A Short Guide to Trace Analysis and Modelling by Microsoft Excel

a) You first need a Microsoft Excel template file, which can be prepared setting to zero the amplitude fields, A_k, in each worksheet *Ricker_n* of the sample file *Ricker-Modelling_400MHz_18_33.xlsx*. In this file, only the yellow fields should be changed.

b) Then, you will use a software tool for extracting a trace (t,A(t)) from a radar profile, where t is the TWTT in ns and A is the reflection amplitude (in 16 or 32 bit counts). The trace can be stored as ASCII file or in a Microsoft Excel file. For example, with GPR Slice it is possible to export a radar profile from its original format to ASCII *.xyza format. Then, a simple software can be used to read the *.xyza and extract a specific trace from the data set. It is important to note that in this case the z field of the *.xyza file must be converted to TWTT using the velocity specified in the heading row.

c) Now you need to find a software for the interpolation of the (t,A(t)) data to the query times: (0,0.1,0.2,...,30.0). In Matlab, you first create the vector of query times by: T = 0:0.1:30. If you need a longer time interval, you can substitute the value 30 by the maximum TWTT of the modelling range. Then, you convert this vector into a column vector by: T = T'. Finally, the interpolated trace can be obtained by the command: *A_interp* = interp1(t,A,T). This trace can be now copied to the *Convolution* worksheet, yellow column C (*A_meas*) (Figure 1).

d) At the next step, you should fill some important fields in the main worksheet, specifically: *Central Frequency*, *Amplitude Scaling*, *Quality Factor Q**, *Wavelet Phase*, and *Uncertainty Parameters*. *Amplitude Scaling* is a scaling parameter that allows to use small numbers to represent trace amplitudes, which are usually very large integers. You can adjust this parameter at your convenience. Regarding the *Wavelet Phase*, we always use 90°-phase wavelets, but you can try any other phase if necessary. Let us consider now the central frequency f_c, which in principle should coincide with the antenna central frequency (e.g., 400 MHz). Because the reflected wavelets always have a breadth that is greater than the input pulse, independently from the reflection depth, we assign the central frequency f_c in such a way that the model ground reflection pulse fits in any case the breadth of the first wavelet of the observed trace. Therefore, we can start with an initial value coinciding with the antenna central frequency but this value will be modified until a satisfactory fit of the first wavelet is found in the worksheet *Ricker 1*. Figure 2 shows the result of this step.

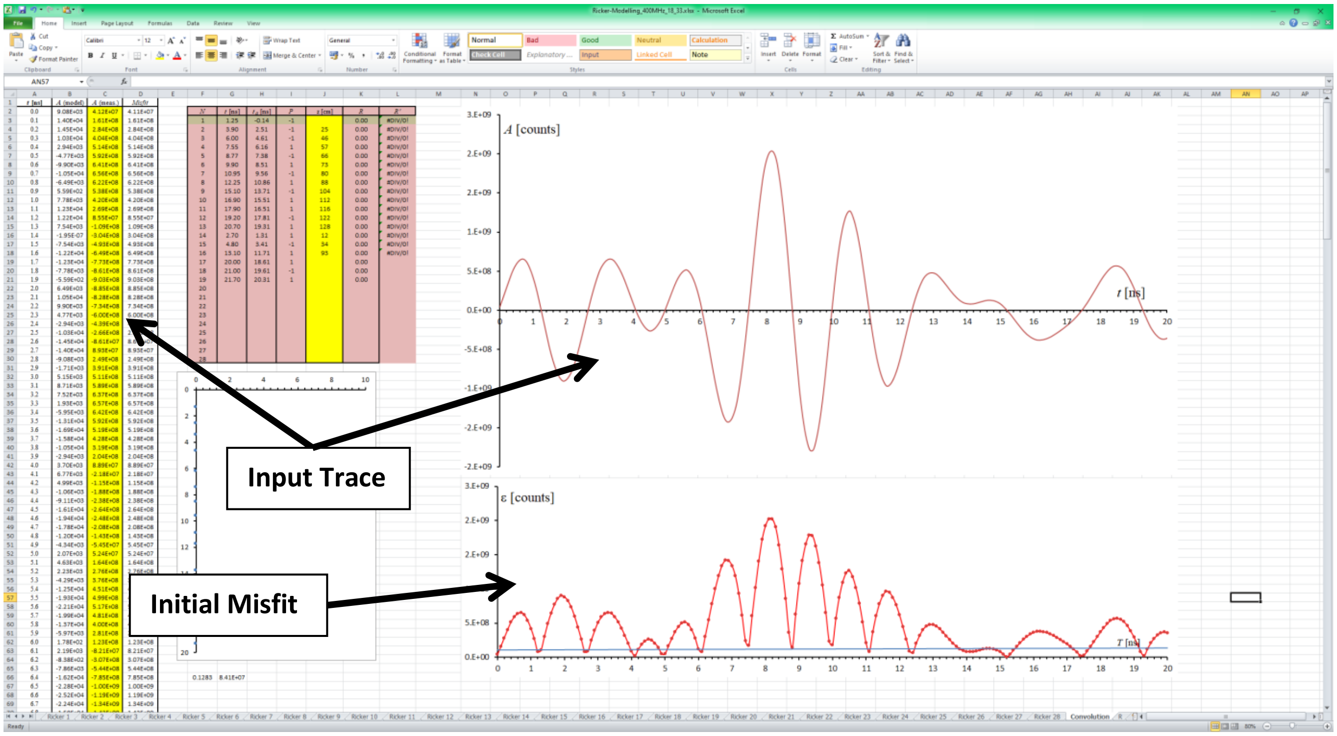

Figure 1. Situation after loading the input trace.

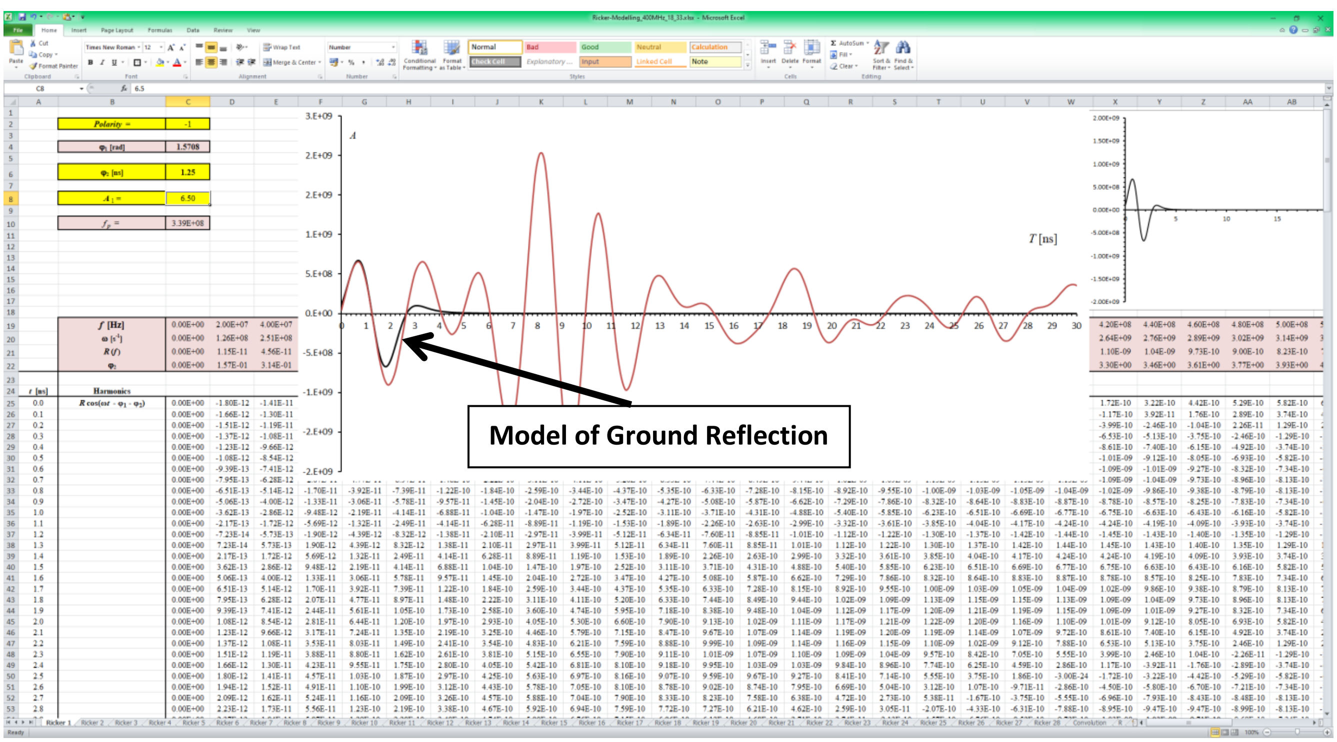

Figure 2. Ground reflection fit.

e) The *Quality Factor Q** allows to specify the wavelet dispersion with TWTT. The initial trial value could be very high, for example you can set $Q^* = 1000$. This parameter should be assigned trying to fit one or two wavelets with appropriate polarity to a deep segment of the observed trace. For example, you could use the last two worksheets, *Ricker 27* and *Ricker 28*, and create a pair of wavelets that approximately fit one of the last wiggles. Then you progressively adjust the parameter Q^* to ensure that the breadth of the model wavelet fits the observed peak. Figure 3 shows a possible fit for the sample trace. In this example, the estimated quality factor Q^* is 200.

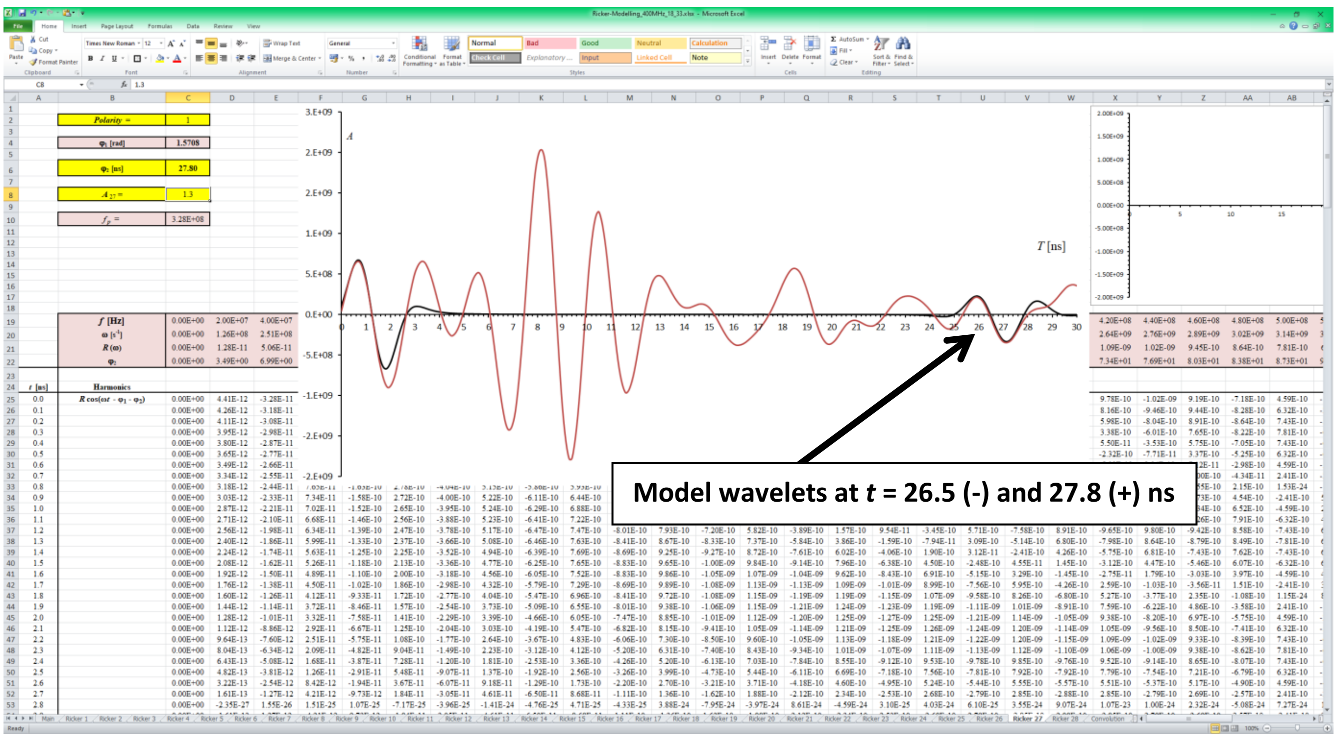

Figure 3. Fitting the quality factor by late wavelets.

f) Finally, we need to assign the *Uncertainty Parameters*. We have a depth-dependent instrumental uncertainty, which increases linearly with TWTT, $\varepsilon_i = at + b$, and a constant spatial uncertainty ε_s. The parameters a and b are specific of the antenna and must be estimated by a single-trace experiment, keeping the antenna at rest in time mode. Parameter ε_s depends on the ground conditions and can be estimated by acquiring few hundreds traces in a small sector of the survey area. Parameters a, b, and ε_s must be loaded in the corresponding fieds of the main worksheet, as indicated in Figure 4.

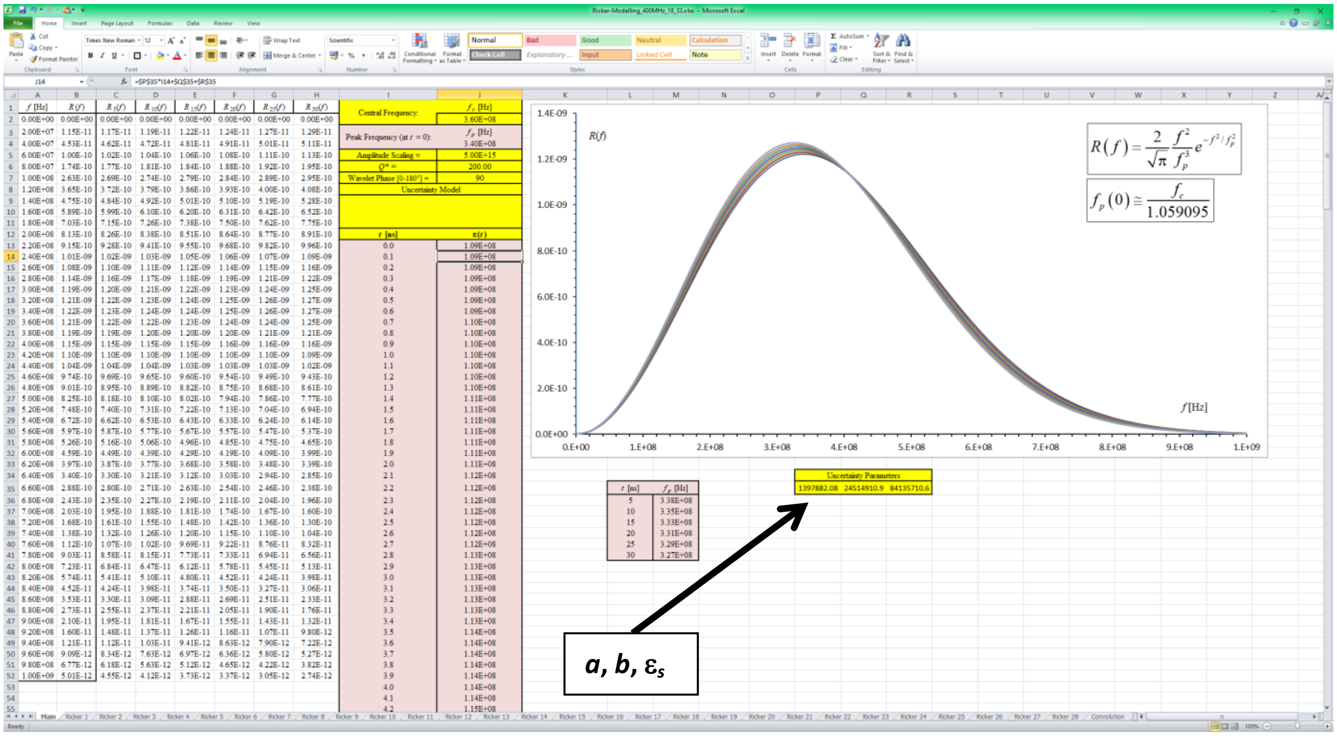

Figure 4. Specifying the uncertainty parameters.

g) At this point, you are ready to start with trace modelling, assigning polarity, amplitude, and central time of each wavelet in the sequence. You will start this procedure at worksheet *Ricker 2* and continue until the whole trace is fit, or at least the segment of trace that is considered in your study. Figure 5 shows the fields where you input the polarity P, the amplitude A_k, and the central wavelet time t_c. For each trial wavelet, you can check the actual level of misfit in the worksheet *Convolution*. Figure 6 shows the situation after the definition of five wavelets.

h) At the end of this procedure, you have that the software has compiled a summary table with the parameters of the model wavelets (Figure 7). This table includes the wavelet number (corresponding to the worksheet where it is defined), its central time t_c, the arrival time calculated on the basis of the wavelet breadth, t_a, the polarity, the scaled amplitude, and the normalized amplitude, calculated assigning -1 to the ground reflection and scaling all the remaining amplitudes. You must fill the yellow column of this table, in order to build the final reflectivity plot in terms of depths. This can be done converting the arrival times into depths through a velocity model.

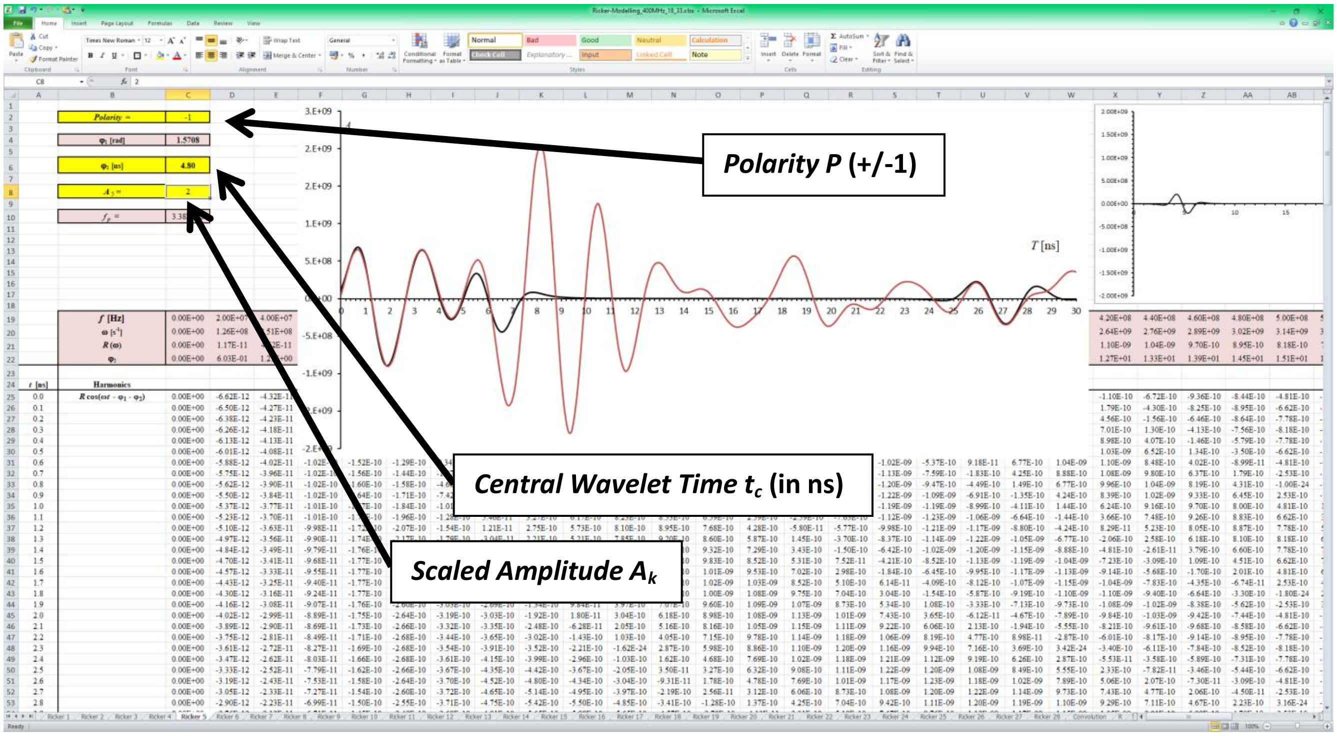

Figure 5. Specifying the wavelet parameters.

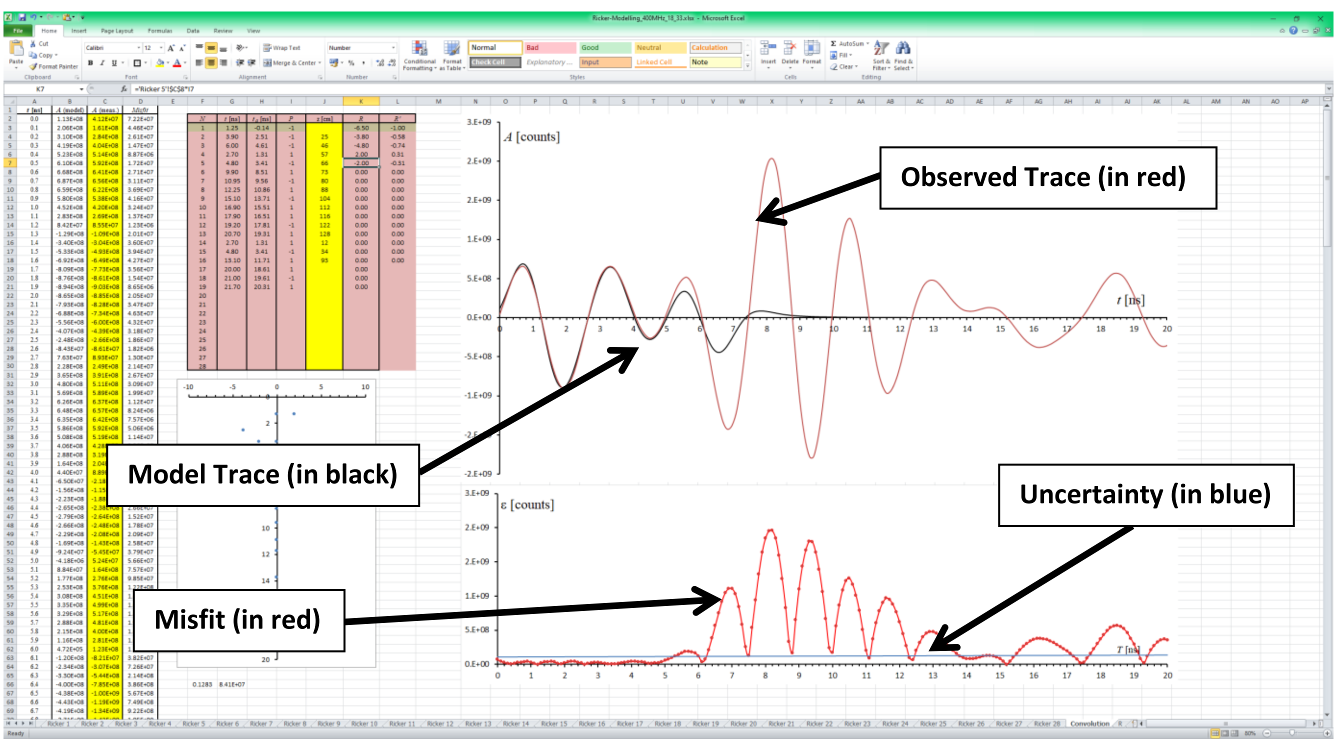

Figure 6. Actual convolution and misfit.

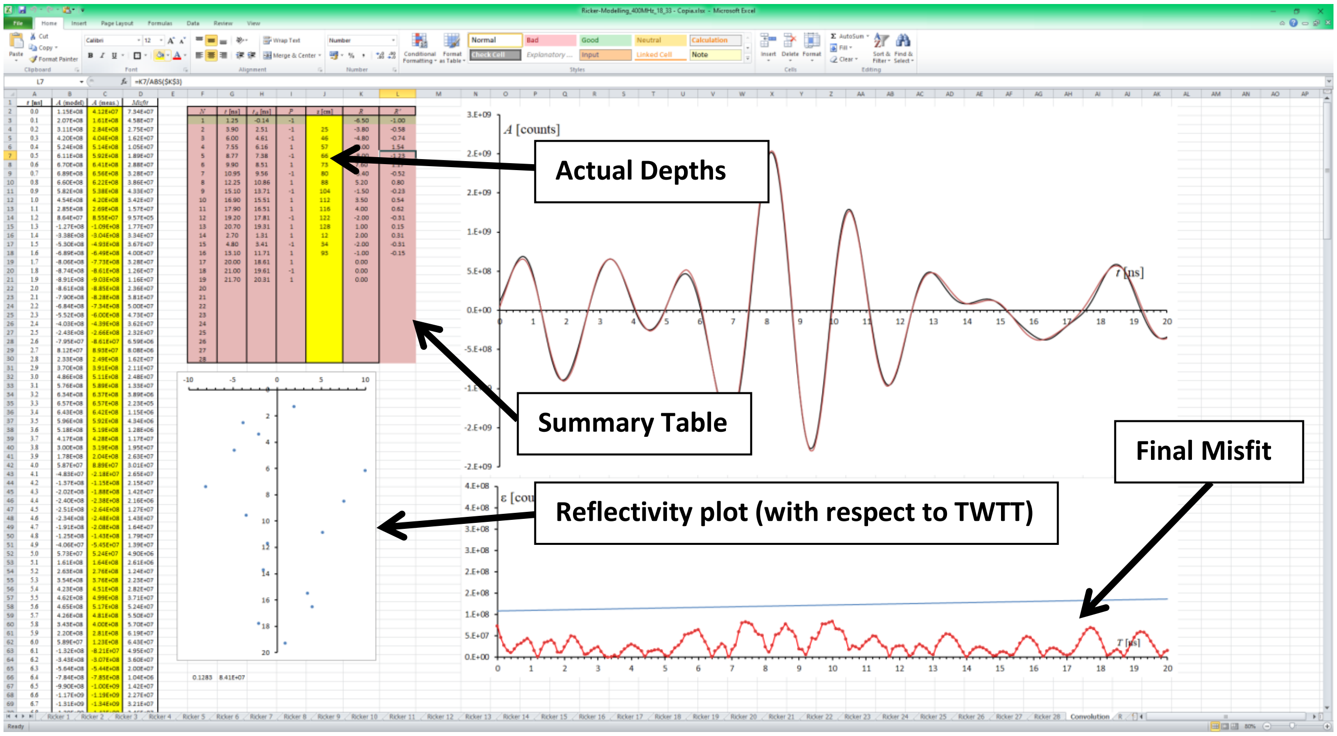

Figure 7. Summary table and reflectivity plot.

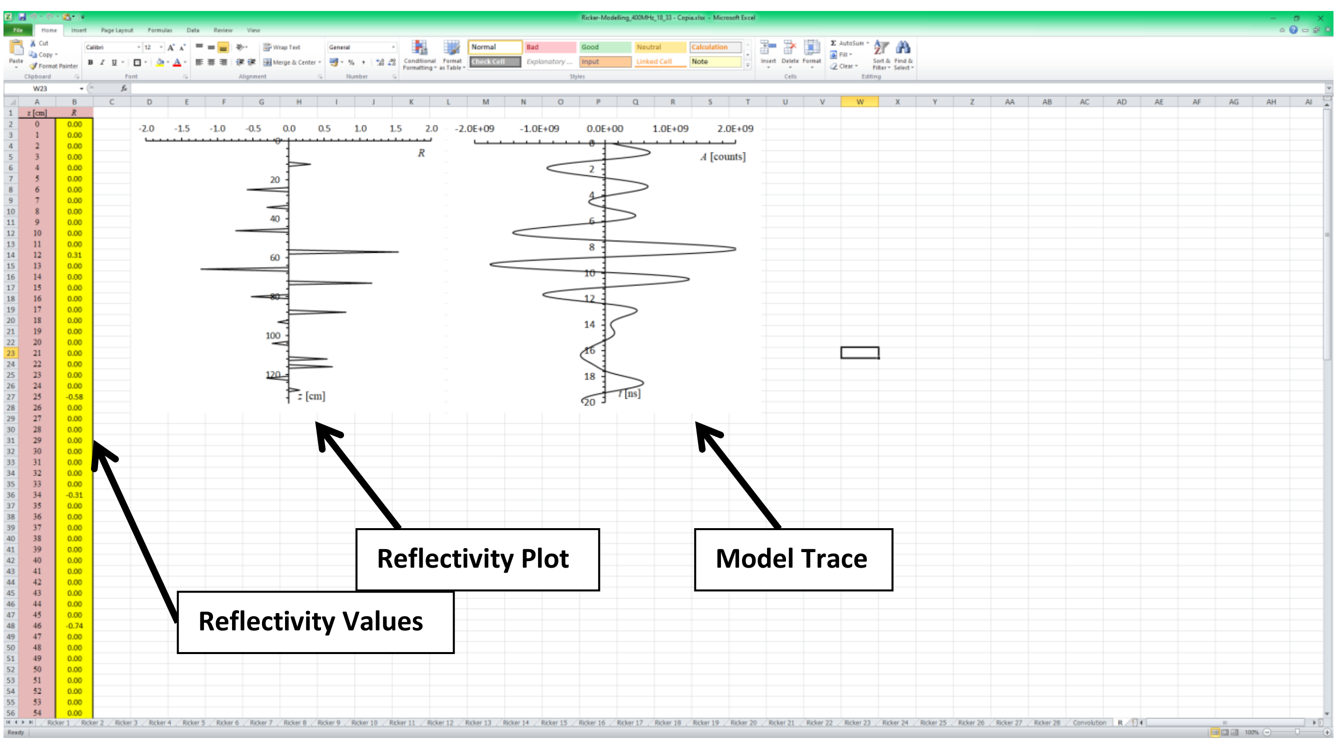

Figure 8. Final reflectivity plot and synthetic trace.

i) The last step requires the reset to zero of column *R* in worksheet *R*, then the assignmnet of reflectivity values from the summary table to the corresponding depths in this worksheet. Figure 8 shows the final reflectivity plot that results from this procedure.