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COLLEGE OF ENGINEERING

Direction Finding Algorithm with Virtual Antenna Array

Background:

Direction finding (DF) based on MUSIC algorithm has been studied and implemented in the wireless communications lab. Simulation results, measurement setup are shown in the figures below. Most of the direction finding (DF) algorithms require multiple antennas with at least $\lambda/2$ spacing. Also, performance of the DF algorithms mainly relies on

- Number of antennas in the antenna array, and
- Spacing between the antennas

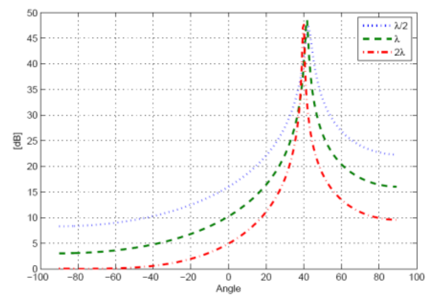
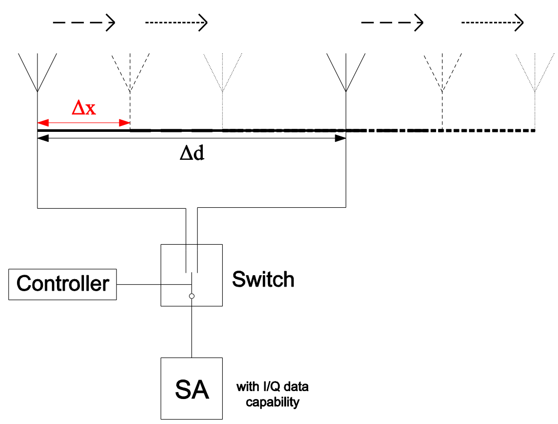


Figure 2: MUSIC Simulations: Effect of the Antenna Distance

Problems:

- Spacing limitations of the field measurements with hand-held spectrum analyzers makes implementing high number of antennas in the array
- Mutual coupling effect grows as the number of antennas increases

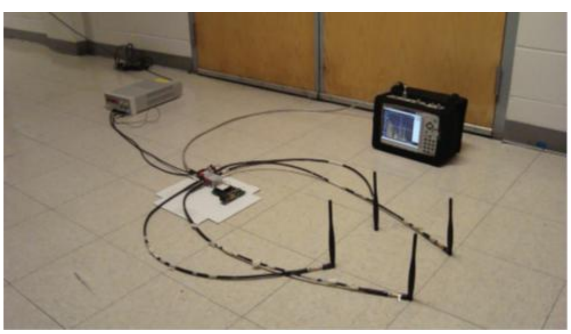


Virtual antenna array scheme

Proposed solution:

4, 6, or 8 antennas are virtually implemented for DF algorithm, by sliding 2 antennas along the same line (Figure at right side). By implementing this technique,

- Higher antenna array realizations is achieved by only 2 antennas,
- Mutual coupling effect is minimized since only 2 antennas are in use for each measurement,
- Simple switch is implemented for practical implementation.



MUSIC DF measurement setup

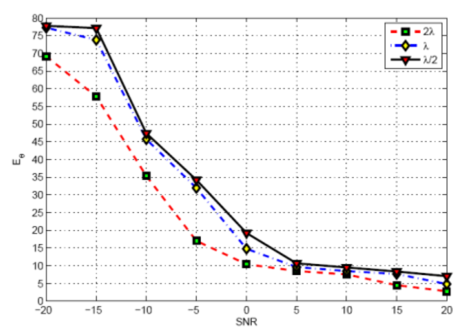


Figure 15: Measurement Results: LTE LOS

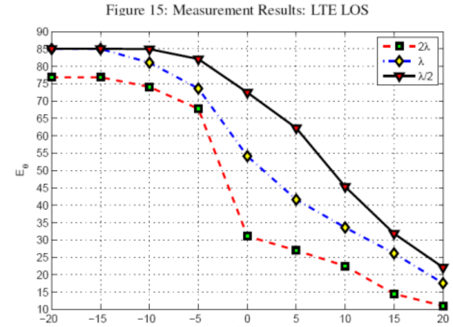


Figure 23: Measurement Results: LTE NLOS

Open Research Areas:

- Mitigation of the effect of multi-path,
- DOA of correlated signals,
- User separability
- …

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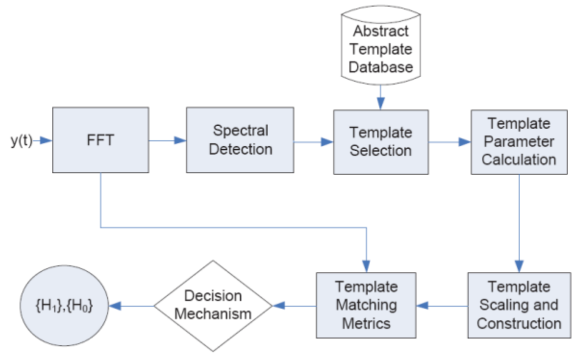
Template Matching for Signal Identification

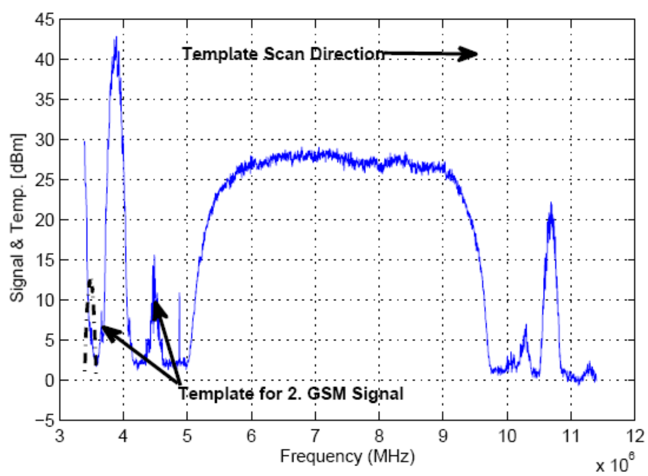
Background:

Frequency spectrum inefficiency is an important problem for wireless communications systems. Spectrum sensing feature of cognitive radio systems introduces methods to improve the spectrum utilization. The performance of the spectrum sensing techniques is affected from the lack of a priori information and the wireless channel knowledge. Thus, sensing performance can be improved by the methods that can identify the wireless signals based on the signal signatures and characteristics. On the other hand, regulations recommend the improvement of wireless throughput by achieving signal orthogonality over spectrum hyperspace. Therefore, new methods depending on specific features of wireless signals should be introduced for signal identification.

Template Matching Framework:

- Template storing for each standard signal, SNR value, bandwidth, and carrier frequency increases the complexity of the technique,
- Searching, and polling the corresponding frequency range from the template database might be time consuming in the case of wide spectrum measurement.



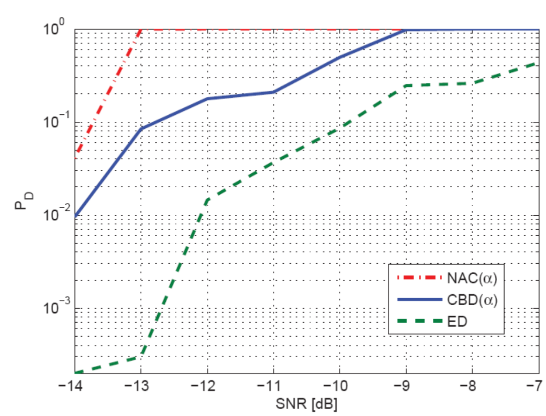


Solutions:

- One abstract template for each standard signal is enough to be stored,
- Template to be utilized is obtained by scaling the abstract template in frequency & power dimensions,
- Two efficient metrics are taken into account:

$$CBD(\alpha) = \left| \sum_p \sum_q \left[\delta t\left(\frac{p-\alpha}{\gamma_1}, \frac{q}{\gamma_2}\right) - t(p-\alpha) \right] \right|$$

$$NAC(\alpha) = \left[\sum_p \sum_q \left[\delta t\left(\frac{p-\alpha}{\gamma_1}, \frac{q}{\gamma_2}\right) t(p-\alpha) \right] \right]$$



CBD(α) & NAC(α) vs. Energy Detection (PF = 0.01)

Open Research Areas:

- Efficient database search algorithm with successive approximation,
- Unauthorized adjacent channel signal detection algorithms,
- Efficient spectral detection under low SNR scenarios,
- Spectral interference scenarios,
- …

Frequency Domain Eye Diagram for Orthogonal Frequency-Division Multiplexing

Background:

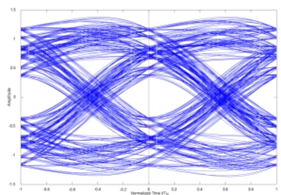
In conventional single-carrier communication systems, investigation of the signals along with multipath channel impairments was possible with eye diagrams thanks to the fact that the symbols are represented in time domain. Effect of inter-symbol interference (ISI) due to multipath delay spread and timing offset are observed with conventional eye pattern.

Problem:

In multicarrier schemes like OFDM, however, the symbols are represented along frequency domain. Therefore, for the channel impairments in OFDM systems,

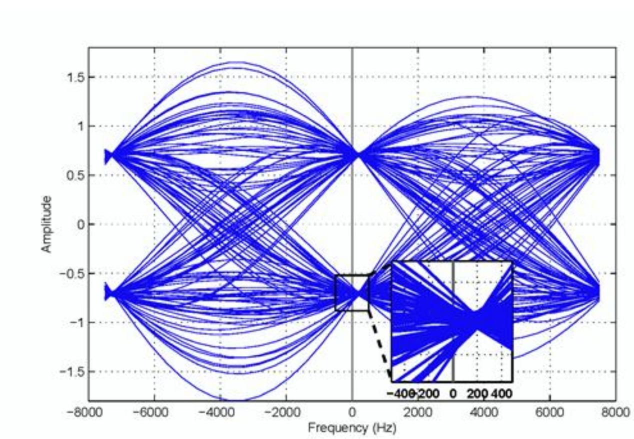
- Can we have an eye diagram in frequency domain?
- Can we visualize the effect of frequency spreading & frequency offset in OFDM?
- Can we identify ICI due to frequency spreading and ICI due to carrier frequency offset?

Impairments	Time	Frequency
Channel based	Delay spread	Doppler spread
Hardware based	Timing offset	Carrier frequency offset



Time domain (conventional) eye diagram

Frequency Domain Eye Diagram (FDED)



Measured FDED when there is 200 Hz carrier frequency offset in the system

Solution:

- We are able to construct eye patterns in frequency domain at the receiver side for OFDM-based signals,
- Effect of frequency spreading and offset are clearly observed,
- Diagram is implemented & verified in the wireless communication systems laboratory.

Open Research Areas:

- New interference visualization techniques for multicarrier waveforms (joint time & frequency),
- Effect of multipath channel on FDED,
- Frequency domain eye diagram for general multicarrier waveforms like FBMC, FMT etc..,
- …

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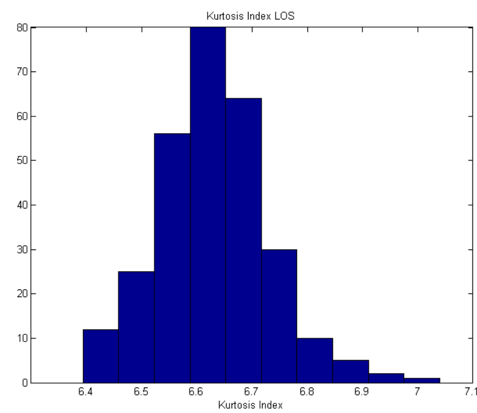
Line of Sight / Non-Line of Sight Identification

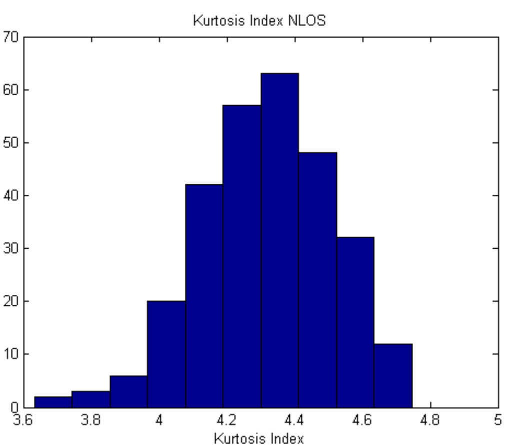
Background:

In wireless communication, it is crucial to know the environment between transmitter and receiver to do localization/positioning precisely, especially in applications such as public safety, intelligent transport system (ITS), health care domain and emergency situations. If the environment is in line of sight (LOS) condition, localization can be achieved accurately. If it is in non-line of sight (NLOS) condition, the transceiver needs to know it. Thus, it can adjust itself and do localization more accurately.

Problems:

- Environment is not known by transceiver. Due to the multipath nature of the environment, positioning can be achieved wrong if the signal comes under NLOS condition.
- In cognitive radio systems, if the environment is known by transmitter, it can increase the data rate if the signal comes under LOS condition. This will provide the longer battery life in mobile devices.





Solution:

- Higher order statistics, i.e. skewness, kurtosis index, are used to achieve the identification indoor environment.
- RMS delay spread and mean access delay characteristics of the signal are attained to identify outdoor environment.
- It is experienced in laboratory environment.

Open Research Areas:

- New algorithms to do positioning with one base station without needing triangulation
- For military applications, achieving this identification with radar systems
- …..