APPENDIX B
PROGRAMS USED IN POLARIZATION-SENSITIVE PROPAGATION MODELING

This appendix lists programs that were used for polarization-sensitive propagation modeling. The programs were written in MATLAB. A brief description of each program file is given, followed by a table listing inputs and outputs with their dimensions and units.

B1. Propagation Files

The following programs are used by VMPS to model multipath propagation including polarization effects. The purpose of each program is described and the output and input parameters are listed in a table.

B1.1 leescatt

This program returns the locations of scatterers that are located on a circle about the mobile unit.

Table B1. Parameters for "leescatt"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Output	scatterer_loc	Scatterer locations (x,y)	Mx2	m
Input	mobile_loc	Center of the ring of scatterers (x,y)	1x2	m
	M	Number of scatterers	Scalar	None
	R	Radius of the ring of scatterers	Scalar	m

B1.2 aoadist

This program returns the angles of arrival/departure from two terminal locations, the angle of reflection, and the distances from each terminal to a scatterer..

Table B2. Parameters for "aoadist"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Output	phi_term1	Angle of arrival at terminal 1	Mx1	rad
	phi_term2	Angle of arrival at terminal 2	Mx1	rad
	phi_R	Angle of reflection (from normal)	Mx1	rad
	ds1	distance from scatterer to teminal 1	Mx1	m
	ds2	distance from scatterer to teminal 2	Mx1	m
Input	Term1_loc	Location of terminal 1 (x,y)	1x2	m
	Term2_loc	Location of terminal 2 (x,y)	1x2	m
	Scatterer_loc	Scatterer locations (x,y)	Mx2	m

B1.3 reflect

This program returns amplituee and phase information for reflected rays based on channel dimensions and characteristics of scatterers or reflectors.

Table B3. Parameters for "reflect"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Output	Propagation	Amplitude and phase of signal (H and V)	Mx2, complex	Real and imaginary components of signal
Input	ds1	distance from scatterer to teminal 1	Mx1	m
	ds2	distance from scatterer to teminal 2	Mx1	m
	phi_R	Angle of reflection (from normal)	Mx1	rad
	Freq	Frequency	Scalar	Hz
	Gamma	Reflection coefficient (H and V), NaN if Fresnel coefficients are to be used	1x2, complex	None
	epsilon_r	Relative permittivity of scatterers	Scalar	None

B1.4 frescoef

This program returns the fresnel coefficients for perpendicular and parallel (vertical and horizontal) polarizations, given the relative permittivity of the reflecting object and reflection angles.

Table B4. Parameters for "frescoef"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Output	GAMMA	Perpendicular and parallel (V and H if plane of incidence is x-y plane) polarized reflection coefficients for each reflecting object	Mx2	None
Input	Er	Relative permitivity of the reflecting object	Scalar	None
	ds2	Reflection angles in radians for each reflecting object	Mx1	rad

B1.5 spsig

This program returns the spatial-polarization signature of a signal received by an antenna array with specified geometry and element patterns.

Table B5. Parameters for "spsig"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Output	spatial_sig	Spatial or spatial-polarization signature	Nx1, complex	Real and imaginary components of signals at each element
Input	phi_term1	Angle of arrival at terminal 1	Mx1	rad
	phi_term2	Angle of arrival at terminal 2	Mx1	rad
	Propagation	Amplitude and phase of signal (H and V)	Mx2, complex	Real and imaginary components of signal
	rx_terminal	1 or 2	scalar	None
	tx_pattern	8-character pattern filename for transmitting antenna	String (8 characters)	None
	rx_geometry	Locations of N receiving array elements (x,y)	Nx2	Wave-lengths
	rx_patterns	Array element patterns 'vo' for vertical omni, 'ho' for horizontal omni, otherwise pattern filename (8 characters each)	String (N rows x 2 or 8 characters)	None

B1.6 getazpat

This program reads the azimuth pattern of an antenna from a file.

Table B6. Parameters for "getazpat"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Outputs	hpat	Horizontally polarized azimuth pattern sampled at phidim angles	1 x phidim, complex	Linear relative gain
	vpat	Vertically polarized azimuth pattern sampled at phidim angles	1 x phidim, complex	Linear relative gain
Inputs	directory	Name of directory where pattern files are stored	String	None
	pattern	Name of pattern files	String, 8 characters	None

B2. Antenna and array pattern files

B2.1 ap

This program returns an array pattern given the locations and patterns of the array elements and a complex weight vector.

Table B7. Parameters for "ap"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Outputs	None (writes pattern files for array)			
Inputs	elements	Matrix of element positions and weights, i^{th} row contains r, theta, phi, |w|,<w of i^{th} element	N x 5	r: wavelengths, theta: degrees, phi: degrees, |w|: relative magnitude, <w: degrees
	indir	Name of directory where pattern files for array elements	String	None
	infilenames	Matrix with i^{th} row containing the filename of the pattern files for i^{th} array element	String matrix, N x 8 characters	None
	outdir	Name of directory where pattern files for array are to be stored	String	None
	outfilename	Filename of pattern files for array	String, 8 characters	None

B2.2 isovert

This program generates the pattern for a vertically polarized isotropic antenna. A similar program, isohoriz, generates the pattern of a horizontally polarized isotropic antenna.

Table B8. Parameters for "isovert"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Outputs	None (writes pattern file for isotropic antenna)			
Inputs	thetares	Sampling resolution in theta	Scalar	Degrees
	phires	Sampling resolution in phi	Scalar	Degrees
	patterndir	Name of directory where pattern files for isotropic antenna are to be stored	String	None
	filename	Filename of pattern files for isotropic antenna	String, 8 characters	None

B2.3 sdipole

This program generates the pattern for a vertically polarized small dipole antenna.

Table B9. Parameters for "sdipole"

Output/ Input	**Parameter name**	**Symbol/Description**	**Dimensions**	**Units**
Outputs	None (writes pattern file for vertically polarized small dipole antenna)			
Inputs	thetares	Sampling resolution in theta	Scalar	Degrees
	phires	Sampling resolution in phi	Scalar	Degrees
	patterndir	Name of directory where pattern files for small dipole are to be stored	String	None
	filename	Filename of pattern files for small dipole	String, 8 characters	None

B2.4 halfwave

This program generates the pattern for a vertically polarized small dipole antenna.

Table B10. Parameters for "halfwave"

Output/ Input	**Parameter name**	**Symbol/Description**	**Dimensions**	**Units**
Outputs	None (writes pattern file for vertically polarized half wave dipole antenna)			
Inputs	thetares	Sampling resolution in theta	Scalar	Degrees
	phires	Sampling resolution in phi	Scalar	Degrees
	patterndir	Name of directory where pattern files for half wave dipole are to be stored	String	None
	filename	Filename of pattern files for half wave dipole	String, 8 characters	None

B2.5 dirantv

This program generates the pattern for a directional, vertically polarized antenna with specified horizontal and vertical beamwidth and sidelobe level.

Table B11. Parameters for "dirantv"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Outputs	None (writes pattern file for directional antenna with main beam centered at (90°,0°))			
Inputs	thetares	Sampling resolution in theta	Scalar	Degrees
	phires	Sampling resolution in phi	Scalar	Degrees
	azbw	Azimuth beamwidth	Scalar	Degrees
	elbw	Elevation beamwidth	Scalar	Degrees
	SLL	Side lobe level	Scalar	dB, ≤ 0, -999 for no sidelobes
	patterndir	Name of directory where pattern files for small dipole are to be stored	String	None
	filename	Filename of pattern files for small dipole	String, 8 characters	None

B2.6 gain

This program calculates the gain of an antenna by integrating the three-dimensional pattern.

Table B12. Parameters for "gain"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Outputs	lingain	Gain relative to isotropic radiator	Scalar	Linear gain relative to isotropic
	dBgain	Gain relative to isotropic radiator	Scalar	Gain in dBi
Inputs	patterndir	Name of directory where pattern files are stored	String	None
	filename	Filename of pattern files	String, 8 characters	None

B3. Programs that Display Antenna Patterns

B3.1 phipat

This program displays the elevation pattern of an antenna for a specified azimuth angle phi.

Table B13. Parameters for "phipat"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Output	None (displays phi cut patterns)	Horizontally and vertically polarized electric field patterns		
Inputs	patterndir	Name of directory where pattern files are stored	String	None
	filename	Filename of pattern files	String, 8 characters	None
	phi	Angle for pattern cut (must be an angle at which pattern is sampled)	Scalar	degrees

B3.2 thetapat

This program displays the azimuth pattern of an antenna for a specified elevation angle theta

Table B14. Parameters for "thetapat"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Output	None (displays theta cut patterns)	Horizontally and vertically polarized electric field patterns		
Inputs	patterndir	Name of directory where pattern files are stored	String	None
	filename	Filename of pattern files	String, 8 characters	None
	theta	Angle for pattern cut (must be an angle at which pattern is sampled)	Scalar	degrees

B3.3 threepat

This program displays the three dimensional pattern of an antenna.

Table B15. Parameters for "threepat"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Output	None (displays three-dimensional patterns)	Horizontally and vertically polarized electric field patterns		
Inputs	patterndir	Name of directory where pattern files are stored	String	None
	filename	Filename of pattern files	String, 8 characters	None

B4 Programs used to Rotate Antenna Patterns

The following programs are used to rotate antenna patterns, and to calculate the new horizontally and vertically polarized patterns after rotation, resampled at the original spherical coordinates.

B4.1 rotpatvh

This program rotates a pattern stored in a specified existing file by the specified angles and writes the resampled horizontally and vertically polarized antenna patterns to a file.

Table B16. Parameters for "rotpatvh"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Output	None (writes pattern files for rotated antenna)	Horizontally and vertically polarized electric field patterns		
Inputs	indir	Name of directory where pattern files for antenna before rotation are stored	String	None
	infilename	Filename of pattern files for antenna before rotation	String, 8 characters	None
	outdir	Name of directory where pattern files for antenna after rotation are to be stored	String	None
	outfilename	Filename of pattern files for antenna after rotation	String, 8 characters	None
	deltaphi	Increment of first rotation in angle phi	Scalar	Degrees
	deltatheta	Increment of second rotation in angle theta	Scalar	Degrees
	deltatau	Increment of third rotation in angle tau	Scalar	Degrees

B4.2 rotate2.m

This program performs the antenna pattern rotation and returns the pattern values and new sample points after rotation.

Table B17. Parameters for "rotate2"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Outputs	RH3	value of pattern samples after 3-dimensional rotation	thetadim x phidim	Linear relative gain
	TH3	"theta" of pattern samples after 3-dimensional rotation	thetadim x phidim	Radians
	PH3	"phi" of pattern samples after 3-dimensional rotation	thetadim x phidim	radians
Inputs	f	Single-polarized pattern of antenna to be rotated	thetadim x phidim	Linear relative gain
	deltaphi	Increment of first rotation in angle phi	Scalar	Degrees
	deltatheta	Increment of second rotation in angle theta	Scalar	Degrees
	deltatau	Increment of third rotation in angle tau	Scalar	Degrees

B4.3 resample

This program resamples the rotated antenna pattern at the sample points of the original pattern.

Table B18. Parameters for "resample"

Output/ Input	Parameter name	Symbol/Description	Dimensions	Units
Outputs	f	Rotated version of original single-polarized antenna pattern	thetadim x phidim	Linear relative gain
Inputs	R	value of pattern samples after 3-dimensional rotation	thetadim x phidim	Linear relative gain
	Theta	"theta" of pattern samples after 3-dimensional rotation	thetadim x phidim	Radians
	Phi	"phi" of pattern samples after 3-dimensional rotation	thetadim x phidim	radians

B4.4 polarize

This program calculates the new horizontally and vertically polarized components of the antenna pattern after rotation and resampling.

Table B19. Parameters for "polarize"

polarize.m

Output/ Input	**Parameter name**	**Symbol/Description**	**Dimensions**	**Units**
Outputs	FrotV	Pattern (for vertical polarization) of antenna after rotation and repolarization	thetadim x phidim	Linear relative gain
	FrotH	Pattern (for horizontal polarization) of rotated antenna after repolarization	thetadim x phidim	Linear relative gain
Inputs	FrotVP	Rotated version of original vertically polarized pattern	thetadim x phidim	Linear relative gain
	FrotHP	Rotated version of original horizontally polarized pattern	thetadim x phidim	Linear relative gain
	deltaphi	Increment of first rotation in angle phi	Scalar	Degrees
	deltatheta	Increment of second rotation in angle theta	Scalar	Degrees
	deltatau	Increment of third rotation in angle tau	Scalar	Degrees