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Battery-Free Antenna Sensors for Strain and Crack Monitoring: Data Report

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Data Report
for
Individual INSPIRE UTC Research Project

Project/Report Title: Battery-Free Antenna Sensors for Strain and Crack Monitoring
Consortium Member/University: Georgia Institute of Technology
Principal Investigator: Yang Wang
Co-Principal Investigator(s):
Project State Date: 06/01/2017
Project End Date: 12/31/2019

Data Types: *Within one month after the project's completion date***,** Principal Investigator is responsible for preparing and submitting a final data report in a format that is easy to understand by any third party. INSPIRE UTC will collect and archive the final data sets from any research project. It is the responsibility of the principal investigator to determine what constitutes final data.

Describe the nature and scale of what you have collected throughout the project period, including data types, file formats, file sizes, etc. Each file should clearly label each row or column of data in any table and label any figure in a brief and self-explanatory manner. For example, the Principal Investigator is required to clearly describe the methods used to create the data (e.g., simulated, observed, experimental, measured, etc.). Unless described in the final project report, the test procedure and measurement instrument need to be specified in the final data report.

A total of 15 data sets are submitted along with the final project report. The submission contains a combination of simulated and experimental data sets. The formats include text files (both *.txt and *.tff), MATLAB data *.mat files, and MATLAB plotting code *.m files.

The simulation and experimental procedures generating each data set is elaborated in detail in the final report, and are thus not repeated herein. Upon unzipping the data package, the 15 data sets can be seen organized in 15 subfolders (some in the first level and some in the second level subfolders).

To help a reader relate the data to the final report, each subfolder name contains the numbering of the report subsection that describes the procedure in detail and plots the data set. Figure numbers in the report are also referred to in the data files, so that a reader can easily relate to the data plots in the report. The following list describes in detail the data set in each of the 15 subfolders.

1. Data set in subfolder \3.1.1.1 Chamber_Test

- "DielectricConstant.mat"
  This file contains dielectric constants of RT/duroid® 6202 substrate at different temperatures.
  'DKTemp' variable – a 12×1 double array including temperature levels.
  'DKValue' variable – a 12×1 double array including dielectric constants of RT/duroid® 6202 substrate.

- "Fig3_2.xlsx"
  This file contains temperature data measured by thermometers in the temperature chamber test of patch antenna sensor with RT/duroid® 6202 substrate.
  'T1' variable – a 12×1 double array including the temperature data measured by thermometer #1.
  'T2' variable – a 12×1 double array including the temperature data measured by thermometer #2.
  'T3' variable – a 12×1 double array including the temperature data measured by thermometer #3.

- "Fig3_3.m"
  This is the main MATLAB function to plot Fig. 3-3, Temperature chamber test results (antenna sensor with RT/duroid® 6202 substrate).

- "Fig3_4.m"
  This is the main function to plot Fig. 3-4, Effect of dielectric constant change during temperature fluctuation (RT/duroid® 6202 substrate).

- "Fig3_5.m"
  This is the main function to plot Fig. 3-5, Resonance frequency change during temperature fluctuation (RT/duroid® 5880 substrate).

- "Plot_FreqvsStrain_1.m"
  This function plots the resonance frequency change during temperature fluctuation. This function is called by "Fig3_3.m".

- "Plot_FreqvsStrain_2.m"
  This function plots the resonance frequency change during temperature fluctuation. This function is called by "Fig3_4.m".

- "Plot_FreqvsStrain_3.m"

This function plots the resonance frequency change during temperature fluctuation. This function is called by "Fig3_5.m".

- "PlotOneSensor.m"
  This function plots the average interrogation power thresholds of patch antenna sensor. This function is called by "Fig3_3.m", "Fig3_4.m", and "Fig3_5.m".

- "resonancefrequency5880.mat"
  This file contains chamber test data of patch antenna sensor with RT/duroid® 5880 substrate.
  'MeanTemp' variable – a 11×1 double array including the average temperatures measured by thermometers.
  'MinFreq' variable – a 11×1 double array including the resonance frequency of the patch antenna at each temperature level.

- "transmittedpower.tff"
  This text file contains interrogation power threshold of the patch antenna sensor with RT/duroid® 6202 substrate measured by Tagformance RFID reader. This file contains 60 data blocks, and each data block contains following variables:
  'Frequency' variable – an 81×1 double array including frequency of the interrogation signal.
  'Transmitted power' variable – an 81×1 double array including measured interrogation power threshold.

2. Data set in subfolder \3.1.1.2 Outdoor_Test

- "Fig3_6.m"
  This is the main function to plot Fig. 3-6, subfigure (b) Resonance frequency change in outdoor temperature test.

- "RO5880RO6202.mat"
  This file contains outdoor test data of patch antenna sensor with RT/duroid® 5880 substrate and patch antenna sensor with RT/duroid® 6202 substrate.
  'ro5880' variable – a 15×1 double array including the resonance frequency of the patch antenna with RT/duroid® 5880 substrate at each time step.
  'ro6202' variable – a 15×1 double array including the resonance frequency of the patch antenna with RT/duroid® 6202 substrate at each time step.
  't' variable – a 15×1 duration array including the time step.
  'temperature' variable – a 15×1 double array including the average temperature measured by thermal couples at each time step.

- "Temperature.xlsx"
  This file contains temperature data measured by thermal couples during outdoor test.
  'TC-1-1' variable – a 15×1 double array including the temperature data measured by thermal couple #1 at reading #1.
  'TC-2-1' variable – a 15×1 double array including the temperature data measured by thermal couple #2 at reading #1.
  'TC-1-2' variable – a 15×1 double array including the temperature data measured by thermal couple #1 at reading #2.
  'TC-2-2' variable – a 15×1 double array including the temperature data measured by thermal couple #2 at reading #2.
  'TC-1-3' variable – a 15×1 double array including the temperature data measured by thermal couple #1 at reading #3.
  'TC-2-3' variable – a 15×1 double array including the temperature data measured by thermal couple #2 at reading #3.

3. Data set in subfolder \3.1.2.1 Constitutive_Relationship\Longitudinal_Direction

- "Fig3_9_10_11.m"
  This is the main function to plot data in Fig. 3-9 Starting values for updating substrate constitutive relationship along longitudinal direction, Fig. 3-10 Optimization results for updating substrate constitutive relationship along longitudinal direction, and Fig. 3-11 Constitutive relationship along longitudinal direction.

- "RO6202Longitudinal.txt"
  This file contains experimental constitutive relationship of RT/duroid® 6202 substrate along longitudinal direction. This file includes a 531×2 double array. The first column is the strain data, and the second column is the stress data.

- "sPoint1000.mat"
  This file contains 1,000 trial sets of starting values for the updating variables of model updating problem for constitutive relationship along longitudinal direction.
  'sPoint1000' variable – a 1000×4 double array including the 1,000 starting points for updating variables.

- "OptData.mat"
  This file contains model updating results of constitutive relationship along longitudinal direction.
  'fval' variable – a 1×1000 double array including the minima of objective function from 1,000 runs.
  'fval_global' variable – a 1×1 double variable representing the global minimum of the objective function.

'x' variable – a 1000× 4 double array including the optimal values of updating variables from 1,000 runs.
'x_global' variable – a 1×4 double array representing the global solution of updating variables.

4. Data set in subfolder \3.1.2.1 Constitutive_Relationship\Transverse_Direction

- "Fig3_12_13.m"
  This is the main function to plot Fig. 3-12 Optimization results for updating substrate constitutive relationship along longitudinal direction, and Fig. 3-13 Constitutive relationship along transverse direction.

- "RO6202Transverse.txt"
  This file contains experimental constitutive relationship of RT/duroid® 6202 substrate along transverse direction. This file includes a 588×2 double array. The first column is the strain data, and the second column is the stress data.

- "sPoint1000.mat"
  This file contains 1,000 trial sets of starting values for the updating variables of model updating problem for constitutive relationship along transverse direction.
  'sPoint1000' variable – a 1000×4 double array including the 1,000 starting points for updating variables.

- "OptData.mat"
  This file contains model updating results of constitutive relationship along transverse direction.
  'fval' variable – a 1×1000 double array including the minima of objective function from 1,000 runs.
  'fval_global' variable – a 1×1 double variable representing the global minimum of the objective function.
  'x' variable – a 1000× 4 double array including the optimal values of updating variables from 1,000 runs.
  'x_global' variable – a 1×4 double array representing the global solution of updating variables.

5. Data set in subfolder \3.1.2.2 Strain_Transfer_Ratio\Experiment

- "Fig3_16.m"
  This is the main function to plot Fig. 3-16 Strain on the patch antenna sensor versus strain on the aluminum plate.

- "Strain.txt"
  This file contains experimental data of strain transfer ratio test. This file includes a 610×6 double array. Column 1~2 are strain data of top copper cladding, and column 3~6 are strain data of aluminum specimen.

6. Data set in subfolder \3.1.2.2 Strain_Transfer_Ratio\Optimization

- "Fig3_18.m"
  This is the main function to plot Fig. 3-18 Strain transfer ratio.

- "straintransferratio_experiment.mat"
  This file contains strain transfer ratio of patch antenna sensor obtained from tensile test.
  'Mean_Strain_Al' variable – a 61×1 double array including the strain of aluminum specimen.
  'Strain_Percent' variable – a 61×1 double array including the strain transfer ratio of patch antenna sensor at each strain level.

- "straintransferratio_initialmodel.txt"
  This file contains strain transfer ratio of patch antenna sensor simulated using initial model parameters. This file includes a 9×2 double array. The first column is the strain on aluminum specimen, and the second column is the simulated strain transfer ratio of patch antenna sensor.

- "straintransferratio_optimizedmodel.txt"
  This file contains strain transfer ratio of patch antenna sensor simulated using updated model parameters. This file includes a 9×2 double array. The first column is the strain on aluminum specimen, and the second column is the simulated strain transfer ratio of patch antenna sensor.

7. Data set in subfolder \3.1.3 Transmission_Line\Experiment

- "Fig3_21.m"
  This is the main function to plot Fig. 3-21 Transmission line test results.

- "s21Data.mat"
  This file contains strain transfer ratio of patch antenna sensor obtained from tensile test.
  's21Data' variable – a 12801×2×56 double array including the S_{21} data of the transmission line at 56 strain levels. For each strain level, the first column is the frequency of input signal, and the second column is the corresponding S_{21}.

- "Strain.txt"
  This file contains strain data of transmission line test. This file includes a 1120×6 double array. Column 1~3 are strain data of aluminum specimen, and column 4~6 are strain data of top copper cladding.

8. Data set in subfolder \3.1.3 Transmission_Line\Optimization

- "Fig3_22.m"
  This is the main function to plot Fig. 3-22 Updating results for dielectric constant updating.

- "objective.m"
  This is the objective function of optimization problem for model updating of electrostriction. This function is called by "Fig3_22.m".

- "s21Data.mat"
  This file contains strain transfer ratio of patch antenna sensor obtained from tensile test. 's21Data' variable – a 12801×2×56 double array including the S_{21} data of the transmission line at 56 strain levels. For each strain level, the first column is the frequency of input signal, and the second column is the corresponding S_{21}.

- "Strain.txt"
  This file contains strain data of transmission line test. This file includes a 1120×6 double array. Column 1~3 are strain data of aluminum specimen, and column 4~6 are strain data of top copper cladding.

9. Data set in subfolder \3.2 Multiphysics_Simulation

- "Fig3_23.m"
  This is the main function to plot Fig. 3-23, subfigure (c) Resonance frequency change from multi-physics simulation on patch antenna sensor.

- "Nonlinear.dat"
  This file contains resonance frequency change of patch antenna sensor obtained from multi-physics simulation. This file includes a 15×2 double array. The first column is the strain applied on aluminum specimen, and the second column is the simulated resonance frequency of patch antenna sensor.

10. Data set in subfolder \3.3.1 Compressive_Test

- "Fig3_24.m"
  This is the main function to plot Fig. 3-24 subfigure (b) Interrogation power threshold and subfigure (c) Resonance frequency change from compression test.

- "Plot_FreqvsStrain.m"
  This function plots the resonance frequency change under strain. This function is called by "Fig3_24.m".

- "PlotOneSensor.m"
  This function plots the average interrogation power thresholds of patch antenna sensor. This function is called by "Fig3_24.m".

- "PlotStressStrain.m"
  This function plots the strain-stress relationship obtained from the compressive test. This function is called by "Fig3_24.m".

- "power.tff"
  This file contains interrogation power threshold of patch antenna sensor measured by Tagformance RFID reader. This file contains 35 data blocks, and each data block contains following variables:
  'Frequency' variable – a 151×1 double array including frequency of the interrogation signal.
  'Transmitted power' variable – a 151×1 double array including measured interrogation power threshold.

- "SolveSlope.m"
  This function calculates the strain sensitivity of patch antenna sensor. This function is called by "Plot_FreqvsStrain.m".

- "strain_1Hz.txt"
  This file contains strain data of compressive test. This file includes a 1500×3 double array. Column 1~3 are strain data of aluminum specimen measured by three strain gages, respectively.

11. Data set in subfolder \3.3.2 Tensile_Test\3.3.2.1 RFID_Patch_Antenna_Test

- "Fig3_26.m"
  This is the main function to plot Fig. 3-26 Tensile test results.

- "Plot_FreqvsStrain.m"

This function plots the resonance frequency change under strain. This function is called by "Fig3_26.m".

- "PlotOneSensor.m"
  This function plots the average interrogation power thresholds of patch antenna sensor. This function is called by "Fig3_26.m".

- "PlotStressStrain.m"
  This function plots the strain-stress relationship obtained from the tensile test. This function is called by "Fig3_26.m".

- "power.tff"
  This file contains interrogation power threshold of patch antenna sensor measured by Tagformance RFID reader. This file contains 35 data blocks, and each data block contains following variables:
  'Frequency' variable – a 61×1 double array including frequency of the interrogation signal.
  'Transmitted power' variable – a 61×1 double array including measured interrogation power threshold.

- "SolveSlope.m"
  This function calculates the strain sensitivity of patch antenna sensor. This function is called by "Plot_FreqvsStrain.m".

- "strain_1Hz.txt"
  This file contains strain data of tensile test. This file includes a 700×3 double array. Column 1~3 are strain data of aluminum specimen measured by three strain gages, respectively.

12. Data set in subfolder \3.3.2 Tensile_Test\3.3.2.2 DualMode_RFID_Patch_Antenna_Sensor\ Passive_Mode

- "Fig3_28.m"
  This is the main function to plot Fig. 3-28 Passive mode tensile test results.

- "Plot_FreqvsStrain.m"
  This function plots the resonance frequency change under strain. This function is called by "Fig3_28.m".

- "PlotOneSensor.m"

This function plots the average interrogation power thresholds of dual-mode patch antenna sensor in passive mode. This function is called by "Fig3_28.m".

- "PlotStressStrain.m"
  This function plots the strain-stress relationship obtained from the tensile test on dual-mode patch antenna sensor in passive mode. This function is called by "Fig3_28.m".

- "power.tff"
  This file contains interrogation power threshold of dual-mode patch antenna sensor measured by Tagformance RFID reader. This file contains 35 data blocks, and each data block contains following variables:
  'Frequency' variable – a 101×1 double array including frequency of the interrogation signal.
  'Transmitted power' variable – a 101×1 double array including measured interrogation power threshold.

- "SolveSlope.m"
  This function calculates the strain sensitivity of dual-mode patch antenna sensor in passive mode. This function is called by "Plot_FreqvsStrain.m".

- "strain_1Hz.txt"
  This file contains strain data of tensile test on dual-mode patch antenna sensor in passive mode. This file includes a 700×4 double array. Column 1~4 are strain data of aluminum specimen measured by four strain gages, respectively.

13. Data set in subfolder \3.3.2 Tensile_Test\3.3.2.2 DualMode_RFID_Patch_Antenna_Sensor\ Active_Mode

- "Fig3_29.m"
  This is the main function to plot Fig. 3-29 Active mode tensile test results.

- "Plot_FreqvsStrain.m"
  This function plots the resonance frequency change under strain. This function is called by "Fig3_29.m".

- "PlotOneSensor.m"
  This function plots the average interrogation power thresholds of dual-mode patch antenna sensor in active mode. This function is called by "Fig3_29.m".

- "PlotStressStrain.m"

This function plots the strain-stress relationship obtained from the tensile test on dual-mode patch antenna sensor in active mode. This function is called by "Fig3_29.m".

- "power.tff"
  This file contains interrogation power threshold of dual-mode patch antenna sensor measured by Tagformance RFID reader. This file contains 35 data blocks, and each data block contains following variables:
  'Frequency' variable – a 61×1 double array including frequency of the interrogation signal.
  'Transmitted power' variable – a 61×1 double array including measured interrogation power threshold.

- "SolveSlope.m"
  This function calculates the strain sensitivity of dual-mode patch antenna sensor in active mode. This function is called by "Plot_FreqvsStrain.m".

- "strainMartlet.mat"
  This file contains strain data of tensile test on dual-mode patch antenna sensor in active mode.
  'mean_strain' variable – a 7×1 double array including the average strain of aluminum specimen.

14. Data set in subfolder \3.4.1 Emulated_Crack_Test

- "Fig3_30.m"
  This is the main function to plot Fig. 3-30 subfigure (b) Resonance frequency change from emulated crack test.

- "resonancefrequency.mat"
  This file contains resonance frequencies of patch antenna sensor at different crack levels.
  'rf' variable – a 11×1 double array including resonance frequencies of patch antenna sensor at different crack levels.

15. Data set in subfolder \3.4.2 Fatigue_Crack_Test

- "Fig3_34.m"
  This is the main function to plot Fig. 3-34 Fatigue test results of the patch antenna sensor.

- "Plot_FreqvsStrain.m"
  This function plots the resonance frequency change during fatigue test. This function is called by "Fig3_34.m".

- "PlotOneSensor.m"
  This function plots the average interrogation power thresholds of patch antenna sensor. This function is called by "Fig3_34.m".

- "transmittedpower.tff"
  This file contains interrogation power threshold of patch antenna sensor measured by Tagformance RFID reader. This file contains 35 data blocks, and each data block contains following variables:
  'Frequency' variable – a 201×1 double array including frequency of the interrogation signal.
  'Transmitted power' variable – a 201×1 double array including measured interrogation power threshold.

Data Format and Metadata Standards: Data will be presented in the format of text descriptions, numbers, tables, figures/illustrations, photos, images, and videos. Texts, numbers, tables, figures, photos, images, and derived equations will be prepared and/or summarized in Word, Excel, and Power Point Presentation according to American Society of Civil Engineers (ASCE) journal standards due to their wide acceptance among potential users in civil engineering. Various versions of data sets will be signified with a number in sequence added at the end of file names. Numbers are specified with no more than 3 significant digits. Images are prepared in JPEG format with a minimum of 300 dpi. Video clips are recorded up to 5 minutes at a minimum rate of 30 fps. Text descriptions in Word document and metadata schema in pdf document will be used to summarize and explain data sets for easy understanding by readers.

Data Access: It is the responsibility of the principal investigator to protect the privacy and confidentiality of study participants and the research prior to archiving data. Final data collected will be stored at **Missouri S&T's Scholars Mine**, which has received its CoreTrustSeal certification in August 2018 and thus met the US DOT repository requirements. They will be publically accessible unless otherwise determined by the principal investigator. Confidential data will be appropriately indicated in the database, and only the research team responsible for the data will be granted access. Clearly indicate the data items you would like to withhold for 12 months before they become available to the public.

N/A

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