

# EMI Effects on Some Wireless Systems (GPS Receivers)

T. Nilsson(1), D. Månsson(2), M. Bäckström (1)

(1) Swedish Defence Research Agency FOI, Box 1165, SE-581 11 Linköping, Sweden.

(2) Div. for Electricity and Lightning Research, Uppsala University, Sweden.

# Outline

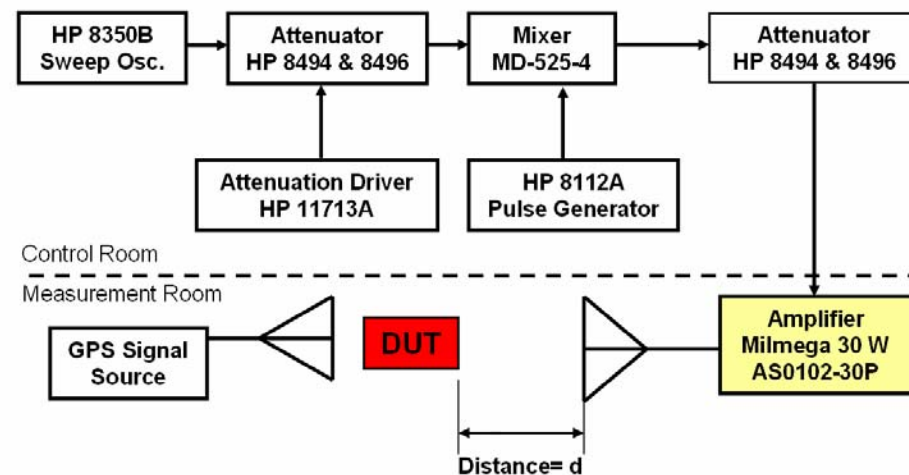
- Introduction
- Measurement Set-ups
- Test Objects
- Measurements and Results
- Summary & Conclusion
- Future Work

# Introduction

- ❖ The threat from electromagnetic weapons (HPM and UWB) is steadily increasing. Both civilian and some military electronic equipment are vulnerable to this type of threat.
- ❖ This presentation shows results from tests on civil electronic equipment. We have focused on common civil systems, that also can be used for military purposes. Three different models of GPS receivers have been tested.
- ❖ The goal was to determine both disturbance and damage levels and also to investigate the orientation dependence of the tested GPS receivers .

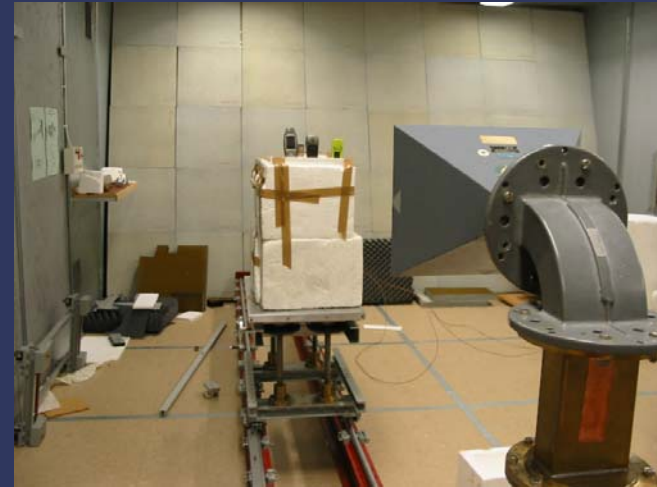
# Interference Measurement Set-up

- Milmega Amplifier, 30 W
- Frequency 1-2 GHz
- CW and Pulsed, PRF = 1 kHz, burst duration = 60 s
- Pulse width = 100 ns
- Rise time ~ 10 ns
- Max. E-field 32 to 55 V/m
- $d = 2.0$  m



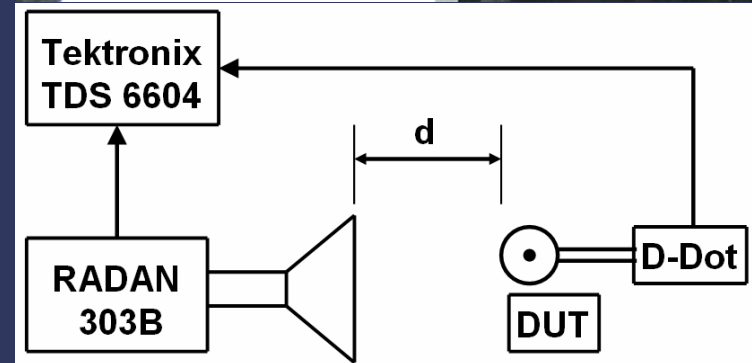
# HPM Measurement Set-up

- Magnetron, 700 kW
- Frequency = 3.0 GHz
- PRF = 1 kHz,  
burst duration = 4 s
- Max E-field = 90 kV/m
- Pulse width = 1  $\mu$ s
- Rise time  $\sim$  10 ns
- $d = 0 - 5$  m

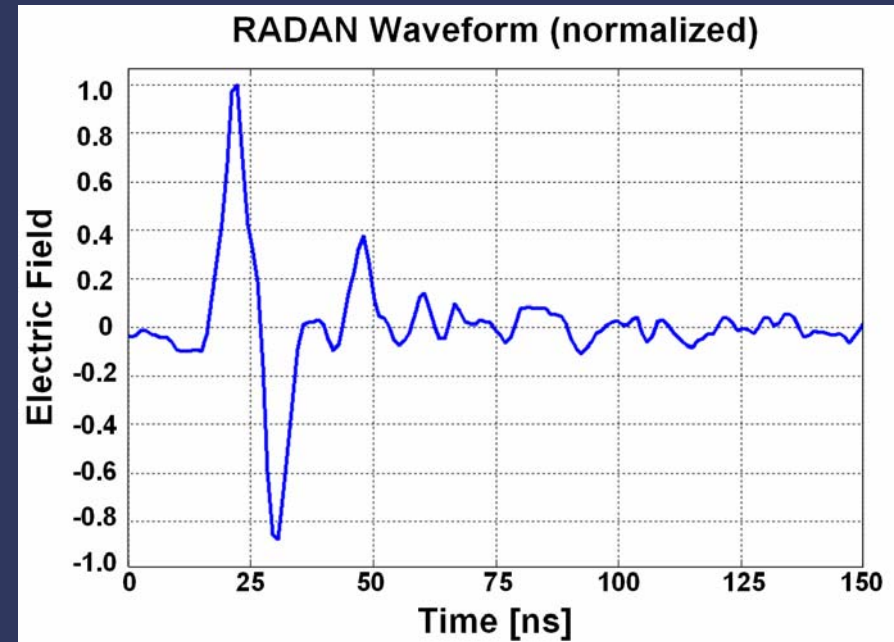
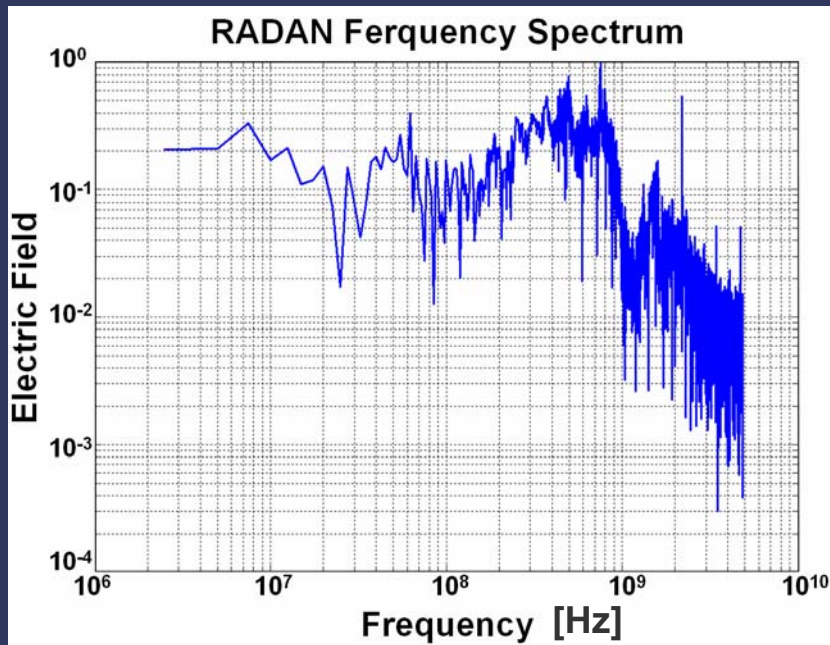


# UWB Measurement Set-up

- ❖ RADAN 303B, Peak voltage 150 kV (50  $\Omega$ )
- ❖ Frequency: Main content is below 1 GHz
- ❖ PRF: single pulse (max PRF = 25 Hz)
- ❖ Max E-field = 70 kV/m
- ❖ Pulse width: 20 ns, Bi-polar pulse
- ❖ Risetime ~ ns
- ❖  $d = 0 - 20$  m



# UWB Measurement Set-up cont.



# Test Objects

## Test Levels

- Level 0 – Not under test.
- Level 1 – No observed effect.
- Level 2 – Interference while radiated.
- Level 3 – Strong interference / crash, Self-recovery.
- Level 4 – Loss of function / crash , Operator-intervention.
- Level 5 – Physical damage, repair or replace.

GPS,  $f_c = 1575.42$  MHz (L1)



GPS A

GPS B

GPS C

# Orietations of GPS Receivers

➤ Orientation 1, Front

➤ Orientation 2, Top

➤ Orientation 3, Side



# Level 2 Interference Measurements

Electric Field [V/m]

## → GPS A

f [GHz]	1.0	1.25	1.575	1.75	2.0
Pulsed	—	—	3.0	9.0	—
CW	0.21	0.25	0.02	0.02	0.14

## → GPS B

f [GHz]	1.0	1.25	1.575	1.75	2.0
Pulsed	—	28	1.0	8.0	—
CW	0.13	0.14	0.0023	0.13	0.08

## → GPS C

f [GHz]	1.0	1.25	1.575	1.75	2.0
Pulsed	—	—	13	26	14
CW	1.1	1.1	0.1	1.0	0.8

# Out-of-band HPM Measurements

Pulse Width = 1  $\mu$ s, PRF = 1 kHz, Frequency = 3.0 GHz, OT = 1

	Level 2, Interference while radiated	Level 4, crash Operator- intervention *	Level 5, Permanent damage. **	Level 5, Permanent damage ***
→ GPS A	0.5 kV/m	4 kV/m	N/A	40 kV/m
→ GPS B	0.7 kV/m	0.9 kV/m	20 kV/m	30 kV/m
→ GPS C	N/A	2 kV/m	5 kV/m	40 kV/m

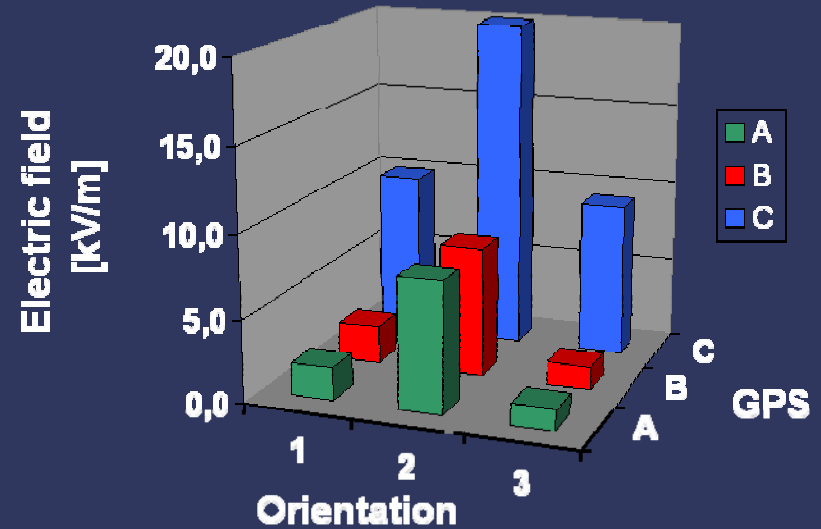
\* Lock-up, no response at all, restart after removal of battery.

\*\* Receiver circuitry damaged, no reception of satellite signals, otherwise OK. \*\*\* Severe physical damage, no response at all.

# Out-of-band UWB Measurements

- The E-field levels presented here are the required levels to achieve level 4 interference
- Level 5 (permanent physical damage), was only achieved for GPS B and C, at a level of several tens of kV/m (orientation 1, front)
- Three different orientations were tested, front(1), top(2) and side(3)

Peak Electric field for Level 4 Intrefrence



Electric Field [kV/m], for Level 4

GPS \ OT	1	2	3
A	2	8	1
B	2	8	2
C	10	20	9

# GPS Receivers after test

- ❖ A first stage of level 5, permanent damage was in some cases seen as reception loss of the satellite signals (otherwise OK), probably was the receiver damaged.
- ❖ The second stage of level 5, permanent damage was seen as flickering or bland LCDs, and no response at all when pressing buttons, etc.

# Summary

- Both disturbance and destruction level measurements were done on the GPS receivers using three different measurement set-ups
- The measurements were done with both HPM- and UWB-pulses
- A total of six GPS receivers were tested, two of each model. The GPS receivers represent different price segments and are from two major GPS manufacturers

# Conclusion

- GPS receivers are very sensitive for in-band disturbances. Due to front-end filter are they less sensitive for out-of-band disturbances, but still rather sensitive.
- Level 4 (out-of-band) disturbances occurred at low E-field levels, in the order of several kV/m.
- Level 5 (out-of-band) damage, require high E-field in the order of tens of kV/m.
- The susceptibility also depends of the orientation of the DUT.

# Future Work

- Tests of military GPS receivers
- Test of civil GPS receiver in military use
- In-band level 5 tests
- Investigation of the failure mechanism, back-door or front-door?