REDUCTION OF INTERFERENCES TO ADJACENT NETWORKS BY COMBINED LATTICE STRUCTURES AND SHRUB BARRIERS

Experimental Work done at 5.8 GHz

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Abstract: The increasing number of wireless LANs using the same spectrum allocation could induce multiple interferences and it also could force the active LANs to continuously retransmit data to solve this problem, overloading the spectrum bands as well as collapsing their own transmission capacity. This upcoming problem can be mitigated by using different techniques, being site shielding one of them. If radio systems could be safeguarded against radiation from transmitter out of the specific network, the frequency reuse is improved and, as a consequence, the number of WLANs sharing the same area may increase maintaining the required quality standards. The proposal of this paper is the use of combined barriers constructed by bushes, supported by lattice structures, in order to attenuate signals from other networks and, so that, to defend the own wireless system from outer interferences. A measurement campaign has been performed in order to test this application of vegetal elements. This campaign was focused on determining the attenuation induced in the propagation channel by several configurations that combine six specimen of *Ficus elastica* and six structures made of four different materials. The wind effect on the canopies is also considered. Then, the relation between the induced attenuation and the interference from adjacent networks has been computed in terms of separation between networks. The network protection against outer unauthorised access could be also improved by means of the proposed technique.

1 INTRODUCTION

Although wireless standards (IEEE802.16, 2003) have been designed to solve connection falls, mainly by retransmission of data, the increasing number of systems using the same spectrum allocation could force the active LANs to continuously retransmit data, overloading the spectrum bands as well as collapsing their own transmission capacity.

The analysis of interferences on wireless wideband communication systems is the topic of different scientific works: considering both narrow band (Giorgetti et al., 2005) and wideband interferences (Yang, 2003). Several strategies have been applied to reduce the interference between adjacent networks. Among these proposals, the control of the transmit power appears to be a successful one (Qiao et al., 2007).

Another problem associated to the wireless technology is network protection. The users do not need to be physically connected to the network nodes. This fact allows external users to utilise the network for private or even for forbidden purposes.

These upcoming problems can be mitigated by using different techniques, being site shielding one of them (Van Dooren et al., 1992). If radio systems could be safeguarded against radiation from transmitters out of the specific area of coverage of the network, the interference could be reduced and, as a consequence, the number of WLANs sharing the same area may increase maintaining the required quality standards.

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The proposal of this work is the use of trees or bushes, supported by a lattice structure, to perform the barrier to attenuate signals from other networks and, so that, to defend the own wireless system from outer interferences. Indoor plants can be used to cut the line of sight between adjacent radio equipment of different networks.

The paper consists of four sections. The section 2 contains the description of measurement equipment and set-up, followed by the procedure used to get the data, and the vegetal species used during the experiment. The section 3 is intended to the results obtained in the measurement campaign, taking into account the median values, as well as its variability and confidence. This section is finished by the evaluation of the improvement of the interference, in terms of the reduction in the shortest distance between adjacent networks to maintain the quality of service. Finally, section 4 contains the conclusions extracted from these results.

2 MEASUREMENTS

The objective of the measurement campaign was to determine the attenuation induced by different barriers in the radio channel at WLAN frequencies. With this aim, the experimental work that forms the core of this paper was developed within an anechoic chamber at the Universidade de Vigo. Different lattice structures were used to support soft vegetation elements that configured the barriers, which were installed in different compositions

Along this section, the measurement setup and procedure are described, followed by an explanation of the vegetation elements and the different lattice structures.

2.1 Measurement Setup

The experimental work has been developed in an anechoic chamber, with approximated dimensions 6 m long, 3 m width and 3 m height. Within this controlled environment, no external waves would disturb the radio link, the multipath propagation is minimized, and all the measured results could be attributed to the elements inside the chamber: the antennas, the supports, the fan, and, of course, the shrub and lattice structure barrier.

The measurement equipment consisted of separated transmitter and receiver. The transmission segment was mounted around a signal generator Rohde & Schwarz SMV-03, feeding a logarithmic-periodic antenna Electro Metrics EM6952 via a low losses coaxial cable. The transmitter was placed in a fixed location pointed following the long axis of the anechoic chamber.

The reception device was a spectrum analyzer Rohde & Schwarz FSP40 acquiring the RF signals by another directive logarithmic-periodic antenna. The antenna was installed on the top of another mast. The data capture was PC controlled using tailor-made software.

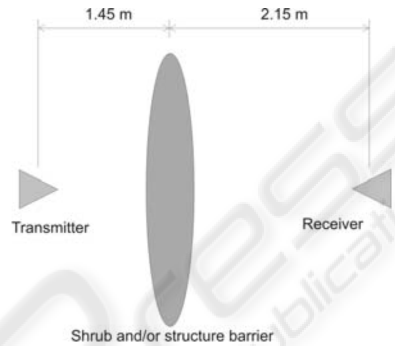

Figure 1: Geometry of the experiment setup.

The relative location of the transmitter, receiver, and obstacle is depicted in figure 1. The distance from the transmitter to the lattice structure was fixed at 1,45 m, and from the lattice to the receiver at 2,15 m.

Furthermore, a fan was used to force artificial wind inside the anechoic chamber. It provides continuous wind with three selectable speeds: 1.9 m/s (speed 1), 3.9 m/s (speed 2), and 4.7 m/s (speed 3), measured by an anemometer manufactured by Aandera.

2.2 Measurement Procedure

Measurements were performed in three steps. First of them consisted of a free space measurement. Placed the transmitter and the receiver at their fixed position, 10,000 records of received power were gotten. Then, the vegetal barriers were installed, and that measurement procedure was repeated.

Six barrier configurations were considered: the supporting lattice itself (configuration number 1); the structure and one line of three shrubs by the transmitter side (2); the structure and two lines of shrubs, one at each side (3); the structure with the line of shrubs by the receiver side (4); just one line of three shrubs (5); and a double parallel line of three shrubs (6). A reference is also measured, in free space conditions, with no barrier between transmitter and receiver. These configurations can be observed at figure 2. The measurements were performed in horizontal and vertical polarisations.

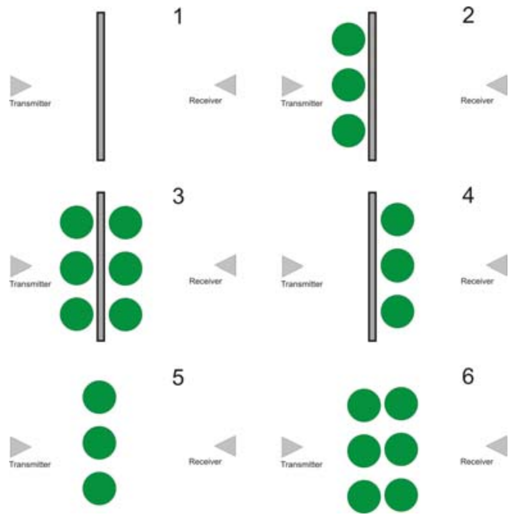

Figure 2: Obstacle configuration.

All these structure configurations were measured in calm conditions, as well as in windy conditions, placing the fan pointing to the obstacle at the transmitter side of the hurdle, and the at the receiver side.

2.3 Vegetation Specimen

The six shrubs used during the measurement campaign are all from the specie *Ficus elastica*, commonly known as ficus. The table 1 contains the dimensions of the shrubs at the time of the measurement campaign.

Table 1: Shrub dimensions.

Height (m)	Canopy diameter (cm)	Leaf size (cm)	
		length	width
1.70	55	7	3

The shrubs had flexible trunks and light canopies. The movement of their leaves under the wind action could be defined as twist and sway.

2.4 Lattice Structures

The lattice structures were selected to check the effect on the propagation channel of both the shape of the structure and the material that constructs it. These elements are designed to be used in gardens or terraces to construct light walls by vegetation. They are originally intended to preserve the privacy in terms of visual frequencies, but they may also be use to preserve the privacy of wireless networks.We used structures made by iron cables (one sample), wood boards (two samples, with different design), resin (also two samples), and PVC plastic (one sample). The general design of each supporting structure is depicted in figure 3.

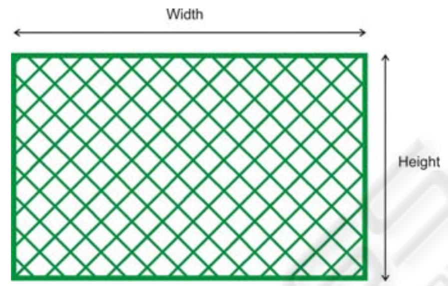

Figure 3: General design of the lattice structure.

The main differences among the structures, as well the constitutive material, are the dimensions of the lattice: how large the holes are, and how width the solid parts are. At figure 4, the definition of different describing parameters could be observed, and its values are summarised at table 2.

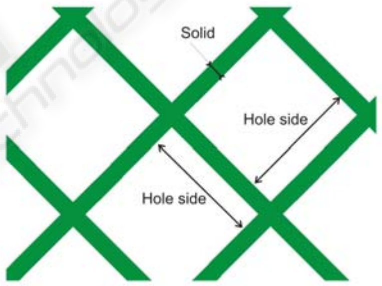

Figure 4: Definition of lattice parameters.

Table 2: Supporting structure dimensions.

material	structure			lattice	
	Height (m)	Width (m)	Depth (cm)	Solid (cm)	Hole side (cm)
Iron	1.8	1.8	0.5	0.5	9.0
Wood 1	1.8	1.8	1.0	3.0	12.0
Wood 2	1.8	1.8	0.5	6.0	7.0
Resin 1	1.0	2.0	0.5	3.5	6.5
Resin 2	1.0	2.0	0.5	2.5	2.7
PVC	1.0	2.0	0.5	1.5	2.5

3 RESULTS

The large amount of data collected has been processed in order to allow the extraction of conclusions. The main results are the median attenuations provided by the barriers at each of the considered frequencies, with each configuration, including windy conditions. They are the contents of the first subsection.

An estimation of the minimum security distance at which elements from two separated networks could be installed with no interference problems could be computed from the median attenuations, and they are presented in the second subsection. The third subsection contains the estimation of the maximum distance of coverage, which could be useful to control the areas of origin of possible external attacks, by limiting the coverage of our network elements.

3.1 Attenuation

The attenuation induced in the propagation channel by the combined barrier (lattice structure and/or shrubs) was computed for each situation by comparing the median measured received power in free space conditions and the median power in obstructed line of sight (OLoS) conditions.

The results show two main trends. On the one hand, in most of the configurations, the attenuation provided by barriers designed as configuration 3 (one line of shrubs at each side of the supporting structure) appears to be larger than that induced by the other “lighter” configurations. On the other hand, the wind effect seems to be negligible in terms of median values, although the wind could be important in terms of variability around these median values.

Besides, the structure itself does not present large effects in terms of attenuation. Even more, depending on the electric size of the holes, the supports could generate diffraction mechanisms and provide slight gains in the received power, in a pseudo lens effect.

Tables 3 to 9 summarise the median attenuations measured at different circumstances: lattice structure, barrier configuration, location of the fan, and wind speed, for vertical polarisation. The configuration 1, which corresponds to the structure with no vegetation, was only measured in static conditions, as the wind is expected not to induce any effect on a rigid element.

In most of the situations, the wind speed seems to induce almost no effect on the median attenuation. However, some differences between the static and windy attenuation measurements appear, but there is not a clear trend: in some conditions the attenuation grows in windy compared to static situations, and in other cases the effect is completely opposite.

Table 10 shows the median attenuations with only vegetation at the barriers, and without lattice structures. They could be useful to be compared to previously presented values.

Table 3: Attenuation (dB) with metallic lattice structure.

Wind		configuration			
from	speed	1	2	3	4
	0	-0.44	11.33	15.92	5.83
tx	1		11.02	19.09	5.91
	2		11.17	18.99	5.95
	3		11.39	18.96	6.20
rx	1		10.73	15.59	5.96
	2		10.62	18.37	5.75
	3		10.09	18.51	5.57

Table 4: Attenuation (dB) with PVC lattice structure.

Wind		configuration			
from	speed	1	2	3	4
	0	-2.55	19.36	32.37	8.24
tx	1		19.56	37.58	8.28
	2		19.40	37.58	8.27
	3		19.56	35.74	8.21
rx	1		15.83	33.30	8.01
	2		15.99	33.71	7.96
	3		16.09	33.71	7.94

Table 5: Attenuation (dB) with wood 1 lattice structure.

Wind		configuration			
From	speed	1	2	3	4
	0	-0.19	24.44	18.85	6.80
Tx	1		24.15	17.88	6.95
	2		24.26	17.53	6.95
	3		24.38	17.41	6.96
Rx	1		22.92	15.48	6.95
	2		22.30	15.67	7.00
	3		20.81	15.97	7.06

Table 6: Attenuation (dB) with wood 2 lattice structure.

Wind		configuration			
from	speed	1	2	3	4
	0	0.85	19.65	25.99	14.03
tx	1		16.63	26.09	11.25
	2		16.35	26.21	11.20
	3		16.43	26.23	11.12
rx	1		19.66	24.24	13.95
	2		19.57	24.22	12.31
	3		19.24	23.92	12.77

Table 7: Attenuation (dB) with resin 1 lattice structure.

Wind		configuration			
from	speed	1	2	3	4
	0	-0.27	14.24	27.89	10.55
tx	1		13.79	29.39	11.75
	2		14.31	29.02	11.67
	3		14.42	29.52	11.62
rx	1		14.22	28.11	10.56
	2		14.39	28.44	10.71
	3		14.58	28.55	10.78

Table 8: Attenuation (dB) with resin 2 lattice structure.

Wind		configuration			
from	speed	1	2	3	4
	0	-0.80	19.44	19.52	17.01
tx	1		15.14	19.32	17.01
	2		14.90	19.13	16.92
	3		14.83	19.21	16.32
rx	1		16.43	19.09	16.12
	2		16.46	19.13	15.80
	3		16.40	19.05	15.52

Table 9: Attenuation (dB) with resin 2 lattice structure.

Wind		configuration			
from	speed	1	2	3	4
	0	0.37	16.48	20.06	19.84
tx	1		15.47	19.62	25.54
	2		15.21	19.24	25.68
	3		15.58	19.27	25.90
rx	1		16.31	20.37	20.89
	2		16.36	21.02	21.45
	3		16.86	21.62	21.62

Table 10: Attenuation (dB) with no lattice structure.

Wind		configuration	
from	speed	5	6
	0	15.34	27.89
tx	1	15.44	27.89
	2	15.44	27.89
	3	15.44	17.58
rx	1	15.80	26.26
	2	15.91	26.17
	3	15.99	25.91

The lattice structures that lead to larger attenuations seem to be the iron one and the closest among those constructed by the same material.

3.2 Reduction in Interference Free Distance

The measured attenuation values could be used to compare the influence of the hurdles in the control of interference. The standard IEEE 802.16a defines different minimum signal to noise ratios (SNR) to maintain its various modulation schemes: QPSK, 16-QAM and 64-QAM (IEEE802.16, 2003), which are summarized in table 11.

Table 11: Minimum SNR to maintain each modulation scheme, IEEE 802.16a.

modulation	coding rate	SNR (dB) at receiver
QPSK	1/2	9.4
	3/4	11.2
16-QAM	1/2	16.4
	3/4	18.2
64-QAM	2/3	22.7
	3/4	24.4

A WLAN element could receive signals from other elements at its own network, and from other at different networks. Considering the co-channel interference as a kind of noise, and applying the Friis equation with the limited SNR values assuming all the network transmitters are emitting the same power, we can compute the improvement provided by the vegetal barrier in terms of interference reduction: comparing the minimum distance to assure the interference would not degrade the performance of the network with and without the hurdle. Thus, a reduction in this distance indicates how much the hurdle improves the network security: it allows installing two networks closer than without the hurdle, and maintaining their performances.

Taking into account the mean of the measured attenuations, the minimum security distance have been computed, and the results are summarized in table 12.

Table 12: Minimum distance to be free from interference.

modulation	**Distance (m)**	
	no hurdle	**hurdle**
QPSK	2.95	0.13
16-QAM	6.6	0.29
64-QAM	13.65	0.59

3.3 Protection Against External Attacks

The presence of the vegetation barrier provides an additional attenuation to the propagation channel: this means that the maximum physical distance to be connected to the network is shortened than when the fence is absent. Thus, uncontrolled accesses could be reduced compared to the open coverage situation with the proposed method.

The sensitivity of the receivers at network elements could be used to compute the performance of the fence in terms of protection against external attacks. The IEEE 802.11 standard defines these sensitivities to be -80 dBm for a bit rate of 1 Mbps, or -75 dBm for 2 Mbps. With these values, we could compute the coverage distances in free space (LoS) and obstructed by a shrub/structure line (OLoS) conditions, knowing that the maximum transmitting power is defined to be 30 dBm. The typical transmitting power is also known, being 13 dBm.

Tables 13 and 14 contain the coverage distances with and without combined structure and vegetation fences when using the maximum and the typical transmitting powers, respectively. Values at both tables indicate a very significant reduction of the coverage distance when the line of sight is only obstructed by a shrub fence. Obviously, actual situations involve one or more walls between the network element inside a building and the possible hacker in the street. This means that the actual distances of coverage would be strongly shorter than those provided at tables 13 and 14. Nevertheless, the coverage distances with typical transmission appear to be enough to avoid attacks from outside the parcel of most corporative buildings.

Table 13: Maximum coverage distances, assuming maximum transmitting power.

transmission rate	**distance**	
	LoS	**OLoS**
1 Mbps	2.60 km	92 m
2 Mbps	1.46 km	52 m

Table 14: Maximum coverage distances, assuming typical transmitting power.

transmission rate	**distance**	
	LoS	**OLoS**
1 Mbps	368 m	13 m
2 Mbps	207 m	7 m

4 CONCLUSIONS

The use of barriers constructed by shrubs supported by lattice structures is proposed to reduce the interference between adjacent wireless networks at 5.8 GHz. The results of an exhaustive measurement campaign are presented along this work, involving six specimen of *Ficus elastica* and six structures made of four different materials. The wind effect on the canopies has been also considered.

The attenuation results show two main trends. On the one hand, the attenuation provided by hard barriers appears to be larger than that induced by the other “lighter” configurations. On the other hand, the wind effect seems to be negligible in terms of median values, although the wind could be important in terms of variability around these median values.

Minimum distance to produce interference and maximum coverage distance have been also computed from the attenuation data. The estimated distances appear to confirm the performance of the vegetation/supporting structure barriers and to validate the thesis of this paper. The minimum interference-free coverage could be reduced to very short values, less than 60 cm, whereas the maximum distance to perform an unauthorised access could move from 368 m to 13 m. Both situations represent interesting improvements in network performance.

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