**Objective:** Develop a digital, C-Band Transmit (Tx) and Receive (Rx) array antenna that transmits and receives multiple spatially and spectrally diverse narrowband signals.

**Description:** Expanded mission areas and the implementation of additional data routing resulting from future warfighting capabilities place more demand on data distribution services in the form of higher data bandwidths and reduced latencies. These demands require improvements in Radio Frequency (RF) spectrum utilization and advances in antenna technologies. Digital array antenna technology promises to enable these improvements by dramatically increasing operational flexibility. Digital arrays are not off the shelf available; but rather, industry contractors develop digital arrays in response to acquisition efforts. The commercial development of multi-beam 5G networks will focus on small picocells. Lower power levels and reduced linearity challenge leave a significant gap preventing commercial technology from being useful in Navy applications. Defense Advanced Research Projects Agency (DARPA) efforts have made digital arrays a more off the shelf technology. Notable among these is the Arrays at Commercial Time Scales (ACT) and Millimeter-wave Digital Arrays (MIDAS) program. These programs focus on the transceiver and beamforming functionality of the array as opposed to the aperture. However, this technology is still not off the shelf and integration work would be required to meet the digital array needs even using this technology. The Navy must overcome some technology risks with a critical one being the development of digital array technology that can operate at the necessary bandwidths and frequencies while in complex RF environments.

The Navy seeks to expand and refine the battlespace by improving and expanding tactical network functionality. Increased data throughput is needed to enable the flow of more data and support of new mission areas. Decreased latency is needed to enable new and compressed kill chains against advancing threats as well as larger networks. Increased network throughput and decreased latency will be attained by developing 4-channel Transmit (Tx) and Receive (Rx) capability for digital communications arrays. The level of improvement in the fielded system will depend on the topology, size, and operation of the network. For large, half-duplex (i.e., cannot transmit and receive simultaneously) networks of four-beam nodes having all nodes connected along a line, the level of throughput improvement will approach a factor of 2. For large, half-duplex networks of four-beam nodes having topologies where all the nodes are connected to each other, the throughput improvement will approach a factor of 4. For other networks, the improvement will be somewhere in between. Of course, the fielded system may have a different number of beams per node. Four was chosen based on engineering judgement as a compromise between complexity, technical challenge, and capability improvement.

The Navy needs a digital communications array to realize simultaneous, multichannel Tx and Rx capability. The digital communications array is a key enabler for higher data throughputs and reduced latency needed to engage evolving threats and enabling significant improvement in utilization of spectrum. This must be done while pushing the boundaries of signal integrity, dynamic range, isolation of signals and resistance to interference to maximize link performance. No technology currently meets all these requirements.
An innovative digital antenna subarray architecture is sought to attain the previously stated requirements. More specific antenna system goals include a 1 x 4 linear configuration and element level signal generation and digitization. Beam steering in azimuth should be ±60º. The subarray should transmit and receive 4 simultaneous beams in half duplex mode. The operational bandwidth is C-band (4 GHz to 8 GHz). Compared to the operational bandwidth, the instantaneous bandwidth is relatively narrow. The element level Equivalent Isotropic Radiated Power (EIRP) should be 0 dBW over the scan volume. The output Error Vector Magnitude (EVM) should be less than 3%. The antenna should be able to receive an incident signal with incident power density measured at the free-space-to-antenna interface ranging from -134 dBWm² to -53 dBWm² and output a digital signal with 20 dB signal to interference plus noise ratio. The goal for the spur free dynamic range is 80 dB. 32 dBm is the goal for the input third order intercept. The polarization should be selectable, with four options. These options should be horizontal, vertical, right hand circular and left hand circular. The polarization loss factor should be less than 0.25 dB. The antenna will be capable of null steering with a null depth goal of 80 dB relative to the mainlobe.

The subarray must be capable of processing 4 narrowband signals located arbitrarily within a contiguous operational bandwidth within C-band. The design should permit any two 1 x 4 subarrays to be connected in any configuration and beam-steered. A two-dimensional array must be capable of having its beam steered in both dimensions. The design should permit connecting 1 x 4 or 4 x 1 subarrays into a contiguous rectangular array of arbitrary size. For example, three 1 x 4 subarrays must be able to be configured to form a 1 x 12 and then reconfigured to form a 3 x 4; without re-flashing firmware. Moreover, both configurations must demonstrate vertical, horizontal, right-hand circular, and left-hand circular polarizations while attaining 0.25 dB of polarization loss factor for each of these four polarizations. The design should include built-in testing to indicate failures that occur. The interface to the digital array on the transceiver side will use a standard format to send digits of data, such as Ethernet. Beam steering commands sent to the array will contain azimuth and elevation angles relative to the array face, frequency and Tx or Rx identification. The antenna system will transmit and receive continuous phase frequency shift keying, phase shift keying, and orthogonal frequency division multiplexing modulations.

Testing, evaluation, and demonstration should include configuring and measuring antenna patterns for a 1 x 12 and 3 x 4 array using the same three (3) 1 x 4 subarrays. Moreover, vertical, horizontal, right-hand circular, and left-hand circular polarizations should be demonstrated. Validation of the prototype will be through comparison of model predictions to measured performance. The location for the demonstration may occur at the small business’s facility or at a Government-identified location.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. Owned and Operated with no Foreign Influence as defined by DOD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been be implemented and approved by the Defense Security Service (DSS). The selected contractor and/or subcontractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this contract as set forth by DSS and NAVSEA in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advance phases of this contract.

PHASE I: Define and develop a concept for a digital C-Band Tx and Rx array antenna. Demonstrate that the concept can feasibly meet the Navy requirements as provided in the Description. Establish feasibility by a combination of initial analysis and modeling. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype in Phase II.

PHASE II: Develop and deliver a prototype digital C-Band Tx and Rx array antenna that demonstrates the performance parameters outlined in the Description. Conduct prototype testing, evaluation, and demonstration (at the small business’s facility or at a Government-identified location). Provide an interface control document guide for developing the signal and control interface for the array. Include configuring and measuring antenna patterns for a 1 x 12 and 3 x 4 array using the same three (3) 1 x 4 subarrays in the demonstration plus vertical, horizontal, right-hand circular, and left-hand circular polarizations. Validate the prototype through comparison of model predictions to measured performance. It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL-USE APPLICATIONS: Support the Navy in transitioning the technology for Navy use. Further refine the prototype for evaluation to determine its effectiveness and reliability in an operationally relevant environment. Support the Navy in the system integration and qualification testing for the technology through platform integration and test events to transition the technology into PEO IWS 6 applications for simultaneous communications links to improve and expand tactical network functionality.

Digital, high-performance antennas will have direct application to private sector industries that involve directional communications between many small nodes over large areas. These applications include transportation, air traffic control, and communication industries.

REFERENCES:


3. Mailloux, Robert J. “Phased Array Antenna Handbook. 2nd ed.” Artech House, Inc.: Norwood, MA, 2005. pdfs.semanticscholar.org/2a93/5a6beae90d9f30e1cf1ef5c17b168456e1b0.pdf


KEYWORDS: Digital Array; Communications Array; Multichannel Tx and Rx; Digital Antenna Subarray Architecture; Narrowband Signals; Digital Antenna Subarray Architecture