Calculation of Loudspeaker Blocked Coil Impedance vs Frequency and Position

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01 Nov2015

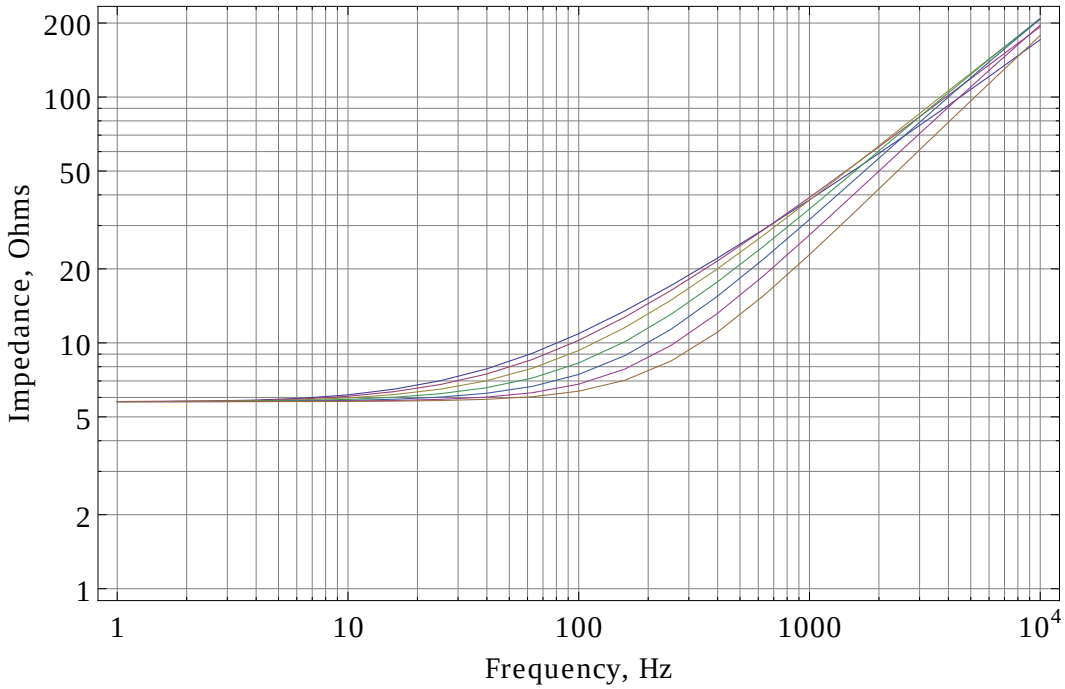
```
(* Base problem name and configuration *)

myFile = "SSF-082.fem";
myCoilName = "Icoil";
myCoilGroup = 1;

(* Displacement range under consideration *)
xmin = -15;
xmax = 15;
dx = 5;

(* Frequency range under consideration.  Specified as Log[10,frequency] *)

wmin = 0; (* 10^0 = 1 Hz *)
wmax = 4; (* 10^4 = 10000 Hz *)
dw = 1 / 5; (* 5 points per decade on a log scale *)

<< c:\\femm42\\mathfemm\\mathfemm.m
```

```
MathFEMM loaded at Tue 10 Nov 2015 21:48:23
```

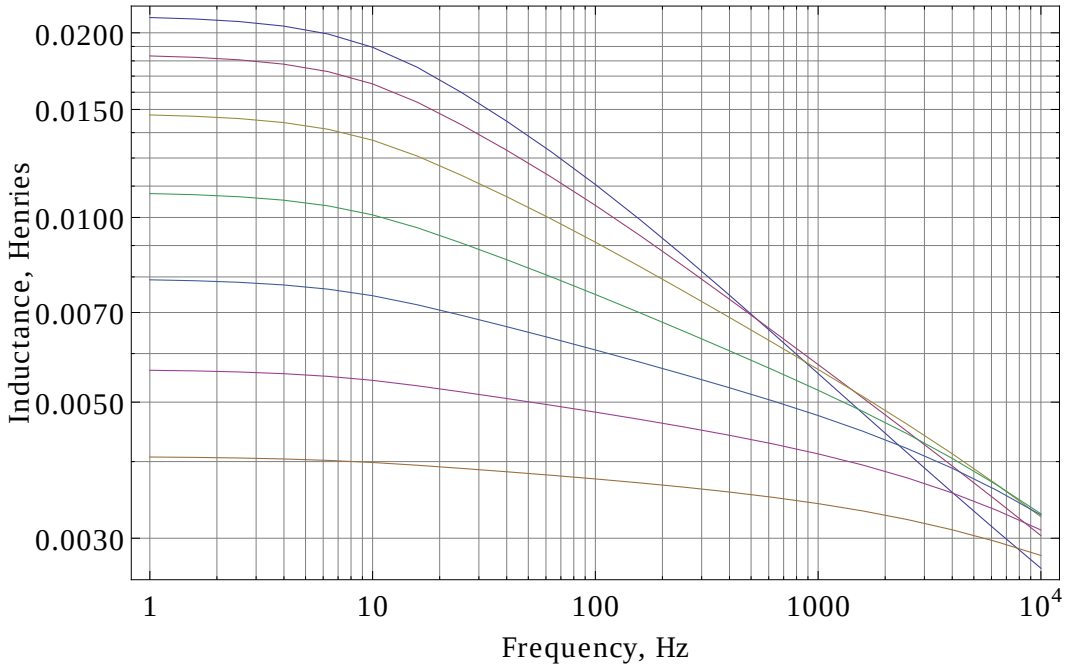
```
OpenFEMM[]

(* Open up base problem and save as the DC operating point with no coil current *)
OpenDocument[NotebookDirectory[] <> myFile];
MISetCurrent[myCoilName, 0];
MISaveAs[NotebookDirectory[] <> "DCProblem.fem"];

(* Open up base problem and save as the
 incremental AC problem with a coil current of 1A *)
(* Incremental AC problem points back to the DC solution
 via the MISetPrevious["DCProblem.ans"] call *)
OpenDocument[NotebookDirectory[] <> myFile];
MISetCurrent[myCoilName, 1];
MISetPrevious["DCProblem.ans"];
MISaveAs[NotebookDirectory[] <> "ACProblem.fem"];

(* Move the coil to the xmin position,
assuming that the geometry is drawn so that the coil is nominally at x=0 *)

DCSetFocus[] := MISetFocus["DCProblem.fem"];

ACSetFocus[] := MISetFocus["ACProblem.fem"];

DCSetFocus[];
MISelectGroup[myCoilGroup];
MIMoveTranslate[0, xmin];
ACSetFocus[];
MISelectGroup[myCoilGroup];
MIMoveTranslate[0, xmin];
```

```
(* Step through the full range of coil positions *)
Lx = {};
Vx = {};
Bl = {};
Xx = {};
Lo = {};
(* At each coil position, evaluate Bl and coil inductance over a range of frequencies *)
For[x = xmin, x ≤ xmax, x += dx,
 Lfd = {};
 Vfd = {};
 DCSetFocus[];
 MIAnalyze[];
 For[k = -6, k ≤ wmax, k += dw,
  ACSetFocus[];
  MIProbDef[10^k];
  MIAnalyze[];
  MILoadSolution[];
  (* Get Bl *)
  If[k == 0,
   MOGroupSelectBlock[1];
   f = Abs[MOBlockIntegral[29]];
   Bl = Append[Bl, {x, f}];
  ];
  (* Get Inductance and Voltage *)
  u = MOGetCircuitProperties[myCoilName];
  Print[{x, 10.^k, u[[3]]}];
  If[k == -6, Lo = Append[Lo, Abs[u[[3]]]];
   k = wmin - dw,
   Lfd = Append[Lfd, {10.^k, u[[3]]}];
   Vfd = Append[Vfd, {10.^k, u[[2]]}];
  ];
 ];
 Lx = Append[Lx, Lfd];
 Vx = Append[Vx, Vfd];
 Xx = Append[Xx, x];
 If[x < xmax,
  DCSetFocus[];
  MISelectGroup[myCoilGroup];
  MIMoveTranslate[0, dx];
  ACSetFocus[];
  MISelectGroup[myCoilGroup];
  MIMoveTranslate[0, dx];
 ];
]

CloseFEMM[]
```

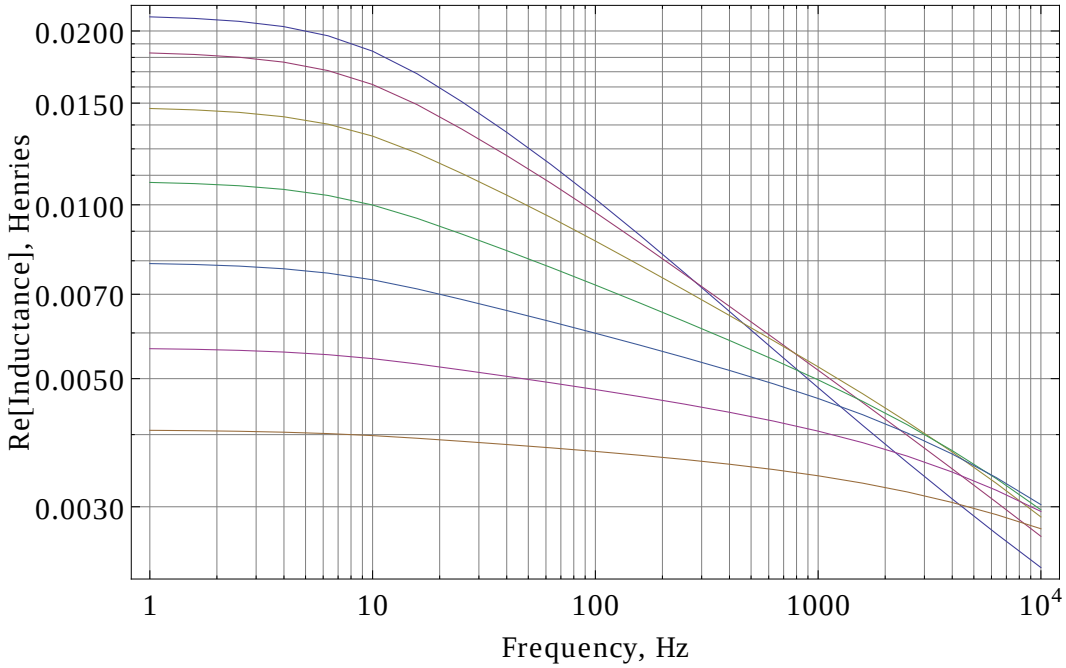
```
ListLogLogPlot[Abs[Vx], Joined → True, Frame → True, GridLines → Automatic,
 ImageSize → 500, BaseStyle → {FontFamily → "Tahoma", FontSize → 14},
 FrameLabel → {"Frequency, Hz", "Impedance, Ohms"}]
```

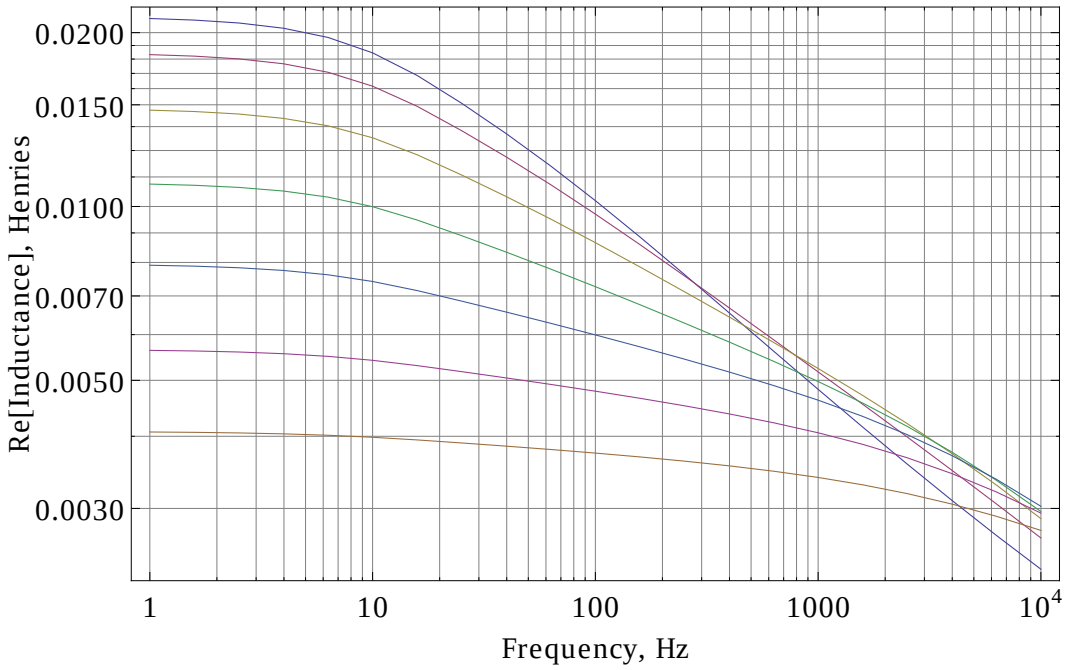


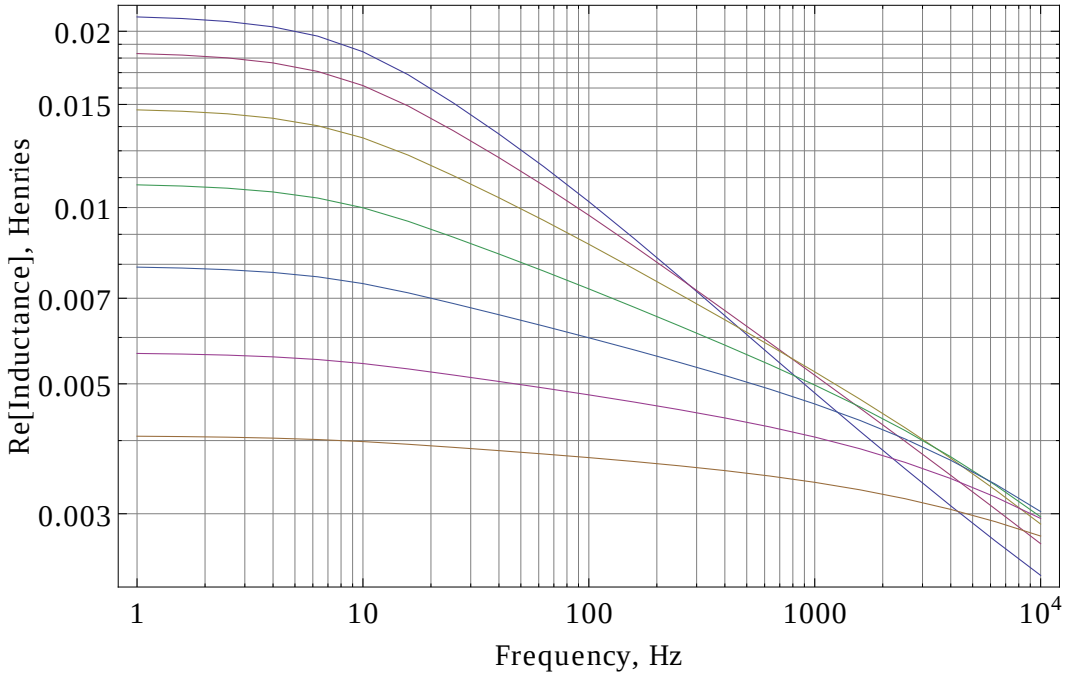

```
ListLogLogPlot[Abs[Lx], Joined → True, Frame → True, GridLines → Automatic,
 ImageSize → 500, BaseStyle → {FontFamily → "Tahoma", FontSize → 14},
 FrameLabel → {"Frequency, Hz", "Inductance, Henries"}]
```



```
ListLogLogPlot[Re[Lx], Joined → True, Frame → True, GridLines → Automatic,
 ImageSize → 500, BaseStyle → {FontFamily → "Tahoma", FontSize → 14},
 FrameLabel → {"Frequency, Hz", "Re[Inductance], Henries"}]
```

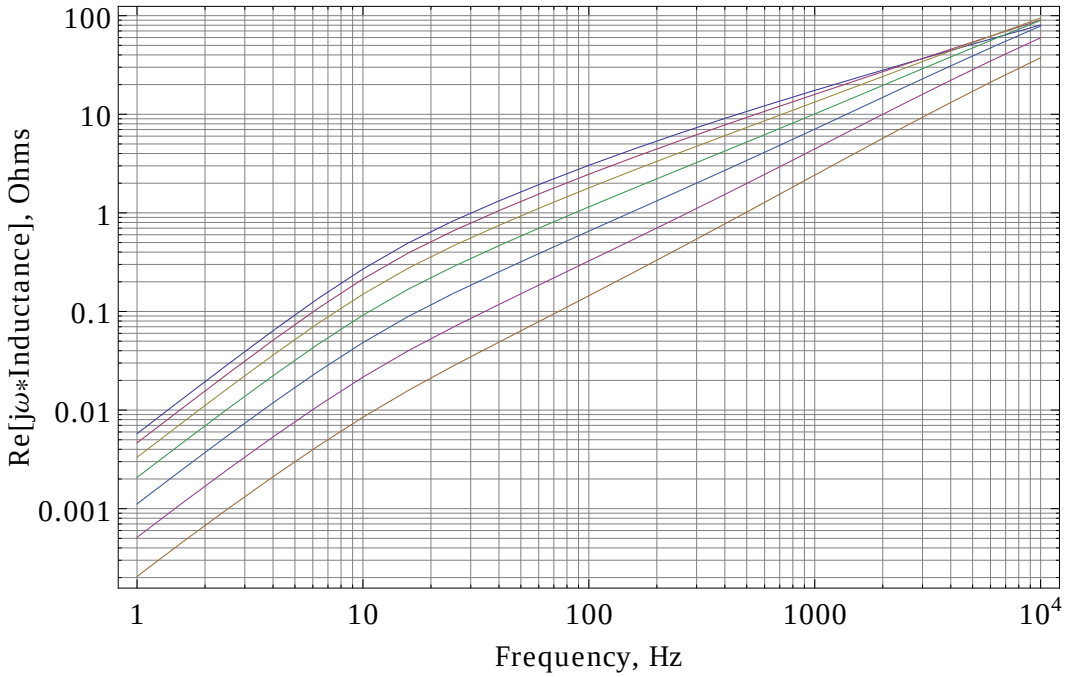




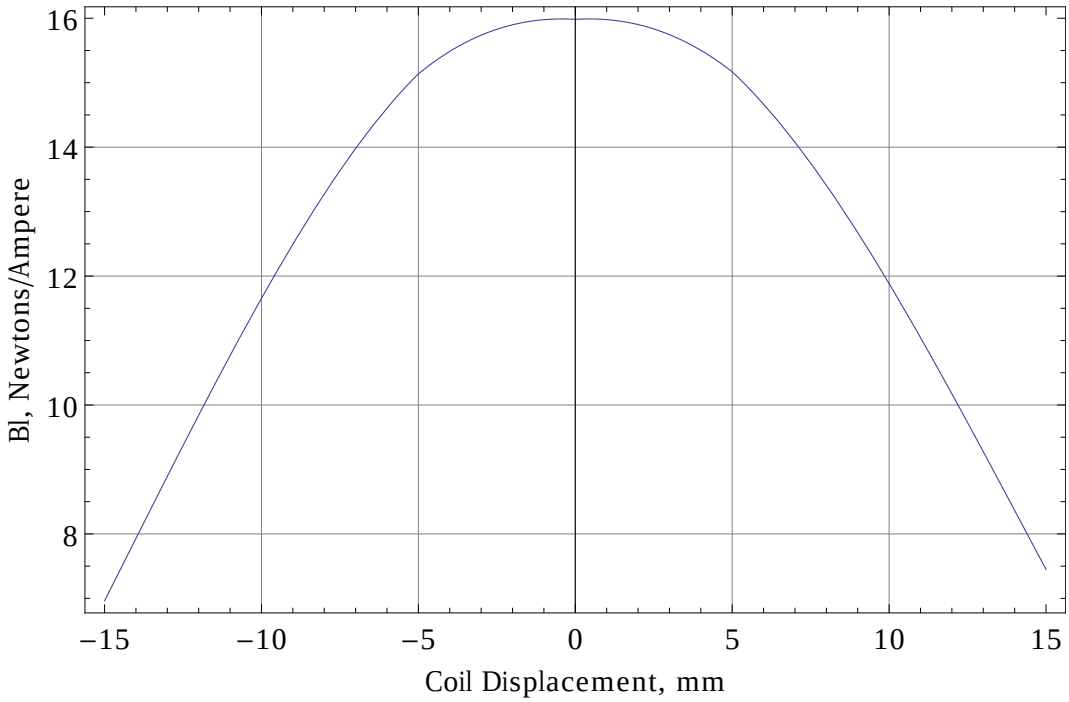



```
Rx = Lx;
For[k = 1, k ≤ Length[Rx], k++,
 r = Transpose[Rx[[k]]];
 r[[2]] = r[[2]] * 2 * Pi * I * r[[1]];
 r = Re[Transpose[r]];
 Rx[[k]] = r;
]
```

```
ListLogLogPlot[Re[Rx], Joined → True, Frame → True, GridLines → Automatic,
 ImageSize → 500, BaseStyle → {FontFamily → "Tahoma", FontSize → 14},
 FrameLabel → {"Frequency, Hz", "Re[jω*Inductance], Ohms"}]
```



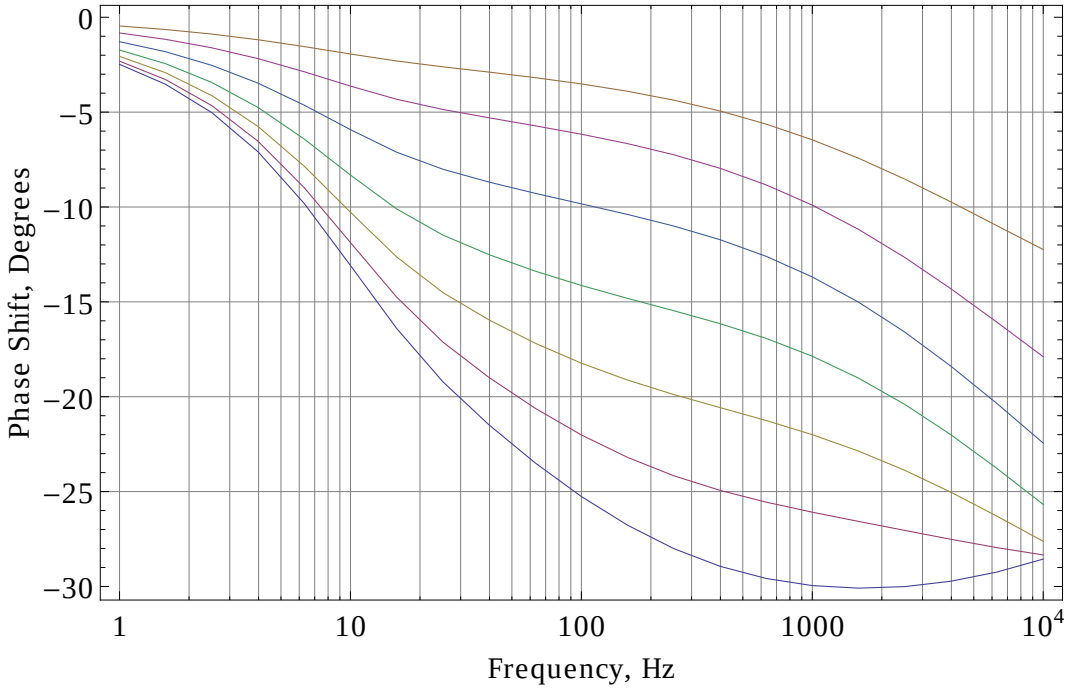

```
Plot[Interpolation[Bl][X], {X, Min[Bl.{1, 0}], Max[Bl.{1, 0}]}, Frame → True,
 GridLines → Automatic, ImageSize → 500, BaseStyle → {FontFamily → "Tahoma", FontSize → 14},
 FrameLabel → {"Coil Displacement, mm", "Bl, Newtons/Ampere"}]
```



```
ang = Table[Transpose[{Abs[Lx[[k]].{1, 0}], Arg[Lx[[k]].{0, 1}] / Degree}], {k, 1, 7}]
```

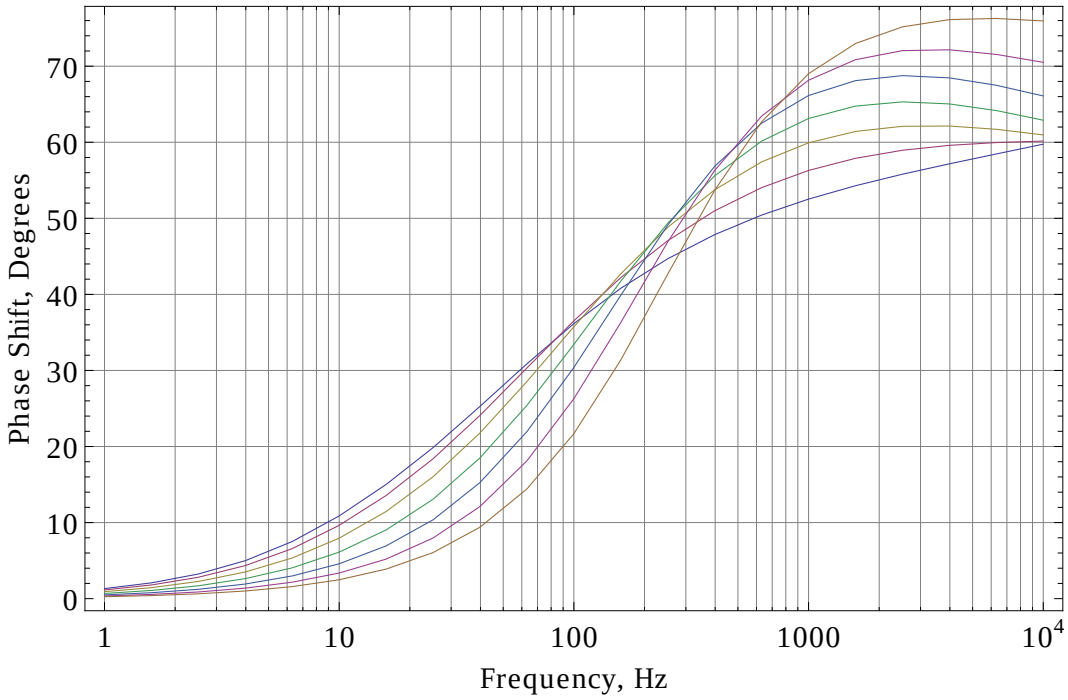
```
{{{1., -2.48191}, {1.58489, -3.53643}, {2.51189, -5.03013},
  {3.98107, -7.09307}, {6.30957, -9.8171}, {10., -13.0828}, {15.8489, -16.4007},
  {25.1189, -19.2095}, {39.8107, -21.4839}, {63.0957, -23.4901},
  {100., -25.2611}, {158.489, -26.7719}, {251.189, -28.0053}, {398.107, -28.937},
  {630.957, -29.5791}, {1000., -29.9544}, {1584.89, -30.0894}, {2511.89, -30.0087},
  {3981.07, -29.7248}, {6309.57, -29.2394}, {10000., -28.5563}},
 {{1., -2.31188}, {1.58489, -3.28918}, {2.51189, -4.66181}, {3.98107, -6.53794},
  {6.30957, -8.98571}, {10., -11.8758}, {15.8489, -14.7497}, {25.1189, -17.1161},
  {39.8107, -18.9867}, {63.0957, -20.6096}, {100., -22.0159}, {158.489, -23.1981},
  {251.189, -24.1654}, {398.107, -24.9343}, {630.957, -25.5561},
  {1000., -26.0856}, {1584.89, -26.5714}, {2511.89, -27.0458},
  {3981.07, -27.5137}, {6309.57, -27.9551}, {10000., -28.3387}},
 {{1., -2.06155}, {1.58489, -2.92796}, {2.51189, -4.13259}, {3.98107, -5.7589},
  {6.30957, -7.85099}, {10., -10.2776}, {15.8489, -12.6313}, {25.1189, -14.5089},
  {39.8107, -15.9524}, {63.0957, -17.1815}, {100., -18.2324},
  {158.489, -19.1217}, {251.189, -19.885}, {398.107, -20.5709},
  {630.957, -21.2531}, {1000., -22.0002}, {1584.89, -22.865}, {2511.89, -23.877},
  {3981.07, -25.0323}, {6309.57, -26.2982}, {10000., -27.6225}},
 {{1., -1.72806}, {1.58489, -2.44907}, {2.51189, -3.4391}, {3.98107, -4.75593},
  {6.30957, -6.42229}, {10., -8.31621}, {15.8489, -10.1023}, {25.1189, -11.479},
  {39.8107, -12.5103}, {63.0957, -13.3808}, {100., -14.1371}, {158.489, -14.816},
  {251.189, -15.4669}, {398.107, -16.1465}, {630.957, -16.9249},
  {1000., -17.8669}, {1584.89, -19.0198}, {2511.89, -20.4028},
  {3981.07, -22.0043}, {6309.57, -23.7841}, {10000., -25.6783}},
 {{1., -1.28727}, {1.58489, -1.81869}, {2.51189, -2.53661}, {3.98107, -3.47325},
  {6.30957, -4.63462}, {10., -5.9252}, {15.8489, -7.11177}, {25.1189, -8.00904},
  {39.8107, -8.68638}, {63.0957, -9.27961}, {100., -9.83419},
  {158.489, -10.3927}, {251.189, -11.004}, {398.107, -11.7208},
  {630.957, -12.5993}, {1000., -13.6873}, {1584.89, -15.015}, {2511.89, -16.5889},
  {3981.07, -18.3883}, {6309.57, -20.3647}, {10000., -22.4445}},
 {{1., -0.828075}, {1.58489, -1.16546}, {2.51189, -1.61204}, {3.98107, -2.18149},
  {6.30957, -2.87312}, {10., -3.62935}, {15.8489, -4.32093}, {25.1189, -4.85886},
  {39.8107, -5.29793}, {63.0957, -5.72151}, {100., -6.16432}, {158.489, -6.66038},
  {251.189, -7.24598}, {398.107, -7.95837}, {630.957, -8.83441},
  {1000., -9.90317}, {1584.89, -11.1791}, {2511.89, -12.6567},
  {3981.07, -14.3078}, {6309.57, -16.0788}, {10000., -17.8914}},
 {{1., -0.460133}, {1.58489, -0.645879}, {2.51189, -0.886274}, {3.98107, -1.18605},
  {6.30957, -1.54501}, {10., -1.93715}, {15.8489, -2.3044}, {25.1189, -2.6113},
  {39.8107, -2.88993}, {63.0957, -3.1835}, {100., -3.51342}, {158.489, -3.90117},
  {251.189, -4.36889}, {398.107, -4.93857}, {630.957, -5.63051},
  {1000., -6.45902}, {1584.89, -7.42829}, {2511.89, -8.5284},
  {3981.07, -9.73154}, {6309.57, -10.9903}, {10000., -12.2406}}}
```

```
ListLogLinearPlot[ang, Joined → True, Frame → True, GridLines → Automatic,
 ImageSize → 500, BaseStyle → {FontFamily → "Tahoma", FontSize → 14},
 FrameLabel → {"Frequency, Hz", "Phase Shift, Degrees"}]
```




```
ang = Table[Transpose[{Abs[Vx[[k]].{1, 0}], Arg[Vx[[k]].{0, 1}] / Degree}], {k, 1, 7}];
```

```
ListLogLinearPlot[ang, Joined → True, Frame → True, GridLines → Automatic,
 ImageSize → 500, BaseStyle → {FontFamily → "Tahoma", FontSize → 14},
 FrameLabel → {"Frequency, Hz", "Phase Shift, Degrees"}]
```



Lx

```
{{{1., 0.0211596 - 0.000917154 i},
   {1.58489, 0.0210273 - 0.0012995 i}, {2.51189, 0.0207843 - 0.00182941 i},
   {3.98107, 0.0203554 - 0.00253289 i}, {6.30957, 0.0196202 - 0.00339503 i},
   {10., 0.0184517 - 0.00428801 i}, {15.8489, 0.0168613 - 0.00496276 i},
   {25.1189, 0.0150894 - 0.00525747 i}, {39.8107, 0.0133696 - 0.0052621 i},
   {63.0957, 0.0117484 - 0.00510593 i}, {100., 0.0102353 - 0.00482974 i},
   {158.489, 0.00885673 - 0.00446841 i}, {251.189, 0.00762496 - 0.00405517 i},
   {398.107, 0.00654669 - 0.00361949 i}, {630.957, 0.00561705 - 0.00318822 i},
   {1000., 0.00482329 - 0.00277962 i}, {1584.89, 0.00414975 - 0.0024045 i},
   {2511.89, 0.00358003 - 0.00206765 i}, {3981.07, 0.0030991 - 0.00176947 i},
   {6309.57, 0.00269416 - 0.00150815 i}, {10 000., 0.00235432 - 0.00128129 i}},
  {{1., 0.0183215 - 0.000739673 i}, {1.58489, 0.018212 - 0.00104664 i},
   {2.51189, 0.0180126 - 0.00146881 i}, {3.98107, 0.0176649 - 0.00202451 i},
   {6.30957, 0.0170775 - 0.00270044 i}, {10., 0.016155 - 0.00339728 i},
   {15.8489, 0.0149099 - 0.00392536 i}, {25.1189, 0.0135276 - 0.00416578 i},
```

```
 {39.8107, 0.0121828 - 0.00419171 i}, {63.0957, 0.0109057 - 0.00410126 i},
 {100., 0.00970176 - 0.00392289 i}, {158.489, 0.00859053 - 0.00368157 i},
 {251.189, 0.00758137 - 0.0034017 i}, {398.107, 0.0066789 - 0.0031051 i},
 {630.957, 0.00587875 - 0.00281109 i}, {1000., 0.00517109 - 0.00253168 i},
 {1584.89, 0.00454469 - 0.00227297 i}, {2511.89, 0.00398864 - 0.00203633 i},
 {3981.07, 0.00349414 - 0.00181999 i}, {6309.57, 0.00305498 - 0.00162129 i},
 {10 000., 0.00266674 - 0.00143822 i}}, {{1., 0.0146833 - 0.000528545 i},
 {1.58489, 0.0146029 - 0.000746896 i}, {2.51189, 0.0144579 - 0.00104462 i},
 {3.98107, 0.0142087 - 0.00143297 i}, {6.30957, 0.0137943 - 0.00190209 i},
 {10., 0.0131516 - 0.00238474 i}, {15.8489, 0.0122905 - 0.00275431 i},
 {25.1189, 0.0113359 - 0.00293353 i}, {39.8107, 0.0104027 - 0.00297358 i},
 {63.0957, 0.0095088 - 0.0029401 i}, {100., 0.00865648 - 0.00285154 i},
 {158.489, 0.00785784 - 0.00272435 i}, {251.189, 0.00711804 - 0.00257458 i},
 {398.107, 0.00643891 - 0.00241649 i}, {630.957, 0.00581608 - 0.00226212 i},
 {1000., 0.00524175 - 0.00211782 i}, {1584.89, 0.00470788 - 0.0019853 i},
 {2511.89, 0.00420751 - 0.00186249 i}, {3981.07, 0.00373646 - 0.0017449 i},
 {6309.57, 0.00329374 - 0.00162774 i}, {10 000., 0.0028808 - 0.00150749 i}},
{{1., 0.0109342 - 0.000329879 i}, {1.58489, 0.0108826 - 0.000465451 i},
 {2.51189, 0.0107905 - 0.00064846 i}, {3.98107, 0.0106349 - 0.000884799 i},
 {6.30957, 0.0103807 - 0.00116848 i}, {10., 0.00999181 - 0.00146053 i},
 {15.8489, 0.00947429 - 0.00168802 i}, {25.1189, 0.00890062 - 0.00180745 i},
 {39.8107, 0.00833632 - 0.00184968 i}, {63.0957, 0.00779049 - 0.0018532 i},
 {100., 0.00726323 - 0.00182939 i}, {158.489, 0.00675967 - 0.001788 i},
 {251.189, 0.00628117 - 0.00173801 i}, {398.107, 0.00582729 - 0.00168709 i},
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 {1584.89, 0.00456676 - 0.00157423 i}, {2511.89, 0.00416104 - 0.00154771 i},
 {3981.07, 0.00375707 - 0.00151828 i}, {6309.57, 0.00335638 - 0.00147923 i},
 {10 000., 0.00296367 - 0.00142494 i}}, {{1., 0.00791159 - 0.00017778 i},
 {1.58489, 0.00788291 - 0.000250305 i}, {2.51189, 0.00783247 - 0.000346987 i},
 {3.98107, 0.0077491 - 0.000470324 i}, {6.30957, 0.00761596 - 0.000617397 i},
 {10., 0.00741561 - 0.000769626 i}, {15.8489, 0.00715099 - 0.000892195 i},
 {25.1189, 0.00685678 - 0.000964761 i}, {39.8107, 0.00656393 - 0.00100283 i},
 {63.0957, 0.00627609 - 0.00102546 i}, {100., 0.00599242 - 0.00103875 i},
 {158.489, 0.00571419 - 0.001048 i}, {251.189, 0.00544062 - 0.00105795 i},
 {398.107, 0.00516979 - 0.00107257 i}, {630.957, 0.00489787 - 0.00109474 i},
 {1000., 0.00461982 - 0.0011251 i}, {1584.89, 0.0043305 - 0.00116157 i},
 {2511.89, 0.00402604 - 0.00119937 i}, {3981.07, 0.0037051 - 0.00123168 i},
 {6309.57, 0.00336977 - 0.00125085 i}, {10 000., 0.00302569 - 0.00124985 i}},
{{1., 0.00563468 - 0.0000814417 i}, {1.58489, 0.00562108 - 0.000114355 i},
 {2.51189, 0.00559759 - 0.000157532 i}, {3.98107, 0.00555985 - 0.000211789 i},
 {6.30957, 0.00550135 - 0.000276099 i}, {10., 0.00541519 - 0.00034348 i},
 {15.8489, 0.00530232 - 0.000400632 i}, {25.1189, 0.00517603 - 0.000439999 i},
 {39.8107, 0.00504796 - 0.000468101 i}, {63.0957, 0.00491895 - 0.000492842 i},
 {100., 0.00478798 - 0.000517125 i}, {158.489, 0.00465459 - 0.000543526 i},
 {251.189, 0.00451733 - 0.000574356 i}, {398.107, 0.00437406 - 0.000611494 i},
```

```
{630.957, 0.00422163 - 0.00065614 i}, {1000., 0.00405617 - 0.000708147 i},
{1584.89, 0.00387376 - 0.000765556 i}, {2511.89, 0.00367134 - 0.000824457 i},
{3981.07, 0.00344764 - 0.000879292 i}, {6309.57, 0.003204 - 0.000923503 i},
{10 000., 0.00294484 - 0.000950671 i}}, {{1., 0.00406919 - 0.0000326797 i},
{1.58489, 0.00406348 - 0.0000458083 i}, {2.51189, 0.00405385 - 0.0000627115 i},
{3.98107, 0.0040389 - 0.0000836193 i}, {6.30957, 0.00401651 - 0.000108333 i},
{10., 0.00398429 - 0.000134759 i}, {15.8489, 0.00394236 - 0.000158645 i},
{25.1189, 0.00389494 - 0.000177638 i}, {39.8107, 0.00384568 - 0.000194136 i},
{63.0957, 0.00379459 - 0.000211054 i}, {100., 0.00374092 - 0.000229684 i},
{158.489, 0.00368399 - 0.000251224 i}, {251.189, 0.00362265 - 0.000276769 i},
{398.107, 0.00355539 - 0.000307215 i}, {630.957, 0.00348016 - 0.000343104 i},
{1000., 0.00339458 - 0.000384304 i}, {1584.89, 0.00329615 - 0.00042975 i},
{2511.89, 0.00318274 - 0.000477277 i}, {3981.07, 0.00305312 - 0.000523609 i},
{6309.57, 0.00290755 - 0.00056466 i}, {10 000., 0.00274824 - 0.00059623 i}}}
```

Vx

```
{{{1., 5.77179 + 0.132949 i}, {1.58489, 5.77897 + 0.209393 i}, {2.51189, 5.7949 + 0.328032 i},
  {3.98107, 5.82938 + 0.509165 i}, {6.30957, 5.90062 + 0.777829 i}, {10., 6.03545 + 1.15936 i},
  {15.8489, 6.26022 + 1.67907 i}, {25.1189, 6.59579 + 2.3815 i}, {39.8107, 7.08228 + 3.34425 i},
  {63.0957, 7.79023 + 4.65755 i}, {100., 8.80064 + 6.43106 i}, {158.489, 10.2157 + 8.81969 i},
  {251.189, 12.1662 + 12.0342 i}, {398.107, 14.8197 + 16.3758 i}, {630.957, 18.4055 + 22.2684 i},
  {1000., 23.2308 + 30.3056 i}, {1584.89, 29.7103 + 41.324 i}, {2511.89, 38.3987 + 56.5023 i},
  {3981.07, 50.0264 + 77.5202 i}, {6309.57, 65.5532 + 106.808 i}, {10 000., 86.2666 + 147.926 i}},
 {{1., 5.77067 + 0.115117 i}, {1.58489, 5.77645 + 0.181358 i}, {2.51189, 5.78921 + 0.284286 i},
  {3.98107, 5.81667 + 0.441866 i}, {6.30957, 5.87308 + 0.677024 i}, {10., 5.97948 + 1.01505 i},
  {15.8489, 6.15692 + 1.48475 i}, {25.1189, 6.4235 + 2.13501 i}, {39.8107, 6.81453 + 3.04738 i},
  {63.0957, 7.39194 + 4.32348 i}, {100., 8.23085 + 6.09579 i}, {158.489, 9.4322 + 8.5546 i},
  {251.189, 11.1348 + 11.9654 i}, {398.107, 13.5331 + 16.7065 i}, {630.957, 16.9103 + 23.3059 i},
  {1000., 21.673 + 32.4909 i}, {1584.89, 28.4005 + 45.2568 i}, {2511.89, 37.9044 + 62.9513 i},
  {3981.07, 51.2902 + 87.4016 i}, {6309.57, 70.0388 + 121.112 i}, {10 000., 96.1266 + 167.556 i}},
 {{1., 5.76935 + 0.0922579 i}, {1.58489, 5.77346 + 0.145418 i}, {2.51189, 5.78251 + 0.228184 i},
  {3.98107, 5.80187 + 0.355415 i}, {6.30957, 5.84143 + 0.546865 i}, {10., 5.91586 + 0.826341 i},
  {15.8489, 6.0403 + 1.22391 i}, {25.1189, 6.22901 + 1.7891 i}, {39.8107, 6.50983 + 2.60212 i},
  {63.0957, 6.9316 + 3.76969 i}, {100., 7.5577 + 5.43903 i}, {158.489, 8.47898 + 7.82498 i},
  {251.189, 9.8294 + 11.2342 i}, {398.107, 11.8106 + 16.1062 i}, {630.957, 14.734 + 23.0574 i},
  {1000., 19.0726 + 32.9349 i}, {1584.89, 25.5358 + 46.8819 i}, {2511.89, 35.1607 + 66.4056 i},
  {3981.07, 49.4119 + 93.463 i}, {6309.57, 70.2944 + 130.578 i}, {10 000., 100.479 + 181.006 i}},
 {{1., 5.7681 + 0.0687017 i}, {1.58489, 5.77066 + 0.10837 i}, {2.51189, 5.77626 + 0.170302 i},
  {3.98107, 5.78816 + 0.266019 i}, {6.30957, 5.81235 + 0.411536 i}, {10., 5.85779 + 0.627804 i},
  {15.8489, 5.93412 + 0.943466 i}, {25.1189, 6.05129 + 1.40475 i}, {39.8107, 6.2287 + 2.08523 i},
  {63.0957, 6.50071 + 3.08848 i}, {100., 6.91546 + 4.56362 i}, {158.489, 7.54655 + 6.7314 i},
  {251.189, 8.50907 + 9.91336 i}, {398.107, 9.98607 + 14.5763 i}, {630.957, 12.2735 + 21.3852 i},
  {1000., 15.8449 + 31.2666 i}, {1584.89, 21.4424 + 45.4767 i}, {2511.89, 30.1926 + 65.6722 i},
  {3981.07, 43.7432 + 93.9787 i}, {6309.57, 64.4067 + 133.061 i}, {10 000., 95.2921 + 186.213 i}},
 {{1., 5.76714 + 0.04971 i}, {1.58489, 5.76852 + 0.0784994 i}, {2.51189, 5.7715 + 0.123617 i},
  {3.98107, 5.77779 + 0.193834 i}, {6.30957, 5.7905 + 0.301929 i},
  {10., 5.81438 + 0.465937 i}, {15.8489, 5.85487 + 0.712108 i}, {25.1189, 5.91829 + 1.08218 i},
  {39.8107, 6.01687 + 1.64189 i}, {63.0957, 6.17256 + 2.48811 i},
  {100., 6.41869 + 3.76515 i}, {158.489, 6.80964 + 5.69029 i}, {251.189, 7.43574 + 8.58674 i},
  {398.107, 8.44892 + 12.9316 i}, {630.957, 10.106 + 19.4172 i}, {1000., 12.8352 + 29.0272 i},
  {1584.89, 17.333 + 43.1239 i}, {2511.89, 24.6949 + 63.5416 i}, {3981.07, 36.5743 + 92.6788 i},
  {6309.57, 55.3527 + 133.592 i}, {10 000., 84.2913 + 190.11 i}},
 {{1., 5.76654 + 0.0354038 i}, {1.58489, 5.76716 + 0.0559757 i},
  {2.51189, 5.76851 + 0.0883448 i}, {3.98107, 5.77132 + 0.139073 i},
  {6.30957, 5.77697 + 0.218097 i}, {10., 5.78761 + 0.340246 i}, {15.8489, 5.80592 + 0.528015 i},
  {25.1189, 5.83547 + 0.816915 i}, {39.8107, 5.88311 + 1.26269 i},
  {63.0957, 5.96141 + 1.95008 i}, {100., 6.09094 + 3.00838 i}, {158.489, 6.30728 + 4.63512 i},
  {251.189, 6.67251 + 7.12955 i}, {398.107, 7.2956 + 10.9412 i}, {630.957, 8.36722 + 16.7363 i},
  {1000., 10.2154 + 25.4857 i}, {1584.89, 13.3894 + 38.5756 i}, {2511.89, 18.7778 + 57.9434 i},
  {3981.07, 27.7597 + 86.2386 i}, {6309.57, 42.3755 + 127.02 i}, {10 000., 65.4932 + 185.03 i}},
 {{1., 5.76623 + 0.0255675 i}, {1.58489, 5.76648 + 0.0404648 i},
  {2.51189, 5.76701 + 0.0639804 i}, {3.98107, 5.76812 + 0.101028 i},
  {6.30957, 5.77032 + 0.159231 i}, {10., 5.77449 + 0.25034 i}, {15.8489, 5.78182 + 0.392587 i},
  {25.1189, 5.79406 + 0.614724 i}, {39.8107, 5.81459 + 0.961952 i},
  {63.0957, 5.8497 + 1.50434 i}, {100., 5.91034 + 2.35049 i}, {158.489, 6.0162 + 3.66858 i},
  {251.189, 6.20284 + 5.71751 i}, {398.107, 6.53448 + 8.89338 i}, {630.957, 7.12621 + 13.7968 i},
  {1000., 8.18062 + 21.3287 i}, {1584.89, 10.0454 + 32.8236 i}, {2511.89, 13.2984 + 50.2321 i},
  {3981.07, 18.8626 + 76.3701 i}, {6309.57, 28.1495 + 115.267 i}, {10 000., 43.223 + 172.677 i}}}
```

Bl

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{{-15, 6.96233}, {-10, 11.6548}, {-5, 15.1372},
 {0, 15.9827}, {5, 15.1687}, {10, 11.8838}, {15, 7.44852}}
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Xx

```
{-15, -10, -5, 0, 5, 10, 15}
```

Lo

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{0.0212878, 0.0184276, 0.0147612, 0.0109843, 0.00793939, 0.00564788, 0.00407479}
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