v1.02 7/16/16

This is the manual for

atlc2

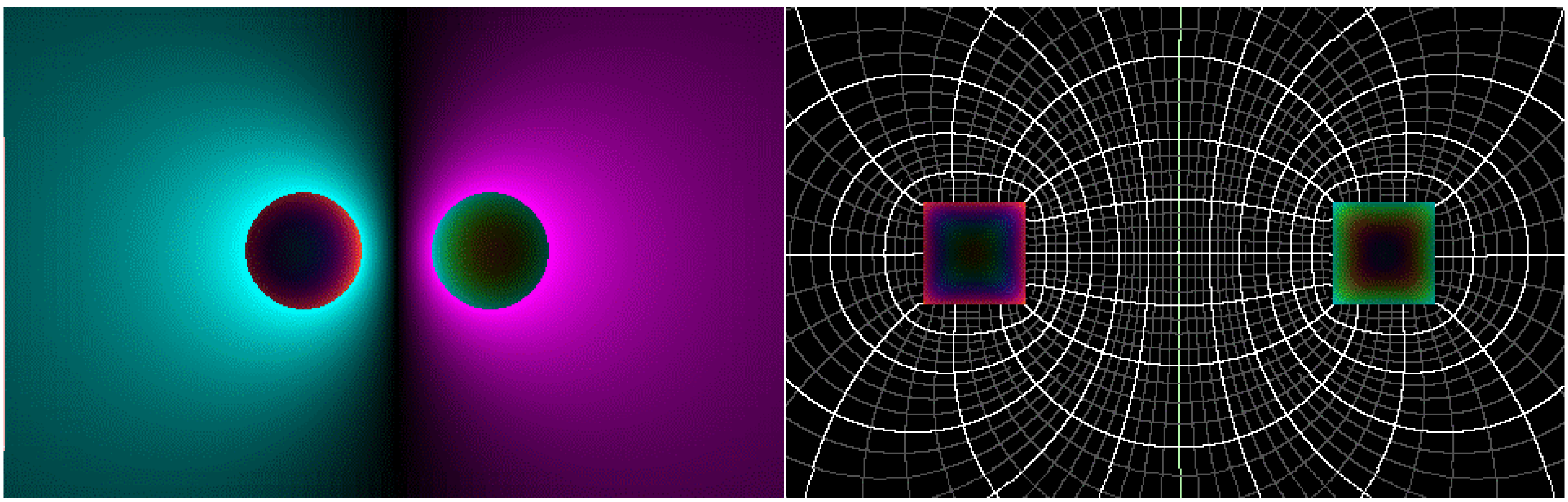
Arbitrary Transmission Line Calculator

This program was inspired by the atlc program written by Dr. David Kirkby, G8WRB.

You submit a drawing showing the cross-section of a transmission line with any geometry. From that, the program will use numerical methods to find Z_0 and the other transmission line parameters. Atlc2 is free.

Download atlc2 for Win32 now (2.4M bytes)
Download atlc2 for Win64 now (4.2M bytes)

(The Win32 version will run on a 64-bit Windows system. The only advantage of the Win64 version is it allows more than 13500 equations.)



Differences between atlc and atlc2

1. Atlc2 applies Faraday's Law to determine the current distribution inside the conductors. From that it calculates the inductance and skin effect resistance. Atlc used only the laws of electrostatics.
2. Atlc2 is well thought out for unshielded lines, solving them rapidly and accurately. (Surrounding them with a ground shield just slows down the program.)
3. The size of the simulation is not related to the size of the drawing. The E field simulation is always 3200 x 3200 pixels.
4. If there is a third conductor, it can either be pinned to ground potential or it can float to an unforced voltage level.
5. Atlc2 is a Windows program. Atlc was a Unix program, not especially user friendly.
6. Atlc2 can internally generate some simple geometries. In such cases no drawing file is necessary.

Atlc2 will accept bitmaps created for atlc.

General description

http://www.hdtvprimer.com/KQ6QV/Schematic.bmp

Atlc2 computes Z_0, vf, L, C, Rs, Gp, and V_O for any geometry. (V_O is the offset voltage necessary for no radiation.)

There are formulas for Z_0 for simple geometries, but they are not always accurate. If the geometry is extreme or complicated, has regions with dielectrics, or if the skin-effect resistance is wanted, then a program like this one is your best hope.

If used properly, atlc2 results are accurate to 1% or better. But it is not fast. It is compute intensive. Some speedups are employed that work well for some geometries, but not others. It can be hard to predict whether a run will take seconds or hours. Run atlc2 on your fastest computer.

Microsoft Paint is a good program for creating the drawing, but any such bitmap editor will work. There must be no de-aliasing, so Photoshop is out and JPEG files will not work. BMP format is assumed but TIFF and PNG files will also work.

Normally red, green, blue, and cyan are conductors and all other colors are insulators. But other color schemes are allowed. Color definitions can be changed at the keyboard or they can be loaded from a file. The line conductors can be any 2 of the 3 primary colors, but if all 3 appear then green is assumed to be ground. Most commonly red is +1 volt (actually +sin ωt), blue is –1, green is 0, and cyan is varying.

Unlike atlc, atlc2 requires a frequency, a definite size, and a conductor resistivity. But you can specify anything if they have little effect on the results. Full red, green, and blue (x0000FF, x00FF00, and xFF0000) are now copper. But slight off-shades are defined for other common metals. Atlc2 has 45 predefined colors for the common materials.

Current version of atlc2: 1.02 7/16/16

Version 1.02 The pixel width can be specified in the file name. The loss field is new. The arrow keys are fixed.

Version 1.01 Control panel rescaling is new.

Version 1.00

This is the first version I am proud of. It has no bugs, so far as I know. If you see anything that might be a bug, please report it to me at kq6qv@aol.com . I will fix it quickly.

Previous versions had problems with charge prediction that sometimes caused them to run very slowly. This has been mostly fixed.

Some small changes to the program:

1. A new checkbox allows E-field prediction (charge prediction) to be skipped. This makes the run time different, but does not change the ultimate numerical result. E-field prediction usually speeds up the program, but for some very large examples makes it slower.

2. Gp calculation is new. (atlc2 log.txt is affected.)

3. If you created a MoreColors.txt file, it should be changed to include tan(delta) values. If you do not know your dielectric's tan(delta) or don't care, specify a 0.

4. I decided to change the name of "C and vf" to "C and Gp". This is a purely cosmetic change.

5. Clicking on "File>Save displayed bitmap as..." now saves the full 3200 x 3200 map, with no zooming.

6. PNG and TIFF files now work again. Saved images will have the same file format as the Usermap.

7. C and Gp now employs up to 32 threads.

8. Rs prediction is now accurate to 5 %.

9. Rescaling is new, allowing Usermaps from files to be resized. (It looks like zooming, but actually changes the number of usermap pixels.)

10. C and Gp predicted L and Zo by assuming vf=1. L and Rs predicted C and Zo by assuming vf=1. Both have been changed to make a guess about vf. The guess averages the permittivities of all the dielectric pixels, weighing them equally. This is often a rather poor guess, but it is usually closer than assuming vf=1.

11. Scripting changes: The entire script file is read into RAM and closed before the script is executed. The "erase" command no longer terminates atlc2. The command "restrict" has been replaced by "box 1", and "CVF" has been replaced by "CGP". "Conductances.txt" is new. Scripts can call other scripts (key F8).

12. E-field lines is new. The line density is adjustable.

Installing atlc2

Atlc2 is a Windows program. It will run on Window 2000 and newer. It might run on some older platforms. The 64-bit version is required if you need more than 13,500 equations.

Tryouts: atlc2 can be executed directly upon download. It does not have to be saved to disk.

There is no formal installation procedure. It is a single **.exe** file and does not require any other files. It is not a registered program and does not show up in the Windows list of installed programs.

You probably should create a new folder and put **atlc2.exe** in that folder. We shall call it the "execution folder". It can have any name but should not be read-only. Atlc2 will record the results of any run that takes longer than 1 minute. Those results go into a file called **altc2 log.txt** in the execution folder.

Drawing files and any files produced by atlc2 can reside in any folder, but the open and save dialogs will always start at the execution folder. So it is most convenient to keep your atlc2 files there.

You may want to create a file that declares colors as conductors or insulators, and assigns physical characteristics to them. This file must be called **MoreColors.txt** and it must be in the execution folder.

Usermap: Preparing the drawing

(De-aliasing is a blurring of edges that makes them less jagged. But it creates unintended colors that atlc2 will not recognize. So you must use an editor that avoids that.)

Commonly red and green are used for fully shielded lines, such as coaxial cable. Otherwise use red and blue. When red and blue are both present, they are adjusted by adding V_O to both, maintaining the 2–Volt difference. (The program searches for a V_O that produces no radiation.) Green is always kept at exactly 0 volts.

The drawing can be in any folder and have any name. But finding the file is easier if you put it in the execution folder and give it the name **Usermap YYY ppp.bmp**, where " YYY" is a phrase describing the drawing. YYY can be a mix of upper and lower case and can contain spaces, but "Usermap" should be as shown. (The open dialog will initially filter out other files.) " ppp" is optional. If it is a string enclosed in parentheses, the string will be moved to the pixel width edit box.

Example: **Usermap Example 1 (.1mm).bmp**

When the checkbox "Restrict to skin depth" is checked, the program automatically blackens out conductor pixels more than 3δ from the surface, where δ is the predicted skin effect depth. (So setting the frequency too low makes the program run longer.) (Using this feature causes a decrease in accuracy of less than 1%.)

The pixels at the edge of the Usermap are special. They are replicated outward until the map is 3200 x 3200. (The four corner pixels are doubly special. They are replicated in two dimensions.)

Floating wires cannot carry a net current, but they can carry local currents (eddy currents). That is, there will be return currents in other floating pixels (so that they sum to zero).

All +1 pixels (usually red) are electrically connected to a voltage source. Thus they are connected to each other. The same is true for -1 wires (usually blue) and ground wires (usually green). But floating wires are connected to each other only if they are exactly the same color. So eddy currents will not link floating wires of different color.

A grounded third wire (usually green) can carry a net current. But if it does then the stated impedance is not a true characteristic impedance. If the ground current is more than a few % then the impedance the program reports should be disregarded.

The standard (internally defined) colors are:

Red	Green	Blue		use	resistivity	permittivity	tanδ	permeability	name
255	0	0	x0000FF	+1	1.7241	1		1	copper
0	255	0	x00FF00	0	1.7241	1		1	copper
0	0	255	xFF0000	-1	1.7241	1		1	copper
0	255	255	xFFFF00	float	1.7241	1		1	copper
224	31	31	x1F1FE0	+1	2.62	1		1	aluminum
31	224	31	x1FE01F	0	2.62	1		1	aluminum
31	31	224	xE01F1F	-1	2.62	1		1	aluminum
31	224	224	xE0E01F	float	2.62	1		1	aluminum
224	31	0	x001FE0	+1	1.62	1		1	silver

31	224	0	x00E01F	0	1.62	1		1	silver
31	0	224	xE0001F	-1	1.62	1		1	silver
31	255	224	xE0FF1F	float	1.62	1		1	silver
224	0	31	x1F00E0	+1	2.44	1		1	gold
0	224	31	x1FE000	0	2.44	1		1	gold
0	31	224	xE01F00	-1	2.44	1		1	gold
0	224	224	xE0E000	float	2.44	1		1	gold
224	63	63	x3F3FE0	+1	9.71	1		1 *	steel
63	224	63	x3FE03F	0	9.71	1		1 *	steel
63	63	224	xE03F3F	-1	9.71	1		1 *	steel
63	224	224	xE0E03F	float	9.71	1		1 *	steel
224	0	63	x3F00E0	+1	11.4	1		1	tin
0	224	63	x3FE000	0	11.4	1		1	tin
0	63	224	xE03F00	-1	11.4	1		1	tin
0	255	224	xE0FF00	float	11.4	1		1	tin
24	63	0	x003FE0	+1	14.5	1		1	60/40 PbSn solder
63	224	0	x00E03F	0	14.5	1		1	60/40 PbSn solder
63	0	224	xE0003F	-1	14.5	1		1	60/40 PbSn solder
63	255	224	xE0FF3F	float	14.5	1		1	60/40 PbSn solder
0	0	0	x000000	insul	1000000	1	0	1	vacuum
255	255	255	xFFFFFF	insul	1000000	1	0	1	vacuum
255	202	202	xCACAFF	insul	1000000	1.0006	0	1	air
130	53	239	xEF3582	insul	1000000	2.07	0.00020	1	teflon
142	142	142	x8E8E8E	insul	1000000	2.2	0.00090	1	duroid 5880
255	0	255	xFF00FF	insul	1000000	2.26	0.00064	1	polyethylene
255	255	0	x00FFFF	insul	1000000	2.5	0.00033	1	polystyrene
239	204	26	x1ACCEF	insul	1000000	4.5	0.011	1	polyvinylchloride
188	127	96	x607FBC	insul	1000000	3.3350	0.03	1	epoxy resin
223	247	136	x88F7DF	insul	1000000	3.7	0.018	1	FR4 PCB
26	239	179	xB3EF1A	insul	1000000	4.8	0.018	1	fiberglass/epoxy PCB
105	105	105	x696969	insul	1000000	6.15	0.00270	1	duroid 6006
220	220	220	xDCDCDC	insul	1000000	10.2	0.00230	1	duroid 6010
213	160	77	x4DA0D5	insul	1000000	100	0	1	Er=100
100	200	255	xFFC864	insul	1000000	75	0.157	1	distilled water
176	224	200	xC8E0B0	insul	1000000	3.78	0.00006	1	quartz
153	255	153	x99FF99	insul	1000000	5.0	0.00540	1	glass

* Atlc2 cannot presently handle ferromagnetic materials.

The tanδ values above are rough typical values. The program assumes tanδ is constant. But for most materials, tanδ varies slightly with frequency and manufacturer. (Tanδ specifies the dielectric loss. It is used only for the calculation of Gp.)

Best practices

The Usermap can have any dimensions. A larger Usermap (a map with more pixels per conductor) will run slower, but a smaller map will not represent fields or curved surfaces as well. The gap between conductors must never be less than 2 pixels, and accurate results usually require a gap of at least 5 pixels.

There is no need or benefit to having empty space around the transmission line. (This is true for shielded and unshielded lines.) The Usermap can be the smallest map that describes the line.

Usually the overriding goal is a Usermap with 1000 to 3000 conductor pixels, which will solve for L and Rs in a couple minutes. Execution time rises dramatically with the conductor pixel total (roughly the cube of the equation total). Solving for L and Rs takes:

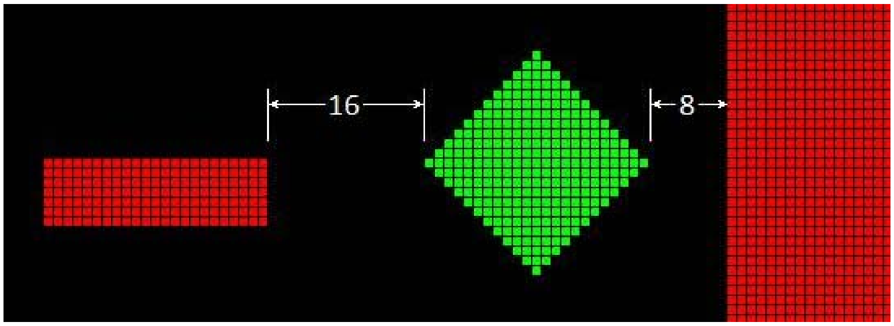
200 conductor pixels -	1 second	on a 1.5 GHz Pentium 4
400 conductor pixels -	4 seconds	on a 1.5 GHz Pentium 4
800 conductor pixels -	1.4 minutes	on a 1.5 GHz Pentium 4
1600 conductor pixels -	13.0 minutes	on a 1.5 GHz Pentium 4
3200 conductor pixels -	100.6 minutes	on a 1.5 GHz Pentium 4
3200 conductor pixels -	7.0 minutes	on a 3.33 GHz Xeon, 1 thread
3200 conductor pixels -	1.2 minutes	on a 3.33 GHz dual Xeon, 12 threads
6400 conductor pixels -	9.0 minutes	on a 3.33 GHz dual Xeon, 12 threads
12800 conductor pixels -	90.0 minutes	on a 3.33 GHz dual Xeon, 12 threads
25600 conductor pixels -	14 hours	on a 3.33 GHz dual Xeon, 12 threads (64-bit version)

So it is best to let the “pixels per inch” be determined by whatever scale gets a reasonable execution time. Execution times to solve for C and Gp are more variable, but runs can be ended early if convergence is seen.

C and Gp finds the capacitance (and Gp) by summing the energy in the field, so some capacitance is missed if a considerable field extends beyond the 3200 x 3200 area. Thus while Usermaps as large as 3200 x 3200 are allowed, C and Gp becomes inaccurate if the conductors are not confined to the central 1600 x 1600 region. Ground planes and fully shielded lines are exceptions to that.

Getting an accurate Rs

Rs will be accurate to ±1% when the skin depth is at least 30 times the pixel width. In other cases, atlc2 estimates the A.C. resistance of each pixel. In these cases, Rs is generally accurate to ±5%. But this is true only if the conductors are not too close. The following diagram shows the minimum spacing if you want Rs accurate to 5%. A corner pixel must be at least 16 pixels from another corner pixel of different voltage, or 8 pixels from a flat or curved surface of different voltage.



If you violate this, atlc2 will report the Rs value using a red font as a warning. To work around that, you will need to make a larger model (with more conductor pixels) and then hollow it out to reduce the pixel count.

Atlc2 might be the only program anywhere that can predict Rs within 5% for any wires with any cross-sections.

Running atlc2

Atlc2 begins by showing one of its internally generated examples. The normal procedure is to click File>Open and select the BMP file that you have prepared. You must type in a “Pixel width” when using an external bit map. Then click Solve>Solve fully. Or File>New will select a different internal example.

Wherever atlc2 asks for a numerical value, the entered value can be an integer or floating point number. The numerical value can be followed by a power-of-ten suffix in “e” form. For example, **13e-3** would be 13 thousandths of an inch. Additional suffixes are allowed:

in	(inches)
m	(meters)
cm	(centimeters)
mm	(millimeters)
AWG	(American wire gauge)

Inches are assumed if there is no suffix.

Some keyboard command keys are available:

U	Show without E or V field
V	Show the V field intensity
E	Show the E field intensity
D	Show the D field intensity (where D is εE)
T	Show the loss distribution (where loss is εEtanδ)
L	Show the V field as a lines plot. (These lines are often perfect circles.)
N	Show the E field as a lines plot (lines of force direction)
B	Show both the E and V field lines
J	Show J-field, not the Usermap (The Usermap substitutes when the J-field is not yet found.)
H	Show all fields high intensity (employs a square root function)
S	Stop solving
+ or =	Zoom in
-	Zoom out
] or PgUp	Rescale larger
[or PgDn	Rescale smaller
> or Insert	denser lines
< or Delete	sparser lines

Enter	redraw plot
&J	Write the entire current map to a text file
&V	Write the entire voltage map to a text file

(The &L, &T, &K, and &G commands are undocumented. They are not of general interest.)

Color definitions can be modified using the keyboard. If the "Show all standard colors" box is checked, the changes are to the internal color table and persist until the program terminates. Otherwise the changes persist only until the Usermap is changed.

MoreColors.txt

This file does not have to exist. Any text editor can be used to create it.

A sample **MoreColors.txt** file:

```
|red:   green:   blue:   use:    Ohms:    Er:      tanDelta:  Mu:  name:
250     20       20      +1      7.3      1        0          1
Cadmium
30      255      30      0       20.6     1        0          1
Lead
180     180      120     insul   0        6.0      0.0007     1
Mica
30      30       30      insul   0        3.5      0.0040     1
Hard rubber
100     140      170     insul   0        4        0.0030     1
Silicone
```

Each line in the file declares and defines one color. All parameters must appear in order. The parameters are:

1. Red value. (0 to 255)
2. Green value. (0 to 255)
3. Blue value. (0 to 255)
4. Function. (must be +1, –1, 0, float, or insul)
5. Resistivity in Ohm-Centimeters. (ignored for insulators)
6. Relative permittivity (ignored for conductors)
7. Loss tangent tanδ. (dielectric loss, ignored for conductors)
8. Relative permeability. (for future use)
9. Material name. (Everything remaining on the line is part of this comment. It may contain blanks.)

If a color duplicates an existing color, the new definition prevails. Atlc2 loads `MoreColors.txt` only once, when it begins. Then the user can use the keyboard to further redefine colors. The program will hold up to 500 colors, but only 256 can appear in a Usermap.

All parameters in this file are delimited by blanks. A tab is treated as a blank. Consecutive blanks are treated as one blank. A "|" character denotes a comment, and all further characters on the line are ignored. Blank lines are allowed.

Implementation details

Atlc2 is written in Delphi XE10 Pascal (about 8000 lines). It uses 64-bit floating point for all calculations.

Atlc2 uses multiple threads (cores) during E field prediction and relaxation (C and Gp), and equation solving (L and Rs). It assumes all of the computer's processors are idle. The program can manage up to 32 threads. One "master" thread parcels out work for the others, which sit in infinite loops when they have nothing to do. So the Task Manager graphs do not necessarily show actual work being done. Any interruption that slows down any thread slows down them all. You should reduce the atlc2 thread count if your system does a lot of other concurrent work. On the author's dual-Xeon workstation, running 12 threads is about 6 times as fast as a single thread with the other 11 cores idle.

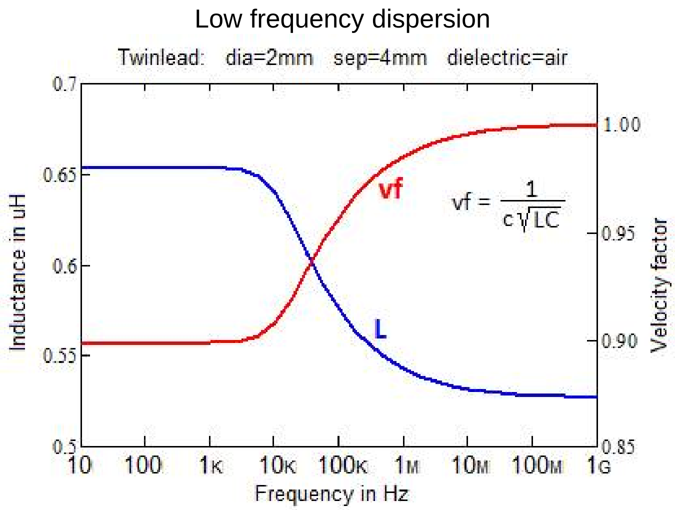
L and Rs

This part of the program works by solving equations, one equation per conductor pixel. The equations force the total net current to equal zero. But there are transmission lines in which this is not true. Some geometries (including coaxial cable) encourage an unbalanced current, which produces an excess charge that is balanced by a virtual charge infinitely far away. Such lines will radiate radio waves at all frequencies if nothing is done about this. Grounding the offending conductor might be sufficient to fix this. A driver circuit that implements V_O will certainly fix it.

If there is a grounded third wire (green) then "Ignd" gives the ground current compared to the red current. Analytically this number is not very useful. It is provided as a convenience. If Ignd is below 4% then it might be safely ignored. Otherwise maybe your whole approach should be reconsidered.

Infinite plane extensions are ignored during L and Rs. Only the conductor pixels in the Usermap contribute toward the solution.

The math used in L and Rs is described at LandRs.html. Atlc2 correctly models low frequency dispersion.



Low frequency dispersion occurs because L changes with frequency but C does not.

C and Gp

A frequency and pixel size are not required when solving for C and Gp. The method used is the same as in atlc. So C is a D.C. surface capacitance. The A.C. capacitance is generally the same at all frequencies.

C and Gp can be thought of as a soap-film-stretching program. Imagine high structures (high voltage) and low structures (low voltage) with a fabric or soapy film stretched between them. The white V-lines (often circles) are elevation lines, like those on a topographical map.

The method is a "relaxation algorithm" that continuously sets the voltage at each pixel to the average of its four closest neighbors. This will eventually stabilize and will be a perfect solution to Gauss's Law. How long it takes depends on how the program initializes the array. The better the program can predict the final field, the quicker the relaxation algorithm will finish.

Prediction uses the formula after distributing the surface charge.

Surface charge distribution is by successive approximations. The E field at each surface pixel is found by summing the contributions from the charges at all the pixels. The field component normal to the surface predicts a new value for the charge at that pixel. About 20 iterations seems to work well.

Presently the prediction cannot guess the effects of dielectrics. So examples with dielectrics take longer for an accurate result. Most other examples finish quickly. Another slow example is any transmission line with a net charge. This will be the case if you use green instead of blue for unshielded lines. Such lines will radiate, and the reported Z_0 is not a true characteristic impedance. Almost certainly you are making a mistake. If you want to design an antenna, you need a very different kind of program.

For unshielded lines, the Usermap is extended outward by adding pixels. These pixels are of two different sizes. Usually the Usermap is extended outward by 100 pixels that are the same size as the Usermap pixels. Then the map is further extended using pixels that are 8 times larger (256 time larger in area), until the size of the map is equivalent to 3200 x 3200 of the Usermap pixels. Note that if you surround the conductors with a lot of empty space (rather than use a smaller Usermap) then more of the smaller pixels are employed, slowing down the run with probably no improvement in the accuracy. (The region with smaller pixels is never smaller than the Usermap.)

L and Rs versus C and Gp

Atlc2 is essentially two programs bundled together. They do roughly the same thing by two different methods. Sometimes you need to run both, but for other cases, one is sufficient. L and Rs tends to be more accurate, but its execution time rises with the cube of the conductor pixel total, which can be prohibitive. `L and Rs` cannot handle multiple dielectrics. `C and Gp` loses accuracy when the conductors are close together. (Close conductors will spike the capacitance, which a coarse grid portrays poorly, but the inductance remains well behaved.)

`C and Gp` is itself two programs bundled together: A charge-shifting program and a relaxation program. Either could do the whole job. The former is usually faster, but the latter is more accurate. So `C and Gp` employs both. In cases where charge-shifting is slower, you might want to skip it, which is done by checking the box “Skip E prediction”. Execution time for prediction rises with the cube of the model size, while relaxation is roughly the square.

If you must use a map too large for `L and Rs`, try this trick: Run `C and Gp` a second time but with all permittivities set to 1, and use the L that it reports. Z_0 = sqrt(L/C)

A discussion of 3-wire transmission lines

Multi-wire transmission lines have multiple characteristic impedances, none of which truly correspond to that of a 2-wire transmission line.

Any 3-terminal linear network can be modeled as 3 impedances in either a “Y” or “delta” configuration. We shall use a “Y” to describe a 3-wire line as seen from the end.
http://www.hdtvprimer.com/KQ6QV/3Wire.bmp

If the green wire is made to float, it will carry no current. Upon running atlc2, let’s designate the resulting impedance Zo_{GCZ} (green current zero). Two more runs of atlc2 will give us Zo_{RCZ} and Zo_{BCZ}. It is evident that:

$Zo_{RCZ} = Zo_B + Zo_G$ $\quad$ $Zo_{GCZ} = Zo_R + Zo_B$ $\quad$ $Zo_{BCZ} = Zo_R + Zo_G$

These can be solved for Zo_R, Zo_G, and Zo_B:

$Zo_R = (Zo_{GCZ} + Zo_{BCZ} – Zo_{RCZ})/2$ $\quad$ $Zo_G = (Zo_{RCZ} + Zo_{BCZ} – Zo_{GCZ})/2$ $\quad$ $Zo_B = (Zo_{RCZ} + Zo_{GCZ} – Zo_{BCZ})/2$

A quarter-wave directional coupler is a common 3-wire transmission line:
http://www.hdtvprimer.com/KQ6QV/DirectionalCoupler.bmp

If the green wire is made to float then there is no green current. Whatever float voltage atlc2 reports will be equal to the center voltage, V_C. Thus:

$Zo_B = Zo_{GCZ} * (V_{float}+1) / 2$ $\quad$ $Zo_R = Zo_{GCZ} – Zo_B$ $\quad$ $Zo_G = Zo_R$ $\quad$ $Zo_{ODD} = 2 * Zo_R$ $\quad$ $Zo_{EVEN} = Zo_R / 2 + Zo_B$

So it is possible to get a complete characterization with a single run of atlc2. In theory this works. In practice, the results are often off by more than 5%. The problem is that the asymmetry in the excitation results in an unbalanced charge, which makes

Zo_{GCZ} inappropriate for determining Zo_{ODD}. You could derive C from the L and Rs run. But it is probably best to make two runs that find Zo_{ODD} and Zo_{EVEN} directly.

Scripting Facility

Although I added this feature for my own use, you might find it useful.

If you enter **ZZZ** in the Name box and then select `File>Run Script`, atlc2 will open the file **`ZZZ.txt`** and execute the commands it finds there. The file name ZZZ can be a mix of upper and lower case and may contain blanks.

When the atlc2 application begins, it looks for the file **`StartupScript.txt`**. If found, atlc2 will execute it.

A sample script file:

```
| A sample script file
twinlead
box 1 F        | restrict to skin depth
total 4000
separation 6mm
diameter 2mm
frequency .001
sweep frequency 25 4
```

The file format rules are the same as for **`MoreColors.txt`**. Only the first 3 characters of each command name are examined. When the argument is a directory or file name, the case and any blanks are preserved. Otherwise the case does not matter but there must be no blanks within an argument. Most commands are simple string moves. Very little error checking is performed. A detected error will abort the script. The "Stop" button will abort the script. No files are kept open during solves or script execution.

Allowed commands: (arg1, arg2, and arg3 are the command arguments)

twinlead	equivalent to File>New>Create twinlead
square	equivalent to File>New>Create square twinlead
coaxial	equivalent to File>New>Create coaxial
pixel	moves arg1 to the "Pixel width" box. (This has no effect unless the Usermap is from a file.)
total	moves arg1 to the "Total conductor pixels" box. (This has no effect unless the Usermap is internally generated.)
frequency	moves arg1 to the "Frequency" box.
separation	moves arg1 to the "Wire separation" box.
diameter	moves arg1 to the "Wire diameter" box.
insulation	moves arg1 to the "Insulation diameter" box.
top	moves arg1 to the "Top distance" box.
bottom	moves arg1 to the “Bottom distance” box.
side	moves arg1 to the "Side distance" box.
skew	moves arg1 to the "Vertical skew" box.
width	moves arg1 to the "Wire width" box for square twinleads.
height	moves arg1 to the "Wire height" box for square twinleads.
center	moves arg1 to the "Center conductor diameter" box for coaxial cables.
inner	moves arg1 to the "Shield inner diameter" box for coaxial cables.
outer	moves arg1 to the "Shield outer diameter" box for coaxial cables.
box	set the checkbox designated by arg1. Arg2 should be a T or F. See note 5.
name	moves arg1 to the "Name" edit box. The case and any blanks within arg1 are preserved.
folder	designates a folder. Thereafter, all references to the execution folder will use this folder instead.
open	like File>Open. A Usermap is loaded from arg1.bmp. See note 1.
solve	equivalent to Solve>Solve fully. See notes 2 and 3.
LRS	equivalent to Solve>Solve for L and Rs. See note 2.
CGP	equivalent to Solve>Solve for C and Gp. See note 3.
sweep	L and Rs parameter sweep. arg1: parameter. arg2: number of runs. arg3: runs per decade. See note 4.
terminate	terminate atlc2.
erase	erase the script file.
window	set the window state for this application. Arg1 gives the window state: 0 - wsNormal, 1 - wsMinimized, 2 - wsMaximized, etc.
launch	launch arg2 as a shell app. See note 1. Arg1 gives the window state: 0 - sw_Hide, 1 - sw_ShowNormal, 3 - sw_ShowMaximized, etc.
save	write the displayed image to the file named by the “name” box. (no prompting)
keyboard	apply each character of arg1 as a keyboard character. (Function keys can be entered as Fn.)

threads	use arg1 threads (cores). Arg1 can be a + or – to increment or decrement the current setting.
beep	sound the console bell (ding).

Note 1	If the first character of the file name is a % then the % is replaced by the execution folder name. Do not follow the % with a \. (A \ will be included automatically.)
Note 2	The computed L is appended to **`ZZZ Inductances.txt`**, and Rs is appended to **`ZZZ Resistances.txt`**. These files are cleared when the script begins.
Note 3	The computed C is appended to **`ZZZ Capacitances.txt`**, the computed Gp is appended to **`ZZZ Conductances.txt`**, and vf is appended to **`ZZZ VFactors.txt`**. These files are cleared when the script begins.
Note 4	Arg1 can be any of these: pixel, total, frequency, separation, diameter, insulation, top, bottom, side, skew, width, height, center, inner, or outer. Each refers to the same edit box as the same-name command above. See note 2. Example: If the frequency box contained 10 then "sweep frequency 5 2" would run `L and Rs` with the frequencies 10, 31.62, 100, 316.2, and 1000 MHz.

Note 5 Specify a number for the desired checkbox:

1	Restrict to skin depth
2	Unending run
3	Skip E prediction
4	Vo zero
10	Add top plane
11	Add bottom plane
12	Add side planes
13	Insulation vertical
14	Insulation horizontal
15	One wire
20	Add floating wire
21	Add grounded wire
30	Air dielectric
31	Show all standard colors