■ Continuum Representation of Wound Coils via an Equivalent Foil Approach

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Original: December 28, 2006
Updated for FEMM 4.2: May 01, 2008

This notebook generates the figures comparing models of a coil in which each turn is explicitly modeled versus a continuum approximation of the coil. The notebook uses the MathFEMM interface to FEMM 4.01 to automate the evaluation of various coil geometries at various frequencies.

```
<< c:\\progra~1\femm42\\mathfemm\\mathfemm.m
```

```
MathFEMM 1.20
The Mathematica interface to FEMM 4.2
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```

A number of standard Mathematica packages are needed, along with some useful definitions

```
<< Graphics`Graphics`;
<< Graphics`Legend`;
Off[General::"spell1"];
Off[General::"spell"];
$TextStyle = {FontFamily → "Times New Roman", FontSize → 14};

OpenFEMM[]
```

The "AnalyzeFile" function performs a set of analyses on a prescribed file on a frequency range of 1kHz to 1MHz at a prescribed step size on a logscale.

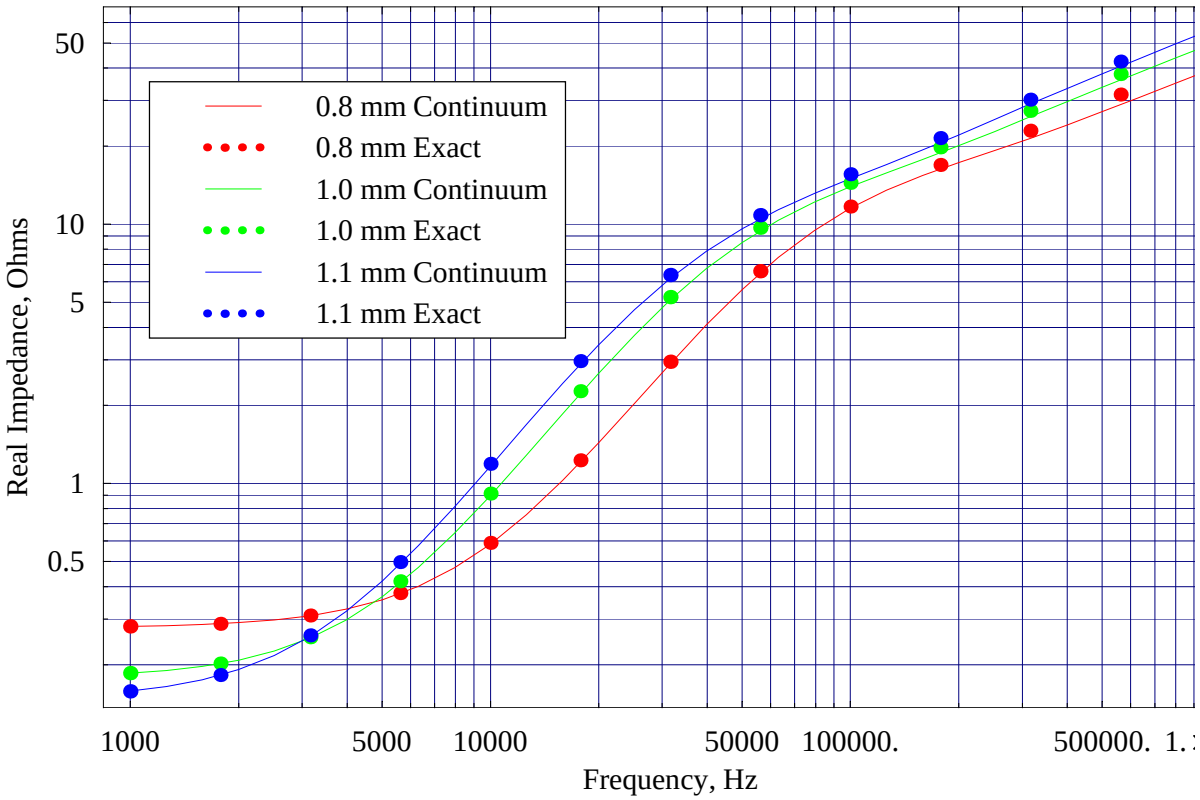
```
AnalyzeFile[fname_, stepsize_] := Module[{k, freq, result},
  OpenDocument[fname];
  MISaveAs["c:\\progra~1\\femm40\\examples\\temp.fem"];
  result = {};
  For[k = 3, k ≤ 6, k += stepsize,
   freq = 10^k;
   MIProbDef[freq, "millimeters", "axi", 10^(-8), 1, 30];
   MIAnalyze[1];
   MILoadSolution[];
   result = Append[result, {freq, MOGetCircuitProperties["icoil"][[2]]}];
   MOClose[];
  ];
  MIClose[];
  result
 ]
```

Continuum approximations and exact representations are analyzed for 0.8 mm, 1 mm, and 1.1 mm diameter copper wires at room temperature

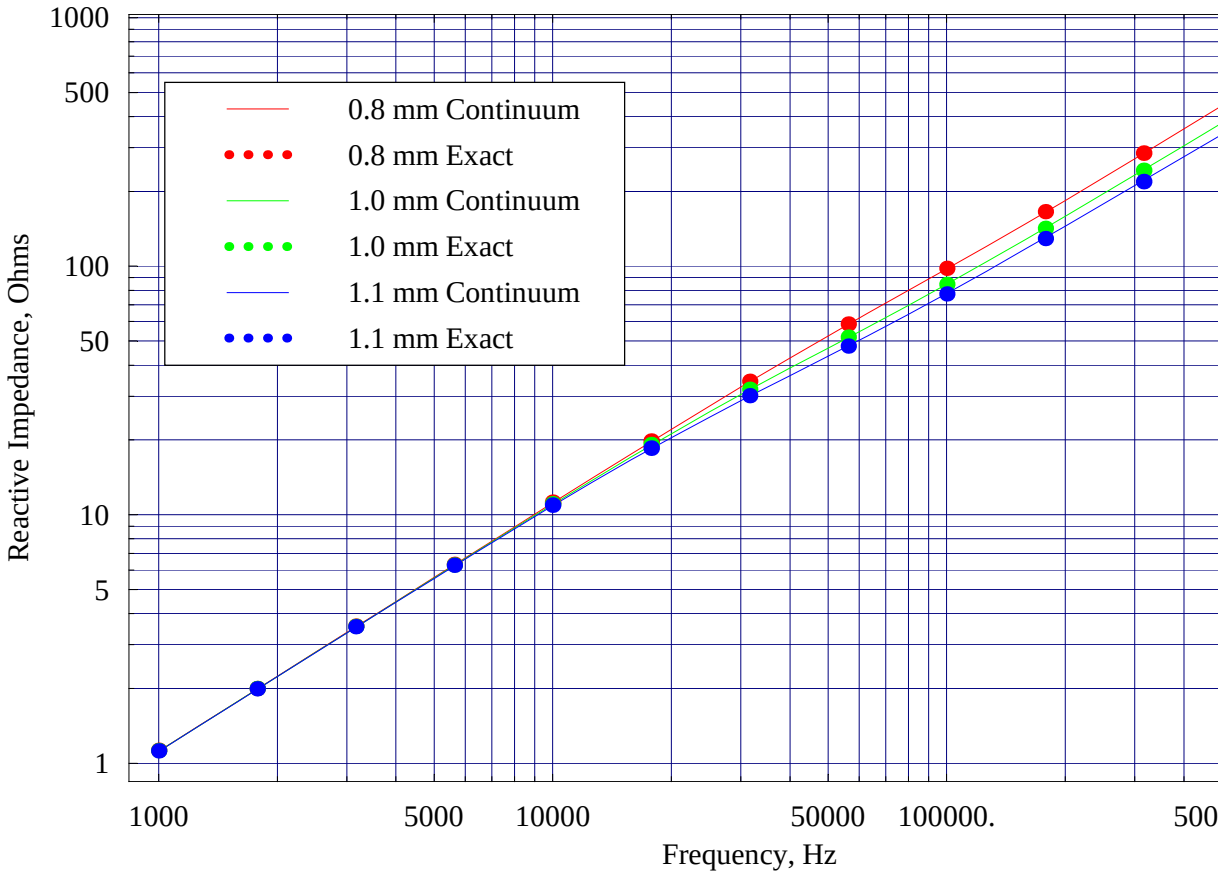
```
a1000 = AnalyzeFile["c:\\temp\\drawfigures\\proximityapprox.fem", 0.1];

x1000 = AnalyzeFile["c:\\temp\\drawfigures\\proximityexact.fem", 0.25];

a800 = AnalyzeFile["c:\\temp\\drawfigures\\proximityapprox2.fem", 0.1];

x800 = AnalyzeFile["c:\\temp\\drawfigures\\proximityexact2.fem", 0.25];

a1100 = AnalyzeFile["c:\\temp\\drawfigures\\proximityapprox3.fem", 0.1];

x1100 = AnalyzeFile["c:\\temp\\drawfigures\\proximityexact3.fem", 0.25];

CloseFEMM[];
```

Now, plots can be generated that compare the impedance of the continuum model to the exact model for the various wire sizes.

```
ShowLegend[
  DisplayTogether[
   LogLogListPlot[Re[a800], PlotJoined → True, PlotStyle → {RGBColor[1, 0, 0]}],
   LogLogListPlot[Re[a1000], PlotJoined → True, PlotStyle → {RGBColor[0, 1, 0]}],
   LogLogListPlot[Re[a1100], PlotJoined → True, PlotStyle → {RGBColor[0, 0, 1]}],
   LogLogListPlot[Re[x800], PlotStyle → {RGBColor[1, 0, 0], PointSize[0.0125]}],
   LogLogListPlot[Re[x1000], PlotStyle → {RGBColor[0, 1, 0], PointSize[0.0125]}],
   LogLogListPlot[Re[x1100], PlotStyle → {RGBColor[0, 0, 1], PointSize[0.0125]}],
   PlotRange → All, Frame → True, FrameLabel → {"Frequency, Hz", "Real Impedance, Ohms"},
   ImageSize → 700, GridLines → {LogGridMinor, LogGridMinor}, DisplayFunction → Identity],
  {{{Graphics[{RGBColor[1, 0, 0], Line[{{0, 0}, {1, 0}}]}], "0.8 mm Continuum"},
    {Graphics[Rectangle[{0, 0}, {1, 1}, ListPlot[{0, 0, 0, 0},
        Axes → False, PlotStyle → {RGBColor[1, 0, 0], PointSize[0.15]},
        DisplayFunction → Identity]]], "0.8 mm Exact"},
    {Graphics[{RGBColor[0, 1, 0], Line[{{0, 0}, {1, 0}}]}], "1.0 mm Continuum"},
    {Graphics[Rectangle[{0, 0}, {1, 1}, ListPlot[{0, 0, 0, 0},
        Axes → False, PlotStyle → {RGBColor[0, 1, 0], PointSize[0.15]},
        DisplayFunction → Identity]]], "1.0 mm Exact"},
    {Graphics[{RGBColor[0, 0, 1], Line[{{0, 0}, {1, 0}}]}], "1.1 mm Continuum"},
    {Graphics[Rectangle[{0, 0}, {1, 1}, ListPlot[{0, 0, 0, 0}, Axes → False,
        PlotStyle → {RGBColor[0, 0, 1], PointSize[0.15]}, DisplayFunction → Identity]]],
     "1.1 mm Exact"}}, LegendPosition → {-0.75, 0.1},
   LegendSize → {0.65, 0.4}, LegendShadow → {0, 0}}];
```



```
GetIm[p_] := Module[{px, py},
  px = Transpose[p][[1]];
  py = Im[Transpose[p][[2]]];
  Transpose[{px, py}]
 ]

ShowLegend[
  DisplayTogether[
   LogLogListPlot[GetIm[a800], PlotJoined → True, PlotStyle → {RGBColor[1, 0, 0]}],
   LogLogListPlot[GetIm[a1000], PlotJoined → True, PlotStyle → {RGBColor[0, 1, 0]}],
   LogLogListPlot[GetIm[a1100], PlotJoined → True, PlotStyle → {RGBColor[0, 0, 1]}],
   LogLogListPlot[GetIm[x800], PlotStyle → {RGBColor[1, 0, 0], PointSize[0.0125]}],
   LogLogListPlot[GetIm[x1000], PlotStyle → {RGBColor[0, 1, 0], PointSize[0.0125]}],
   LogLogListPlot[GetIm[x1100], PlotStyle → {RGBColor[0, 0, 1], PointSize[0.0125]}],
   Frame → True, FrameLabel → {"Frequency, Hz", "Reactive Impedance, Ohms"},
   ImageSize → 700, GridLines → {LogGridMinor, LogGridMinor}, DisplayFunction → Identity],
  {{{Graphics[{RGBColor[1, 0, 0], Line[{{0, 0}, {1, 0}}]}], "0.8 mm Continuum"},
    {Graphics[Rectangle[{0, 0}, {1, 1}, ListPlot[{0, 0, 0, 0},
        Axes → False, PlotStyle → {RGBColor[1, 0, 0], PointSize[0.15]},
        DisplayFunction → Identity]]], "0.8 mm Exact"},
    {Graphics[{RGBColor[0, 1, 0], Line[{{0, 0}, {1, 0}}]}], "1.0 mm Continuum"},
    {Graphics[Rectangle[{0, 0}, {1, 1}, ListPlot[{0, 0, 0, 0},
        Axes → False, PlotStyle → {RGBColor[0, 1, 0], PointSize[0.15]},
        DisplayFunction → Identity]]], "1.0 mm Exact"},
    {Graphics[{RGBColor[0, 0, 1], Line[{{0, 0}, {1, 0}}]}], "1.1 mm Continuum"},
    {Graphics[Rectangle[{0, 0}, {1, 1}, ListPlot[{0, 0, 0, 0}, Axes → False,
        PlotStyle → {RGBColor[0, 0, 1], PointSize[0.15]}, DisplayFunction → Identity]]],
     "1.1 mm Exact"}}, LegendPosition → {-0.75, 0.1},
   LegendSize → {0.65, 0.4}, LegendShadow → {0, 0}}];
```


1000
500
100
50
10
5
1
Reactive Impedance, Ohms
0.8 mm Continuum
0.8 mm Exact
1.0 mm Continuum
1.0 mm Exact
1.1 mm Continuum
1.1 mm Exact
1000
5000
10000
50000
100000.
500
Frequency, Hz