<u>'EMCFiltr' Filter Simulation Software written by C.Bateman - 1996. updated August 1997.</u>

The **'EMCFiltr'** name is a trademark of C.Bateman Engineering.

<u>Introduction.</u>

Version #4 Updates
Due to the restrictions imposed by Font sizes etc. two versions of certain screens are provided within this software, optimised for either VGA 640*480 screen or SVGA 800*600 screen.

Unlike previous versions, both VGA and SVGA screens have been included in the one 'exe' file. The software now senses the screen resolution being used and automatically loads or adjusts the appropriate screen.

Installation will still be satisfactory should you change Windows resolution after installing the software. At 1024 * 768 screen resolution, appearance is improved if you use the 'Large Fonts' choice in Windows settings.

You can now rescale the 'Group Delay' plot to examine interesting areas. Simply click on your chosen resolution. Since each simulation calculates filter behaviour at 50 logarithmic frequencies for each decade, Group Delay plots at even the highest resolution, are satisfyingly smooth.

The magnetic model choices have been re-labelled with the specific material, the materials chosen being those most commonly used in EMC Filter manufacture. The Fair-Rite 43 ferrite used as a single turn bead, exhibits usable attenuation over many decades. The MPP (Micro Permalloy Powder) material is commonly used to wind multi-turn toroids used in single line EMCFilters. Both materials have the special merit of maintaining inductance, thus attenuation, over many decades, even when passing a significant DC current. This MPP core model is also usable with many low to medium permeability ferrites, provided they are not loaded with DC current.

The nine schematics are targeted especially to simulating a mainstream single line EMC Filter. However since twin line filters in either differential or common mode reduce to these same schematics, the program can be used to simulate twin line filters, simply by choosing the relevant circuit for each mode, then running two separate simulations.

However if you need to simulate only twin line filters, a similar but twin line only, dedicated program is available.

Previous users will notice a new screen has been added, following the selection of capacitor style and dielectric, inductor style and core material on the start-up screen. The program which runs invisibly while this new screen displays, prepares all the modelling data needed for the chosen components, ready for use by the simulation engine. This new screen requires no user actions.

This revision uses exactly the same fixed point modelling data by frequency as used for the previous versions components. However a 'Cubic Spline' interpolating engine has now been adopted, to provide an even smoother calculation of model data for the intermediate frequencies, compared to the previous interpolation method. Consequently while the insertion loss calculations are not visibly different, the Return Loss and Group Delay plots at high resolutions, are now smoother and even more accurate.

Using a 486 DX2-66 processor, this 'Cubic Spline' interpolating engine adds less than two seconds to the program's initial configuration time. In previous versions, each simulation run interpolated the modelling data needed, wasting time for every run. Consequently this small start up delay, is more than recovered during the first and subsequent simulations.

This upgrade offers much enhanced usability. Furthermore since I no longer need to maintain two different screen resolution software versions, it facilitates the development and introduction of new component models.

I shall be most pleased to introduce modelling data for other components, on request from registered users.

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Limitations of the Evaluation Version .

There is no difference in either program code, simulation method, or component data by frequency, between the evaluation and full program versions. Indeed the one source code now generates either the evaluation software or the full program.

The full program provides analysis of all nine pre-set Filter configurations, with choice of component base materials. The evaluation version functions exactly the same, except it is restricted to full analysis only of the Two-Tee filter style. All schematics are available and can be actioned for value change etc., but not proceed to the analysis stage.

To attract your attention to this Two_T selection, the 'Two_T Filter' button legend has been underscored in the evaluation version of the program.

To avoid 'divide by zero' errors the program automatically applies a safe minimum value, overriding any zero or null value input you make. It accepts and works down to the extremely small values, of 0.1 pH and 0.1 pF. The Evaluation versions minimum values however have been increased, simply to ensure evaluation users can only use more reasonable values.

Installation.

This program requires Windows 3.1 or higher, with 8 Mbytes of RAM. It has been written using Visual Basic 3, in order to provide the smallest installation file sizes, when used with Windows 3.1 or Windows for Workgroups machines.

If you have purchased either the evaluation disc or the full version, directly from the writer, then all files needed have been supplied.

The evaluation version only, is also available on Internet as a zip-file, 'EMCFILT2.ZIP' which can be quickly downloaded. If you have downloaded 'EMCFILT2.ZIP', then please action the 'Downloaded Software' section before proceeding with the install.

(Please note the original version as file EMCFILTR.ZIP which may still be found on Internet is for the original demo version only. Versions 2 & 3 were not uploaded to Internet so 'EMCFILT2.ZIP' is the latest evaluation version)

To install follow the usual Windows practise of **File Run 'A:\SETUP'** .

As usual, first close any running programs. Use ALT+TAB to check no other Windows programs are in use or are running in the background. It is also advisable to close down any supplementary programs, such as Dashboard, or SCSI utilities etc., should you have these or similar running in your system.

When installation is complete the program body **'EMCFiltr.exe'** together with a copy of this manual, will have been installed in the directory named **EMCFiltr.**

SetupEMC.exe also the **EMCFiltr program group** will have been installed in your Windows directory. Also if not previously present, three standard Microsoft files, needed to run a compiled Visual Basic program will have been added to your Windows/System directory.

VBRUN300.DLL
DDEML.DLL
VER.DLL

You need take no action, the file **Setup.exe** checks for their existence and actions accordingly (see **setup.lst** on the disc).

This install makes no alterations to your existing 'Ini' files or autoexec.bat or config.sys hence can be easily un-installed by simply deleting the program and the program group while running Windows, then deleting the **EMCFiltr** directory and the **SetupEMC.exe** file from your Windows directory.

Having completed the installation, simply double 'click' on the **EMCFiltr** Icon to explore the program.

Packing List.

The full file listing required for **EMCFiltr** installation is:-

```
A:\    Manual.txt  This file
       DDEML.DL_
       EMCFILTR.EX_
       SETUP.EXE
       SETUP.1ST
       SETUPEMC.EX_
       SETUPKIT.DL_
       VBRUN300.DL_
       VER.DL_
```

Downloaded Software Only.

Copy the compressed downloaded file EMCFILT2.ZIP into an empty directory, then unzip its contents using PKUNZIP to extract the installation files needed. The SETUP program can then be run from this directory.

The evaluation version of 'EMCFiltr' can be downloaded from many Internet software archive sites. To minimise storage and download times, most FTP sites insist the file **VBRUN300.DLL** be excluded from the package. This file if not already on your system, is commonly available from most sites. If not already in your Windows\System directory it must first be obtained and copied to your Windows\System directory, before installing the EMCFiltr software.

The current version of VBRUN300.DLL used to write this software was 3.00.0538 12/5/93 unpacked size 398,416 bytes. This version or newer, is required.

Familiarisation.

Overview.

The quickest way to check program operation is to repeatedly push **Enter,** which will cycle the program through each default, or last used screen in turn, to quickly check program installation.

Having ascertained the program is functioning at all four user screens, try choosing a filter style - say Two-Tee, and run using the default values, its not a very good Filter.

Return to the schematic screen. Place the mouse cursor over one of the 'Red' component values. Notice how the cursor changes shape to indicate when it is located over the box which allows revision of component values. Simply overtype, backspace or delete, just as you would to correct a word processor document. Try setting silly component values e.g. 0.0 etc.

To avoid 'divide by zero' errors, the program automatically overrides any invalid input you make to a safe minimum value. The Evaluation version's minimum values have been set to 10 uH and 0.01 uF, to ensure use only of normal values during the evaluation period. The full program however is not restricted and will accept extremely small values, down to 0.1 pH and 0.1 pF (0.0000001 uH. or 0.0000001 uF.).

Component values for capacitors are input relative to uF and inductors relative to uH, typical of those value ranges commonly used for filter design.

To facilitate entry of component parasitics, values for self-capacitance are input as pF and self- inductance as nH. Minimum permitted values for these parasitics being 0.5 pF for self-capacitance and 0.5 nH for self-inductance, representative of the best commercial components. Using Discoidal capacitors this limit becomes 0.00005 nH.

While the program will accept entry in scientific notation, the values input still relate to the uF, uH etc. prompts as displayed, so unless scientific notation values are input relative to the displayed standards, incorrect values will be assigned to the simulator. If you should decide to input in scientific notation, simply type 'val' E - 6 etc., the ^ or exponent symbol (ASCII 94) should not be used.

Simply overtype, backspacing or deleting as needed, the displayed values with your desired values, taking note of the uF and uH, pF and nH, notations. The actual values used in simulation are displayed on the simulator output screen.

Hardcopy printouts can be easily produced using a screen capture program. For this the writer generally uses Paint Shop Pro.

All schematic values you input are remembered and re-displayed when you return to update the schematic, until the program is finally closed.

Clicking on the EXIT button or alternately pushing ESCAPE quits the program from all screens. However the program can only respond at the completion of any current task e.g. loading models or plotting of one frequency scan.

In a like fashion pushing ENTER actions the next screen or re-runs the simulator.

Let us now design an actual filter.

Step by Step.

Let us try redesigning the default Two-Tee Filter to a specification. Lets assume as a target, good transfer of audio to 12 kHz, with interference rejection better than 40 dB at 40 kHz and better than 70 dB at 100 kHz and above.

Exit the program by pushing ESCAPE, then re-run to restore to the original defaults.

Select 'Chip' capacitor, then push 'Enter' or 'click' on the 'E.M.C. Filter Analysis Program Simulator' button, to start the simulator.

After a couple of seconds delay, during which the selected capacitor and inductor models appropriate to each of the 350 frequencies used in simulation, are prepared for use, the 'Select Filter Style' screen will automatically appear.

Click on the button labelled 'Two_T Filter' to select the Two_Tee Filter schematic circuit net-list Generator form.

Click on the button labelled 'Source/Load' to start the simulation run using, using the MIL220 Standard 50 Ohms Source and Load impedances.

These default Two-Tee filter values, result in an awful filter in every respect.- Terrible Return Loss - Inadequate Pass Band Transmission and poor out of band high frequency EMC attenuation.

Follow these steps in turn, while observing the changes in the filter

simulation.
1) Try halving the capacitors to 0.5 uF		Looks better
2) Make all inductors 300 uH.		Better again.
3) Increase inductors to 500, 1000 , 500 uH		Very much better, but Return
Loss poor.
4) Reduce two outboard inductors to 300 uH	Not quite good enough.
5) Try reduced capacitance say 0.33 uF.		Almost to spec.
6) Try smaller changes to inductance values
Try 330 uH, 920 uH, 330 uH		Looks good.
7) Make DC resistances attainable.
Try 0.5 ohm, 1.0 ohm, 0.5 ohms		Still good.
8) Reduce inductor Self Capacitances to 2.5 pF	Specification surpassed.

The above few steps give a good indication of the affect on Return Loss, Insertion Loss and Group Delay, of various component changes. Dependant on the wanted signal transmission requirements further fine-tuning may be needed to improve the Group Delay response.

Obviously the result from step 8), indicates very clearly that efforts would be needed to provide inductors having little self-capacitance - see the inductor section.

Components used.

A choice of Ceramic Capacitor models is provided, which cover almost all miniature EMC Filter design needs. The Surface Mount 'chip' models automatically default to typical inductance values, appropriate to their sizes. Depending on physical size these can exhibit 0.5 to 1.3 nH of Self Inductance. Other capacitor styles have quite differing Self Inductances. With the so called 'Discoidal' types this inductance will be almost zero, again automatically provided by the schematics. Capacitors with wire leads exhibit much higher inductances. Use the appropriate size 'chip' but adding representative lead wire inductance to the default self-inductance values.

The default inductors assume use of either medium u type 43 Fair-Rite beads, or 125 permeability MPP Toroidal cores, which between them cover almost all present EMC Filter design needs. These carefully chosen materials provide usable inductance values with small Self Capacitance. While a default value of 10 pF has been chosen as representative of a properly wound small toroid, since this capacitance is determined by your winding and assembly techniques, a suitable value must be input.

The D.C resistance of inductors depends on wire gauge and winding methods. It cannot be pre-determined so must be input. The software calculates the frequency dependant AC core loss resistance for the selected core material, which is then added, frequency by frequency, to this D.C. resistance value, to model the actual 'Q' of the inductor by frequency.

The program thus allows the Capacitor and Inductor base materials to be chosen for each simulation. The components then determine the Frequency Dependant variables needed for realistic simulation.

Filter reverse engineering.

Frequently this software will be used to simulate an existing Filter design to be used with source and load impedances other than 50 ohms. In which case simply overtype with the desired impedances needed.

Most Filter specifications state the capacitance materials, capacitance and inductance values used. Alternately the total capacitance for Pi (two capacitors) and total inductance for T (two inductors) and the larger Filter styles, generally stated as minimum values. Inductor information is less common. A telephone call to the makers technical support will often fill in the details.

If not available, all is not lost. Simply 'reverse engineer' the Filter by inserting the stated capacitances perhaps at +10%, then guess at an inductance value and analyse the Filter, compare results with stated claims. Generally after five or six attempts the Filter will have been reverse engineered with sufficient accuracy. You can then use these derived values to analyse the Filter's behaviour with any desired source and load impedance combination.

Remember the catalogue claims will be chosen such that no Filter fails insertion loss testing, so it is common practise to much underclaim at the higher frequencies, since small construction variances have the most affect as frequency increases.

To restrain all output on the page, plotted results are allowed to overrange only by 105%. Consequently Insertion Loss or Group Delay plots are both flattened to this maximum value. In practice, measurement of an real EMC Filter using the MIL220 method, few Filters or measurement systems will exceed this -105 dB restriction.

Two earlier articles which I wrote about EMC Filters might prove useful:-

1)Measuring Insertion loss of low pass RFI filters. Electronic Product Design,

December 1989
2)Understanding emi filters. Electronics World & Wireless World May 1996

Let us now look into return loss and group delay, concluding with some aspects of capacitors and inductors.

Significance of Return Loss.

EMC Filters are used to pass either a wanted signal or source of power, without attenuation, while severely attenuating all unwanted Interference or EMC signals. The wanted signal being generally at a lower frequency than that of the interference

In order to pass low frequencies with little attenuation, the inductors used must have a low DC Resistance, hence unlike an attenuator the Filter cannot attenuate EMC by dissipating it. Since energy cannot be destroyed, the only remaining mechanism is to 'return' (Reflect) the unwanted EMC back to its source. This is exactly the mechanism by which Low Pass EMC Filters work. Depending on the input impedance of the filter, wanted signals, which should pass through the Filter, can also be reflected. Automatically resulting in a loss of wanted signal.

The perfectly matched Filter would lose by Reflection less than 1% of the wanted signal. Expressed in dB, this equates to a Return Loss signal -40dB lower than the incident wanted signal. A Return Loss of -26dB which equates to a VSWR of 1.1:1 would be perfectly acceptable in practise, reflecting 5% of the signal. Return Losses of -20dB and less are not desirable.

Obviously Return Loss results from the value of source and load impedances used as well as the Filter's Input impedance and design, thus making these an important parameter when designing for EMC suppression with good transmission of a wanted signal.

With Filters for DC Power supplies, Return Loss traditionally has been ignored, resulting in the oft quoted advice to design for maximum mismatch between source and Filter. While this technique provides excellent results for power systems, it is the worst possible bad practise whenever a wanted signal must be transmitted through the Filter.

Significance of Group Delay.

Group Delay is a simple presentation of relative phase with frequency. A 'linear phase' Filter would exhibit a straight line 'Group Delay' plot within the wanted Pass Band and would thus pass all wanted frequencies with effectively no change in their component phases.

With digital signals it is frequently necessary to ascertain the shape degradation of a waveform after it has passed through a filter. This is possible by performing a Fourier conversion from the stimulus signals waveshape (Time Domain) into its Frequency Domain equivalents. These are then used in turn as stimulus in the EMCFiltr simulator, then reconverting the EMCFiltr output using reverse Fourier Transform back to Time Domain when any changes are clearly visible.

C.Bateman Engineering has working software for this method, running on the Archimedes version of EMCFiltr. This could be ported to run under Windows if sufficient demand is found.

Interested? - then please contact the writer.

Inductors.
Inductor characteristics suffer from two main and little published anomalies.

Every inductor regardless of construction, possesses some capacitance, both from wire turn to wire turn within the winding and wire turn to any core or coil former used. More significantly, a toroidal winding can also possess significant capacitance between its two ends of the winding. If the toroid is fully wound with start and end windings in close proximity, this capacitance can exceed 100 pF, dependant on toroid size. The net result of these capacitances is called the 'Self Capacitance' of the inductor.

Self capacitance is not generally declared as a distinct parameter for commercial inductors, but is covered by the Self Resonant Frequency claim, from which it can be estimated, making due allowance for the materials reduced permeability at the resonance frequency.

This estimate can quickly be refined by running the simulator for an inductor, amending the self capacitance as needed, to agree the resonance frequency.

Many EMC Filters are required to pass DC or AC current and still provide their claimed attenuation. Assuming an Air cored inductance this presents no problem, however due to size constraints, use of a magnetic core is almost inevitable.

All inductors wound using magnetic core materials have limited performance when subject to either AC or DC current loading, due to loss of magnetic permeability with increasing current density, or

Ampere Turns. This effect is especially important in the case of DC currents. While an increased air gap can be helpful in minimising inductance change with current increase, this air gap also much reduces the initial inductance attained.

Use of two equal windings carrying equal but opposing currents can result in zero loading on the magnetic core. This technique can only be applied when both supply and return currents can be used, as is common for AC Mains supply filters.

Two extremes of air gap are common - the Solenoid Wound inductor, which has the maximum possible air gap - the toroid Wound inductor, which for Ferrite materials has essentially a small, and distributed air gap.

Certain toroids, based on the modern magnetic 'MPP' materials (micro Permalloy powder), have been specially formulated to provide enhanced performance with DC current loadings. However the material is expensive and only low to medium permeability is generally commercially available.

The EMCFiltr software provides the essential frequency dependant characteristics for the materials used. Simply input the inductance value, applicable at the AC or DC load current and temperature which the inductor must support.

With any toroidal core, while special winding techniques which reduce the turn to turn distributed capacitance can be used, the fundamental and most beneficial method to reduce self capacitance, is to ensure sufficient space, perhaps 30 degrees, separating the start and finish windings. If the toroid is fully wound and especially if start and finish windings coincide, or overlap, very high self capacitances result from the magnetic material combined with the very thin insulation coatings used on wire and toroid.

For example, a fully 360 degree scramble wound 25 mm toroid of 1000 turns, wound with overlapping start finish windings can exhibit a self capacitance of more than 50 pF. The same toroid wound using only say a 330 degrees scramble winding, can easily halve this capacitance.

If the toroid is potted for mechanical stability, or impregnated for protection, the initial wound self-capacitance will then increase, dependant on materials used.

Obviously smaller toroids with fewer turns will have less capacitance which can be further reduced by bank or Pie winding, similar to the methods common for high frequency solenoid inductors, which increase air gaps and minimise the voltage drop, between adjacent windings.

Thus Self Capacitance can range from 0.5 pF to 10 pF and above, dependant on inductor winding techniques and construction used. While it is easy to attain say 10 pF self-capacitance for a part wound toroid, lesser values become more difficult. Consequently the simulator defaults to suggest 10 pF for all schematic circuits. This value of course can be overwritten, as appropriate.

The toroid inductor chosen for this program is based on the commonly available 125_u_MPP and similar medium_u_Ferrite core materials, as regularly used in EMC Filters.

The Bead inductor choice has been based on the behaviour of the type 43_Fair-Rite Ferrite bead materials also very commonly used.

Most simulators require a ferrite bead be modelled as an inductance in series with a resistor. Unfortunately this is unrealistic task, since ferrite beads are not specified this way by their suppliers, instead are characterised for impedance by frequency.

In line with the 'EMCFiltr' program concept of simplest possible use, this program also characterises ferrite beads by impedance and frequency.

The program assumes a nominal Bead as being Fair-Rite 43 material and having 100 Ohms impedance at 100 MHz. If using a 43_Fair-Rite bead of greater impedance, simply multiply the bead number as appropriate.

In like fashion, when using a lower impedance bead, simply input as a partial Bead.

For example a larger bead having 384 Ohms impedance at 100 MHz, is input as 3.84 Beads. Alternately using their surface mount bead having only 47 Ohms at 100 MHz, input as 0.47 Beads. The full program will happily accept partial bead values, simply converting this number into the correct bead characteristics, however the evaluation version is restricted to one bead, as its minimum input.

Capacitors.

Two capacitor constructions, offering the best possible attenuation performance, by virtue of their inherent input output screening and isolation if correctly housed, are the so-called 'Discoidal' and the tubular 'Feedthrough' types. Other materials are possible, but commercially these are usually made using Ceramic materials. While available in all Ceramic formulations, to attain high capacitance with small size, the 'Hi-K' X7R and Z5U are the most common.

The Discoidal style offers the lowest possible Self Inductance values, less than 0.1 nH being common, which compares favourably with the 1 nH typical of a small surface mounted ceramic chip capacitor. Self Inductance can severely degrade attenuation at frequencies above 10 MHz.

If made using low 'K' or COG ceramic, the miniature tubular 'Feedthrough' can be modelled by selecting COG or X7R dielectric and entering a value for self inductance, intermediate in value between that used for the Discoidal and Surface Mount Chip styles.

However resulting from their physical size and the dielectric constants used, tubular 'Feedthroughs' made using X7R or Z5U materials can only be correctly modelled at frequencies above 100 MHz, by likening them to a transmission line. For this reason, a special simulator for high 'K' 'Feedthrough' capacitors has been written. Those interested in this approach, should contact C.Bateman.

At lower frequencies, a mixture of several capacitor constructions in one filter is possible. Run the EMCFiltr program based on the characteristics of the 'best' capacitor needed, degrading the models by increasing the inductances appropriate for those poorer devices.

At higher voltages and especially with domestic 230 v AC mains class X or class Y requirements, impregnated paper or plastic film capacitors are generally used. Having low frequency characteristics midway between COG and X7R ceramic. Resulting from their inevitable size increase, much higher Self Inductance values will pertain, however in general this should not exceed that of a 0.8 mm wire having the same length as the capacitor's body. i.e. approx. 0.7 nH per mm of body length. To this must be added approx. 0.7 nH per mm of total wire lead plus that of any printed board tracks used.

Wire leaded multilayer ceramic capacitors are simply ceramic chips with lead wires added. Radial leaded capacitors can be easily modelled. Use the appropriate type and size 'chip' but increasing the default self-inductance values to include representative lead wire inductances.

Almost all capacitors have a voltage, temperature and frequency coefficient of capacitance. While the 'EMCFiltr' program provides for their frequency dependant behaviour, voltage and temperature capacitance effects are covered by inputting suitably adjusted capacitance values. These voltage and temperature effects can be especially significant when using X7R or Z5U ceramic materials.

However not all ceramic capacitors are so affected. The common COG or NPO ceramic formulations behave as almost ideal capacitors, having only small capacitance or power factor changes. While more expensive, the 'Hi-Q' high frequency ceramic formulations offer performance to more than 1 GHz with extremely stable capacitance and power factor changes, almost impossible to measure, below 100 MHz. The most nearly perfect capacitor.

About the Software.

Simulators come in three basic forms:-
The most common circuit simulation software derives from the 'Spice' system detailed in Lawrence Nagel's doctoral thesis. This was funded and targeted expressly towards the simulation of Integrated Circuits having amplitude dependant non-linearities, thus the basis of 'Spice' is modelling in the 'Time' domain and not 'Frequency' domain. While it is true that 'Spice' offers 'Small Signal Simulation' by Frequency this does not permit the use of measured frequency dependant variables. Thus ensuring major errors compared to real parts, when simulating Filters. A further difficulty is the need to generate a sizeable sub-circuit for a 'Reflection Bridge' in order to obtain Return Loss information.

Lower cost 'Frequency Domain' simulators which calculate node by node the 'Kirchoff' solutions, are available but these again assume 'idealised' capacitor and inductor models. While it is obviously possible to apply a fixed series loss resistor, since with real components this resistance is frequency dependant, this technique is only effective when applied to a very restricted range of frequencies. Additionally with real components, the capacitive and inductive component values change rapidly with frequency. Unfortunately with some commercial simulator versions, Return Loss simulation, is simply not possible.

Those simulators based on measured 'S Parameters' are generally used for RF or Microwave design only, since the software can be extremely expensive. This method can however provide all the required outputs. Measurement of 'S Parameters' for capacitors and inductors is extremely time consuming, and expensive 'characterised' jigging is essential, otherwise the measurement is valueless. While most RF rated semiconductors have 'S Parameter' information available, this is almost non-existent for capacitors and inductors, especially those not specifically intended for RF use. However if the required 'S Parameter' data is made available, this method gives the most exact simulations possible.

Capacitors made using the highest 'K' ceramic materials, while physically small, due to the product of their size with the square root of this high dielectric constant, can appear electrically 'long' even at frequencies below 100 MHz. For example a 10 mm long tubular feedthrough assembled using a 'K' of 5000, has an electrical length of 700 mm, i.e. one quarter wavelength at 108 MHz. In consequence they can only be properly modelled using distributed model or transmission line techniques. These electrical resonances are easily measured as peaks and troughs of impedance.

This problem is present to a lesser extent also with conventional high 'K' ceramic chip capacitors, and 'Discoidal' types, which can exhibit resonant behaviours. C.Bateman Engineering has already developed a simple transmission line based simulator, specially targeted to demonstrating these problems.

Any simulation based on 'idealised' components will differ significantly from practical measured results of working Filters. The maximum simulated insertion loss will far exceed measured results. At frequencies below Filter resonance the insertion loss will be much overstated while above resonance it will be understated. These differences can accrue to many dB's difference. In one practical case I well recall, a customer requested a prototype filter be made with the capacitor and inductor values, which unknown to us had been derived from a Spice simulation. When built the prototype filter performed extremely well, measuring 110 dB at 1 MHz. The customer furiously rejected this prototype, since from his Spice simulation he was expecting better than 148 dB.

'EMCFiltr'

'EMCFiltr' has been devised to provide acceptable simulation accuracy while avoiding any need for 'S Parameter' data for capacitors and inductors. It provides Frequency Domain solutions using Kirchoff solutions, yet requires no prior knowledge or expertise since the frequency dependant parameters have been taken from component makers published data and inbuilt in the software.

Simply choosing the required material ensures the correct frequency dependant parameters are used for your simulation.

The 'EMCFiltr' software models Insertion Loss strictly in accordance with the US Specification MIL-STD-220A, which is recognised world wide. The 'EMCFiltr' software is available for PC computer systems running Windows 3.1 or better, also the Acorn Archimedes platform.

Real world capacitors and inductors, when correctly measured, each comprise three elements, all of which are strongly frequency dependant.

Capacitors translate to a 'series' combination of capacitance, inductance and resistance, with capacitance being dominant at the lower frequencies, i.e. below self resonance.

Inductors similarly equate to a 'parallel' combination of capacitance and inductance both being in 'series' with resistance, with inductance being dominant at frequencies below self resonance.

For both components, the resistive part comprises a fixed resistance value in series with a frequency dependant variable resistance.

For inductors this fixed resistance is the dc resistance of the winding (DCR), the variable part (included in the EMCFiltr materials model) results from the various frequency dependant magnetic losses which cause the 'Q' value to change with frequency.

For capacitors the fixed part is the irreducible resistance (included in the EMCFiltr materials model) as measured at high frequency (TSR), largely comprising metallic connection resistances. The variable resistance (included in the EMCFiltr materials model) derives from the dielectric AC losses, described as tan , being strongly frequency dependant. At lower frequencies this loss can amount to many K Ohms of series resistance, dependant on capacitance value.

Having 'modelled' the required frequency dependant variables, EMCFiltr can provide the simplest possible, no-learning curve, simulation for EMC Filters, automatically ensuring realistic answers. All standard EMC Filter schematics are pre-drawn, and Return Loss and Group Delay are automatically provided, no user configuration is needed.

The **EMCFiltr** software package is a node by node solution by frequency for Kirchoff, but considerably enhanced by using true three component models for each part with the frequency dependency variations required to simulate real world parts. This frequency dependency is derived from manufacturers published characteristics and stored as data in the software. Hence assuring realistic simulation results.

The 'standard' version software is targeted to Filter users and provides a choice of base capacitor and inductor materials commonly used in the production of Filters. Thus providing a simple but quality introduction to understanding and simulating EMC Filters, both in education and industry.

The 'professional' edition, in development, is targeted towards those intending to manufacture Filters, and while based on the standard version's simulator engine, this version provides the facility for the user to 'tailor' the frequency dependant material models to chosen materials.

The high dielectric constants used with some ceramic capacitors and their physical size, can result in narrow band resonance modes. Given the precise physical descriptions of these parts, these resonance modes can also be modelled. This however is incompatible with the objectives of simplest possible no-learning curve approach of this 'standard' version, hence is available only in the 'enterprise' edition software being developed for use by EMC Filter manufacturers.

Conditions of use.

This software is supplied in accordance with established software licence conditions. No warranties are implied or expressed as to its suitability for any purpose and usage is restricted to one computer at any time for each purchased version.

The evaluation versions are supplied in order to assess the suitability of the EMCFiltr simulator for your needs.

The evaluation versions only may be freely copied as desired provided the full package is distributed unchanged and complete as supplied you including all text files.

This software must not be reverse engineered.

Technical Support.

The full version of this software is offered with unlimited technical support and low cost upgrade plans.

However before requesting assistance, please ensure you have read the appropriate section of this manual. The software is exceedingly easy to use, and well bombproofed. Hopefully all questions have been anticipated, and already covered in the manual.

On the other hand I really do want to know about any difficulties you experience and look forward also to receiving suggestions which can be incorporated in the next release.

Any updated version of the full software, issued within six months from your purchase, will be supplied free of charge to registered users.

After this six months period all updates, also upgrades to the other software packages, will be available for a nominal cost.

Software Purchase.

At the present time arrangements have been made to allow payment for the registered or full program version to:- RegNet.Com part of Wintronix Inc. 21200 Trumpet Drive #201. Santa Clara. CA. 91321-4441 or via Internet :-

http://www.regnet.com current price $185

Alternately EMCFiltr can be purchased direct from the author for £100 inc.(sterling cheques). With the software and manual supplied direct to you by E-Mail. Purchasers not having E-Mail can receive the software on floppy disc sent anywhere in the world via Air-Mail for an additional £5 to cover postage costs. Mailed versions will also include a hardcopy of the manual.

The latest details for software, sources, downloads and purchase prices will always be found on my Web page.

http://ourworld.compuserve.com/homepages/cyrilb

Technical support is available from:-

C.Bateman Engineering
'Nimrod'
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About the Author.

First trained as an RF Electronics Engineer in the mid '50's, subsequently became a capacitor applications and design engineer for one of the then largest capacitor manufacturers. As an application engineer, was deeply personally involved with both the birth of the Hi-Fi and Colour Television industries in England, and designed the very first Aluminium Electrolytic Capacitors optimised for Hi-Fi sound quality in 1969. These were used in the first volume production quality amplifier, the original Goodmans 90 and 100 series.

Around the time the NASA Apollo program got underway in America, he also inherited the EMC Filter Applications tasks.

Subsequently as the use of EMC Filters increased, principally in Military Equipments, in 1976 he founded a trading house called 'STC-Mercator' which was tasked to import components of all types, especially EMC Filters, not available from UK Manufacturers.

Subsequently as the volume of EMC Filters needed increased, he was tasked to set-up a UK design / development program to manufacture these Filters, and gain full European Quality approvals. For this operation he wrote all the design and measurement software needed to both gain approvals and for their production, which was 100% Insertion Loss tested and Certified to 1 GHz.

While still with Mercator, in 1983 as a result of pressures from customers design engineers, wrote his first computer simulation program designed to aid selection of the most appropriate Filters for applications needing differing source and load impedances.

As a result he has had much practical experience of Filter simulation both with his own programs and commercial simulators, ranging from various Spice based programs to professional Microwave Design Systems.

Recently has been responsible for characterising commercial RF chip capacitors, deriving their 'S Parameters', up to 3 GHz.

He is now an independent design consultant working principally with RF topics, EMC Filters and Capacitors.