MIMICKING BATS' ECHOLOCATION: A BIOMIMETIC APPROACH FOR INDOOR HUMAN TARGET DETECTION

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Abstract

In complex indoor environments, severe static clutter from indoor objects brings great challenges to human target detection, making the performance of existing clutter suppression methods not ideal. In this paper, we imitate the target discrimination method of **bats**, proposing a detection method for indoor human targets leveraging **dual-frequency radar signal and electromagnetic properties**. By analyzing the distinct power ratios of dual-frequency echoes, our approach **classifies** human targets and static clutter **from the signal source** rather than suppressing the existing clutter, solving the problem that existing clutter suppression methods do not perform well in complex indoor environments. Simulation results prove the effectiveness of this method.

Introduction

One major application for radar system is the detection of indoor human targets. However, radar clutter will decrease the detection capability of human targets by increasing the false alarm and miss rates, while submerging the target echo signal. Instead of precisely detecting and categorizing echoes as clutter from the source, **current clutter suppression strategies mainly focus on lessening the existing clutter signals' impact**. Consequently, these techniques frequently encounter difficulties in successfully separating the intended object from a complicated clutter environment.

Given the insufficiency of current approaches shown in Fig. 6, our study leverages dual-frequency radar signal and electromagnetic properties to distinguish between targets and clutter from the source **by simulating the natural sound patterns of bats**. In Section 2, we provide a theoretical analysis in support of this. Section 3 presents the simulation experiments, Section 4 presents the discussion and the conclusion.

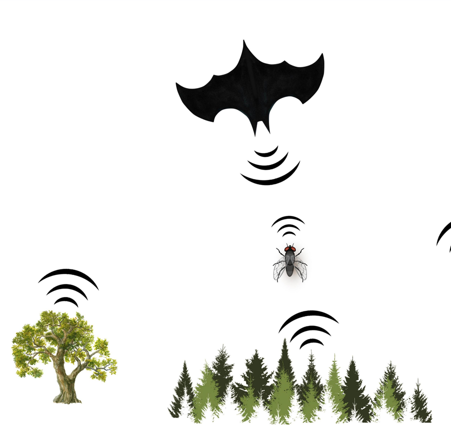


Figure 1. Bats can accurately distinguish prey targets and clutter.

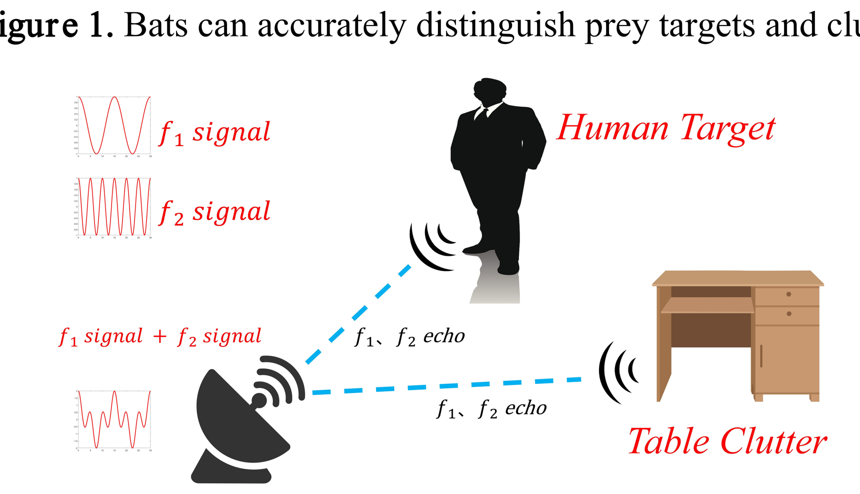


Figure 2. Indoor environment model.

Modelling and Theory Analysis

As shown in Fig. 1, bat sonar can precisely detect small insect prey in the intricate jungle environment and has outstanding clutter-identifying capacity [5]. Bates et al. [6] clearly illustrated that bats can distinguish between prey targets and clutter by **emitting signals of two different frequencies**. [7] further demonstrated that bats can distinguish targets by **comparing the power ratio of the two frequencies of echo signals from each target**. Hence, we distinguish indoor human targets by mimicking bat's echolocation pattern.

As seen in Fig. 2, we constructed a simple indoor environment model that contains static clutter composed of the table and a target to be identified composed of the human. According to the radar equation, the echo power of a single-frequency signal P_r can be expressed as

$$P_r = \frac{P_t G_t G_r \lambda^2 \sigma_{RCS}}{(4\pi)^3 R^4}$$

Mimicking bats distinguish targets by comparing the power ratio of the two frequencies of echo signals, for a single target, its echo power ratio can be expressed as

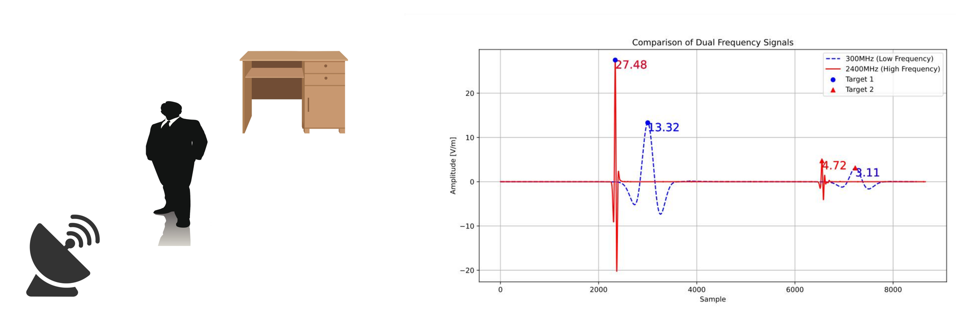
$$P_{ratio}(\varepsilon_r) = \frac{P_r(f_2, \varepsilon_r, \sigma_{cond})}{P_r(f_1, \varepsilon_r, \sigma_{cond})} = \frac{\lambda_2^2 \sigma_{RCS}(f_2, \varepsilon_r, \sigma_{cond})}{\lambda_1^2 \sigma_{RCS}(f_1, \varepsilon_r, \sigma_{cond})}$$

considering

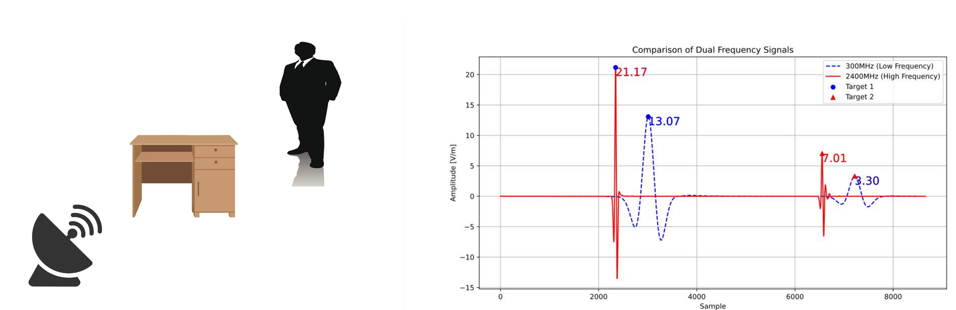
$$\lambda = \frac{c}{f}$$

so $P_{ratio}(\varepsilon_r)$ can be rewritten as

$$P_{ratio}(\varepsilon_r) = \frac{P_r(f_2, \varepsilon_r, \sigma_{cond})}{P_r(f_1, \varepsilon_r, \sigma_{cond})} = \frac{f_1^2 \sigma_{RCS}(f_2, \varepsilon_r, \sigma_{cond})}{f_2^2 \sigma_{RCS}(f_1, \varepsilon_r, \sigma_{cond})}.$$



Scene 1 (a)



Scene 1 (b)

Figure 3. **Scene 1**: target and clutter are in a straight line, (a) shows the human target is in front of the table clutter, (b) shows the human target is behind the table clutter.

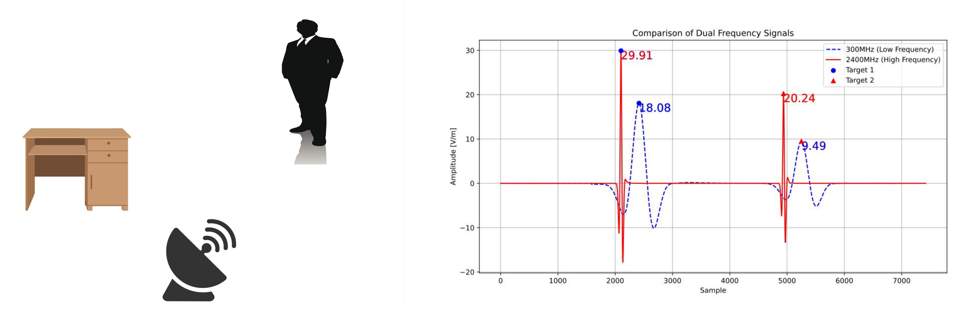


Figure 4. **Scene 2**: target and clutter are on the left and right sides of the radar.

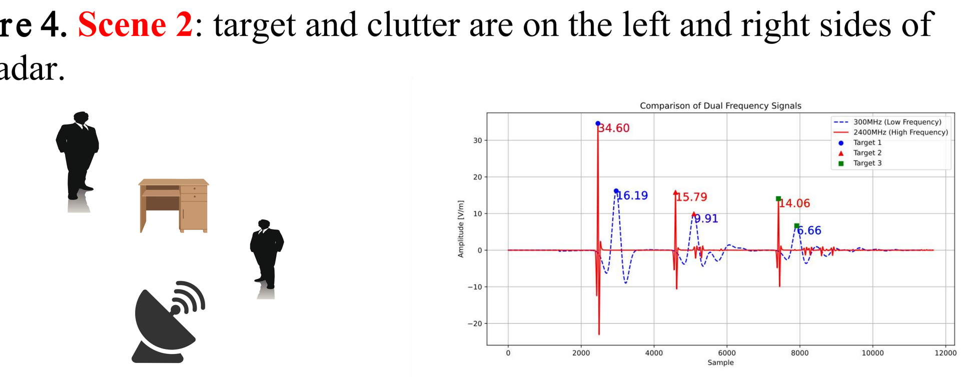


Figure 5. **Scene 3**: multi-human detection.

Simulations and Results

Fig. 3 (Scene 1) shows the indoor **single-human** detection situations. The human target, radar, and table clutter are all in a straight line in scene 1, with (a) the human target in front of the table clutter and (b) the human target behind it.

Fig. 4 (Scene 2) also shows the scenario of indoor **single-human** detection. In scene 2, the human target and the table clutter are on the left and right sides of the radar.

The indoor **multi-human** detection scene is depicted in Fig. 5 (Scene 3). In this scenario, we have one table clutter and two human targets (human 1 is on the right, while human 2 is on the left). Table 1 displays all of the simulation findings.

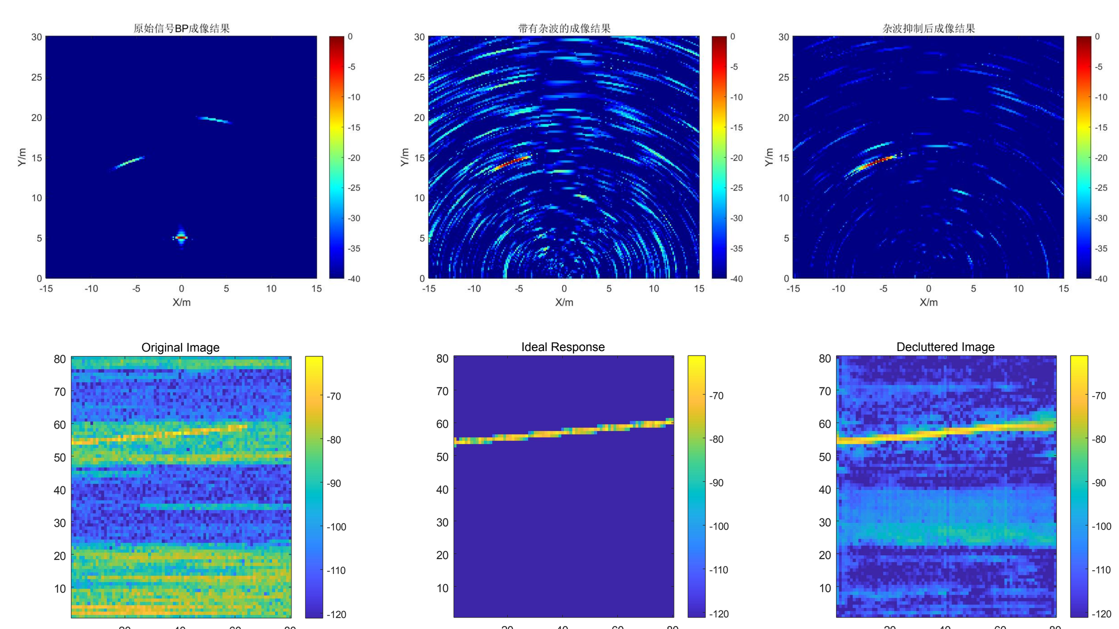


Figure 6. Current clutter suppression strategies mainly focus on lessening the existing clutter signals' impact.

Scene \ Power ratio	Human	Table Clutter
Scene 1(a)	4.26	2.30
Scene 1(b)	4.51	2.62
Scene 2	4.55	2.74
Scene 3	4.57 4.46	2.54

Table 1. Summary of simulation results.

Discussion and Conclusion

In complicated indoor situations, our work suggests a dual-frequency radar signal-based clutter suppression technique that **successfully separates static table clutter from human targets**. The findings demonstrate that under the simulated scenarios, **the human target's echo power ratio is higher than that of table clutter, allowing for discrimination between the two, regardless of the relative positions of the human target and the table clutter, as well as the number of human targets.** By separating targets from clutter at the source, this technology overcomes the drawbacks of conventional methods and provides increased accuracy for applications such as healthcare monitoring, smart home systems, and security surveillance.

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