Background

1. Global Positioning System (GPS) is the ubiquitous system for outdoor positioning, however, it performs very poorly indoors.
2. Received Signal Strength Indicator (RSSI) based techniques commonly used for indoor positioning only carry distance information, and they requires at least three beacon sources to locate an object〔Fig. **1**〕.

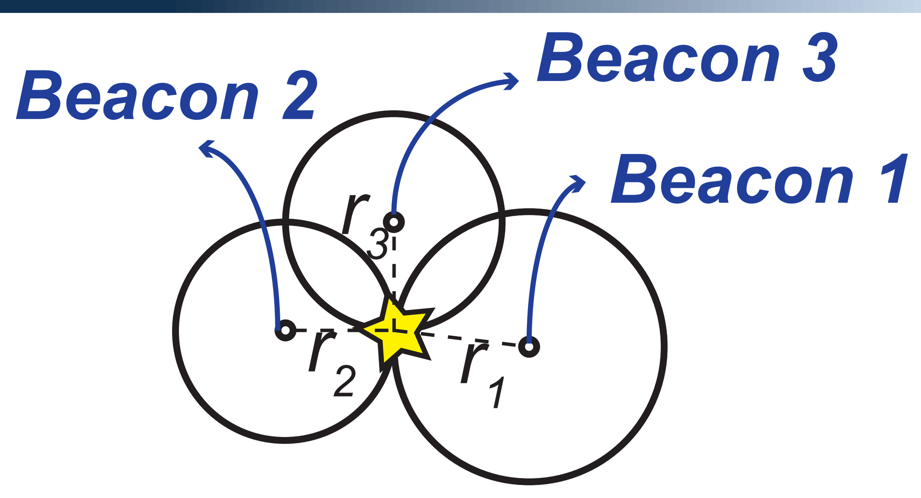

Fig. 1. Multi-beacon positioning system

3. Current methods of magnetic-based positioning, such as pattern matching and DC magnetic field signal strength, require extensive site surveys and sophisticated setup procedures. Yet, an easy-setup system for precise indoor positioning is highly desirable.

Objectives

Investigation into a new 3D positioning system that can achieve:

1. **single-source positioning** by calculating the distance (r), elevation angle (θ) and azimuth angle (φ) between an object and the reference point〔Fig. **2**〕;
2. precise indoor positioning in **3-dimensional space**; and
3. easy setup without site surveys.

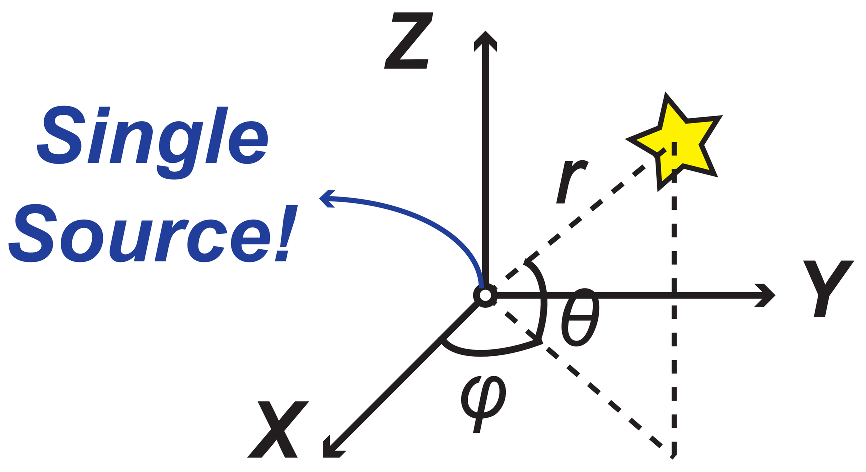

Fig. 2. Single-source positioning system

Methods

Calculation of Distance (r) using Received Signal Strength (RSS)

1. Extreme low frequency time-varying magnetic field signals are sent from the source, and the field strength can be determined by the **amplitude** of the signal.
2. Using quasistatic approximation, a magnetic dipole field model is obtained to tell the relationship between the distance and the magnetic field strength〔Fig. **3**〕, i.e. (μ_0: Magnetic Constant; M : Magnetic Dipole Moment),

$$\boldsymbol{B} = \frac{\mu_0}{4\pi}\frac{M}{r^3}(2\sin\theta\,\hat{\boldsymbol{r}} - \cos\theta\,\hat{\boldsymbol{\theta}}) \qquad (1)$$

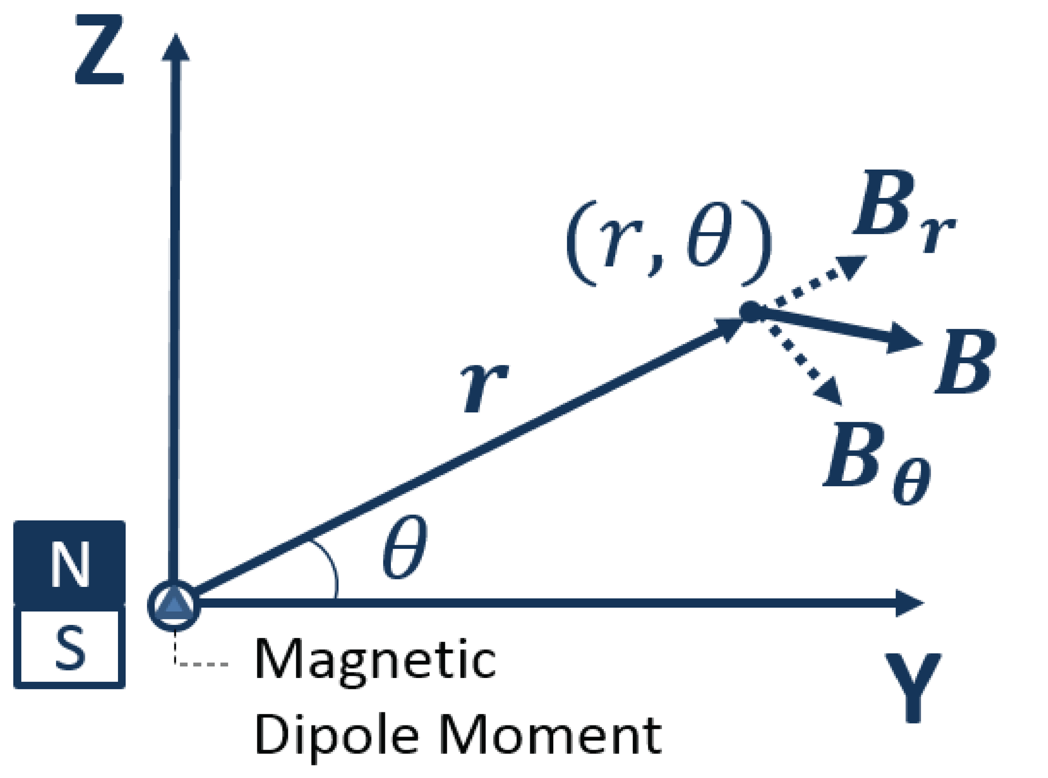

Fig. 3. Magnetic dipole field model

Calculations of Elevation Angle ($\boldsymbol{\theta}$) and Azimuth Angle ($\boldsymbol{\varphi}$)

1. Concept of a Rotating Magnetic Field

Magnetic field strength received by an object **varies** over time, and the peak field strength occurs when magnetic dipole's north and south poles face the object〔Fig. **4** & **5**〕.

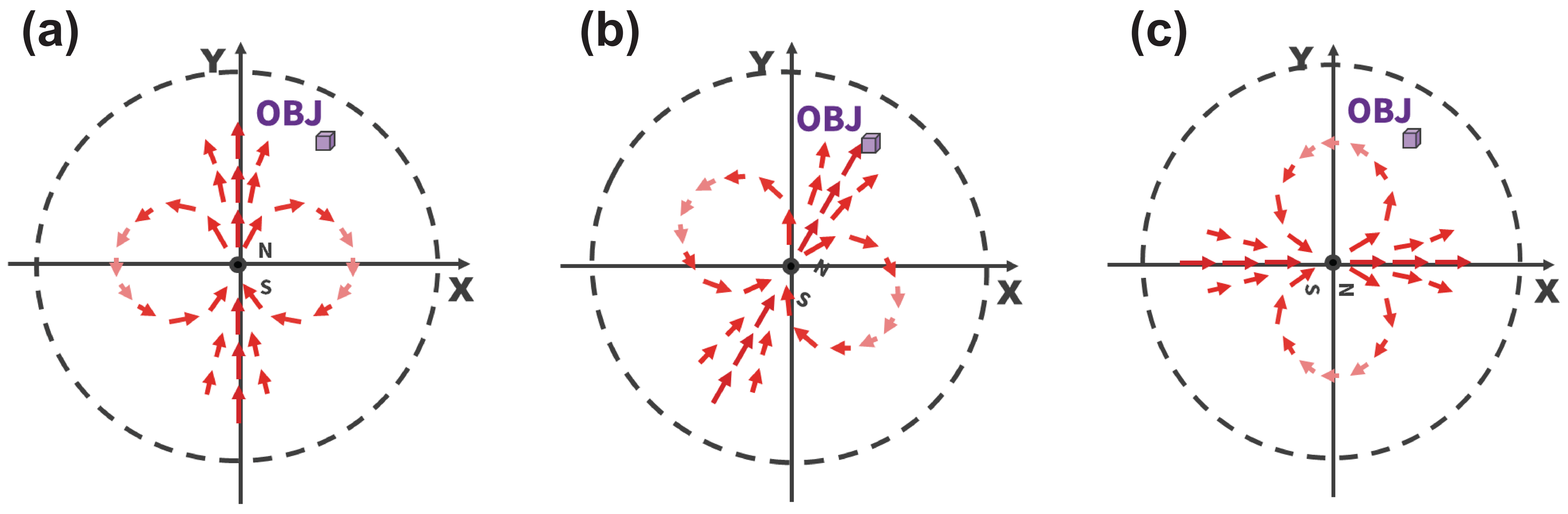

Fig. 4. Magnetic field generated by a rotating magnetic dipole at different timestamps (red arrows are magnetic flux lines)

(a) Field at t_1 (b) Field at t_2 (c) Field at t_3

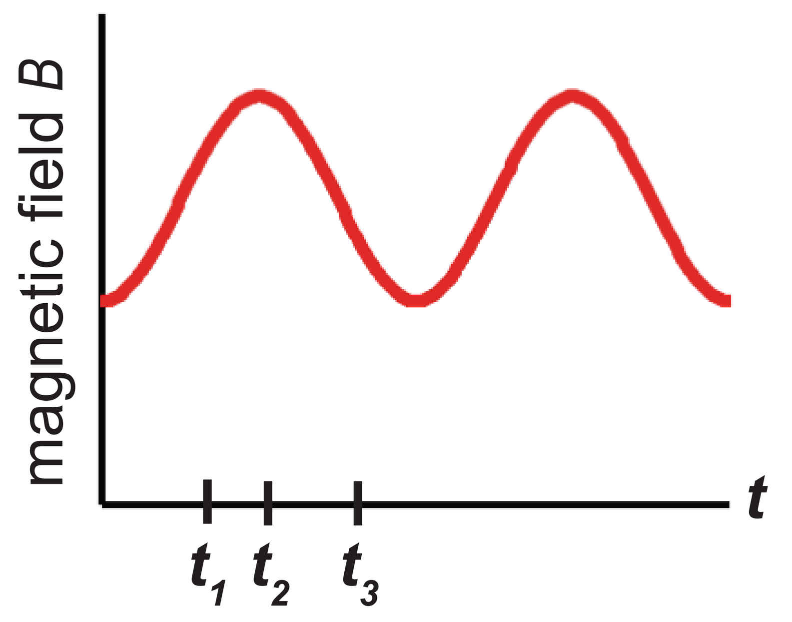

Fig. 5. Magnetic field strength received by an object in a rotation cycle

2. Calculations of Angles using a Rotating Magnetic Field

A. In this study, a rotating magnetic field is created by feeding **phase-quadrature** signals to two mutually orthogonal coils.

B. While focusing 0 to 180 degrees of a rotating cycle, the peak strength of magnetic field occurs at $\tilde{t}$, and the angle of an object is calculated $\tilde{\theta}$, i.e. (ω: the angular frequency of a rotating magnetic field)〔Fig. **6**〕,

$$\tilde{\boldsymbol{\theta}} = \boldsymbol{\omega}\tilde{\boldsymbol{t}} \qquad (2)$$

C. Angle calculations for a complete 360 degrees will be achieved during system development.

D. $\tilde{r}$ is the distance from the origin point to the object.

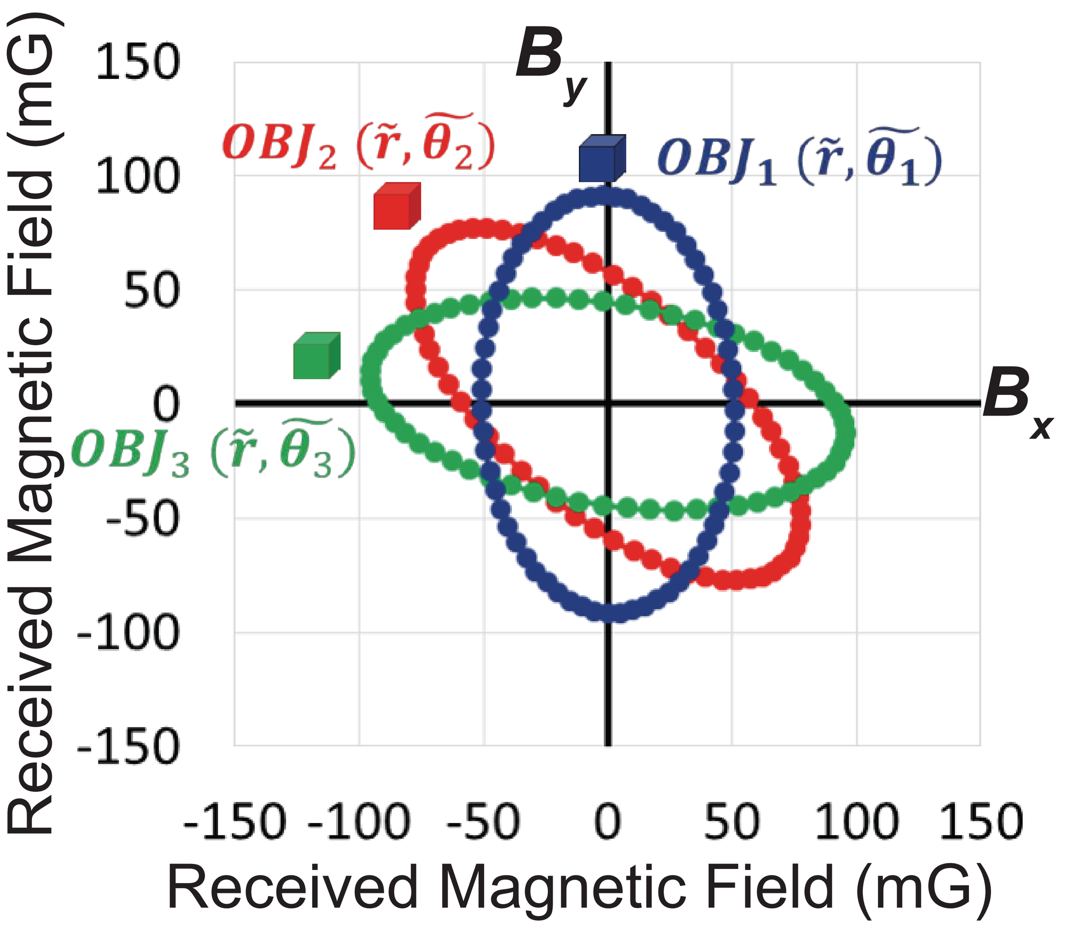

Fig. 6. Magnetic field received over time by three objects at different angles while two axes of each sensor are fixed on X and Y axis