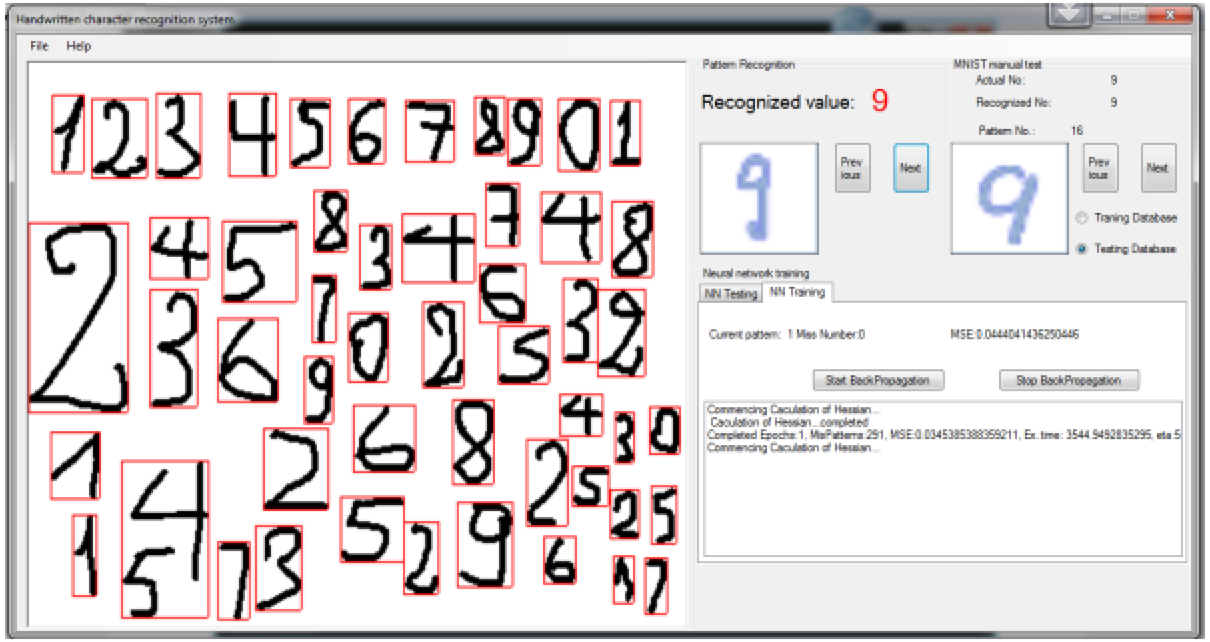


Real-world Context



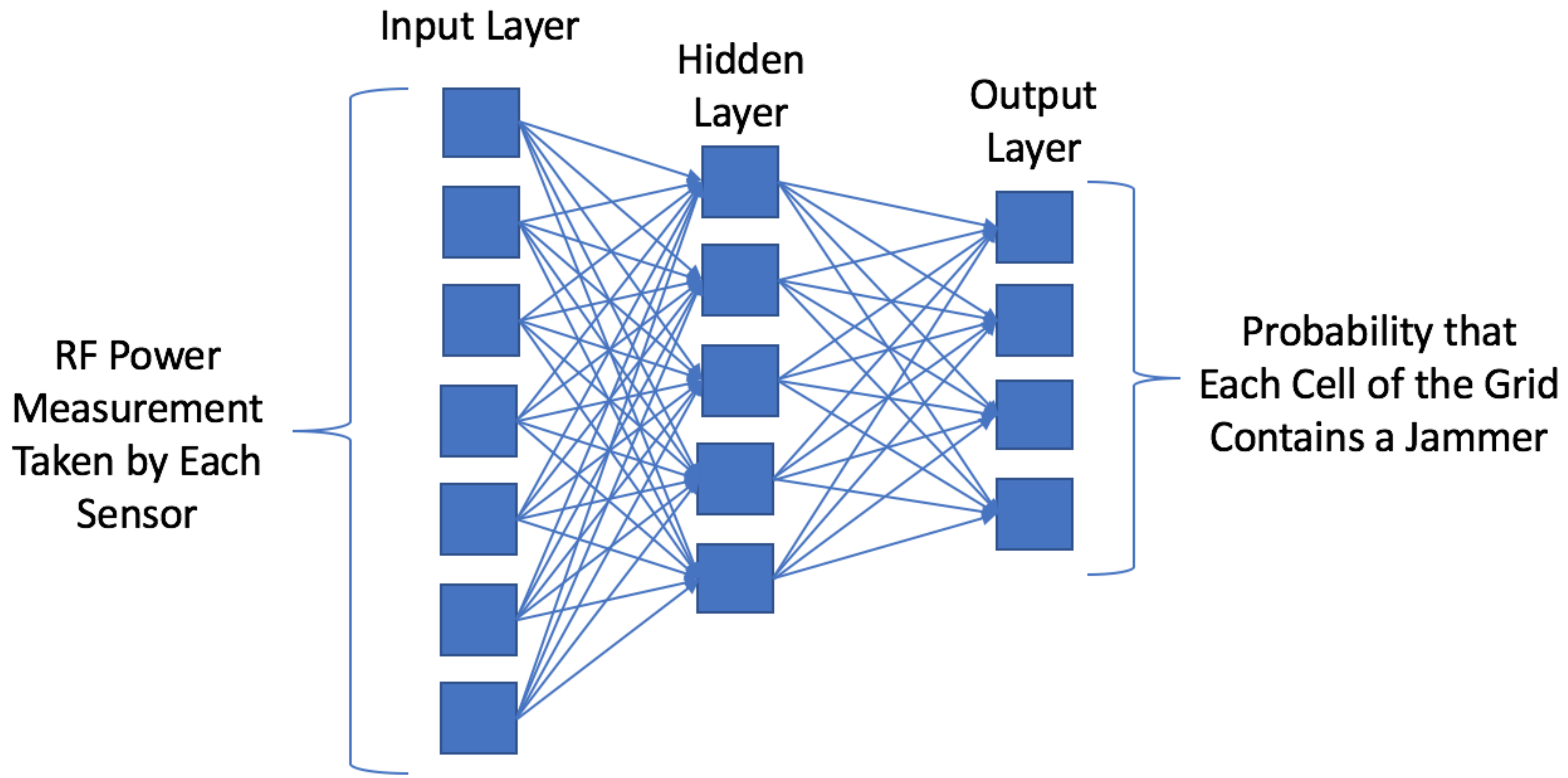
Neural Networks for Optical Character Recognition

https://kuanhoong.files.wordpress.com/2016/01/mnistdigits.gif

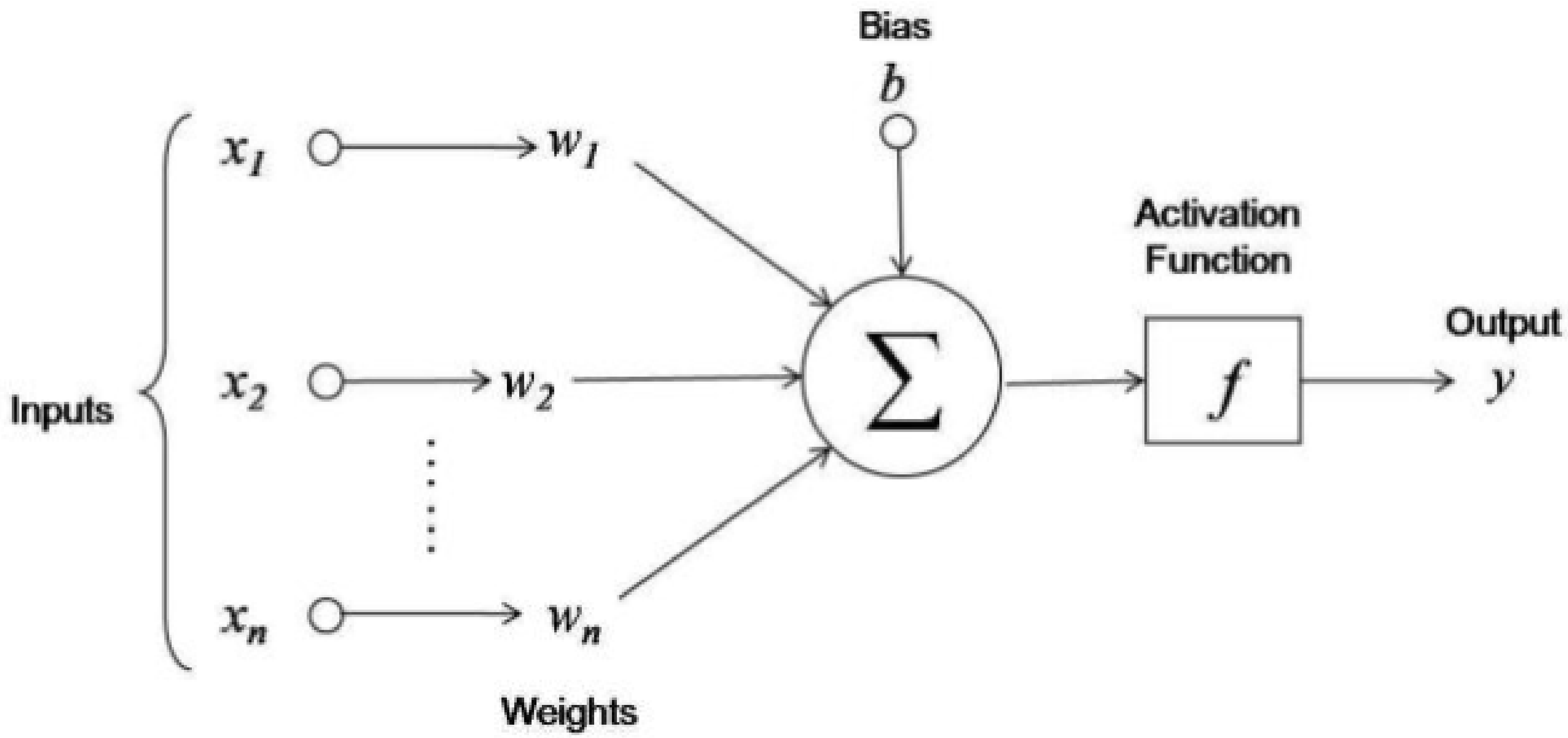


http://www.codeproject.com/KB/recipes/NNHandwrittenCharRecCs/image001_Small.png

Sample Neural Network Structure

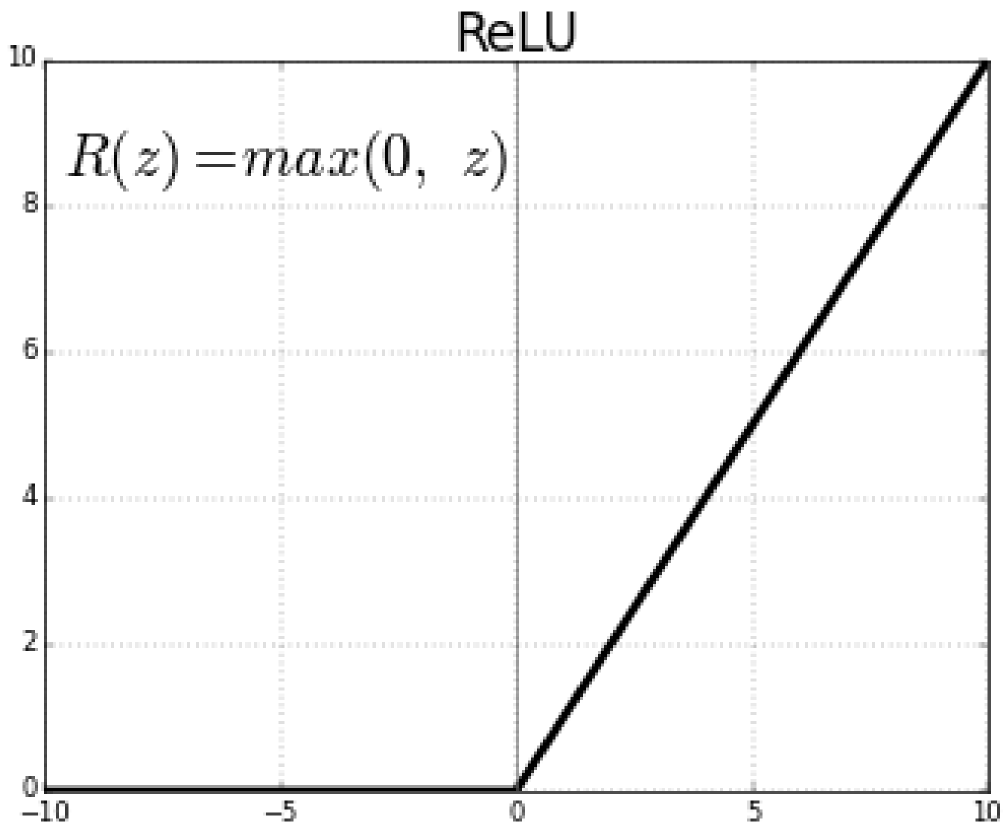


Artificial Neuron

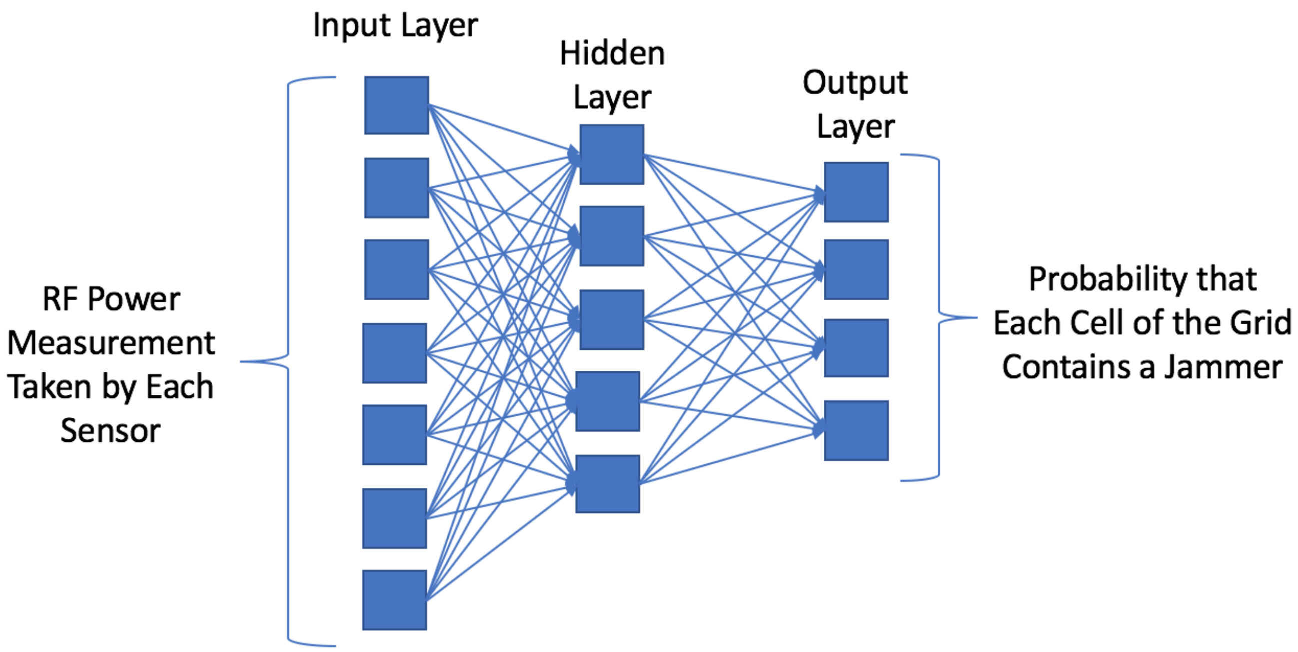


http://blanco.io/blog/machine-learning/neural-networks-and-backpropagation/

Activation Function



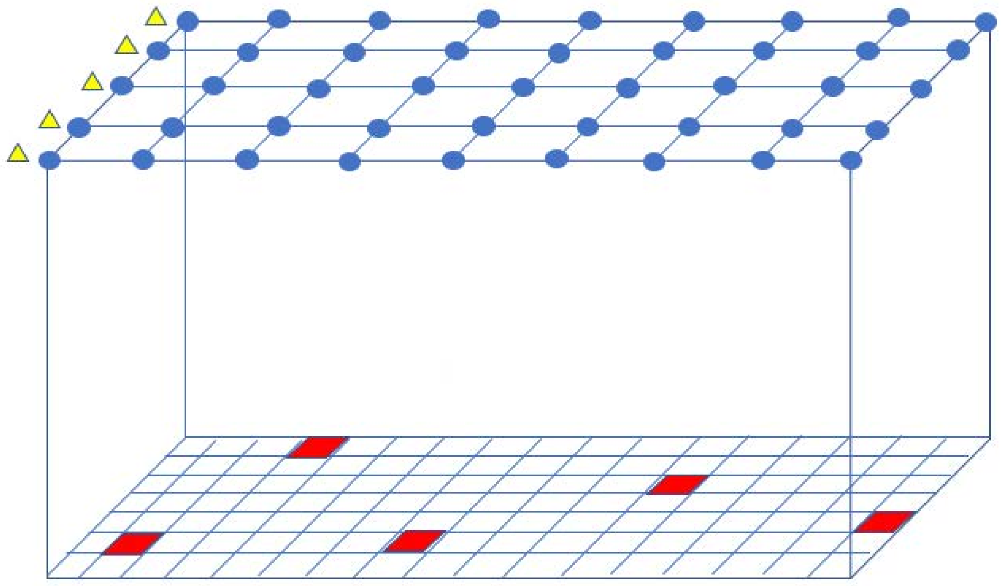
https://ml4a.github.io/images/figures/relu.png



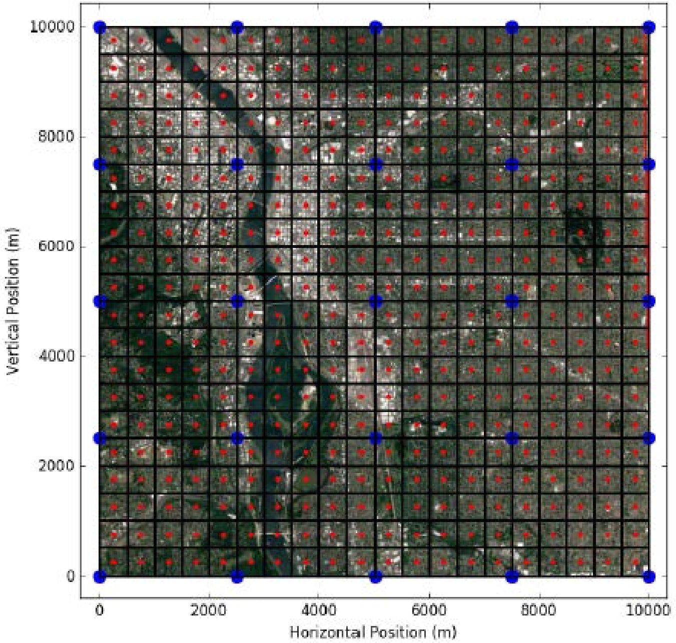
Creation of Training Sets

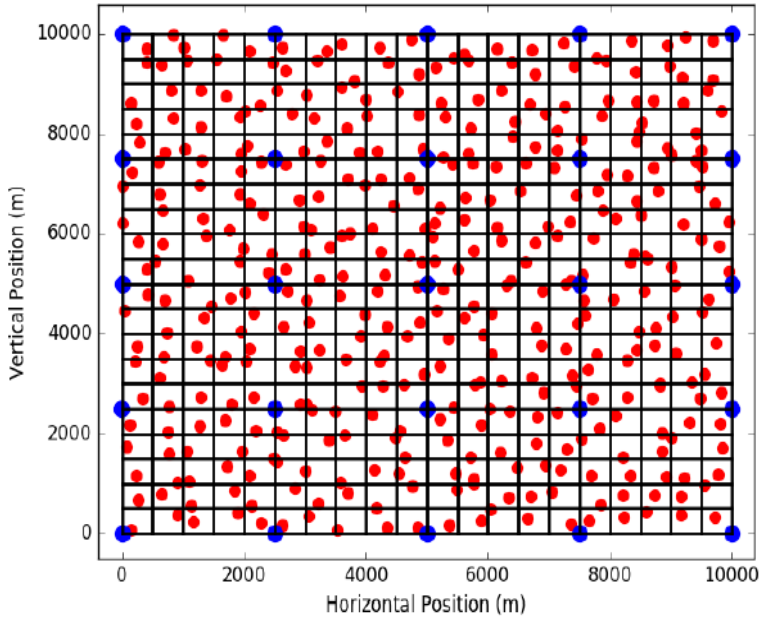
- Goal: Choose a representative sample of sets of training samples that contain different numbers of interference sources.
- Proposed Solution: Randomly select m samples of combinations sets of size [1,…,10] from a total pool of size ${}_{400}C_m$. For those samples, simulate the aggregate power measurements at 25 sensor positions.

m	Total Size of Training Set (n_c)	m	Total Size of Training Set (n_c)
10	490	1000	9400
30	670	3000	27400
100	1300	10000	90400
300	3100	30000	270400



Easy and Hard Training Sets





- Tx Power: 100 W
- Altitude: 0 m
- Position w/in Cell: Centered
- Sensor position error: 0 m

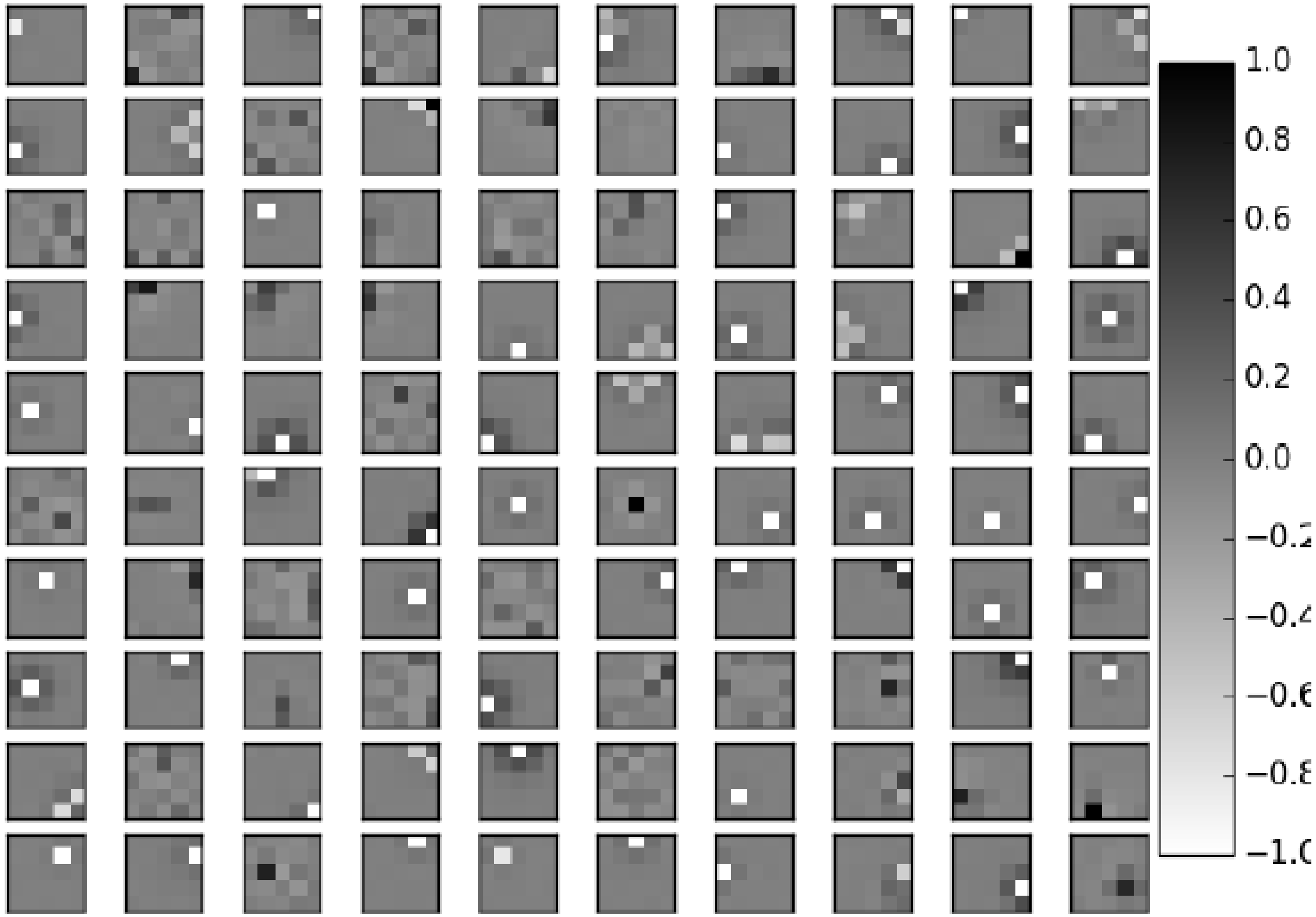
- Tx Power: Random ϵ [50,150] W
- Altitude: Random ϵ [-3,3] m
- Position w/in Cell: Random
- Sensor position error: Random ϵ [-2,2] m

Ok cool, but it’s hard to implement the neural network right?

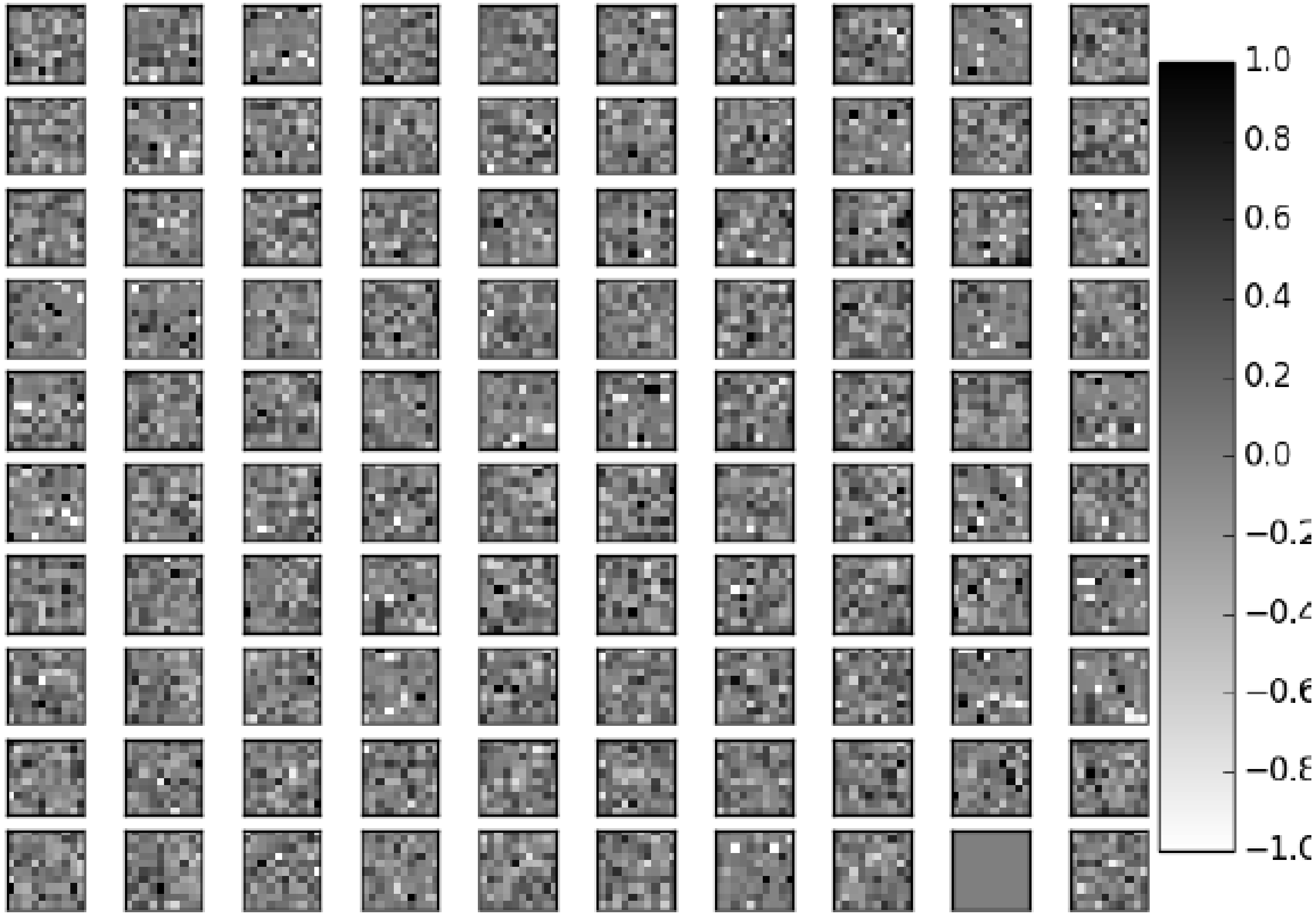
- Not with Python!

```
from sklearn.neural_network import MLPClassifier

mlp = MLPClassifier(hidden_layer_sizes=(100, 100, 100,), verbose=10, random_state=1, solver='adam',
    max_iter=1000) #create the pre-trained neural network

mlp.fit(X_train,y_train) #train the neural network with the training set

predictions = mlp.predict(X_test) #predictions are 1 if the probability is 0.5 or higher
predictions_proba = mlp.predict_proba(X_test) #predictions as raw probabilities
predictions_log_proba = mlp.predict_log_proba(X_test) #predictions as probabilities on a log scale
```

First Hidden Layer of Trained Neural Network

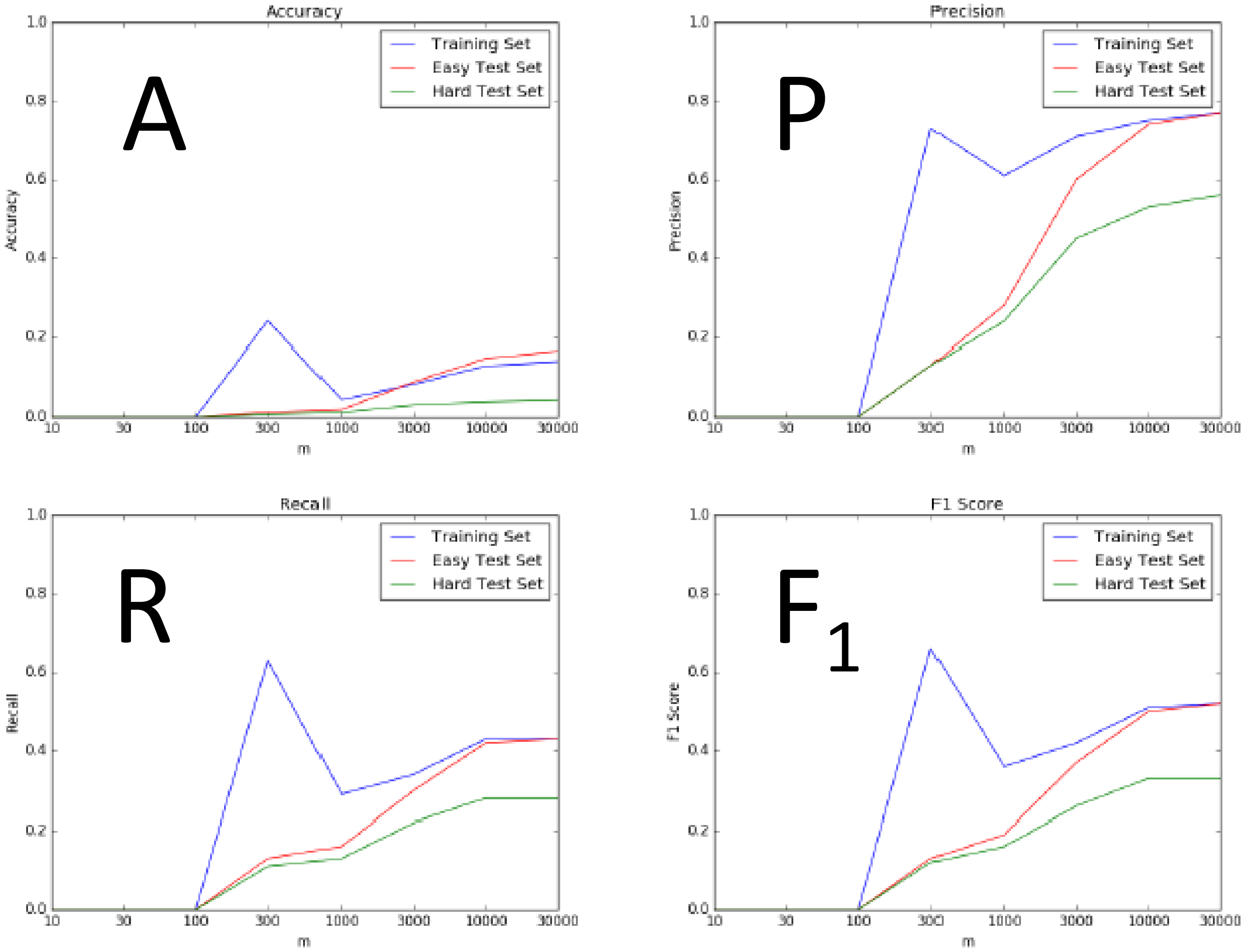


Second Hidden Layer of Trained Neural Network

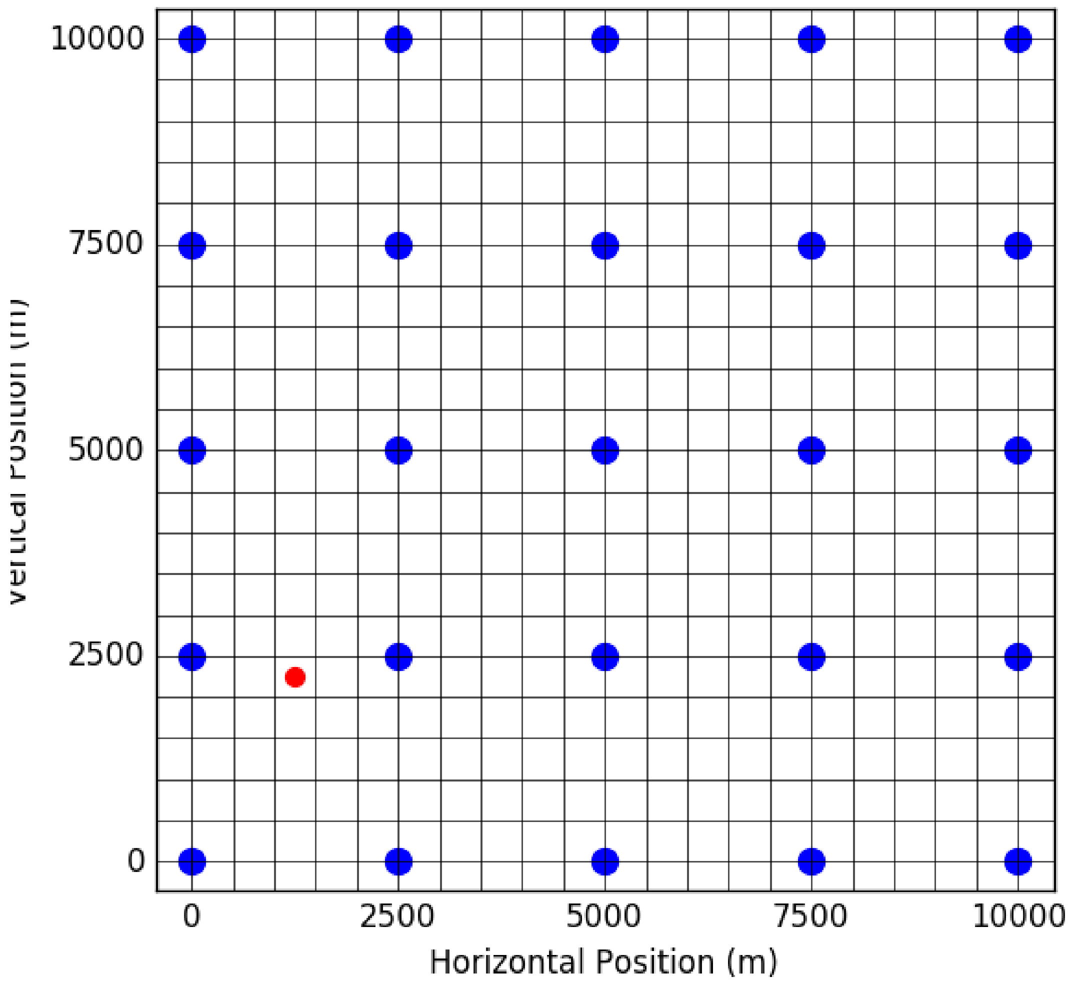


Performance Metrics

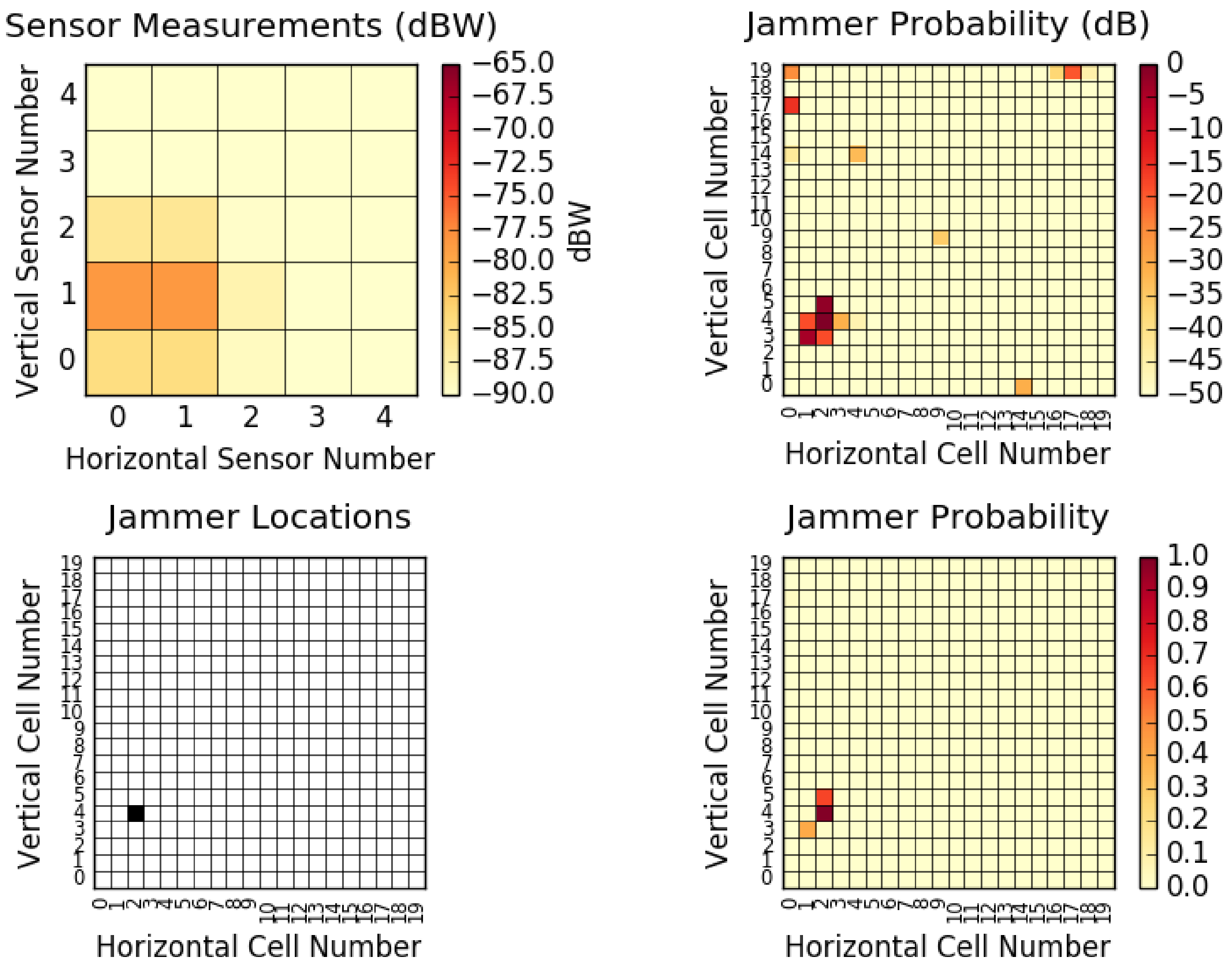
- Accuracy $$A = \frac{T_p + T_n}{T_p + F_p + T_n + F_n}$$
- Precision $$P = \frac{T_p}{T_p + F_p}$$
- Recall $$R = \frac{T_p}{T_p + F_n}$$
- F_1 Score $$F_1 = 2\frac{P \times R}{P + R}$$



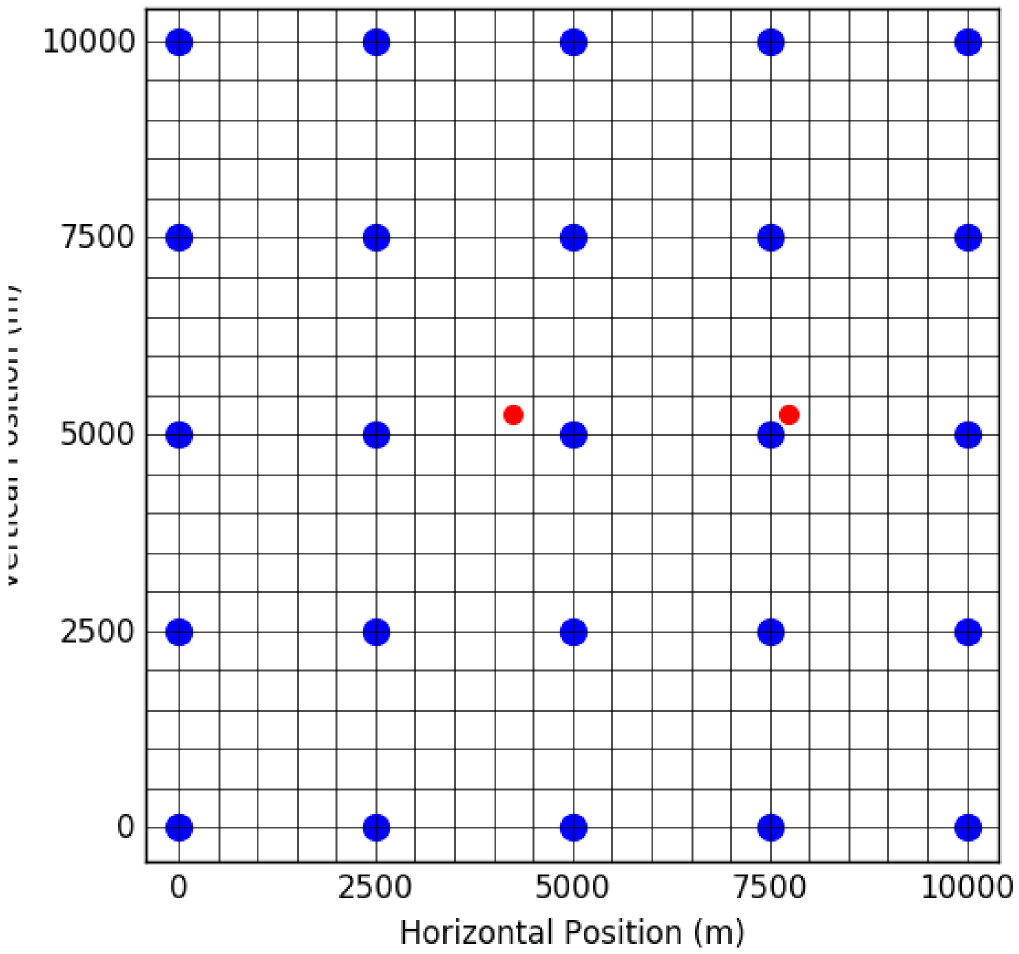
One Interference Source



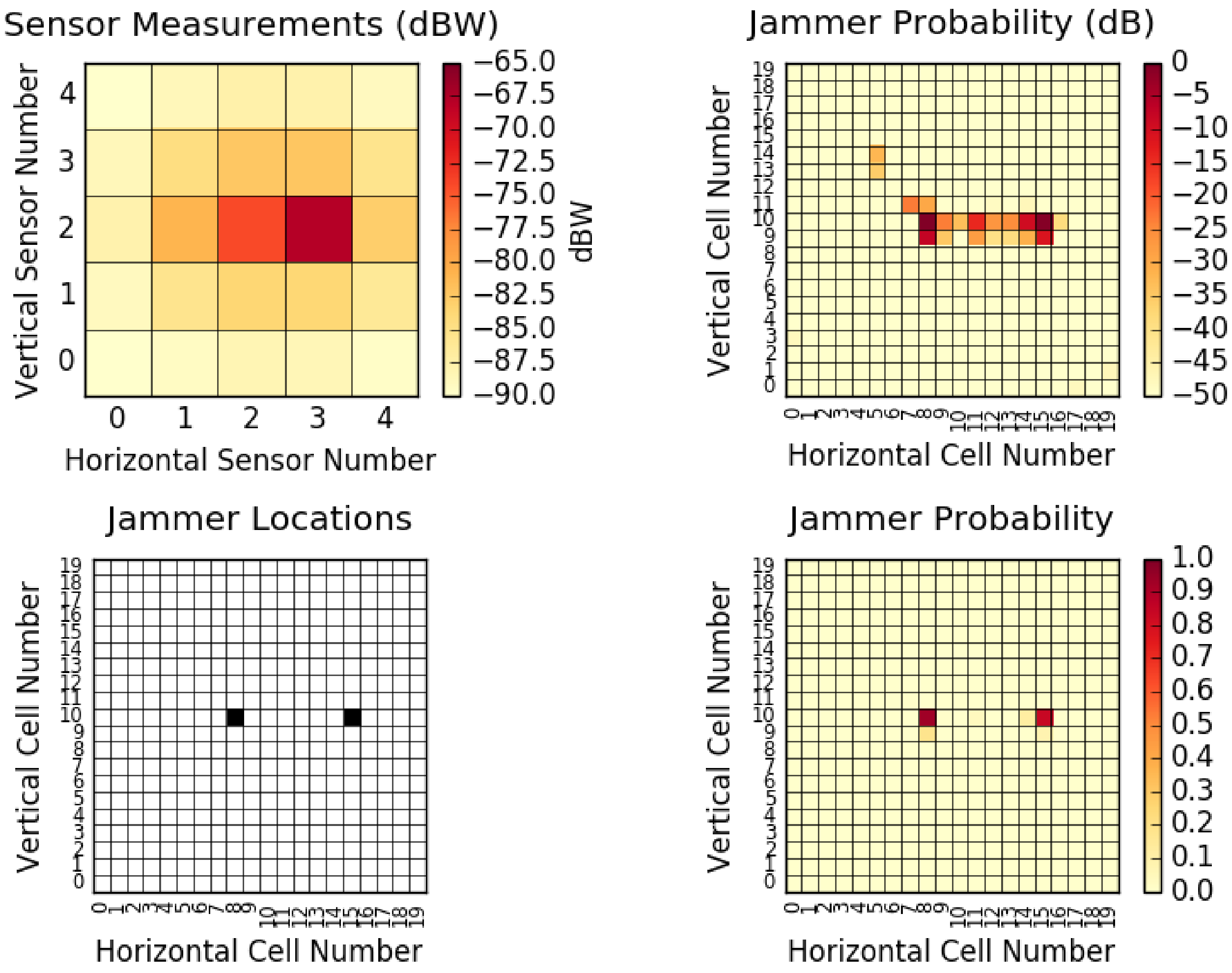
One Interference Source



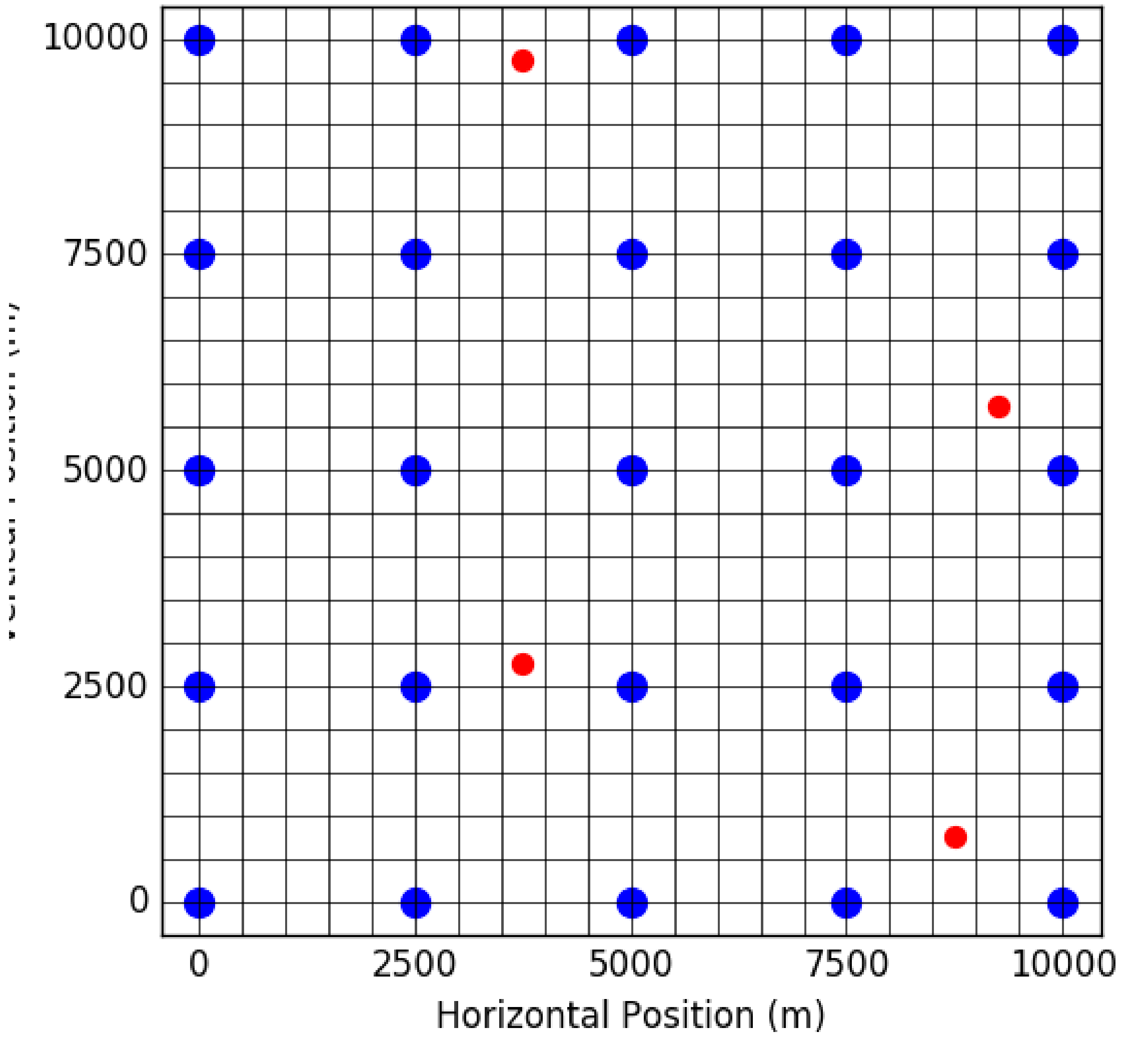
Two Interference Sources



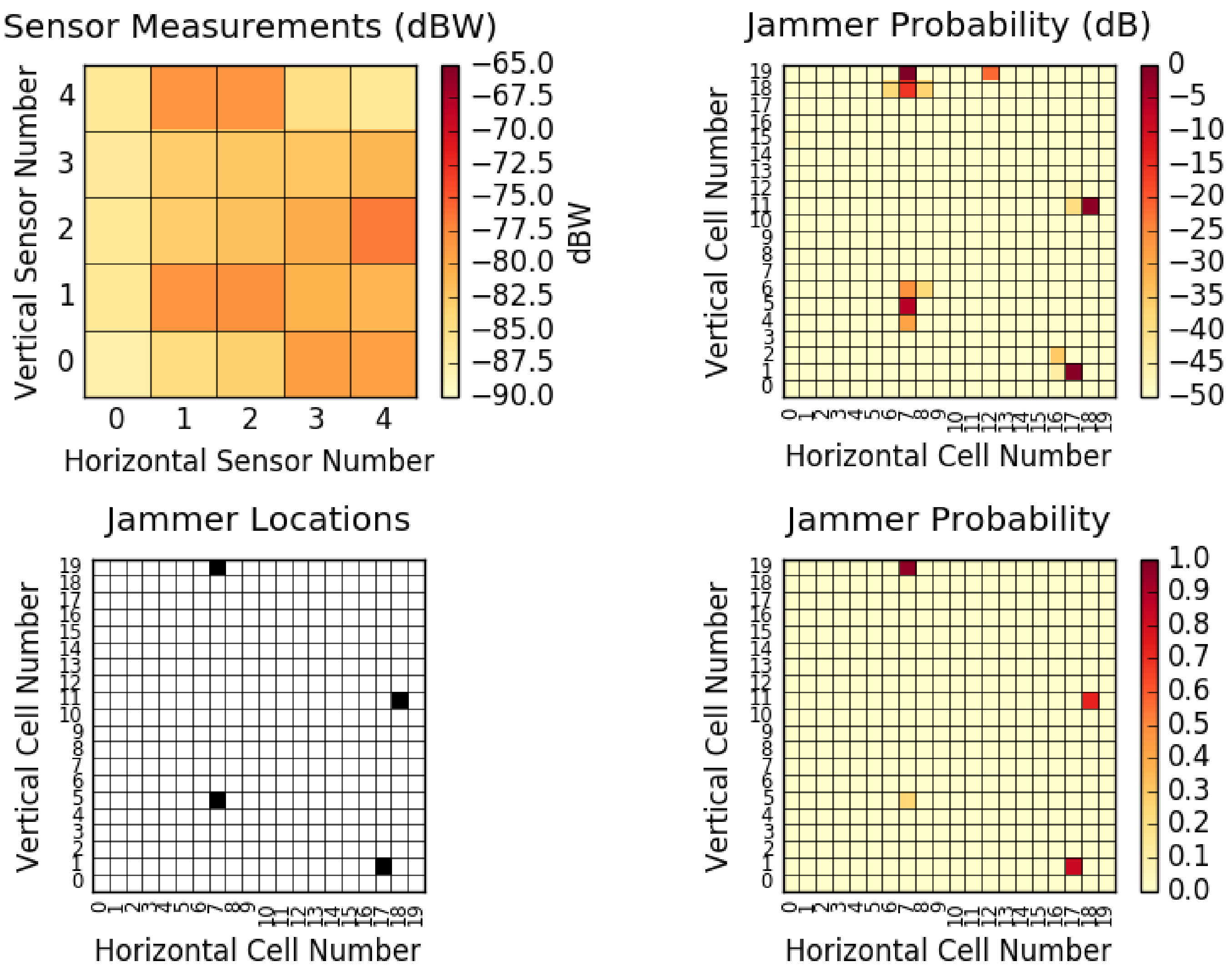
Two Interference Sources



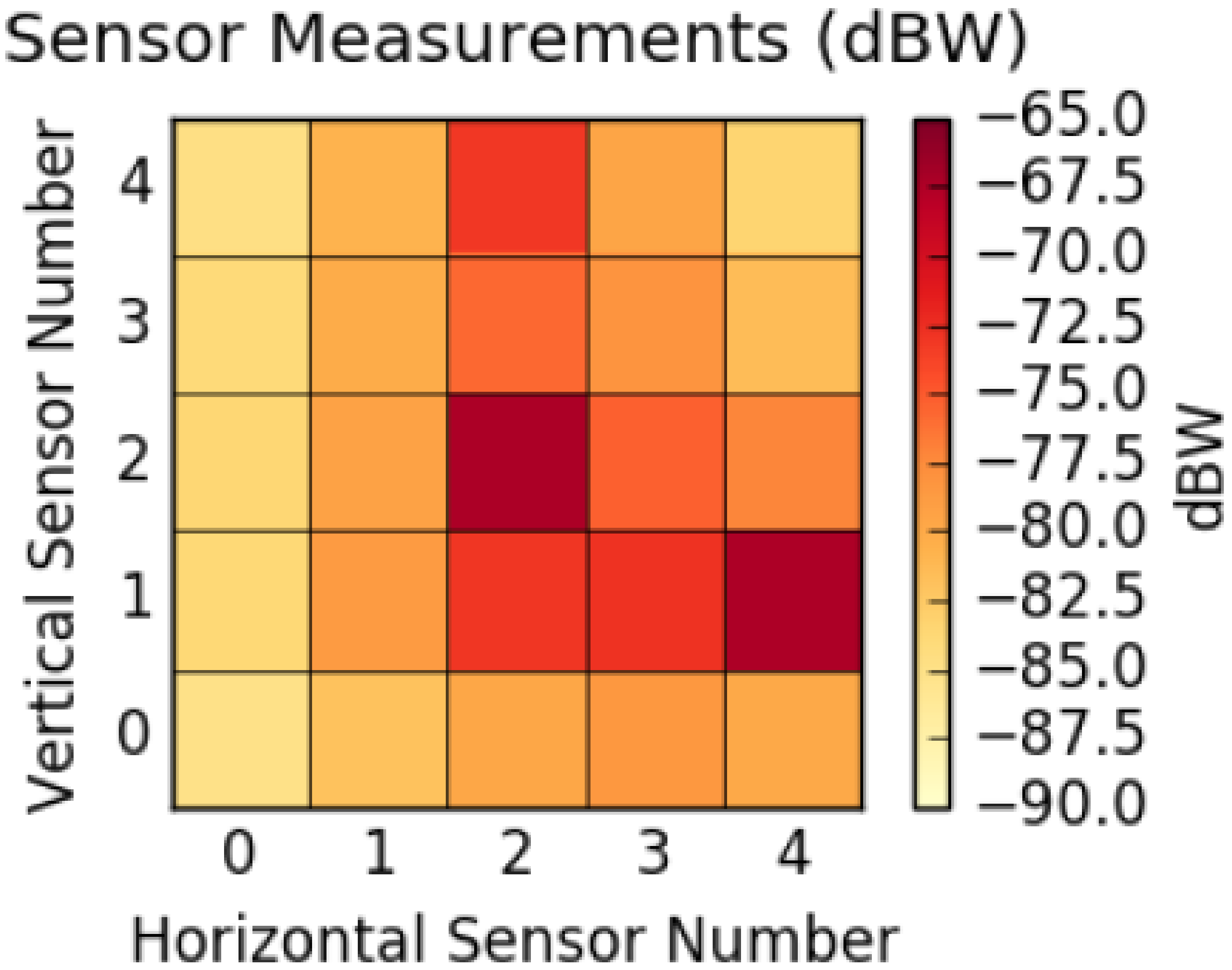
Four Interference Sources



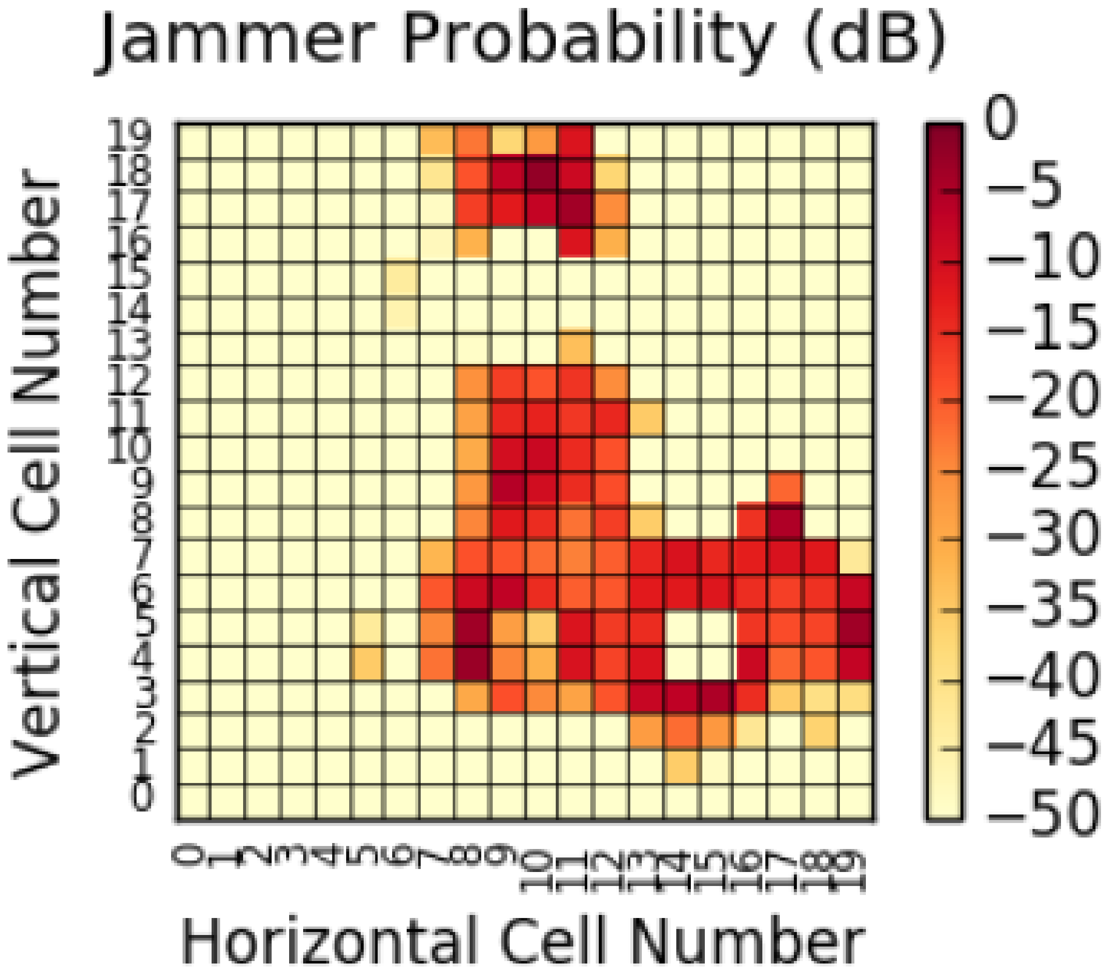
Four Interference Sources

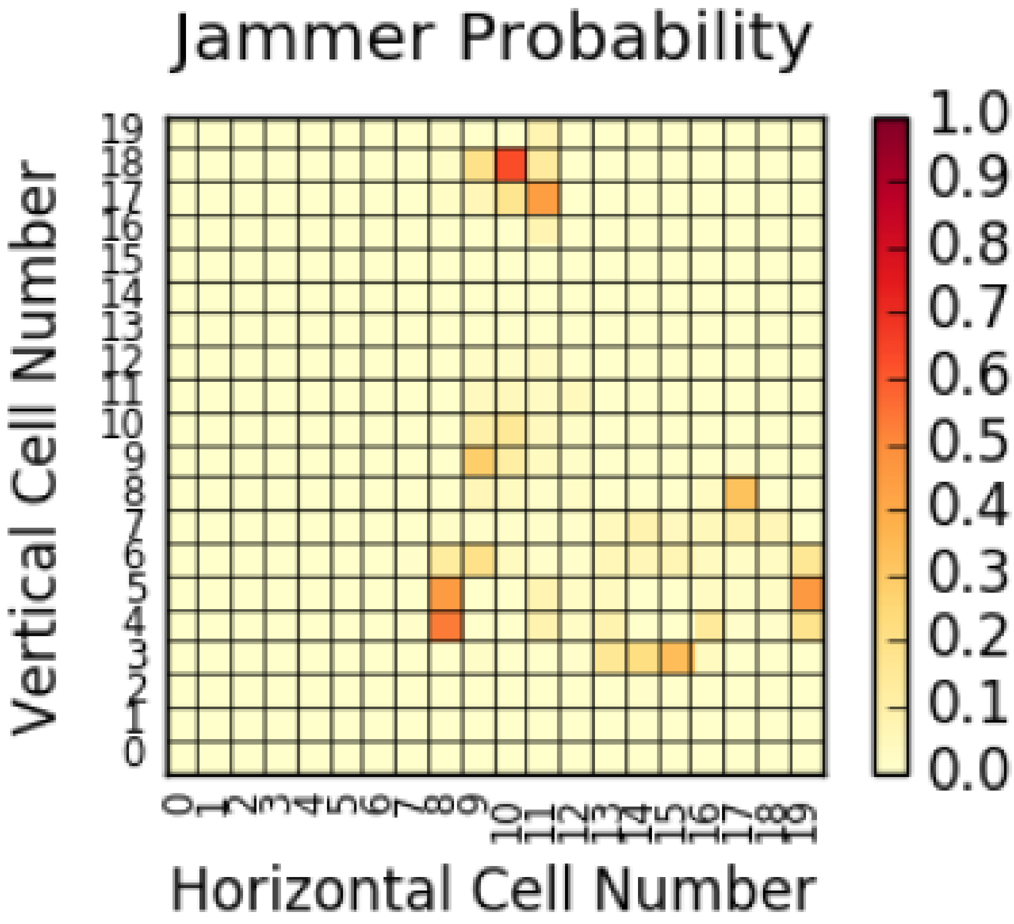


How many interference sources?



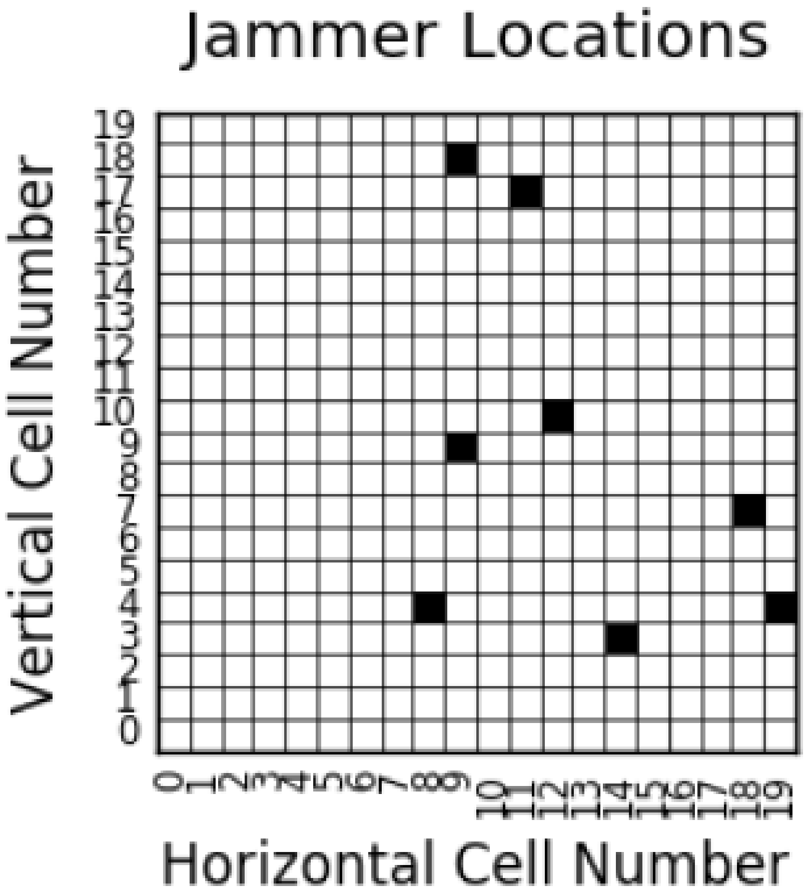
How many interference sources?

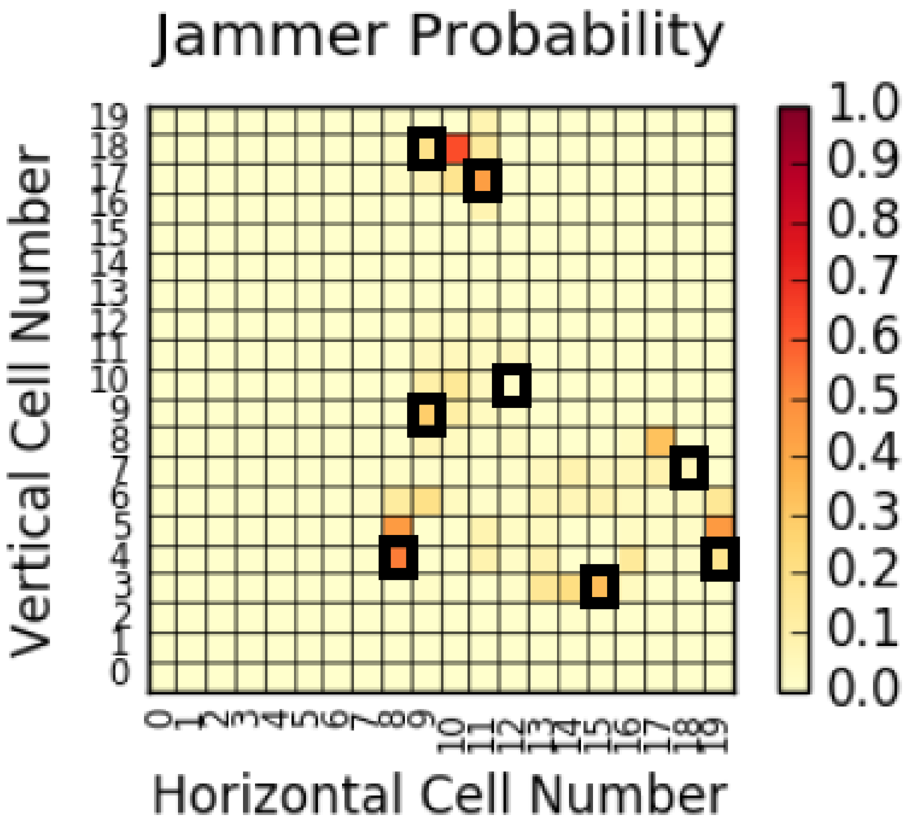




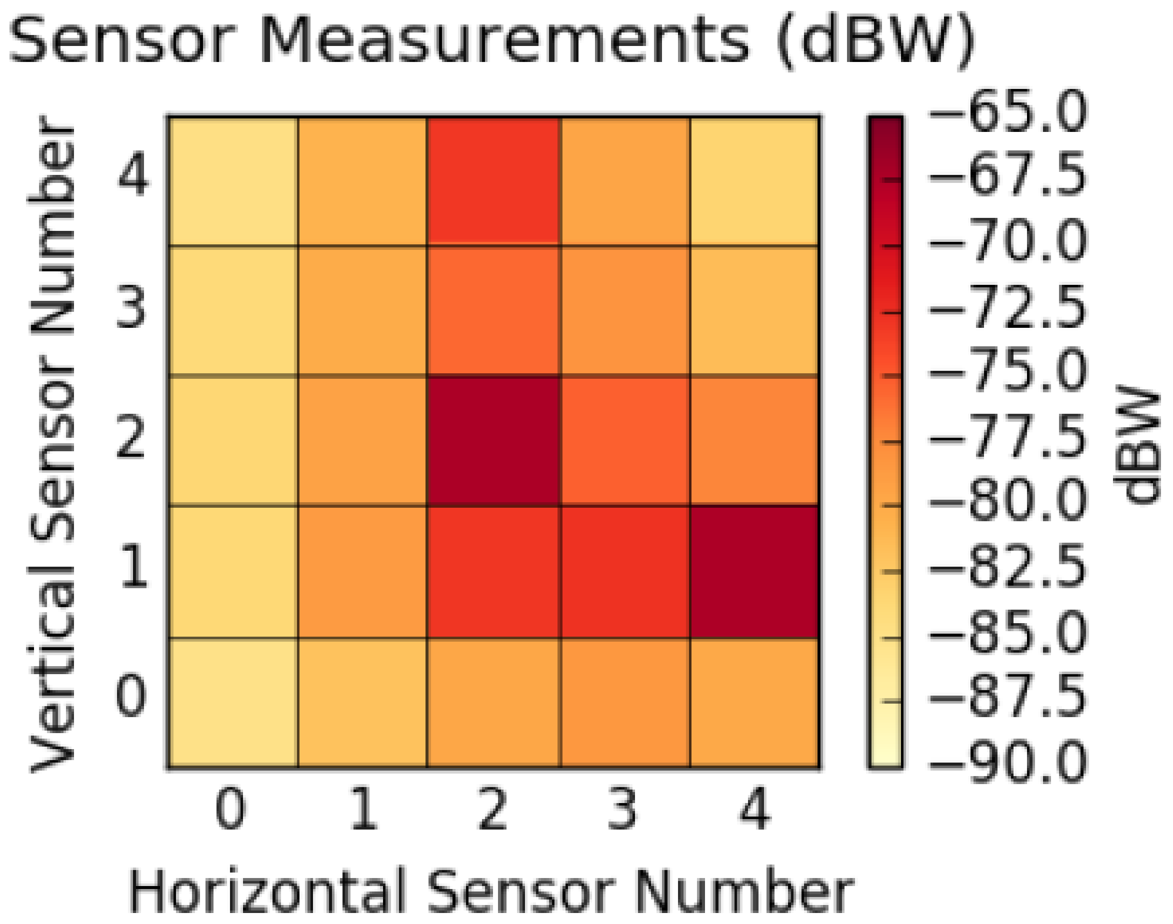
How many interference sources?

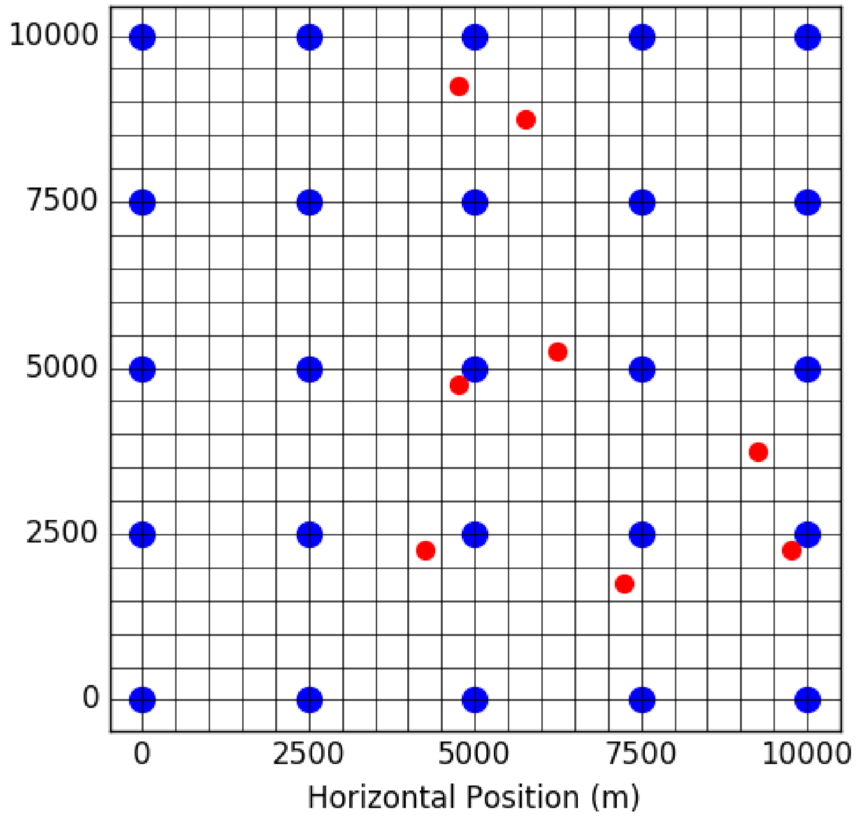
- 8 interference sources.



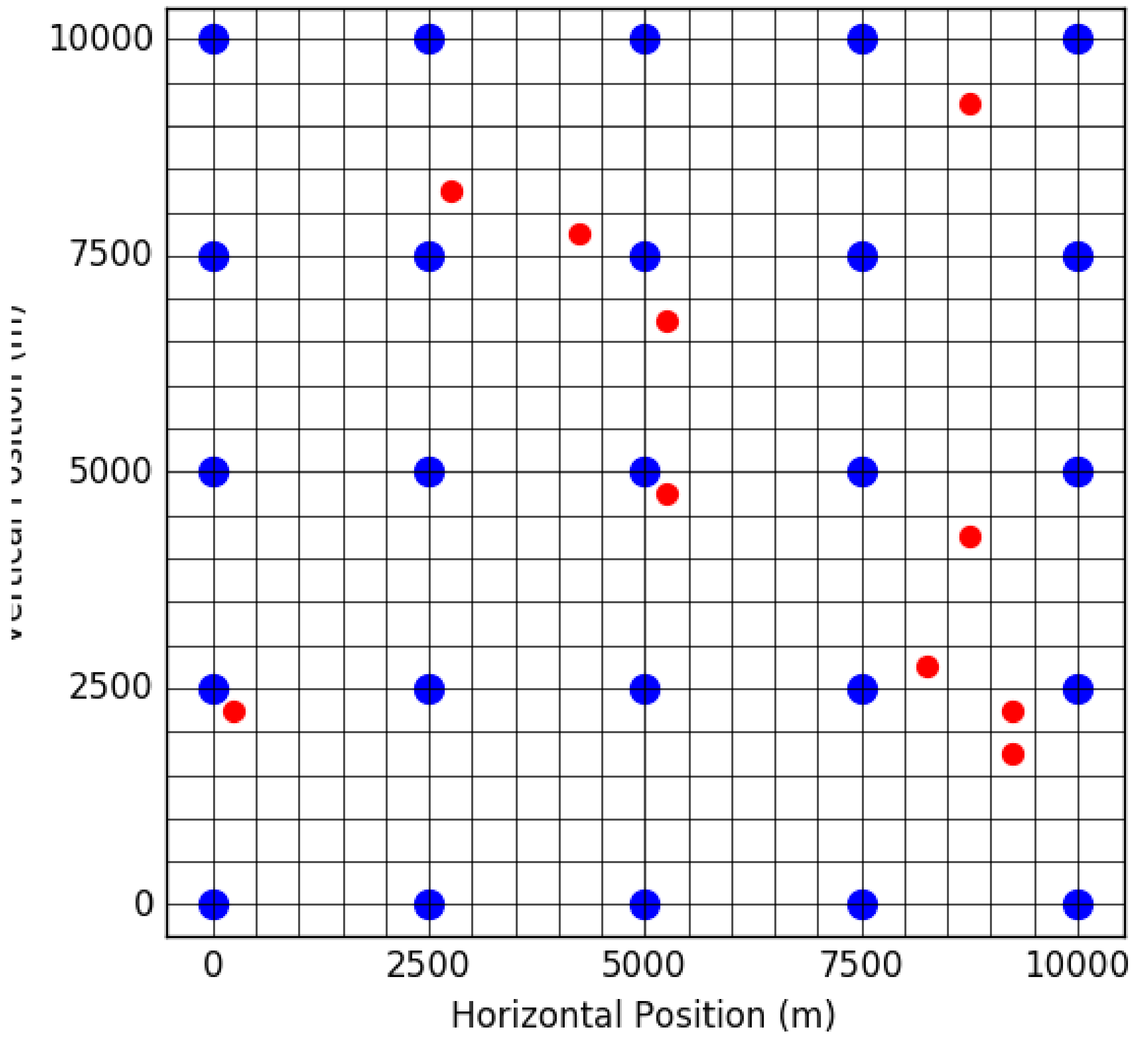


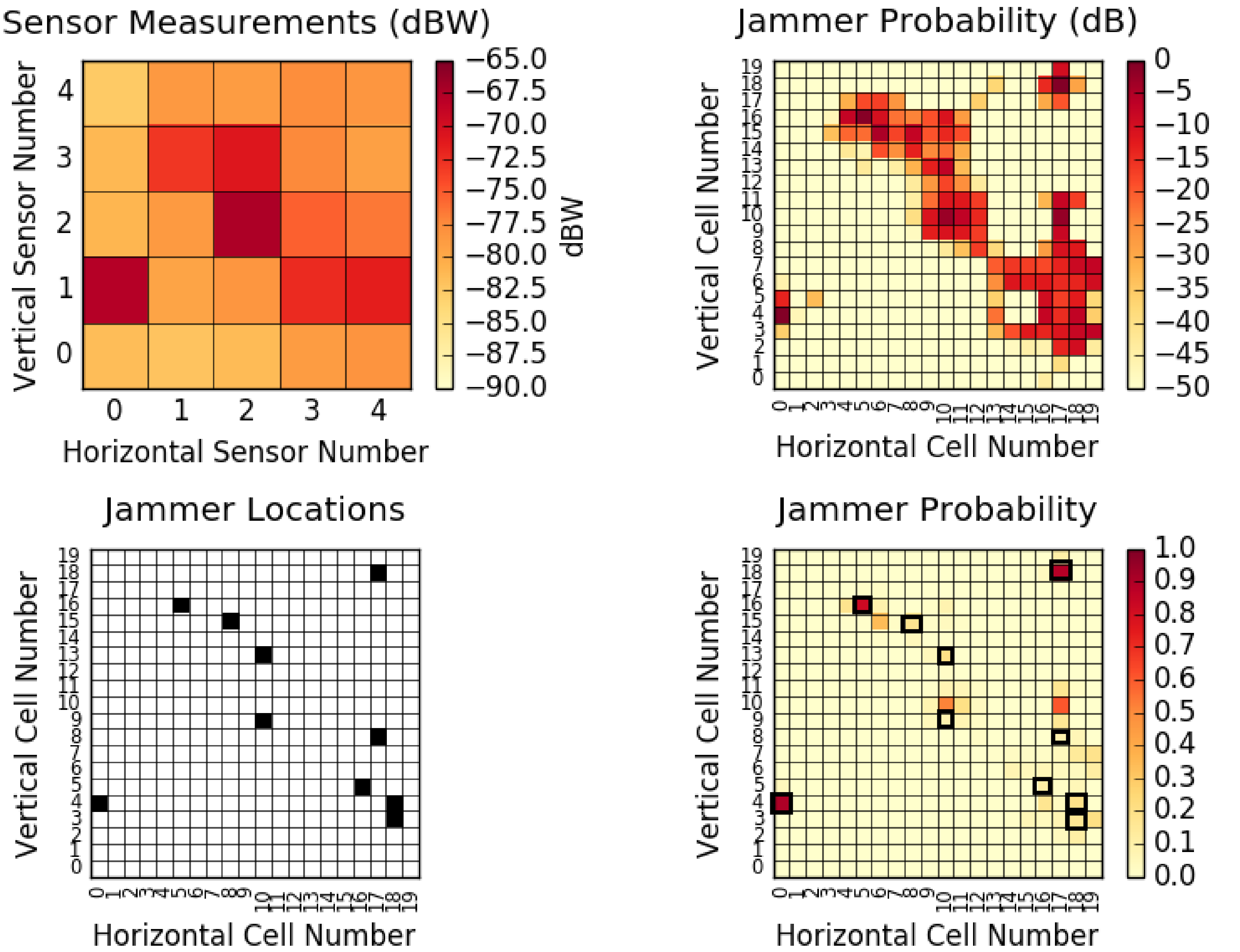
Eight Interference Sources





Ten Interference Sources

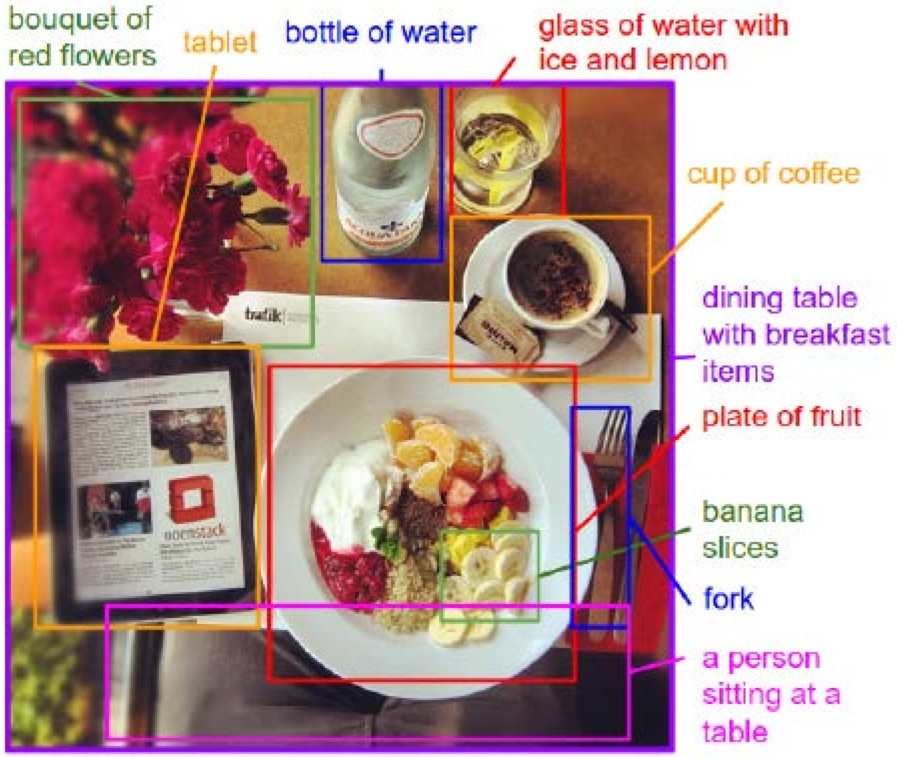



Sensor Measurements (dBW)
Vertical Sensor Number
Horizontal Sensor Number
dBW
Jammer Probability (dB)
Vertical Cell Number
Horizontal Cell Number
Jammer Locations
Vertical Cell Number
Horizontal Cell Number
Jammer Probability
Vertical Cell Number
Horizontal Cell Number

Conclusion and Future Work

- This framework has the potential to open up the interference source localization problem to a wide variety of machine learning techniques.

- Future Work:
    - Incorporate more sophisticated propagation models
    - Perform simulations on accurate terrain models
    - Tune the neural network macro parameters to improve performance
    - Implement technique on a testbed
    - Extend framework to utilize convolutional and recurrent neural networks so as to localize mobile jammers and non-uniform beam patterns.



"a young boy is holding a baseball bat."

http://cs.stanford.edu/people/karpathy/deepimagesent/

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