

Keysight

# Measuring High Impedance Sources Using the U8903B Audio Analyzer

Application Note



## Introduction

This note details the input impedance of the U8903B Audio Analyzer, and shows that this needs to be understood and carefully considered when measuring high impedance sources.

A method of using an impedance matching attenuator to overcome high impedance measurement problems is described and a simple accessory is demonstrated which uses the U8903-109 BNC accessory kit.

Methods for aligning such a matching attenuator and compensating for its loss are shown alongside the ease with which frequency response measurements can be made on the U8903B.

## Input Impedance

Audio Analyzers such as U8903B invariably have an unbalanced input resistance of 100 k $\Omega$ . This is relatively high by most standards but compared to an Oscilloscope or DMM is it actually quite low. Users therefore need to be aware of potential divider effects when measuring sources with output impedance of more than some 10's of ohms.

As well as the 100 k $\Omega$  input resistance, Audio Analyzer's have some finite input capacitance. Some of this capacitance is deliberate, it forms an input low pass filter with a corner frequency way above the measurement range of the instrument. The purpose of this filter is to remove any high frequency (RF) content from the input signal that could otherwise upset the audio measurement circuitry. In the case of the U8903B, the input capacitance of the measurement circuitry is around 150 pF, with perhaps another 30 pF due to cabling. Taking all this into consideration the input impedance against frequency is shown in Figure1. Here we see that the impedance is around 40 k $\Omega$  at 20 kHz and less than 1 k $\Omega$  at 1 MHz.

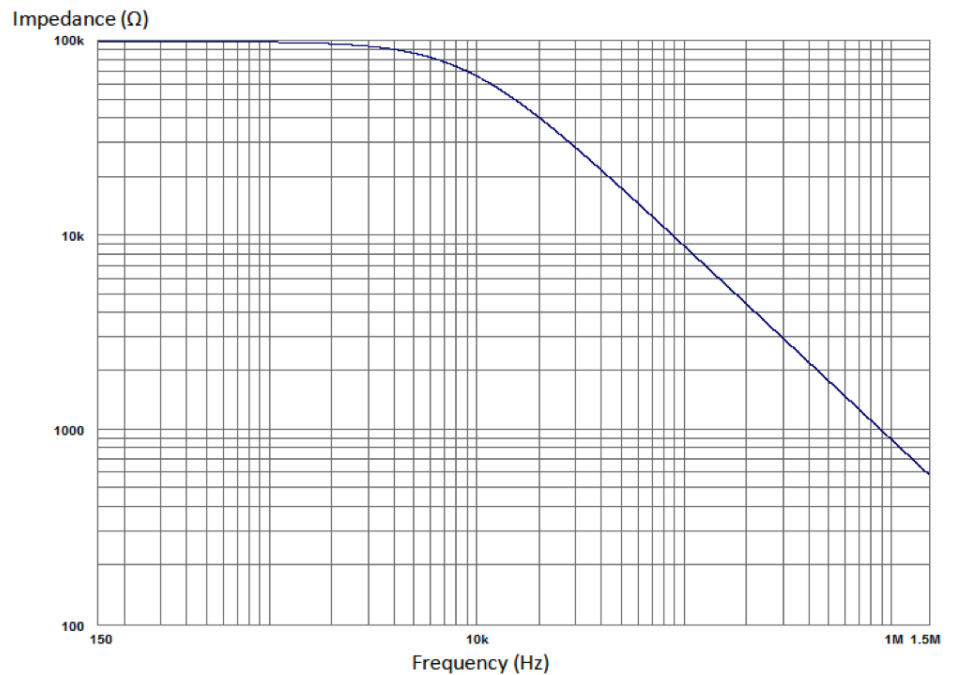


Figure 1.

## Measuring High Impedance Source's

Generally, Audio Analyzers are used with low impedance sources and high impedance loads so the input impedance graph in the previous section is not of high importance. There are however situations where care must be taken. Measuring a transformer or perhaps some intermediate stage of a circuit could yield source impedances of some thousands of ohms.

This high source impedance will then form a low pass filter when combined with the input impedance of the Audio Analyzer, this will in turn degrade any flatness or level measurement.

Taking a 50 k $\Omega$  source as an example, this forms a filter with a corner around 26 kHz, which means significant roll-off can be expected in the audio band.

Figure 2 shows the result of a frequency sweep which is easily made on the U8903B, this is with the 50 k $\Omega$  source connected directly to the Analyzers input connector, connecting via a cable shows a considerably worse result due to the extra cable capacitance.

This measurement shows an undesirable 2.1 dB of roll-off at 20 kHz. Note also that the initial flat part of the plot is around -3.5 dBv, this is due to the potential divider formed by the 50 k $\Omega$  source and the 100 k $\Omega$  input resistance of the Analyzer. This can easily be compensated for as will be shown later.

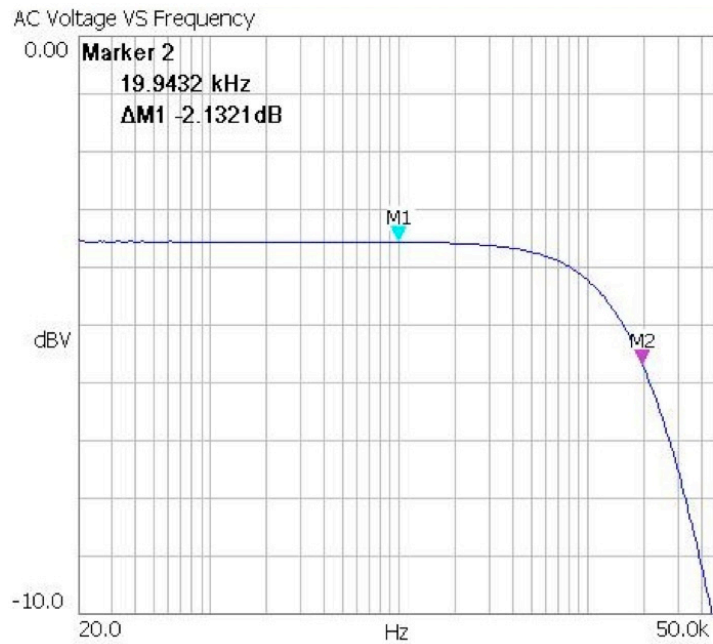


Figure 2.

## Attenuating Matching Network

The error due to roll-off could of course be corrected mathematically, this would however require accurate knowledge of the individual components in the measurement, cable capacitance, source impedance against frequency etc.

An all-round solution is to somehow increase the Audio Analyzers input impedance without adversely affecting other parameters. There are a number of ways to achieve this, a buffer amplifier might be an obvious choice but this comes with limitations on range, it also requires a power supply. Its input might also be susceptible to susceptible to RF ingress which results in a duplication of the original problem solved in the Audio Analyzer by applying some parallel capacitance.

A simple reliable way to overcome the problem is to use an attenuating impedance matching network as shown in Figure 3.

This arrangement shows a 10:1 divider and is very similar to what can be found in a standard 10:1 oscilloscope probe. The theory here is that the series matching network forms a high pass filter which compensates for the low pass effect on the input of the Audio Analyzer. Compensation is ideal when  $R1C1=R2C2$ , this offers the widest bandwidth and best flatness. Component values are never exact however and there are parasitic effects to consider. C1 is therefore a trimmer capacitor that can be tweaked for best performance.

The device under test now sees an Analyzer input impedance of 1 M $\Omega$  in parallel with 18 pF.

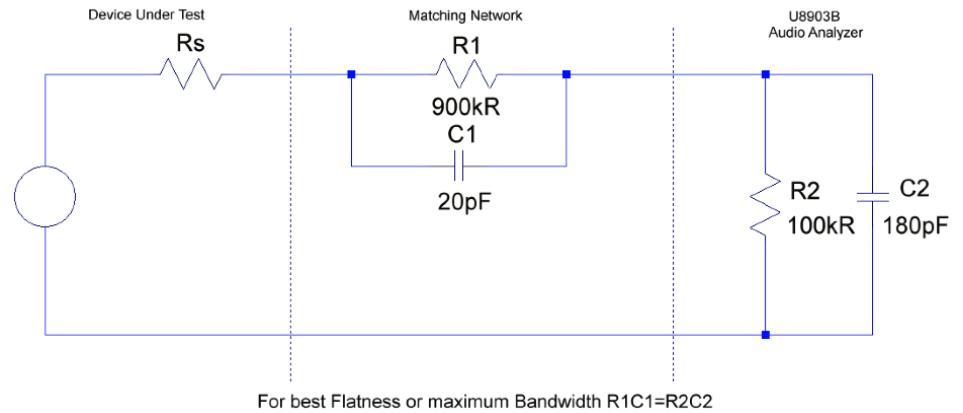


Figure 3.

## U8903-109

This example shows how the U8903-109 BNC Accessory kit is used to house the matching components R1 and C1. Details on how to use this kit can be found in the application note with the same title (publication number 5991-1466EN) <http://cp.literature.agilent.com/litweb/pdf/5991-1466EN.pdf>

The capacitor used in this particular example was TZC3P200A110B00 (20 pF) from Murata whilst the resistor was part H8909KBYA (909 k $\Omega$ ) from TE connectivity. The two parts are soldered in parallel then soldered into the U8903-109 BNC kit as shown in Figure 4.

The assembly can be loosely screwed together until the network has been compensated and then perhaps secured more permanently using lock tight.

Using the U8903-109 BNC kit for this application offers a repeatable reliable accessory that can be connected directly to the input of the U8903B. The result is also extremely well shielded as is the requirement for any high impedance network.



Figure 4.

## Compensation

To achieve best flatness or bandwidth, the series capacitor must be adjusted precisely such that the input capacitance of the Analyzer is canceled.

Adjustment can be done by repeatedly doing frequency sweeps and adjusting the capacitor each time until the desired result is achieved. A more real time adjustment method is to use a square wave as is the technique used to calibrate 10:1 scope probes.

The generator on the U8903B is set to output a square wave of 10v, the frequency not being particularly relevant since it is the rising and falling edges that are of interest. Looking at the time domain plot on the Analyzer the capacitor is adjusted for the best flat topped square wave possible. This corresponds to flattest, widest bandwidth.

The U8903B time domain plot shown in Figure 5 shows the result of a well-adjusted matching network.

The edges of the square wave appear to contain some ringing, this is not actually what is happening however. This expected result is due to the finite 96 kHz bandwidth of the Analyzer ignoring the higher order harmonics that the edges of the square wave offer.

This measurement is perfectly adequate for the given application. The U8903B does however offer the industries widest bandwidth option of 1.5 MHz. Figure 6 shows the same measurement made using the wideband option. This plot shows an almost perfect square wave with just a hint of overcompensation from the matching network.

Figure 7 shows the results of a poorly adjusted network measured on the standard bandwidth Analyzer. In the undercompensated state C1 is too small and the low pass effect from R2C2 rounds off the edges of the square wave. In the overcompensated state C2 is too large causing some high frequency peaking or a differentiating function on the square wave edge.

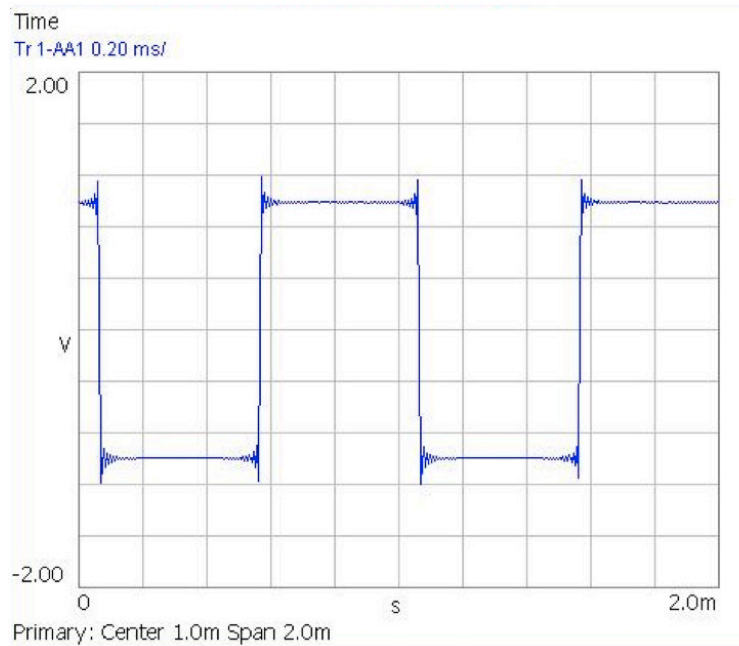


Figure 5.

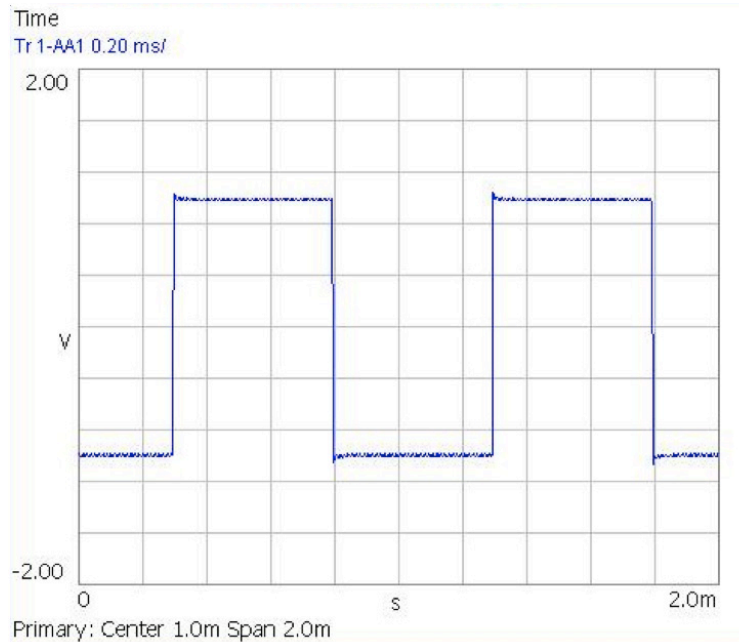


Figure 6.

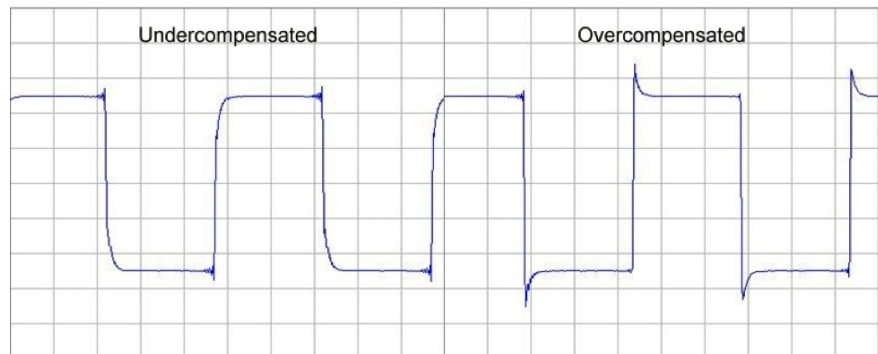


Figure 7.

## Measurement Results

With the matching network built, connected to input of the U8903B and compensated properly a measurement was made with a 50 kΩ source resistor in circuit.

The results shown in Figure 8 are very pleasing, 6 mdB error at 20 kHz as opposed to 2.1 dB without the matching network. The error at 50 kHz is around 0.4 dB.

With the flatness of the measurement system now in good shape using the matching network there remains the issue of the absolute error. The absolute error in this case will be  $100\text{ k}\Omega / (50\text{ k}\Omega + 909\text{ k}\Omega + 100\text{ k}\Omega)$  or  $-20.5\text{ dB}$ . It's very easy to correct for this by using the External Gain compensation in the Analyzer menu as shown in Figure 9. Using this feature means that the Analyzer will display the level at the DUT as opposed to the Analyzer input port. The measurement in Figure 8 already has this in place as can be seen by the fact that marker 1 is on the 0 dBV line.



Figure 8.

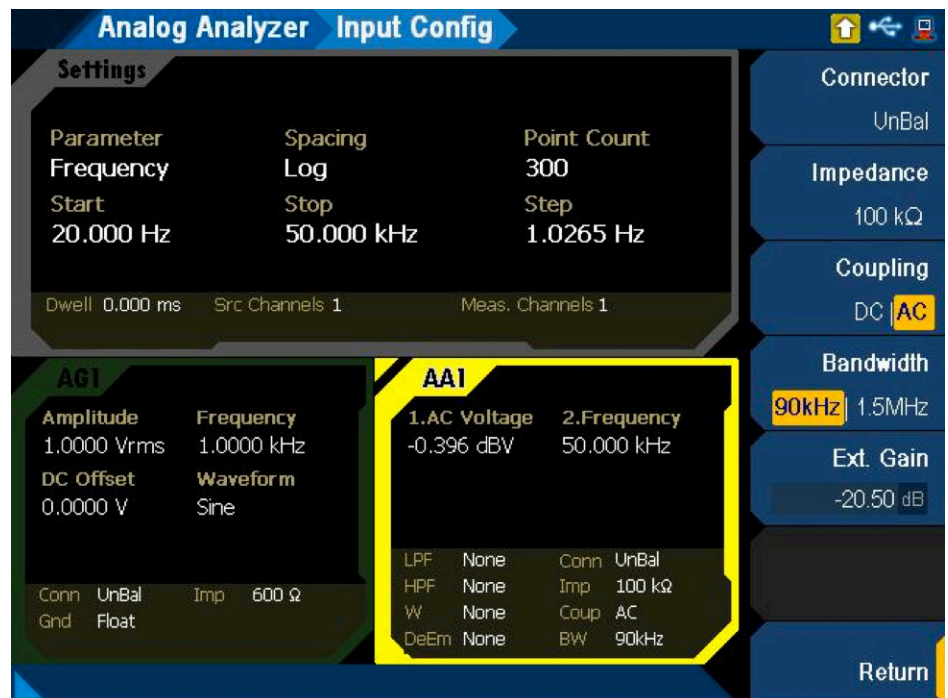


Figure 9.



## Other Considerations

As well as increasing the input impedance of the measurement system the fact that the matching network acts as an attenuator means that voltages out-with the range of the U8903B can be measured. Consideration to component choice must of course be made with respect to voltage handling.

Another point to note when using an attenuating matching network is that the noise floor on the Analyzer will appear higher. This is because noise level is naturally proportional to source resistance and in this case the source resistance the Analyzer sees at low frequencies at least is going to be around 90 k $\Omega$  as opposed to the few 10's of ohms expected when making more conventional measurements.

It is advisable to use a tuned matching network only on the channel it was calibrated on otherwise differences in instrument input capacitance or cable capacitance will come into play.

## Conclusions

This note explains details of the U8903B input impedance and describes how this must be considered when measuring high impedance sources. An example accessory is shown which uses the U8903-109 BNC accessory kit to increase the input impedance of the Analyzer. Measurement comparisons are shown with and without the accessory in circuit. Compensation of the matching attenuator is described and the unique benefits of the U8903B 1.5 MHz option are shown. The ease of which frequency response sweeps can be made on the instrument is highlighted as are various other measurements.

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