Effects of Complex Wall Structures on Antenna Radiation Characteristics

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***Abstract*—Future indoor wireless systems must have a high level of performance in terms of quality and capacity. High performance systems require careful deployment of access points. However, there are relatively few degrees of freedom available to the system planner during the deployment of these systems. The antenna type, location and orientation need to be carefully selected to achieve high performance, as measured path losses can be significantly affected by the antenna's radiation characteristics. Most studies of antenna deployment effects on indoor wireless system performance make use of radiation patterns measured in free-space conditions. In practice, antennas will be mounted on complex inhomogeneous dielectric structures such as cavity walls (comprised of two drywall layers with timber or steel supporting frames). This paper reports results of a research project investigating how complex cavity wall structures influence the radiation characteristics of access point antennas, and to what extent any such effects could be exploited to improve system performance.**

I. Introduction

The increasing demand for wireless communications due to the proliferation of mobile wireless devices dictates that current and future indoor wireless systems must be high performance, both in terms of quality (i.e. SINR) and capacity. A high capacity system can be achieved via frequency reuse and a dense deployment of access points. However, this brings interfering co-channel access points closer together which decreases the quality. This observation suggests that informed deployment strategies are important in engineering high performance indoor wireless systems.

From a design perspective, there are relatively few degrees of freedom when deploying indoor wireless systems. Modulation and coding are locked into standards (e.g. IEEE 802.11 derivatives) and these cannot be changed at the time of deployment. However, factors such as access point location [1], antenna type [2], [3], orientation [2], [3] and environmental modification [4]–[7] can be optimized to achieve high performing systems. The antenna is a critical component in any wireless system, and measured path losses can be significantly affected by the radiation characteristics of the antenna [2], [3], [8].

Most studies of antenna deployment effects on indoor wireless systems performance make simplified assumptions regarding the radiation characteristics of access point antennas, usually assuming that radiation patterns are measured in free-space conditions [1]–[3]. In reality, access points are usually mounted on complex inhomogeneous structures such as cavity walls, which are made up of two drywall layers with timber or steel supporting frames. The presence of these complex wall structures in the near-field of the antenna may affect its radiation characteristics as compared to those measured in free-space conditions [9]–[11]. This paper reports results from a research project investigating how complex wall structures influence the radiation characteristics of access point antennas, and to what extent any such effects could be exploited to improve system performance.

The effects of complex wall structures on antenna radiation characteristics are reported in Section II. Guidelines for system planners are discussed in Section III, and the paper is concluded in Section IV.

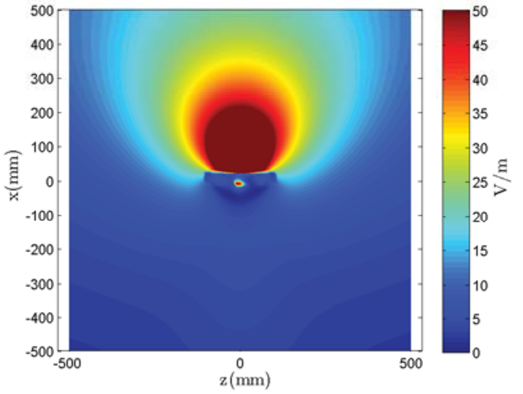
II. Antenna performance in the presence of complex walls

A 2.45-GHz rectangular patch antenna was initially modeled in free-space, and then in the presence of complex wall structures using CST Microwave Studio® (CST MWS). To investigate the effects that internal stud materials have on the antenna radiation characteristic, both timber- (Wall 1) and steel- (Wall 2) framed drywall were considered. In addition, the effects of antenna placement on the radiation characteristics was also investigated by considering three locations, namely (i) Case A— antenna located on stud, (ii) Case B— antenna located in between studs, and (iii) Case C— antenna located at the corner of a room.

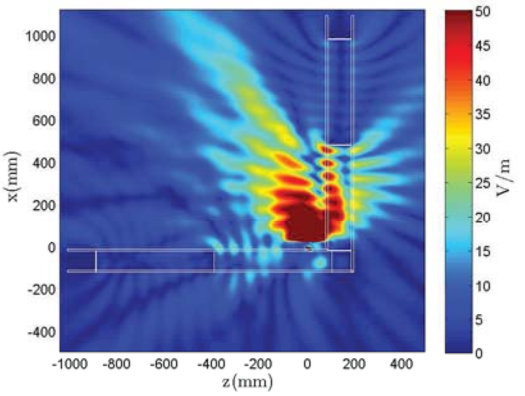
In Cases A and B, the radiation pattern of the antenna was found to be distorted, but the main lobe directionality was preserved (as compared to free-space). In contrast, the main lobe directionality of the antenna was shifted in Case C, focusing the radiation away from the perpendicular wall, as shown in Fig. 1. In addition, the radiation characteristics of the antenna were found to be similar (for each corresponding case) when mounted on either Wall 1 or Wall 2, which suggests that the material used for internal studs have minimal impact on radiating fields.

III. Implications on system planning

It is observed that the presence of complex wall structures in the near-field of an antenna can have a significant effect on its radiation characteristics. In general, the radiation pattern



(a) Free-space.



(b) Case C.

Fig. 1: E_z-field magnitude of antenna (a) in free-space and (b) placed on corner of a room constructed with Wall 2 (steel studs).

was found to be distorted when mounted on complex wall structures. However, the level of distortion is dependent on the location of the antenna on the wall.

Significantly, in Cases A and B the directionality of the antenna is preserved as compared to its radiation characteristic in free-space. This observation suggests that using the antenna radiation pattern measured in free-space during system planning could be sufficient when the antenna is mounted on a flat wall, regardless of whether the antenna is located on, or in between, studs.

In contrast, the directionality of the antenna is shifted when it is located at the corner of a room, which implies that using the free-space radiation pattern in this instance could lead to erroneous results during system planning. Previous studies [2], [3] have shown that an increase in system performance could be achieved by using directional antennas (with suitable orientation) as opposed to omnidirectional antennas. This observation suggests that the directional shift of the antenna's main lobe when mounted on corners of rooms could potentially be exploited to mitigate co-channel interference, thus improving system performance.

IV. Conclusions

It is becoming increasingly important to design high performance indoor wireless systems to accommodate for the high user density. Previous studies have shown that system performance can be significantly affected by the radiation characteristics of access point antennas. However, most studies make simplified assumptions regarding antenna radiation pattern, utilizing the radiation characteristics of antennas measured in free-space conditions. In reality, antennas are usually mounted on walls with lateral inhomogeneity (due to internal studs) which distorts the radiation pattern. It was found that the level of distortion depends on the location of the antenna on the wall. The directionality of the antenna's main lobe was preserved when it is located on or between studs, which suggests that utilizing antenna radiation patterns measured in free-space conditions could be sufficient for the purpose of system planning. However, the directionality of the main lobe was shifted when mounted on the corner of a room. This observation suggests that utilizing free-space radiation pattern is inappropriate when the antenna is mounted at the corner of a room. In addition, the focusing effect of the antenna radiation when mounted at the corner of a room could potentially be exploited to enhance system performance by reducing co-channel interference.

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