Radar renewal: Phased array technology could improve reliability, capabilities of air traffic control system

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GTRI researcher Tracy Wallace is helping the Federal Aviation Administration weigh the feasibility of replacing current U.S. air traffic control systems with more efficient and reliable multifunction phased-array radar (MPAR). Credit: Gary Meek

(Phys.org) -- Aircraft operating in U.S. airspace rely on several different types of ground-based radars to help them fly safely. Yet these radars, based on older technologies that use many mechanical components, require frequent repairs as well as costly periodic maintenance programs.

A research team from the Georgia Tech Research Institute (GTRI) is working with the Federal Aviation Administration (FAA) and National Oceanic and Atmospheric Administration (NOAA) to investigate alternative approaches to the radars that currently support the nation's air traffic control and weather monitoring systems. The multi-year study is examining the feasibility of replacing that group of radars with a single system based on phased-array technology, an advanced design that uses solid-state electronics in place of many mechanical components.

As part of the NextGen Surveillance and Weather Radar capability program, one of the alternative approaches specifically being considered by the FAA is called multifunction phased-array radar (MPAR). MPAR has the capability to surpass current technologies in both reliability and ease of maintenance, said Tracy Wallace, a researcher who is leading GTRI's participation in the study.

A single MPAR installation at an airport could potentially replace all the conventional radars typically found in several locations around major airports today. Moreover, MPAR technology could enhance the capabilities of the nation's air traffic control and weather monitoring systems.

"The central question is whether converting to a phased-array system would be practical from a cost perspective," Wallace said. "Currently we're advising the government on the feasibility – including the expenditure, technical and scheduling issues – of developing an MPAR program. We're also preparing to support the investigation with modeling studies of prospective MPAR designs."

The FAA utilizes multiple surveillance platforms to maintain control of air traffic within the National Airspace System. There are several different radars in service to support the related tasks of tracking aircraft and monitoring weather conditions, including:

- Airport surveillance radar (ASR), which are moderate-range systems used to follow aircraft within 60 nautical miles of an

airport;
- Air route surveillance radar (ARSR), which are long-range systems used to track aircraft as they fly between airports and as they approach U.S. borders;
- Terminal Doppler weather radar (TDWR), used near airports primarily to monitor wind-shear conditions.

Also important to air traffic control are NEXRAD radars, which are maintained and operated by NOAA, in conjunction with the National Weather Service (NWS). These long-range, pulse Doppler radars supply valuable weather information. They are used to monitor weather conditions faced by aircraft, and they are often seen on media reports, particularly during severe weather events such as tornadoes.

“It is conceivable,” said Wallace, “that a single MPAR radar could encompass the functionality of both the FAA radars and the NEXRAD radars, which would further the cost advantages of the newer technology.”

Solid-State Advantages

Conventional air traffic and weather monitoring radars utilize a traditional rotating dish antenna, which mechanically changes the direction of its signal beams. The antenna moves physically among set positions, transmitting and receiving radar signals at each position.

Because rotating antennas can only update tracking information once per revolution, they offer slower and less-effective performance than phased-array technology. They’re also prone to mechanical problems that can result in sudden and complete failure to function.

By contrast, phased-array radars are fully solid state; they don’t rotate and have no mechanical moving parts. Instead, they typically employ a grid made up of hundreds or thousands of fixed antenna elements, each of which transmits and receives a signal beam.

Using a technique called phase-shifting, each element can steer its signal beam electronically, enabling it to move continuously from one position to the next. At the same time, the array design lets the elements work together. The result is an aggregation of radar beams – each individually computer guided – able to scan large areas and track acquired targets without interruption.

The phased-array design also offers built-in redundancy – it continues to operate even if some individual antenna elements fail. The consequence of individual element failures is usually only a slight degradation of sensitivity, and non-working elements can typically be replaced with limited downtime.

Increased Capability

Another important MPAR advantage involves its ability to steer multiple signal beams to an area of special interest, such as a weather cell, a potential wind shear condition, or a specific aircraft target of interest. That capability can result in a major increase in the volume of data available about a specific target or volume of space in which severe weather might be forming.

“Unlike today’s technology, an MPAR installation would have the capability to track aircraft while simultaneously offering greatly improved weather sensing,” Wallace said. “The hope in the weather community is that it will offer much faster forecasts of extreme weather conditions such as tornadoes, because users could devote more signal-beam energy to a particular weather spot and measure changes over time at a faster update rate.”

GTRI, which began this MPAR feasibility work in 2009, is collaborating on the study with the Lincoln Laboratory of the Massachusetts Institute of Technology, as well as a number of other contractors and government organizations. A final FAA decision on whether to develop and deploy MPAR technology will likely not be made until 2017 or later.

Because that final decision will hinge on affordability, costs must be greatly reduced compared to current phased-array systems such as those used by the military, Wallace said. Such cost reductions will require both novel approaches to MPAR design and more-efficient manufacturing techniques.

“So far, cost estimates for converting to MPAR technology look promising,” Wallace said. “But we will have to be certain that the savings from lower repair and maintenance costs and decreased downtime will outweigh the initial replacement investment.”

The large volume of data produced by an MPAR system means that computing-related tasks such as signal processing are certain to increase greatly, he added. The GTRI team is investigating these high-performance processing requirements, along with software that can analyze data from many incoming signal beams and determine where to steer each beam next.

Antenna cost and effectiveness are likely to be key considerations, Wallace said, and industry is expected to offer numerous antenna designs aimed at providing an optimal solution. It’s likely that competing MPAR antenna designs will have to be compared, in a common simulation environment, as part of the feasibility study.

“We anticipate using our internally developed GTRI antenna-modeling tools to make apples-to-apples comparisons among a number of designs,” Wallace said. “That kind of data will help shed light on a critical question — whether future MPAR systems can be both affordable and effective."

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