CASA VPMANAGER NOTES (June 2011)

References: /home/yashar/casa/code/xmlcasa/implement/synthesis/vpmanager.xml

http://casa.nrao.edu/docs/CasaRef/vpmanager-Tool.html

1. Introduction and Overview

Short Description: Tool for specifying voltage patterns and primary beams.

The **vpmanager**, or voltage pattern manager, creates a table with the description of one or more voltage patterns (vp) or primary beams (pb). There is a mapping between telescope name and the vp or pb description. The vp description table can be read by imager's **setvp** method, which instantiates the corresponding voltage patterns from the descriptions and applies them to the images. While the vp description table can have multiple telescopes in it, limitations to the internal visibility buffers currently limit the functionality within imager to a single telescope.

2. What vpmanager does

2.1 Set a Given Telescope's VP/PB model

The vpmanager recognizes the names of several telescopes: ATCA, GBT, GMRT, HATCREEK, NMA, NRAO12M, NRAO140FT, OVRO, VLA, WSRT. New telescopes and their default VP/PB models will need to be added to the system.

2.2 Common VP/PB Models

Many common voltage pattern (vp) and primary beam (pb) models have been coded into casa. Currently, the recognized models include DEFAULT, ATCA_L1, ATCA_L2, ATCA_L3, ATCA_S, ATCA_C, ATCA_X, GBT, GMRT, HATCREEK, NRAO12M, NRAO140FT, OVRO, VLA, VLA_INVERSE, VLA_NVSS,VLA_2NULL, VLA_4, VLA_P, VLA_L, VLA_C, VLA_X, VLA_U, VLA_K, VLA_Q, WSRT, and WSRT_LOW. In all cases, the VP/PB model and the beam squint (if present) scale linearly with wavelength. If DEFAULT is selected, the appropriate VP/PB model is selected for the telescope and observing frequency.

2.2.1 1-D Beam Models

Most beam models are rotationally symmetric (excepting beam squint). From the beam parameterization in terms of the various coefficients and other terms, an internal lookup table with 10000 elements is created for application of the VP/PB to an image.

2.2.2 Beam Squint

The VP/PB models include beam squint. The VLA_L, VLA_C, VLA_X, VLA_U, VLA_K, and VLA_Q models (which are the defaults for those VLA bands), have the appropriate squint magnitude and orientation, though the orientation has not been verified through processing actual data.

2.2.3 Multiple VP/PB Models for one MS

The VPManager can have VP information for multiple telescopes. However, the internals of imager cannot yet deal with VP/PB's for multiple telescopes. In the case of a MS with multiple telescopes present, the primary beam

of the first telescope present in the MS will be used, even if it is not the first telescope specified in the VP description table produced by vpmanager.

2.2.4

Antenna-dependent Voltage Patterns are not yet supported.

Two-dimensional Voltage Pattern Images are supported via **setpbimage**.

2.3 Example

The following example shows a simple way to make a new voltage pattern table. Note that this can be more easily done from the **toolmanager**.

```
#
# make the vpmanager
#
vptool = casac.homefinder.find_home_by_name('vpmanagerHome')
vp =vptool.create()
#
# Lets say we want an Airy Disk voltage pattern for our
# HATCREEK data, but we want to use the system default
# for the OVRO data:
#
vp.setpbairy(telescope='HATCREEK', dopb=T, dishdiam='6.0m',
        blockagediam='0.6m',  maxrad='2arcmin',
        reffreq='100GHz', dosquint=F)
vp.setcannedpb(telescope='OVRO', dopb=T, commonpb='DEFAULT', dosquint=F)
vp.summarizevps()
vp.saveastable(tablename='California.Beaming')
print "Last example.  Exiting..."
exit()
```

3. Vpmanager Methods, Functions, Arguments, and Parameters

- **vpmanager:** Construct a vpmanager tool. The vpmanager constructor has no arguments.

- **saveastable:** Save the vp or pb descriptions as a table. Input: **tablename** – name of table to save vp descriptions in (allowed: string). Each description is in a different row of the table.

- **summarizevps:** Summarize the currently accumulated VP descriptions to the logger. Input: **verbose --** Print out full record? Otherwise, print summary (allowed: bool; default: false).

- **done**: Terminate/eliminate the current vpmanager.

- **setcannedpb:** Select a vp/pb from our library of common pb models. We have many vp/pb models ready to go for a variety of telescopes. If 'DEFAULT' is selected, the system default for that telescope and frequency is used. Input arguments are:

  - **telescope**: Which telescope in the MS will use this vp/pb (allowed: string; default: VLA)?

  - **othertelescope:** If telescope=="OTHER", specify name here (allowed: string).

  - **dopb:** Should we apply the vp/pb to this telescope's data (allowed: bool; default: true)?

  - **commonpb:** List of common vp/pb models: DEFAULT code figures it out.

  - **dosquint:** Enable the natural beam squint found in the common vp model (allowed: bool; default: false).

  - **paincrement**: Increment in Parallactic Angle for asymmetric (ie, squinted) vp application (allowed: any; default: variant 720 deg)

  - **usesymmetricbeam:** Not currently used (allowed: bool; default: false)

- **setpbairy**: Make an airy disk vp. Information sufficient to create a portion of the Airy disk voltage pattern. The Airy disk pattern is formed by Fourier transforming a uniformly illuminated aperture and is given by

  vp_p(i) = (areaRatio * 2.0 * j_{1}(x)/x - 2.0 * j_{1}(x*lengthRatio)/(x*lengthRatio))/ areaNorm,

  where areaRatio is the dish area divided by the blockage area, lengthRatio is the dish diameter divided by the blockage diameter, and

  x = \frac{i * maxrad * 7.016 * dishdiam/24.5m}{N_{samples} * 1.566 * 60}.

  Input arguments are:

  - **telescope**: Which telescope in the MS will use this vp/pb (allowed: string; default: VLA)?
  - **othertelescope**: If telescope=="OTHER", specify name here (allowed: string).
  - **dopb**: Should we apply the vp/pb to this telescope's data (allowed: bool; default: true)?
  - **dishdiam**: Effective diameter of dish (allowed: any; default: variant 25.0m).

- **blockagediam**: Effective diameter of subreflector blockage (allowed: any; default: variant 2.5m).
- **maxrad**: Maximum radial extent of the vp/pb (scales with 1/freq) (allowed: any; default variant 0.8deg).
- **reffreq**: Frequency at which maxrad is specified (allowed: any; default: variant 1.0GHz).
- **squintdir**: Offset (Measure) of RR beam from pointing center, azel frame (scales with 1/freq) (allowed: any; default: variant)
- **squintreffreq**: Frequency at which the squint is specified (allowed: any; default: variant 1.0GHz).
- **dosquint**: Enable the natural beam squint found in the common vp model (allowed: bool; default: false).
- **paincrement**: Increment in Parallactic Angle for asymmetric (ie, squinted) vp application (allowed: any; default: variant 720 deg).
- **usesymmetricbeam**: Not currently used (allowed: bool; default: false).

• **setpbcospoly:** Make a vp/pb from a polynomial of scaled cosine. A voltage pattern or primary beam of the form

VP(x) = sum_{i} (coeff_{i} cos^{2i}(scale_{i} x).

This is a generalization of the WSRT primary beam model. Input arguments are:

- **telescope**: Which telescope in the MS will use this vp/pb (allowed: string; default: VLA)?
- **othertelescope**: If telescope=="OTHER", specify name here (allowed: string).
- **dopb**: Should we apply the vp/pb to this telescope's data (allowed: bool; default: true)?
- **coeff**: Vector of coefficients of cosines (allowed: doubleArray; default: -1).
- **scale**: Vector of scale factor of cosines (allowed: doubleArray; default: -1).
- **maxrad**: Maximum radial extent of the vp/pb (scales with 1/freq) (allowed: any; default: variant 0.8 deg).
- **reffreq**: Frequency at which maxrad is specified (allowed: any; default: variant 1.0GHz).
- **isthispb**: Do these parameters describe a PB or a VP? (allowed: string; default: PB).
- **squintdir**: Offset (Measure) of RR beam from pointing center, azel frame (scales with 1/freq) (allowed: any; default: variant)
- **squintreffreq**: Frequency at which the squint is specified (allowed: any; default: variant 1.0GHz).
- **dosquint**: Enable the natural beam squint found in the common vp model (allowed: bool; default: false).
- **paincrement**: Increment in Parallactic Angle for asymmetric (ie, squinted) vp application (allowed: any; default: variant 720 deg).
- **usesymmetricbeam**: Not currently used (allowed: bool; default: false).

• **setpbgauss**: Make a Gaussian vp/pb. Make a Gaussian primary beam given by

PB(x) = e^{- (x/(halfwidth*sqrt{1\log(2)})) }.

Input arguments are:

- **telescope**: Which telescope in the MS will use this vp/pb (allowed: string; default: VLA)?
- **othertelescope**: If telescope=="OTHER", specify name here (allowed: string).
- **dopb**: Should we apply the vp/pb to this telescope's data (allowed: bool; default: true)?

- **halfwidth**: Half power half width of the Gaussian at the reffreq (allowed: any; default: variant 0.5 deg).
- **maxrad**: Maximum radial extent of the vp/pb (scales with 1/freq) (allowed: any; default: variant 0.8 deg).
- **reffreq**: Frequency at which maxrad is specified (allowed: any; default: variant 1.0GHz).
- **isthispb**: Do these parameters describe a PB or a VP? (allowed: string; default: PB).
- **squintdir**: Offset (Measure) of RR beam from pointing center, azel frame (scales with 1/freq) (allowed: any; default: variant)
- **squintreffreq**: Frequency at which the squint is specified (allowed: any; default: variant 1.0GHz).
- **dosquint**: Enable the natural beam squint found in the common vp model (allowed: bool; default: false).
- **paincrement**: Increment in Parallactic Angle for asymmetric (ie, squinted) vp application (allowed: any; default: variant 720 deg).
- **usesymmetricbeam**: Not currently used (allowed: bool; default: false).

• **setpbinvpoly**: Make a vp/pb as an inverse polynomial. The inverse polynomial describes the inverse of the VP or PB as a polynomial of even powers:

1/VP(x) = sum_{i} coeff_{i} * x^{2i}.

Input arguments are:

- **telescope**: Which telescope in the MS will use this vp/pb (allowed: string; default: VLA)?
- **othertelescope**: If telescope=="OTHER", specify name here (allowed: string).
- **dopb**: Should we apply the vp/pb to this telescope's data (allowed: bool; default: true)?
- **coeff**: Coefficients of even powered terms (allowed: doubleArray; default: -1).
- **maxrad**: Maximum radial extent of the vp/pb (scales with 1/freq) (allowed: any; default: variant 0.8 deg).
- **reffreq**: Frequency at which maxrad is specified (allowed: any; default: variant 1.0GHz).
- **isthispb**: Do these parameters describe a PB or a VP? (allowed: string; default: PB).
- **squintdir**: Offset (Measure) of RR beam from pointing center, azel frame (scales with 1/freq) (allowed: any; default: variant)
- **squintreffreq**: Frequency at which the squint is specified (allowed: any; default: variant 1.0GHz).
- **dosquint**: Enable the natural beam squint found in the common vp model (allowed: bool; default: false).
- **paincrement**: Increment in Parallactic Angle for asymmetric (ie, squinted) vp application (allowed: any; default: variant 720 deg).
- **usesymmetricbeam**: Not currently used (allowed: bool; default: false).

Example: If you have a single dish image with a beam which is not defined in the casa database then this example is a guide of how to do that. Say, you know the beam of the single dish as a gaussian.

```
#create a beam pattern table using vpmanager

vpman=vpmanager();

vpman.setpbgauss(telescope='OTHER', othertelescope='BONN',halfwidth='1arcmin',maxrad='20arcmin',
reffreq='1.4GHz');

vpman.saveastable('bonn.pb')

vpman.done()

##....would have done your usual imager setup (defineimage etc), then:

im.setvp(dovp=True, usedefaultvp=false, vptable='bonn.pb')
```

• **setpbnumeric**: Make a vp/pb from a user-supplied vector. Supply a vector of vp/pb sample values taken on a regular grid between x=0 and x=maxrad. We perform sinc interpolation to fill in the lookup table.

Input arguments are:

- **telescope**: Which telescope in the MS will use this vp/pb (allowed: string; default: VLA)?
- **othertelescope**: If telescope=="OTHER", specify name here (allowed: string).
- **dopb**: Should we apply the vp/pb to this telescope's data (allowed: bool; default: true)?
- **vect**: Vector of vp/pb samples uniformly spaced from 0 to maxrad(allowed: doubleArray; default: -1).
- **maxrad**: Maximum radial extent of the vp/pb (scales with 1/freq) (allowed: any; default: variant 0.8 deg).
- **reffreq**: Frequency at which maxrad is specified (allowed: any; default: variant 1.0GHz).
- **isthispb**: Do these parameters describe a PB or a VP? (allowed: string; default: PB).
- **squintdir**: Offset (Measure) of RR beam from pointing center, azel frame (scales with 1/freq) (allowed: any; default: variant)
- **squintreffreq**: Frequency at which the squint is specified (allowed: any; default: variant 1.0GHz).
- **dosquint**: Enable the natural beam squint found in the common vp model (allowed: bool; default: false).
- **paincrement**: Increment in Parallactic Angle for asymmetric (ie, squinted) vp application (allowed: any; default: variant 720 deg).

- **usesymmetricbeam**: Not currently used (allowed: bool; default: false).

• **setpbimage**: Make a vp/pb from a user-supplied image. Experimental: Supply an image of the E Jones elements. The format of the image is:

- **Shape**: nx by ny by 4 complex polarizations (RR, RL, LR, LL or XX, XY, YX, YY) by 1 channel.
- **Direction coordinate**: Az, El
- **Stokes coordinate**: All four ``stokes'' parameters must be present in the sequence RR, RL, LR, LL or XX, XY, YX, YY.
- **Frequency**: Only one channel is currently needed - frequency dependence beyond that is ignored.

One or two images may be specified - the real (must be present) and imaginary parts (optional).

Note that beamsquint must be intrinsic to the images themselves. This will be accounted for correctly by regridding of the images from Az-El to Ra-Dec according to the parallactic angle.

Input arguments are:

- **telescope**: Which telescope in the MS will use this vp/pb (allowed: string; default: VLA)?
- **othertelescope**: If telescope=="OTHER", specify name here (allowed: string).
- **dopb**: Should we apply the vp/pb to this telescope's data (allowed: bool; default: true)?
- **realimage**: Real part of vp as an image (allowed: string).
- **imagimage**: Imaginary part of vp as an image (allowed: string).

- **setpbpoly**: Make a vp/pb from a polynomial The VP or PB is described as a polynomial of even powers:

VP(x) = sum_{i} coeff_{i} * x^{2i}.

Input arguments are:

- **telescope**: Which telescope in the MS will use this vp/pb (allowed: string; default: VLA)?
- **othertelescope**: If telescope=="OTHER", specify name here (allowed: string).
- **dopb**: Should we apply the vp/pb to this telescope's data (allowed: bool; default: true)?
- **coef**: Coefficients of even powered terms(allowed: doubleArray; default: -1).
- **maxrad**: Maximum radial extent of the vp/pb (scales with 1/freq) (allowed: any; default: variant 0.8 deg).
- **reffreq**: Frequency at which maxrad is specified (allowed: any; default: variant 1.0GHz).
- **isthispb**: Do these parameters describe a PB or a VP? (allowed: string; default: PB).

- **squintdir**: Offset (Measure) of RR beam from pointing center, azel frame (scales with 1/freq) (allowed: any; default: variant)
- **squintreffreq**: Frequency at which the squint is specified (allowed: any; default: variant 1.0GHz).
- **dosquint**: Enable the natural beam squint found in the common vp model (allowed: bool; default: false).
- **paincrement**: Increment in Parallactic Angle for asymmetric (ie, squinted) vp application (allowed: any; default: variant 720 deg).
- **usesymmetricbeam**: Not currently used (allowed: bool; default: false).

• **createantresp**: The AntennaResponses table serves CASA to look up the location of images describing the response of observatory antennas. Three types of images are supported: ”VP” - real voltage patterns, ”AIF” - complex aperture illumination patterns, ”EFP” - complex electric field patterns. For each image, a validity range can be defined in Azimuth, Elevation, and Frequency. Furthermore, a antenna type (for heterogeneous arrays), a receiver type (for the case of several receivers on the same antenna having overlapping frequency bands), and a beam number (for the case of multiple beams per antenna) are associated with each response image.

The images need to be stored in a single directory DIR of arbitrary name and need to have file names following the pattern

```
obsname_beamnum_anttype_rectype_azmin_aznom_azmax_elmin_elnom_elmax_freqmin_freqnom_freqmax_frequnit_comment_functype.im
```

where the individual name elements mean the following (none of the elements may contain the space character, but they may be empty strings if they are not numerical values):

obsname
- name of the observatory as in the Observatories table, e.g. ”ALMA”

beamnum
- the numerical beam number (integer) for the case of multiple beams, e.g. 0

anttype
- name of the antenna type, e.g. ”DV”

rectype
- name of the receiver type, e.g. ””

azmin, aznom, azmax
- numerical value (degrees) of the minimal, the nominal, and the maximal Azimuth where this response is valid, e.g. ”-10.5_0._10.5”

elmin, elnom, elmax
- numerical value (degrees) of the minimal, the nominal, and the maximal Elevation where this response is valid, e.g. ”10._45._80.”

freqmin, freqnom, freqmax
- numerical value (degrees) of the minimal, the nominal, and the maximal Frequency (in units of frequnit) where this response is valid, e.g. ”84._100._116.”

frequnit
- the unit of the previous three frequencies, e.g. ”GHz”

comment
- any string containing only characters permitted in file names and not empty space

functype
- the type of the image as defined above (”VP”, ”AIF”, or ”EFP”)

The createantresp method will then extract the parameters from all the images in DIR and create the lookup table in the same directory.

Input arguments are:

- **imdir**: Path to the directory containing the response images (allowed: string)
- **starttime:** Time from which onwards the response is valid, format YYYY/MM/DD/hh:mm:ss (allowed: string)
- **bandnames**: List containing the names of the observatory's frequency bands (allowed: stringArray).
- **bandminfreq**: List containing the lower edges of the observatory's frequency bands, e.g. [”80GHz”,”120GHz”] (allowed: stringArray).
- **bandmaxfreq:** List containing the upper edges of the observatory's frequency bands, e.g. [”120GHz”,”180GHz”] (allowed: stringArray).