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Delay Spread Control Hiding First Hit Objects

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Abstract— **This paper proposes a methodology for the prediction and eventual cancellation of the main scatterer effects on broadcast radio channels. We assume the possibility of using absorbing material or paint to reduce the reflectivity of some surfaces and virtually "hide" the scatterer, so as to control the maximum Delay Spread in terrestrial Digital Video Broadcasting systems. A desirable condition for the DVB-T2 operators is to limit the Delay Spread of radio channel in conditions where it is not possible to change the location or the orientation of the transmitting antenna; moreover, this can be useful to limit the Inter-Symbol Interference (ISI) and to improve the balance between the interleaving time and the channel capacity. In order to prove the applicability of object hiding, we used ray-tracing 3D techniques to identify the objects that can be hidden or camouflaged, and calculating the effect of objects on parameters of the DVB channel, in this case the delay spread. The results of the simulation applying physical hiding of object shown a expected reduction of Delay Spread.**

Index Terms—Delay Spread, DVB-T2, Ray Tracing, Multipath Channel.

I. Introduction

Multi-path propagation causes fading and may distort and attenuate received signal on radio channel [1]. This multipath causes that the transmitted bits of a digital signal get mixed together (Inter-Symbol Interference, ISI); besides, it is often unavoidable in radio systems due to the propagation channel undergoes several perturbations. Usually, there are two techniques that we can employ to reduce the effects of multi-path fading on the system performance: diversity reception and adaptive equalization. However, the interleaving time, typically over 70 ms, was introduced to provide protection against impulsive noise and time-selective fading on DVB-T2 systems [2]. Nevertheless, for the specific channel capacity, the operator can improve the balance between the interleaving time and the equalization. On the other hand, distant interactions can generate, at many locations, excess delays greater than the guard interval, thus generating interference [3].

Then, for a DVB-T2 operator is desirable to limit the delay spread of the radio channel in situations where we cannot change the configuration, location or orientation of the transmitting antenna, and diversity or equalization techniques fail to improve the system performance. Therefore, other strategies must be implemented to minimize the impact of excess delays on radio channel.

This paper presents an alternative option to limit the excess delay on a radio channel based on the detection of scatterer objects and hiding of such objects, usind 3D ray tracing techniques. For the validation of such technique, we use a simulation scenario that has been previously validated for the ray tracing model[4].

The paper is organized as follows: in section II we describe the simulation scenario, in section III we describe the channel modeling process, in section IV we describe the prediction technique used, in section V we discuss the results obtained and in section VI, conclusions and further work.

II. Outdoor Scenario

The simulated and analyzed scenario was a small sub-urban macrocell including areas in both inside and outside of the main campus of the Universitat Politècnica de València (Spain) [4].

Fig. 1 shows the scenario used for the simulation. This scenario has a 2 km x 2 km area, with slightly inclined streets and complex buildings around the campus.

Fig 1. Scenario of the main campus of the Universitat Politecnica de Valencia, the red point is the location of transmitter

For our simulation, the transmitter (Tx) is located on the top of the building inside of the main campus at 24 m height, thus providing a medium coverage; the EIRP of all transmitters is 36.01 dBm. The transmitter has two panel antennas oriented at 114° and 316° azimuth respectively. The antennas are vertically-polarized panel type with 62° half-power beam-width in the horizontal plane, 28° in the vertical plane and 12.15 dBm gain.

Our initial analysis consisted of a series of received power measurements along the streets, inside and outside of the main campus and around the transmitter. Fig. 2 shows the different receiver points which are localized centered along the street. This measurements was used to validate the model for propagation losses purposes.

The transmitter provided a DVB signal with a frequency of 496 MHz. Receiving antenna is a vertical quarter-wave length antenna and is positioned at 1.8 m. above the terrain. The routes for all the simulation include localizations with LOS and NLOS. We defined 1380 reception points for calculating the effect of objects on propagation parameters for the DVB channel.

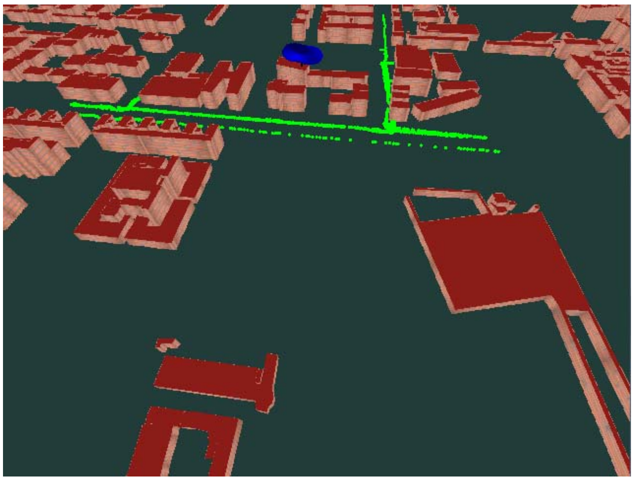

Fig 2. Localization reception points(green spheres) for LOSs and NLOS. The transmitter localization is indicated for a blue bounding

III. SIMULATION OF MULTIPATH CHANNEL

We used the 3D ray-tracing techniques in combination with our urban 3D model and the implementation of the algorithms and techniques with game engine and GPU. Our previous work has shown that these techniques are appropriate for obtaining multipath parameters with high accuracy and fast processing time [4] [5] [6].

We used the ray-tracing 3D techniques to obtain the low-pass impulse response of the channel $h(t,\tau)$ as:

$$h(\tau,t) = \sum_{n=1}^{N(t)} A_n(t) e^{-j2\pi f_c \tau_n(t)} \delta(\tau - \tau_n(t)) \quad (1)$$

Thus, the multipath channel is represented as a power delay profile (PDP) expressed by (1) [4].

The characterization of wideband radio channel in time domain is obtained from the PDP and the first and second order moments, the mean excess delay and RMS delay spread.

The mean excess delay and RMS delay spread quantify the multipath channel scattering properties and these parameters determine the dispersion of the channel, making it a better indicator of the system performance about the ISI [1].

The mean excess delay is the "center of gravity" of the profile; defined by:

$$\bar{\tau} = \frac{\sum_k P(\tau_k)\tau_k}{\sum_k P(\tau_k)} \quad (2)$$

Where $P(\tau_k)$, is the individual power and τ_k isthe delay according to each tap.

The RMS delay spread is the second moment or spread of the taps; defined by:

$$\sigma_\tau = \sqrt{\overline{\tau^2} - (\bar{\tau})^2} \quad (3)$$

and,

$$\overline{\tau^2} = \frac{\sum_k P(\tau_k){\tau_k}^2}{\sum_k P(\tau_k)} \quad (4)$$

Using the 3D ray tracing model, we use the rays that reach each one of the receiving points and estimate the RMS delay spread and other channel parameters. Because the model have to identify each of the reflection and diffraction points, we also can identify the objects that have more influence on the RMS delay spread.

IV. PREDICTION OF FIRST HIT OBJECTS

We have identified with a unique attribute or name, each of the objects in the environment (Wall, Street, Horizontal Edge, Vertical Edge and Roof). This attribute allows us to identify uniquely and individually each element. In this way, it was possible to save the identification of the first objects impacted that arrive successfully at the receiver for each path. We assumed that the objects of first hit are good candidates to hide due to the fact that these objects derive the following paths that arrive to the receiver. Moreover, the number of objects of first impact is less in proportion to the second and third hit.

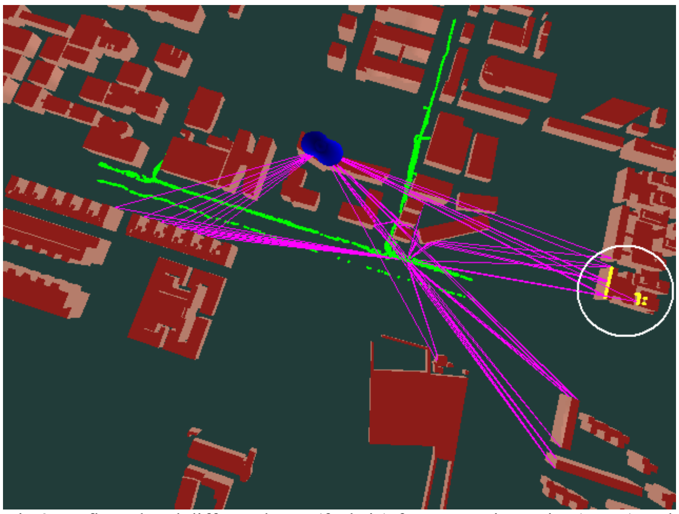

Fig 3. Reflected and diffracted rays (fuchsia) for a reception point (green) and candidates object to hide (yellow objects within the white circle)

This method was applied, in order to identify the objects from first hit using data obtained from the multipath channel simulation. Fig. 3 shows the results of the ray tracing procedure, with reflections and diffractions, for the estimation of a reception point. The ray-tracing model estimates the parameter values of the propagation wave using the game engine.

In this process we have implemented an algorithm to identify the paths that have the greatest impact on the delay spread. The paths that reduce the RMS delay spread values up to 10% were identified for each reception point. These paths were deleted one by one until we obtained the desired percentage. Then we identified the first hit object on each path and finally we grouped the objects according to the identification attribute. As a result, we obtained 114 first hit candidate objects to hide.

Table I summarizes the classification for candidate objects to hide. Vertical edges (VE) represents 70%, horizontal edges (HE) represents 23% and walls only 7% of total objects. These results shows that the main contribution to the delay spread for this scenario is due to the edges.

With this results, we proceeded to hide each candidate object individually and analyze its effect on the RMS delay spread standard deviation over all the channel. The results in Table II demonstrate that only five of the 10 objects produce an improvement greater than 1% on the RMS delay spread. It was determined that these objects are the best candidates to hide. Fig. 3 shows the five objects identified (yellow) within the white circle

TABLE I. CLASSIFICATION OF CANDIDATE OBJECTS TO HIDE

Object Class	Object Number	%
Vertical Edge	80	70
Horizontal Edge	26	23
Wall	8	7
Street	0	0
Roof	0	0
Total	114	100

TABLE II. IMPROVEMENT ON STD DEVIATION OF THE RMS DELAY SPREAD

Attribute or name	Improvement %
HE,1056.9375855.01041.5897.0	6.5
HE,1083.0892.01078.0906.0	5.3
VE,1088.1875897.5	3.9
VE,1083.00892.0	2.4
VE,1085.375904.5	2.0
VE,1078.00906.0	0.9
VE,838.1875516.5	0.7
HE,1084.0864.01079.75878.0	0.5
VE,356.5474.5	0.4
VE,578.0749.0	0.3

V. ANALYSIS AND RESULTS

For the analysis and evaluation of the proposed methodology we "virtually" hide selected objects and calculated the mean and the standard deviation for RMS delay spread on all over the channel (1380 reception points). For our analysis we proceeded to identify and classify each of the five candidate objects being hidden. Table III summarizes these objects.

TABLE III. CANDIDATE OBJECTS TO HIDE

Object	Object Class	Unique identification attribute
S_1	Horizontal Edge	HE,1056.9375855.01041.5897.0
S_2	Horizontal Edge	HE,1083.0892.01078.0906.0
S_3	Vertical Edge	VE,1088.1875897.5
S_4	Vertical Edge	VE,1083.00892.0
S_5	Vertical Edge	VE,1085.375904.5

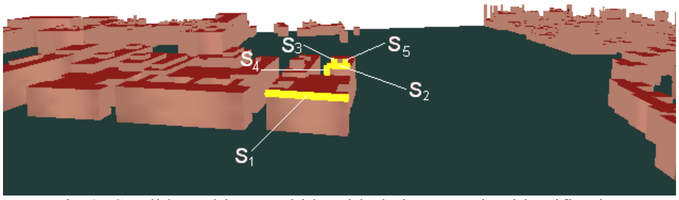

Fig 4. Candidate objects to hide with their respective identification

Fig. 4 shows the location of the objects to hide within the simulated scenario, according to the results mentioned above.

Fig. 5 shows the mean (blue line) and standard deviation (red line) for RMS delay spread. The mean and standard deviation, decrease as the objects are hidden in the scenario, S_0 indicates the initial conditions; S_1 indicates the hiding of the first object; $S_{1,2}$ indicates the hiding of two objects, and so on, until $S_{1,2,3,4,5}$ which indicates the hiding of five objects. Finally, the mean and standard deviation are decreased in 29.89% and 37.04%, respectively from their initial values.

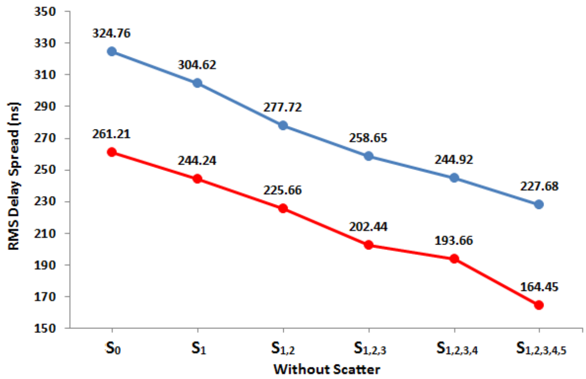

Figure 5. Mean (blue line) and standard deviation (red line) for RMS delay spread

Fig. 6 shows the mean (blue line) and standard deviation (redline) for mean excess delay. The mean and the standard deviation decrease as the objects are hidden in the scenario. The mean and standard deviation are decreased in 21.33% and 26.24%, respectively.

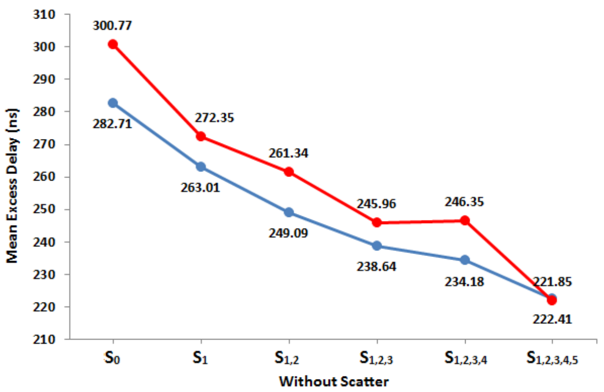

Figure 6. Mean (blue line) and standard deviation (red line) for Mean Excess Delay.

Fig. 7 shows the values of RMS delay spread for both, with and without the first hit object hiding technique. From the figure we can conspicuously evidence that our approach (blue line) effectively limit the delay spread in those reception points where the existing multipath channel shows a very long excess delay spread (red line).

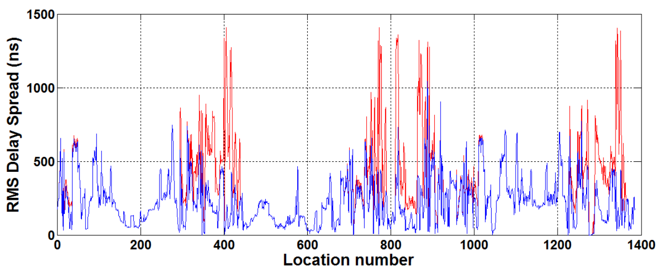

Figure 7. Overlaid of RMS delay spread values with (blue line) and without the first hit object technique (red line).

A hiding object technique can be implemented by applying shielding paints based on electro-conductive coating on the candidates objects to hide [7]. The shielding paint can be applied on interior and exterior walls, edges, roof and floors.

VI. CONCLUSIONS

We showed results for a novel technique than can be employed to limit the excess delay to DVB and 4G services using the method of the first hit object hiding. The use of the 3D ray tracing technique is very effective and feasible to identify the scatterers which most contribute to the excess delay. Using absorbing material or shielding paint we can hide the identified scatterers in the scenario reducing the values of Mean Excess delay and RMS delay spread in existing urban scenarios.

This methodology can also be applied to improve the available capacity in 4G systems.

This technique allows to improve the performance of OFDM and MIMO based technologies in real existing scenarios.

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