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Achievement of high data rates by using high gain antennas in indoor pico cells

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The transmission performance of a high speed indoor radio communication system at 60GHz based on (single carrier) QPSK transmission is evaluated. The main objective of the underlying research is to examine how far high data rates can be achieved with a highly directional antenna placed at desktop level and a centralised antenna at ceiling height that radiates downwards in order to illuminate a circular coverage area below. The results can serve as a reference for tradeoff considerations with respect to the complexity and performance of more sophisticated transmission schemes such as OFDM. Simulation results of achievable data rates are presented. These results indicate that a relatively simple transmission scheme can be applied to provide high data rates in the order of 100–200Mbit/s.

Introduction: In the framework of the European ACTS project MEDIAN [1] a wireless local area network (WLAN) demonstrator system has been designed and developed for the 60GHz frequency band. The target user rate amounts to 150Mbit/s. To enable this data rate, coded OFDM with 512 subcarriers is applied. In addition, the portable stations must be equipped with highly directive antennas in order to achieve sufficient link budget for this high data rate. Consequently, the channel dispersion is very low. This, in turn, indicates that high data rates should be feasible with simple single carrier schemes. Especially in light of the necessity to reduce the complexity of the OFDM part, in order to allow application in small sized portable stations, it is useful to have a reference of what can already be achieved with a low complexity single carrier scheme under similar channel conditions. For antennas with low directivity (up to 16dBi) the transmission performance obtainable with simple single carrier transmission has already been characterised for a variety of typical indoor environments [2, 3]. In this Letter, we present the complementary results for indoor radio transmission using a highly directive horn antenna (25dBi directivity) at the portable station. In particular, these results have significance for the initial high-capacity 60GHz wireless LAN systems because the state-of-the-art 60GHz technology with respect to feasible RF-transport power and front end noise figure necessitates the use of highly directive antennas in order to achieve sufficient link budget.

The modulation format under consideration is quaternary phase shift keying (QPSK). This scheme is chosen since it represents more sophisticated schemes such as offset QPSK and Gaussian minimum shift keying which are envisaged for wireless LAN products. These schemes can cope better with channel non-linearities or have improved bandwidth efficiency but they show similar performance with respect to the probability of error. It is therefore expected that an evaluation of QPSK performance yields a certain generality of the results.

Communication link under consideration: A pseudorandom binary sequence which produces zeros and ones with equal probability is input to the transmitter consisting of a symbol generator and a modulator. The symbol generator converts the binary input symbols to QPSK symbols according to the Gray coding scheme by generating real and imaginary samples from the constellation diagram. The resulting (rectangular) sample pulses are shaped by means of a (square-root) raised-cosine filter with roll-off factor of 0.5. The indoor radio channel is modelled as a tapped-delay-line filter. In this manner, the attenuated and delayed rays are represented by a delay tap and corresponding weighting coefficients. Impulse responses have been obtained with the help of geometric raytracing according to geometrical optics. Additive white Gaussian noise is added to the output of the channel block. The receiver block consists of a raised-cosine filter (the same as was used in the transmitter module) and an ideal detector. The probability of bit error is evaluated by comparing the sequence at the output of the receiver with the original sequence at the input of the transmitter.

Simulation procedure: Simulations have been performed to determine the maximum feasible data rate \( R_{\text{max}} \) for a given probability of bit error threshold \( P_{\text{e}} \) with \( P_{\text{e}} = 10^{-4} \). In all cases the noise level at the input of the receiver was such that the ratio of the energy per received bit and the power spectral density of the noise \( E_b/N_0 \) equals 10dB.

Two indoor environments were considered: room A (10 × 10 × 4m) and room B (4 × 4 × 4m). The walls, ceiling and floor of both rooms have moderate/typical reflectivity properties. The BS antenna was modelled to uniformly illuminate a circular coverage area, with a diameter of 8m, 3m below which the portable station antenna was assumed to be located. It was assumed to be positioned at ceiling height in the middle of the room under consideration. Thus, in room A, the walls are not directly illuminated by the base station antenna whereas in room B the walls are directly illuminated. The portable station antenna was assumed to be located at a height of 1 m (i.e. the height of the coverage area) and positioned on intersections of a horizontal grid of 0.25 × 0.25m² for room A and 0.1 × 0.1m² for room B. Because of the symmetry of the considered configuration it was sufficient to simulate only one quadrant of each room.

Simulation results: Fig. 1 shows the spatial distribution of feasible data rate in one quadrant of room A for the case in which line-of-sight (LOS) conditions hold. The associated bit error probability threshold amounts to \( P_{\text{e}} = 10^{-4} \). It shows that high data rates (≥ 200Mbit/s) are feasible within the coverage area with exception of the position just beneath the base station antenna. These can also be reached outside the actual coverage area. However, it is likely that the received power will be unacceptably low there.

Fig. 2 shows the spatial distribution of feasible data rates in one quadrant of room B in the LOS situation. The associated bit error probability threshold amounts to \( P_{\text{e}} = 10^{-4} \). The walls in room B are illuminated by the base station antenna so that reflections occur which lead to relatively high RMS delay spread values. Thus, in turn, leads to lower data rates as compared to those obtained in room A. From Fig. 2 it can be derived that data rates of 80Mbit/s and higher can be achieved with 5% outage throughout the room. It is indicated by the relatively large grey part that there are no specific 'good areas' and 'bad areas'. This is because the BS station illuminates the entire room.

Fig. 1 Maximum data rates achievable in room A

Fig. 2 Maximum data rates achievable in room B
Conclusions: The results confirm the conjecture that, with QPSK transmission in the 60GHz band, data rates in excess of 200Mbit/s can be obtained by using a high gain antenna at the portable station for the case in which the base station antenna does not directly illuminate the walls of the room. When the walls are directly illuminated by the base station antenna, moderate data rates of 80Mbit/s can still be achieved with low (5%) outage probability.

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References

Dual-frequency planar antenna for handsets

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Cellular telephone handsets are now being designed to have dual-mode capabilities. In particular, GSM and DCS1800 modes are used in Europe, and PCS and AMPS modes are used in the USA. A novel planar dualband internal antenna for handsets which operates in the 0.9 and 1.8GHz bands is proposed. The dualband antenna has almost the same size as a conventional internal antenna operating in the 0.9GHz band. Good dual-band operation was obtained for frequency ratios in the range 1.3-2.7.

Introduction: Dual-frequency antennas are required in dual-band cellular communication systems. Many types of dual-band internal antennas based on two separate antenna elements, including an L type antenna or an inverted F antenna, have been investigated and developed [1, 2]. Using a capacitive feed and a capacitive load, a compact planar inverted F antenna fed at two points suitable for dual-frequency operation has also been developed [3].

The aim of this Letter is to propose a novel dual-band internal antenna fed by a single feed, which is small and has a low profile, to be used at dual frequencies in the 0.9 and 1.8GHz mobile telephone bands. The proposed antenna consists of an outer and an inner antenna for a low resonance frequency, and an inner antenna for a high resonance frequency.

Antenna configuration: The configuration of the proposed dual-band internal antenna is shown in Fig. 1. The proposed dual-band antenna consists of an outer quarter-wave-length annular-ring antenna with a short-circuited plane for a low resonance frequency, and an inner quarter-wave-length rectangular patch antenna for a high resonance frequency.

The input impedances and radiation patterns were calculated and measured to verify the performance of the proposed antenna.

Analysis and experimental results: To clarify the characteristics of the proposed dual-band internal planar antenna, the input impedances and radiation patterns were measured and calculated as parameters of the length $L_o$ and the width $W_o$ of the inner antenna, because the input impedance depends heavily on these parameters.

The measured and calculated resonance frequencies against length of inner antenna

$$L_o = 150.0\, \text{mm}, \quad W_o = 100.0\, \text{mm}, \quad h = 80.0, \quad W_a = 40.0\, \text{mm}, \quad W_d = 30.0\, \text{mm}, \quad L_0 = 10.0\, \text{mm}, \quad h = 5.0\, \text{mm}, \quad d = 5.0\, \text{mm}$$

The measured and calculated resonance frequencies against the length $L_o$ of the inner antenna are shown in Fig. 2. The measured and calculated results agreed very well. The low resonance frequency $f_L$ remained almost constant in spite of changes in the length $L_o$ of the inner antenna. On the other hand, the high resonance frequency $f_H$ was reduced gradually by increasing the length $L_o$ of the inner antenna. As seen in Fig. 2, the frequency ratio of $f_H/f_L$ can be controlled in the range 1.3-2.7. At $L_o = 30.0\, \text{mm}$, the high resonance frequency for DCS-1800 and the low resonance frequency for GSM were obtained as 1.8 and 0.85GHz, respectively.

The impedance matching depends strongly on the two parameters: the distance $d$ between the feed position and the short-circuited plane and the length $L_o$, as shown in Fig. 1. To achieve...