ANALYSIS OF VIVALDI ANTENNA WITH METHOD OF MOMENTS IN MATLAB

Z. Lukeš, Z. Raida

Dept. of Radio Electronics, Brno University of Technology
Purkyňova 118, 612 00 Brno, Czech Republic
Phone: +420 541 149 117, E-mail: lukes@feec.vutbr.cz

1 Introduction

The Vividli antenna (also known as *Tapered Slot Antenna - TSA*) belongs among slotline antennas with endfire radiation. Three basic types of TSA are depicted at the Fig. 1.

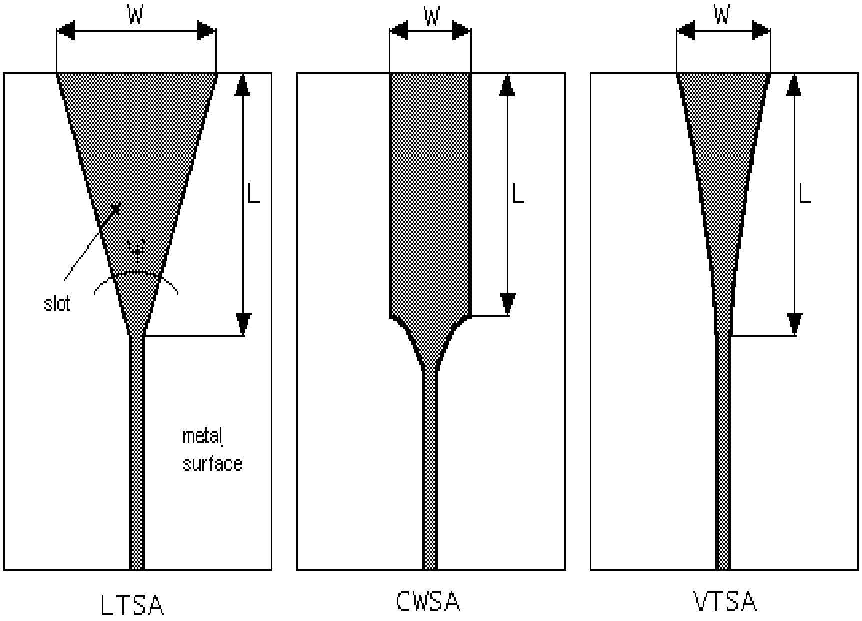
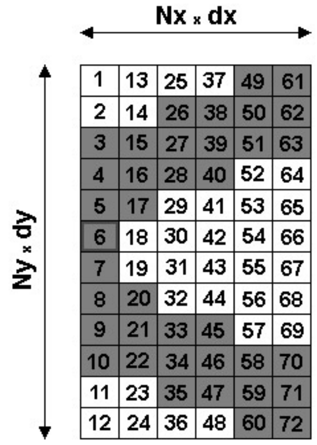


Fig. 1 *Basic types of Vivaldi antenna*

Vivaldi antennas are fabricated from two thin metallic parts, which are separated by an air space or a dielectric substrate. In our development, we concentrated on a LTSA (Linear Taper Slotline Antenna) type. In the analysis by the method of moments, we have to discretize the surface of the Vivaldi antenna as shown in the Fig. 2.

If the discretization of the Vivaldi antenna is finished, then the program for the moment analysis can be run. The program consists in three parts: **Pre-processing**, **Computational Kernel** and **Post-processing**.



1	13	25	37	49	61
2	14	26	38	50	62
3	15	27	39	51	63
4	16	28	40	52	64
5	17	29	41	53	65
6	18	30	42	54	66
7	19	31	43	55	67
8	20	32	44	56	68
9	21	33	45	57	69
10	22	34	46	58	70
11	23	35	47	59	71
12	24	36	48	60	72

Fig. 2 *Discretization of the Vivaldi antenna*

2 Pre-processing

Entering input data of the analysis is the main aim of the pre-processing. Input data are loaded in the form of a bitmap file, which contains the discretized surface of the Vivaldi antenna. As a deisretization element, a rectangle is used (see Fig. 2). The discretized surface can be painted in an arbitrary bitmap picture editor. The picture is recommended to be of 256-colour form.

As shown in the Fig. 3, there is a bar in the upper-left corner of the editing window, which includes coded antenna properties. In the first four segments, frequencies of the analysis are encoded. In the second four segments, dimensions of discretization elements (in millimeters) are encoded. Last two segments contain information about the amplitude of source voltage (in volts). Using the colour bar, the data of the analysis are automatically computed. The code table of colours is shown in the Fig. 4. In MATLAB, the described task can be solved by the following source code:

```
global  I11  I12  I21  I22                 %definition of global parameters
fprintf(1,'All projects : ');
dir *.bmp;
file=input('Enter name of BMP file with extension : ','s');
picture=imread(file);   %read bitmap picture with motive of structure

data=picture(1:10,1);                         %read input data
picture(:,1)='';                              %delete bar of data
%Colour decoding of data bar
for i=1:10
   if data(i,1)==146 data(i,1)=1;
   elseif data(i,1)==128 data(i,1)=2;
   elseif data(i,1)==144 data(i,1)=3;
   elseif data(i,1)==16 data(i,1)=4;
   elseif data(i,1)==18 data(i,1)=5;
   elseif data(i,1)==219 data(i,1)=6;
   elseif data(i,1)==224 data(i,1)=7;
   elseif data(i,1)==252 data(i,1)=8;
   elseif data(i,1)==28 data(i,1)=9;
   elseif data(i,1)==31 data(i,1)=0;
   end
end
data=double(data);
frekvence=(data(1,1)*10)+(data(2,1)*1)+(data(3,1)*0.1)+(data(4,1)*0.01);
%frequence in GHz
lam = 0.3/frekvence;                                   %length of wave
k0  = 2*pi/lam;                                        %wave number
dx=data(5)*0.001+data(6)*0.0001;   %size of elementary cell x in meters
dy=data(7)*0.001+data(8)*0.0001;   %size of elementary cell y in meters
Napeti=data(9,1)*1+data(10,1)*0.1;   %size of source in the volts

Nx=size(picture,2);                  %number of cells in direction x
Ny=size(picture,1);                  %number of cells in direction x

w=dx;
h=dy;
```

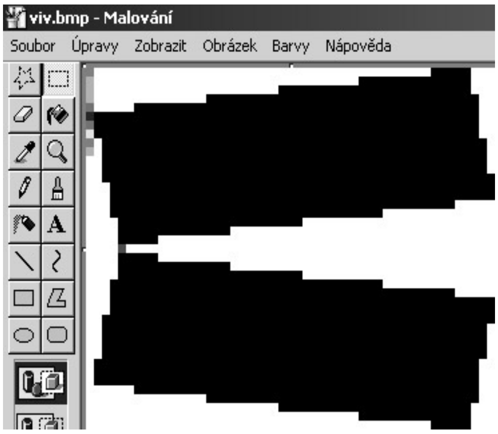


Fig. 3 *Painting a motive of the Vivaldi antenna*

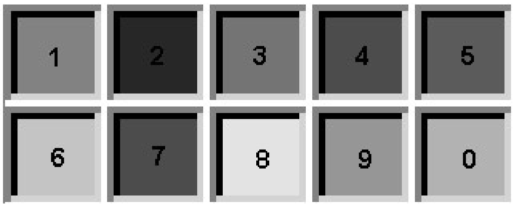

1
2
3
4
5
6
7
8
9
0

Fig. 4 *Code table of colours*

In the next part of the program, the edited motive of the antenna surface is converted to the form, which is suitable for the moment method. If the discretization cell is painted in white (255), then its surface is not metallic (the cell is marked as a zero-cell).

The cell painted in red (224) is understood as a source-cell (a voltage source is assumed over the cell). A metallic motive of the structure is painted in black.

Conversion of the edited antenna to the numeric format can be implemented by the following MATLAB code:

```
N=0;
M=0;
x=[];
for i=1:Nx
   for j=1:Ny
      N=N+1;
      cislo_segmentu=picture(j,i);
      if cislo_segmentu==255  %if color is white = 255, then this is…
                               zero-cell segment
         M=M+1;
         x(1,M)=N;            %vector of zero-cells (motive not painted)
      elseif cislo_segmentu==224 %if color is red = 224, then this is
                                 source segment.
         Napajeni=N;             %number of source cell
         sloupce=M;              %number of zero cells before source cell
      end
   end
end
```

3 Computational Kernel

The kernel computes self- and mutual impedances between two coplanar cells in the motive of the Viavaldi antenna. Computations are based on the method of moments [1].

Computing a self-impedance of a discretization cell, an integral containing a weak singularity has to be evaluated. The singularity can be solved by l’Hospital rule.

Next, an exponential integral $E(x) = Ci(|x|) - j\, Si(x)$ has to be evaluated also. This can be accomplished using series published in [2]. The respective MATLAB code is listed below:

```
function out = E(x)

% exponential integral for real argument

a1 = [ -0.25,  0.01041667, -0.00023148,  0.00000310, -0.00000003]';
b1 = [  1.00, -0.05555556,  0.00166667, -0.00002834,  0.00000031]';

a2 = [ 38.027264, 265.187033, 335.677320,  38.102495];
b2 = [ 40.021433, 322.624911, 570.236280, 157.105423];

a3 = [ 42.242855, 302.757865,  352.018498,  21.821899];
b3 = [ 48.196927, 482.485984, 1114.978885, 449.690326];

for m=1:3
 for n=1:2
  if x(m,n)<=1
   f=a1(1)*x(m,n)^2+a1(2)*x(m,n)^4+a1(3)*x(m,n)^6+a1(4)*x(m,n)^8+...
     a1(5)*x(m,n)^10;
      Ci = 0.577216 + log( abs( x(m,n))) + f;
      Si = b1(1)*x(m,n)+b1(2)*x(m,n)^3+b1(3)*x(m,n)^5+b1(4)*x(m,n)^7+...
      b1(5)*x(m,n)^9;
    else
      f=x(m,n)^8+a2(1)*x(m,n)^6 + a2(2)*x(m,n)^4 + a2(3)*x(m,n)^2 + a2(4);
      f=f/(x(m,n)^8 + b2(1)*x(m,n)^6+b2(2)*x(m,n)^4+b2(3)*x(m,n)^2+b2(4));
      g=x(m,n)^8+a3(1)*x(m,n)^6 + a3(2)*x(m,n)^4 + a3(3)*x(m,n)^2 + a3(4);
      g =g/(x(m,n)^8 + b3(1)*x(m,n)^6+b3(2)*x(m,n)^4+b3(3)*x(m,n)^2+b3(4));
      g = g / x(m,n);
      Ci = f*sin( x(m,n))/x(m,n) - g*cos( x(m,n))/x(m,n);
      Si = (pi/2) - f*cos( x(m,n))/x(m,n) - g*sin( x(m,n))/x(m,n);
    end;
    out(m,n) = Ci - j*Si;
  end
end
```

That way, self- and mutual impedances for all the possible combinations of the Vivaldi antenna segments are computed. Using those partial impedances, an impedance matrix of the antenna can be built (the zero-cells, where the motive is not painted, have to be removed).

If the impedance matrix is finished, we can compute the admittance matrix of the antenna, and current distribution over metallic parts of the surface the Vivaldi antenna can be determined:

```
%Computing of admittance matrix
clc;
pause(0.01);
fprintf(1,'Computing 4 from 5 : Computing admittance matrix...');
Y=inv(Z);
clear Z;
```

For a known source cell and for a known number of zero-cells foregoing that, we can simply determine the complete admittance matrix of the antenna related to the source. This method is much quicker than inserting all zero columns and rows into the admittance matrix, because we need the current distribution from source to computing input impedance only.

```
Y=Y(:,Napajeni-sloupce);   %Selecting admit. bar in the source cell

m=size(Y,1);               %Insert zero cells to admit  matrix
for i=1:length(x)
   clc;
   fprintf(1,'Computing 5 from 5 : Insert zero cells for visualization :');
   fprintf('\n\nAll number zero bars and lines for visualization=...
          %1.0f',length(x));
   fprintf('\n\nInserting bar and line # = %1.0f',i);
   l=x(i);
   Y((l+1):(m+1),:)=Y((l:m),:);
   Y(l,:)=0;
   m=m+1;
end
```

Now, we can compute the input impedance of the antenna and visualize the current distribution.

```
U=Napeti;                %Size of source
Im=Y*U;                  %Computing of current distribution
Zvstupni = 1/Y(Napajeni) %Computing input impedance
clear Y;
```

4 Post-processing

In the Fig. 5, the current distribution of the Vivaldi antenna is displayed (frequency *f* = 10GHz, length of metal parts *L* = 15 cm, width of metal parts *W* = 6 cm, width of the excitation slot *D* = 3.8 mm, angle between metallic parts φ = 15°).

The developed MATLAB program is able to compute values of the input impedance in the frequency range 9 to 11 GHz. Computed values were compared with measurements of the physical model of the antenna. The model was measured using the vector analyzer HP8408B. Values of impedances are shown in Fig. 6 and Fig. 7.

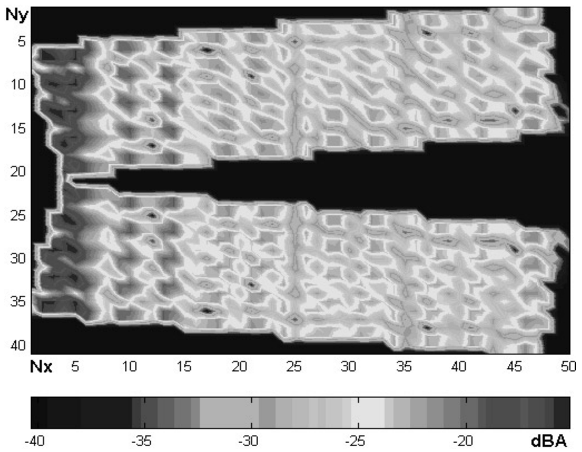


Fig. 5 *Current distribution on Vivaldi antenna on f=10GHz*

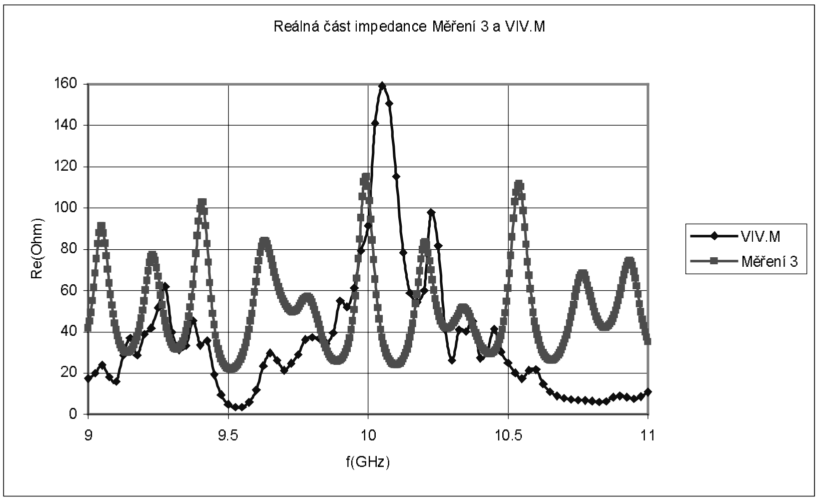


Fig. 6 *Real part of antenna input impedance in Ohms*

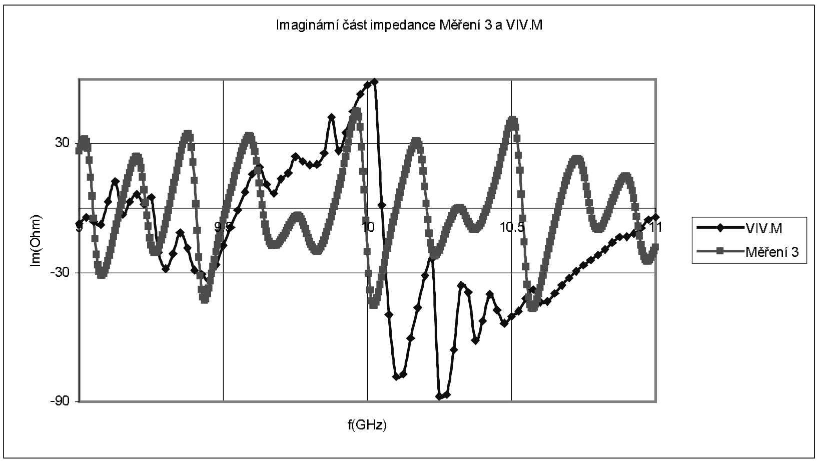


Fig. 7 *Imaginary part of antenna input impedance in Ohms*

5 Conclusion

In the paper, an exploitation of MATLAB for analyzing Vivaldi antennas is described. The program uses bitmap-handling abilities of MATLAB for importing the analyzed structure. A powerful computational kernel of MATLAB is exploited for implementing an efficient analysis tool.

The main advantages of the program consist of the fact that:

- An antenna of an arbitrary 2-D structure can be analyzed by the developed program;
- Data input can be simply loaded into the program as a bitmap picture;
- The program is optimized for the fastest computation.

References

[1] JANASWAMY, R. An Accurate Moment Method Model for the Tapered Slot Antenna. *IEEE Transactions on Antennas and Propagation.* 1989, vol. 37, no. 12, p.1523-1528.

[2] ZHANG,S.,JIN,J. *Computation of Special Functions.* A Wiley-Interscience Publication, p. 680-688, 1996.