

Why do Toyota Car Key Antennas Suck?



Motivation / Problem

I noticed my mom's newer Honda CRV could be unlocked from a lot farther away than my Toyota Camry. For my project I wanted to solve the problem of why my Toyota car key unlocks from a shorter distance, while other car keys seem to work from much farther away.

This project investigates whether the limited range could be caused by the antenna design inside the key fob and presents possible solution.

Background Information

Remote keyless entry systems allow a driver to lock, unlock, or open a vehicle without physically inserting a key into the door. The Toyota key fob works as a small RF transmitter, so when a button is pressed the key sends a coded radio frequency signal to a receiver inside the car. If the received code matches what the car expects, the car performs the requested action, such as unlocking the doors.

Antenna Details

Vehicle: 2022 Toyota Camry

Key type: smart key fob

FCC ID: HYQ14FBC

Operating frequency: 315 MHz

Antenna Length: ~6 cm

Antenna type: Small PCB trace antenna
inside the key fob



Ideal Antenna Calculations

Wavelength Calculation using Operating Frequency:

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^8 \text{ m/s}}{315 \times 10^6 \text{ Hz}} = 95.2 \text{ cm}$$

A common efficient antenna size is a quarter-wavelength antenna:

$$L = \frac{\lambda}{4} = \frac{95.2 \text{ cm}}{4} = 23.8 \text{ cm}$$

Antenna Comparative Analysis

How does our calculated antenna length differ from our actual car key antenna?

$$\frac{6 \text{ cm}}{23.8 \text{ cm}} = 0.252 = 25.2\%$$

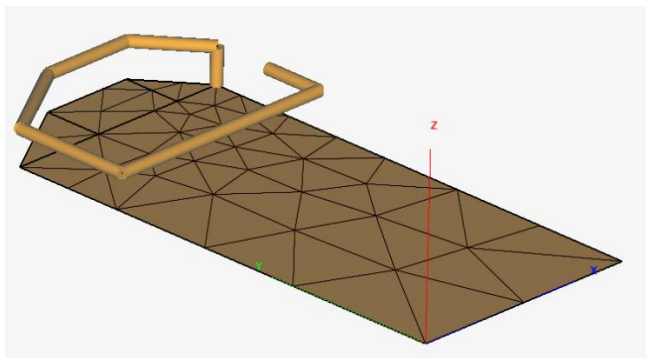
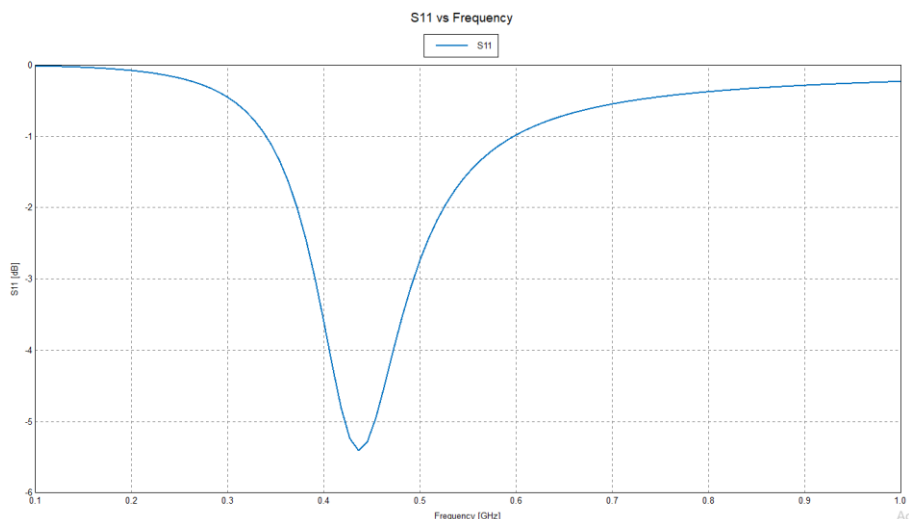
Why does this matter?

The actual Toyota car key antenna is only about 25% of the ideal quarter-wave antenna length. This means it is electrically short, which can reduce how much RF power is radiated toward the car.

- Lower radiation efficiency
- Harder to impedance match
- Smaller effective range
- More sensitive to the user's hand

These are some of the main problems that occur because our antenna is shorter than the ideal length.

Simulation of Original Key Fob



Observations from FEKO

From the plot we can see that the car key is detuned, and the resonance is closer to 415 MHz. Since the real car key operates at 315 MHz, the antenna has a smaller effective range to unlock the car.

Why does this matter?

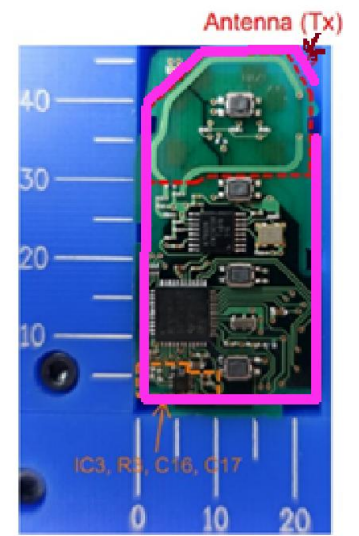
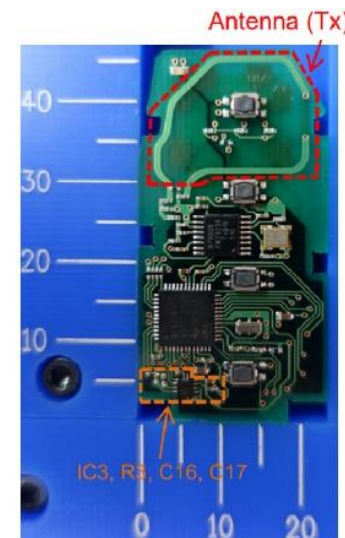
This supports the idea that the range of the key fob antenna is being bottlenecked by the length of the pcb antenna. Since the antenna is much smaller than an ideal quarter-wave antenna, the real design needs a matching network, PCB material, and nearby components to help tune it correctly. If the antenna is shifted away from 315 MHz, even by a moderate amount, the car may receive a weaker signal, causing the key to only work at shorter distances.

Range Issue Solution

Introducing Remote Start

Modern Toyota key fobs use push-button start, where the user no longer needs a physical key to start the car. This gives the key fob more usable internal space for the PCB, battery, and antenna layout.

For my solution, this extra space could be used to design a longer PCB antenna that wraps around more of the key fob instead of only using a short section near the top. Increasing the antenna's effective electrical length would help shift the resonance closer to 315 MHz, improve matching, and potentially increase the usable range.



4-Button type

4-Button type

New Antenna Comparative Analysis

How does our calculated antenna length differ from our actual car key antenna?

$$L_{\text{Solution}} = 12 \text{ cm}$$

$$L_{\text{Ideal}} = 23.8 \text{ cm}$$

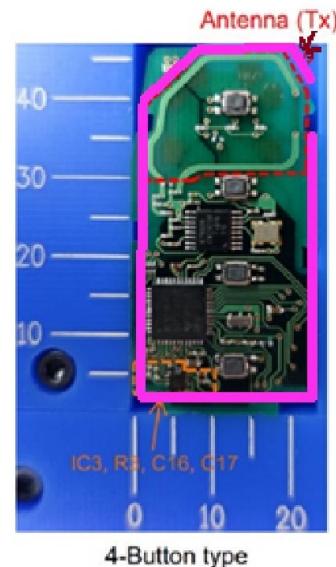
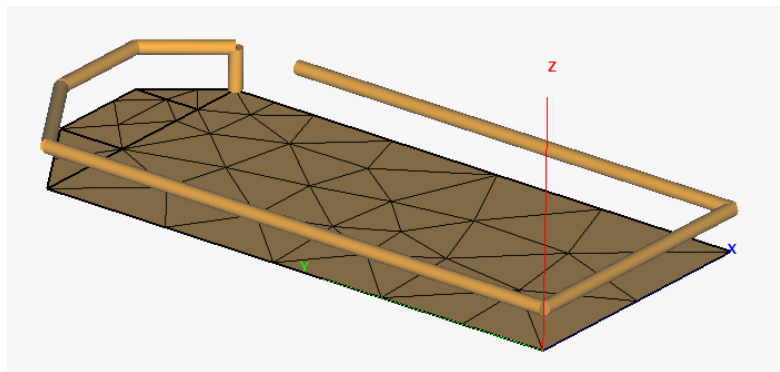
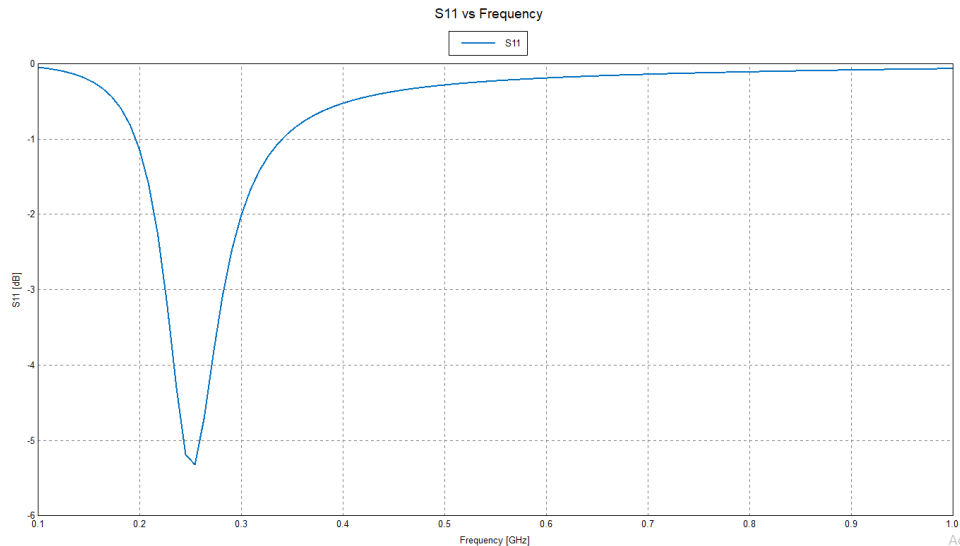
$$\frac{12 \text{ cm}}{23.8 \text{ cm}} = 0.504 = 50.4\%$$

Why is this a reasonable solution?

Doubling the antenna length from 6 cm to 12 cm makes the antenna closer to the ideal quarter wavelength at 315 MHz. A longer antenna has a greater effective electrical length, which can help shift the resonance closer to the operating frequency, improve impedance matching, and allow more RF power to be radiated toward the car instead of being reflected back into the circuit.

It's important to note that the goal is not to make the key work from extremely far away. For security and practicality, the key should only work within a reasonable distance. A target range of around 60 feet would be a good improvement over the current range, while still preventing the car from being unlocked from too far away.

Simulation of New Key Fob



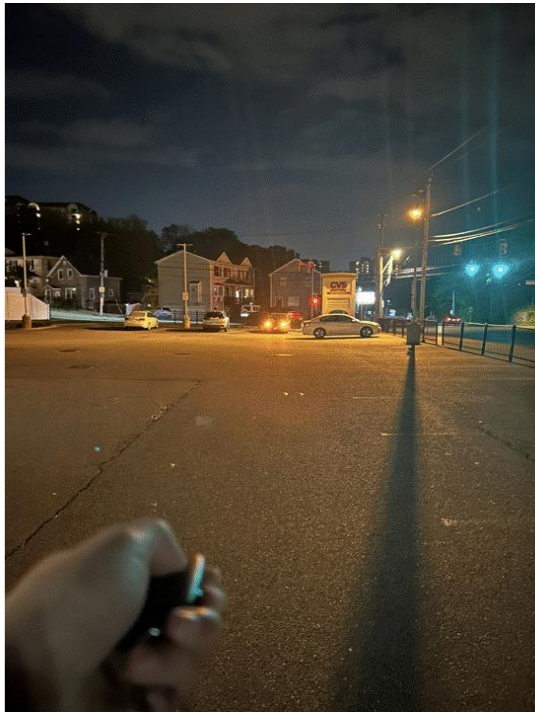
Observations from FEKO

From the plot, the new key fob antenna has a resonance around 250 MHz. This is lower than the Toyota key's actual operating frequency of 315 MHz, meaning the antenna is now slightly over tuned. Compared to the previous design, the resonance shifted closer to the target frequency, showing that increasing the antenna length helped move the antenna response in the right direction.

Why does this matter?

The simulation shows that antenna length has a major effect on resonance. By increasing the antenna length from 6 cm to 12 cm, the antenna became electrically longer and resonated at a lower frequency. Even though this version is not perfectly centered at 315 MHz, it supports the main solution that using more space inside a keyless fob for a longer meandered antenna can improve tuning and potentially increase range.

Demo of Key vs Keyless antenna



Test Direction	With Key	Keyless	Difference
Front of car	35 Feet	+80 Feet	At least 45 Feet
Back of car	35 Feet	+80 Feet	At least 45 Feet
Side of car	30 Feet	+80 Feet	At least 50 Feet

Final Conclusions

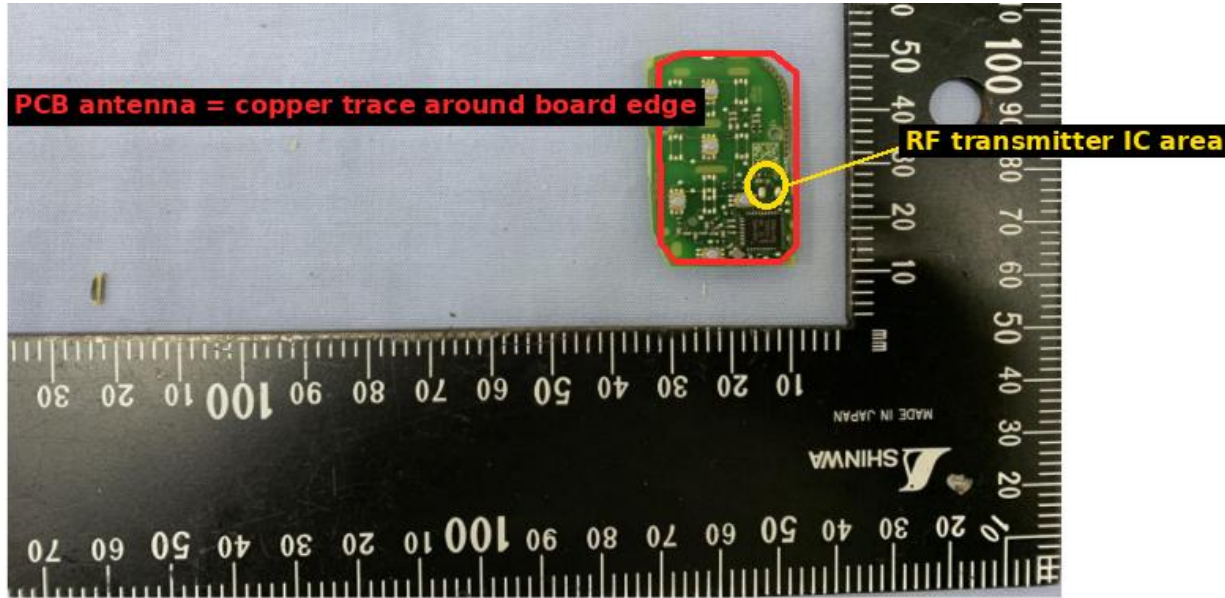
The Toyota key fob's short range is likely caused by its antenna being much smaller than the ideal size for 315 MHz. An ideal quarter-wave antenna would be about 23.8 cm, but the actual PCB antenna is only around 6 cm, making it electrically short.

Because of this, the antenna can have lower efficiency, worse matching, and be more affected by the user's hand, battery, and nearby metal. The FEKO simulations showed that increasing antenna length can shift the resonance closer to the target frequency. A practical solution is to use the extra space in a push-button-start key fob for a longer meandered PCB antenna, improving range while keeping it reasonable for security.

Sources Used

- [1] J. A. Bickford, A. E. Duwel, M. S. Weinberg, R. S. McNabb, D. K. Freeman, and P. A. Ward, “Performance of electrically small conventional and mechanical antennas,” *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 4, pp. 2209–2223, Apr. 2019, doi: 10.1109/TAP.2019.2893329.
- [2] B. Josephson, “The quarter-wave dipole,” *WESCON/57 Conference Record*, San Francisco, CA, USA, 1957, pp. 77-90, doi: 10.1109/WESCON.1957.1148706. keywords: {Dipole antennas;Antenna theory;Impedance;Broadband antennas;Coaxial components;Aircraft;Antenna feeds;Receiving antennas;UHF antennas;TV},
- [3] Locksmith Keyless, “2022 Toyota Camry Smart Key Fob 4B FCC# HYQ14FLA,” *Locksmith Keyless*. [Online]. Available: <https://www.locksmithkeyless.com/products/2022-toyota-camry-smart-key-fob-4b-fcc-hyq14fla>. [Accessed: May 17, 2026].
- [4] DENSO Corporation, “Electronic Key FCC ID: HYQ14FLA, IC Number: 1551A-14FLA, Internal Photos,” *FCC Internal Photos*, pp. 1–2.
- [5] Wikipedia contributors, “Toyota Camry,” *Wikipedia, The Free Encyclopedia*. [Online]. Available: https://en.wikipedia.org/wiki/Toyota_Camry. [Accessed: May 17, 2026].
- [6] N. M. Tripathi, “Miniaturized meander PCB antenna for 433MHz,” in *Proc. 2015 IEEE Applied Electromagnetics Conference (AEMC)*, Guwahati, India, Dec. 2015, pp. 1–2, doi: 10.1109/AEMC.2015.7509184.
- [7] Z. N. Low, J. H. Cheong, and C. L. Law, “Low-cost PCB antenna for UWB applications,” *IEEE Antennas and Wireless Propagation Letters*, vol. 4, pp. 237–239, 2005, doi: 10.1109/LAWP.2005.852577.

Additional Slides



I had a really hard time finding the PCB antenna for my mom's 2026 Honda HRV. Maybe because it was so new, I have no clue honestly. To the left is the Honda HRV 2021 PCB antenna for the remote start key. It looks like the loop antenna goes all the way around, supporting my idea of increasing the antenna length.

Where I found the photo:

[8] Continental Automotive GmbH, "Internal Photos — FCC ID KR5TP-4," FCC ID.io. Accessed: May 20, 2026. [Online]. Available: <https://fccid.io/KR5TP-4/Internal-Photos/Internal-Photos-4769160>

