Relays Part 1

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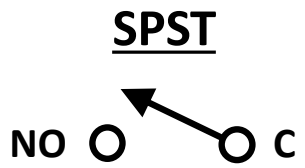
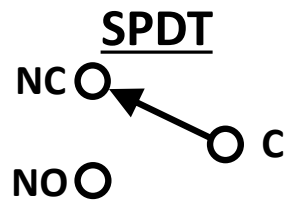
Acknowledgement

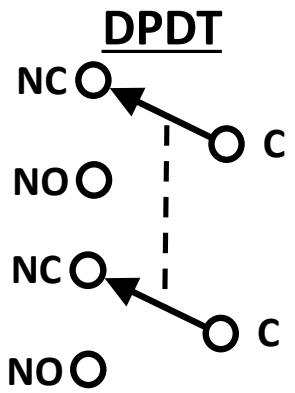
- Some of the material shown in this presentation was obtained from Tom Rauch's W8JI.com website

Relay Basics

- A relay is an electrically operated switch
  - Mechanical
  - Solid state
- More than 18 *basic* types
- Typical switching configurations:
  - Single Pole Single Throw (SPST)
  - Single Pole Double Throw (SPDT)
  - Double Pole Single Throw (DPST)
  - Double Pole Double Throw (DPDT)







- Nomenclature
  - Normally open (NO)
  - Normally closed (NC)
  - Common/Pole (C)

} N (normal) refers to de-energized

Relay Basics (cont'd)

- Typical ham applications:
  - RF (low SWR & low RF loss)
  - Signal routing
  - High power switching
  - Fast
    - Used for QSK (break-in) applications
    - Low/medium power RF (reed)
    - High power RF (vacuum)
  - Any combination of: Low voltage, Low current, High voltage, High current
- AC (60Hz) & DC coils

Relay Ratings

- W8JI: Manufacturer relay ratings don’t represent RF performance
  - Ratings are usually for:
    - Hot switching
    - Into specified load types
    - At low frequencies (or dc)
    - At fixed voltages
  - Closed contact current capability:
    - Is usually much higher than manufacturer’s current rating
    - More representative of ham applications
- Contact rating is a complicated topic with numerous parameters

Relay Ratings (cont'd)

- For RF applications, need to consider:
  - RF loss
    - Skin Effect
  - SWR
    - Unless relays are designed for RF applications, they can degrade SWR
      - Cascaded SWRs will add or subtract depending on their respective phases
        - Two 1.5:1 SWRs in tandem can result in >2.2:1 net SWR
  - Peak RF voltages increase as the $\sqrt{SWR}$
  - Peak RF currents increase as the $\sqrt{SWR}$

  $E = \sqrt{PxR}$

  $I = \sqrt{P/R}$
  - Usually large relays are not as good as small relays for RF applications
    - More inductance
    - Less contact pressure due to large contacts
    - Non-optimal contact materials

Relay Ratings (cont'd)

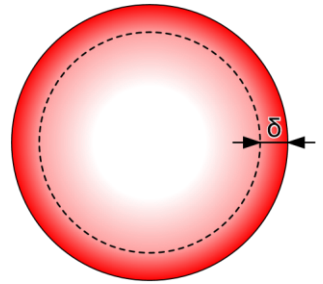
- Hot Switching:
  - RF vs 60 Hz hot switching?
    - Relay contacts can be destroyed if opened or closed while RF is present
    - Damage can occur very quickly with plated contacts
    - ***Tx/Rx system timing of relays is important***
  - RF hot switching can also damage other components
    - Power transistors in solid state amps
    - Plasma arcs in tube amplifiers
      - Plasmas are self-sustaining
        - Once started, plasmas continue until power is removed
      - Damage occurs in seconds, not minutes
    - Relay contacts can fuse together

Relay Ratings (cont'd)

- Contact oxidation:
  - Silver can oxidize quickly (in weeks) and result in intermittent contact
  - Oxidation problem is worst with non-gold plated contacts that are rarely activated and have no residual current flowing thru them (wiping current)
  - Gold (plate) is the best contact material for low current/low cycle applications
    - Gold does not oxidize
    - Only used on plated (ie, low current) contacts
  - Sometimes intermittent operation is caused by contamination, not oxidation

Skin Effect

- Skin effect (δ):
  - Skin effect is due to opposing eddy currents induced by the changing magnetic field resulting from an alternating current (Maxwell's equations)
  - Pushes current to the outer surfaces of conductors
    - Increases inductance & resistance (loss)
    - Increases contact bar and wire heating in relays
    - Worse with braided wires which are lossy RF conductors
  - Example (copper):
    - At 14 MHz skin depth = 17um = 0.0007 in



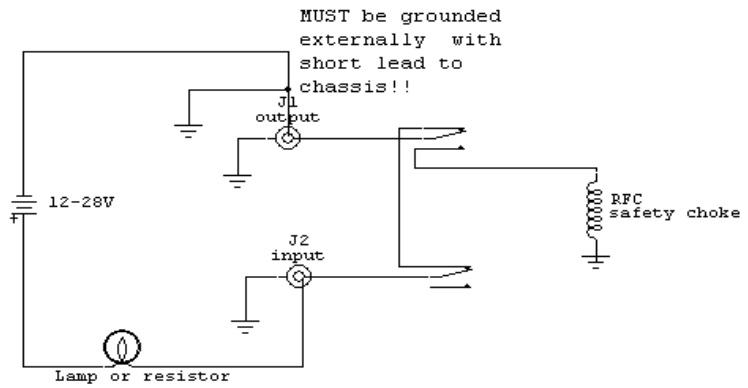
$$\delta = \sqrt{\frac{\rho}{\pi \times f \times \mu}}$$

Relay Contact Cleaning

- **W8JI**: “Relays (and switches) *almost never* cause input SWR issues or intermittent operation *during transmit”.*
- I disagree!
  - Intermittent SWR & power are frequently the first signs of burned contacts
  - Intermittent operation can also result from a “sticky” relay armature
- Nonplated relay contacts can be cleaned with special file
- Contamination can also cause intermittent operation
  - **Using an abrasive material can remove thinly plated material!**
    - This can make a relay unusable
  - Best ways to clean:
    - Use:
      - De-Oxit
      - WD40 and cardboard or cloth (or non-glossy paper per W8JI ??)
        - May not be an option with enclosed relays
      - Apply a small DC "wiping" current while cycling the relay

Relay Contact Cleaning (cont'd)

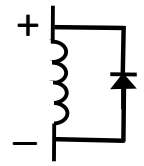
- **W8JI c**ircuit for cleaning relays in external amplifiers

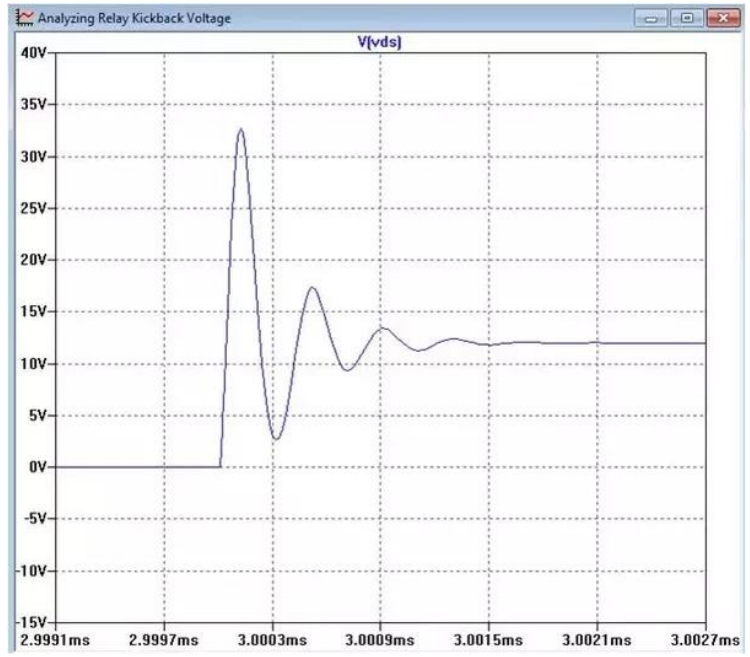


- It isn't clear to me why he presented this circuit
  - Amplifier relays are not likely to have contact oxidation or contamination problems
    - They are frequently activated and have moderate to high currents flowing in the contacts
  - This type of cleaning is automatically done whenever the amplifier is in line but turned off

Relay Misc

- Back EMF (voltage spike) can damage components
  - Cause: Current thru an inductor cannot change instantaneously
    - Back EMF of a relay coil = di/dt (i = relay current & t = delta time)
    - di/dt is the amount current change per unit of time
      - As dt => 0, V => infinity
    - V never gets to infinity because of arcing across the contacts
    - Voltage can reach >10x supply voltage
  - Back EMF voltages can:
    - ***Exceed transistor breakdown voltage***
    - Burn switch & relay contacts
  - Suppression techniques:
    - DC coils => back biased diode
    - AC coils => “snubber” or back-to-back Zener diodes
    - All of these methods can slow down the release time and reduce life of the relay (W8JI) **(?)**



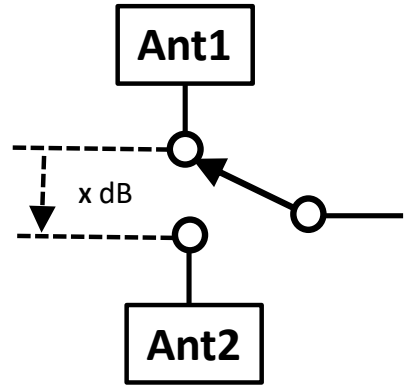


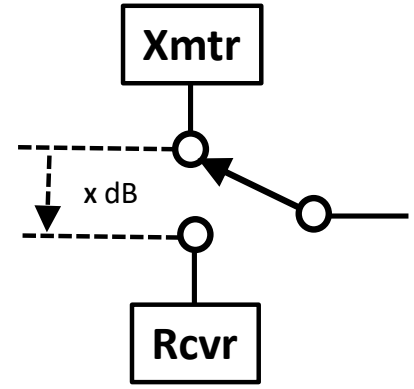
Relay Misc (cont'd)

- Some AC relays buzz when activated
  - Not sure why some do and some don't (even with the same P/N)
  - Fixes:
    - Replace relay with one with the same P/N
    - Replace relay with a different P/N
    - Convert over to a DC supply for the relay coil
      - **Note: A 120 VAC coil may only need 10-20 VDC to operate properly**
- Add a DC "wiping current" to the relay contacts
  - Some mfgs of ham equipment have started doing this
- RF isolation requirements can be important for both relays and switches
  - Rarely discussed in ham publications

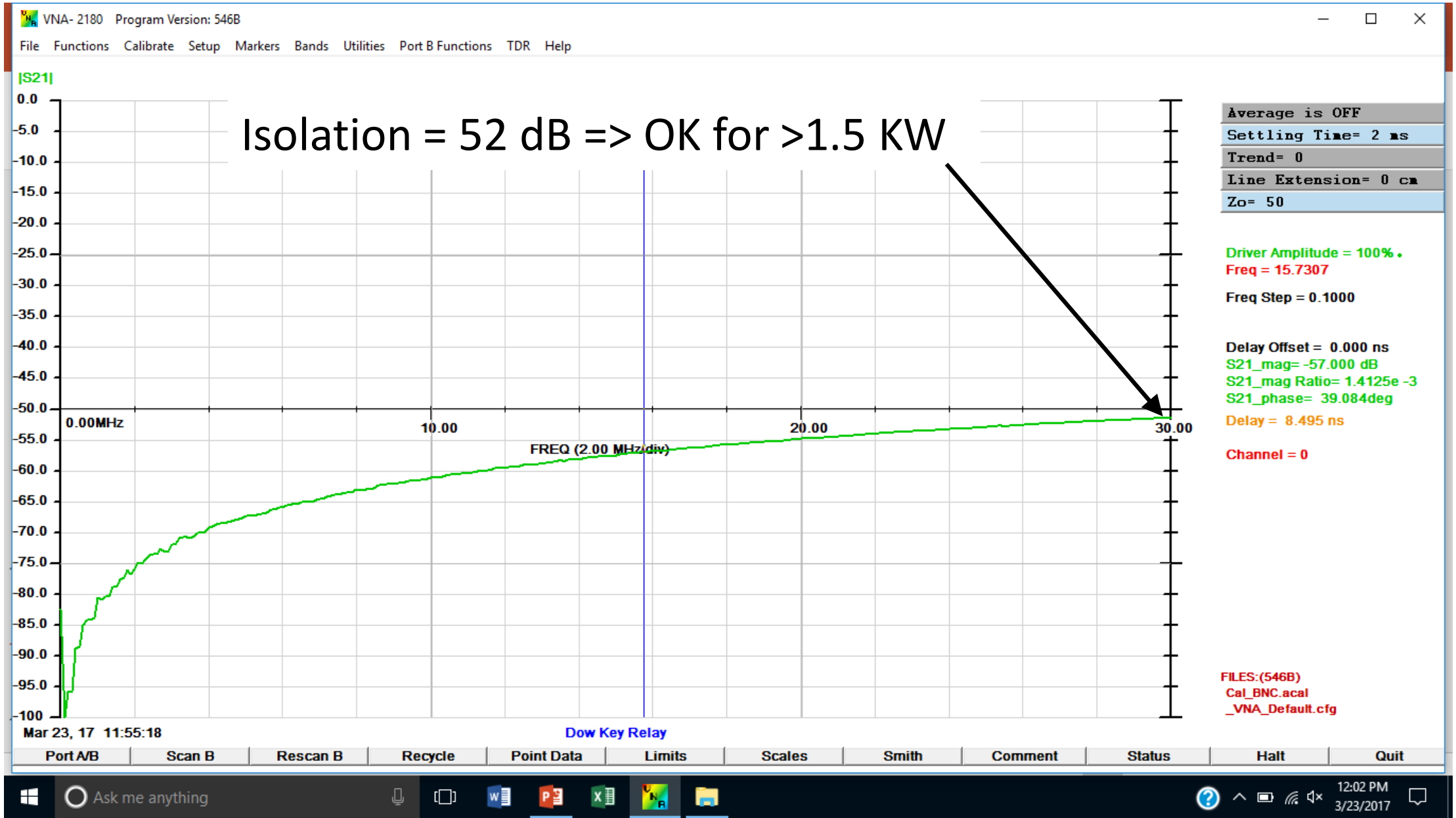
RF Isolation

- Specifies the amount of unwanted coupling between two circuits
- RF isolation requirements:
  - For antenna switching applications
    - Strong signal bleed thru can cause problems in a receiver
      - IMD interference
      - Adjacent signal interference
  - For switching between transceivers:
    - Maximum allowed input to a receiver usually not spec'd
    - Damage level is typically assumed to be 100 mW (+20 dBm)
      - **Note: This number applies even when the receiver is turned OFF!**
      - Minimum isolation required for RF relay or switch:
        - Transmit power = 100 W => 30 dB
        - Transmit power = 1500 W => 42 dB

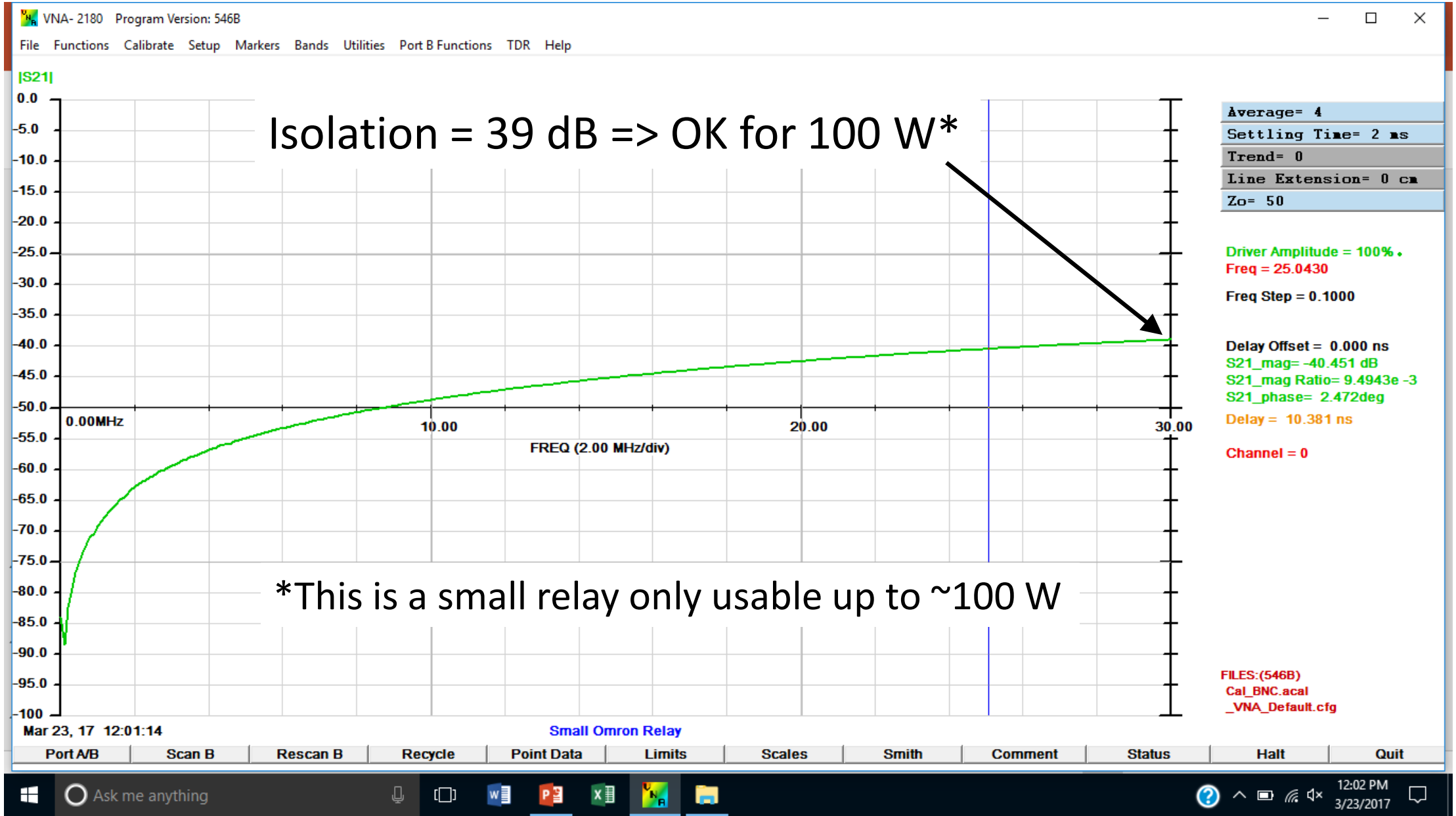




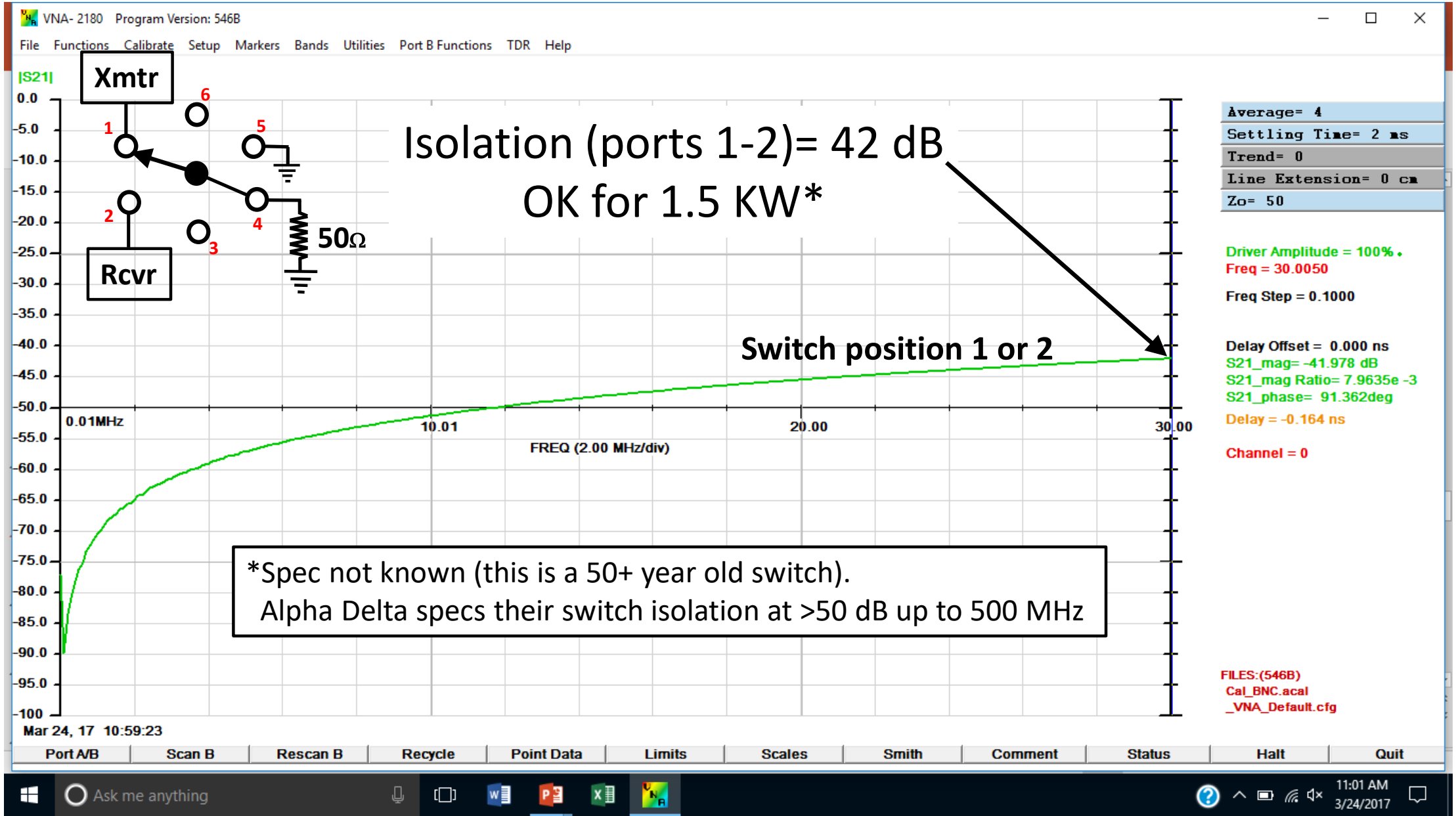
RF Isolation Example 1: Dow Key 1 KW RF Relay



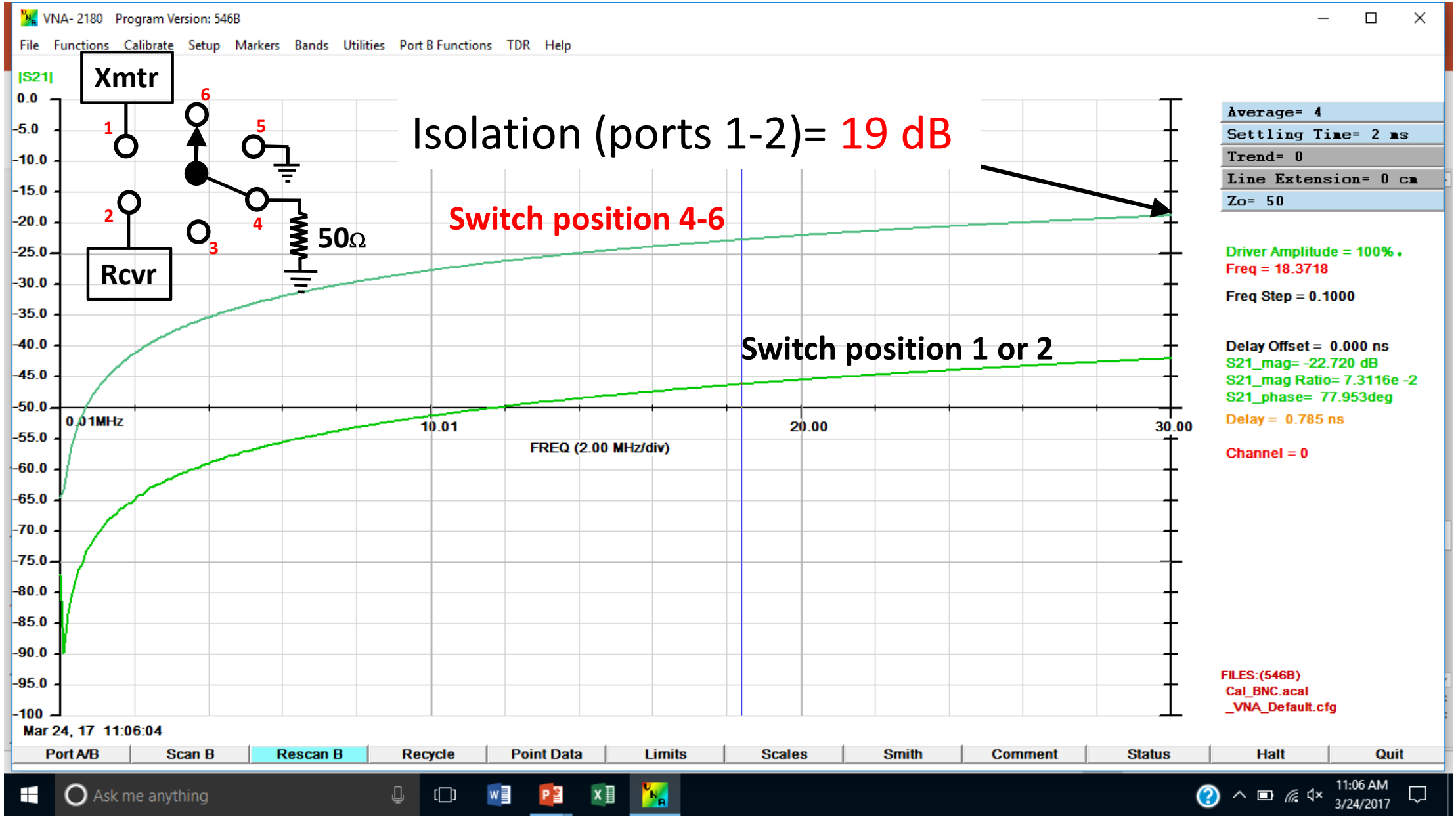
RF Isolation Example 2: Small Omron Relay



RF Isolation Example 3: Heathkit RF Switch



RF Isolation Example 3: Heathkit RF Switch (cont'd)

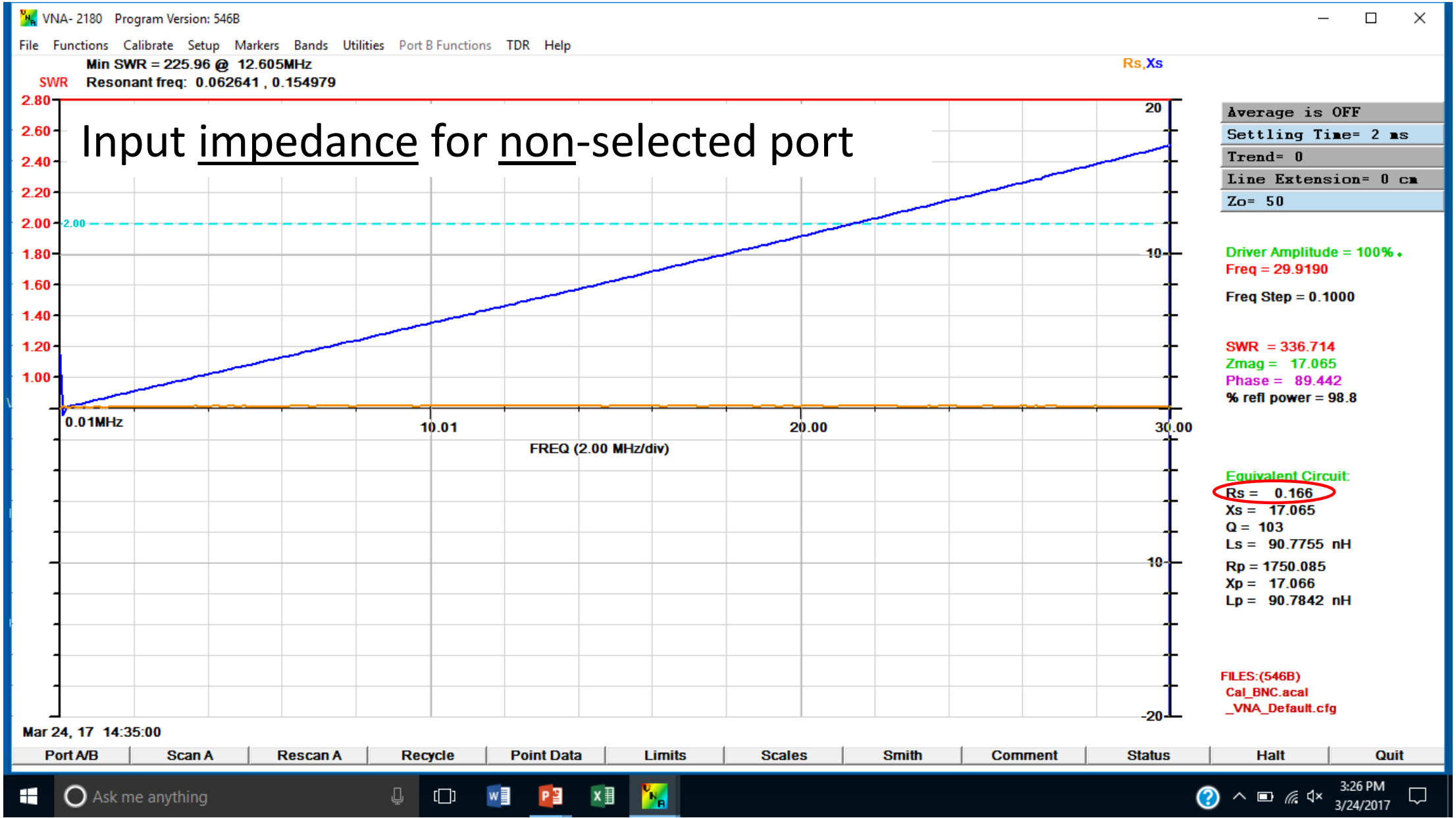


RF Isolation Example 3: Heathkit RF Switch (cont'd)

- This is an antenna switch shorts unused inputs to ground
  - Input resistance to ground for a non-selected port measures **0.1 ohm** with DVM!

Why isn't the isolation greater than 19 dB between ports that are shorted to ground?

RF Isolation Example 3: Heathkit RF Switch (cont'd)



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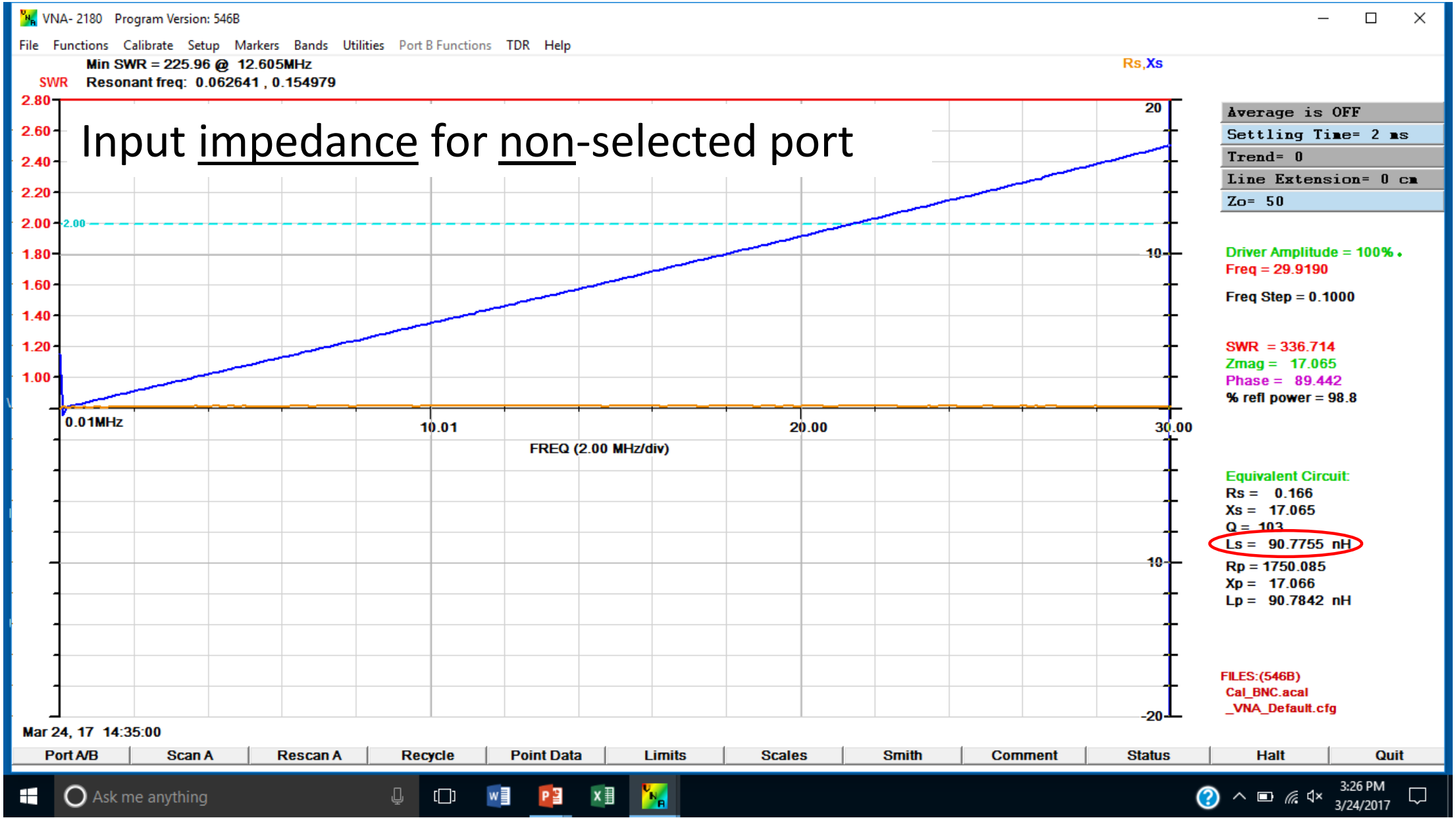

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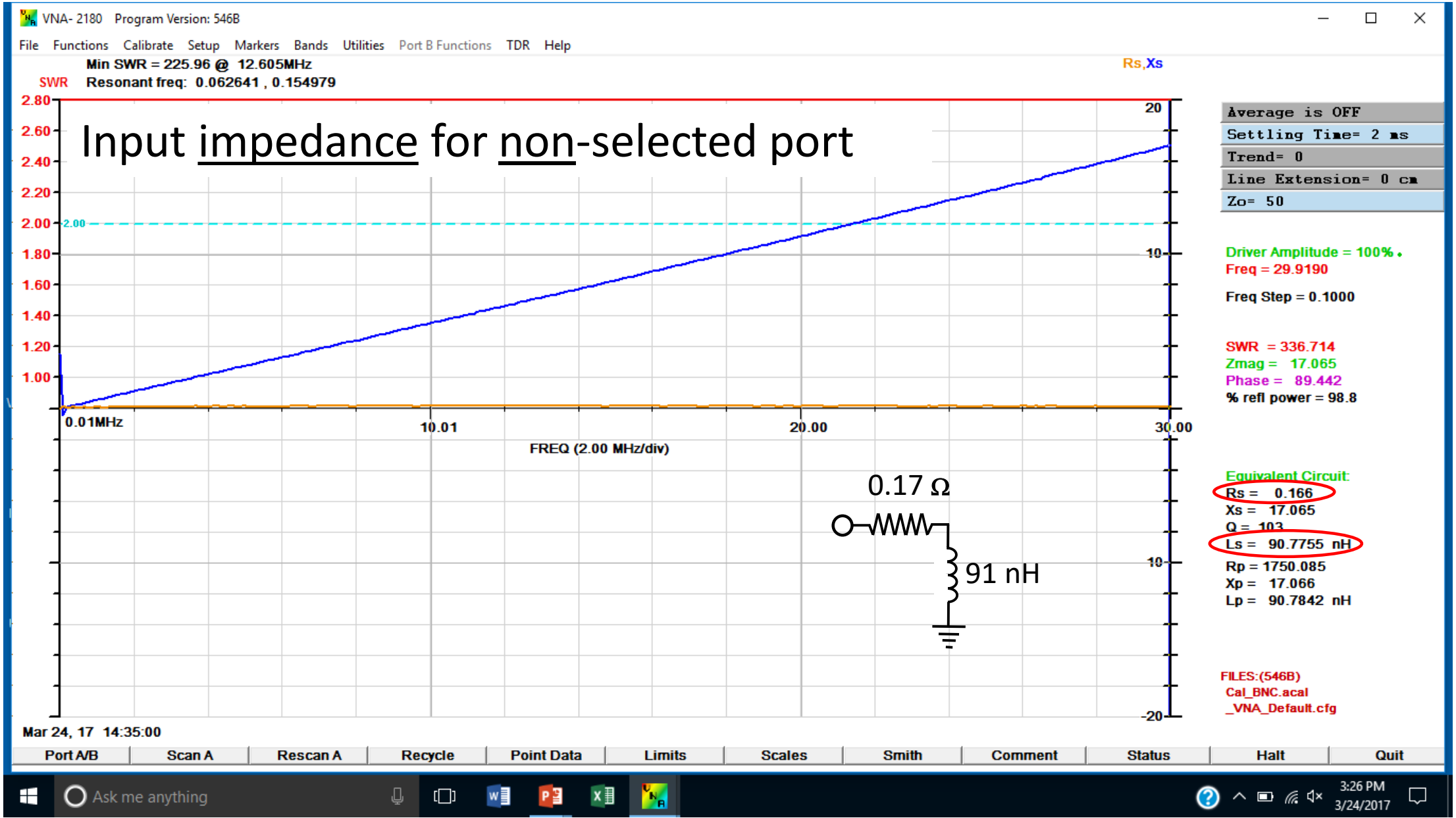
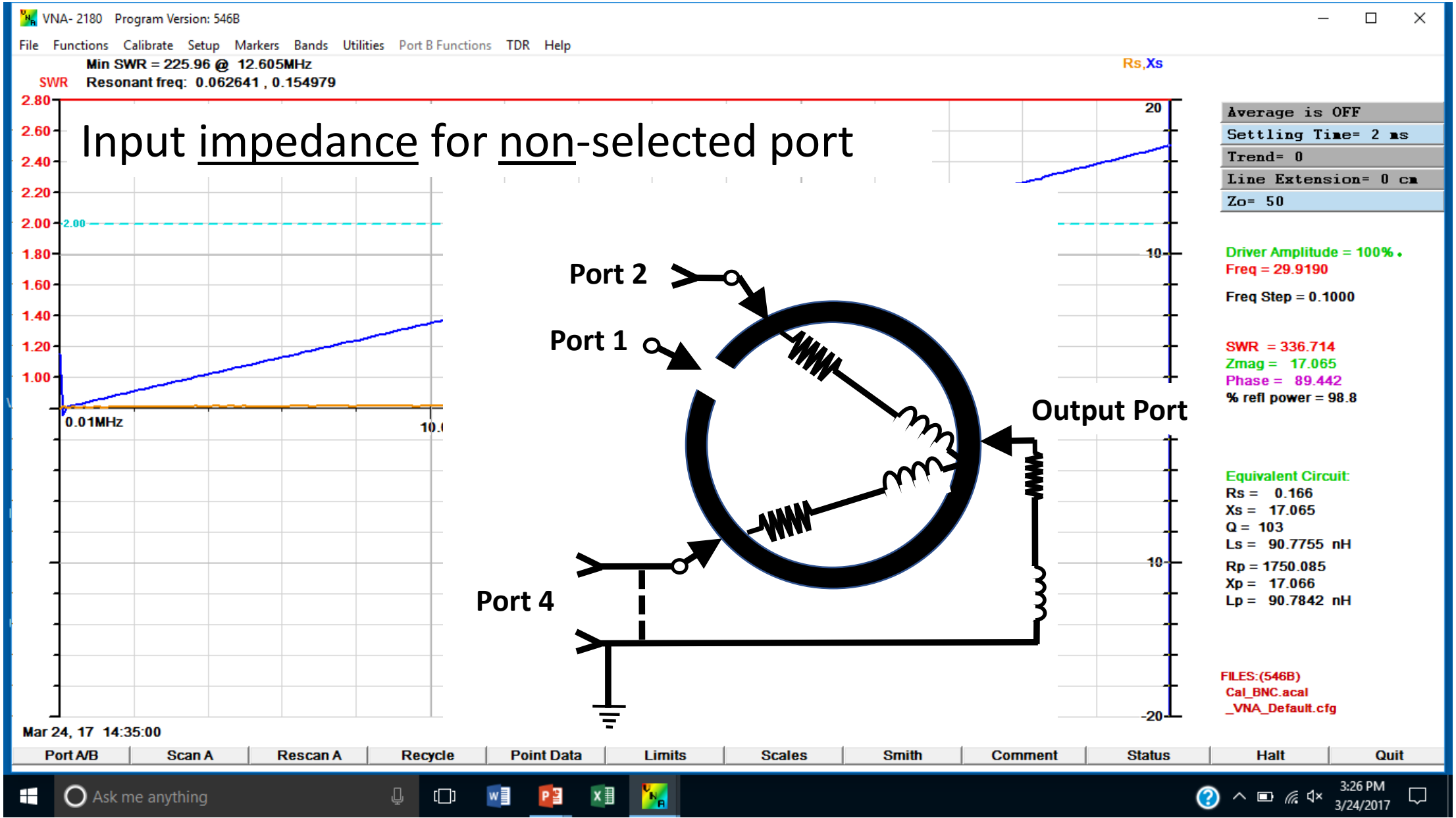


RF Isolation Example 3: Heathkit RF Switch (cont'd)



RF Isolation Example 3: Heathkit RF Switch (cont'd)

- This characteristic may exist with all antenna switches
  - Manual or relay
  - Results from the grounding of unused ports
    - Grounding of unused ports is for protection against static and lightning
- Is this a big problem?
  - Not likely when used as an antenna switch
  - Possible risk when used to switch transceivers
    - Biggest risk is with tube transmitter and solid state receiver
      - No SWR shutdown circuits in tube transmitters
      - Many Pi Net antenna tuners can match a short under some conditions
      - Solid state receivers have low damage levels compared to tube receivers

System Timing

- “System” timing refers to timing of all components switched during Tx⇔Rx
  - Important when using VOX or QSK
- Improper “System” timing can cause hot switching
- “System” timing accounts for all Tx/Rx switching delays
  - Some radios ensure hot switching
  - Many newer transceivers provide adjustable delays
  - W8JI shows how to measure system timing
    - Requires a dual trace triggered scope
  - W8JI gives an example of a dual relay driver circuit with adjustable delay times for use with older equipment

Sequence of Events Timing

- Receive to transmit sequence:
  - The operator initiates the transmit sequence
  - Amplifier output relay makes full contact
  - The amplifier input relay makes full contact
  - Amplifier bias is switched from standby to operate (if applicable)
  - RF from the transmitter appears at the input of the amplifier
  - RF appears at the output of the amplifier
- This entire sequence can take >15ms with large open-frame relays

Sequence of Events Timing (cont'd)

- Transmit to receive sequence:
  - The operator terminates the transmit sequence
  - RF output from the transmitter ceases
  - Amplifier bias returns to standby (if applicable)
  - Amplifier input relay drops (returns to receive position)
  - Amplifier output relay drops (returns to receive position)

Relays Part 2

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