Analysis of the Realistic Resolution with Angle of Arrival for Indoor Positioning

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ABSTRACT

The increasing importance of localizing objects in indoor environments is the motivation for much research on localization algorithms. This paper focuses on the maximum achievable resolution for Angle of Arrival as a means to position objects inside rooms using equipment within the field of wireless sensor networks, thus dealing with restricted resources. A clear view on beamforming using antenna arrays is represented and is proven to be useful in Angle of Arrival measurements. A detailed overview of a dedicated algorithm, leads the authors to draw conclusions concerning the resolution. A reference value is defined, which allows the authors to calculate the realistic resolution for all room dimensions. In order to verify these theoretical outcomes with practical results, the development of a quadrature demodulation based antenna array architecture, operating at 2.4 GHz, is presented. The latter is based on a study of different phase shifting technologies.

Keywords: Angle of Arrival, Antenna Array, Beamforming, Indoor, Localization, Resolution, RF Communication

INTRODUCTION

Nowadays, many indoor applications benefit from localization capabilities. Using Personal Digital Assistant (PDA) or smartphone tracking to guide visitors in exhibitions or hotels, locating expensive equipment in hospitals or location based home automation are some possible implementations. The increasing importance of localizing objects in indoor environments is the motivation for this research. A wide range of localization techniques can be used, such as: Received Signal Strength (RSS) (Van Nieuwenhuyse, Ottoy et al., 2008), Time Difference of Arrival (TDoA) (Van Nieuwenhuyse, Wyffels et al., 2010) and Angle of Arrival (AoA) (Rong & Sichitiu, 2009). Due to the growing interest in using antenna arrays in important wireless communication.
communication standard such as WiFi (IEEE 802.11n) (Van Nee, 2006) and WiMAX (IEEE 802.16d/e/j/m) (Qinghua, 2009; Motorola, 2007), this article will focus on the use of AoA for localization purposes. The main objective is to localize objects or mobile devices inside a chamber, with emphasis on the limited amount of resources in the sense that it should be applicable in wireless sensor networks.

Positioning with AoA is based on the concept of beamforming (Fujitsu, 2008) i.e. the effect of combining multiple antenna elements to steer beams in a desired direction. Adjusting parameters such as amplitude and phase can direct the beam. The angle resulting in the maximum power at the mobile devices is an indication for its position. In this research a distinction is made between two types of nodes. First, there are the intelligent anchor nodes having a well known fixed position and supporting an antenna array. Typically these nodes are net powered. Secondly, there exist simple mobile devices which only have one battery powered antenna element and a potentially dynamic position. Multiple intelligent anchor nodes cooperate to track the position of the mobile node, aiming for maximum localization accuracy.

In the first place, this paper focuses on the calculation of the maximum achievable resolution of the mobile node. This resolution is dependent on the number of intelligent nodes, their position, the constitution of the antenna arrays and room dimensions. Modification of these parameters is evaluated throughout this paper.

Next, the focus of this article is shifted towards the hardware implementation of a linear phased antenna array. This is elaborated in such a way that it allows us to verify the value of the theoretical model by using practical results. Later on it will be used to compare different Direction of Arrival estimation techniques (Zhizhang, Gopal, & Yiqiang, 2010; Chandran, 2006). Problems in the architecture, such as phase shifting of RF signals, will be encountered.

This paper is organized as follows; the first section describes how beamforming can be applied to carry out Angle of Arrival measurements in order to track mobile nodes. The second section tackles the decision concerning the suitable antenna array configuration for the intended application. The maximum realistic indoor resolution is determined in the third section. It covers the calculation concept and presents the achieved results. Next the focus is shifted towards the hardware implementation. Starting with an analysis of different phase shifting technologies, to end with a discussion on the antenna array architecture. Finally, the general conclusions and future work on this topic are presented.

BEAMFORMING TO PERFORM ANGLE OF ARRIVAL LOCALIZATION

Angle of Arrival Concept

In the AoA concept each anchor node tries to locate the mobile node. Therefore it steers the receiving beam pattern of its antenna array, and measures the received power emitted by the mobile node. The direction with maximum power is an indication for the mobile node’s position in the case of neglecting possible fading due to reflections. The beam width, related to the used antenna system, is a measure for the maximum achievable accuracy.

Multiple intelligent anchor nodes cooperate to find the mobile node’s position. Each of them defines a zone, depending on the beam width of the antenna system, in which the mobile node is positioned. The intersection of the different zones marks out where the mobile node most likely can be situated. The surface area of the intersection, as indicated in Figure 1, can be defined as the resolution of the system for that specific position of the mobile node.

Analysis of the Linear Phased Antenna Array Beam Patterns

Since it is one of the fundaments of AoA, this paragraph indicates the theoretical background related to the phased antenna array concept. Several configurations of antenna arrays could be found useful, namely linear, circular and
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