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Patrice Pajusco

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Double characterisations of power angular spectrum in macro-cell environment

P. Pajusco

A propagation experiment using a uniform linear array at the base station in rural and suburban area is presented. Wideband parameters, clusters behaviour and angular parameter at the base and mobile stations are analysed. Statistical results are provided and typical situations are presented.

Introduction: MIMO is a very promising technology for future wireless telecommunications. Innovation on air interface and coding requires realistic space-time propagation channel models in different configurations. Most of the published results are focused on urban area and direction of arrival at the base station. However, the knowledge of spatial properties at both the base station and the mobile station is necessary to precisely set up a MIMO propagation channel [1]. An efficient way is to perform double directions of arrival measurements [2]. However, such experiments are complex and a few publications are only available.

This letter reports the results of a simple wideband experiment performed with a uniform linear array at the base station. These measurements aim to estimate the power angular spectrum at both mobile and base stations. Directions of arrival at the base station are estimated by beam forming, using the antenna array. Directions of departure at the mobile station are estimated by transforming the Doppler spectrum into angular spectrum. This experiment is focused on rural and suburban areas where spatial characterisations are not very numerous. The paper analyses the statistical results and presents the typical behaviour. Cluster behaviour during mobile motion is also investigated. These data represent relevant information to refine geometrical MIMO channel model.

Measurement set-up : Wideband channel measurements using a uniform linear array were performed at 2 GHz on a 10 MHz frequency bandwidth (-3dB). The transmitter equipment was located in the mobile which was driving at a constant speed. The receiver was located on an isolated and high building (35 meters height) at the limit of the suburb. One snapshot was composed of 600 measurement points triggered by a 90 Hz frequency generator. According to the mobile speed, one

snapshot corresponds to about 30m run length ($\sim\lambda/3$ spatial sampling). Six different pointing azimuths were investigated. For each azimuth configuration, more than 40 snapshots were measured. During this experiment, more than one million complex channel impulse responses were collected. The maximum distance between transmitter and receiver was about 5 km. Measurements were considered in open area when the mobile was not surrounded by constructions (typically on a road out of the suburban). Elsewhere, measurements were considered in suburban area.

This experiment aimed to characterize the power angular spectrum at the both sides of the propagation radio channel. On the receiver side, a uniform linear array was used. It was made of 10 directive elements with 1 dummy element at each side. The gain of each element was about 12 dBi (4 directive dipoles vertically coupled). An omni directional antenna was also used to estimate the total received power and derive the side lobe level of the direction of arrival algorithm. This omni directional antenna was located one meter above the antenna array. These 11 antennas were connected to the wideband channel sounder. In the mobile, the transmitting antenna was mounted on a metallic plan. Considering a constant speed, measurement at the mobile could be assimilated to a uniform linear array. More details about this equipment, the data processing and the calibration process may be found in [3].

General wideband characteristics:

The power delay profile computed over 40λ at the base station is similar on each antenna element. Some differences of a few decibels between antennas are easily explained by the antenna pattern. The ITU-R selectivity parameters were computed with a constant dynamic level of 20 dB. Measurements with lower dynamic were not taken into account. Measurements outside the antenna aperture (120°) were removed from the statistical analysis. In suburban area, the median value of Delay Spread and Delay Windows 50% are respectively 90ns and 55ns. In open area, these value are twice smaller, respectively 40 and 18 ns.

To characterise wideband fast fading, the m parameter of the Nakagami distribution was estimated for each excess delay using the moment method. To minimize the influence of noise, a minimum of 15 dB above noise floor was required. The highest values are usually found on the strongest path, however significant values can be also found on far paths. In suburban area, the median value of m values on the strongest path is about 2. In open area, this value increases to 9.

Power azimuth profile at the base station: Directions of arrival at the base station were estimated by the beam forming method. Such an approach is very convenient and fast to analyze a large amount of data. Our weighting function $b_m(\theta)$ to estimate the field strength in the θ direction was :

$$b_m(\theta) = \frac{a(\theta)^*}{\sqrt{a(\theta).a(\theta)^*}}.W \quad (1)$$

where $a(\theta)$ is the antenna array response in the direction θ and W a Chebyshev weighting function. This windowing reduces sidelobe level at a constant value of 20 dB. The cut-off level was defined from the average total received power on the array and omni directional antenna. Directions of arrival only above this threshold were taken into account. Directions of arrival were computed on each significant multipath of the instantaneous channel impulse response and averaged along a 40λ run. The space-time diagrams at the base station were processed on all measurements. An example of a typical file is presented in figure 2. The mobile was located in suburban area at 19° relatively to the base station. Usually, the different clusters come from similar directions. The maximum of power on the power angular spectrum usually comes from the mobile geometrical direction. The strong correlation between these parameters is shown in figure 1. The angular spread at the base station is similar in both environments. The average value is 4° with a standard deviation of 2° which is much smaller than in urban area where we found respectively 14° and 5° [5]. The difference between the geometrical direction of the mobile and the direction of the maximum received power is also a very interesting parameter. It can have a direct impact on the accuracy of location techniques. In urban area, this parameter can be modelled by a centre Gaussian distribution function. The standard deviation is about 16° near the base station and decreases to 8° far away [4][5]. This assumption is also valid in rural/suburban area but the standard deviation is much smaller due to the small number of scatters. The standard deviation is 2.7° when distance is below 2 km and decreases to 1.7° above.

Power azimuth profile at the mobile station: Statistical distribution of multi-path is important for wideband modeling. However, the knowledge of directions of departure is required for MIMO geometrical models. Directions of departure were estimated from the Doppler spectrum. In most of cases, the Doppler spectrum shape is continuous and the limits $[-\frac{v}{\lambda}, +\frac{v}{\lambda}]$ are easy to define.

Considering the simple relation ship between Doppler frequency and angle of departure, it is very simple to derive the azimuth Doppler spectrum at the mobile. This simple approach has a conical ambiguity (ambiguity between right and left in 2D). However, such an analysis is very simple and provides valuable information. This estimate was computed on each significant multipath of channel impulse response and average over the 40λ run. Typical space-time behaviour at the mobile (average along 30 meter run) in suburban is presented in figure 3. The variation of the most significant clusters is presented in figure 4.

Directions of arrival are very different from one excess delay to another. Such space-time diagram are different from one location to another. However, these plots remain similar if we move locally at the base station antenna (analysis using different antennas of the base station) or if we perform other measurements at the same location. These space time diagrams represent real signatures of mobile locations. More generally, the received power is widely spread all around the mobile which can be separated in two different components:

- A few significant clusters with 'constant' geometrical properties during the mobile run. It corresponds to deterministic and predictable components: visible street corner, visible roof top diffraction, specular reflection... These components have finite but significant life duration.
- diffuse and smaller components distributed all around the mobile. These components come from very local scatterers around the mobile: reflections on moving cars, very local obstacles, trees.... Such components have very short life duration or geometrical properties that change significantly when the mobile moves.

In the rural area, the most significant cluster is the direct path corresponding to the base station direction. In suburban area, there are more clusters and the direction of the main cluster is not always the base station. The power variation of clusters changes significantly and independently during the mobile travel. Some clusters appear while another disappear. The average angular spread (computed between 0 and 180°) is about 35° in suburban environment and 20° in rural environment.

Conclusion:

Results of azimuth distribution at both the base and mobile stations were presented in the two specific rural and suburban environments. Typical and statistical behaviours were shown. In both

configurations, two types of components were identified: a few significant clusters with nearly constant geometrical properties, diffuse components all around the mobile. Such results provide additional data to improve the configuration of MIMO geometric channel models.

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Author's affiliation:

Patrice PAJUSCO, France Télécom R&D
6, avenue des Usines - BP 382 - 90007 Belfort, France
patrice.pajusco@francetelecom.com

Figure captions:

Fig. 1 : Linear relation between direction of arrival and mobile azimuth

Fig. 2 : Typical space-time distribution of power at the base station in suburban area

Fig. 3 : Typical space-time distribution of power at the mobile in suburban area

Fig. 4 : Power fluctuation of clusters along the run of figure 3

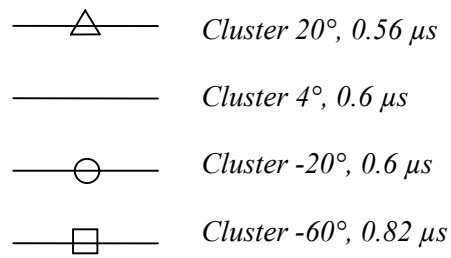


Figure 1

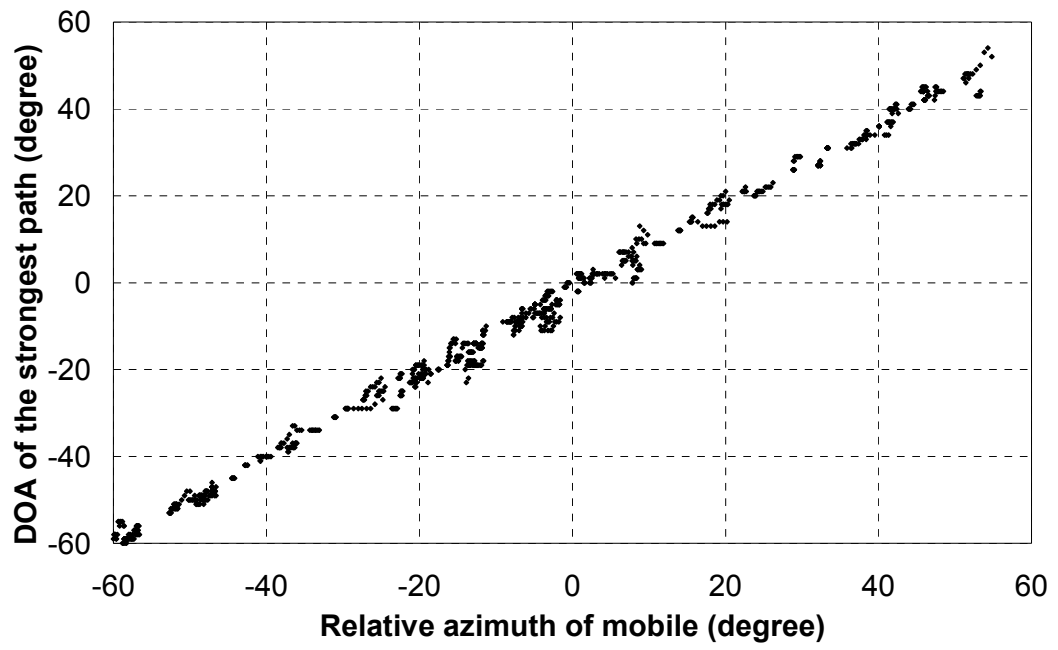


Figure 2

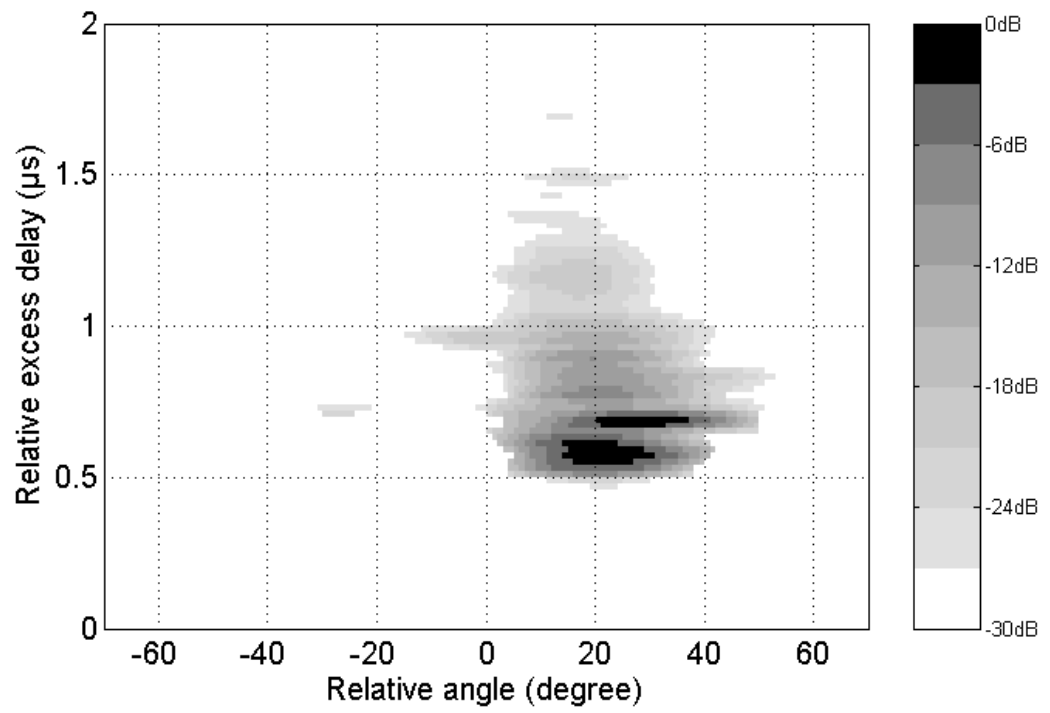


Figure 3

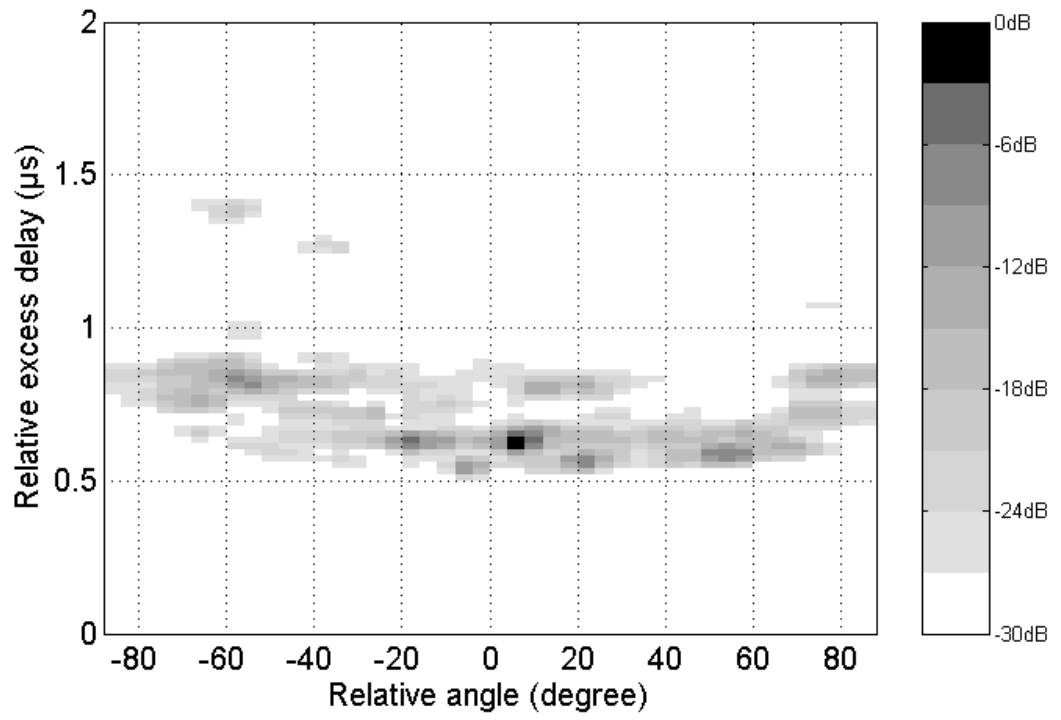


Figure 4

