

76-81 GHz Radar Sea Surface and Maritime Target Measurements

Trial Purpose

The purpose of the described maritime radar trials was to conduct imaging radar measurements of sea surface clutter/reflections and targets of opportunity in the 76-81 GHz frequency band. This is the first part of the University of Birmingham data collection for the EPSRC funded STREAM project.

EP/S033238/1 Sub-THz Radar sensing of the Environment for future Autonomous Marine platforms

Repository Overview

Due to extremely large files sizes (~6 GB per file), neither the full raw radar data files nor full pre-processed radar imagery data files can be included. Example data is however included and the full dataset is described and may be available on request.

Measurement Description

Measurement Types

Two types of radar data collection measurements were conducted, azimuth scanned imaging measurements (Figure 1) and staring measurements (Figure 2). Corner reflector and noise calibration measurements have also been conducted.

All scanning measurements covered a field-of-view (FoV) of 60° and chirps are transmitted with constant angular separation across the FoV. Both scanned and staring measurement types used the same fan beam imaging antennas.

Details of the scanned and staring measurements parameters, i.e. number of chirps etc. can be found in the **dataset description** section, details of the radar hardware use can be found in the **radar hardware configuration** section.

Details of any targets and important information within the measurements are also found in the dataset description.

A ZED stereo video camera was used to provide ground truth to radar data/imagery.

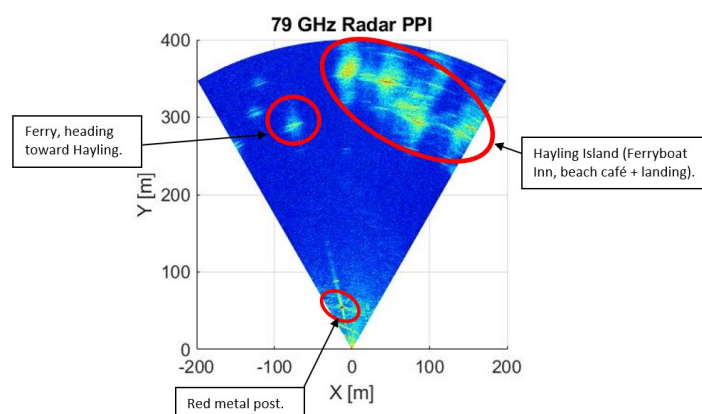


Figure 1. Example of scanned radar imagery PPI and ground truth video data (file:sea_13).

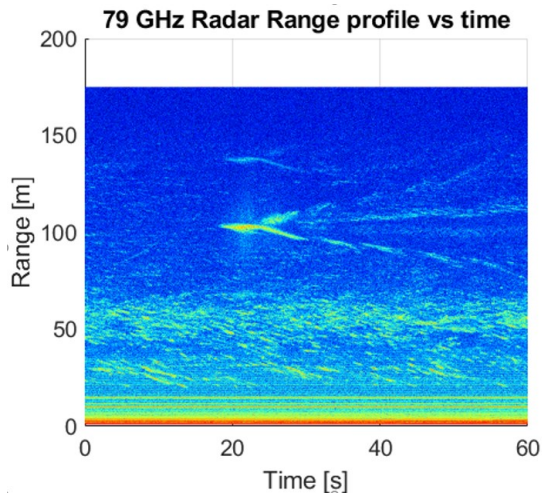


Figure 2. Example of time series of range profiles formed from multiple chirps from a staring measurement, with corresponding ground truth (file:stare_4)

Measurement Site and Scene

The measurement site was located on Ferry Road, Southsea, Portsmouth, PO4 9LY, U.K., looking across Langstone Harbour towards Hayling Island. GPS Coordinates: $50^{\circ} 47' 40.4772''$ N, $1^{\circ} 1' 46.0596''$ W.

A Google Map plan view of the trials site can be found in Figure 3. A panoramic photo of the test area of sea surface is found in Figure 4.



Figure 3. Google Map view of trials site, radar is positioned on Westerly side of harbour entrance looking in an Easterly direction.

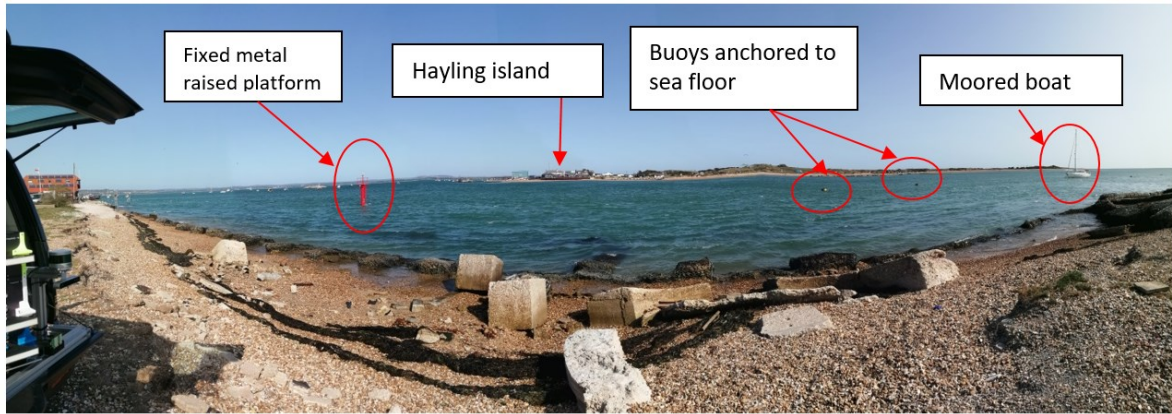


Figure 4. Panoramic view of the test scene

The data contained in this repository were recorded on 17th September 2020. Wind and wave data from Channel Light Vessel and Sandettie Light Vessel can be found in Appendix A.

Data was not available for the nearest light vessel to the trial site, the Greenwich Light Vessel, as measurements from this have not been reliably available since March 2020. The sea conditions near the trials site were probably an average of the two measurements obtained, a wave height equivalent sea state of about 3-4 and wind equivalent of sea state 5-6. However, the sea conditions in the harbour entrance channel where the measurements were conducted were much calmer, in littoral waters and also greatly affected by tidal flows. At the time they were estimated visually to be a maximum of sea state 2.

Hardware Configuration

Radar

The radar used for data gathering is a bespoke 76-81 GHz FMCW quasi-monostatic radar with dual receivers each with IQ output, the specification is outlined in Table I below. Details of the antenna used for Tx/Rx in all measurement are found in Table II. An image of the setup is shown in Figure 5.

Table I. Radar parameters

Radar Parameter	Value	Units	Comment
Centre Frequency, f	78.5	GHz	
Transmit Power, P_t	13	dBm	Average across band
Bandwidth	5	GHz	
Chirp Duration	1, 2	ms	Both used during experimentation (see dataset description)
PRF(PRI)	200 (5), 166.7 (6)	Hz (ms)	PRF's for 1 and 2 ms chirp durations respectively
ADC Sample Rate	40	MHz	
Intermediate Frequency Filter Bandwidth	10	MHz	

The radar is mechanically scanned and consecutive scan directions are reversed i.e. scans operate consecutively in a clockwise and then counter-clockwise manner.

Data recorded to file is the de-ramped FMCW IF signal – FFT required to form range profile. Due to the large size of raw data files they cannot all be provided directly in this repository, but may be available on request.

Table II. Antenna Parameters

Antennas were measured (two-way) in quasi-monostatic configuration (gain is ‘one-way’ gain)

Antenna Type	Az. Beam Width (Two Way) [°]	El. Beam Width (Two Way) [°]	Antenna Gain $G_t = G_r$ [dBi]
Elevation Fan Beam	1.7	7.2	30

Video

A ZED stereo video camera has been used to provide ground truth the radar measurements.

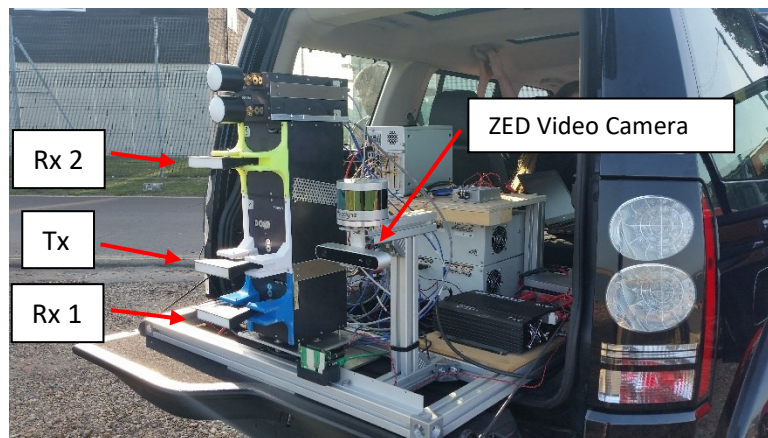


Figure 5. Quasi-monostatic 76-81 GHz FMCW radar with two receivers.

Dataset Description

The full dataset description is found in Table II. Examples of data processed to into range profile format are included in the repository, relating to scanned file ‘sea_4’ and staring file ‘stare_4’, both include video ground truth.

The data is supplied as an array of complex range profiles (formed after FFT of de-ramped FMCW data), the data are stored as a MATLAB .mat array of doubles.

The data represents radar ranges from 0 m up to ~400 m, with range resolution of ~3cm (according to previously described bandwidth).

For the scanned data file, the array has 3 dimensions:

- Dimension 1: Range bin number
- Dimension 2: Chirp number within scan (angular position within FoV)
- Dimension 3: Scan number

For the staring data file, the array has 2 dimensions.

- Dimension 1: Range bin number
- Dimension 2: Chirp number

Date: 16/09/2020 File name: time recorded	Chirps (per scan for scanning, total for staring)	Chirp Duration (ms)	Number of scans	Scan Rate (Hz)	Collection time (s)	Scanned field of view (deg.)	Notes
Sea_1: 13:43	166	1	30	1	30	60	Starts with a catamaran in FOV moving from left to right. At 15 seconds, the catamaran turns 180 degrees on the right in the FOV.
Sea_2: 13:56	166	2	60	1	60	60	5 seconds into scan, a boat travelling towards land (right to left) producing a visible wake.
Sea_3: 14:07	166	2	60	1	60	60	Just a scan of the red post only against sea clutter after repositioning radar to face its direction.
Sea_4: 14:08	166	2	60	1	60	60	Scan starts with a wind surfer travelling from 50m to the right across the FOV.
Sea_5: 14:10	166	2	60	1	60	60	A slow boat travels about 75m away at the beginning

							of the scan, passes behind the red post. Partial video data for this set.
Sea_6: 14:16	166	2	60	1	60	60	Scan starts with a fast boat passing around 175m away, producing a visible wake.
Sea_7: 14:23	166	2	60	1	60	60	Radar turned towards buoys. A large stationary sailboat is anchored near the "3rd buoy" counting left to right. A jet skier is in the distance (about 200m from eye estimate).
Sea_8: 14:30	166	2	60	1	60	60	Platform raised at one end by 2 inches, so the radars have a slightly steeper grazing angle. Just recording the buoys.
Sea_9: 14:37	111	2	90	1.5	60	60	Speed boat approaches FOV in the last few seconds of the scan.

Sea_10: 14:40	111	2	90	1.5	60	60	Scan starts with boat in centre of FOV around 200m from the radars, travelling from right to left producing a small wake.
Sea_11: 14:45	166	2	60	1	60	60	Radar repositioned to look at Hayling island, whilst keeping 2 buoys in the FOV. Scan contains sea clutter and buoys only.
Sea_12: 14:57	166	2	60	1	60	60	At 32 seconds a boat passes the radar at a range of around 50m, traveling quite quickly producing a visible wake.
Sea_13: 15:23	166	2	60	1	60	60	Radar is repositioned to face the red metal pole, and path of the Hayling island ferry. Beginning of the scan has the ferry traveling to Hayling island over 200m away.

Sea_14: 15:38	166	2	60	1	60	60	26 seconds into the scan, a jet skier passes by from right to left in the centre of the channel, around 175m. Drives up and down the channel. Partial video data for this recording.
Sea_15: 15:41	166	2	60	1	60	60	The jet skier continues to make sharp turns in the field of view throughout scan, the ferry departs at the end of the record. Partial video data for this set.
Sea_16: 15:42	166	2	59 recorded (1 missed)	1	60	60	The ferry departs and travels from Hayling to Eastney. No video data for this set.
Sea_17: 15:52	166	2	59 recorded (1 missed)	1	60	60	Jet ski in tow, the jet ski pulls up to the shore of Hayling island.
Sea_18: 15:55	166	2	58 recorded (2 missed)	1	60	60	Jet-ski close to Hayling island.

Sea_19: 16:30	648	2	3	0.25	10	70	Test
Stare_1: 14:52	11136	2	N/A	N/A	~60	N/A	Radar is positioned to stare at one of the buoys to the right of the Eastney shore.
Stare_2: 14:55	10752	2	N/A	N/A	~60	N/A	Staring at the buoys still.
Stare_3: 15:05	10496	2	N/A	N/A	~60	N/A	Staring at the buoys once more.
Stare_4: 15:08	11136	2	N/A	N/A	~60	N/A	20s in, a boat travelling slowly passes the beam, producing a visible wake.
Stare_5: 15:16	11136	2	N/A	N/A	~60	N/A	The radar is repositioned to face the red metal post (but not staring at the post). 40s in a boat travels past the beam travelling towards the left, around 75m away. Produces a visible wake.
Stare_6: 15:18	10496	2	N/A	N/A	~60	N/A	Wind starts to pick up in this stare.
Stare_7: 15:21	11136	2	N/A	N/A	~60	N/A	Sea clutter only stare. Note a large return comes from the

							ground clutter, could be from metal cages that emerge when tide gets lower.
Stare_8: 15:26	11136	2	N/A	N/A	~60	N/A	Sea clutter only stare.
Stare_9: 15:28	10624	2	N/A	N/A	~60	N/A	Sea clutter, and ferry crossing.
Stare_10: 16:40	10880	2	N/A	N/A	~60	N/A	Sea clutter only stare
Stare_11: 16:42	10624	2	N/A	N/A	~60	N/A	Sea clutter only stare.
Stare_12: 16:45	10624	2	N/A	N/A	~60	N/A	Sea clutter only stare.
Stare_for_cal	1536	2	N/A	N/A	~10	N/A	18 dBsm corner reflector on top of a tripod, 8m away from the radar.
Stare_for_cal_2	1792	2	N/A	N/A	~10	N/A	18 dBsm corner reflector on top of a tripod, 8m away from the radar.
Scan_for_cal_2	166	2	10	1	10	20	18 dBsm corner reflector on top of a tripod, 8m away from the radar.
Noise_1	11136	2	N/A	N/A	~60	N/A	Staring measurement with RAM

							covering both transmitter and receiver antennae of the 79 GHz.
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Appendix A

Channel Light Vessel

		Previous observations															
MM	DD	TIME (GMT)	WDIR	WSPD kts	GST kts	WVHT ft	DPD sec	APD sec	MWD	PRES in	PTDY in	ATMP °F	WTMP °F	DEWP °F	SAL psu	VIS nmi	TIDE ft
09	17	1900	E	28.0	-	4.9	-	7	-	30.21	-0.03	63.9	62.6	55.2	-	11.0	-
09	17	1800	E	21.0	-	4.6	-	7	-	30.22	-0.04	63.7	62.8	56.1	-	11.0	-
09	17	1700	E	22.0	-	6.2	-	7	-	30.23	-0.04	63.7	62.8	55.0	-	11.0	-
09	17	1600	ENE	26.0	-	6.9	-	7	-	30.24	-0.04	63.3	62.8	56.1	-	5.0	-
09	17	1500	ENE	27.0	-	7.5	-	6	-	30.26	-0.03	63.0	62.8	56.7	-	5.0	-
09	17	1400	ENE	27.0	-	6.9	-	6	-	30.27	-0.03	62.2	62.6	56.7	-	5.0	-
09	17	1300	ENE	26.0	-	8.2	-	6	-	30.28	-0.02	62.8	62.6	57.0	-	2.0	-
09	17	1200	ENE	22.9	-	7.2	-	7	-	30.29	-0.02	62.6	62.4	57.6	-	2.0	-
09	17	1100	NE	27.0	-	6.6	-	7	-	30.29	-0.00	62.2	62.4	57.0	-	5.0	-
09	17	1000	NE	27.0	-	5.9	-	7	-	30.31	+0.01	62.1	62.2	56.8	-	5.0	-
09	17	0900	ENE	24.1	-	7.9	-	7	-	30.31	+0.04	62.1	62.4	57.4	-	5.0	-
09	17	0800	ENE	31.1	-	5.9	-	7	-	30.30	+0.04	61.9	62.6	57.0	-	5.0	-
09	17	0700	ENE	25.1	-	5.6	-	7	-	30.29	+0.01	61.2	62.6	57.0	-	5.0	-
09	17	0600	ENE	33.0	-	5.6	-	7	-	30.27	-0.02	61.5	62.8	57.4	-	5.0	-
09	17	0500	ENE	31.1	-	6.6	-	7	-	30.27	-0.04	62.2	62.8	57.9	-	5.0	-
09	17	0400	NE	25.1	-	3.9	-	6	-	30.29	-0.03	63.0	62.8	59.0	-	5.0	-
09	17	0300	NE	24.1	-	3.3	-	5	-	30.28	-0.03	63.1	62.8	59.4	-	5.0	-
09	17	0200	ENE	27.0	-	2.0	-	5	-	30.30	+0.00	63.3	62.8	59.5	-	5.0	-
09	17	0100	NE	19.0	-	1.3	-	8	-	30.31	+0.02	63.9	62.6	60.8	-	5.0	-
09	17	0000	NE	22.0	-	1.3	-	9	-	30.31	+0.03	64.4	62.6	60.3	-	5.0	-
09	16	2300	NNE	18.1	-	1.3	-	9	-	30.29	+0.04	64.9	62.6	59.9	-	11.0	-
09	16	2200	NNE	14.0	-	1.6	-	8	-	30.29	+0.05	64.9	62.6	60.1	-	5.0	-
09	16	2100	NE	8.9	-	1.6	-	8	-	30.28	+0.04	64.2	63.0	60.1	-	2.0	-

Sandettie Light Vessel

Previous observations

MM	DD	TIME (GMT)	WDIR	WSPD kts	GST kts	WVHT ft	DPD sec	APD sec	MWD	PRES in	PTDY in	ATMP °F	WTMP °F	DEWP °F	SAL psu	VIS nmi	TIDE ft
09	17	1900	NE	22.0	-	3.3	-	5	-	30.29	-0.02	63.5	64.4	50.9	-	11.0	-
09	17	1800	NE	21.0	-	3.3	-	6	-	30.29	-0.04	62.8	64.6	49.6	-	27.0	-
09	17	1700	NE	22.0	-	3.3	-	6	-	30.29	-0.04	62.1	64.8	52.0	-	11.0	-
09	17	1600	NNE	22.9	-	3.9	-	6	-	30.32	-0.04	61.7	64.8	50.5	-	11.0	-
09	17	1500	NE	24.1	-	3.9	-	6	-	30.32	-0.04	62.2	64.8	49.8	-	11.0	-
09	17	1400	NE	24.1	-	3.6	-	6	-	30.34	-0.04	61.3	64.6	50.0	-	11.0	-
09	17	1300	ENE	22.9	-	3.6	-	7	-	30.35	-0.01	61.3	64.8	50.2	-	11.0	-
09	17	1200	ENE	22.9	-	3.6	-	7	-	30.37	-0.01	61.3	64.6	51.1	-	11.0	-
09	17	1100	ENE	25.1	-	3.9	-	6	-	30.38	-0.00	61.3	64.2	52.5	-	11.0	-
09	17	1000	NE	25.1	-	3.9	-	6	-	30.37	+0.00	61.0	64.0	51.1	-	11.0	-
09	17	0900	ENE	28.0	-	4.3	-	6	-	30.38	+0.02	61.0	64.0	50.4	-	11.0	-
09	17	0800	NE	26.0	-	3.9	-	6	-	30.38	+0.03	61.2	64.2	51.3	-	11.0	-
09	17	0700	NE	25.1	-	3.9	-	6	-	30.37	+0.03	61.2	64.2	51.6	-	11.0	-
09	17	0600	NE	20.0	-	3.9	-	6	-	30.36	+0.01	61.2	64.4	52.2	-	11.0	-
09	17	0500	NE	21.0	-	4.6	-	6	-	30.35	-0.01	61.5	64.4	52.7	-	11.0	-
09	17	0400	NE	21.0	-	4.9	-	6	-	30.34	-0.01	60.1	64.6	51.8	-	5.0	-
09	17	0300	NE	25.1	-	4.9	-	6	-	30.35	-0.01	62.2	64.6	54.0	-	11.0	-
09	17	0200	NE	27.0	-	4.9	-	7	-	30.37	+0.01	62.4	64.4	54.5	-	5.0	-
09	17	0100	NE	24.1	-	4.6	-	7	-	30.35	+0.03	63.0	64.4	55.8	-	5.0	-
09	17	0000	NE	26.0	-	4.9	-	7	-	30.36	+0.05	62.4	64.4	55.9	-	5.0	-
09	16	2300	NE	25.1	-	4.9	-	6	-	30.35	+0.05	63.0	64.4	57.2	-	5.0	-
09	16	2200	ENE	25.1	-	5.2	-	6	-	30.32	+0.05	63.0	64.4	58.1	-	5.0	-
09	16	2100	NE	24.1	-	4.6	-	5	-	30.31	+0.06	61.7	64.6	57.4	-	5.0	-
09	16	2000	NNE	22.0	-	3.9	-	5	-	30.29	+0.06	63.7	64.8	59.5	-	5.0	-