

Phased Array System Toolbox 1.0

Design and simulate phased array signal processing systems

Phased Array System Toolbox™ provides algorithms and tools for the design, simulation, and analysis of phased array signal processing systems. These capabilities are provided as [MATLAB®](#) functions and MATLAB System objects. The system toolbox includes algorithms for waveform generation, beamforming, direction of arrival estimation, target detection, and space-time adaptive processing.

The system toolbox lets you build monostatic, bistatic, and multistatic architectures for a variety of array geometries. You can model these architectures on stationary or moving platforms. Array analysis and visualization tools help you evaluate spatial, spectral, and temporal performance. The system toolbox lets you model an end-to-end phased array system or use individual algorithms to process acquired data.

The system toolbox includes examples and demos that provide a starting point for implementing user-defined phased array systems.

Key Features

- Algorithms available as MATLAB functions and MATLAB System objects
- Monostatic, bistatic, and multistatic phased array system modeling
- Array analysis and 3D visualization; physical array modeling for uniform linear arrays, uniform rectangular arrays, and arbitrary conformal arrays on platforms with motion
- Broadband and narrowband digital beam-forming functions, including MVDR/Capon, LCMV, time delay, Frost, time delay LCMV, and subband phase shift
- Space-time adaptive processing algorithms, including displaced phase center array (DPCA), adaptive DPCA, sample matrix inversion (SMI), and angle-Doppler response visualization
- Direction of arrival algorithms, including MVDR, ESPRIT, beamscan, root MUSIC, and monopulse
- Waveform synthesis functions for pulsed CW, linear FM, stepped FM, and staggered PRF signals, and waveform visualization tools for ambiguity function and matched filter response
- Algorithms for TVG, pulse compression, coherent and noncoherent integration, CFAR processing, plotting ROC curves, and estimating range and Doppler

Phased Array Design and Analysis

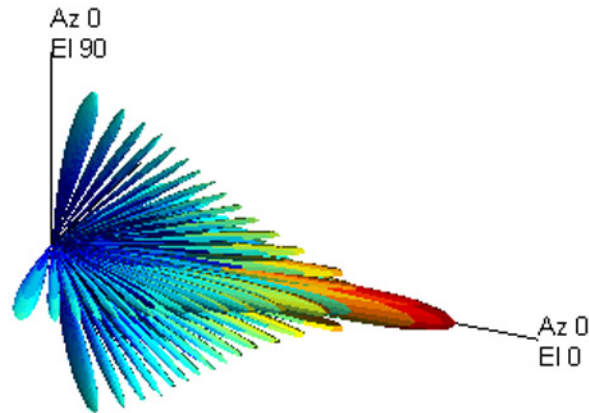
Phased Array System Toolbox enables you to model and analyze the behavior of common array geometries and user-defined array geometries. Common array geometries include:

- Uniform linear array (ULA)
- Uniform rectangular array (URA)
- Conformal array

You can define your own array geometry by specifying the number of elements, the element spacing, and each element's position and orientation in 3D space. The individual element response and radiation pattern can be either isotropic, cosine shaded, or it can be specified by your own 3D pattern. Your response and radiation pattern can either be described by an ideal analytic function or it can be defined from measured data. Shading (tapering) can be applied across the entire array.

The system toolbox provides tools to visualize and analyze the radiation pattern of individual elements or of the whole array in aggregate. With the tools, you can measure or visualize:

- Array gain
- Array response
- Delay between elements
- Steering vector
- Element response



Three dimensional beam pattern for a 30 x 30 uniform rectangular array.

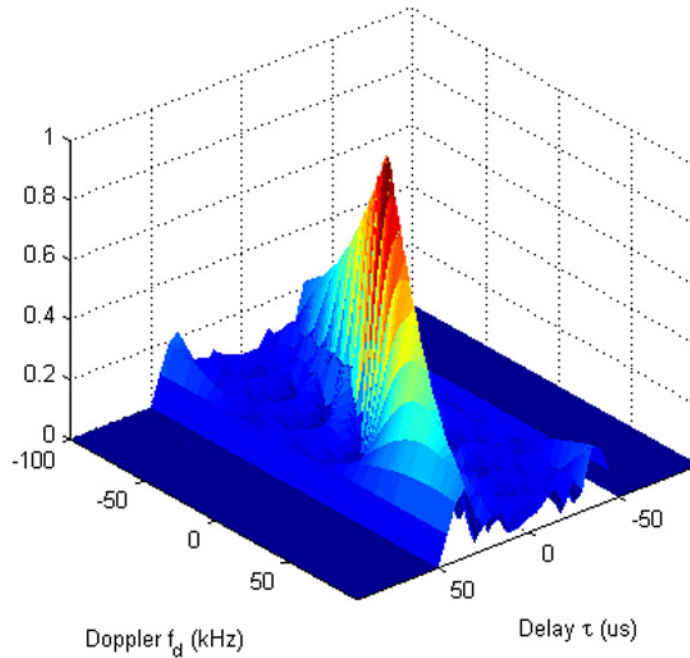
Waveform Design and Analysis

Phased Array System Toolbox supports waveform design and analysis for many common waveforms, including:

- Constant frequency (PCW)
- Linear frequency modulation (LFM)
- Stepped FM

The system toolbox provides a number of configurable parameters for each waveform, such as pulse repetition frequency (PRF), sample rate, pulse duration, and bandwidth. You can also design waveforms with staggered PRFs to address blind-speed problems in ground moving target indicator (GMTI) systems. Waveform envelopes can be either rectangular or Gaussian weighted.

The system toolbox also provides tools to visualize your waveform design, such as the ambiguity function (AF). The AF provides insight into the waveform characteristic in terms of range resolution, Doppler resolution, and the coupling between range and Doppler. The ideal matched-filter response is also provided.



Ambiguity function for an LFM waveform.

Transmitter and Receiver Modeling

Phased Array System Toolbox supports a generalized framework for modeling the physical transmission of a waveform, its propagation through the environment, and its ultimate reception. This framework allows for monostatic and bistatic system models. In addition, you can model array elements as part of a platform whose dynamics (initial position and velocity) are user-defined. You can deploy transmitter elements and receiver elements either on a common platform for monostatic modeling or on separate platforms for bistatic modeling. You can also model stationary system geometries by specifying a zero-velocity vector.

Transmitter Modeling

The system toolbox provides tools to model transmitter behavior by specifying parameters such as:

- Gain
- Peak power
- Loss factor
- Platform motion

Receiver Modeling

You can also model the reception of a signal at the receiver array to accommodate a variety of situations of interest. You can control the receiver array's behavior using the following attributes:

- Narrowband or broadband model
- Far-field or near-field model
- Array shading
- Platform motion

After a signal has been received across the array elements, you can configure the receiver front-end model parameters such as:

- Gain
- Loss factor
- Noise bandwidth
- Noise figure
- Reference temperature

You can also configure receiver models for either coherent or noncoherent processing.

Target and Environment Modeling

Target Modeling

You can model targets as point reflectors, which are principally defined by the radar cross section (RCS). Phased Array System Toolbox target models support the following target types:

- Nonfluctuating RCS models (Swerling 0 or 5)
- Fluctuating RCS models (Swerling 1-4)

With the system toolbox you can model more complex, distributed targets by creating a collection of distributed point reflectors. You can also model target motion by specifying the appropriate dynamics, such as initial position and velocity.

Environment Modeling

The system toolbox includes free-space environment models that simulate one-way or two-way propagation delays. It models both time delay and phase shift incurred during propagation. One-way propagation is useful for modeling bistatic systems. Two-way propagation enables you to model monostatic systems. You can model user-specified complex models with [MATLAB](#) algorithms. Alternatively, you can integrate third-party and proprietary environment models with the system toolbox's environment model.

The system toolbox also provides a barrage-jammer model to generate a wideband interference signal with user-specified radiated power. You can use multiple jammers to model complex electromagnetic environments.

Spatial Signal Processing

Digital Beamforming

Beamforming is a fundamental spatial signal processing operation of a phased array system. Phased Array System Toolbox supports 1D and 2D beamforming techniques, as well as conventional and adaptive beamforming techniques.

The system toolbox provides the Capon algorithm, a common adaptive beamformer for suppressing interference, and the linearly constrained minimum variance (LCMV) beamformer, for avoiding situations where self-nulling can occur. For broadband signals, the system toolbox provides adaptive algorithms such as the Frost and time delay LCMV beamformers. You can also use subband processing as an alternative to time delays for broadband signals.

The system toolbox supports the following digital beamforming techniques:

Narrowband, including Conventional (phase shift), MVDR (Capon), and LCMV

Broadband, including Frost, time delay, time delay LCMV, and subband phase shift

Direction of Arrival Estimation

Estimating the direction of arrival (DOA) of incident signals is a fundamental spatial signal processing operation. For various array geometries, the system toolbox provides several processing techniques for estimating DOA.

Uniform linear array:

- Sum and difference monopulse
- Beamscan
- MVDR (Capon)
- High-resolution techniques, including ESPRIT, beamspace ESPRIT, root MUSIC, root WSF

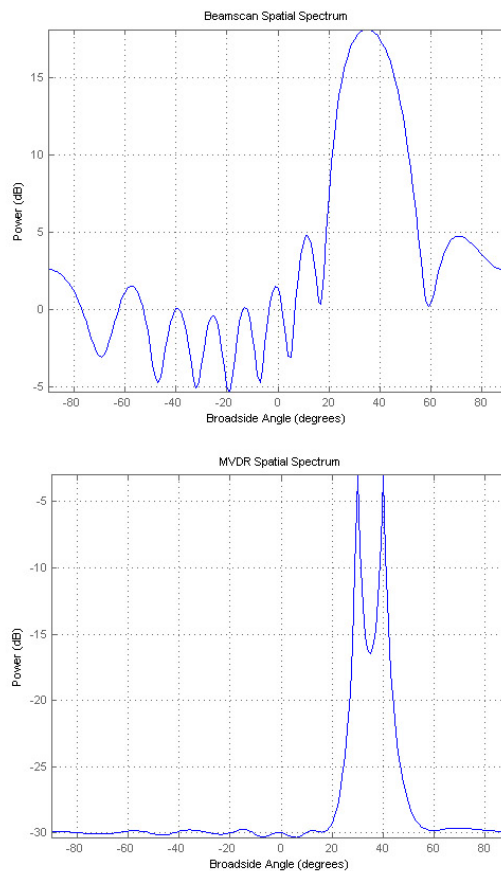
Uniform rectangular array:

- Sum and difference monopulse
- Beamscan
- MVDR (Capon)

Conformal array:

- Beamscan
- MVDR (Capon)

When using the high-resolution DOA techniques, you can specify the criterion used to estimate the number of signals, either the Akaike Information Criterion (AIC) or the Minimum Description Length (MDL) criterion.



Two unresolved targets at 30 degrees and 40 degrees (top). The targets are resolved using the MVDR technique (bottom).

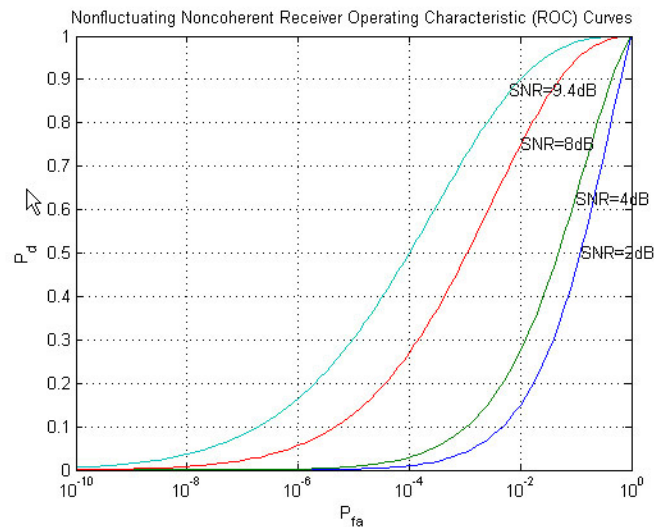
Temporal Signal Processing

After a signal has been propagated through the receiver array and receiver frontend, you can process the resultant radar cube using a number of temporal signal processing techniques provided by Phased Array System Toolbox, including:

- Time-varying gain control (TVG)
- Pulse compression
- Coherent and noncoherent integration

At this point in the processing chain, the system toolbox provides algorithms for detection and estimation of parameters of interest, such as range and Doppler. The following signal processing tools enable you to numerically characterize and visualize the detection performance of your system:

- Constant false alarm rate (CFAR) processing
- ROC curve visualization
- Neyman-Pearson detector threshold
- Albersheim and Shnidman equations



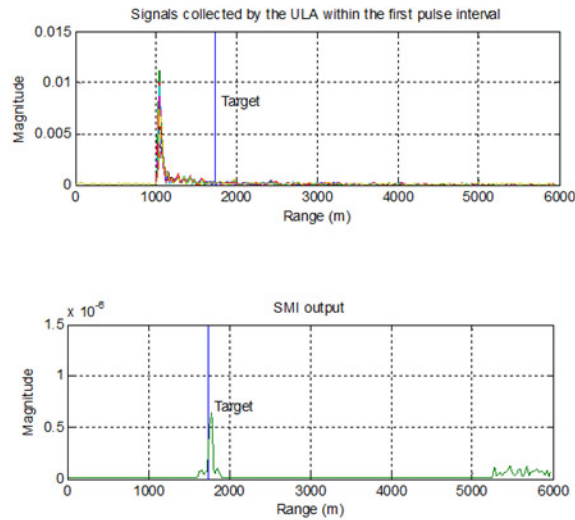
Receiver operating characteristic (ROC) curves for various SNR environments.

Space-Time Adaptive Processing

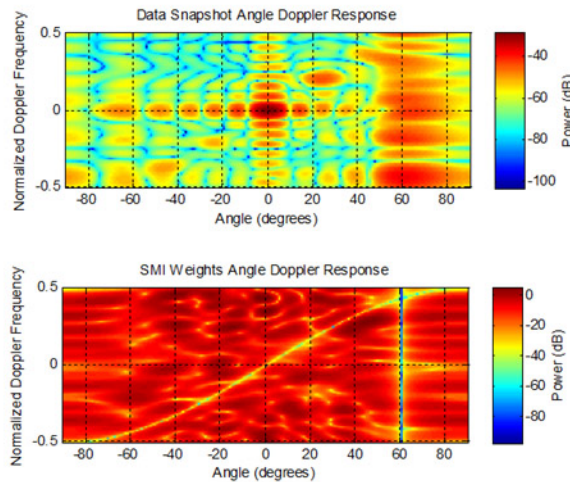
For suppressing clutter and jammer interference, Phased Array System Toolbox provides several space-time adaptive processing (STAP) algorithms:

- Displaced phase center array (DPCA)
- Adaptive DPCA
- Sample matrix inversion (SMI)

Although the SMI algorithm is computationally intensive and typically not a candidate for real-time implementation, it is useful as an ideal reference, against which other algorithms can be compared. An angle-Doppler response tool provides a useful visualization of the overall performance of the output of the various STAP algorithms.



Target obscured (top, blue vertical line) by clutter return at 1000 meters. After SMI STAP processing (bottom), the clutter return is suppressed and the target return is detectable.



Angle-Doppler response for combined clutter and target returns (top) and SMI weights (bottom) used for clutter suppression that render the target detectable.

Resources

Product Details, Demos, and System Requirements

www.mathworks.com/products/phased-array

Trial Software

www.mathworks.com/trialrequest

Sales

www.mathworks.com/contactsales

Technical Support

www.mathworks.com/support

Online User Community

www.mathworks.com/matlabcentral

Training Services

www.mathworks.com/training

Third-Party Products and Services

www.mathworks.com/connections

Worldwide Contacts

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