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Adjustment of C-Band radar with mobile vertical pointing X-band radar

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1 Introduction

Weather radar has a significant potential for improving the function of sewer systems and wastewater treatment plants by supplying distributed precipitation information for whole catchments (Einfalt et al, 2004). Information on both intensity and spatial distribution offers possibility for better real time control of the sewer system and wastewater treatment plant.

Traditionally, research within urban drainage has relied on rain gauges for precipitation data. The clear advantage of rain gauges is the simplicity and accuracy of the measuring technique. The primary disadvantage is the limited number of rain gauges. Often, there are only a few rain gauges in the catchments and sometimes there are none. Pedersen et. al, 2005 illustrated that spatial variation in the precipitation could have significant effects on the subsequent runoff, even for small urban catchments. For urban drainage application it is important that the radar is able to measure with as high spatial resolution as possible. Jensen and Overgaard, 2002 demonstrated that local area weather radar based on a marine X-band system could measure with high spatial resolution. However, this is only possible in areas where these short range radars are installed. For most cities and for rural areas, the long range C-band radar is the preferred radar. In order to get most information from the C-band radar it is necessary to adjust it as accurate as possible. With only a few local rain gauges, this can be a serious challenge.

This study proposes to use a mobile vertical pointing X-band radar (VPR) to measure the local precipitation. By mounting the radar on a vehicle, measurements can be made in many places during the same storm event, thus improving the possibility for adjustment. The mobile vertical pointing radar (VPR) offers the possibility to study the accuracy of the stationary C-band radar at different distances. Also, the radar can be transported to interesting areas where it actually rains and not depends on chance, whether the thunderstorm moves above a fixed rain gauge. Due to the robust marine design of the system, the VPR can also be fitted to busses or trains, which regularly travels along the same routes, thereby automating the procedure.

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2 Methodology

2.1 Vertical X-band radar

The VPR is based on the very affordable Furuno 1715 marine X-band radar, Table 1. The radar uses a microstrip patched array antenna, Fig.1, with a horizontal beam width of 5.2^o and a vertical beam height of +/- 25^o.

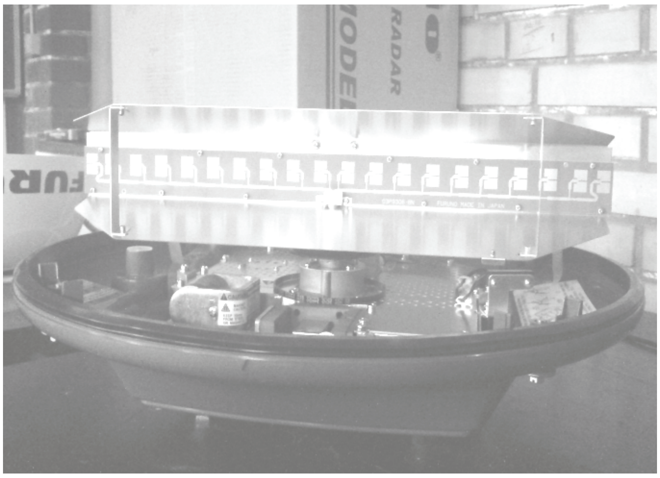

Fig. 1. Furono 1715 Microstrip Antenna. The drive is disengaged and the antenna is fixed with springs.

However, the antenna is rotated so it is always pointing vertical above the vehicle. This is achieved by disengaging the rotational step motor and fixing the antenna with springs.

The antenna is mounted on top of the car with fixed mountings, Fig 2.

Fig. 2. The modified Furono 1715 Microstrip Antenna mounted on top of a car.

The signal is acquired after the IF amplifier in the antenna and before any processing has taken place in the display unit. The video signal is measured with a 200 MHz Pc-oscilloscope (Picoscope 3206, Pico technology) and transferred directly to a laptop for final processing and presentation. The Picoscope is controlled by in-house developed software for optimal acquisition rate and data quality. Pulse width and PRF are controlled from the display unit. For all the experiments, the pulse width is set to 0.8 μs and the PRR to 600 HZ. The maximum detection range is set to 10,000 meters.

The position and orientation of the car is measured with an ordinary USB GPS, connected to the laptop. The data are encoded, so that position and signal can always be compared. The GPS data are transferred to Google Map and compared to satellite maps for quality control and verification of blocking objects (bridges, tunnels, overhanging signs and lighting).

Unfortunately, the drawback of using marine X-band radar as a platform for the VPR is that not all hardware specifications are disclosed by the manufacturer. A direct conversion from voltage in the IF amplifier to dBZ is therefore not possible. Instead, both the X-Band and the C-band data are converted to rain intensity and compared.

A simple exponential attenuation model is used for adjusting for attenuation though rain. Time series of the video are extracted in a temporal position equal to 500 m above ground level. The samples are acquired with an interval of 5 seconds. Each sample is an average of 500 individual pulse measurements. The precipitation is for simplicity assumed to be constant in the first 500 meter above ground level. The marine antenna would under normal conditions yield the radar unpractical for vertical profiling of the atmosphere due to the large asymmetrical main lope. However, as the measurements are taken in a fixed altitude of only 500 meter, the sampling volume is sufficiently small. Also, due to the principle of measuring in the same distance from the radar, all radar constants and volume corrections can be assumed to be constant.

2.2 C-Band Radar

All the current DMI radars are manufactured by Enterprise Electronic Corporation (EEC). The radar network consists of 4 radars, Fig 3. The weather radar at Sindal, which is used in this study, is a converted ERE radar, e.g. the antenna system is ERE, but the electronics has been upgraded to EEC standard in 2003. Volumes are generated with a spatial resolution of 500 m in range and about a degree in azimuth. The CAPPI layers are all generated with a spatial resolution of 2000 m.

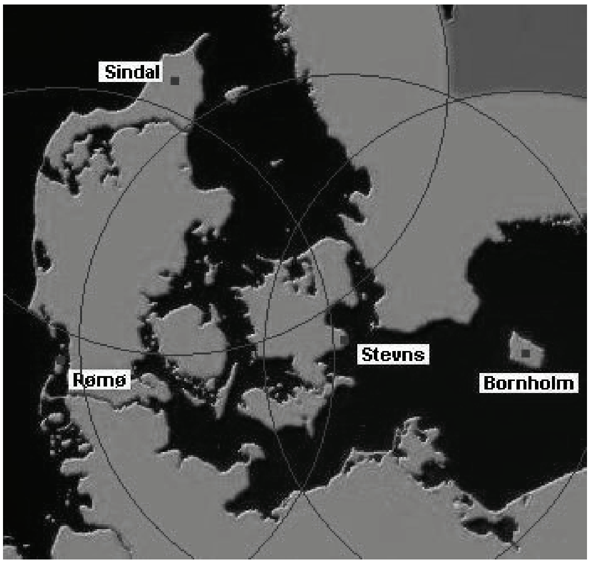

Fig. 3. Location and range of DMI C-band radars

Volume data is collected every 10 minutes with 9 elevation levels. The data are then converted to CAPPI format. The reflectivity is stored with a 2 x 2 km resolution. The direct distance between the Sindal and the Aalborg radar is 53 km.

Table 1. Data on C and X-band radar

Location	Sindal, Denmark (DMI)	Aalborg, Denmark (AAU)
Type	C-Band	X-Band, VPR
Year	2003	2007
Model	DWSR 2500C	Furuno 1715
Horizontal	1 º	5.2 º
Vertical	1 º	+/- 25 º
Resolution	500 m.	< 25 m.
Peak Power	250 kW	2.2 kW
Pulse width	0.4, 0.8, 2.0 μsec	0.08, 0.3, 0.8 μsec
PRF	250 – 120 Hz	600 – 3000 Hz

3 Results

The study was originally designed for mobile measurement with the X-band VPR and direct comparison with C-band

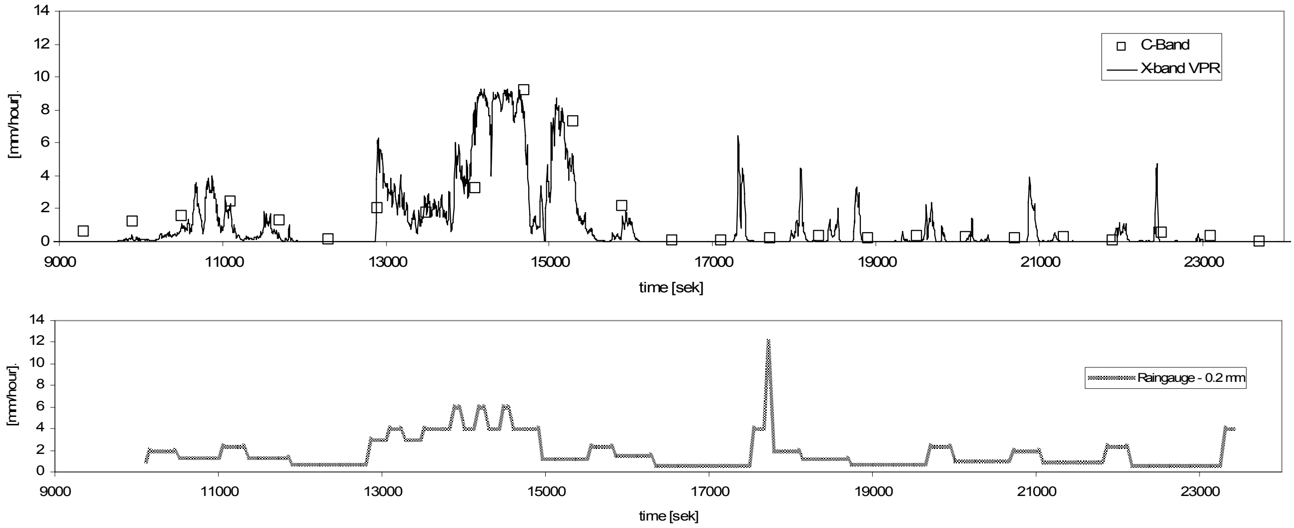

Fig. 4. Comparison between VPR and C-Band horizontal radar at the 18/1 2008. The X-band VPR are located 53 km from the C-band radar. The rain gauge is placed 5 km. from the X-band VPR.

data. Unfortunately, due to database malfunction with the C-band radar it was not possible during the study period to perform the comparative test. Instead, the tests are separated into stationary test, where the C-band and X-band are compared at a fixed position and mobile test, where the X-band measures without C-band data. New mobile tests are expected be performed in February/Marts 2008.

3.1 Stationary test

In this test, the VPR is placed stationary at the laboratory roof at Aalborg University.

The raw data is illustrated in Fig 5, where a one-hour window is visible.

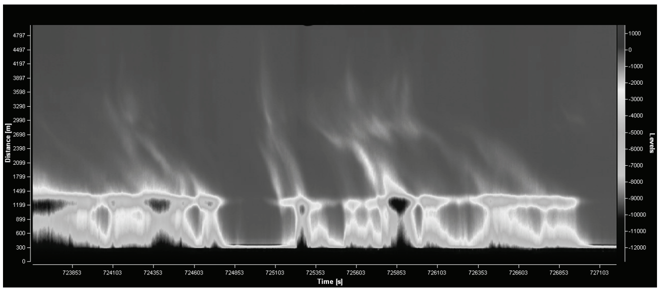

Fig. 5. Example of raw VPR data above Aalborg 12/1 2008. A brigthband is located at approximately 1200 m over ground level.

The results from the VPR is continuously presented in a HTI plot, Fig 5. It is possible to identify a brightband located approximately 1200 meters above ground level. The data is not corrected for attenuation and antenna geometry at this point.

The C-band dBZ is converted into rain intensity by a standard Marshal-palmer model, calibrated with a rain gauge 5 km away from the X-band radar. This is due to a major malfunction of the local rain gauge (blown away in a storm).

The measurements are compared in Figure 4. There is a good agreement between the X-band and the C-band. It is not possible to compare directly with the rain gauge measurements, due to the spatial distance between the instruments. However, the general trend of the X-band and C-band radar is confirmed with the nearby rain gauge. The results also reveal the temporal dynamics of the precipitation, which is difficult to capture with the C-band with its present resolution and sampling interval.

3.2 Mobile test.

Although C-band data are not available, a measuring campaign with the mobile X-band VPR, Fig 2, is still performed.

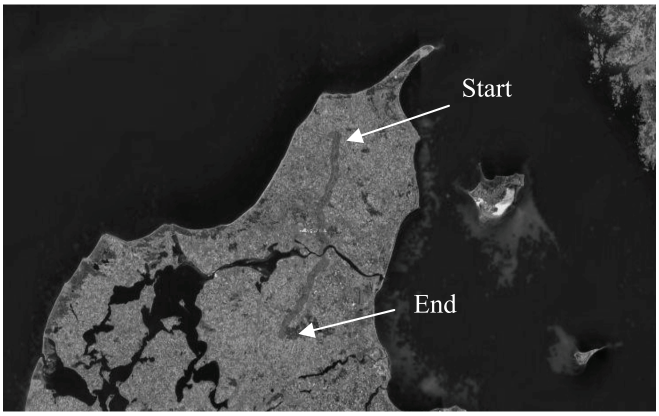

Fig. 6. GPS Track of mobile X-band VPR 6/12 2007 (Google Map©).

The measurement starts at Hjørring (close to the Sindal radar) and ends at Haverslev, Fig 6.

The route selected is on the main highway in northern Jutland, Denmark. The start and end of the route coincides – purely accidentally – with two different fastfood restaurants.

The results are similar to the stationary measurements, except from the fact, that they are measured with horizontal velocities between 110 – 130 km/h (legal speed limits on highways in Denmark).

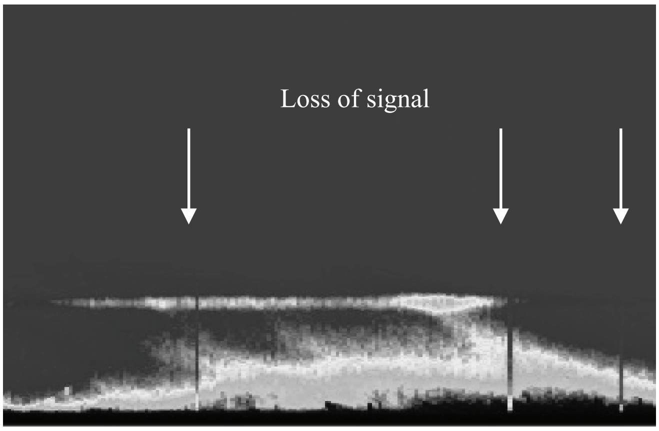

Fig. 7. HTI plot with distinct interruptions in the measurement.

As can be seen from Figure 7, the signal is periodically lost during the measurement. Comparing the timestamp with the GPS position reveals that the car at these positions passes under a bridge, Fig 8, or an overhanging sign.

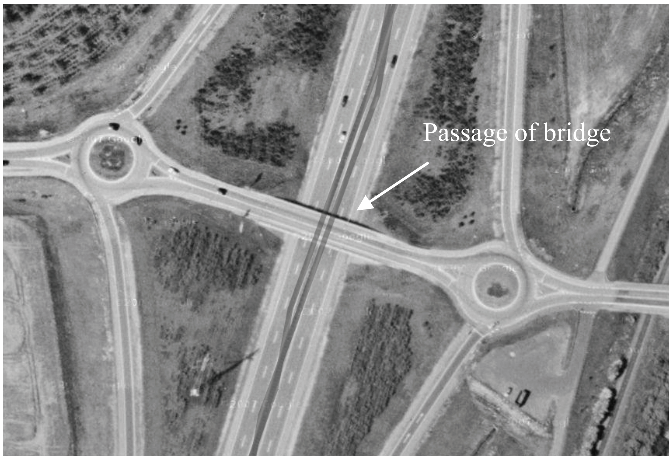

Fig. 8. Google Map© with GPS track overlay (both ways). The first loss of signal in Figure 7 is coinciding with passage beneath the bridge.

4 Discussion and conclusion

Although it was not possible to conduct the comparison between the mobile X-band VPR and the stationary C-band radar in January 2008, the results indicate that the vertical pointing mobile radar has some merits towards measuring local precipitation. The primary advantage is that the measurement can be performed at great speed, which would not be possible with traditional rain gauges. Also, the VPR would be able to measure in between high buildings, where local wind conditions would affect ordinary rain gauges. The potential for this simple type of VPR is to attach the radar to busses or trains which follows regular routes at fixed intervals. By adding a 3G High-speed data modem to the setup, the radar can be in continuously contact with the central computer and provide data for real-time calibration.

The results also highlights challenges, which needs to be overcome before practical application of the system can commence. Primarily, the antenna geometry is a practical problem. Due to the +/- 25 angle on the main lope, the sampling volumes becomes very large at altitude. At 1000 meter, the measuring cross section of the main lope will be in the order of 900 m. x 90 m. However, this should be compared to the CAPPI data with a resolution of 2000 m x 2000 m.

The sidelopes of the antenna can under certain circumstances generate false echoes, when the radar is moved trough the landscape. This seems to be a problem when highway goes over a hilltop. When the road goes through cities, the echo dissipates due to the close proximity of buildings. A “dry” run of the route has to be conducted in order to identify the size of the problem.

One practical application of the X-Band VPR is the identification of brightband conditions. The vertical resolution of the radar is less than 25 meter. This makes it possible to measure the beginning and to some extent the thickness of the brightband. This could be helpful when analyzing volume data from the C-band radar at larger distances from the radar. At the edge of the operational distance of the C-band radar, the vertical size of the main lope would be around 1000 meter. In this situation, the VPR data could be helpful in correcting the data.

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