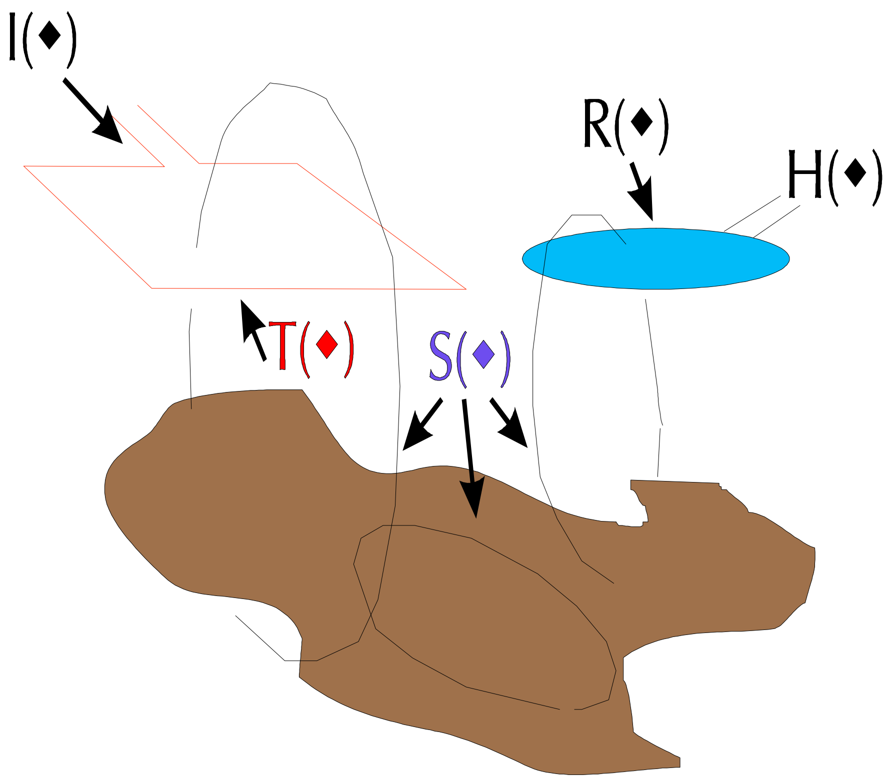
FSEMTRS
Frequency to Time Domain Transformation



Transformation to Time Domain Software
for Frequency Domain Electromagnetic Modelling Programs

EMIGMA Documentation release version 7.8

software & manual copyright

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FOREWORD

Our definitions:

spectrum:

the frequencies present in an electromagnetic signal and their strengths

waveform:

A representation of the shape of a wave that indicates the wave's characteristics, such as frequency and amplitude.

periodic:

A quantity, f(t), is periodic when it behaves according to the relation

$$f(t) = f(t+kT), \qquad \text{for all } t, \qquad k = 0,1,2,...$$

where T is the smallest number such that this holds then T is called the period.

basefrequency:

The inverse of T the period.

interpolation:

the action of estimating values from known ones in the same range

1. Overview:

FSEMTRS© (ω -> T)
is designed to take the frequency domain response determined by a modelling or simulation program and transform it to the representation of a physical response in time domain**.** It can represent a measured physical response from either a commercial, experimental or theoretical measuring system. Our cover figure represents the basic components involved.

This process consists of representing mathematically 3 systems and the interaction between these three systems. These three systems are the transmitter, **TX**, the **Earth** and the receiver, **RX**. The input into the entire system can usually be considered as the current input into the transmitter. The manufacturer of the specific equipment attempts to know exactly the characteristics of the input current, ***I(ω)***, and to measure an output response, ***H(ω)***. The modelling program attempts to simulate the response of the Earth, **S(ω)**. In general the transmitter has a system response, ***T(ω)***, due to the input current and the receiver has a system response, ***R(ω)***, to the input of an electromagnetic wave. For example, if the transmitter is a large loop and it lies on top of a relatively conducting Earth then the waveform inside the loop will tend to distort the input current and this can be somewhat uncontrollable. Similarly, the receiver, especially a coil type receiver, is often bandwidth limited. This limit results in some degree of phase and magnitude distortion,especially at high frequencies. Thus, in the frequency domain the overall system can be represented as:

$$H(\omega) = I(\omega)T(\omega)S(\omega)R(\omega)$$

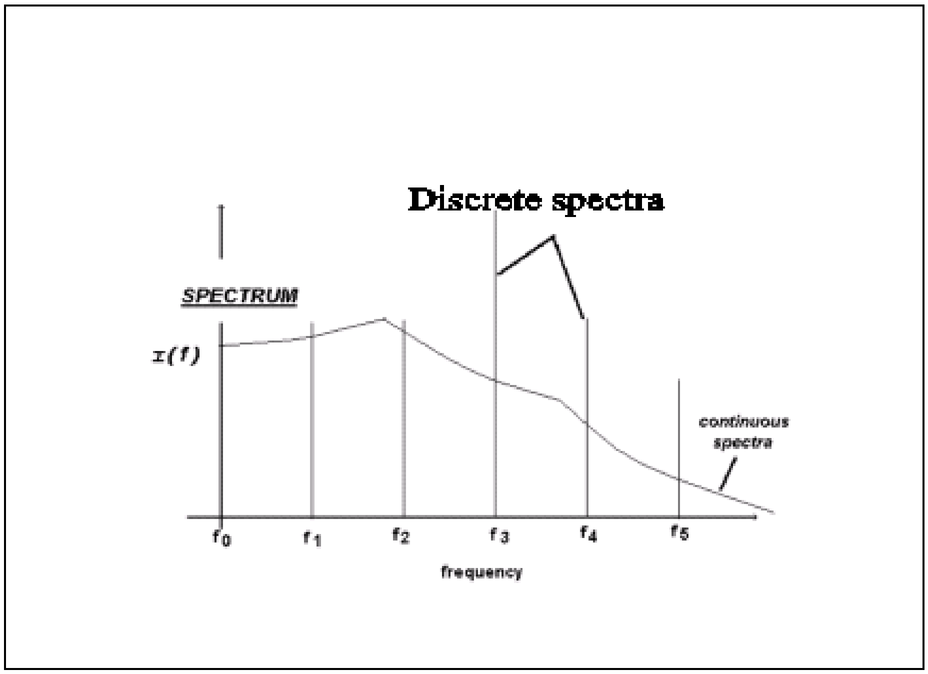
At present, **FSEMTRS** does not take into consideration distortions of the current waveform in the TX and only to a limited extent the response limitations of the RX. In future, these considerations will be built into the transformation with an ability for the user to define his/her own TX/RX system characteristics.

This release of **FSEMTRS** allows the use of 4 fundamental types of waveform, ***I(t)**,* all of which are tunable to the user's requirements. **EMIGMA**©'s role is to generate ***S(ω)***, the so called impulse response of the Earth. **FSEMTRS** has been designed to provide a smooth interface to other *PetRos EiKon* modelling software.

2. The spectrum

2.1 Introduction

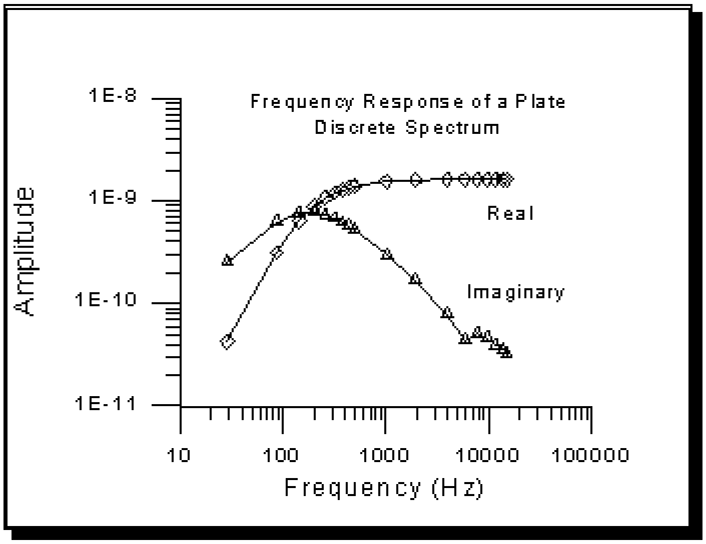
Any time dependent waveform can be decomposed into its spectral or frequency contributions as illustrated in the above figure. In general, there will be both a continuous part to the spectrum as well as a line or discrete spectrum. In the case of a continuous distribution, it is the spectral density function for which information is required to perform numerical or digital spectral analysis. However, in the case of discrete spectra we wish to know the location and magnitudes of these "jumps".



A truly periodic waveform will have only a line or discrete spectrum with energy at multiples of the basefrequency. No actualised waveform is, however, truly periodic (non-causal). However, in practical situations, where the transmitting waveform is repeated many, many times before, during and after measurement; the relative amount of energy in the continuous part of the spectrum reduces while the magnitude of the spectral lines at the multiples of the basefrequency continue to grow as the number of repetitions increases.

Since, in practice, the waveform is often repeated thousands of times before measurement and thousands of time during measurement, we take the position that only the periodic element of the waveform is of significant interest. The measurement, of course, has no knowledge that the waveform will be turned off and therefore that is not of relevant interest. In practice, there are remnants of the continuous spectra still present but this spectrum is very small in comparison with the discrete spectrum.

2.2 Interpolation



Interpolation is the action of estimating values from known ones in the same range. Extrapolation, on the other hand, is the action of estimating values from known ones outside the same range. This version of **FSEMTRS** has the ability to interpolate the spectra of a response, extrapolation will be available in an upcoming version. This interpolation procedure is based upon the assumption the impulse response of the Earth is continuous and somewhat smooth in frequency domain. Thus, in principle, the response at any frequency can be determined if estimates are available near the required frequency.

Transforming frequency domain data to time domain requires the base frequency and harmonics of the periodic waveform to be generated. One advantage of using interpolation is that the number of frequencies that need to be generated to produce time domain data can be greatly reduced. A second advantage is that from one sampled suite of spectra, many suites of different base frequencies and their harmonics can be produced. For example, three suites of odd harmonics based on 30Hz , 50Hz and 150Hz could be generated from one spectral suite.

The above figure shows the "typical" frequency domain response of a conductor. Since the response is smooth, and therefore to a certain extent predictable, we can use interpolation with some degree of reliability. The triangle and diamond shaped markers represent the position of a 30Hz base frequency and some of its odd harmonics. The range of frequencies spans 30 to 15,400 Hz. The number of odd harmonics in this range is 512 but can be generated with good accuracy by interpolation using 100 frequencies. This corresponds to speeding up time domain calculations by a factor of five !

There are 2 methods to perform the interpolation, the basic is a simple quintic spline which is performed when there is a high density of frequency samples, but in 2002 , we introduced a much more accurate interpolation technique which is utilized when the sampling is coarse. These are automatic and do not require user specification.

EMIGMA Version 6 and V7.x has a new waveform mode - `(S)pectral` . This allows easy rapid sampling of the impulse response of your model. The output files are recognized as a spectral type file by **FSEMTRS** and interpolation for the required basefrequency is then initiated automatically

3. The Coefficients of Fourier expansions

(for 'youse guys' interested in the arithmetic)

3.1 Transmitter current:

We consider a driving current, ***I(t)***, in the transmitter which is completely periodic with period *T*. ***I(t)*** can be represented by a Fourier expansion:

$$I(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} \left(a_n \cos\frac{2n\pi t}{T} + b_n \sin\frac{2n\pi t}{T} \right) \quad \textbf{(1)}$$

or

$$I(t) = RE\left[\sum_{n=0}^{\infty} c_n \exp^{\frac{i2n\pi t}{T}} \right] \quad \textbf{(2)}$$

where

$$a_n = \frac{2}{T}\int_o^T I(t)\cos\frac{2n\pi t}{T}dt \quad \textbf{(3)}$$

and

$$b_n = \frac{2}{T}\int_o^T I(t)\sin\frac{2n\pi t}{T}dt \quad \textbf{(4)}$$

If we represent the base frequency, *1/T*, as f_0 then the harmonics are given by nf_0,, and **(2)** can be rewritten as:

$$I(t) = RE\left[\sum_{n=0}^{\infty} c(\omega_n) \exp^{i\omega_n t} \right] \quad \textbf{(5)}$$

3.2 Response Function:

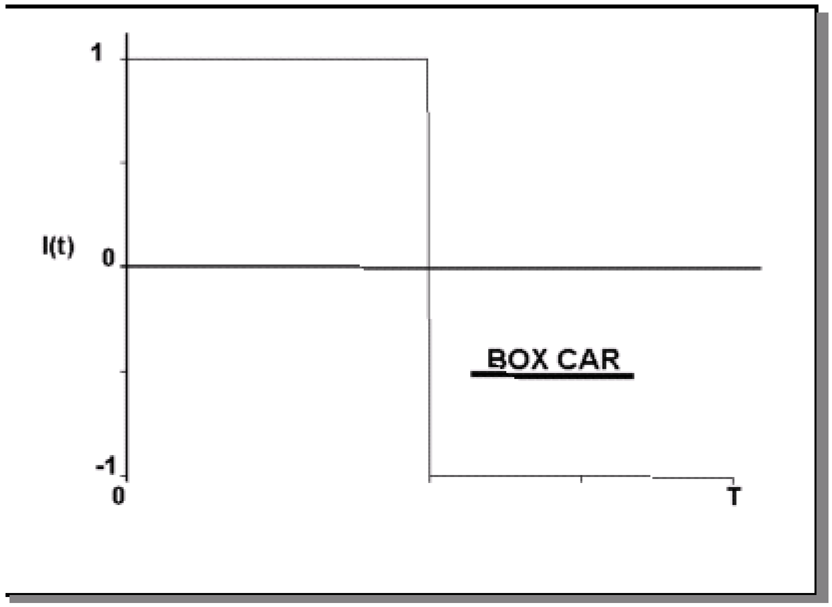
If we assume the response of the transmitter wire or coil is unity for all frequencies, then the transmitter will generate a primary or source field having a temporal form **I(t).** The Earth responds as a linear system to any input from the transmitter. That is, for an input **H(ω)** a proportional output $\mathbf{H_T(\omega)}$ will be generated. It is this system or response function from the Earth which electromagnetic modelling programs such as ***EMIGMA*** generate. However, ***EMIGMA***, like most frequency domain solutions normalizes the response functions or solutions such that the input energy is normalized to be uniform for all frequencies. The solutions are therefore the spectral solutions to an impulse waveform, *Δ(t)*, where the input energy is white (constant in frequency). For a generalized source waveform proportional to **I(t)**, the measured fields are convolutions of the impulse response, $\mathbf{H_\Delta(t)}$, with the current waveform, **I(t).** We will return to the determination of the simulated time domain responses later in the manual.

4. Current waveforms:

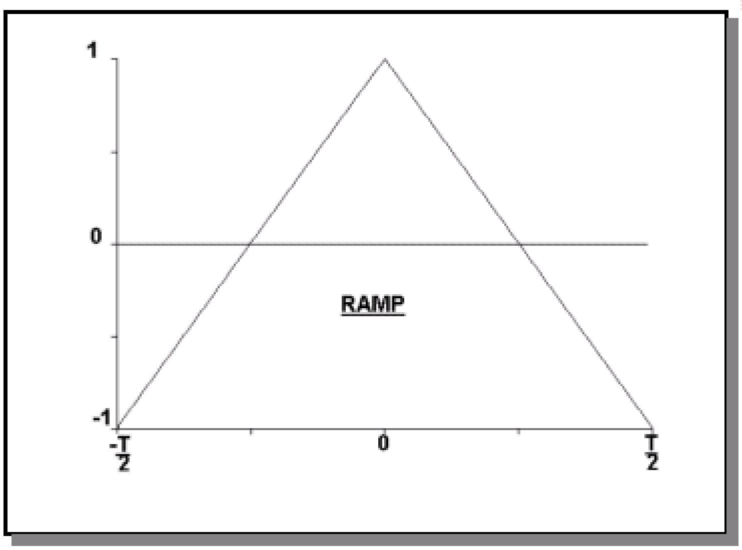
FSEMTRS offers several current waveforms for which to convolve the impulse responses generated by ***EMIGMA*** to simulate time domain responses.

4.1 The BoxCar:

The BoxCar is simply on for a half period (**T**) followed by a negative on for a half-period. When the time derivative is taken its creates an impulse once every half period. No off-time is allowed for this waveform.

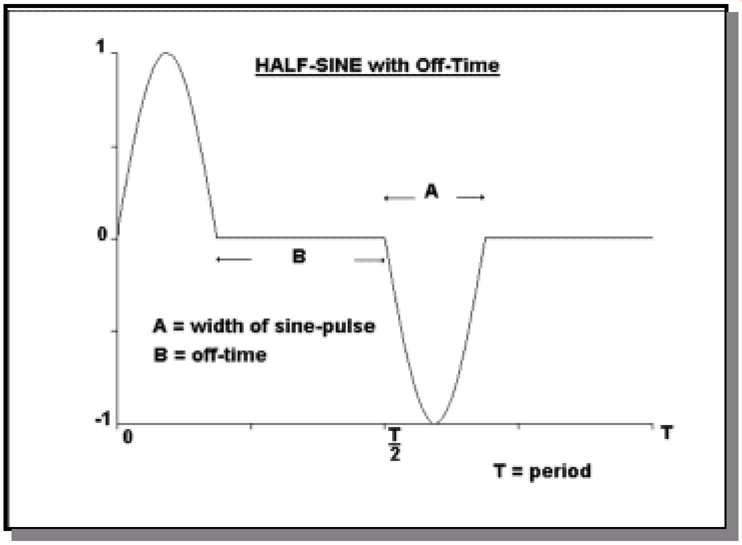


4.2 The Ramp:



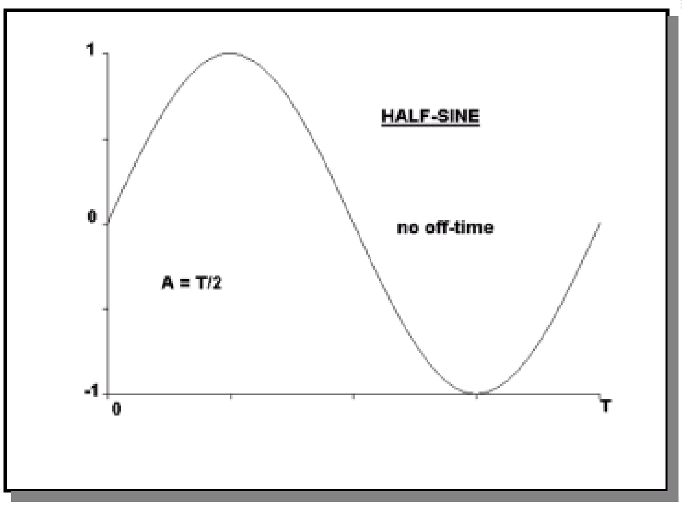
The ramp has a linear rise followed by a linear decay. The slope of the triangle is ±4/T. This waveform simulates the current in the UTEM system (Lamontagne Geophysics) or the Spectrem airborne system. This also used when modelling the Spectrum system.

4.3 The Half-Sine:

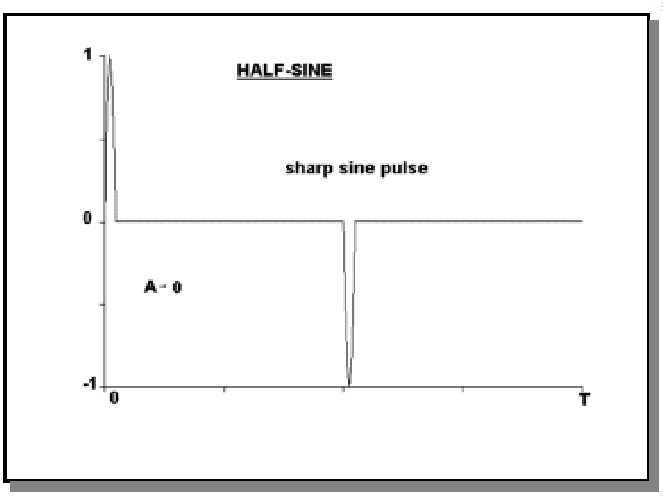


The early INPUT system used a current waveform which had an on-pulse which approximated a half period of a sine function and then an off-time followed by a negative repetition to remove any DC offset. The response was then measured and stacked with many repetitions. In the figure on the right, the width of the half sine on-pulse is A and B is the width of the off-time in a half period.

The *Geotem* and *Questem* systems now use this type of waveform.



The width of the half sine pulse, A, is switchable in the software. This defines the off-time width, B, since the period, T, is specified by the fundamential frequency in input. In the example below, there is no off-time, i.e. B=0.



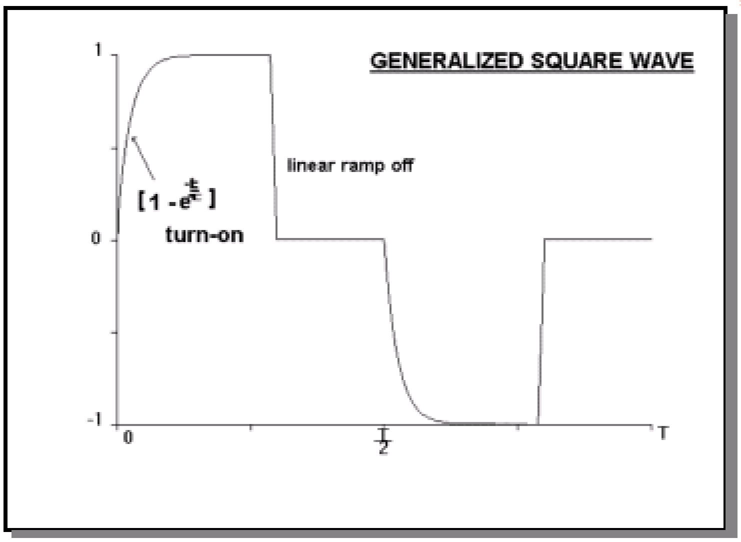
In the next case, the on-pulse is very sharp and could be used to simulate some types of radar systems.

4.4 Generalized Square Wave Duty Cycle:

The final waveform for the current is a generalized square wave with switchable off-time. In this case, the current is turned on with an exponential rise. This waveform can be tuned within

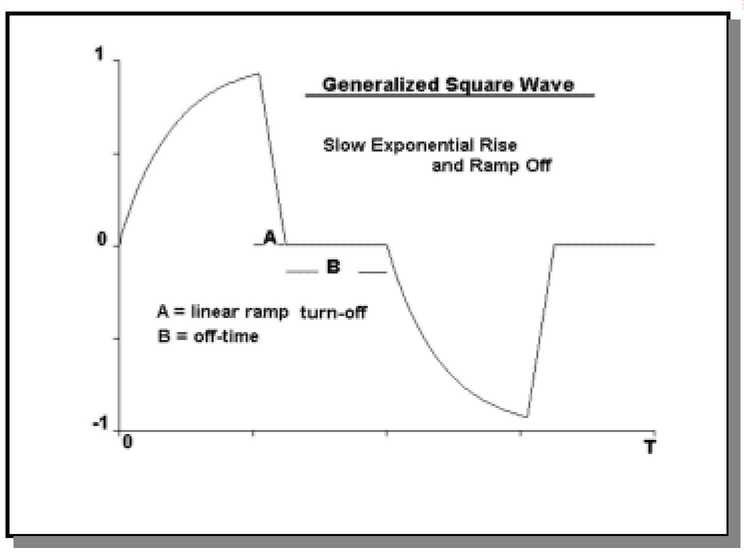
$$A\left(1 - e^{-\frac{t}{\tau}}\right) \tag{4.1}$$

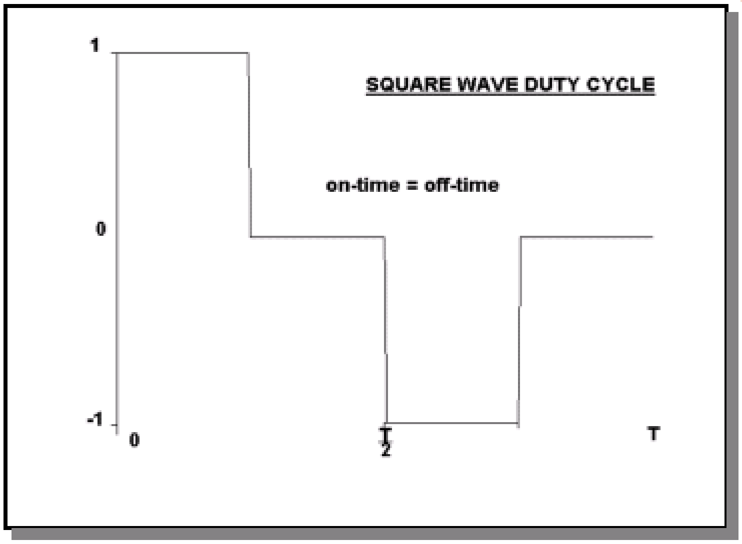
FSEMTRS to simulate many commercial waveforms.such as Crone, Geonics and Zonge TEM systems. But it is also used for time domain IP as the bipolar waveform is required. However, the ramp time is very short compared to the entire period.



The constant, τ, is called the decay constant and if the time , t, is in msec then τ is also given in msec. The current is turned off by a linear ramp.

When using this waveform, the decay constant τ is variable as is the width of the off-time, B, and the width of the linear turn-off time, A. In the example to the right a large value of τ is used causing a slow rise time. This slow rise coupled by a wide turn-off time and a relatively long off time compared to T produces a waveform which has not leveled off before it begins to turns off.





This waveform can also be used to generate a classic duty cycle square wave with sharp edges by using a very small value for the decay constant and the turn-off time as illustrated below. Here the length of turn on, (T/2 - A - B), is much larger than τ. A is much smaller than B and the turn-on time.

4.5 Fourier series representations of the waveforms:

4.5.1 Generation of Fourier coefficients:

The waveforms listed and illustrated in the previous sections are available to the user as current waveforms. ***FSEMTRS*** generates the Fourier coefficients for the user once the waveform has been selected along with the various settings.

4.5.2 Basefrequency:

The basefrequency of the EM system is set by the user by his/her selection of the fundamental harmonic which is communicated to the software through the input of the impulse or Earth response from the electromagnetic modelling program (*e.g*. ***EMIGMA***). The frequency domain response from the modelling program must consist of the responses for the fundamental harmonic plus additional harmonics in monotonic order with no gaps in the spectrum. The user may end the frequency domain series at any frequency desired, however. In ***EMIGMAV6&7*** and ***FSEMTRSV3***, interpolation between harmonics is available and not all harmonics need be calculated in the simulation or modelling algorithms.

4.5.3. The Representation of the Time Series:

Transforming the spectral responses F(ω) of a function f(t) generates an approximation or representation of the function. How accurate this representation is to the true function depends on the form of the function, f(t) and the number of harmonics or frequencies used to represent the function. ***Physically it is always useful to remember that no physical system is band unlimited***. We consider possible errors in the representation in the next section and indicate the process the user must follow in ensuring that they have used an adequate number of harmonics.

5. INTERPOLATION

5.1 Introduction

In many geophysical software applications, simple logarithmic frequency sampling is used for transformation to time domain. This is often appropriate for magnetic TEM applications in free-space. However, in a conducting earth for both electric fields and magnetic fields, there can be very rapid variations in the frequency domain response with more than one sign change occurring in the frequency domain data. This requires a more precise sampling of frequencies. EMIGMA is designed to sample impulse frequency responses in suites which increase logarithmically but have linear sampling within each suite.

The interpolation routines within ***FSEMTRS*** inputs the frequency domain data in the form of the **flds.spt** file output by ***EMIGMA GeoTutor*** or a spectral data type in V7.8 to produce a user defined base frequency and its odd harmonics. The frequency sampling scheme produced with the (S)pectral option (Waveform Generation Section) in ***EMIGMA*** produces the following frequencies:

```
set#-1  0.017Hz,.0.019.to 0.17Hz   in increments of n where n= 0.02*(nskip+1)
set#0  0.17Hz,.19Hz.. to 1.71Hz    in increments of n where n=  .02*(nskip+1)
set#1: 1.7Hz, 1.9Hz.. to 17.1Hz    in increments of n where n=   .2*(nskip+1)
set#2  17Hz,19Hz ..   to 171Hz     in increments of n where n=    2*(nskip+1)
set#3  170Hz,190Hz .. to 1710Hz    in increments of n where n=   20*(nskip+1)
set#4  1700Hz,1900Hz. to 17,100Hz in increments of n where n=  200*(nskip+1)
set#5  17KHz,19KHz..  to 171KHz    in increments of n where n= 2000*(nskip+1)
set#6  170KHz,190KHz to 1.71MHz    in increments of n where n=20000*(nskip+1)
set#7  1700KHz,1900KHz to 17.1MHz  in increments of n where n=200000*(nskip+1)
```

`nskip` ranges from 0 to 7 and thus the number of frequencies generated per set depends on the value of nskip. In V6.4, a new interpolation technique is being offered in Fall, 200 allowing nskip to vary up to 15.

nskip	# of frequencies per set	# total number of frequencies
0	80	80 x number of sets selected
1	42	42 x number of sets selected
2	29	29 x number of sets selected
3	23	23 x number of sets selected
4	19	19 x number of sets selected
5	16	16 x number of sets selected
15	8	8 x number of sets selected

(*Note: The number of frequencies required is shown on the Waveform page)*

For the interpolation to work, there are a fixed number of frequencies generated outside the range of each set. Because this number of frequencies does not decrease as nskip increases, the total of frequencies per set converges at about nskip=7. With the interpolation routines provided until Fall 2000, a maximum nskip of 5 was recommended to ensure no loss of accuracy from the simulations. However, a more sophisticated interpolation routine introduced in V6.4 allows nskip up to 15 effectively reducing simulation time from the recommended nskip = 4 by a factor of about 60%.

The advantage of using the combination of the spectrum generation and the skipping feature is that it greatly reduces the number of frequencies that need to be produced to build a time domain response and therefore reduces computation time. The second advantage is that once a frequency sampled spectrum of a certain geometry is produced, the time domain response of that same geometry can be produced quickly, varying both time domain waveform and base frequency of the system. In the old version, if the user wanted to determine the time domain response of a different base frequency, he or she would have to run the modeling software again.

The frequency generation sampling scheme was developed as a compromise between creating a strictly linear or strictly log frequency sampling scheme. While recognizing that the frequency spectrum does have some log characteristics, this is not strictly true.

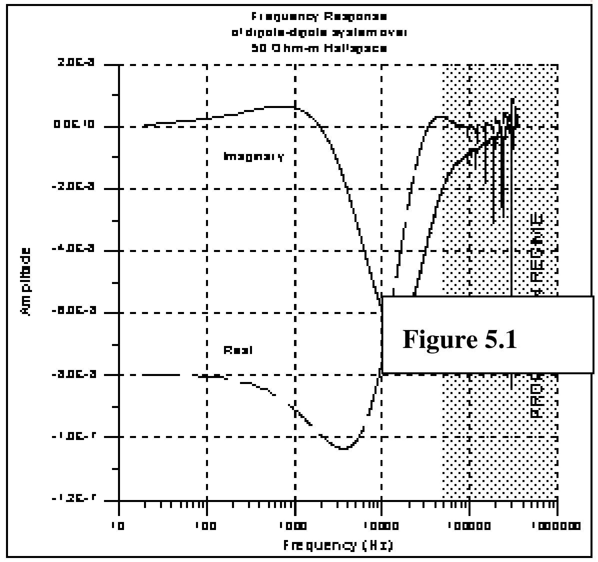


Figure 5.1

For example, around the region of the peaks (see Figure 5.1) of both the real and imaginary curves, the response does not behave in a strictly log fashion. Using a combination of log sampling with interpolation will often fail to reproduce the position and amplitude of these peaks and hence, can result in large errors when transforming the data. Because the position and sharpness of these peaks varies depending on the model, using a strictly log sampling scheme introduces large errors. This problem is compounded when working in the propagation regime (Figure 5.1) where using the log sampling scheme and interpolation completely breaks down. Because *PetRos EiKon* is involved in the interpretation and simulation of both typical Time domain (e.g. Crone, UTEM, GEOTEM, VTEM, ...) systems which are band limited and therefore rarely sense propagation effects, and higher frequency systems such as radar and tomography systems which operate mostly in a propagation regime, the combined log and linear sampling scheme developed is designed to accommodate a wide range of frequencies and is therefore robust.

5.2 Discussion of bandwidth and hints on using FSEMTRS

Time domain systems are band limited acting as low frequency filters, usually with a cutoff ranging between 20 to 70KHz. In other words, when using the sampling scheme and interpolation of ***FSEMTRS***, using frequencies up to the set#4 (1.7 to 17kHz) is all that is required to provide a good first pass approximation to the response. This is especially true if you are using the Lanczos damping which dampens the higher frequency response much like real systems. To obtain better accuracy use up to set#5. There is no advantage gained in using higher frequencies since these time domain systems do no measure this part of the response.

5.3 Comparing systems and/or base frequencies

With the help of the frequency spectrum generator, it is now easier to compare different systems and examine the effect of varying the base frequency. In this example, the three profiles shown were generated from the same spectral data file. With ***FSEMTRS***, it is now possible to select the system and its base frequency. The geometry of the survey is shown in Figure 5.2 and comparisons in Figures 5.3, 5.4 and 5.5.

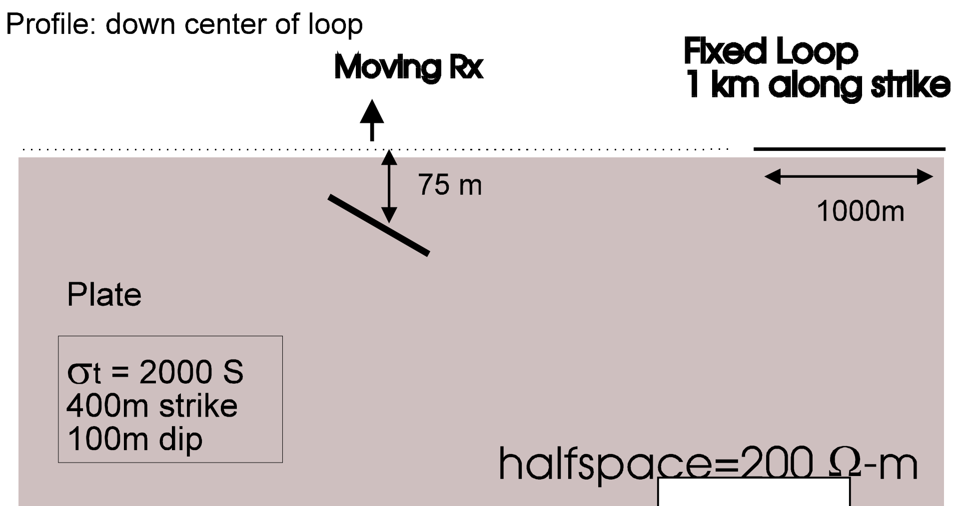


Fig. 5.2

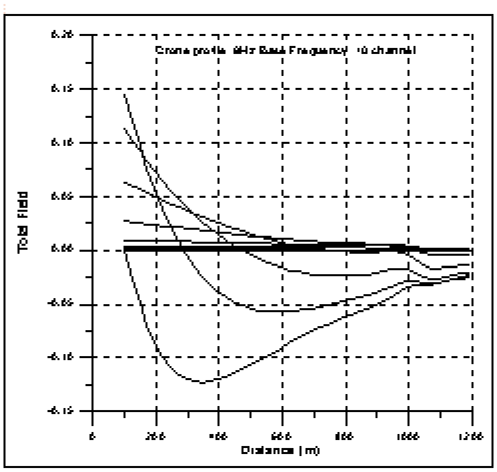


Figure 5.3

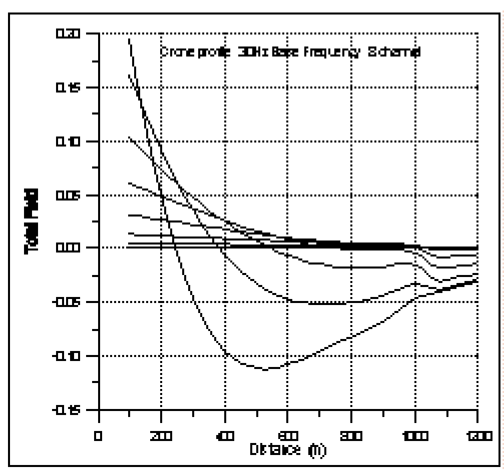


Figure 5.4

In Figure 5.3 a 8Hz base frequency is utilized with a Crone waveform while in Figure 5.4, the base frequency is increased to 30Hz. In Figure 5.5 a UTEM waveform is

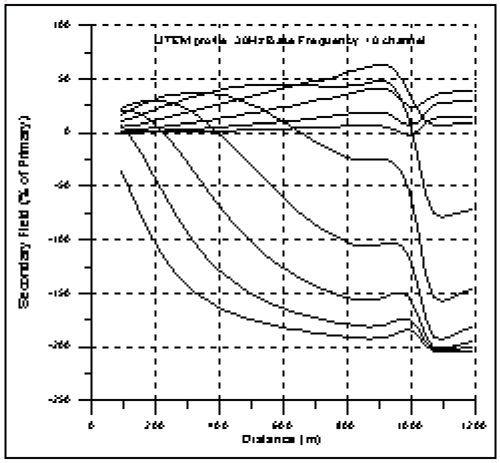


Figure 5.5

utilized with a 30Hz base frequency. The response of each time channel is plotted down the profile.

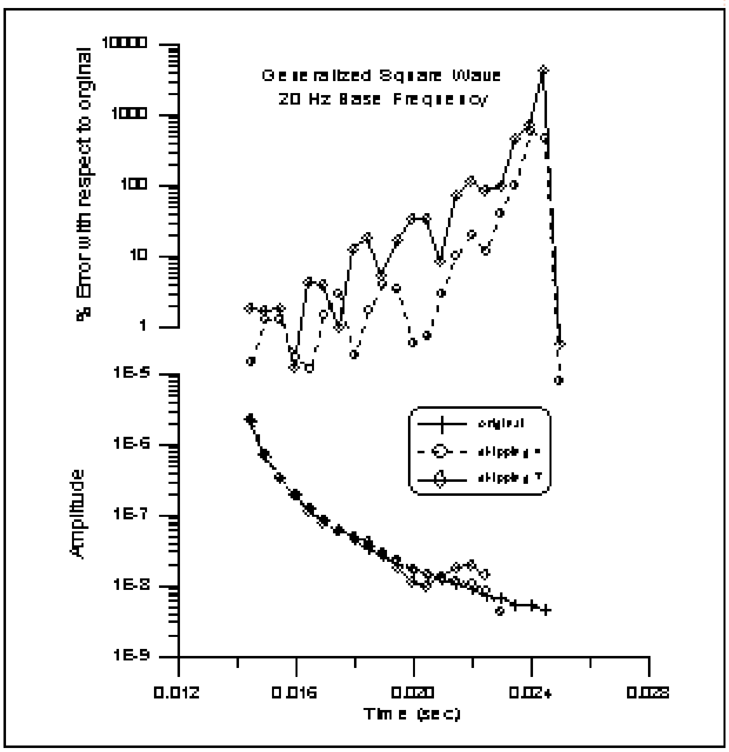


Figure 5.6

5.4 Errors

The errors due to interpolation (the variation between the values calculated exactly at the odd harmonic frequencies and the interpolated values) depend on several factors:

1) *interpolation errors*: There are two sources of interpolation errors. The first is related to how far the interpolated frequency is from the known value. The second is related to the variation in the frequency response. If there is a rapid variation in the frequency response, it will be more difficult for the interpolation scheme to match the true values.

2) *small value errors*:
These errors increase as the value to be interpolated decreases. This generally means that for systems that measure the time derivative of the magnetic field in the off-time, there can be a large relative error in interpolation as seen in the figure 5.6. Therefore, as the base frequency of a system decreases, and secondary field measurements decrease in amplitude, the size of these errors will increase.

Errors tend to be largest for the late time channels. Although this error can be large in percentage terms, it is not large in absolute terms since these values are close to zero.

3) *discontinuity errors:* These errors are largest close to discontinuities or rapid changes in the response such as delta function (derivative of a step) or step (derivative of a ramp). This effect depends on the frequency spectrum that is available. If high frequency components are transformed, this error effect does not extend far from the discontinuity. If only lower frequency components are being transformed, this error will extend further from the step or discontinuity.

Small value errors tend to be larger than discontinuity errors. Figure 5.6 shows increasing error as amplitude decreases. However, since these numbers are very small, the largest percentage errors are not that significant. The “skipping 4" curve of Figure 5.6 closely matches the original. Notice how percentage error drops on the last point, near the discontinuity, where on-time and therefore larger values are approaching.

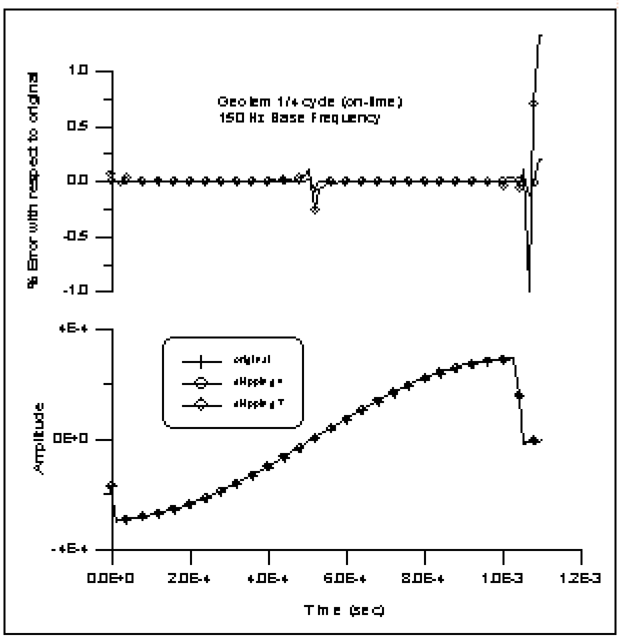


Figure 5.7

The profiles of Figure 5.7 show an extremely good match to the original for nskip=4 and nskip=7. The largest errors are discontinuity errors, where the values at the edges are close the off-time. The only other errors are near the 0.6ms mark where the amplitude of the field crosses zero.

Generally speaking, Nskip=4 usually provides good accuracy. Decreasing the number of frequencies generated is only worthwhile for systems or time windows that measure in the on time.

6. The Error

For a continuous periodic function, the Fourier series expansion is guaranteed to converge everywhere. Although all of the waveforms used here are continuous throughout a period, the derivatives of these waveforms are not necessarily continuos. Similarly, the final response out of a receiver for either an electric or a magnetic field or their time derivatives may not be continuous. However, an examination of the representation of the original waveforms by the Fourier series is instructive and useful in determining estimates of the number of harmonics required. The user should, when using the transform, investigate for themselves the nature of the convergence of the final time series as a function of the number of harmonics and the temporal position in the period. We offer a few examples here:

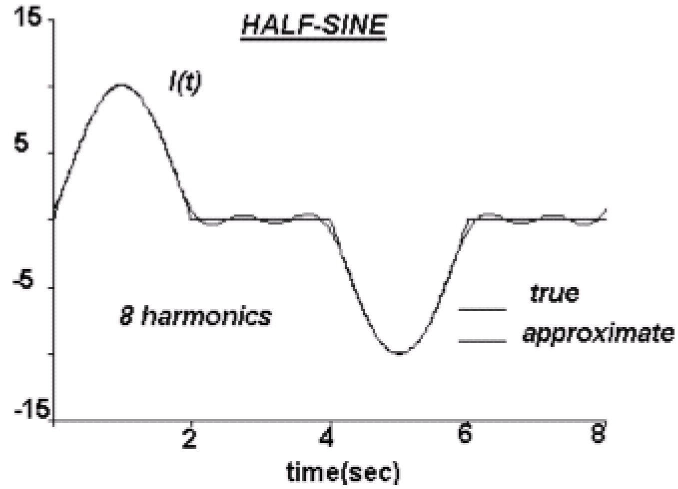


Figure 6.1: Fourier approximation a half-sine wave with 8 harmonics.

6.1 The Half-Sine

Figure 6.1 shows the representation of a typical half-sine using only 8 harmonics. The behaviour of this representation is independent of the actual period. We see that for the half-sine, we get a fairly good representation of the on-pulse for 8 harmonics but there are oscillations in the off-time. Physically the off-time oscillation relate to too abrupt damping of the high frequencies.

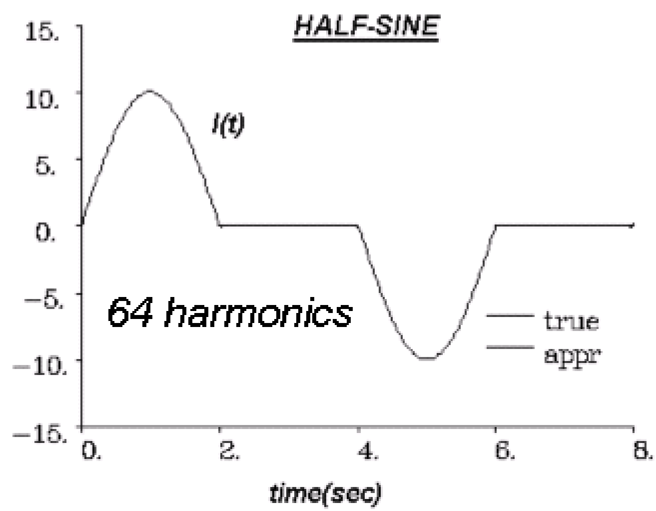


Figure 6.2 Fourier approximation of a half sine wave with 64 harmonics.

When we increase the number of harmonics to 64 (Figure 6.2) then we get an accurate representation everywhere in the period. The accuracy near the off-time could be of concern depending on the time windows used and the accuracy required.

This would be the case when we measure magnetic fields with a coil receiver. Note from Figure 6.3 that the 8 harmonic representation is rather poor except at the centre of the on-time (0-2 and 4-6). When we use 64 harmonics the picture is better (Fig. 6.4) but at the discontinuities of the function (0.,2.,4.,6.) we find the maximum error. There are oscillations during the off-times but these may not be significant relative to the error in the data. Consider if we were using a 140Hz Input system then 64 harmonics would take us almost to 9 Khz. We would have to consider above these frequencies a drop off in the coil response and well as phase distortion effects. This implies that there are probably oscillations in the real data as well. In practise, the hardware is designed with low-pass filters to remove the oscillations both in early time and in late time.

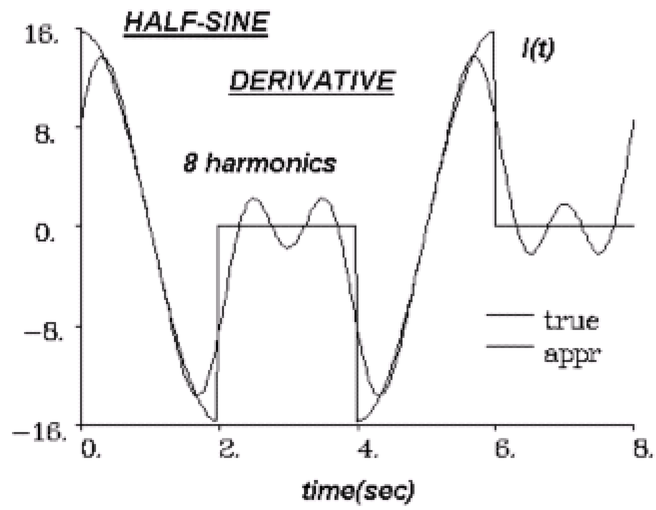


Figure 6.3 Fourier approximation of the time derivative of a half sine with 8 harmonics.

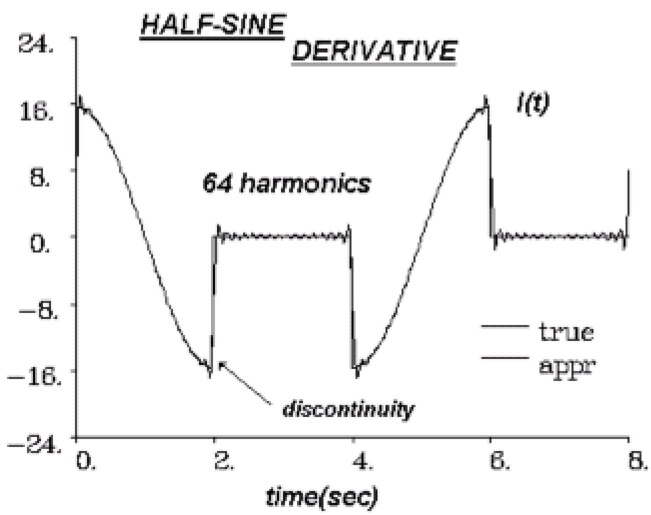


Figure 6.4 Fourier approximation of half sine derivative using 64 harmonics.

6.2 Generalized Square Wave:

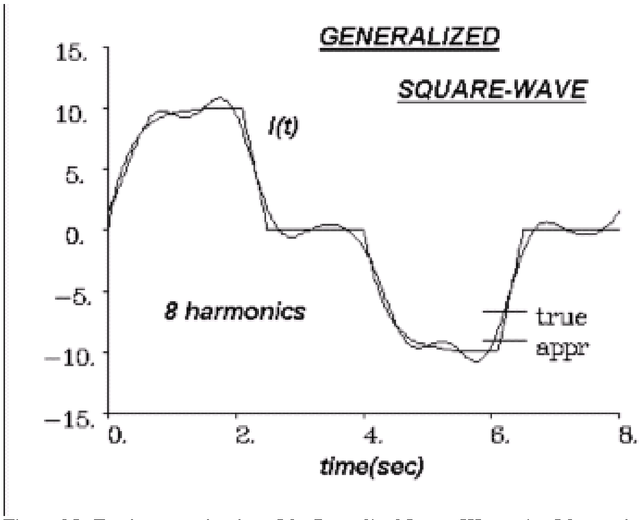


Figure 6.5 Fourier approximation of the Generalized Square Wave using 8 harmonics.

Figure 6.5 shows the representation of a Generalized Square Wave with 8 harmonics. Note the inadequateness of the representation in the off-time.

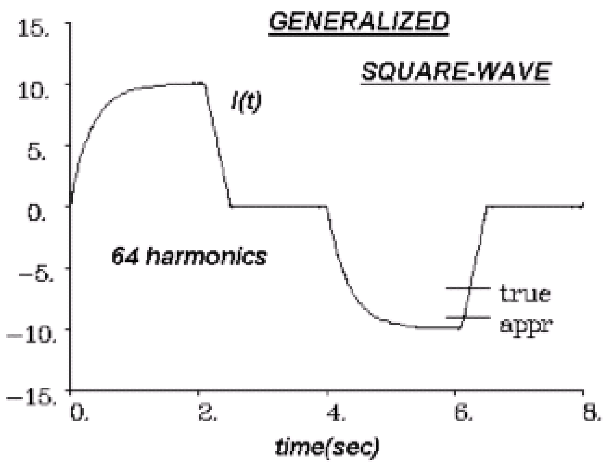


Figure 6.6 Fourier approximation of the waveform of Figure 6.5 with 64 harmonics.

Figure 6.6 shows the Fourier representation of the Generalized Square Wave with 64 harmonics. As in the half-sine case, the representation with 64 harmonics is good for this continuous waveform.

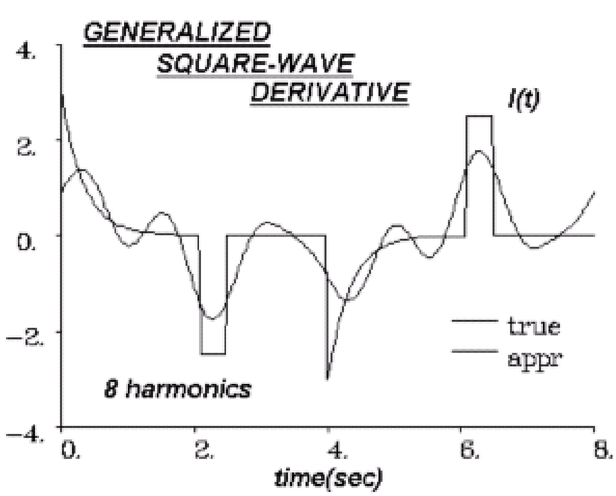


Figure 6.7 Fourier representation of the time derivative of the Generalized Square Wave of Figure 5 and 6 with 8 harmonics.

Figure 6.7 illustrates the representation of the derivative of the waveform *(e.g.* coil receiver) of Figures 6.5 and 6.6 with only 8 harmonics. In this case, 8 harmonics only gives a rough approximation of the waveform everywhere throughout the period.

Figure 6.8 illustrates the representation with 64 harmonics. In the case of a 30Hz base frequency EM37 system this would represent a band width up to 1920 Hz and probably does not represent sufficient harmonics to obtain an
undistorted response. However the representation is quite good unless we wished to measure during the ramp-off time or very early in the off-time.

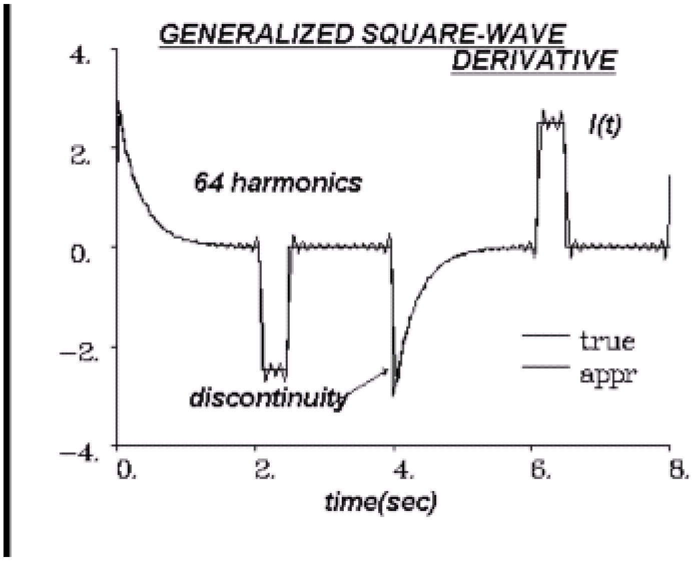


Figure 6.8 Fourier representation of derivative of the Generalized Square Wave using 64 harmonics.

If we were to utilize the Lancos low-pass filtering, we would notice much smoother responses as dictated by the lack of high frequency energy in the resulting waveform. The user may find it instructive to transform the free space responses under a (G)eneralized Square Wave format and utilize the interactive window creation rather than the window gate files (.par) to see just how the effects of low pass filters in time domain systems modify very early and very late time responses.

We have not included examples of representing the ramp or the box-car but the user may find it interesting to do these experiments with these waveforms to further their understanding of the spectral representation process.

7. The Software: FSEMTRS

7.1 Overview:

FSEMTRS convolves current waveforms with a simulated impulse response from the Earth, normalizes and then samples at prescribed times. A schematic diagram of this process is shown in the diagram below (Figure 7.1).

EMIGMA Input:
FSEMTRS is designed to read **".spt**" files, the output from Forward Simulation. This file contains the spectral impulse response of several fields due to the chosen modelling structure at several stations on a profile(s). Ths file must contain a selection of frequencies utilizing the (S)pectral Waveform option in ***EMIGMA***. In this case, frequencies less than the desired base frequency must have been chosen so as to enable ***FSEMTRS*** to correctly interpolate the low frequencies. The highest harmonic to be determined by ***FSEMTRS*** also depends on the spectral selection. In Versions 6.2 and higher, if the waveform information is available as is the case when either field data is present or when the simulation began from a previous time-domain model, then the transform will be performed automatically.

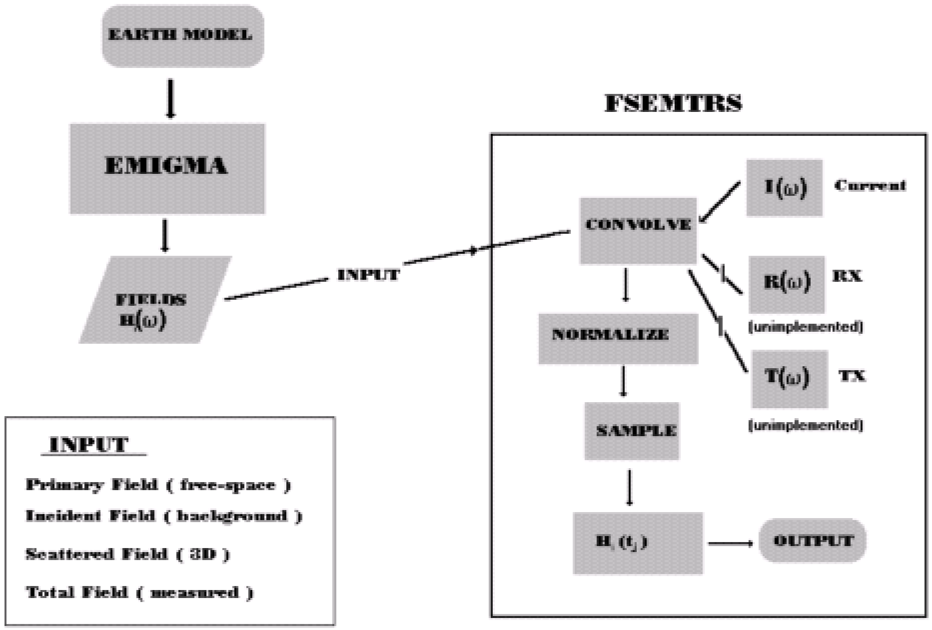
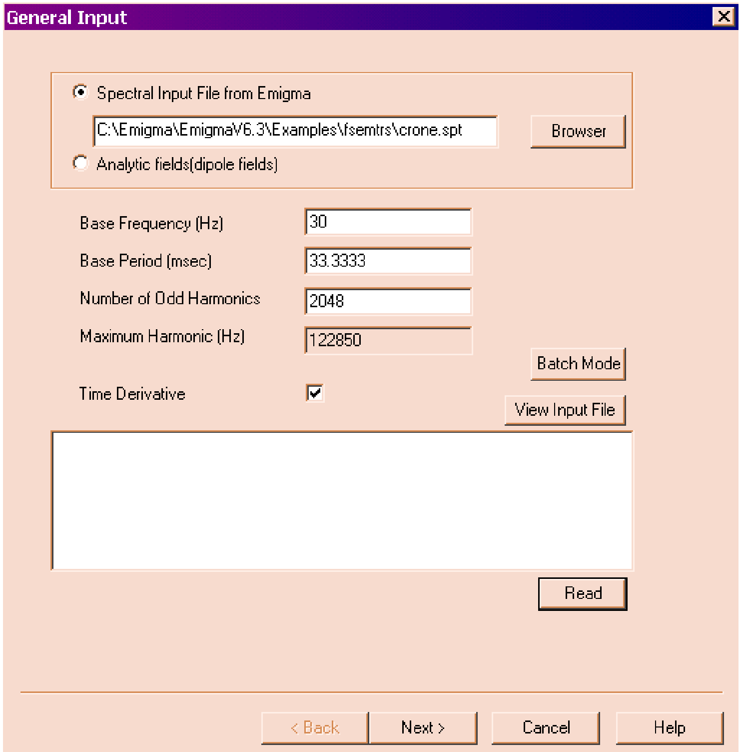


Figure 7.1

FSEMTRS compiles from the input file the Fourier series for 4 fields (Primary(*Source*), Incident, Scattered, Total) at each RX for the *measured* field component. ***FSEMTRS*** then convolves each of these fields with the current waveform spectral response and then transforms the result producing 4 times series at each station. These time series are then normalized and an output time series produced.

7.2 Current Transform Instructions

Note that the following instructions are for the standalone version of EMIGMA V6.4's FSEMTRS (GeoTutor). A fast transform is now allowed in Forward Simulations in both V6.4 and V7.7. The fast transform option is default and performed automatically. You will be asked if you wish to have this performed. If Yes, then the software will perform the simulation and then the transform and save only the final TEM output. If NO, then the intermediate Spectral data will be saved.. This will allow the frequency to time domain transform to be run automatically if either the model was built from imported time domain data or you used a previously transformed file as a starting model. Note that the following instructions apply to both the standalone and the fast transform.



>>> Page 1 - FSEMTRS - Input Data and Bandwidth

1) **Select sprectral file** which is output from Forward Simulations consists of simulated data for a Spectral suite of frequencies i.e. you have chosen a start and an end frequency and the number of skips.

In V7.7, several selections will be available.

2) **Select the base frequency or period of your data.** This may automatically be found if a time domain survey is found by the software.

3) **Number of Odd Harmonics->** We have set a reasonable default of 2048 but this is not a maximum. When you adjust this number the Maximum Harmonic window is updated when you Click on that window

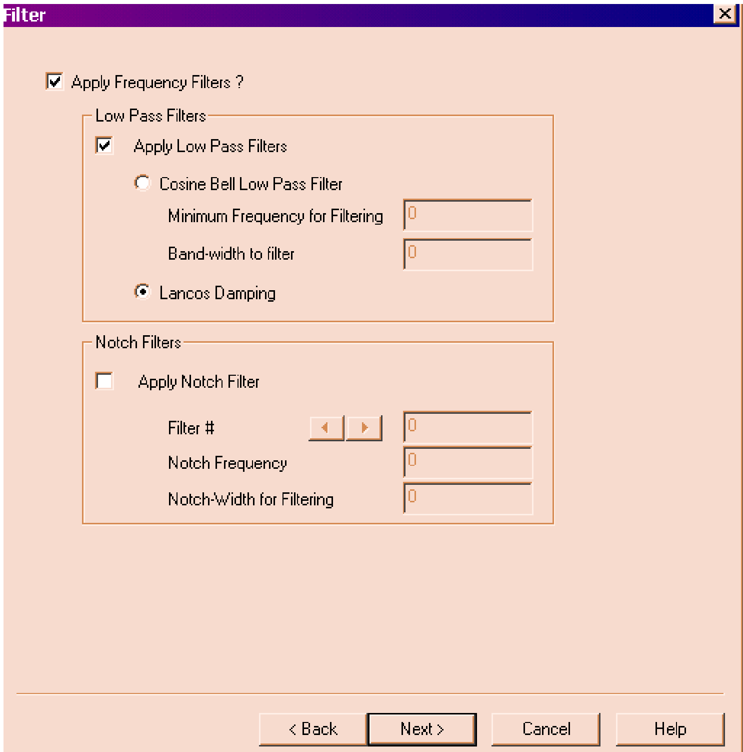
4) **The time derivative of the field is selected but may be turned off** If electric fields are read then time derivative is automatically de-selected. Note: If the user wishes to simulate B-fields for a time domain system then they must turn-off the derivative.

5) **View Input File** - reads file in and allows you to view to file for checking in the white box below.

6) **Next>** automatically reads the file, makes correctons to settings and continues to next page. Read - reads the file makes changes but remains on this page for you to view changes or make additional changes.

7) **If the software detects a "Spectral Survey"** then a message is issued and you may proceed to the next page. Spectral surveys allow the software to interpolate the harmonics of the basefrequency to allow transformation to time domain.

Note> If you are transforming a file that has been imported, select the read button and most selections in the transform will be detected from the file and set for you. Check each to make sure the sections are correct.



>>> Page 2 - FSEMTRS - Set Numerical Filters

1) Select Low Pass and Notch Filters

2) No EM/IP or Resistivity system has an infinite bandwidth. Due to electrical and hardware limitations all systems either explicitly or implicitly apply some sort of Low Pass filters.

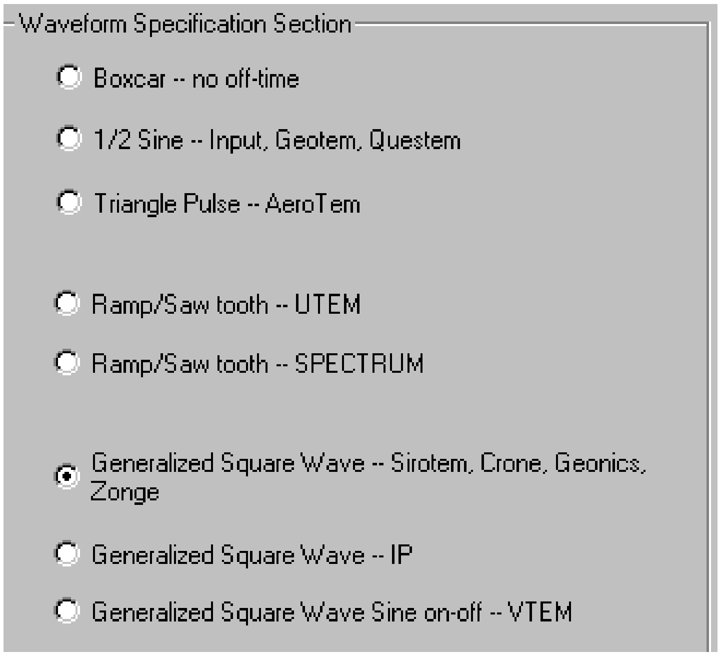
3) Low Pass Filters - each system has its own specific low pass filters but here we allow the setting of 2 types of low pass filters. The default filter is a Lancos filter which is a simple smooth low pass. The 2nd filter is a Cosine bell which may be selected by you.

4) Cosine bell - Set the inital frequency at which the low-pass begins and set its width. Beyond the initial+width frequency, no power will pass into the numerical transform.

5) Notch filters - These are standard notch filters with a centre point and a width. At the present time, only one notch is allowed but should you require more, please contact us and we will build a new application allowing the number that you may require.

6) Should you require a specialized low-pass filter, we would be happy to oblige. Please contact us with the details.

>>> Page 3 - FSEMTRS - Set Current Waveform



1) Select Your current waveform - Please refer to the Transform manual

2) The Boxcar is simply ON then -On with no off-time

3) 1/2 Sine can be tailored to suit only INPUT data, new and old GEOTEM data or Questem data or merely any waveform of the 1/2 sine type. Remember that if you are measuring with a coil you are sensing the derivative of the magnetic field and the free-space waveform of B is a half-cosine.

4) Ramp/Saw tooth – UTEM or SPECTREM

5) The Generalized Square Wave is a very generic waveform and many systems conform to this waveform. You will be asked to set characteristics on the next page.

6) IP - although IP utilizes the Generalized Square wave, we have made some default settings to ensure that the turn-on and turn-off characteristics can generallly be ignored by the user.

7) The AeroTem system has a small triangular pulse prior to turning off while the VTEM is turned on with a half sinewave and off similarly. Generally, it is about a 40% duty cycle.

>Page 4 - FSEMTRS - Set Waveform characteristics

On this page, you will select specifics of your chosen waveform. The details of this page are waveform dependent.

NOTE: Remember that all these systems switch polarity every half-cycle. This is to allow with stacking, the removal of all DC offsets. Thus, every half-cycle is repeated in every period but with opposite polarity.

1) INPUT waveform - The length of a half-cycle is displayed. You may select the width of the sine pulse while the amount of off-time is automatically updated as the width of half-cycle minus the width of the sine pulse.

2) UTEM - no page appears for this waveform

3) SPECTRUM - no page appears for this waveform.

4) Generalized Square Wave -

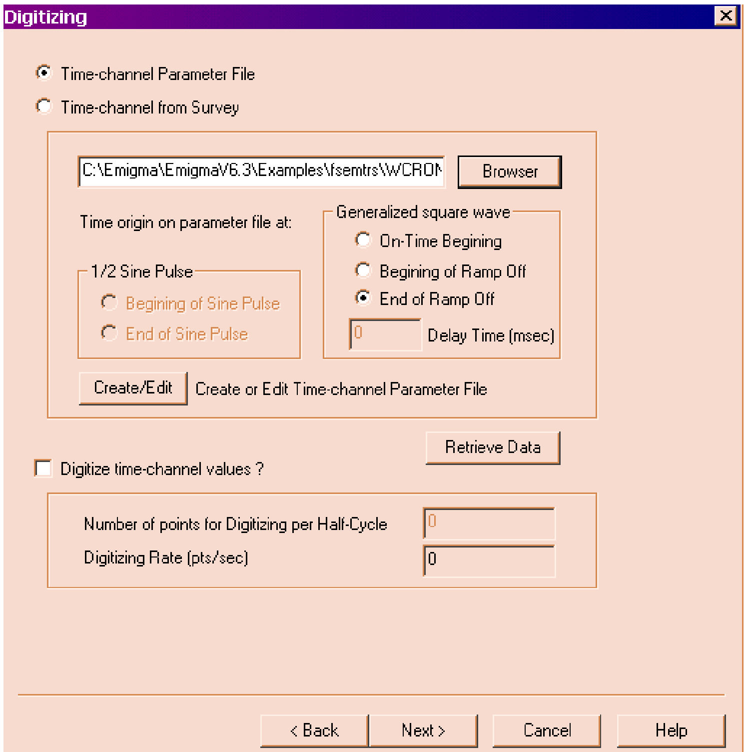
- time constant for turn ON.
- Ramp Time - length of the linear ramp from ON to OFF
- OFF-Time - lenght of time the current is off
- Beginning of Ramp - Half-Period - Off-time - Ramp-time

5) IP - can only be selected for Electric field data - please contact us if you have questions

6) Normalize - if you wish to Normalize your Output please check this Box

>>> Page 5 - FSEMTRS - Set Measurement Windows

Note: If your data contains measured field data or a previous time-domain simulation, this page is already selected as the time windows are detected in the time domain survey.



1) Time-Channel Parameter File: This file is a simple ASCII file containing the number of time window gates, the beginning gate of each time window and its ending gate. The format is borrowed from the old UofT PLATE program. You will find several examples of them in your EXAMPLES directory is the fsemtrs sub-directory.

2) Specific waveform settings: The time gates are relative to some time origin in the waveform. You may select from several suitable time origins for either the 1/2 sine or the generalized square wave.

As an example, if you wish to generate ON-time measurements in a GEOTEM survey, simply select "Beginning of Sine Pulse" as the origin and set all of your window times relative to the beginning of the sine-pulse

3) Editing the parametre file: After selecting a time-channenl file, select the Create/Edit button and you will be taken to an interface allowing you to edit this time-window information. Allowing to modify times, add new windows or delete windows and finally to save the resulting changes.

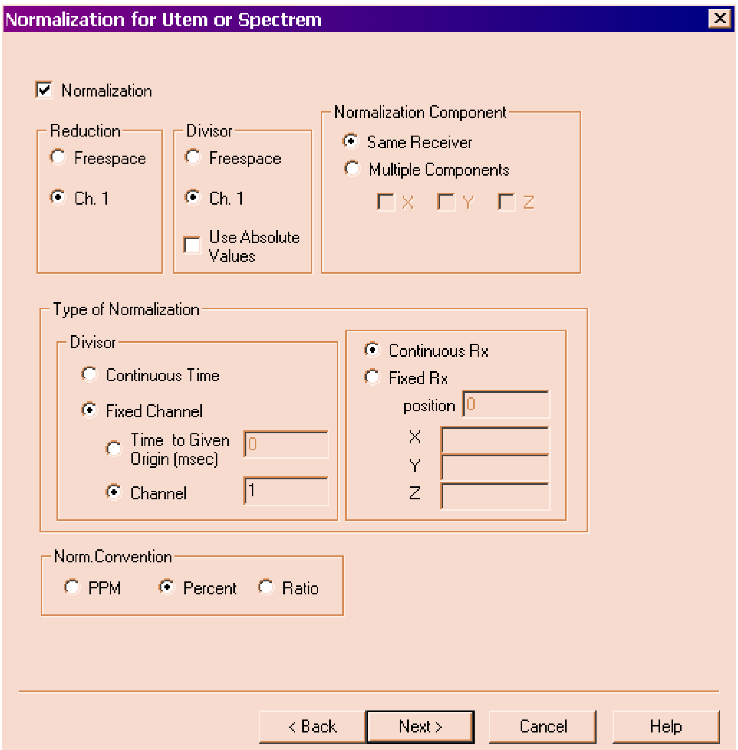
4)Digitize Time-Channel Values: If you desire to calculate several measurements in a given time window which are later bined and average (so-called integrated measurements), you may do so here.

>>> Page 6 - FSEMTRS - Normalization Procedures

If your data is normalized, then you must set the normalizaton criteria on this page.

NOTE: If your data contains measured data or a previous time-domain simulation, then this page is automatically set from you previous data or simulation

NOTE: This page varies with wavefrom



1) 1/2 sine:

a) Divisor :
- This may be either Free-Space or Total Field (i.e. measured at survey height)

b) Norm convention :
- output units

c) Normalizaton component:
- your data may be normalized either to same component as measured or to Multiple components (i.e. X,Y and Z)

2) UTEM data: is normalized reduced prior to normalization

a) Reduction - subtract Ch1 or Free-space prior to normalization

b) Divisor - divide by Ch1 or Free-space utilize the actual value of the absolute value of the divisor

c) Normalization component - same as above

d) Type of Normalization - Time
- continuous time or fixed time

e) Type of Normalization - Position
- continuous or fixed RX

Note: Fixed Rx not available at present (please contact us)

f) Normalizaton convention - output units

3) Generalized Square Wave:

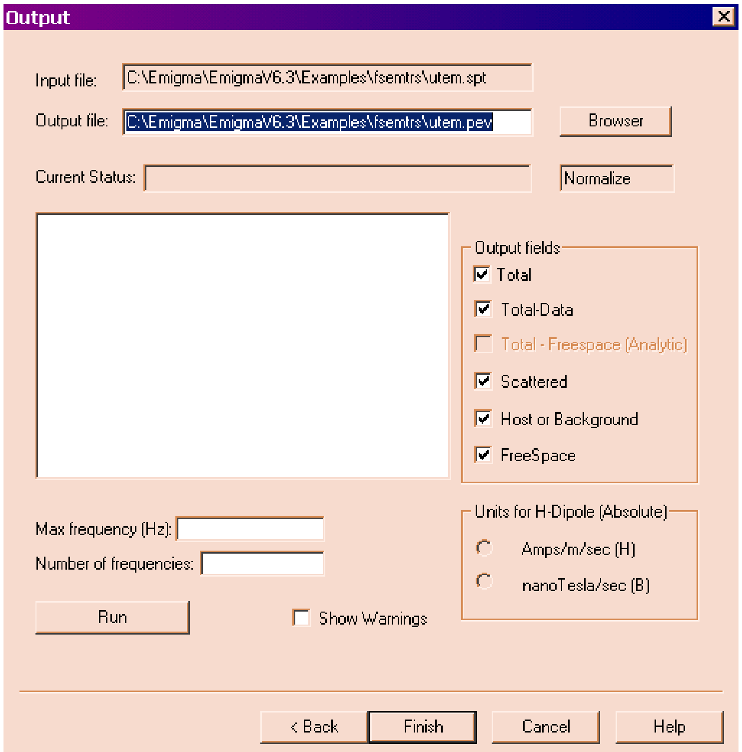
a) Divisor - divide by Ch1 Free-space, Total Field or just Host (Background) utilize the actual value of the absolute value of the divisor
Here you must set the time which you wish to use for normalization.
The Default for this time is during the On-time relative to your selected time-origin on the previous page

b) Noralization component - same as above

c) Normalizaton convention - output units

4) IP waveform: - same as (3) above

>>> Page 7 - FSEMTRS - Output settings



1) Output filename - we have selected a default but you may edit this

2) Units - this depends on the type of data being transformed

a) Magnetic Field Data
- for coil data the selections are
Amp/m/sec or nanotesla/sec
- if magnetic field data is required (no time derivative) then
the units are Amp/m or nanotesla/sec

b) Electric Field Data
- Volts or mV or if time derivative Volts/sec or mV/sec

NOTE: If the data is normalized then these units cannot be selected

3) Output fields

- Total refers to the simulated total field - Host + Scattered
- Host or Background - is the field measured in the absence of any 3D anomalies
- Total - FreeSpace - Calculated Total - Calculated FreeSpace
- Total - FreeSpace (analytic) - This field is calculated in frequency domain prior to transformation

NOTE: When selections are complete, the proper sequence is to select the RUN button.

Messages will indicate successful completion and writing of the output file. You may then return to the first page to select another file or select FINISH to close the application.