Receiver Front End Protection

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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 \( (V_{BE}\text{ max}) \) determines damage level for receiver front ends
    • Typical \( V_{BE}\text{ max} \) for small signal bipolar RF transistors is \( \sim 2 \text{ V} \) \( [\sim 50 \text{ mW or } 17 \text{ dBm}] \)
      • 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 \( (1.0 \text{ V}_{\text{peak}}) \)
    • ARRL tests receivers at +10 dBm \( (10 \text{ mW}) \)
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)

Limiting starts at +5 dBm
RF Output
+0.7 V (+7 dBm)

0 V

Back To Back Diodes Clipping Level

+20 dBm RF input power
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?

8.30 Volt 0.150 Amp
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?

Gas discharge tube (GDT)
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 2\textsuperscript{nd} Receiver With a K3S/10 Transceiver

- Why add a 2\textsuperscript{nd} receiver?
  - Diversity receive
  - Monitor two different bands simultaneously
  - \textit{Split operation}
  - 2\textsuperscript{nd} Rx has better \textit{performance than transceiver Rx}

- Important considerations:
  - Connecting a 2\textsuperscript{nd} 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

“TEE” connection

- To K3S/10 Transceiver
- To 2nd Receiver
- To Antenna

2 Pin Cinch Connector

PTT

+12VDC

Reg

+12 VDC

Yes

No

2nd Rx Connected

Rx

TX

"TEE" connection
Option 1: T/R Switch

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

To K3S/10 Transceiver

12 W →

Yes

No

2nd Rx Connected

Rx

TX

+12VDC

PTT

2 Pin Cinch Connector

To Antenna

To 2nd Receiver

? W →

? W

+12 VDC Reg

+12 VDC
Option 1: T/R Switch

The full 12W divides evenly between receiver and antenna
Option 2: T/R Switch + Diode Limiter

“TEE” connection

To K3S/10 Transceiver

To 2nd Receiver

Max output level: +7 dBm

To Antenna

2 Pin Cinch Connector

PTT

+12VDC

2 x 1N3600

Yes

No

2nd Rx Connected

Rx

TX

+12 VDC Reg

+12VDC
Option 2: T/R Switch + Diode Limiter

K3S SWR protection circuit limits output to <100 mW

To K3S/10 Transceiver

<100 mW

To 2nd Receiver

Max output level: +7 dBm

2 x 1N3600

<100 mW

To Antenna

+12 VDC

PTT

2 Pin Cinch Connector
Back To Back Diodes Clipping Level

RF Output
+0.7 V (+7 dBm)

0 V

100 mW RF input power
Option 3: T/R Switch + Diode Limiter With 9:1 Impedance Transformer

To K3S/10 Transceiver

To 2nd Receiver

Max output level: -4 dBm

“TEE” connection

To Antenna

2 x 1N3600

FT37-43 Cores
Trifilar wound
AWG 28 wire
7 turns
3:1 voltage

+12 VDC

2 Pin Cinch Connector

PTT

+12 VDC Reg

2nd Rx Connected

Rx

Yes

No

Max output level: -4 dBm
Option 3: T/R Switch + Diode Limiter With 9:1 Impedance Transformer

What if?

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

To K3S/10 Transceiver

Max output level: -4 dBm

2 Pin Cinch Connector

+12 VDC

FT37-43 Cores
Trifilar wound
AWG 28 wire
7 turns
3:1 voltage

TX

Rx

To Antenna

PTT

2nd Receiver

+12 VDC

Reg
Option 2 Clipping Level

RF Output
+0.22 V (-4 dBm)
0 V

+20 dBm RF input power
Option 2: SWR Into Back-to-Back 9:1 Transformers

- Two transformers back-to-back
- No diodes
Option 2: Back-to-Back 9:1 Transformer Insertion Loss

- Two transformers back-to-back
- No diodes
- Does not include 3 dB split 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