Application of Five-Sector Beam Antenna for 60 GHz Wireless LAN

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ABSTRACT

The application of a switched five-sector beam antenna in high-speed indoor wireless LAN systems operating in the 60 GHz band is investigated. The effects of line-of-sight obstruction as well as the influence of the access-point antenna height are experimentally studied in a typical small-sized office room. The results are compared with those obtained with alternative antenna configurations.

INTRODUCTION

The 60 GHz band is of much interest since this is the band in which a massive amount of spectral space has been allocated world-wide for (unlicensed) dense wireless local communications [1]. A key research issue is still to find adequate antenna solutions for 60 GHz wireless LAN applications. One of the major hurdles to overcome is that diffraction (i.e., the ability of radio waves to bend around edges) is relatively low at 60 GHz. Consequently, antenna obstruction by an object or person may easily result in a substantial drop in received power.

The application of fan-beam antennas, as proposed in [2], yields considerable received power under line-of-sight (LOS) conditions. The effect of LOS path obstruction is, however, about 11 dB. This raises the question whether alternative antenna solutions could alleviate the shadowing problem, for instance, by introducing and exploiting path diversity. A well-known method is to apply a sector antenna at the portable station (PS) with the possibility to switch between the different sectors, as proposed in [3]. This ability to switch to another sector at the AP is especially advantageous in case other access points can be selected to communicate with when the communication path becomes blocked by shadowing. In this paper, however, we consider the diversity gain that can be achieved by applying a sector antenna in case there is only *one* access point (AP) for the PS to communicate with. This will likely be the case in a small sized office room or living room.

EXPERIMENTAL SET-UP, LOCATION AND ANTENNAS USED

The measurement set-up used for the study was built around an 8510C-network analyser [4]. The (complex) channel impulse responses have been measured in the 58-59 GHz band with 401 data points. A Kaiser window was applied with a side-lobe level of -44 dB. With this window a time domain resolution of 2 ns is achieved.

The measurements have been conducted in an office room at Eindhoven University of Technology. A plan view of the room is shown in Fig. 1. The size of the room is 8.75*4.90*3.10 m^3. Sides 1 and 2 are smoothly plastered concrete walls. Side 3 consists of glass window from a height of 1 m to the ceiling and a metal heating radiator below. Side 4 is a concrete wall covered with wood and the floor is linoleum on concrete. The ceiling consists of aluminium plates and light holders.

A vertically polarised E-plane sectoral horn, representing the AP antenna was located as indicated in Fig. 1. This antenna produces a fan-beam that is wide in azimuth and narrow in elevation. Its beam was aiming towards the middle of the room. In general, the placement of the antenna in a corner provides relatively ease of installation when compared with mounting the antenna on the ceiling as proposed in many publications.

A similar fan-beam antenna was applied at the PS to represent the individual sectors of a five-sector antenna. Measurements have been performed at twenty PS positions, which are all indicated in Fig. 1. At each measurement position, the antenna was pointed with 0º, 72º, 144º, 216º and 288º azimuth deviation from the boresight direction of the AP antenna beam. In addition, the PS antenna beam was elevated towards the AP antenna. Furthermore, an omnidirectional antenna (biconi-

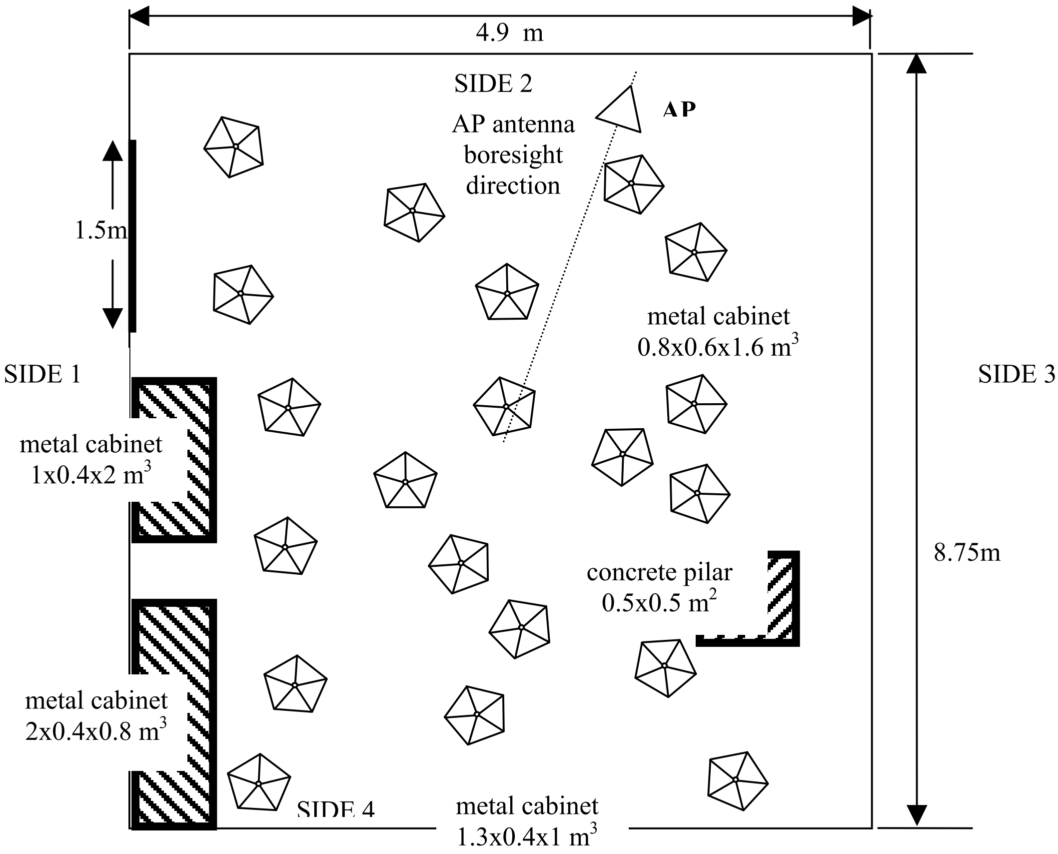

Fig. 1. Plan view of office room

cal horn with pan-cake shaped beam as described in [5]) was applied at the PS for comparison. As opposed to the fan-beam antennas, the beam of the omnidirectional antenna was not elevated but always kept in horizontal direction. All measurements have been performed under unobstructed LOS conditions. The different characteristics of the applied antennas are given in Table 1.

MEASUREMENTS, RESULTS AND DISCUSSION

Channel impulse responses were measured at randomly chosen positions within the room. These positions are indicated in Fig. 1. The height of the PS antenna at each measurement position was fixed at 1.4 m above the ground.

Figures 2a, b and c depict the normalised received power (NRP), i.e., the total received power within the measurement bandwidth normalised on the transmitted power versus separation distance between AP and PS antenna, for AP antenna heights of 1.4 m, 1.9 m and 2.4 m, respectively. Also included are the results obtained with the omnidirectional antenna under unobstructed LOS (dots) as well as obstructed LOS (circles) conditions. These values for the obstructed (OBS) case have been derived from the measurement results obtained under LOS conditions by mathematical removal of the LOS component in the received impulse responses. The highest NRP values (indicated as crosses) all correspond with the most ideal situation of (unobstructed) LOS between the AP antenna and the PS antenna sector that aims towards the PS antenna, as expected. Now let us assume that, as

Table 1. Antenna parameters

Type of PS antenna	half power beamwidth in degree		Gain in dBi
	E-plane	H-plane	
Fan-beam antenna	12.0	70.0	16.5
Omnidirectional antenna	9.0	omnidirectional	6.5

soon as obstruction occurs, the AP switches to the sector that provides the best alternative, i.e., the highest NRP.

From Fig. 2a,b and c we can conclude that a drop in NRP of about 9 dB (on average) will be the result. According to [2] the drop in NRP due to LOS path obstruction is about 11 dB in case one single fan-beam antenna is used at the PS. This indicates that, the gain in link budget provided by the considered switched five-sector antenna is only about 2 dB. This can be explained by the fact that the "best" alternative sector has to rely on relatively weak reflected power when compared with the power that comes via the direct path. When compared with the case of an obstructed omnidirectional PS antenna (circles), the switched five-sector antenna provides about 7 dB more link budget, on average.

Furthermore, Fig. 2a, b and c show an interesting relationship between the height of the AP antenna and the (absolute) values of NRP. In particular when we compare Fig. 2a with Fig. 2c we see that NRP values obtained with an AP antenna height of 1.4 m are significantly higher than the corresponding values for AP antenna height of 2.4 m. The average difference amounts to about 9 dB! A factor that contributes to this difference is the misalignment of both antennas in elevation which commensurates with their height difference. The misalignment occurred because the AP antenna beam was always aimed at the centre of the room for all considered positions of the PS.

Figures 3a, b and c depict the rms delay spread (RDS) versus separation distance between AP and PS antenna, again for AP antenna heights of 1.4 m, 1.9 m and 2.4 m, respectively. Also included are the results obtained with the omnidirectional antenna under unobstructed LOS (dots) conditions. The lowest RDS values (indicated as circles) correspond with the most ideal situation of (unobstructed) LOS between the AP antenna and the PS antenna sector that aims towards the PS antenna, as expected.

From Fig. 3a, b and c we can conclude that switching to another antenna section almost always results in a considerable, about a factor 3, higher RDS value. These figures also show a clear relationship between the height of the AP antenna and the (absolute) values of RDS. When we compare Fig. 3a with Fig. 3c we see that RDS values obtained with an AP antenna height of 1.4 m are about a factor 2 lower than the corresponding values for AP antenna height of 2.4 m. This indicates, that the antenna misalignment makes the reflective environment a more prevalent factor.

The NRP and RDS values for the fan beam antenna all include the LOS component although the sectors that will be chosen when obstruction occurs will not "see" this LOS component because of the obstruction. When compared with the boresight direction, however, the fan-beam pattern at 72º is already 15 dB down whereas the vast majority of the NRP values of "best alterative sectors" are only 10 dB or less under the values for the ideal unobstructed 0º fan beam. Therefore, these contributions will not be significant and will not affect the conclusions that follow.

CONCLUSIONS

The effectiveness of a switched five-sector antenna for 60 GHz indoor WLAN has been examined for the case that there is only one AP for the PS to communicate with. The results indicate that application of such a sector antenna at the PS yields a link-budget advantage of only a few dBs at maximum when compared with the use of a single fan-beam antenna. When compared with the use of an omnidirectional antenna, the advantage is about 7 dB. This advantage must be paid with increased system complexity regarding antenna switching and additional measures to increase multipath robustness.

The results also indicate that the height of the AP antenna has a substantial influence on NRP as well as RDS. If the AP antenna height equals the height of the PS antenna (i.e., 1.4 m) then NRP values are in the order of 9 dB higher than those obtained with the AP antenna at 2.4 m. In addition, the RDS values are, on average, a factor 2 lower. Hence; the AP fan-beam antenna can be placed slightly above table-height. This is a favourable result since table-height is in many cases the place where the AP can be readily connected to the fixed backbone network!

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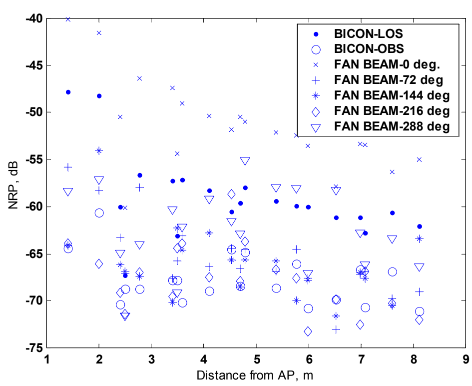

Fig. 2a. NRP for AP antenna height of 1.4 m

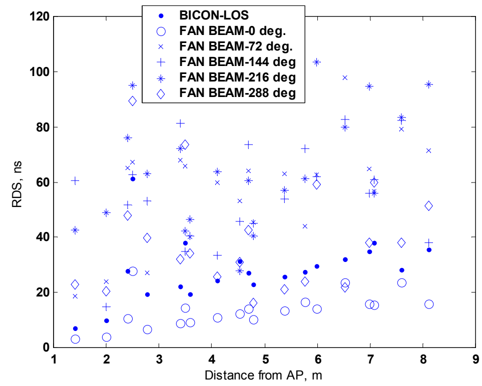

Fig. 3a. RDS for AP antenna height of 1.4 m

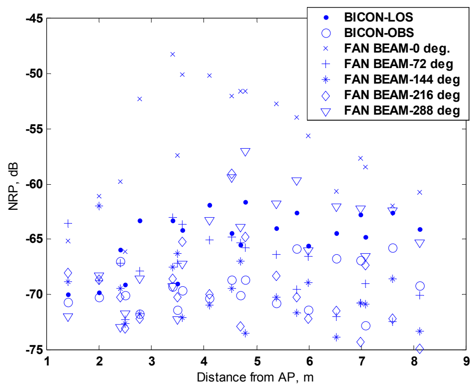

Fig. 2b. NRP for AP antenna height of 1.9 m

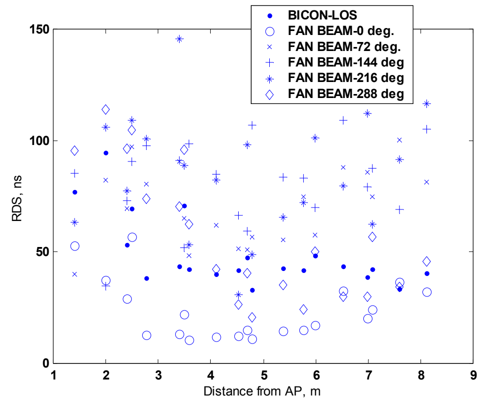

Fig. 3b. RDS for AP antenna height of 1.9 m

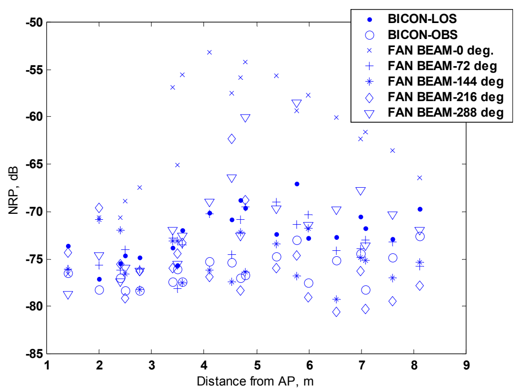

Fig. 2c. NRP for AP antenna height of 2.4 m

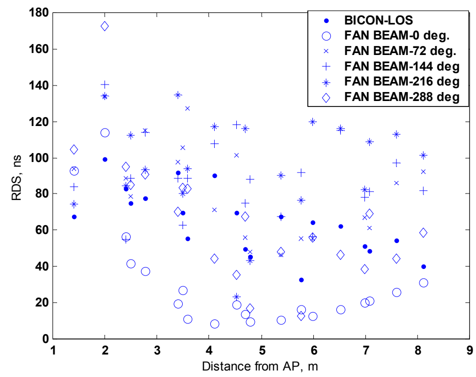

Fig. 3c. RDS for AP antenna height of 2.4 m