Appendix B

DVD Contents

The accompanying DVD provides a number of resources that parallel the material in the book, as well as the data that was used to generate much of the analysis material in the book.

B.1 ORGANIZATION OF FILES

The top-level organization of the DVD is shown in Figure B.1. The first folder (`Book Figures`) provides full color .pdf files for the graphics in the book. The second folder (`Link Spread Sheet`) contains the link margin spreadsheet used in Chapter 2. The third folder (`Data Bases`) contains processed frequency domain samples, as well as summary files that include the statistical characteristics of each of the sample sets. The last folder (`MATLAB Routines`) provides computation of Monotonic Index distribution parameters, and some example code to access the databases through a control file to automate database collection selection.

B.2 BOOK FIGURES

The book figures are in folder `Book Figures`. The content of this folder is shown in Figure B.2. Each book chapter has its own folder, and within each folder the figures are titled `Figure1, Figure2,` and so forth.

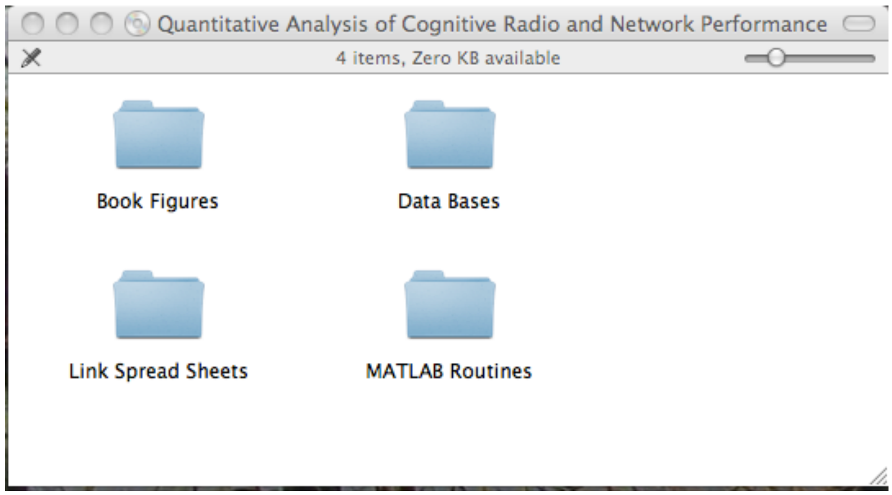


Figure B.1 DVD root level.

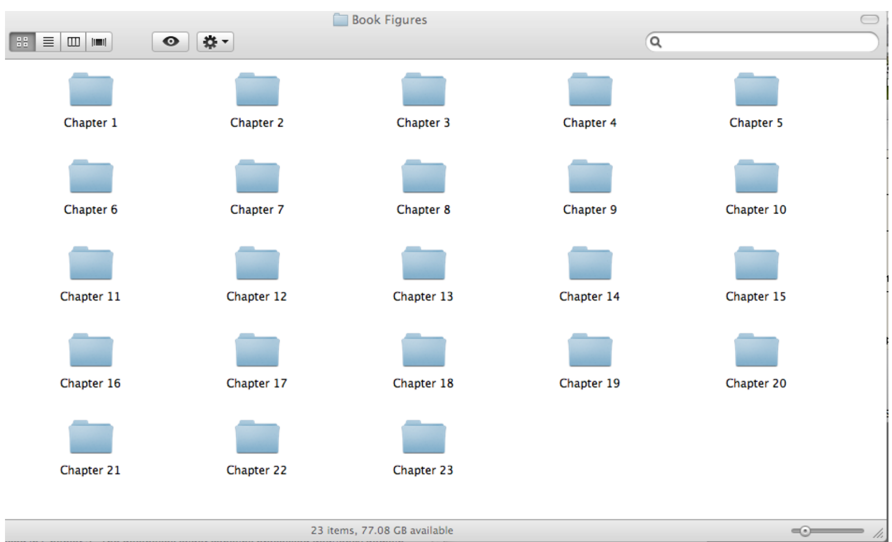


Figure B.2 Book chapter figures.

Table B.1
DVD File Set Index

Index	*Collection*
1	`Chicago`
2	`New York Day 1`
3	`New York Day 1`
4	`Vienna`
5	`Tysons`
6	`Riverbend`
7	`NRAO`
8	`Aggregated`

B.3 COMMUNICATIONS LINK MARGIN SPREADSHEET

The `Link Spread Sheet` folder contains the link analysis spreadsheet from Chapter 2 in Microsoft Excel format. The link margin spreadsheet implements the computations provided in Chapter 2 for the example link characteristics, using the same variable definitions as in Table 2.3 and Table 2.4. An image of the worksheet page is shown in Figure B.3. The boxed values are the ones to be entered to compute a link margin; the other values are computed by the spreadsheet.

B.4 SPECTRUM MEASUREMENTS DATA

B.4.1 Overview

Spectrum samples are provided for the six spectrum measurement campaigns described in Chapter 6. For ease of processing, a set of analysis results for each set is also provided, which enables the closed-form analysis to be performed without processing the sample sets individually. The folder containing these samples is shown in Figure B.4. The raw data is provided to support other analysis methodologies.

Each of the sample sets includes three files: one with raw spectrum data, one with constant signaling bandwidth, spectrum occupancy analysis, and one with proportional bandwidth, front-end analysis. In the following discussion, `xxx` represents one of the spectrum collection names (from Table B.1).

Simple Link Budget Analysis Tool

Chapter 2, Tables 2.1 - 2.2

Example Transmitter Link Margin

Transmit Power	10.0	dBm
Xmit Antenna Gain(Loss)	-1.0	dB
Path Loss	-74.0	dB
Fade Margin	-20.0	dB
Power at Rcvr	-85.0	dBm
Rcv. Antenna Gain	-1.0	dB
Rcvr Power	-86.0	dBm

Required Energy at Receiver

Thermal Noise	-114.0	dBm
Additional Rcvr Noise	15.0	dB
Estimated Rcvr Noise Floor	-99.0	
Required SNR	10.6	dB
Minimum Rcvr Power	-88.4	dBm

Link Margin	2.4	dB
Min Transmit Power	7.6	dBm

Computations - Transmitter Side

Tranmit Power	0.01	watts is	10.0	dBm
Frequency	2.4	GHz is	0.125	meters
Range	50	meters		
Path Loss	74.0	dB		

Computations - Receiver Side

Noise Temperature	290	K
Rcvr Bandwidth	1,000,000	Hz
Thermal Noise Power	-114.0	dBm

Modulation

Required Eb/No	10.6	dB
Data Rate	1,000,000	bits/sec
Required Energy/Noise	10.6	dB

Figure B.3 Link margin spreadsheet.

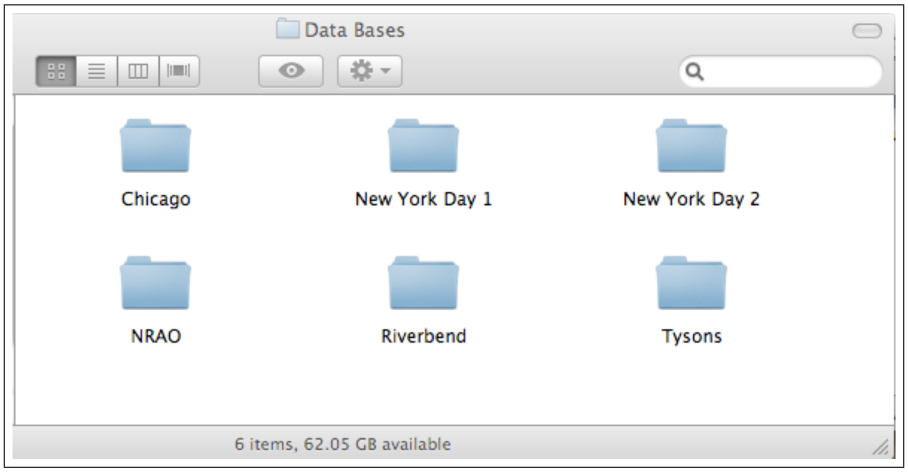


Figure B.4 Spectrum sample databases folder.

B.4.2 Frequency Domain Files

The `xxxSampleSet.mat` file contains a set of spectrum power measurements at 25 kHz intervals for time index `t` and frequency index `f`. The specific frequencies for each index are provided by the variables in the structure. The power values are in dBm, and there is one column per measurement interval. The file is a MATLAB structure, including the fields shown in Table B.2.

The `Measurements(t,f)` matrix is a set of power measurements in dBm. Each entry is the integrated power over `BandStep` of spectrum, which is the frequency bin size, at time `t`. The first entry frequency is `From` MHz, and they are linearly incremented. Each time increment is approximately one minute.

This structure can be loaded into MATLAB (assuming you have set a path to the database folder and its subfolders) by:

```
load ('ChicagoSampleSet.mat'),
```

or whatever collection name (from Table B.1) is desired, substituting for `Chicago`. A screenshot of this structure is shown in Figure B.5.

Table B.2
SampleSet Frequency Domain Structure Filelds

Field	Contents
`name`	The collection name (in this case `Chicago`)
`BandStep`	The bandwidth of each frequency bin, in MHz (in this case `25 kHz`)
`From`	The lower frequency of the first bin, in MHz (in this case `30 MHz`)
`Measurements(t, f)`	A matrix of measurements. In this case, there are 40 time intervals and 114,783 frequency bins.
`IntegratedPower(f)`	Mean power over the entire duration of the sample set for the given frequency bin
`Created`	Date file was created, in MATLAB format date
`CreatedDateString`	Date file was created, as a string

Index	Meaning and Range
`t`	Time Index, from `[1.. size(Measurements,1)]`
`f`	Frequency Index, from `[1.. size(Measurements,2)]`

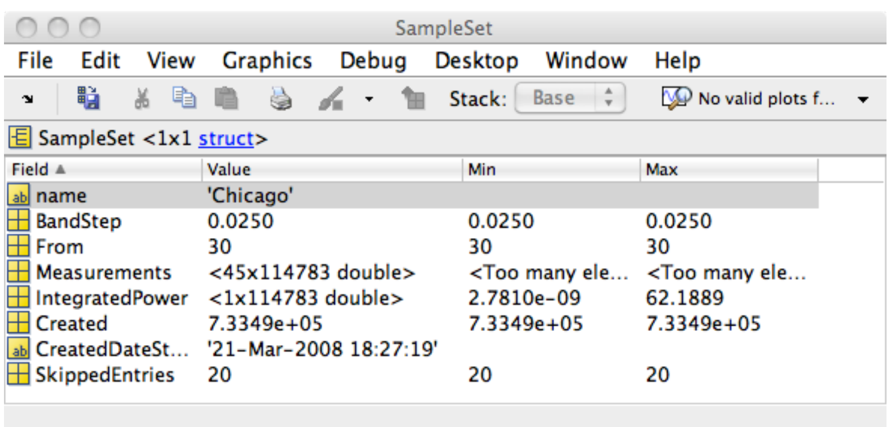


Figure B.5 MATLAB structure for frequency domain.

B.4.3 Spectrum Occupancy Statistics

The *xxx*SpectrumOccupancyStatistics.mat file contains a set of spectrum occupancy statistics (where *xxx* is the name of a collection from Table B.1). This loads the MATLAB structure SpectrumOccupancyStatistics, with the fields shown in Table B.3. Note that some fields that are in the structure are not required in the analysis.

There are two data analysis results in this data set. One provides the CDF of the spectrum occupancy distribution, and one provides the distribution parameters, and the polynomial coefficients for the estimation function. The CDF is computed for a range of values starting at MindBm, and incrementing by Step to a maximum of MaxdBm. The amplitude value of each CDF index a is in AmplitudeList (1, a). Population provides the total number of measurements equal to or less than this value in AmplitudeList (1, a). CDFPopulation is the normalized (0..1) probability distribution for this same data. Both CDFPopulation and Population are indexed (f, a), where f is the filter index, and a is the amplitude index.

MindBm, MaxdBm, a, b, Mean and Variance contain the beta distribution characteristics associated with each bandwidth value. Polya, Polyb, PolyMinE, and PolyMaxE provide the polynomial estimators for the distribution functions.

FWidth (1, f) is the bandwidth in MHz for the respective entry.

AmplitudeList (1, a) is the amplitude for an entry. All of the collections provide 40 different bandwidth analysis sets.

A screenshot of this structure is shown in Figure B.6.

B.4.4 Front-End Statistics

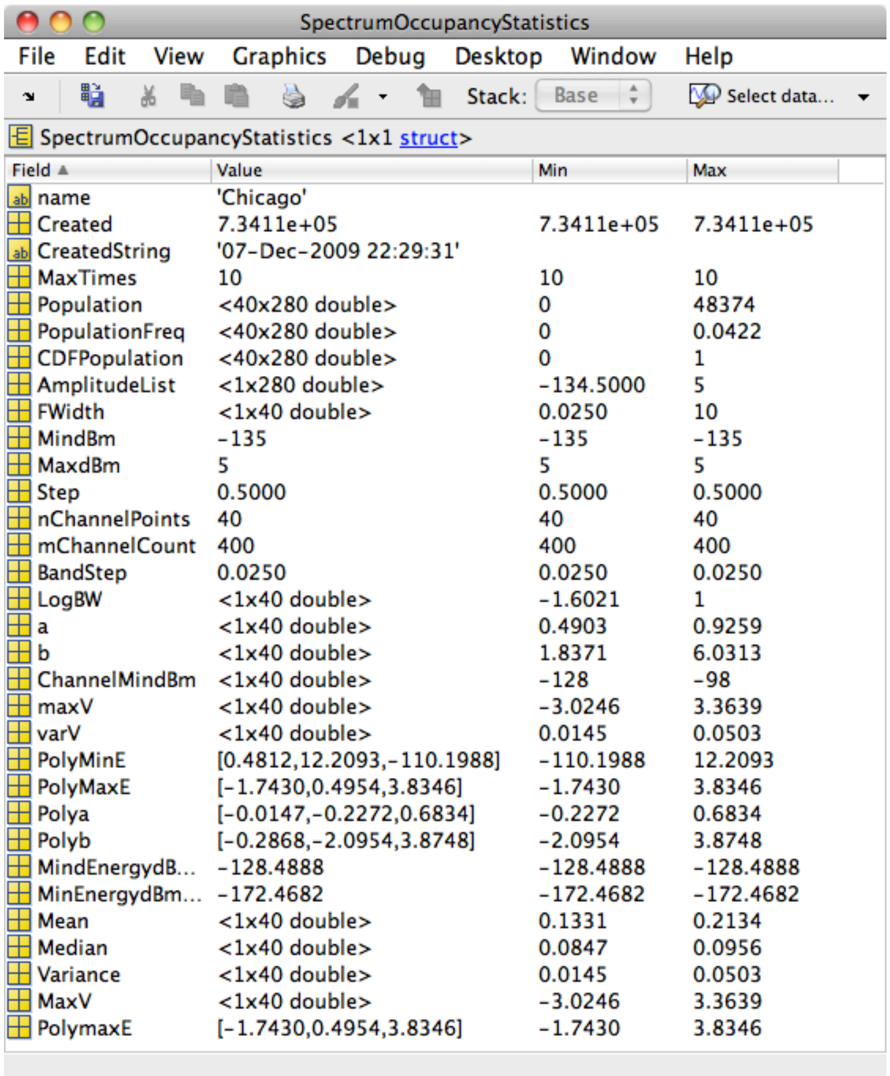
The *xxx*FEEnergyStatistics.mat file contains a set of front-end energy statistics (where *xxx* is the name of a collection from Table B.1). This loads the MATLAB structure SpectrumOccupancyStatistics, with the fields shown in Table B.4. Note that some fields that are in the structure are not used in the analysis. There are two data analysis results in this data set. The CDF is computed for a range of values starting at MindBm, and incrementing by BandStep to a maximum of MaxdBm. The value of each amplitude index a range is in AmplitudeList (1,a). Population(f, a) provides the total number of measurements equal to, or less than the value of Amplitude(1, a) for filter index f. CDFPopulation is the normalized (0..1) probability distribution for

Table B.3

SpectrumOccupancyStatistics Structure Filelds

Field	*Contents*
`name`	The collection name
`Created`	Date file was created, in MATLAB format date
`Median (1, f)`	The median value of the beta distribution mean parameter for each bandwidth
`AmplitudeList(1, a)`	The power for each increment
`MindBm`	Minimum power for the CDF array
`MaxdBm`	Maximum power for the CDF array
`Population (f, a)`	The cumulative number of measurements under the threshold power, per filter bandwidth
`CDFPopulation (f, a)`	Normalized `Population`, providing the CDF of the distribution between `MindBm` and `MaxdBm`
`FWidth (1, f)`	The width of each bandwidth entry
`nChannelPoints`	The number of bandwidth entries
`a (1, f)`	The value of the beta distribution α parameter for each bandwidth
`b (1, f)`	The value of the beta distribution β parameter for each bandwidth
`ChannelMindBm (1, f)`	The minimum value of the energy for each bandwidth
`maxV (1, f)`	The maximum energy parameter for each bandwidth
`PolyMinE (o)`	The coefficients of the polynomial equations for the FE_{min} estimator
`PolyMaxE (o)`	The coefficients of the polynomial equations for the FE_{max} estimator
`Polya (o)`	The coefficients of the polynomial equations for the α estimator
`Polyb (o)`	The coefficients of the polynomial equations for the β estimator
`Mean (1, f)`	The mean value of the distribution for each bandwidth
`Variance (1, f)`	The value of the variance of the distribution for each bandwidth
`ChannelMindBm (1, f)`	The minimum energy parameter for each bandwidth
`MindEnergydBmBin`	Lowest energy in a bin for the entire sample set
`MinEnergydBmHz`	Lowest energy in power per hertz

Index	*Meaning and Range*
`a`	CDF amplitude index, from `[1.. (MaxdBm-MindBm)/Step]`
`f`	Signaling bandwidth index, from `[1.. nChannelPoints]`
`o`	Polynomial coefficient order, specific to the polynomial

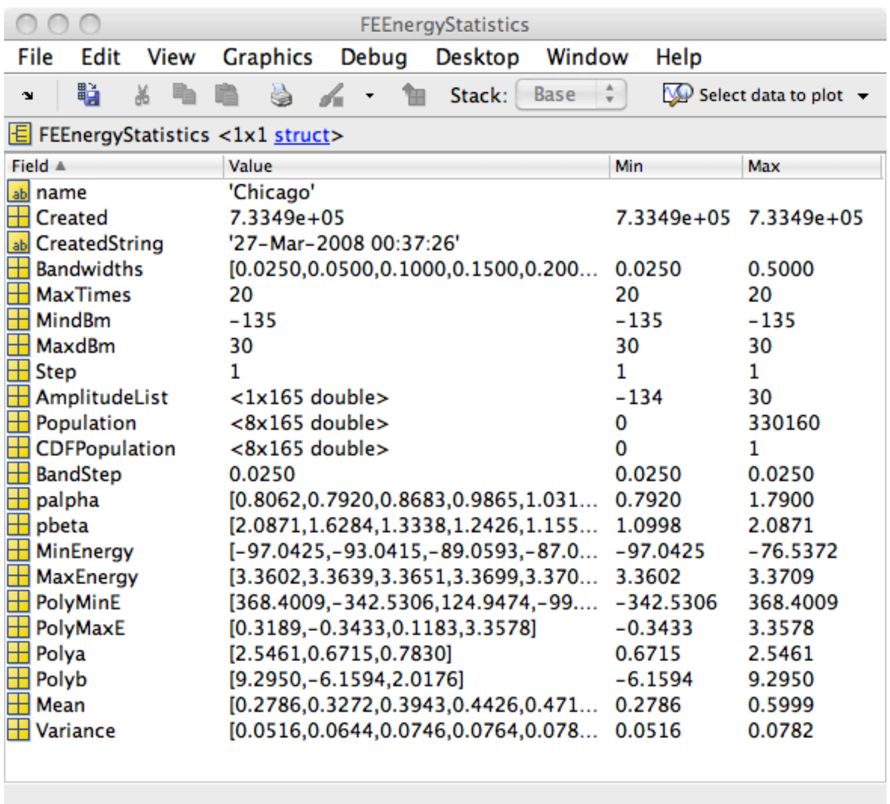


Field	Value	Min	Max
name	'Chicago'		
Created	7.3411e+05	7.3411e+05	7.3411e+05
CreatedString	'07-Dec-2009 22:29:31'		
MaxTimes	10	10	10
Population	<40x280 double>	0	48374
PopulationFreq	<40x280 double>	0	0.0422
CDFPopulation	<40x280 double>	0	1
AmplitudeList	<1x280 double>	-134.5000	5
FWidth	<1x40 double>	0.0250	10
MindBm	-135	-135	-135
MaxdBm	5	5	5
Step	0.5000	0.5000	0.5000
nChannelPoints	40	40	40
mChannelCount	400	400	400
BandStep	0.0250	0.0250	0.0250
LogBW	<1x40 double>	-1.6021	1
a	<1x40 double>	0.4903	0.9259
b	<1x40 double>	1.8371	6.0313
ChannelMindBm	<1x40 double>	-128	-98
maxV	<1x40 double>	-3.0246	3.3639
varV	<1x40 double>	0.0145	0.0503
PolyMinE	[0.4812,12.2093,-110.1988]	-110.1988	12.2093
PolyMaxE	[-1.7430,0.4954,3.8346]	-1.7430	3.8346
Polya	[-0.0147,-0.2272,0.6834]	-0.2272	0.6834
Polyb	[-0.2868,-2.0954,3.8748]	-2.0954	3.8748
MindEnergydB...	-128.4888	-128.4888	-128.4888
MinEnergydBm...	-172.4682	-172.4682	-172.4682
Mean	<1x40 double>	0.1331	0.2134
Median	<1x40 double>	0.0847	0.0956
Variance	<1x40 double>	0.0145	0.0503
MaxV	<1x40 double>	-3.0246	3.3639
PolymaxE	[-1.7430,0.4954,3.8346]	-1.7430	3.8346

Figure B.6 MATLAB SpectrumOccupancyStatistics structure.

this same data. Both `CDFPopulation` and `Population` are indexed `(f, a)`, where `f` is the filter index, and `a` is the amplitude index.

`MindBm`, `MaxdBm`, `a`, `b`, `Mean` and `Variance` contain the beta distribution characteristics associated with each bandwidth entry. `Polya`, `Polyb`, `PolyMinE`, and `PolyMaxE` provide the polynomial estimators for the distribution functions. `Bandwidths(1, f)` is the bandwidth ratio for the respective entry. `Amplitude(1, a)` is the amplitude for an entry. In all of the collections, there are eight different bandwidth analysis sets provided. A screenshot of this structure is shown in Figure B.7.



Field	Value	Min	Max
name	'Chicago'		
Created	7.3349e+05	7.3349e+05	7.3349e+05
CreatedString	'27-Mar-2008 00:37:26'		
Bandwidths	[0.0250,0.0500,0.1000,0.1500,0.200...	0.0250	0.5000
MaxTimes	20	20	20
MindBm	-135	-135	-135
MaxdBm	30	30	30
Step	1	1	1
AmplitudeList	<1x165 double>	-134	30
Population	<8x165 double>	0	330160
CDFPopulation	<8x165 double>	0	1
BandStep	0.0250	0.0250	0.0250
palpha	[0.8062,0.7920,0.8683,0.9865,1.031...	0.7920	1.7900
pbeta	[2.0871,1.6284,1.3338,1.2426,1.155...	1.0998	2.0871
MinEnergy	[-97.0425,-93.0415,-89.0593,-87.0...	-97.0425	-76.5372
MaxEnergy	[3.3602,3.3639,3.3651,3.3699,3.370...	3.3602	3.3709
PolyMinE	[368.4009,-342.5306,124.9474,-99....	-342.5306	368.4009
PolyMaxE	[0.3189,-0.3433,0.1183,3.3578]	-0.3433	3.3578
Polya	[2.5461,0.6715,0.7830]	0.6715	2.5461
Polyb	[9.2950,-6.1594,2.0176]	-6.1594	9.2950
Mean	[0.2786,0.3272,0.3943,0.4426,0.471...	0.2786	0.5999
Variance	[0.0516,0.0644,0.0746,0.0764,0.078...	0.0516	0.0782

Figure B.7 MATLAB FEEnergyStatistics structure.

Table B.4
FEEnergyStatistics Structure Filelds

Field	Contents
`name`	The collection name
`Created`	Date file was created, in MATLAB format date
`CreatedString`	Date file was created, in string format
`Bandwidths (1,f)`	List of bandwidth factors for each increment `b`
`MindBm`	Minimum power for the CDF array
`MaxdBm`	Maximum power for the CDF array
`Step`	Increment in power for the CDF array
`AmplitudeList (1, a)`	The power for each increment
`Population (f, a)`	The cumulative number of measurements under the threshold power, per filter bandwidth
`CDFPopulation (f, a)`	Normalized `Population`, providing the CDF of the distribution between `MindBm` and `MaxdBm`
`BandStep`	The step in bandwidth for each preselector filter increment
`palpha (o)`	beta distribution α parameter in any filter of that bandwidth
`pbeta (o)`	beta distribution β parameter in any filter of that bandwidth
`MinEnergy (1, f)`	Minimum power in any filter of that bandwidth
`MaxEnergy (1, f)`	Maximum power in any filter of that bandwidth
`PolyMinE (1,f)`	The coefficients of the polynomial equations for the FE_{min} estimator
`PolyMaxE (1, b)`	The coefficients of the polynomial equations for the FE_{max} estimator
`Polya (1, f)`	The coefficients of the polynomial equations for the α estimator
`Polyb (1, f)`	The coefficients of the polynomial equations for the β estimator
`Mean (1, f)`	The value of the CDF distribution mean parameter
`Variance (1, b)`	The value of the CDF distribution variance parameter

Index	Meaning and Range
`a`	CDF amplitude index, from `[1.. size(Bandwidths, 2)]`
`f`	Preselector bandwidth index, from `[1.. nChannelPoints]`
`o`	Polynomial coefficient order, specific to the polynomial

B.5 MATLAB ROUTINES

B.5.1 Monotonic Indices

The DVD includes a structure containing the polynomials to determine the values of the beta distribution parameters in two structure files, `SOMonotonic` and `FEMonotonic`. Example code for applying these structures to compute the synthetic spectrum distribution of Chapter 8 is shown in Figure B.8.

```
load ('FEMonotonic')
load ('SOMonotonic')

IDensity = .0864   % Set the following index variables
IIntensity = 130
BW = .20;
b0 =25;

DV =  [1; IDensity;  IDensity^2; (IIntensity/10); ...
(IIntensity/10)^2; (log10(b0)); (log10(b0))^2]
SOa =10^sum (SOMonotonic.aIndexPoly .* DV)
SOb = exp( sum(SOMonotonic.bIndexPoly .* DV))
SOmin = sum(SOMonotonic.MinIndexPoly .* DV)
SOmax = sum(SOMonotonic.MaxIndexPoly .* DV)

DV =  [1; IDensity;  IDensity^2; (IIntensity/10); ...
(IIntensity/10)^2; (log10(BW)); (log10(BW))^2]
FEa =10^sum (FEMonotonic.aIndexPoly .* DV)
FEb = 10^ sum(FEMonotonic.bIndexPoly .* DV)
FEmin = sum(FEMonotonic.MinIndexPoly .* DV)
FEmax = sum(FEMonotonic.MaxIndexPoly .* DV)
```

Figure B.8 Monotonic Index Distribution Determination

B.5.2 MATLAB Access Routine

Each file type can be manually loaded into MATLAB, but to make the process easier, a small routine is available in the MATLAB routines folder to manage the files. This routine can load any of the sample collections sets and any one of the analyzed aggregation files. The program should set the path to the `Samples.mat` file. Similarly, the sample set index (`set`) should be set to the value of the collection

Table B.5
DVD File Type Index

Index	*File Type*	*Contents*
1	`SampleSets`	Frequency domain measurements
2	`FEEnergyStatistics`	Front-end energy distributions
3		Unused
4	`SpectrumOccupancyStatistics`	Signal bandwidth statistics

files, as shown in Table B.1. Your program can then set the index of the file type and collection to open any of the files, or loop through all of the files. The `FileType` index is shown in Table B.5.

```
set = from Table B.1;
FileType = from Table B.5;
CFn = 'Samples.mat';
load (CFn);
```