Investigating a new method to find S-parameters and breakdown positions in radio frequency cavities

Kathryn Jones (University of Oxford)

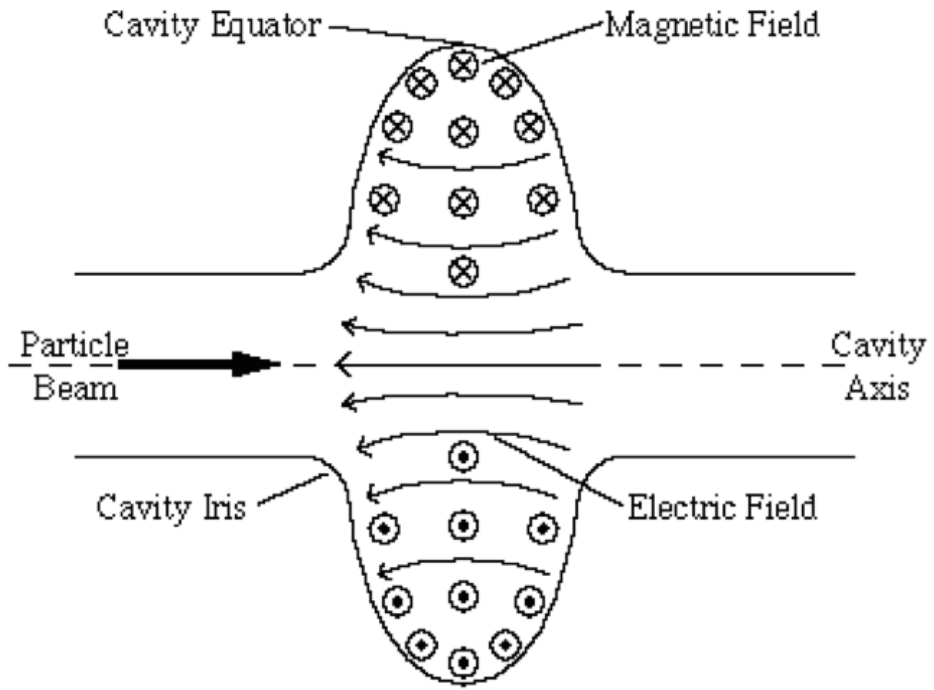


Figure 1: Electromagnetic waves inside a radio frequency cavity(3)

Image: Cornell University, SRF group

Test structure set-up at CERN

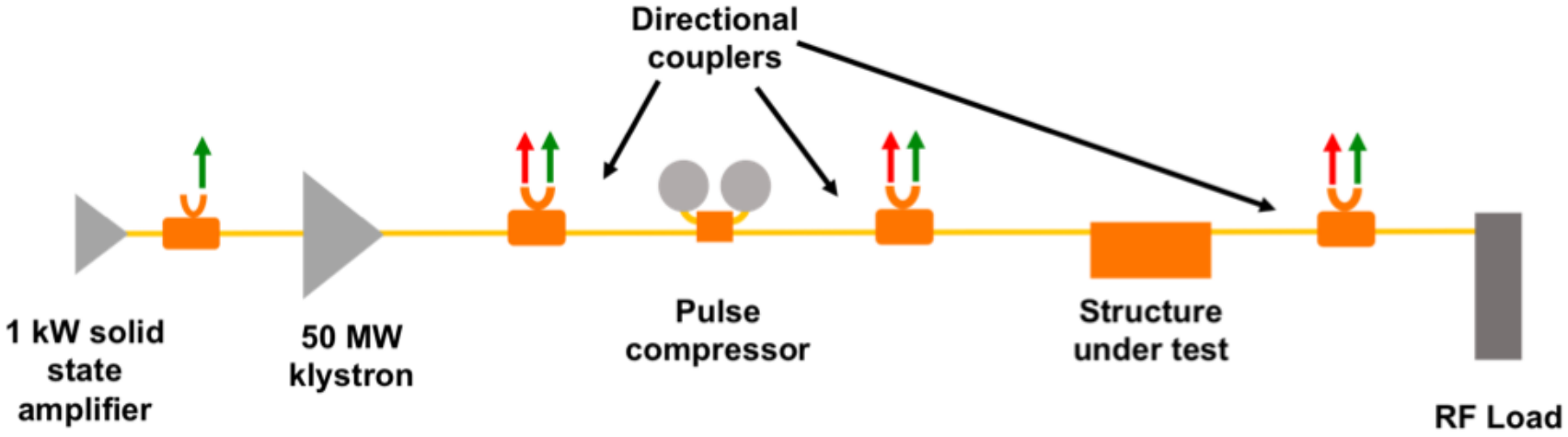


Figure 2: Xbox 2 Block Diagram(4)

Image: Jan Paszkiewicz

Test structure set-up at CERN

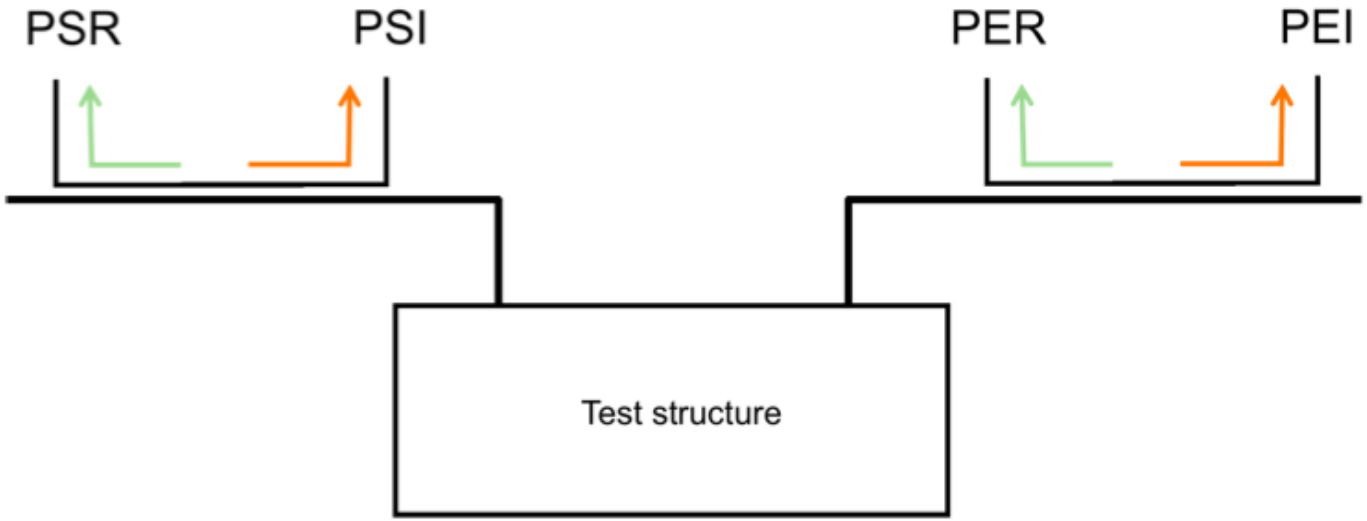
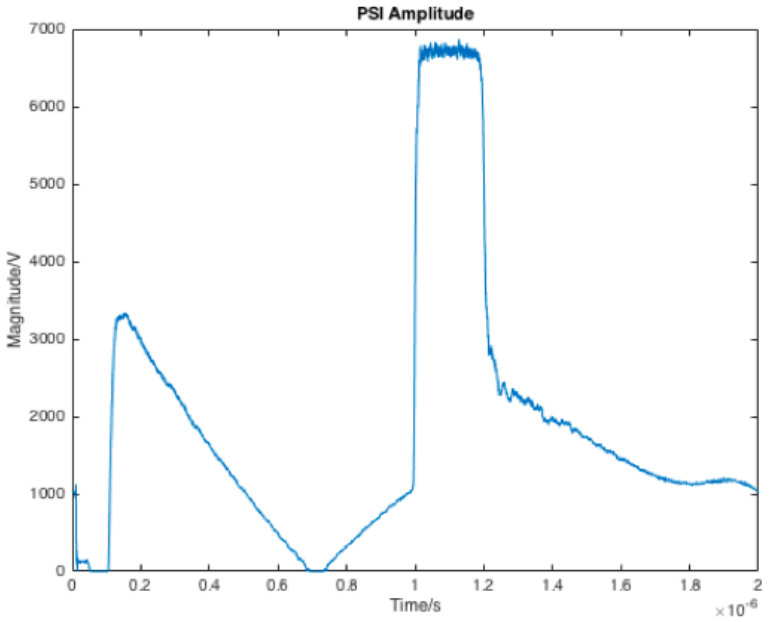
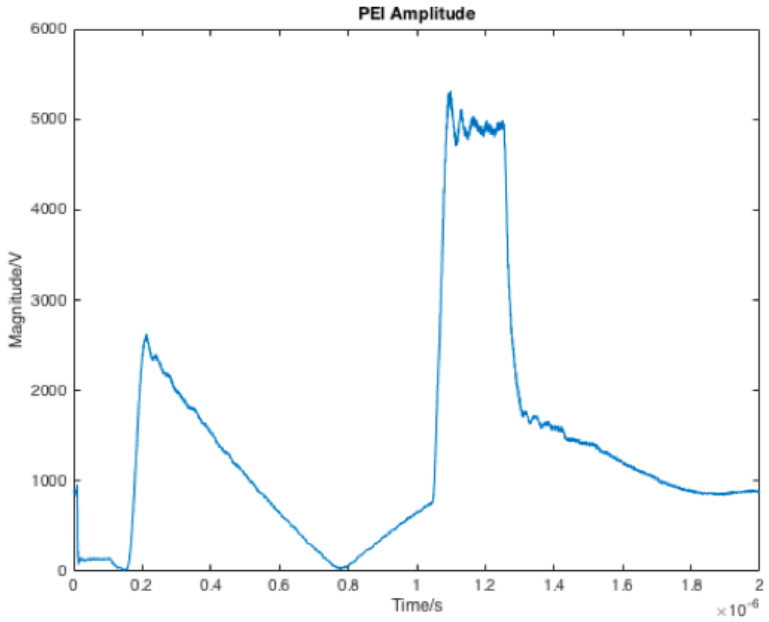


Figure 3: Test structure signal diagram

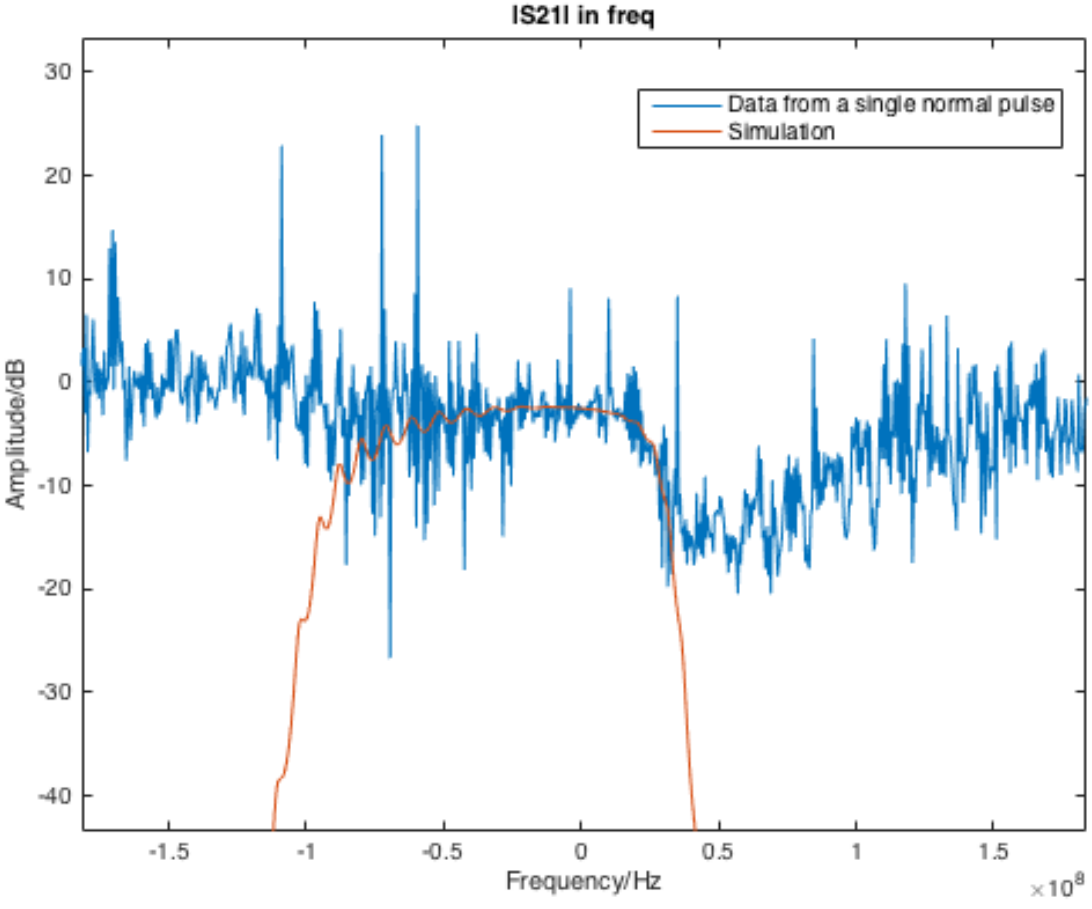


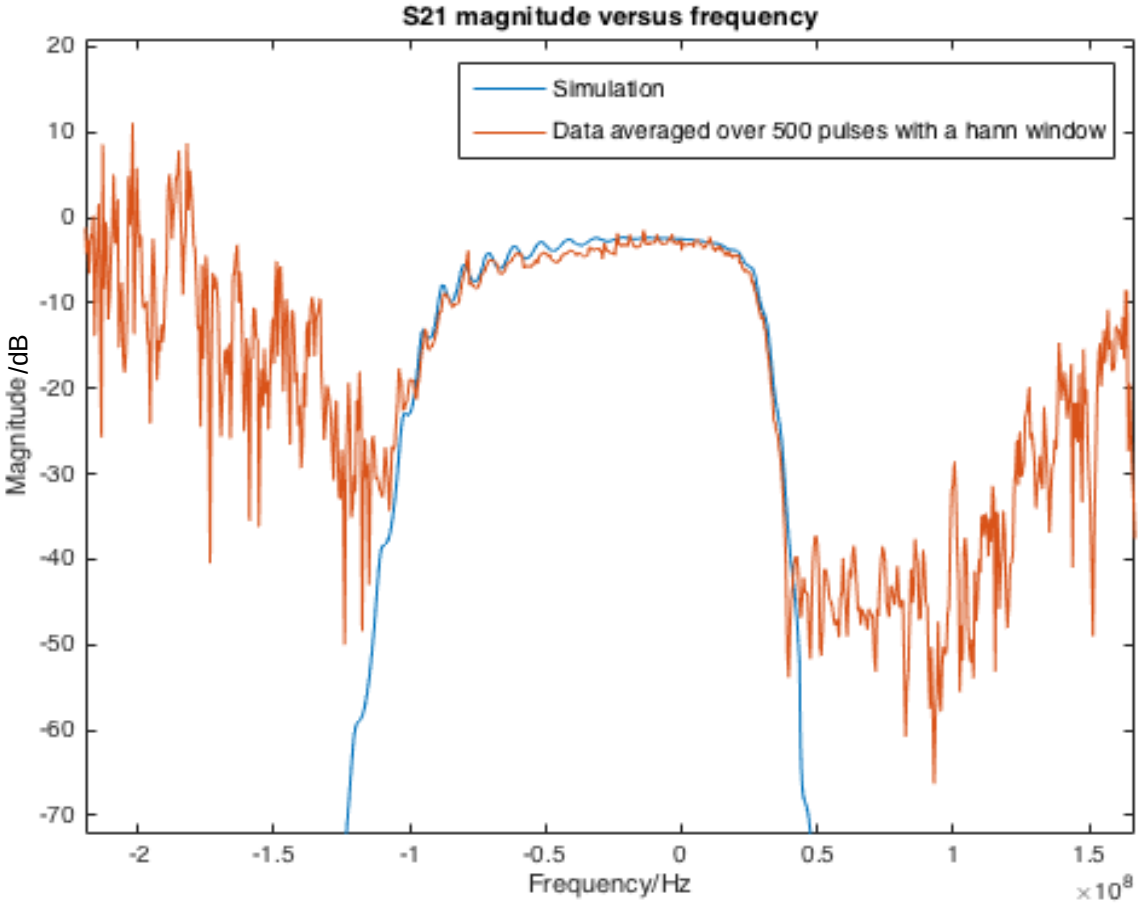
(a) PSI

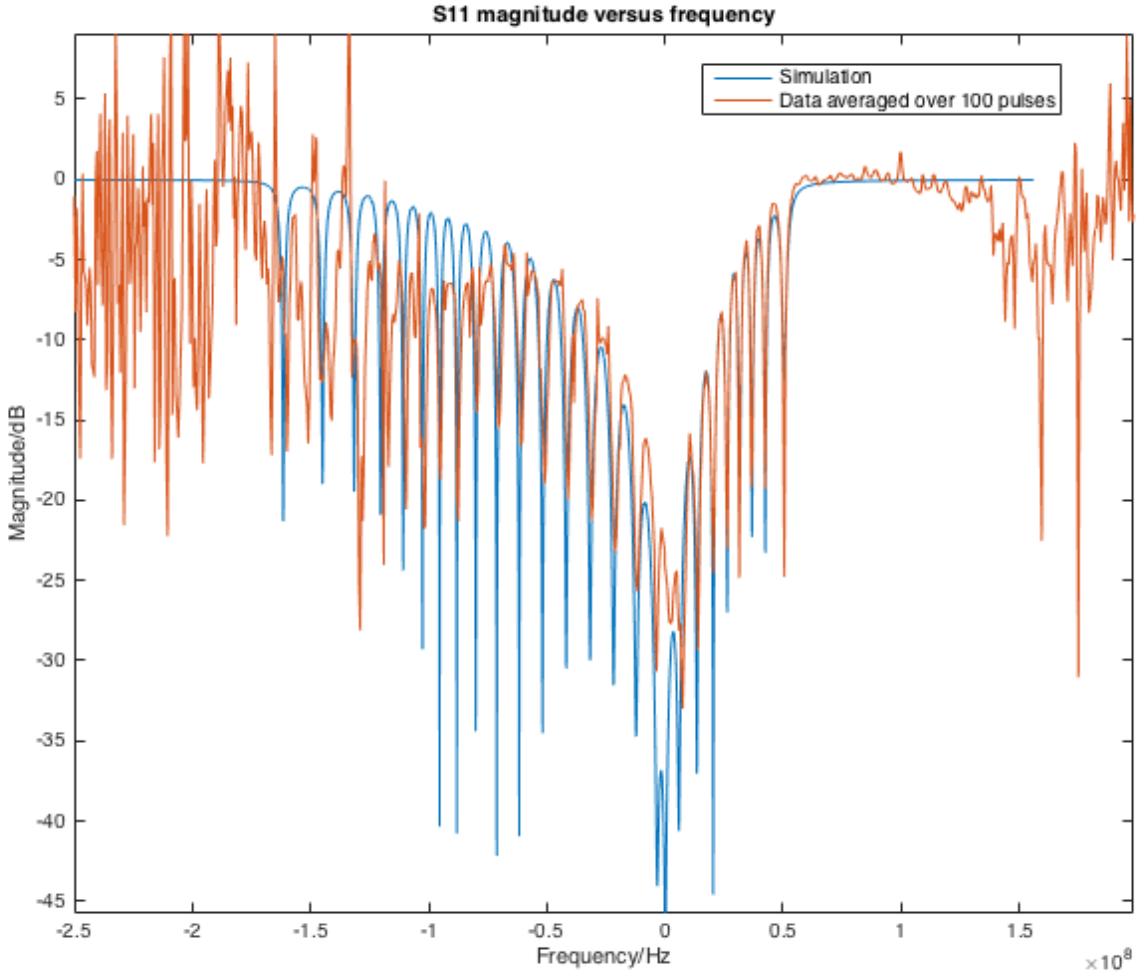


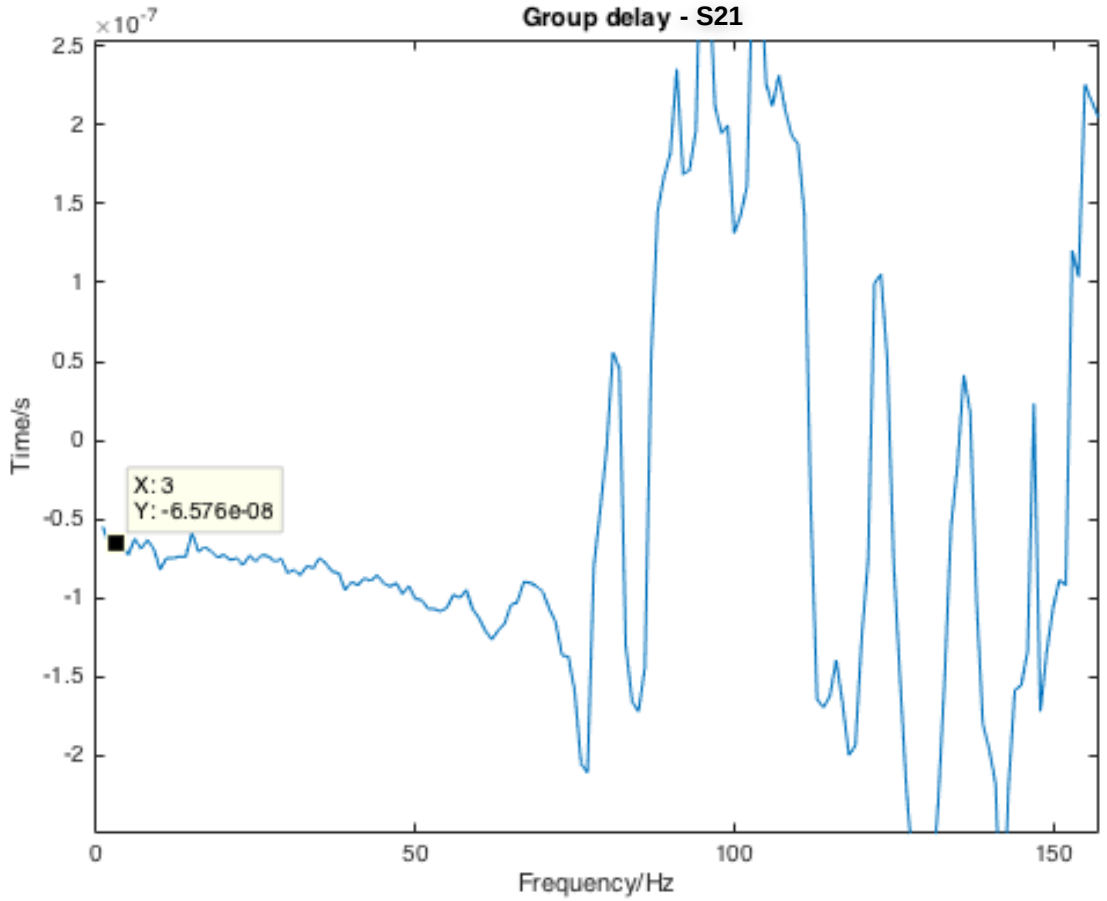
(b) PEI

Figure 4: Amplitude of single pulses of different signals

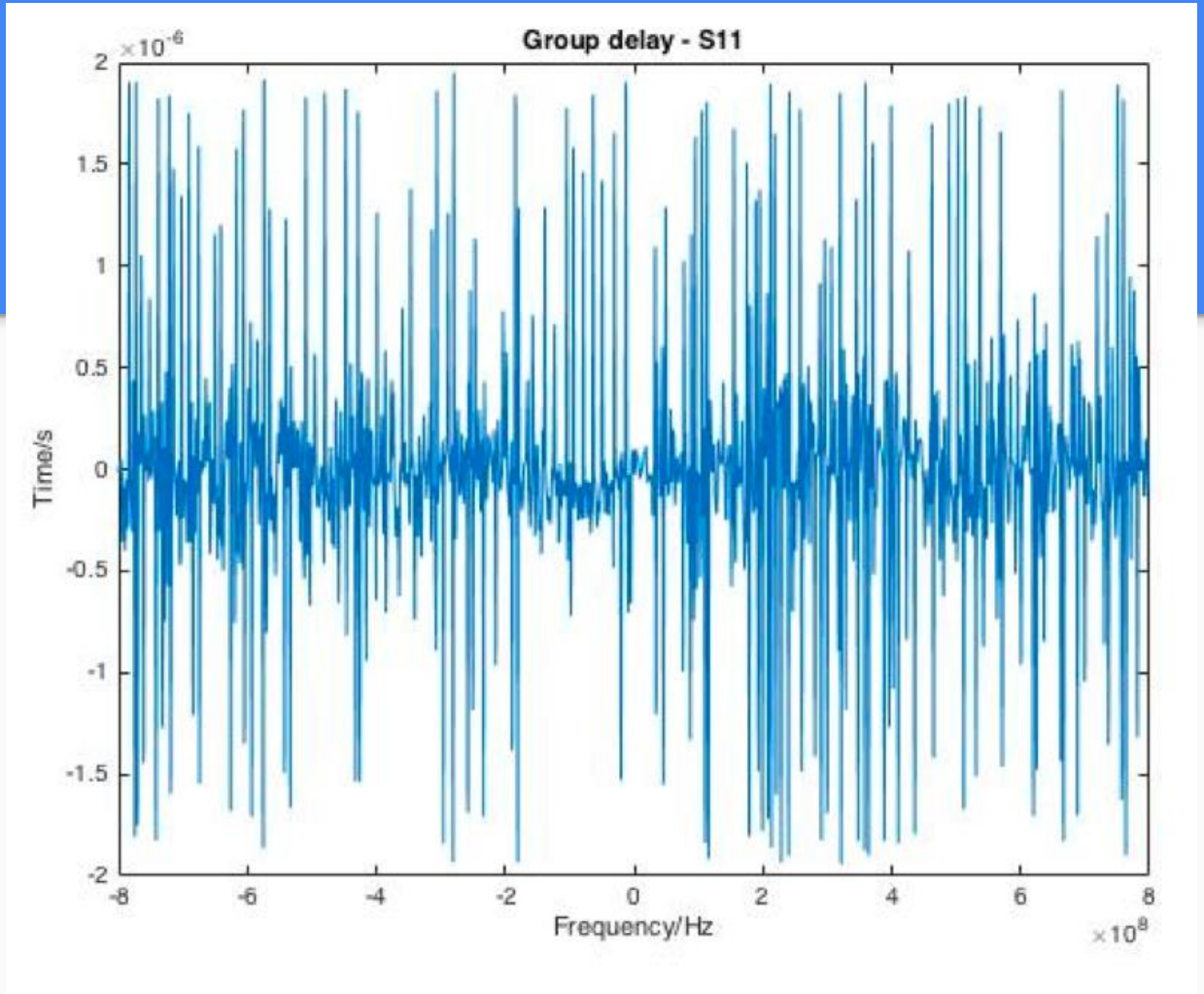

IS21I in freq
Data from a single normal pulse
Simulation
Amplitude/dB
30
20
10
0
-10
-20
-30
-40
-1.5
-1
-0.5
0
0.5
1
1.5
Frequency/Hz
×10^8

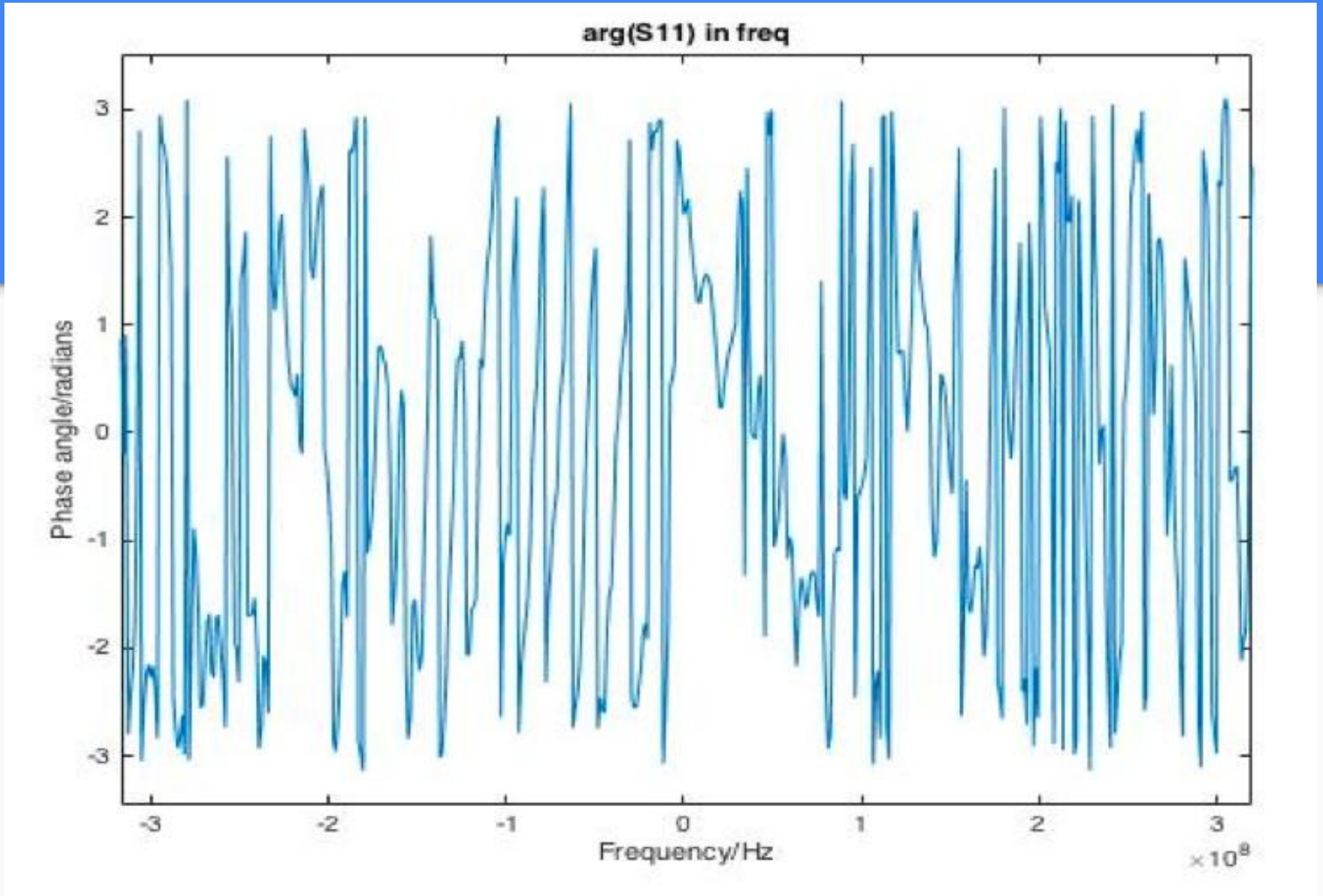

S21 magnitude versus frequency
Simulation
Data averaged over 500 pulses with a hann window
Magnitude /dB
Frequency/Hz
×10^8
20
10
0
-10
-20
-30
-40
-50
-60
-70
-2
-1.5
-1
-0.5
0
0.5
1
1.5


S11 magnitude versus frequency
Simulation
Data averaged over 100 pulses
Magnitude/dB
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
Frequency/Hz
×10^8



Measured group delay from S21 = **65.8ns**


Group delay - S11
×10^-6
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Time/s
-8
-6
-4
-2
0
2
4
6
8
Frequency/Hz
×10^8


arg(S11) in freq
Phase angle/radians
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
Frequency/Hz
×10^8

Breakdown position results

Table 1: Edge method versus S-parameter results

Event	Edge method position/s	S-parameter method position/s
07 17 02 50 44 596	1.0255×10^{-8}	5.95×10^{-9}
07 17 03 11 38 646	3.1294×10^{-9}	No visible slope
07 17 03 12 13 120	1.6613×10^{-8}	4.98×10^{-9}
06 17 11 07 22 602	8.5122×10^{-10}	No visible slope
06 17 11 12 59 589	8.9572×10^{-9}	3.07×10^{-9}
06 17 11 14 00 179	5.9861×10^{-9}	No visible slope
06 17 14 32 42 978	1.6120×10^{-9}	4.25×10^{-9}
06 17 11 13 06 528	1.2225×10^{-8}	1.17×10^{-8}

Summary: S-parameters

- Finding the S-parameters of normal pulses using this new method worked very well, matching the simulation data to within 1dB over the centre frequency when using the hann window and averaging.
- Currently, the S-parameters are only measured before the installation of the structure and when it has been removed.

Why this method is useful to find S-parameters

- No changes to the system need to be done to get the data, it is already easily available.
- All past data can be used. Therefore, in theory, we have S21 and S11 data throughout the conditioning history of the structure - can be used to see if the geometry of the structure changes during this process, and how fast it does so.

Summary: Breakdown positions

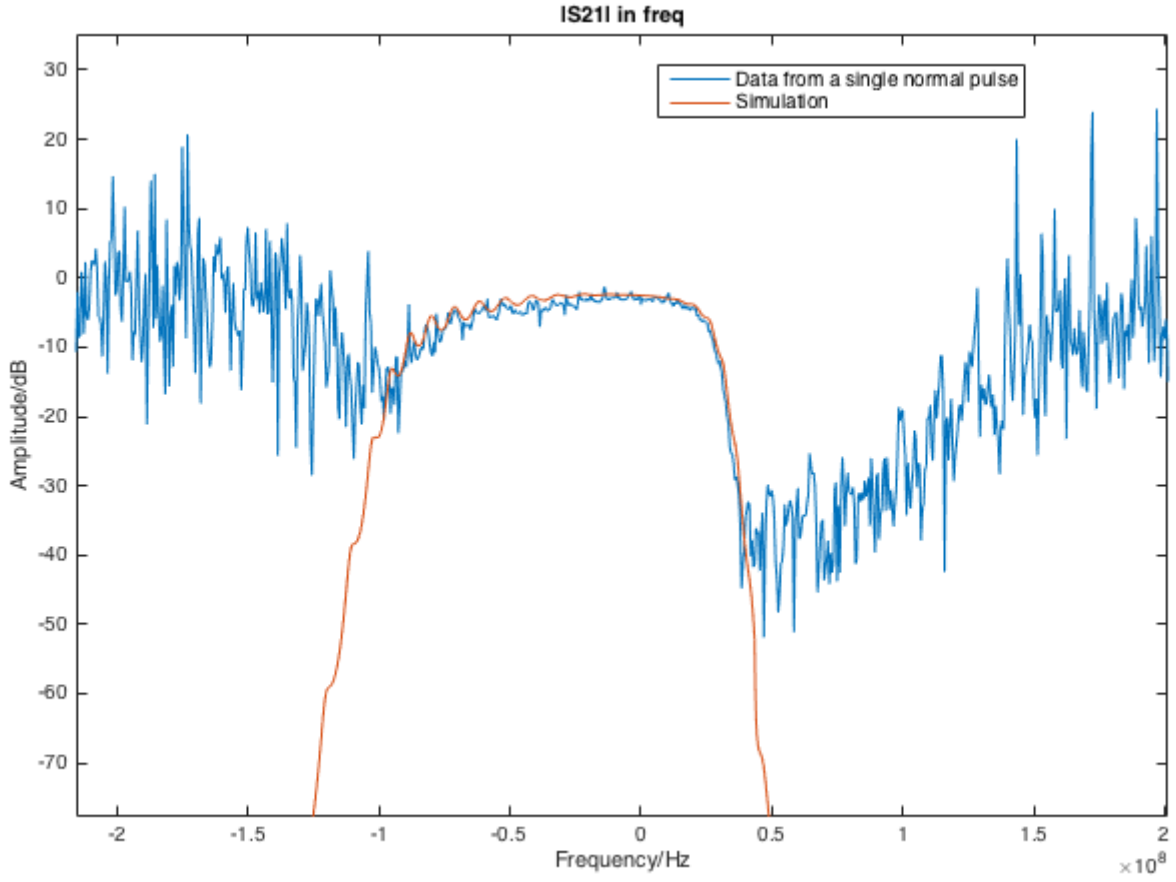
- The breakdown position results were inconclusive, but don’t completely rule out the method.
- If this project was given time to continue further, I would have liked to install a better data collection system with a finer resolution to see if this had a positive effect on the group delay data.
- Different smoothing techniques or filters could be investigated and applied to the data. This could remove issues with large phase jumps and noisy data.

Overall...

- This group delay method assumes that breakdowns behave as a solid stationary wall, which they are not.
- A breakdown is a plasma that is inherently unstable and may act completely different than this method assumes.
- However if this issue could be overcome and breakdowns were able to be located using this method, it would certainly assist researchers to further understand the nature of breakdowns and how they move within the accelerating structures, which would ultimately contribute the CLIC project.

Thank you for listening

Additional slides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Data from a single normal pulse
Simulation
Amplitude/dB
Frequency/Hz
×10^8
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10
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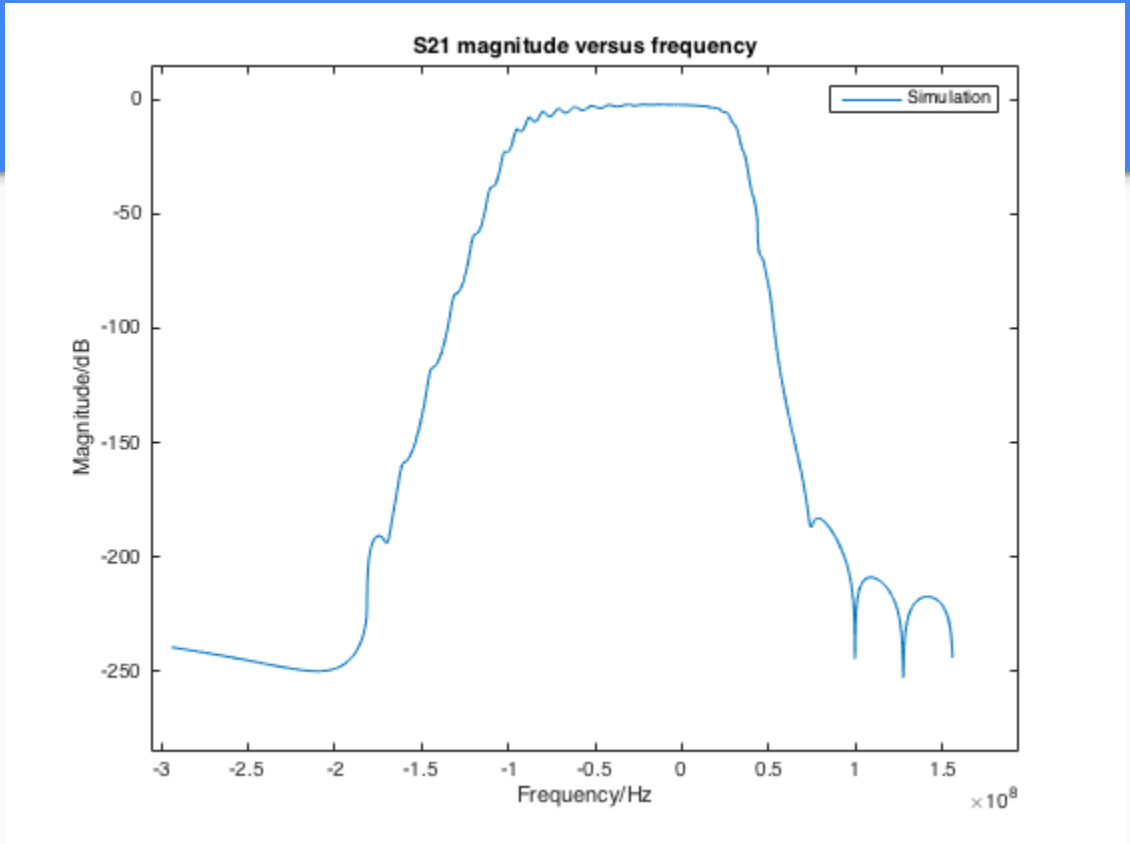
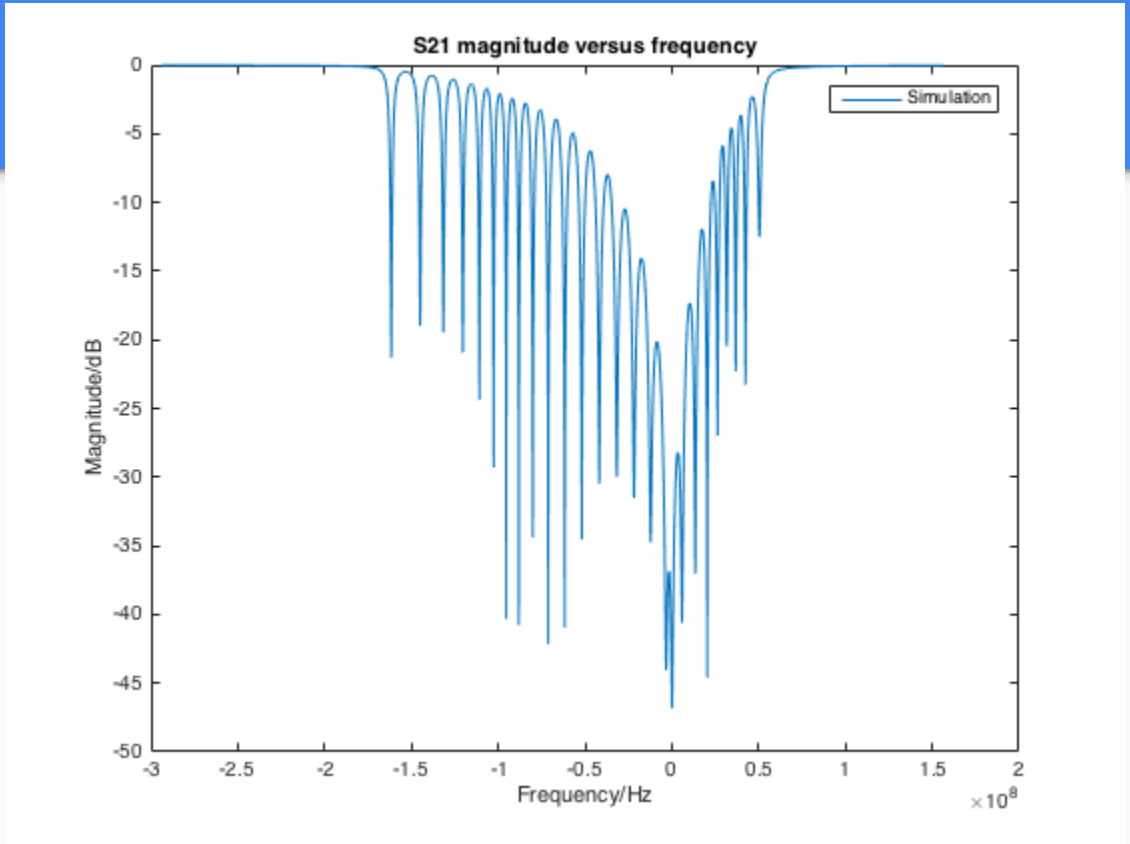
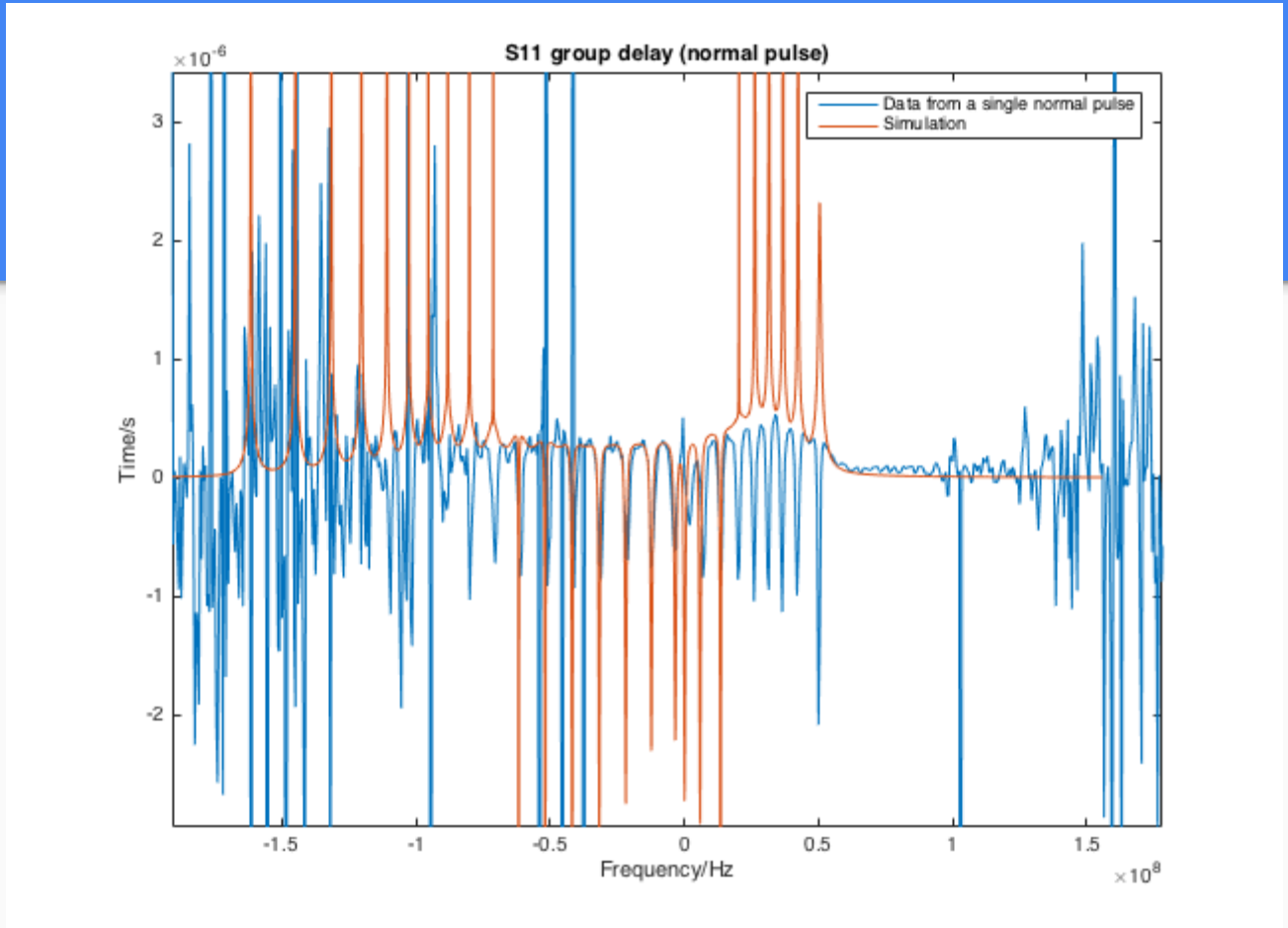
-10
-20
-30
-40
-50
-60
-70
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

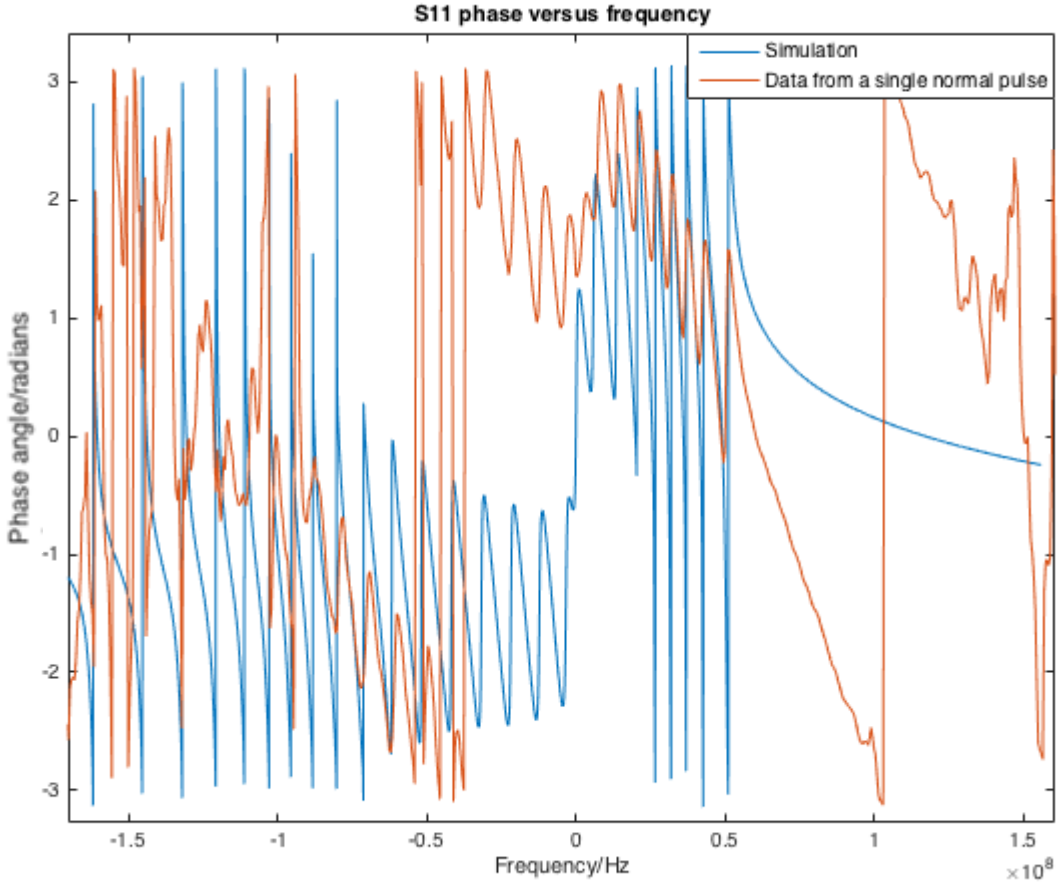
Frequency sweep of S21 - Simulation



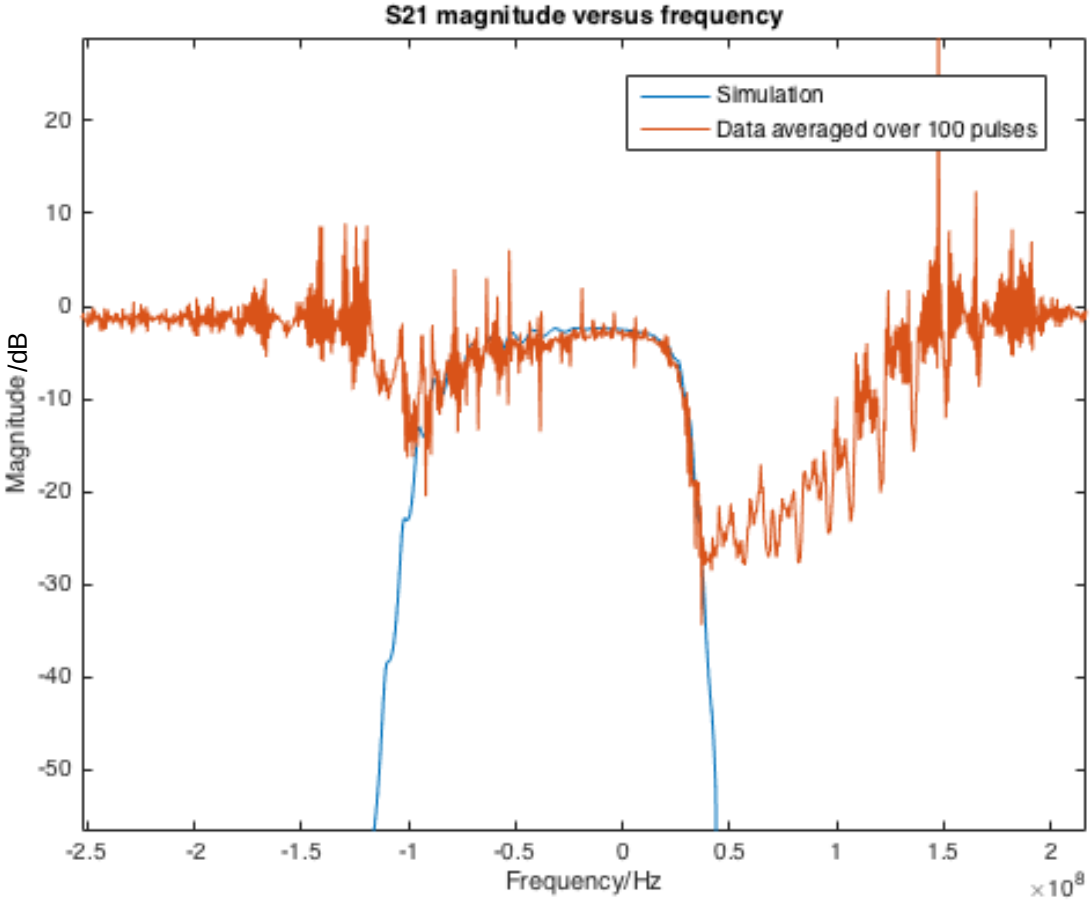
Frequency sweep of S11 - Simulation




S11 group delay (normal pulse)
×10^-6
3
2
1
0
-1
-2
Time/s
Data from a single normal pulse
Simulation
-1.5
-1
-0.5
0
0.5
1
1.5
Frequency/Hz
×10^8



Aliasing problem as the resolution of the simulation is 5x greater than the data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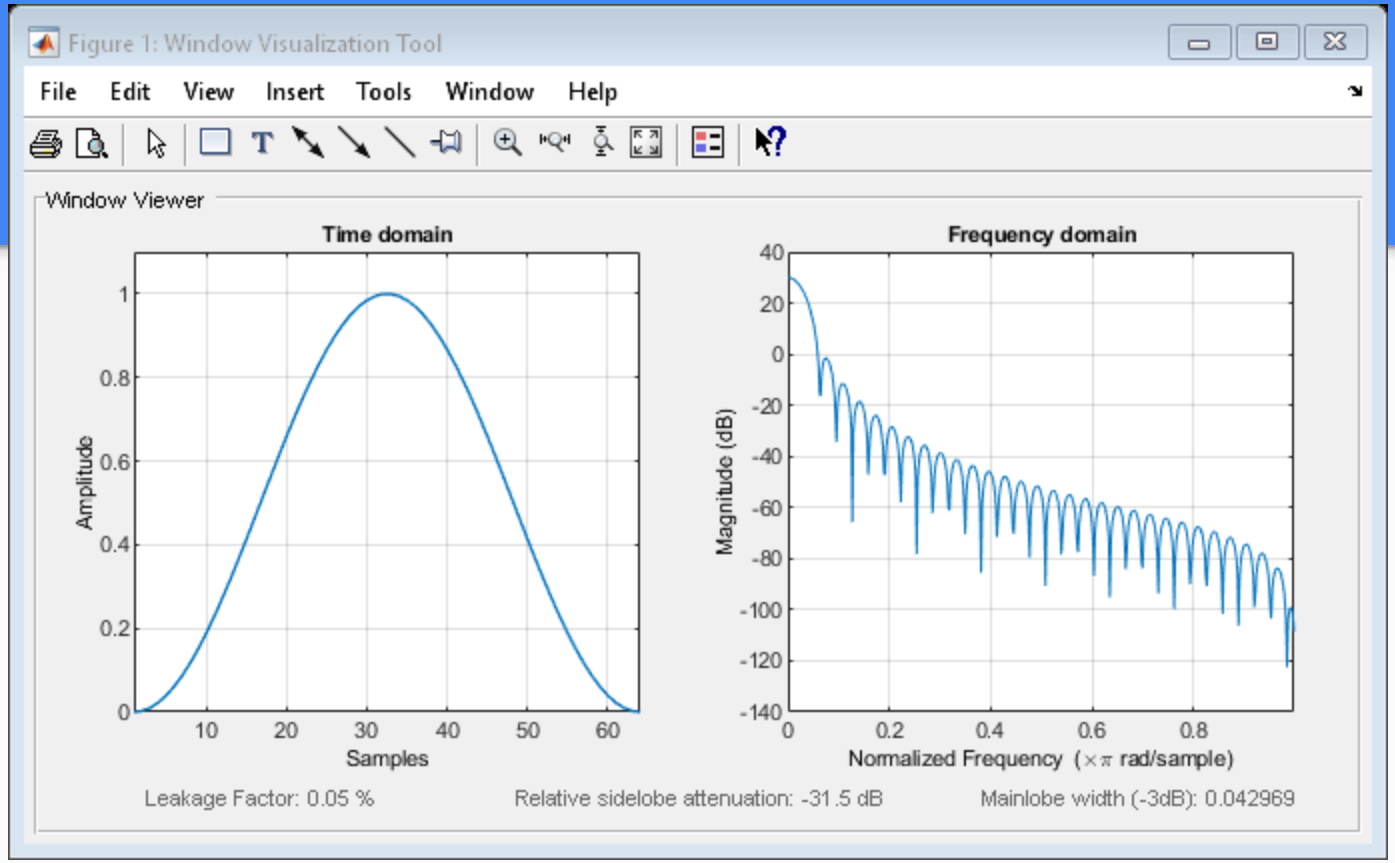
10
0
-10
-20
-30
-40
-50
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Frequency/Hz
×10^8



The hann() function in Matlab