UAV-based absolute radar calibration

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1. Introduction

➢ **Current calibration methods:**

1) Metal sphere hanging underneath a tethered balloon
2) Trihedral corner reflector locating on the top of a tower or mast

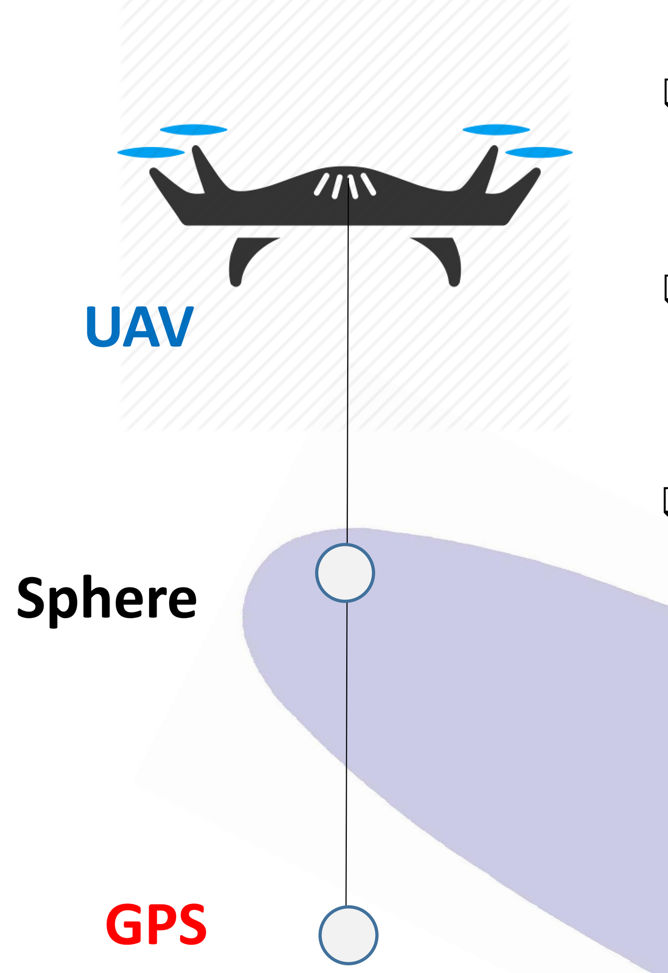
➢ **Shortcomings :**

1) Location bound
2) Costly for tower setup or helium balloon purchase
3) Non-repeatable for mobile radar
4) Impossible for vertically-pointing cloud radar

➢ **Proposed method**

1) A UAV serves as the aerial platform carrying a metal sphere
2) Flying over radar illumination areas to complete the calibration process
3) Real-time single-frequency precise point positioning (PPP) type GNSS solution to retrieve the sphere position

2. Basic principle



❑ Radar constant

$$C_0(dB) = 10\log_{10}\left\{\frac{\lambda^2}{\pi^5|K_w|^2}\left[\frac{(4\pi)^3}{P_t G_0^2 \Delta R}\right]\left(\frac{8\ln 2}{\pi\theta_1\phi_1}\right)10^8\right\}$$

❑ Metal sphere deviated from boresight *(θ, ϕ)*

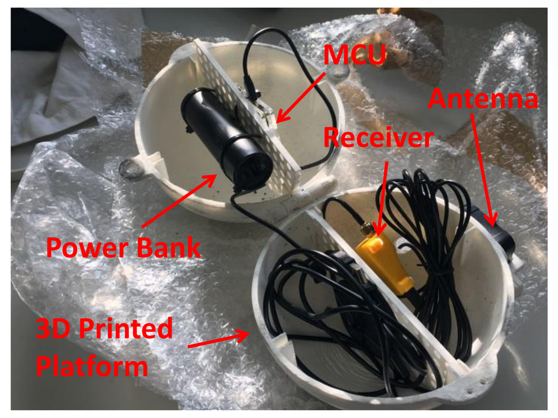
$$P_{sp}(\theta,\phi)R_{sp}^4 = \frac{P_t\left[G_0 f(\theta,\phi)\right]^2\lambda^2\sigma_{sp}}{(4\pi)^3}$$

❑ Radar constant deviated from boresight *(θ, ϕ)*

$$C(\theta,\phi)(dB) = 10\log_{10}\left\{\frac{\lambda^4}{\pi^5|K_w|^2}\left[\frac{\sigma_{sp}}{P_{sp}(\theta,\phi)R_{sp}^4\Delta R}\right]\left(\frac{8\ln 2}{\pi\theta_1\phi_1}\right)10^8\right\}$$

$$C_0(dB) = C(\theta,\phi)(dB) + 20\log_{10}\{f(\theta,\phi)\}$$

How to obtain the radar constant in different position?



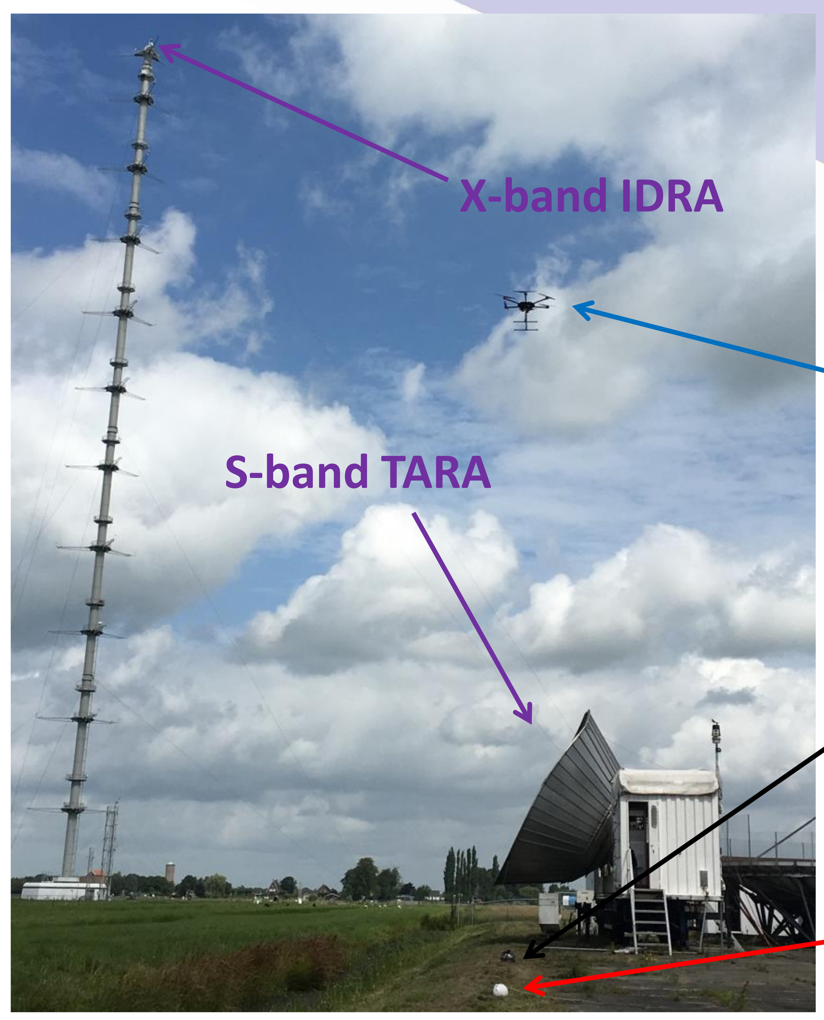
3. Equipment and calibration setup

❑ **UAV**

MATRICE 600	Specifications
Type	Micro-drone hexacopter
Dimension	Diameter 167 cm, height 62 cm
Weight	9.1 kg with batteries
Payload	Max 6 kg
Flight mode	Automatic with waypoint or based on radio control
Hovering Accuracy	Vertical: ±0.5 m, Horizontal: ±1.5 m
Max Speed	18 m/s (No wind)
Endurance	No payload: 35 min, 6 kg payload: 16 min

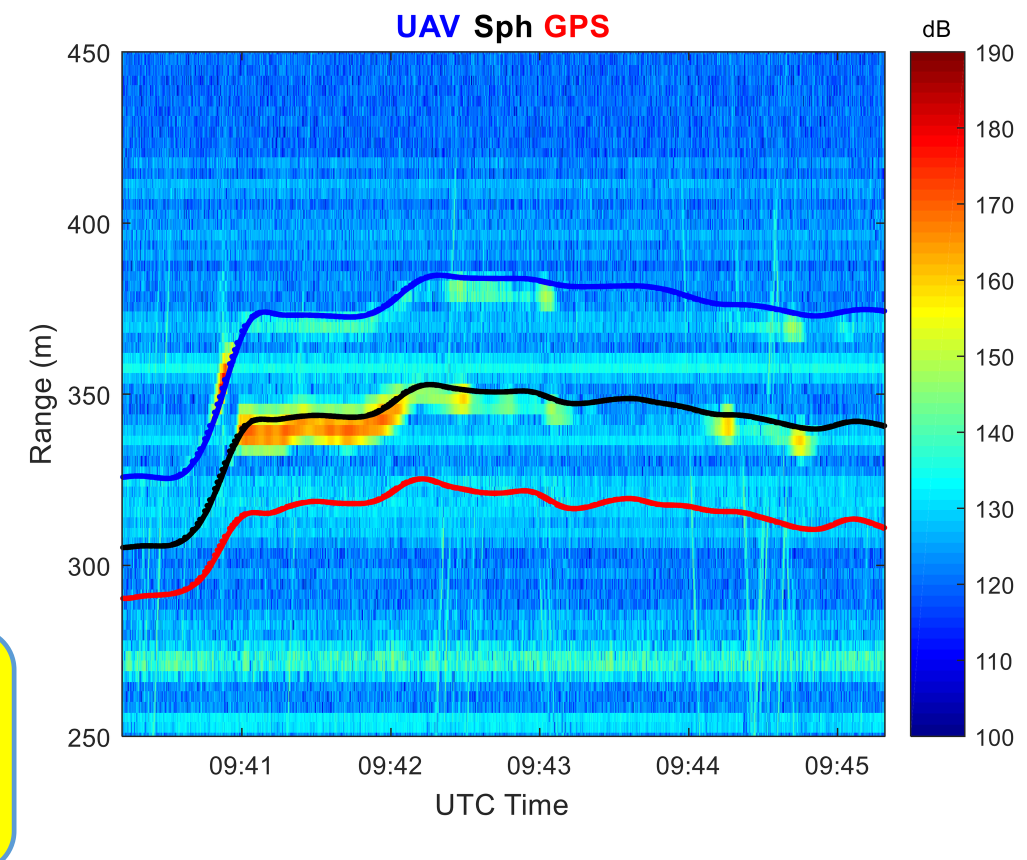
➢ The GPS in the UAV and external GPS box are used to locate the position of metal sphere.

➢ The sphere is located between the UAV and GPS box using light connecting line with the same length.

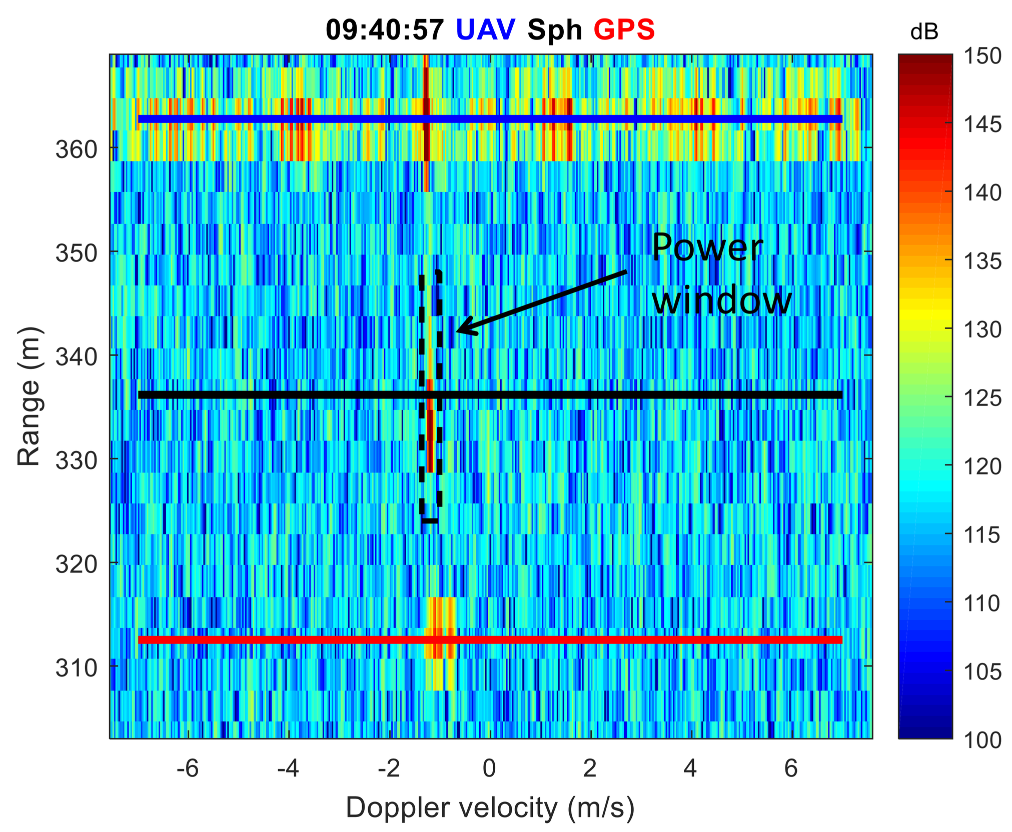


4. Measurements

❑ **Time domain**



❑ **Frequency domain**



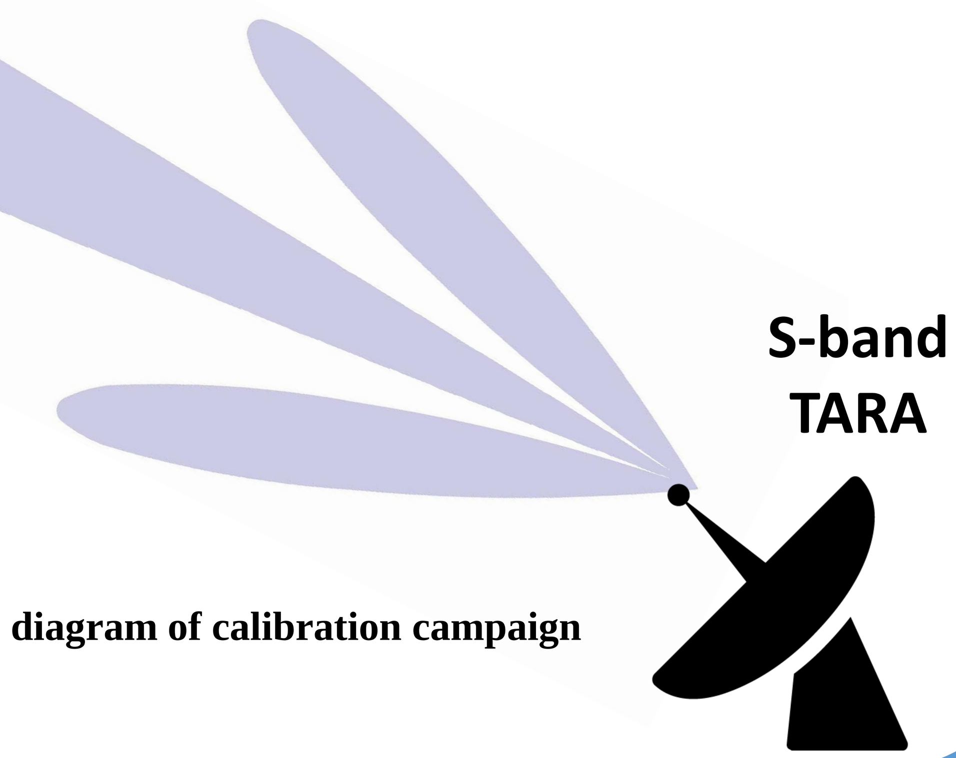
➢ The routes of UAV, sphere and GPS box are visible in the time domain.

➢ These objects are observed in the frequency domain to further distinguish from each other.

➢ A power window in the frequency domain is used to calculate the sphere receiving power.

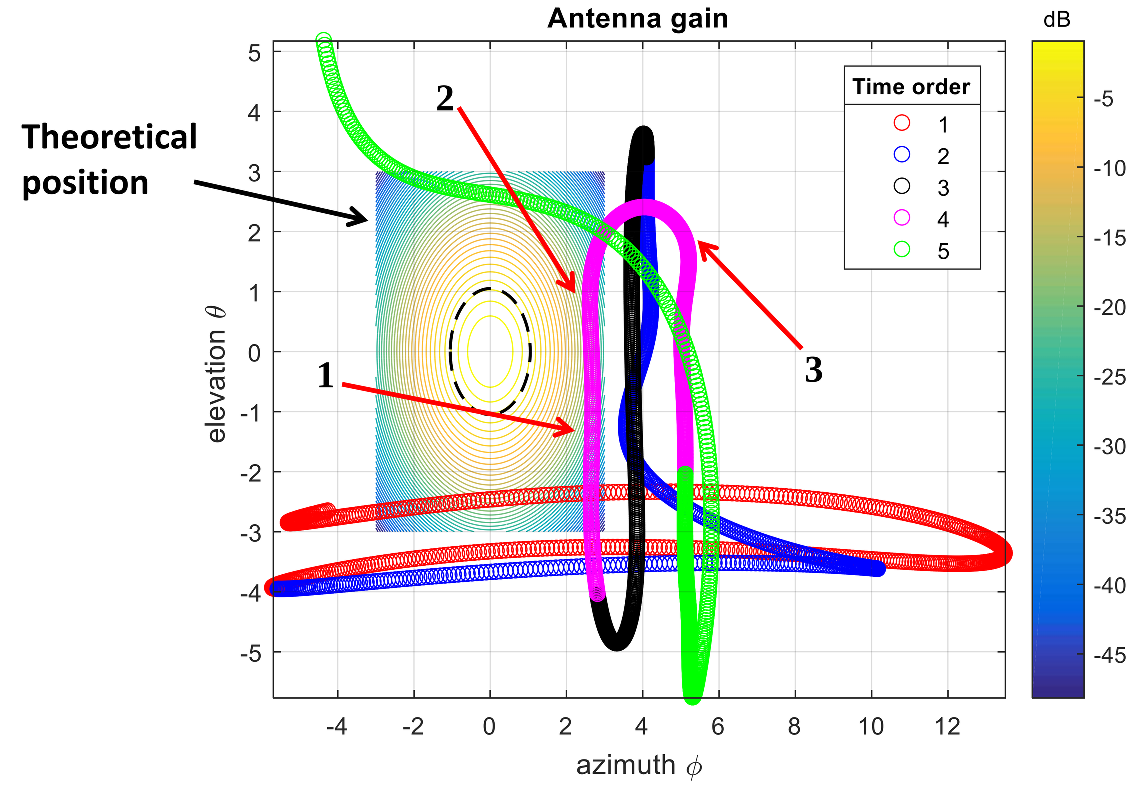
➢ Only data that sphere is not severely contaminated by ground clutter are selected.

❑ **Schematic diagram of calibration campaign**

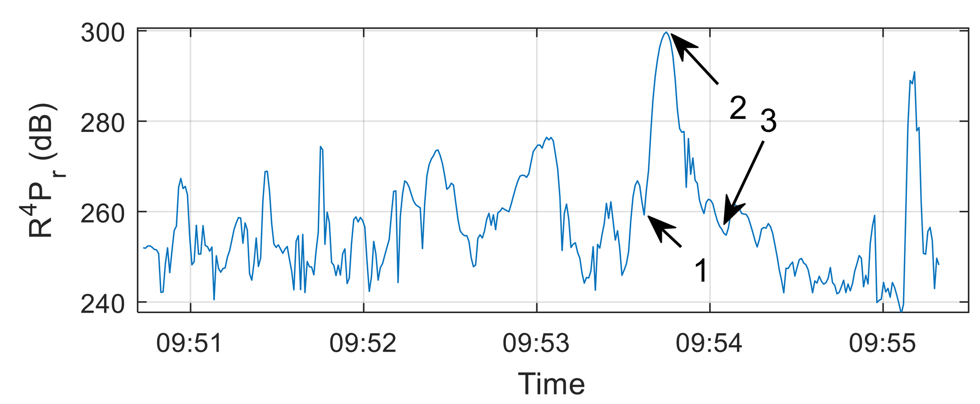


5. Alignment calibration

❑ **Azimuth-elevation output**



❑ $P_{sp}(\theta,\phi)R_{sp}^4$ **calculation**



➢ The theoretical antenna beam pattern is given and sphere is moving around to cross the antenna beam.

➢ A Gaussian-shape result is present from Position 1 via Position 2 to Position 3, and at Position 2 it reaches the maximum.

➢ Azimuth difference of Position 1 and Position 2 is 0.05º, and elevation difference is 2.42º which is exactly first null beam width.

➢ Hence, the elevation angle of Position 2 presents the elevation boresight, which means the elevation angle deviation is 0.98º.

Conclusion

❖ A novel radar calibration technique which uses an industrial-grade UAV to carry a metal sphere is proposed.

❖ Receive power from metal sphere is calculated in the range-Doppler domain, which separates from UAV, GPS device and ground clutter.

❖ After the completion of alignment calibration, sphere can be designed to position in the antenna main beam to complete the calibration progress.

❖ In the future, radar constant in different position C*(θ, ϕ)* can be obtained.

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