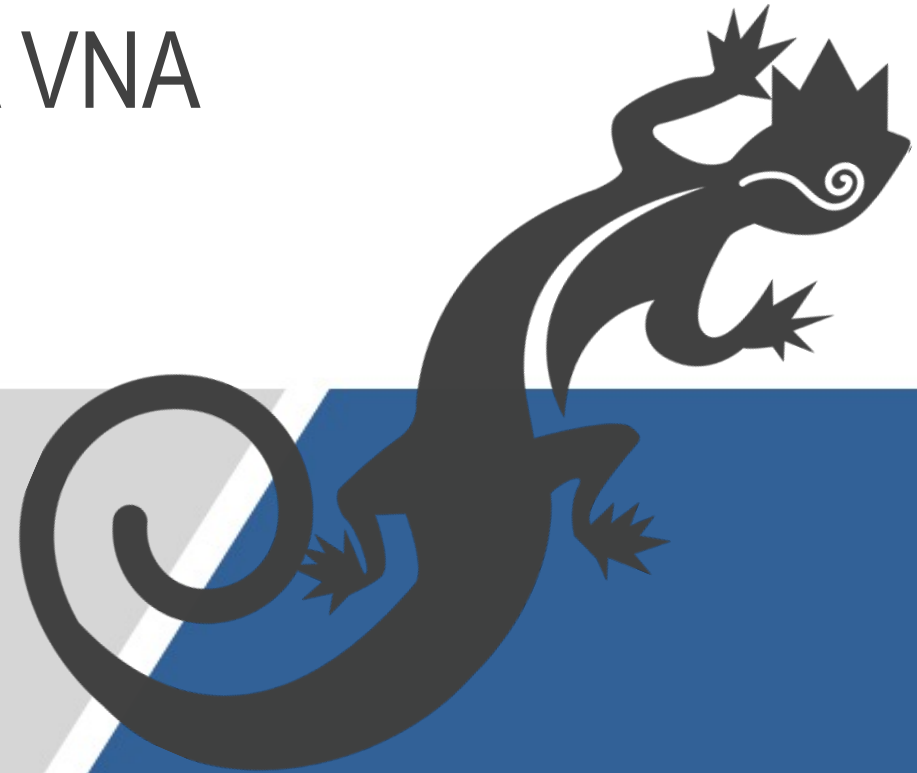


TIME DOMAIN GATING WITH A VNA

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COPPER MOUNTAIN
TECHNOLOGIES

HOW IS A TIME DOMAIN MEASUREMENT MADE?

- Let's assume we are making a 1-port measurement
- The VNA measures reflections looking into a transmission line
- Imagine that the transmission line is shorted and the VNA sweeps from very low to very high frequencies
- At very low frequencies, the returning reflection may not be phase shifted much at all, and the two-way time delay is easily estimated from that phase shift

HOW IS A TIME DOMAIN MEASUREMENT MADE?

- At some higher frequency, the phase will rotate through an entire 360 degrees and the two-way delay is ambiguous, if this is the only information that we have
- Fortunately, the ambiguity is resolved if we make another measurement at a different frequency
- If both signals have seen a full 360 degrees rotation, the phase change between the two signals will be twice what one might expect. In fact, the two-way time delay is simply $\frac{d\Phi}{d\omega}$

HOW IS A TIME DOMAIN MEASUREMENT MADE?

- This shows that it is possible to determine the time delay (or position if the guide velocity is known) to a reflection if a number of measurements are made over frequency
- In fact, the comprehensive way to do this is take the Inverse Fourier Transform of the complex reflection data
- The result of this is the Time Domain representation of the reflection data

THE FOURIER TRANSFORM AND ITS INVERSE

- The Fourier transform from a time domain function to the frequency domain is given by: $F(f) = \int_{-\infty}^{\infty} g(t) e^{-j\omega t} dt$
- Its inverse is: $g(t) = \int_{-\infty}^{\infty} F(f) e^{j\omega t} df$
- The discrete Fourier Transform and its inverse are:

$$X_k = \sum_{n=0}^{N-1} x_n e^{\frac{-j2\pi nk}{N}} \quad x_n = \sum_{k=0}^{N-1} X_k e^{\frac{j2\pi nk}{N}}$$

THE FOURIER TRANSFORM AND ITS INVERSE

- If we plug an array of real values x_k in the time domain into the Fourier transform, we get a complex result in two halves.
- One half represents positive frequencies, and the other half contains negative frequencies with complex conjugates of the positive frequency data
- If we want to produce a real valued time function, we should plug in negative and positive frequencies where the negative frequencies contain the complex conjugates into the IDFT

$$\dots \hat{x}_3, \hat{x}_2, \hat{x}_1, 0, x_1, x_2, x_3 \dots$$

- Where the “hats” are complex conjugates

$$X_k = \sum_{n=0}^{N-1} x_n e^{-j2\pi nk} \quad \text{DFT}$$

$$x_n = \sum_{k=0}^{N-1} X_k e^{j2\pi nk} \quad \text{IDFT}$$

THE FOURIER TRANSFORM AND ITS INVERSE

- Plugging the array with negative frequency conjugated data into the IDFT gives us twice as much time domain resolution
- Note that the values plugged in to the IDFT must be equally spaced with zero in the middle. This method is used for Lowpass Impulse and Step modes
- Frequency domain points could be 6 MHz, 12 MHz, 18 MHz... 6 GHz, 1000 points in total
- This creates a negative and positive array centered at zero with no discontinuity
- If the first point is 60 MHz and the next is 66 MHz, there would be a discontinuous gap from -60 to 0 and then to 60 MHz, thus there is no point in using the negative image

USING THE TIME DOMAIN DATA

- We know that if we plug the frequency domain data into the IDFT and then plug that result back into the DFT, we will get our original data back
- If we run the frequency data through the IDFT, zero out some of the time data, and then run it back through the DFT, we will now have frequency data with reflections that occurred during the zeroed-out time removed!

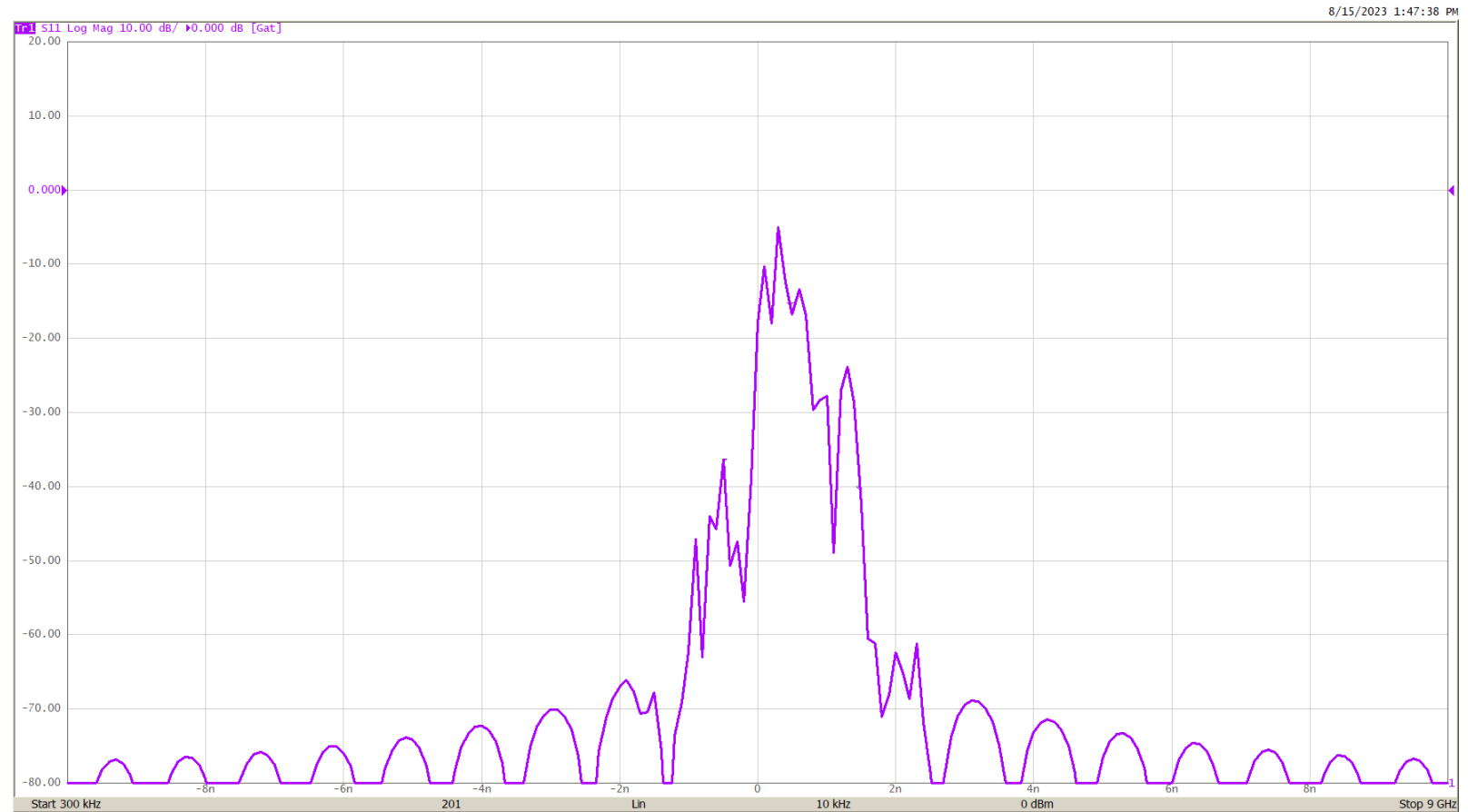
USING THE TIME DOMAIN DATA

- We can also choose to eliminate all reflections except for those which occur in a given time frame
- We simply window **IN** that data and zero everything else
- This is helpful for making measurements with microwave horns where you only want to see the reflection from the DUT and not from other objects in the room

USING THE TIME DOMAIN DATA

- This is what is done in Time Domain Gating
- Now you can't actually just zero out a section of data. The discontinuity would cause large sidelobes in the DFT result
- Data is driven to zero smoothly in a chosen section using a window function such as a Gaussian
- This affects data on either side of the desired time slice, but it can't be helped

LET'S TRY IT OUT!



QUESTIONS?

