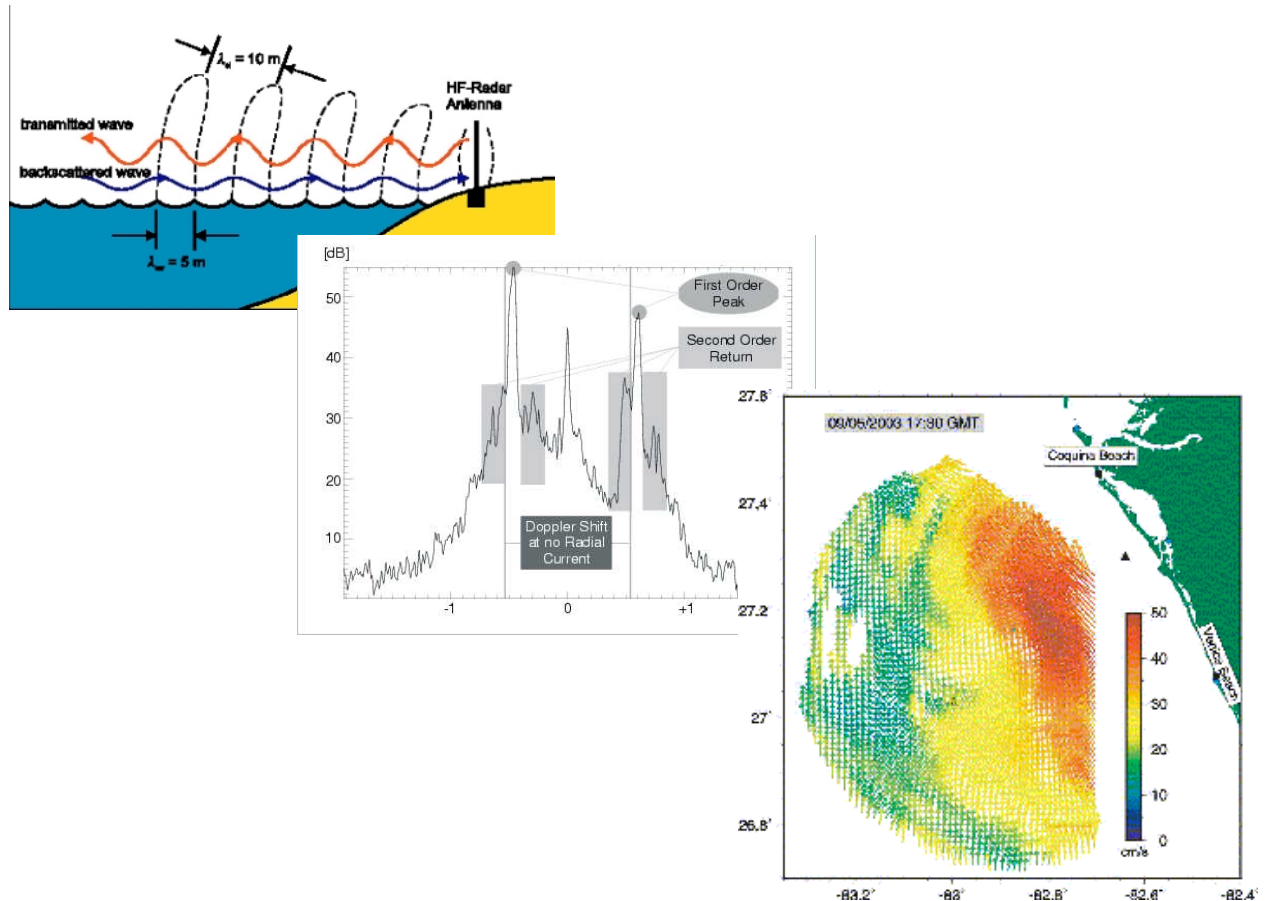


FMcw Radar "WERA"



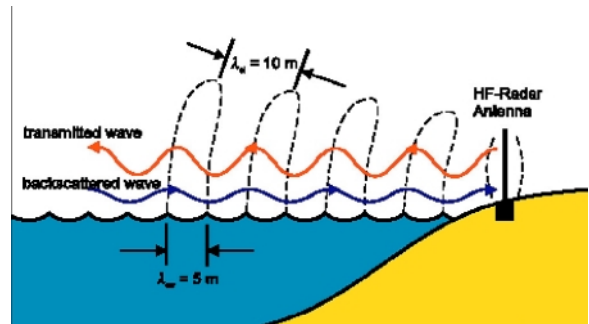
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FMcw Radar "WERA"

1. Introduction

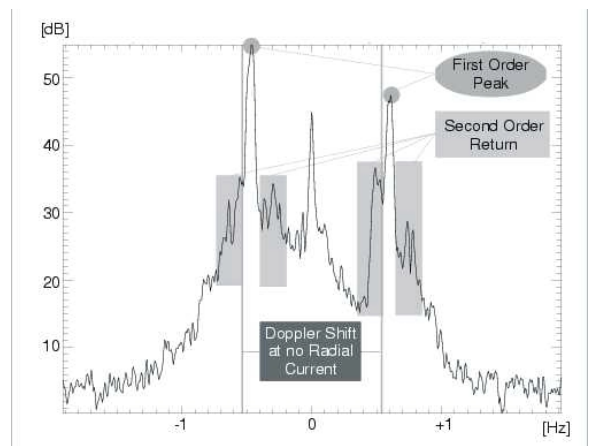
The WERA system (WavE RAdar) is a shore based remote sensing system to monitor ocean surface currents, waves and wind direction. This long range, high resolution monitoring system based on short radio wave radar technology. The vertical polarised electromagnetic wave is coupled to the conductive ocean surface and will follow the curvature of the earth.



This over the horizon oceanography radar can pick up back-scattered signals (Bragg effect) from ranges of up to 200 km.

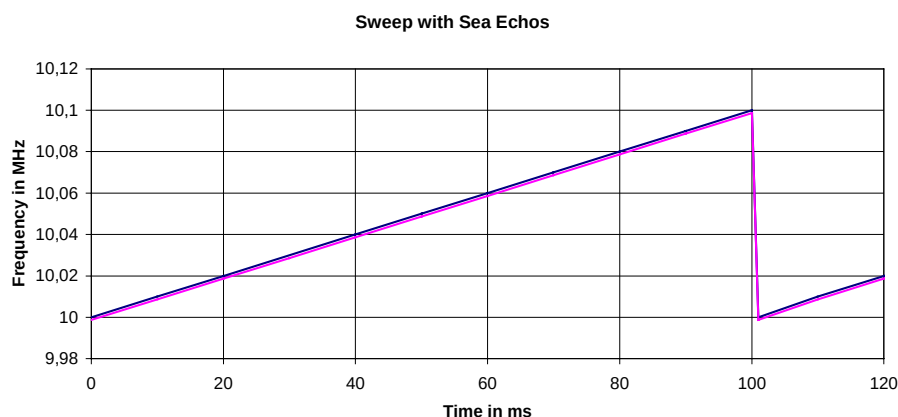
Fields of Applications:

- Long Range Ship Tracking for Home Land Security
- Vessel Traffic Services for Maritime Safety
- Search and Rescue in Case of Accidents
- Disaster Warning for Tropical Cyclons and Tsunamis
- Coastal Engineering for Offshore Constructions
- Environmental Protection for Coastal Zones



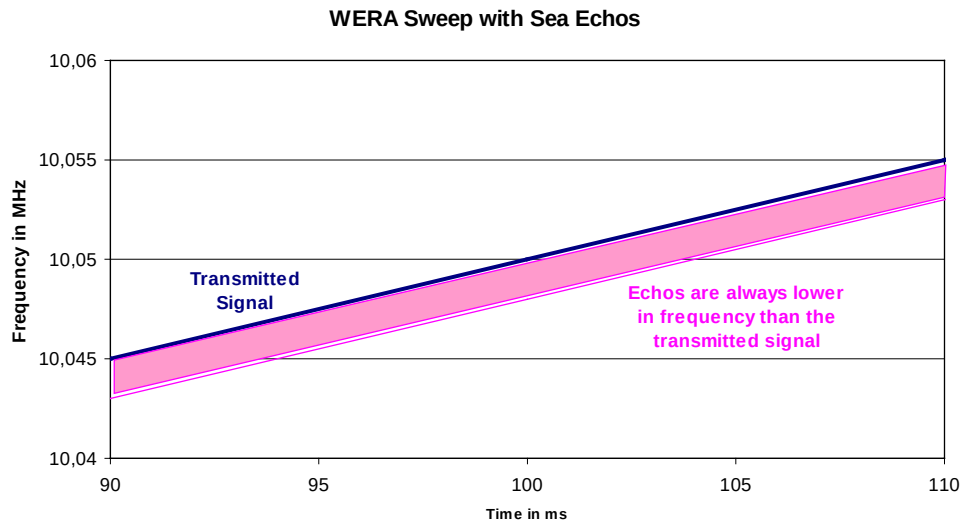
2. Operation Mode

A continuously swept rf-signal is transmitted. The reflected signal has a frequency offset compared to the actual transmitted signal.



FMcw Radar "WERA"

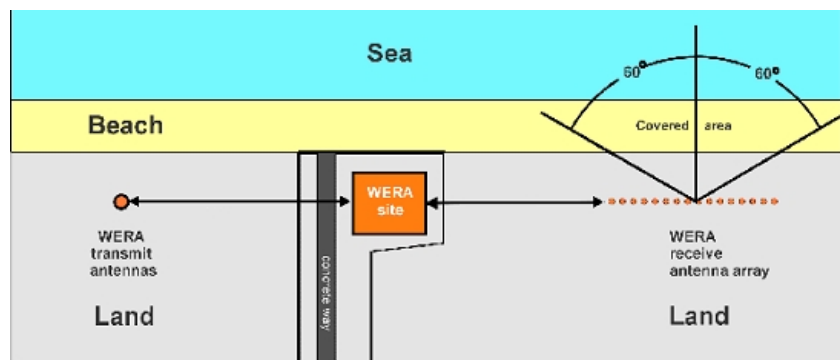
The radar is continuously transmitting with very low rf power, no gating or pulsing sequences are used.



The receiver is continuously switched on, to pick up signals from all over the defined range. These systems provide best signal to noise performance due to the extreme low noise FMcw transmission mode.

- + No gating results in a **clean radio spectrum**
- + **No self generated noise** within the used band
- + **Very low noise** outside the used band
and almost no interference with other radio band users
- + **Low power transmitted**
e.g. results in: **range of 150 km** **@ 11 MHz**
 @ 4 Watts-cw

The required decoupling between transmitter and receiver has to be achieved by means of using separate locations for Rx and Tx antennae.



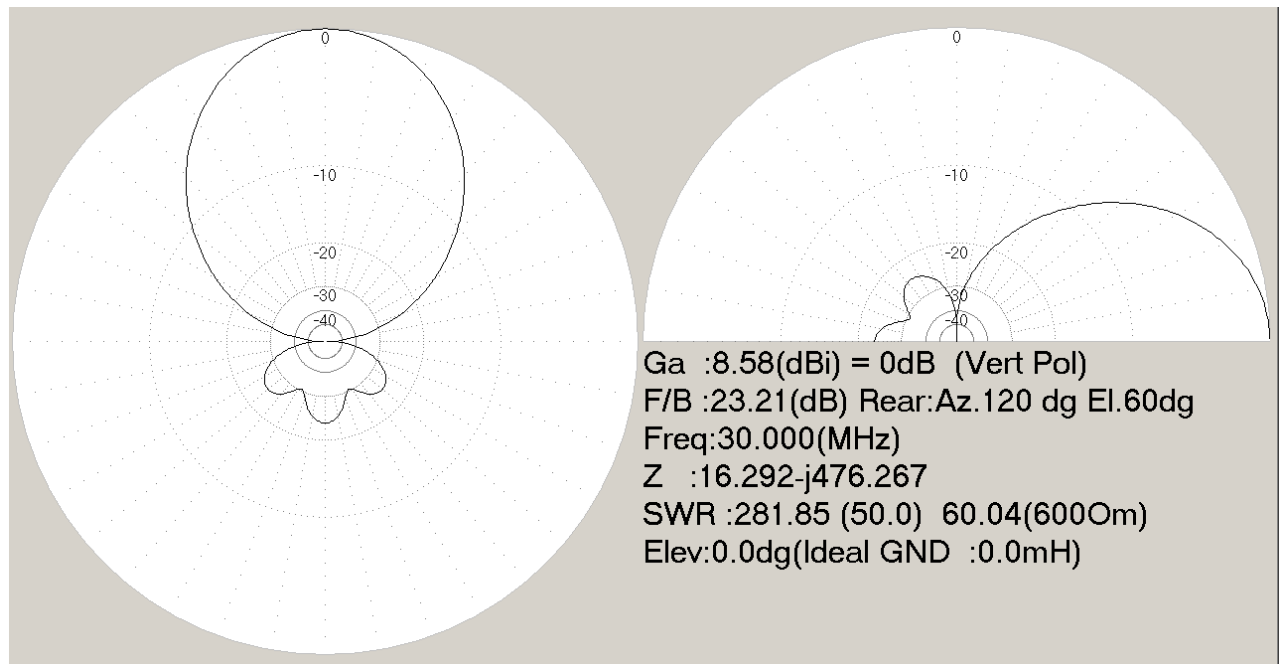
FMcw Radar "WERA"

3. Technical Specification

1. Max. amplifier output power: 30 Watts-cw
2. Antenna characteristic: vertical polarized array of 4 short mono-poles with radials
directivity 99 % towards the sea, azimuth $\pm 60^\circ$
3. Harmonic suppression: > 60 dB
4. Modulation: FM-cw with very slow sweep period of typically 0.3 sec
Bandwidth typical: 100 kHz
preferred BW > 300 kHz to allow for frequency adaptation
5. Automatic Freq. Selection: The system will scan the allocated band to find a free gap
(listen before talk) for the required sweep bandwidth. The center frequency
will be adjusted to match the sweep band with the free
gap. If the gap is not wide enough, the sweep bandwidth
will be reduced, resulting in a coarser range resolution.
This frequency selection procedure will be carried out
prior to each radar cycle, typically all 10 to 30 minutes.
6. System control: Remote controlled, to be switched off immediately if a
primary license user may complain.

4. Antenna Pattern and Concept

The WERA transmit antenna array consists of 4 vertical mono-poles to generate an antenna pattern as sketched below.



FMcw Radar "WERA"

The geometrical orientation and the phase (0° and 126°) of the input signals can be derived from the input parameters of the simulator:

Name	TX-Array			Freq	30	MHz	☐ Lambda			
Wire 4	automatische Segmentation	DM1	400	DM2	40	SC	2.0	EC	1	☒ Verbindungen halten
No.	X1(m)	Y1(m)	Z1(m)	X2(m)	Y2(m)	Z2(m)	R(mm)	Seg.		
1	0.0	0.0	1.0	0.0	0.0	3.5	14.0	0		
2	0.0	5.0	1.0	0.0	5.0	3.5	14.0	0		
3	1.5	0.0	1.0	1.5	0.0	3.5	14.0	0		
4	1.5	5.0	1.0	1.5	5.0	3.5	14.0	0		
next										

Source 4				☒ Automatischer Wert	Load 4						☒ Lasten verwenden
No.	PULSE	Phase dg	Voltage	No.	PULSE	Type	L(uH)	C(pF)	Q	f(MHz)	
1	W1B	126.0	0.25	1	w1b	LC	3.0	0.0	30.0		
2	W2B	126.0	0.25	2	w2b	LC	3.0	0.0	30.0		
3	W3B	0.0	0.25	3	w3b	LC	3.0	0.0	30.0		
4	W4B	0.0	0.25	4	w4b	LC	3.0	0.0	30.0		
next				next							

This array configuration will be used to check the antenna pattern only. The distance along shore is 0.5 Lambda and perpendicular to the shore line 0.15 Lambda. The 4 elements are not tuned and matched perfectly and no radial elements are used in this simulation.

The optimization for the antenna poles is carried out with another simulation, e.g. for a 16.9 MHz system (see below).

Element # 1: Antenna pole (starting at 1.5 m above ground, 3 m long, 28 mm diameter)

Element # 2 to 4: Radials, 2.12 m long (0.12 Lambda to get good VSWR), 2 mm diameter

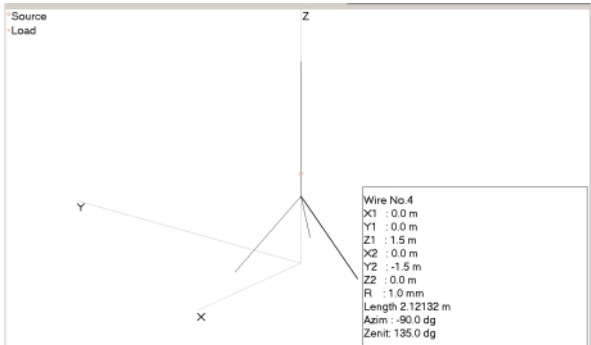
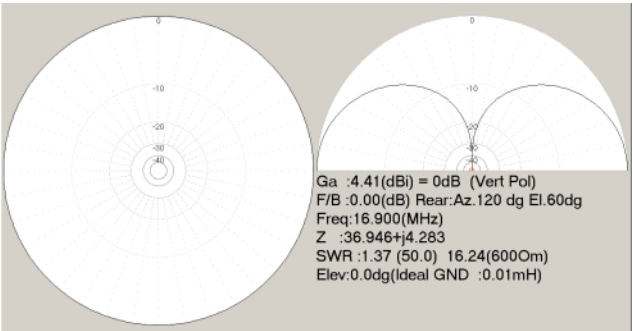
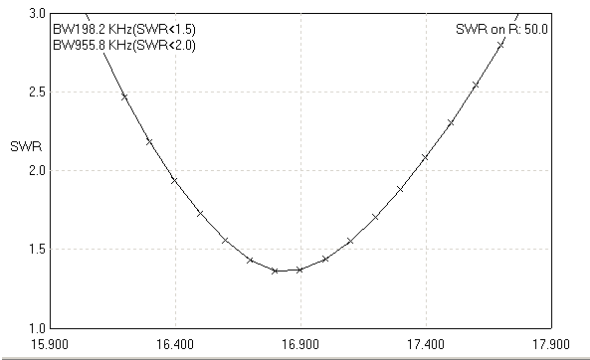
Load: Inductivity of 2.6 µH to get 0.25 Lambda electrical length

Name	Mono-3m-16MHz9-225-Rad-6508			Freq	16.900	MHz	☐ Lambda			
Wire 4	automatische Segmentation	DM1	400	DM2	40	SC	2.0	EC	1	☒ Verbindungen halten
No.	X1(m)	Y1(m)	Z1(m)	X2(m)	Y2(m)	Z2(m)	R(mm)	Seg.		
1	0.0	0.0	1.5	0.0	0.0	4.5	14.0	0		
2	0.0	0.0	1.5	1.275	0.75	0.0	1.0	0		
3	0.0	0.0	1.5	-1.275	0.75	0.0	1.0	0		
4	0.0	0.0	1.5	0.0	-1.5	0.0	1.0	0		
next										

FMcw Radar "WERA"



Source 1				Load 1						
No.	PULSE	Phase dg	Voltage	No.	PULSE	Type	L(uH)	C(pF)	Q	f(MHz)
1	w1b	0.0	1.0	1	w1b	LC	2.6	0.0	40.0	
next				next						

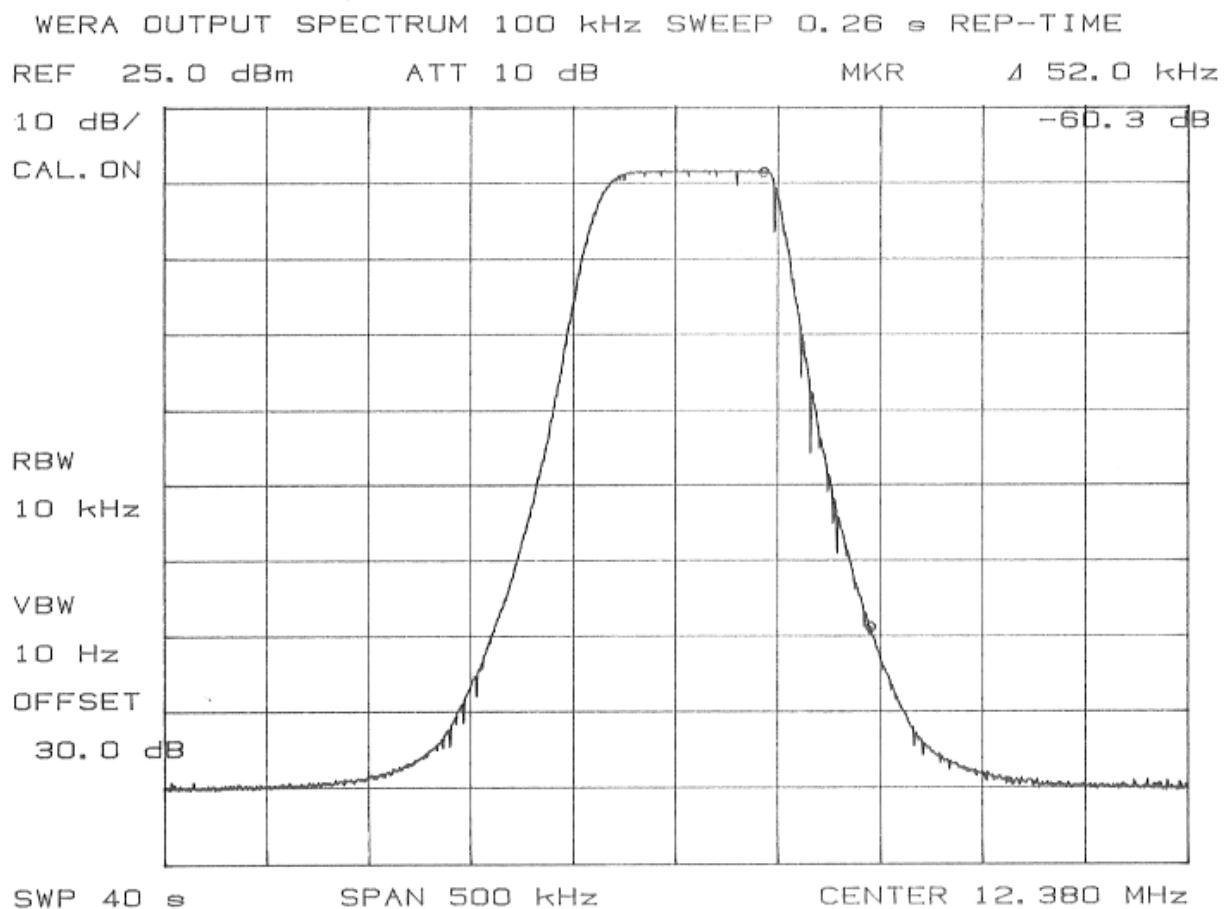


The WERA receive antenna array consists of 8 to 16 vertical mono-poles to build a linear array. Software beam forming is used to steer a beam over an angel of about +/- 60 degrees.

FMcw Radar "WERA"

5. WERA Output Spectrum

The radar signal is a very slow swept carrier. Due to the saw-tooth shape a little portion of the transmitted energy will be transferred out of the band limits of the sweep range. Due to the phase continuous switching characteristic of the direct digital synthesizer this out-band energy has a very low level. The plot below displays a spectrum of a 100 kHz sweep with the typical 260 ms repetition time. The level drops down to -60 dBc at about 50 kHz out of band limits.

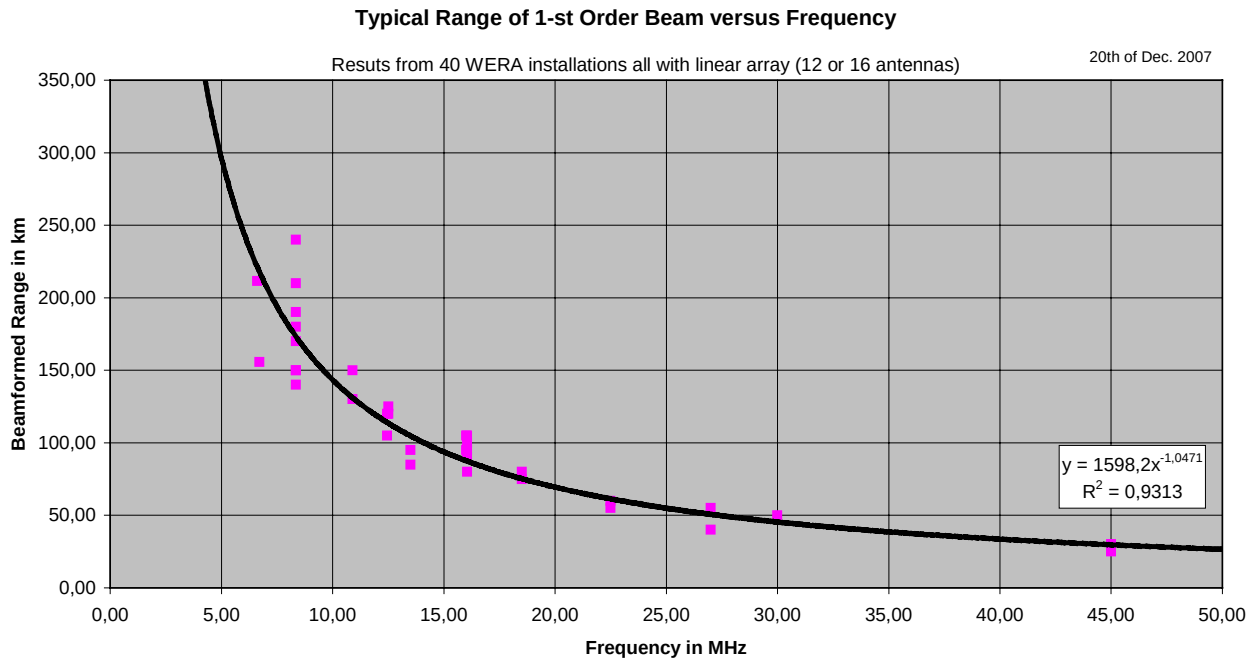


6. Listen before Talk Mode

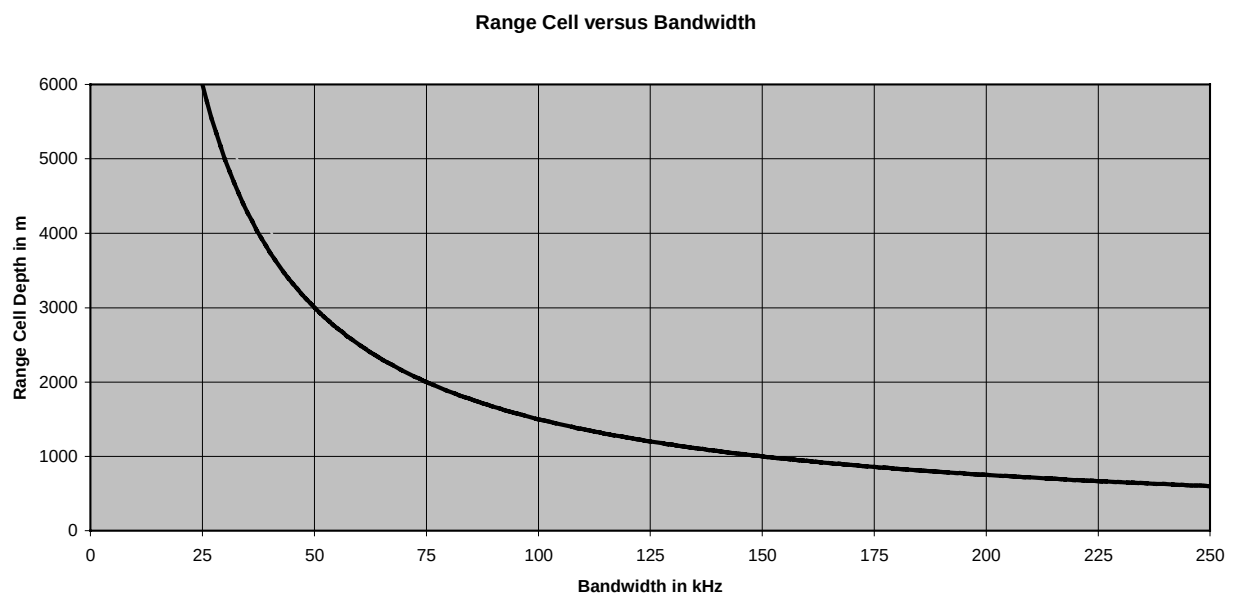
The "Listen before Talk" mode uses a frequency scan of the entire band prior to the next sweep. Within 1 minute the band is scanned 16 times with a resolution bandwidth of 1 kHz to get 16 spectra. Within this "time over frequency map" the system looks for a frequency "slot" with the required bandwidth that has a noise level below -120 dBm/Hz. If this requirement can't be fulfilled, the system looks for a smaller slot for a reduced sweep width to get at least good data with coarse spatial resolution. If no gap with this low noise condition is found, the lowest noise gap is used with the smallest possible sweep width (typically 50 kHz).

7. Limiting Factors of Bandwidth and Center Frequency

The center frequency is chosen mainly to guarantee the required operating range. Low frequencies give longer ranges.



The sweep bandwidth affects the range resolution of the system. A wider bandwidth results in a higher spatial resolution.



FMcw Radar "WERA"



8. Preferred Operating Frequencies and Bandwidth

The system users have various demands depending on their applications. The frequencies listed below are bands, where the WERA user may have a good chance to get a secondary license to operate their systems.

a) Extreme Long Range

Range: > 300 km

Application: Ship Tracking for Home Land Security and Vessel Traffic Services

Preferred Frequency: 4.1 to 4.4 MHz

Bandwidth (typical): 50 kHz

Typical Radiated Power (ERP): 80 W

Temporal Operation Mode: Continuous

(interrupted for scans to adjust frequency if required)

b) Very Long Range

Range: > 250 km

Application: Ship Tracking for Home Land Security and Vessel Traffic Services

Preferred Frequency: 6.2 to 6.5 MHz

Bandwidth (typical): 100 kHz

Typical Radiated Power (ERP): 80 W

Temporal Operation Mode: Continuous

(interrupted for scans to adjust frequency if required)

c) Long Range

Range: > 150 km

Application: Vessel traffic services, Search and Rescue, Ship Tracking

Preferred Frequency: 8.2 to 8.8 MHz

Bandwidth (typical): 100 kHz

Typical Radiated Power (ERP): 80 W

Temporal Operation Mode: 2 times 10 min per hour (continuous for ship tracking)

d) Medium Range 1

Range: > 80 km

Application: Vessel Traffic Services, Search and Rescue

Preferred Frequency: 12.2 to 13.2 MHz

Bandwidth (typical): 150 kHz

Typical Radiated Power (ERP): 80 W

Temporal Operation Mode: 2 times per hour for 10 min active

The logo for HELZEL, featuring the word "HELZEL" in a blue, sans-serif font with a stylized blue wave above it.	Document: WERA-FMcw-Radar-080623.doc	2008-06-23
	Thomas Helzel	Page 9 of 10

FMcw Radar "WERA"

e) Medium Range 2

Range: > 60 km

Application: Vessel Traffic Services, Search and Rescue

Preferred Frequency: 16.4 to 17.4 MHz

Bandwidth (typical): 150 kHz

Typical Radiated Power (ERP): 80 W

Temporal Operation Mode: 2 times per hour for 10 min active

f) Normal Range

Range: > 40 km

Application: Vessel Traffic Services, Search and Rescue, Coastal Engineering

Preferred Frequency: 22 to 22.8 MHz

Bandwidth (typical): 300 kHz

Typical Radiated Power (ERP): 80 W

Temporal Operation Mode: 2 times per hour for 10 min active

g) Short Range

Range: > 30 km

Application: Vessel Traffic Services, Search and Rescue, Coastal Engineering

Preferred Frequency: 43.7 to 46.6 MHz

Bandwidth (typical): 1000 kHz

Typical Radiated Power (ERP): 80 W

Temporal Operation Mode: 2 times per hour for 10 min active

Summary

The modern coastal radars can be used for various, valuable applications. The required technical demands are:

- Low transmitted power (< 100 W-ERP)
- Directive transmitting antenna (focus towards the ocean)
- Operation in low noise mode (FMcw)
- Listen before talk mode can be used

Depending on application:

- Operating band 4 to 50 MHz
- Required bandwidth from 50 to 1000 kHz