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**P25 / TETRA Network  
Planning Using  
EDX SignalPro®**

# P25 / TETRA Network Planning Using EDX SignalPro®

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## **Introduction**

Public Safety wireless networks are a critical component in the operation of all national emergency services. P25 and TETRA are two different types of open interoperability standards used for public safety wireless systems and define the specifics of the underlying radio communication technologies. One benefit of using open standards such as P25 and TETRA, rather than using manufacture specific systems, is that equipment from different manufactures will be interoperable, increasing reliability while reducing overall system cost. These technologies are a type of land mobile radio (LMR) system which also includes older analog standards. P25 and TETRA however, use digital modulation allowing both voice and data communication to be used on existing narrowband radio channels. Designing these new digital radio networks requires careful planning to provide high levels of performance and reliability while also being cost effective.

EDX SignalPro® is a comprehensive RF planning tool that is well-suited to planning and optimizing these types of radio networks. This practical white paper describes the operation of these digital technologies, outlines their key performance parameters and shows how EDX SignalPro can be used to successfully design and optimize P25 and TETRA LMR systems.

## P25 and TETRA Network Planning

When you run a P25 or TETRA system RF study in EDX SIGNAL or SignalPro, the program will extract terrain and land-use (clutter) data, calculate signal levels, and build a composite area study grid in the same way it does in the main program for any type of transmitter or network. Before you enter equipment data or run any studies it is helpful to review *Section 8.4 of the EDX software Reference Manual* for more background on the common ways that you set up studies in EDX programs. It is important to be fluent with the basic operation and functions of *EDX SignalPro* before attempting to run studies on P25 or TETRA systems.

Both P25 and TETRA networks are composed of digitally modulated radios that multiplex users onto a radio channel using TDMA (Time Domain Multiple Access) methods. There can be one or more radio channels in use in a particular area by one or more transmitters. Channel bandwidth is typically 25 KHz, 12.5 KHz or 6.25 KHz. Signal coverage is always limited by the receiver's signal threshold (sensitivity) as well as interference from other transmitters using the same channel or adjacent channels.

## Entering Equipment Information

Before studies can be run, you must first define your equipment within the EDX program. Entering specifications for transmitters is relatively straightforward. Transmitter power, antenna system gains and losses, antenna types and antenna heights are the basic parameters that determine the effective power radiated from the antenna into the surrounding coverage area. The frequency entered for each transmitter is the nominal value used by the propagation model to determine path loss and Fresnel zone clearance for that transmitter.

Receiver parameters for both the Base Transmitter and the Mobile unit are also relatively straightforward. Antennas and transmission system gains and losses need to be entered and then the noise at the receiver needs to be determined. This level can be automatically calculated within the Receiver Parameters dialog box in the program by entering the channel bandwidth and the overall noise figure for the receiver and antenna system.

**Sector Receive Parameters**

**Antenna:**

Use antenna type database ?

Antenna type: [ ]

Antenna Pattern:  Use file  Omni/Isotropic

Polarization:  Horizontal  Vertical

Antenna pattern filename: [ C:\pats\26SD9890.pat ] [ Browse & Display... ]

Az. orient.: [ 180.0 ] Beam tilt: [ -2.0 ]  Rotate antenna Beam tilt az.: [ 180.0 ]

Antenna COR height (AGL): [ 30.00 ] m

Cross polarization rejection: [ 15.00 ] dB

Diversity receive antenna?

Effective diversity gain: [ 5.00 ] dB

**Transmission System:**

Transmission line type: [ 7/8" foam ]

Transmission line length: [ 20.00 ] m

Transmission line loss: [ 0.75 ] dB

Multiplexer/circ. loss: [ 0.00 ] dB

Misc. system losses: [ 0.00 ] dB

Antenna gain: [ 10.00 ] dBi

Radome loss: [ 0.00 ] dB

**Receiver:**

Use Receiver Type Database:

Receiver Type: [ ]

Required service threshold: [ -111.0 ] dBmW

Required service C/(I+N) ratio: [ 16.0 ] dB

Predicted Uplink Interference: [ N/A ] dBmW

Measured Uplink: [ -160.0 ] dBmW

Use measured uplink interference

Receiver noise level: [ -127.0 ] dBmW

Receiver system noise figure: [ 6.0 ] dB

Tower top amplifier or multicoupler in use

[ Specify amplifier characteristics ]

Equivalent receiver noise bandwidth: [ 0.0125 ] MHz

Receiver filter file code: [ 0 ]

Adjacent channel rejection: [ 20 ] dB

Set receive antenna and transmission system to be the same as the transmit antenna and transmission systems.

[ Set receive antenna and transmission systems same as TX. ]

[ OK ] [ Cancel ] [ Help ]

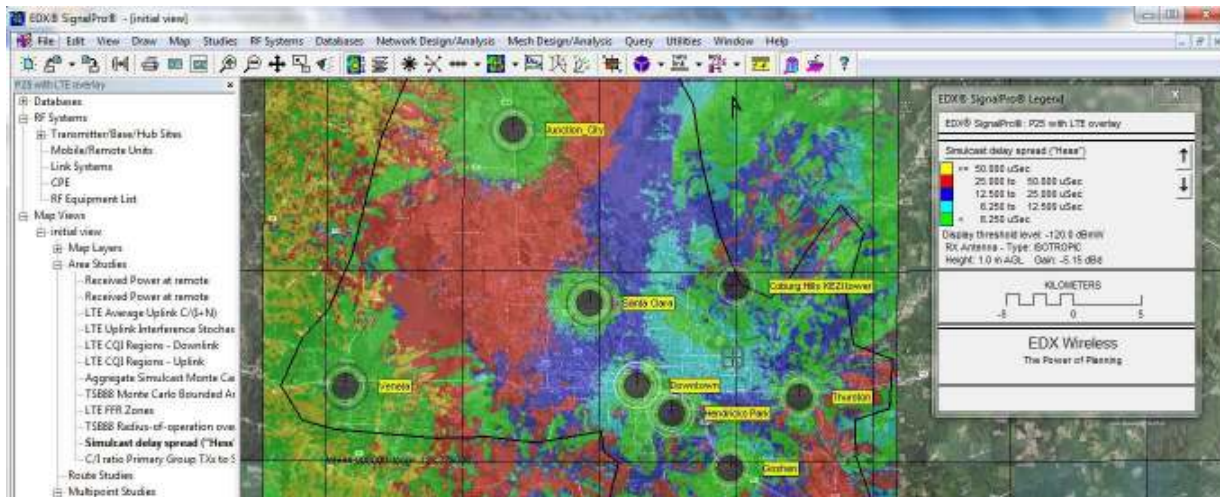
For Base Site receivers the use of a tower top amplifier or multicoupler is supported. There is a special entry box for this which will help to calculate the effective system gain as well as the effect on system noise. EDX software predicts thermal (“kTB”) noise at the receiver. For many systems, especially collocated and VHF systems, there is a higher level of externally-generated noise than internally-generated thermal noise. If the measured noise level at the receiver input is known, it should be entered as the “Receiver noise level” for the receiver.

There are similar parameters needed for the Remote/Mobile unit as found under **RF Systems - > Mobile/Remote unit.**

## Starting a P25/TETRA System Design

The *EDX SignalPro* program stores information for a study in ".XML" files the project directory. The project files contain all the parameters and other information needed to completely reproduce a study map on your screen when you open a selected project. The project includes the specific parameters for each of your transmitter sites/sectors, or links, as well as information about the databases, propagation models, and base map features. Projects are explained in *Chapter 3* of the *Reference Manual*.

*An example SignalPro TSB-88 study plot of a UHF T-band P25 system showing the simulcast delay spread:*

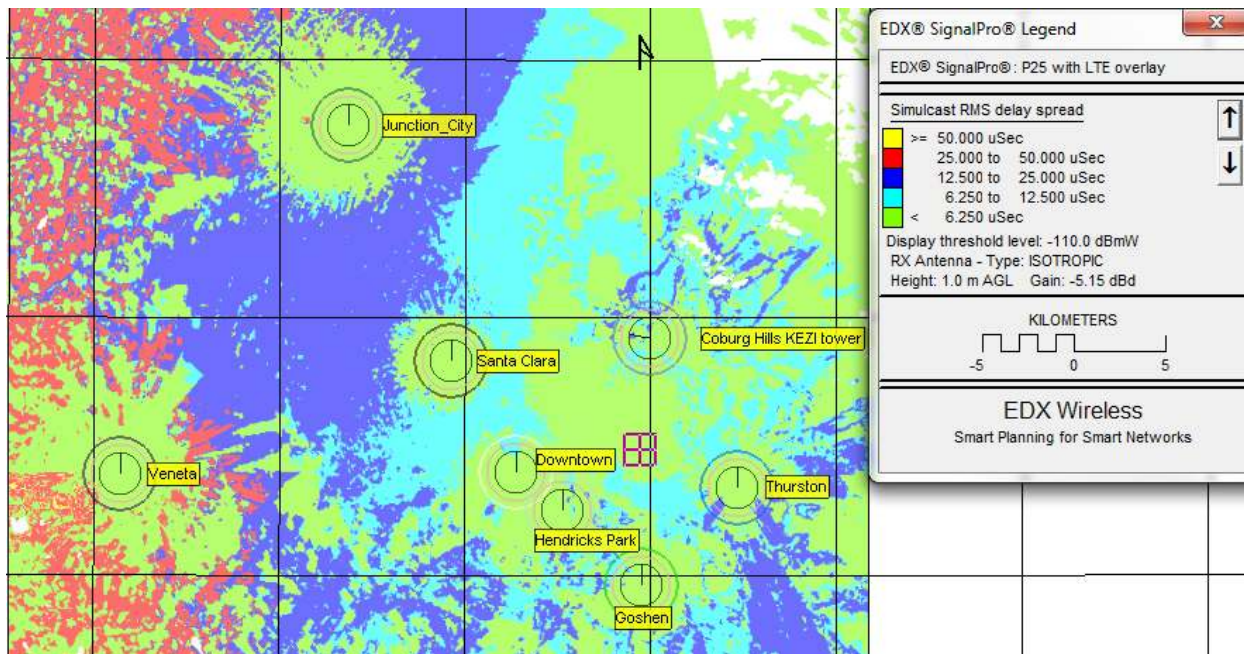


*This TSB-88 "Hess" simulcast delay spread study plot is shown overlaid on a Microsoft Bing aerial map, available in SignalPro.*

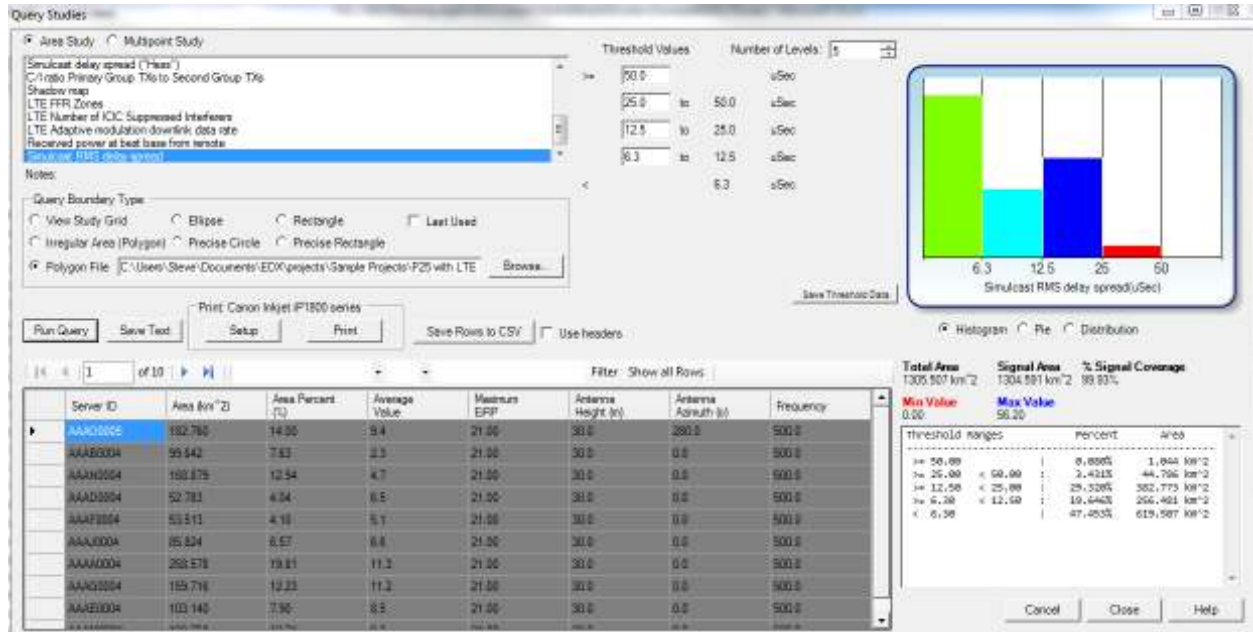
## “Tuning” Simulcast delays

Simulcast is when you use multiple base stations operating on the same radio channel to enhance coverage in overlap areas. Since this can have both coverage and capacity improvements, it is commonly used instead of multicast (each base station using separate channels). In order for simulcast coverage to be useful, the signals that arrive from multiple base stations must be above the receiver signal level threshold and they must arrive within a narrow window of time in order to not create inter-symbol interference. Weaker signals (those that are lower than the received signal level from the strongest base station minus the simulcast capture ratio) don't enhance or degrade system performance.

This often requires tuning of the simulcast delays, especially for systems that use tall sites and/or have a large coverage area. For example, here is a Simulcast RMS delay spread study plot for a UHF P25 system before the simulcast delays were tuned (all set to 0):



Here is a query of the statistics of this study:



The areas with highest simulcast delays are in the western portion of the coverage area and are due to the strong signals from a mountaintop site in the east (Coburg Hills KEZI). The simulcast delays at each point can be queried for a more refined analysis.

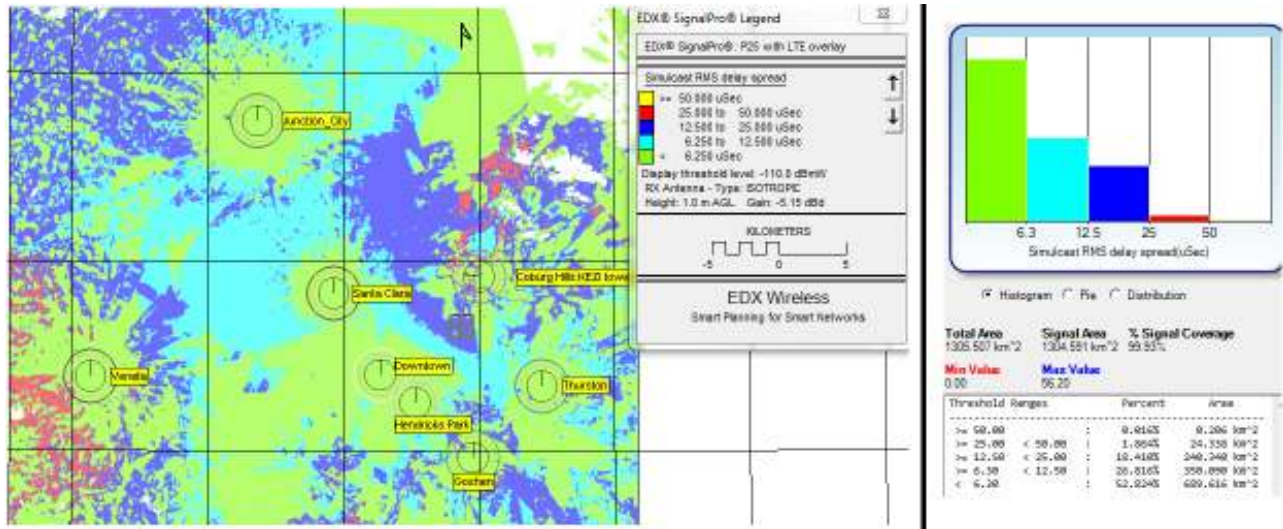
Below is a point query of a location that has high simulcast RMS delay spread:

Raw signal data for 'Simulcast RMS delay spread'

Sector	Downlink Power	Uplink Power	Distance	Bearing	Transit time
AAAO0005	-68.4 dBmW	-75.4 dBmW	27.0 km	88.8 deg	89.1 uS
AAAG0004	-69.7 dBmW	-76.7 dBmW	16.3 km	92.4 deg	53.9 uS
AAAM0004	-70.5 dBmW	-77.5 dBmW	7.0 km	192.4 deg	23.1 uS
AAAA0004	-89.1 dBmW	-96.1 dBmW	16.0 km	41.7 deg	52.9 uS

Note that at this point, there are three transmitters with received signals within a few dB of each other; all of them would be significant signals at the receiver. The strongest signal (AAAO0005) is considered the reference signal with a transit time to the receiver of 89.1uS. For ease of analysis we subtract 89.1 from all the transit times. Therefore the relative delay from AAAG0004 (with respect to AAAO0005) is -35.2uS and the relative delay from AAAM0004 is 66uS. Depending on the type of P25 or TETRA system being deployed, these delays will likely create inter-symbol interference that degrades simulcast performance in this area.

If the sites in the valley are “tuned” by adding group delays to some transmitters, the Simulcast RMS delay spread study plot and statistics improve, as can be seen below:



## Basic Studies

For study and analysis of basic system performance the equipment information described in the previous section about equipment parameters is sufficient. The following list shows the types of basic studies for which this information is sufficient:

- Shadow Map (Line-of-sight)
- Minimum Remote AGL
- Path loss between base and remote
- Received Power
- Field Strength
- Received Voltage
- Strongest (most likely) server
- Received power at best voting receiver
- Number of base receivers with power above threshold
- Number of servers at remote
- Number of servers within capture ratio
- Simulcast RMS delay spread
- Maximum simulcast delay spread
- Aggregate power flux density



What this means is that whether you have a traditional FM two-way system, or a digital P25 or TETRA system, or any other type of radio system, these basic studies can be run by simply knowing the base and remote transmitter ERP (effective radiated power), the directional radiation characteristics of all antennas, and the base and remote receiver antenna system gain/loss. Modulation type, digital coding, channel bandwidth, noise and interference or other unique system parameters are not necessary for these studies and are not used.

After you set up your terrain, clutter and optional building databases and choose the settings for your propagation model these basic studies can be run and displayed on the EDX SignalPro map. Note that the frequency entered for each transmitter is the nominal value used by the propagation model to determine path loss and Fresnel zone clearance for that transmitter.

## Studies Using Noise and Interference

EDX SignalPro also provides a number of other studies that require the consideration of noise and interference in order to give a correct result. In fact, one could say that it is these type of studies that show most clearly how a proposed P25 or TETRA radio system will perform since the ratio of signal (or carrier) versus noise plus interference ("C/(I+N)") at the receiver is actually what determines the ability of the receiver to successfully decode the modulated carrier. For example, in order for a traditional FM modulated signal using a 25KHz channel to be received with at least an audio quality of 20dB SINAD (TIA-TSB88 DAQ of 3.4) the C/(I+N) ratio at the receiver needs to be at least 20dB. Listed in table A below are the approximate required C/(I+N) ratios for the modulation types used in P25 and TETRA systems<sup>1</sup>.

Technology	Channel	Mod Type	C/(I+N)	
TETRA	25KHz	$\pi/4$ DQPSK	19dB	
P25	12.5KHz	QPSK-C	17dB	Phase I - DL
P25	12.5KHz	C4FM	18dB	Phase I - UL
P25	6.25KHz	DQPSK	16dB	Phase II - DL
P25	6.25KHz	CPM	19dB	Phase II - UL

**Table A** - Approximate C/(I+N) values needed for a TIA-TSB-88 DAQ of 3.4.

The following is a representative list of studies that need C/(I+N) in order to calculate the desired result. These are studies that can be useful in planning/analyzing P25/TETRA networks:

- $C/(I+N)$  at remote
- BER (Bit Error Rate)
- Percent log-normal reliability
- Uplink percent log-normal reliability
- Uplink percent log-normal reliability using voting receivers
- TIA/TSB-88 studies. These are important for evaluating and ensuring P25 system performance during the development phase.

Available TSB-88 Studies in SignalPro include:

- TSB-88 Monte Carlo bounded area coverage
- TSB-88 Radius-of-operation overlap reliability
- Aggregate simulcast Monte Carlo reliability
- Simulcast delay spread using Hess's calculation

It is important to note that many of these studies calculate their result using  $C/(I+N)$  as an input value which is applied to a formula or table to arrive at the result value. For example, the BER study uses a data file located in the *dig\_sys.dat* file located in the **..\Library Data\equipment** folder of the EDX program installation directory. This file contains a table for each modulation type (BPSK, QPSK, 16QAM, etc.) that correlates  $C/(I+N)$  value to a bit error rate in parts-per-million. Additional detail on how each study calculates its result is found in *Appendix F of the Reference Manual*.

For some of the studies listed above, it is necessary to know what is the minimum acceptable  $C/(I+N)$  ratio at the receiver for acceptable performance. This is also known as "Required service  $C/(I+N)$ " value found in the Receiver Parameters in the EDX program. This value is the dB difference between the noise threshold of the receiver and the receiver's service threshold. "Acceptable performance" is defined usually by the old SINAD value or the newer TSB88 DAQ (Digital Audio Quality) metric. You should determine what dB ratio is appropriate for your system and enter it into the Receiver parameters.

## Interference Calculation

The noise calculation at the receiver is determined by the parameters you enter in the Receiver Parameters dialog of the EDX program. The interference at the receiver is determined each time a study is run. Obviously the interference will vary depending upon the location of the remote/mobile unit. For a given mobile location, the signal from all transmitters is calculated. Then, the signals from all those transmitters who are classified as interferers are power summed to determine the interference level at the remote receiver. If the remote unit has a directional antenna then the pattern shape of this antenna is used to attenuate interfering signals that are off-axis to the main beam of the antenna.

EDX programs take into account the following additional factors when analyzing interference:

- **Channel center frequency** - this is the frequency either assigned to the transmitter when there is no channel plan in use, or it is the active channel when a channel plan is used.
- **Channel bandwidth** - either the noise bandwidth of the receiver or the channel bandwidth of a channel if a channel plan is in use.
- **Antenna pattern shape** - as determined by the antenna pattern file.
- **Antenna polarization** - the remote unit is assumed to take on the same polarization as the transmitter providing service to the unit.

As noted above, the channel center frequency is determined based on whether or not a channel plan is being used. In EDX SIGNAL and EDX SignalPro without the Network Design Module (prior to v8.1), there was no option to include a channel plan. Therefore, the channel center frequency was taken to be the value of the transmitter frequency as entered in the Transmitter details.

## Using a Channel Plan

In EDX Signal with the Network Design Module or in EDX SignalPro v8.1 (and later) you can choose to use a channel plan that allows you to consider that a transmitter may transmit on several channels simultaneously. The Network Design Module also includes a feature to automatically choose channels for a transmitter by finding the best channel assignment for lowest system interference. This feature is explained later in this document under Automatic Frequency Planning.

To begin, you need to create a channel plan template file that contain the channels you are going to be using in your system. A "channel" is described as having an index number to designate it, (i.e. 1,2,3...) a center frequency and a bandwidth. The format of the EDX channel plan template is described in Section 3.2 of the Multipoint Systems reference manual. For use with mobile systems only the first four values on each line are used (although the other values on the line must also be present) and the "channel use" type should always be "D". A sample of this channel plan template file is **WiMAX\_3.5GHz\_sample.cpt** as found in the `..\Library Data\cpt` folder of the EDX program installation directory.

In basic SignalPro v8.1+ you can set a channel plan in **RF Systems -> Generic Systems Channel Plan**. This channel plan will then be used for all transmitters whose **System Type** is set to "Generic". This is the most straightforward way to use a channel plan in your studies. Even if you have the Network Design Module installed you can still use this "Generic" plan if you like. Just remember that you won't be able to do Automatic Frequency Planning using this channel plan.

To manually set channels for your transmitters you can edit the Transmitter site details and click on the **Channels/Traffic** button. If you get an error message this means you haven't properly defined a channel plan template file or your Transmitter System Type is not set properly.

To assign channels simply click on a line. A red line means this channel is active for this transmitter. It is important to note that if you don't activate any channels you will still be able to run studies that are based only on received power level. But, if you run a study that calculates interference, this particular transmitter won't generate interference because there are no channels active.

These channel assignments can also be done using the **RF Systems -> Spreadsheet Editor -> Sectors Channels data**. This method allows you to see the assignments for a number of transmitters at one time and this method can be effective for intuitively seeing how to manually assign channels for best channel re-use.

## TSB-88 Studies

The U.S.A. Telecommunications Industry Association (TIA) has developed a standard known as TSB-88. In this standard, there are descriptions of various types of radio systems and suggested ways to determine the coverage and the quality of performance of these systems. The intent of this standard is to create a common understanding of radio system design and deployment so that all parties (owners, designers, installers and end users) can agree on what constitutes an optimally-performing system. In this way it is similar to what the International Telecommunications Union (ITU) Recommendations are intended to accomplish.

EDX SignalPro contains a TSB-88 study module that contains several studies that are based on TSB-88 recommendations. The primary study in this group is the "TSB-88 Monte Carlo bounded area coverage" which is used to determine what percentage of area within a service boundary meets certain TSB-88 Channel Performance Criteria (CPC). The other studies in this module are either based on TSB-88 Monte Carlo  $C/(I+N)$  calculation methods or are useful studies for P25/TETRA systems.

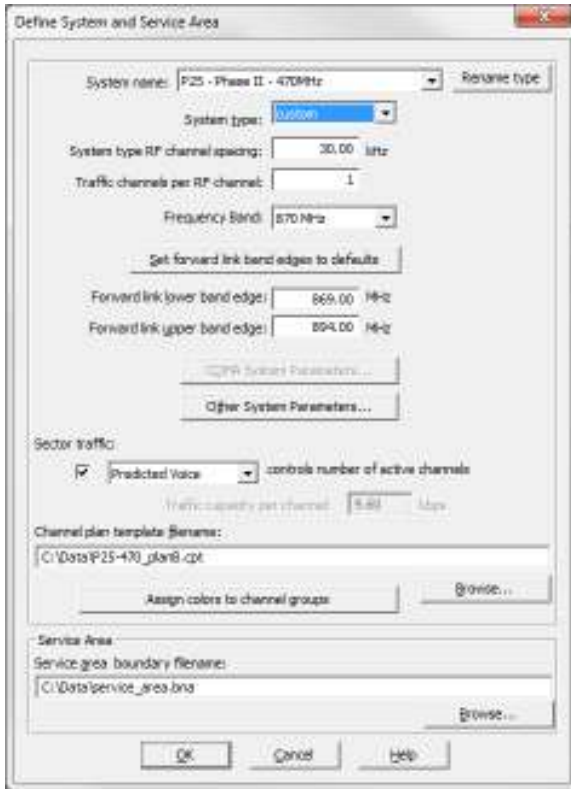
See the *Section 8.7 (Chapter 8) of the Reference Manual* for full details on setting up and running the TSB-88 Studies.

## Automatic Frequency Planning

If you have EDX SignalPro with the Network Design Module you can use the automatic channel planning function to have the program quickly come up with the optimum channel assignment(s) for each transmitter in a multicast system. In order to use this function you need to create a custom system type.

Select the **Network Design/Analysis -> Mobile and Nomadic systems -> System type and service area**. Select "custom" from the **System Type** list. Edit the **System Name** entry to show a meaningful name for your system type. Use the Browse button to select the desired channel plan template file for the **Channel plan template filename:** entry. You will also need to create a polygon boundary file that describes the service boundary of your system. The name of this file should be placed in the **Service area boundary filename:** entry. None of the other entries in this dialog box are necessary.

You should now set the **System Type** in the Transmitter details for all of your transmitters to the **System Name** you created. This ensures you have the correct channel plan in use for those transmitters.



To set up and run automatic frequency planning see Section 3.4 in the "Network: Mobile/Nomadic Systems" reference manual.

## References

[1] "Wireless Communications Systems Performance in Noise and Interference-Limited Situations" Telecommunications Industry Association Systems Bulletin - TSB-88-D, April 2012.

[www.tiaonline.org](http://www.tiaonline.org)

[2] "Simulcast Project 25" EF Johnson Technologies, Inc., January, 2013.

[www.efjohnsontechnologies.com](http://www.efjohnsontechnologies.com) (White Papers)