# Cable Reflection Demo

EE3C11

# The setup


**Signal generator**
Output impedance: 50Ω
Output signal:

- Square wave
- Frequency: 1.5MHz
- Amplitude: $2V_{pp}$

# The setup

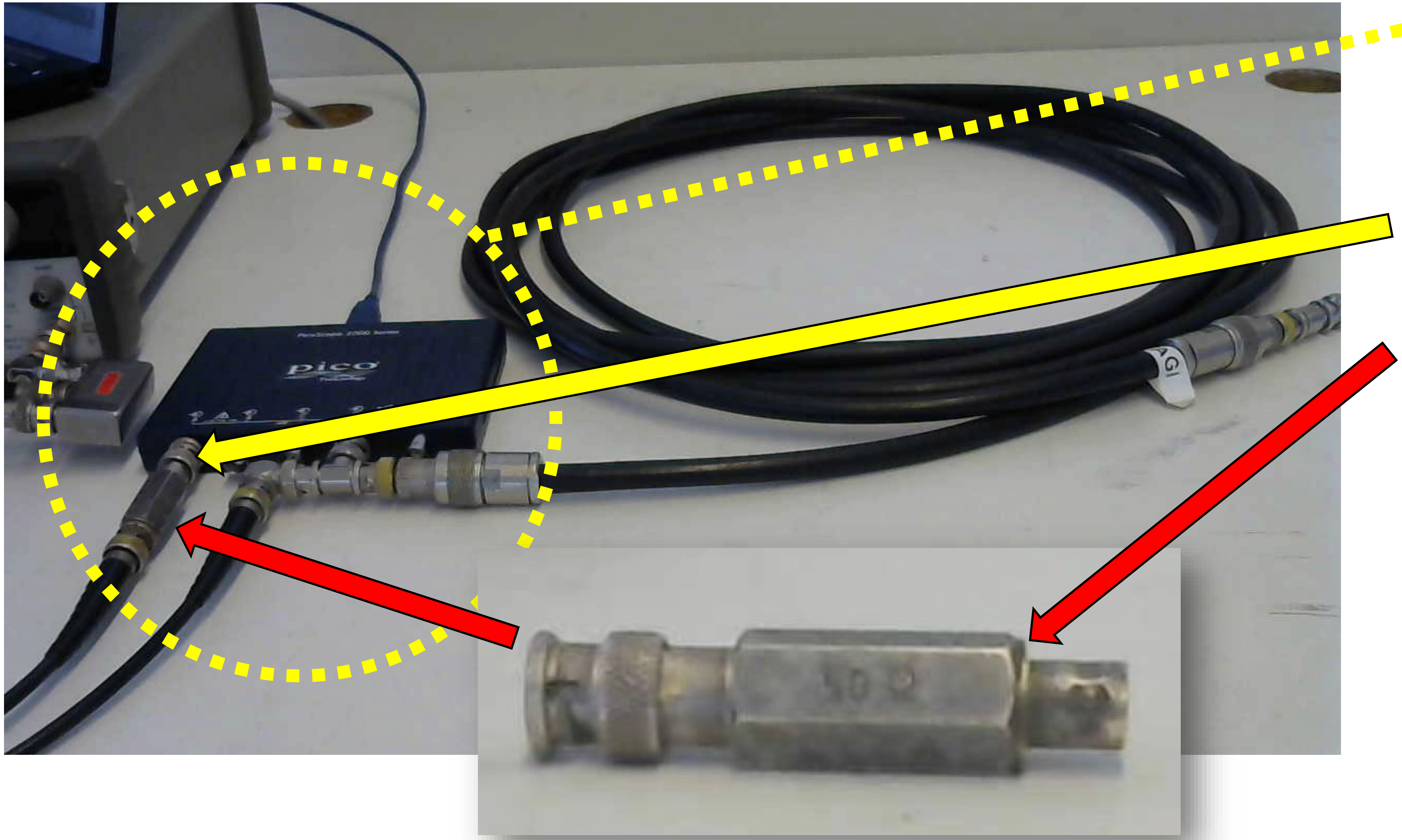

**Power splitter**

Input impedance: 50Ω

**2 equal outputs:**

Output impedances: 50Ω

# The setup



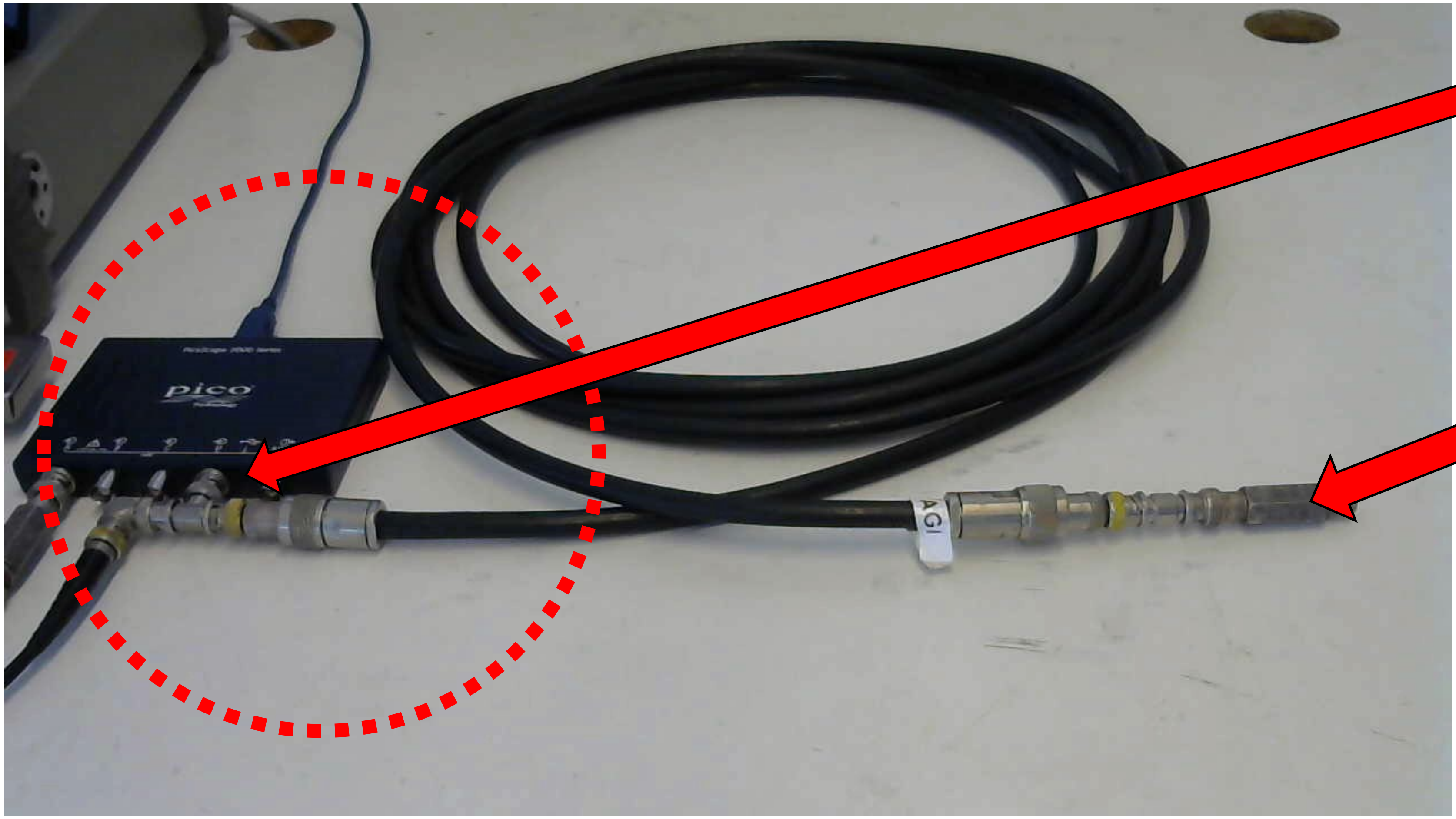
**Digital oscilloscope**
4 equal inputs:
High input impedance: 1MΩ

The input of Channel A is connected to one of the outputs of the power splitter.

The input of Channel A is shunted with a 50Ω “feed through” resistor to properly terminate this side of the short cable coming from the power splitter.

*The signal measured at Channel A is used reference.*

# The setup



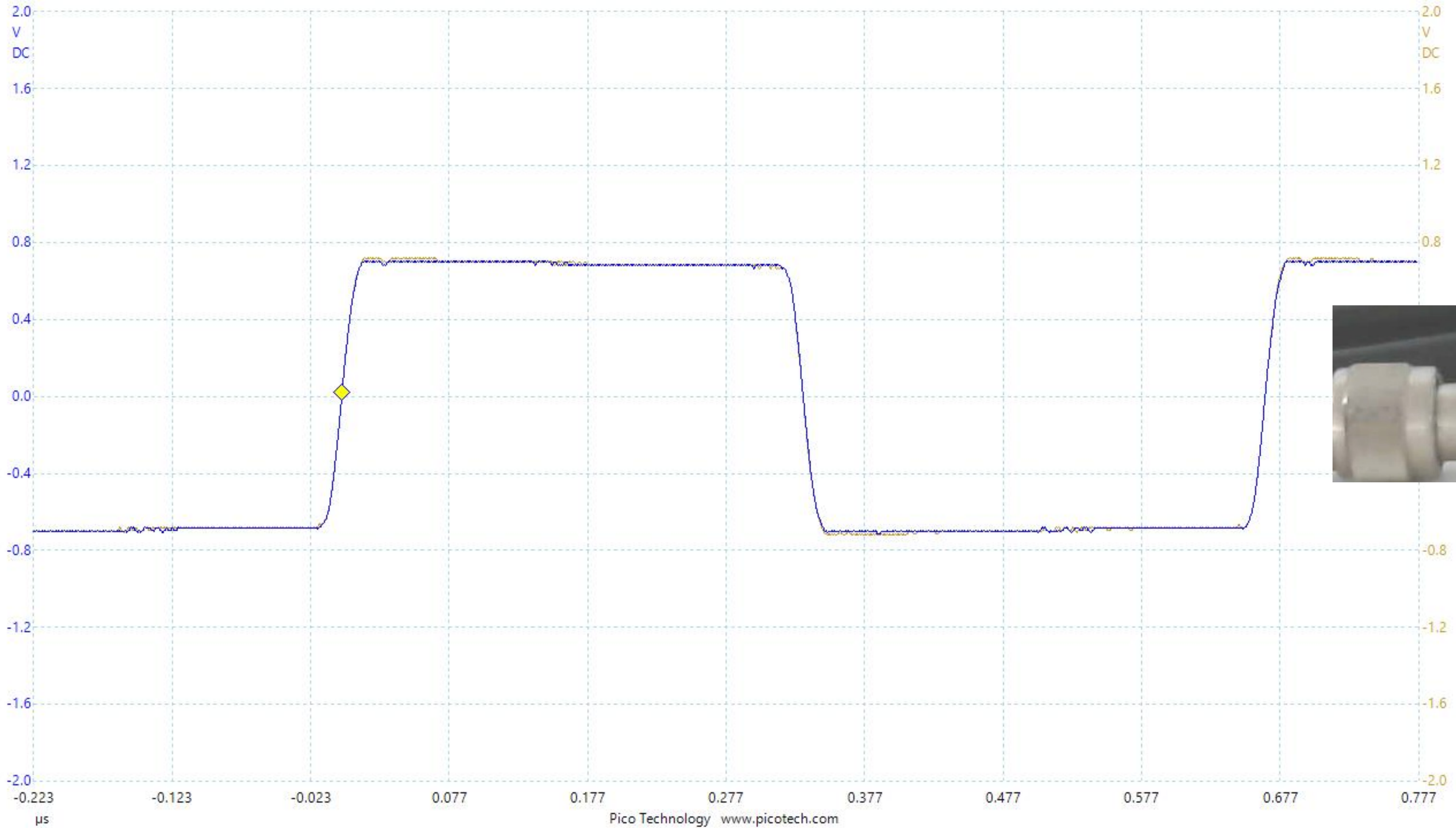

**Digital oscilloscope**
Channel D is both connected to the other side of the power splitter and a **cable with a length of 6m.**
**The cable has a so-called “characteristic impedance” of 50Ω.**

In this picture is can be seen that the cable is terminated with a
50Ω “feed through” resistor.

*The signal measured at Channel A is used reference.*

# Measurements

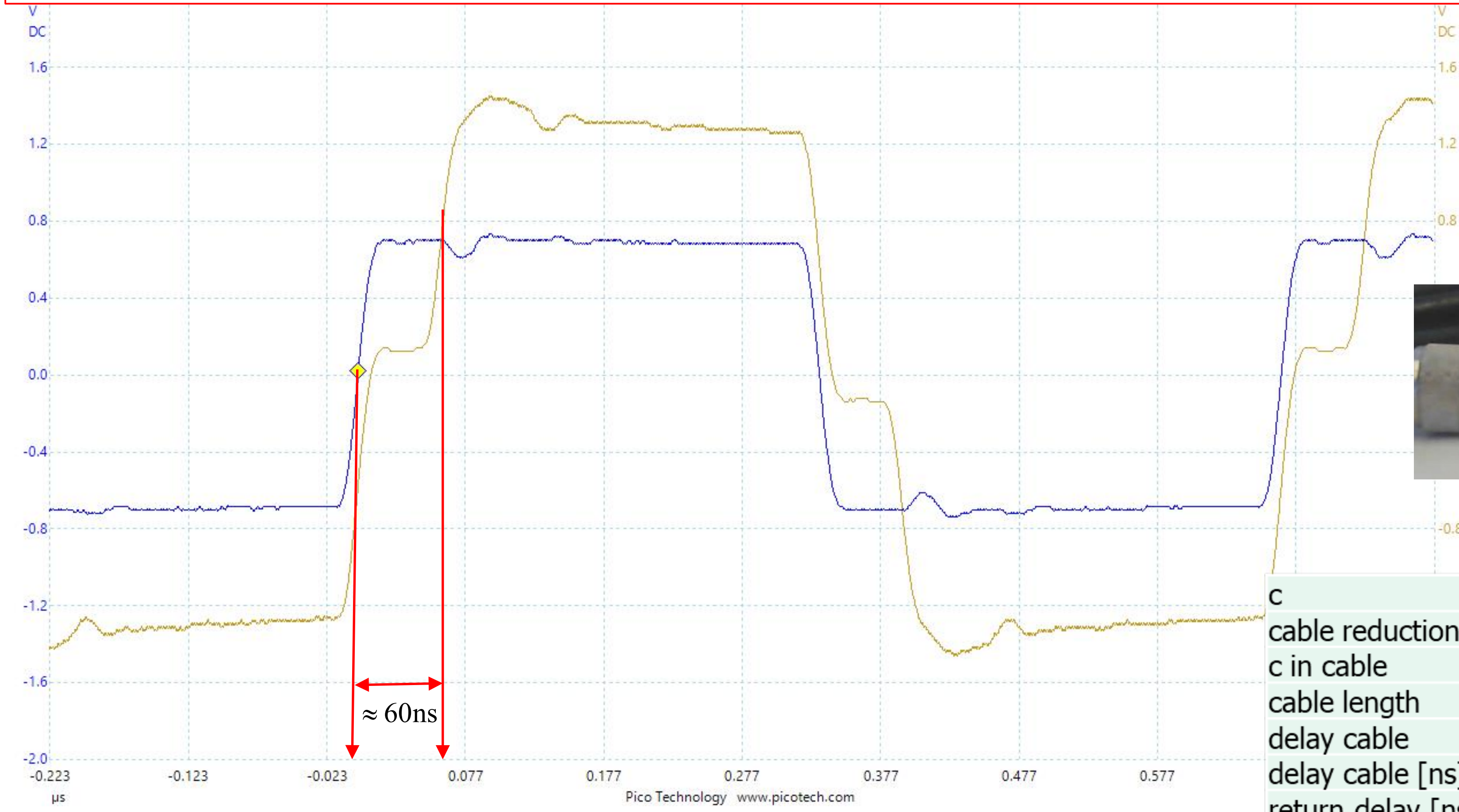
The signals from channel A and D overlap. Itdoes not matter that the termination of channel D is done with a **50Ω** resistor at the end of the 6m cable. The characteristic impedance of the cable **(50Ω)** matches the impedance of the termination resistor **(50Ω).** The signal that travels into the cable is not reflected at end of the cable but dissipated in the resistor that is terminating the cable.
*The combination of cable and termination behaves at input D as if just a* 50Ω *resistor was connected in parallel to the input, just like it is for channel A.*




*The signal measured at Channel A is used reference.*

**Conditions**
- Output impedance of power splitter: **50Ω**
- 6m cable terminated with **50Ω**

The signals from channel A (blue) has not (really) changed. The signal at channel D has completely changed.
**Because the cable is left open at the end,** the signal is **reflected** there and travels back to the input. In the cable the speed of light is lower (see the table). This means that the pulse takes around 30ns to travel to the end of the cable and another 30ns to travel back to the input.
So it takes around 60ns for the pulse to return back to the input where it adds to the signal that is coming from the power splitter at that time.
The returning pulse can be clearly identified in the figure. *Note that for a considerable amount of time the amplitude is twice the original amplitude.*
(This is the reason why removing the antenna from a transmitter can lead to destruction of the transmitter output stage.)

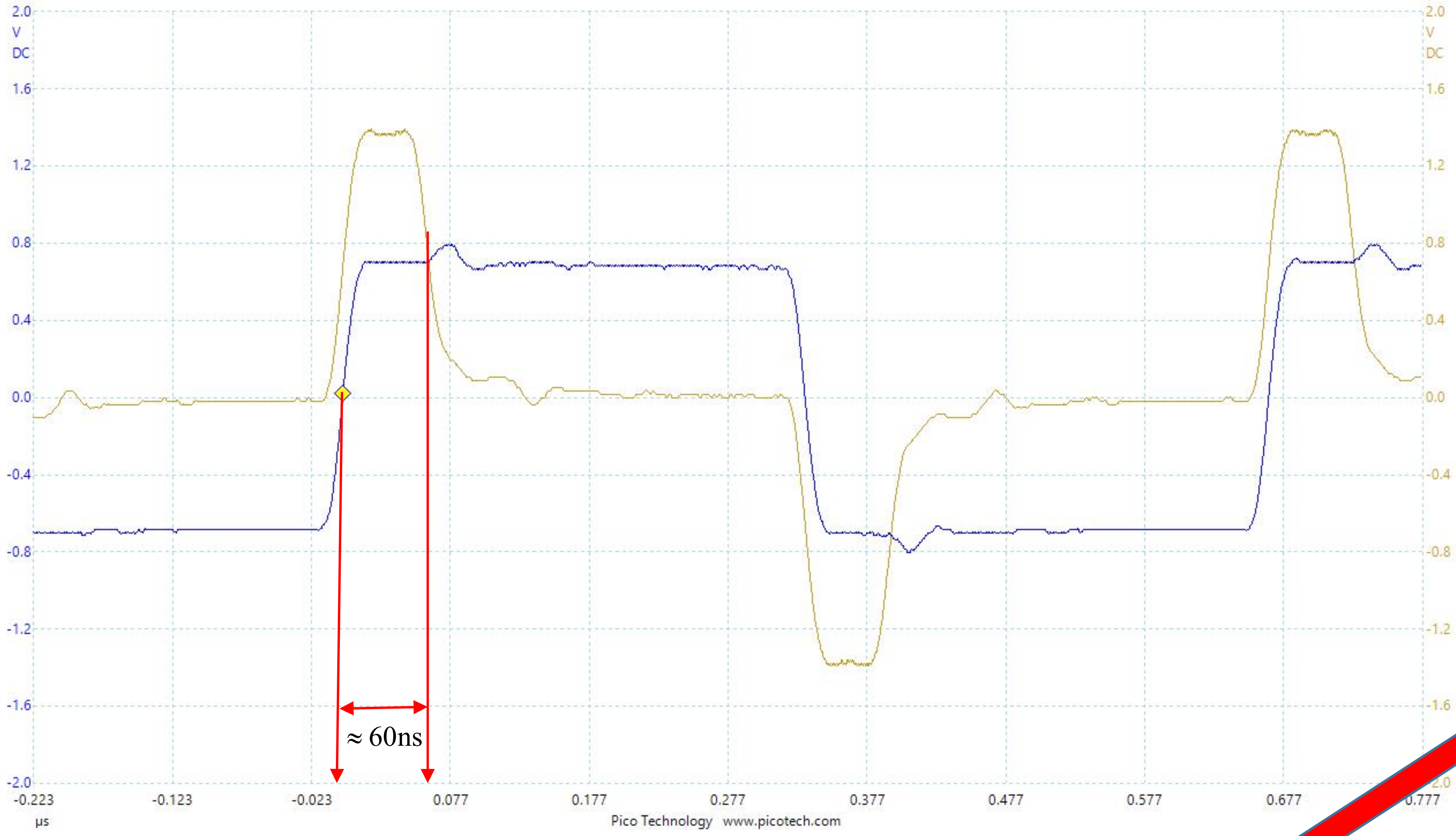


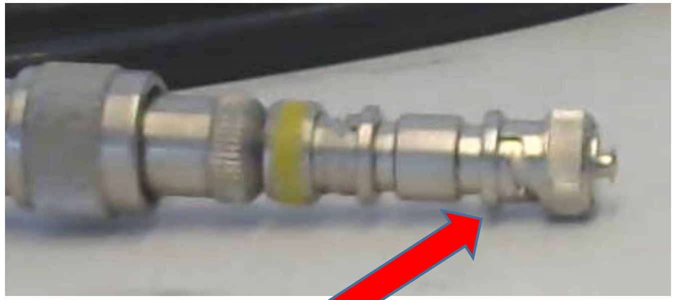

| | | |
|---|---|---|
| c | 299792458 | m/s |
| cable reduction of c | 0,666666667 | |
| c in cable | 199861638,7 | m/s |
| cable length | 6 | m |
| delay cable | 3,00208E-08 | s |
| delay cable [ns] | 30,02076857 | ns |
| return delay [ns] | 6,00415E-08 | s |
| Lowest Resonant frequency at cable = 0.5 Wavelength | | |
| Lowest Resonant Frequency | 16655136,56 | Hz |
| Lowest Resonant Frequency [MHz] | 16,65513656 | MHz |

**Conditions**

- Output impedance of power splitter: **50Ω**
- 6m cable left open at the end.

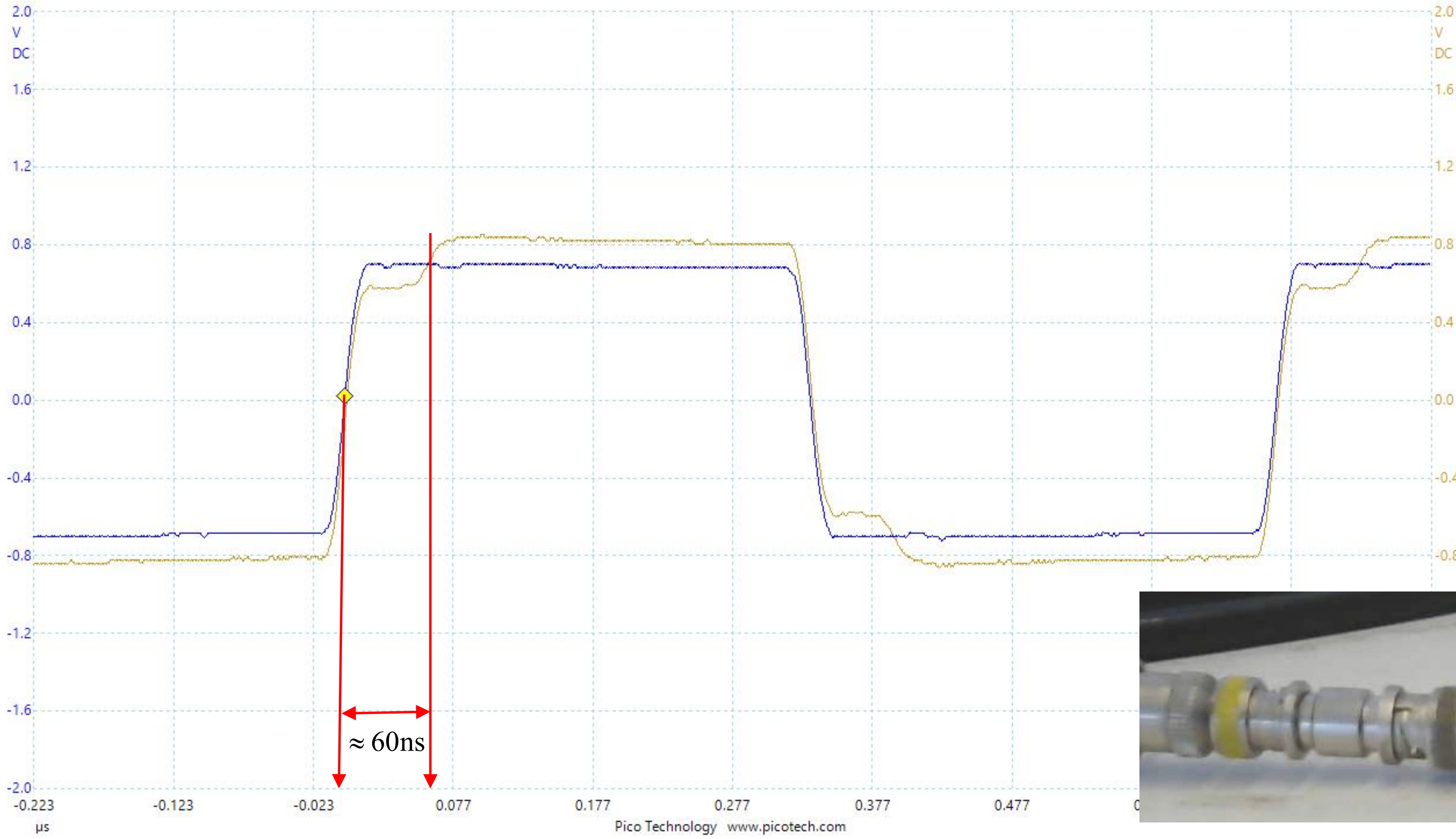
The signals from channel A (blue) has not (really) changed. The signal at channel D has completely changed.
**Because the cable is shorted at the end,** the signal **is inverted and reflected** there and travels back to the input.
Again it takes around 60ns for the reflected inverted pulse to return to the input where it adds to the signal that is coming from the power splitter at that time. Because it is inverted, the sum of the signals equals zero.



**Conditions**
Output impedance of power splitter: **50Ω**
6m cable terminated with a "short circuit cap"

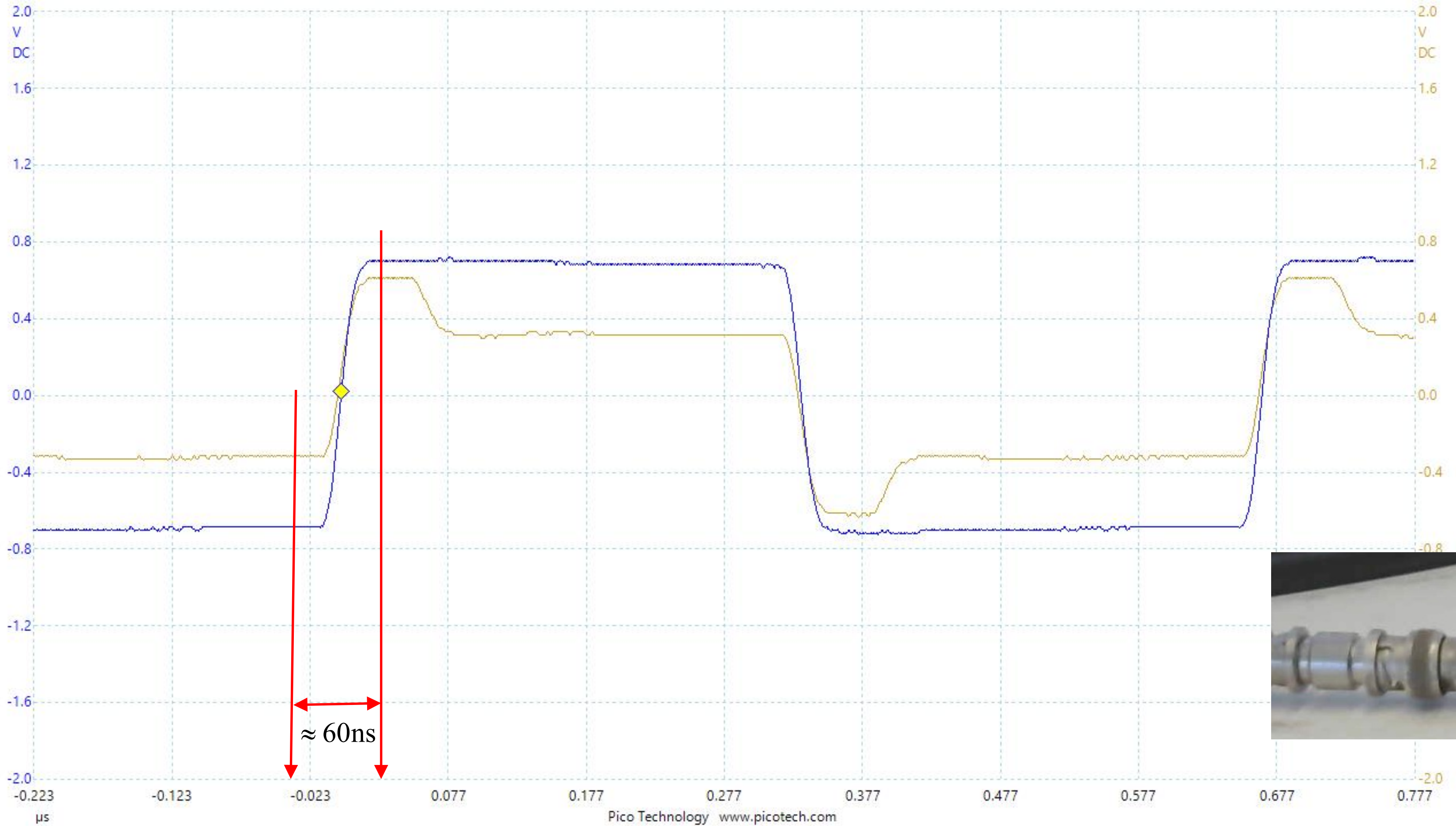
The signals from channel A (blue) has not (really) changed. The signal at channel D has completely changed.
**Because the cable is terminated with 75Ω** the signal is **partly reflected** there. This part travels back to the input.
It takes again around 60ns for the pulse to return to the input where it adds to the signal that is coming from the power splitter at that time.





**Conditions**
Output impedance of power splitter: **50Ω**
6m cable terminated with **75Ω**

The signals from channel A (blue) has not (really) changed. The signal at channel D has completely changed. **Because the cable is terminated with 75Ω and 50Ω *in parallel which effectively results in a termination with 30Ω*.**
This 30Ω is lower than the characteristic impedance of the cable so the signal is **inverted and partly reflected** there. This part travels back to the input. It takes again around 60ns for the pulse to return to the input where it adds to the signal that is coming from the power splitter at that time. Because the reflected signal is inverted, the addition results in a lower amplitude at the input of the cable.

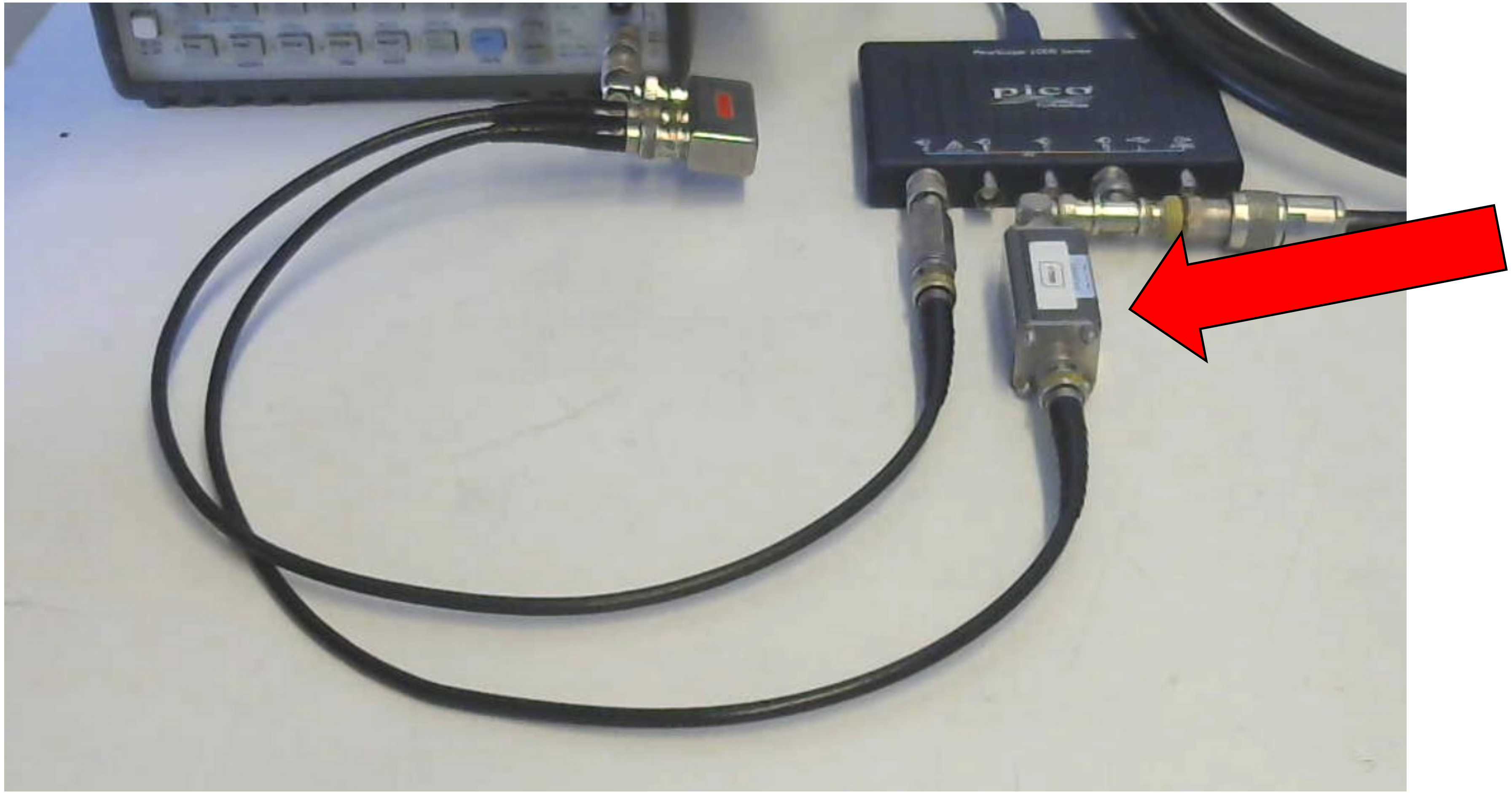




**Conditions**

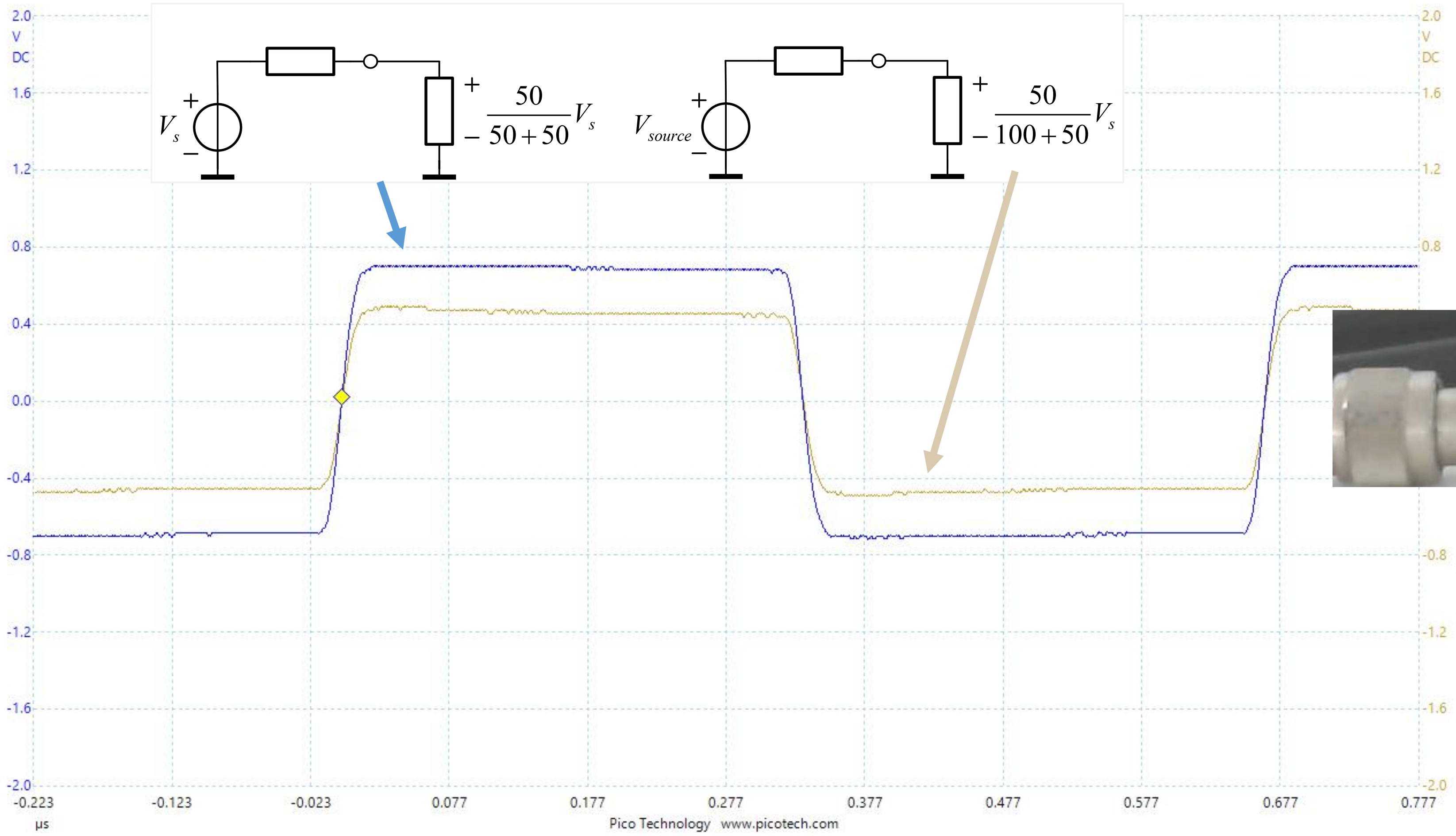
- Output impedance of power splitter: **50Ω**
- 6m cable terminated with **75Ω and 50Ω *in parallel* which results in a termination with 30Ω**

# Change of setup




A resistor of 50Ω (in the box) is put in series with the signal coming from the power splitter.
**So effectively the cable is now driven from 100Ω which is twice the characteristic of the cable.**

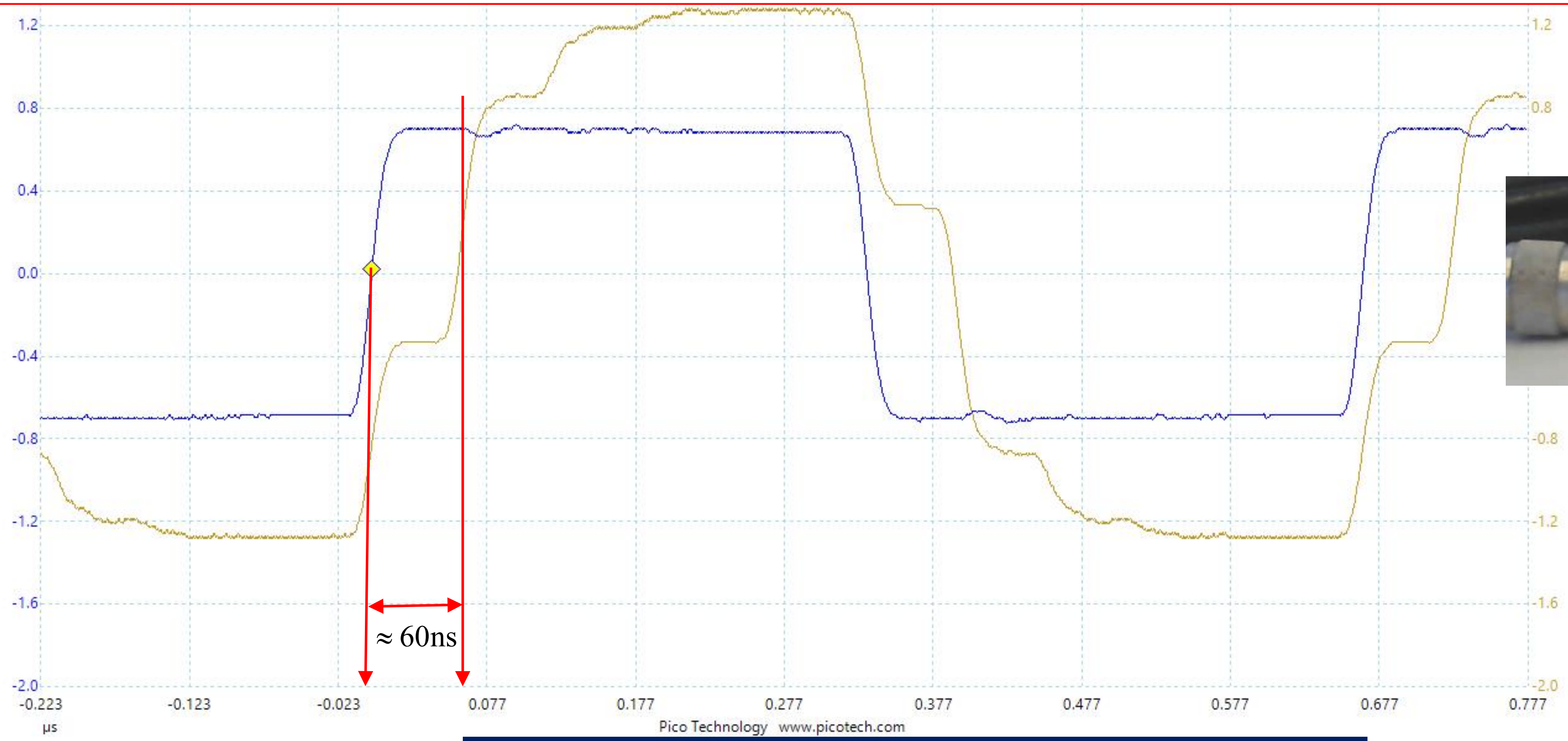
It can be seen that the signals from channel A and D have the same shape. There are no reflections although the cable is driven from **100Ω.**
Only the amplitude is lower.
At the end of the 6m cable the characteristic impedance of the cable **(50Ω)** matches the impedance of the termination resistor **(50Ω).**
*The combination of cable and termination behaves at input D as if just a* 50Ω *resistor was connected in parallel to the input, just like it is for channel A.*




*The signal measured at Channel A is used reference.*

**Conditions**
- Output impedance of power splitter: **<u>100Ω</u>**
- 6m cable terminated with **50Ω**

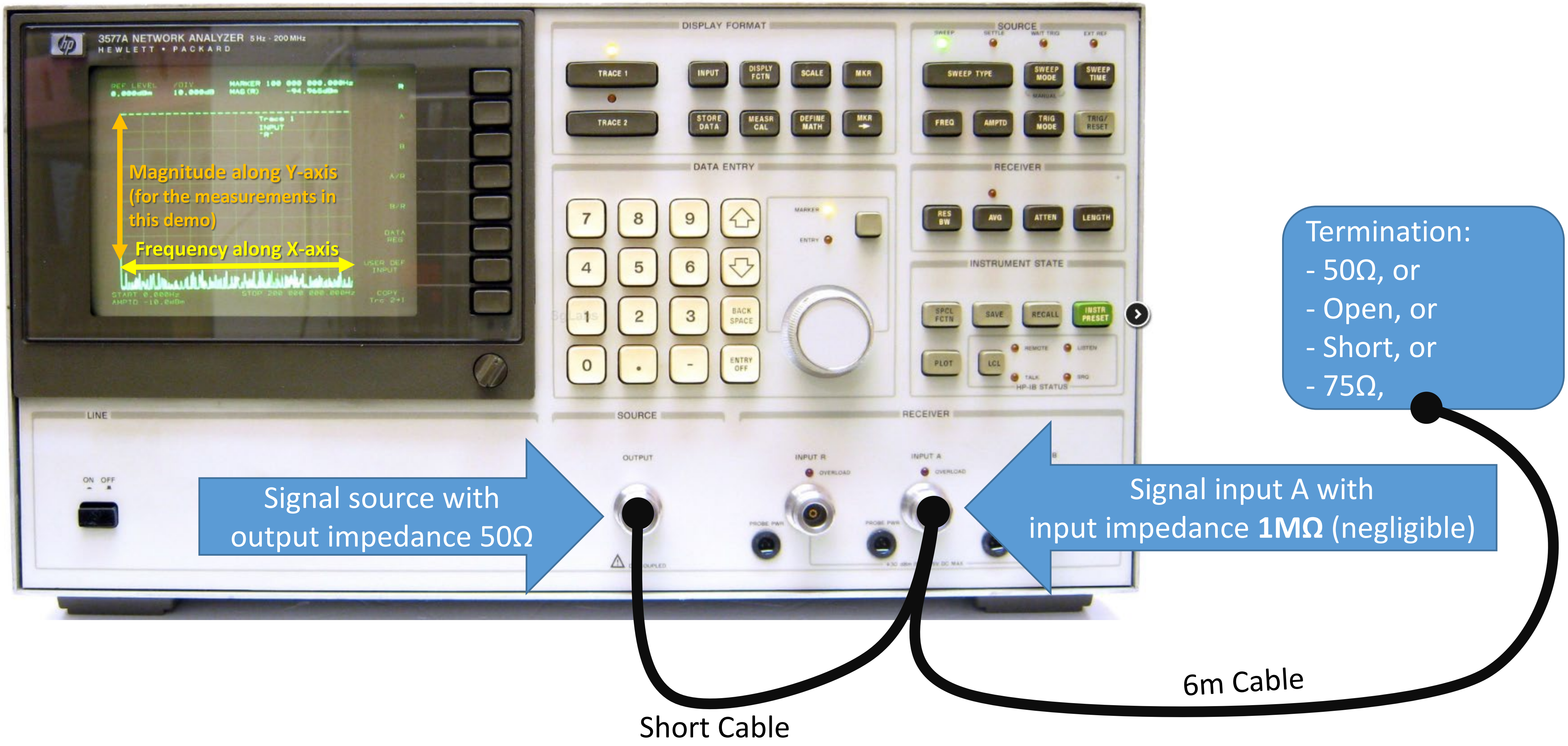
**Because the cable is left open at the end,** the signal is **reflected** there and travels back to the input.
There is also a mismatch at the input, because the cable is driven from **100Ω, so the signal is again (partly) reflected there.**
This reflected a reduced pulse travels to the end of the cable again where it is again reflected. This second reflection manifests itself 60ns after the first reflection. Then the process repeats.
This produces a waveform that looks like a “discrete exponential curve”.
When the cable had been shorter making the reflections arrive closer to each other, the “discrete” character could become unobservable.
In that case the cable could be modeled as if it were just a capacitor. This is how the distributed transmission line model for a cable can be reduced to a lumped capacitor model under certain conditions.




**Conditions**

- Output impedance of power splitter: **100Ω**
- 6m cable left open at the end.

# Measurements with Network Analyzer

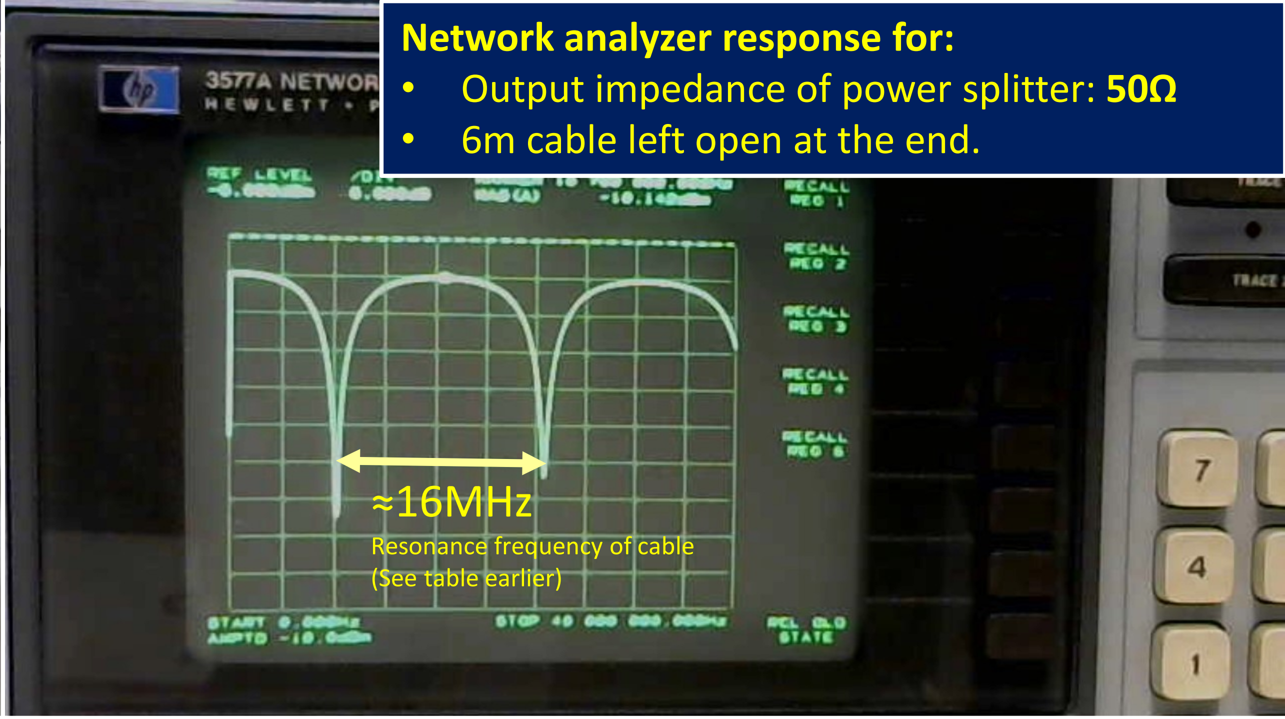


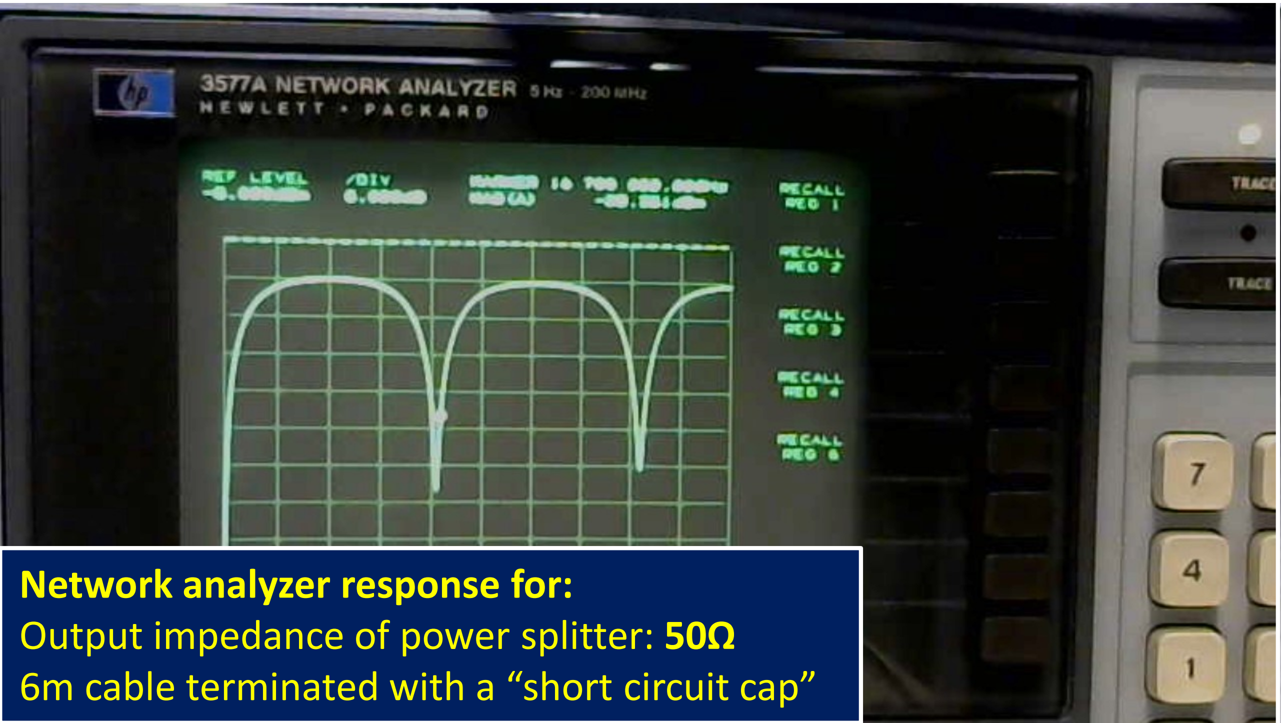
**Network analyzer response for:**

- Output impedance of power splitter: **50Ω**
- 6m cable terminated with **50Ω**


**Network analyzer response for:**

- Output impedance of power splitter: **50Ω**
- 6m cable left open at the end.

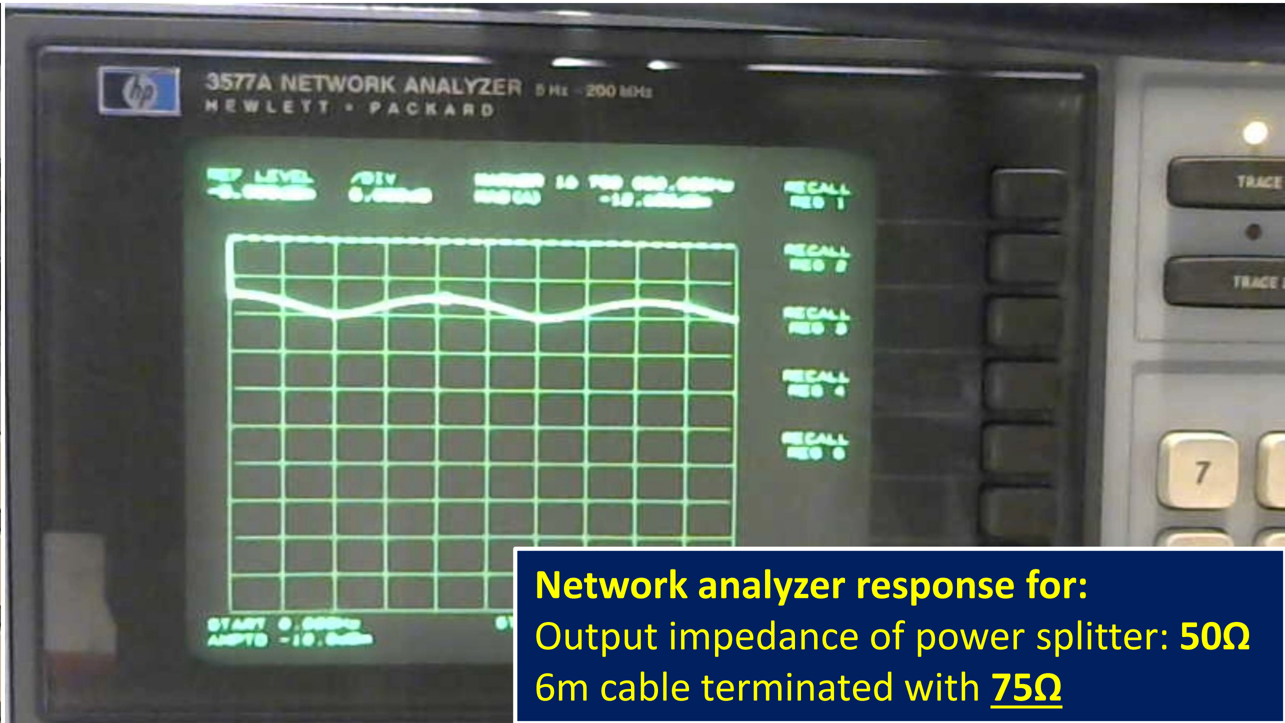



**Network analyzer response for:**

Output impedance of power splitter: **50Ω**

6m cable terminated with a “short circuit cap”




**Network analyzer response for:**

Output impedance of power splitter: **50Ω**

6m cable terminated with **75Ω**