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Advanced RF Sensors

In the wake of the Cold War, the threat we face has changed dramatically! It has shifted from one of large, predictable threats from known opponents to one of dynamic, rapidly evolving, and emerging threats from previously unknown opponents.

The expensive, technically complex ICBMs have given way to small, unmanned aircraft and inexpensive jammers made from microwave oven parts. Large numbers of simple targets pose enormous challenges to sensor systems designed for small numbers of predictable targets. The sensor systems of the future will need to be easily transportable systems that can be rapidly positioned where they are needed. They must be flexible enough to adapt to a changing environment and inexpensive enough to destroy large numbers of targets at minimal cost.

The Special Project Office's (SPO) RF sensors programs are addressing specific aspects of these emerging threats. There is a threat from proliferated low-cost cruise missiles, remote-piloted vehicles, and small aircraft. I'll show you how our Low-Cost Cruise Missile Defense Program is developing low-cost seekers to respond to attacks by a large number of these threats.

Electronic countermeasures (ECM) also pose a considerable threat to our sensor and communications systems. I'll discuss how our RECAP Program is working on reconfigurable antennas that will be able to rapidly change the frequency and polarization to minimize suppression by ECM.

The dynamics of the Cold War contributed to a geographic view of military threats. That assessment has changed radically. It has given way to a volatile and unpredictable array of hot spots around the world.

We need to field ever more capable radar systems when and where they're needed.   This requires RF sensors that are dramatically more flexible, transportable, and capable than current generation ones.

Under the Lightfoot Program, the SPO is developing concepts for affordable, transportable radar systems with a significantly greater power-aperture product that extends the detection range for low cross-section threats.

The KASSPER Program is working on new signal processing architecture that uses vast amounts of environmental information to reduce the clutter while improving target detection in complex environments.

These programs are made possible through advanced enabling technologies such as RF micro-electromechanical, or MEMS, switches, single-chip transmit/receive (T/R) modules, and ultra-light weight structures that support our crucial goals of low-cost, flexibility, and transportability.

The Low-Cost Cruise Missile Defense (LCCMD) Program is developing a Ka-band electronically scanned seeker that will aid development of low-cost interceptors. These weapons will be used to counter attacks by large numbers of unsophisticated cruise missiles, light aircraft, or remotely piloted vehicles.

Without LCCMD, we would be forced to counter these threats with expensive missiles designed for much more sophisticated threats. Developing a low-cost seeker is crucial to the goal of producing low-cost interceptors. DARPA has set a $40,000 goal for the seeker and an overall $100,000 limit to produce an interceptor.

The onboard seeker, a Ka-band radar using an electronically steered array (ESA) antenna, will acquire and home in on the target. DARPA awarded a contract in the second quarter of FY02 to build an ESA-based seeker using MEMS phase shifters. A complete form-factored seeker will be ready for testing in the last quarter of FY04.

However, we recognize other emerging technologies might increase performance and reduce cost even further. Therefore, DARPA has issued a Broad Agency Announcement to encourage additional innovation in developing a low cost Ka-band radar seeker.

Let me explain the MEMS technology being used in the seeker and other sensor programs. MEMS are tiny mechanical devices, as small as several microns, that can be built using integrated circuit fabrication techniques. They currently are used in applications such as accelerometers for automobile air bags and micromirror positioners for large-screen TVs.

We are working to develop radio-frequency MEMS components for LCCMD and other sensor programs. The MEMS device of interest for RF applications is a basic on/off switch. The switch is inherently small, lightweight, and easily manufactured in large quantities. Those advantages combined with low power consumption, low loss, linear operation, and high bandwidth make MEMS a natural for SPO sensor applications.

However, the MEMS lifetimes are currently too low for many nonseeker sensor applications. Also, the power handling capability is small, and the cost of packaged devices makes them too expensive for inclusion in large arrays.

The RF MEMS Improvement Program (RMIP) is addressing these shortcomings by requiring contractors to improve the RF characteristics, lifetimes, manufacturability, and affordability of their RF MEMS devices. We intend to increase operational lifetimes from the current few hundreds of millions of cycles to 100 billion cycles, increase power-handling capability from milliwatts to watts, and reduce the cost of packaged devices from many tens of dollars to less than $5 by the time RMIP finishes in the fourth quarter of FY05.

The Reconfigurable Aperture (RECAP) Program is developing antenna aperture technologies that dramatically increase antenna bandwidth capabilities. This allows us to develop wideband and multiband radars and communication systems that operate through a single aperture. This enables these systems to adapt to dynamic and emerging ECM threats or to be used for different functions at different times.

While the original goal of the RECAP Program was to obtain ultra-wide bandwidth through reconfiguration of a series of contiguous narrow bands, two RECAP designs have achieved scanning phased array apertures with greater than 7:1 instantaneous bandwidth without requiring any reconfiguration. These ultra-wide instantaneous bandwidth apertures are of extreme interest to the ELINT/SIGINT collectors who need to monitor a wide range of frequencies at the same time. RECAP technologies are currently being applied to the Future Combat Systems (FCS) Program. Several RECAP designs are being integrated into the FCS communications system that provide links all deployed pieces of hardware.

The FCS integrators are interested in both RECAP antenna designs and in the reconfigurable high-impedance ground planes developed by the program. Such surfaces have been designed to enable extremely thin—less than 1/50th of a wavelength—UHF antennas that achieve frequency agility by varying a control signal on the high-impedance ground plane rather than varying the antenna itself.

Future military conflicts will require highly transportable RF sensors. The Lightfoot Program is developing technologies to produce very large, stowable, lightweight, low-power phased-array radars. These large aperture antennas will satisfy radar power-aperture requirements with very low radiated power. This means less cooling, less prime power, less fuel, and less weight. Lightfoot radars will be easily transported and moved by small crews to keep abreast of changing battle conditions. In addition to Lightfoot's ground-based applications, the technology can be used on high altitude airships platforms for homeland defense or mobile air defense. The Lightfoot Program plans to issue a BAA early in FY03.

DARPA is interested in innovative beamformers architecture for large lightweight arrays. We are interested in RF, optical, digital beamformers, as well as hybrid approaches. We also are interested in using the low-cost commercial technology base for T/R components.

We are asking high-volume MMIC foundries to design low power T/R chips, which include the phase shifter and control circuits, based on the same devices, design rules, and production processes used for commercial markets. Cost per chip is critical since Lightfoot antennas may have 100,000 T/R chips or more. Our goal is less than $10 per chip.

Lightfoot antennas must be very large since they radiate much lower transmit power than those using conventional military T/R modules. This is forcing the development of new lightweight methods to bring DC power, RF signals, and control signals to every T/R chip. The antenna structure requires significant development to create a design that is lightweight, large and stable when deployed, yet stowable into a small volume for transport. This effort is building on technology developed for space-based phased-array antennas, with additional requirements for repeated stowing and an inflatable radome for environmental protection.

The Knowledge Aided Sensor Signal Processing Expert Reasoning (KASSPER) Program uses advances in physical and electromagnetic knowledge and continuous improvements in embedded computing to dramatically improve our view of the battlefield. In the early days of radar, signal processing was implemented through analog circuits, which forced a fairly simple statistical characterization of the world.

Early radar developers realized they could not accurately model either the environment or their own systems well enough to predict the exact clutter response from each resolution cell. To correct this, they created a sliding window average of the clutter response to give an estimate of the clutter in the resolution cell.

Unfortunately, the real world seldom behaves like the stationary, homogeneous statistical clutter we use in this process.

Large discretes such as power lines, water towers, and buildings are common in the hot-spot urban areas of future conflicts. But we already know where the towers, roads, and buildings are located. KASSPER takes advantage of this information.

The KASSPER Program allows signal processors to replace statistics with site-specific information available from databases, dynamic maps updated by SAR and previous sensor passes, and with consideration of the physics underlying radar returns.

In April, DARPA began a series of annual KASSPER workshops jointly sponsored with the Air Force Research Laboratory (AFRL). These workshops provide both classified and unclassified forums for discussions on using prior knowledge of complex clutter, development of intelligent signal processing algorithms, and real-time processing architectures.

These SPO RF sensor programs are contributing to a flexible, agile, and affordable RF sensor capability that will greatly increase our ability to respond to the emerging threats of the 21st century. These technological advances are not limited to SPO sensor programs, but also are being considered for use in a variety of current and future applications.

Our new programs—the LCCMD seeker, Lightfoot transportable radar, reconfigurable apertures, and KASSPER—will greatly increase the capability and affordability of our future sensor systems.

I encourage you to send me your creative ideas in these or other RF sensor areas.

Thank you.