Receiver Front End Protection

Bill Leonard N0CU

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Topics

- What damages receiver front ends
- Common types of receiver front end protectors
- Example: homebrew protector

What Damages Receiver Front Ends?

- Damage results from exceeding a semiconductor's junction breakdown voltage
  - Base-Emitter junction (V_{BE} max) determines damage level for receiver front ends
    - Typical V_{BE} max for small signal bipolar RF transistors is ~2 V [~50 mW or 17 dBm]
      - Doesn't change when receiver is powered OFF
  - Damage:
    - Is instantaneous (nanoseconds)
    - Initial result of an overvoltage can vary from no change in performance to a dead device
    - Can be a "latent" failure
      - Not uncommon with ESD failures
- What is the maximum input power/voltage to a receiver?
  - Rarely spec'd by mfgs of ham equipment
  - Commonly used guideline: +10 dBm (1.0 V_{peak})
    - ARRL tests receivers at +10 dBm (10 mW)

What Damages Receiver Front Ends? (cont'd)

- Common sources for overvoltage at receiver front ends
  - Lightning
  - ESD
  - High RF voltages
    - Field day
    - SO2R stations
    - **Separate receiver and transmitter sharing the same antenna**

Lightning

- Best option: keep ***all*** lightning energy ***outside of the shack***
  - Disconnect transmission line at a point ***outside of the shack***
  - ***Use of relays doesn't equate to "disconnecting"***
- 2nd best option: keep as much energy as possible outside of the shack
  - "Properly" ground everything ***outside the shack***
  - Use a lightning protector ***outside of the shack***
    - ***These devices are not intended to protect receiver front ends***
      - Threshold voltage can be >500 V
- Other options
  1. Disconnect transmission line inside the shack
     - Use a glass jar to reduce fire risk
  2. Install a receiver front end protector with lightning protection
     - A Gas Discharge Tube (GDT) is used to minimize ***catastrophic*** damage from lightning
     - A GDT probably won't protect the receiver front end

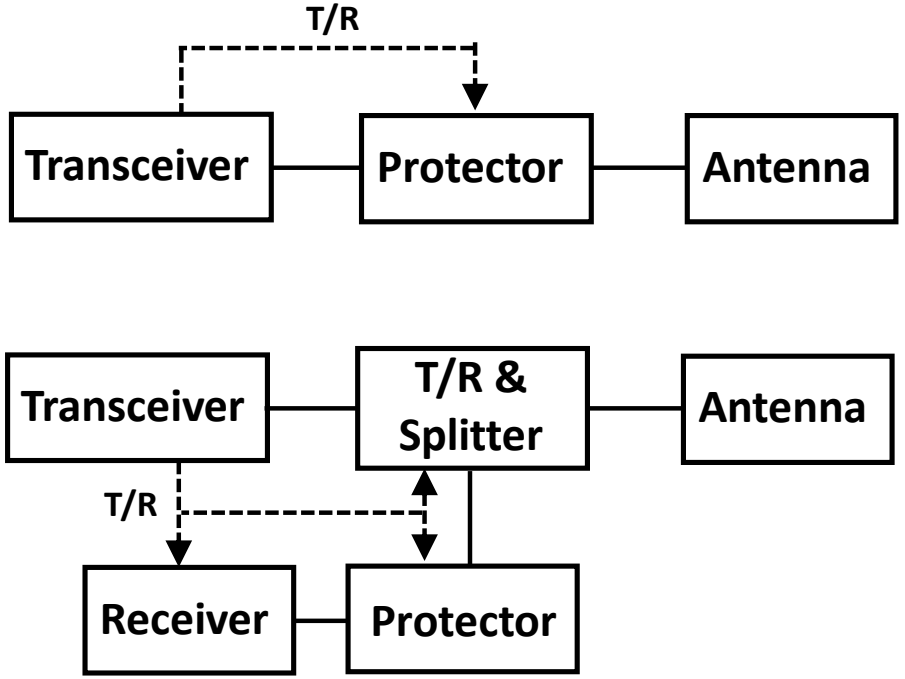
ESD

- ESD is frequently reported as the cause of receiver front end failures
- **Risk mitigation: bleed charge off of every antenna**
  - For each antenna, ground
    - All non-selected antennas (ex: via remote antenna switch)
      - All antennas when not using the station
    - Via RF choke?
    - Via DC bleed resistor(s) (AD5X website)
      - Use a high voltage, high value resistor
        - Ex: 3 MΩ rated to 10 KV (costs ~$6)
        - If you run high power to a highly reactive antenna, you might need 2-3 of these resistors in series
  - Do ***NOT:***
    - Install DC bleed component at receiver antenna input
    - Connect unterminated transmission line to radio without bleeding off charge first

Typical Applications

- Receive only: single receiver always connected to an antenna

- Transmit and receive



Receiver Front End Protectors

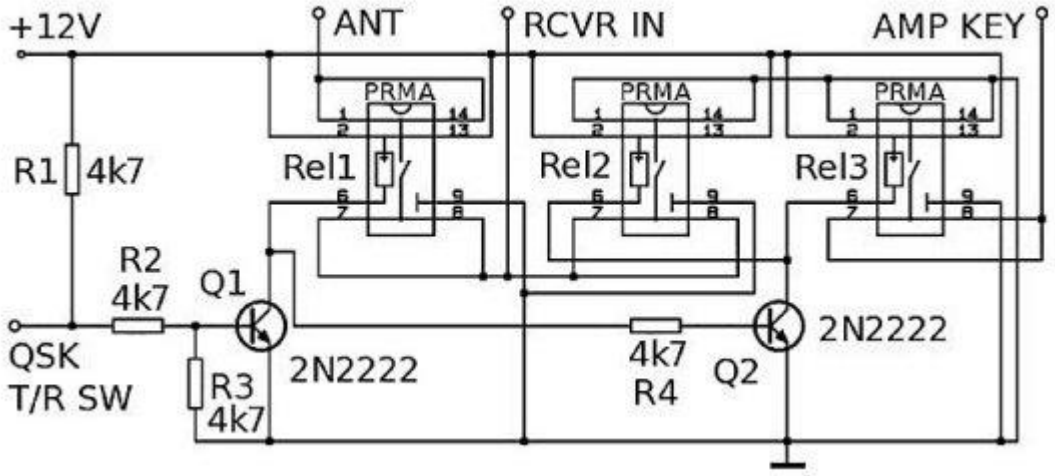
- Common types:
  - T/R switch
  - Back to back diodes
  - Gas Discharge Tube (GDT)
    - Won’t protect a receiver from damage
  - Back to back diodes with loss
    - Light bulb
    - Transformer (loss comes from saturation of transformer core)
  - T/R switch with back to back diodes
  - T/R switch with back to back diodes and loss
  - “Automatic Two-Transceiver Commutator” for SO2R applications (ACOM 2S1)
- Filter vs protection device
  - Filters are better choices than protection devices for some RF environments (ie, near AM broadcast stations)
    - Severe IMD interference

T/R Switch

- Used for protection from co-located transmitters
  - Can offer a high level of protection, but only against co-located transmitters
  - Protection is achieved via configuration
    - During transmit the receiver input is:
      - Disconnected from the antenna and
      - Grounded
    - ***All relays must switch properly*** to achieve full protection
    - No protection when you don't control the transmitter
      - Ex: field day operations
- Relay timing is important in QSK (break-in CW mode) applications
- Good isolation may be required
  - Between relay contacts
  - Unwanted coupling

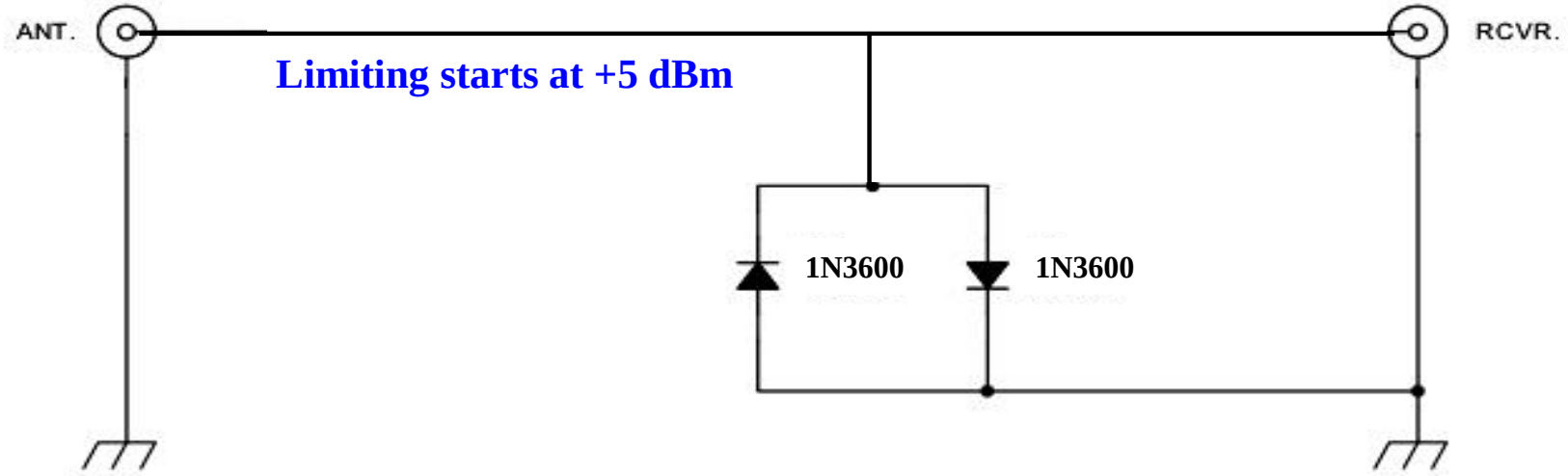
Commercial Units (T/R Switch)

- KD9SV Receiver Front End Protector (P/N SV-FESSS @ DX Engr)
  - T/R switch
    - Rel1 disconnects receiver from antenna input during transmit
    - Rel2 shorts receiver input to ground during transmit
  - What happens with loss of:
    - +12V
    - T/R switch signal?

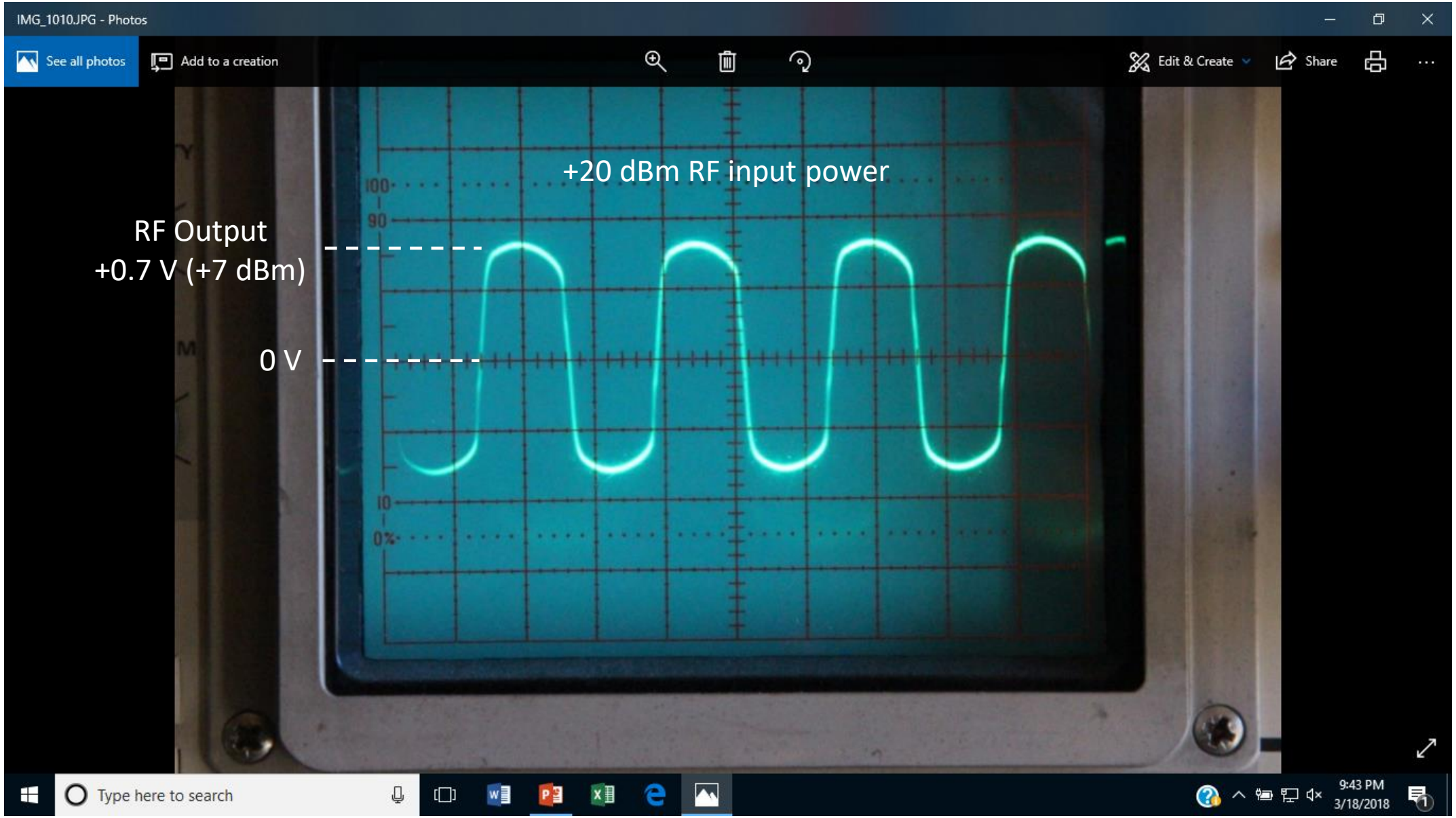


Back to Back Diodes

- Simple and cheap
- Protection not dependent upon configuration
- Diode type is not critical (except, don't use PIN diodes)
- Limited to low input power levels => receive only applications
  - +30 dBm = 1 watt max (when using ½ watt diodes)
  - If either diode fails open => receiver front end not protected
- Spurious signals in receiver can be a problem
  - Some mfgs offer choices on spurious levels (DX Engineering RG-5000 series)

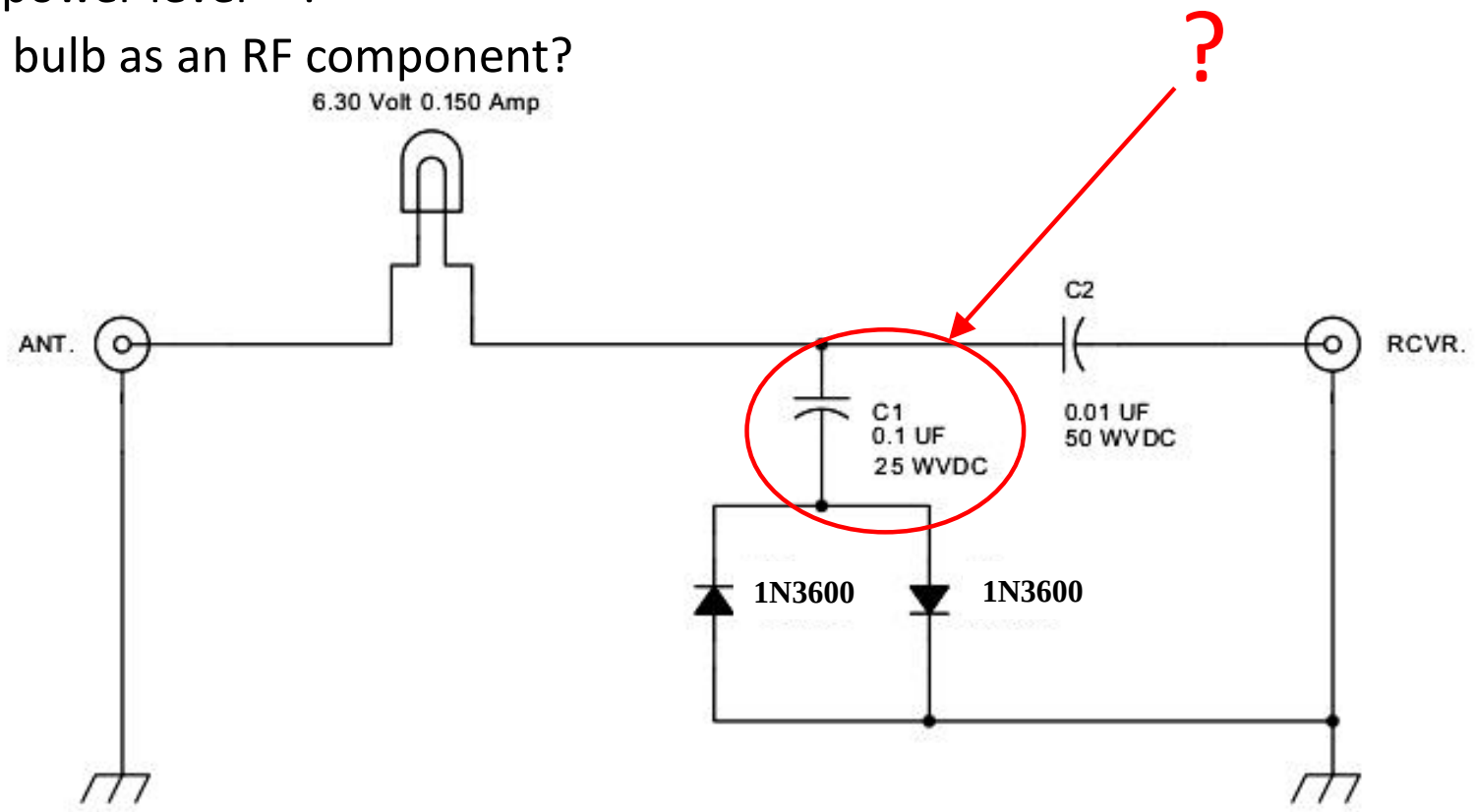


Back To Back Diodes Clipping Level



Back to Back Diodes With Loss (Light Bulb)

- Light bulb adds loss at high power levels => reduces dissipation in diodes
- Popular circuit that has been around for some time
  - No design or performance info found
    - Max power level = ?
    - Light bulb as an RF component?



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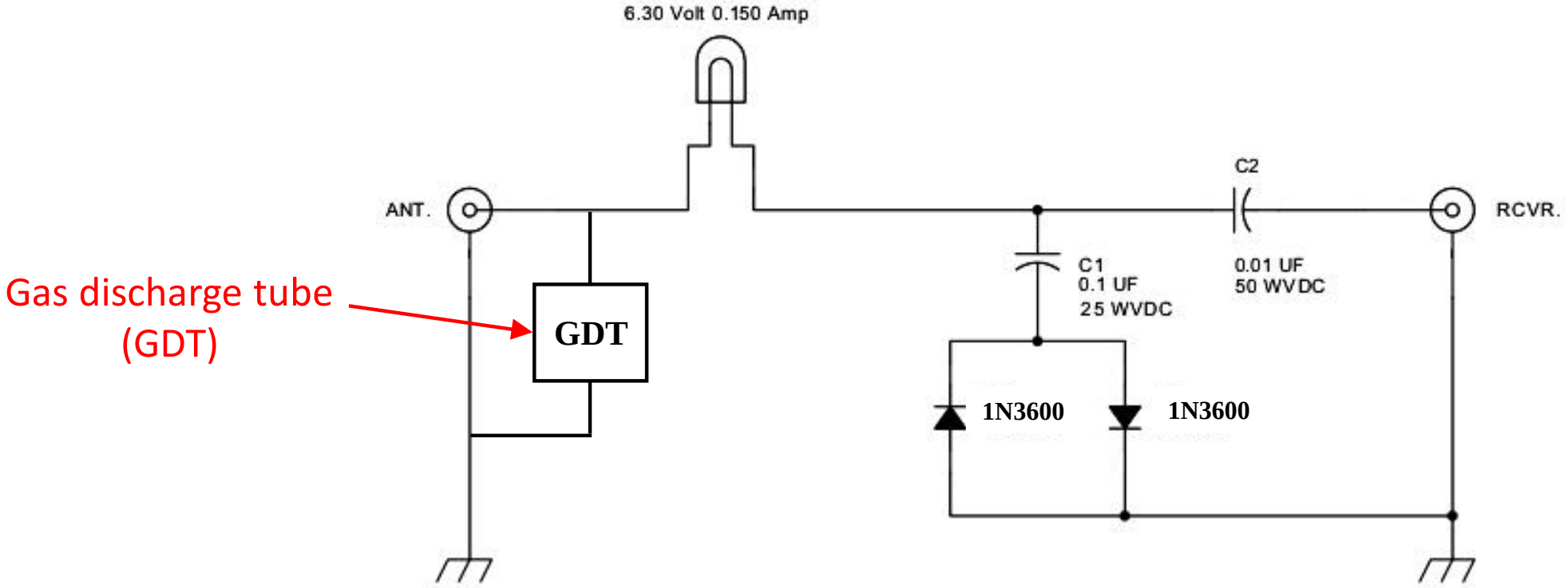
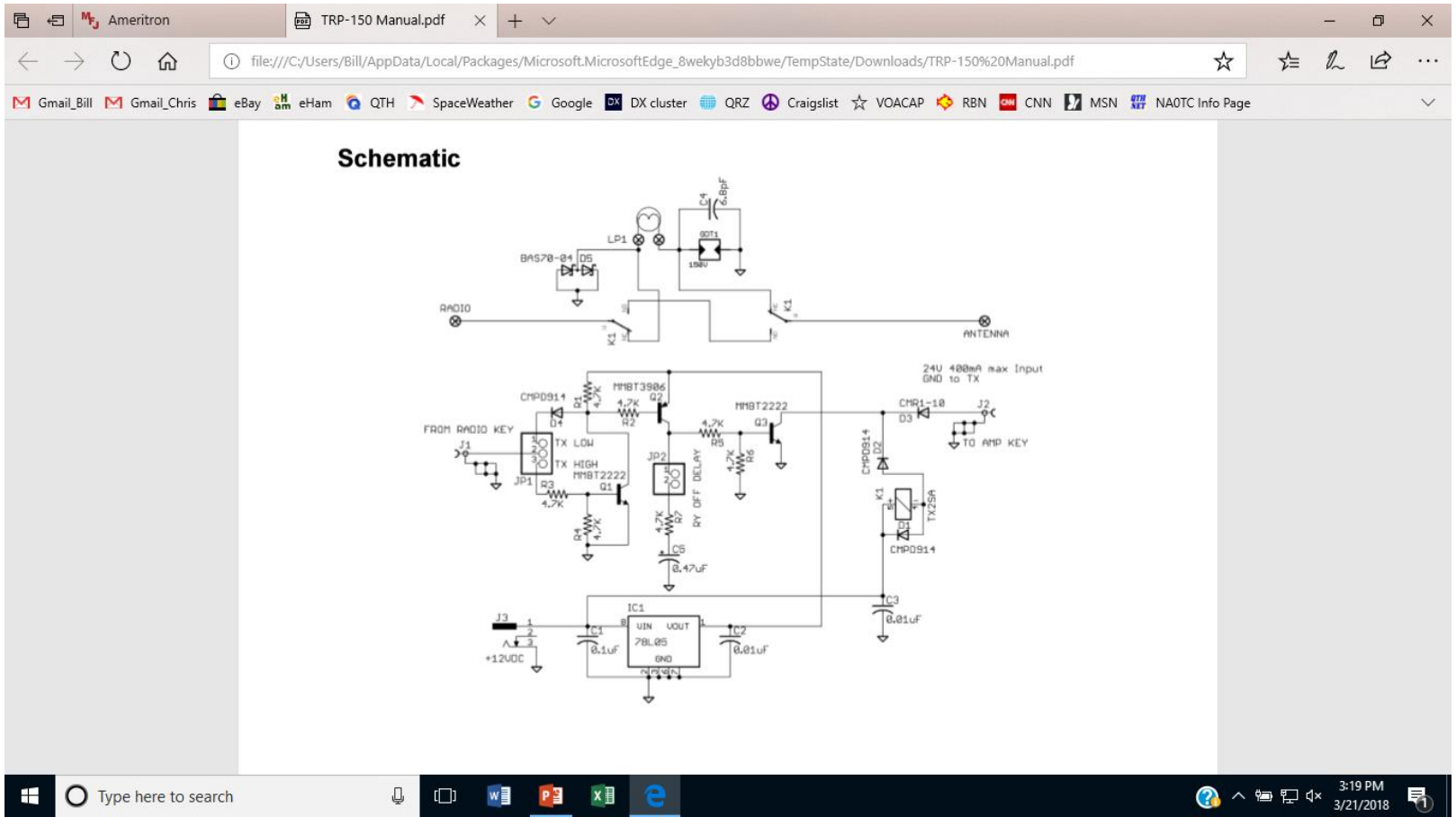


T/R Switch With Back To Back Diodes And Lamp

Ameritron TRP-150

Notes:

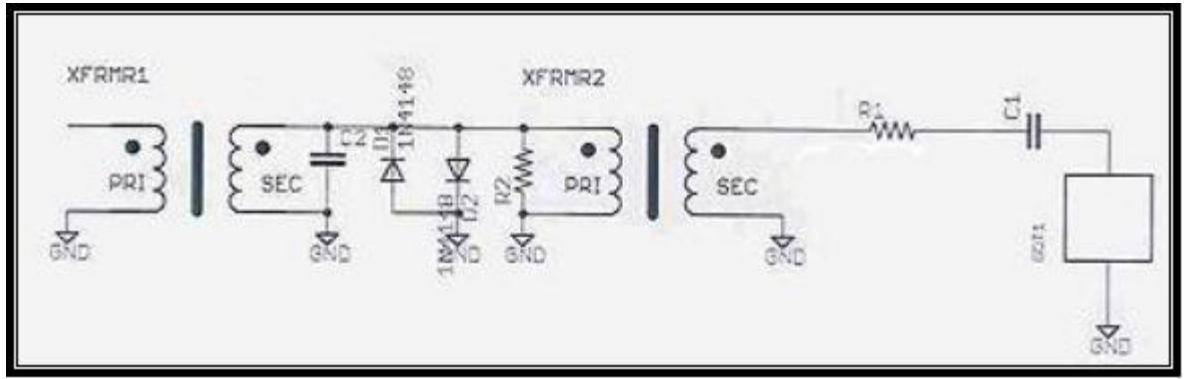
- Maximum RF power is 100 watts
- **Ameritron: "Do not transmit into the TRP-150 when the FROM RADIO KEY line is not connected."**



Back to Back Diodes With Loss (Transformer)

Array Solutions: AS-RXFEP Receiver Front End Protector

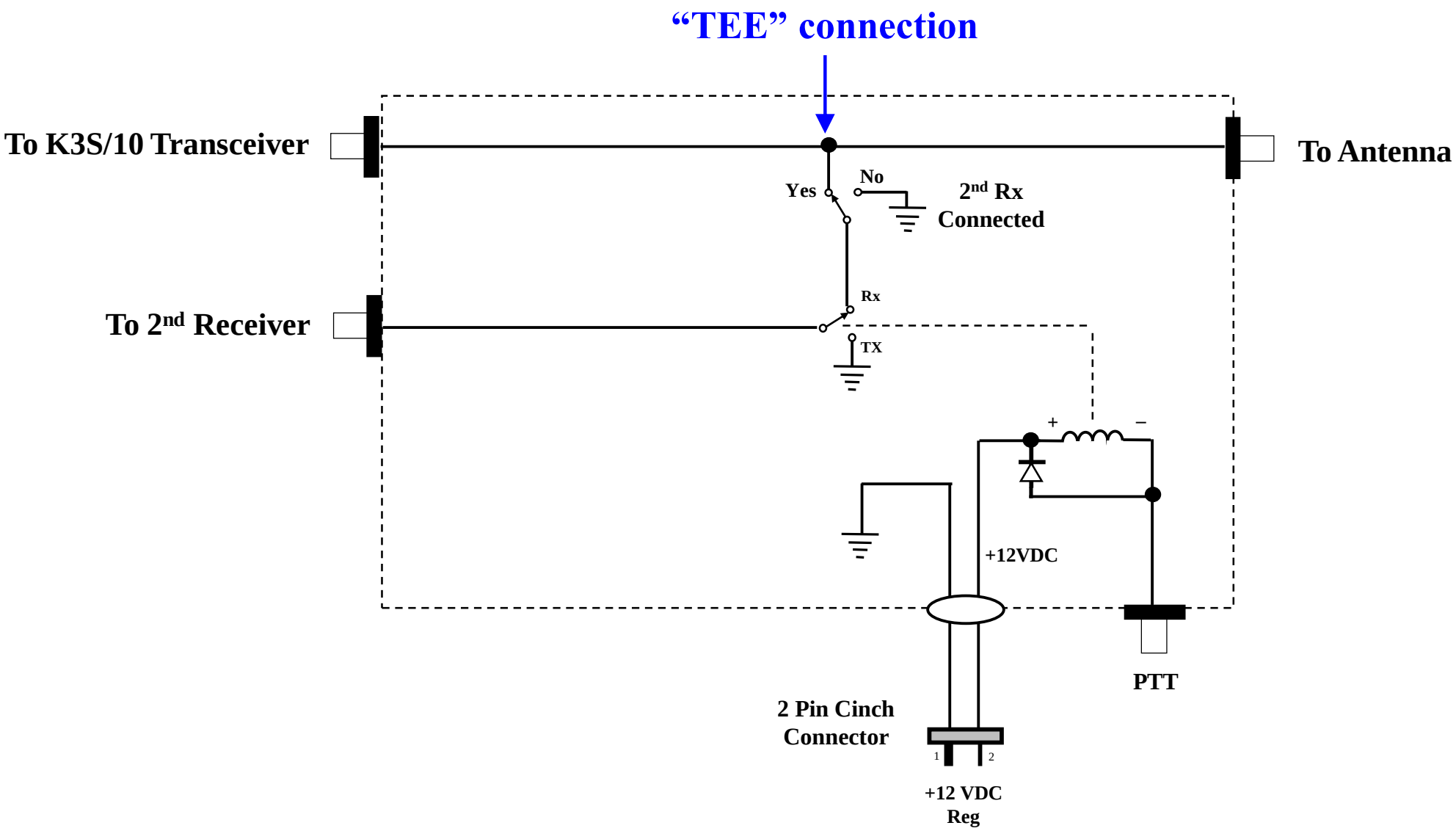
- Uses transformer coupling and diodes
  - When transformers saturate they become resistors
    - Diodes don't have to dissipate all of the power
  - Design issues: power level for core saturation and core power dissipation
- Lightning protection (GDT) limits to 75 V (+48 dBm)
- **Receive only** – tested with 10 watt RF input
  - "The maximum output (+10 dBm) is a few dB below the damage threshold of common transceivers like the FT-1000MP."



Example: Separate 2nd Receiver With a K3S/10 Transceiver

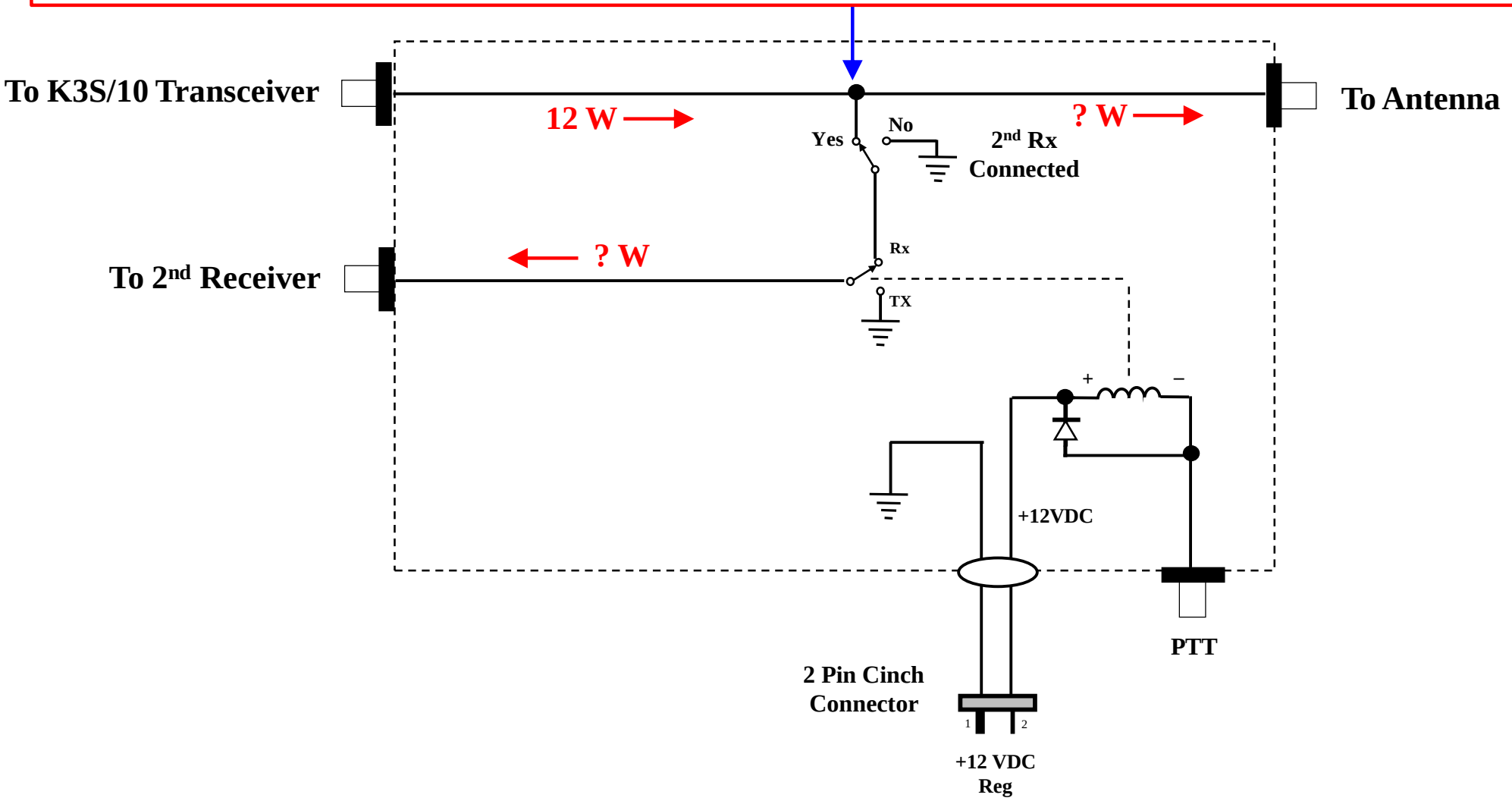
- Why add a 2nd receiver?
  - Diversity receive
  - Monitor two different bands simultaneously
  - ***Split operation***
  - ***2nd Rx has better performance than transceiver Rx***
- Important considerations:
  - Connecting a 2nd receiver will reduce received signal levels by 3+ dB
  - "TEE" vs. "Hybrid" coupling
    - "TEE" coupling is adequate for this application
      - Both receivers directly connected to same antenna
    - Hybrid coupler is an expensive overkill for this application
  - This is a **QRP** example
    - K3S/10 transmitter has a 12W max output
      - Max output power with high SWR is <100 mW (+20 dBm)

Option 1: T/R Switch



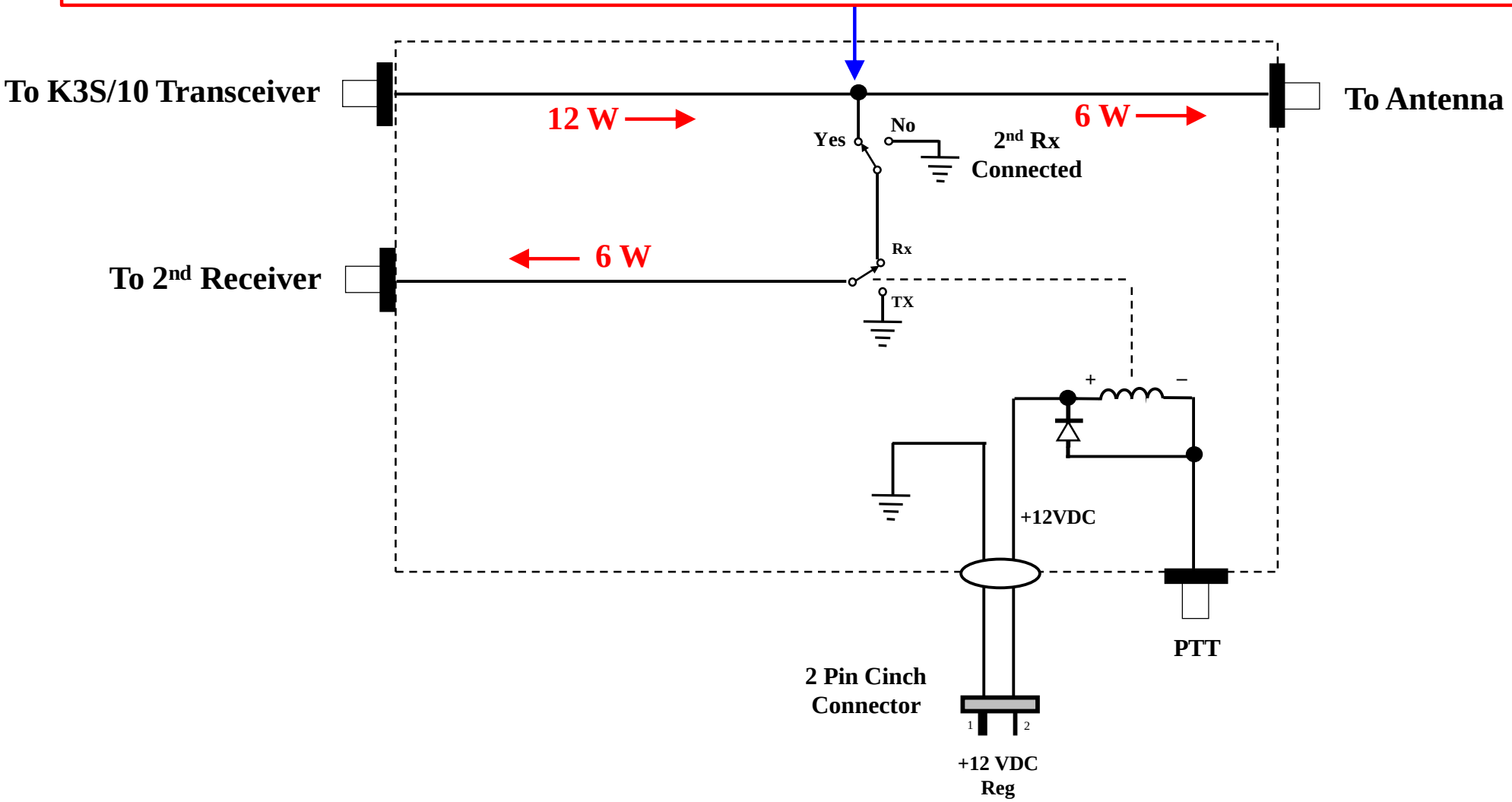
Option 1: T/R Switch

What happens if the relay doesn't activate during transmit?

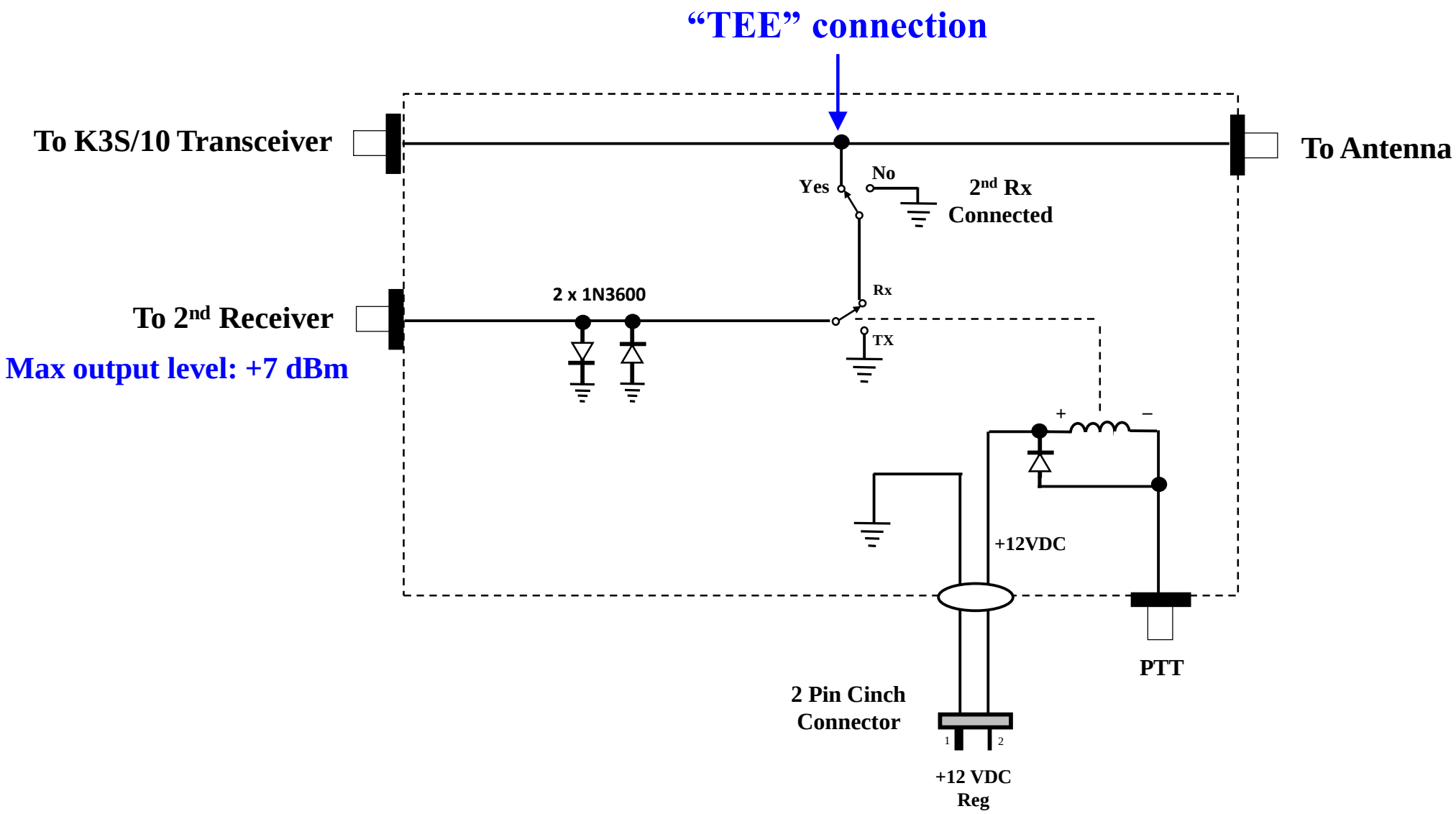


Option 1: T/R Switch

The full 12W divides evenly between receiver and antenna

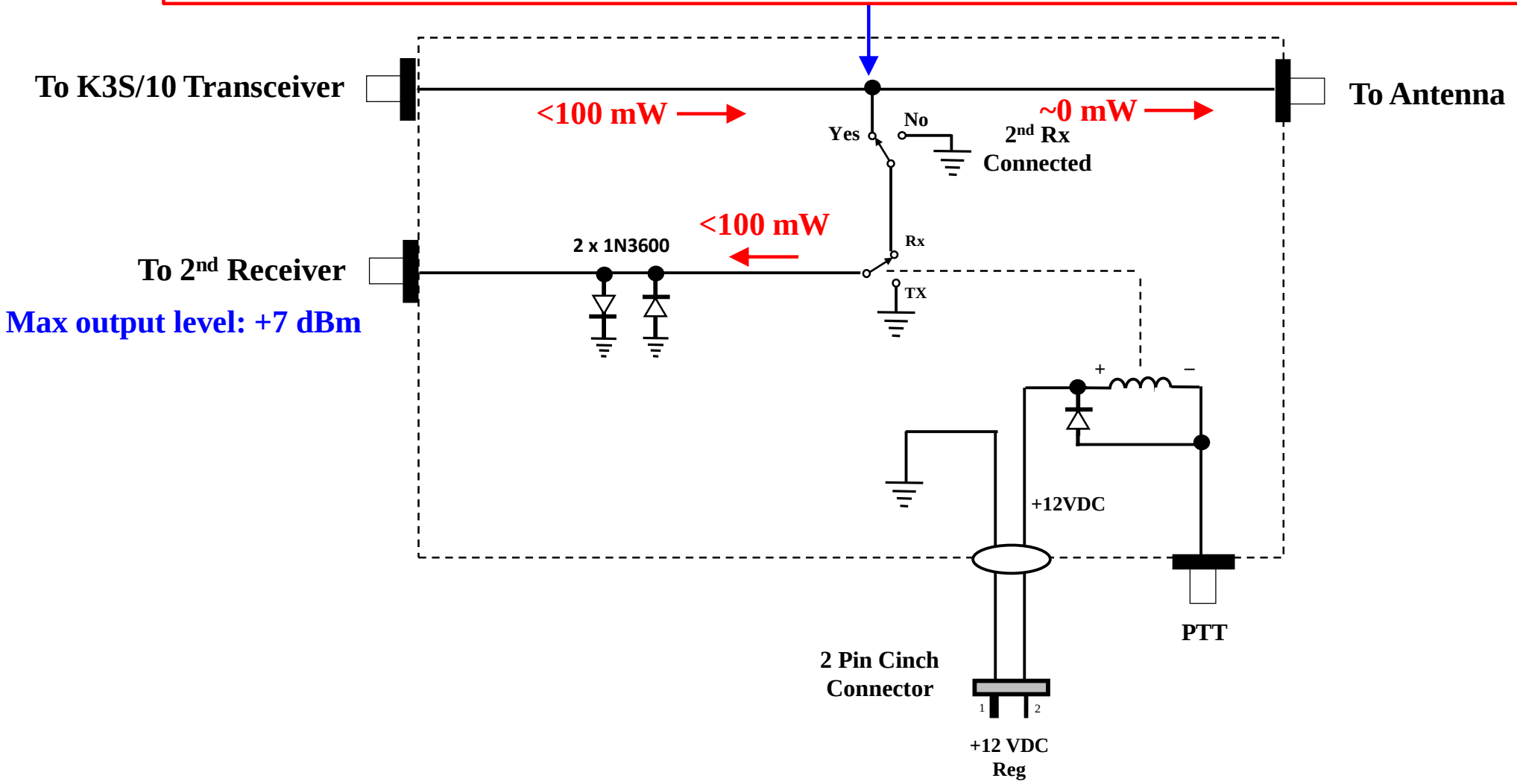


Option 2: T/R Switch + Diode Limiter

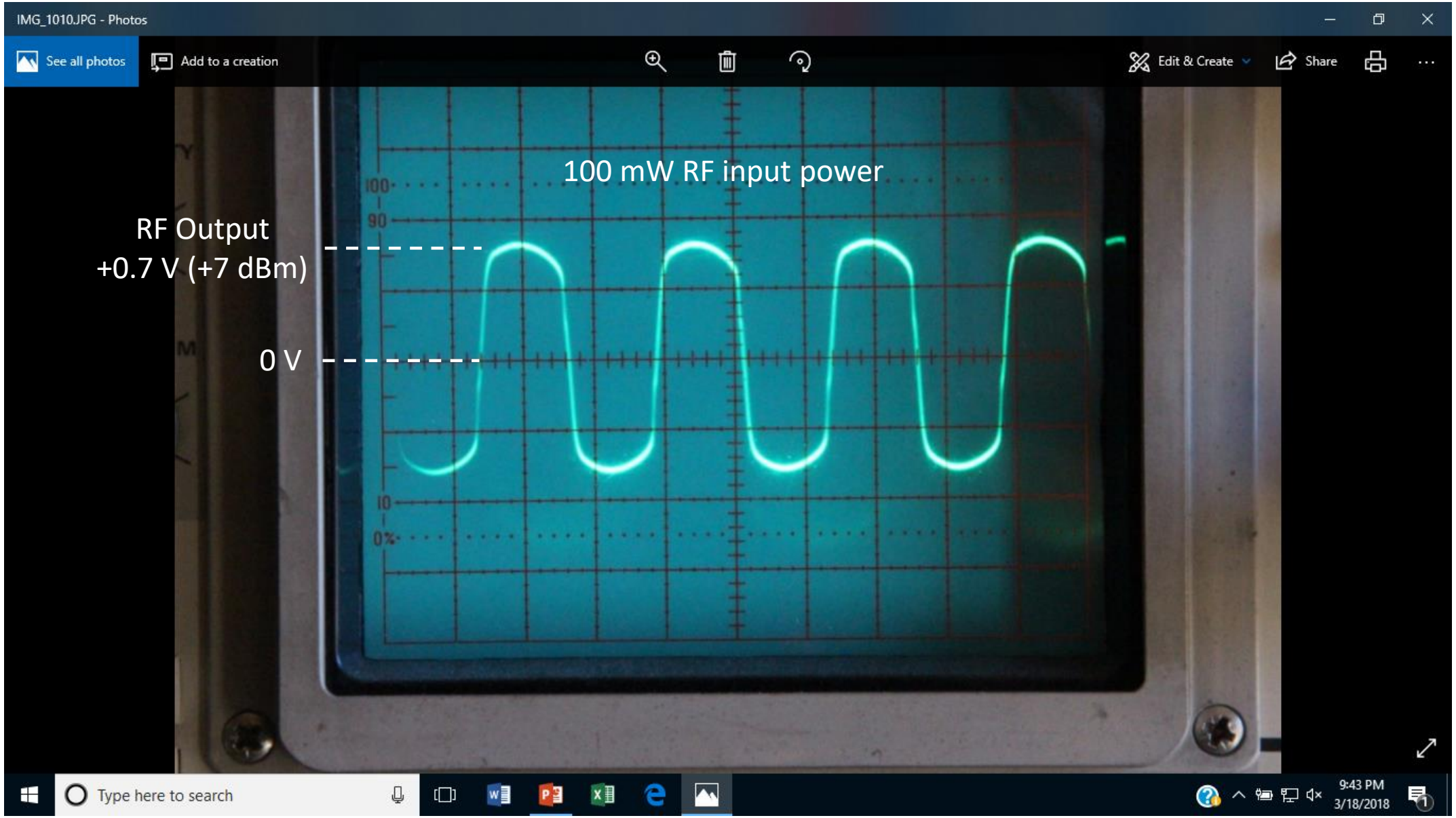


Option 2: T/R Switch + Diode Limiter

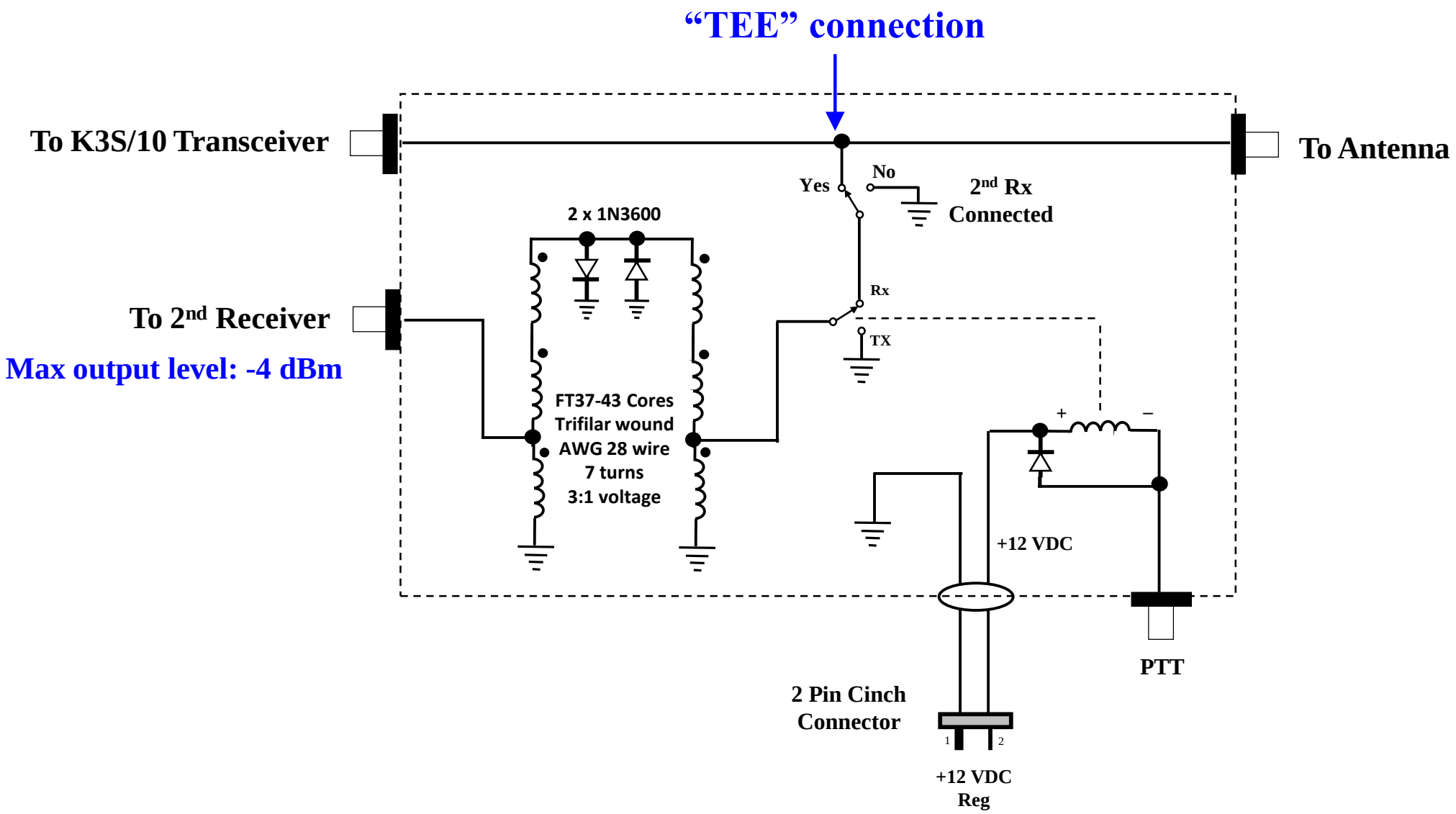
K3S SWR protection circuit limits output to <100 mW



Back To Back Diodes Clipping Level



Option 3: T/R Switch + Diode Limiter With 9:1 Impedance Transformer



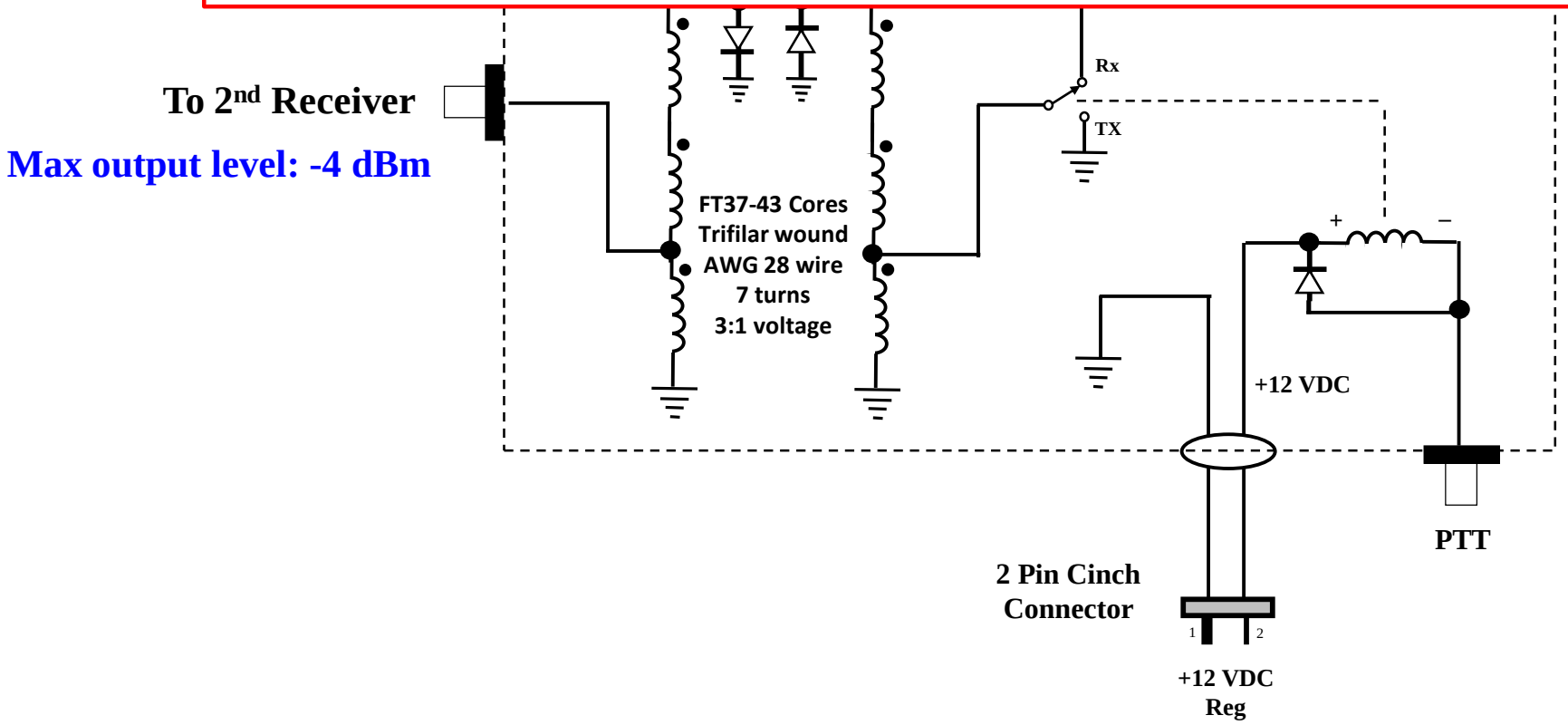
Option 3: T/R Switch + Diode Limiter With 9:1 Impedance Transformer

"TEE" connection

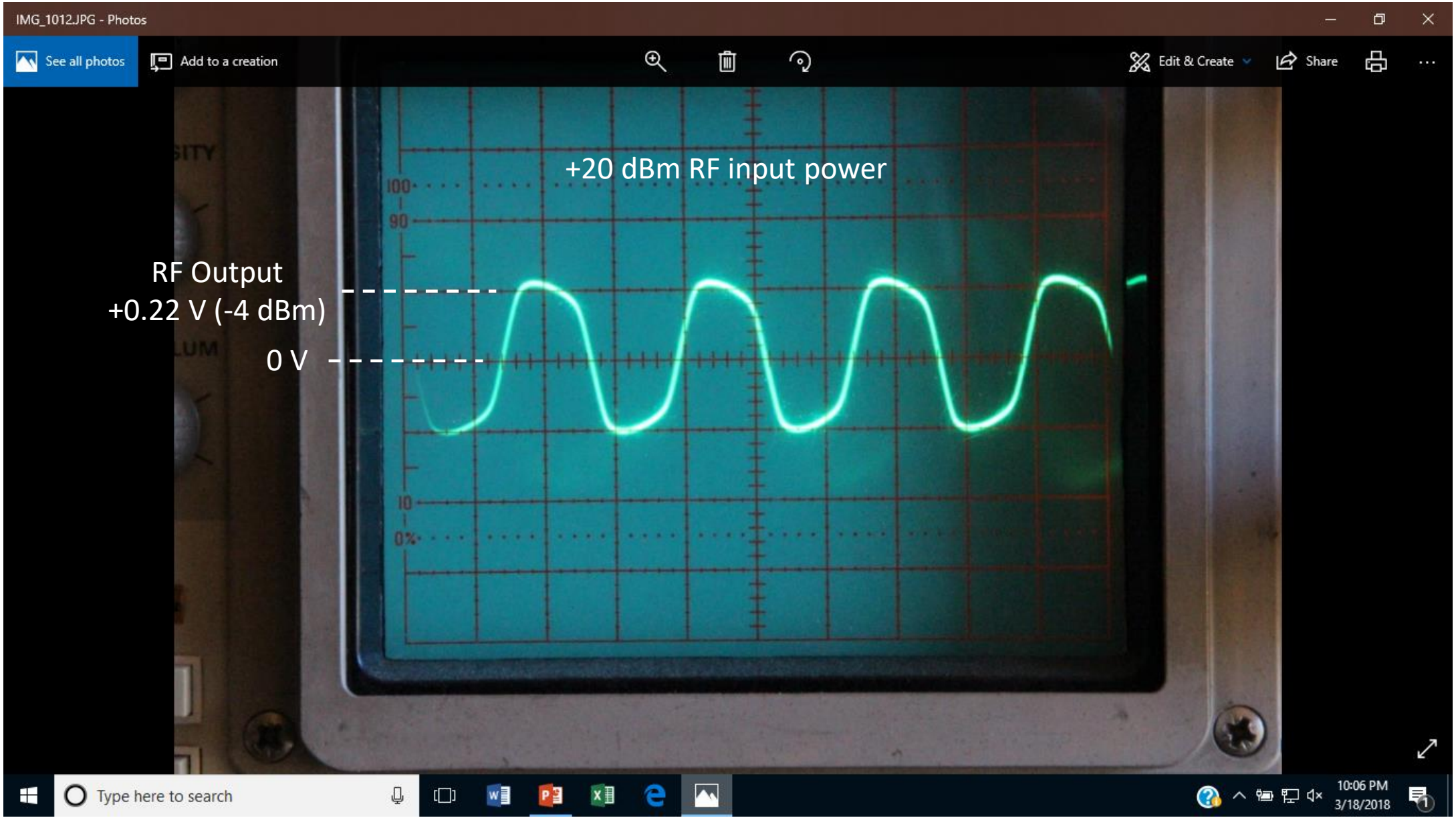
What if?

- The transceiver's SWR protect threshold did work
- The transceiver put out 200W

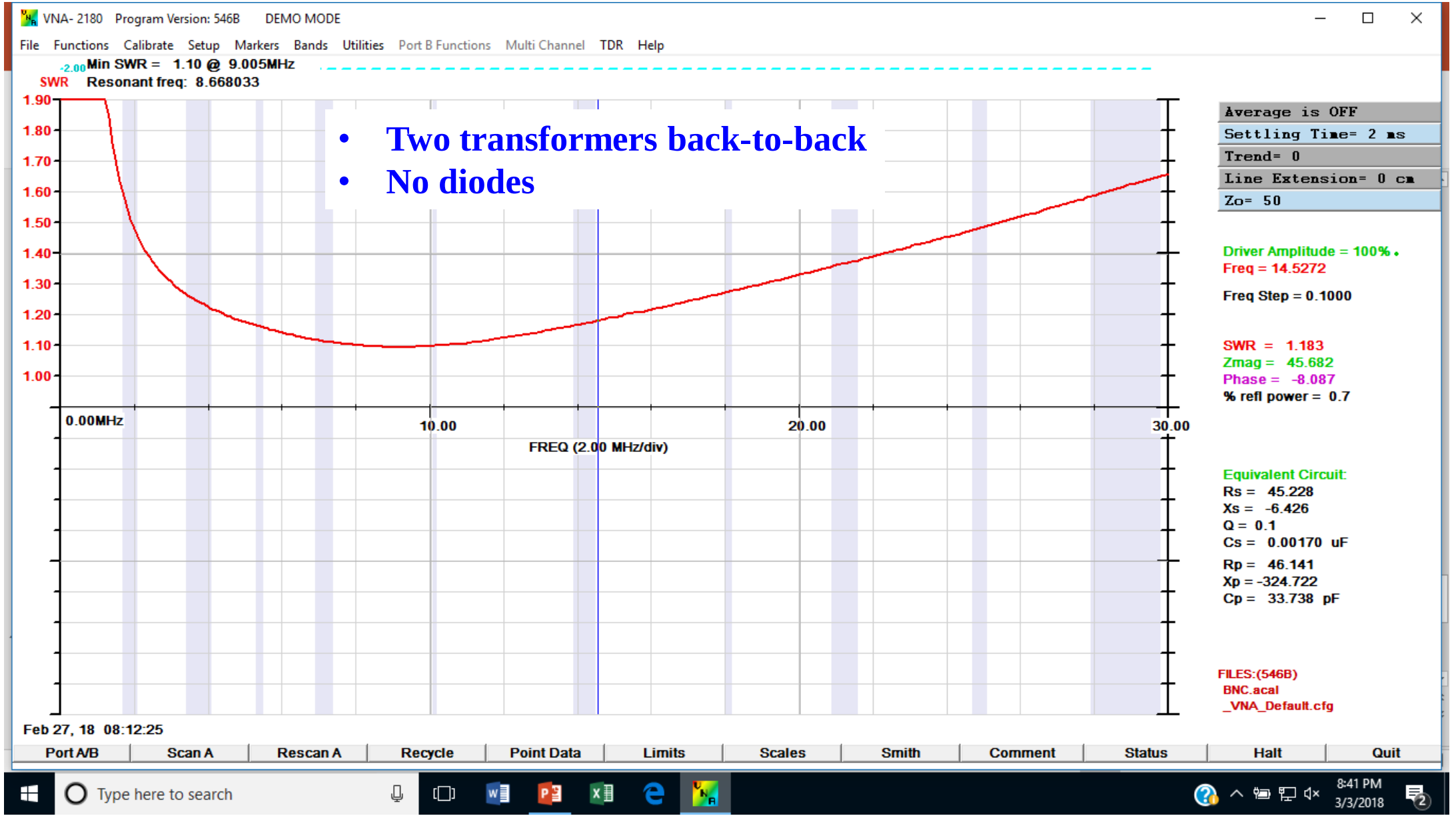
To K3S/10 ... na



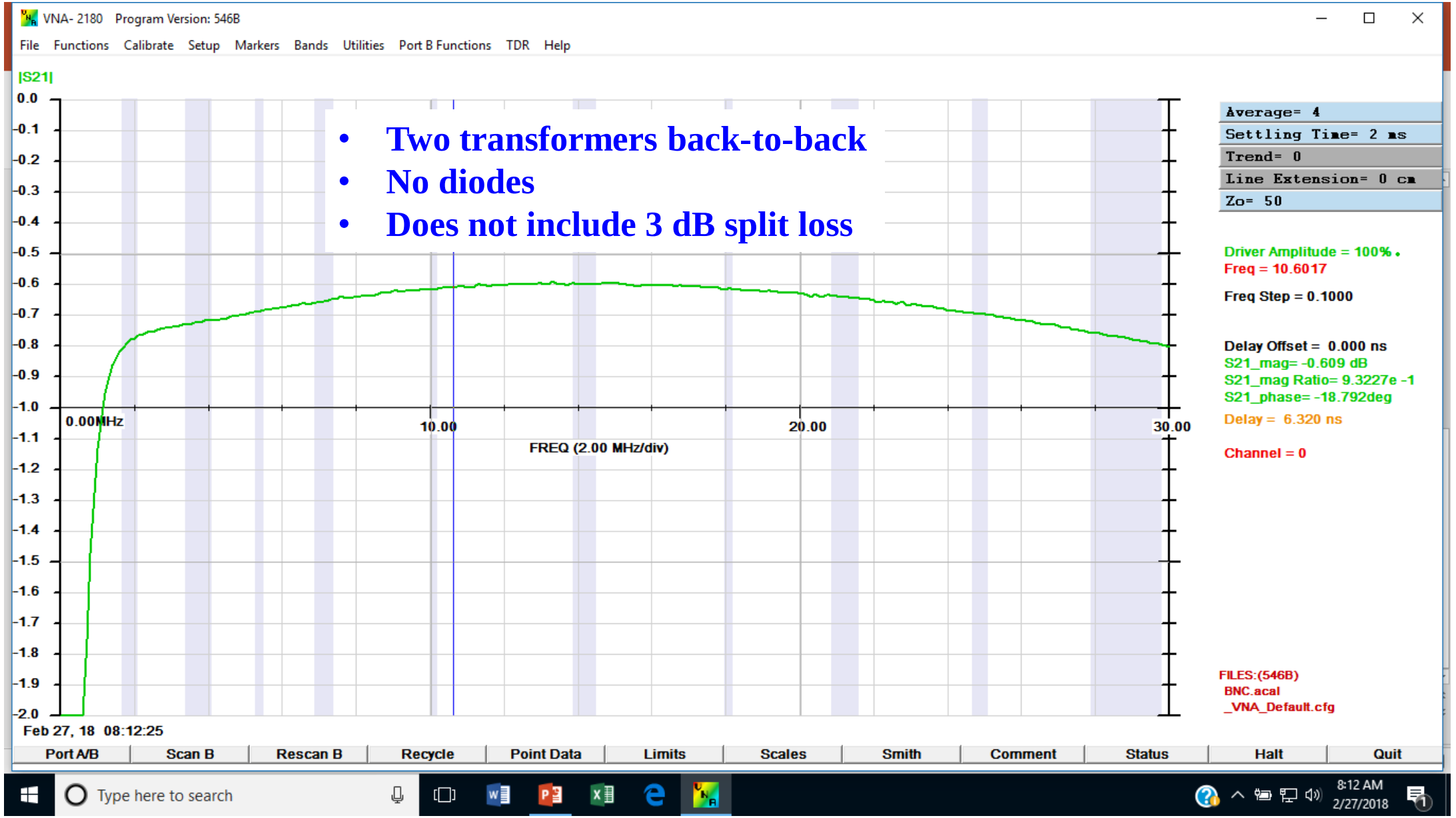
Option 2 Clipping Level



Option 2 : SWR Into Back-to-Back 9:1 Transformers



Option 2 : Back-to-Back 9:1 Transformer Insertion Loss



Summary

- Do you need a receiver front end protector?
  - Probably not if you:
    - Continuously bleed DC off all of your antennas
    - Use good ESD practices
    - Disconnect your antenna from receiver inside the shack
    - Don’t operate near high power transmitters (ie, Field Day)
- T/R switch protectors:
  - Only protect against co-located transmitters you control
  - Carefully evaluate the consequences of each possible failure mode
    - If the relays don’t switch properly:
      - Your receiver may have little or no protection, or
      - Your transmitter could have a direct copper path to your receiver input
- Lightning protection devices probably won’t prevent receiver damage