Measuring void content with GPR

Current test with PaveScan and a comparison with traditional GPR systems

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RAMBOLL

Hålrum med GPR

SBUF-projekt pågår för att utvärdera möjligheterna att ersätta provkroppstestning av hålrumshalt med oförstörande GPR-teknik

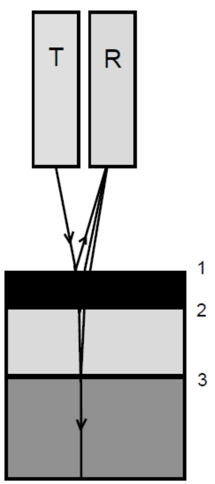
Användbar både som produktionskontroll och vid slutbesiktning

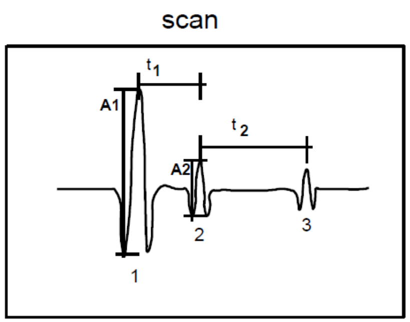
Tester utförda 2017 och 2018, pilotprojekt under 2019 där utvärderingsmetoden testas

GSSI PaveScan

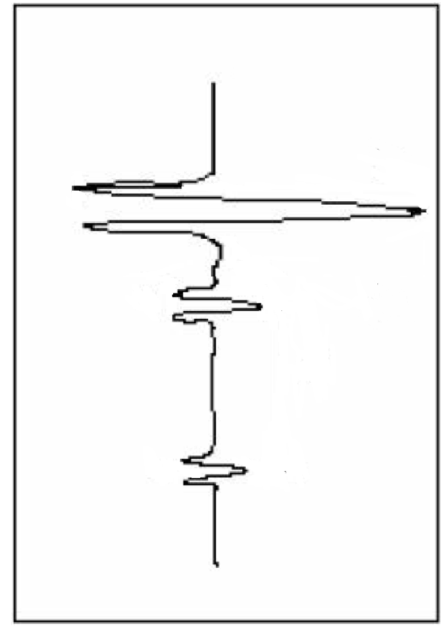
GPR Theory (the short short version)

Horn Antenna Pair





t_1 = travel time in pavement
t_2 = travel time in base
A1 = amplitude of reflection from asphalt
A2 = amplitude of reflection from base



$$\sqrt{\varepsilon} = \frac{1 + \frac{A_0}{A_m}}{1 - \frac{A_0}{A_m}}$$

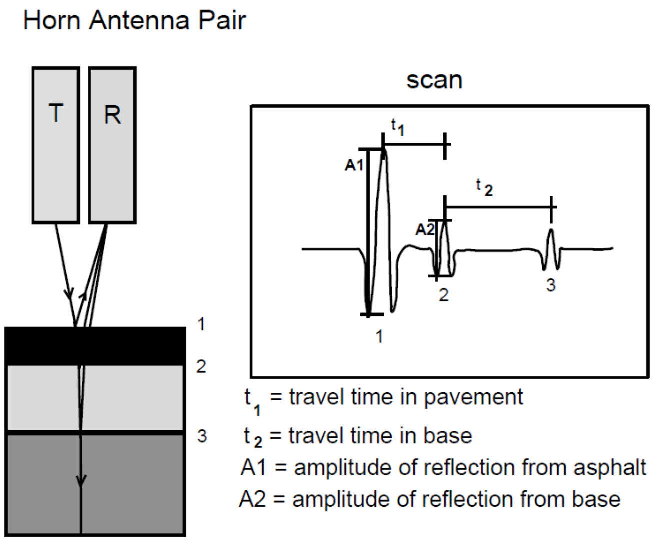
$$h = \frac{\tau \cdot c}{2 \cdot \sqrt{\varepsilon_r}}$$

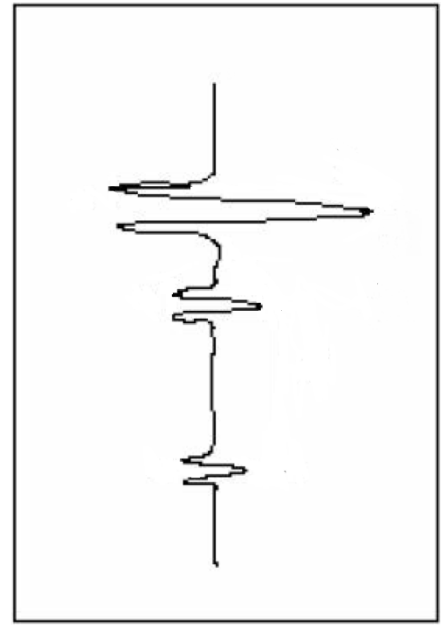
c	=	the speed of light in vacuum (0.3 m/ns)
τ	=	the pulse length (ns)
ε_r	=	medium's relative dielectricity

"The vertical resolution is roughly half the wave length of the pulse, which in turn is dependent on the relative permittivity of the material"

Sources: MaraNord Guidelines, TDOK 2014:0150, T Saarenketo

GPR Theory (the short short version)





$$\sqrt{\varepsilon} = \frac{1 + \frac{A_0}{A_m}}{1 - \frac{A_0}{A_m}}$$

$$K_{(i)} = \frac{\ln 272.93 - \ln H_{(i)}}{1{,}3012 \cdot X_{(i)}}$$

där $\begin{cases} H_{(i)} = Hålrumshalt, referensprov \\ X_{(i)} = Permittivitet\ i\ referenspunkt \end{cases}$

$$Y_{(x)} = 272.93 \cdot e^{-1.3012 \cdot K \cdot \varepsilon_x}$$

där $\begin{cases} K = Kalireringskonstant\ enligt\ (6) \\ \overline{\varepsilon_x} = Permittivitet,\ lvärde\ per\ meter\ enligt\ (5) \end{cases}$

Sources: MaraNord Guidelines, TDOK 2014:0150, T Saarenketo

GSSI PaveScan


Purpose and overview

Benchmark PaveScan against other GPR systems in order to investigate differences, strengths and weaknesses

Add-on: Combine GPR data with texture data (MPD)

Test objects

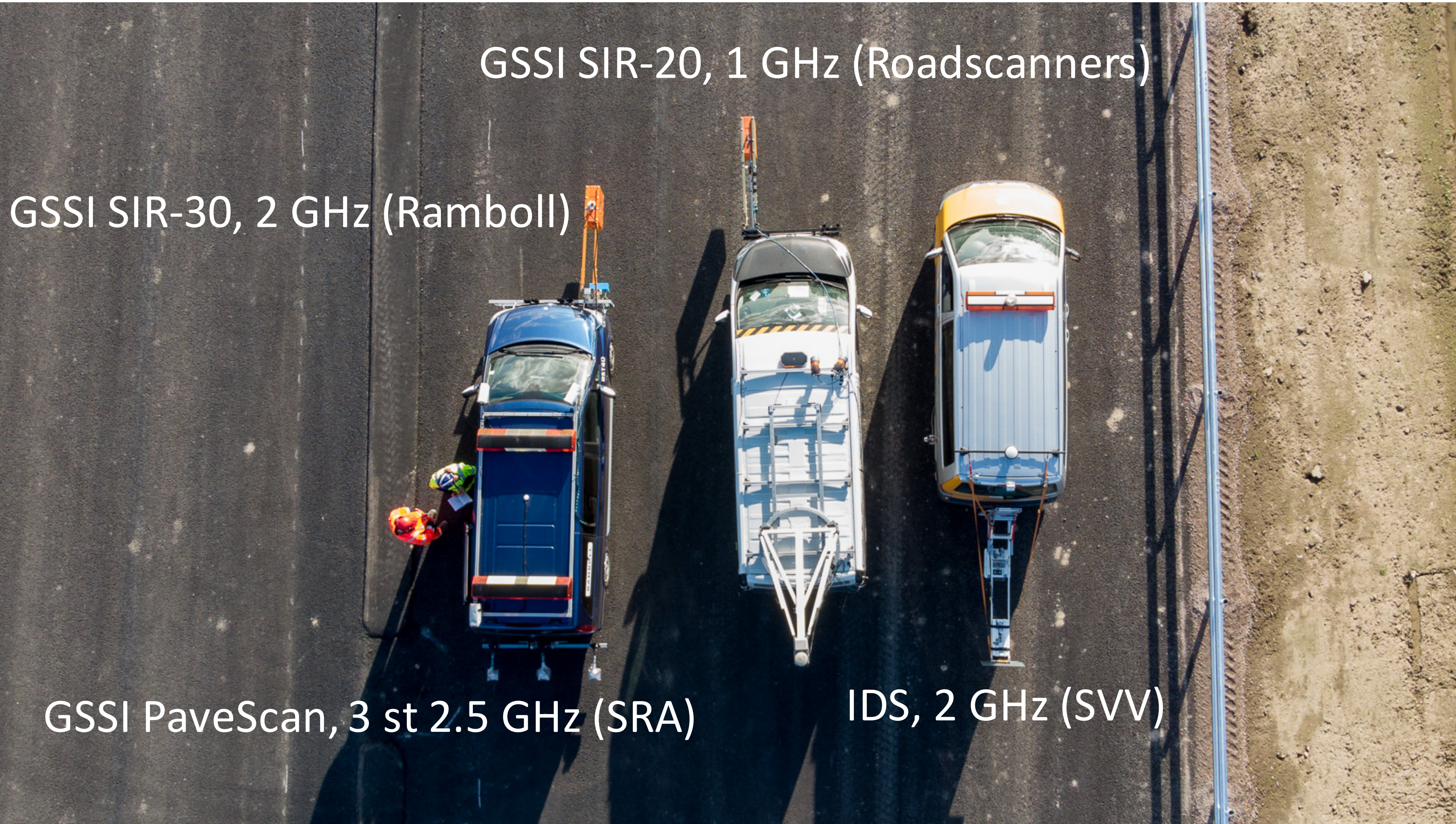
- Selected by SRA, one with new asphalt and one subjected to traffic

- E20 Hova
  - Newly paved surface, not exposed to traffic (unfortunately a bit dirty)
  - 2 sections, both 573 m long
  - 3 runs on each direction
    Right/left wheel path + middle
  - 9 static measurements + drill cores

- E20 Örebro
  - Highway exposed to one year of traffic
  - 2 sections, 10 474 m and 11 177 m
  - 1 run in each direction, right wp
  - 9 static measurements + drill cores

- Poor weather conditions

Participating systems



Participating systems

E20 Hova

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  - Newly paved surface, not exposed to traffic (unfortunately a bit dirty)
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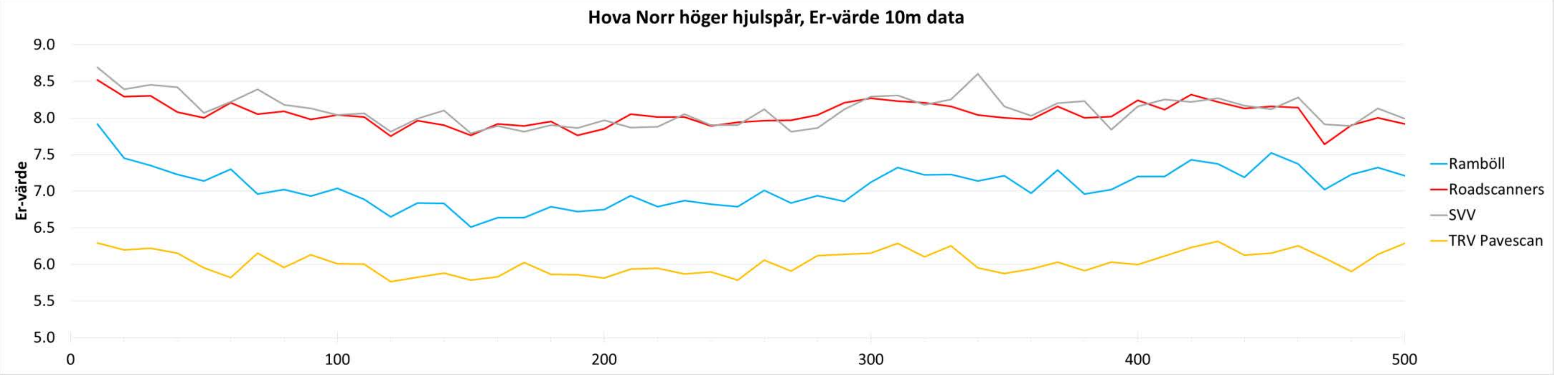
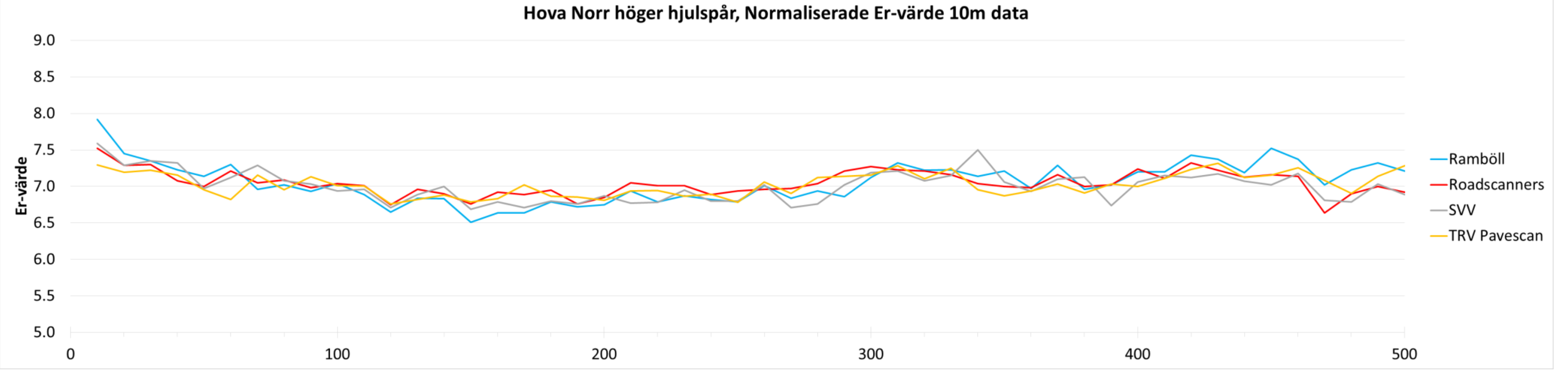
ABb22

paved 2 weeks before

E20 Hova

- Difference in measured E_r-values between the systems, probably due to differences in signal processing and influence depth
- Normalized E_r-values show good match





E20 Örebro

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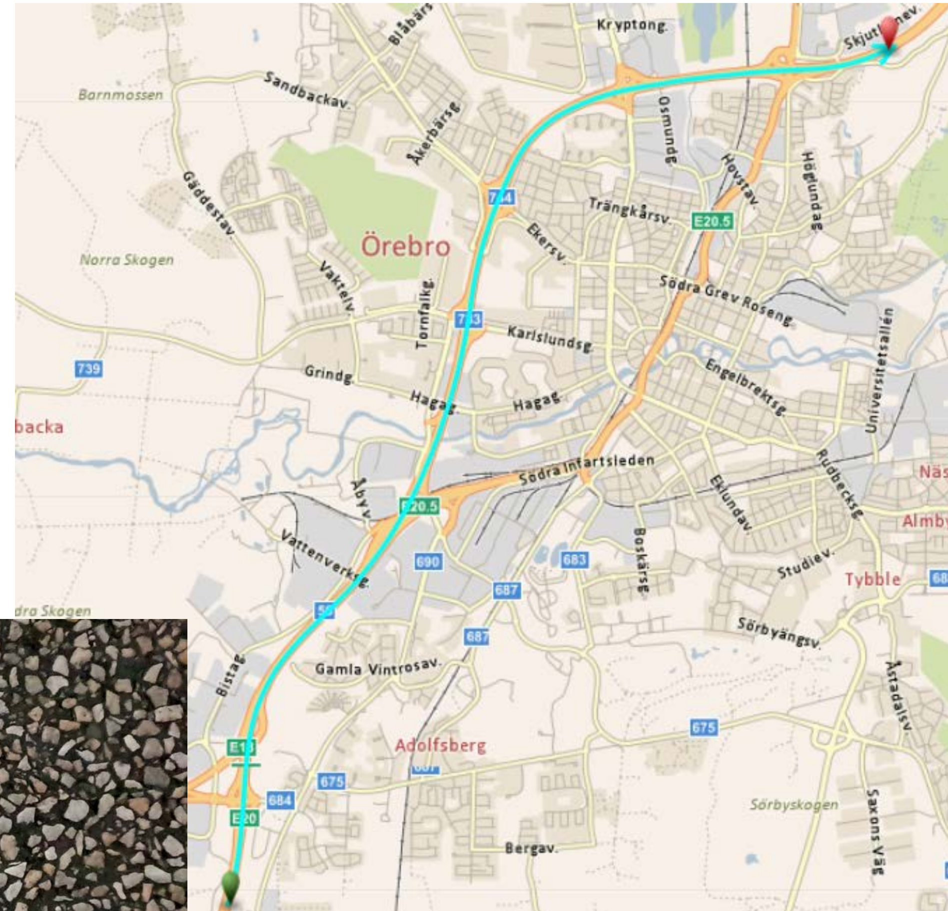
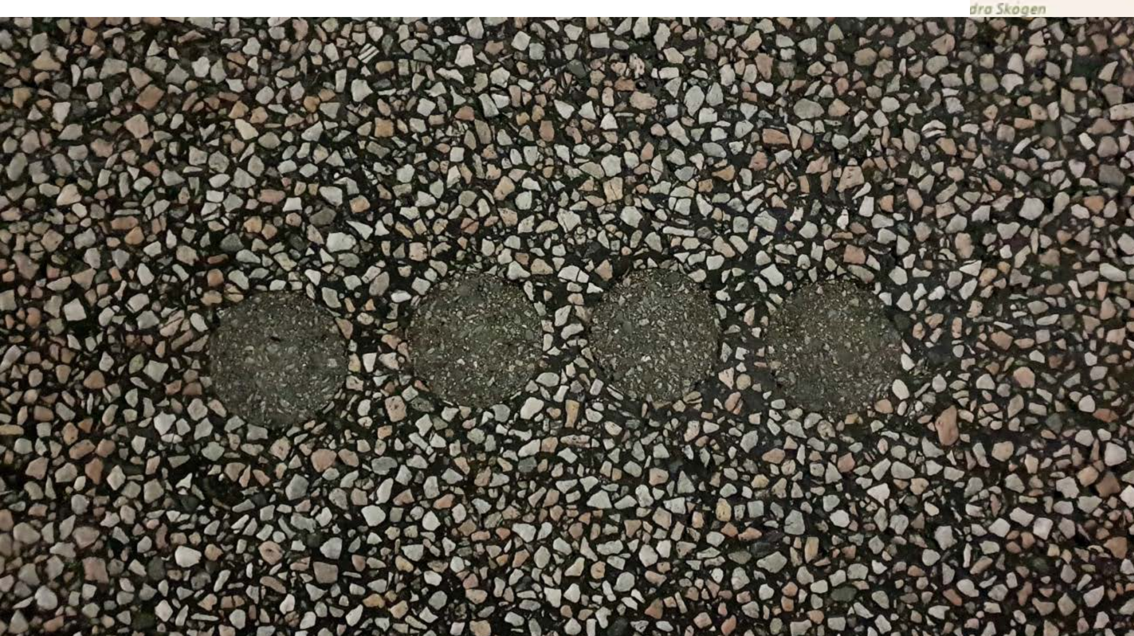


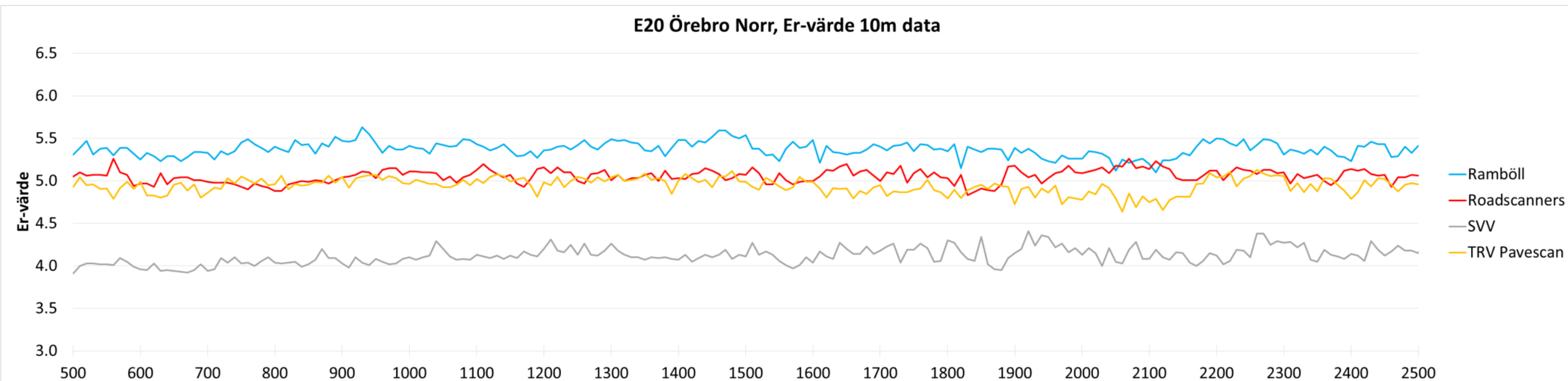


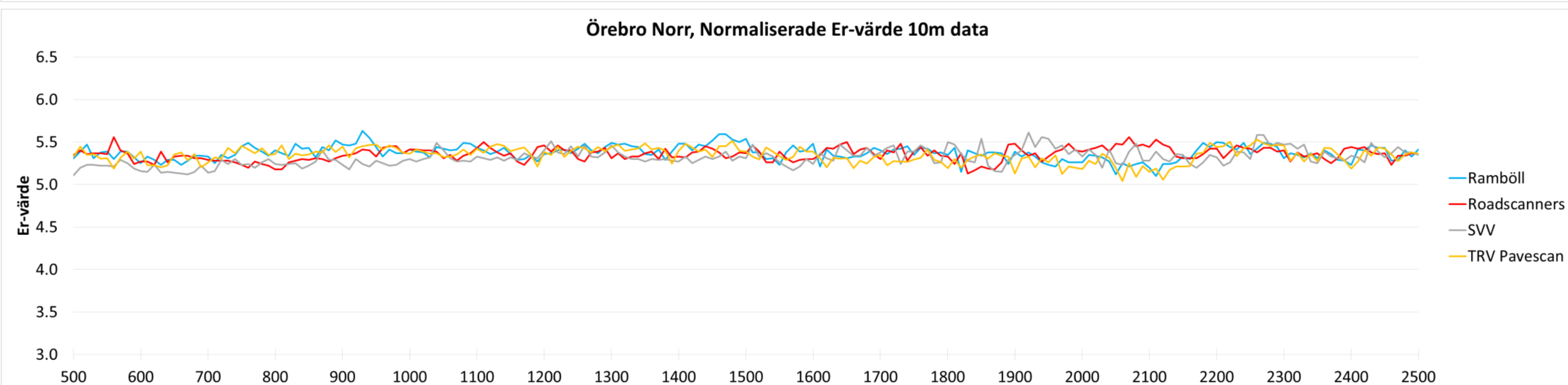
ABS16

paved june/july 2018

E20 Örebro

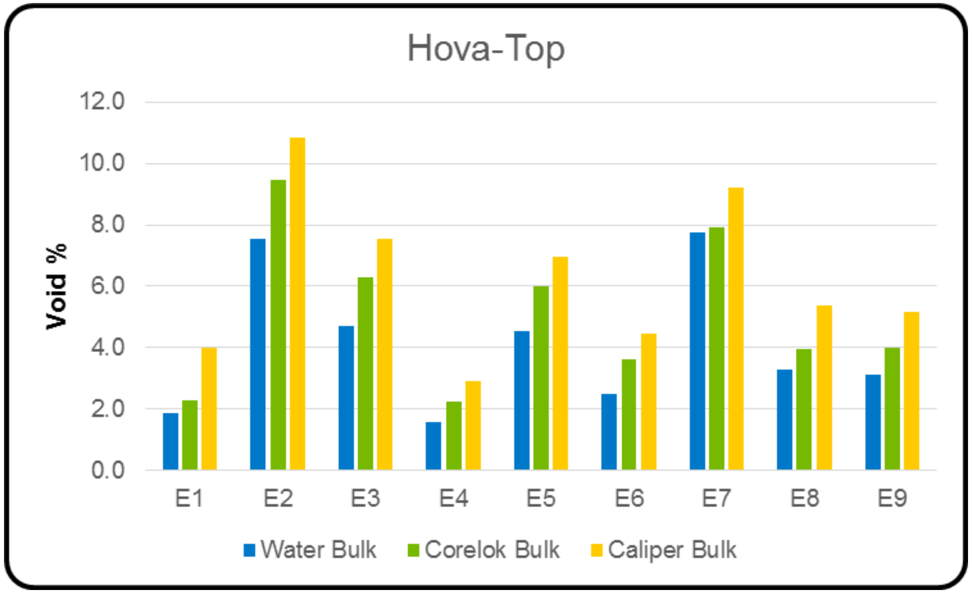
- Homogent objekt som har legat ett år sedan åtgärd
- Skillnad i mätta och beräknade absolutvärden på E_r-värde, vilket är väntat då det finns ett beroende på system, centralfrekvens och signalbearbetning
- Normaliserade E_r-värden visar på god samstämmighet (nedre diagrammet)



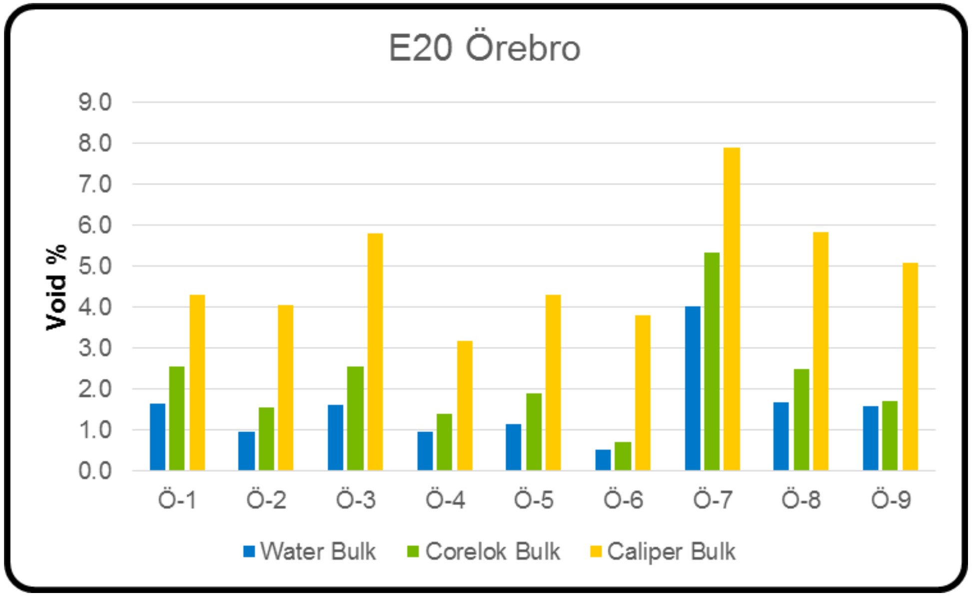


E20 Örebro

	Iastrada nr:	Märkning	Thickness [mm]	Water Bulk	Void %	Corelok Bulk	Void %	Caliper Bulk	Void %	Compact
Top	11A180865	E1	65	2.641	1.9	2.630	2.3	2.584	4.0	2.691
	11A180866	E2	76	2.515	7.5	2.463	9.4	2.425	10.8	2.720
	11A180867	E3	75	2.563	4.7	2.520	6.3	2.486	7.5	2.689
	11A180868	E4	69	2.627	1.6	2.609	2.2	2.591	2.9	2.669
	11A180869	E5	68	2.587	4.5	2.548	6.0	2.522	6.9	2.710
	11A180870	E6	68	2.611	2.5	2.581	3.6	2.559	4.4	2.678
	11A180871	E7	69	2.511	7.8	2.506	7.9	2.471	9.2	2.722
	11A180872	E8	59	2.596	3.3	2.578	3.9	2.540	5.4	2.684
	11A180873	E9	65	2.609	3.1	2.585	4.0	2.554	5.2	2.693



	lastrada nr:	Märkning	Thickness [mm]	Water Bulk	Void %	Corelok Bulk	Void %	Caliper Bulk	Void %	Compact
Top	11A180912	Ö-1	36	*2.379*	*1.7*	*2.357*	*2.6*	*2.315*	*4.3*	2.419
	11A180913	Ö-2	31	*2.397*	*1.0*	*2.382*	*1.6*	*2.322*	*4.0*	2.420
	11A180914	Ö-3	37	*2.395*	*1.6*	*2.372*	*2.5*	*2.293*	*5.8*	2.434
	11A180915	Ö-4	37	*2.403*	*0.9*	*2.392*	*1.4*	*2.349*	*3.2*	2.426
	11A180916	Ö-5	39	*2.387*	*1.2*	*2.369*	*1.9*	*2.311*	*4.3*	2.415
	11A180917	Ö-6	37	*2.401*	*0.5*	*2.397*	*0.7*	*2.322*	*3.8*	2.414
	11A180918	Ö-7	39	*2.346*	*4.0*	*2.314*	*5.3*	*2.251*	*7.9*	2.444
	11A180919	Ö-8	32	*2.383*	*1.7*	*2.364*	*2.5*	*2.283*	*5.8*	2.424
	11A180920	Ö-9	34	*2.378*	*1.6*	*2.375*	*1.7*	*2.293*	*5.1*	2.416



Summary

- The tests proved the basic theory, GPR is basically GPR
- Care has to be taken to limitations
  - Effect of different frequencies
  - Limitations in layer thicknesses
- Important to differentiate between control and guidance of the production phase, versus quality inspections of the end product

Why does the frequency matter?

"The vertical resolution is roughly half the wave length of the pulse, which in turn is dependent on the relative permittivity of the material AND of course the frequency spectrum of the system"

$$h = \frac{\tau \cdot c}{2 \cdot \sqrt{\varepsilon_r}}$$

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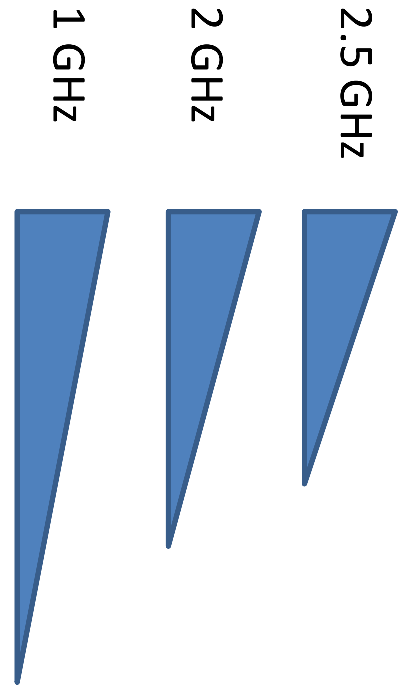

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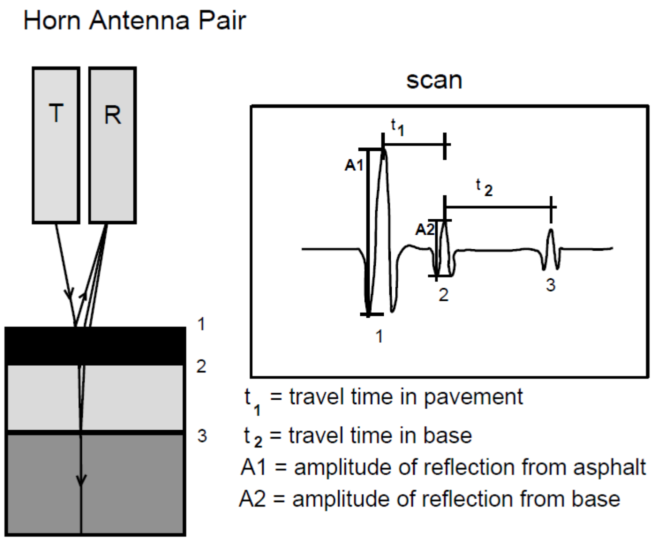

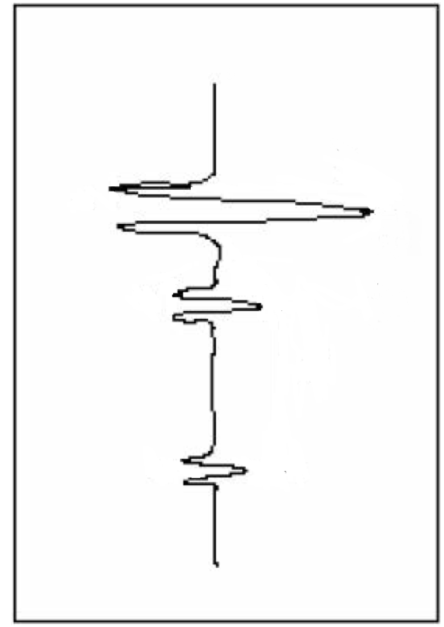

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$$Y_{(x)} = A \cdot e^{B \cdot \varepsilon_x}$$

där $\begin{cases} \overline{K} = Kalireringskonstant\ enligt\ (6) \\ \overline{\varepsilon_x} = Permittivitet,\ lvärde\ per\ meter\ enligt\ (5) \end{cases}$

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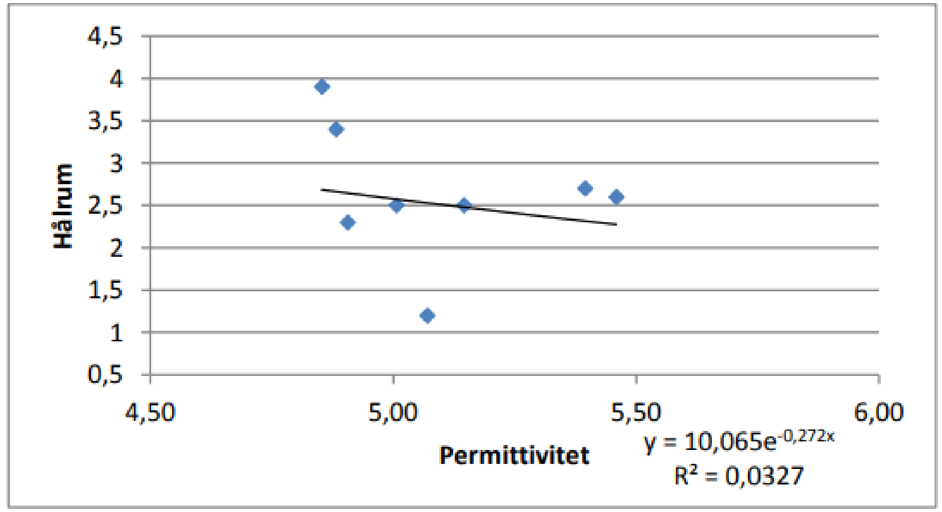
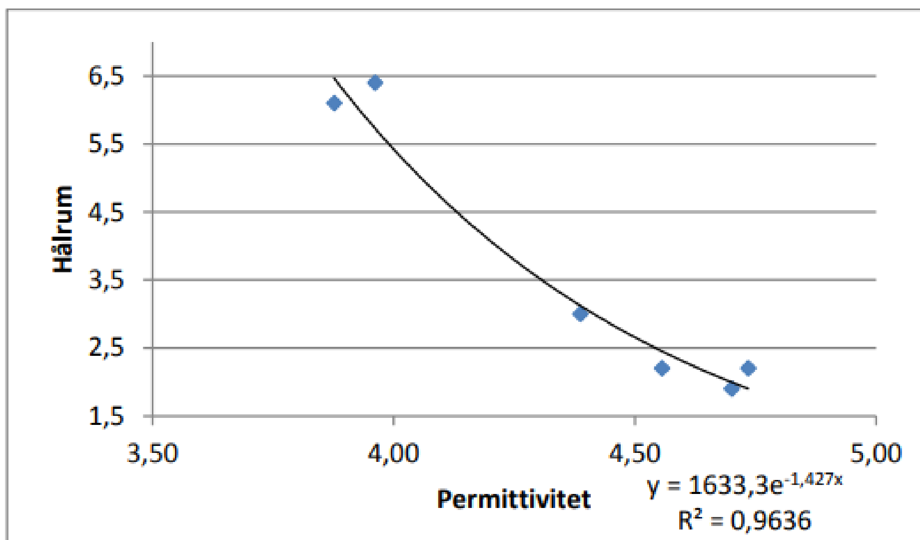
Sammanfattning

Beläggningsobjekt	**R^2**
1	0,759
2	0,936
3	0,054
4	0,966
5	0,776
6	0,866
7	0,058
8	0,962
9	0,650
10	0,931
11	0,032
12	0,012

2017





Sammanfattning

Metoden fungerar, men som med de flesta metoder är utförandet väldigt viktigt

Största påverkan kommer från vattenhalten i beläggningen, det måste vara helt torrt!

Efterpackning av trafik, testning inom 2-4 veckor