NetOps VIII

Transient Suppression and Attenuation

Jim Bollwerk

CERI/The University of Memphis

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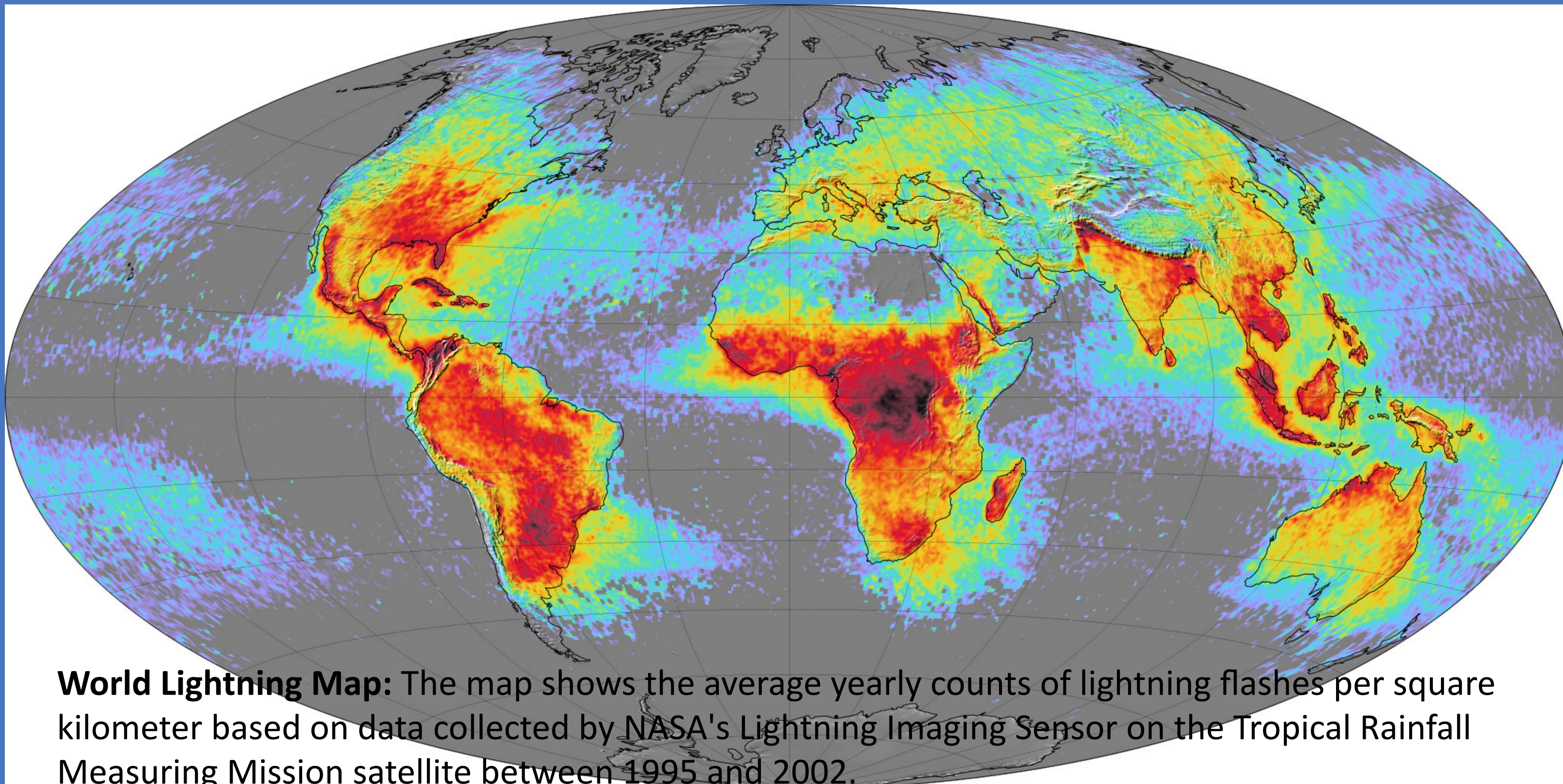
Primary transients which keep us up at night are surges caused by LIGHTNING!



World Lightning Map: The map shows the average yearly counts of lightning flashes per square kilometer based on data collected by NASA's Lightning Imaging Sensor on the Tropical Rainfall Measuring Mission satellite between 1995 and 2002.

About 2,000 thunderstorms at any given time produce about 100 Lightning flashes per second

In the continental US there is on average 1.3 Lightning flashes per second

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Number of Cloud-To-Ground Flashes by State from 2006 to 2015

State	Flashes In 2015	Average Flashes 2006 to 2015
Alabama	730,828	747,187
Arizona	704,526	606,742
Arkansas	654,797	853,135
California	162,935	84,772
Colorado	629,581	523,788
Connecticut	8,833	20,059
Delaware	8,249	13,922
D.C.	795	683
Florida	1,412,565	1,192,724
Georgia	735,153	691,449
Idaho	122,876	82,194
Illinois	663,685	792,479
Indiana	395,847	451,499
Iowa	591,417	674,486
Kansas	1,179,272	1,022,120
Kentucky	527,869	533,960
Louisiana	864,949	813,234
Maine	42,733	53,378
Maryland	71,391	81,506
Massachusetts	15,182	24,823
Michigan	166,378	260,915
Minnesota	448,363	361,808
Mississippi	649,035	787,768
Missouri	1,054,081	1,066,703
Montana	307,545	318,628
Nebraska	979,186	747,311
Nevada	187,587	141,229
New Hampshire	16,487	24,721
New Jersey	20,425	48,688
New Mexico	1,033,658	792,932
New York	103,018	194,497
North Carolina	415,306	469,062
North Dakota	335,265	296,727
Ohio	268,215	412,702
Oklahoma	1,181,718	1,088,240
Oregon	58,623	53,420
Pennsylvania	185,682	293,286
Rhode Island	2,728	2,516
South Carolina	291,590	378,270
South Dakota	690,465	474,145
Tennessee	451,210	537,786
Texas	4,071,174	2,878,063
Utah	240,682	215,298
Vermont	15,175	29,958
Virginia	256,350	309,273
Washington	24,789	25,592
West Virginia	118,212	185,192
Wisconsin	190,593	276,142
Wyoming	347,035	279,632
TOTALS	**23,634,058**	**22,214,643**

These cloud-to-ground lightning flashes were measured by the National Lightning Detection Network® (NLDN®) over the land area inside state borders. The NLDN does not cover Alaska or Hawaii. The NLDN is owned and operated by Vaisala.

VAISALA

Vaisala Inc.
2705 E. Medina Road
Tucson, Arizona 85756
www.vaisala.com

Updated February 2016

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Rank of Cloud-To-Ground Flash Densities by State from 2006 TO 2015

State	Ave. Flashes Per Year	Flashes Per Square Mile
1. Florida	1,192,724	20.8
2. Louisiana	813,234	17.6
3. Mississippi	787,768	16.5
4. Arkansas	853,135	16.0
5. Oklahoma	1,088,240	15.6
6. Missouri	1,066,703	15.3
7. Alabama	747,187	14.4
8. Illinois	792,479	14.1
9. Kentucky	533,960	13.3
10. Tennessee	537,786	12.8
11. Indiana	451,499	12.5
12. Kansas	1,022,120	12.4
13. South Carolina	378,270	12.2
14. Iowa	674,486	12.0
15. Georgia	691,449	11.7
16. Texas	2,878,063	10.9
17. D.C.	683	10.1
18. Ohio	412,702	10.0
19. Nebraska	747,311	9.7
20. North Carolina	469,062	9.5
21. Maryland	81,506	8.2
22. Virginia	309,273	7.7
23. West Virginia	185,192	7.6
24. Delaware	13,922	7.0
25. New Mexico	792,932	6.5
26. Pennsylvania	293,286	6.5
27. New Jersey	48,688	6.4
28. South Dakota	474,145	6.2
29. Arizona	606,742	5.3
30. Colorado	523,788	5.0
31. Wisconsin	276,142	4.9
32. Michigan	260,915	4.5
33. Minnesota	361,808	4.3
34. North Dakota	296,727	4.2
35. Connecticut	20,059	4.1
36. New York	194,497	4.0
37. Vermont	29,958	3.2
38. Massachusetts	24,823	3.1
39. Wyoming	279,632	2.9
40. New Hampshire	24,721	2.7
41. Utah	215,298	2.5
42. Rhode Island	2,516	2.3
43. Montana	318,628	2.2
44. Maine	53,378	1.6
45. Nevada	141,229	1.3
46. Idaho	82,194	1.0
47. Oregon	53,420	0.6
48. California	84,772	0.5
49. Washington	25,592	0.4

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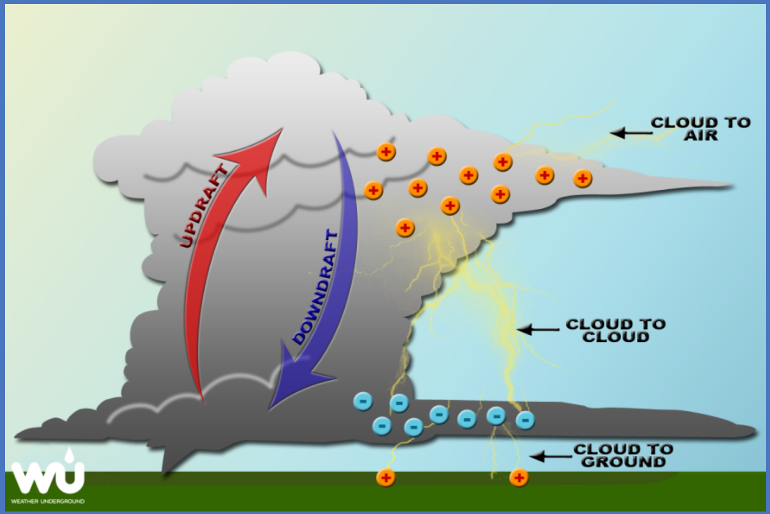
The Formation of Lightning

As hot air rises in a thunderhead ice particles are formed and these cold air columns then fall. These rising and falling air columns cause constant collisions between the ice particles and static charges builds up



Eventually the static charge becomes large enough to cause the air to break down

An initial small charge breaks out seeking and ideal path, primarily either cloud-to-cloud or cloud-to earth

Once the path is established a series of *strokes* which comprise a *flash* follows

How Lightning is Formed
What the component manufactures and site protection designers look at

Research data compiled during the past 40 years characterizes a typical lightning event as a *flash* composed of multiple *strokes* with the possibility of many lower-current return strokes which can be a significant source of damage due to poor grounding

The total *flash* lasts less than 0.2 seconds and each *flash* is composed multiple *strokes* (4+) which are separated by about 40 micro-seconds The lapse between *strokes* is what causes the lightning to seem to flicker

The Power of Lightning

The typical rise time to peak current per stroke is about 1-10 micro-seconds

The typical event will carry currents in the 10-50 kilo ampere (kA) range

Fourier analysis characterizes a typical event as having energy in the DC-1 MHz range

About 75% of the energy from a *flash* is dissipated as heat and can raise the temperature of the typical 3 km long lightning channel by 15,000 to 30,000 ^{o}C

But there's still plenty of energy to wreak havoc!

A Few Grounding Principles

When your site takes a lightning strike
proper grounding and bonding is critical for the transient suppression devices to work properly

The Grounding should provide a low resistance return path to the earth for transient surges

In some cases this requires a distributed grounding system to help dissipate the energy over a larger area

For distributed systems try and minimize the differential ground potential and isolate sensitive circuits so high current transients won't use them as a path to ground

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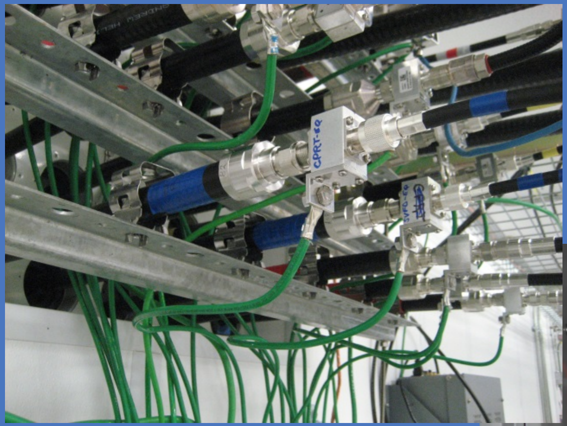
What are we protecting?



- RF telemetry systems
- AC power systems
- DC power systems
- Analog data systems
- Digital data acquisition systems
- GPS systems

The grounding and transient suppression systems primary function is to limit differential voltages across the Inputs and Outputs of these systems or devices while conducting as much event current as possible to earth ground

RF inputs/outputs and radios

Starr Mtn, TN Central Receive

CERI

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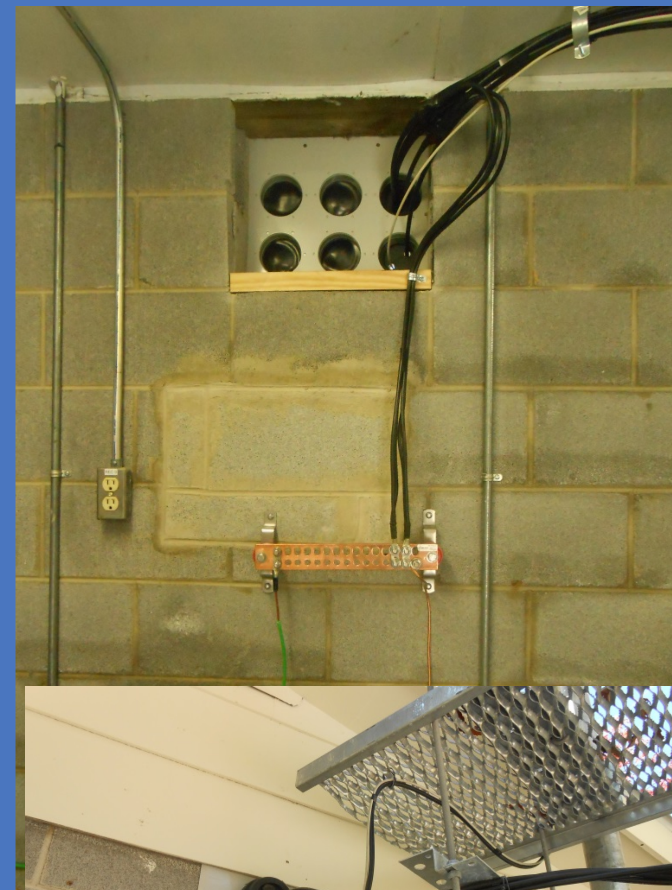
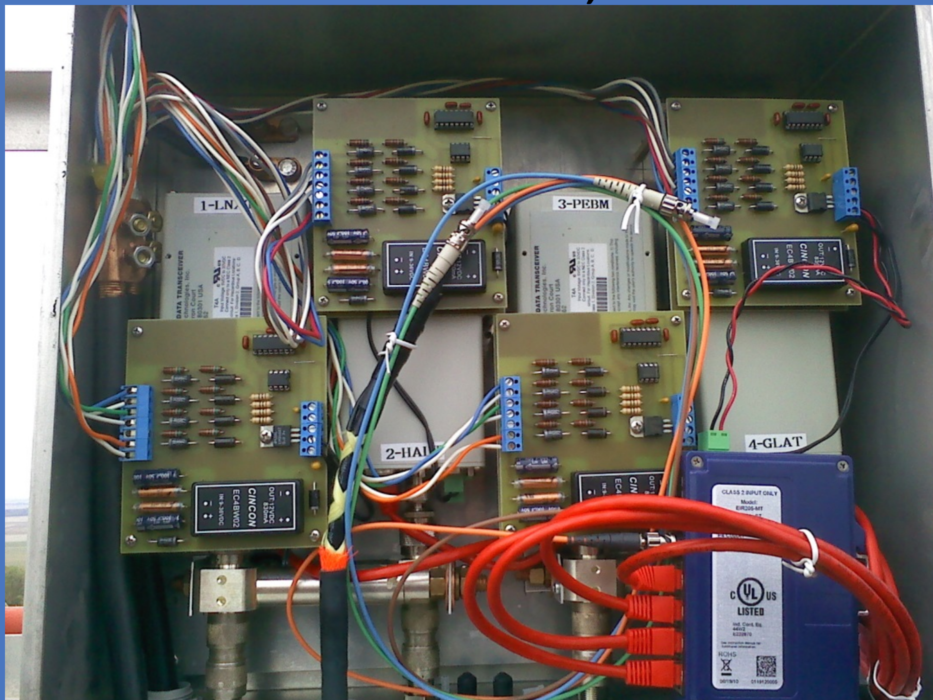
High Peak, NC Central Receive



New Madrid,MO and Lenox, TN Central Receives



AC power systems

BCRT, Bacon Ridge, TN

CLTN
Cedars of
Lebanon SP, TN

ASTN, Avondale Springs, TN

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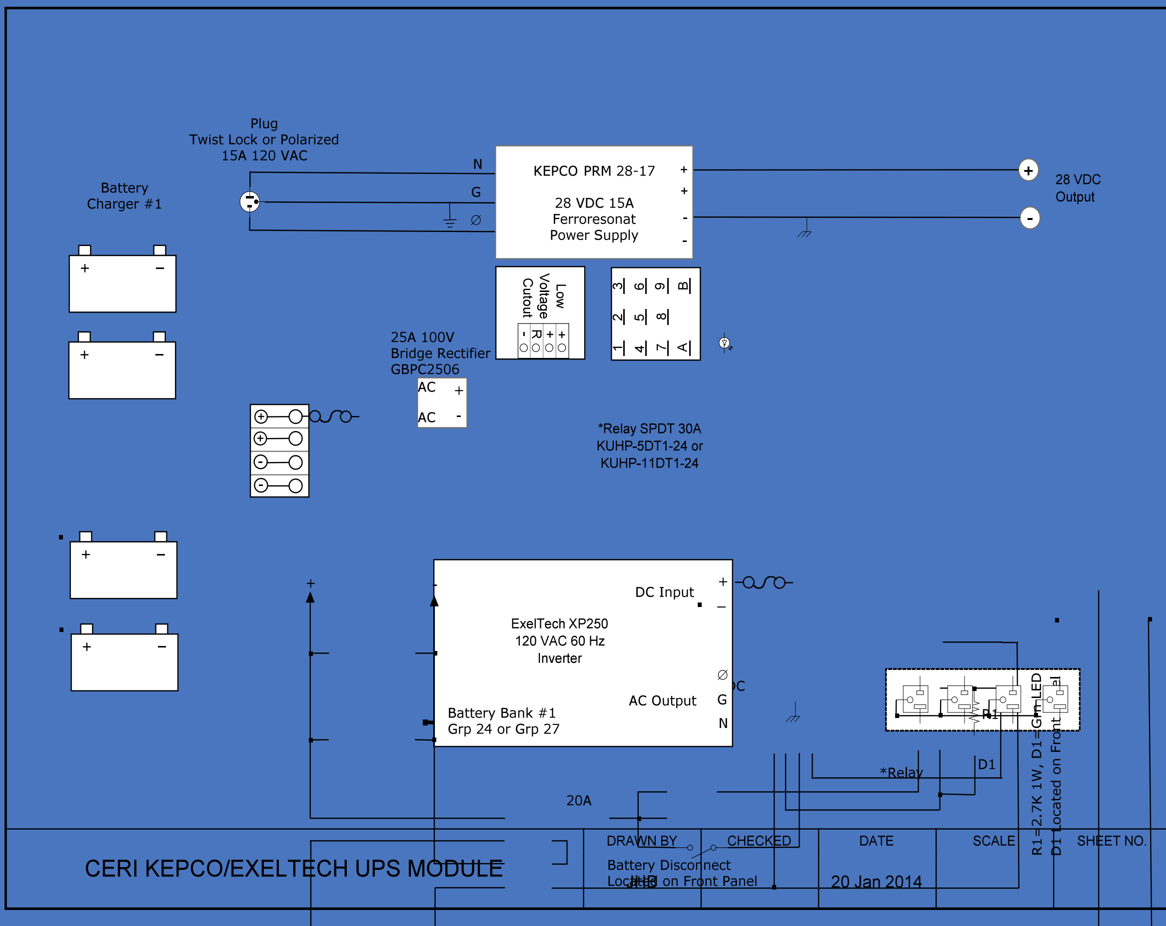
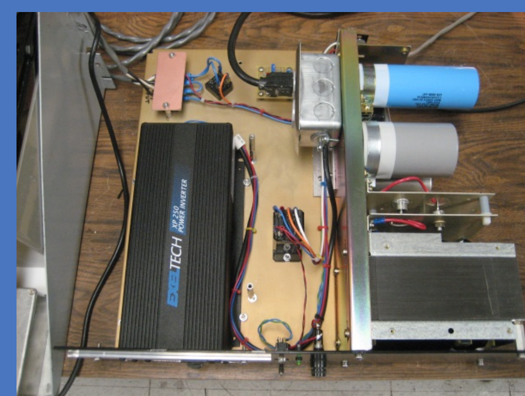
AC power systems





NMSZ and ETSZ CR Node Racks

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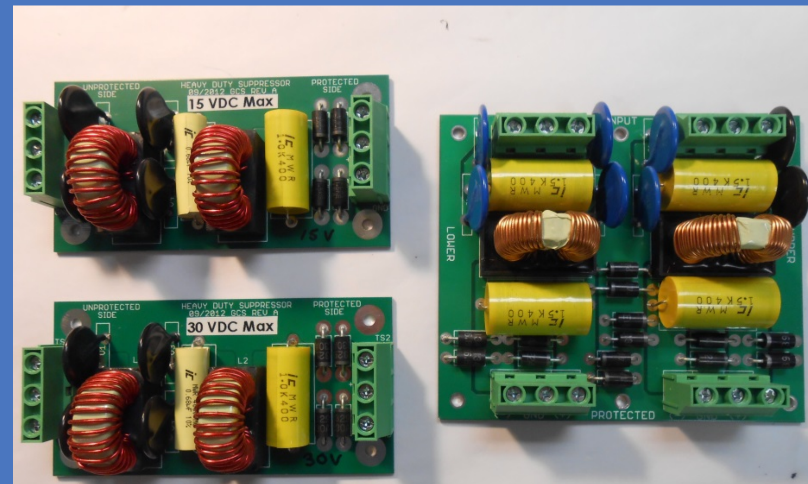
DC Power and Analog Balanced Lines

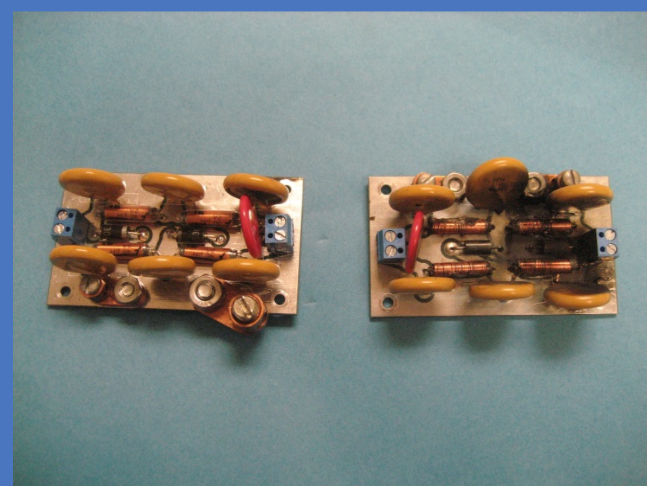
Comparison of common surge suppression devices

Device	High Energy High Current	Low let-through Voltage	No follow-on current (non crowbar)
Silicon Devices	✗✗	✓✓	✓
MOVs	✓	✓	✓
Traditional Spark Gaps	✓✓	✗	✗✗



Heavy Duty TSP for DC power and 24 VDC Solar Systems

BAB, Bad Ass Balun



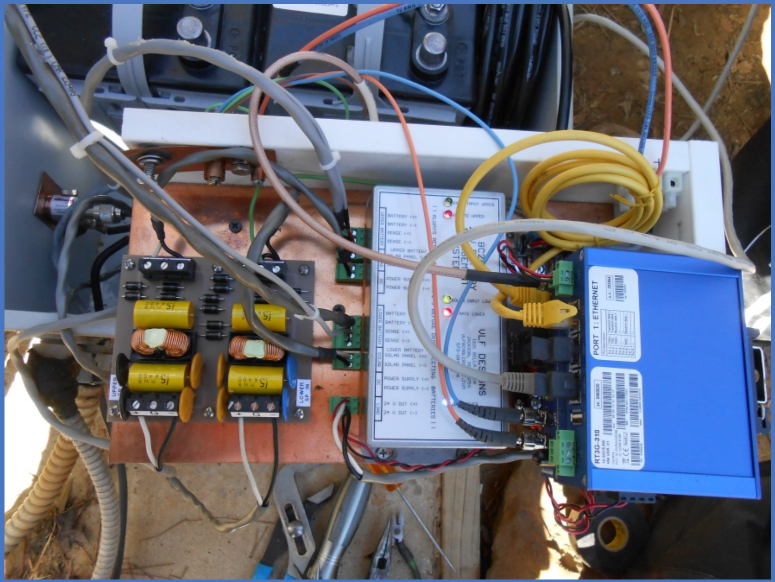
Two and Three Stage Suppressors

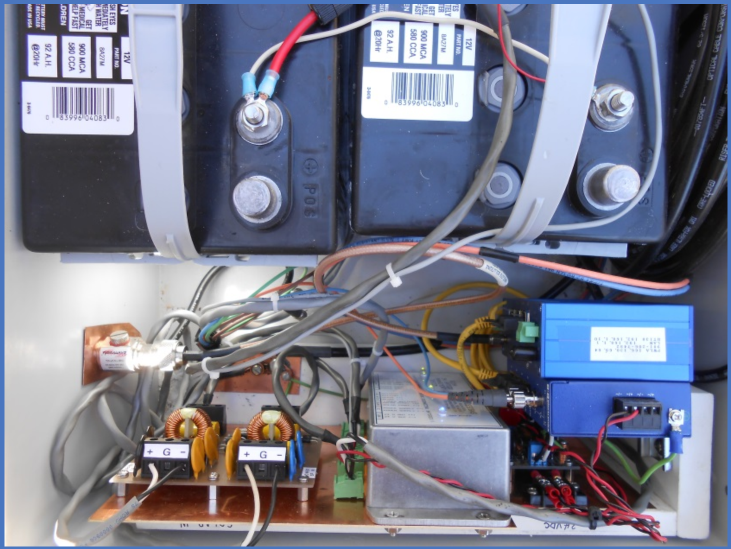
The first stage uses gas tubes which are extremely fast and have good bulk current capability

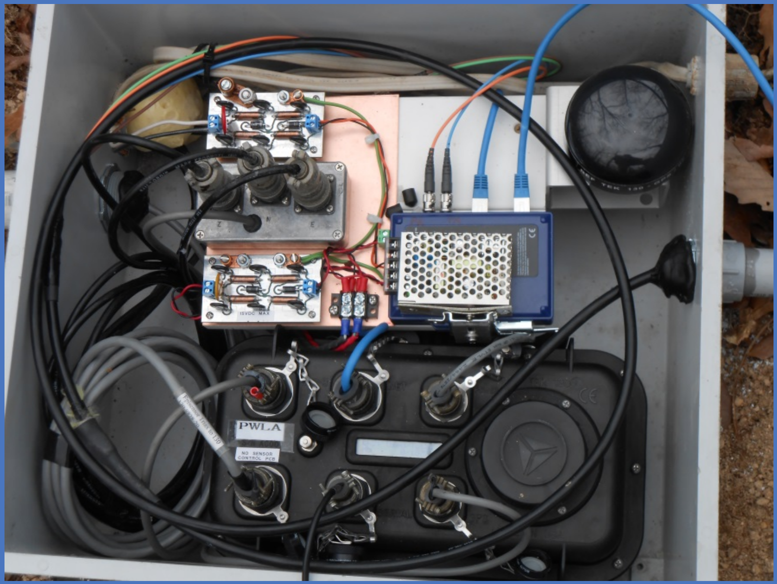
The second stage utilizes MOV's(metal oxide varistors) because of their good bulk surge capability. They are isolated from the first stage by inductors which cause a voltage drop and allow the gas tubes to fire even though the MOV's have a lower clamping voltage.

The final stage uses silicon avalanche type devices which have good clamping action. They are isolated from the second stage by resistors, inductors or a transformer. If the surge current is excessive they will fail safe by shorting out.

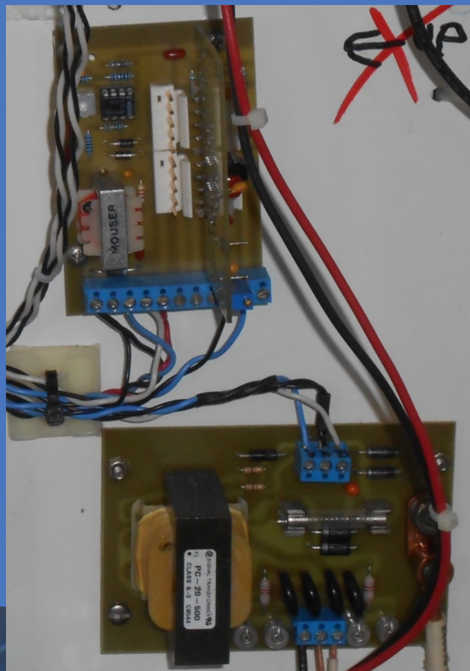
PWLA, Pickwick Lake, AL





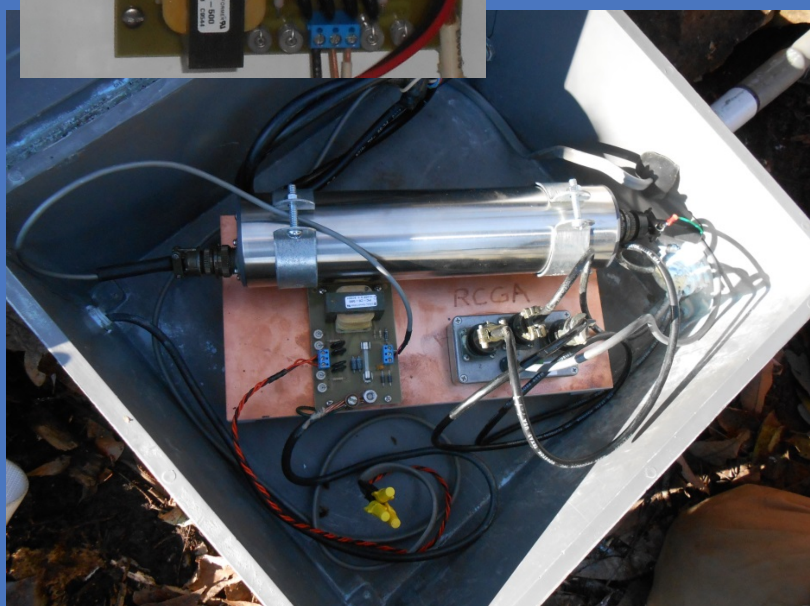


Analog Amp/Vco Systems

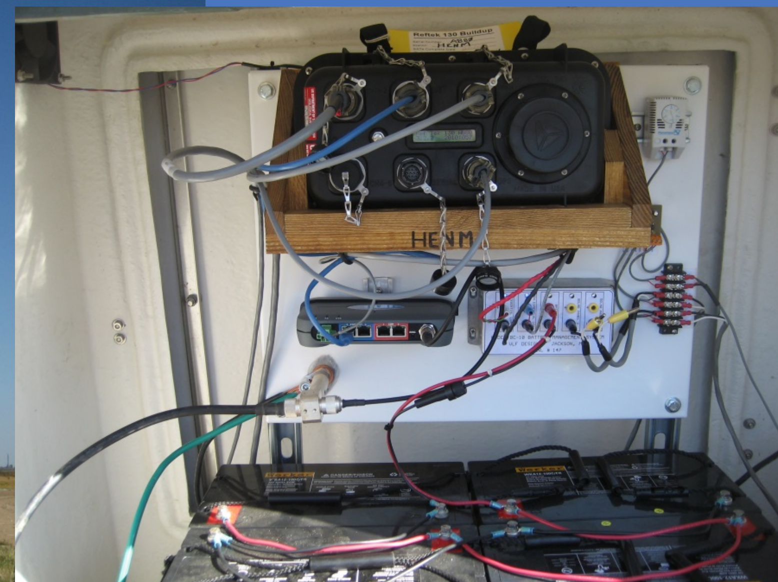


CCRT
Cow Camps Ridge, TN

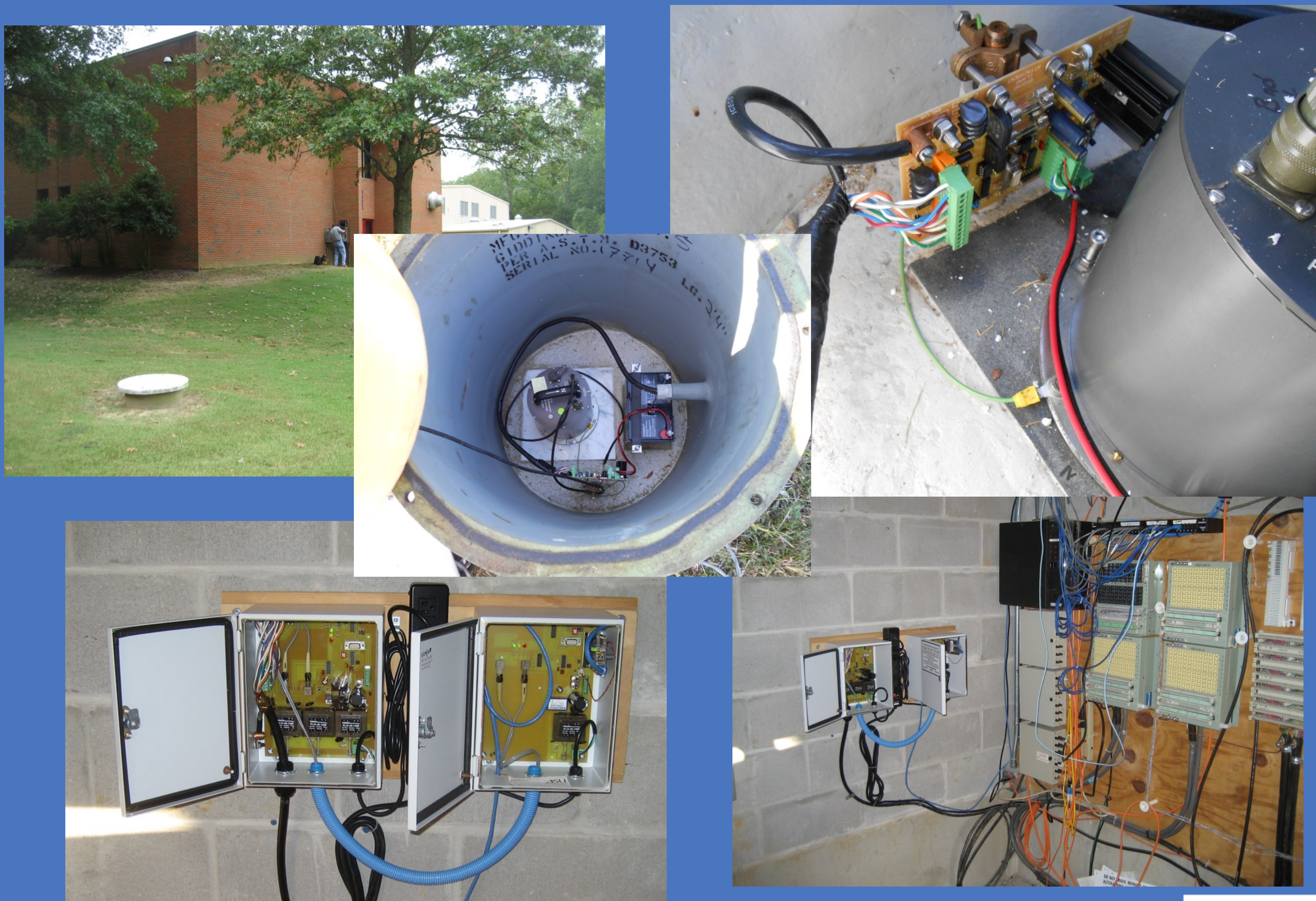
RCGA
Rock City, GA



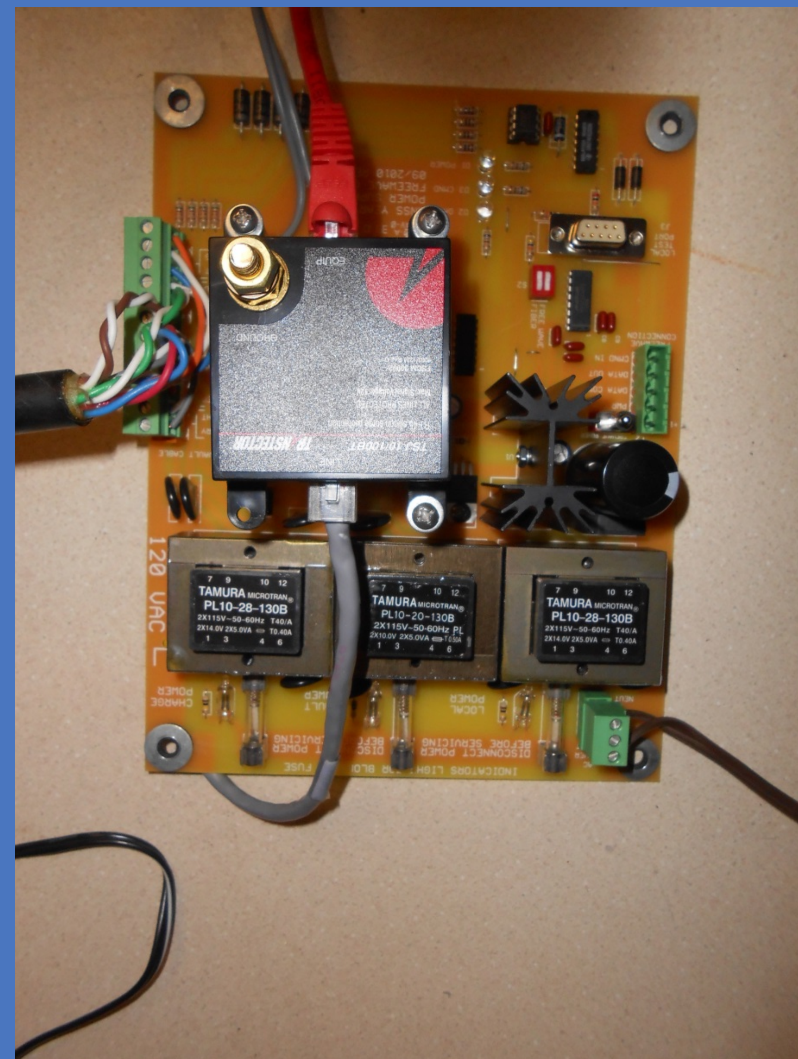
HENM
Henderson Mound, MO

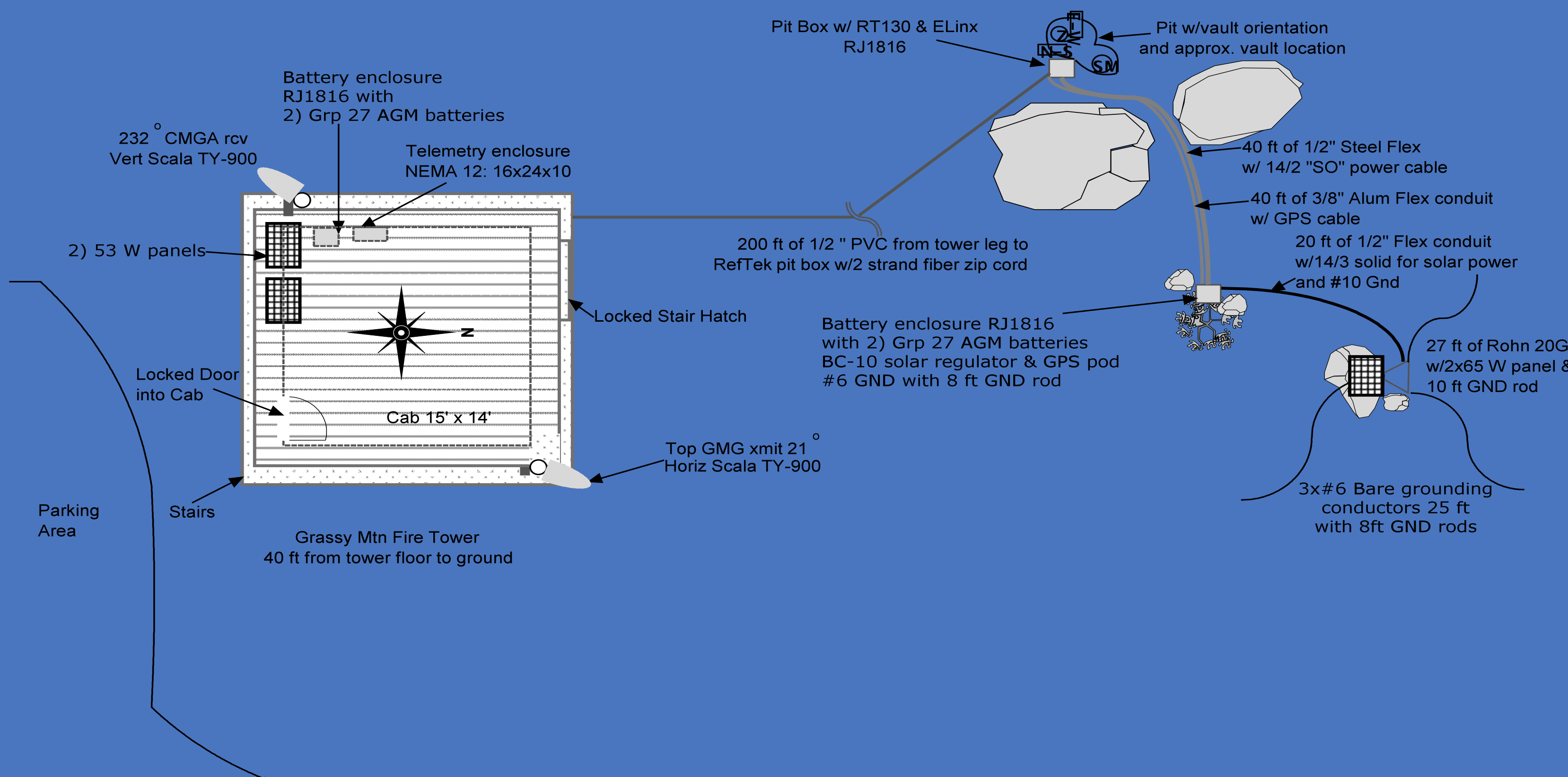


CMG-5TD Strong Motion Stations



Basalt/Obsidian
Strong Motion Station Conversion





	DRAWN BY	CHECKED	DATE	SCALE	SHEET NO.
Site Layout ***GMG- Grassy Mountain, GA***	JHB		8/29/2014	1" = 10'	

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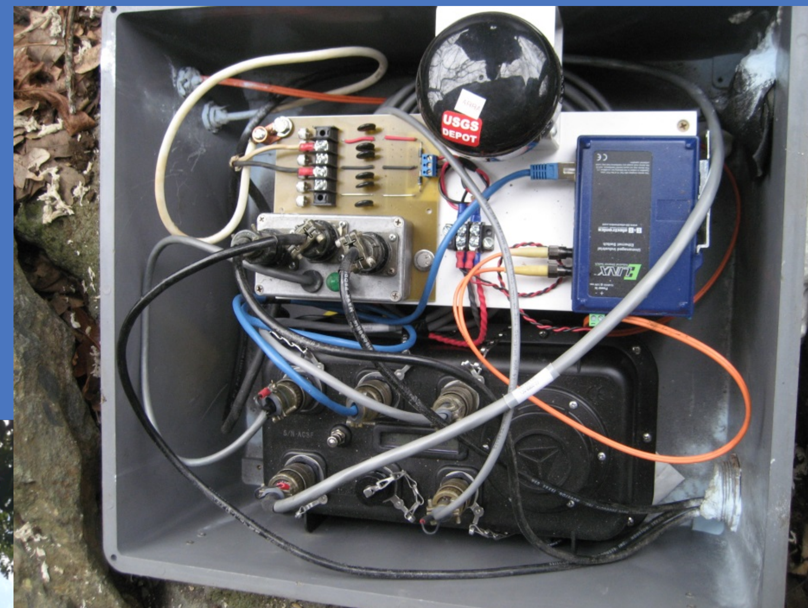

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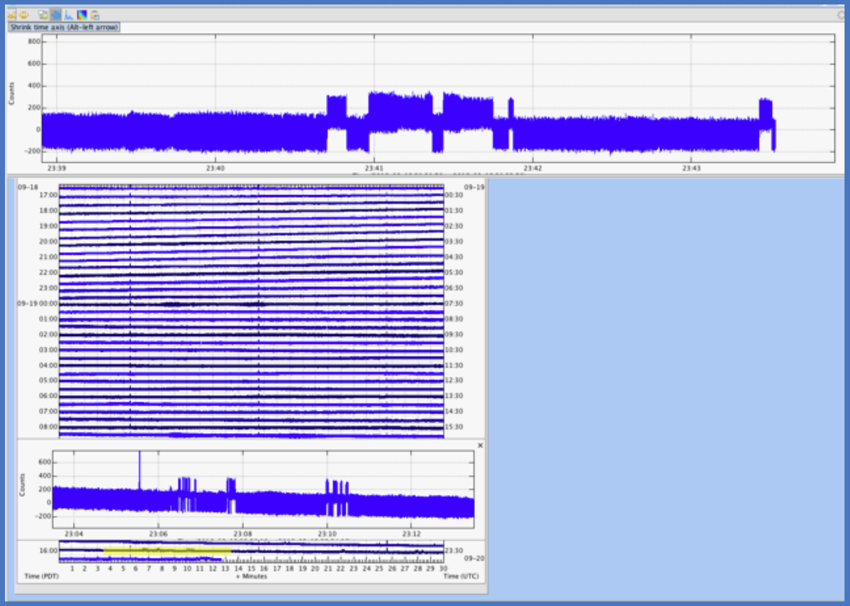
A PNSN transient noise attenuation problem submitted Marc Biundo

We broke the issue down into two problems before heading to the site(Mt. Hebo EEW Station Oregon Coast.)

1. Periodic (every 10 minute) transients.
2. Random transients.

Toolkit for problem assessment:
Oscilloscope
Hand Held consumer grade 400Mhz walkie talkie.... (controllable source of transients)
PC with access to real time data logger traces.
RF Chokes, snap on, various sizes....
Camera

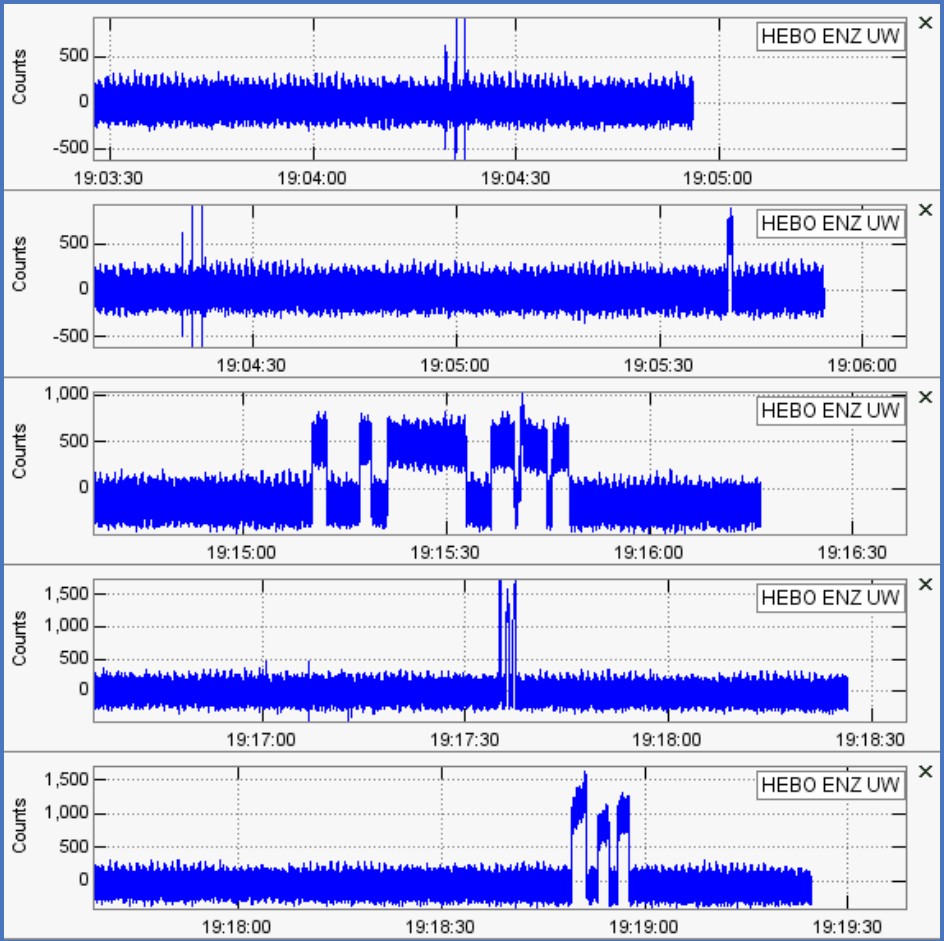


I had never been to the site, but found this when I arrived....
RF Towers

I had never been to the site, but found this when I arrived....
RF Towers

Heater, above....

While onsite confirmed problems and was able to recreate same signal and magnitude of transient with test equipment.
Top three traces are a base line of capturing the problem before any changes/modifications are made.
Bottom two traces show how to control/stimulate the issue at the same magnitude....



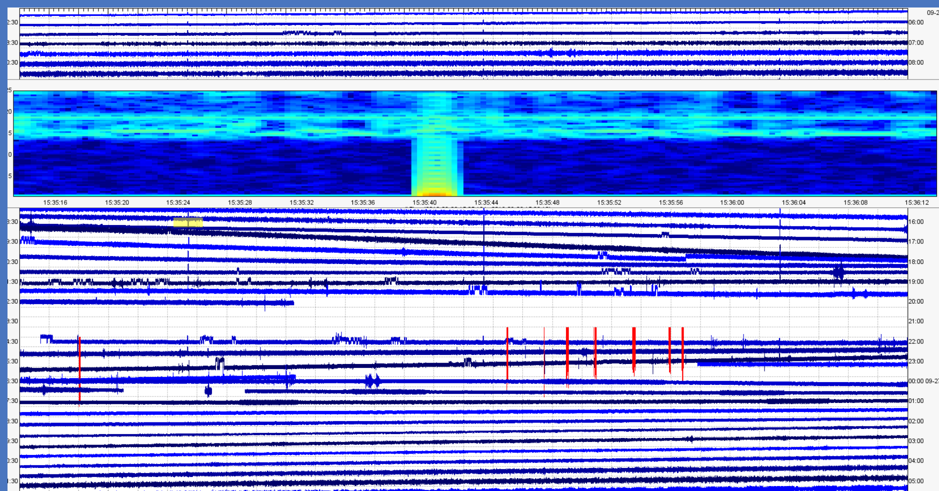
Goal: Attenuate transients.
Approach:
Assess instrumentation cables, placement, layout...etc...
Add RF Chokes on any or all compromised Seismic system(digitizer) cables....
Assess any power cables; UPS, DC Supply, AC Heater and move them away from instruments.

Test:
Recreate problem and reduce/eliminate it! Confirm with different variations.... Make sure you did not inject new problems!
Monitor and document process to keep a running history of the problem, potential fix and approach.

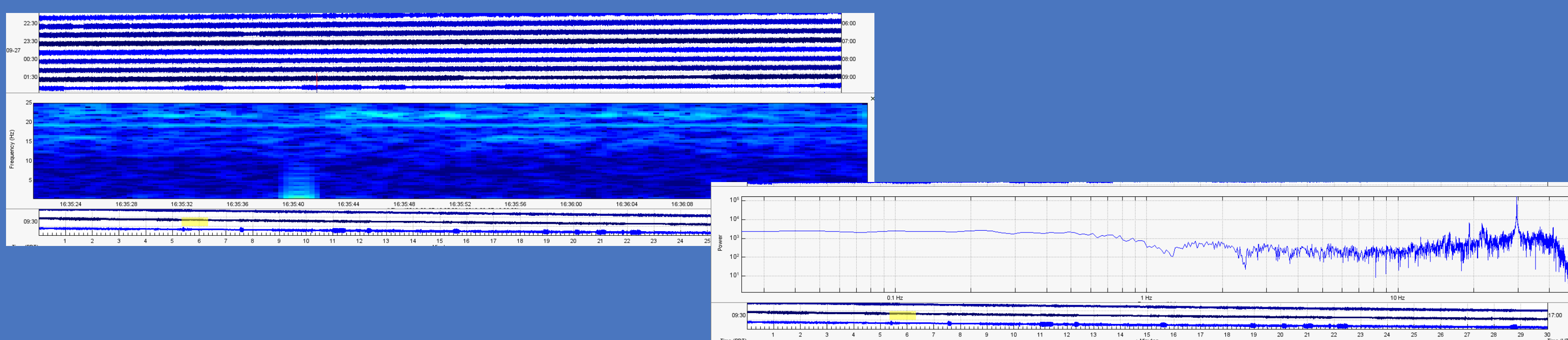
Results:
1. Periodic transients attenuated.
2. Random transients attenuated.
Success? Would like to observe for a week or so to confirm. AND Make sure we did not compromize seismic signal by injecting a filter into the analog signal chain....

Looking at spectrum of the periodic pulse, before/after....

Before attenuation:



after attenuation:



Snap on transient suppressing RF Chokes:

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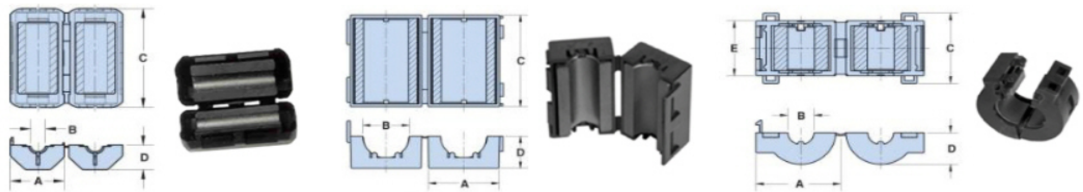

Figure 1 Figure 2 Figure 3

Dimensions: Top numbers are in millimeters, bottom numbers are in nominal inches.
+ = Test Frequency

All Materials / Freqs

Part Number	Fig.	Solid Equivalent	Frequency Range	Max Cable Diameter	A	B	C	D	E	Wt. (g)	Impedance					
											500 kHz	1 MHz	25 MHz	100 MHz	250 MHz	500 MHz
0475181651	2	2675023002	Low Frequency 200 kHz - 30 MHz (75 material)	4.9 0.193	13.00 (0.512”)	05.10 (0.201”)	23.00 (0.906”)	06.05 (0.238”)	–	6.5	35	66	–	–	–	–