Mathematica Based Reader For NTIA Data

by
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Commercial Introduction

This submission describes a Mathematica based reader for the NTIA data set described in NTIA Report 93-292, January 1993, ITS Catalog Number ITSIR001. The data set is available from NTIA at a price of $215.00. The reader described in this document is available from Knowledge Implementations, Inc. for a price of $495.00 and is shipped with a copy of the original ITS data disks and includes the source code for the package ITSRead.m. Mathematica itself is also available to IEEE 802 participants through Knowledge Implementations, Inc. at a discounted price. To order either the ITS reader or Mathematica itself please contact Knowledge Implementations, Inc. at 914-986-3492 and speak with either Larry Van Der Jagt or Linda Kane.

Knowledge Implementations, Inc. is also involved in contract engineering. We are currently analyzing this data and evaluating the impact of the propagation characteristics detailed in this data on RadioLAN operation at both the Physical and MAC Layer. We would be happy to discuss opportunities to perform customized analysis of this or other data to meet the needs of individual clients. We could also perform format conversion on the data to meet the needs of a client's non-Mathematica based system.

On the need for a Standardized Data Reporting Format

Much discussion has taken place in IEEE 802.11 regarding the topic of conformance testing and channel modeling. This discussion has often centered around the question of whether performance and conformance testing of implementations should be performed using measured data sets that are representative of the "real world", or mathematical models that behave like that "real world". In either case there is a need for measured data that can be used to verify the characteristics of propagation environment in which RadioLAN devices are expected to operate. There have been hundreds of research papers published on this topic and for the most part every researcher has their own specific ways of analyzing data and reporting results. The wide variety of approaches to analysis used and the academician's desire to present summaries and conclusions has resulted in much of the data being interesting, but not useful for actual use in benchmarking and testing systems.

In order to improve upon this situation and encourage the interchange of data and an ability to compare data sets, on an "apples to apples" basis, a standardized testing and reporting framework is needed. If such a framework were available measurements could be taken by individual researchers and shared with other researchers allowing for models and experiments to be based on a wider crosssection of actual "real world" propagation conditions.

The format in which the NTIA data is reported can easily form the basis for this effort to begin. Work is needed to fill in various aspects of the format to allow for normalization between data taken with differing test equipment in different situations, but the format forms a beginning. The details of this file format can be found in IEEE P802.11-93/41R "Indoor Wideband Propagation Data", by Robert J. Aschatz, Peter B. Papazian and Michael Roadifer, originally presented in March 1993.

The Reader

Knowledge Implementations, Inc. has developed a Mathematica based Reader that extracts data from the ITS Data files. To use the reader it is first necessary to load the routines from the package ITSRead.m. This package contains a number of custom routines developed to read the ITS data and load the packages Statistics`DataManipulation and Statistics`DescriptiveStatistics. These standard packages contain a number of routines that are quite useful in analyzing the data once it is extracted with the custom routines.

```
<<RadioLAN`ITSRead`
```

Many of the routines expect to operate on a particular file that has been assigned to the Global symbol filename. The selection of what file the routines should operate on is done in the next cell. Note that a complete pathname needs to be provided here. If you are using a Windows based system a pathname might look as follows. C:\\ITSDATA\\T1P46.TXT. Please note the double slashes in order to overcome the impact of the use of the slash character as an escape character. A Machintosh version of the assignment is as follows

```
filename="Hard Disk:T1P46DATA.txt";
```

Having assigned the name of the file to be operated on to the filename symbol the first of the extraction functions can be demonstrated. This function is the ExtractCharacteristics Function. The following cells demonstrate its usage message and an example of its operation.

```
?ExtractCharacteristics
```

ExtractCharacteristics[file] reads the file header associated with the file name that is passed as a parameter.

```
ExtractCharacteristics[filename]
```

```
Institute for Telecommunication Sciences
325 Broadway, Boulder, CO 80303
Data Release: 06/11/93
Reference: NTIA Report 93-292
TESTNAME: Soft Partitioned Office
TX Location is {0., 0.}
TX Power is 17.6
TX Loss is 19
TX Antenna Gain is 2.5
RX Loss is 10
RX Antenna Gain is 2.5
Number of Chips is 127
Number of Impulse Responses is 569
```

The ExtractCharacteristics function assigns values to a number of symbols in order to make this information available for use in other calculations. CHIPS is the number of chips, TXLOC is transmitter location, TXPWR is transmitter power, TXLOSS is transmitter loss, TXANT is transmit antennae gain, RXLOSS is receiver loss, RXANT is receiver antennae gain, and IRMMANY is the number of impulse responses in this path.

Three functions are provided that extract the impulse response specific information for a number of impulse responses. These functions are ExtractIRM, ExtractRXLOC, and ExtractNOISE and they extract the information that is specific to an individual impulse response measurement. The impulse responses within a file are numbered starting from zero. Each of these extraction functions takes a start number and a stop number and extracts information for the responses between start and stop. These functions assume that the file to be used is that assigned to the Global symbol "filename". The usage information and an example of the operation of each of these functions appears in the following cells.

following cells.

First, the ExtractIRM function is used to read the IRM path triples for two measurements into a matrix.

```
?ExtractIRM

ExtractIRM[startlocation_,stoplocation_] reads the impulse response data from the file that is
   assigned to the global symbol filename. It reads impulse responses that are numbered between
   the startlocation parameter and the stoplocation parameter. After executing this routine the
   impulse responses are stored in a matrix the first index selects which IRM with startlocation
   being the first and stoplocation being the last, the second index is the individual peak
   samples within an IRM and the third index runs from 1-3 indicating (time,magnitude,phase)

twoIRMs=ExtractIRM[40,41];

Dimensions[twoIRMs]

{2, 128, 3}

MatrixForm[twoIRMs]
```

22.1 520 0.04	23.5 550 0.02	25. 567 0.	26.5 575 0.02	27.9 577 -0.02	29.4 556 -0.03	30.9 546 0.01	32.3 531 0.02	33.8 529 0.01	35.3 522 -0.01	36.8 512 -0.07	38.2 517 -0.14
	39.7 523 -0.22	41.2 535 -0.29	42.6 539 -0.33	44.1 559 -0.36	45.6 561 -0.37	47. 556 -0.4	48.5 560 -0.44	50. 544 -0.45	51.5 539 -0.56	52.9 525 -0.65	54.4 507 -0.73
	55.9 521 -0.77	57.3 522 -0.8	58.8 515 -0.72	60.3 521 -0.67	61.8 536 -0.66	63.2 543 -0.75	64.7 514 -0.91	113.2 506 -1.03	114.7 577 -0.85	116.1 577 -0.91	120.6 1278 2.86
	122. 2247 2.6	123.5 3073 2.37	125. 3179 2.22	126.4 2627 2.02	127.9 1644 1.6	129.4 2258 0.16	130.9 4978 -0.31	132.3 7552 -0.55	133.8 9215 -0.7	135.3 9422 -0.77	136.7 8248 -0.84
	138.2 6207 -0.85	139.7 3726 -0.79	141.1 1121 -0.42	142.6 1531 1.84	144.1 2839 2.02	145.6 3009 1.97	147. 2205 1.85	148.5 1241 1.91	150. 571 2.47	152.9 663 -2.22	157.3 1231 2.04
	158.8 1677 1.8	160.3 2052 1.56	161.7 2360 1.37	163.2 2402 1.16	164.7 2152 0.85	166.1 2154 0.37	167.6 2594 -0.04	169.1 3228 -0.32	170.5 4013 -0.55	172. 4634 -0.71	173.5 4941 -0.8
	175. 5028 -0.84	176.4 4987 -0.89	177.9 4916 -0.93	179.4 4437 -0.98	180.8 3886 -1.	182.3 3370 -0.93	183.8 3249 -0.93	185.3 3186 -0.97	186.7 3076 -1.01	188.2 2924 -1.05	189.7 2812 -1.14
	191.1 2585 -1.21	192.6 2296 -1.31	194.1 1798 -1.34	195.5 1207 -1.24	197. 718 -1.12	201.4 557 0.27	202.9 715 -0.07	204.4 762 -0.22	205.8 897 -0.62	207.3 1091 -0.73	208.8 1207 -0.72
	210.2 1126 -0.58	211.7 1039 -0.52	213.2 982 -0.55	214.7 1017 -0.6	216.1 1103 -0.64	217.6 1159 -0.71	219.1 1239 -0.91	220.5 1384 -1.14	222. 1510 -1.34	223.5 1472 -1.4	224.9 1505 -1.4
	226.4 1424 -1.41	227.9 1249 -1.43	229.4 1033 -1.34	230.8 893 -1.08	232.3 843 -0.81	233.8 822 -0.73	235.2 738 -0.65	236.7 718 -0.59	238.2 652 -0.47	239.7 618 -0.39	241.1 525 -0.14
	242.6 530 -0.07	244.1 559 0.11	245.5 570 0.15	247. 534 0.17	252.9 562 -1.97	254.4 684 -2.19	255.8 755 -2.33	257.3 772 -2.44	258.8 748 -2.51	260.2 610 -2.56	267.6 604 0.06
	269.1 683 0.18	270.5 699 0.29	272. 649 0.47	273.5 526 0.68	329.3 506 -2.21	330.8 502 -2.16					
26.5 485 0.49	27.9 500 0.5	29.4 496 0.45	30.9 493 0.47	52.9 498 0.06	54.4 498 0.	55.9 496 -0.07	57.3 500 -0.07	58.8 497 -0.12	63.2 487 0.	64.7 505 -0.06	66.2 520 -0.15
	67.6 507 -0.21	69.1 521 -0.32	70.6 516 -0.41	72. 520 -0.47	73.5 509 -0.48	75. 535 -0.42	76.5 541 -0.38	77.9 546 -0.36	79.4 566 -0.39	80.9 556 -0.36	82.3 533 -0.37
	83.8 510 -0.4	88.2 486 -0.63	94.1 489 -1.08	120.6 883 -2.23	122. 1558 -2.46	123.5 2253 -2.81	125. 3078 -3.08	126.4 3581 3.05	127.9 3704 2.94	129.4 3201 2.86	130.9 2187 2.44
	132.3 1773 1.64	133.8 2167 0.63	135.3 3337 0.15	136.7 3765 0.01	138.2 3480 0.06	139.7 3082 0.42	141.1 3045 0.86	142.6 3364 1.25	144.1 4290 1.55	145.6 4289 1.63	147. 4056 1.55

148.5	150.	151.4	152.9	154.4	155.8	157.3	158.8	160.3	161.7	163.2
3581	2933	2084	1867	2181	2616	2681	2635	2657	2666	2645
1.36	1.24	0.98	0.54	0.23	0.35	0.52	0.67	0.81	0.98	1.14
164.7	166.1	167.6	169.1	170.5	172.	173.5	175.	176.4	177.9	179.4
2495	2238	2004	1926	1576	1451	1372	1267	1261	1347	1514
1.29	1.36	1.35	1.29	1.06	0.73	0.23	-0.09	-0.52	-0.86	-1.08
180.8	182.3	183.8	185.3	186.7	188.2	189.7	191.1	192.6	194.1	195.5
1492	1317	1304	1593	1855	1934	1886	1660	1428	1011	623
-1.16	-1.08	-0.96	-0.84	-0.77	-0.79	-0.82	-0.87	-0.99	-0.99	-0.65
198.5	200.	201.4	202.9	204.4	205.8	207.3	208.8	210.2	211.7	213.2
499	573	516	559	570	750	1018	1085	1121	1225	1318
0.94	0.91	0.49	-0.13	-1.13	-1.64	-1.8	-2.	-2.17	-2.26	-2.37
214.7	216.1	217.6	219.1	220.5	222.	223.5	224.9	226.4	227.9	232.3
1428	1535	1550	1671	1693	1636	1416	1195	959	653	505
-2.32	-2.32	-2.27	-2.25	-2.15	-2.15	-2.2	-2.28	-2.35	-2.35	-0.45
233.8	235.2	236.7	238.2	239.7	247.	248.5	249.9	251.4	252.9	254.4
643	679	729	673	577	491	562	562	514	555	650
-0.57	-0.58	-0.74	-1.02	-1.37	2.81	2.71	2.72	2.89	3.08	-3.04
255.8	257.3	258.8	260.2	261.7	282.3	283.8	285.2	286.7	288.2	289.6
711	738	719	640	517	513	539	546	536	542	527
-3.	-2.98	-2.99	-3.07	3.08	2.24	2.23	2.24	2.24	2.22	2.21
291.1	292.6	294.	295.5	297.	298.5					
507	508	512	506	524	494					
2.18	2.23	2.22	2.17	2.1	2.07					

Next, the ExtractRXLOC function is used to read the receiver locations for the impulse responses read above. The output is an x,y value for each IRM requested.

?ExtractRXLOC

ExtractRXLOC[startlocation_,stoplocation_] pulls the receiver location data for the IRMs located between startlocation and stoplocation, with locations being the number of a particular IRM

ExtractRXLOC[40,41]

{{-0.6, 3.71}, {-0.6, 3.75}}

Finally, the ExtractNOISE function is used to read the noise parameter associated with each IRM requested.

?ExtractNOISE

ExtractNOISE[startlocation_,stoplocation_] pulls the noise level data for the IRMs located between startlocation and stoplocation, with locations being the number of a particular IRM

ExtractNOISE[40,41]

{{219}, {176}}

In the cells that follow 10 impulse responses will be extracted from the file and the function calcIRMs will be executed on that data. This function generates interpolation tables that allow the impulse responses to be dealt with as functions of time. The function calcIRMs builds two matrices of interpolation tables. One for the Q component of the IRM and one for the I component of the IRM.

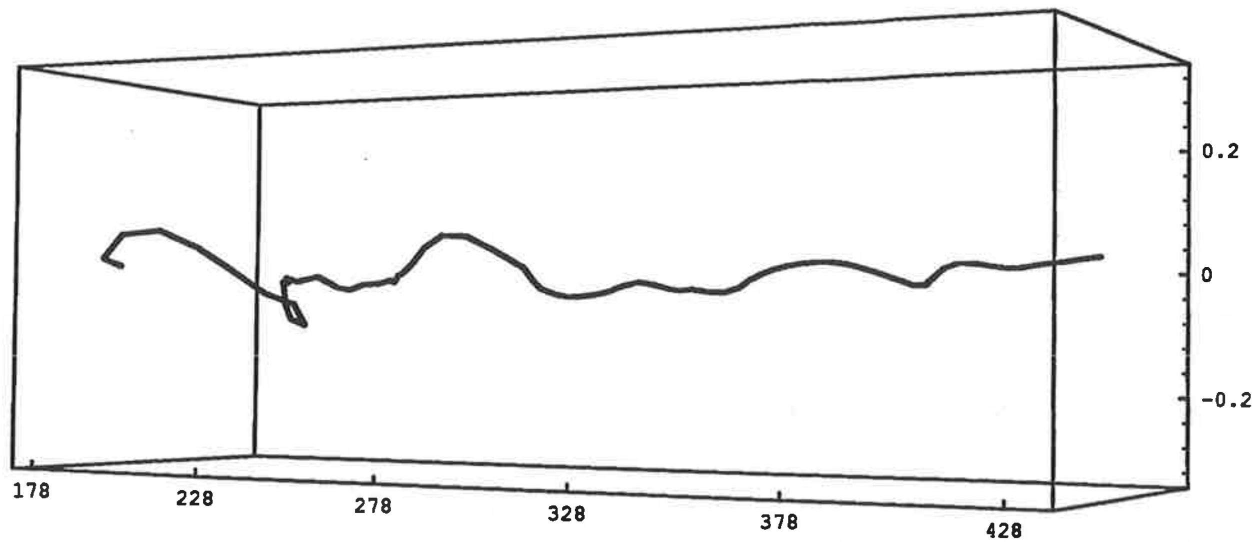
The following cells select some impulse response from approximately the middle of the path file. Each of the displays below are the first in a series of 10 displays that are intended to be viewed as an animation when operating on line.

tenIRM=ExtractIRM[300,309];
locations=ExtractRXLOC[300,309];

calcIRMs[tenIRM];

Show3DIRM[tenIRM,locations]

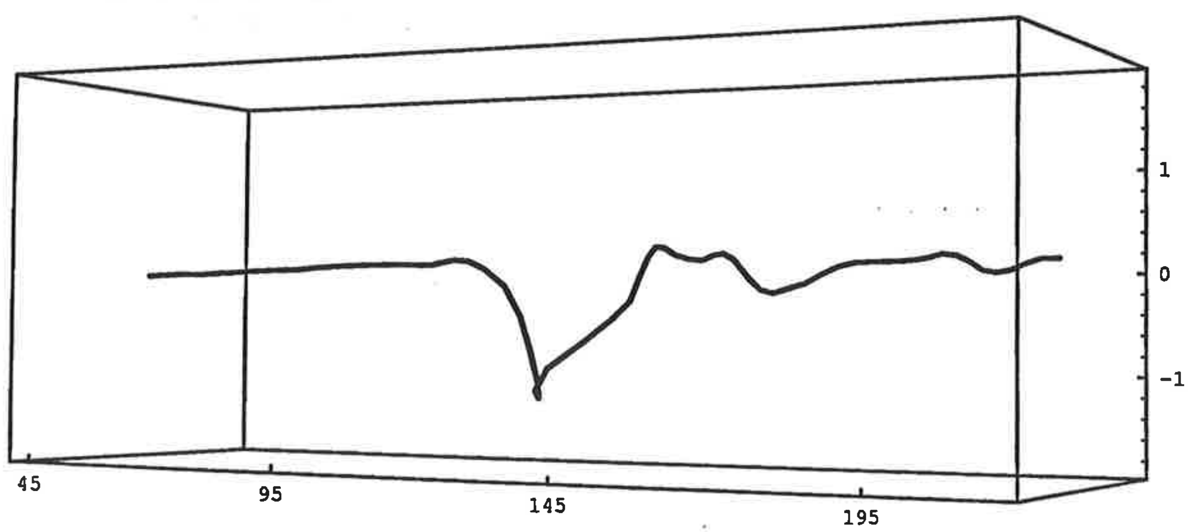
Location {-0.6, 14.81}



For comparison the first impulse responses in the file are illustrated below.

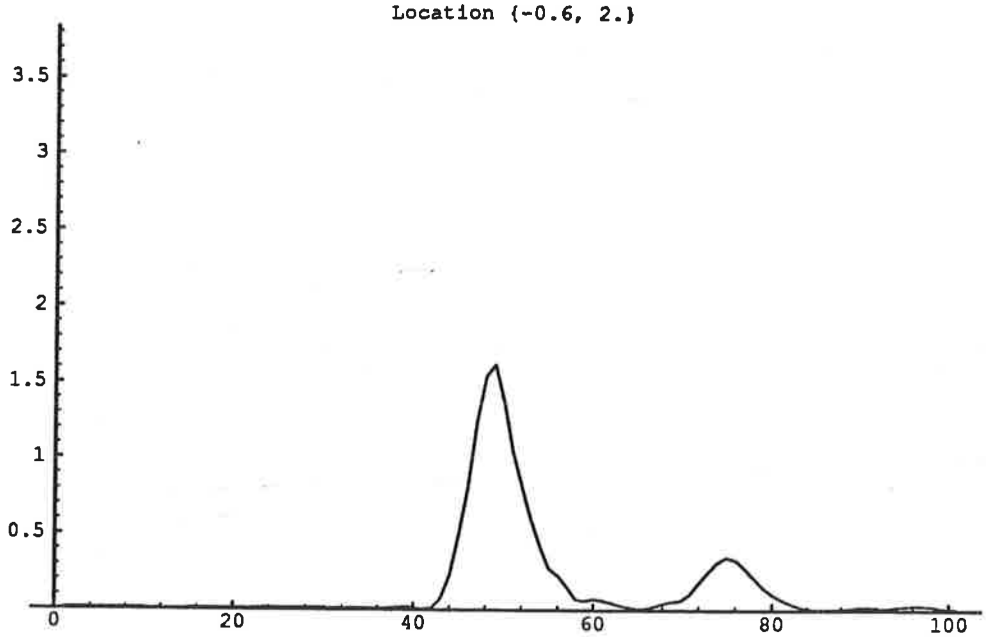
```
tenIRM=ExtractIRM[0,9];
locations=ExtractRXLOC[0,9];
calcIRMs[tenIRM];
Show3DIRM[tenIRM,locations]
```

Location {-0.6, 2.}



The cell that follows illustrates the power delay profile of the first ten impulse responses. Again this is collapsed to just the first display, and is intended to be viewed as an animation.

```
ShowPDP[tenIRM,locations]
```



Conclusion

This notebook provides data extraction and visualization tools that can be used with impulse response data stored in the NTIA data format. It is hoped that the NTIA data and these tools will be the first in a much larger series of data sets and analysis tools that will utilize this format. For RadioLAN to be truely successful it will be necessary for it to operate robustly in as wide a range of real world environments as possible. Efforts such as those of NTIA in collecting this data will help to make that possible.