IMPROVEMENT OF WIRELESS NETWORK ISOLATION AND SECURITY BY SHRUB BARRIERS

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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 bushes as a hurdle 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 by several specimens of seven different vegetal species. 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

The proliferation of wireless local area networks (WLANs) could be collapsed due to their own success: an enormous number of corporate WLANs are going to cohabit in office buildings sited in the financial quarters of our cities, and a lot of mismatches could appear as a result of the interference among several of them. Although wireless standards are prepared 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; so these users could access the system from places that could be out of system manager's control. This fact allows external users to utilise the network for private purposes or even for forbidden actions.

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. The proposal of this work to perform site-shielding is the use of trees or bushes as a barrier to attenuate signals from other networks and, so that, to defend the own wireless system from outer interferences. Interior plants can be used to cut the line of sight between adjacent radio equipment of different networks. On the other hand, decorative trees can be used in gardens around office blocks to reduce the outdoor coverage of wireless networks

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around the own building. This outdoor coverage reduction has another advantage, as it represents an additional protection against hacker attacks or a limit to external users, signifying an improvement in network security (Cuiñas et al., 2006). This proposal is softer and more ecological than conductive shielding, and cheaper than frequency-selective walls as introduced at (Sung et al., 2006).

A measurement campaign has been performed at two different wireless frequency bands: 2.4 GHz and 5.8 GHz in order to validate this application of vegetal hurdles. Measurements are focused on determining the attenuation induced by lines of small trees or bushes. Seven different species have been considered, as well as five configurations: two linear ones, a double line and two zig-zag dispositions, one denser than the other.

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

Narrow band measurements have been used to characterise the effect of the vegetal barriers in the radio channel. The measurement setup is based on commercial equipment used as transmitter and receiver, in co-ordination with an automated linear positioner. Five barrier configurations were considered, involving elements of seven different species.

2.1 Measurement Setup

The measurement set-up consists of separate transmitter and receiver segments, and an automated linear positioner, as depicted in figure 1. The distance between transmitter and receiver, is 6 meters, and the vegetal barrier is placed just in the middle, at 3 meters from transmitter and receiver.

The transmitter segment is built around a signal generator Rohde-Schwarz SMR-40, which provides pure tones in the frequencies of interest. This generator feeds a log-periodic antenna Electrometrics EM 6952, gaining 4.7 dB at 2.4 GHz, and 4.8 dB at 5.8 GHz. The antenna is placed in a fixed location, at 1.25 meters height.

The receiver segment is based on a spectrum analyser Rohde-Schwarz FSP40, which receives the signal captured by another log-period antenna, identical to the transmitting one. The antenna, placed at 1.25 meters height, is installed on a positioning system, which consists of a 2.5 meter linear table with a millimetre screw along it. This positioning system is controlled from a PC, by means of an indexer. The same software manages the operation of the spectrum analyser, constructing an automated measurement system.

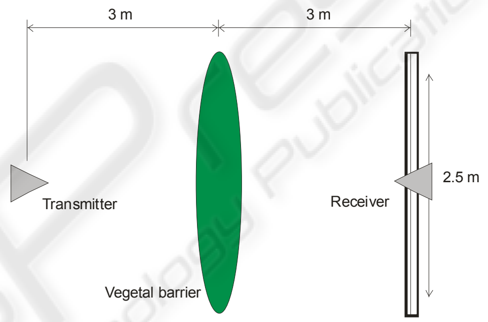

Figure 1: Basic geometry of measurement system.

2.2 Measurement Procedure

Measurements were performed in two steps: a free space measurement used as a reference, and a blocked-by-trees measurement. The first of them consisted of a free space measurement. Placing the transmitter antenna at its position, a complete movement along the receiver locations was done, getting 8001 samples of received power at each measurement point. Then, the vegetal barriers were installed, and this measurement procedure was repeated. This method is applied in both horizontal and vertical co-polar situations.

Five barrier configurations were considered. The figure 2 depicts the linear disposition (configuration number 1), which consists of nine trees, separated 40 cm among adjacent elements. The configuration 2 contains just the central five elements in the barrier.

The configuration 3 consists of two parallel lines of trees, each of them containing five elements. The separation between tree lines is again 40 cm.

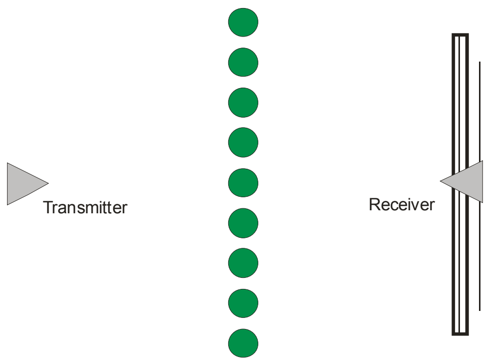

Figure 2: Linear disposition (configuration 1).

The configuration 4, the zig-zag, is composed of nine trees installed in two parallel lines, separated 40 cm each, as depicted in figure 3. Finally, the configuration 5 is like the fourth one, but doubling the distance between adjacent trees within the same line.

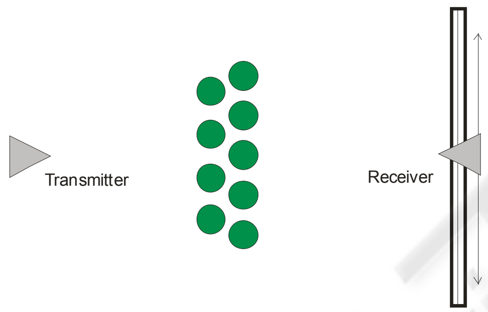

Figure 3: Zig-zag disposition (configuration 4).

2.3 Vegetal Species

Both indoor and outdoor vegetal species have been considered in this study, as indoor could be interesting to reduce the interference, whereas outdoor could be used to protect the network against external attacks.

The indoor species analyzed in the measurement campaign are: *Heptapleurum arboricola gold capella* (commonly known as schefflera), *Dypsis lutescens* (areca), and *Ficus elastica* (ficus). All of them are common indoor species used frequently as decorative elements at buildings and indoor yards.

The outdoor species have been chosen either for been typically used to make private fences in a short time, or because of massive foliage that favors electromagnetic shielding. In order to analyze both characteristics, the species considered have been: *Callistemon laevis* (commonly known as callistemon or bottlebrush), *Camellia japonica* (camellia), *Juniperus communis hibernica* (Irish juniper) and *Thuja atrovirens* (white cedar).

The table 1 summarises the sizes of the specimens, as well as of their leaves.

Table 1: Dimensions of the shrubs in cm.

Specie	shrub		leaf	
	height	diameter	length	width
areca	150	70	25	1
schefflera	160	60	10	4.5
ficus	170	55	7	3
callistemon	150	80	7	4
camellia	165	90	8	6
Irish juniper	205	55	2	0.5
thuja	165	45	0.5	0.2

3 RESULTS

3.1 Attenuation

At any location, 8001 samples of received power have been measured. Median values at any point have been considered, in order to eliminate spurious or outlier measured values. Then, attenuation due to vegetal barriers has been computed by comparing received power in free space condition to received power in obstructed line of sight situation.

Figures 4 and 5 show the median attenuations induced by barriers conformed by Irish junipers, with horizontal polarisation, at 2.4 GHz and 5.8 GHz respectively. Both figures contains the results measured with linear and zig-zag dispositions, this means, configurations number 1 and 4, respectively.

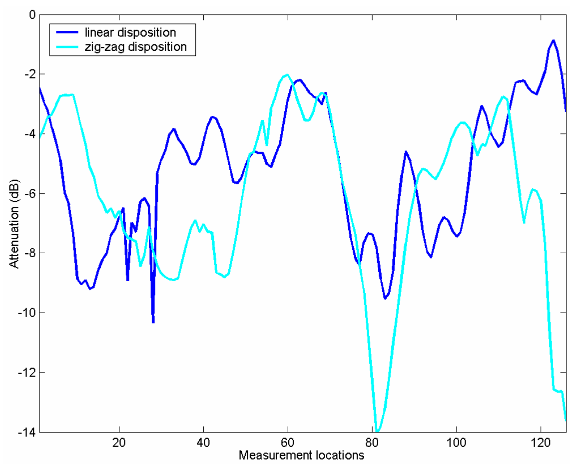

Figure 4: Median attenuation (dB) due to Irish junipers at 2.4 GHz, with horizontal polarisation.

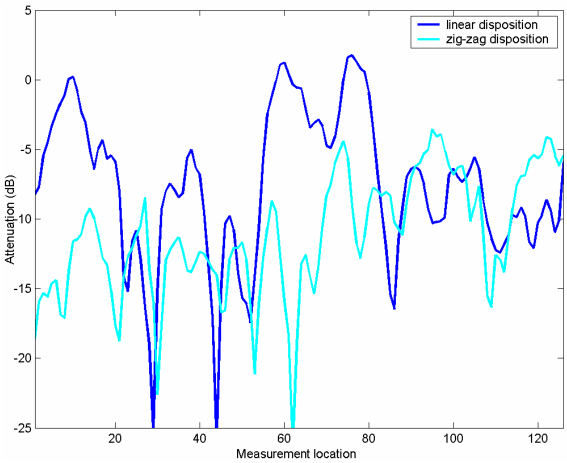

Figure 5: Median attenuation (dB) due to Irish junipers at 5.8 GHz, with horizontal polarisation.

The table 2 contains the median attenuations at 2.4 GHz for horizontal polarization, and the table 3 for vertical polarization. Median is the statistics used as it is less sensitive to measured outliers than mean. Configurations 3 and 4 provide higher attenuation than the others.

Table 2: Median attenuation (dB) at 2.4 GHz, with horizontal polarization.

Specie	Hurdle configuration				
	C1	C2	C3	C4	C5
areca	0.1	0.2	0.4	2.9	0.1
schefflera	0.4	0.8	1.6	1.9	0.7
ficus	2.2	2.8	4.3	4.7	2.7
callistemon	2.1	2.5	3.5	3.3	1.5
camellia	3.1	3.2	3.9	5.9	2.9
Irish juniper	5.2	5.2	8.9	6.2	4.5
thuja	1.6	1.5	1.8	2.1	1.4

Table 3: Median attenuation (dB) at 2.4 GHz, with vertical polarization.

Specie	Hurdle configuration				
	C1	C2	C3	C4	C5
areca	3.2	3.5	2.5	2.1	3.2
schefflera	0.1	0.9	1.5	1.0	0.4
ficus	2.1	4.1	5.1	5.9	2.0
callistemon	3.3	3.0	6.9	5.4	3.0
camellia	5.4	5.5	6.9	8.2	5.2
Irish juniper	9.6	9.8	10.7	10.1	8.0
thuja	3.5	3.8	5.6	6.2	3.5

The table 4 contains the median attenuations at 5.8 GHz for horizontal polarization, and the table 5 for vertical polarization. As observed for 2.4 GHz, configurations 3 and 4 provide stronger attenuations than the others. This is probably due to they are denser and more compact than configurations 1, 2 and 5. Shrubs at these configurations configure lighter barriers.

Table 4: Median attenuation (dB) at 5.8 GHz, with horizontal polarization.

Specie	Hurdle configuration				
	C1	C2	C3	C4	C5
areca	0.1	0.1	0.9	4.1	0.1
schefflera	0.1	0.2	5.6	6.7	1.0
ficus	6.2	5.4	9.3	11.3	5.3
callistemon	1.1	4.0	6.5	7.7	2.4
camellia	10.1	12.4	12.1	13.2	10.7
Irish juniper	6.8	5.9	13.2	10.6	8.1
thuja	3.9	5.1	6.3	6.8	4.7

Table 5: Median attenuation (dB) at 5.8 GHz, with vertical polarization.

Specie	Hurdle configuration				
	C1	C2	C3	C4	C5
areca	2.0	2.4	5.1	3.8	2.6
schefflera	2.5	2.9	6.1	6.4	2.4
ficus	7.1	8.4	10.7	9.9	7.1
callistemon	10.5	13.0	14.5	14.6	11.1
camellia	10.4	11.3	14.2	13.5	10.5
Irish juniper	15.7	13.7	21.2	19.8	15.4
thuja	5.2	7.2	12.0	8.8	4.4

3.2 Variability

The measured attenuations present certain variability around its first order statistics. This variability is the result of several effects: the measurement system noise itself, the movement of the leaves that is translated into changes in the barrier configuration, the differences in humidity of the plants during the measurement period, and so on.

If the central statistic were the mean, the natural measure of variability would be the standard deviation. But as we used the median as the central statistic, this variability could be evaluated as a function of the inter quartile range (IQR) of each measured series. The IQR corresponds to the distance between the first and the third quartile, indicating how much concentrating the measurements are around the median (which is the second quartile). The maximum IQR measured with indoor species at the barrier resulted to be 12 dB, whereas with outdoor species that was 6 dB.

3.3 Application to Interference Mitigation

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 (IEEE Standard, 2003).

Table 6: 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.

By using the mean of the measured attenuations, the minimum security distance, using a QPSK scheme, is reduced from 2.95 m without barrier to 0.8 m when the hurdle is installed. If a 16-QAM scheme is implemented, the distance reduces from 6.6 m to 1.79 m. And if a 64-QAM modulation is in use, the distance decreases from 13.65 m to 3.69 m.

3.4 Application to Protection Against External Attacks

The presence of the vegetal barrier provides an additional attenuation to the propagation channel: this means that the physical distance to be connected to the network is shorter than when the fence is absent. When installing such fences in the gardens around office buildings, the coverage of the WLANs in the surroundings is reduced, and this means that the outdoor area from which an attack could be shouting is compacted. Thus, this outdoor coverage could be modelled to extend no far away the limits of the parcel around the company, not allowing the network access from public places as the street. Uncontrolled accesses could be reduced compared to the open coverage situation with the proposed method.

4 CONCLUSIONS

The use of hurdles constructed by trees is proposed as a method to reduce the interference among WLANs in high-traffic areas.

Measurements of radiofrequency attenuation due to rows of trees, done at two WLANs frequency bands, appear to support this proposal. Results show a reduction up to 10.7 or 21.2 dB at 2.4 and 5.8 GHz, respectively. Vegetal species susceptible to conform the barriers have to fit more conditions that just electromagnetic absorption: they must have everlasting leaves, be tall enough to cut the line of sight between transmitter and receiver, and present densely foliated specimens.

The improvement in terms of reduction of distance between networks to assure the interference will not degrade their performances has been also evaluated. The minimum security distance, using a QPSK scheme, appears to be reduced from 2.95 m without barrier to 0.8 m when the hurdle is installed. If a 16-QAM scheme is implemented, the distance reduces from 6.6 m to 1.79 m. And if a 64-QAM modulation is in use, the distance decreases from 13.65 m to 3.69 m.

This reduction in coverage is an advantage to control external attacks, too.

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