

Terrapin RCM Solver v1.0

User's Guide



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Introduction:

The Terrapin RCM Solver v1.0 is a first generation stand-alone, GUI software that utilizes the “Random Coupling Model¹”(RCM) and the “Terrapin Algorithm²” to make statistical predictions for the induced voltages at specific points within a complicated, real-world 2D or 3D enclosure given a minimum of user-specified input information. In addition, the software has the capability to accurately determine universal and detail-independent impedance, admittance and scattering fluctuations in real-world 2D and 3D enclosures. The current version of the software is written for 2-port, 2D or 3D ray-chaotic enclosures. Extensions to this software to other cases can be explored in consultation with the authors.

We strongly encourage the user to evaluate this software and compare its predictions with independent measurements on real-world enclosures. We urge you to contact us regarding your comments/criticisms so that we may improve the design and functionality of future versions of this software.

Installation: Windows XP

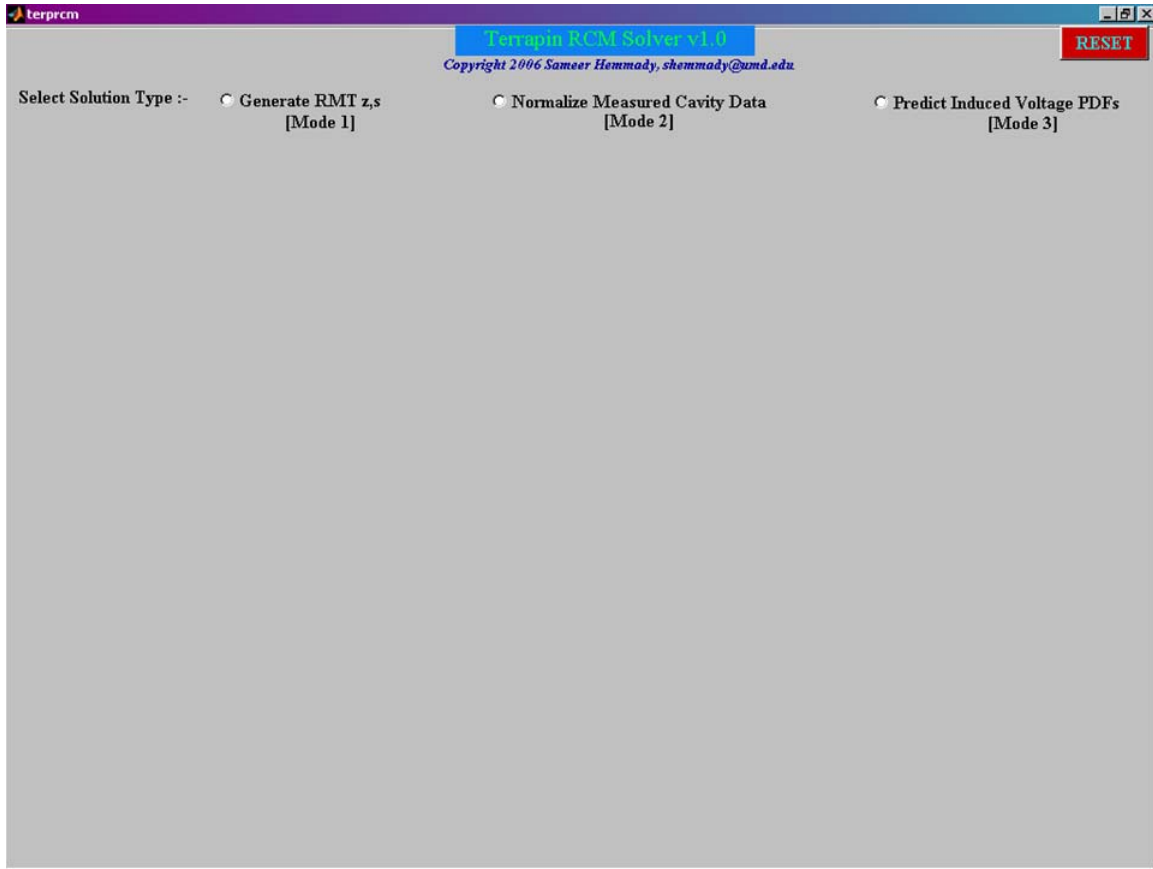
The CD comes equipped with all the files necessary to run this software. In addition, the user is provided with some sample data-sets with which to familiarize himself/herself with the software and its functionality.

The software and all associated files are located in the folder “Terrapin RCM v1.0” on the CD.

1. Copy the folder “Terrapin RCM v1.0” on to your hard-disk.
2. Open the copied folder “Terrapin RCM v1.0” which is now present on your hard-disk.
3. Click on the file “MCRInstaller.EXE”. The contents of this file will now extract on to your hard-disk. This may take a few minutes depending upon processor speed. This is only a one-time operation. It is not required to run this step every time you use the software. During this extraction process, the Matlab Component Runtime (MCR) compiler and standard matlab libraries are installed.
4. Once the extraction process has completed, the software is now ready to use.
5. Click on the file “terprcm.EXE” to initiate the software. A status-prompt screen should appear for about 3 seconds following which the title screen of the Terrapin RCM v1.0 should open. See screenshot on next page.

¹ Zheng, Antonsen, Ott, Electromagnetics **26**, 3 (2006); Electromagnetics **26**, 37 (2006), Hemmady, *et.al.* Phys. Rev. Lett. **94**, 014102 (2005).

² www.csr.umd.edu/anlage/RCM/index.htm



Title-screen of Terrapin RCM Solver v1.0

Navigating “Terrapin RCM Solver v1.0”:

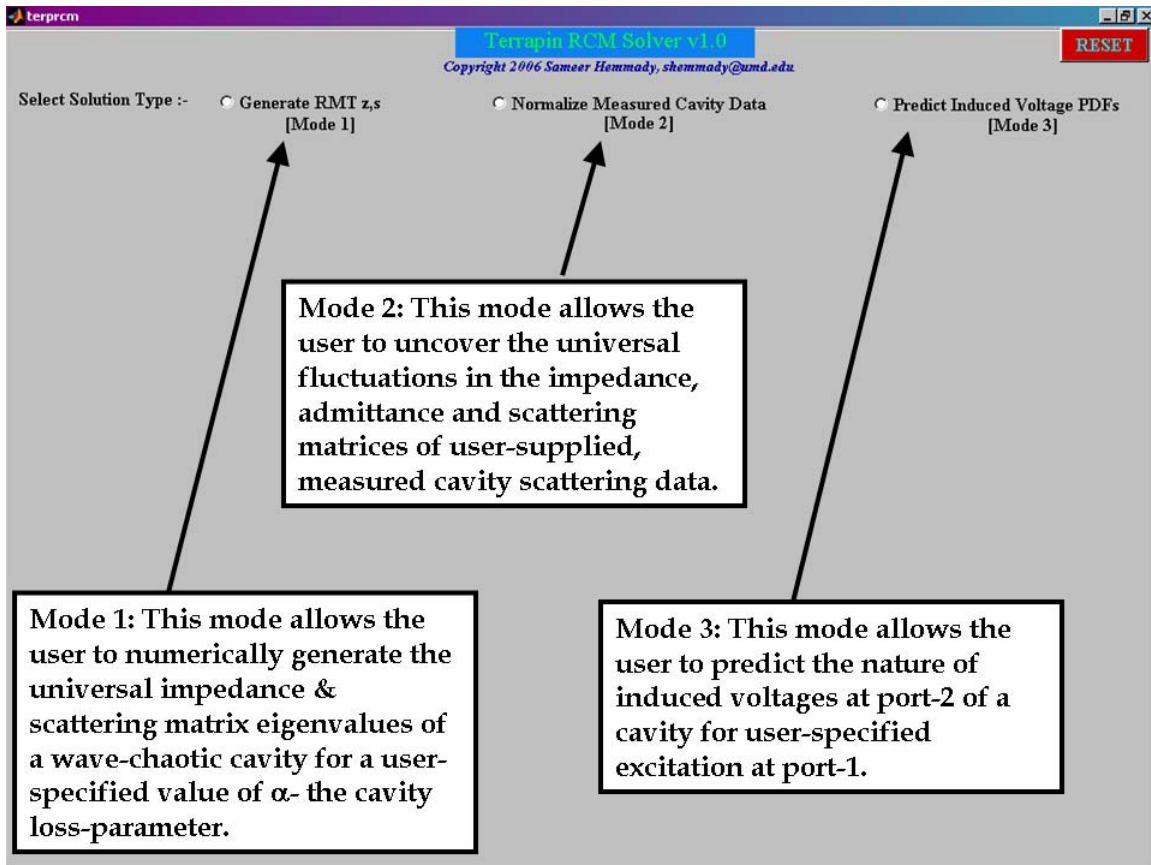
The software is designed to operate in 3 modes of operation (also known as “solution types”).

Generate RMT z,s [Mode 1]: In this mode, the user is prompted to specify the value of the cavity loss-parameter α which determines the shapes and scales of the universally fluctuating impedance and scattering matrix of a complicated enclosure. The software then uses this value of α to numerically generate a large ensemble of these universally fluctuating quantities and allows the user to export these quantities to a file.

Normalize Measured Cavity Data [Mode 2]: In this mode, the user is prompted to supply the measured cavity and radiation scattering matrix files of a real-world enclosure. The software then uses the “Random Coupling Model” to uncover the universal fluctuations in the impedance, admittance and scattering matrix of the real-world enclosure. The software also has the functionality of

calculating the ONERA- Scattering Ratio³ and the Maryland-Impedance Ratio⁴ from the user-supplied data files.

Predict Induced Voltage PDFs [Mode 3]: In this mode, the user is prompted to supply the measured/numerically generated radiation scattering matrix file for the ports of interest within a complicated real-world enclosure. The user is also prompted to specify the value of the cavity loss-parameter α . The software then determines the distribution of the induced voltages on the second port for a user-specified excitation at port-1. This mode works on the formalism of the “Terrapin Algorithm”.



Navigating the “Terrapin RCM Solver v1.0”.



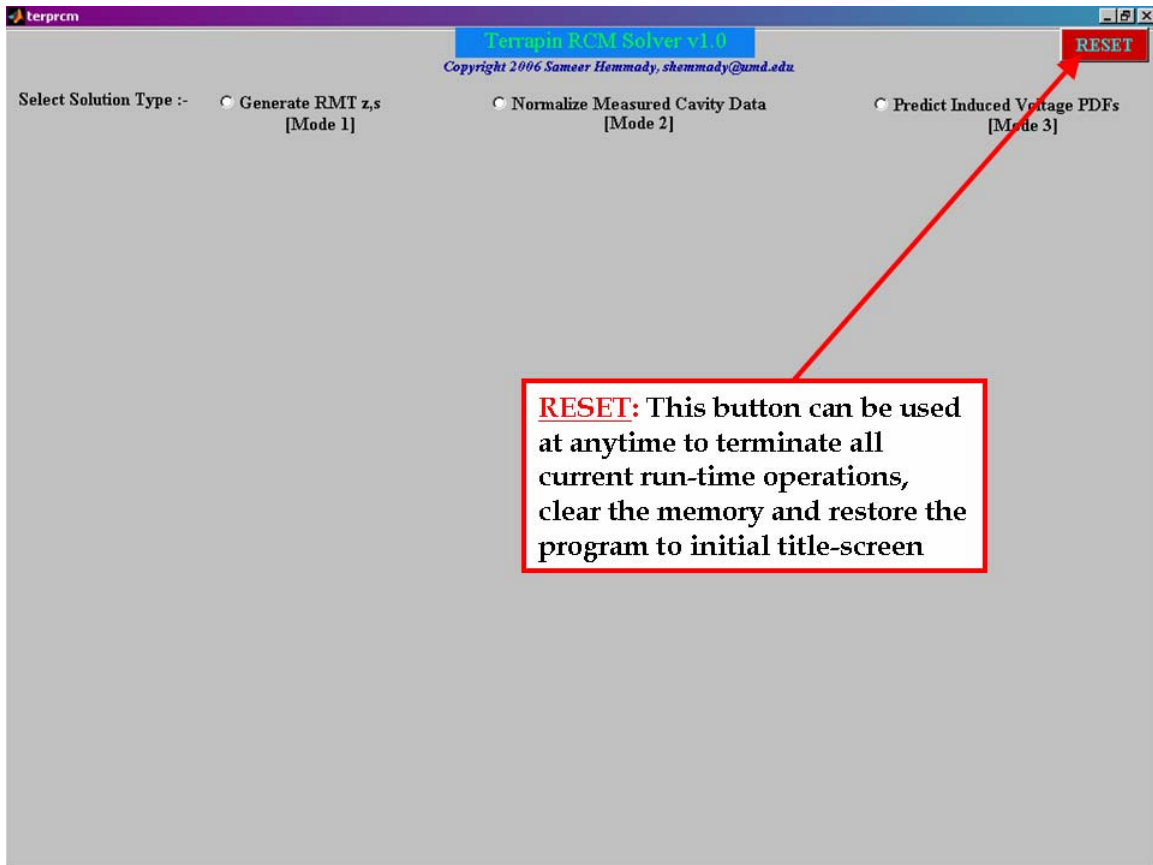
CAUTION: Always activate only one mode at a time. Activating two or more modes can result in the software becoming unstable.

³ C. Fiachetti and B. Michielsen, Electron. Lett. **39**, 1713 (2003).

⁴ Zheng, *et.al.* Phys. Rev. E. **73**, 046208 (2006).

Recovering from an unstable state:

In the event that the software enters an undesirable state. The user is provided with a red “**RESET**” button on the upper-right hand of the screen. This has the effect of terminating all current run-time processes associated with the Terrapin RCM Solver v1.0, clearing the memory and reinitiating the compiler. The software returns back to the initial title-screen and awaits further user action.



The use of the RESET button.

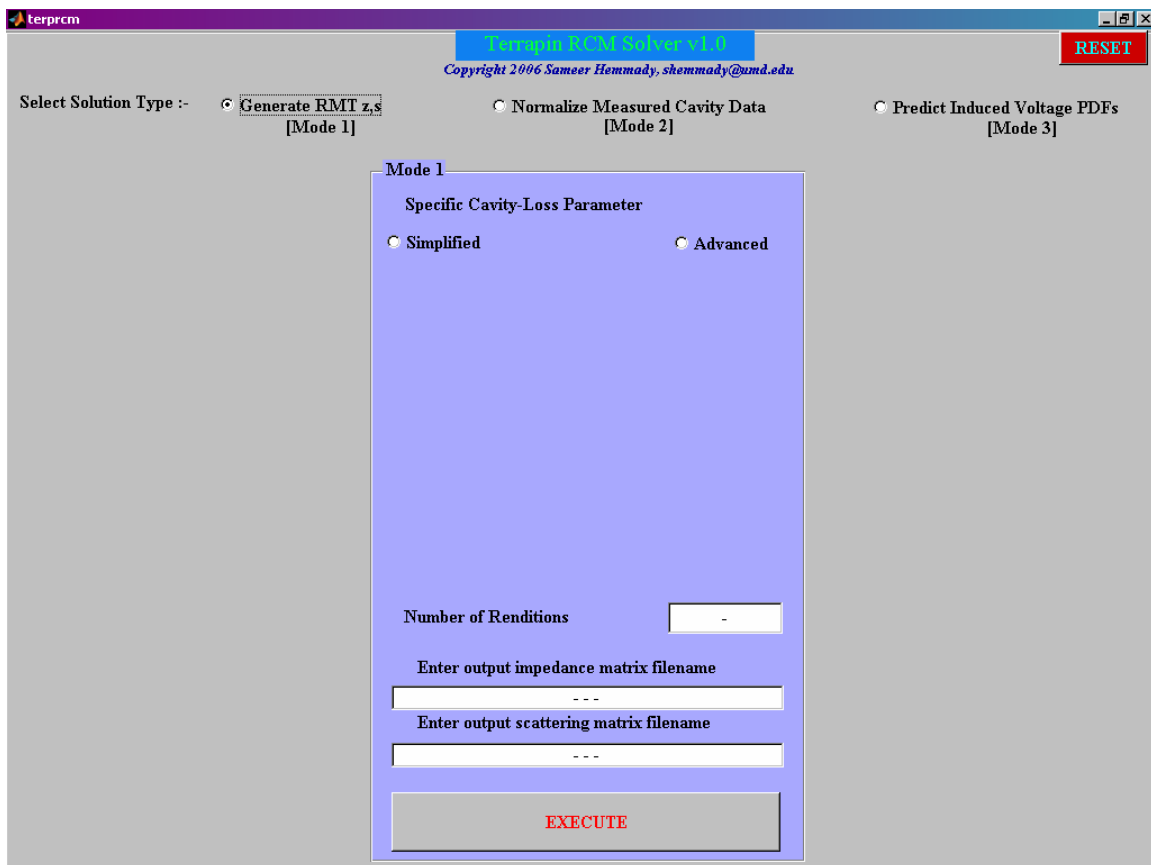


TIP: It is good practice to always **RESET** the software after every user-session in a given mode of operation. This prevents the possibility of erroneous data that has been stored in the memory in a prior session from corrupting the computations in the next session.

Tutorial: Generating RMT z,s [Mode 1]

In this section we provide the user with a step-by-step procedure to operate the “Terrapin RCM Solver v1.0” in Mode 1. In this mode, the user is prompted to specify the value of the cavity loss-parameter α which determines the shapes and scales of the universally fluctuating impedance and scattering matrix of a complicated enclosure. The software then uses this value of α to numerically generate a large ensemble of these universally fluctuating quantities and allows the user to export these quantities to a file.

1. Upon executing the Terrapin RCM Solver v1.0 and arriving at the Title-screen, click the radio-button entitled “Generating RMT z,s [Mode 1]”. The following screen will appear.



2. The user is prompted to specify the Cavity-Loss Parameter α . The software provides two options- Simplified **OR** Advanced. In the simplified mode, the user is prompted to directly specify the value of α . In the advanced mode, the user has greater flexibility and can use the software to calculate the value of α for a specific cavity setup. For simplified mode operation go to step 3. For advanced mode operation go to step 7.



CAUTION: Always activate either the Simplified OR the Advanced mode. Activating both can result in the software becoming unstable.

3. Clicking the radio-button marked “Simplified” will bring up the following screen.

terprcm

Terraqta PCM Solver v1.0

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RESET

Select Solution Type :- Generate RMT z,s [Mode 1] Normalize Measured Cavity Data [Mode 2] Predict Induced Voltage PDFs [Mode 3]

Mode 1

Specific Cavity-Loss Parameter

Simplified Advanced

Enter Cavity-Loss Parameter

Number of Renditions

Enter output impedance matrix filename

Enter output scattering matrix filename

EXECUTE

The user can now directly enter the value of the Cavity-Loss Parameter in the space provided. The Cavity-Loss Parameter is a non-negative real number, e.g. 0, 2.5, 3.154, etc.

4. The user can then specify the “Number of Renditions” in the space provided.



TIP: Typically, a value of 50,000 or more provides a good statistical estimate for the quantities to be determined. This will result in 50,000 impedance or scattering matrices to be written to the output files.

5. The user can now specify the output impedance and scattering matrix filenames in the appropriate space provided. e.g. "zout.txt" and "sout.txt". **NOTE:** the ".txt" extension is required. You can also specify a ".dat" extension if necessary.
6. Now press "EXECUTE" and sit back, relax... A progress bar should appear indicating the percentage of the process that has completed. When the process is finished, the resultant universal impedance and scattering matrix quantities are stored in the user-specified filenames in the same directory as the software.
7. Clicking the radio-button marked "Advanced" will bring up the following screen.

The screenshot shows the Terraqin BCM Solver v1.0 software interface. At the top, there is a title bar with 'terprcm' and a 'RESET' button. Below the title bar, the software title 'Terraqin BCM Solver v1.0' and copyright information 'Copyright 2006 Samser Hemmady, shemmady@umd.edu' are displayed. The main interface has three radio buttons for 'Select Solution Type': 'Generate RMT z,s [Mode 1]', 'Normalize Measured Cavity Data [Mode 2]', and 'Predict Induced Voltage PDFs [Mode 3]'. The 'Advanced' mode is selected. The interface is divided into several sections: 'Mode 1' with 'Specific Cavity-Loss Parameter' (radio buttons for 'Simplified' and 'Advanced'), '2-D Cavity' and '3-D Cavity' (radio buttons), 'Center Frequency (GHz)' (text input), 'Volume in cubic meters for 3-D [Area in square meters for 2-D]' (text input), 'Cavity Q' (text input), 'Result: Cavity-Loss Parameter' (text input), 'Number of Renditions' (text input), 'Enter output impedance matrix filename' (text input), and 'Enter output scattering matrix filename' (text input). At the bottom, there is an 'EXECUTE' button.

8. In the "Advanced" mode, the user can allow the software to determine the value of the Cavity-Loss Parameter α , for a specific setup.
9. Click on either "2-D Cavity" **OR** "3-D Cavity" depending upon your desired setup.
10. Enter the Center Frequency in GHz in the space provided ,e.g. 2, 0.075, etc.
11. Enter the Volume in cubic meters if you have chosen the "3-D Cavity" option in step 9; else enter the Surface-Area of the cavity in square meters if you have chosen the "2-D Cavity" in step 9.

12. Enter the typical value of Cavity Q that you would expect for your setup at the frequency specified in step 10.
13. Now follow steps 4, 5 and 6. At the end of the process, the resultant value of the Cavity-Loss Parameter that corresponds to your input parameters in steps 9,10,11 will be displayed in the space marked "Result: Cavity-Loss Parameter".

Format of the output files from Solution Type 1 (Mode 1):

Assume that the filenames that correspond to the output impedance and output scattering matrix files are "zout.txt" and "sout.txt" respectively. Each file will contain a large number (as specified by the value of the "Number of Iterations") of real-numbers that correspond to the normalized (universal) impedance and scattering matrices. A typical file structure will look as below:

	Re[z ₁₁] or Re[s ₁₁]	Re[z ₁₂] or Re[s ₁₂]	Re[z ₂₁] or Re[s ₂₁]	Re[z ₂₂] or Re[s ₂₂]		Re[z ₁₁] or Re[s ₁₁]	Re[z ₁₂] or Re[s ₁₂]	Re[z ₂₁] or Re[s ₂₁]	Re[z ₂₂] or Re[s ₂₂]
		Im[z ₁₁] or Im[s ₁₁]		Im[z ₁₂] or Im[s ₁₂]		Im[z ₂₁] or Im[s ₂₁]		Im[z ₂₂] or Im[s ₂₂]	
	0.18213	-0.99818	0.84916	0.11414	0.63286	-0.03571	0.39166	0.52449	
	0.02162	-0.4235	0.79793	-0.50864	0.61323	0.14853	0.25176	2.17794	
	0.36132	1.06234	0.54616	-0.6026	0.63482	-0.23643	0.42185	-0.80975	
	0.28765	0.0401	0.05567	-0.48524	0.60565	0.65151	0.08125	-1.24666	
Each row represents one matrix →	0.32034	1.29255	0.55954	-0.52622	0.68425	0.72475	0.49976	0.98419	
	0.12101	-0.9097	0.9646	0.79525	0.67223	-0.89457	0.20754	1.30183	
	0.95813	1.51249	0.02783	1.03058	0.36665	-1.45543	0.56844	0.32398	
	0.54788	-0.38255	0.42843	-0.2789	0.32442	-0.26882	0.56569	1.31037	
	0.48163	0.99011	0.56428	-1.56302	0.19107	-1.25469	0.30649	-0.37908	
	0.14965	-0.192	0.79218	0.646	0.99771	0.94877	0.79621	-2.19104	
	0.1847	0.01934	0.14018	0.09842	0.29572	0.41846	0.16744	0.06969	
	0.06645	0.17867	0.68599	2.05491	0.95249	-0.8458	0.63628	-2.75247	
	0.77145	0.69037	0.45146	0.64898	0.80211	0.78466	0.29735	-0.27942	
	0.92409	-0.8169	0.45799	0.08549	0.08441	-1.16249	0.15894	0.08052	
	0.72871	-0.63699	0.49892	-0.61751	0.78182	0.29162	0.99504	-1.56506	
	0.27806	-0.24926	0.16949	-1.0854	0.08539	-1.73365	0.73255	-0.62789	
	0.48295	-2.63007	0.31756	-0.48208	0.90362	0.3967	0.90433	-1.19897	
	0.16685	1.03721	0.88447	0.1549	0.3335	-1.00835	0.44023	-1.61361	
	0.77321	-0.78053	0.96972	-0.70674	0.70176	-2.12449	0.36059	0.80652	
	0.23687	0.33875	0.39771	-0.79878	0.86895	-0.0642	0.92581	-0.30937	

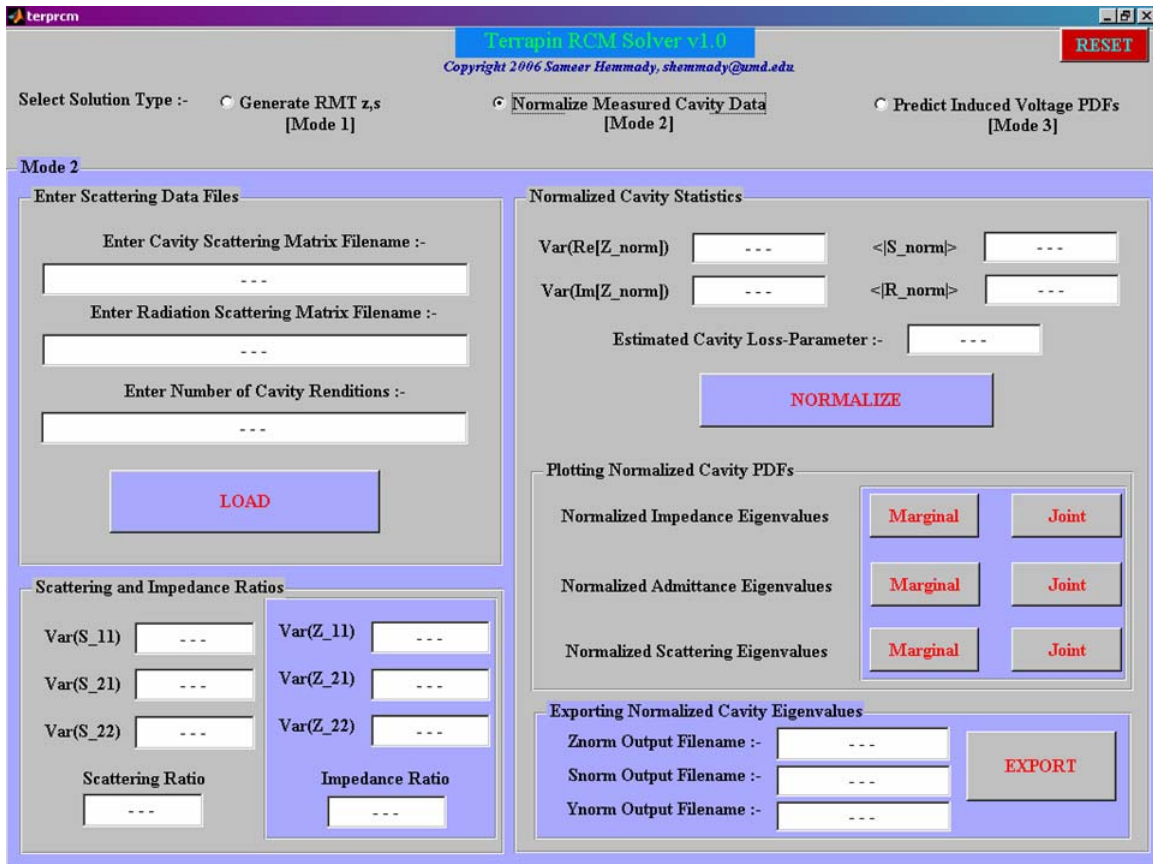
where z_{xy} or s_{xy} , (x,y=1,2) represent the elements of the z or s matrix with usual electromagnetic convention. Each row is a matrix that represents the cavity Impedance or Scattering matrix for a given value of α when the driving ports are perfectly-coupled (ideally-matched) to the cavity. The list of numbers shown in the figure above is purely for the purposes of showing the user how the output data file is formatted. It is NOT actual data generated by the software.

Tutorial: Normalize Measured Cavity Data [Mode 2]

In this section we provide the user with a step-by-step procedure to operate the “Terrapin RCM Solver v1.0” in Mode 2. In this mode, the user can use the software to uncover and plot universal fluctuations in the impedance, admittance and scattering matrices for a user-supplied cavity data-file. The software makes use of the measured cavity scattering matrix and the measured cavity radiation matrix files along the lines of the impedance-normalization process of the Random Coupling Model.

For the benefit of the first-time user, we have provided two sample data files- “Scav.txt” and “Srad.txt”. The file “Scav.txt” contains 104 measurements of a 3D mode-stirred cavity which is driven by two ports in the frequency range of 4-5 GHz (in 300 equi-spaced frequency steps). The file “Srad.txt” contains a single measurement of the radiation scattering matrix of the two driving ports in the frequency range of 4-5GHz (in 300 equi-spaced frequency steps).

1. Upon executing the Terrapin RCM Solver v1.0 and arriving at the Title-screen, click the radio-button entitled “Normalize Measured Cavity Data [Mode 2]”. The following screen will appear.




2. Type "Scav.txt" in the space provided for the Cavity Scattering Matrix file name.
3. Type "Srad.txt" in the space provided for the Radiation Scattering Matrix file name.
4. Type "104" in the space provided for the Number of Cavity Renditions.
5. Click "LOAD". A progress bar should appear indicating the percentage of the process that has completed. When the process is finished, the relevant values for the variances of the cavity Scattering and Impedance matrix elements will appear in their respective spaces. The software will also compute the resultant ONERA Scattering and Maryland Impedance Ratio for the user-supplied data set.
6. Now click "NORMALIZE". A progress bar should appear indicating the percentage of the process that has completed. When the process is finished, the relevant values for the quantities of the normalized(universal) cavity Scattering and Impedance matrix elements will appear in their respective spaces.
7. The user can now also click on any of the buttons marked "Marginal" or "Joint" to plot the resultant universal marginal or joint PDFs of the impedance, admittance or scattering eigenvalues. (PDF=Probability Density Function).

8. The user also has the option to export these normalized (universal) eigenvalues {real-part, imaginary-part} to a file. Specify the name of the files where you would like to store the normalized impedance, admittance and scattering eigenvalues and then click "EXPORT". A progress bar should appear indicating the percentage of the process that has completed.

The formatting for the Scav.txt data file is shown on the next page. Please format your own measured cavity data sets as shown in order to successfully use this software. Make sure your measured cavity and radiation files are in the same directory as the software.

NOTE: The user-supplied Radiation Scattering Matrix data file should have the same format as above. However, there should be only one measured rendition of the radiation scattering matrix.



 **TIP:** When using your own measured cavity data-sets, keep in mind that the value of α changes as a function of frequency. So, use measured cavity and radiation data-sets only over frequency ranges where you know the losses change insignificantly over the given frequency range. We have found that 1 GHz is typically a good frequency-span to work with.

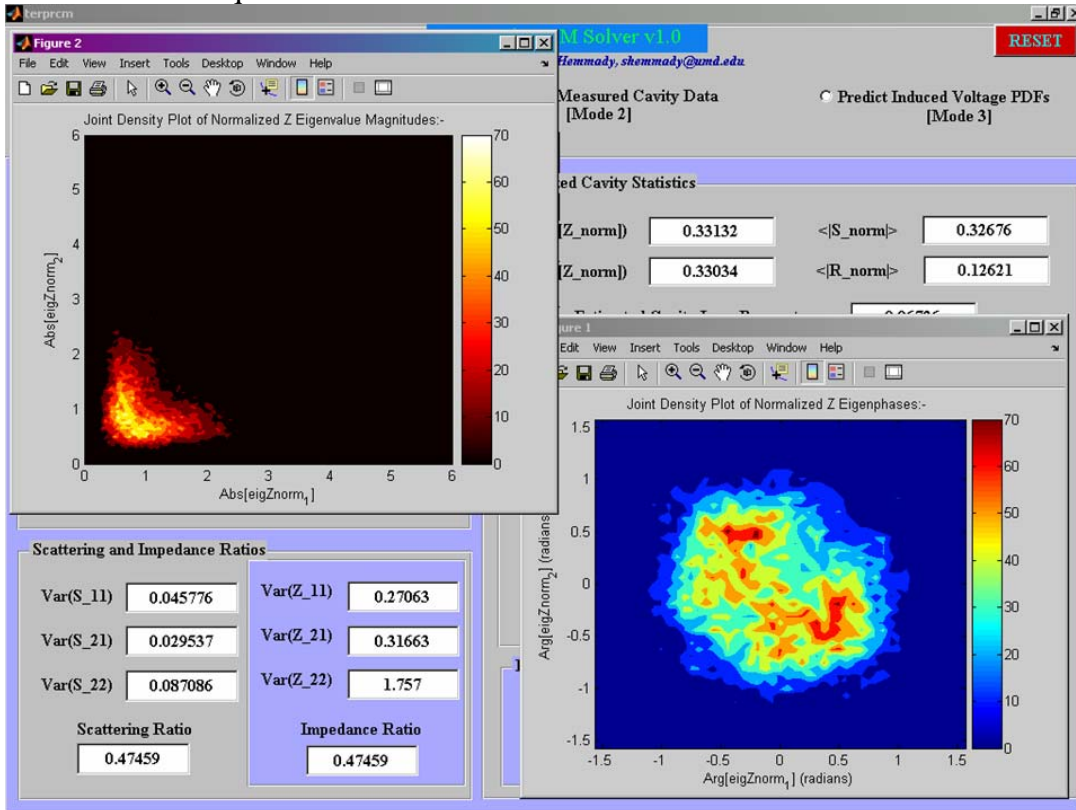
	Re[S ₁₁]	Re[S ₁₂]	Re[S ₂₁]	Re[S ₂₂]				
Rendition 1	0.12101	-0.9097	0.9646	0.79525	0.67223	-0.89457	0.20754	1.30183
	0.95813	1.51249	0.02783	1.03058	0.36665	-1.45543	0.56844	0.32398
	0.54788	-0.38255	0.42843	-0.2789	0.32442	-0.26882	0.56569	1.31037
	0.48163	0.99011	0.56428	-1.56302	0.19107	-1.25469	0.30649	-0.37908
	0.14965	-0.192	0.79218	0.646	0.99771	0.94877	0.79621	-2.19104
Rendition 2	0.1847	0.01934	0.14018	0.09842	0.29572	0.41846	0.16744	0.06969
	0.06645	0.17867	0.68599	2.05491	0.95249	-0.8458	0.63628	-2.75247
	0.77145	0.69037	0.45146	0.64898	0.80211	0.78466	0.29735	-0.27942
	0.92409	-0.8169	0.45799	0.08549	0.08441	-1.16249	0.15894	0.08052
	0.72871	-0.63699	0.49892	-0.61751	0.78182	0.29162	0.99504	-1.56506
	0.27806	-0.24926	0.16949	-1.0854	0.08539	-1.73365	0.73255	-0.62789
	0.48295	-2.63007	0.31756	-0.48208	0.90362	0.3967	0.90433	-1.19897
	0.16685	1.03721	0.88447	0.1549	0.3335	-1.00835	0.44023	-1.61361
	0.77321	-0.78053	0.96972	-0.70674	0.70176	-2.12449	0.36059	0.80652
	0.23687	0.33875	0.39771	-0.79878	0.86895	-0.0642	0.92581	-0.30937

Formatting user-supplied Cavity data files

Shown above is the typical format for arranging your measured cavity scattering matrix file in order to successfully use this software. The measured data is arranged into 8 columns as shown. Each row represents the elements of one scattering matrix at a given frequency. If you are measuring the cavity scattering response from 4 to 5 GHz in 1000 equi-spaced frequency steps, then there will be 1000 rows corresponding to the 1000 scattering matrix values measured at each frequency. This set of 1000 rows will correspond to the first measured rendition of the cavity. A similar set of 1000 rows which corresponds to your second measured rendition of the

cavity will follow, as shown above. The difference between rendition sets is caused because of either moving some perturbation within the cavity such as a metal ball, or a mode-stirrer which serves to significantly alter the field configurations within the cavity.

The radiation scattering matrix file should also be constructed to conform to the format above. However, only one measurement of the radiation scattering matrix rendition set is required.



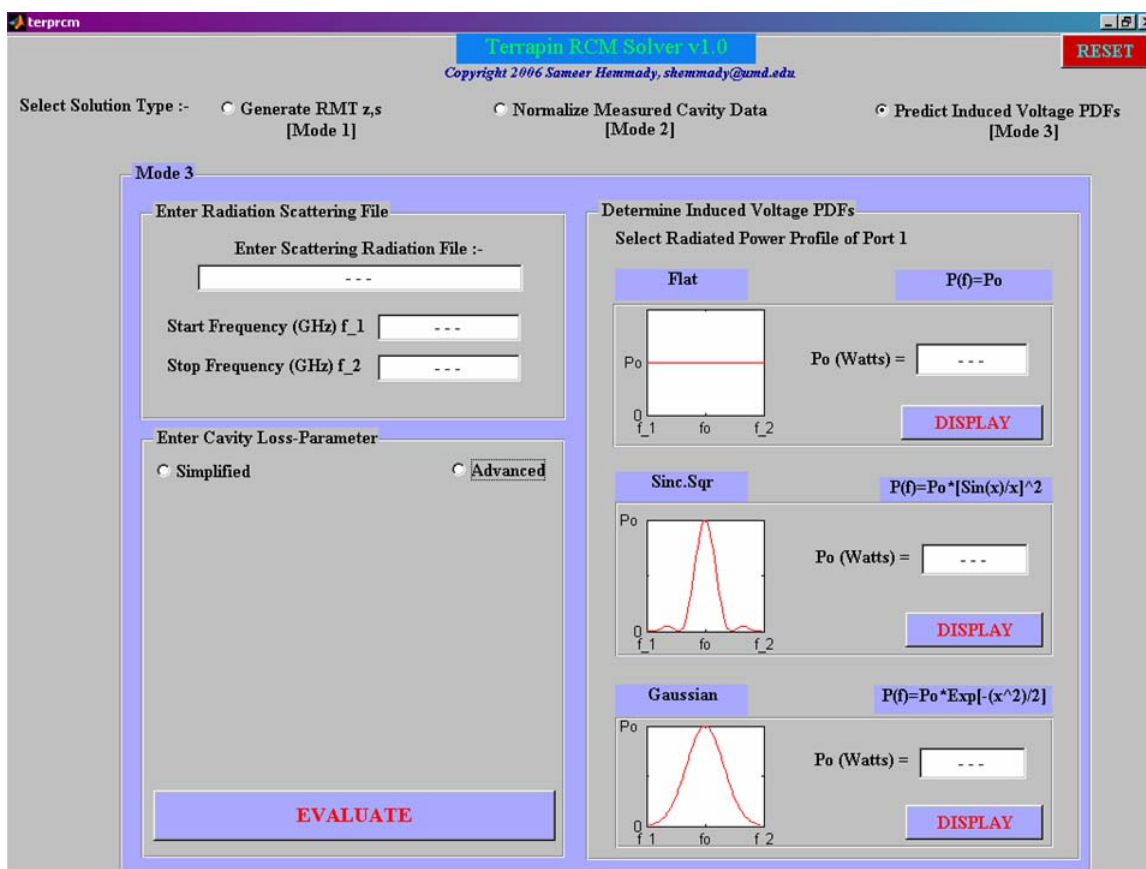
Screenshot : Plots for the Joint PDF of the Universal Impedance eigenvalues

Shown above is a typical screenshot obtained upon successfully plotting the Joint PDF of the universal impedance eigenvalues. The figure in “yellow-red-black” color-code shows the joint PDF between the eigenvalue magnitudes of the normalized (universal) impedance. The figure in the “red-green-blue” color-code shows the joint PDF between the eigenphases of the normalized (universal) impedance.

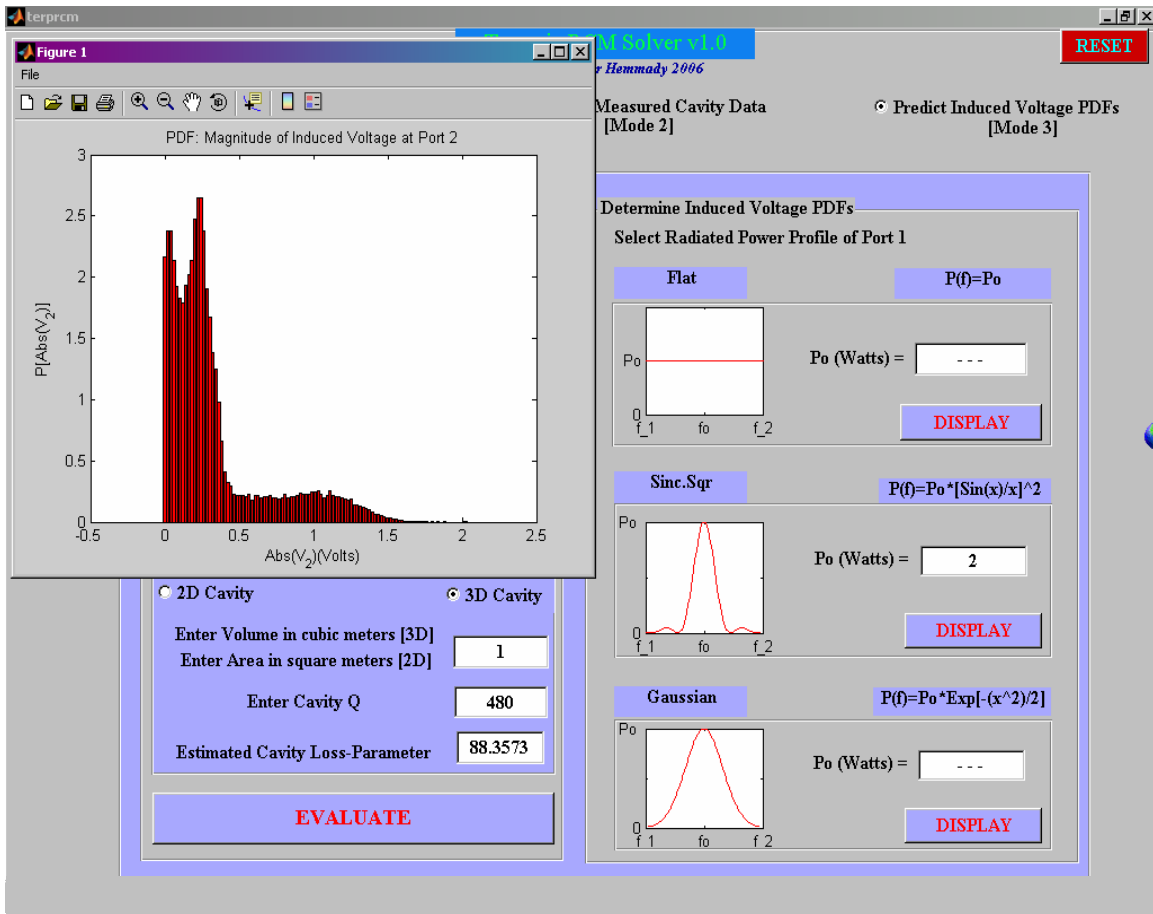
Tutorial: Predict Induced Voltage PDFs [Mode 3]

In this section we provide the user with a step-by-step procedure to operate the “Terrapin RCM Solver v1.0” in Mode 3. In this mode, the user can use the software to make statistical predictions for the nature of the induced voltages at Port-2 in a complicated 2D or 3D enclosure for a user-specified excitation at Port-1.

1. Upon executing the Terrapin RCM Solver v1.0 and arriving at the Title-screen, click the radio-button entitled “Predict Induced Voltage PDFs [Mode 3]”. (PDF=Probability Density Function). The following screen will appear.



2. The user can then enter the file name of the user-supplied radiation scattering matrix file. For instructions on user-supplied files refer to pages 11, 12. For the benefit of the first-time user, we have provided the file "Srad.txt" which contains a single measurement of the radiation scattering matrix of two driving ports in a 3D mode-stirred cavity, in the frequency range of 4-5GHz (in 1000 equi-spaced frequency steps). Enter "Srad.txt" in the space provided.
3. Enter the start and stop frequencies in GHz in the appropriate spaces. Use "4" and "5" for Start and Stop frequency if using Srad.txt.
4. The user can then specify the Cavity-Loss Parameter in either the Simplified mode or Advanced Mode. Refer to pages 7,8 for further details.
5. Click "EVALUATE". A progress bar should appear indicating the percentage of the process that has completed. When the process is finished, the resultant value of the Cavity-Loss Parameter is displayed if the "Advanced" option is selected in step 4.
6. The user can then select an appropriate excitation at port-1 of the cavity. The current version supports three port-1 radiated power-profiles :
 - a. Flat Response : User-specified value of P_o Watts from f_1 to f_2 .
 - b. Sinc-Squared Response: User-specified value of P_o Watts from f_1 to f_2 .
 - c. Gaussian Response: User-specified value of P_o Watts from f_1 to f_2 .
7. Upon selecting the desired port-1 excitation by specifying the value of P_o (in Watts), the user can click the appropriate "DISPLAY" button to plot the distribution of the real, imaginary, magnitude and phase of the induced voltages at port-2 for the user-specified excitation at port-1.



Shown above is a typical screenshot obtained upon successfully plotting the PDF of Induced Voltages on Port-2 for a 2-Watt peak Sinc-Square excitation from Port-1.

Finally,



TIP: It is good practice to always **RESET** the software after every user-session in a given mode of operation. This prevents the possibility of erroneous data that has been stored in the memory in a prior session from corrupting the computations in the next session.

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