# Antenna Selection and Deployment Strategies for Indoor Wireless Communication Systems

by

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# Abstract

Effective antenna selection and deployment strategies are important for reducing co-channel interference in indoor wireless systems. Low-cost solutions are essential, and strategies that utilise simple antennas (such as directional patches) are advantageous from this perspective. However, performance is always an issue and the improvements achievable through clever antenna deployment need to be quantified. In this thesis, an experimental investigation of indoor propagation comparing the performance of directional antennas and multiple-element arrays (MEAs) with omni-directional antennas is reported. Estimation of the performance of a direct sequence code division multiple access (DS-CDMA) system operating in a variety of deployment scenarios allows the identification of a range of performance-limiting factors and the optimal deployment strategies.

It is shown that the orientation of single-element directional antennas can significantly impact on system performance compared to omni-directional antennas in traditional systems. The deployment of MEAs with an active diversity combining scheme can further improve system performance by more than one order of magnitude. From the perspective of system planning, the choice of antenna selection and deployment options depends on the current and future demand for system performance and the financial resources available. An evolutionary path has been proposed to provide a smooth transition from conventional (low-cost) to high-performance (high-cost) antenna systems as demand dictates.

Other performance-limiting factors in indoor wireless systems include the physical environment and external interference. It is also shown that electromagnetically-opaque obstacles in the environment can amplify the effectiveness of the antenna deployment by acting as physical zone boundaries that restrict interference. External interference has been shown to cause a significant degradation to the performance of an indoor system when the carrier-to-external-interference ratio (CEIR) is below 30 dB. This performance degradation can be minimised by appropriate antenna deployment, although the optimum antenna orientations depends on the strength of the external interference.

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# Contents

# List of Abbreviations and Acronyms

| | |
|---|---|
| **ACK** | Acknowledgement |
| **AMPS** | Advanced Mobile Phone System |
| **AWGN** | additive white Gaussian noise |
| **BER** | bit-error-rate |
| **BPSK** | binary phase-shift keying |
| **CDF** | cumulative distribution function |
| **CDMA** | code division multiple access |
| **CEIR** | carrier-to-external-interference ratio |
| **CIR** | carrier-to-interference ratio |
| **CNR** | carrier-to-noise ratio |
| **CSMA/CA** | carrier-sense multiple access with collision avoidance |
| **CSMA/CD** | carrier-sense multiple access with collision detection |
| **CTS** | Clear to Send |
| **CW** | continuous-wave |
| **DAMPS** | digital advanced mobile phone system |
| **DCOM** | distributed component object model |
| **DS** | direct sum |
| **DS-CDMA** | direct sequence code division multiple access |
| **DSMA** | direct sequence multiple access |
| **EDGE** | Enhanced Data Rates for GSM Evolution |
| **EGC** | equal gain combining |
| **EIRP** | effective isotropic radiated power |
| **FAF** | floor attenuation factor |
| **FDD** | frequency division duplexing |
| **FDMA** | frequency division multiple access |
| **FHMA** | frequency hopped multiple access |

| | |
|---|---|
| **FLMTS** | Future Land Mobile Telephone System |
| **FSK** | frequency-shift keying |
| **GO** | geometrical optics |
| **GPRS** | General Packet Radio Service |
| **GSM** | Global System for Mobile communication |
| **GUI** | graphical user interface |
| **i.i.d.** | independent and identically distributed |
| **ICI** | inter-carrier interference |
| **IDFT** | inverse discrete Fourier transform |
| **IFFT** | inverse fast Fourier transform |
| **i.i.d.** | identical independently distributed |
| **IMT** | International Mobile Telecommunication |
| **IS** | ideal selection |
| **ISI** | inter-symbol interference |
| **ISM** | Industrial, Scientific and Medical |
| **ITU-R** | International Telecommunication Union — Radiocommunication Sector |
| **LMCS** | local multipoint communication systems |
| **LOS** | line-of-sight |
| **MAC** | medium access control |
| **MAI** | multiple-access interference |
| **MEA** | multiple-element array |
| **MIMO** | multiple-input multiple-output |
| **MISO** | multiple-input single-output |
| **MRC** | maximal gain combining |
| **MUI** | multiple-user interference |
| **NLOS** | non line-of-sight |
| **NMT** | Nordic Mobile Telephone |
| **OFDM** | orthogonal frequency division multiplexing |
| **OFDMA** | orthogonal frequency division multiple access |
| **PCB** | printed circuit board |
| **PDC** | Personal Digital Cellular |
| **PDF** | probability density function |

| | |
|---|---|
| **PHY** | physical |
| **PIFA** | planar inverted F-antenna |
| **RF** | radio frequency |
| **RTS** | Request to Send |
| **RV** | random variable |
| **SDMA** | space division multiple access |
| **SIMO** | single-input multiple-output |
| **SIR** | signal-to-interference ratio |
| **SMS** | short message service |
| **SNR** | signal-to-noise ratio |
| **STC** | space-time coding |
| **SVD** | singular value decomposition |
| **TACS** | Total Access Mobile communication Systems |
| **TDD** | time division duplexing |
| **TDMA** | time division multiple access |
| **ULA** | uniform linear array |
| **UMTS** | Universal Mobile Telecommunication System |
| **UTD** | uniform theory of diffraction |
| **VCO** | voltage controlled oscillator |
| **VLSI** | very large scale integration |
| **VSWR** | voltage standing wave ratio |
| **WAF** | wall attenuation factor |
| **WECA** | Wireless Ethernet Compatibility Alliance |
| **WLAN** | wireless local area network |