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Including Embedded Element Antenna Characteristics in Winner II Channel Models and Comparison with Isotropic Propagation Environment

Ulf Carlberg[#], Per-Simon Kildal[*], Jan Carlsson[#,*]

[#]*SP Technical Research Institute of Sweden*
Box 857, SE-50115 Borås, Sweden
{ulf.carlberg, jan.carlsson}@sp.se

[*]*Dept. of Signals and Systems, Chalmers University of Technology*
SE-41296 Gothenburg, Sweden
per-simon.kildal@chalmers.se

***Abstract*—An independent implementation of a part of the Winner II channel models is compared with the isotropic propagation environment. Convergence of diversity gain and capacity to their ergodic values is presented for a terminal with two antennas using embedded element far-field functions.**

I. Introduction

Mobile terminals communicate wirelessly with a base station over a propagation channel. Through the channel there is usually not only a line-of-sight (LOS) component, but several scattered waves which vary stochastically with time. This gives rise to fading which may result in dropped connections or low throughput for the user. Techniques such as diversity and multiple-input multiple-output (MIMO) may be used to mitigate fading and increase throughput. In order to study these techniques and to be able to evaluate terminals under representative channel conditions, it is important to have an understanding of the fading channel.

We have developed a computer code in Matlab referred to as ViRM-Lab (Visual Random Multi-path environment Laboratory) [1], [2], which simulates a fading environment for a terminal. The simulation approach is based on generating a set of incoming plane waves with the angle-of-arrivals taken from a specified statistical distribution. The user of the software tool may in the end when all has been implemented specify the (average) polarization balance of the incoming waves, as well as Doppler shift and time delay. The terminal may be specified with several antenna ports and the embedded element far-field function for each antenna and mutual coupling can be included in the calculations.

After calculating the port response for several realizations of the incoming plane waves, the diversity gain [3] and the average capacity [4], [5] will converge to an ergodic value that is representative for the particular terminal orientation in the particular environment chosen.

However, the user may also specify that the terminal is moved around in the environment, changing both position and orientation during the simulation.

In reality the environment often has a non-uniform distribution of incoming waves, and the terminal has a non-isotropic far-field function. But, on the other hand, both the user orientation and the environment are often changing, such as when a person is using a mobile phone.

The Winner II channel models, developed by Hentilä *et al.* [6] provide geometry based stochastic numerical electromagnetic propagation models between base stations and mobile terminals for a number of propagation scenarios. The defined scenarios include indoor office, large indoor hall, indoor-to-outdoor, urban microcell, suburban macro-cell, urban macro-cell, and so on. The numerical models of these scenarios have been constructed from the statistical distribution of a number of measured channels. The models assume a number of clusters with several incoming plane waves from each cluster. The waves have parameters such as delay, power, Doppler shift, angle-of-arrival, angle-of-departure, and polarization. All scenarios are modeled with this approach, but with different parameters. The Winner II channel models also allow for MIMO systems, i.e., several antennas at both receive and transmit side.

In the present paper we show how we have implemented the spatial part of the Winner II channel models into ViRM-Lab, and present results where we compare these more complex and detailed environments to the much simpler isotropic environment. The purpose is to find out by simulations the advantage of using more advanced channel models, in particular if the terminal is changing position as well as orientation during simulation.

The organization of the paper is as follows. In the following section, we will describe the isotropic environment and how we model it in ViRM-Lab. In the section after that, the implementation of the Winner II channel models in ViRM-Lab is described. Then, we will show results calculated with the Winner II channel models by ViRM-Lab and compare these with calculations for the isotropic environment. Results will be presented both for a terminal in a fixed position and for a terminal that is randomly moved around in the azimuth plane with a randomly varying 3-D orientation. Finally, we will draw some conclusions based on the convergence of the results, both regarding the ergodic value of diversity gain and capacity, and how many samples are needed to reach these values.

II. Isotropic Propagation Environment

A statistical fading environment may be modeled by random incoming plane waves on an antenna for many realizations. In ViRM-Lab the user may choose from many kinds of statistical distributions of the angle-of-arrival of the incoming plane waves. In the present paper we focus on the isotropic environment where it is equally probable that a wave comes from any direction. The number of plane waves for each realization is varied from one to twenty. A visualization of one realization of twenty incoming plane waves, and the resulting magnitude of the voltage received on a port of a vertical incremental dipole is illustrated in Fig. 1. The latter received voltage is illustrated for the dipole in several spatial positions in a circular region of radius 5 wavelengths in the xy-plane.

In the main results presented in this paper we represent the user as a receiver consisting of two vertical dipole antennas. The antennas are separated with 0.4 wavelengths and the embedded element far-fields have been calculated with the full-wave method of moment solver WIPL-D [7], when the non-excited dipole is terminated by 50 ohm. The far-field functions of the two dipoles are graphically illustrated in Fig. 2. When we gather samples for the isotropic environment, the receiver is in a fixed position and orientation for all realizations.

In ViRM-Lab we may then calculate the capacity and diversity gain for each realization and study the convergence of these parameters to their ergodic values by averaging over several realizations.

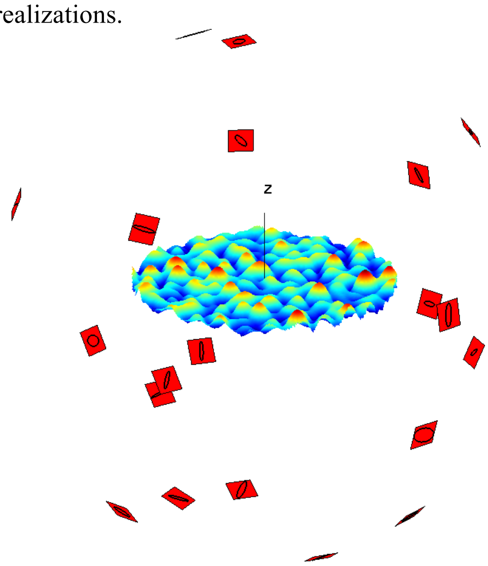

Fig. 1 Visualization of the isotropic environment. The red patches represent plane waves coming from random directions distributed uniformly over the far-field sphere. The polarization of each wave is randomly polarized and shown as an ellipse in each red patch. In the center of the coordinate system there is a region where the magnitude of the voltage received by an incremental z-directed dipole in the xy-plane is shown. It is Rayleigh distributed over this plane.

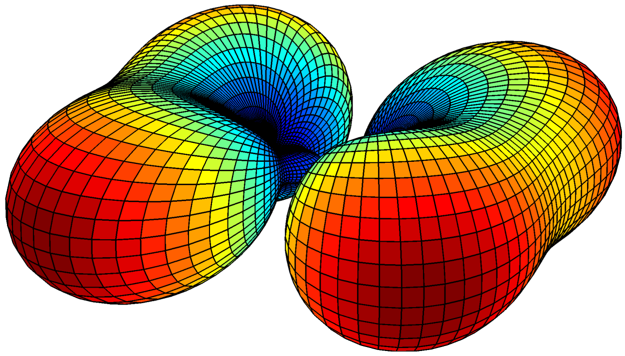

Fig. 2 Radiation patterns of the far-field functions of two vertical half-wavelength dipoles separated with 0.4 wavelengths calculated with a full wave solver. Note that *two* separate far-field functions, one for each antenna, are shown.

III. Winner II Channel Models

The main idea in the Winner II channel models [6] is to define a number of clusters of incoming plane waves. There are a lot of parameters defined, e.g., time delay and Doppler shift that we have not implemented in ViRM-Lab yet. There are also some differences in our implementation of the clusters compared to the Winner models. We have defined the clusters as spatial points in the three-dimensional space, see Fig. 3. In the original Winner models, the clusters are defined as coming from a certain angular direction and having a certain angular spread. Our way of modeling the clusters will be very similar to the original way, even though the angular spread is changing depending on the position of the user.

The spatial points in each cluster represent a plane wave going through that point and the user. The magnitudes of the plane waves are random and Rayleigh distributed. We always assume that the plane waves are interacting with the antenna's far-field, no matter how close the user is to the cluster points.

The center of each cluster is positioned on a circle in the azimuth plane with radius 70 wavelengths, see Fig. 3. Each cluster has the points normally distributed in x-, y-, and z-direction with a standard deviation of five wavelengths. There is always twenty points in each cluster.

We let the user move around in this environment back-and-forth in x-direction with an increase in y-direction every time the x-direction is reversed. The z-position is always zero. This results in the user covering a square shown in Fig. 3. The step between each position is one wavelength, so we know that each sample is independent. Also the orientation of the user is changed between every ten steps. The orientation is random with an isotropic distribution.

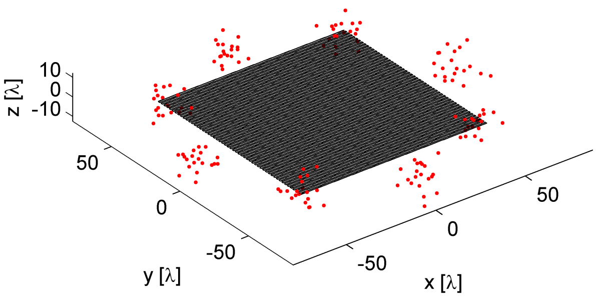

Fig. 3 Spatial positions of eight clusters with twenty points in each cluster. The square in the middle represent the receiver path.

IV. Results

We present the apparent diversity gain [3] and the maximum available theoretical capacity [8] in the present paper. The latter depends on the signal-to-noise ratio (SNR) which we choose to be 15 dB, when referred to the average received power of a single-antenna user using an antenna with 100% efficiency and the same receiver performance as the receivers at the ports of the simulated antenna under test.

First, we show an environment with only one cluster or one incoming plane wave per realization in Fig. 4 and Fig. 5. It is clear that the apparent diversity gain and capacity converge to the same value for an increasing number of samples, even if the convergence rate is rather slow. These cases are not rich enough, i.e., there are too few waves for each position or realization in order to be representative of most real environments. Still, the apparent diversity gain converges towards the ergodic value in a rich multipath environment.

In Fig. 6 and Fig. 7 the apparent diversity gain and capacity are calculated for eight clusters or eight plane waves per realization. Eight clusters are the minimum number of clusters used in the Winner II channel models. Here we see a fast convergence towards the ergodic value, and we see that each parameter converge to the same value regardless if it is calculated in a (rich) isotropic environment or a cluster environment. It is also evident that we need to gather only a few hundred samples in order to achieve convergence. This is consistent with our experience.

Finally, Fig. 8 and Fig. 9 present the apparent diversity gain and capacity for twenty clusters or twenty incoming plane waves per realization. This is the maximum number of clusters used in the Winner II channel models. The results converge again towards the same ergodic values independent of type of environment. The convergence rate is slightly improved compared to the previous case.

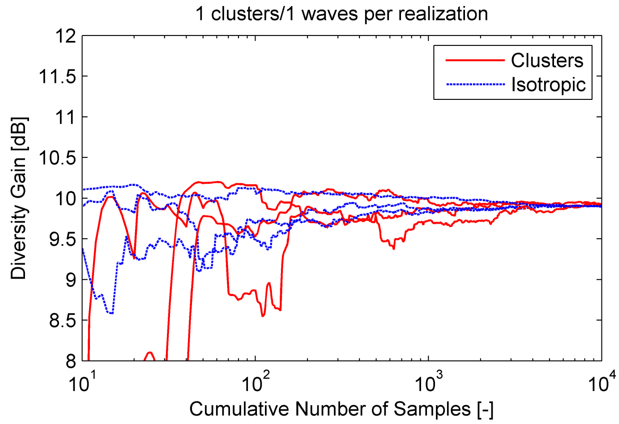

Fig. 4 Apparent diversity gain of the two vertical parallel dipoles defined in Fig. 2 in an environment with one cluster (red curves) or one incoming wave per realization (blue curves) averaged over an increasing number of samples. The three curves for each of these environments represent three separate calculations.

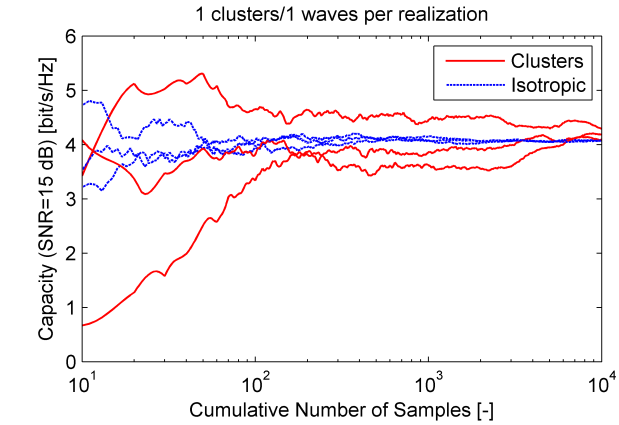

Fig. 5 Maximum available theoretical capacity for a signal-to-noise ratio of 15 dB of the example two dipoles in Fig. 2 when located in an environment with one cluster (red curves) or one incoming wave per realization (blue curves) averaged over an increasing number of samples. The three curves for each of these environments represent three separate calculations.

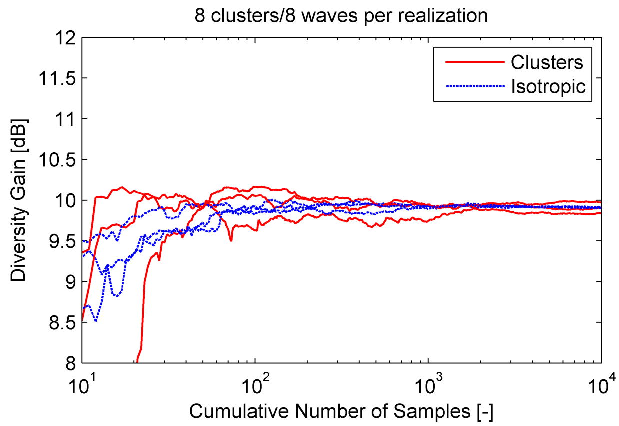

Fig. 6 Apparent diversity gain of the example two dipoles in Fig. 2 in an environment with eight clusters (red curves) or eight incoming waves per realization (blue curves) averaged over an increasing number of samples. The three curves for each of these environments represent three separate calculations.

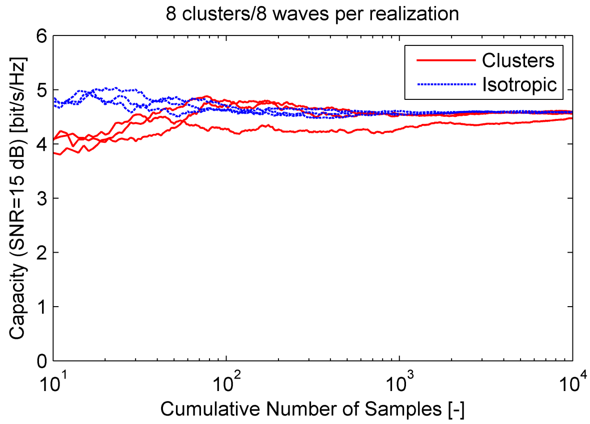

Fig. 7 Capacity for a signal-to-noise ratio of 15 dB apparent diversity gain and capacity in an environment with eight clusters (red curves) or eight incoming waves per realization (blue curves) averaged over an increasing number of samples. The three curves for each of these environments represent three separate calculations.

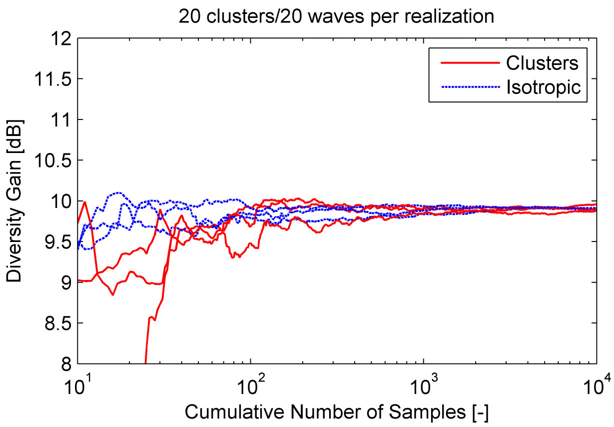

Fig. 8 Apparent diversity gain of the example two dipoles in Fig. 2 in an environment with twenty clusters (red curves) or twenty incoming waves per realization (blue curves) averaged over an increasing number of samples. The three curves for each of these environments represent three separate calculations.

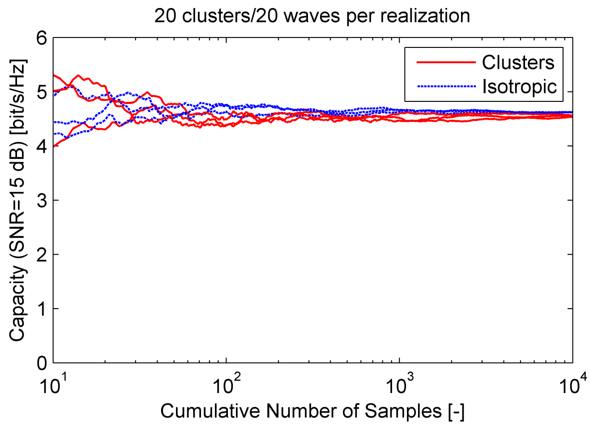

Fig. 9 Capacity for a signal-to-noise ratio of 15 dB of the example two dipoles in Fig. 2 in an environment with twenty clusters (red curves) or twenty incoming waves per realization (blue curves) averaged over an increasing number of samples. The three curves for each of these environments represent three separate calculations.

V. CONCLUSIONS

We have shown that when a user is moving around in a propagation environment modeled by fixed clusters like in the Winner II propagation model, with fixed wave amplitudes, the ergodic values of the diversity gain and capacity will be the same as when these values are calculated in an isotropic environment.

ACKNOWLEDGMENT

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