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Result of a measurement campaign of DVB-T signals with an indoor two antennas diversity receiver

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Result of a measurement campaign of DVB-T signals with an indoor two antennas diversity receiver

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Abstract

This paper concludes on the results of a governmental French R&D project intended to test the capability of diversity receivers to extend the coverage for in-home DVB-T reception with respect to standard receivers, and facilitate the entering into service of digital television in France. Measurements of DVB-T signals have been carried out in a few selected premises, using a diversity receiver and several arrangements of dual access antennas. The results show about 10 dB gain in the link margin, which will translate into a significant coverage improvement.

I Introduction

The terrestrial segment of digital TV broadcasting has entered commercial deployment at a pace significantly differing among the various countries. In addition the nature of the modulation (16 QAM or 64 QAM, 2K or 8K mode respectively) also differs, which has appreciable consequences not only on the channel capacity but also on the quality of the reception. In France DVB-T has just entered commercial service in march 2005. Among the handicaps to surmount, the need to adapt to new frequencies the anti-interference band pass filters currently existing in many RF distribution networks of multi-flat building, is susceptible to slow down the commercial success of DVB-T.

For this purpose the French project RECITENT which was jointly supported by the ministries of industry, research and culture/communication, has the goal to investigate fixed DVB-T reception using in-home antennas, with a particular focus on diversity reception. Silicon chips specifically designed for this purpose are currently developed by one partner of the project. It has indeed been demonstrated several times that dual antenna ports, together with a diversity reception capability of the receiver, very significantly improved the reception quality and robustness [1]. This is why looking at diversity techniques for in-home reception specially merits investigation in the above mentioned context [2]. One of the goals of the project was to carry out a measurement campaign of DVB-T signals reception, in various areas where experimental transmissions of broadcasters were available. Aside from an evaluation of the coverage which could be achieved for these transmissions [4], the other goal was to test the potential performance of diversity reception based on a variety of antenna solutions. A preliminary part of the work has been presented in a previous COST 273 meeting [3], showing the improvement of signal magnitude by spatial, angular or polarization diversity. However due to measurement limitations some assumptions had to be made in the analysis, such as the absence of correlation between received antenna signals. Nevertheless

the main conclusions highlighted the better performance of horizontal polarization even indoor, and the apparently slightly better performance of spatial diversity over angular diversity.

We here present the results of the final RECITENT measurement campaign, using a receiver fully implementing diversity reception of DVB-T signals. The measurements were carried out in the same environments as in the first campaign, and they highlight the very significant SNR gain and performance improvement attained with dual antennas diversity reception. The impact of this gain on coverage maps is illustrated for an SFN (Single Frequency Network) configuration in a last section.

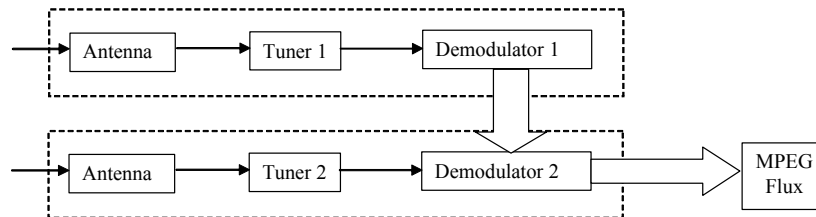


Figure 1: schematic diversity reception using a 'master' and a 'slave' signal path

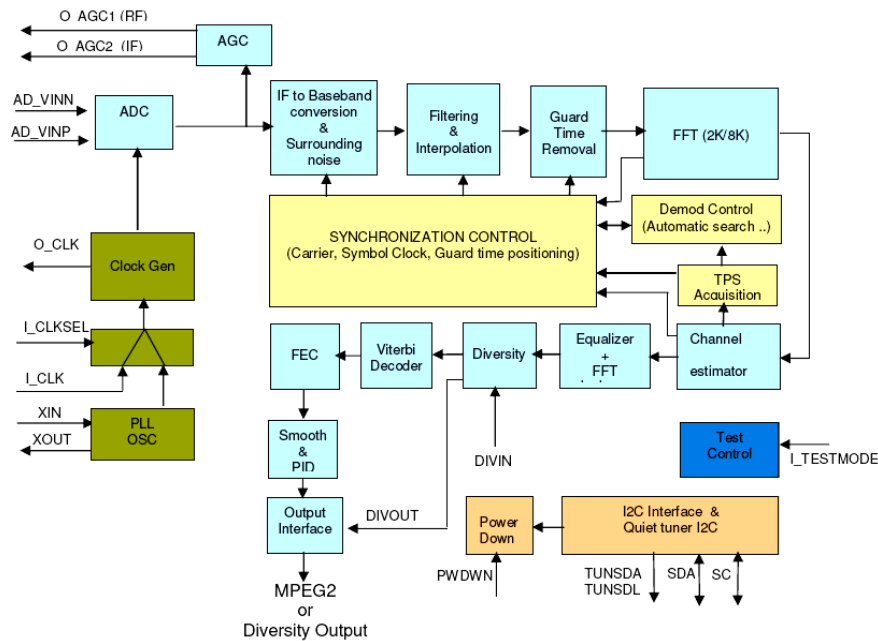


Figure 2: architecture of the DVB-T demodulator



a)



b)

Figure 3: a) SAGEM decoder ; b) diversity reception card developed within RECITENT

II Experimental aspects

The measurements have been carried out with a SAGEM decoder optimised for a portable receiver (Figure 1). This decoder is a variant of a commercial model, modified by the incorporation of a diversity reception card including two specifically designed DIBCOM chips (DIB3000MP). This approach relies on a double tuner and double demodulator architecture. Figure 2 shows a schematic representation of the diversity scheme used in the receiver : one of the reception ports ('master') compares both received signals ('master' and 'slave') and carries out the computation of combined signals based on maximal ratio combining (MRC), and Figure 3 shows a view of the hardware.

Three types of dual port antennas have been used and are illustrated in Figure 4.

- A parallel pair of specially designed planar dipoles operating in horizontal polarization, spatially separated by 30 cm.
- A quasi co-localized perpendicular pair of such antennas, also operating in horizontal polarization. Due to mechanical and access constraints, these antennas are not at the same altitude. The spatial shift of about 10 cm contributes somewhat to spatial diversity, although this antenna arrangement essentially targets angular polarization.
- A parallel pair of commercial planar antennas operating in horizontal polarization, also spatially separated by 30 cm. Differently from the previous ones, these antennas are "active", i.e. they contain a low noise amplifier which is supposed to amplify the received signal and improve the SNR.

Figure 5 shows the simulated 3D antenna patterns of the two dual antenna configurations, and Figure 6 the measured return loss.

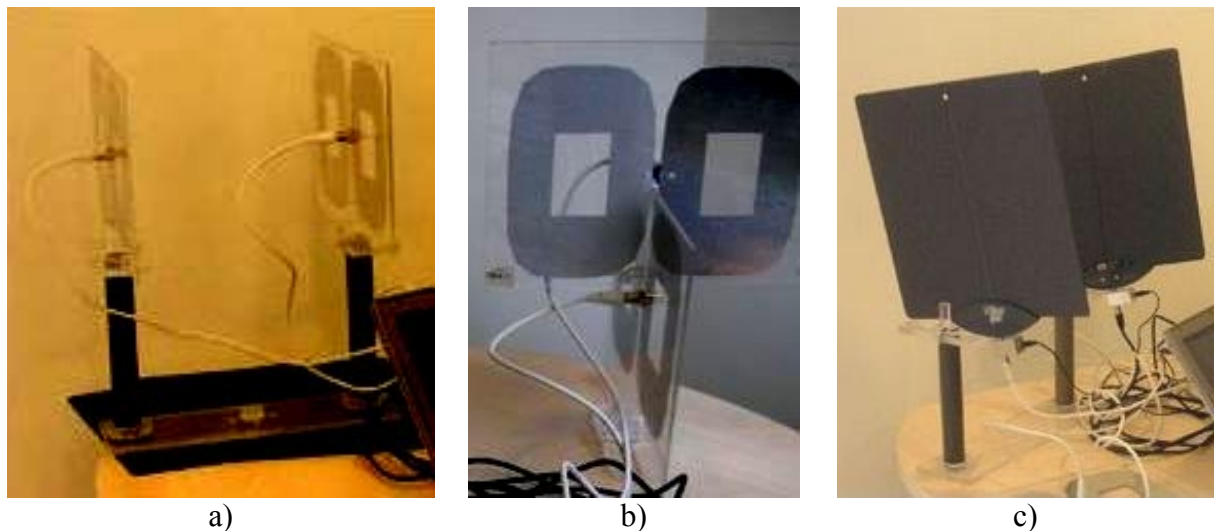


Figure 4: a) two parallel planar dipoles ; b) two perpendicular quasi co-localized planar dipoles ; c) two parallel commercial active planar antennas

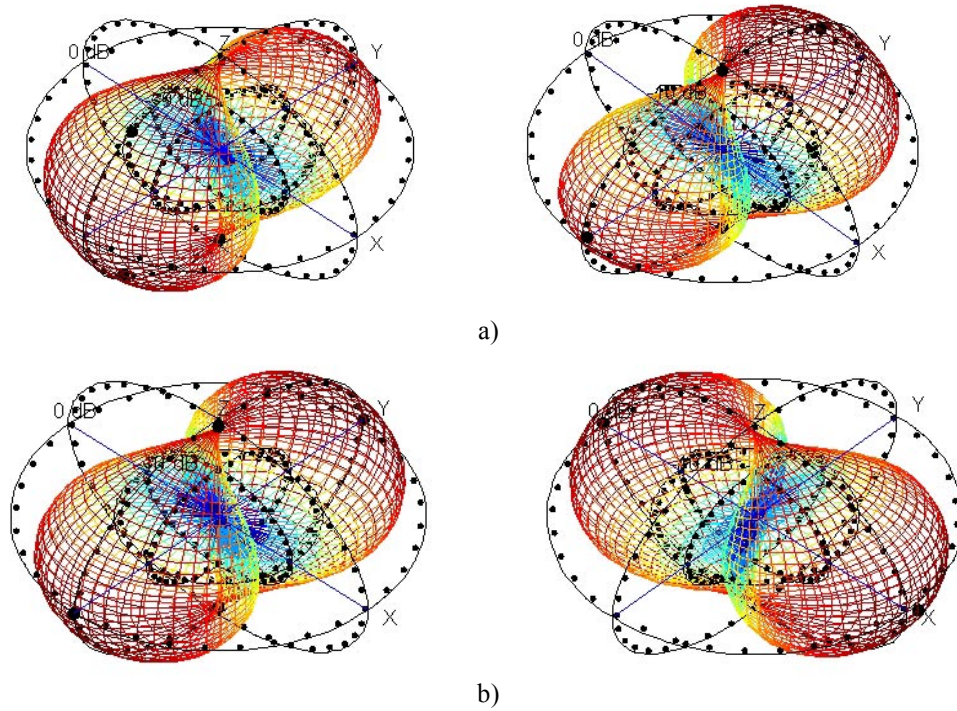


Figure 5: H-polarized radiation patterns of a) two planar dipoles and b) the perpendicular quasi-colocated planar dipoles. In each case the other antenna is loaded with the nominal 75Ω impedance

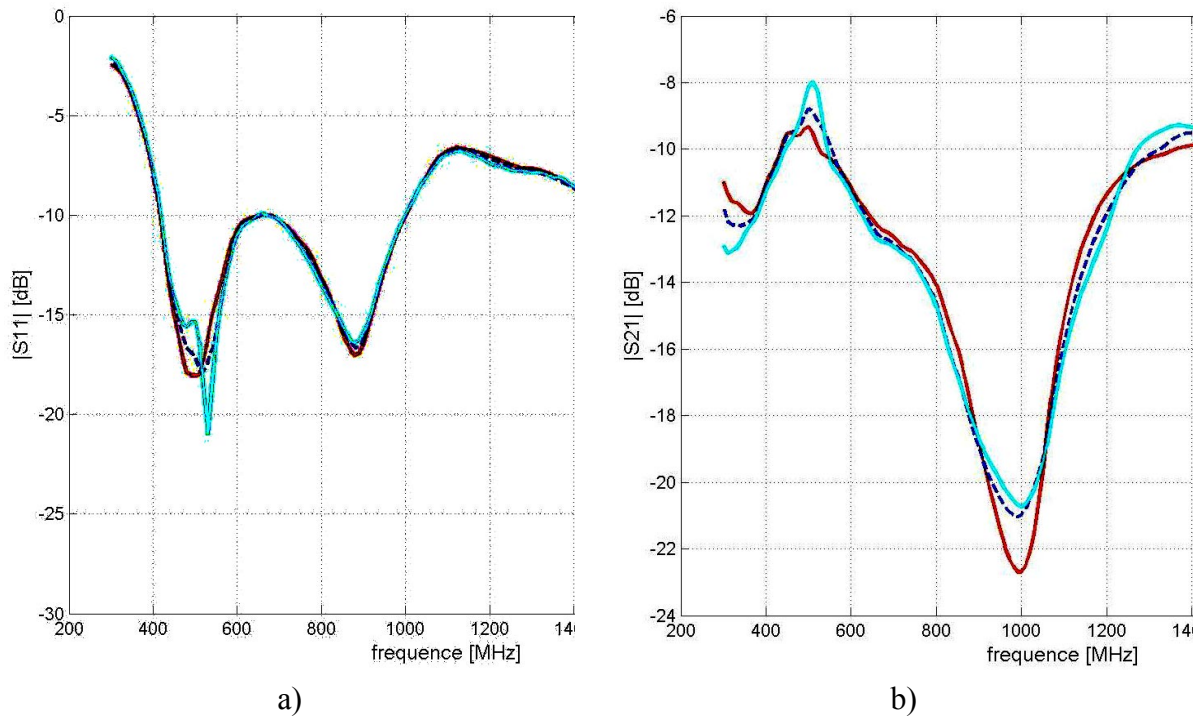


Figure 6: a): return loss of a planar dipole from 200 to 2000 MHz ; b) transmission coupling between two planar dipoles of the quasi-colocalized arrangement. In all cases the S parameters are computed with a nominal 75Ω impedance. The various colours correspond to different measurements

III Measurement scenarios

III-1 Measurement methodology

The measurements were carried out with signals received from the Eiffel tower TDF transmitter between March 14th and March 22nd 2005. Five frequency channels were tested (474 to 586 MHz). The measurement methodology was as follows :

- In each investigated room, the measurement locations were selected according to a practicality criterion taking into account the logical placement of an indoor TV receiver (e.g. in a corner or along a wall). For each location, the most favourable position for a given frequency (522 MHz) was roughly researched and retained before the actual measurements.
- The measurement itself consisted in determining three times the received power level in dBm, the carrier to noise ratio CNR in dB, and the BER of the 5 channels multiplex. The diversity receiver hardware capability allowed to get at the same time the power and the CNR on both reception channels ; however for the single antenna case only the BER from the master channel could be obtained, in addition to the BER of the two antenna combined signals.

III-2 Scenarios

The measurements have been carried out in two buildings, the first being ENSTA close to the boundary between Paris and its suburbs, and the second the “Copernic” building located at Noisy le grand, which is a small city in the east of Paris at about 10 km distance from its borders. These same locations had been selected for the 1st RECITENT measurement campaign [3], however the transmitters were not located at the same place (Eiffel tower presently, vs. three transmitters in SFN mode at the periphery of Paris in the previous campaign). A detailed view of the buildings and floorplans is shown in the annex (Figure 13 to Figure 17)

IV Results

The results have been analysed in order to highlight several features :

- Comparison between the BER of the single antenna and the BER for each of the dual antenna configurations
- Comparison between the received frequency multiplex for the single antenna and for each of the dual antenna configurations
- Computation of average, minimal and maximal values for the received power and the CNR

The latter are summarized in Table 1. Although the power received from the active antennas is logically much higher, there is no improvement in CNR. Actually the best results are obtained for each measured building for the passive spatial diversity antennas configuration, closely followed by the angular diversity configuration.

Figure 7 to 9 present the measured results for the sixth floor in Copernic building and for two floors (ground level and third floor) of ENSTA building, which are three

representative examples of the measured locations. The first kind of plots shows histograms of the BER for the 5 frequency channels of the multiplex and for the various antenna combinations. The second kind shows histograms of the number of correctly received frequencies of the multiplex, i.e. the horizontal axis goes from 5 (all frequencies are correctly received) to zero (no received signal).

The simple observation of these plots is very instructive. The improvement brought by diversity reception is very significant. This is seen both on the BER statistics for the various frequencies and for the number of correctly received frequencies. The most valuable improvement occurs in difficult reception conditions, which actually constitute the very reason why the RECITENT project was started (e.g. Ferber lecture hall in ENSTA at ground floor).

Again we see a great similarity of results between the various antenna diversity configurations, although statistically there are small differences and the spatial diversity configuration seems slightly better. This confirms the results of the first measurement campaign [3]. The similarity between angular and spatial diversity for the same planar dipole antennas is the most surprising. We indeed expect differences related to the local angular power spectrum, since in the pure spatial diversity configuration the orientation of both antennas is the same, while the angular diversity case covers perpendicular orientations. Since the horizontal dipole has a pattern null in its axis, the former configuration might be unfavourable if the dominant direction of arrival falls into this null. When the receiver location is in line of sight of the transmitter (high lying floors), the high value of the power level suffices to receive in proper conditions whatever the antenna orientation. On the other hand in deep or low locations, the indoor multipath richness is presumably sufficient to cover many azimuthal directions within the antenna pattern, which explains the little difference between antenna configurations.

Table 1: statistical data over all locations of Copernic and ENSTA for the received power level and the CNR, for the three antenna diversity configurations

	Copernic			ENSTA		
		Power (dBm)	C/N (dB)		Power (dBm)	C/N (dB)
Active antennas, spatial diversity	av..	-48,1	22	av.	-61,9	17,7
	Min	-66,9	12,4	min	-70,9	5,7
	Max	-33,7	28,3	max	-50,1	22,5
	Number	477	477	Number	404	404
Passive antennas, angular diversity	av.	-61,4	22,1	av.	-71,8	18
	Min	-77,7	13,1	min	-83,4	3
	Max	-44,4	28,2	max	-56,4	23,1
	Number	474	474	Number	449	449
Passive antennas, spatial diversity	av.	-57,7	22,7	av.	-69,5	18,5
	Min	-79,3	8,6	min	-80,9	3
	Max	-40,6	28,3	max	-50,4	23,4
	Number	476	476	Number	433	433

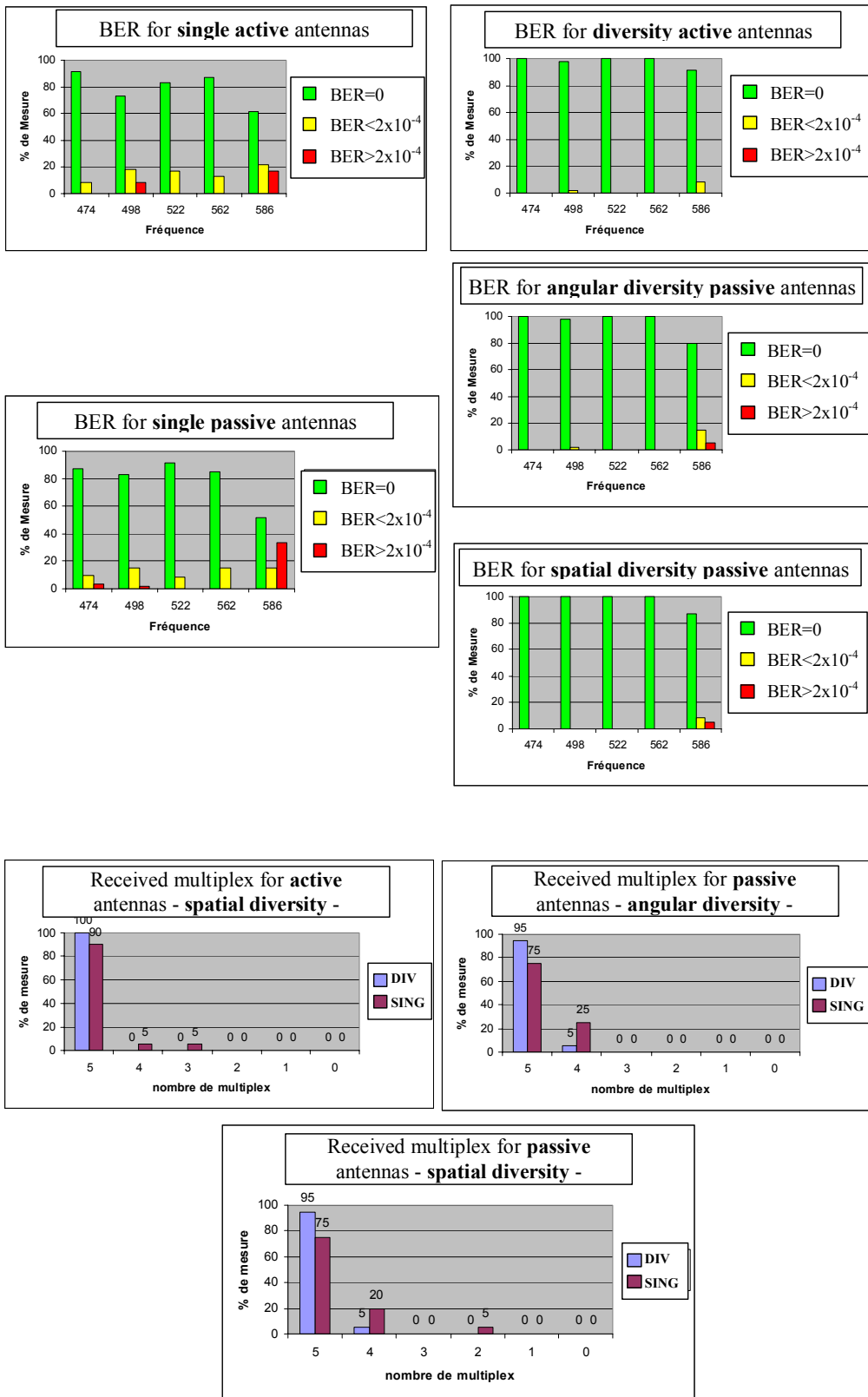


Figure 7: Copernic building, 6th floor ; up : BER histograms for the 5 frequencies ; down : histogram of the number of correctly received frequencies. DIV means diversity, SING means single antenna

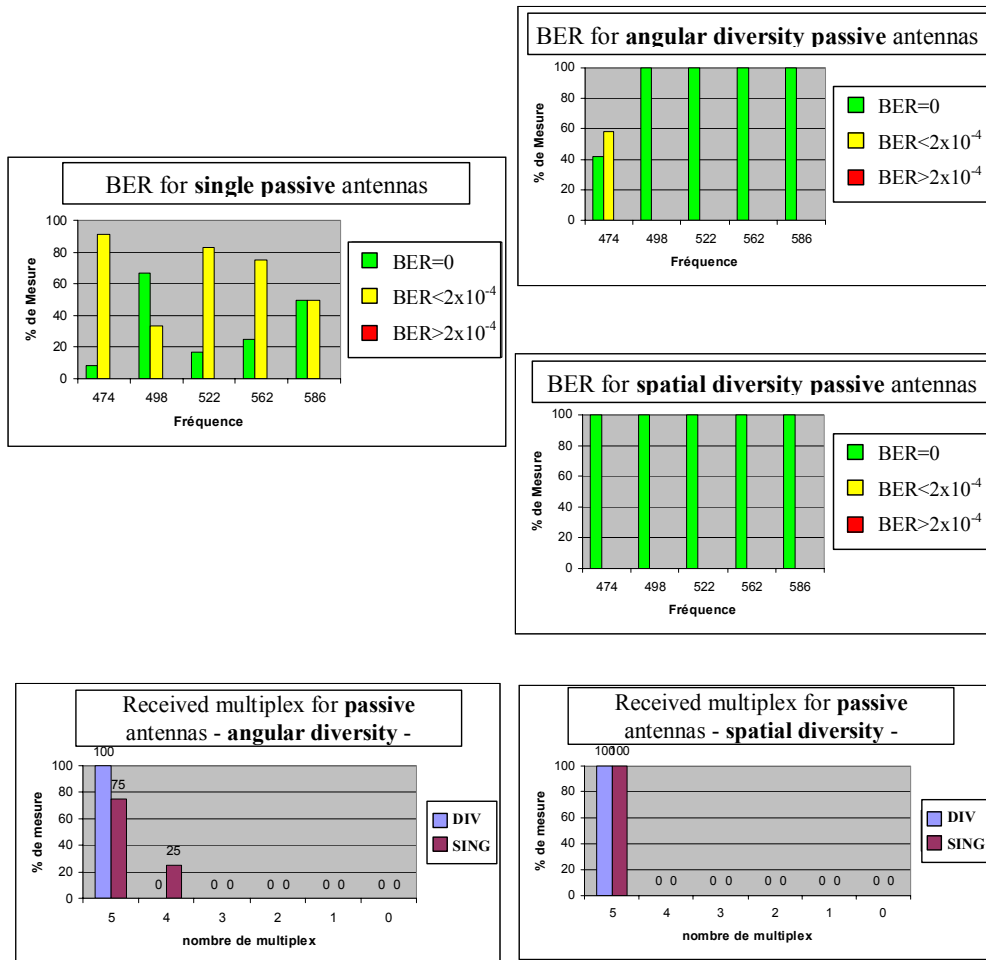


Figure 8: ENSTA, 3rd floor ; up : BER histograms for the 5 frequencies ; down : histogram of the number of correctly received frequencies. DIV means diversity, SING means single

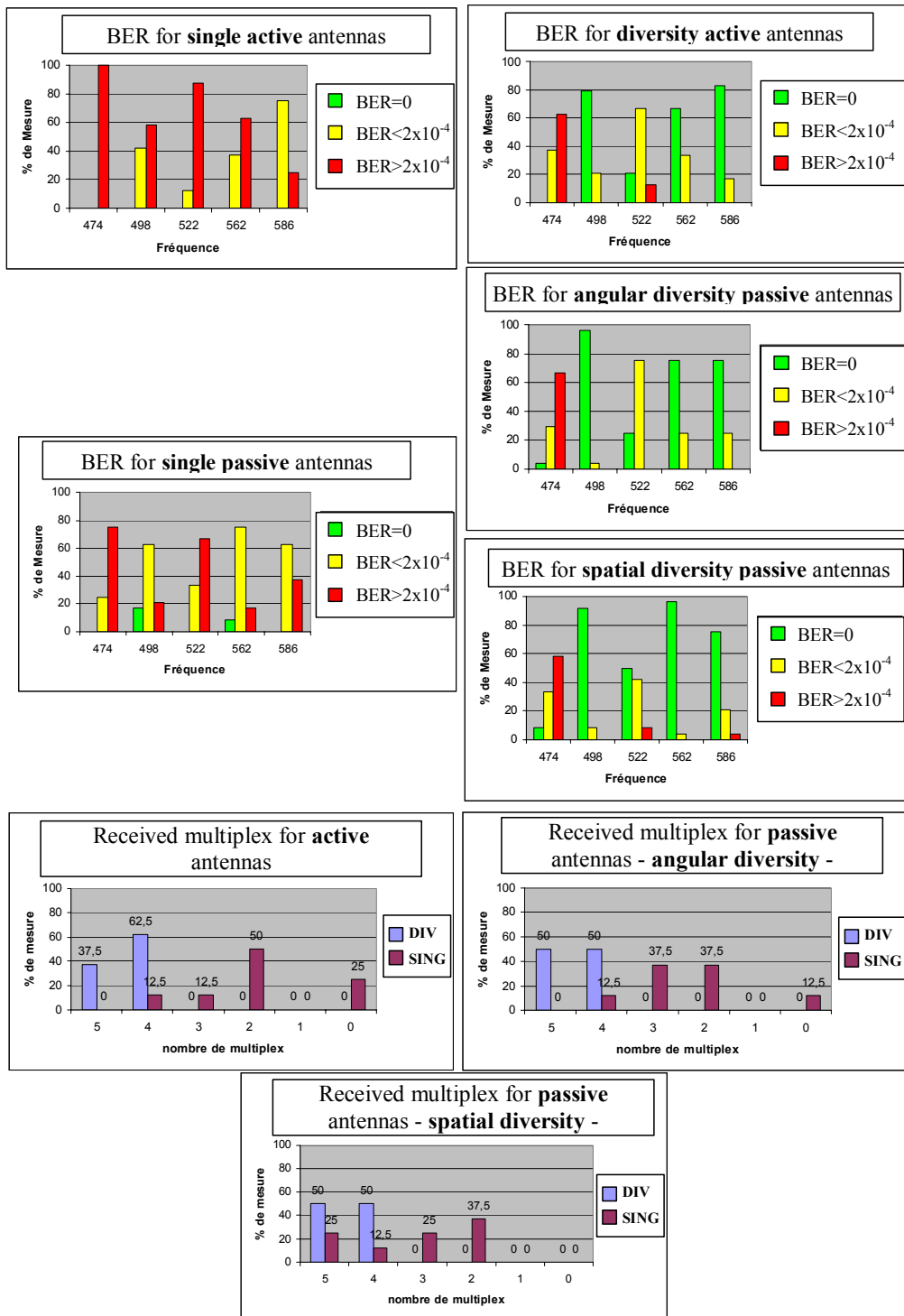


Figure 9: ENSTA, FERBER lecture hall ; up : BER histograms for the 5 frequencies ; down : histogram of the number of correctly received frequencies. DIV means diversity, SING means single

Finally by grouping all the data together, it was possible to plot the percentage of received frequencies of the multiplex vs. the received power level, for both single and two antennas diversity reception. This very interesting plot shows that for a given percentage there is about 10 dB power level difference between the single antenna reception and diversity reception. This is a rather high figure, which expresses the important performance

improvement brought by diversity reception (Figure 10).

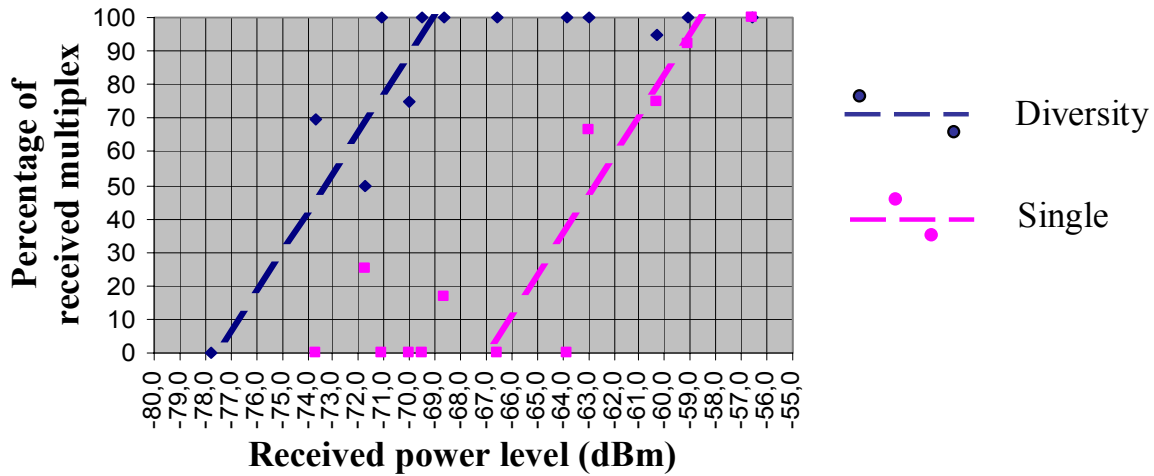


Figure 10: complete summary of single antenna reception vs. diversity reception, seen through the percentage of correctly received frequencies.

V Impact of the diversity gain on radio coverages

In this section we present the in-building coverage maps simulated by a 3D ray-tracing tool, taking into account multipath phenomena over the whole city of Paris intra-muros. The tool has been calibrated thanks to a massive measurement campaign as described in [3] and [4]. Radio coverage maps are shown from ground to fifth floor levels, in the case of a SFN network with three transmitters at the border of Paris. The gain in cover rates obtained from the dual antenna diversity is also given. For the simulations, a 3D Volcano Minicell model has been used [5]. The computation step is 10 meters. Transmitting antennas are omni-directional, and the rays were launched over the whole area (> 10km). The 3D geodatabase has a pixel size of 5m.

Table 2: SFN cover rate without reception antenna diversity

-76 dBm	Cover rate
Ground-floor	77.1 %
Third-floor	93.1 %
Fifth-floor	97.6 %

V-1 Radio coverage maps without antenna diversity at the reception

The results extracted from the predicted coverage maps at the ground-, third- and fifth-floors in Paris for -76 dBm sensitivity level are summarized in Table 2, assuming a modulation QAM64 code 2/3 and a margin to take disturbances into account (multi-path, adjacent channel interference, etc).. A large part of the in-building reception is not covered at the ground-floor level (27%). But the percentage of non-covered in-building reception is under 10% above the third-floor level.

In order to take into account the thresholds appearing in fig. 10, coverage maps are shown in Figure 11 of the in-building coverage for a standard reception antenna (0 dBi), at ground and fifth floor levels. It is clear that at the lowest levels, or in the center of Paris, correct reception is not achieved for standard indoor antennas.

V-2 Radio coverage with antenna diversity at the reception

The antenna diversity techniques described in the previous sections resulted in a 10 dB gain in the link budget. Thus the expected cover rates with these antenna diversity techniques are computed with the power threshold -73 dBm. In fig. 12 are again shown the in-building coverage maps at ground and fifth floor levels. The difference with fig. 11 is striking. The 10dB gain brought by diversity techniques in the link budget is clearly illustrated in these simulations. Such maps could be associated to geomarketing and population data in order to assess the gain in covered households.

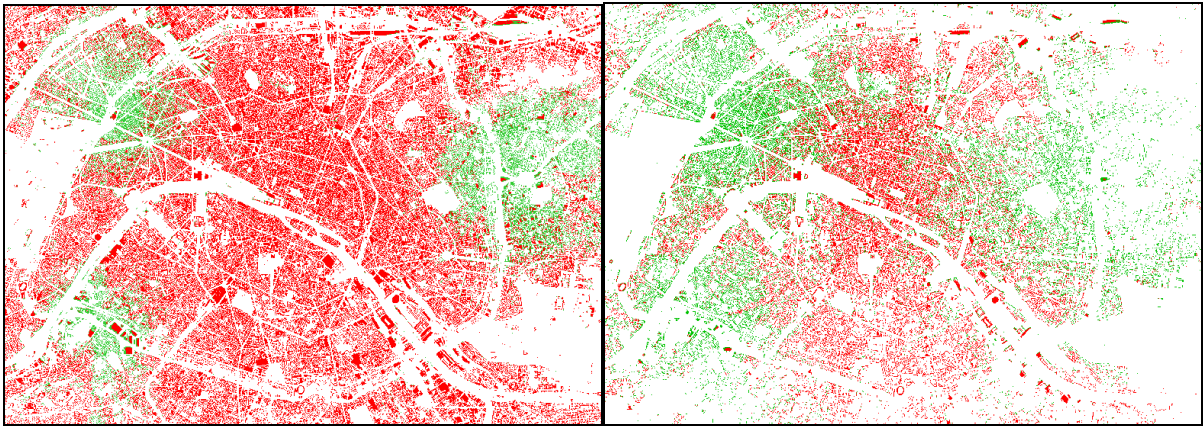


Figure 11: coverage map at the ground-floor (left) and fifth floor (right) levels for the SFN configuration without reception diversity; the receiver threshold is -63 dBm; the green areas are covered; the red ones are not covered.



Figure 12: coverage map at the ground-floor (left) and fifth floor (right) levels for the SFN configuration with reception diversity; the receiver threshold is -73 dBm; the green areas are covered; the red ones are not covered.

VI Conclusion

The RECITENT project has demonstrated the large performance improvement brought in indoor DVB-T reception by two antennas diversity combining, using dedicated chips implementing MRC over all OFDM subcarriers. The reception sensitivity is improved by 10 dB, which allows a much smaller BER and a larger number of received frequency channels in difficult reception conditions. This improvement has as a consequence a better coverage for a given transmitter power, and an easier market penetration of DVB-T with respect to analog TV. This depends on the actual industrial development of the associated technologies. As regards the receiver hardware, chips implementing diversity reception have already been developed and may be integrated into the TV sets. As regards the antennas, an extra development and design work should be carried out for their efficient integration into the TV set or for their easiness of use. The very close results between spatial and angular diversity indicates some versatility in this design and in the antenna configuration. The major problem is probably the size reduction of antennas, while preserving their gain performance together with the operating bandwidth, which is very large to cover the relevant fraction of the UHF band.

References

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- [5] "A new approach for radio propagation modeling in urban environment: Knife-edge diffraction combined with 2D ray-tracing", Y. LOSTANLEN, Y. Corre, Y. Louet, Y. Le Helloco, Vehicular Technology Conference Spring, VTC 2002, Birmingham, USA, May 2002

Annex : pictures and floorplans

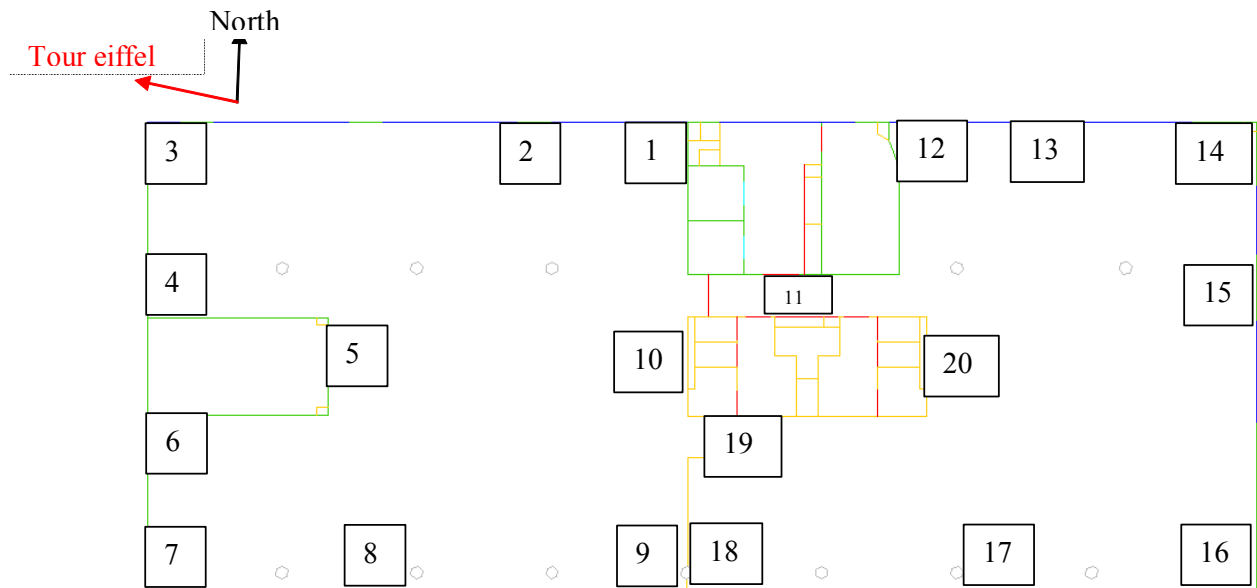


Figure 13: Typical measurement locations at 6th and 7th floor in Copernic building

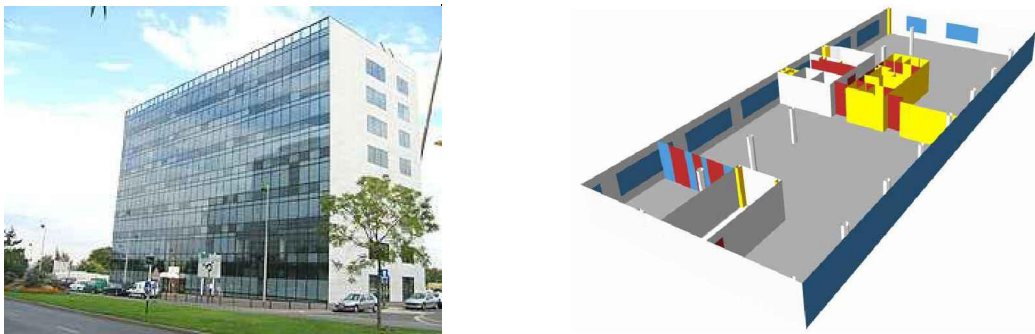
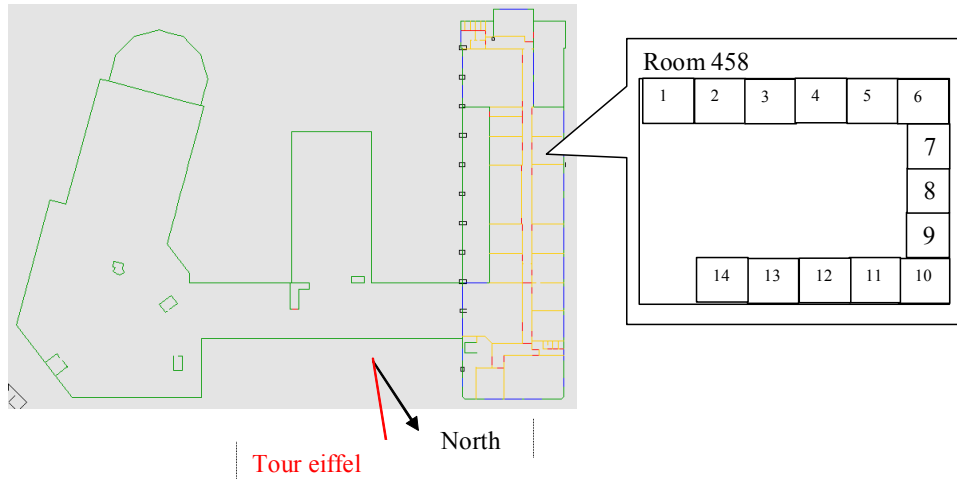


Figure 14: left : view of the COPERNIC building ; right : VRML representation of one floor

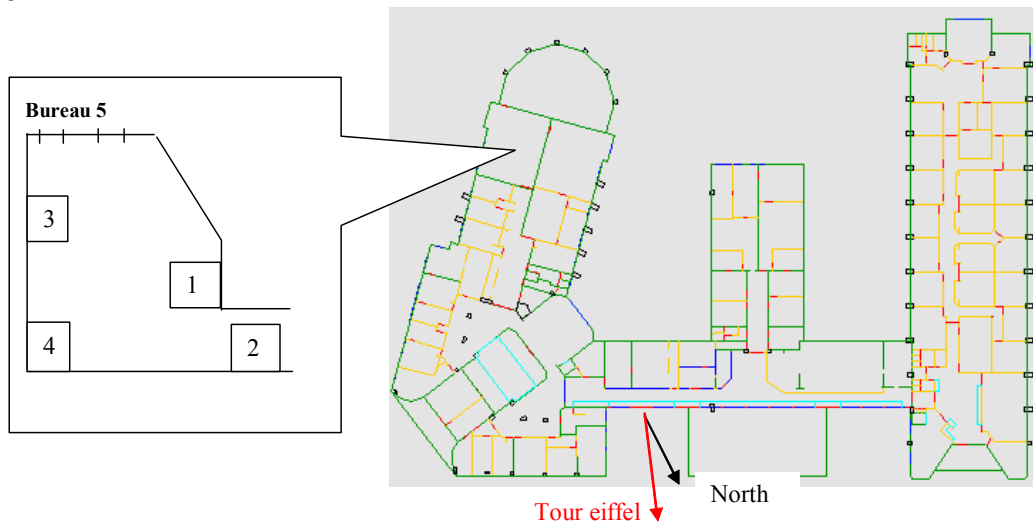


Figure 15: outer view of ENSTA

4th floor



3rd floor



2nd floor

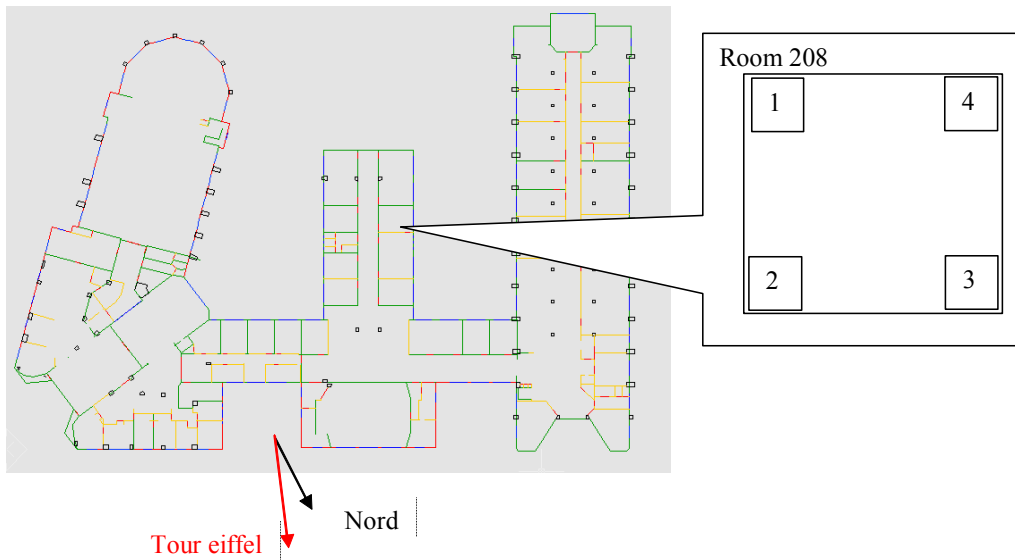
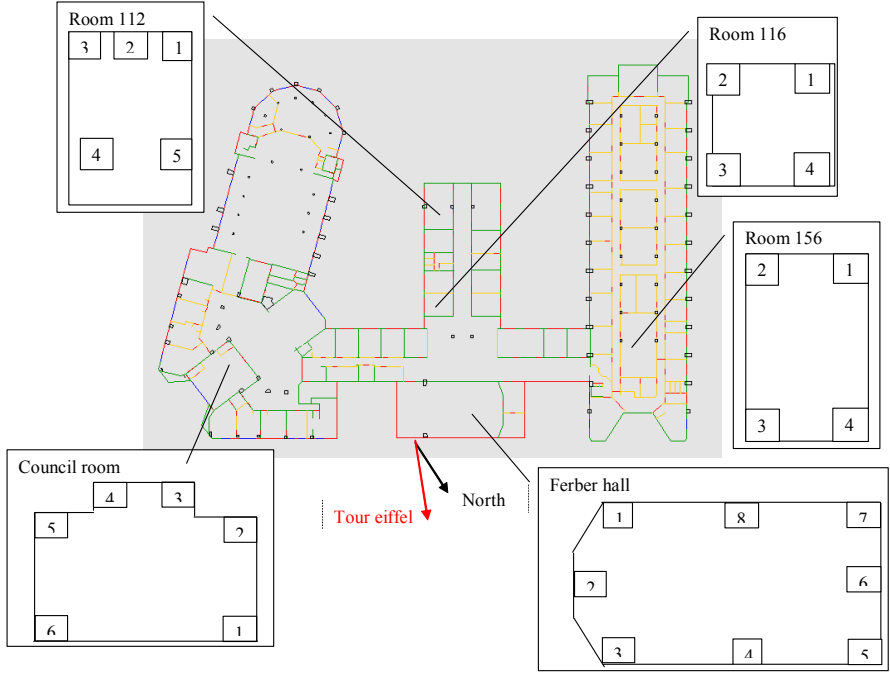


Figure 16: measurement locations in ENSTA premises at 4th, 3rd and 2nd floor

1st floor



underground floor

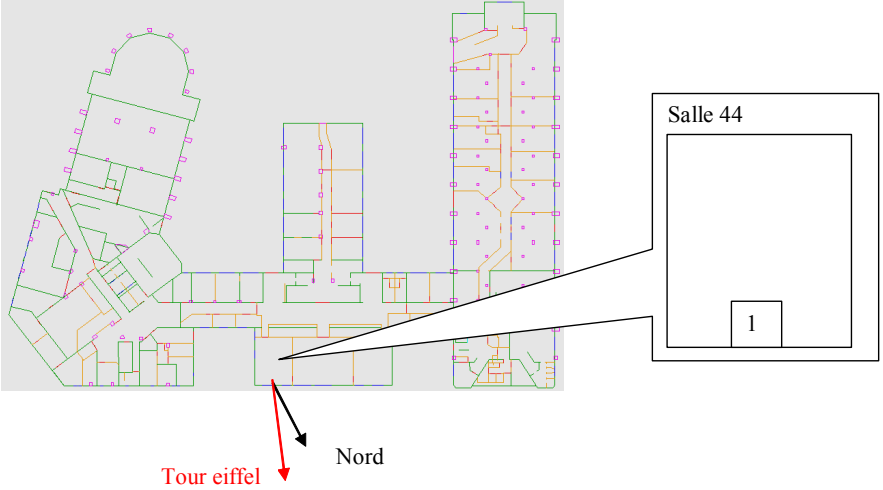


Figure 17: measurement locations in ENSTA premises at 1st and underground floor