Cross-talk and Attenuation Tests for Cables and Splitters used with CAEN 792AA VME QDC

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Contents

Introduction

This report describes the testing carried out on the RG174 Cable Assembly and the Passive Analog Splitters for use with CAEN 792AA VME QDC. The Cable Assembly accepts BNC connections at one end, and a 17-pin rectangular header (similar to those used in ribbon cables) at the other. These cables are needed in order to use the CAEN V792AA QDC with existing 50Ω analog electronics for the Blowfish neutron detector array. Its assembly and preliminary testing results can be found in the report *U of S RG174 Cable Assembly for CAEN 792AA QDC* (Ref. [1]). The splitters are used to equally split analog signals from the cable assembly terminated by a 17-pin rectangular socket connector, and then pass the signals through a pair of rectangular socket connectors to a pair of CAEN V792AA QDC. The splitters are needed to measure the signals from the cable with different gate lengths, providing pulse shape discrimination for neutrons in the Blowfish neutron detector array. The assembly and the preliminary testing of these splitters can be found in the report *U of S Passive Analog Splitters for use with CAEN 792AA VME QDC* (Ref. [2]).

1 Cable Assembly Testing

For the cable assembly testing, three cable assemblies were randomly chosen from those completed, and on each of these assemblies, three cables (BNC ends) were randomly chosen. The chosen cables and assemblies are outlined in the following table:

Assembly	Cable		
	First	Second	Third
1	15	9	7
4	0	5	4
7	12	6	8

1.1 Cable Attenuation

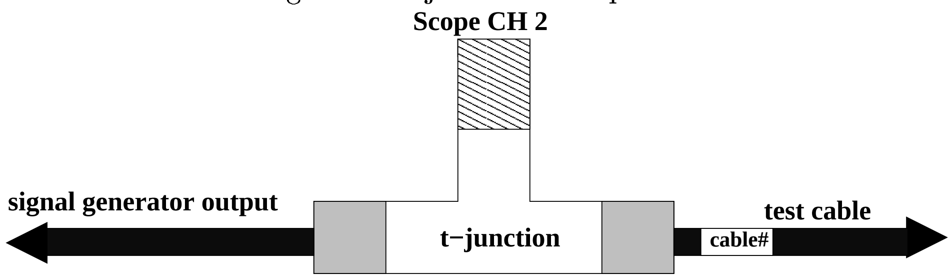
In measuring the attenuation that occurs in the cable assembly, the output of the signal after it goes through the cable was compared to the original input signal. The attenuation was measured for various frequencies for an input signal of approximately 1V. The following parts and components were used for the cable assembly attenuation testing:

- RG174 Cable Assembly for CAEN 792AA QDC
- Tektronix TDS 210 2-Channel real-time digital oscilloscope
- FLUKE 6080A Synthesized RF Signal Generator (10kHz - 1056MHz)
- 2 BNC t-junctions
- 50Ω BNC terminator
- A PC with the program ScopeMe

The components were connected as follows:

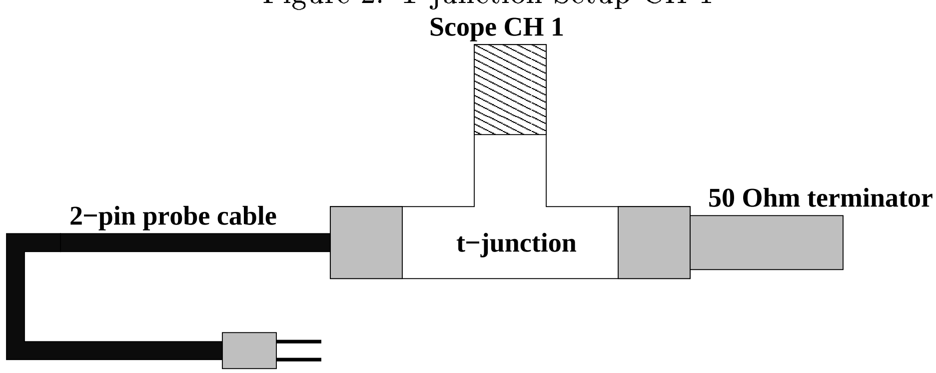
- A BNC-end RG174 cable was used to connect the output of the signal generator to one of the t-junctions. This t-junction was connected to both the a BNC end of the cable being tested and to channel 2 of the oscilloscope. See Figure 1.

Figure 1: T-junction Setup CH 2



- Channel 1 of the oscilloscope was connected to the other t-junction, with one output carrying a 50Ω terminator, and the other a probe cable. The probe cable was constructed for testing of the cable assemblies and splitters, and it has a BNC end, and another end that has two pins (one signal, one ground). The pins were made to fit into a channel of the socket connectors of a cable or a splitter. See Figure 2.

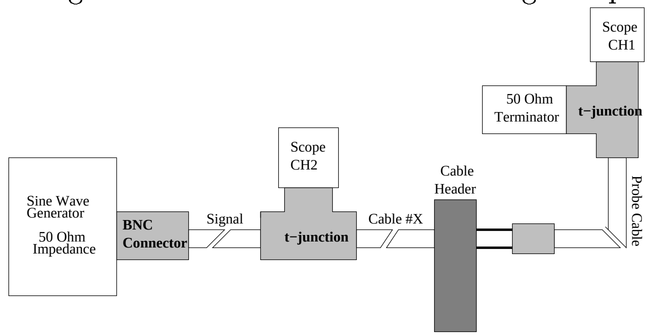
Figure 2: T-junction Setup CH 1



- The 50Ω terminator was used to ensure that there was no reflection due to an impedance mismatch at the oscilloscope input. (The oscilloscope had a 1MΩ input that was not adjustable.) The oscilloscope input had a 1MΩ impedance (which was not adjustable) and the RG174 probe cable had 50Ω resistance. To match these impedances the terminator was placed in parallel with the input, creating a 50Ω total impedance.

- The probe cable was inserted into the channel of the socket connector that corresponds to the numbered BNC end of the cable assembly connected to the t-junction carrying the signal from the generator. Thus, the signal should travel through the cable and into the probe, which was connected to the oscilloscope. See Figure 3.

Figure 3: Cable Attenuation Testing Setup



With the input voltage maintained at 1V, the frequency on the generator was varied from 5kHz to 50MHz in 5MHz increments, and data was collected using the program ScopeMe. The data for each frequency was taken as follows:

- With the voltage and frequency set to the desired values and the components connected as described above, two signals were displayed on the oscilloscope. Channel 2 was the signal directly from the signal generator, and Channel 1 was the signal after traveling through the cable assembly. The waveforms were very similar in shape and size when viewed on the same scale on the oscilloscope.

- Using ScopeMe nine data measurements were made (3 assemblies * 3 cables each = 9 tests). For instructions on how to use this program see the ScopeMe manual. The program input the waveform data from the oscilloscope and calculated the average values of frequency, signal voltage, and cable output voltage for the nine measurements. It also calculated the error for these quantities, in the form of standard deviation. All of these values were output to a data file.

- NOTE: All voltages are in RMS. To get maximum voltages the values can be multiplied by $\sqrt{2}$, and to get peak-to-peak voltages the RMS voltages can be multiplied by $2\sqrt{2}$.

The data file now contained signal and cable output data for each of the frequencies of interest. See Appendix A: Results.

1.1.1 Cable Attenuation Analysis

The data gathered for cable attenuation was analyzed as follows:

1. The percentage of the input signal that appeared as output for various input frequencies was plotted. See Figure 4. Important features of this plot include a maxima in the percentage of the signal that is output around 30MHz, and a minima around 40MHz, after which the data becomes unreliable (the signal appears to be amplified).

2. For comparison purposes the attenuation for a single RG174 cable with BNC ends was also measured. The length of the cable used was 2.98m (as compared to 3.04m in the cable assemblies). See Figure 5. This plot shows a minima in the percentage of input signal output at approximately 25MHz, and a maxima at approximately 40MHz, after which the percentage drops off significantly.

Figure 4: Output as a Percentage of Input Voltage vs. Input Frequency for 1.0 V signal in a Cable Assembly

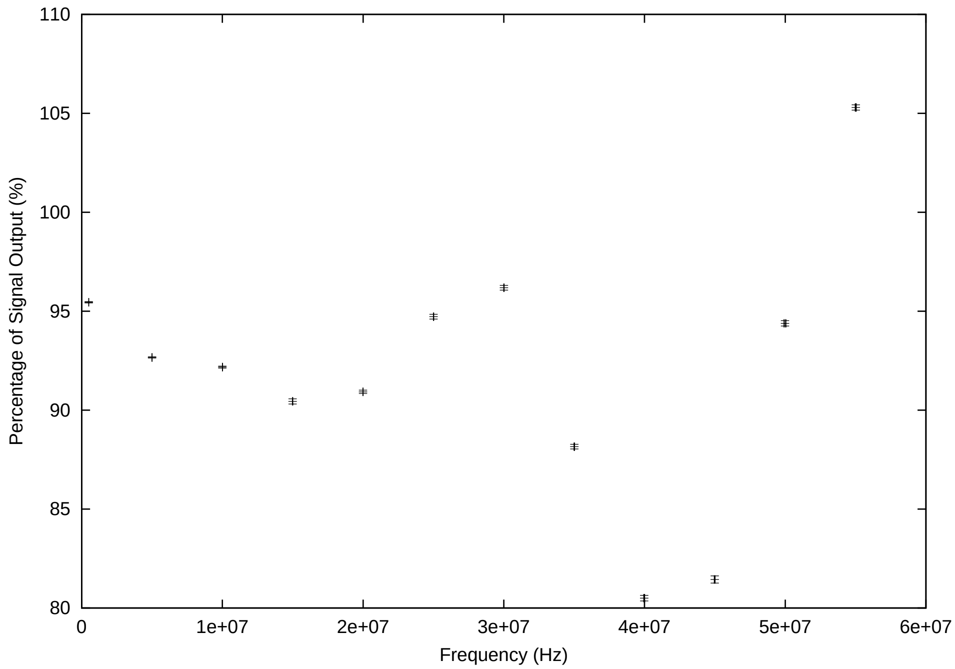
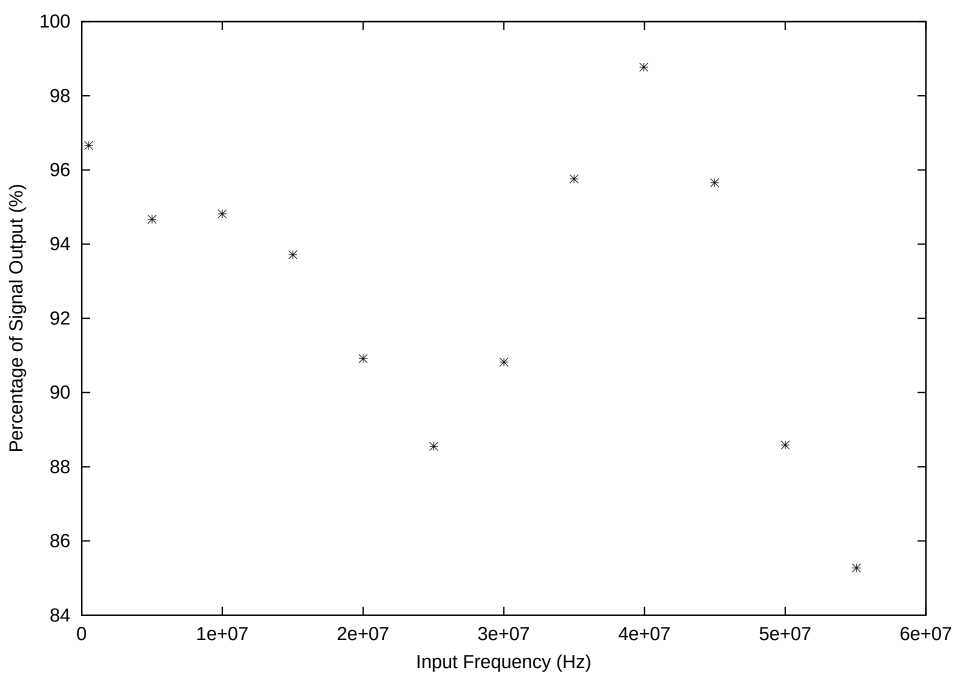


Figure 5: RG 174: Output as a Percentage of Input Voltage vs.Input Frequency for 1.0 V signal for RG174 Cable



1.2 Cable Cross-talk

The main concern for the facilitation of cross-talk was the exposed copper wires soldered to the pins of the socket connector of the cable. These wires are the exposed core of the RG174 cable with the dielectric, the ground braid, and the insulation removed. Since the concern was signal being present in neighboring exposed wires, cross-talk was measured in the channels directly beside the one carrying the signal. The following parts and components were used for the cable assembly cross-talk testing:

- RG174 Cable Assembly for CAEN 792AA QDC
- Tektronix TDS 210 2-Channel real-time digital oscilloscope
- FLUKE 6080A Synthesized RF Signal Generator (10kHz - 1056MHz)
- 2 BNC t-junctions
- 2 50Ω BNC terminators
- 50Ω resistor or 2-pin channel terminator
- A PC with the program ScopeMe

The components were connected as follows:

- Like for the cable attenuation testing setup, a BNC end RG174 cable was used to connect the signal from the generator, and the channel being tested on the cable to channel 2 of the oscilloscope. Channel 1 was connected to a 50Ω terminatotr and to the probe cable (as discussed in the cable attenuation testing).
- The probe cable was inserted into the channel of the socket connector that corresponds to the neighboring channel to the signal and a 50Ω resistor was inserted into the channel carrying the signal. Thus, the signal should travel through the cable and into the resistor, eliminating any reflection at this point. The probe should pick up any cross-talk in the neighboring pins. To remove any reflection in the cross-talk cable, a 50Ω terminator is placed on its BNC end. See Figure 7.
- Note that a custom 2-pin channel terminator was created to replace the need for a 50Ω resistor, as repeated use of the resistors left the wire ends bent and somewhat strippped. The custom terminators consisted of a surface mount resistor soldered onto a socket connector with pins on both sides. See Figure 6.

Figure 6: Custom Terminator

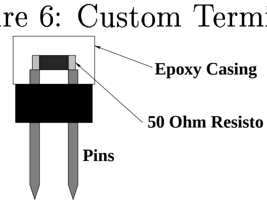
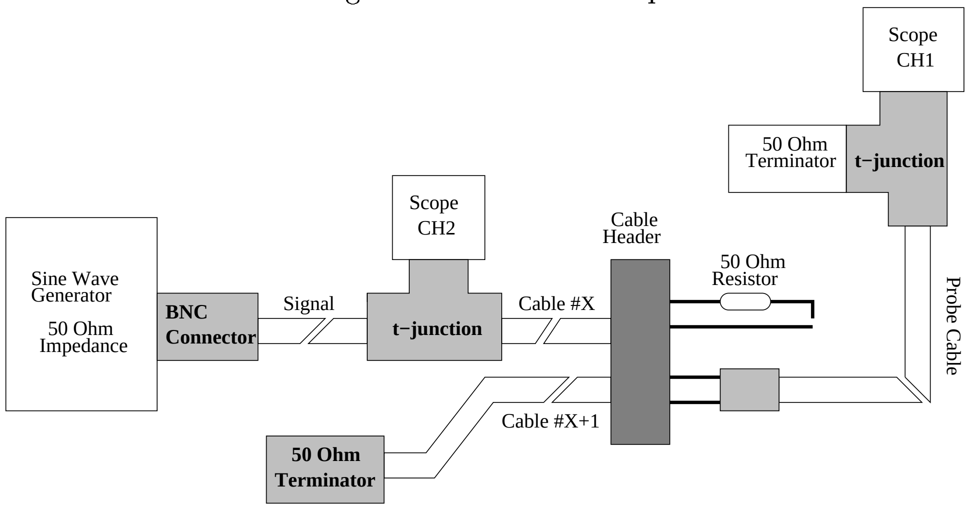


Figure 7: cross-talk setup



1.2.1 Cable Cross-talk vs. Voltage

To find the dependence of cross-talk on the input voltage, the cross-talk was measured at various voltages for a given input frequency. With the frequency maintained at a chosen value, the voltage on the generator was varied from 0.5V to 2.0V in approximately 0.5V increments, and data was collected using the program ScopeMe. The data for each voltage was taken as follows:

- With the voltage and frequency set to the desired values and the components connected as described above, two signals were displayed on the oscilloscope. Channel 2 was the signal directly from the signal generator, and Channel 1 was the cross-talk signal. The waveforms were viewed on the oscilloscope. Note that different scales will be needed for the channels to view meaningful waveforms.
- Using ScopeMe nine data measurements were made (3 assemblies * 3 cables each = 9 tests). ScopeMe input the waveform data from the oscilloscope and calculated the average values of frequency, signal voltage, and cable output voltage for the nine measurements. It also calculated the error in these quantities, in the form of standard deviation. All of these values were output to a data file.
- NOTE: All voltages are in RMS. To get maximum voltages the values can be multiplied by $\sqrt{2}$, and to get peak-to-peak voltages the RMS voltages can be multiplied by $2\sqrt{2}$.

The data file now contained signal and cable output data for each of the voltages of interest for the given frequency. This was repeated for 20MHz, 30MHz and 40MHz signals. See Appendix A: Results.

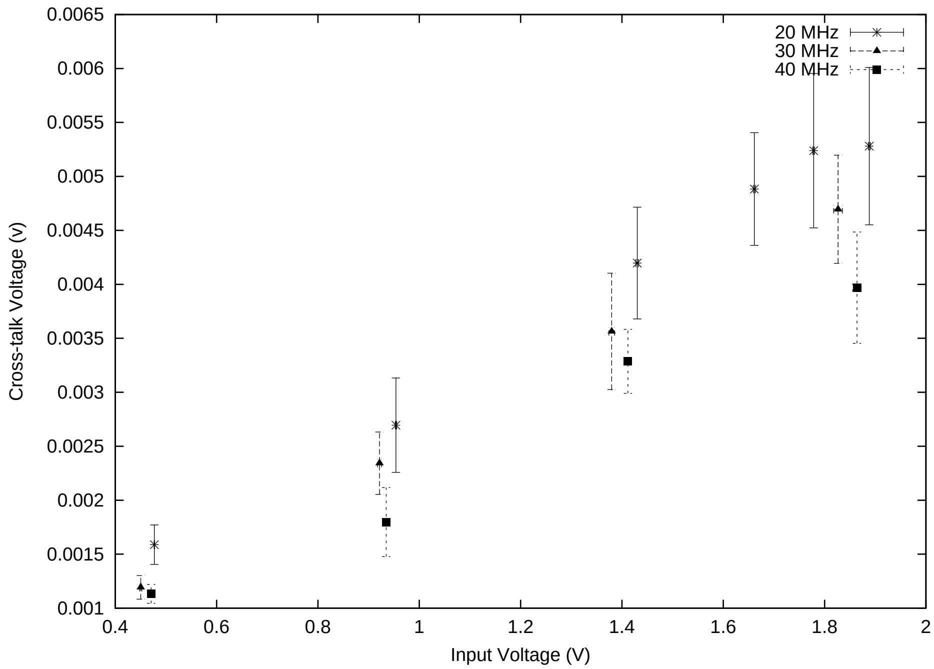
1.2.2 Cable Cross-talk vs. Voltage Analysis

The data gathered for cross-talk with respect to input voltage was analyzed as follows:

1. Input voltage was plotted against the cross-talk voltage data for the various frequencies. See Figure 8. The result was an approximately linear relationship between the voltage of

the signal put into the cable, and the cross-talk voltage present in neighboring channels. The slope of this relationship was dependent on input frequency.

Figure 8: Cable Assembly Cross-talk vs. Voltage for Various Frequencies



2. The percentage of the input voltage that appeared as cross talk was plotted against the input voltage. See Figure 9. This was done for three frequencies of interest, 20MHz, 30MHz and 40MHz. Within error, the percentage of the input signal that appeared as cross-talk stayed constant for all measured voltages with each frequency.

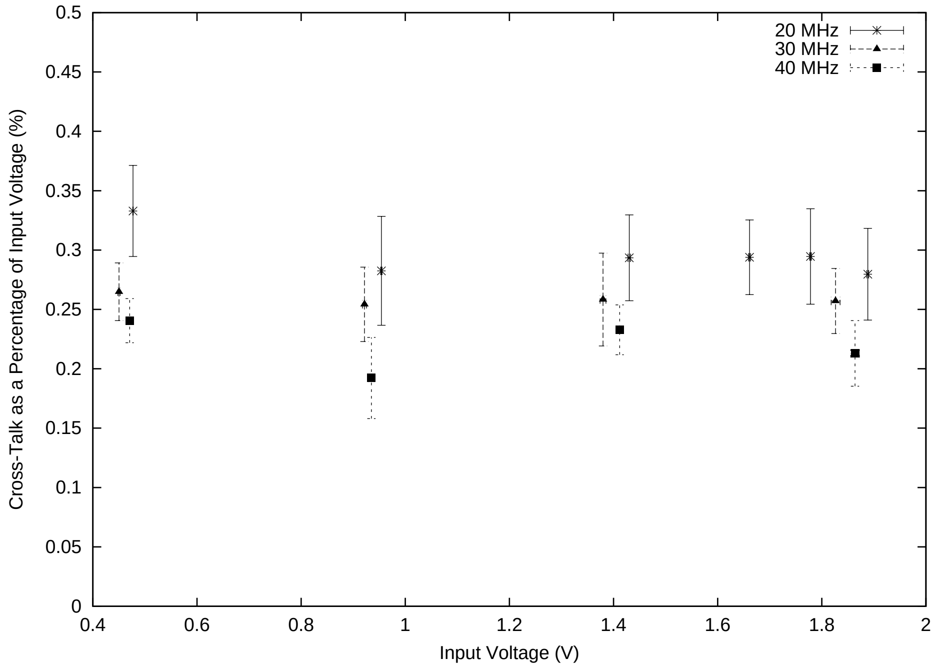
1.2.3 Cable Cross-talk vs. Frequency

To investigate the dependence of cross-talk on input frequency, the cross-talk was measured at various frequencies for an input of approximately 1.0V. With the input voltage maintained at 1V, the frequency was varied from 5kHz to 50MHz in 5MHz increments, and data was collected using the program ScopeMe. The data for each frequency was taken as follows:

- With the voltage and frequency set to the desired values and the components connected as described above, two signals were displayed on the oscilloscope. Channel 2 was the signal directly from the signal generator, and Channel 1 was the cross-talk signal. The waveforms were viewed on the oscilloscope.

- Using ScopeMe nine data measurements were made (3 assemblies * 3 cables each = 9 tests). ScopeMe input the waveform data from the oscilloscope and calculated the average values of frequency, input voltage, and cable output voltage for the nine measurements. It also calculated the error for these quantities, in the form of standard deviation. All of these values were output to a data file.

Figure 9: Cross-talk as a Percentage of Input Voltage vs. Input Voltage for Various Frequencies



The data file now contained signal and cable output data for each of the frequencies of interest for the given voltage. See Appendix A: Results.

1.2.4 Cable Cross-talk vs. Frequency Analysis

The data gathered for cross-talk with respect to input frequency was analyzed as follows:

1. The cross-talk was plotted as a percentage of input voltage with respect to frequency. See Figure 10. The peak remains at 25-30MHz, and the minima at 40MHz.

2. Since the cross-talk itself may be affected by attenuation, the ratio of cross-talk to attenuated output voltage was examined. This was done by plotting the cross-talk as a percentage of the attenuated output voltage for various frequencies. Important features of this plot include maxima at 25-30MHz and 45MHz, and a minima at approximately 40MHz. At frequencies above 50MHz the cross-talk appears to drop off significantly. See Figure 11.

Figure 10: Cross-talk as a Percentage of Input Voltage vs. Input Frequency for Cables

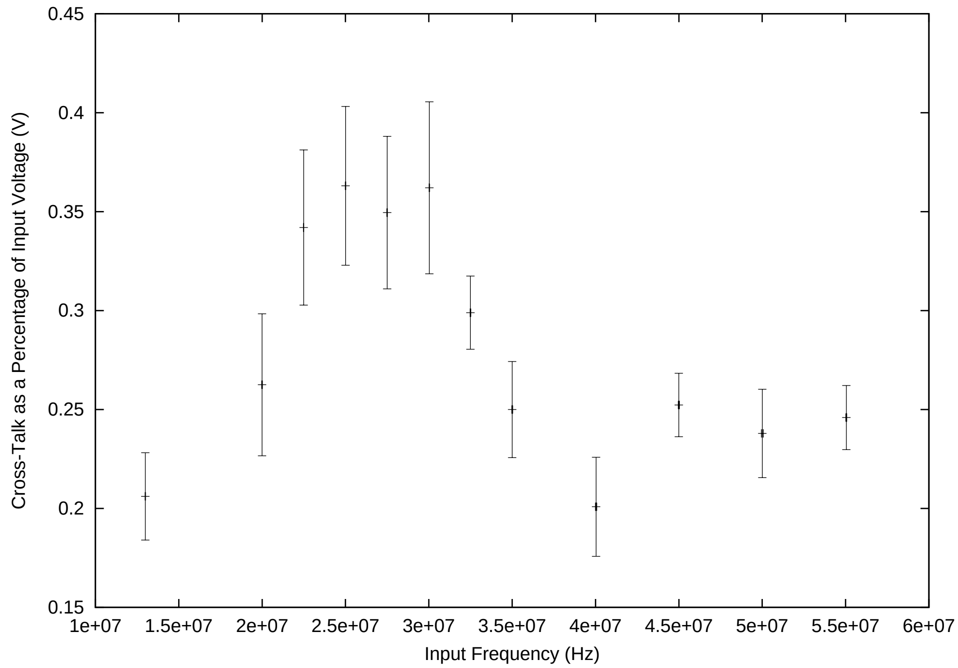
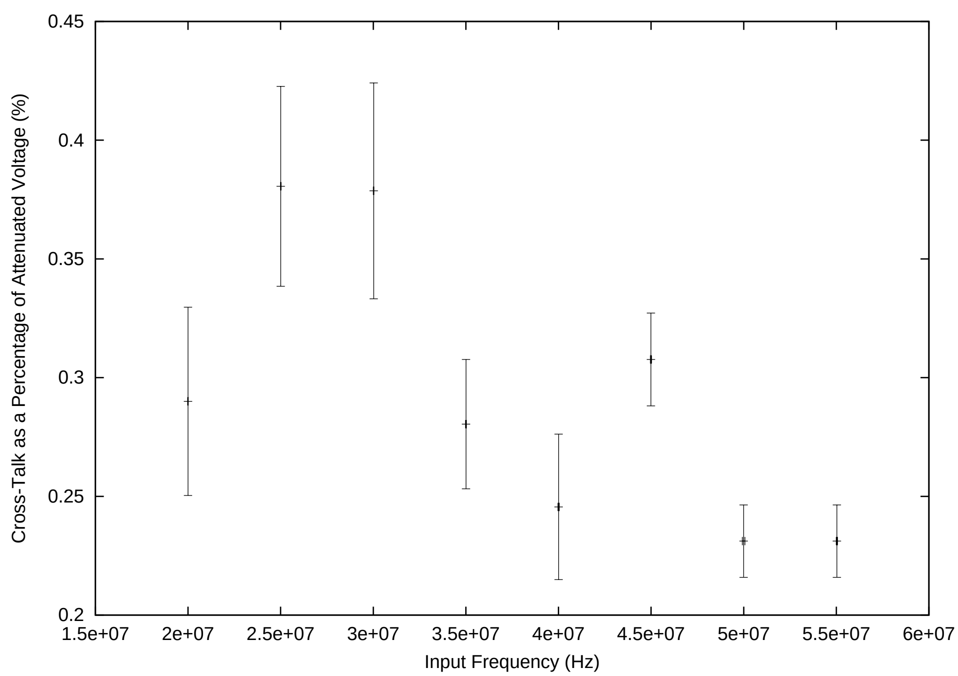


Figure 11: Cross-talk as a Percentage of Attenuated Output Voltage vs. Input Frequency for Cables



2 Measuring the Length of the Cables

In this section, we will use the digital oscilloscope to measure the length of the cables. The length in meters is not important. That length should be about 3m. It is the time that it takes for a pulse to travel down the cable that is important. Luckily, the scope makes this measurement quite simple.

All sixteen cables from the ten assemblies created in the first batch were measured.

2.1 A Quick Calculation

The speed of light in a vacuum can be computed by

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} \tag{1}$$

where ϵ_0 is the permitivity of free space and μ_0 is the permeability of free space. If we are in a dielectric of permitivity $\epsilon = \epsilon_r \epsilon_0$ then the speed of the electromagnetic radiation is

$$v = \frac{1}{\sqrt{\epsilon \mu_0}} = \frac{c}{\sqrt{\epsilon_r}}. \tag{2}$$

Thus, a signal sent down a coaxial cable with permitivity ϵ will travel at speed v. (Ref. [3])

Let us do a quick calculation to ensure that our measured answers are reasonable. As suggested in Ref. [3] a coaxial cable may have a Teflon dielectric with permitivity approximately $\epsilon \approx 2\epsilon_0$. Thus, $v \approx 2 \times 10^8\mathrm{m/s}$. If the cable has length of $L \approx 3m$ then we can compute the amount of time it takes for a pulse to travel down the cable by

$$t = \frac{L}{v} \approx \frac{3\mathrm{m}}{2 \times 10^8\mathrm{m/s}} = 15\mathrm{ns}. \tag{3}$$

We expect that the pulse will take approximately 15ns to travel down the cable.

2.2 Setting up the Scope

This procedure used a BNC Model 8010 pulse generator and a Tektronix TDS 210 digital oscilloscope. Connect the trigger from TRIG OUT of the pulse generator to EXT TRIG on the scope. A t-junction and terminator will be needed as in figure 12.

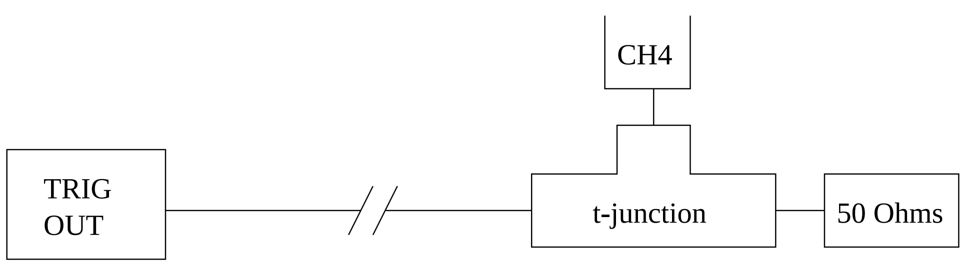


Figure 12: Connecting the trigger.

To connect the signal output, connect 5V MAX from the pulse generator to a 50Ω coaxial cable. Connect the other end of this cable to a t-junction and connect that junction to CH2 on the scope and the test cable. Connect the probe to a t-junction and terminator. Connect the probe's t-junction to CH1 on the scope. Now, connect the probe to the ribbon-cable end of the cable to be tested. See figure 13.

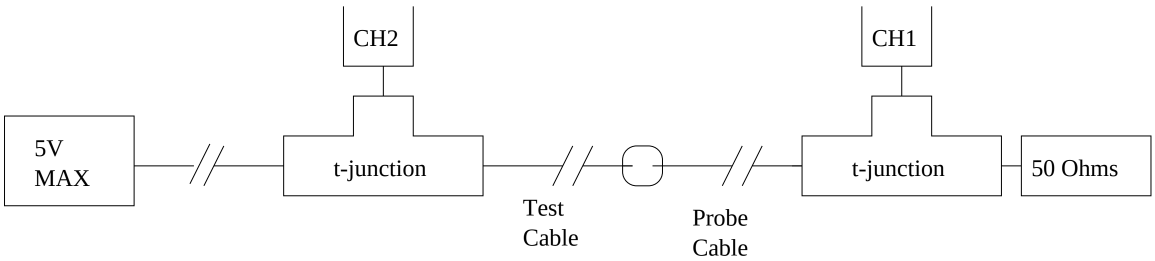


Figure 13: Connecting the signal.

Set the pulse generator so that is emits a short pulse. Settings used were:

- FREQ = 100kHz
- DELAY =30ns (as small as possible)
- WIDTH = 30ns (as small as possible)
- AMPL 4.10 V (NOTE: Not RMS)

The pulse generator used was a bit flaky so there may be been a difference between the settings and what was actually outputted. Figure 14 shows what was observed on the oscilloscope. Also, the cursors were set to time to get an idea of what the computer should measure for the time it takes for the pulse to travel down the cable.

2.3 Programming the Computer

The following algorithm was added to the ScopeMe software to compute the time it takes for a pulse to travel down the test cable and probe.

1. Get the waveform data from the scope.
2. Compute the average value of each pulse. Recall that a pulse is attenuated by the cable so the average value on channel 1 will be less than channel 2.
3. Find t_1 and t_2 which are defined as the first time the pulse reaches its average voltage for channels 1 and 2 respectively.
4. Compute $|t_2 - t_1|$ and use this as the amount of time it took the pulse to travel down the cable.
5. Write this information to the disk using three columns. The three columns are the assembly number, the cable number and the time computed in the previous step.

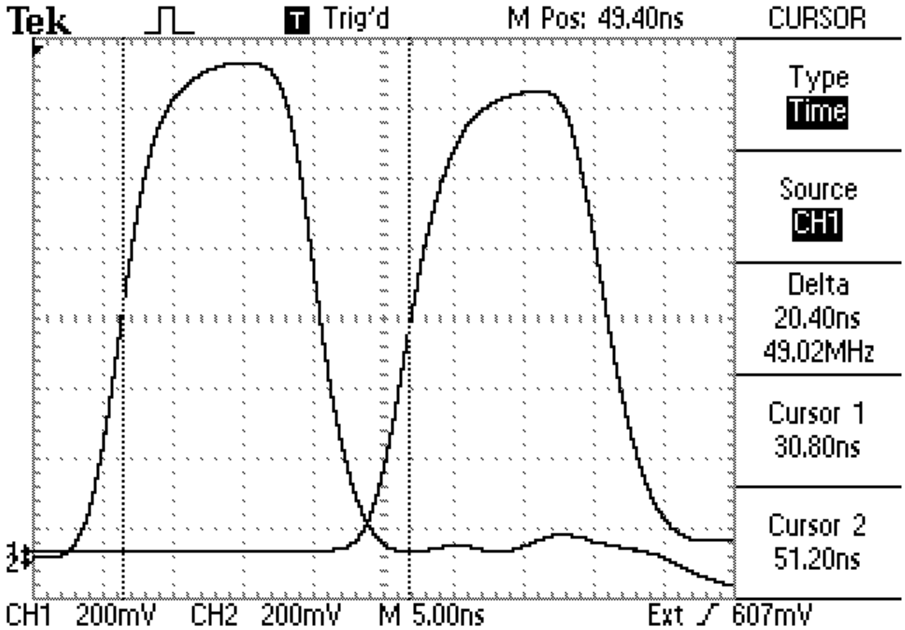


Figure 14: Hardcopy output from the oscilloscope.

6. Repeat for all cables.

For these measurements, the scope was set to 5ns/div, with 10 divisions. Thus, the scope displayed 50ns worth of data using 250 pixels. Each pixel on the scope was 0.2ns. However, the scope returned 2500 data-points to the computer. Thus, each data-point represented 0.02ns. In section 2.5 the resolution of the above method will be further discussed.

2.4 Measuring the Cable and Probe

Figure 15 shows the results of measuring the propagation time for the cables. The mean time is 20.364ns with a standard deviation of 0.032ns. First one should note that all but one of the measurements fell within a 0.2ns interval from 20.25ns to 20.45ns. Upon remeasuring the one outcast point, which corresponds to cable 3 of assembly 9, an average time of 20.267ns was recorded given three measurements. Thus, even cable3 of assembly 9 appears to be in the 0.2ns interval.

Since a pixel has width 20ns, the difference between these points was not resolvable on the scope display. Now the resolution of the above technique must be studied to find out if using the computer has increased the resolution or if the variation in time is simply due to a lack of resolution by the scope.

2.5 The Resolution of the Method

For this section, cable 8 of assembly 10 was tested 16 times as described in section 2.3. The results are displayed in figure 16. Looking at figure 16 we see that the measurements for a single

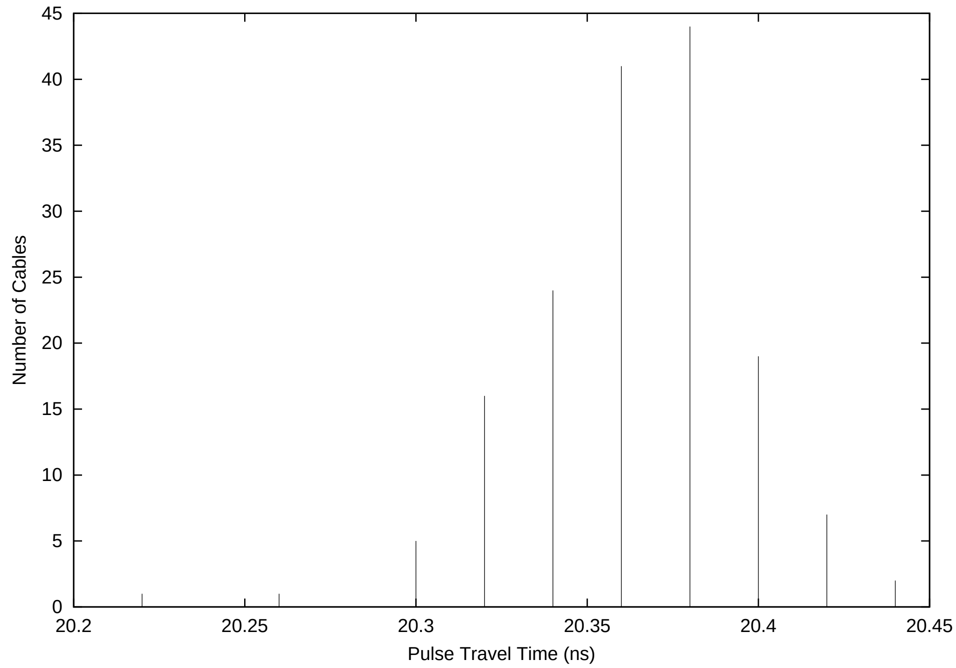


Figure 15: The distribution of the 16 propagation time measurements for the probe.

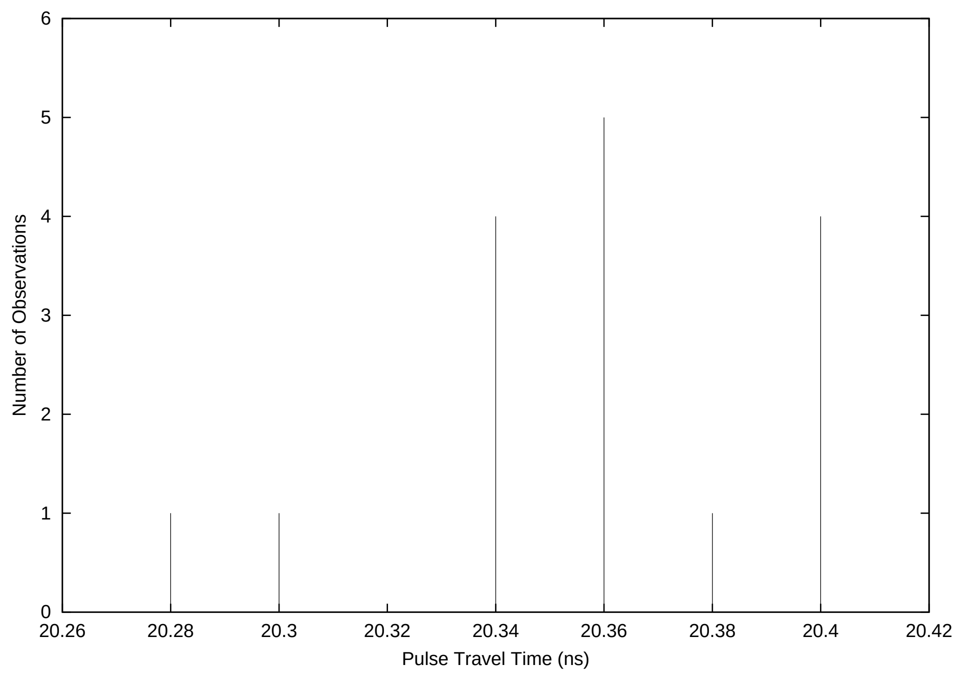


Figure 16: The distribution of propagation times through the cable-probe setup for the first ten assemblies.

cable tends to drift back and forth. This suggests that the resolution is not 0.02ns, but rather on the order of 0.2ns.

While it is unknown exactly why, there is a reasonable hypothesis. The scope displays only 250 of the 2500 data-points that it sends to the computer. For those other 2250 data-points, are they measured or interpolated? It is unknown whether the scope measured all 2500 data-points or whether it measures 250 and interpolates the other 2250. If it does indeed interpolate the 2250 data-points, that would help explain why the measurements of a single cable drifts back and forth.

2.6 Measuring the Probe Alone

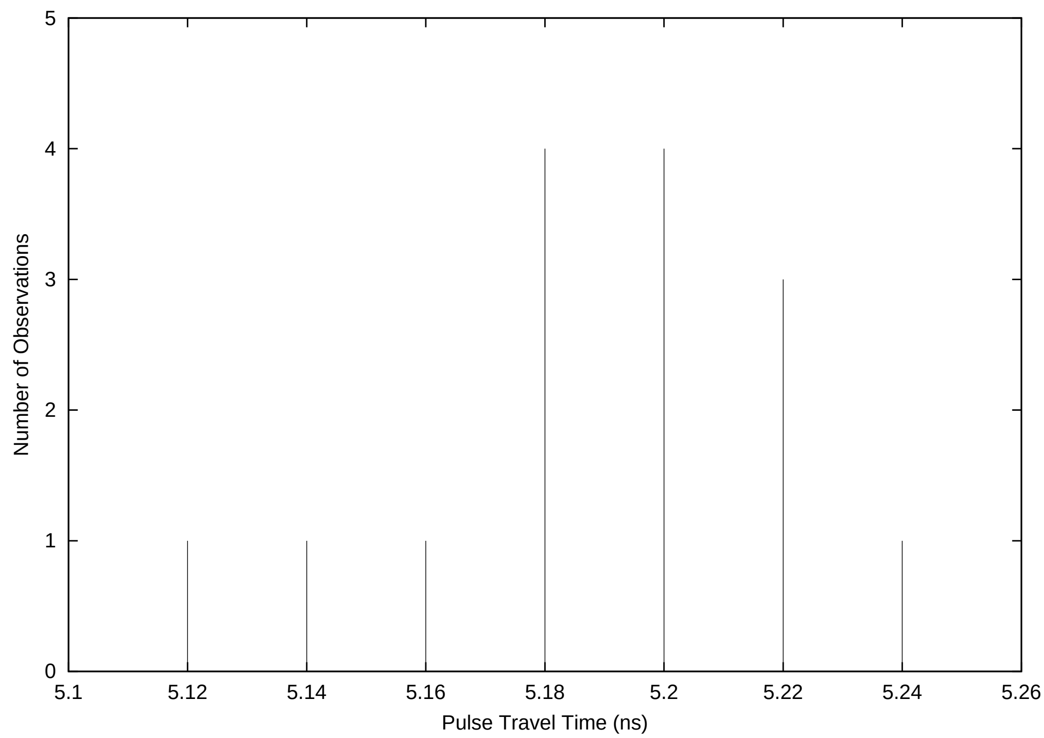


Figure 17: The distribution of the 16 propagation time measurements for the probe.

To find an estimate for the length of the cables, we need an estimate for how long the probe is. The measurements should be expected to vary since connecting the probe to the coaxial connector was mechanically difficult. One prong had to touch the inner conductor while the other touched the ground. Despite this limitation, figure 17 shows that all measurements came between 5.12ns and 5.24ns with a mean of 5.194ns.

Now, to compute the average length of the cables, take the combined time of 20.364ns measured in section 2.4 and the probe propagation time of 5.194ns. Subtracting give a length of 15.170ns. This is quite close to our rough estimate of 15ns calculated in section 2.1. Rounding this to 2 decimal places gives 15.17ns.

2.7 Conclusion

The average propagation time of the cables was measured to be 15.17ns. The technique used in determining the time was only able to accurately resolve to 0.2ns. The measured distribution of times falls within 0.2ns so we do not know how individual cables vary with time. However, since the spread is only over 0.2ns, the actual distribution is likely unimportant.

3 Splitter Testing

In testing the splitters it is important to note that the RG174 cables tested above were used to connect the splitters to the signal. Thus, all of the effects outlined above (cross-talk and attenuation) were present before the splitters received the signal. Since the splitters can and will only be used in conjunction with these cables, it is not important to test them independently.

3.1 Splitter Attenuation

For the splitter attenuation testing, three splitters were chosen from the 14 completed, and on each of these splitters, a set of channels were randomly chosen on each socket connector of the splitter for the testing. The chosen splitters and channels are outlined in the following table:

Splitter No.	Channels	
	Header 1	Header 2
2	2	2
14	14	14
3	8	8

In measuring the attenuation that occurs in the splitter the output of the signal after it goes through the cable and the splitter was compared to the original input signal. The attenuation was measured for various frequencies for an input signal of approximately 1V. The following parts and components were used for the splitter attenuation testing:

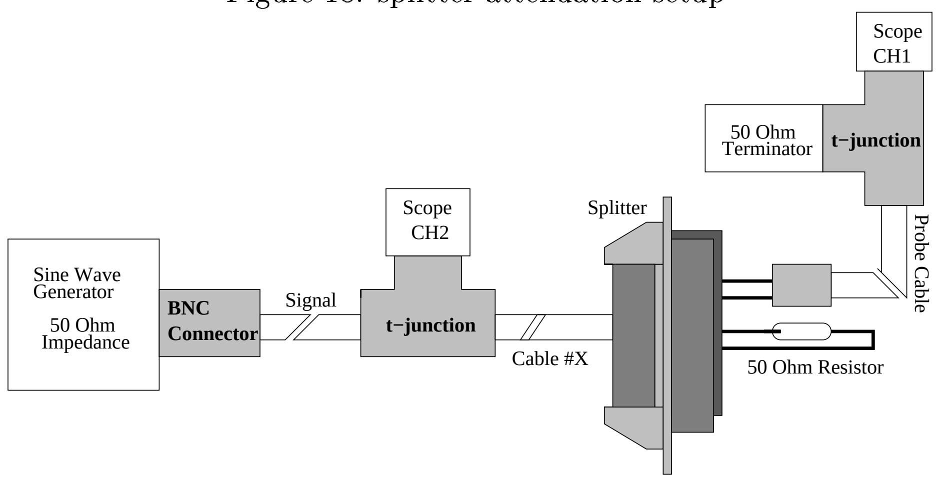
- RG174 Cable Assembly for CAEN 792AA QDC
- Passive Analog Splitter for use with CAEN792AA QDC
- Tektronix TDS 210 2-Channel real-time digital oscilloscope
- FLUKE 6080A Synthesized RF Signal Generator (10kHz - 1056MHz)
- 2 BNC t-junctions
- 50Ω BNC terminator
- 3 50Ω resistors
- A PC with the program ScopeMe

The components listed above were connected as follows:

- A BNC-end RG174 cable was used to connect the output of the signal generator to one of the t-junctions. This t-junction was connected to both the a BNC end of the cable being tested and to channel 2 of the oscilloscope. See Figure 1.
- Channel 1 of the oscilloscope was connected to the other t-junction, with one output carrying a 50Ω terminator, and the other the probe cable (same as used for cable testing). See Figure 2.

- The probe cable was inserted into the socket connectors on the splitter carrying the signal from the generator. A 50Ω terminating resistor was inserted into the other socket connector, in the same channel. This resistor ensures proper impedance matching. Thus, the signal should travel through the cable, be split in half, and travel into the probe, which was connected to the oscilloscope. See Figure 18.

Figure 18: splitter attenuation setup



With the voltage maintained at 1V, the frequency on the generator was varied from 5kHz to 50MHz in 5MHz increments, and data was collected using the program ScopeMe. The data for each frequency was taken as follows:

- With the voltage and frequency set to the desired values and the components connected as described above, two signals were displayed on the oscilloscope. Channel 2 was the signal directly from the signal generator, and channel 1 was the signal after traveling through the cable assembly and the splitter. The waveforms were very similar in shape but had to be viewed on different scales on the oscilloscope, as the splitter divides the signal into two parts, half of the original signal going to each socket connector output.

- Using the ScopeMe program six data measurements were made (3 splitters * 1 channel * 2 socket connectors = 6 tests). ScopeMe input the waveform data from the oscilloscope and calculated and output (to the data file) the average values of frequency, signal voltage, and splitter output voltage for the six measurements, as well as their error (standard deviation).

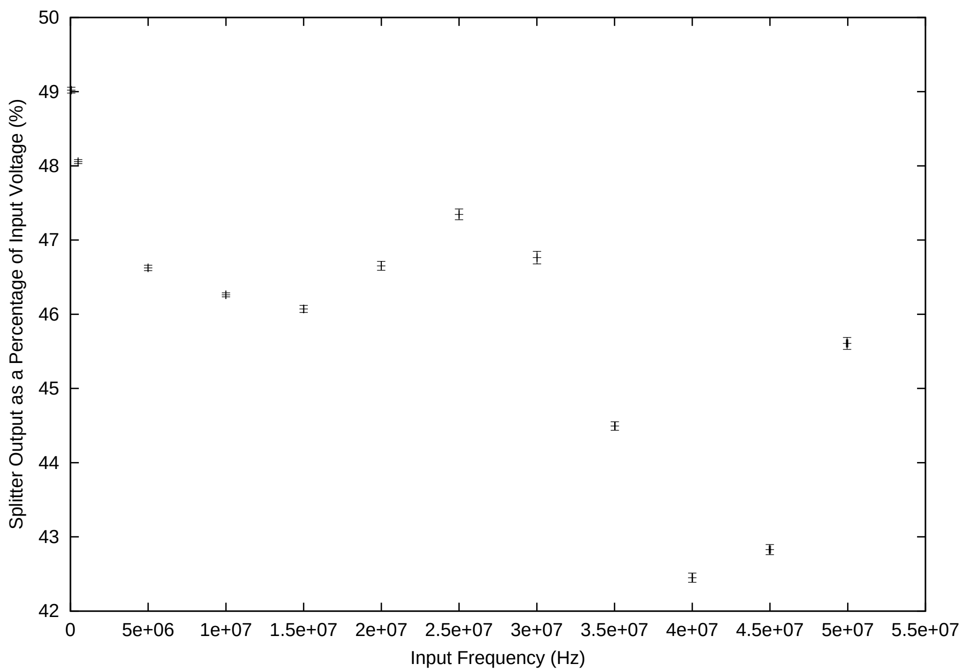
- NOTE: All voltages are in RMS. To get maximum voltages the values can be multiplied by $\sqrt{2}$, and to get peak-to-peak voltages the RMS voltages can be multiplied by $2\sqrt{2}$.

The data file now contained data for each of the frequencies of interest. See Appendix A: Results.

3.1.1 Splitter Attenuation Analysis

In analysis of the splitter attenuation data, it is important to note that the function of the splitter is to split the input signal in half. Thus, the output of the splitter should ideally be 1/2 the input voltage. The data gathered for splitter attenuation was analyzed as follows: The percentage of the signal that appeared out of the splitter for various input frequencies was plotted. See Figure 19. Note that an ideal, non-atteunated output would be 50%. Much like Figure 14, this plot identifies a maximum around 25MHz and a minimum around 40MHz, with the highest values occurring at frequencies less than 1MHz.

Figure 19: Output as a Percentage of Input Voltage vs. Input Frequency for 1.0 V signal



3.2 Splitter Cross-talk

The main concern for the facilitation of cross-talk was the exposed solder and pins on the surface of the splitter. Since the concern was signal "leaking out" to neighboring exposed solder and pins, cross-talk was measured in the channels directly beside the channel carrying the signal, and compared to the input, with varying voltage and varying frequency.

For the splitter cross-talk testing, three splitters were randomly chosen from the 14 completed, and on each of these splitters, a set of channels were chosen on each socket connector of the splitter for the testing. The chosen splitters and channels are outlined in the following table:

Splitter No.	Channels		Signal Channel
	Header 1	Header 2	
2	7	9	8
14	7	9	8
3	7	9	8

To measure the cross-talk that occurs in the splitter the amount of signal in the channel neighboring the signal-carrying channel was compared to the signal itself. The following parts and components were used for the splitter cross-talk testing:

- RG174 Cable Assembly for CAEN 792AA QDC
- Passive Analog Splitter for CAEN 792AA QDC
- Tektronix TDS 210 2-Channel real-time digital oscilloscope
- FLUKE 6080A Synthesized RF Signal Generator (10kHz - 1056MHz)
- 2 BNC t-junctions
- 2 50Ω BNC terminators
- 3 50Ω resistors
- A PC with the program ScopeMe

The components were connected as follows:

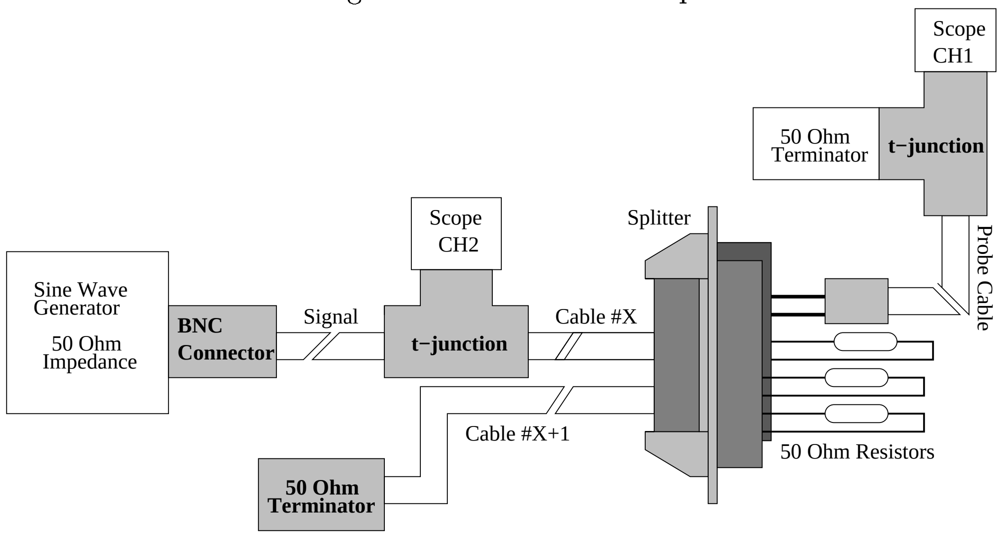
- A BNC-end RG174 cable was used to connect the output of the signal generator to one of the t-junctions. This t-junction was connected to both the BNC end of the cable being tested and to channel 2 of the oscilloscope. See Figure 1.
- Channel 1 of the oscilloscope was connected to the other t-junction, with one output carrying a 50Ω terminator, and the other the probe cable. See Figure 2.
- The probe cable was inserted into the channel of the socket connector that corresponds to the neighbor of the channel carrying the signal from the generator. The 50Ω resistor was inserted into the channel of the socket connector that corresponded to the BNC end carrying the signal. The other two 50Ω resistors were placed in the corresponding channels on the other socket connector on the splitter, to prevent reflections due to an impedance mismatch. To remove any reflection in the cross-talk cable from the cable assembly, a 50Ω terminator is placed on its BNC end. The signal should travel through the cable and into the resistor, eliminating any reflection at this point. The probe should pick up any cross-talk in the neighboring pins. See Figure 20.

3.2.1 Splitter Cross-talk vs. Voltage

To find the dependence of cross-talk on input voltage, cross-talk was measured for varying voltages. With the frequency maintained at a chosen value, the voltage on the generator was varied from 0.5V to 2.0V, and data was collected using ScopeMe as follows:

- With the voltage and frequency set to the desired values and the components connected as described above, two signals were displayed on the oscilloscope. Channel 2 was the signal directly from the signal generator, and Channel 1 was the cross-talk signal.
- Using ScopeMe six data measurements were made (3 splitters * 1 channel * 2 socket connectors = 6 tests). ScopeMe input the waveform data from the oscilloscope and calculated the average values of frequency, signal voltage, and splitter output voltage for the six measurements, and the standard deviation. All of these values were output to a file, see Appendix A: Results.

Figure 20: Cross-talk Setup



3.2.2 Splitter Cross-talk vs. Voltage Analysis

The data gathered for cross-talk with respect to input voltage was analyzed as follows:

1. The input voltage was plotted against cross-talk voltage for the various frequencies. The result is a linear relationship, the slope changing with input frequency. See Figure 21.

2. The input voltage was also plotted against the percentage of the input voltage that appeared as cross talk. The results appear to be approximately linear. See Figure 22.

3.2.3 Splitter Cross-talk vs. Frequency

To find the dependence of cross-talk on input frequency, the cross-talk was measured at various frequencies for an input of approximately 1.0V. With the voltage maintained at 1V, the frequency on the generator was varied from 5kHz to 50MHz in 5MHz increments, and data was collected using the program ScopeMe. The data for each frequency was taken as follows:

- With the voltage and frequency set to the desired values and the components connected as described above, two signals were displayed on the oscilloscope. Channel 2 was the signal directly from the signal generator, and Channel 1 was the cross-talk signal. The waveforms were viewed on the oscilloscope. Note that different scales will be needed for the channels to view meaningful waveforms.

- Using ScopeMe six data measurements were made (3 splitters * 1 channel * 2 socket connectors = 6 tests). ScopeMe input the waveform data from the oscilloscope and calculated the average values of frequency, signal voltage, and splitter output voltage for the six measurements. It also calculated the error for these quantities, in the form of standard deviation. All of these values were output to a data file, see Appendix A: Results.

Figure 21: Splitter Cross-talk vs. Voltage for Various Frequencies

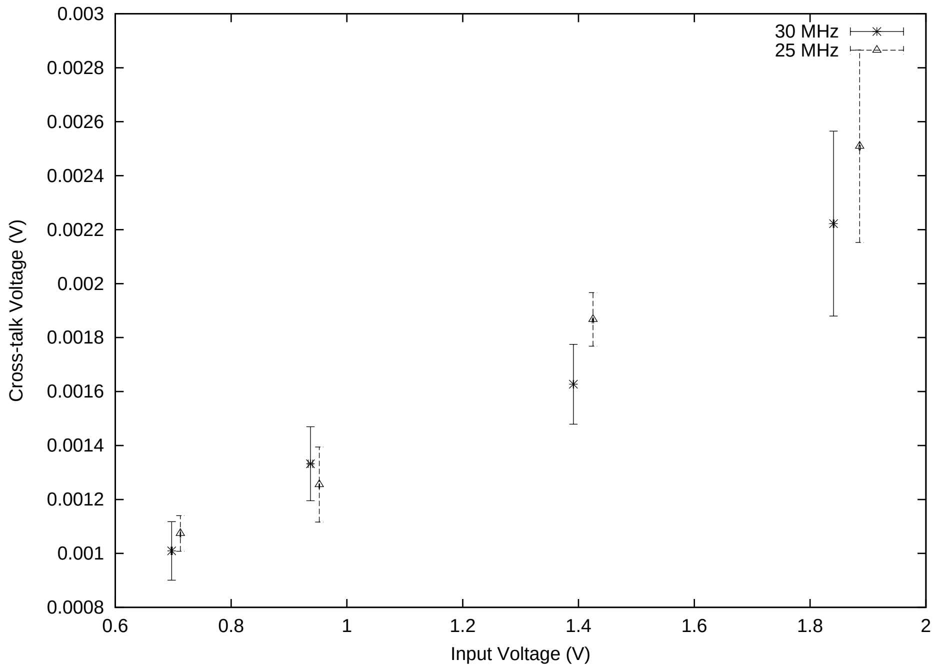
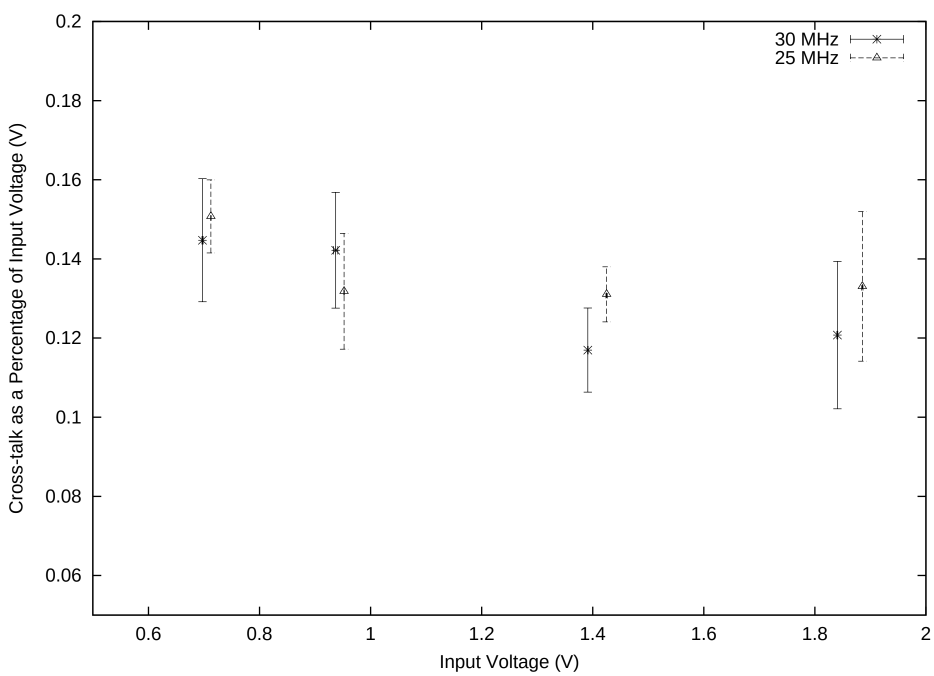


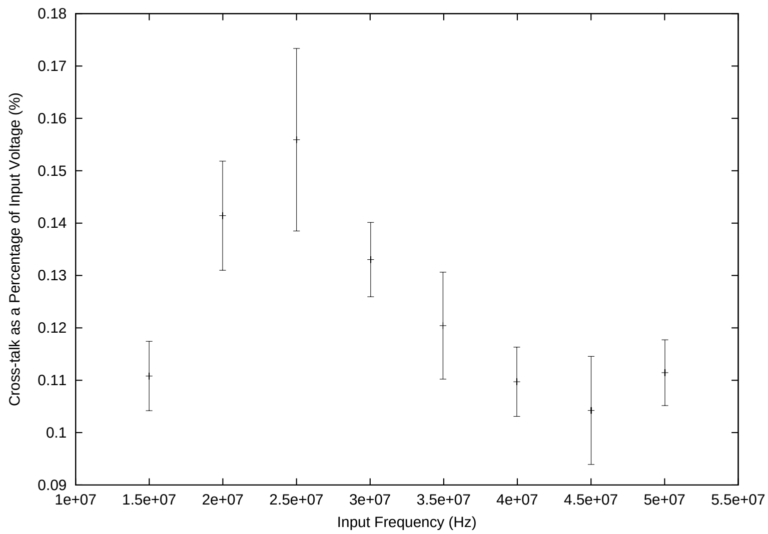
Figure 22: Cross-talk as a Percentage of Input Voltage vs. Input Voltage for Various Frequencies for Splitters



3.2.4 Splitter Cross-talk vs. Frequency Analysis

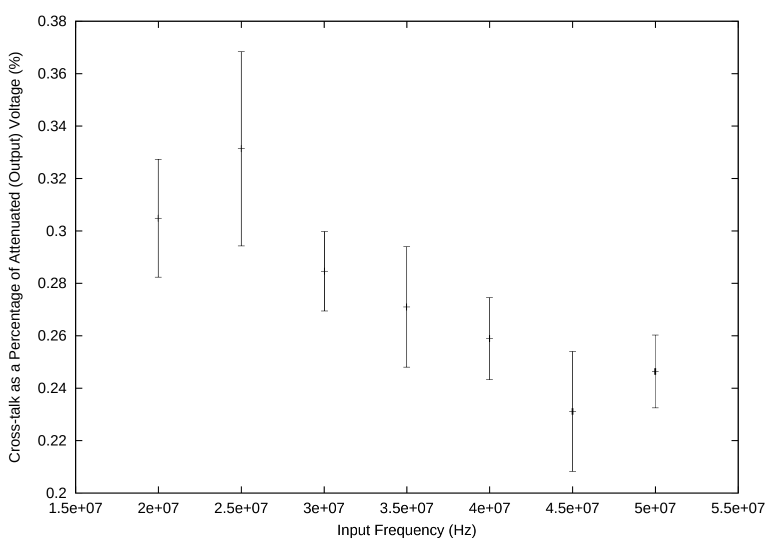
Cross-talk was plotted as a percentage of input voltage vs. frequency. This plot has a maximum at about 25MHz and a minimum at about 45MHz. See Figure 23.

Figure 23: Cross-talk as a Percentage of Input Voltage vs. Input Frequency for Splitters



Cross-talk was plotted as a percentage of the attenuated output voltage for various frequencies. See Figure 24. Important features of this plot include a maximum in the cross-talk percentage of approximately 25MHz that lowers to a minimum at approximately 45MHz.

Figure 24: Cross-talk as a Percentage of Attenuated Output Voltage vs. Input Frequency for Splitters



4 Conclusions

4.1 Cable Assembly Conclusions

The following conclusions can be drawn from the testing done on the cable assemblies:

- The attenuation of the signal by a cable assembly is frequency dependant. For the frequencies up to 40MHz the output appears between $\sim 80\%$ and $\sim 96\%$. Minimum attenuation appears at 30MHz and maximum attenuation appears at 40MHz.
- Since the attenuation distribution of the cable assembly differs from that of an ordinary RG174 cable, it can be inferred that the attenuation occurs both in the cable itself and in the header end of the cable assembly.
- The amount of cross-talk voltage present in a cable assembly is dependant on the input frequency and the input voltage. Cross talk appears to be linearly related to input voltage. The distribution of cross-talk with respect to frequency contains a peak between 25-30MHz.
- Cross-talk was typically less than 0.5% of the input voltage for the frequencies measured.
- The average propogation time of the cables was measured to be 15.17ns, resolved to 0.2ns with the technique used.

4.2 Splitter Conclusions

The following conclusions can be drawn from the testing done on the splitters:

- The attenuation of the signal by a splitter is frequency dependant. For frequencies up to 40MHz the output appears between ~42% and ~49% of the original signal (ideally it would be 50% due to the nature of the splitter). Minimum attenuation appears around 25MHz and maxium attenuation appears around 40MHz.
- The attenuation of the signal is unable to be measured in the splitter alone, it was only measured with a cable assembly attached. The distribution of the attenuation is similar to that of the cable alone, but it is not exact, so it is possible to infer that some attenuation occurs in the splitter itself.
- The amount of cross-talk voltage present in a splitter is dependant on the input frequency and the input voltage. Cross talk appears to be linearly related to inptu voltage. The distribution of cross-talk with respect to frequency contains a peak between 25-30MHz.
- Cross-talk was typically less than 0.2% of the input voltage and less than 0.4% of the attenuated output voltage for the frequencies measured.

4.3 Recommendations

The following recommendations could be made to reduce the cross-talk and attenuation effects:

- Connections could be arranged such that adjacent cells are not on adjacent lines.

References

[1] Wurtz, Ward *et. al.*, *U of S RG174 Cable Assembly for CAEN 792AA QDC*,(2003).

[2] Robb, Jennifer *et. al.*, *U of S Passive Analog Splitters for use with CAEN 792AA VME QDC*,(2003).

[3] Hirose, Akira and Longren, Karl *Introduction to Wave Phenomena*, John Wiley and Sons Inc., New York. (1985).

Appendix A: Results

Cable Attenuation Results

Frequency	Error	Voltage CH1	Error	Voltage CH2	Error	% of Signal	Error
1.999557E+07	1.066839E+04	9.071122E-01	8.573885E-04	9.976367E-01	1.942321E-03	90.92610567	0.08594196
1.000001E+07	4.330128E+03	9.198761E-01	4.939971E-04	9.979806E-01	1.911442E-03	92.17374566	0.04949967
5.000565E+06	4.803365E+03	9.349002E-01	3.31946E-04	1.008906E+00	1.250373E-03	92.66474776	0.03290158
4.999035E+05	4.745262E+02	9.681735E-01	3.196467E-04	1.014309E+00	2.575082E-04	95.451534	0.03151374
1.499378E+07	1.184191E+04	9.140346E-01	1.329058E-03	1.010622E+00	3.347923E-03	90.44277682	0.13150891
2.500975E+07	1.63016E+04	9.59589E-01	1.202034E-03	1.013032E+00	2.346111E-03	94.72445096	0.11865706
3.001203E+07	1.800913E+04	9.658777E-01	1.221469E-03	1.004173E+00	4.80506E-03	96.18638422	0.1216393
3.500859E+07	2.381819E+04	9.003757E-01	1.209337E-03	1.021358E+00	5.324383E-03	88.15476062	0.11840481
3.997875E+07	3.915811E+04	8.165637E-01	1.421481E-03	1.014401E+00	5.28757E-03	80.49713082	0.14013009
4.498655E+07	2.938932E+04	8.279396E-01	1.862249E-03	1.016604E+00	4.662033E-03	81.44170198	0.18318332
4.998075E+07	8.160803E+04	9.480196E-01	1.334735E-03	1.004402E+00	4.026352E-03	94.38647076	0.13288852
5.501225E+07	3.939175E+04	1.066264E+00	1.377433E-03	1.012632E+00	3.595228E-03	105.29629717	0.13602503

Cable Cross-talk Results

20 MHz

Frequency	Error	Voltage CH1	Error	Voltage CH2	Error	% of Signal	Error
1.999617E+07	1.403677E+04	4.19689E-03	5.17527E-04	1.430134E+00	2.378755E-03	0.29346131	0.03618731
2.000308E+07	5.396243E+03	2.694869E-03	4.377718E-04	9.540336E-01	1.489847E-03	0.28247108	0.04588641
2.000198E+07	9.118393E+03	1.58836E-03	1.830581E-04	4.771293E-01	5.457904E-04	0.33289928	0.03836656
2.000275E+07	1.42425E+04	4.883084E-03	5.219282E-04	1.66132E+00	1.993638E-03	0.29392796	0.03141648
1.999527E+07	1.481756E+04	5.23861E-03	7.154618E-04	1.778303E+00	1.676863E-03	0.29458478	0.04023284
1.999722E+07	1.562753E+04	5.280816E-03	7.288756E-04	1.888283E+00	1.950328E-03	0.27966232	0.03859991

30 MHz

Frequency	Error	Voltage CH1	Error	Voltage CH2	Error	% of Signal	Error
3.002659E+07	1.156022E+04	2.342873E-03	2.888131E-04	9.215918E-01	3.832365E-03	0.25422025	0.03133851
3.001142E+07	4.365087E+04	1.192301E-03	1.093387E-04	4.501652E-01	2.266095E-03	0.26485855	0.02428857
3.001177E+07	2.444386E+04	3.563967E-03	5.39604E-04	1.37983E+00	5.58633E-03	0.2582903	0.03910656
3.002779E+07	3.104256E+04	4.69559E-03	5.007725E-04	1.826493E+00	8.600408E-03	0.25708229	0.02741716

40 MHz

Frequency	Error	Voltage CH1	Error	Voltage CH2	Error	% of Signal	Error
4.001424E+07	1.868215E+04	1.797105E-03	3.195544E-04	9.348295E-01	5.018622E-03	0.1922388	0.03418317
4.00107E+07	2.774698E+04	1.132081E-03	8.744475E-05	4.70667E-01	1.983369E-03	0.24052695	0.0185789
4.00178E+07	1.688373E+04	3.287115E-03	2.966271E-04	1.411724E+00	6.064632E-03	0.23284403	0.02101169
4.002491E+07	8.432228E+03	3.968681E-03	5.157721E-04	1.863874E+00	8.231753E-03	0.21292646	0.02767205

Splitter Attenuation Results

Frequency	Error	Voltage CH1	Error	Voltage CH2	Error	% of Signal	Error
1.500075E+07	5.261317E+03	4.646045E-01	4.834833E-04	1.008425E+00	3.977477E-04	46.07229095	0.0479444
1.999068E+07	7.860284E+03	4.67263E-01	6.076999E-04	1.001571E+00	4.280683E-04	46.65300812	0.06067467
2.500001E+07	7.905701E+03	4.747996E-01	7.32626E-04	1.00282E+00	9.196796E-04	47.34644303	0.07305658
3.001202E+07	1.139338E+04	4.715798E-01	8.558577E-04	1.008428E+00	1.188322E-03	46.76385424	0.08487048
3.50222E+07	2.00254E+04	4.473126E-01	5.812976E-04	1.00534E+00	1.807101E-03	44.49366384	0.057821
4.000003E+07	2.023925E+04	4.268688E-01	6.292505E-04	1.005584E+00	1.781266E-03	42.44984009	0.06257563
4.499106E+07	4.901746E+04	4.332752E-01	6.912483E-04	1.011674E+00	1.347143E-03	42.82755117	0.06832718
1.000167E+07	4.086565E+03	4.663135E-01	2.692262E-04	1.007966E+00	8.602874E-04	46.26282037	0.02670985
4.999585E+06	1.8816E+03	4.670071E-01	3.62697E-04	1.001632E+00	1.03971E-03	46.62461862	0.0362106
4.997504E+05	3.531999E+02	4.829174E-01	2.693889E-04	1.004886E+00	3.223481E-04	48.05693382	0.02680791
5.002511E+04	6.668304E+01	4.928107E-01	3.984656E-04	1.0053E+00	2.965327E-04	49.02125734	0.03963649
4.995845E+07	4.908047E+04	4.585365E-01	8.029239E-04	1.00539E+00	1.891226E-03	45.60782383	0.07986193

Splitter Cable Cross-talk Results

25 MHz

Frequency	Error	Voltage CH1	Error	Voltage CH2	Error	% of Signal	Error
2.5E+07	0E+00	1.255333E-03	1.39245E-04	9.523344E-01	4.067356E-04	0.13181641	0.01462144
2.499584E+07	1.290323E+04	1.867408E-03	9.929543E-05	1.42493E+00	1.207966E-03	0.13105261	0.00696844
2.5E+07	0E+00	1.074042E-03	6.579505E-05	7.124816E-01	5.47286E-04	0.15074663	0.00923463
2.500209E+07	9.411388E+03	2.50907E-03	3.566492E-04	1.885536E+00	1.162868E-03	0.13306932	0.018915

30 MHz

Frequency	Error	Voltage CH1	Error	Voltage CH2	Error	% of Signal	Error
3.000301E+07	1.505402E+04	1.332428E-03	1.370409E-04	9.371492E-01	3.868409E-03	0.14217885	0.01462317
3.001802E+07	9.31375E+03	1.009283E-03	1.083973E-04	6.97408E-01	1.143041E-03	0.14471916	0.01554288
3.000901E+07	1.770079E+04	1.627084E-03	1.478896E-04	1.391119E+00	4.795457E-04	0.11696224	0.01063098
3.000429E+07	1.415682E+04	2.22233E-03	3.42668E-04	1.840542E+00	8.584627E-04	0.12074324	0.01861778