



## Wideband HF Channel Availability – Measurement Techniques and Results

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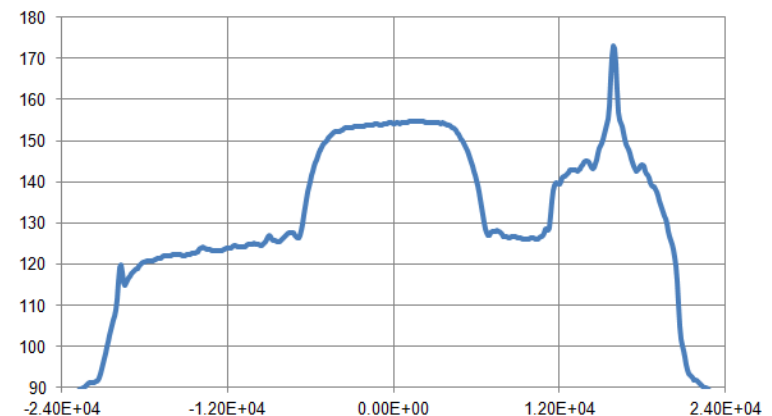
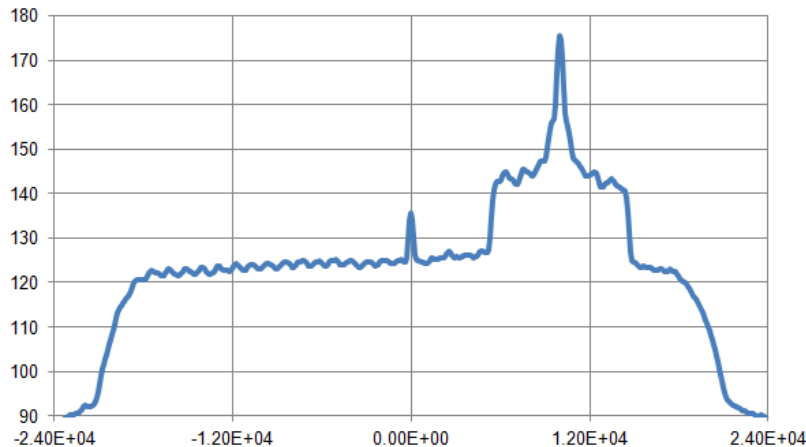
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- Background / Goals
- Channel Availability measurement System
- Data collection software / Analysis Methodology
- Results to Date
- Conclusions and Future Work
- Acknowledgements

- Updated U.S. MIL-STD 188-110C defines a Wideband HF suite of modem waveforms using bandwidths from 3-24 kHz, providing user throughputs of 75 through 120000 bps
- Automated “Cognitive” HF systems must, in addition to finding the best channel to use, determine the available bandwidth, which may not be the same as the allocated bandwidth



- Harris developed an Inexpensive system that could be easily fielded to measure Wideband HF channel availability, this approach to measurement and analysis presented in a Nordic HF13 Conference paper
  - System is passive, monitors received noise and interference
- Wideband HF of great interest to users, industry, and Governments.
  - Two major approaches
    - US Mil STD is a variable Contiguous Bandwidth scheme
    - France (Thales) developing a multi 3kHz channel approach
    - Both systems are impacted by the availability of HF channels
- HF Industry Association (HFIA) decided to create a working group to field measurement systems around the world, collect and analyze the data

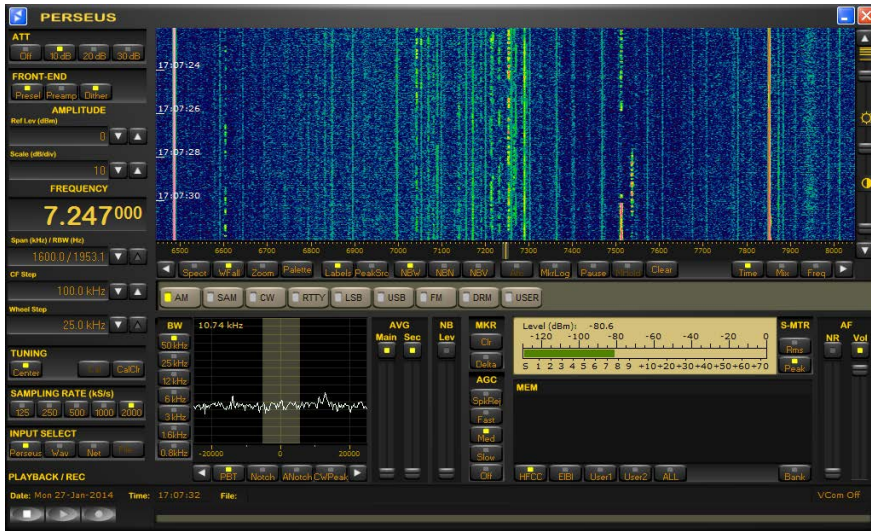
# Goals of the HFIA Wideband HF Channel Availability Working Group

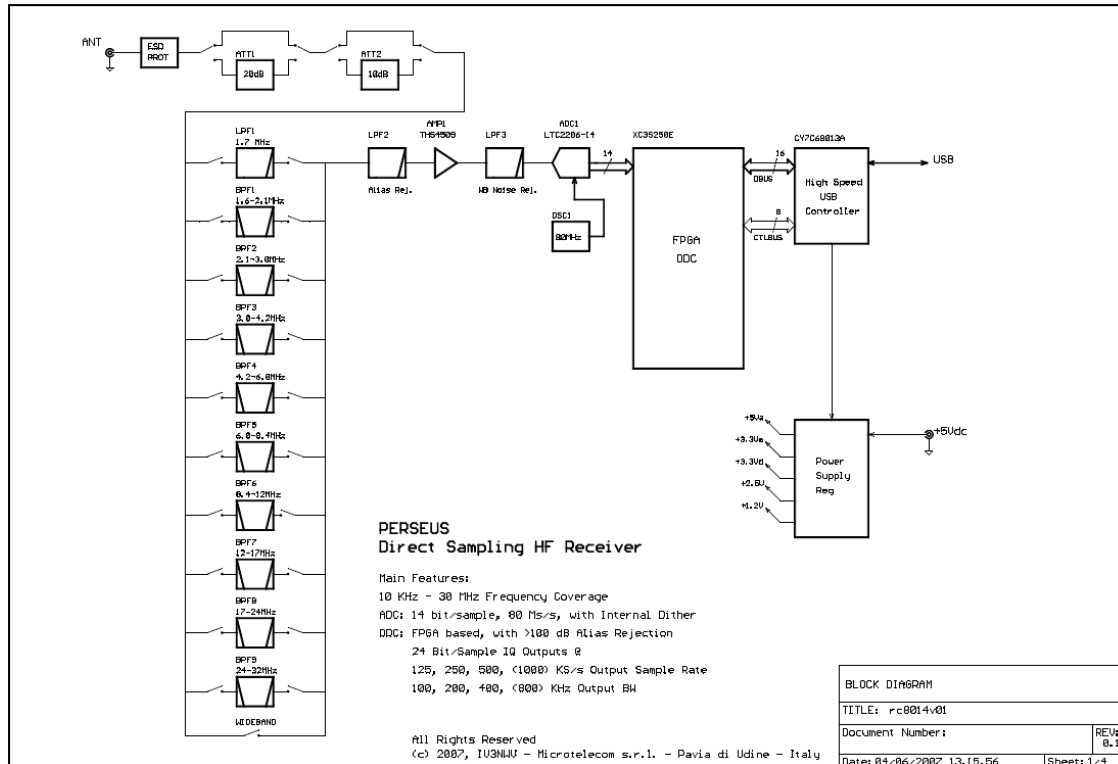


- Field a substantial number of HF wideband channel availability measurement stations in diverse locations worldwide
- Use common hardware, (SDR and antenna), collection software, and analysis software so that results can be easily and accurately compared between all sites
- Share the collected data and analysis results among all members of the HFIA
- Begin testing as soon as possible
- Present and compare results at HFIA Working Group meetings



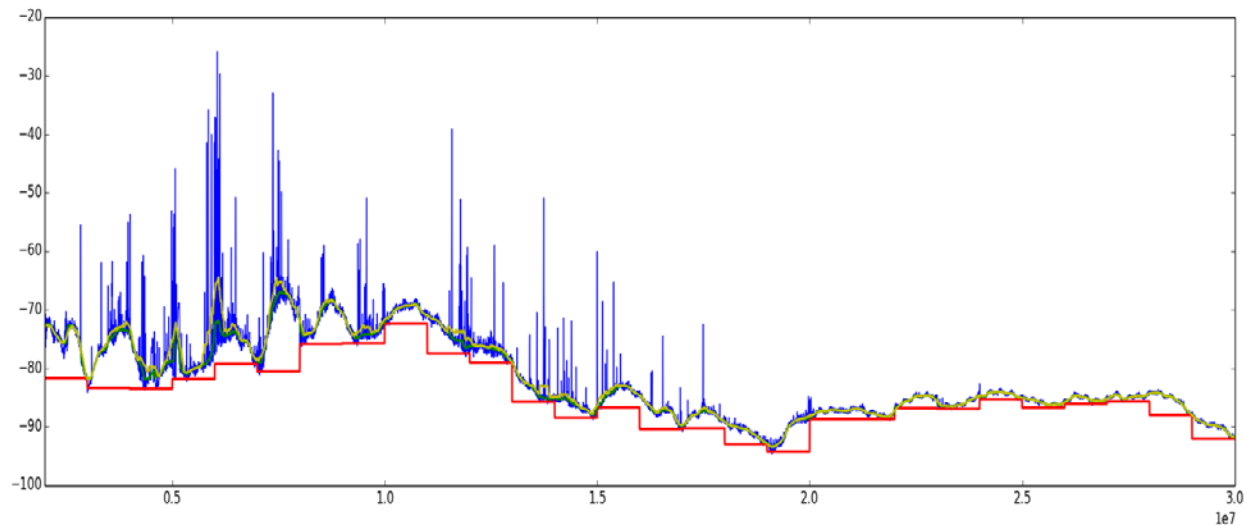
# Channel Availability Measurement System





- High Level Overview:
- Set LO to 2.5 to MHz
- Set pre-selector
- Set sample-rate= 2 Ms/s
- Gather USB samples
- Use a 4096 pt FFT
- Kaiser Window
- FFT Bin = 488.28125 Hz
- Average 488-(1 sec)
- Store off “middle” 2048 pts representing LO-0.5 MHz to LO+0.5Mhz
- Increase LO by 1.0 MHz
- Repeat
- 2-30MHz in 30 secs
- Repeat every 60 seconds

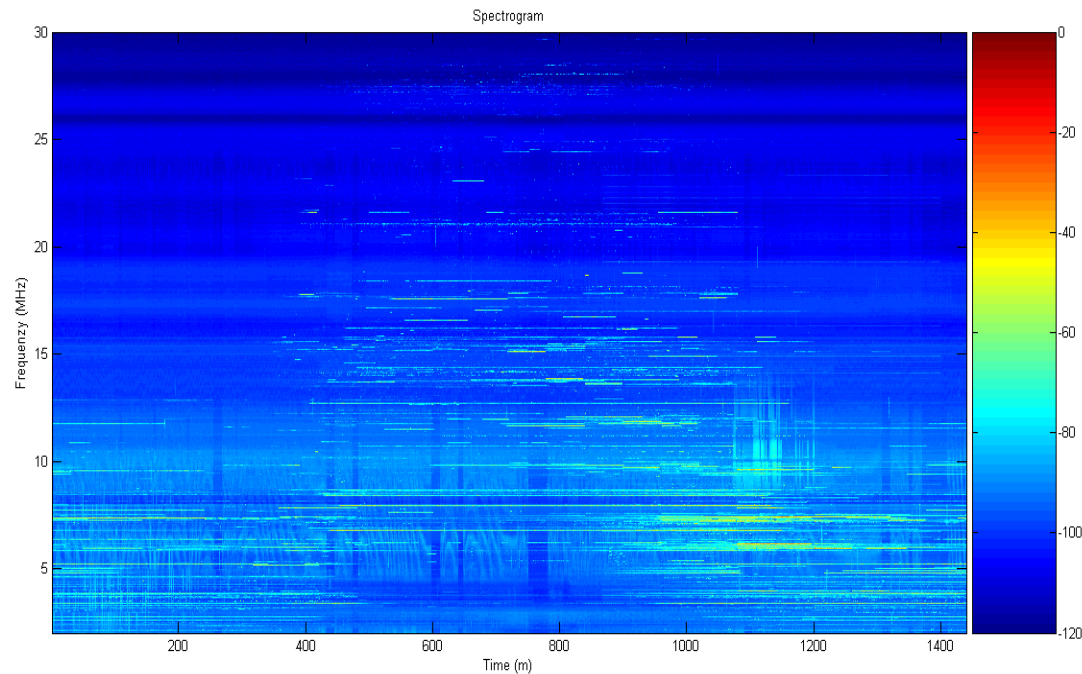
- Each sweep observation file processed in 1 MHz segments
- Measured RX power divided into 3 kHz bins
- A noise floor is calculated by median filtering the spectrum
- For each 3 kHz bin, if the RX power was 10dB above the noise floor it was considered occupied-unavailable
- Each sweep observation file converted to 9334 values, (1,0) indicating if that 3 kHz segment was occupied





- If a specific 3 kHz bin was available for 3 observations in a row it was considered available for the current minute - Channel Minute Availability (CMA)
- This biases the availability to channels that are relatively unused for a few minutes and not experiencing sporadic use or interference (Good for tactical messaging)
- CMA is a good best case metric which assumes all channels equally available and a low overhead adaptive wideband HF ALE system
- For each 3 KHz bin, it could have up to 60 available minutes in an hour.
- For each 1 MHz segment there can be a total of  $60 * 1000000 / 3000 = 19980$  (3 kHz)
- Results displayed as a normalized CMA ( 0.0 – 1.0)
- Processing repeated for any bandwidth of interest ( 6-48kHz)

- Spectrogram of “raw” measured data
- Hønefoss in southern Norway [3]
- The expected frequency rise during mid-day is easy to see as are some bands of light interference. At approximately 1100 minutes and centered at 10 MHz there is a portion of higher channel usage.





# Results to Date III



- Results of data collected by Thales in Belgium [12].
- CMA obtained for both 3 kHz and 24 kHz channel availability.
- As expected as wider bandwidth channels are required, the overall channel availability diminishes due to interferers which leave less contiguous unused bandwidth.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
0	0.72	0.63	0.60	0.64	0.66	0.60	0.87	0.58	0.98	0.91	0.97	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	0.71	0.64	0.56	0.65	0.64	0.59	0.86	0.55	0.95	0.86	0.95	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	0.69	0.62	0.54	0.66	0.63	0.61	0.87	0.62	0.94	0.86	0.95	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	0.69	0.63	0.57	0.61	0.64	0.64	0.88	0.65	0.91	0.88	0.97	0.99	0.99	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	0.72	0.66	0.58	0.61	0.63	0.66	0.89	0.66	0.93	0.87	0.97	0.97	0.99	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	0.73	0.67	0.57	0.66	0.65	0.68	0.90	0.66	0.96	0.92	0.97	0.97	0.99	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	0.72	0.66	0.63	0.62	0.68	0.69	0.90	0.72	0.95	0.92	0.97	0.95	0.98	0.88	1.00	0.97	1.00	0.91	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	0.70	0.64	0.72	0.72	0.70	0.73	0.82	0.74	0.94	0.87	0.94	0.88	0.89	0.72	0.97	0.80	0.99	0.86	0.99	0.95	0.99	0.99	1.00	0.99	0.99	0.99	1.00	1.00
8	0.68	0.63	0.73	0.77	0.66	0.68	0.73	0.71	0.87	0.74	0.84	0.77	0.79	0.64	0.91	0.75	0.95	0.94	0.96	0.96	0.98	0.99	0.99	0.97	0.91	0.94	0.98	0.98
9	0.73	0.73	0.73	0.79	0.71	0.65	0.72	0.68	0.83	0.67	0.81	0.71	0.71	0.63	0.86	0.71	0.90	0.92	0.92	0.90	0.96	0.94	0.97	0.97	0.86	0.84	0.95	0.98
10	0.77	0.76	0.75	0.81	0.75	0.65	0.74	0.69	0.81	0.73	0.80	0.70	0.71	0.63	0.88	0.68	0.90	0.92	0.92	0.88	0.94	0.94	0.96	0.96	0.87	0.83	0.96	0.99
11	0.87	0.86	0.78	0.81	0.78	0.73	0.76	0.72	0.84	0.75	0.75	0.67	0.71	0.66	0.88	0.66	0.90	0.92	0.92	0.89	0.94	0.97	0.95	0.96	0.85	0.84	0.94	0.98
12	0.87	0.78	0.80	0.87	0.79	0.72	0.76	0.68	0.83	0.68	0.73	0.65	0.73	0.65	0.86	0.69	0.88	0.91	0.90	0.87	0.91	0.95	0.93	0.96	0.84	0.82	0.94	0.95
13	0.92	0.78	0.81	0.87	0.80	0.74	0.77	0.56	0.83	0.62	0.73	0.67	0.75	0.65	0.87	0.66	0.88	0.92	0.91	0.83	0.93	0.96	0.93	0.96	0.83	0.81	0.94	0.95
14	0.80	0.74	0.76	0.87	0.77	0.67	0.74	0.44	0.82	0.56	0.69	0.63	0.73	0.60	0.87	0.70	0.89	0.93	0.92	0.82	0.93	0.93	0.93	0.96	0.81	0.73	0.90	0.99
15	0.88	0.78	0.77	0.77	0.68	0.54	0.72	0.42	0.83	0.57	0.71	0.64	0.72	0.64	0.89	0.69	0.89	0.96	0.96	0.85	0.96	0.99	0.96	0.98	0.93	0.86	0.94	0.99
16	0.82	0.78	0.70	0.65	0.51	0.46	0.68	0.34	0.85	0.63	0.71	0.66	0.75	0.61	0.93	0.79	0.93	0.96	0.98	0.92	0.99	0.99	0.98	0.99	0.99	0.97	0.99	1.00
17	0.76	0.72	0.70	0.67	0.51	0.42	0.71	0.37	0.86	0.66	0.79	0.66	0.83	0.64	0.94	0.90	0.98	0.99	1.00	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	0.73	0.64	0.67	0.69	0.58	0.50	0.76	0.40	0.93	0.74	0.87	0.80	0.94	0.78	0.98	0.93	0.99	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	0.74	0.51	0.64	0.67	0.57	0.46	0.70	0.42	0.94	0.74	0.90	0.91	0.96	0.86	0.97	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	0.73	0.53	0.64	0.70	0.63	0.54	0.80	0.51	0.97	0.88	0.98	0.98	0.97	0.96	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	0.69	0.53	0.67	0.74	0.69	0.63	0.85	0.66	0.98	0.93	0.99	0.99	0.98	0.99	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	0.73	0.52	0.66	0.73	0.67	0.59	0.84	0.64	0.99	0.92	1.00	1.00	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
23	0.70	0.55	0.62	0.70	0.65	0.62	0.85	0.59	0.98	0.89	0.98	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
0	0.48	0.26	0.28	0.38	0.45	0.39	0.73	0.30	0.94	0.79	0.91	0.96	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
1	0.48	0.27	0.24	0.35	0.42	0.41	0.73	0.33	0.90	0.68	0.87	0.98	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
2	0.43	0.25	0.26	0.37	0.40	0.39	0.75	0.38	0.89	0.70	0.88	0.96	0.99	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
3	0.43	0.26	0.26	0.33	0.41	0.39	0.76	0.42	0.84	0.73	0.93	0.94	0.99	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
4	0.50	0.31	0.24	0.29	0.41	0.41	0.74	0.34	0.85	0.71	0.95	0.90	0.98	0.90	0.99	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	
5	0.49	0.36	0.24	0.34	0.40	0.45	0.75	0.44	0.90	0.82	0.94	0.92	0.99	0.93	0.98	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	
6	0.48	0.33	0.35	0.34	0.43	0.44	0.78	0.50	0.88	0.81	0.94	0.89	0.95	0.71	0.99	0.92	1.00	0.89	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.99	
7	0.41	0.26	0.45	0.47	0.40	0.43	0.62	0.53	0.85	0.71	0.86	0.72	0.74	0.49	0.93	0.66	0.98	0.83	0.98	0.90	0.99	0.99	1.00	0.99	0.97	0.96	0.99	
8	0.40	0.23	0.43	0.49	0.33	0.38	0.46	0.38	0.67	0.50	0.58	0.53	0.52	0.37	0.77	0.58	0.86	0.87	0.88	0.89	0.96	0.98	0.98	0.95	0.83	0.81	0.94	0.98
9	0.45	0.39	0.37	0.51	0.39	0.37	0.42	0.28	0.59	0.36	0.57	0.45	0.40	0.33	0.67	0.49	0.76	0.83	0.80	0.79	0.90	0.88	0.94	0.91	0.65	0.56	0.88	0.98
10	0.45	0.45	0.37	0.54	0.46	0.36	0.44	0.33	0.54	0.44	0.51	0.43	0.42	0.33	0.72	0.47	0.79	0.83	0.85	0.74	0.87	0.88	0.93	0.88	0.67	0.55	0.86	0.98
11	0.67	0.72	0.47	0.64	0.50	0.51	0.46	0.35	0.61	0.45	0.43	0.38	0.43	0.38	0.72	0.42	0.79	0.83	0.84	0.74	0.90	0.94	0.91	0.87	0.65	0.56	0.83	0.97
12	0.72	0.69	0.50	0.70	0.58	0.48	0.48	0.29	0.62	0.37	0.41	0.39	0.46	0.36	0.69	0.45	0.78	0.81	0.80	0.73	0.82	0.91	0.88	0.89	0.63	0.51	0.85	0.93
13	0.80	0.65	0.54	0.71	0.57	0.43	0.51	0.22	0.59	0.29	0.46	0.41	0.49	0.38	0.68	0.45	0.77	0.82	0.83	0.64	0.87	0.94	0.89	0.87	0.63	0.52	0.82	0.93
14	0.52	0.50	0.43	0.69	0.47	0.38	0.44	0.16	0.57	0.31	0.41	0.34	0.45	0.32	0.65	0.54	0.78	0.86	0.82	0.65	0.84	0.90	0.87	0.88	0.55	0.37	0.75	0.99
15	0.71	0.62	0.48	0.51	0.33	0.31	0.43	0.15	0.59	0.34	0.42	0.34	0.48	0.39	0.71	0.48	0.78	0.90	0.88	0.71	0.91	0.98	0.91	0.95	0.80	0.62	0.85	0.99
16	0.63	0.53	0.32	0.38	0.16	0.27	0.40	0.13	0.63	0.36	0.42	0.39	0.53	0.37	0.79	0.61	0.85	0.91	0.94	0.81	0.97	0.99	0.96	0.98	0.97	0.88	0.96	1.00
17	0.50	0.47	0.31	0.37	0.12	0.25	0.43	0.15	0.69	0.41	0.56	0.45	0.67	0.44	0.84	0.76	0.95	0.98	0.99	0.89	1.00	1.00	1.00	1.00	1.00	0.98	0.97	0.99
18	0.49	0.38	0.30	0.42	0.33	0.32	0.55	0.21	0.85	0.54	0.66	0.62	0.86	0.57	0.95	0.80	0.99	1.00	1.00	0.97	1.00	1.00	1.00	1.00	1.00	0.98	0.99	1.00
19	0.49	0.23	0.31	0.43	0.30	0.27	0.45	0.25	0.84	0.56	0.76	0.77	0.90	0.68	0.87	0.95	0.90	0.96	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.97	1.00	1.00
20	0.47	0.22	0.31	0.45	0.40	0.35	0.66	0.26	0.93	0.73	0.93																	

# Results to Date IV



- Results of data collected by the working group is provided by Babcock [13]
- Data was collected at their Forest Moor site in Yorkshire, UK using a conical wideband RX antenna.
- This data again shows the expected time of day variations of channel utilization including the lack of lower frequency propagation during the day, and the corresponding increased use of these frequencies during the evening hours as well as wide availability of the higher frequencies.
- Highlights the need of spatially diverse measurement locations in order to capture channel occupancy otherwise missed due to the realities of HF propagation.
- One interesting segment shows some channel utilization, during the day in the 26-28 MHz band. This could possibly be some Citizens band or Land Mobile radio utilization.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
0	0.61	0.36	0.34	0.49	0.34	0.37	0.58	0.27	0.76	0.64	0.83	0.91	0.96	0.92	0.95	0.99	0.99	1.00	0.98	0.99	0.98	0.99	0.99	1.00	0.98	0.98	0.99	1.00
1	0.59	0.40	0.29	0.48	0.34	0.41	0.56	0.28	0.75	0.58	0.85	0.88	0.96	0.93	0.96	0.98	0.99	1.00	0.98	0.99	0.99	0.99	0.98	1.00	0.98	0.99	0.99	1.00
2	0.57	0.41	0.32	0.51	0.37	0.43	0.56	0.35	0.80	0.52	0.82	0.89	0.96	0.88	0.96	0.97	0.99	1.00	0.98	0.99	0.98	0.99	0.98	1.00	0.98	0.99	0.99	1.00
3	0.58	0.44	0.37	0.48	0.41	0.42	0.56	0.46	0.85	0.64	0.86	0.91	0.96	0.90	0.96	0.99	0.99	1.00	0.98	0.99	0.98	0.99	0.99	1.00	0.98	0.99	0.99	1.00
4	0.56	0.42	0.34	0.49	0.39	0.44	0.57	0.43	0.80	0.62	0.94	0.94	0.96	0.94	0.96	0.99	0.99	1.00	0.98	0.98	0.98	0.99	0.98	1.00	0.98	0.99	0.99	1.00
5	0.58	0.48	0.39	0.44	0.38	0.43	0.51	0.39	0.72	0.68	0.88	0.87	0.95	0.87	0.96	0.98	0.99	0.99	0.98	0.99	0.99	0.99	0.98	1.00	0.98	0.99	0.99	1.00
6	0.61	0.53	0.41	0.48	0.38	0.42	0.56	0.54	0.74	0.67	0.83	0.79	0.89	0.69	0.95	0.89	0.99	0.99	0.97	0.99	0.99	0.99	0.98	1.00	0.98	0.99	0.99	1.00
7	0.58	0.54	0.43	0.55	0.39	0.44	0.60	0.59	0.77	0.64	0.81	0.66	0.73	0.56	0.86	0.68	0.97	0.97	0.95	0.91	0.98	0.99	0.99	1.00	0.97	0.96	0.99	1.00
8	0.60	0.57	0.45	0.62	0.35	0.50	0.59	0.53	0.69	0.49	0.61	0.60	0.54	0.54	0.80	0.63	0.92	0.97	0.94	0.88	0.95	0.98	0.96	0.98	0.92	0.80	0.95	1.00
9	0.61	0.69	0.53	0.64	0.32	0.55	0.60	0.48	0.69	0.47	0.60	0.57	0.48	0.53	0.77	0.65	0.86	0.92	0.87	0.84	0.92	0.97	0.95	0.91	0.68	0.55	0.87	0.99
10	0.65	0.82	0.58	0.70	0.34	0.58	0.62	0.50	0.66	0.48	0.60	0.56	0.54	0.51	0.76	0.57	0.84	0.92	0.92	0.80	0.91	0.96	0.91	0.91	0.66	0.39	0.82	0.98
11	0.79	0.87	0.59	0.81	0.44	0.63	0.63	0.49	0.64	0.50	0.55	0.55	0.58	0.52	0.75	0.54	0.86	0.92	0.92	0.79	0.89	0.96	0.85	0.88	0.55	0.27	0.75	0.97
12	0.78	0.90	0.65	0.82	0.48	0.66	0.65	0.47	0.65	0.47	0.58	0.53	0.57	0.52	0.69	0.57	0.85	0.94	0.91	0.77	0.92	0.97	0.88	0.91	0.60	0.31	0.77	0.98
13	0.76	0.94	0.87	0.85	0.51	0.62	0.71	0.38	0.72	0.49	0.61	0.53	0.56	0.47	0.67	0.56	0.78	0.91	0.87	0.66	0.89	0.96	0.90	0.91	0.57	0.25	0.73	0.94
14	0.79	0.90	0.80	0.78	0.39	0.51	0.66	0.29	0.68	0.37	0.53	0.48	0.51	0.39	0.69	0.60	0.80	0.91	0.86	0.65	0.85	0.95	0.89	0.91	0.52	0.22	0.66	0.94
15	0.90	0.95	0.91	0.86	0.60	0.58	0.77	0.42	0.73	0.45	0.61	0.60	0.60	0.54	0.75	0.60	0.79	0.91	0.90	0.79	0.89	0.97	0.91	0.92	0.65	0.29	0.73	0.96
16	0.86	0.87	0.70	0.70	0.27	0.35	0.60	0.21	0.64	0.29	0.56	0.50	0.52	0.45	0.72	0.65	0.81	0.91	0.87	0.73	0.90	0.97	0.92	0.92	0.61	0.29	0.75	0.97
17	0.67	0.54	0.41	0.51	0.15	0.27	0.56	0.25	0.66	0.36	0.51	0.50	0.43	0.40	0.75	0.69	0.84	0.92	0.89	0.81	0.93	0.97	0.93	0.94	0.72	0.50	0.86	0.97
18	0.58	0.35	0.45	0.49	0.15	0.30	0.57	0.26	0.71	0.39	0.53	0.54	0.49	0.52	0.85	0.71	0.88	0.97	0.93	0.86	0.97	0.98	0.96	1.00	0.94	0.83	0.97	0.99
19	0.59	0.37	0.47	0.49	0.16	0.27	0.52	0.21	0.69	0.34	0.59	0.58	0.58	0.63	0.85	0.84	0.93	0.99	0.94	0.93	0.97	0.98	0.97	1.00	0.95	0.85	0.98	0.99
20	0.59	0.39	0.46	0.51	0.21	0.31	0.58	0.24	0.71	0.41	0.67	0.66	0.65	0.66	0.89	0.86	0.94	0.98	0.94	0.96	0.98	0.98	0.98	1.00	0.96	0.92	0.99	0.99
21	0.57	0.36	0.38	0.50	0.23	0.32	0.51	0.27	0.74	0.50	0.71	0.75	0.70	0.75	0.90	0.91	0.96	0.99	0.96	0.98	0.99	0.99	0.98	1.00	0.98	0.97	0.99	1.00
22	0.53	0.32	0.37	0.53	0.29	0.37	0.61	0.29	0.73	0.54	0.72	0.83	0.84	0.87	0.94	0.97	0.99	0.99	0.98	0.99	0.99	0.99	0.98	1.00	0.98	0.97	0.99	1.00
23	0.61	0.37	0.38	0.51	0.31	0.39	0.62	0.29	0.74	0.48	0.84	0.89	0.94	0.89	0.96	0.98	0.99	1.00	0.98	0.99	0.98	0.99	0.98	1.00	0.98	0.98	0.99	1.00



- HFIA meets every six months
- Tools and software in place
- Planned Data Collection:
  - Rockwell plans a series of measurements in Iowa, Washington (Seattle area), Las Cruces, Tampa, Brazil, Australia (two sites), Singapore, and India.
  - Harris plans to continue measurements in western New York / UK.
  - Norway is planning a series of measurements in throughout Norway.
  - Results expected from Europe as well by Thales
- Investigation Focus
  - Effects of observation times and revisit rates in the measurement system
  - Antenna deployment issues
  - Comparison of different antenna systems for measurement
  - Correlation of results with assigned HF bands
  - Use of results for performance prediction on specific links

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  - Rohde & Schwarz - Germany,
  - French Ministry of Defense (DGA),
  - Fraunhofer - Germany,
  - Babcock – UK,
  - Rockwell Collins
  - Harris Corporation – USA
- can be found on the HFIA website; [www.hfindustry.com](http://www.hfindustry.com).