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TDOA measurement based GDOP analysis for radio source localization

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Abstract

The revolution brought by GPS has lead to the development of various positioning applications. These applications use measurements (travel time of signal or time of flight) in determining the position. The time of flight requirement in GPS has restricted its use in positioning of unknown objects. Whereas, localization of an unknown enemy Radio Source (URS) such as enemy radar system, tracking of Unmanned Aerial Vehicle (UAV) etc., have high demand in the field of defence in a country like India, they require a new type of measurement technique called Time difference of Arrival (TDOA). There are various factors that affect the position accuracy including amount of measurement noise, algorithm employed for positioning and sensor URS geometry. The sensor-URS geometry is one of the most predominant factors in determining the accuracy estimate and is referred to as Geometry Dilution of Precision (GDOP). This is a well defined problem in positioning systems that use GPS/Time of arrival (TOA) measurements. However, it needs to be refined for URS localization systems/TDOA measurements. This paper mainly focuses on explaining and deriving the concepts of GDOP in relation to TDOA measurement based URS localization systems. For a comprehensive understanding, an illustrative example of localizing an URS with TDOA measurements is explained and discusses the effect of sensor geometry with the help of GDOP profiles. In addition, this paper explains the process of identifying an optimal sensor configuration for URS localization systems. For the purpose of simulation, five sensors arranged in two different configurations are considered. A target surveillance area of 3600 Sq-Kms with 169 target zones is used in generation of GDOP profiles over the Indian subcontinent.

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1. Introduction

Tracking and monitoring an URS is a critical task in the field of defence for safe guarding the country from enemy attacks, guiding military troops in the enemy territory etc. The essential requirements for such positioning systems are set of sensors and a central processing unit. These systems localize the position of an URS relative to the origin defined with reference to the sensor network location. The Radio frequency signal emitted from URS reaches the sensors at different times[1]. These time differences are used in determining the position of URS and are called TDOA measurements. For example, in order to find the three dimensional position of an URS shown in Fig.1, the system needs to have three or more sensors and a central processing system preinstalled at known locations.

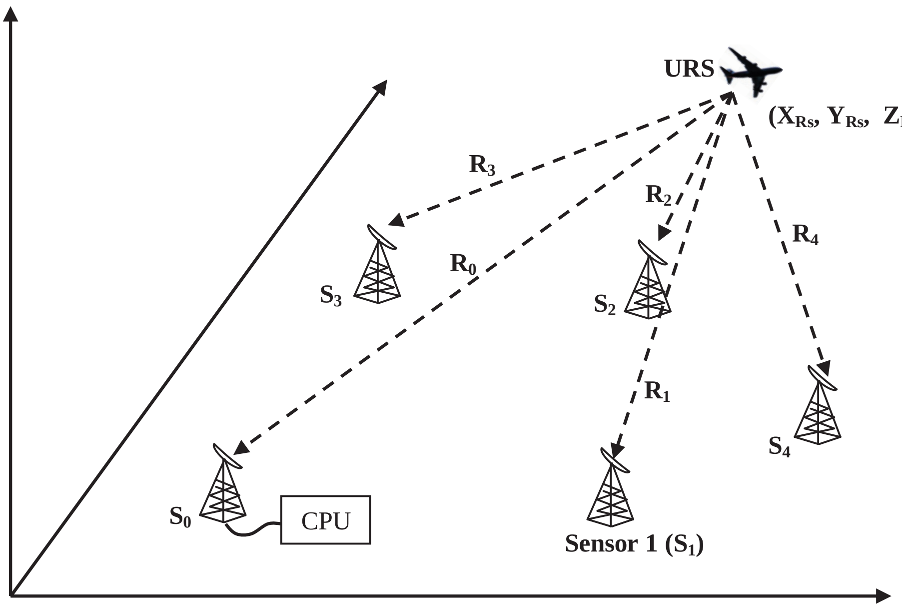

Fig.1. Localization of Unknown Enemy Radio Source with TDOA measurements

1.1. URS localization with TDOA measurements

Localization of the URS shown in Fig.1 with TDOA measurement technique[2] is explained in this section. The scenario uses five sensors with S_0 as the reference sensor (origin) and $R_0, R_1, .., R_4$ represent the range between URS and i^{th} Sensor, S_i where i=0,1,2,3 and 4.

Let the TDOA measurement observed between reference sensor, S_0 and the i^{th} sensor, S_i is given as

$$TDOA_{0i} = t_0 - t_i \quad (1)$$

Where, t_0 = Arrival time at S_0 sensor, t_i = Arrival time at S_i sensor and i=1, 2, 3 and 4.
Hence, the observed range difference of arrival between Sensor, S_0 and the i^{th} sensor, S_i is referred to as $RDOA_{0i}$ and is calculated by multiplying the $TDOA_{0i}$ with the velocity of signal (c) (Eq.2)

$$RDOA_{0i} = c \times TDOA_{0i} = c \times (t_0 - t_i) = R_0 - R_i \qquad \text{where, i=1, 2, 3 and 4} \quad (2)$$