## NAME

splat – An RF **S**ignal **P**ropagation, **L**oss, **A**nd **T**errain analysis tool

## SYNOPSIS

splat [-t *transmitter_site.qth*] [-r *receiver_site.qth*] [-c *rx antenna height for LOS coverage analysis (feet/meters) (float)*] [-L *rx antenna height for Longley-Rice coverage analysis (feet/meters) (float)*] [-p *terrain_profile.ext*] [-e *elevation_profile.ext*] [-h *height_profile.ext*] [-H *normalized_height_profile.ext*] [-l *Longley-Rice_profile.ext*] [-o *topographic_map_filename.ppm*] [-b *cartographic_boundary_filename.dat*] [-s *site/city_database.dat*] [-d *sdf_directory_path*] [-m *earth radius multiplier (float)*] [-f *frequency (MHz) for Fresnel zone calculations (float)*] [-R *maximum coverage radius (miles/kilometers) (float)*] [-dB *maximum attenuation contour to display on path loss maps (80-230 dB)*] [-fz *Fresnel zone clearance percentage (default = 60)*] [-plo *path_loss_output_file.txt*] [-pli *path_loss_input_file.txt*] [-udt *user_defined_terrain_file.dat*] [-n] [-N] [-nf] [-ngs] [-geo] [-kml] [-metric]

## DESCRIPTION

**SPLAT!** is a powerful terrestrial RF propagation and terrain analysis tool for the spectrum between 20 MHz and 20 GHz. **SPLAT!** is free software, and is designed for operation on Unix and Linux-based workstations. Redistribution and/or modification is permitted under the terms of the GNU General Public License, Version 2, as published by the Free Software Foundation. Adoption of **SPLAT!** source code in proprietary or closed-source applications is a violation of this license and is **strictly** forbidden.

**SPLAT!** is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY, without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

## INTRODUCTION

Applications of **SPLAT!** include the visualization, design, and link budget analysis of wireless Wide Area Networks (WANs), commercial and amateur radio communication systems above 20 MHz, microwave links, frequency coordination and interference studies, and the prediction of analog and digital terrestrial radio and television contour regions.

**SPLAT!** provides RF site engineering data such as great circle distances and bearings between sites, antenna elevation angles (uptilt), depression angles (downtilt), antenna height above mean sea level, antenna height above average terrain, bearings, distances, and elevations to known obstructions, Longley-Rice path attenuation, and received signal strength. In addition, the minimum antenna height requirements needed to clear terrain, the first Fresnel zone, and any user-definable percentage of the first Fresnel zone are also provided.

**SPLAT!** produces reports, graphs, and high resolution topographic maps that depict line-of-sight paths, and regional path loss and signal strength contours through which expected coverage areas of transmitters and repeater systems can be obtained. When performing line-of-sight and Longley-Rice analyses in situations where multiple transmitter or repeater sites are employed, **SPLAT!** determines individual and mutual areas of coverage within the network specified.

Simply typing `splat` on the command line will return a summary of **SPLAT!**'s command line options:

```
          --==[ SPLAT! v1.2.1 Available Options... ]==--

   -t txsite(s).qth (max of 4 with -c, max of 30 with -L)
   -r rxsite.qth
   -c plot coverage of TX(s) with an RX antenna at X feet/meters AGL
   -L plot path loss map of TX based on an RX at X feet/meters AGL
   -s filename(s) of city/site file(s) to import (5 max)
   -b filename(s) of cartographic boundary file(s) to import (5 max)
   -p filename of terrain profile graph to plot
```

```
     -e filename of terrain elevation graph to plot
     -h filename of terrain height graph to plot
     -H filename of normalized terrain height graph to plot
     -l filename of Longley-Rice graph to plot
     -o filename of topographic map to generate (.ppm)
     -u filename of user-defined terrain file to import
     -d sdf file directory path (overrides path in ~/.splat_path file)
     -m earth radius multiplier
     -n do not plot LOS paths in .ppm maps
     -N do not produce unnecessary site or obstruction reports
     -f frequency for Fresnel zone calculation (MHz)
     -R modify default range for -c or -L (miles/kilometers)
    -db maximum loss contour to display on path loss maps (80-230 dB)
    -nf do not plot Fresnel zones in height plots
    -fz Fresnel zone clearance percentage (default = 60)
   -ngs display greyscale topography as white in .ppm files
   -erp override ERP in .lrp file (Watts)
   -pli filename of path-loss input file
   -plo filename of path-loss output file
   -udt filename of user defined terrain input file
   -kml generate Google Earth (.kml) compatible output
   -geo generate an Xastir .geo georeference file (with .ppm output)
-metric employ metric rather than imperial units for all user I/O
```

## INPUT FILES

**SPLAT!** is a command-line driven application and reads input data through a number of data files. Some files are mandatory for successful execution of the program, while others are optional. Mandatory files include 3-arc second topography models in the form of SPLAT Data Files (SDF files), site location files (QTH files), and Longley-Rice model parameter files (LRP files). Optional files include city location files, cartographic boundary files, user-defined terrain files, path-loss input files, antenna radiation pattern files, and color definition files.

## SPLAT DATA FILES

**SPLAT!** imports topographic data in the form of SPLAT Data Files (SDFs). These files may be generated from a number of information sources. In the United States, SPLAT Data Files can be generated through U.S. Geological Survey Digital Elevation Models (DEMs) using the **usgs2sdf** utility included with **SPLAT!**. USGS Digital Elevation Models compatible with this utility may be downloaded from: *http://edcftp.cr.usgs.gov/pub/data/DEM/250/.*

Significantly better resolution and accuracy can be obtained through the use of SRTM-3 Version 2 digital elevation models. These models are the product of the STS-99 Space Shuttle Radar Topography Mission, and are available for most populated regions of the Earth. SPLAT Data Files may be generated from SRTM data using the included **srtm2sdf** utility. SRTM-3 Version 2 data may be obtained through anonymous FTP from: *ftp://e0srp01u.ecs.nasa.gov:21/srtm/version2/*

The **strm2sdf** utility may also be used to convert 3-arc second SRTM data in Band Interleaved by Line (.BIL) format for use with **SPLAT!**. This data is available via the web at: *http://seamless.usgs.gov/website/seamless/*

Band Interleaved by Line data must be downloaded in a very specific manner to be compatible with **srtm2sdf** and **SPLAT!**. Please consult **srtm2sdf**'s documentation for instructions on downloading .BIL topographic data through the USGS's Seamless Web Site.

Despite the higher accuracy that SRTM data has to offer, some voids in the data sets exist. When voids are detected, the **srtm2sdf** utility replaces them with corresponding data found in existing SDF files (that were presumably created from earlier USGS data through the **usgs2sdf** utility). If USGS-derived SDF data is not available, voids are handled through adjacent pixel averaging, or direct replacement.

SPLAT Data Files contain integer value topographic elevations (in meters) referenced to mean sea level for 1-degree by 1-degree regions of the earth with a resolution of 3-arc seconds. SDF files can be read in either standard format (*.sdf*) as generated by the **usgs2sdf** and **srtm2sdf** utilities, or in bzip2 compressed format (*.sdf.bz2*). Since uncompressed files can be read slightly faster than files that have been compressed, **SPLAT!** searches for needed SDF data in uncompressed format first. If uncompressed data cannot be located, **SPLAT!** then searches for data in bzip2 compressed format. If no compressed SDF files can be found for the region requested, **SPLAT!** assumes the region is over water, and will assign an elevation of sea-level to these areas.

This feature of **SPLAT!** makes it possible to perform path analysis not only over land, but also between coastal areas not represented by Digital Elevation Model data. However, this behavior of **SPLAT!** underscores the importance of having all the SDF files required for the region being analyzed if meaningful results are to be expected.

## SITE LOCATION (QTH) FILES

**SPLAT!** imports site location information of transmitter and receiver sites analyzed by the program from ASCII files having a *.qth* extension. QTH files contain the site's name, the site's latitude (positive if North of the equator, negative if South), the site's longitude (in degrees West, 0 to 360 degrees, or degrees East 0 to -360 degrees), and the site's antenna height above ground level (AGL), each separated by a single line-feed character. The antenna height is assumed to be specified in feet unless followed by the letter *m* or the word *meters* in either upper or lower case. Latitude and longitude information may be expressed in either decimal format (74.6864) or degree, minute, second (DMS) format (74 41 11.0).

For example, a site location file describing television station WNJT-DT, Trenton, NJ (*wnjt-dt.qth*) might read as follows:

```
WNJT-DT
40.2828
74.6864
990.00
```

Each transmitter and receiver site analyzed by **SPLAT!** must be represented by its own site location (QTH) file.

## LONGLEY-RICE PARAMETER (LRP) FILES

Longley-Rice parameter data files are required for **SPLAT!** to determine RF path loss in either point-to-point or area prediction mode. Longley-Rice model parameter data is read from files having the same base name as the transmitter site QTH file, but with a format (*wnjt-dt.lrp*):

```
15.000  ; Earth Dielectric Constant (Relative permittivity)
0.005   ; Earth Conductivity (Siemens per meter)
301.000 ; Atmospheric Bending Constant (N-units)
647.000 ; Frequency in MHz (20 MHz to 20 GHz)
5       ; Radio Climate (5 = Continental Temperate)
0       ; Polarization (0 = Horizontal, 1 = Vertical)
0.50    ; Fraction of situations (50% of locations)
0.90    ; Fraction of time (90% of the time)
46000.0 ; ERP in Watts (optional)
```

If an LRP file corresponding to the tx_site QTH file cannot be found, **SPLAT!** scans the current working directory for the file "splat.lrp". If this file cannot be found, then default parameters will be assigned by **SPLAT!** and a corresponding "splat.lrp" file containing these default parameters will be written to the current working directory. The generated "splat.lrp" file can then be edited by the user as needed.

Typical Earth dielectric constants and conductivity values are as follows:

```
                     Dielectric Constant  Conductivity
Salt water       :        80                5.000
Good ground      :        25                0.020
Fresh water      :        80                0.010
Marshy land      :        12                0.007
Farmland, forest :        15                0.005
Average ground   :        15                0.005
Mountain, sand   :        13                0.002
City             :         5                0.001
Poor ground      :         4                0.001
```

Radio climate codes used by **SPLAT!** are as follows:

```
1: Equatorial (Congo)
2: Continental Subtropical (Sudan)
3: Maritime Subtropical (West coast of Africa)
4: Desert (Sahara)
5: Continental Temperate
6: Maritime Temperate, over land (UK and west coasts of US & EU)
7: Maritime Temperate, over sea
```

The Continental Temperate climate is common to large land masses in the temperate zone, such as the United States. For paths shorter than 100 km, there is little difference between Continental and Maritime Temperate climates.

The seventh and eighth parameters in the *.lrp* file correspond to the statistical analysis provided by the Longley-Rice model. In this example, **SPLAT!** will return the maximum path loss occurring 50% of the time (fraction of time) in 90% of situations (fraction of situations). This is often denoted as F(50,90) in Longley-Rice studies. In the United States, an F(50,90) criteria is typically used for digital television (8-level VSB modulation), while F(50,50) is used for analog (VSB-AM+NTSC) broadcasts.

For further information on these parameters, see: *http://flattop.its.bldrdoc.gov/itm.html* and *http://www.softwright.com/faq/engineering/prop_longley_rice.html*

The final parameter in the *.lrp* file corresponds to the transmitter's effective radiated power, and is optional. If it is included in the levels and field strength level contours when performing Longley-Rice studies. If the parameter is omitted, path loss is computed instead. The ERP provided in the *.lrp* file can be overridden by using **SPLAT!**'s *-erp* command-line switch. If the *.lrp* file contains an ERP parameter and the generation of path-loss rather than signal strength contours is desired, the ERP can be assigned to zero using the *-erp* switch without having to edit the *.lrp* file to accomplish the same result.

## CITY LOCATION FILES

The names and locations of cities, tower sites, or other points of interest may be imported and plotted on topographic maps generated by **SPLAT!**. **SPLAT!** imports the names of cities and locations from ASCII files containing the location of interest's name, latitude, and longitude. Each field is separated by a comma. Each record is separated by a single line feed character. As was the case with the *.qth* files, latitude and longitude information may be entered in either decimal or degree, minute, second (DMS) format.

For example (*cities.dat*):

```
Teaneck, 40.891973, 74.014506
Tenafly, 40.919212, 73.955892
Teterboro, 40.859511, 74.058908
```

```
Tinton Falls, 40.279966, 74.093924
Toms River, 39.977777, 74.183580
Totowa, 40.906160, 74.223310
Trenton, 40.219922, 74.754665
```

A total of five separate city data files may be imported at a time, and there is no limit to the size of these files. **SPLAT!** reads city data on a "first come/first served" basis, and plots only those locations whose annotations do not conflict with annotations of locations read earlier in the current city data file, or in previous files. This behavior minimizes clutter in **SPLAT!** generated topographic maps, but also mandates that important locations be placed toward the beginning of the first city data file, and locations less important be positioned further down the list or in subsequent data files.

City data files may be generated manually using any text editor, imported from other sources, or derived from data available from the U.S. Census Bureau using the **citydecoder** utility included with **SPLAT!**. Such data is available free of charge via the Internet at: *http://www.census.gov/geo/www/cob/bdy_files.html*, and must be in ASCII format.

## CARTOGRAPHIC BOUNDARY DATA FILES

Cartographic boundary data may also be imported to plot the boundaries of cities, counties, or states on topographic maps generated by **SPLAT!**. Such data must be of the form of ARC/INFO Ungenerate (ASCII Format) Metadata Cartographic Boundary Files, and are available from the U.S. Census Bureau via the Internet at: *http://www.census.gov/geo/www/cob/co2000.html#ascii* and *http://www.census.gov/geo/www/cob/pl2000.html#ascii*. A total of five separate cartographic boundary files may be imported at a time. It is not necessary to import state boundaries if county boundaries have already been imported.

## PROGRAM OPERATION

**SPLAT!** is invoked via the command-line using a series of switches and arguments. Since **SPLAT!** is a CPU and memory intensive application, this type of interface minimizes overhead and lends itself well to scripted (batch) operations. **SPLAT!**'s CPU and memory scheduling priority may be modified through the use of the Unix **nice** command.

The number and type of switches passed to **SPLAT!** determine its mode of operation and method of output data generation. Nearly all of **SPLAT!**'s switches may be cascaded in any order on the command line when invoking the program.

**SPLAT!** operates in two distinct modes: *point-to-point mode*, and *area prediction mode*. Either a line-of-sight (LOS) or Longley-Rice Irregular Terrain (ITM) propagation model may be invoked by the user. True Earth, four-thirds Earth, or any other user-defined Earth radius may be specified when performing line-of-sight analysis.

## POINT-TO-POINT ANALYSIS

**SPLAT!** may be used to perform line-of-sight terrain analysis between two specified site locations. For example:

```
splat -t tx_site.qth -r rx_site.qth
```

invokes a line-of-sight terrain analysis between the transmitter specified in *tx_site.qth* and receiver specified in *rx_site.qth* using a True Earth radius model, and writes a **SPLAT!** Path Analysis Report to the current working directory. The report contains details of the transmitter and receiver sites, and identifies the location of any obstructions detected along the line-of-sight path. If an obstruction can be cleared by raising the receive antenna to a greater altitude, **SPLAT!** will indicate the minimum antenna height required for a line-of-sight path to exist between the transmitter and receiver locations specified. Note that imperial units (miles, feet) are specified unless the *-metric* switch is added to **SPLAT!**'s command line options:

```
splat -t tx_site.qth -r rx_site.qth -metric
```

If the antenna must be raised a significant amount, this determination may take a few moments. Note that the results provided are the *minimum* necessary for a line-of-sight path to exist, and in the case of this simple example, do not take Fresnel zone clearance requirements into consideration.

*qth* extensions are assumed by **SPLAT!** for QTH files, and are optional when specifying -t and -r arguments on the command-line. **SPLAT!** automatically reads all SPLAT Data Files necessary to conduct the terrain analysis between the sites specified. **SPLAT!** searches for the required SDF files in the current working directory first. If the needed files are not found, **SPLAT!** then searches in the path specified by the *-d* command-line switch:

```
splat -t tx_site -r rx_site -d /cdrom/sdf/
```

An external directory path may be specified by placing a ".splat_path" file under the user's home directory. This file must contain the full directory path of last resort to all the SDF files. The path in the *$HOME/.splat_path* file must be of the form of a single line of ASCII text:

```
/opt/splat/sdf/
```

and can be generated using any text editor.

A graph of the terrain profile between the receiver and transmitter locations as a function of distance from the receiver can be generated by adding the *-p* switch:

```
splat -t tx_site -r rx_site -p terrain_profile.png
```

**SPLAT!** invokes **gnuplot** when generating graphs. The filename extension specified to **SPLAT!** determines the format of the graph produced. *.png* will produce a 640x480 color PNG graphic file, while *.ps* or *.postscript* will produce postscript output. Output in formats such as GIF, Adobe Illustrator, AutoCAD dxf, LaTeX, and many others are available. Please consult **gnuplot**, and **gnuplot**'s documentation for details on all the supported output formats.

A graph of elevations subtended by the terrain between the receiver and transmitter as a function of distance from the receiver can be generated by using the *-e* switch:

```
splat -t tx_site -r rx_site -e elevation_profile.png
```

The graph produced using this switch illustrates the elevation and depression angles resulting from the terrain between the receiver's location and the transmitter site from the perspective of the receiver's location. A second trace is plotted between the left side of the graph (receiver's location) and the location of the transmitting antenna on the right. This trace illustrates the elevation angle required for a line-of-sight path to exist between the receiver and transmitter locations. If the trace intersects the elevation profile at any point on the graph, then this is an indication that a line-of-sight path does not exist under the conditions given, and the obstructions can be clearly identified on the graph at the point(s) of intersection.

A graph illustrating terrain height referenced to a line-of-sight path between the transmitter and receiver may be generated using the *-h* switch:

```
splat -t tx_site -r rx_site -h height_profile.png
```

A terrain height plot normalized to the transmitter and receiver antenna heights can be obtained using the *-H* switch:

```
splat -t tx_site -r rx_site -H normalized_height_profile.png
```

A contour of the Earth's curvature is also plotted in this mode.

The first Fresnel Zone, and 60% of the first Fresnel Zone can be added to height profile graphs by adding the *-f* switch, and specifying a frequency (in MHz) at which the Fresnel Zone should be modeled:

```
splat -t tx_site -r rx_site -f 439.250 -H normalized_height_profile.png
```

Fresnel Zone clearances other 60% can be specified using the *-fz* switch as follows:

```
splat -t tx_site -r rx_site -f 439.250 -fz 75 -H height_profile2.png
```

A graph showing Longley-Rice path loss may be plotted using the *-l* switch:

```
splat -t tx_site -r rx_site -l path_loss_profile.png
```

As before, adding the *-metric* switch forces the graphs to be plotted using metric units of measure.

When performing a point-to-point analysis, a **SPLAT!** Path Analysis Report is generated in the form of a text file with a *.txt* filename extension. The report contains bearings and distances between the transmitter and receiver, as well as the free-space and Longley-Rice path loss for the path being analyzed. The mode of propagation for the path is given as *Line-of-Sight*, *Single Horizon*, *Double Horizon*, *Diffraction Dominant*, or *Troposcatter Dominant*.

Distances and locations to known obstructions along the path between transmitter and receiver are also provided. If the transmitter's effective radiated power is specified in the transmitter's corresponding *.lrp* file, then predicted signal strength and antenna voltage at the receiving location is also provided in the Path Analysis Report.

To determine the signal-to-noise (SNR) ratio at remote location where random Johnson (thermal) noise is the primary limiting factor in reception:

$$SNR = T - NJ - L + G - NF$$

where **T** is the ERP of the transmitter in dBW in the direction of the receiver, **NJ** is Johnson Noise in dBW (-136 dBW for a 6 MHz television channel), **L** is the path loss provided by **SPLAT!** in dB (as a *positive* number), **G** is the receive antenna gain in dB over isotropic, and **NF** is the receiver noise figure in dB.

**T** may be computed as follows:

$$T = TI + GT$$

where **TI** is actual amount of RF power delivered to the transmitting antenna in dBW, **GT** is the transmitting antenna gain (over isotropic) in the direction of the receiver (or the horizon if the receiver is over the horizon).

To compute how much more signal is available over the minimum to necessary to achieve a specific signal-to-noise ratio:

$$Signal\_Margin = SNR - S$$

where **S** is the minimum required SNR ratio (15.5 dB for ATSC (8-level VSB) DTV, 42 dB for analog NTSC television).

A topographic map may be generated by **SPLAT!** to visualize the path between the transmitter and receiver sites from yet another perspective. Topographic maps generated by **SPLAT!** display elevations using a logarithmic grayscale, with higher elevations represented through brighter shades of gray. The dynamic range of the image is scaled between the highest and lowest elevations present in the map. The only exception to this is sea-level, which is represented using the color blue.

Topographic output is invoked using the *-o* switch:

```
splat -t tx_site -r rx_site -o topo_map.ppm
```

The *.ppm* extension on the output filename is assumed by **SPLAT!**, and is optional.

In this example, *topo_map.ppm* will illustrate the locations of the transmitter and receiver sites specified. In addition, the great circle path between the two sites will be drawn over locations for which an unobstructed path exists to the transmitter at a receiving antenna height equal to that of the receiver site (specified in *rx_site.qth*).

It may desirable to populate the topographic map with names and locations of cities, tower sites, or other important locations. A city file may be passed to **SPLAT!** using the *-s* switch:

```
splat -t tx_site -r rx_site -s cities.dat -o topo_map
```

Up to five separate city files may be passed to **SPLAT!** at a time following the *-s* switch.

County and state boundaries may be added to the map by specifying up to five U.S. Census Bureau cartographic boundary files using the *-b* switch:

```
splat -t tx_site -r rx_site -b co34_d00.dat -o topo_map
```

In situations where multiple transmitter sites are in use, as many as four site locations may be passed to **SPLAT!** at a time for analysis:

```
splat -t tx_site1 tx_site2 tx_site3 tx_site4 -r rx_site -p profile.png
```

In this example, four separate terrain profiles and obstruction reports will be generated by **SPLAT!**. A single topographic map can be specified using the *-o* switch, and line-of-sight paths between each transmitter and the receiver site indicated will be produced on the map, each in its own color. The path between the first transmitter specified to the receiver will be in green, the path between the second transmitter and the receiver will be in cyan, the path between the third transmitter and the receiver will be in violet, and the path between the fourth transmitter and the receiver will be in sienna.

**SPLAT!** generated topographic maps are 24-bit TrueColor Portable PixMap (PPM) images. They may be viewed, edited, or converted to other graphic formats by popular image viewing applications such as **xv**, **The GIMP**, **ImageMagick**, and **XPaint**. PNG format is highly recommended for lossless compressed storage of **SPLAT!** generated topographic output files. **ImageMagick**'s command-line utility easily converts **SPLAT!**'s PPM files to PNG format:

```
convert splat_map.ppm splat_map.png
```

Another excellent PPM to PNG command-line utility is available at: *http://www.libpng.org/pub/png/book/sources.html*. As a last resort, PPM files may be compressed using the bzip2 utility, and read directly by **The GIMP** in this format.

The *-ngs* option assigns all terrain to the color white, and can be used when it is desirable to generate a map that is devoid of terrain:

```
splat -t tx_site -r rx_site -b co34_d00.dat -ngs -o white_map
```

The resulting .ppm image file can be converted to .png format with a transparent background using **ImageMagick**'s **convert** utility:

```
convert -transparent "#FFFFFF" white_map.ppm transparent_map.png
```

## REGIONAL COVERAGE ANALYSIS

**SPLAT!** can analyze a transmitter or repeater site, or network of sites, and predict the regional coverage for each site specified. In this mode, **SPLAT!** can generate a topographic map displaying the geometric line-of-sight coverage area of the sites based on the location of each site and the height of receive antenna wishing to communicate with the site in question. A regional analysis may be performed by **SPLAT!** using the *-c* switch as follows:

```
splat -t tx_site -c 30.0 -s cities.dat -b co34_d00.dat -o tx_coverage
```

In this example, **SPLAT!** generates a topographic map called *tx_coverage.ppm* that illustrates the predicted line-of-sight regional coverage of *tx_site* to receiving locations having antennas 30.0 feet above ground level (AGL). If the *-metric* switch is used, the argument following the *-c* switch is interpreted as being in meters rather than in feet. The contents of *cities.dat* are plotted on the map, as are the cartographic boundaries contained in the file *co34_d00.dat*.

When plotting line-of-sight paths and areas of regional coverage, **SPLAT!** by default does not account for the effects of atmospheric bending. However, this behavior may be modified by using the Earth radius multiplier (*-m*) switch:

```
splat -t wnjt-dt -c 30.0 -m 1.333 -s cities.dat -b counties.dat -o
map.ppm
```

An earth radius multiplier of 1.333 instructs **SPLAT!** to use the "four-thirds earth" model for line-of-sight propagation analysis. Any appropriate earth radius multiplier may be selected by the user.

When performing a regional analysis, **SPLAT!** generates a site report for each station analyzed. **SPLAT!** site reports contain details of the site's geographic location, its height above mean sea level, the antenna's height above mean sea level, the antenna's height above average terrain, and the height of the average terrain calculated toward the bearings of 0, 45, 90, 135, 180, 225, 270, and 315 degrees azimuth.

## DETERMINING MULTIPLE REGIONS OF LOS COVERAGE

**SPLAT!** can also display line-of-sight coverage areas for as many as four separate transmitter sites on a common topographic map. For example:

```
splat -t site1 site2 site3 site4 -c 10.0 -metric -o network.ppm
```

plots the regional line-of-sight coverage of site1, site2, site3, and site4 based on a receive antenna located 10.0 meters above ground level. A topographic map is then written to the file *network.ppm*. The line-of-sight coverage area of the transmitters are plotted as follows in the colors indicated (along with their corresponding RGB values in decimal):

```
site1: Green (0,255,0)
site2: Cyan (0,255,255)
site3: Medium Violet (147,112,219)
site4: Sienna 1 (255,130,71)

site1 + site2: Yellow (255,255,0)
site1 + site3: Pink (255,192,203)
site1 + site4: Green Yellow (173,255,47)
```

```
site2 + site3: Orange (255,165,0)
site2 + site4: Dark Sea Green 1 (193,255,193)
site3 + site4: Dark Turquoise (0,206,209)

site1 + site2 + site3: Dark Green (0,100,0)
site1 + site2 + site4: Blanched Almond (255,235,205)
site1 + site3 + site4: Medium Spring Green (0,250,154)
site2 + site3 + site4: Tan (210,180,140)

site1 + site2 + site3 + site4: Gold2 (238,201,0)
```

If separate *.qth* files are generated, each representing a common site location but a different antenna height, a single topographic map illustrating the regional coverage from as many as four separate locations on a single tower may be generated by **SPLAT!**.

## LONGLEY-RICE PATH LOSS ANALYSIS

If the *-c* switch is replaced by a *-L* switch, a Longley-Rice path loss map for a transmitter site may be generated:

```
splat -t wnjt -L 30.0 -s cities.dat -b co34_d00.dat -o path_loss_map
```

In this mode, **SPLAT!** generates a multi-color map illustrating expected signal levels in areas surrounding the transmitter site. A legend at the bottom of the map correlates each color with a specific path loss range in decibels or signal strength in decibels over one microvolt per meter (dBuV/m).

The Longley-Rice analysis range may be modified to a user-specific value using the *-R* switch. The argument must be given in miles (or kilometers if the *-metric* switch is used). If a range wider than the generated topographic map is specified, **SPLAT!** will perform Longley-Rice path loss calculations between all four corners of the area prediction map.

The *-db* switch allows a constraint to be placed on the maximum path loss region plotted on the map. A maximum path loss between 80 and 230 dB may be specified using this switch. For example, if a path loss beyond -140 dB is irrelevant to the survey being conducted, **SPLAT!**'s path loss plot can be constrained to the region bounded by the 140 dB attenuation contour as follows:

```
splat -t wnjt-dt -L 30.0 -s cities.dat -b co34_d00.dat -db 140 -o
plot.ppm
```

## SIGNAL CONTOUR COLOR DEFINITION PARAMETERS

The colors used to illustrate signal strength and path loss contours in **SPLAT!** generated coverage maps may be tailored by the user by creating or modifying **SPLAT!**'s color definition files. **SPLAT!** color definition files have the same base name as the transmitter's *.qth* file, but carry *.lcf* and *.scf* extensions.

When a regional Longley-Rice analysis is performed and the transmitter's ERP is not specified or is zero, a *.lcf* path loss color definition file corresponding to the transmitter site (*.qth*) is read by **SPLAT!** from the current working directory. If a *.lcf* file corresponding to the transmitter site is not found, then a default file suitable for manual editing by the user is automatically generated by **SPLAT!**. If the transmitter's ERP is specified, then a signal strength map is generated and a signal strength color definition file (*.scf*) is read, or generated if one is not available in the current working directory.

A path-loss color definition file possesses the following structure (*wnjt-dt.lcf*):

```
; SPLAT! Auto-generated Path-Loss Color Definition ("wnjt-dt.lcf") File
;
; Format for the parameters held in this file is as follows:
```

```
;
;    dB: red, green, blue
;
; ...where "dB" is the path loss (in dB) and
; "red", "green", and "blue" are the corresponding RGB color
; definitions ranging from 0 to 255 for the region specified.
;
; The following parameters may be edited and/or expanded
; for future runs of SPLAT!  A total of 32 contour regions
; may be defined in this file.
;
;
 80: 255,   0,   0
 90: 255, 128,   0
100: 255, 165,   0
110: 255, 206,   0
120: 255, 255,   0
130: 184, 255,   0
140:   0, 255,   0
150:   0, 208,   0
160:   0, 196, 196
170:   0, 148, 255
180:  80,  80, 255
190:   0,  38, 255
200: 142,  63, 255
210: 196,  54, 255
220: 255,   0, 255
230: 255, 194, 204
```

If the path loss is less than 80 dB, the color Red (RGB = 255, 0, 0) is assigned to the region. If the path-loss is greater than or equal to 80 dB, but less than 90 db, then Dark Orange (255, 128, 0) is assigned to the region. Orange (255, 165, 0) is assigned to regions having a path loss greater than or equal to 90 dB, but less than 100 dB, and so on. Greyscale terrain is displayed beyond the 230 dB path loss contour.

**SPLAT!** signal strength color definition files share a very similar structure (*wnjt-dt.scf*):

```
; SPLAT! Auto-generated Signal Color Definition ("wnjt-dt.scf") File
;
; Format for the parameters held in this file is as follows:
;
;    dBuV/m: red, green, blue
;
; ...where "dBuV/m" is the signal strength (in dBuV/m) and
; "red", "green", and "blue" are the corresponding RGB color
; definitions ranging from 0 to 255 for the region specified.
;
; The following parameters may be edited and/or expanded
; for future runs of SPLAT!  A total of 32 contour regions
; may be defined in this file.
;
;
128: 255,   0,   0
118: 255, 165,   0
```

```
 108: 255, 206,   0
  98: 255, 255,   0
  88: 184, 255,   0
  78:   0, 255,   0
  68:   0, 208,   0
  58:   0, 196, 196
  48:   0, 148, 255
  38:  80,  80, 255
  28:   0,  38, 255
  18: 142,  63, 255
   8: 140,   0, 128
```

If the signal strength is greater than or equal to 128 db over 1 microvolt per meter (dBuV/m), the color Red (255, 0, 0) is displayed for the region. If the signal strength is greater than or equal to 118 dbuV/m, but less than 128 dbuV/m, then the color Orange (255, 165, 0) is displayed, and so on. Greyscale terrain is displayed for regions with signal strengths less than 8 dBuV/m.

Signal strength contours for some common VHF and UHF broadcasting services in the United States are as follows:

```
Analog Television Broadcasting
------------------------------
Channels 2-6:       City Grade: >= 74 dBuV/m
                       Grade A: >= 68 dBuV/m
                       Grade B: >= 47 dBuV/m
--------------------------------------------
Channels 7-13:      City Grade: >= 77 dBuV/m
                       Grade A: >= 71 dBuV/m
                       Grade B: >= 56 dBuV/m
--------------------------------------------
Channels 14-69:   Indoor Grade: >= 94 dBuV/m
                    City Grade: >= 80 dBuV/m
                       Grade A: >= 74 dBuV/m
                       Grade B: >= 64 dBuV/m

Digital Television Broadcasting
-------------------------------
Channels 2-6:       City Grade: >= 35 dBuV/m
             Service Threshold: >= 28 dBuV/m
--------------------------------------------
Channels 7-13:      City Grade: >= 43 dBuV/m
             Service Threshold: >= 36 dBuV/m
--------------------------------------------
Channels 14-69:     City Grade: >= 48 dBuV/m
             Service Threshold: >= 41 dBuV/m

NOAA Weather Radio (162.400 - 162.550 MHz)
------------------------------------------
           Reliable: >= 18 dBuV/m
       Not reliable: <  18 dBuV/m
Unlikely to receive: <  0 dBuV/m

FM Radio Broadcasting (88.1 - 107.9 MHz)
```

```
----------------------------------------
Analog Service Contour:  60 dBuV/m
Digital Service Contour: 65 dBuV/m
```

## ANTENNA RADIATION PATTERN PARAMETERS

Normalized field voltage patterns for a transmitting antenna's horizontal and vertical planes are imported automatically into **SPLAT!** when a Longley-Rice coverage analysis is performed. Antenna pattern data is read from a pair of files having the same base name as the transmitter and LRP files, but with *.az* and *.el* extensions for azimuth and elevation pattern files, respectively. Specifications regarding pattern rotation (if any) and mechanical beam tilt and tilt direction (if any) are also contained within **SPLAT!** antenna pattern files.

For example, the first few lines of a **SPLAT!** azimuth pattern file might appear as follows (*kvea.az*):

```
183.0
0       0.8950590
1       0.8966406
2       0.8981447
3       0.8995795
4       0.9009535
5       0.9022749
6       0.9035517
7       0.9047923
8       0.9060051
```

The first line of the *.az* file specifies the amount of azimuthal pattern rotation (measured clockwise in degrees from True North) to be applied by **SPLAT!** to the data contained in the *.az* file. This is followed by azimuth headings (0 to 360 degrees) and their associated normalized field patterns (0.000 to 1.000) separated by whitespace.

The structure of **SPLAT!** elevation pattern files is slightly different. The first line of the *.el* file specifies the amount of mechanical beam tilt applied to the antenna. Note that a *downward tilt* (below the horizon) is expressed as a *positive angle*, while an *upward tilt* (above the horizon) is expressed as a *negative angle*. This data is followed by the azimuthal direction of the tilt, separated by whitespace.

The remainder of the file consists of elevation angles and their corresponding normalized voltage radiation pattern (0.000 to 1.000) values separated by whitespace. Elevation angles must be specified over a -10.0 to +90.0 degree range. As was the convention with mechanical beamtilt, *negative elevation angles* are used to represent elevations *above the horizon*, while *positive angles* represents elevations *below the horizon*.

For example, the first few lines a **SPLAT!** elevation pattern file might appear as follows (*kvea.el*):

```
 1.1    130.0
-10.0   0.172
-9.5    0.109
-9.0    0.115
-8.5    0.155
-8.0    0.157
-7.5    0.104
-7.0    0.029
-6.5    0.109
-6.0    0.185
```

In this example, the antenna is mechanically tilted downward 1.1 degrees towards an azimuth of 130.0 degrees.

For best results, the resolution of azimuth pattern data should be specified to the nearest degree azimuth, and elevation pattern data resolution should be specified to the nearest 0.01 degrees. If the pattern data specified does not reach this level of resolution, **SPLAT!** will interpolate the values provided to determine the data at the required resolution, although this may result in a loss in accuracy.

## IMPORTING AND EXPORTING REGIONAL PATH LOSS CONTOUR DATA

Performing a Longley-Rice coverage analysis can be a very time consuming process, especially if the analysis is repeated repeatedly to discover what effects changes to the antenna radiation patterns make to the predicted coverage area.

This process can be expedited by exporting the Longley-Rice regional path loss contour data to an output file, modifying the path loss data externally to incorporate antenna pattern effects, and then importing the modified path loss data back into **SPLAT!** to rapidly produce a revised path loss map.

For example, a path loss output file can be generated by **SPLAT!** for a receive site 30 feet above ground level over a 50 mile radius surrounding a transmitter site to a maximum path loss of 140 dB using the following syntax:

```
splat -t kvea -L 30.0 -R 50.0 -db 140 -plo pathloss.dat
```

**SPLAT!** path loss output files often exceed 100 megabytes in size. They contain information relating to the boundaries of region they describe followed by latitudes (degrees North), longitudes (degrees West), azimuths, elevations (to the first obstruction), and path loss figures (dB) for a series of specific points that comprise the region surrounding the transmitter site. The first few lines of a **SPLAT!** path loss output file take on the following appearance (*pathloss.dat*):

```
119, 117    ; max_west, min_west
35, 33      ; max_north, min_north
34.2265434, 118.0631104, 48.171, -37.461, 67.70
34.2270355, 118.0624390, 48.262, -26.212, 73.72
34.2280197, 118.0611038, 48.269, -14.951, 79.74
34.2285156, 118.0604401, 48.207, -11.351, 81.68
34.2290077, 118.0597687, 48.240, -10.518, 83.26
34.2294998, 118.0591049, 48.225, 23.201, 84.60
34.2304878, 118.0577698, 48.213, 15.769, 137.84
34.2309799, 118.0570984, 48.234, 15.965, 151.54
34.2314720, 118.0564346, 48.224, 16.520, 149.45
34.2319679, 118.0557632, 48.223, 15.588, 151.61
34.2329521, 118.0544281, 48.230, 13.889, 135.45
34.2334442, 118.0537643, 48.223, 11.693, 137.37
34.2339401, 118.0530930, 48.222, 14.050, 126.32
34.2344322, 118.0524292, 48.216, 16.274, 156.28
34.2354164, 118.0510941, 48.222, 15.058, 152.65
34.2359123, 118.0504227, 48.221, 16.215, 158.57
34.2364044, 118.0497589, 48.216, 15.024, 157.30
34.2368965, 118.0490875, 48.225, 17.184, 156.36
```

It is not uncommon for **SPLAT!** path loss files to contain as many as 3 million or more lines of data. Comments can be placed in the file if they are proceeded by a semicolon character. The **vim** text editor has proven capable of editing files of this size.

Note as was the case in the antenna pattern files, negative elevation angles refer to upward tilt (above the horizon), while positive angles refer to downward tilt (below the horizon). These angles refer to the elevation to the receiving antenna at the height above ground level specified using the *-L* switch *if* the path between transmitter and receiver is unobstructed. If the path between the transmitter and receiver is obstructed, then the elevation angle to the first obstruction is returned by **SPLAT!**. This is because the Longley-Rice model considers the energy reaching a distant point over an obstructed path as a derivative of the energy scattered from the top of the first obstruction, only. Since energy cannot reach the obstructed location directly, the actual elevation angle to that point is irrelevant.

When modifying **SPLAT!** path loss files to reflect antenna pattern data, *only the last column (path loss)* should be amended to reflect the antenna's normalized gain at the azimuth and elevation angles specified in the file. (At this time, programs and scripts capable of performing this operation are left as an exercise for the user.)

Modified path loss maps can be imported back into **SPLAT!** for generating revised coverage maps:

```
splat -t kvea -pli pathloss.dat -s city.dat -b county.dat -o map.ppm
```

**SPLAT!** path loss files can also be used for conducting coverage or interference studies outside of **SPLAT!**.

## USER-DEFINED TERRAIN INPUT FILES

A user-defined terrain file is a user-generated text file containing latitudes, longitudes, and heights above ground level of specific terrain features believed to be of importance to the **SPLAT!** analysis being conducted, but noticeably absent from the SDF files being used. A user-defined terrain file is imported into a **SPLAT!** analysis using the *-udt* switch:

```
splat -t tx_site -r rx_site -udt udt_file.txt -o map.ppm
```

A user-defined terrain file has the following appearance and structure:

```
40.32180556, 74.1325, 100.0 meters
40.321805, 74.1315, 300.0
40.3218055, 74.1305, 100.0 meters
```

Terrain height is interpreted as being described in feet above ground level unless followed by the word *meters*, and is added *on top of* the terrain specified in the SDF data for the locations specified. Be aware that each user-defined terrain feature specified will be interpreted as being 3-arc seconds in both latitude and longitude. Features described in the user-defined terrain file that overlap previously defined features in the file are ignored by **SPLAT!**.

## SIMPLE TOPOGRAPHIC MAP GENERATION

In certain situations it may be desirable to generate a topographic map of a region without plotting coverage areas, line-of-sight paths, or generating obstruction reports. There are several ways of doing this. If one wishes to generate a topographic map illustrating the location of a transmitter and receiver site along with a brief text report describing the locations and distances between the sites, the *-n* switch should be invoked as follows:

```
splat -t tx_site -r rx_site -n -o topo_map.ppm
```

If no text report is desired, then the *-N* switch is used:

```
splat -t tx_site -r rx_site -N -o topo_map.ppm
```

If a topographic map centered about a single site out to a minimum specified radius is desired instead, a command similar to the following can be used:

```
splat -t tx_site -R 50.0 -s NJ_Cities -b NJ_Counties -o topo_map.ppm
```

where -R specifies the minimum radius of the map in miles (or kilometers if the *-metric* switch is used). Note that the tx_site name and location are not displayed in this example. If display of this information is desired, simply create a **SPLAT!** city file (*-s* option) and append it to the list of command-line options illustrated above.

If the *-o* switch and output filename are omitted in these operations, topographic output is written to a file named *tx_site.ppm* in the current working directory by default.

## GEOREFERENCE FILE GENERATION

Topographic, coverage (*-c*), and path loss contour (*-L*) maps generated by **SPLAT!** may be imported into **Xastir** (X Amateur Station Tracking and Information Reporting) software by generating a georeference file using **SPLAT!**'s *-geo* switch:

```
splat -t kd2bd -R 50.0 -s NJ_Cities -b NJ_Counties -geo -o map.ppm
```

The georeference file generated will have the same base name as the *-o* file specified, but have a *.geo* extension, and permit proper interpretation and display of **SPLAT!**'s .ppm graphics in **Xastir** software.

## GOOGLE MAP KML FILE GENERATION

Keyhole Markup Language files compatible with **Google Earth** may be generated by **SPLAT!** when performing point-to-point or regional coverage analyses by invoking the *-kml* switch:

```
splat -t wnjt-dt -r kd2bd -kml
```

The KML file generated will have the same filename structure as a Path Analysis Report for the transmitter and receiver site names given, except it will carry a *.kml* extension.

Once loaded into **Google Earth** (File --> Open), the KML file will annotate the map display with the names of the transmitter and receiver site locations. The viewpoint of the image will be from the position of the transmitter site looking towards the location of the receiver. The point-to-point path between the sites will be displayed as a white line while the RF line-of-sight path will be displayed in green. **Google Earth**'s navigation tools allow the user to "fly" around the path, identify landmarks, roads, and other featured content.

When performing regional coverage analysis, the *.kml* file generated by **SPLAT!** will permit path loss or signal strength contours to be layered on top of **Google Earth**'s display in a semi-transparent manner. The generated *.kml* file will have the same basename as that of the *.ppm* file normally generated.

## DETERMINATION OF ANTENNA HEIGHT ABOVE AVERAGE TERRAIN

**SPLAT!** determines antenna height above average terrain (HAAT) according to the procedure defined by Federal Communications Commission Part 73.313(d). According to this definition, terrain elevations along eight radials between 2 and 10 miles (3 and 16 kilometers) from the site being analyzed are sampled and averaged for each 45 degrees of azimuth starting with True North. If one or more radials lie entirely over water or over land outside the United States (areas for which no USGS topography data is available), then those radials are omitted from the calculation of average terrain.

Note that SRTM elevation data, unlike older 3-arc second USGS data, extends beyond the borders of the United States. Therefore, HAAT results may not be in full compliance with FCC Part 73.313(d) in areas along the borders of the United States if the SDF files used by **SPLAT!** are SRTM-derived.

When performing point-to-point terrain analysis, **SPLAT!** determines the antenna height above average terrain only if enough topographic data has already been loaded by the program to perform the point-to-point analysis. In most cases, this will be true, unless the site in question does not lie within 10 miles of the boundary of the topography data in memory.

When performing area prediction analysis, enough topography data is normally loaded by **SPLAT!** to perform average terrain calculations. Under such conditions, **SPLAT!** will provide the antenna height above average terrain as well as the average terrain above mean sea level for azimuths of 0, 45, 90, 135, 180, 225, 270, and 315 degrees, and include such information in the generated site report. If one or more of the eight radials surveyed fall over water, or over regions for which no SDF data is available, **SPLAT!** reports *No Terrain* for the radial paths affected.

## RESTRICTING THE MAXIMUM SIZE OF AN ANALYSIS REGION

**SPLAT!** reads SDF files as needed into a series of memory "pages" within the structure of the program. Each "page" holds one SDF file representing a one degree by one degree region of terrain. A *#define MAXPAGES* statement in the first several lines of *splat.cpp* sets the maximum number of "pages" available for holding topography data. It also sets the maximum size of the topographic maps generated by **SPLAT!**. MAXPAGES is set to 9 by default. If **SPLAT!** produces a segmentation fault on start-up with this default, it is an indication that not enough RAM and/or virtual memory (swap space) is available to run **SPLAT!** with the number of MAXPAGES specified. In situations where available memory is low, MAXPAGES may be reduced to 4 with the understanding that this will greatly limit the maximum region **SPLAT!** will be able to analyze. If 118 megabytes or more of total memory (swap space plus RAM) is available, then MAXPAGES may be increased to 16. This will permit operation over a 4-degree by 4-degree region, which is sufficient for single antenna heights in excess of 10,000 feet above mean sea level, or point-to-point distances of over 1000 miles.

## ADDITIONAL INFORMATION

The latest news and information regarding **SPLAT!** software is available through the official **SPLAT!** software web page located at: *http://www.qsl.net/kd2bd/splat.html*.

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