The Use of Space Diversity for UHF Digital TV Mobile Reception

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Abstract: - Diversity schemes are being used on mobile cellular networks to combat the effect of multipath fading mainly at the base station site. Since digital TV will be deployed using UHF bands, this paper proposes to study the feasibility of using space diversity for the mobile digital TV reception since these kind of system is also subjected to multipath effects.

This work experimentally investigates the use of space diversity at the mobile digital TV terminal in order to quantify the real benefit this scheme can provide to digital TV reception when mobility is present. The gain results are presented in dB related to the 10% multipath fading probability occurrence improvement.

Key-Words: - Space diversity, Mobile digital TV, experimental results.

1. Introduction

Fading is considered the main effect on performance degradation of mobile cellular systems. Its effects will also appear on digital TV systems where mobility is present. Hence, in order to combat the multipath effects this paper will discuss the feasibility of use techniques that can counteract these effects.

Diversity technique is probably the most efficient way to combat multipath and it is based on the fact that fading instants occurred in each radio channel are statistically independent. Hence, if certain information is redundantly available on two or more channels (known as diversity branches), the probabilities that this information is affected by a deep fade, occurring simultaneously on all of the branches is very low. Accordingly, with an appropriated algorithm (known as combining method) it is possible to obtain a resultant signal where the effects of fading are minimized, [1, 2].

Basically, there are two kinds of fading on a mobile radio environment, the large-scale fading (shadowing effect) and the small-scale fading (multipath effect). The way diversity is used to minimize each one of these fading is different. Macroscopic diversity, technique used to combat large scale fading variations, is not suitable for digital TV transmission since in general only one base station is used to transmit the signal. Whenever shadow fading occurs on a mobile digital TV link other ways will need to be proposed to combat these effects. Some authors have been proposing the use of simulcast transmission mainly on areas with difficult coverage problems. In this situation, other base station transmitter can be strategically positioned so that all mobile terminals have better chance of a clear radio path to at least one base station. Hence, the large-scale fading can be minimized. The obstruction effects of building, hills or any other terrain characteristics could be avoided, [3].

The methods of counteracting small-scale fading use microscopic diversity. The term microscopic refers to the distances involved in obtaining, at least, two independents radio resources. There are several techniques for obtaining diversity branches, but the most important is space diversity [4].

Space diversity, also known as antenna diversity, is one of the most popular forms of diversity used in wireless systems. This method relies upon the random spatial distribution of the signal to produce uncorrelated fading envelopes when two or more receiver antennas are separated in space. The implementation of this kind of diversity scheme is ease mainly on low UHF transmissions and over large areas available on the roof of buses and trains, [5,6].

2. Measurement Set-up

In order to investigate the effect of space diversity techniques on a digital TV mobile system, a measurement set-up was assembled and a series of measurements were carried out on an appropriate environment described, Figure 1.

The transmitter site utilized for the measurements was a 28-floor residential building with approximately 70 m height from the street level. The terrain around the transmitter site is practically plain but surrounded by mountains and at sea side. It is a morphological suburban area with medium concentration of tall residential buildings (20 to 30 floors on average) and dense vegetation. The measurement routes were selected in order to provide radial and transversal path ranging from 3 to 8 Km long. There is virtually line-of-sight condition on all routes except on areas with building obstruction. Very heavy vehicle traffic was present during measurement time. The route of the mobile unit can be visualized on the map of Figure 1.

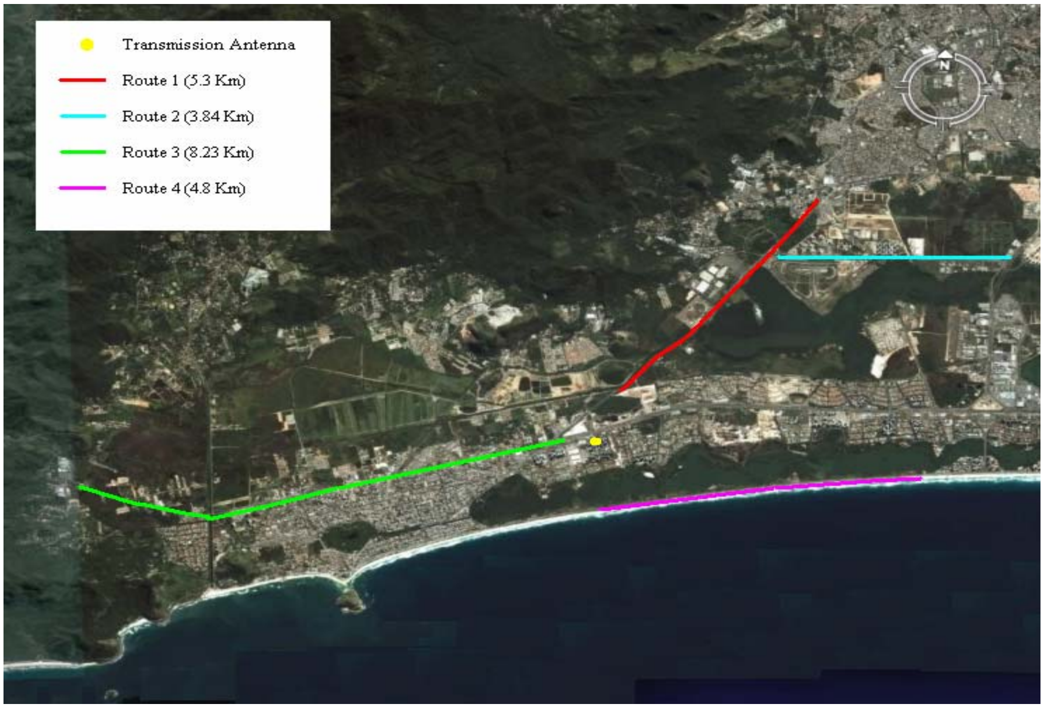


Figure 1 – Measurement environment and routes used

On the transmitter site, a 100 W CW generator (LINEAR UHF), was used only with the first power stage providing 10 W power to the 11.2 dBi transmitter antenna (TTLS4UA) shown in Figure 2 with its horizontal radiation diagram. The channel set aside for the experimental work was UHF channel 42 (641 MHz central frequency). The receiver site was mounted inside a van fed by a separated set of four 12 V batteries. Two omnidirectional antennas were used placed on the top of the van over a 1.1 m long rail. The signals received from these antennas were fed into two HP-8594E Spectrum Analyzers used on these experiments. In order to keep the receiver noise figure as low as possible, two Mini-Circuits ZEL-0812LN low noise amplifiers were installed between the antennas and the Spectrum Analyzers together with two narrow band LARK band pass filters. These configurations guarantee a very low minimum detectable signal with practically no off band interference. A HP pavilion laptop computer equipped with an A/D converter was used to sample the rear panel video output of the Spectrum Analyzers set to the zero span mode.

On the mobile unit a 2.14-dB gain omni-directional antenna was used. These antennas were home built and uses a dual orthogonal half-wave dipoles with an appropriated circuit to provide onmi reception on the horizontal plane. Figure 3 shows the two antennas on the top of the mobile unit. The gain and radiation diagrams of these two antennas were measured on an anechoic chamber.

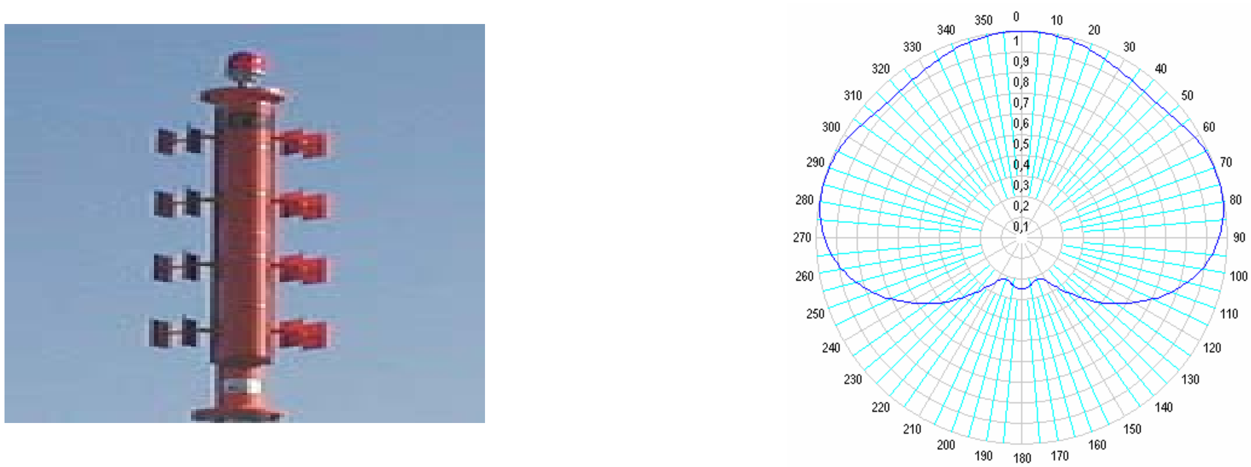


Figure 2 – The transmitter antennae and its horizontal radiation pattern

Figure 3 - The two reception antennas

The mobile unit has also a fifth wheel attached to the vehicle rear wheel to provide distance measurements.

3. Space Diversity

For these measurements was assumed that the information is redundantly received over independent branches by receiver antennas separated in space. We recall that, although the signal is transmitted by one single antenna, due to the scattering effects of the obstructions in the environment, the signal arrives at the receiver in the form of various (infinite) signals (multipath propagation), [7,8].

The elevated position of the base station makes it relatively uncluttered by nearby scatters, in marked contrast to the almost uniform angular distribution of scatters surrounding the mobile. As a result, the angular distribution of received waves at the transmitter station is narrower than that at the mobile unit. Thus, small antenna separations are enough to provide diversity gain at the mobile terminal. In these experiments the available space on the top of the mobile vehicle allows antenna separation up to 2 wavelengths. Hence, it was decided to use 0.5λ, 1.0λ, 1.5λ and 2.0λ separations for all measurement routes. Among the large number of the received signals, those experiencing independent fading must be discriminated. In other words, a correlation function between signals should be determined.

Space diversity was examined from measurements of the received signal envelopes of two antennas (with the same polarization) as a function of separation d. The normalized correlation coefficient of the signal envelopes provides a measure of the minimum required antenna separation, and the cumulative distribution function of the faded envelope provides a measure of the expected increase in performance (gain). Figure 4 shows the trace of 250 m distance received signals at the two antennas together with the local mean variation.

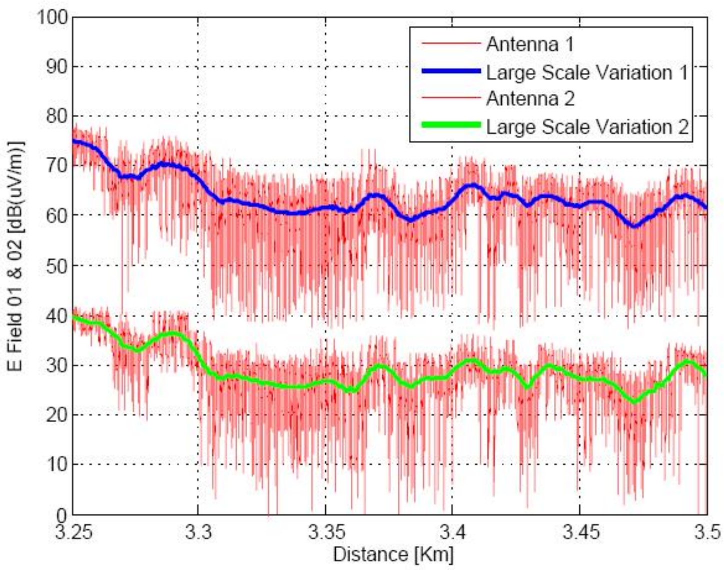


Figure 4 – Traces of the received signal with 30 dB(μV/m) off set.

This figure shows that, in order to compute the correlation coefficient, it was necessary to remove the variation of the local mean inherent in the recorded waveforms primarily because the local means on both branches would be expected to be highly correlated. A moving average technique was employed for this purpose, and then the correlation coefficient between the small-scale fading components of the signals was calculated. Figure 5 shows the measured correlation coefficient for various base station antenna separations of route 1.

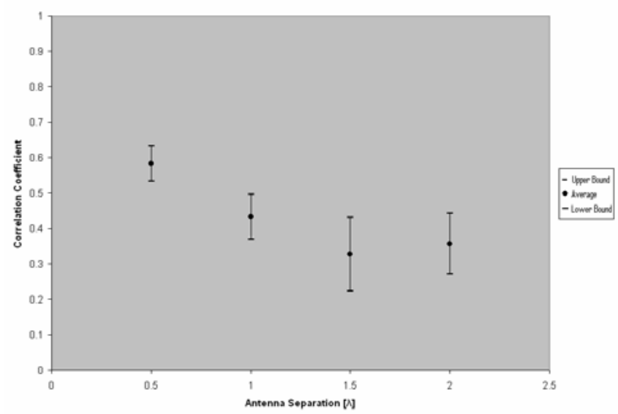


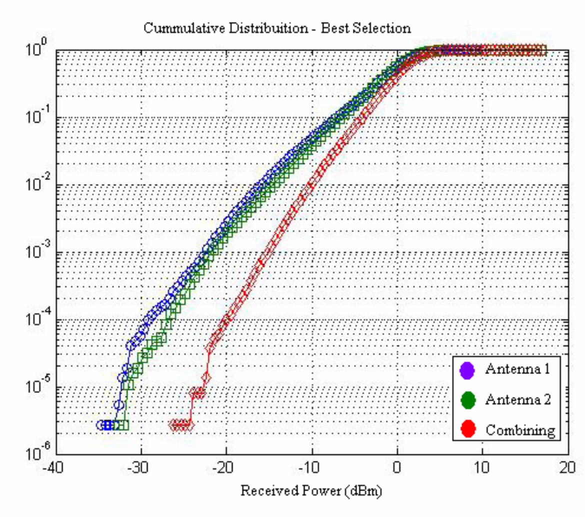
Figure 5 – Correlation coefficient

To assess the performance improvements from the signal statistics obtained through diversity combining, two-branch selection, equal gain or maximal ratio combining, calculations were developed with the recorded envelopes of the two branches for space diversity scheme [5].

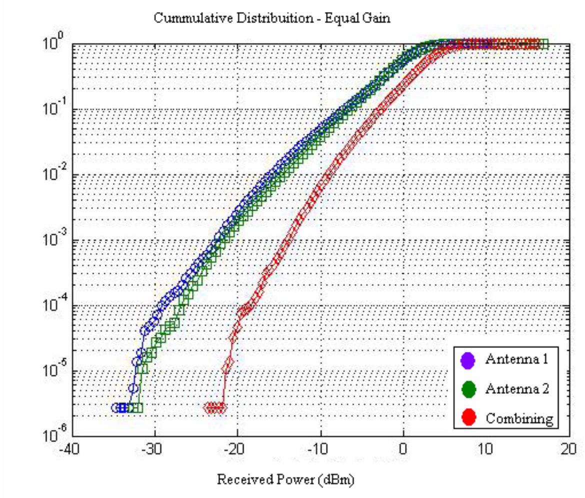
The cumulative probability distribution curves of both input signals as well as the combiner output have been produced, Figure 6. From these plots, we can deduce the performance of the method called diversity gain, which is defined as the difference in signal level of the branch with the lower mean and that received at the output of the diversity combiner for a given probability. In this work, the diversity gain has been evaluated at a level of fading exceeded 90% of the time, [6]. The results are summarized on Table 1.

Separation	ρ	gain BS	gain EG	gain MR
0.5	0.55	2.07	3.82	4.05
1.0	0.42	2.37	4.03	4.30
1.5	0.34	2.80	4.27	4.60
2.0	0.32	2.64	4.16	4.48
mean		2.47	4.07	4.36

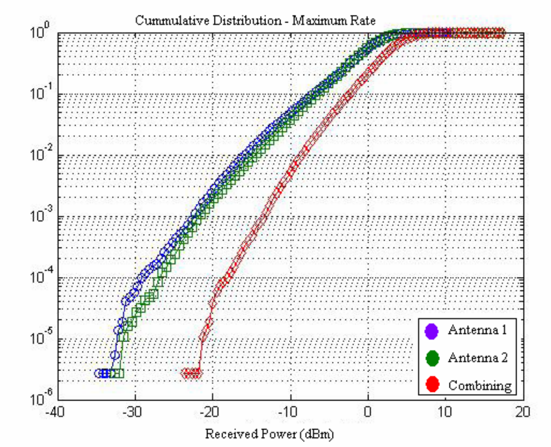
Table 1 – Space diversity (average results)



(a) Best selection



(b) Equal gain



(c) Maximum rate

Figure 6 – Cumulative probability distributions

6 – Conclusions

This work has presented an experimental access to space diversity technique for the mobile reception of digital TV signal. Although this technique is common on mobile cellular networks, its is used at the base station site where larger separation (about 10 wavelength) is required to provide enough decorrelation between the signal at the diversity branches. Here we have shown the results of space diversity for the mobile digital TV reception that can be used on buses and/or trains. A specific set-up was assembled with the transmitter site on the top of a tall building overlooking to the coverage area. The two identical receiving antennas were installed on the roof of a van carrying all the receiver system.

Correlation coefficient measurements have shown that for a confident space diversity use, the antennas needed to be separated at least by 1 wavelength apart in order to obtain a correlation level less than 50%. With this correlation, up to 4.6 dB gain was obtainable for the maximum rate combining technique. Other less expensive combining techniques have given less gain but it is still an option to combat the multipath effect present on this king of channel.

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