Algorithm Optimization and Model Comparison in MIMO OTA Testing

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Abstract. 3GPP, CTIA and COST name the testing method for evaluating the performance of multi-antenna terminals as multiple input multiple output over the air test. In several proposed methods, multiple probe anechoic chamber-based testing method for MIMO capable equipment is attractive due to its ability to reconstruct spatial-temporal characteristic in controllable way. In this paper, power allocation among multiple probes will be investigated to emulate a given channel model, specified by its power azimuth spectrum (PAS), accurately. In the optimization algorithm, an effective power allocation algorithm is obtained by introducing the constraint of the maximum deviation (average angle of arrival AOA and azimuth extension AS) between the target PAS and the simulated PAS. After adding the constraints, the research can turn the problem into a convex optimization problem and solve it in the CVX convex optimization toolkit in Matlab. In the simulation, the proposed algorithm is compared with the reference algorithm least squares method in the related literature. The simulation results show that the proposed optimization algorithm is better than the reference algorithm and the optimization performance of the proposed algorithm is confirmed.

1. Introduction
The test methods fall into two main group: Anechoic chamber candidate methods and Reverberation chamber candidate methods. In the setup of the chamber, the anechoic chamber method measures the channel environment performance without artificial cable. However, an RF cable connection is required in the reverberation chamber method, which affect the channel performance. The reconstructed channel environment by reverberation chamber is related to the reverberation chamber itself, which is statistically isotropic in spatial domain of the receiver, and does not match the actual channel. This paper form the channel simulation dilemma with the constrained discrete PAS shape when the angular positions of the OTA probes are fixed. The dilemma can be explicated as a convex problem and the paper use Matlab to solve it. The novelty of the method is that adding limitation on the discrete PAS shape and transformed the problem into convex optimization problem. The complexity can be greatly reduced. In addition, the paper discusses the connection between the number of probes and performance. The performance of the proposed algorithm and least square method are compared. Emulation results approve that the proposed algorithm presents better.

2. Background

2.1. Multiple Probes Anechoic Chamber method
The multiple probes anechoic chamber (MPAC) method has several advantages. Firstly, we can change the channel model by software flexibly. Secondly, the parameters of PAS are controllable. Thirdly, the important parts of the channel such as baseband processing, RF front end and antennas are tested at once. It is better than the traditional conductive test. The traditional test like LTE conformance test lacks consideration of the impact of the antenna. However, the probe in the anechoic chamber is expansive. The cost is worth discussing when using multiple probes to improve accuracy.

2.2. Channel model
Typically, a spatial distribution called power azimuth spectrum is selected to model the spatial characteristics of the wireless channel. A signal propagating through multipath. The propagating phenomenon scattering, diffraction and reflection cause the multipath characteristics. In the related literature about PAS, four type PAS models have been widely studied: Wrapped Gaussian, truncated Laplacian, uniform and Von Mises distribution.

The spatial channel model (SCM) is a stochastic model based on geometry. It use ray-tracing techniques to approximate the multipath environment. It has three scenarios: urban macro, urban micro and suburban macro. There are six fixed main paths corresponding to the respective delay, power and angle characteristics in each scenario. Each main path has 20 sub-paths.

The SCME model is an extension model of SCM[1]. The mid-path and intra cluster parameters are added. The 20 sub-paths of each main path are divided into three mid-paths. Therefore it has 18 mid-paths. The parameters such as time delay and power are obtained depending on the deviation in the cluster.

2.3. Antenna power weight
$g_{k,n} = P_n(\theta_k)$ is a straight forward method to obtain power weight, $\theta_k$ is direction of the kth OTA antenna [2]. However, this method does not consider the size of the test area. This is analogous to a conventional filter design, where the method of sampling continuous impulse response does not produce optimal filter coefficients with a limited number of taps [2].

The spatial correlation function is a parameter in the power azimuth spectrum and the PAS is a Fourier transform pair. We can use spatial correlation function to determine discrete PAS instead of directly sampling the continuous PAS. The method to find the best power weight is to sample the test area with the virtual array of ideal isotropic antennas. We need to minimize the mean squared error between theoretical correlations and correlations resulting from a discrete PAS [2].

2.4. Design simulation procedure
3. Algorithm for optimal probe power weights

3.1. Spatial correlation function

Figure 1. The flow chart of Design simulation

Figure 2. MIMO ring
Figure 2 illustrates the probes that are arranged in the MIMO ring. The angular location of probe is \( \theta_n \), \( \theta_n \in [0, 2\pi] \). \( N \) is the number of probes. The Formula (1) can calculate the spatial correlation for an antenna pair.

3.2. Optimized algorithm
For Prefaded signals synthesis, vertical polarization and horizontal polarization can be simulated independently [3] [4]. The method for vertical polarization is also applicable to horizontal polarization when ignoring the polarization factor. The basic idea of the channel optimization algorithm is: When the channel model is directional, within the specified FoM error, the 8-probe uniform distribution method in a MIMO ring can be optimized by an appropriate algorithm. It expands the size of the test area when the number of channel emulator channels is fixed. In other words, the occupancy of the channel emulator channel number is reduced in the same condition of the test area size. As a result, the complexity and cost of the system are decreased.

Firstly, we need to minimize the deviation. The spatial correlation function is a figure of merit. The emulated result of mean angle of arrival and the angle spread need to match the target value well. Secondly, we need to constrain the maximum deviation between the target PAS and a discrete PAS.

4. Comparison of two algorithms

4.1. Comparison in data
The correlation errors for each cluster are shown in Table 1. We can see clearly that the correlation errors of each cluster in proposed algorithm is smaller than those result in referenced algorithm.

| \( |\rho - \hat{\rho}| \) | cluster1 | cluster2 | cluster3 | cluster4 | cluster5 | cluster6 |
|------------------|---------|---------|---------|---------|---------|---------|
| Proposed         | 0.0183  | 0.0039  | 0.1112  | 0.0091  | 0.0162  | 0.0092  |
| Referenced       | 0.0234  | 0.0118  | 0.2637  | 0.0162  | 0.0181  | 0.0202  |

The results under SCME model are shown in the Table 2. In proposed algorithm, the AS and AoA matches well with the target value compared with those in least square algorithm do.

| AS             | cluster1 | cluster 2 | cluster 3 | cluster 4 | cluster 5 | cluster 6 |
|----------------|----------|-----------|-----------|-----------|-----------|-----------|
| Target         | 35.0000  | 35.0000   | 35.0000   | 35.0000   | 35.0000   | 35.0000   |
| Proposed       | 34.9000  | 34.9000   | 35.1000   | 34.9000   | 34.9000   | 34.9000   |
| Referenced     | 39.8156  | 36.4583   | 42.3874   | 36.2669   | 38.1750   | 39.7749   |
| AoA            | cluster1 | cluster2  | cluster3  | cluster4  | cluster5  | cluster6  |
| Target         | 65.7489  | 45.6454   | 143.1863  | 32.5131   | -91.0551  | -19.1657  |
| Proposed       | 65.6000  | 45.7000   | 143.1000  | 32.6000   | -78.0000  | -19.2485  |

4.2. Comparison in different AoA
This paper set 8 probes and the angle is arrange from 0 to 2\( \pi \). Simulation results show that the cluster performed better when it has same AoA with the OTA antennas. When the cluster is in the midpoint of the antenna, the performance is the worst. The result in figure 3 also shows that the proposed method is better than referenced method.
5. Conclusion
Firstly, the comparison was made between only two algorithms (proposed algorithms and least square algorithm) in the paper. In order to have a better comparison, more existing algorithms should be introduced in the project.

Secondly, this paper repeatedly modifying the variables N (number of probes) and the mean Φp in the program and found out the value of the key points. This problem need be solved in the further work.

Thirdly, the outcome is the simulation result based on Matlab. The comparison of two algorithm can be made in a practical MIMO OTA setup. It is closer to the real environment and the data are more convincing. However, it takes more time and money to build the test system. If conditions permit, a real environment test should be done.

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