August 2022

Detecting the Direction of a UWB Anchor or Tag Using Secondary Radiation

Kiavash Faraji

Detecting the Direction of a UWB Anchor or Tag Using Secondary Radiation

ABSTRACT

An ultra-wideband (UWB) tag is a device that can be attached to objects to locate them or for other operations such as unlocking a device based on proximity to another device. Common implementations utilize at least three antennas on the device that detects a precise location of a UWB tag. This disclosure describes techniques that leverage secondary radiation caused by the metal case of a laptop (or other devices) to accurately locate a UWB tag while utilizing just two antennas, simplifying hardware design and reducing cost.

KEYWORDS

- Ultra-wideband (UWB)
- UWB anchor
- UWB tag
- Front-back ambiguity
- Direction finding
- Location determination
- Triangulation
- Secondary radiation

BACKGROUND

An ultra-wideband (UWB) tag is a device that can be attached to objects (keychains, smartphones, etc.) to track their locations. A UWB tag on the user's person (e.g., in their pocket or smartglasses) can be used to unlock a laptop.

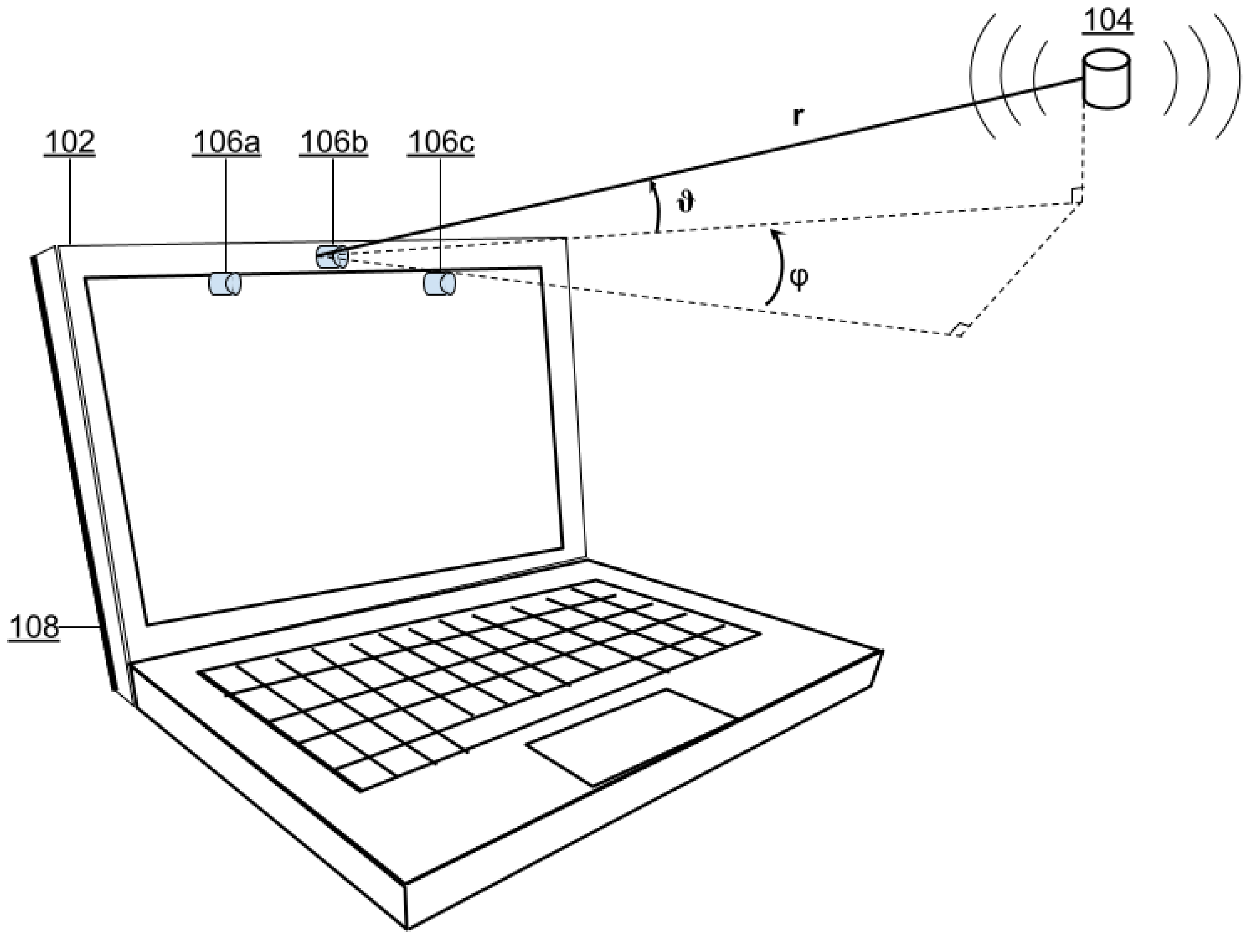

Fig. 1: A laptop with three antennas can locate an object emitting UWB waves (the size and the inter-antenna distances are exaggerated for clarity)

Fig. 1 illustrates a laptop (102) with three antennas (106a-c) receiving ultra-wideband (UWB) waves from a UWB tag (104) some distance away. With three antennas, the laptop can locate without difficulty the UWB tag, e.g., its distance (r) and its directional (angular) coordinates (ϑ and φ). Location determination can be done by a variety of techniques, e.g., triangulation based on time-of-flight and phase-difference comparison. Typically, the laptop has a metallic back (108). While Fig. 1 shows a laptop, antennas can be used on any device such as tablet, TV, smart speaker, smartphone, etc.

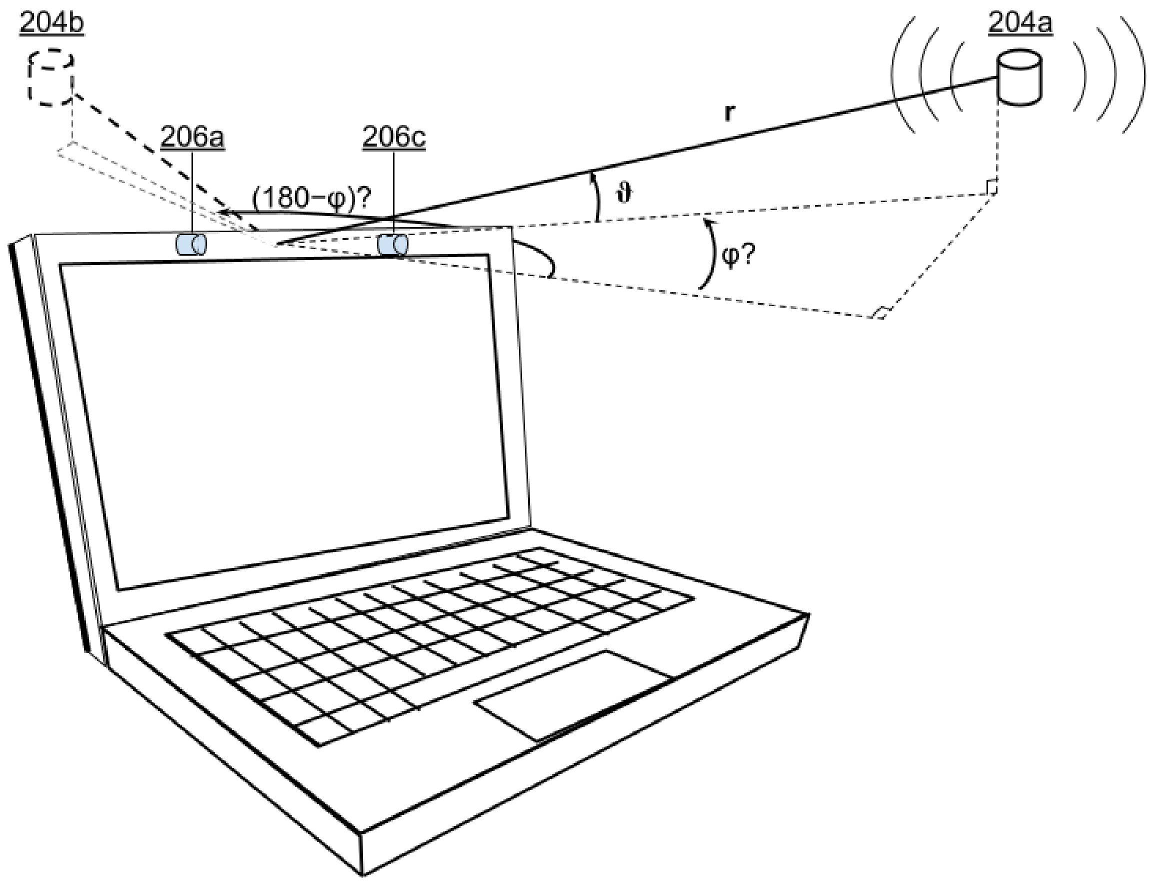

Fig. 2: A laptop with two antennas can locate an object emitting UWB waves up to one reflection; e.g., it suffers from front-back ambiguity

However, if the laptop has two (206a, 206c), not three, antennas, it cannot precisely locate the UWB tag; rather, it locates the tag up to an uncertainty of a reflection. For example, it can determine that the tag is at either its true position (204a) or at a mirror-image position (204b). This uncertainty in position is referred to as front-back ambiguity. In the illustration of Fig. 2, with two antennas, the distance (r) and the altitude (ϑ) can be determined; however, the azimuth can only be determined to within a sign (φ or 180−φ).

Front-back ambiguity can have serious security implications. For example, if a UWB tag attached to a user’s smartphone is used to unlock the laptop, then the laptop can potentially unlock even if the user was *behind*, not in front of, the screen. The use of three antennas, although presently critical to precisely locating a UWB tag, adds to hardware complexity and expense, limiting UWB adaptation to high-end products.

DESCRIPTION

This disclosure describes techniques that leverage secondary radiation caused by the metal case of the laptop (or other device) to resolve front-back ambiguity.

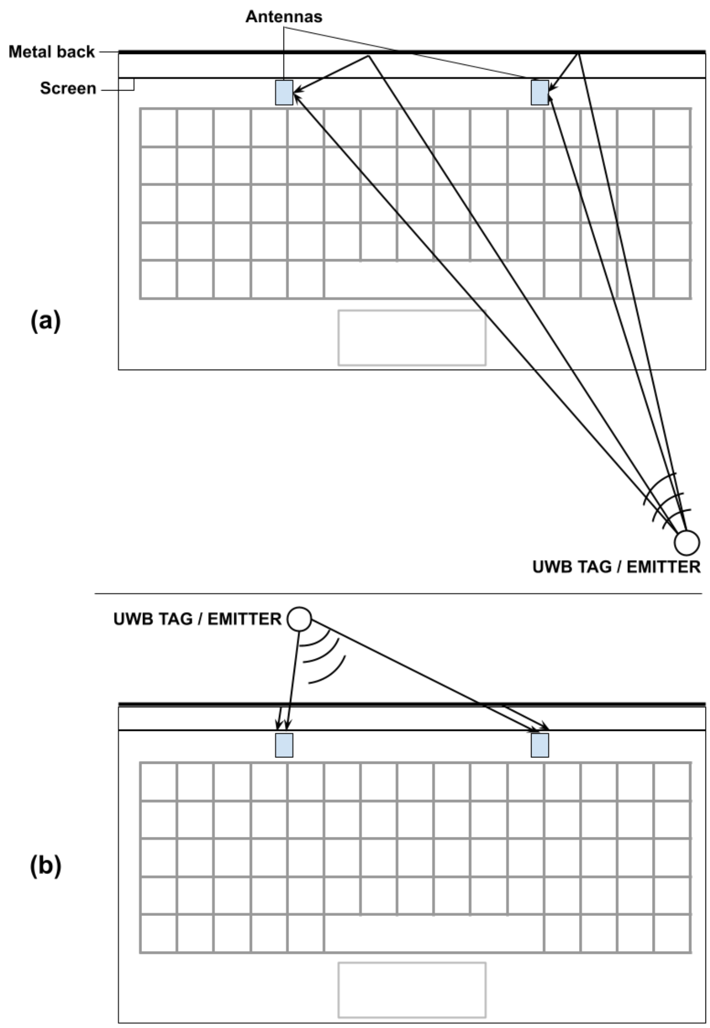

Fig. 3: Top view of laptop determining the direction of the UWB tag with just two antennas: (a) UWB tag in front of the screen; (b) UWB tag behind the screen

Fig. 3 illustrates a top view of a laptop with just two UWB antennas in operation to determine the direction of a UWB tag or emitter. The character of radiation reflected off the metal back of the laptop differs based on whether the UWB tag is in front of the laptop or behind. In particular, a UWB tag that is in front of the laptop (Fig. 3a) generates secondary radiation (radiation reflected off the metal surface) that is slightly delayed with reference to the primary radiation (radiation directly emitted by the UWB tag). Further, the secondary radiation, being reflected off metal, is 180° out of phase with reference to the primary radiation.

On the other hand, the primary radiation from a UWB tag behind the laptop (Fig. 3b) that reaches antennas in the front of the laptop is comparatively lower in magnitude, as metal is a good electromagnetic shield. Secondary radiation reaches at almost the same time as, and has a 90-degree phase difference with, primary radiation.

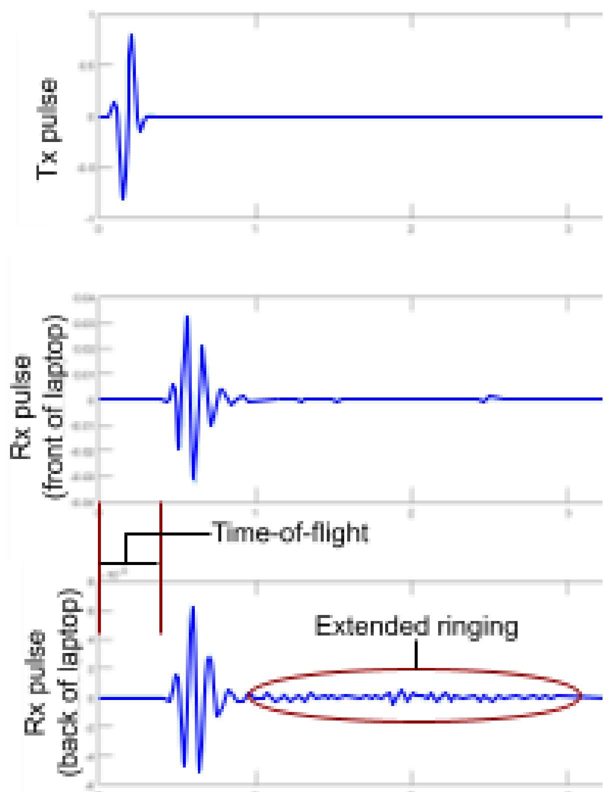

Fig. 4: When the UWB tag is at the back of the laptop, the received pulse displays an extended ringing in time. When the UWB tag is in front of the laptop, there is very little, if any, extended ringing.

The aforementioned characteristics of front-origin and back-origin UWB waves are evident in the time-domain waves received by the antennas, illustrated in Fig. 4. When the UWB tag is at the back of the laptop, the received pulse displays an extended ringing in time. When the UWB tag is in front of the laptop, there is very little, if any, extended ringing. The time delay between the transmitted and the received pulses is the time of flight and corresponds to the distance between the UWB tag and the laptop.

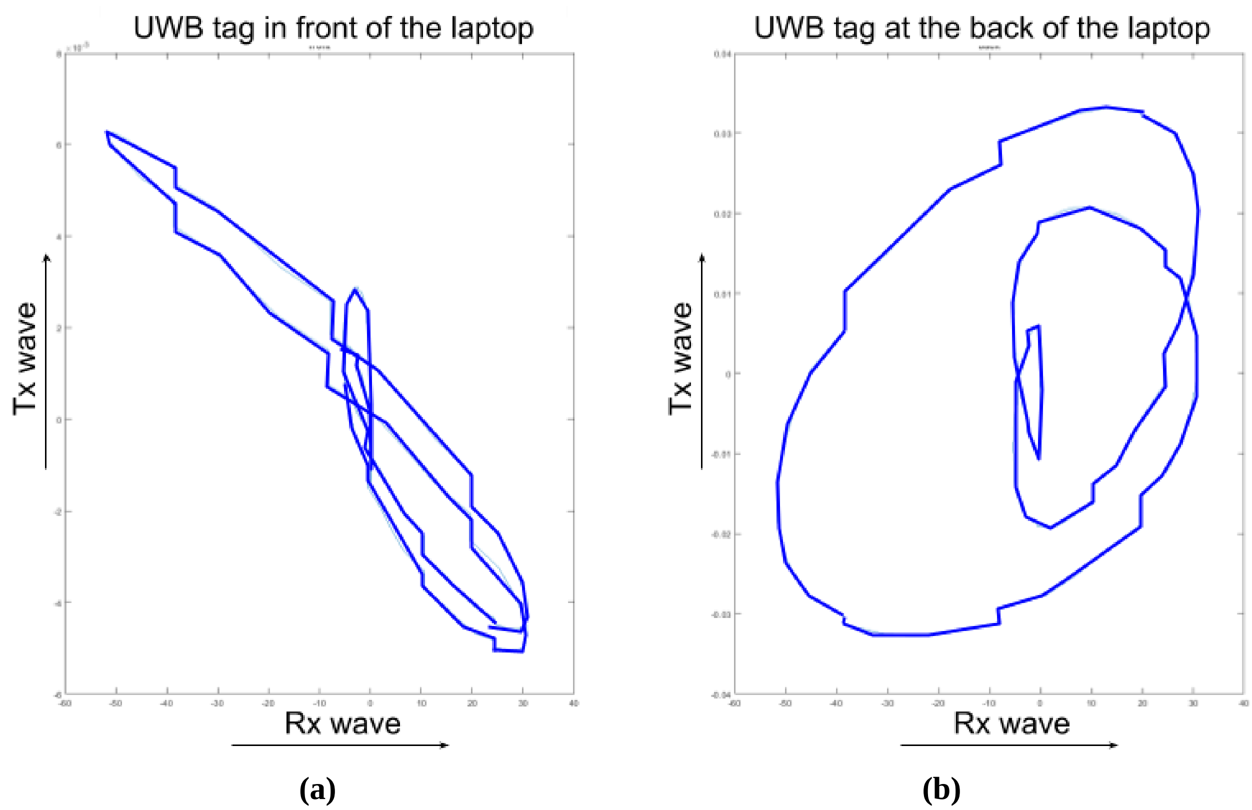

Fig. 5: Lissajous figures when the UWB tag is: (a) in front of the laptop; (b) behind the laptop

The aforementioned characteristics of front-origin and back-origin UWB waves are evident in their Lissajous figures, which are plots of the transmitted pulse against the received pulse after factoring out the time-of-flight delay (upon aligning the transmit and receive pulses). A Lissajous figure is obtained by de-parametrizing time - by obtaining an implicit mathematical relationship between the transmit and receive pulses.

Illustrated in Fig. 5(a), the Lissajous figure of the received pulse when the UWB tag is in front of the laptop is nearly a line at a slope of 135°, a characteristic of waves that are 180° out of phase. The Lissajous figure of the received pulse when the UWB tag is at the back of the laptop (Fig. 5b) is a spiral, e.g., a collapsing ellipse, a characteristic of waves that are 90° apart in phase and decaying in magnitude (extended ringing).

In this manner, the characteristics of the received pulses can be used to determine whether the UWB tag is in front of or behind the laptop, hence resolving front-back ambiguity with just two antennas.

Further to the descriptions above, a user may be provided with controls allowing the user to make an election as to both if and when systems, programs, or features described herein may enable the collection of user information (e.g., information about a user's devices, a user's preferences, or a user's current location), and if the user is sent content or communications from a server. In addition, certain data may be treated in one or more ways before it is stored or used so that personally identifiable information is removed. For example, a user's identity may be treated so that no personally identifiable information can be determined for the user, or a user's geographic location may be generalized where location information is obtained (such as to a city, ZIP code, or state level) so that a particular location of a user cannot be determined. Thus, the user may have control over what information is collected about the user, how that information is used, and what information is provided to the user.

CONCLUSION

This disclosure describes techniques that leverage secondary radiation caused by the metal case of a laptop (or other device) to accurately locate a UWB tag while utilizing just two antennas, simplifying hardware design and reducing cost.

REFERENCES

[1] Milad Heydariaan, Hossein Dabirian and Omprakash Gnawali. "AnguLoc: Concurrent angle of arrival estimation for indoor localization with UWB radios." In *2020 16th International Conference on Distributed Computing in Sensor Systems (DCOSS)*, pp. 112-119. IEEE, 2020.