Accufix System Enhancements for eLoran

Presented to:

NAV08/ILA37
London, UK
28 October, 2008

PRESENTED BY:

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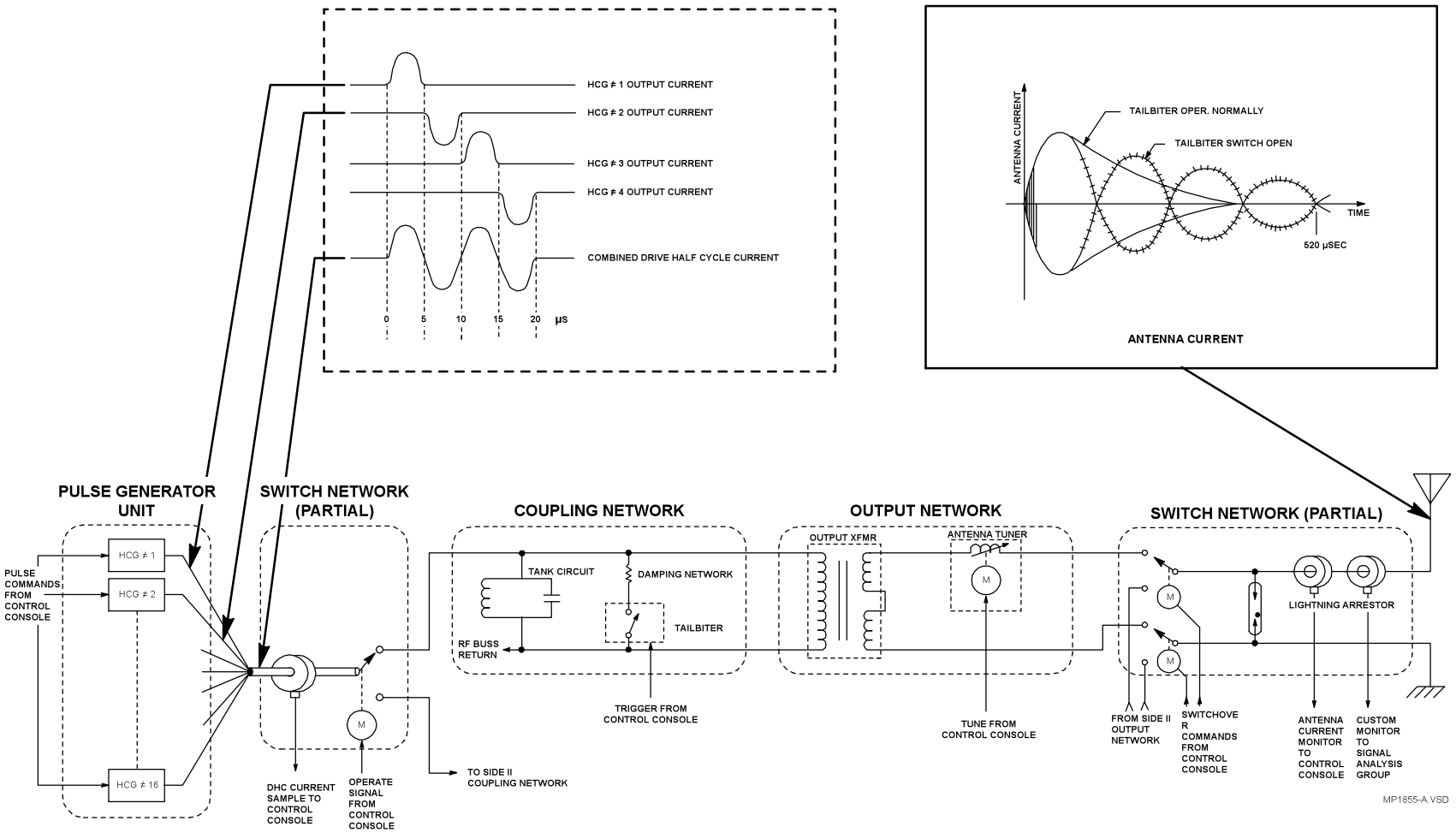
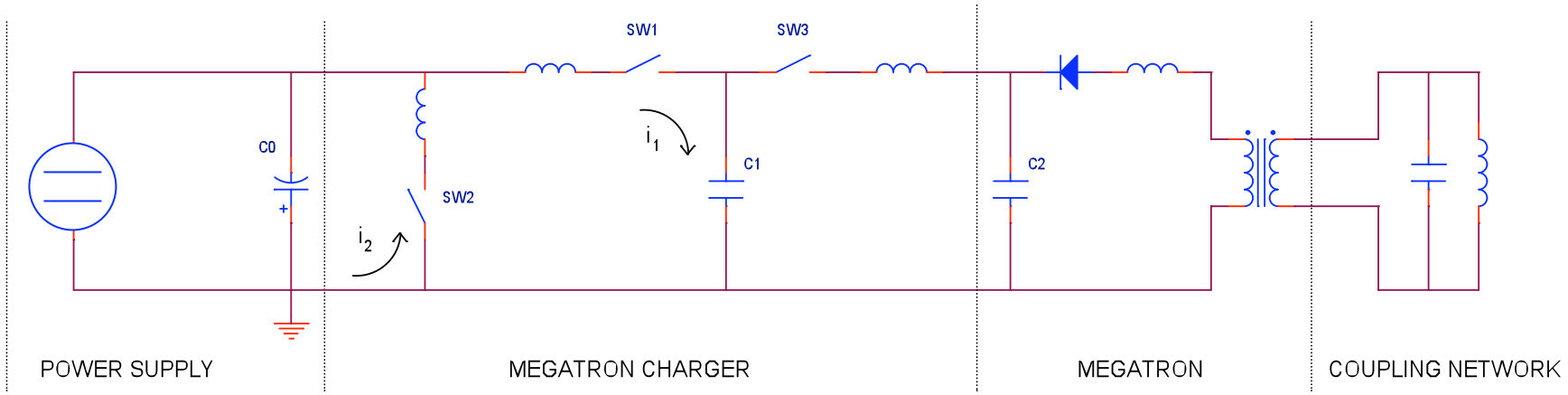
Overview

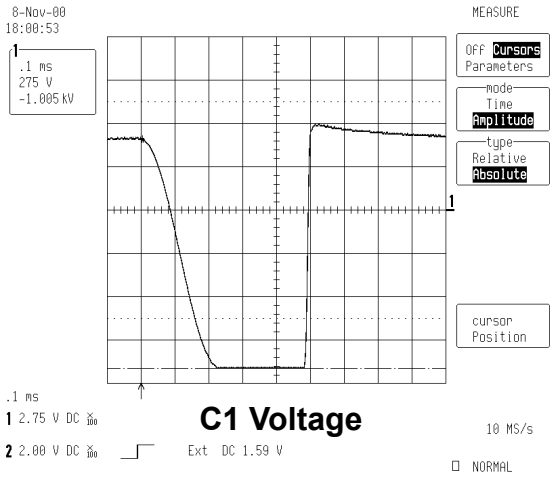
- Brief description of Accufix transmitter means of pulse generation and control
- eLoran evolving signal standards
- Audit of Accufix performance for eLoran
- Evolution of Accufix design
- Impact to existing owners and operators
- Summary

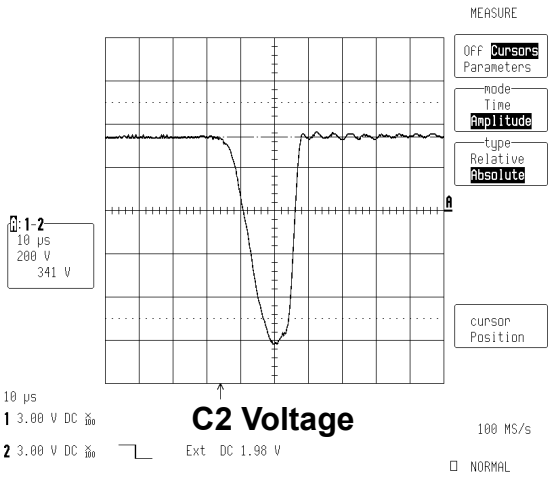
Accufix Pulse Generation and Control

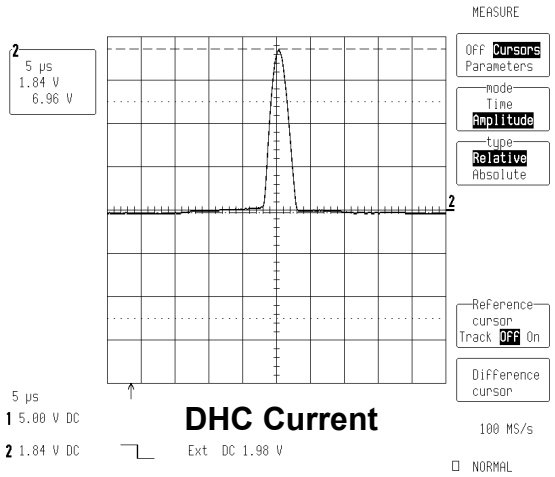


Accufix Pulse Generation and Control

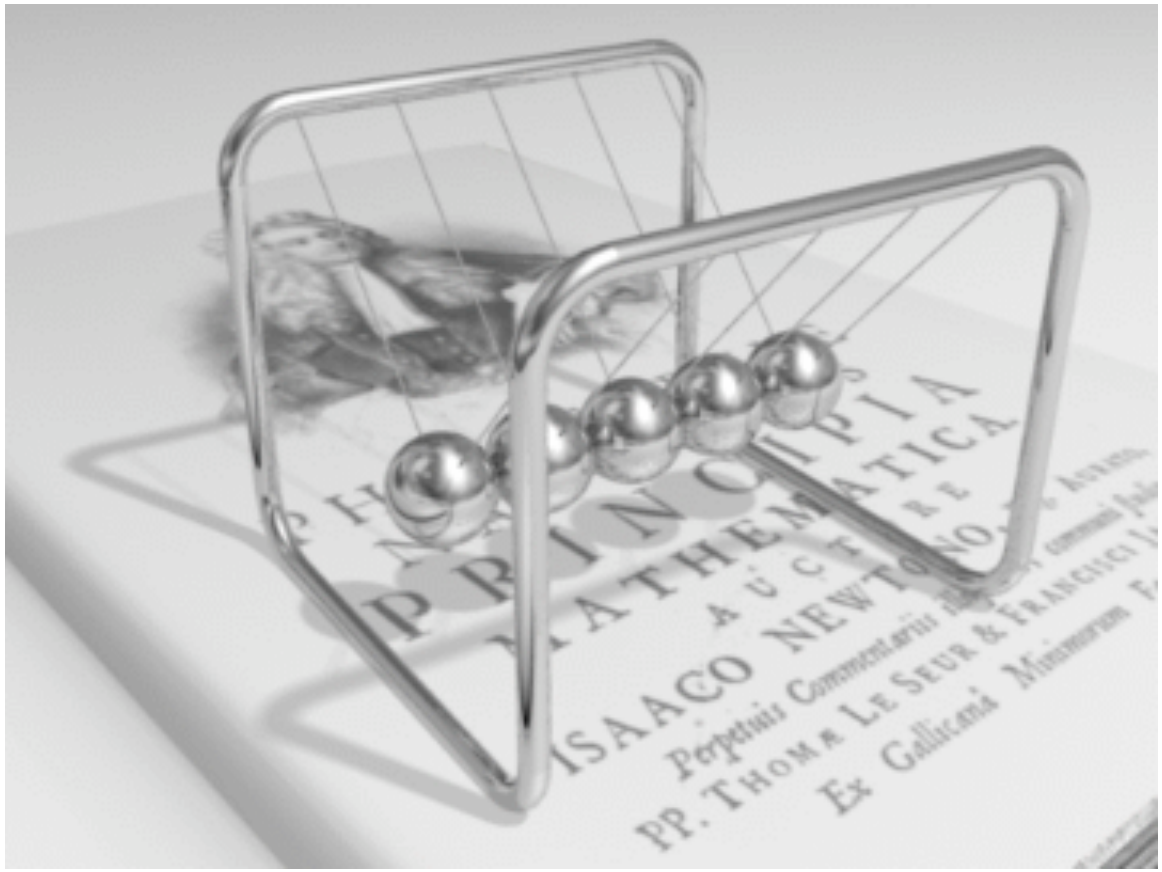








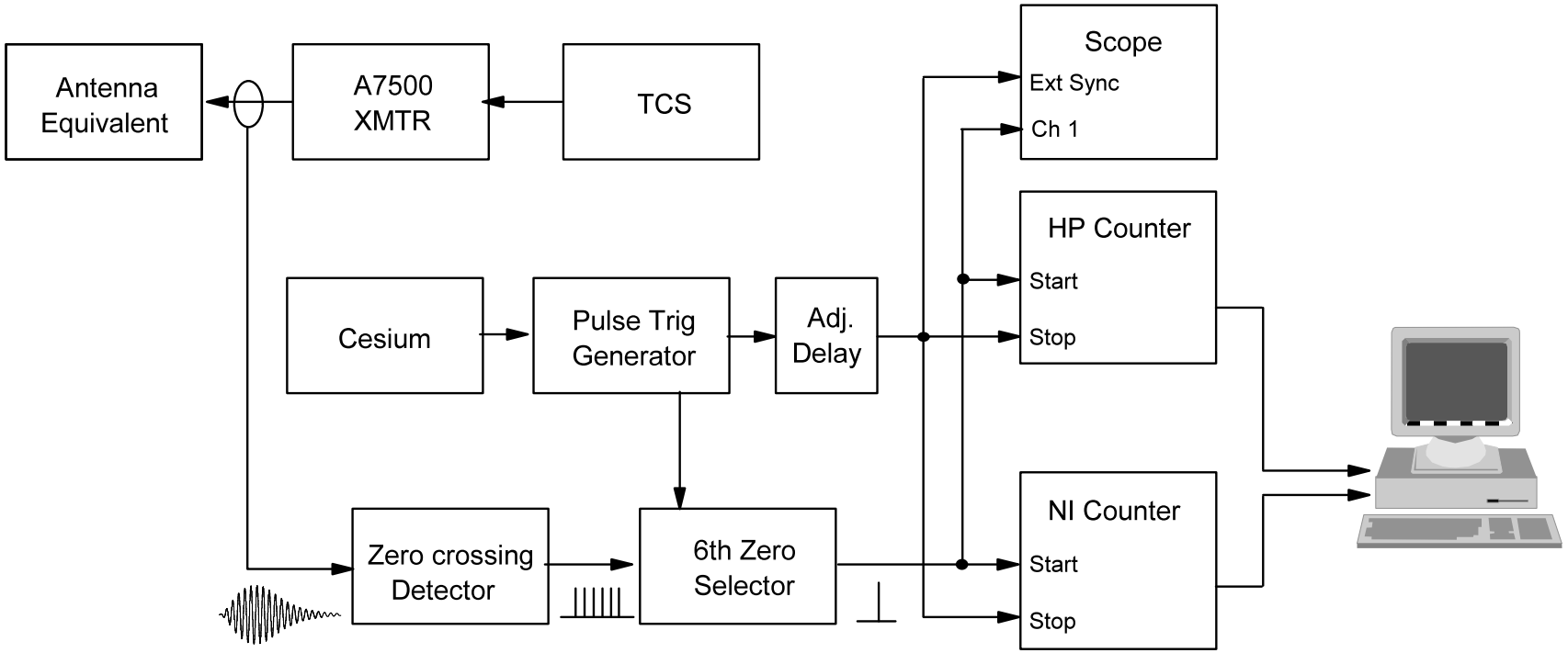
Accufix Pulse Generation and Control



Consequence of eLoran Standards

- Performance requirements evolving
- Some new performance requirements are expressed in terms of the 1, 5, & 10 second exponential averages needed by mode and also in the intra-pulse timing stability requirements. More to follow?
- Receiver manufacturers want generally tighter tolerances everywhere to reduce the problems they already have to deal with.

Accufix 7500 Assessment – Test Set-Up

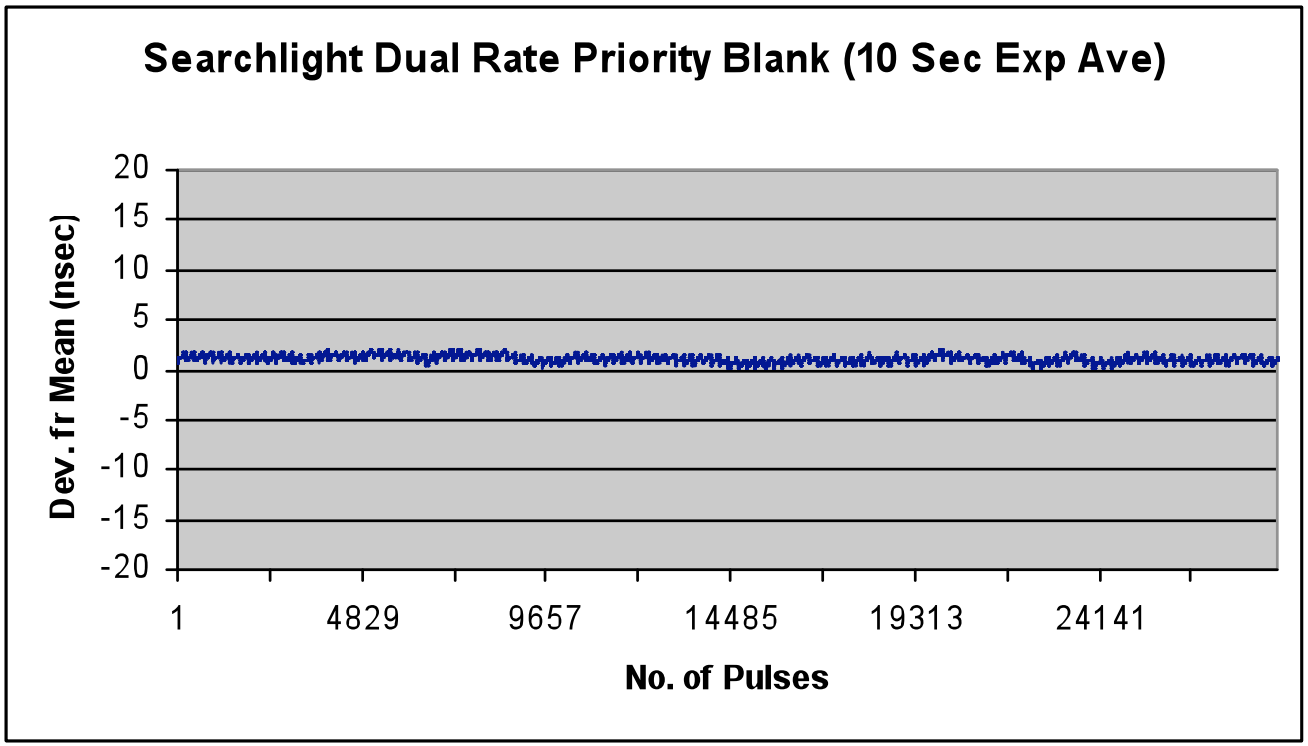


Accufix 7500 Assessment – Test Set-Up

- Baseline measurements
  - Single and Dual (multiple pairs) rate, full power
- Test measurements
  - TCS switchovers
  - Coupling/Output Networks switchovers
  - Effect of mistuned Coupling networks
  - Tuning bumps
  - HCG Maintenance
  - Blink mode
  - Pulse to Pulse timing
- Analyzed >7.5 Million pulses

Test Data – Baseline "All Good" Condition

- The 10 second exponential average of all navigation pulses shall be < 25 ns of UTC; Timing receiver requirement.



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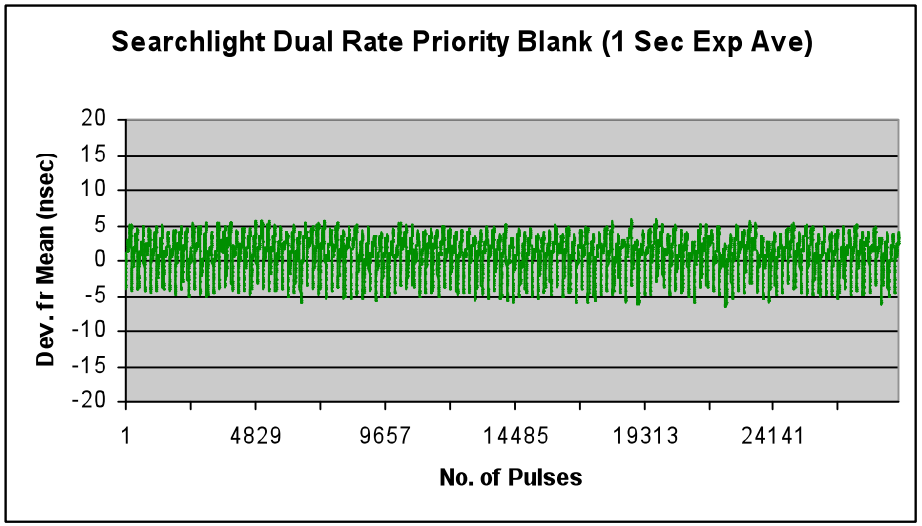
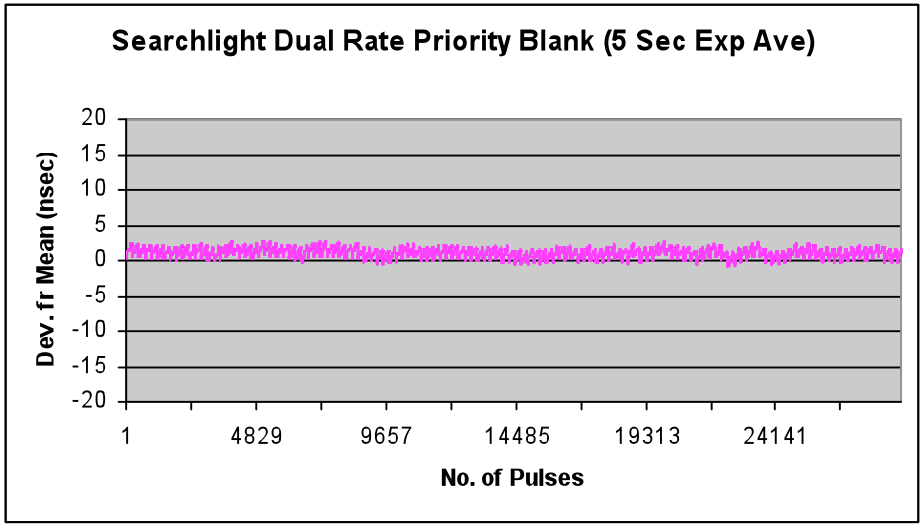


- The 1 second exp. average of all navigation pulses <100 ns of UTC; Aviation (RNP 0.3) requirement.



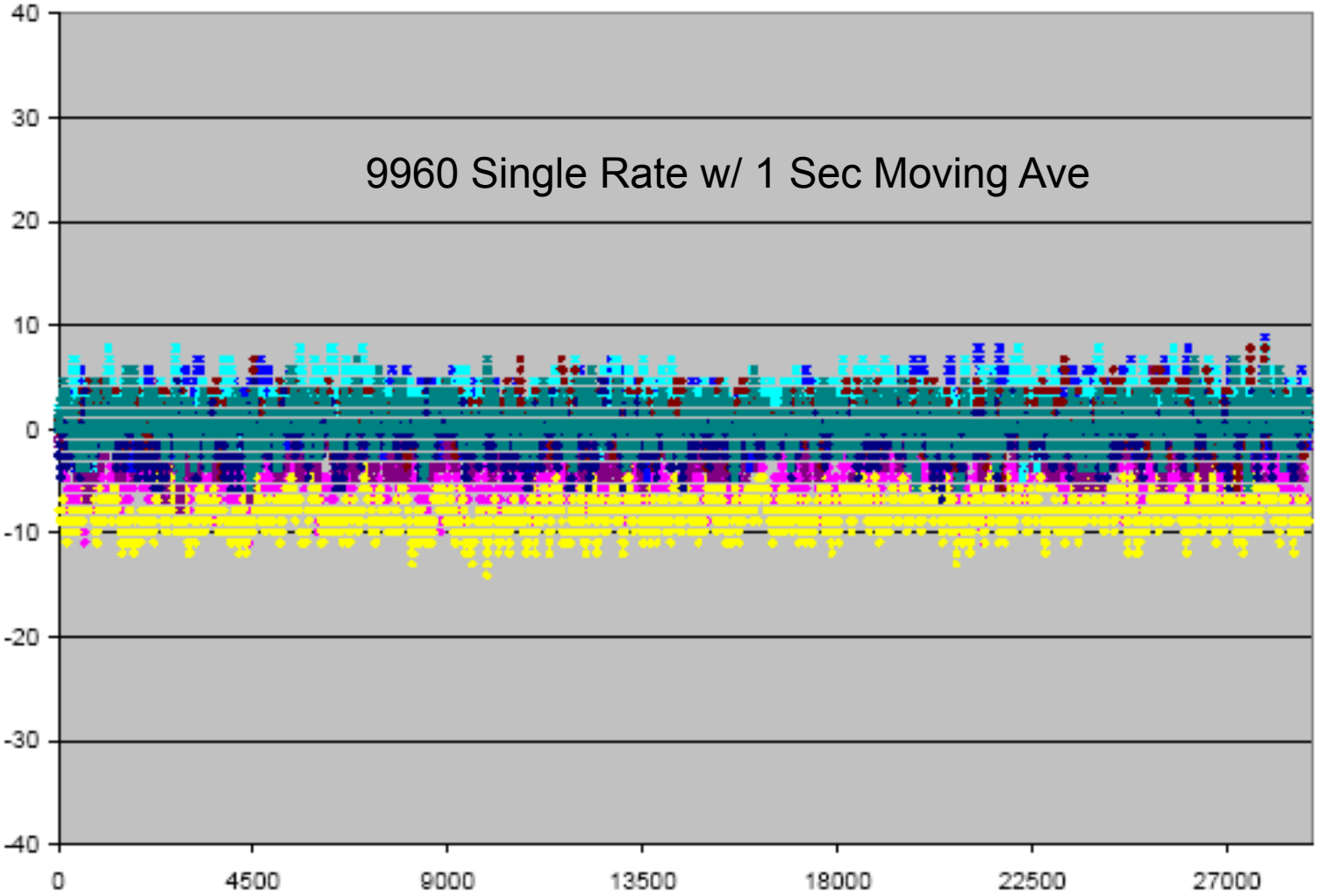
- The peak to peak variation of 5 second exp. average of all navigation pulses <10 ns within 20 minute period; Maritime HEA and Frequency requirement.

Test Data – Baseline "All Good" Condition

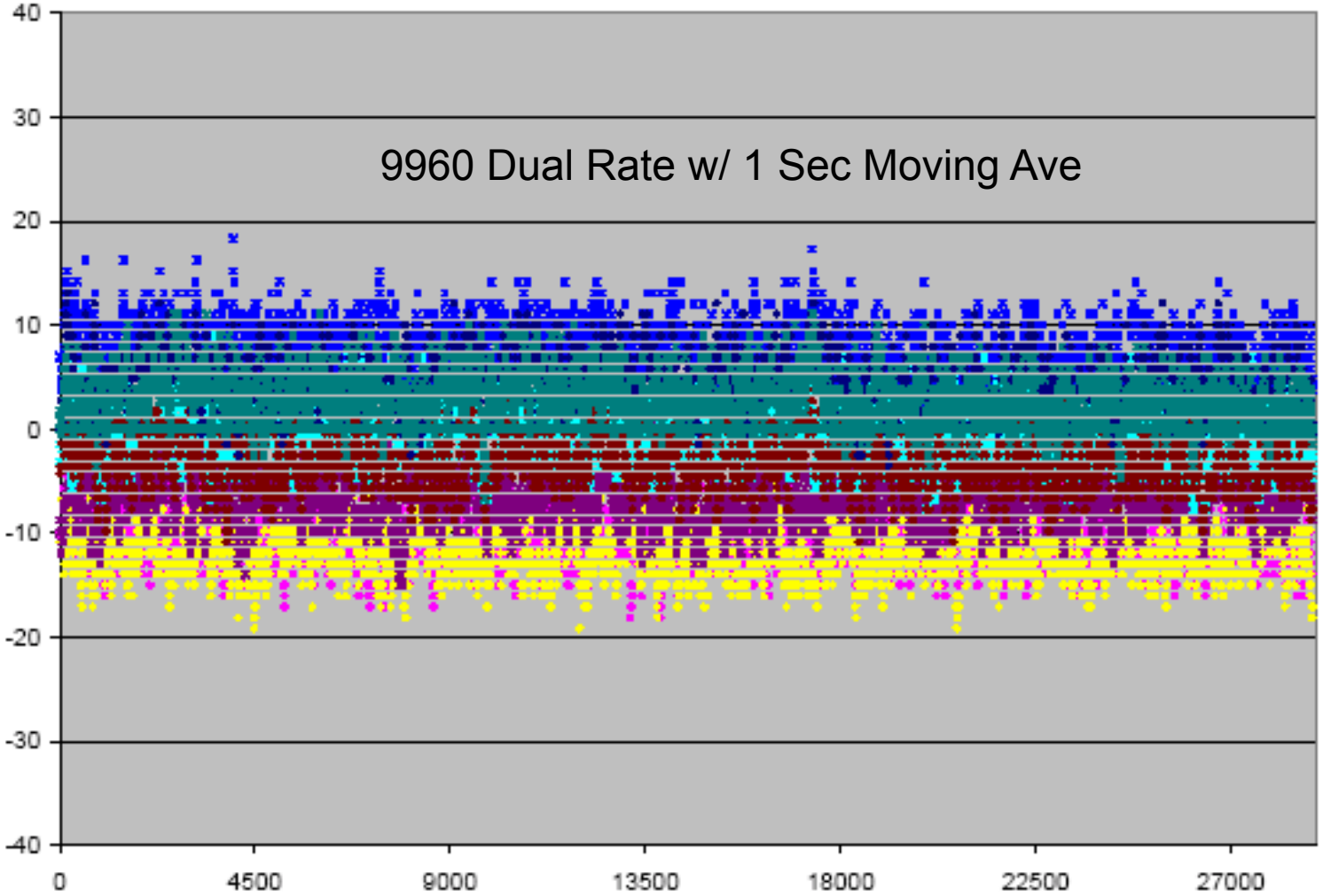
		Raw	5Hz Exp	1Hz Exp	0.2Hz Exp
Single Rate 9960	Std Dev	8.3	2.2	0.8	0.5
	Latest	66	12	4	3
	Earliest	-33	-9	-4	-2
Dual Rate 9960	Std Dev	17.8	7.8	1.5	0.6
	Latest	95	37	8	3
	Earliest	-42	-22	-7	-3
Dual Rate 9940	Std Dev	14.8	9.3	2.5	0.7
	Latest	87	41	9	3
	Earliest	-38	-18	-6	-3

- Values in the above table are in nanoseconds for a one hour data set of ~290,000 pulses. At the 5 second averaging interval (0.2Hz) all performance requirements are met. Effects of jitter and dispersion are visible in the raw and 5Hz (automatic blink setting?) data.

Single Rate Dispersion for "All Good"



Dual Rate Dispersion for "All Good"

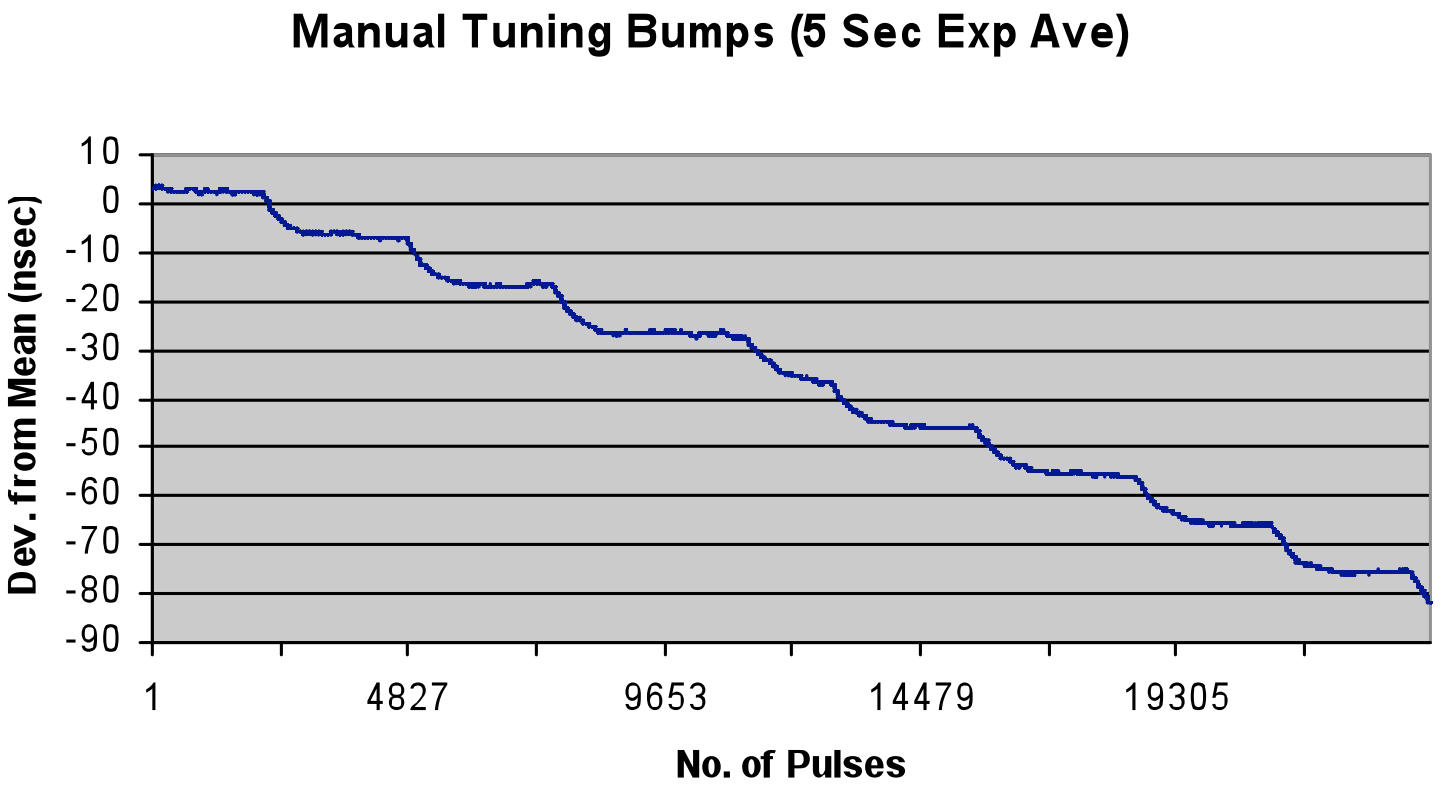


Accufix 7500 Assessment – Tests Run

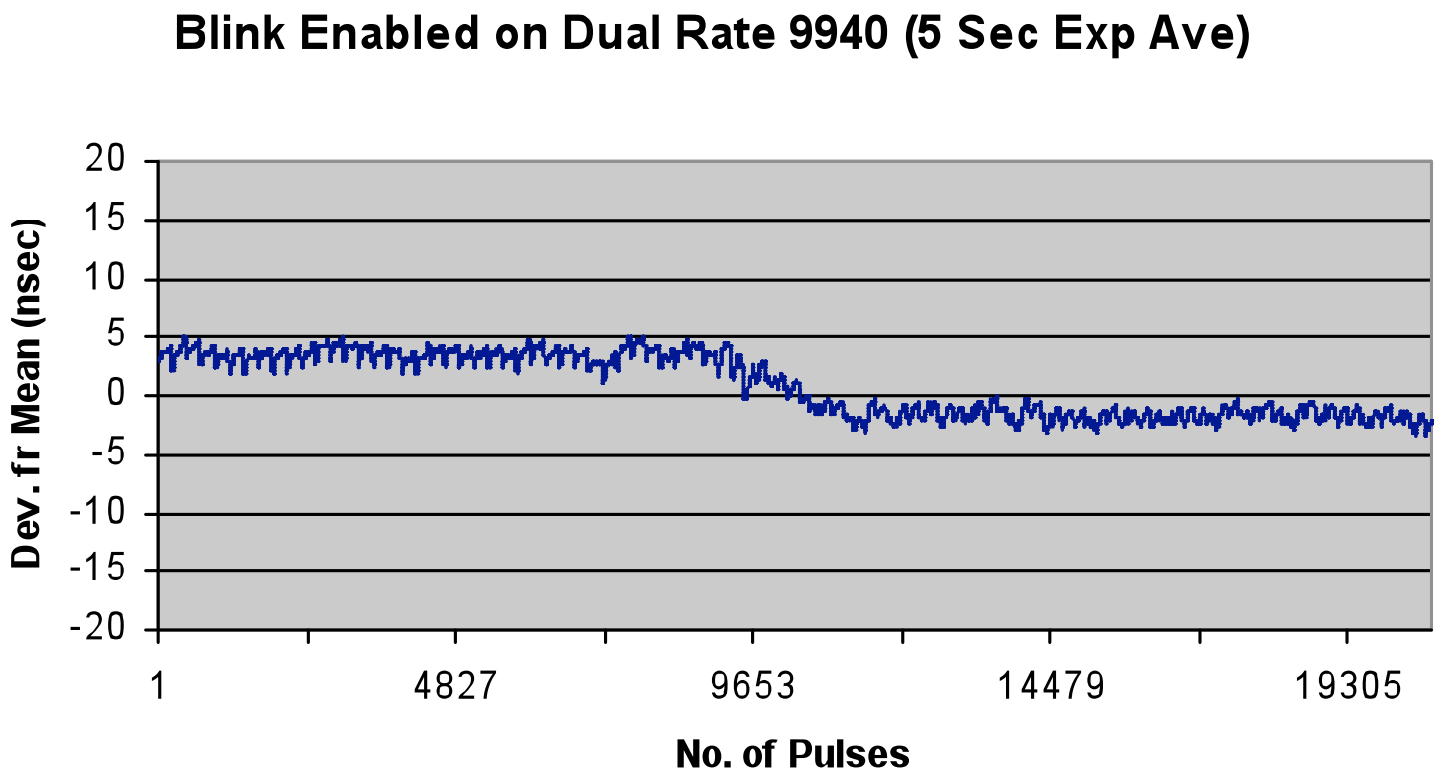
- Transmitter stability under simulated operating conditions is acceptable. The issue is thus managing the likely real expected & unexpected events including:
  - Antenna system changes
  - Maintenance practices
  - Fault tolerance
  - Redundancies
  - Operational Concepts

Test Data – Typical Conditions

- Tuner responds to changes in either the tank or antenna system and is measured by digital sampling of antenna ground return



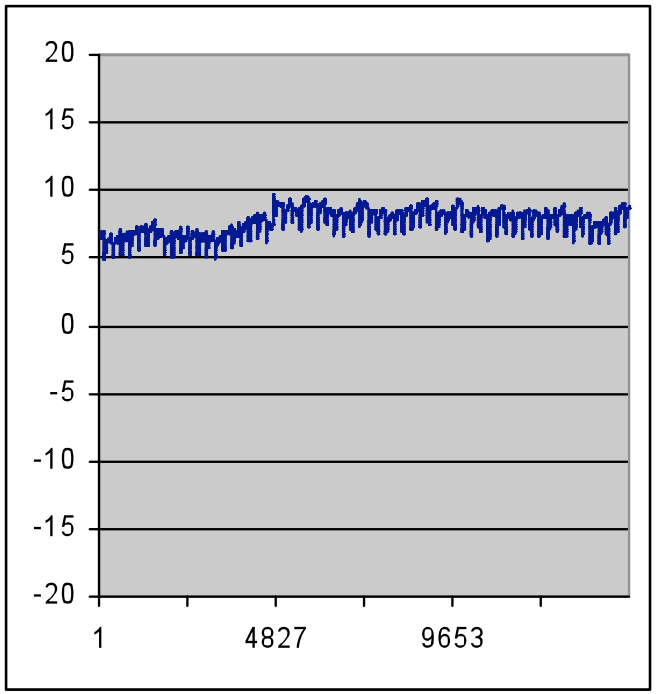
Test Data – Typical Conditions

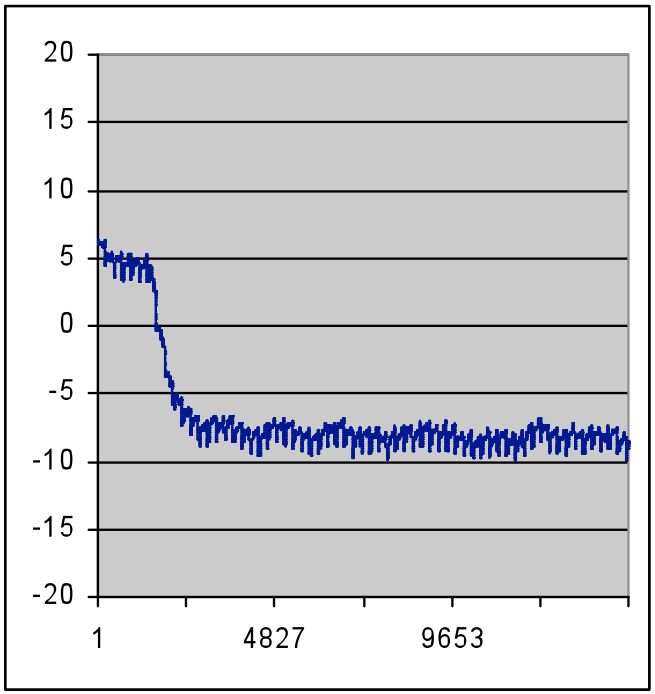


- Pulse dispersion means that when two of eight pulses disappear in the blink sequence that there is a resulting timing bias

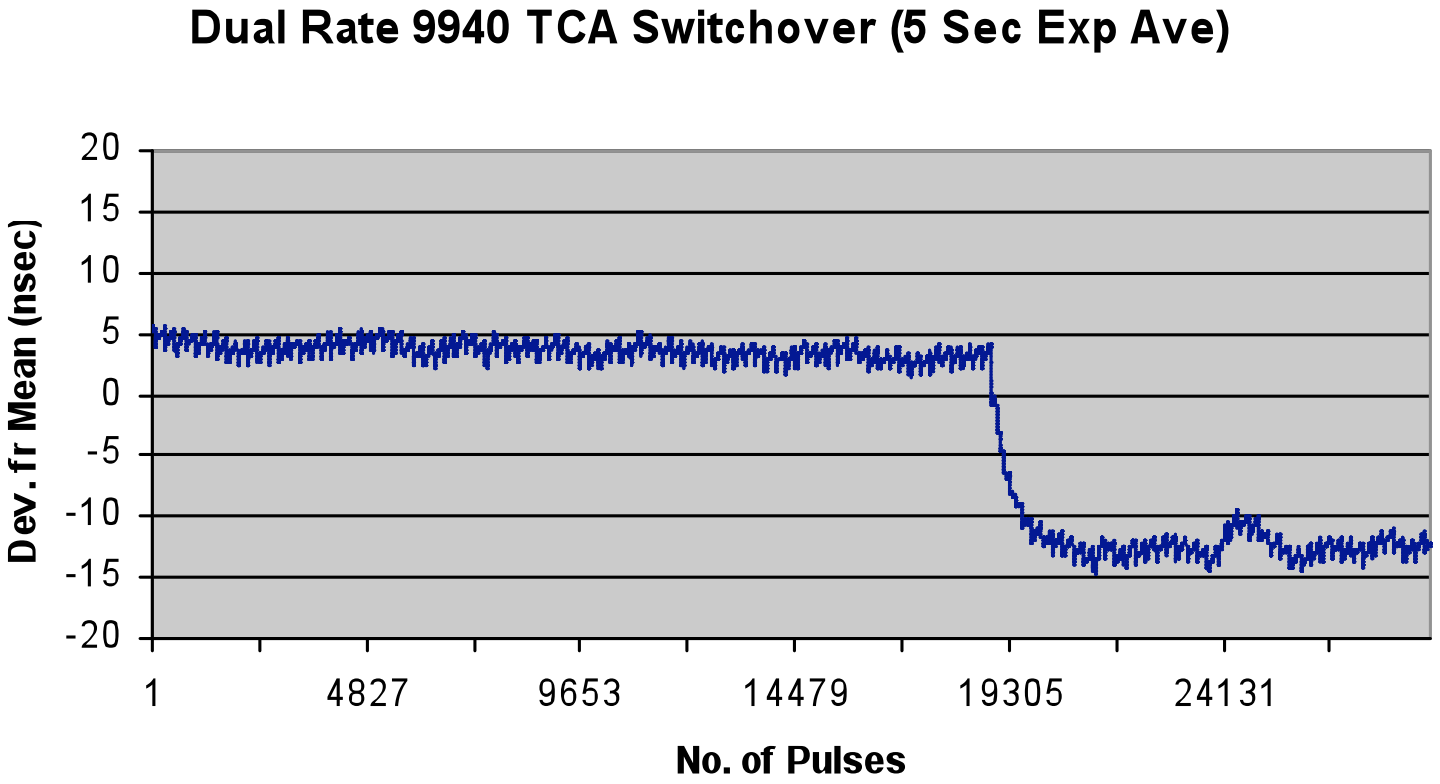
Test Data – Typical Conditions

- HCG maintenance (common) or failure (rare) result in allocation dependent errors exhibiting a jump when turned off and a minor wobble when turned on.





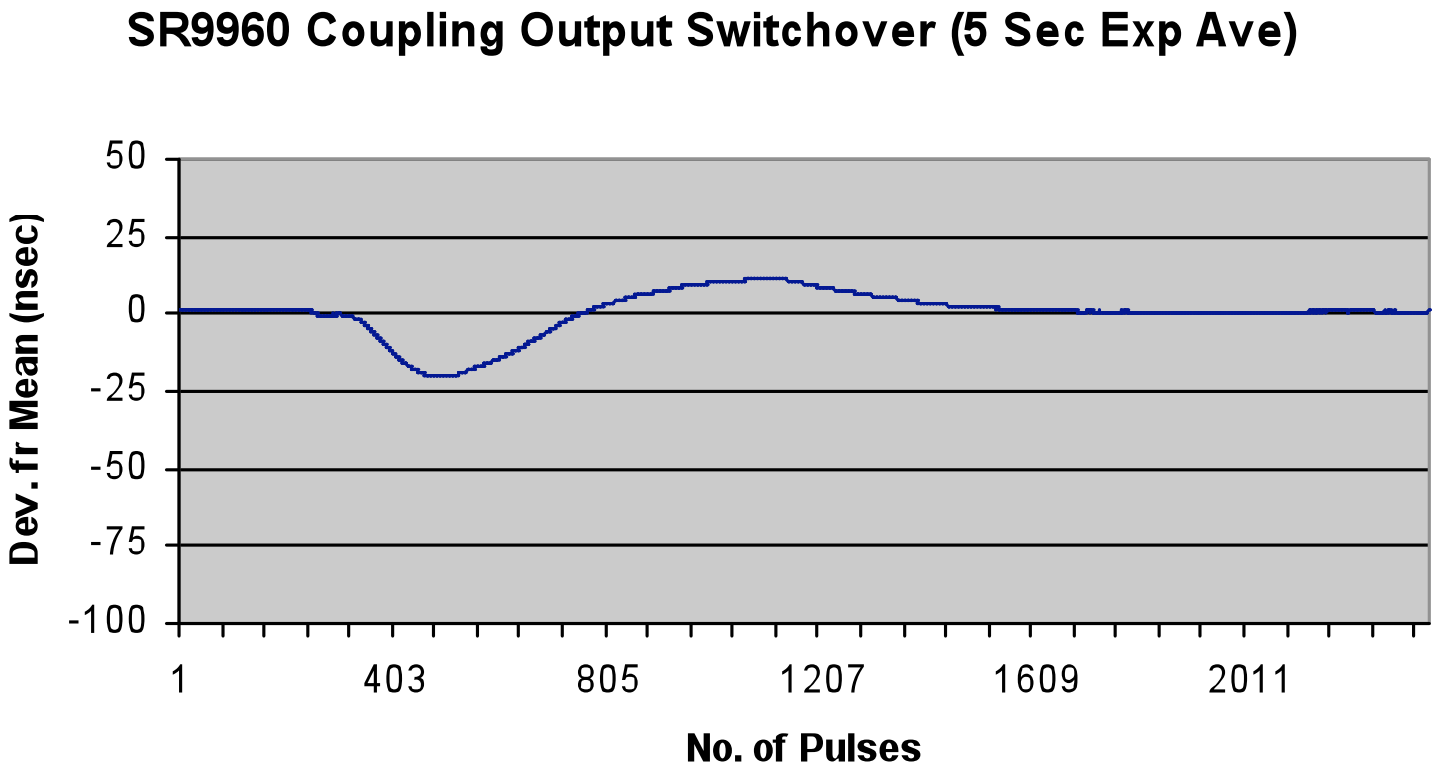
Test Data – Typical Conditions



- Ambiguity <25nsec exists in ToT from TCS. At start-up this is compensated with external loop but a commanded switchover may create an unnecessary timing jump

Test Data – Typical Conditions

- The Coupling Output Switchover causes an interruption of triggers for ~2.5 seconds that results in a timing wobble with a duration of about 15 seconds



Pulse Zero Crossing Stability

- Two allocations of DHC were tested

Zero Crossing	Time (us)	Tolerance (ns)	5-5-3-3	4-4-4-4
4	20	±5	-16	-17
5	25	±5	-5	-5
6	30	Standard	0	0
7	35	±5	3	4
8	40	±5	4	6
9	45	±5	5	4
10	50	±5	4	5
11	55	±5	5	5
12	60	±5	5	4

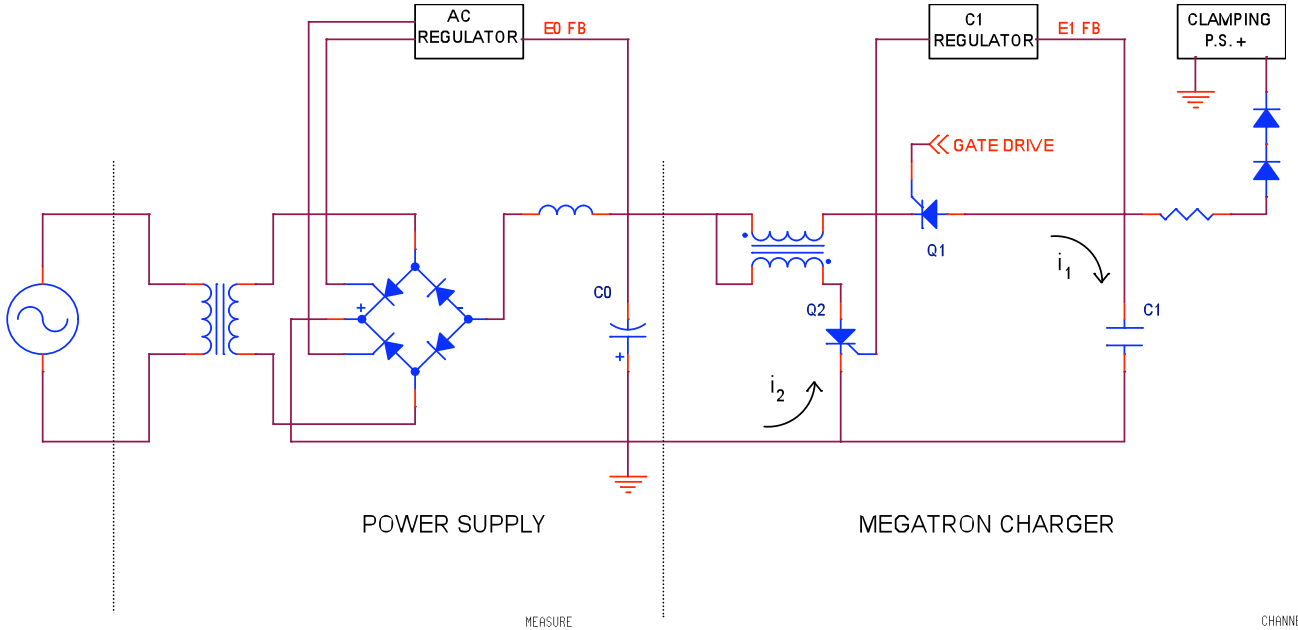
Test Data & Analysis – Summary

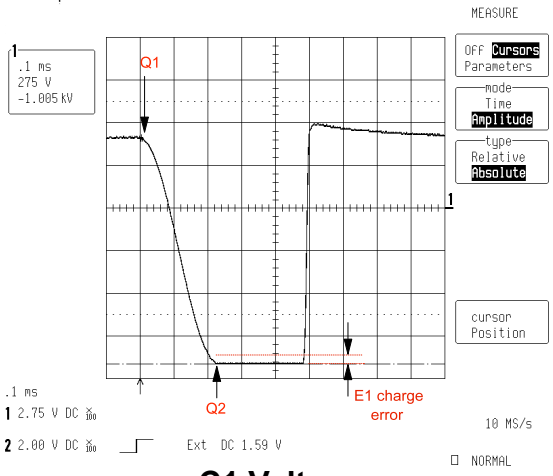
Test	Issue	Cause
SR Full Power	Minor Pulse Jitter	E1 Control
DR Full Power	Cross Rate Jitter Minor Pulse Jitter	E0 Control E1 Control
Tuning Match & Response	Timing Jump	Tuning limit too high
Blink	Timing Jump	E0 Control
HCG Maint & Failure	Timing Wobble Timing Jump	E0 Control Ambiguity
TCA Switchover	Timing Wobble Varying ToT	E0 Control Ambiguity
Coupling Output Switch	Timing Wobble Timing Jump	E0 Control Tank/Tuning Mismatch
Zero Crossing 4-12	#4 > desired threshold	DHC relative timing

Test Summary with Solutions

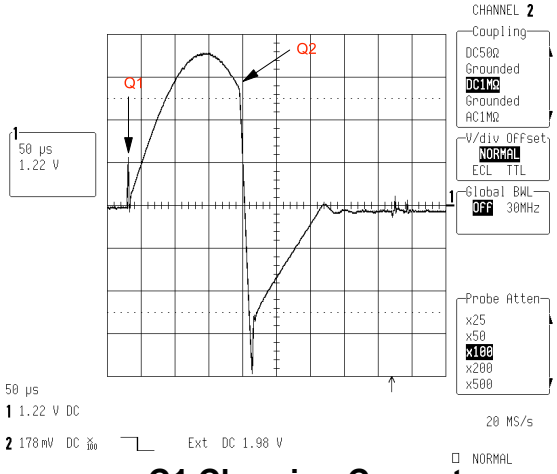
Test	Issue	Cause	Solution
SR Full Power	Minor Pulse Jitter	E1 Control	Component Change
DR Full Power	Cross Rate Jitter Minor Pulse Jitter	E0 Control E1 Control	HCGPS Redesign Component Change
Tuning Match & Response	Timing Jump	Tuning limit too high	TCA Software
Blink	Timing Jump	E0 Control	HCGPS Redesign
HCG Maint & Failure	Timing Wobble Timing Jump	E0 Control Ambiguity	HCGPS Redesign TCA Software
TCA Switchover	Timing Wobble Varying ToT	E0 Control Ambiguity	HCGPS Redesign TCA Software
Coupling Output Switch	Timing Wobble Timing Jump	E0 Control Tank/Tuning Mismatch	HCGPS Redesign Parallel Tuning
Zero Crossing 4-12	#4 > desired threshold	DHC relative timing	Config File Adjust

Accufix Power Supply Regulation



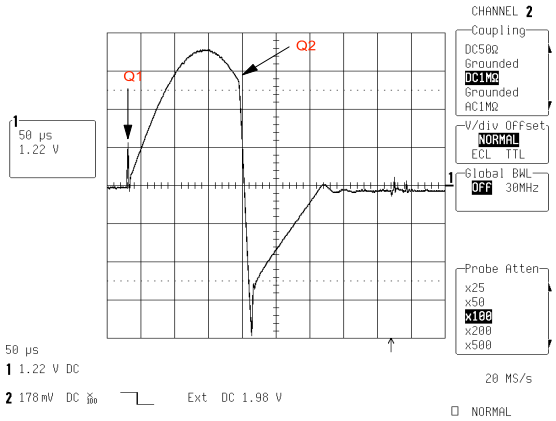


C1 Voltage

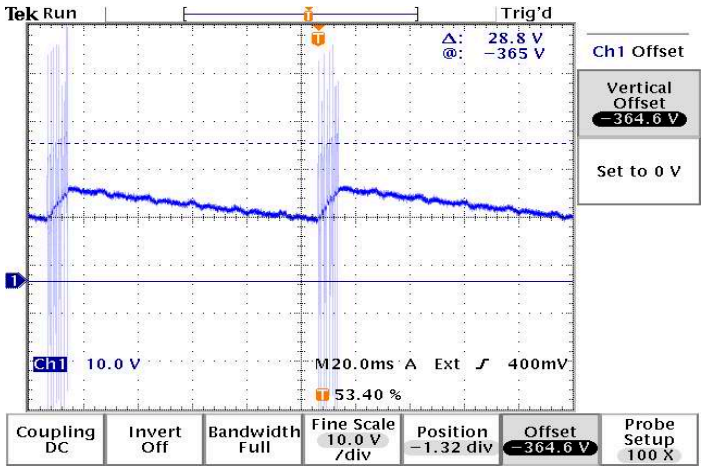


C1 Charging Current

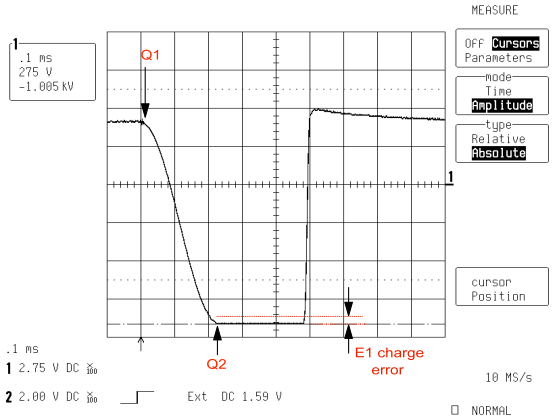
Accufix Power Supply Regulation



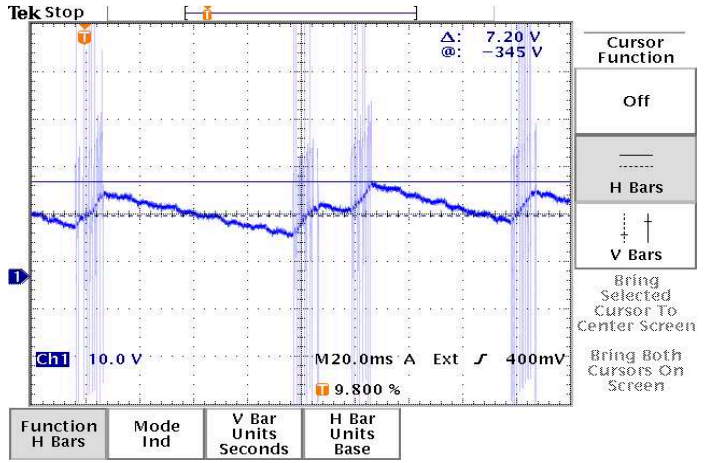
C1 Charging Current



E0 Voltage Single Rate



C1 Voltage



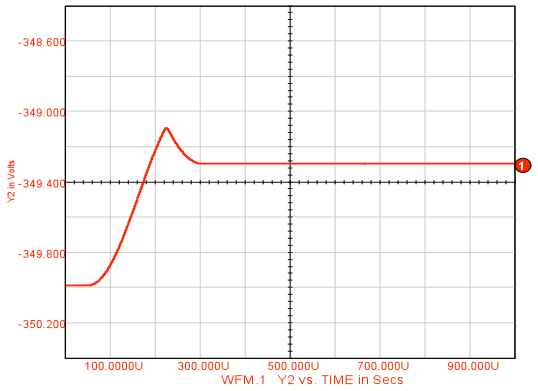
E0 Voltage Dual Rate

Accufix Power Supply Regulation

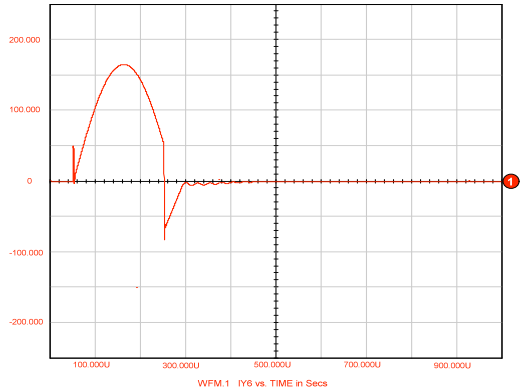
- Present Concept - Phase Control
  - The difference between E0 and “Set E0” is fed to the integrator;
  - Output is compared with a ramp that is reset synchronously with “nulls” of line voltage;
  - When the ramp voltage reaches the level established by the integrator, a comparator enables Gate Drive generator and capacitor C0 is charged;
- Revised Concept
  - Continuous regulation of E0
  - Eliminates need for either ramp or feedback loop
- Verification through simulation

Simulation of Power Supply Regulation

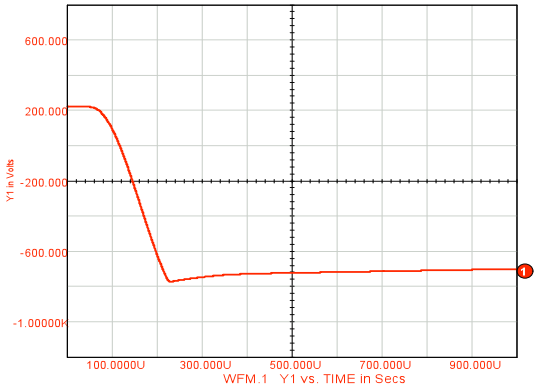
E0 Voltage

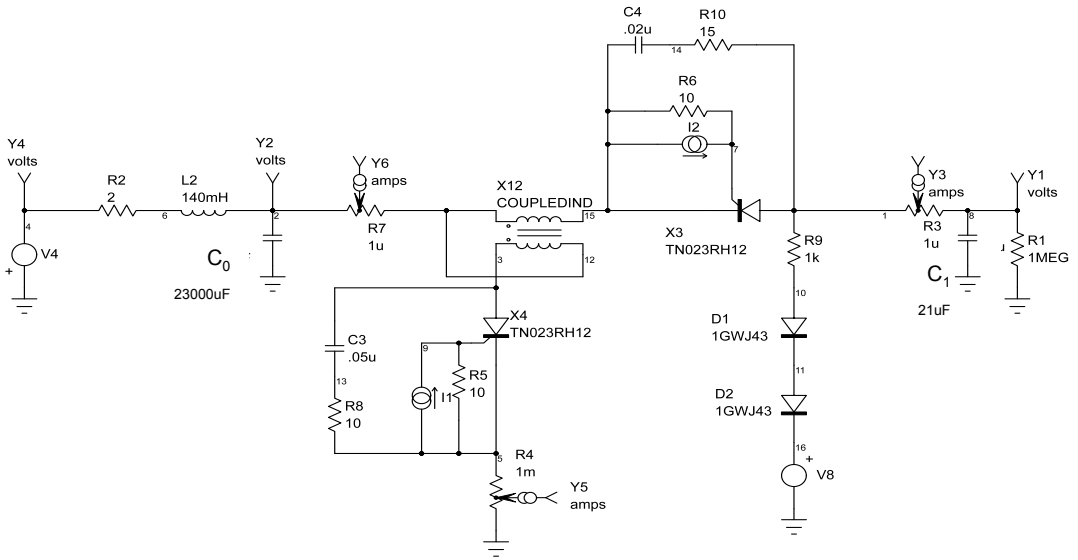


C1 Charging Current

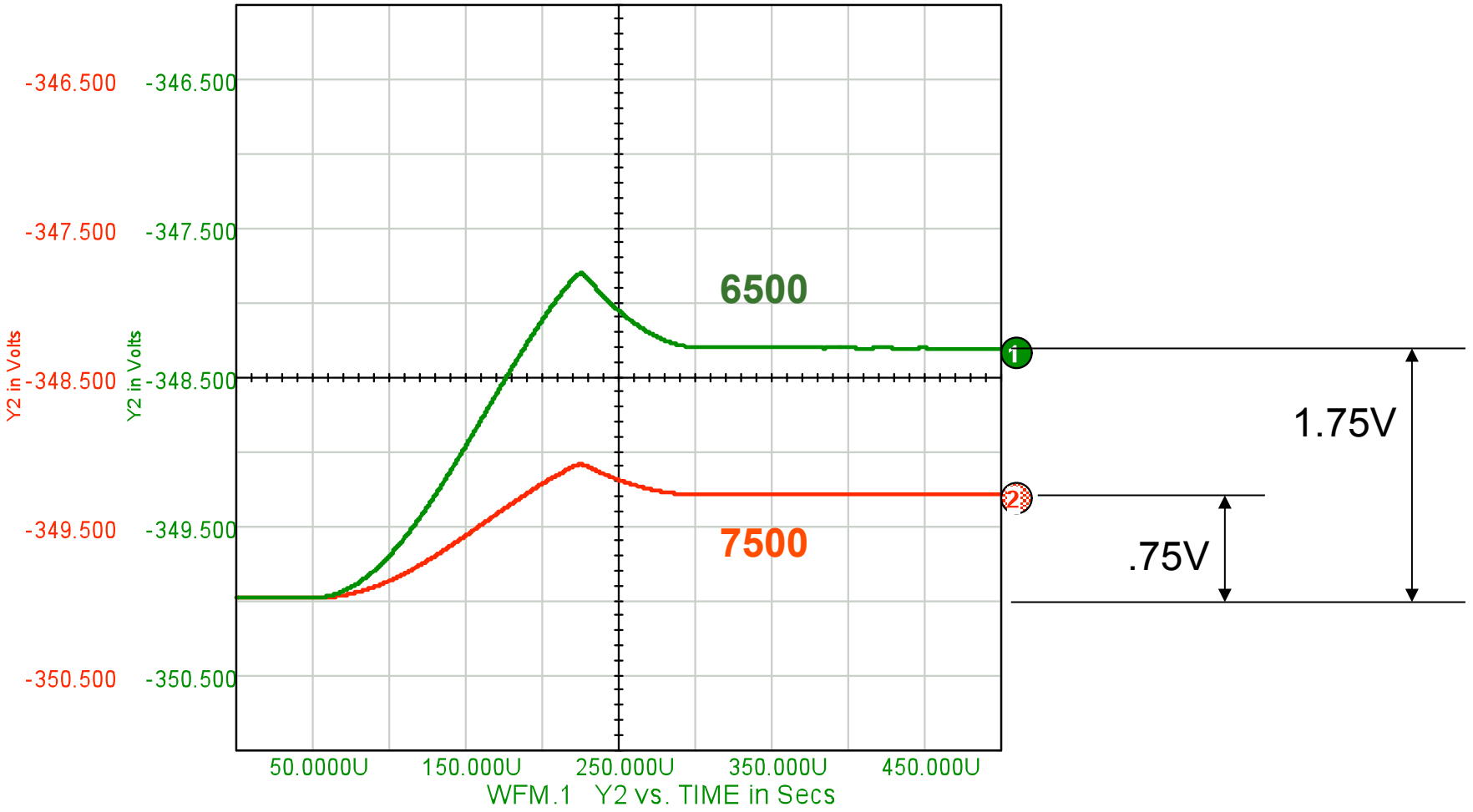


C1 Voltage (leading edge)



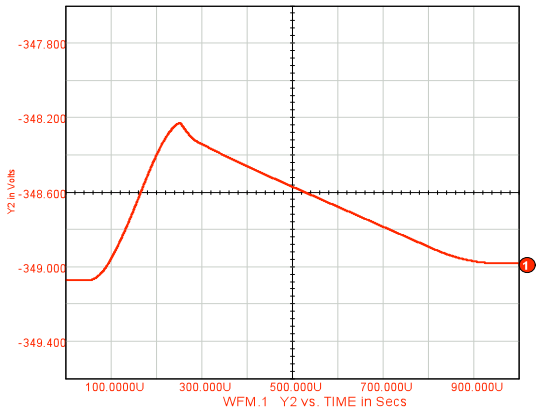


Simulation of Power Supply Regulation

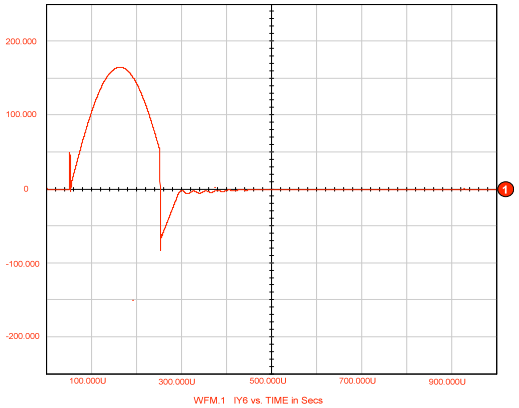


Simulation of Power Supply Regulation

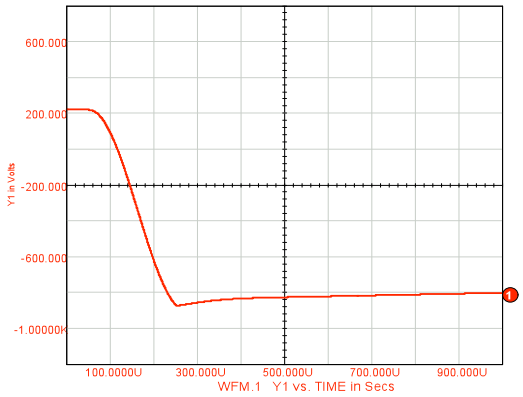
E0 Voltage



C1 Charging Current



C1 Voltage (Leading Edge)



PS Redesign Expected Performance

- Shaded areas in yellow benefit
- Dispersion will be reduced on both single and dual rate
- Slow Dual Rate effect is eliminated
- Individual raw outliers will still exist but reduced in magnitude
- Permits tight tolerance on ABS (~25nsec)
- Applicable to AN/FPN-64 and Accufix 6500

		Raw	5Hz Exp	1Hz Exp	0.2Hz Exp
Single Rate 9960	Std Dev	8.3	2.2	0.8	0.5
	Latest	66	12	4	3
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	Latest	87	41	9	3
	Earliest	-38	-18	-6	-3

Upgrade Path for Existing Systems

- Accufix 7500 (USCG post 2001)
  - Minor power supply upgrade
  - TCS software upgrade
- Accufix 6500 (NELS/FERNS 1990s) & Accufix 6500 (Saudi/China/France 1980s) & AN-FPN-64 various generations (USCG and CCG)
  - Replace Power supply
  - Replace Control Console (Except Niijima)

Summary

- The Megapulse principle of pulse generation and control is elegantly simple
- New receiver technologies and higher performance requirements are placing new demands on the "certainty" of signal characteristics.
- These requirements are evolving through processes such as RTCM but hopefully will be firmed in the nearest future
- Existing and Modernized Loran systems must be upgraded to meet eLoran