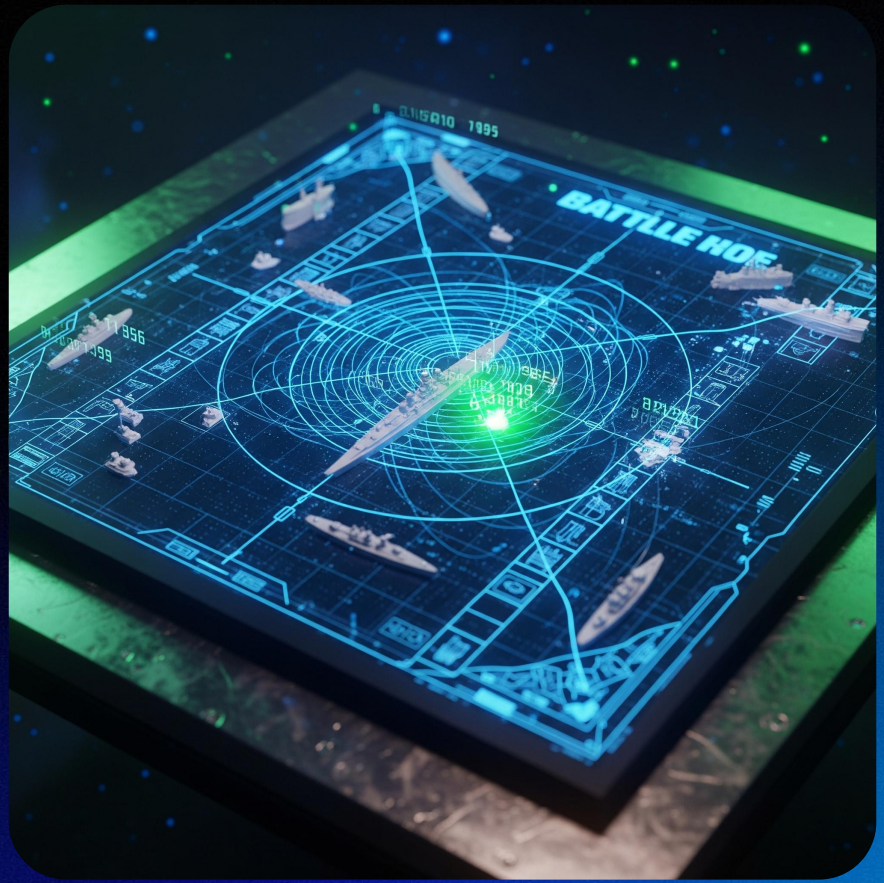
Quantum Radar: Concept & Problem

- In classical Battleship, you must probe every single square until you find all ships. This is inefficient. A "miss" gives you some information, but a "hit" is the only way to find a ship.
- We use a quantum circuit to perform an "interaction-free" measurement on an entire row or column at once.
- Our "Quantum Guess": Instead of asking, "Is there a ship at (1, 2)?", we ask, "Is there any ship in Row 1?"
- The Goal: Maximize our E.V. (Elitzur-Vaidman) Score, which we define as finding all ships with the fewest number of classical "HITs".



Quantum Circuit

Our "Quantum Radar" circuit is based on the same principle as Grover's search algorithm, which is a powerful tool for detecting a "marked" item in a list.

H-Gates (Superposition):

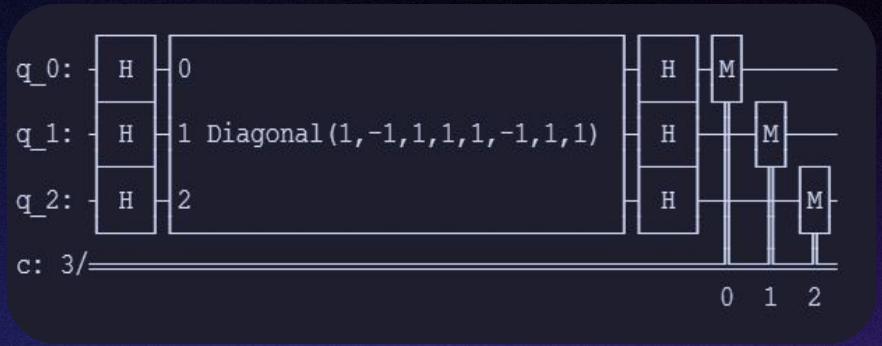
We use Hadamard (H) gates on n qubits (where 2^n > row length) to create a uniform superposition of all 2^n possible squares in that line. Our "quantum light" is now checking all paths simultaneously.

The Oracle (The "Bomb"):

This is a custom Diagonal gate. It "marks" any state corresponding to a ship's location by flipping its phase (multiplying it by -1). This is our "interaction." Crucially, it doesn't measure or collapse the state, it just "tags" it.

H-Gates (Interference):

We apply H gates again. This causes all the quantum states to interfere. If no ship was present: The Oracle did nothing. The second H gates perfectly reverse the first H gates (H CDOT H = I). The state returns to |00...0>. If a ship was present: The phase-flipped state(s) now interfere destructively with the others. The final state will not be |00...0>.



The Three Outcomes:

- **Measure |00..> "MISS":** Constructive interference succeeded. We are 100% certain no ship is in that line.
- **Measure anything else "DETECT":** Destructive interference occurred. We are 100% certain a ship is present, but we don't know which square it's in. This is the "interaction-free" detection!
- **"HIT":** This is not an outcome of our quantum circuit. A "HIT" is a classical action we take after the quantum scan, which counts against our E.V. Score.

Game Strategy & E.V. Score

Quantum Scanning (No "Hits")

- We run our quantum_scan_line circuit on all rows.
- Any row that returns "MISS" is marked as 'O' (safe).
- We then run our quantum_scan_line circuit on all columns.
- Any column that returns "MISS" is marked as 'O' (safe).

Classical Pinpointing (The "Hits")

- After Phase 1, our board is narrowed down. We identify a small list of candidate squares.
- A square (r, c) is a candidate only if Row r returned "DETECT" and Column c returned "DETECT".
- We now loop through only this small candidate list and perform a classical probe (a "HIT").
- Each probe increments our Total Hits then we use Total Hits / Total points = E.V. Score..

Result

As the demo shows, for a 8x8 board, we can find all ships with just a few hits (e.g., 16) instead of the 64 (worst-case) or ~32 (average) classical probes. We successfully used quantum interference to find ships without "touching" them.