Omnidirectional Direction Finding Antenna System

Amplitude-Based DoA Estimation for RF Signals from 800 MHz to 6 GHz

Graduate

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Objective: Direction-finding systems are essential tools in aviation, maritime navigation, interference hunting, and defense. This project was initiated in the context of radio frequency measurement technology, where there is interest in compact systems capable of estimating the direction of arrival (DoA) of signals from all directions. The goal is to enable autonomous, long-term monitoring of radio transmissions. To ensure modularity and field compatibility, the system is designed to work with a portable, single-channel spectrum analyzer. The covered frequency range from 0.8 to 6 GHz includes commonly used bands such as cellular, WiFi, and Bluetooth.

Approach: The system employs antipodal Vivaldi antennas, as shown in Fig. 2, to cover the broad frequency range. Corrugations enhance directivity at lower frequencies, while a director improves the beam shape at higher frequencies, maximizing performance at relatively low cost. Eight antennas are arranged in a circular array to provide direction-dependent signal amplitudes. These are sequentially connected to a spectrum analyzer via the RF front end (Fig. 1), which uses high-speed switches to cycle through the antennas in quick succession. This also enables more advanced methods, such as phase-based direction finding using time-modulated arrays.
The developed direction-finding software runs on a standard laptop, connected to the front end via USB Type-C. This connection is used to transfer data as well as power. The program estimates the direction of arrival of incoming signals using an amplitude-comparison-based algorithm and visualizes the result.

Result: Simulations show that the system can estimate the direction of arrival of signals at the calibrated frequencies (0.8, 1.6, 2.4, 3.6, 5.2, and 6.0 GHz) with a root mean square error (RMSE) below 20°. At 2.4 GHz, an RMSE of 5° is achieved. These results were confirmed by field measurements. Under ideal conditions, the system is expected to locate a class 2 Bluetooth device transmitting 2.5 mW at a distance of 100 to 200 m with an RMSE below 5°.

Figure 1: The RF front end PCB used to sequentially switch the antenna signals through to the spectrum analyzer.
Own presentment

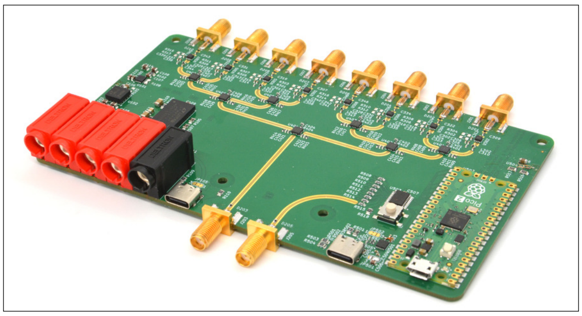


Figure 2: A single antipodal Vivaldi antenna inside the anechoic chamber used to confirm the simulated antenna pattern.
Own presentment

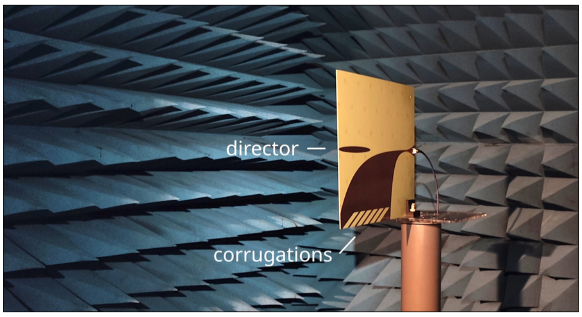
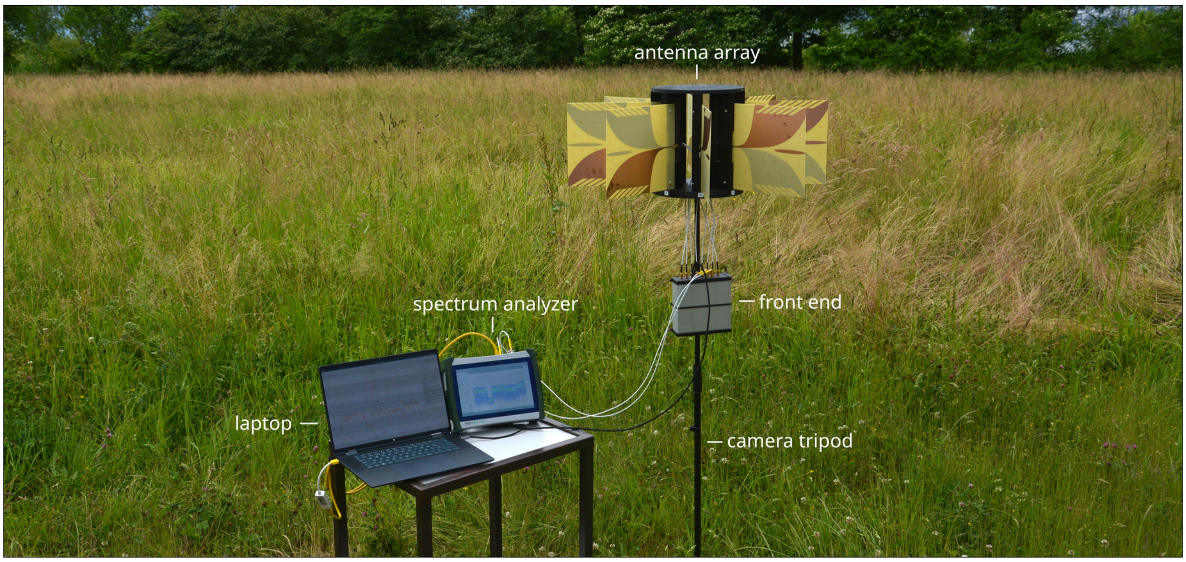


Figure 3: The complete omnidirectional direction-finding system in action.
Own presentment



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Subject Area
Wireless Communications

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