Embedded Planar Printed Smart Antenna Array for UAVs

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Introduction

The goal of this project is to outfit an unmanned aerial vehicle (UAV) with a smart antenna array that is embedded within its wings. A smart antenna can modify its radio frequency (RF) ration patter to increase range and bandwidth or to tune-out sources of interference, unlike a conventional antenna setup. The smart antenna is in the form of a planar printed antenna consisting of 12 individually controllable antenna elements. A feed circuit for the smart antenna takes the RF signal and shifts the phase angles of the signal for each of the 12 elements to create the desired RF radiation pattern. An embedded controller was developed for the smart antenna to calculate the position and orientation of the plane relative to base station. An R/C airplane based prototype of the complete system was developed which contains the smart antenna, a feed circuit and an embedded processor to control the smart antenna setup.

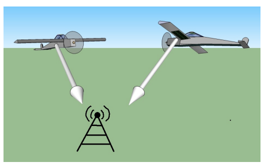

Figure 1: Visual Representation

Figure 2: Smart Antenna Array

Design

The embedded controller is designed to calculate the correct phase angles for each of the smart antenna's elements. The controller calculates a vector from the plane to the base station, using the position and orientation data obtained from its sensors. The phase angles are calculated from that vector and sent to the smart antenna's feed circuit as an 48-bits data frame.

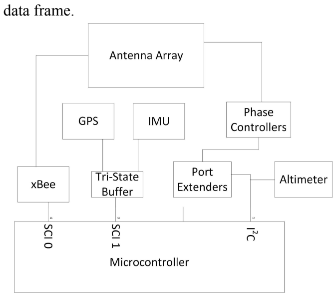

Figure 3: Hardware Block Diagram

An HCS-12 microcontroller is selected for the embedded controller's processor. A GPS and altimeter are used to obtain the UAV's position while an inertial measurement unit sensor is used to obtain the orientation of the UAV. Three 16-bit port expanders are used to communicate with phase shifters in the smart antenna's feed circuit. An Xbee Wireless Transceiver is used to generate the RF signal for the smart antenna.

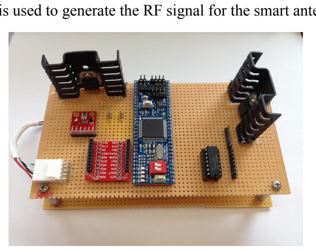

Figure 4: Picture of the Assembled Embedded Controller

A tri-state buffer is used to switch between the GPS and the IMU data streams on the SCI-1 port of the HCS-12. The altimeter is internally compensated for pressure and temperature conditions to provide an accurate altitude measurement. The altimeter and the port expander share an I2C port hosted by HCS-12.

Algorithm

Two coordinate systems are defined for the purpose of this project: one fixed coordinate system with an axis centered at the base station, and one moving coordinate system with an axis centered on the airplane. The vector from the plane to the base station is calculated in the fixed axis and transformed into the moving axis using a rotational transformation matrix. This method of determining the plane's orientation has low error and is quickly completed on the embedded controller.

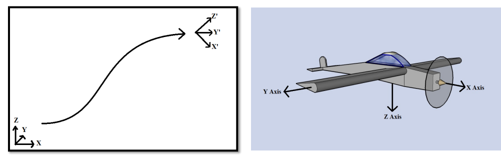

Figure 5: Conceptual Diagrams

Software

The software on the embedded controller is designed to update the smart antenna's feed circuit four times every second. The embedded controller continuously obtains data serially from the IMU and GPS via interrupts. Using this data and the data from the altimeter, the embedded controller calculates the vector between the plane and the ground station. From that vector, the phase angles for the 12 different antenna elements is calculated and the phase angles are outputted through 48-bits in parallel to the phase shifters connected to the antenna's elements.

Results

The algorithm is programmed in Matlab and testing showed that the algorithm is functioning properly. The embedded controller is assembled and bench tested with the smart antenna array. Testing of the system consisted of walking the system around a fixed base station and capturing data points comprising of the sensor values and the resulting vector. The captured sensor data was plotted and analyzed visually. This test showed promising results.

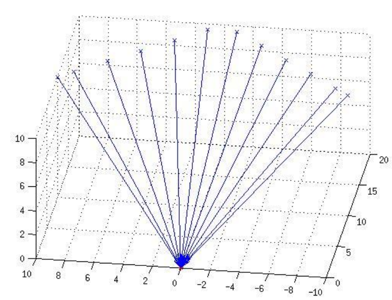

Figure 6: Simulated Data

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