"Do's and Don'ts"
in the application of high-power RF amplifiers in EMC test systems

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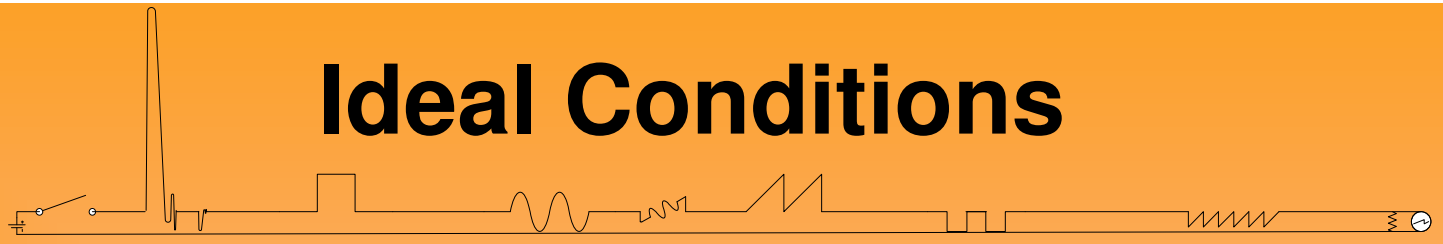
Summary

- Optimum amplifier environment
- The EMC reality
- Review of amplifier technologies
  - Tube (Vacuum tube)
  - Traveling Wave Tube (TWT) Amplifiers
  - Solid-State: Different classes
- Amplifier input protection
- Load connection precautions
- Optimum way to monitor and record RF power
- Installation concerns

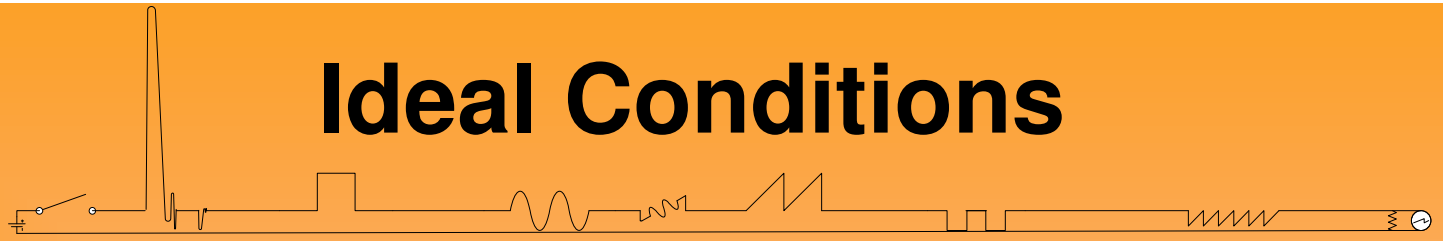
Ideal Conditions



What Amplifiers Love

- Always run in a low ambient room temperature
  - <72℉
- Use in a dust free environment
- Have clean power supplied
- Install in a fixed location by professionals
- Never exceed required input level
  - depends on specification of each amplifier
- Never have a load fail
- Connect amplifier only to a matched load
  - 50 Ω loads <1.5:1VSWR
- Only use fully tested and verified coax & waveguide

Ideal Conditions



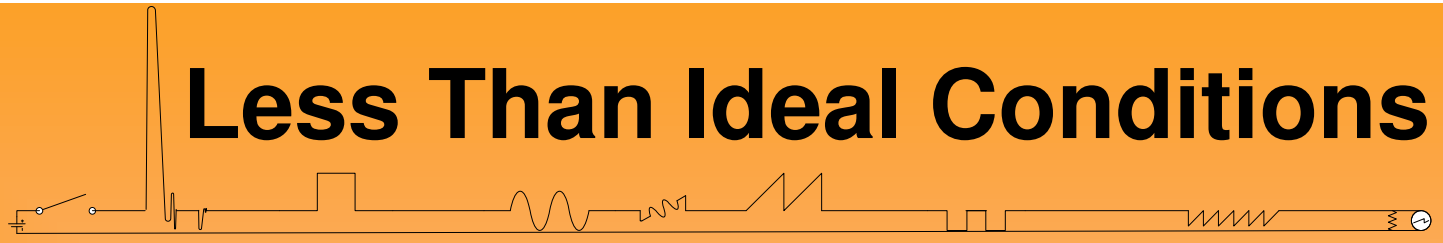
Estimate ~ 80% – 90% of the worlds amplifiers are designed for single uses.
transmitters, cell phones, radios…

These types of applications have known environmental conditions.

- Load is constant
- Frequency is usually narrowband
- Trained professionals are installing
- Environmental temperature constraints are known

Amplifiers can be designed much more easily in these cases and are simple.

Less Than Ideal Conditions

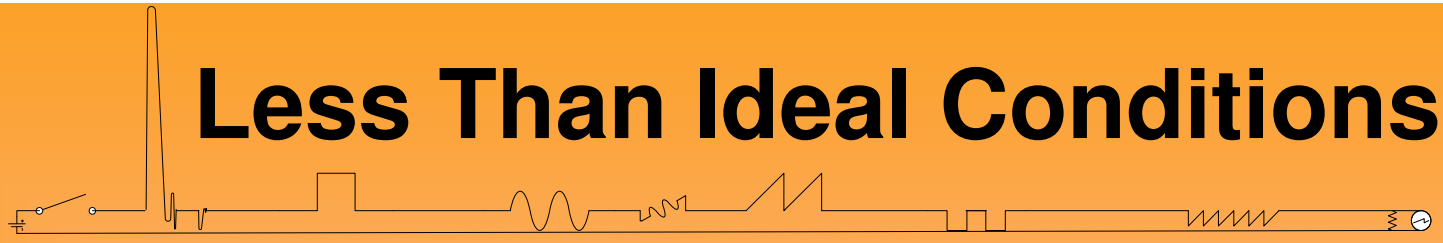


EMC testing does not fall anywhere near ideal or simple conditions.

The extremes for the EMC market

- High VSWR Amplifier is still required to deliver power or at a minimum not be damaged
- Bad loads, cables, connections
- Use in many tests, locations, and setups
- EMC Test engineers & technicians do not have to be amplifier experts

Less Than Ideal Conditions

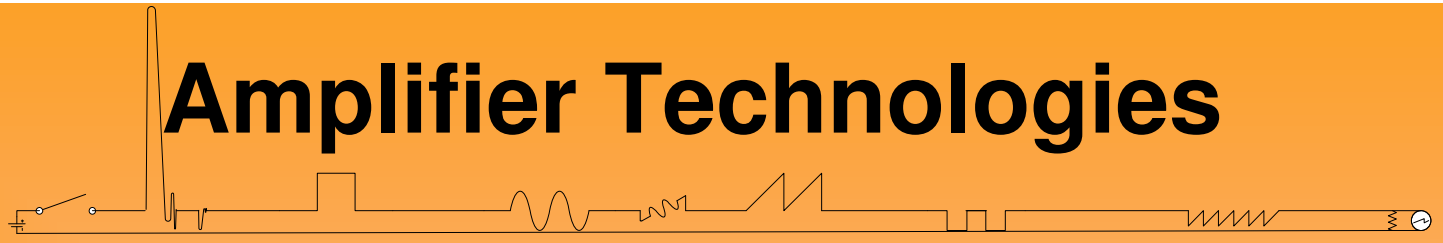


What is needed

Different engineering techniques are used to extend these constraints so the amplifier is more useful.

- Better heat removal for extended operating temperature range, which inherently extends the life of the amp
- Use better, more durable power supplies
- Rugged physical design
- Class A design
- Added VSWR protection (active protection)
- Added ability to handle VSWR

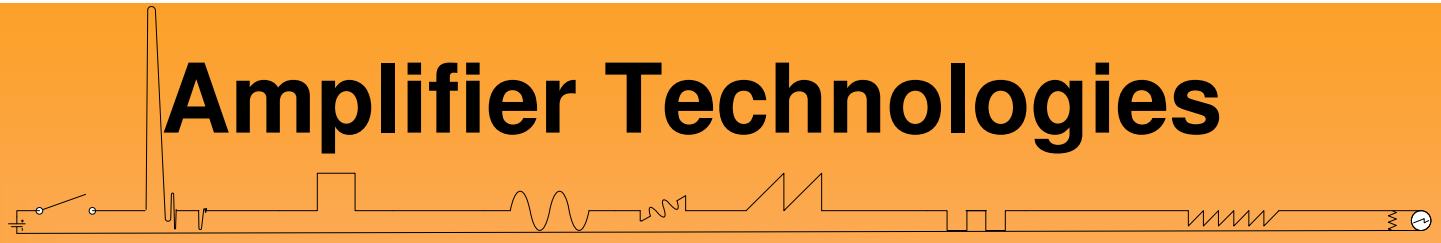
Amplifier Technologies



- Tube (Tetrode tube)
- TWT (Traveling Wave Tube) Amplifier
- Solid-state
  - Class A
  - Class AB
  - Class B

What are the differences?

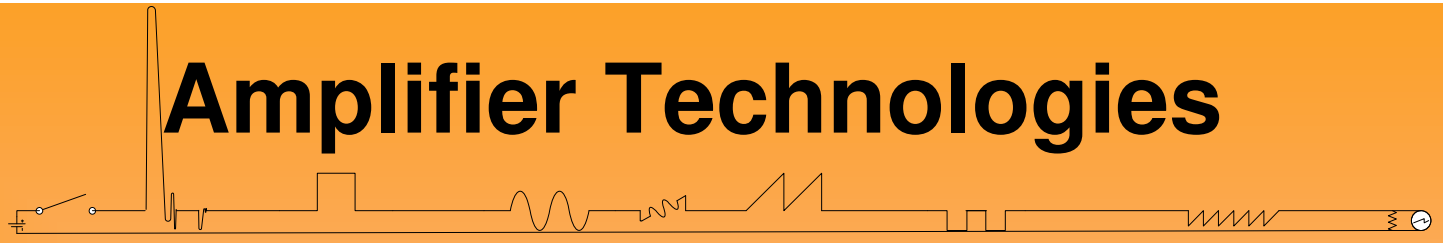
Amplifier Technologies



Amplifier	Linearity 1dB point	Harmonics at 1dB	Harmonics above 1dB*	Noise power density/ Spurious	Ability to handle VSWR*	Frequency coverage
Tube	Bad	Good	Worst	Bad	Best	Low freq. <250 MHz
TWTA	Worst	Worst	Worst	Worst	Worst	High freq. >1 GHz
Solid state Class A	Best	Best	Best	Good	Best	Full coverage lower power at high frequencies
Solid state Class AB	Bad	Good	Good	Good	Good to bad	Full coverage lower power at high frequencies
Solid state Class B	Bad	Good	Bad	Best	Good to bad	Full coverage lower power at high frequencies

* Results greatly depends on how the technology is implemented

Amplifier Technologies



Important specifications (other than the power, frequency, and VSWR protection you require) are **linearity** and **harmonics,** which are related.

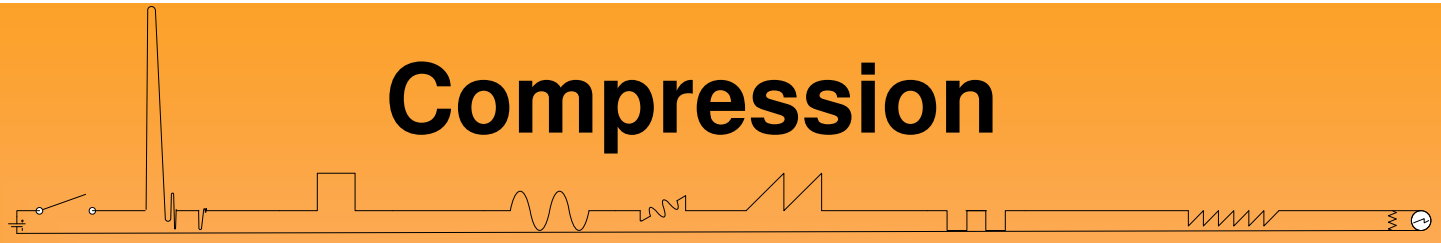
High harmonics may have undesirable effects on recorded test levels.

As the amplifier approaches compression the harmonics increase.

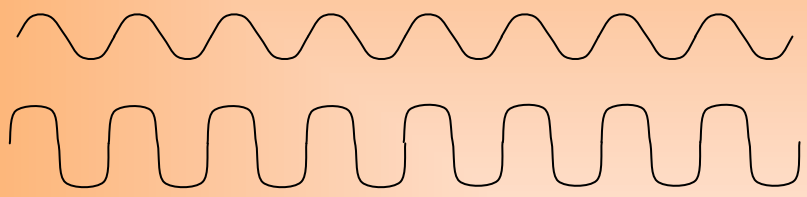
Class A solid state amplifiers seem to have the best performance even into compression. But large variations can be seen depending on the technology used.

A recommended level is -6dBc of the field. Example: IEC 61000-4-3

Compression



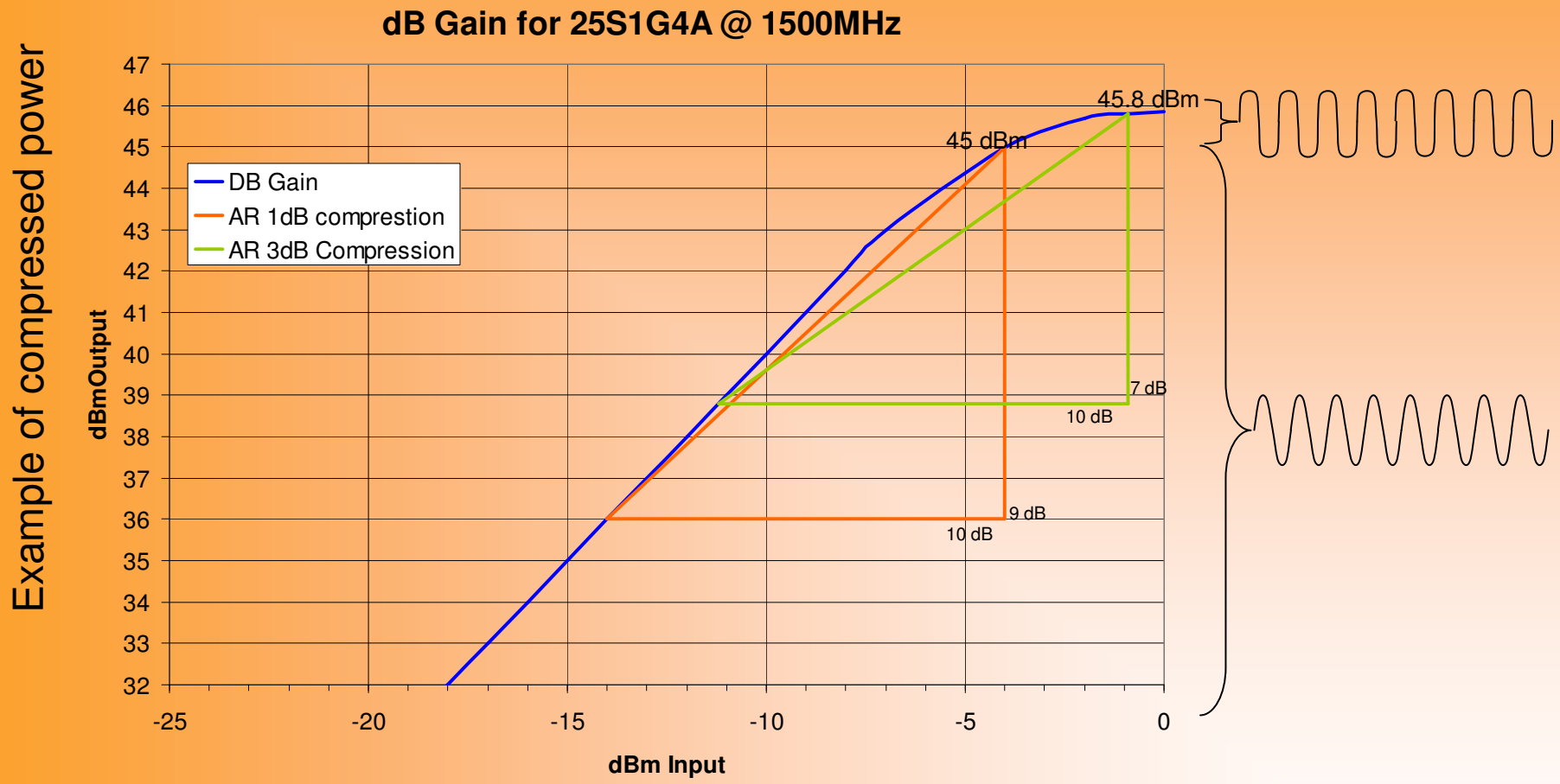
•Running the test while the amplifier is in compression will distort the test signal



Harmonics

• The compressed wave starts to resemble a square wave, producing higher harmonics.

Compression



Compression points at one frequency

Amplifier Driving

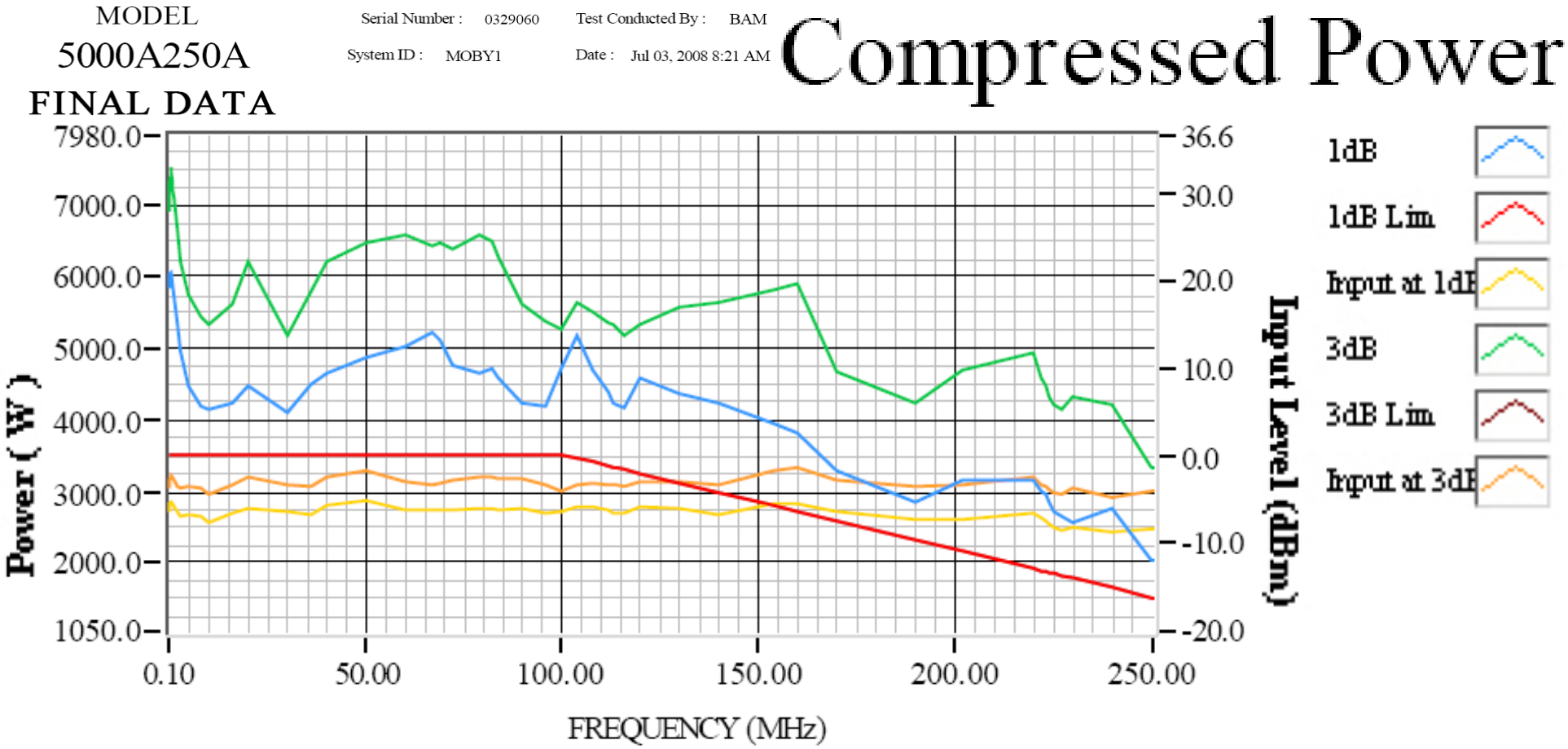
What is the correct drive level to the amplifier?

There will always be a max drive level before damage.

- Most of AR's amps have +13dBmmax input level.
- In most cases there is no reason to come even close to max input level.
- Amplifiers are rated with a 0dBm input to reach rated output.
- Most testing should not be done with saturated power
  - Therefore -5 - -10 dBm may be all you need to drive the amplifier

Amplifier Driving

This brings us to the proper input to produce the desired linear output



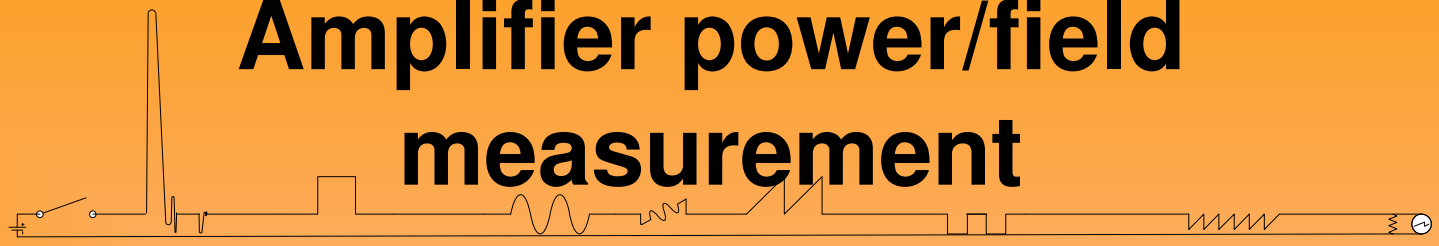
Amplifier Driving

An amplifier requiring 0 dBm input to reach rated output does not mean 0dBm of input is required to get the results you may need.

TWT amplifiers in some cases with a 0dBm input and full gain will be over driving the TWT. Over time this could be damaging.

Application Note # 45 Input Power Requirements…
For further explanation

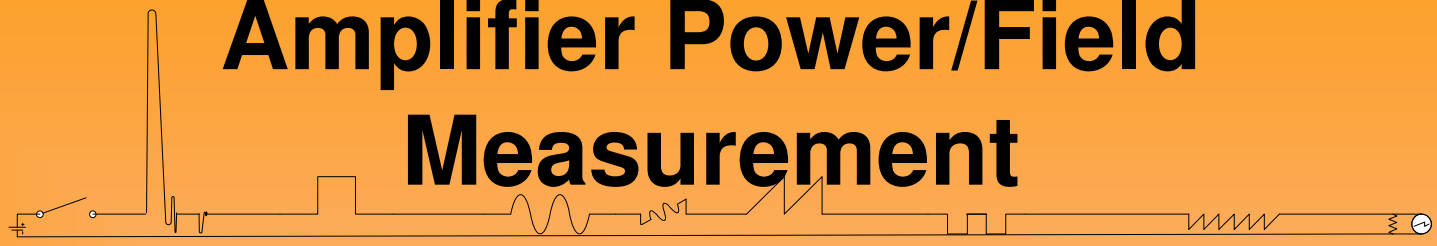
Amplifier power/field measurement



What is the proper way to measure power and field?

- What is the measurement device
  - Power meter (w/directional coupler)
    - Diode sensor
    - Thermocouple sensor
    - Peak power meter
  - Field probe
    - Diode sensor
    - Thermocouple sensor
    - Pulse probe
  - Spectrum analyzer

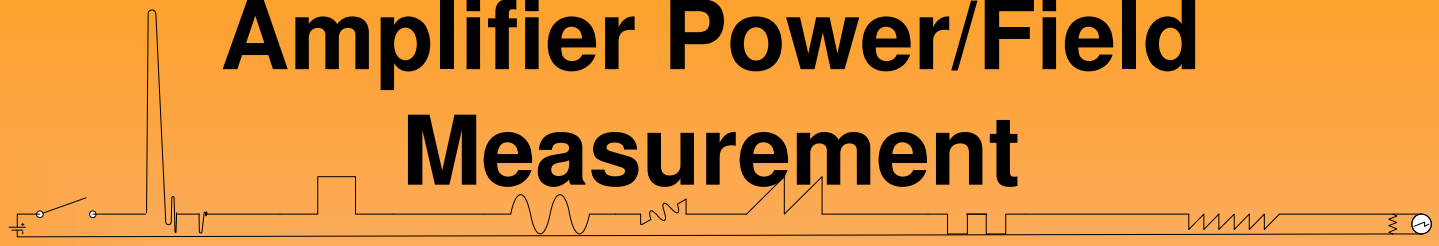
Amplifier Power/Field Measurement



Technology differences

Diode	Thermocouple
• More sensitive • Can measure true RMS of a **CW** signal. • Can be used to measure RMS of modulated signals if used within the linear region. Usually this is in the lower region but it's difficult to know exactly. • A signal in compression can have error in the actual reading.	• Less sensitive • Less dynamic range • Measures true RMS of **any** signal

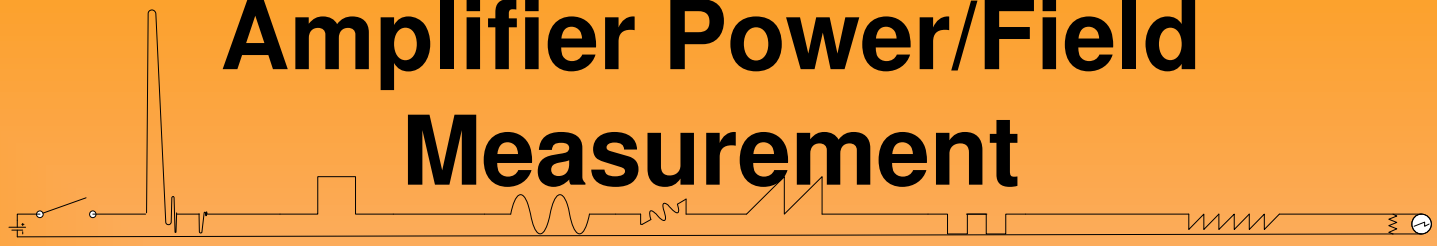
Amplifier Power/Field Measurement



Technology differences

Broad-Band Device (power meter, field probe)	Frequency Selective Device (Spectrum Analyzer)
• Will measure whole frequency spectrum including harmonics • Care must be taken that harmonics are not contributing to reading • Can be very accurate if used correctly • Easy setup and use	• Can discern between different frequency signals • Measures peak • RMS = Peak/SQRT(2) • Can measure modulated signals • Time consuming setup

Amplifier Power/Field Measurement

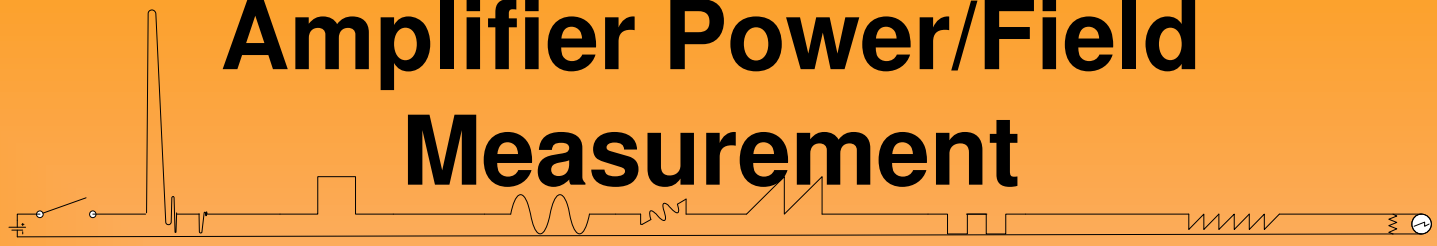


• For measuring amplifier output, using a directional coupler with a power meter is acceptable. Care should be taken in a reverberation chamber, for example.

• In most ALSE testing, forward power is a relative number and care only needs to be taken that this can be reproduced.

• If harmonics are a concern harmonic filters can be used.

Amplifier Power/Field Measurement



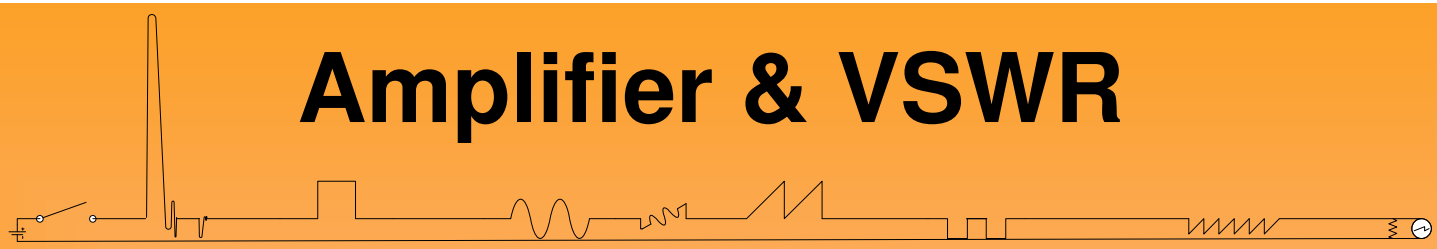
Verify measurements are correct when using a broad-band device to take measurements

- It is a good idea to verify the readings are correct with a spectrum analyzer.

1. Run a calibration with the power meter and then a calibration with the spectrum analyzer to see if the forward power reading matches up
2. Use an antenna and spectrum analyzer to spot check V/m reading from probe during calibration especially where the amplifier is being driven hard.

Don't assume that if the harmonics are out of band that they are no longer a factor! (amplifier, probe, antenna…)

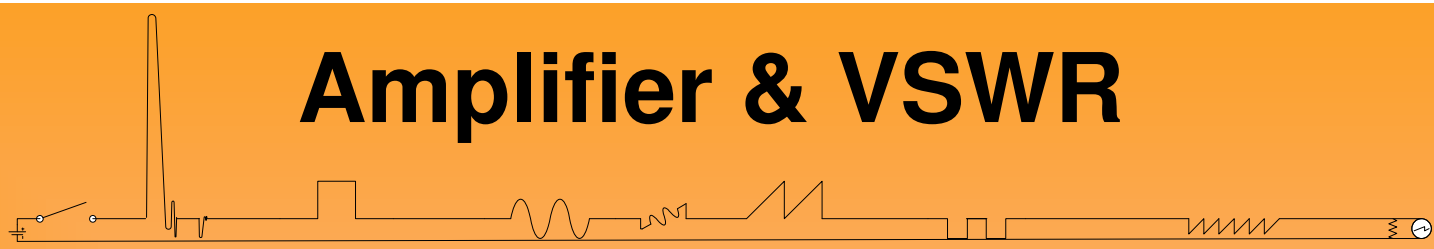
Amplifier & VSWR



- The amplifier's ability to deal with VSWR will determine the possible use and application.

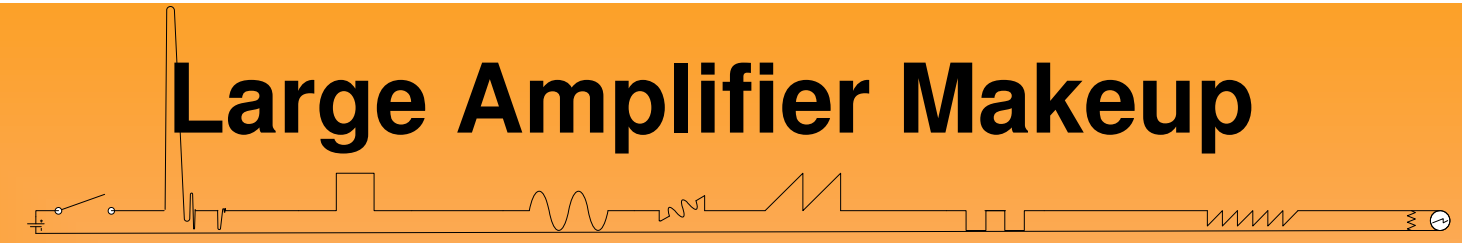
- TWTAs have a relatively low threshold to VSWR
  - The TWT will fail at high VSWR without protection or precautions.
  - 2:1 VSWR at rated power
    1. Fold back at 20% reflected power (best) [AR]
       pulsed amps fold back at 50% reflected power [AR]
    2. Shutdown at 2:1 VSWR
    3. Rely on user to take responsibility to be proactive
- Low Power Solid State can have high threshold to VSWR
  - Dependent on technology used
    - Infinite VSWR handling, no protection needed [AR]

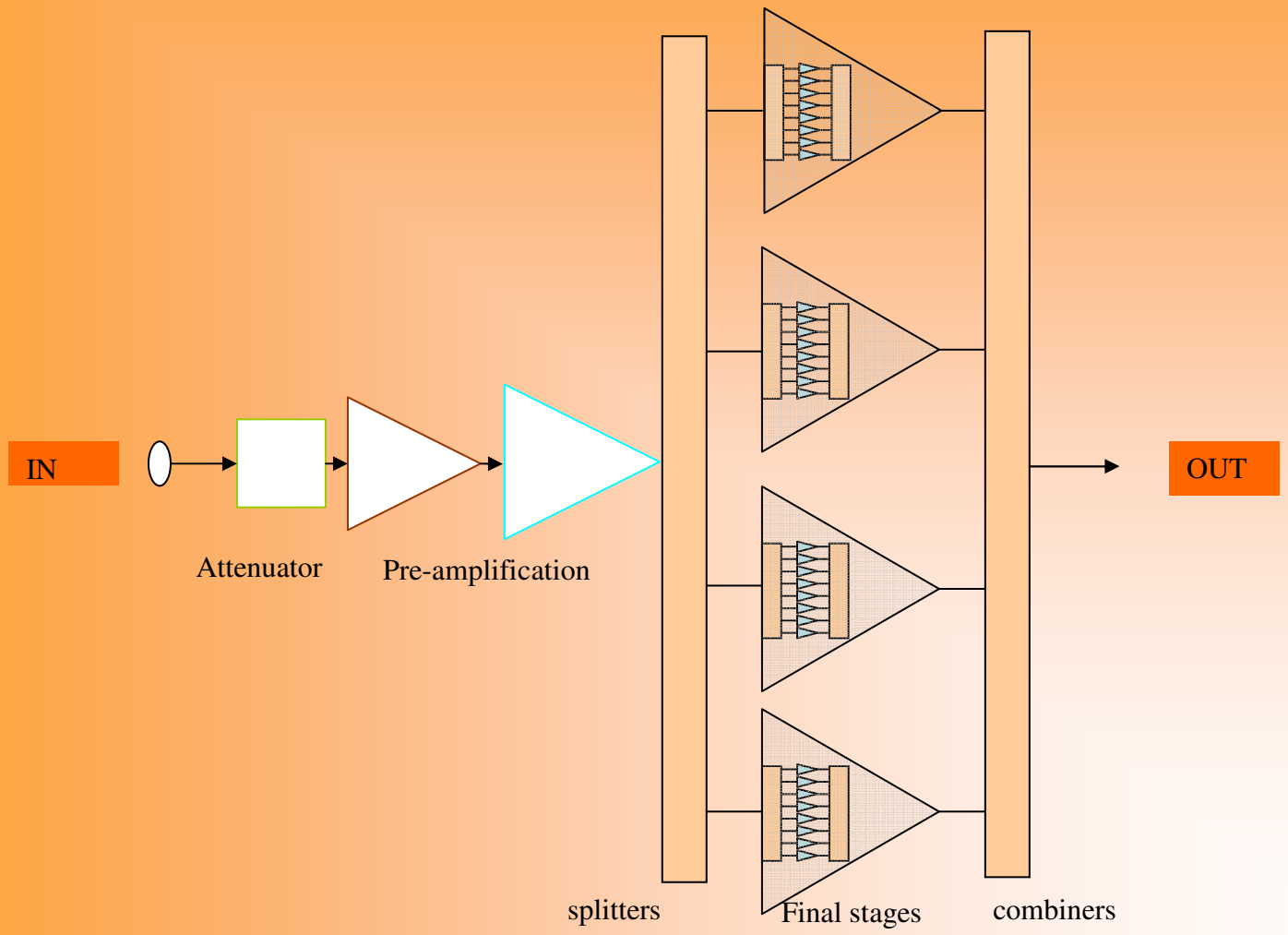
Amplifier & VSWR



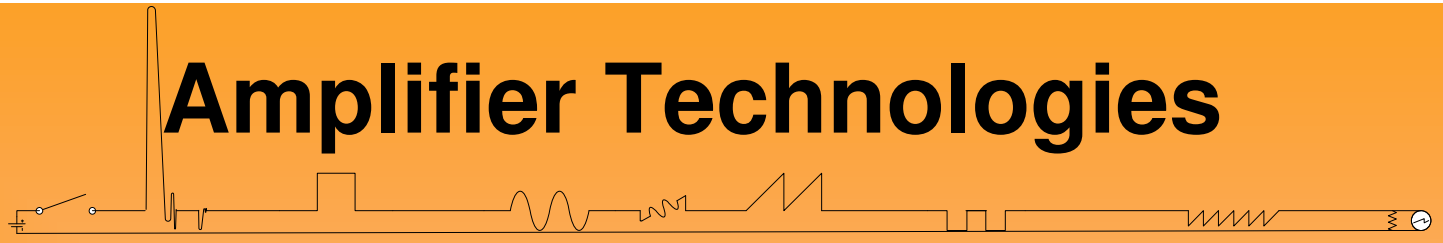
- High Power Solid State can have high threshold to VSWR
  - Dependent on technology used
    - High VSWR handling, some protection required
    - Can handle up to 50% of rated power (6:1 VSWR) when used at full power
      - Folds back so that reverse power does not exceed reverse power limit
    - Why can't higher power amplifiers handle infinite VSWR like lower power versions?
      - Combining

Large Amplifier Makeup



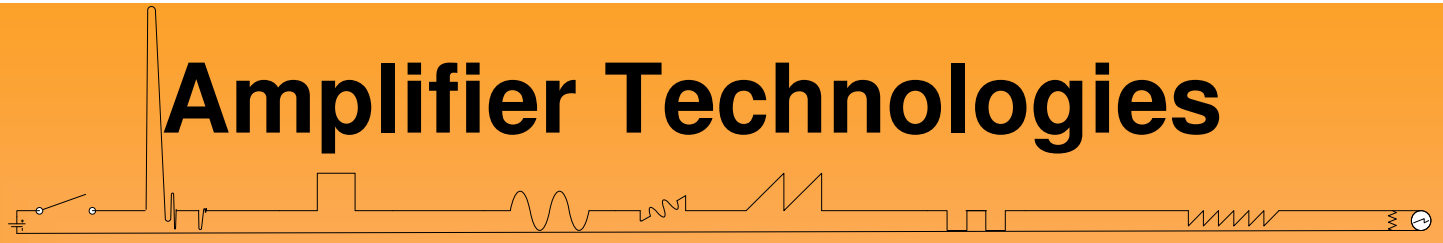


Amplifier Technologies



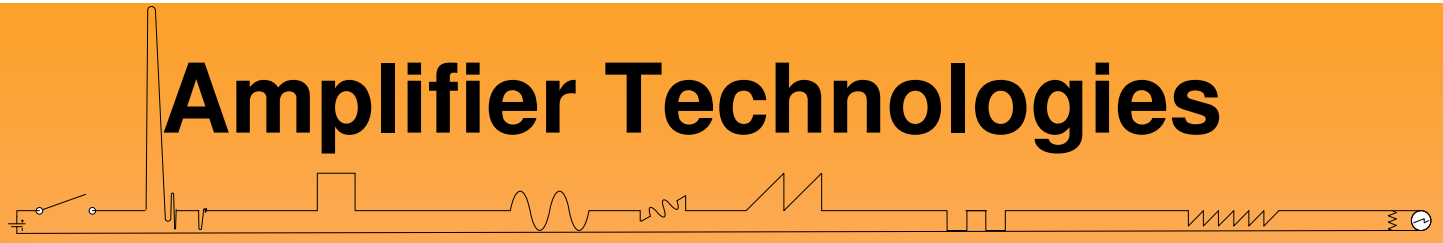
- Why is protection from mismatch needed?
  - There is only so much that can be done to protect the amplifier without adding exorbitant cost

Amplifier Technologies



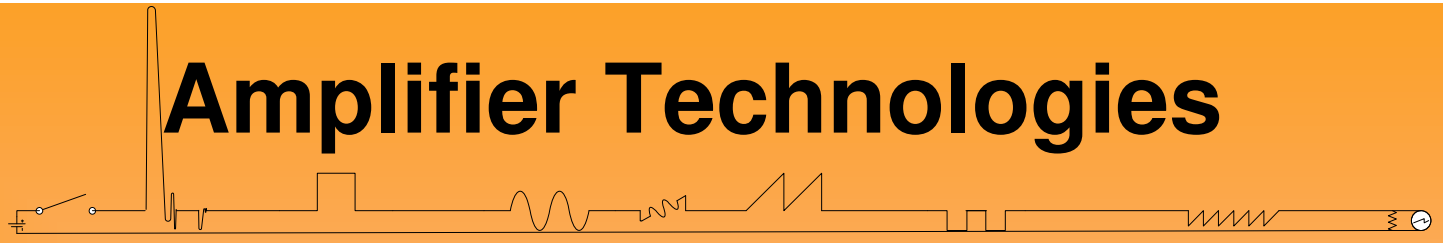
- General care
  - Keep original packaging for shipping
    - If new packaging is required contact AR for suggestions
  - Do not disconnect RF connection while amplifier is not in standby!
    - The amplifier is protected from this but you are not!
  - Make sure heat is not re-circulated back into amplifier
    - Temperature is monitored and protected in the amplifier, but cooler is always better

Amplifier Technologies



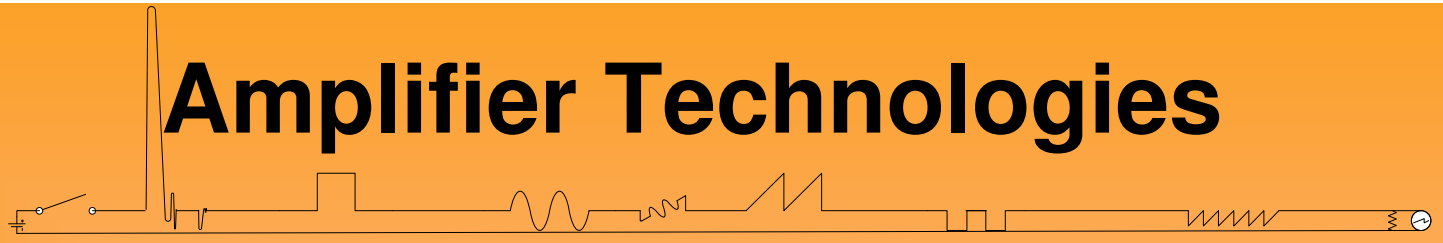
- Tube [Vacuum tube] amplifiers
  - Oil cooling system
  - New unit: make sure to fill oil correctly.
  - Do not tip over and place on it's side to work on!
  - Will drive full power and not fold-back into any load.
  - Maintain recommended operating temperature.
  - Over time tubes will slowly decrease power output and require replacement.

Amplifier Technologies



- TWTA
  - TWT is most expensive part of the amplifier (Protect It)
  - Make sure heat outtake and intake are not confined
  - Be very careful not to overdrive input!
    - This can be damaging to the TWT.
  - Take care not to let the amplifier sit unused for extended periods of time [months – years].
    - The TWT will “Gas up”, then when activated the Tube may be damaged.
    - A De-gassing start up routine needs to be used
  - Do not leave the TWTA powered up and not being used for extended periods of time.
    - Tube can “Gas up”
    - Do not disable sleep mode feature
  - Take care not to use badly mismatched loads
    - AR’s amps are fully protected for all mismatches but is still stressful to TWT

Amplifier Technologies



- Solid-state
  - Do what ever you want they can take it!

Any questions?

Thank you for your attention!!!

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