Performance Evaluation of Low Frequency Equipment for Livestock Identification

J.Bishop, P.Viaud, T.Pinato
JRC Tempest Testing Laboratory
Traceability and Vulnerability Assessment Unit (TRVA)
Institute for the Protection & Security of the Citizen (IPSC)
Joint Research Centre (JRC)
Via Enrico Fermi, 2749
I-21027 Ispra (VA)
Italy

http://eid.jrc.ec.europa.eu
tempest@jrc.ec.europa.eu

http://www.ukas.org/testing/schedules/Actual/4262Testing Single003.pdf

Legislative Requirements

EU legislation:

Refers to international standards:

- ISO 11784: identification code structure
- ISO 3166: codes for country of origin
- ISO 11785: low-frequency RFID technical concept

Sets performance requirements (in terms of tag reading distances):

- 50cm for all types of tag by static readers
- 20cm for ruminal boluses by portable readers
- 12cm for eartags by portable readers

Defines who may demonstrate conformity with these requirements:

- ISO 17025 accredited laboratories.

See also
http://www.iso.org/iso/resources/conformity_assessment/mechanisms_for_performing_conformity_assessment.htm

Subject of Investigation

12 RFID readers submitted for type approval testing from 5 manufacturers:

Agrident	APR / AWR / ASR	Allflex	2530 / 4060
Edit ID	HiPR 603A	Gallagher	HR1 / HR3 / R / BR
Shearwell	SDL400 / SDL130		

15 sets of 5 identifiers each from 9 manufacturers drawn from batches of 50 samples submitted for type approval testing:

EM 4305	34 / 22mm GETs
EM 4569	Ø30mm air-coil
NXP HTS	Ø25 (2) / 30mm air-coils; 50 / 34 / 22 / 12mm GETs
TIRIS	Ø25mm air-coil; 32 / 23mm GETs
Rumitag	Ø25 / 30mm air-coils

Physics: Activation field generation

Reader drives alternating current (134.2kHz) through a loop antenna to create a pulsed, low-frequency magnetic field of strength:

$$H = \frac{INa^2}{2\left(a^2 + r^2\right)^{3/2}} \approx \frac{INa^2}{2r^3} \text{ when } r >> a$$

where H = magnetic field strength [A.m^{-1}]
I = current in the loop antenna [A]
N = number of turns in the loop antenna
a = radius of loop antenna [m]
r = distance from loop center, perpendicular to loop plane [m]
NB: $1/r^3$ implies 60dB/decade reduction of H with distance

Emissions legislation limits H to 66dBμA/m at 10m (126dBμA/m at 1m)

Appendix 9, ERC REC 70-03, 2 June 2009

Physics: Tag activation

Alternating magnetic flux from the reader loop antenna which passes through the tag coil antenna induces a voltage across its terminals:

$$V = 2\pi f N S Q \mu_0 H \sin\alpha$$

where $2\pi f$ = frequency of alternating magnetic field [s^{-1}]
N = number of turns in the tag coil antenna
S = area of tag coil antenna [m^2]
Q = tag antenna resonant circuit quality factor
μ_0 = permeability of free space [$N.A^{-2}$]
H = magnetic field strength [$A.m^{-1}$] ($\mu_0 H$ = magnetic flux density)
$\sin\alpha$ = sine of angle between magnetic field and plane of tag
= 1 when α = 90º i.e. field perpendicular to tag coil

Induced voltage is maximised when the reader and tag antennae are parallel – optimum orientation.

Electrical engineering: Data transfer

Data encoded in the tag's integrated circuit are returned to the reader by one of two protocols:

Full-duplex B (FDX-B):

- Reader field provides carrier and clock signals for the tag;
- Tag data modulates carrier's amplitude;
- Analogy: Morse code (dots and dashes for 0's and 1's).

Half-duplex (HDX):

- Tag stores energy drawn from the reader field;
- Tag sends frequency modulated signal in the interval between reader activation field pulses;
- Analogy: Tone Dialling (two different tones for 0's and 1's).

Readers must work with both protocols, so require distinct functions for receiving and decoding FDX-B and HDX signals.

Method of Investigation

1. Measured reading distances of every tag with each reader in various configurations:

    reader antennae (optional stick, or different size panel antennae);

    operating modes (e.g. synchronisation on and off; adaptive timing on and off etc.);

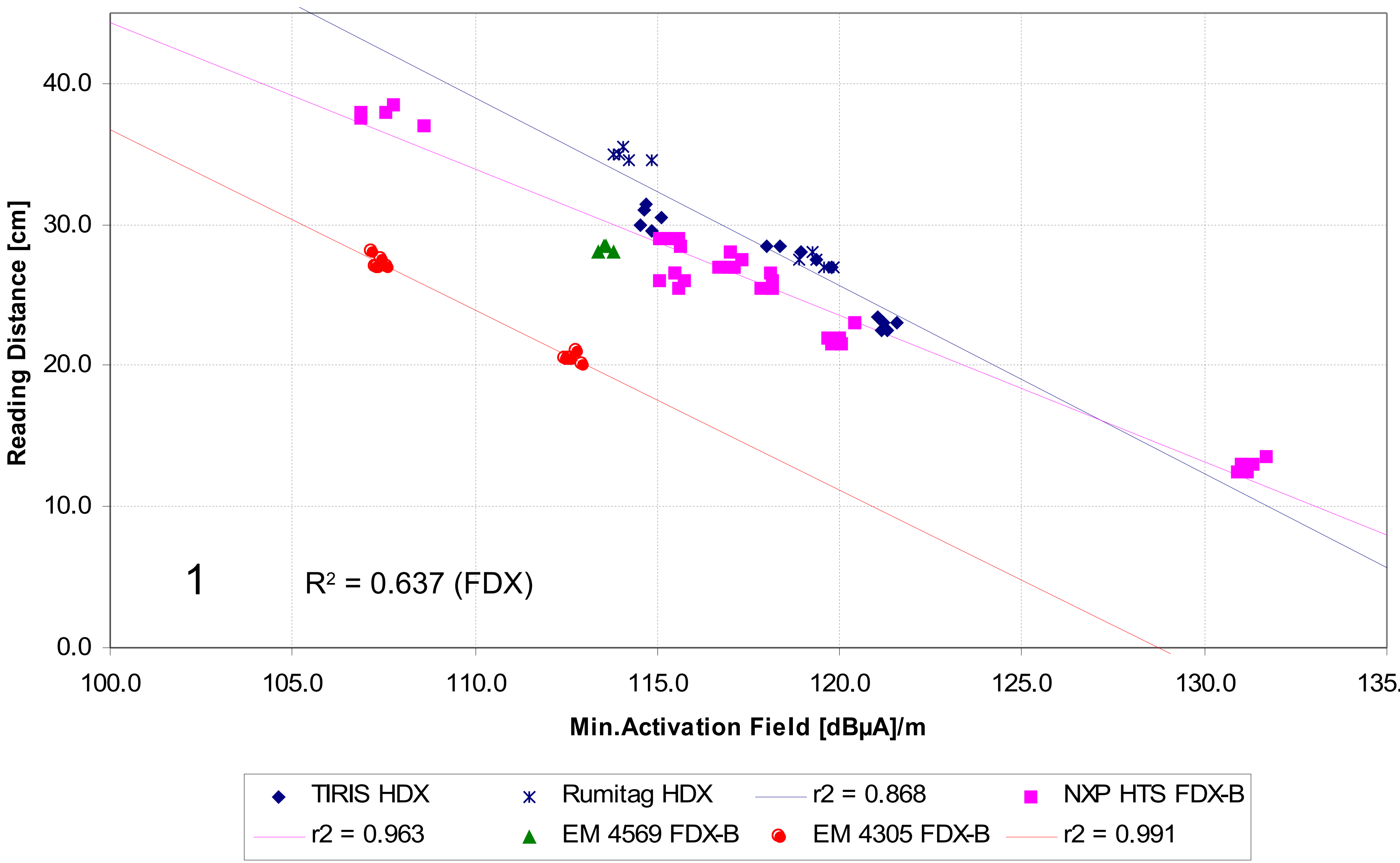
    reader firmware versions.

    Resulted in 30 sets of reading distance data.

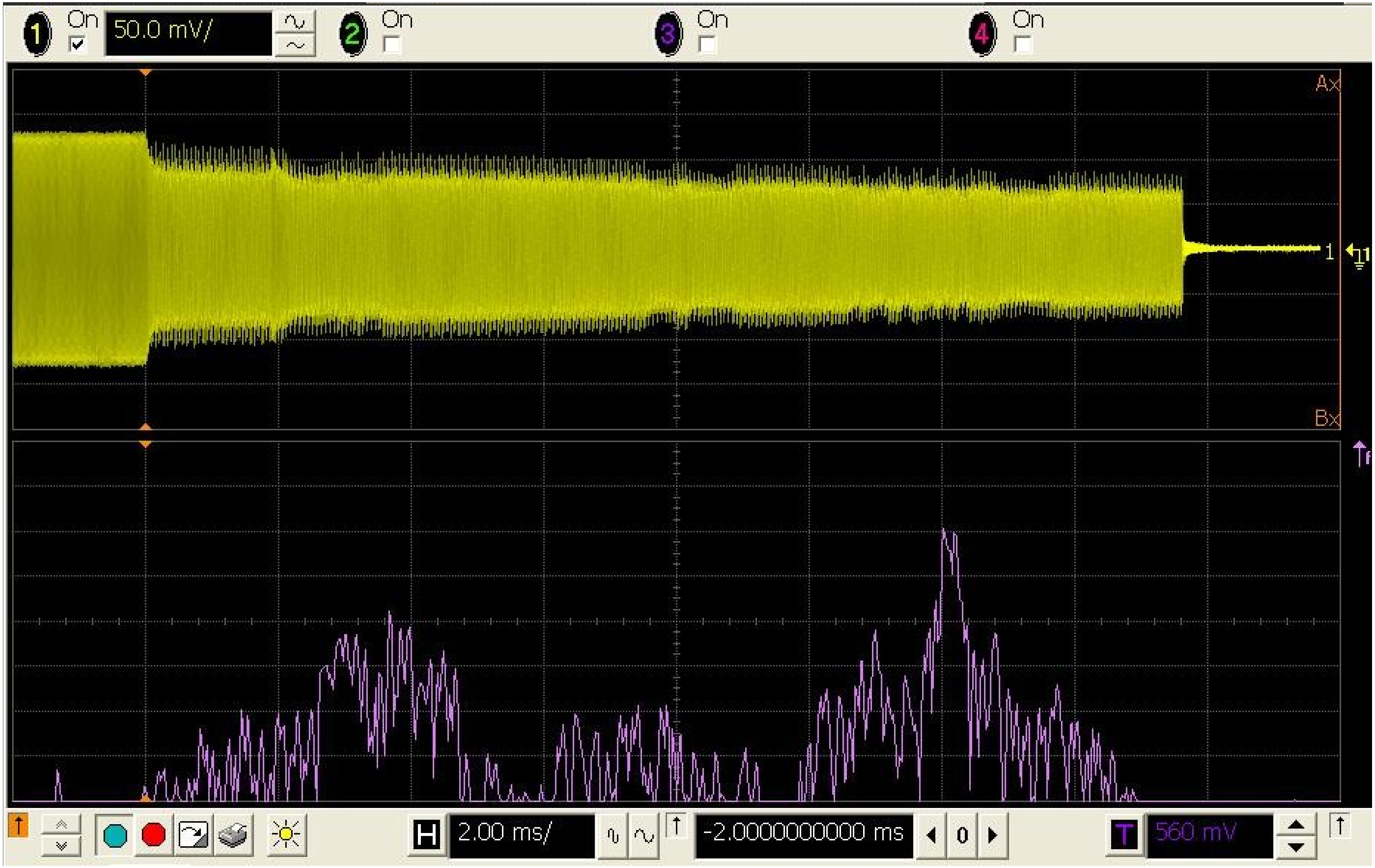
6. Measured minimum activation field of every tag.
    NB: ISO 24631-3 reference antenna assembly had to be modified to measure small 12mm GET devices.

7. Compared reading distance (RD) data with minimum activation field (MAF) data.

Reader No.1 (Portable)

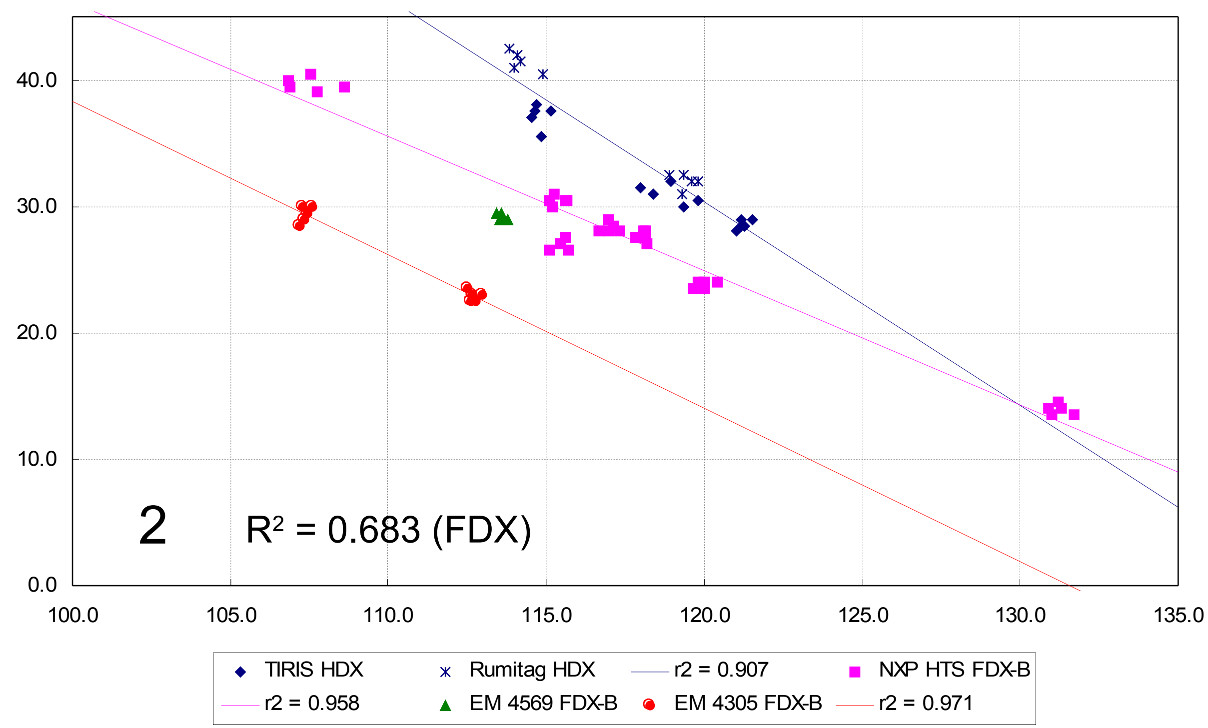


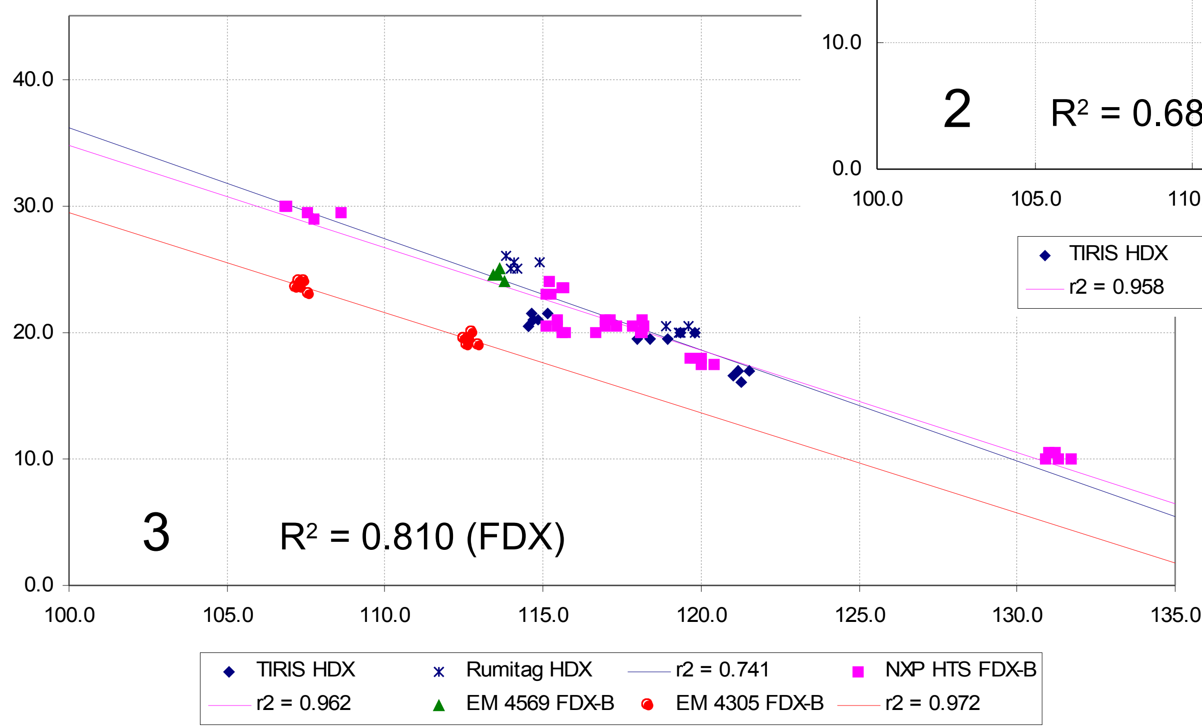
HDX Signal – Time & Frequency Domains



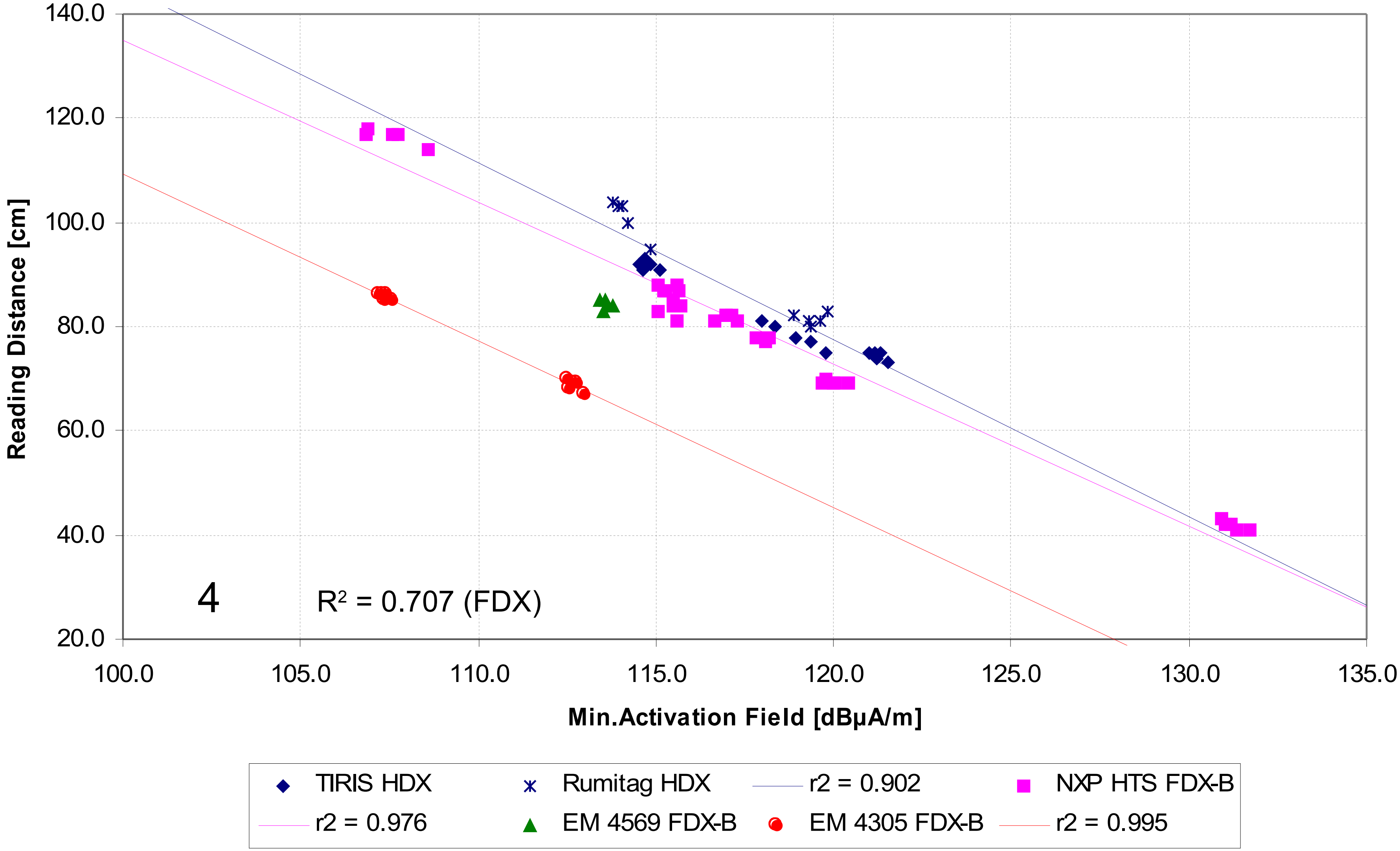
Reader Nos. 2 & 3 (Portable)

RD [cm] vs. MAF [dBµA/m]



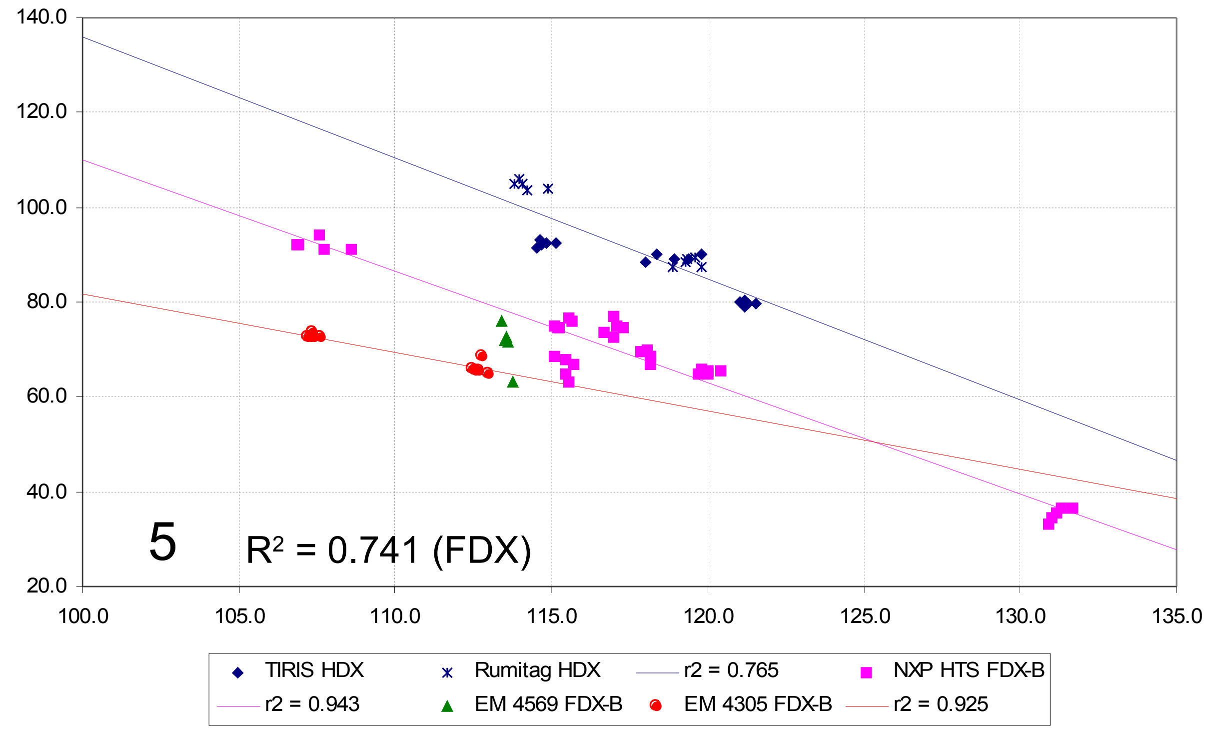


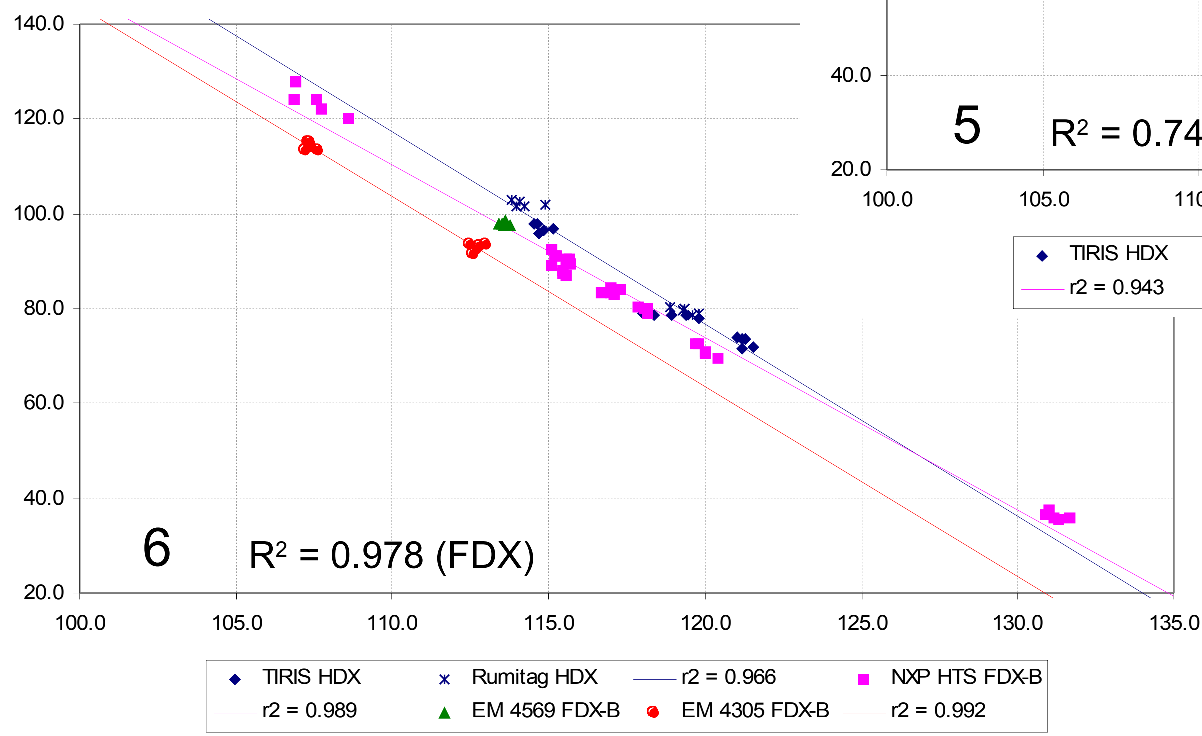
Reader No.4 (Static)



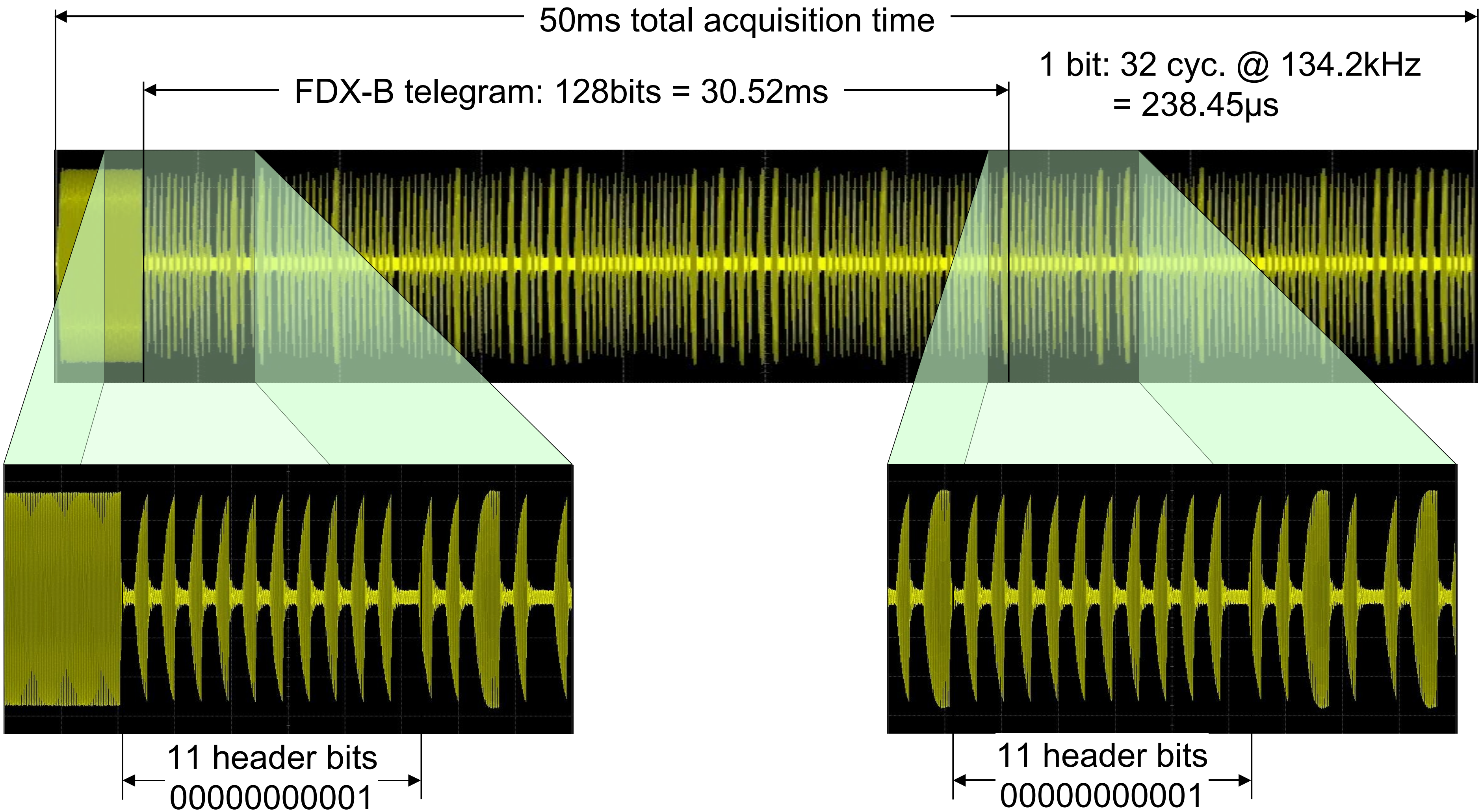
Reader Nos.5 & 6 (Static)

RD [cm] vs. MAF [dBµA/m]





FDX-B Signal – Time Domain



Reader determines pulse on/off durations to extract data bit sequence

FDX-B Bit Modulation Amplitude

Burst Width measurement:

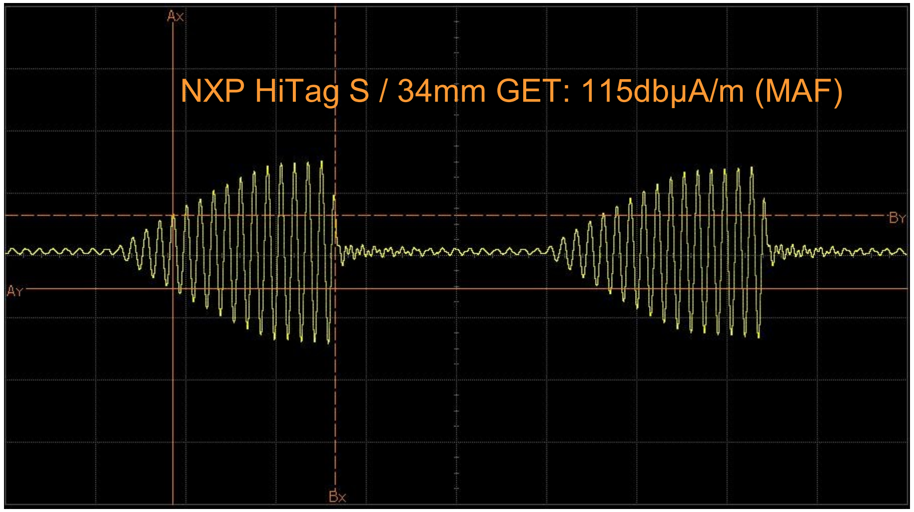
- Amplitude & time constraints on pulse duration measurements
- Amplitude: % signal levels
- Time: % carrier cycles
- Relative quantities reduce influence of test stand geometry

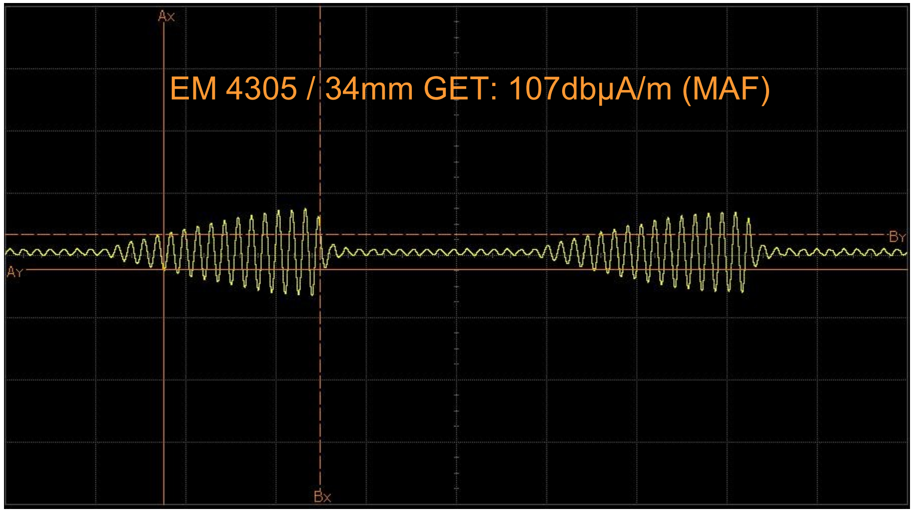
Example:

- Amplitude: 30% - 50% - 70%
- Time: 1.5 cycles / 11.1µs
- Field strength = MAF

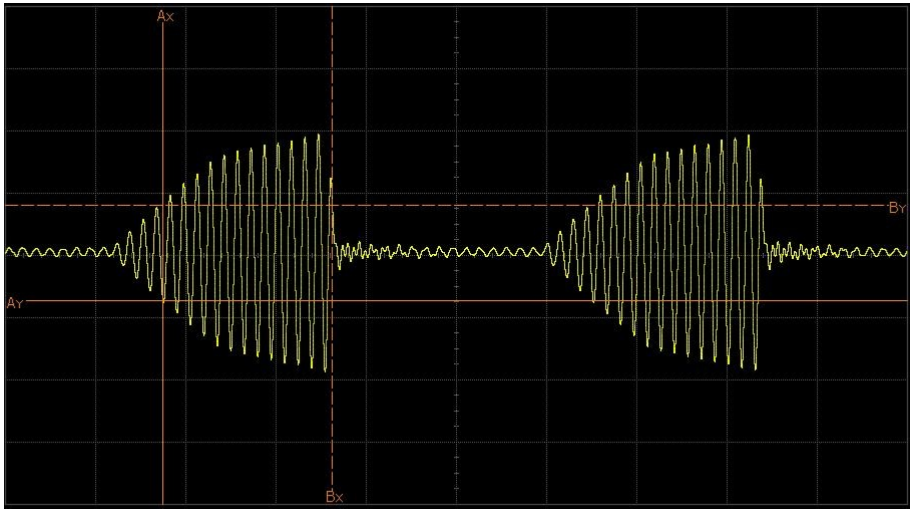
Chip	Duration	CRC
NXP HTS	90µs	Yes
EM 4305	86µs	Yes

y = 50mv/ x = 50µs/

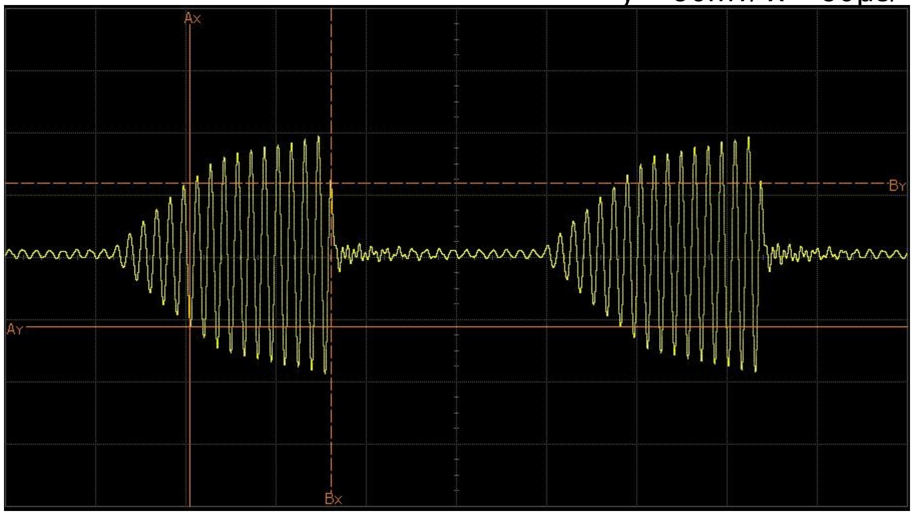


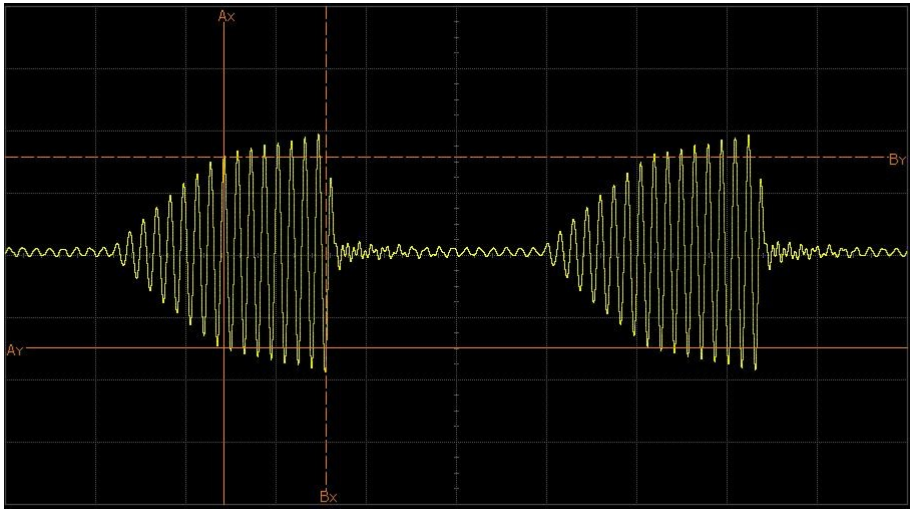


FDX-B Bit Modulation Amplitude



y = 50mv/ x = 50µs/





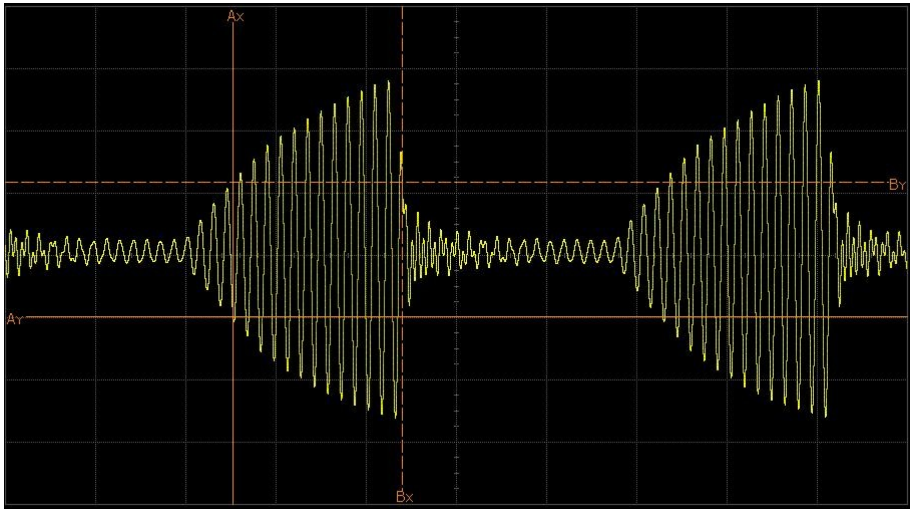
NXP HiTag S / 34mm Glass Tag

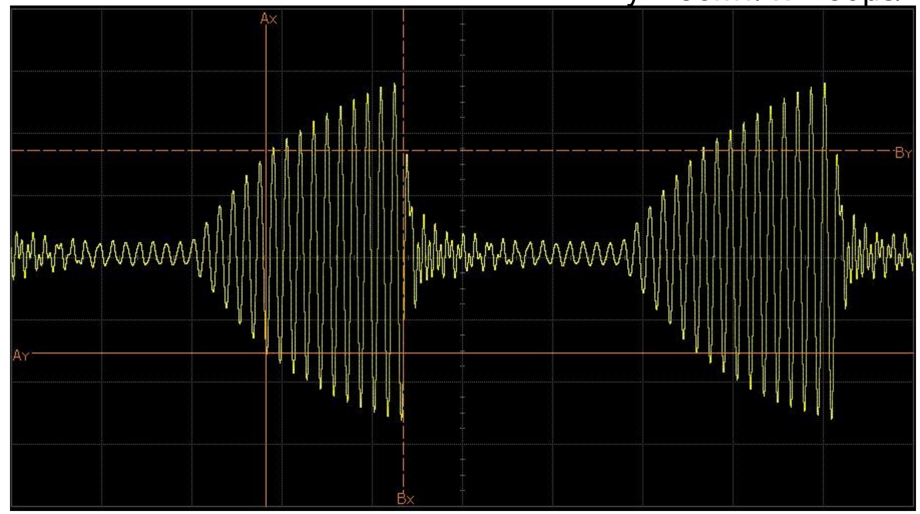
Field strength 119dbµA/m

Thresholds	Duration	CRC
30%-50%-70%	93µs	Yes
20%-50%-80%	78µs	Yes
10%-50%-90%	56µs	No

FDX-B Bit Modulation Amplitude

y = 50mv/ x = 50µs/

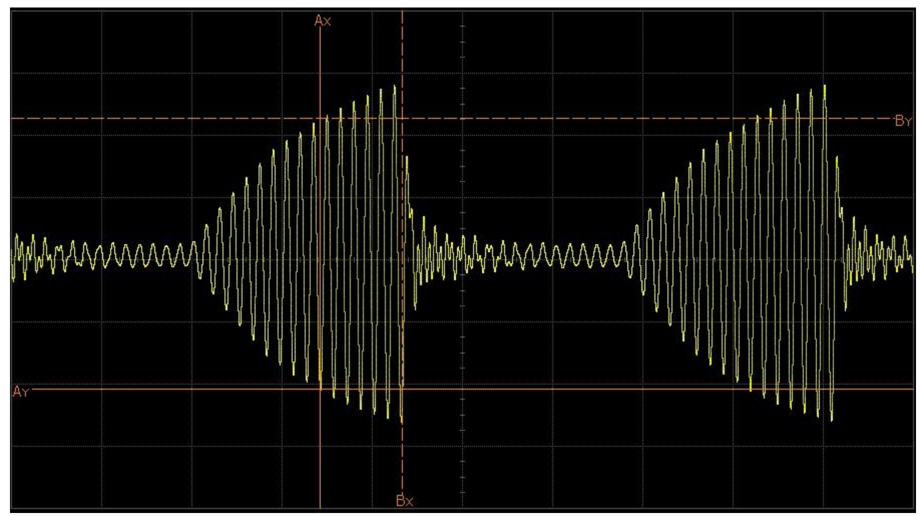




EM 4305 / 34mm Glass Tag

Field strength 120dbµA/m

Thresholds	Duration	CRC
30%-50%-70%	93µs	Yes
20%-50%-80%	78µs	Yes
10%-50%-90%	45µs	No



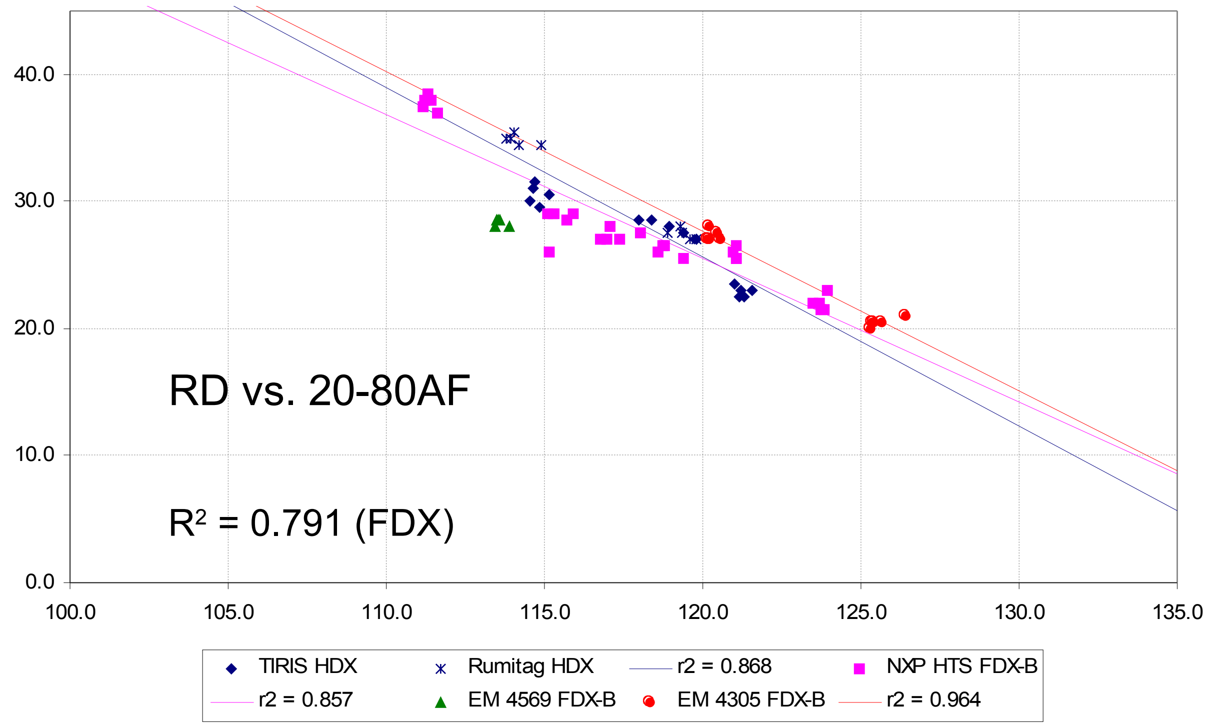
FDX Data Analysis

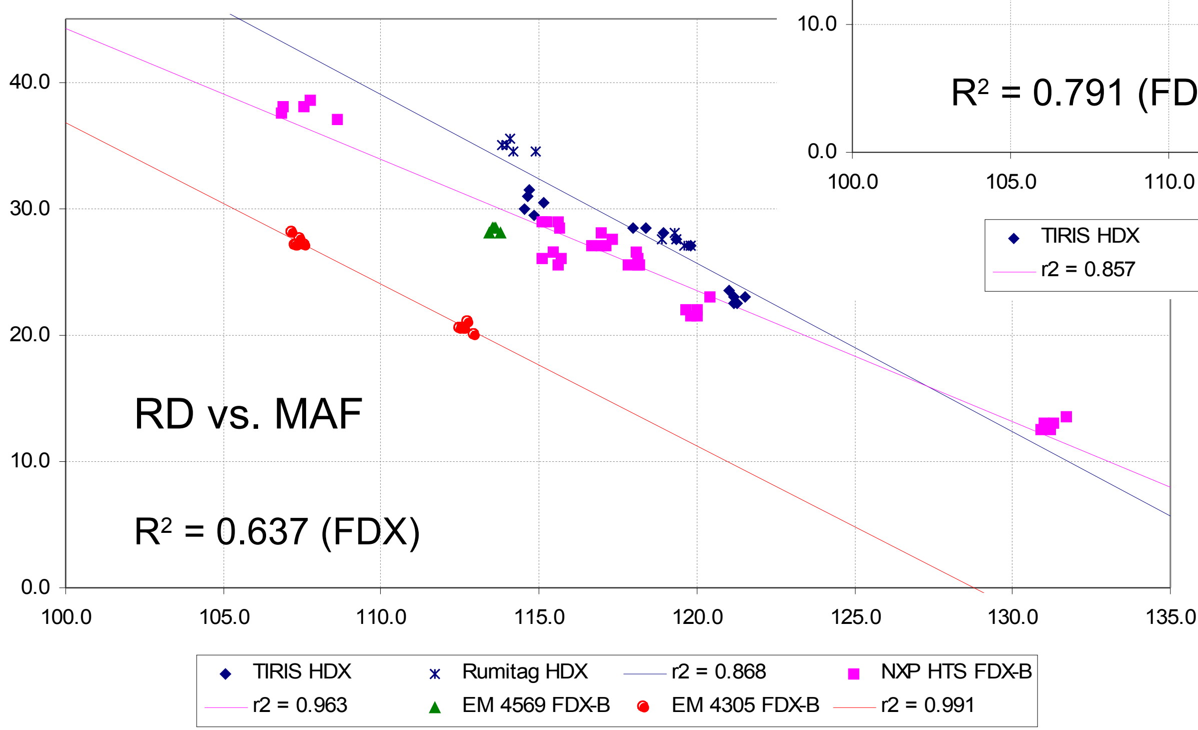
- Straight line fit (least-squares) to 120 sets of RD vs AF data;
- Computed mean values and standard deviations of R^2 for each measurement condition:

Data Set	MAF	10%-90%	20%-80%	30%-70%
Mean	0.673	0.819	0.673	0.772
σ	0.150	0.141	0.128	0.095

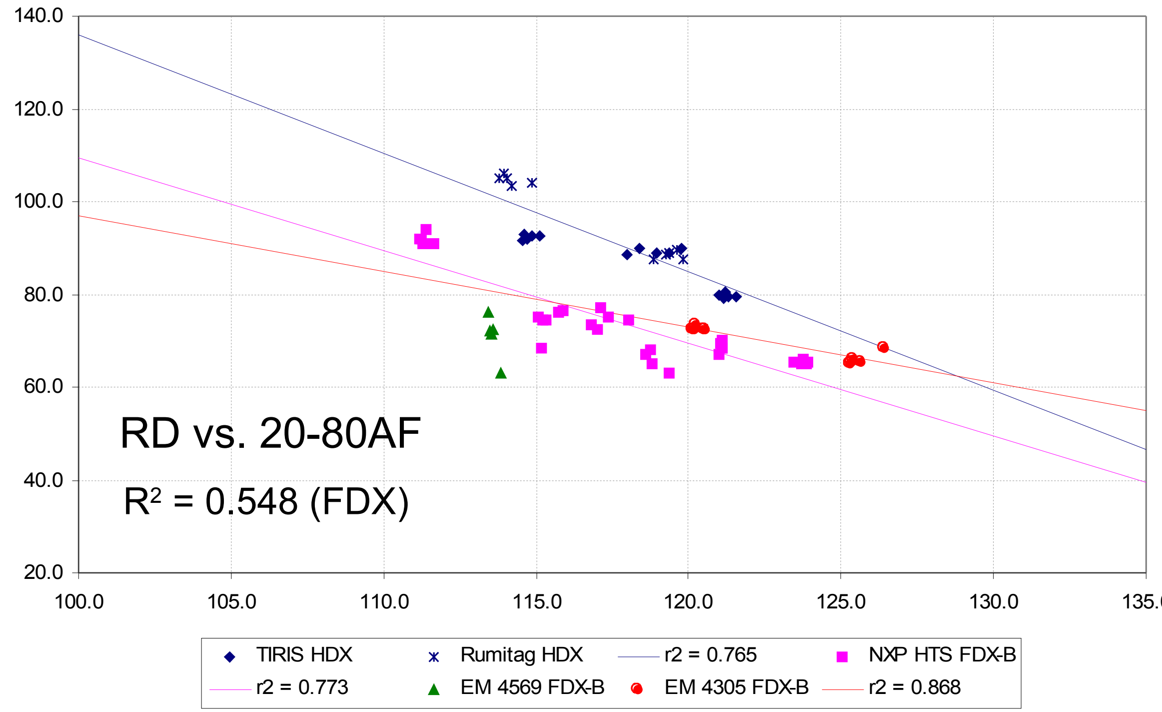
10%-90% mask gives highest mean
30%-70% mask gives lowest standard deviation

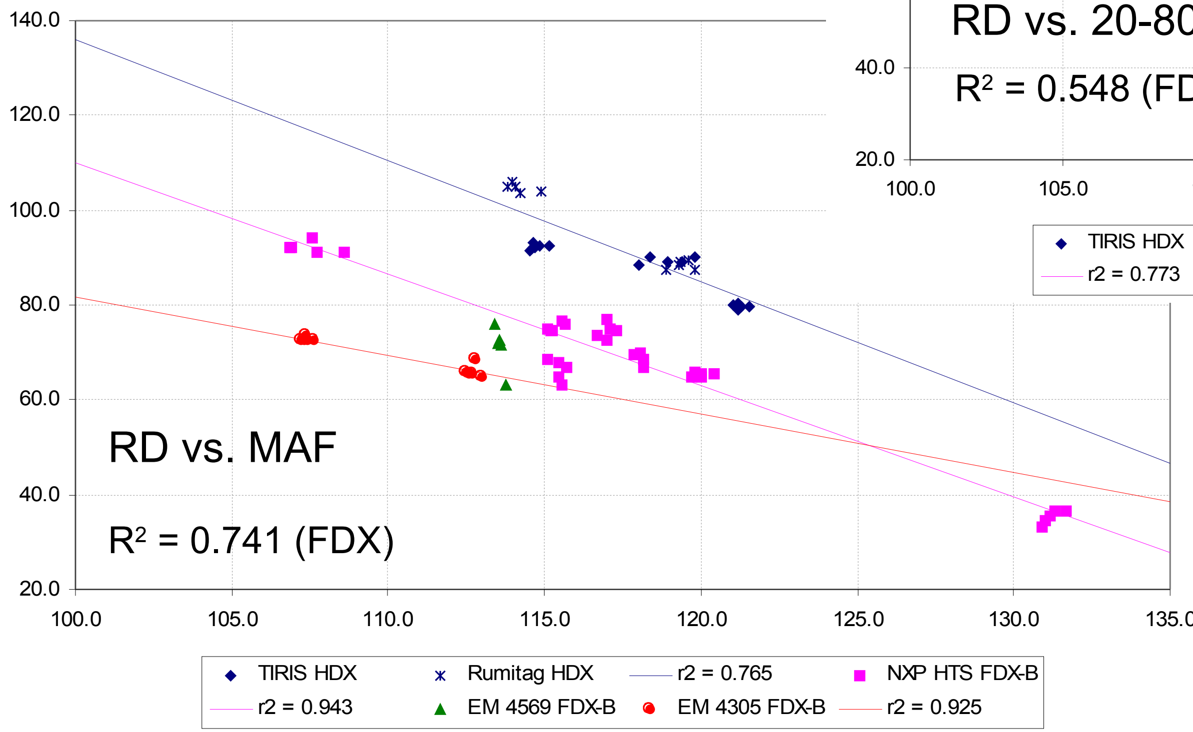
Reader No.1 (Portable)



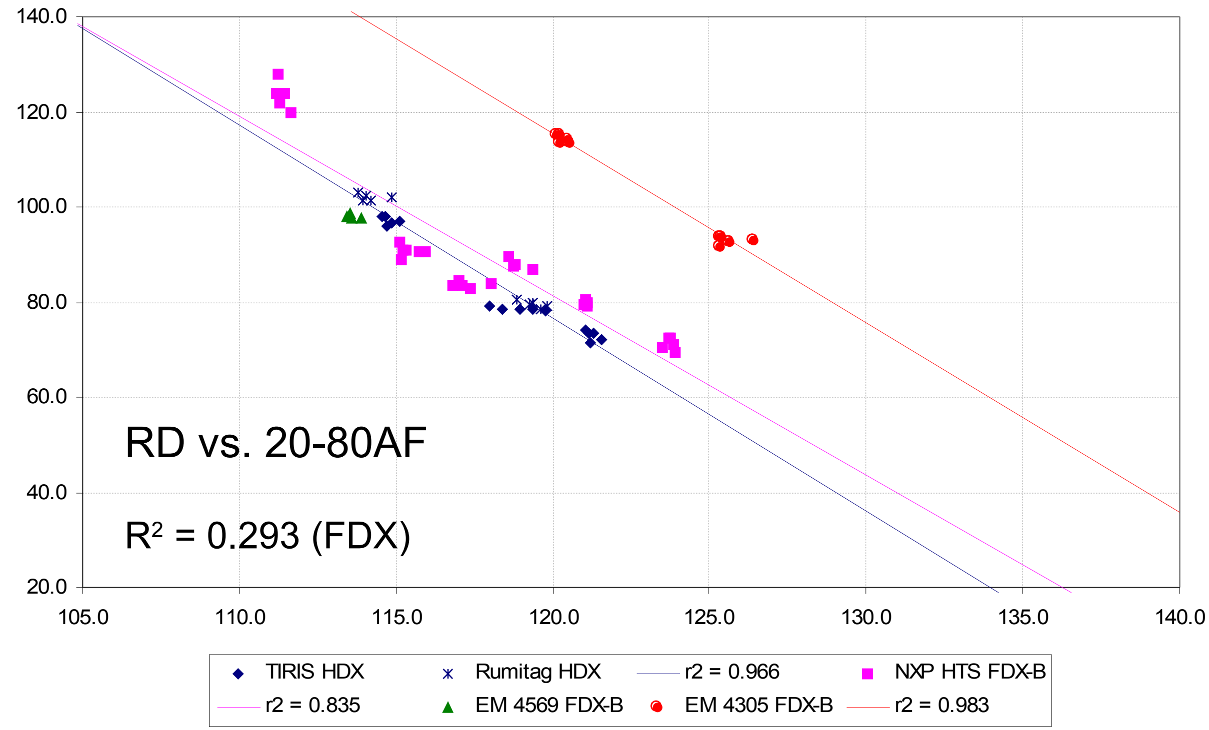


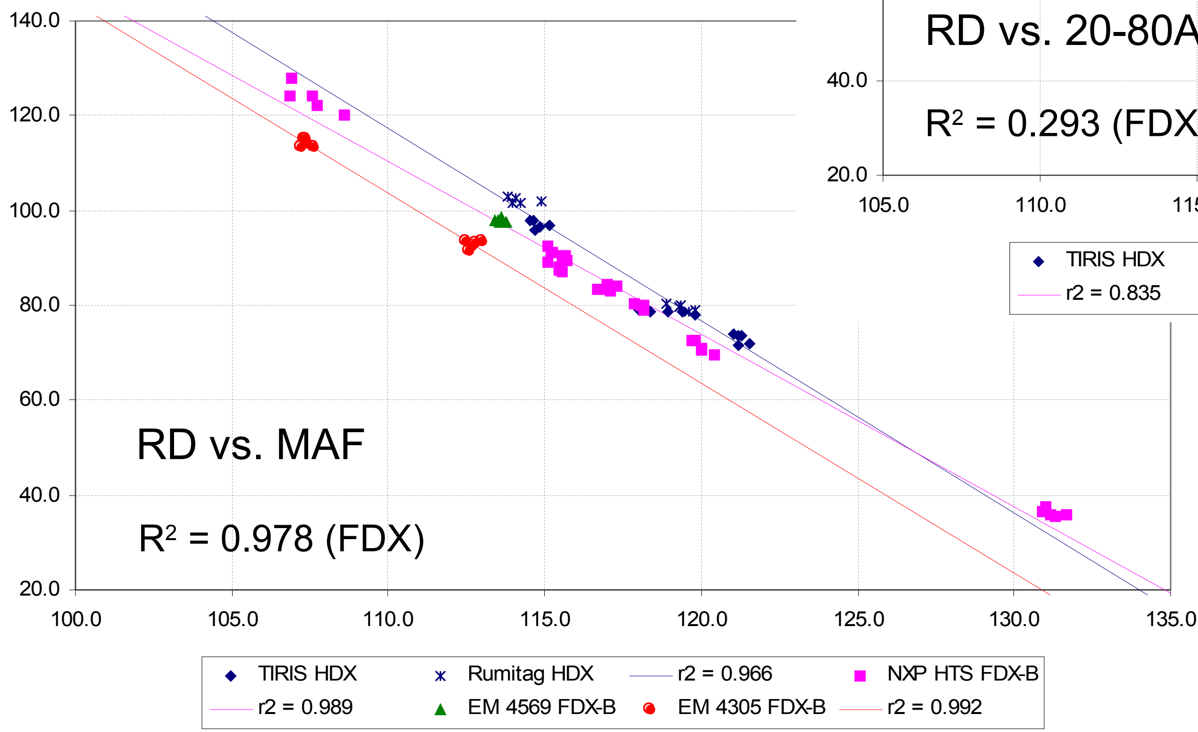
Reader No. 5 (Static)





Reader No.6 (Static)





Conclusions

- Performance of tags containing the same chip is determined by the tag antenna i.e. number of turns, area, Q.

- Identifiers from different manufacturers containing the same chip and antenna (i.e. pre-fabricated inlays or GETs) have similar performance.

Conclusions

Selection criteria for tags could be based on:

an activation field value measured with a standard mask (e.g. 125 dBµA/m with 30%-70% or 25%-75% thresholds);

reading distance measurements with any reader having consistent performance, tags in optimum orientation;

limits on minimum size of tag antennas.