3rd ROS Workshop – NURC – La Spezia, Italy – 11,13 Octobre 2011

High Resolution Surface Currents Mapping using Direction Finding Method in Bistatic HF Radar Configuration: A Good Match

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And whether a man dispassionately
Sees to the core of life
Or passionately
Sees the surface
The core and the surface
Are essentially the same......

....From wonder into wonder
Existence opens.

The Way of Life, according to Lao Tzu

High Resolution Surface Currents Mapping using Direction Finding Method in Bistatic HF Radar Configuration : Summary

Current speed measurement is deduced from the doppler shift of the proeminent doppler Bragg lines.This process needs the knowledge of the Direction of the Bragg waves BWD, and of the Bragg waves Doppler frequency (pair) BWDF0 in the absence of surface current.

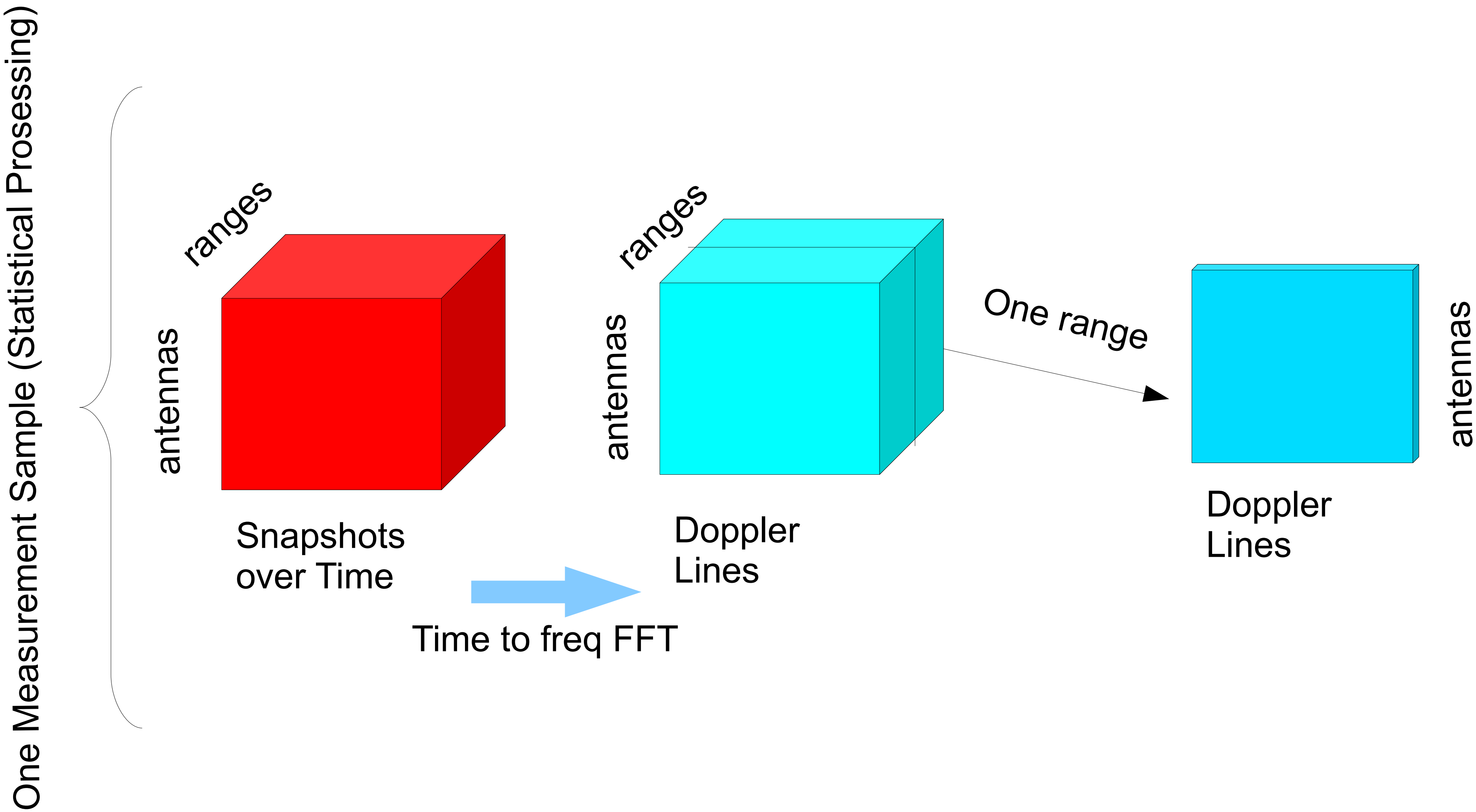
In MONOSTATIC mode, Direction BWD is radial, and BWDF0 is constant over all ranges and all bearings.

In BISTATIC configuration, BWD and BWDF0 depend on range, and vary very fastly with bearing at short ranges. As a consequence, the efficient omnidirectional BW doppler bandwidth widens.

1/ a High Azimutal Resolution Radar encompasses the needed bearing accuracy.

2/ the Direction Finding (DF) algo. benefits from this widening as it finds more doppler lines to process, yielding more sources and filling more bearings, even when the current map is flat and weak (the situation in which the monostatic DF radar fails to directly give a useful coverage).

Common First Processing Stages of Oceanographic Radar Signals



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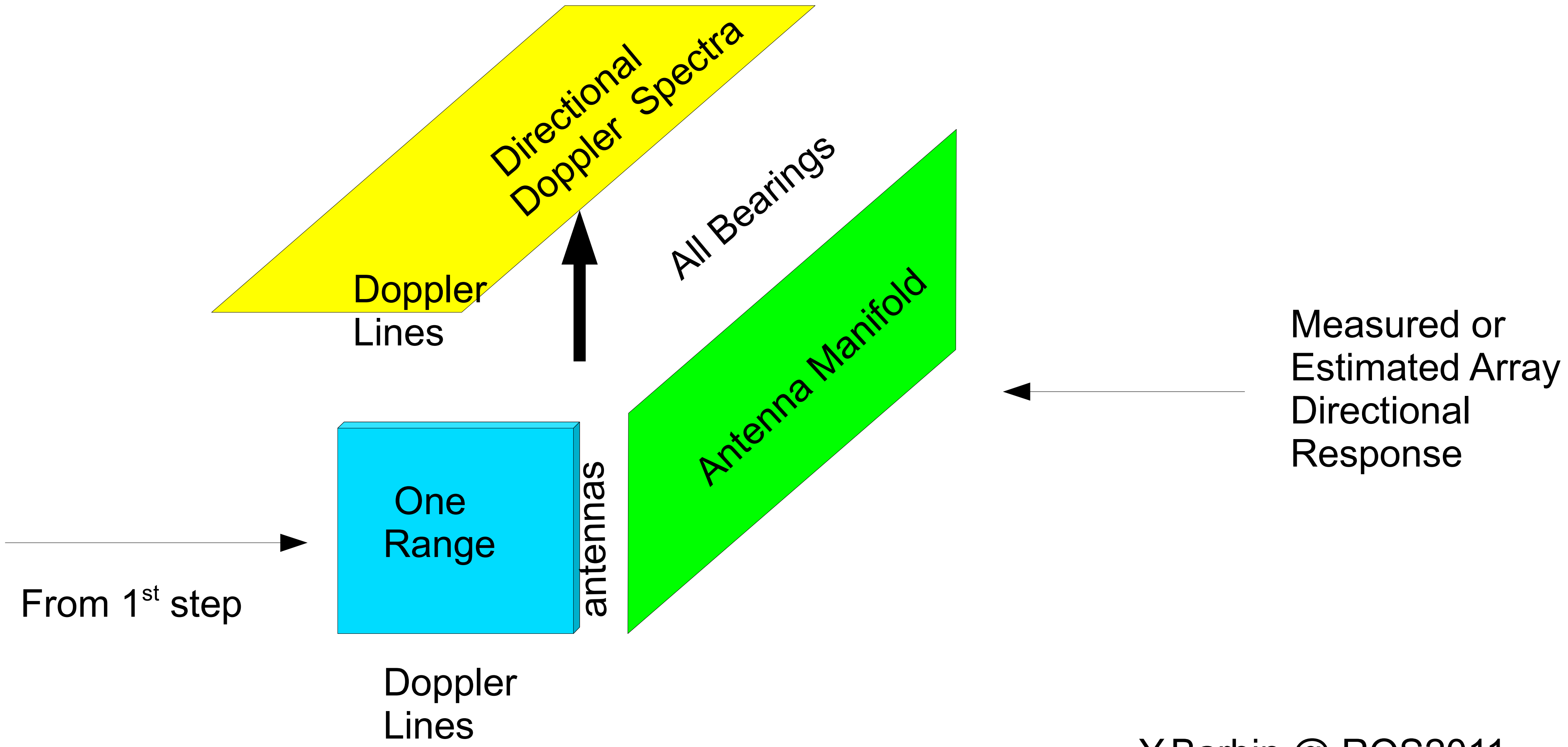
Beam Forming (Step1):
Getting the Directional Doppler Spectra



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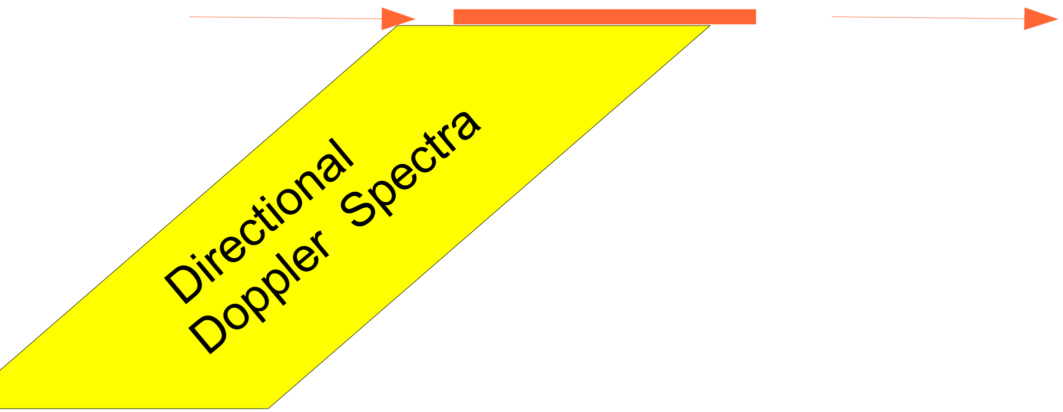
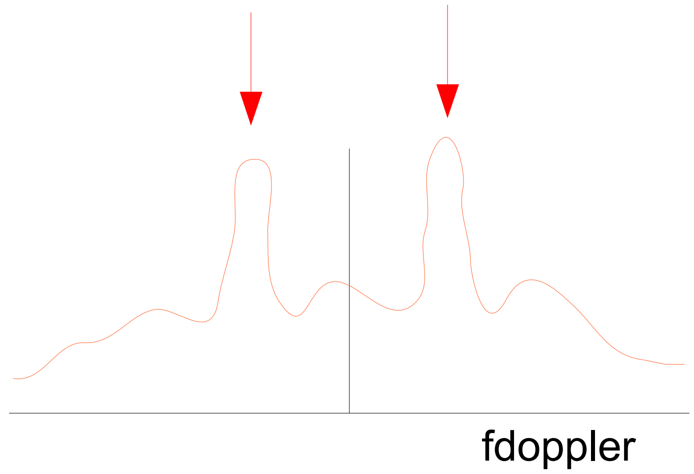
Beam Forming cont'd:
For each selected Bearing,
Find the Bragg Lines

One
Bearing



Then, find The Bragg Lines
(the two fdopps showing max power)



The doppler spectrum power gathered
-over a range resolution and at a given range distance
-power summed over the samples
-for a given BEARING VICINITY (the azimutal resolution)

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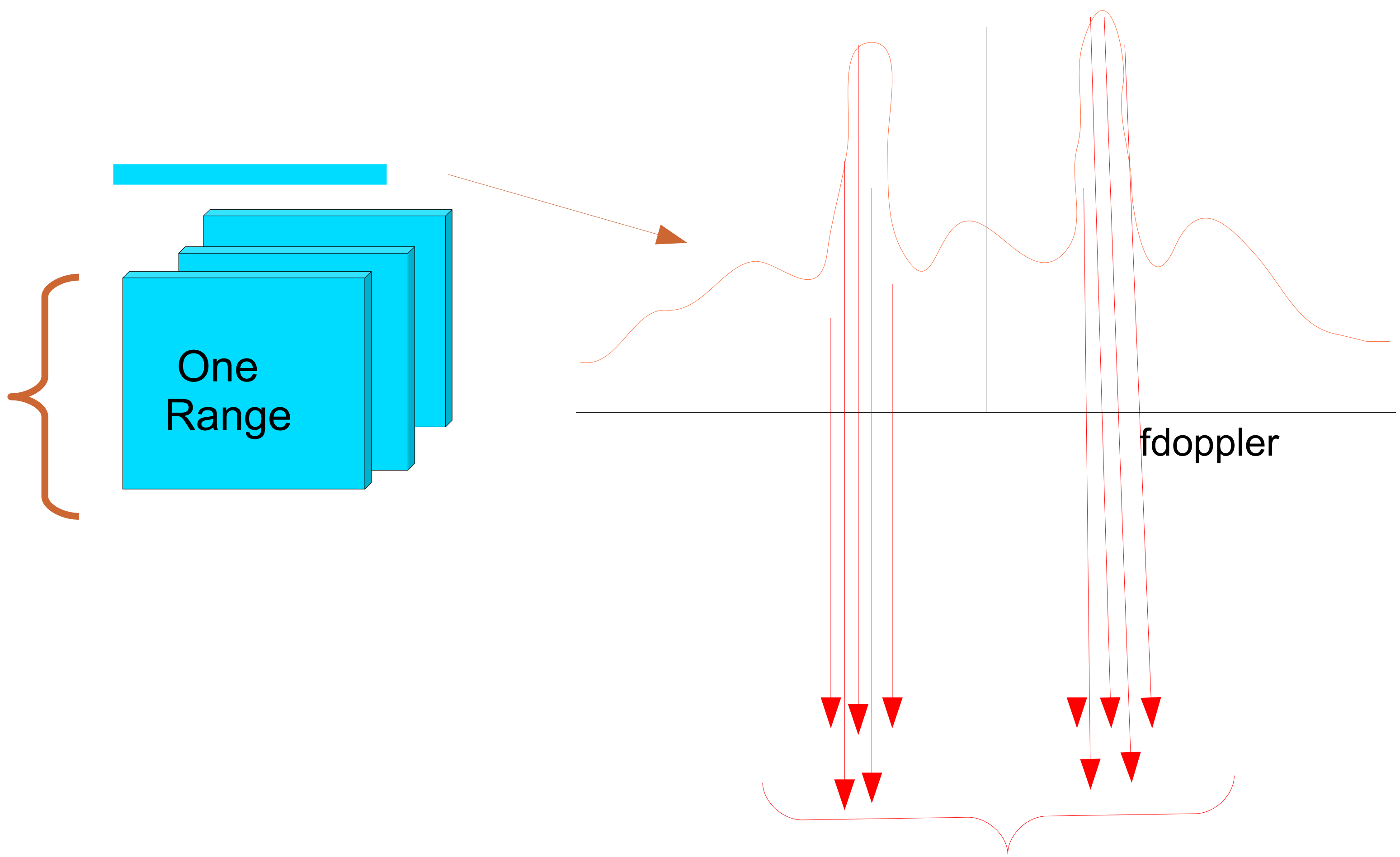
Direction Finding Processing (Step 1)



Selecting the List of Energetic Lines
assumed to be Shifted Bragg lines

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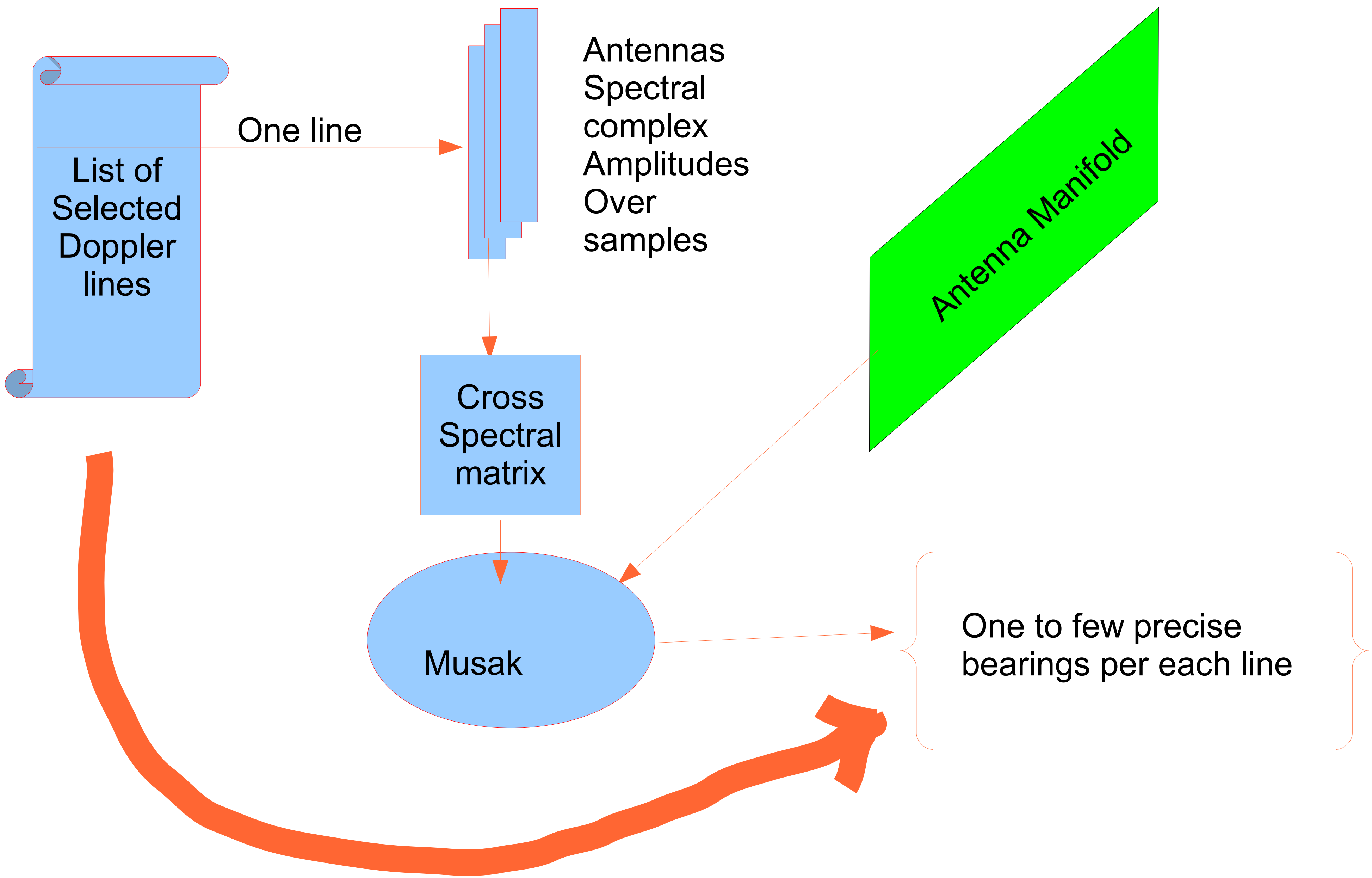
Direction Finding Processing (cont'd)



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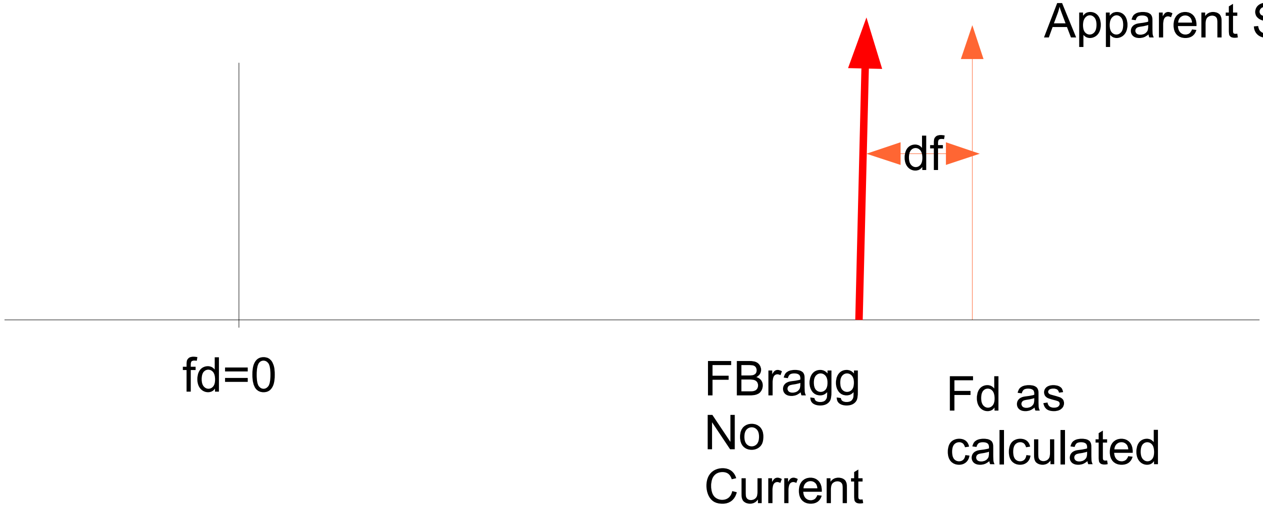
Back to Basics : The Bragg lines shift signature of the surface currents

With BF, we end up with BW Doppler Frequencies lines for each calculated Bearing Vicinity

With DF, we end up with precise bearings (sources) pointed by given Doppler Frequencies,
Some Bearing Vicinities might get empty, whereas other might get several (different) lines

Detecting any current in a bearing defined cell, and measuring its apparent speed projection :
The Apparent (projected) Surface Speed is related to the Bragg Line Shift

Apparent Speed=(Fd-FB)*(λem/2)



But, What do we know about « Fbragg No Current »?

Monostatic Radial Geometry vs the Bistatic Hyperbolic Geometry

In Monostatic radar,
-Equi-radio-pathlength lines are the CIRCLES around the radar station,
-The direction that modifies the radio path length is along the RADIUS,
-The resonant Bragg waves are running along the radius,
-So, at all distances, and for all directions, the resonant Bragg waves wavelength is always half of the radio wavelength,
-Then, all Bragg waves have then the same phase speed (NB : if depth is enough)
-As the Bragg waves speed is always radial, then, at a given Radar frequency:
Fbragg0 is constant all over the domain

In Bistatic radar,
-Equi-radio-pathlength lines are ELLIPSES, TX and RX station are the Focal points.
-The direction that best modifies the radio-path-length is normal to the ELLIPSES and along local HYPERBOLA,
-The refecting and resonant Bragg waves are aligned with the ellipses and are running along the local HYPERBOLA,
-So, for each radar delay, and for each bearing, the resonant Bragg waves direction and wavelength are locally defined, as well as their phase speed (dont forget depth). Further more, as the Bragg waves move along the hyperbola, only their projected speed over the radio path length produces doppler shift,
The different effects do not compensate, and then in particular:
Fbragg0 varies with bearing , and mostly for the closer ellipses

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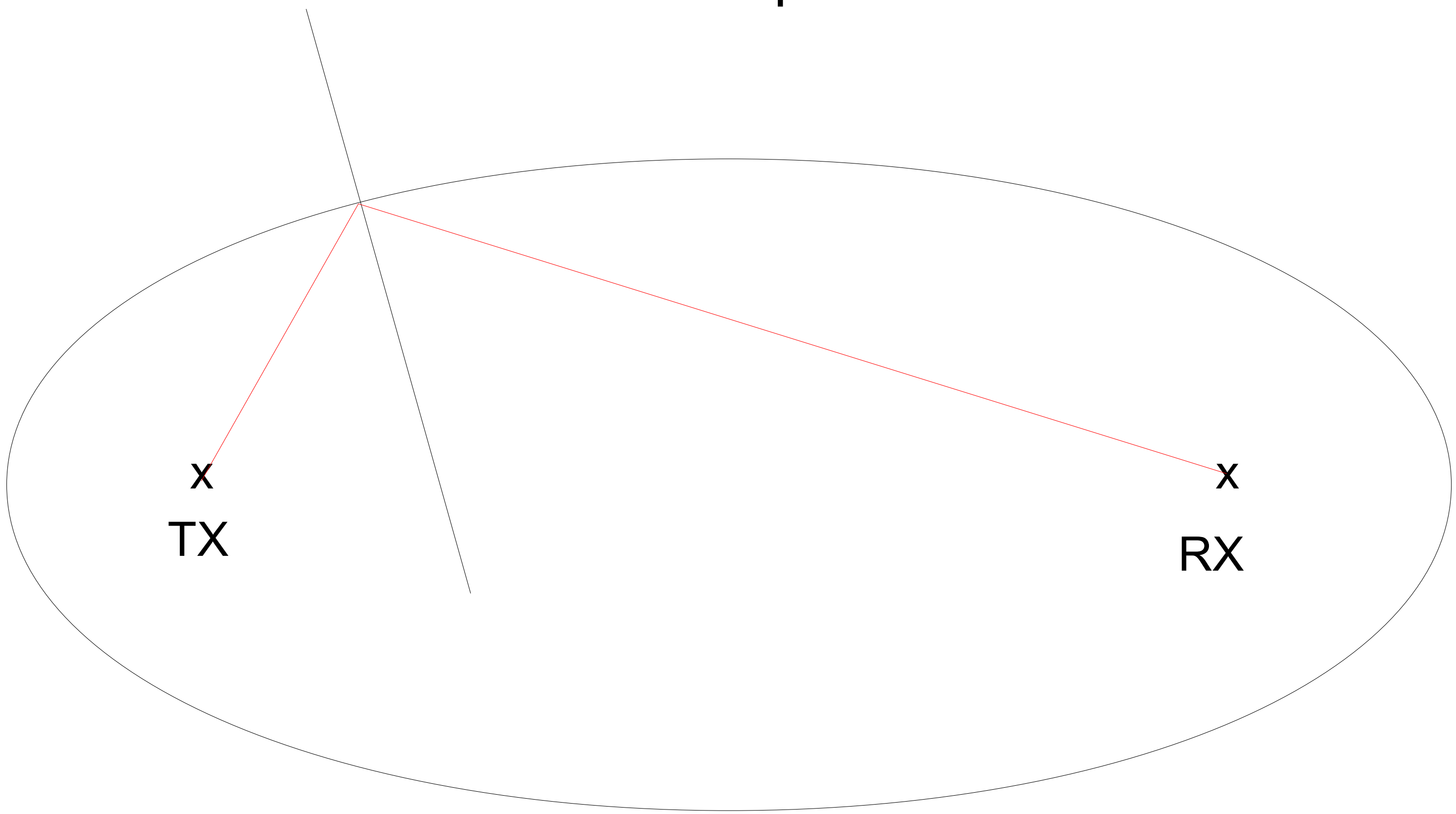
BISTATIC GEOMETRY :
The equi-radio-pathlength scattering points are along ELLIPSES,
TX and RX stations are at the Focal points.



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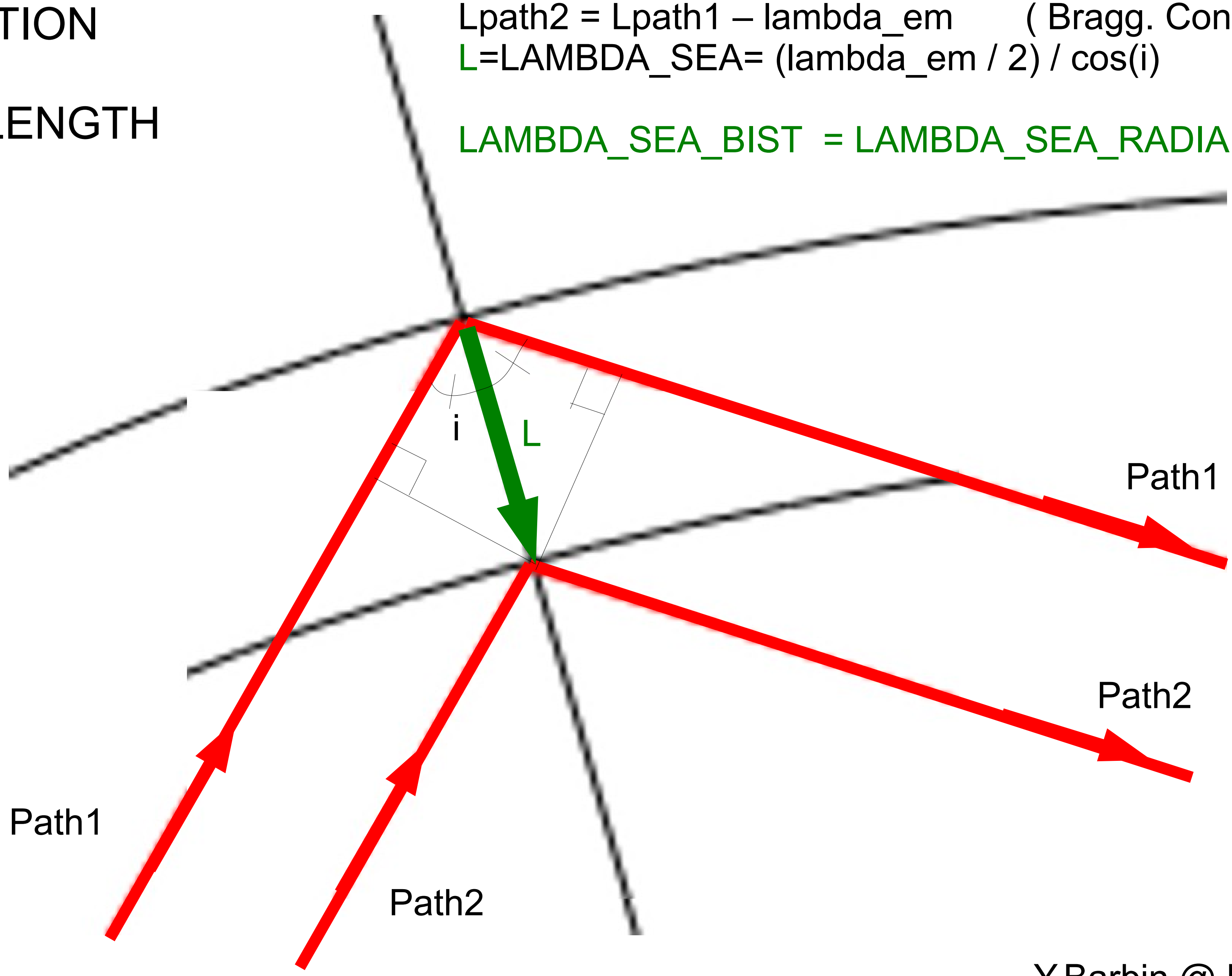
BRAGG WAVES DIRECTION & WAVELENGTH

Lpath2 = Lpath1 - (2 x L x cos(i))
Lpath2 = Lpath1 – lambda_em   (Bragg. Cond.)
L=LAMBDA_SEA= (lambda_em / 2) / cos(i)

LAMBDA_SEA_BIST = LAMBDA_SEA_RADIAL / cos(i)



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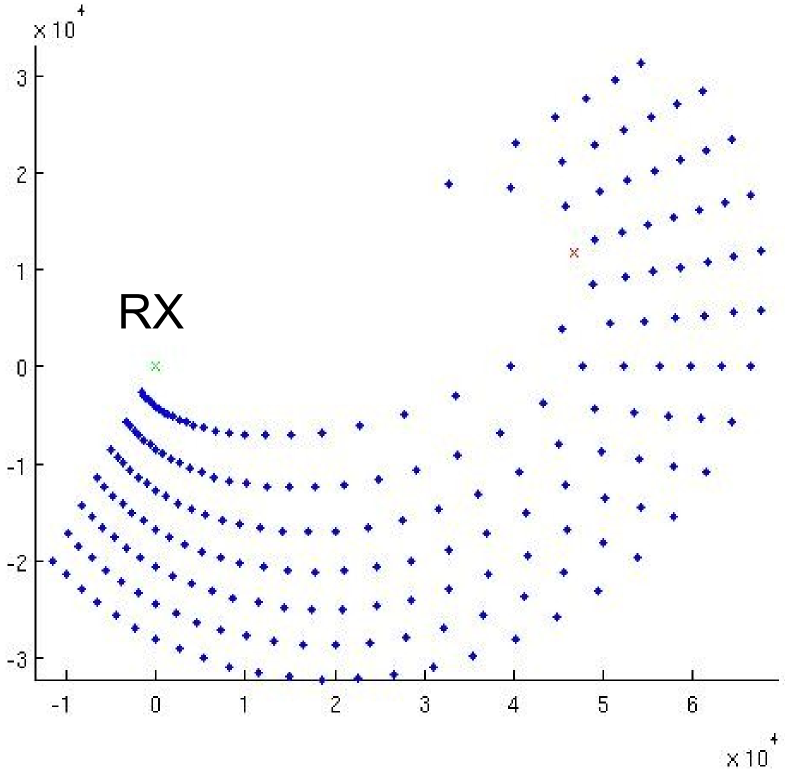
BIST_BW_LAMBDA = MONO_BW_LAMBDA / cos(i)

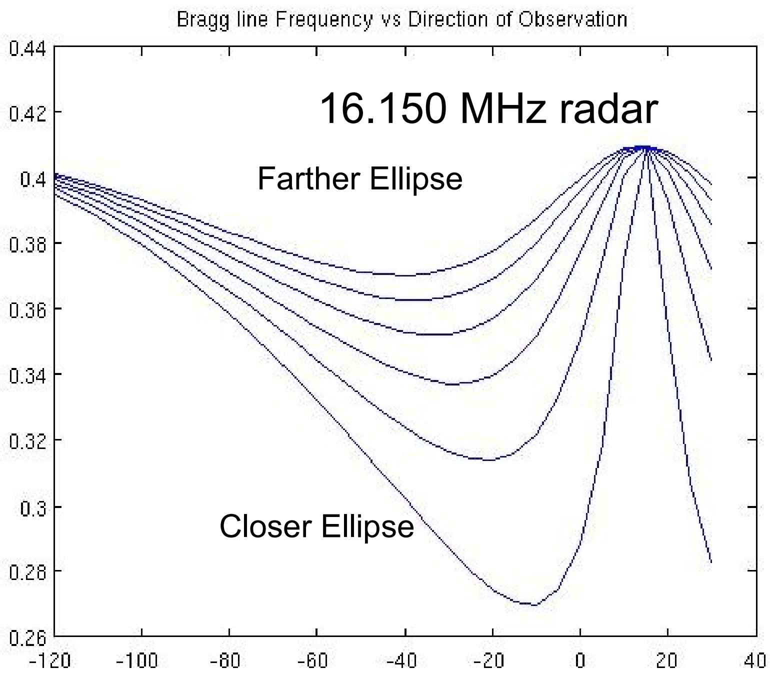
BIST_BW_PHASE_SPEED = MONO_BW_PHASE_SPEED / sqrt(cos(i))

BIST_BW_DOPPLER_SPEED= BIST_BW_PHASE_SPEED x cos(i)

BIST_BW_DOPPLER_FREQ. = MONO_BW_DOPPLER_FREQ x sqrt(cos(i))

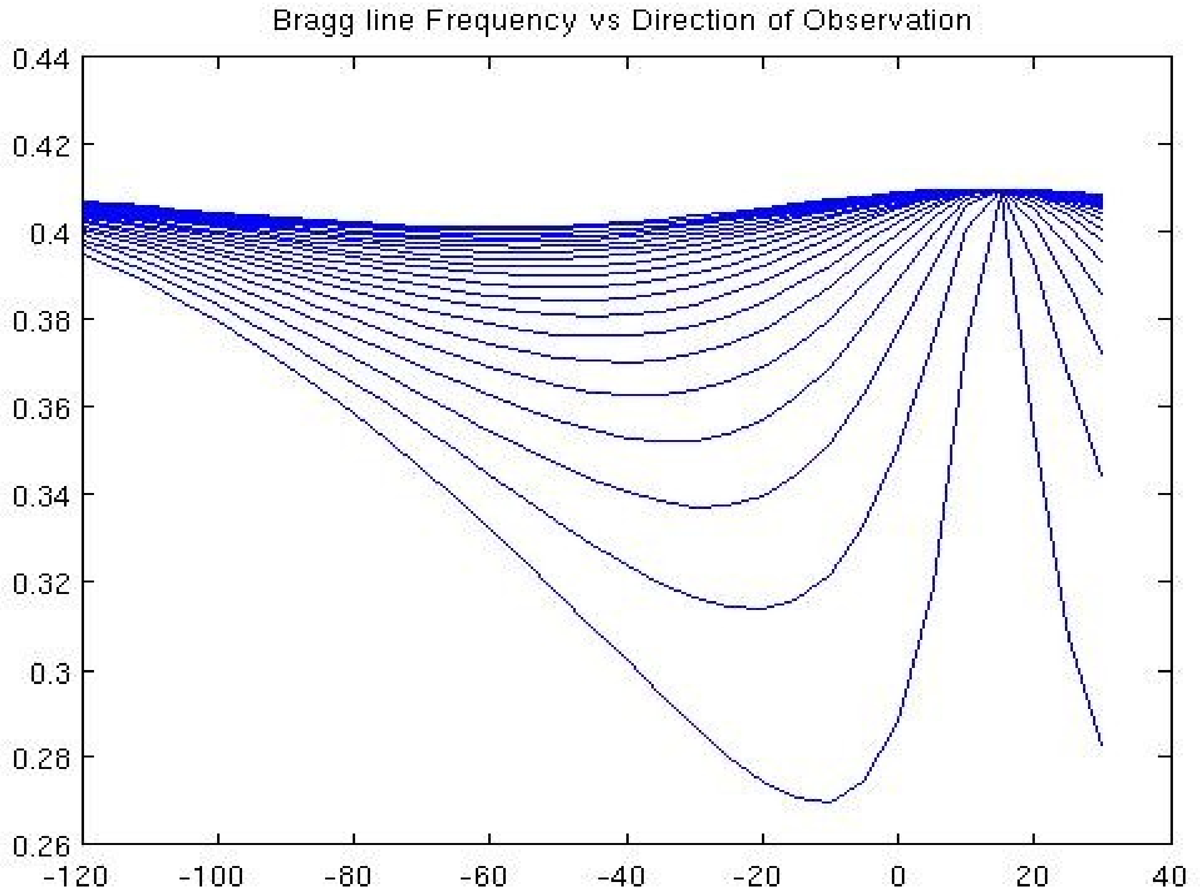
The incidence angle to the ellipse normale « i », depends on range and bearing





Yes, farther away, the BISTATIC configuration is converging to the MONOSTATIC configuration of a radar sitting right at the middle of the RX to TX segment

16.150 MHz radar



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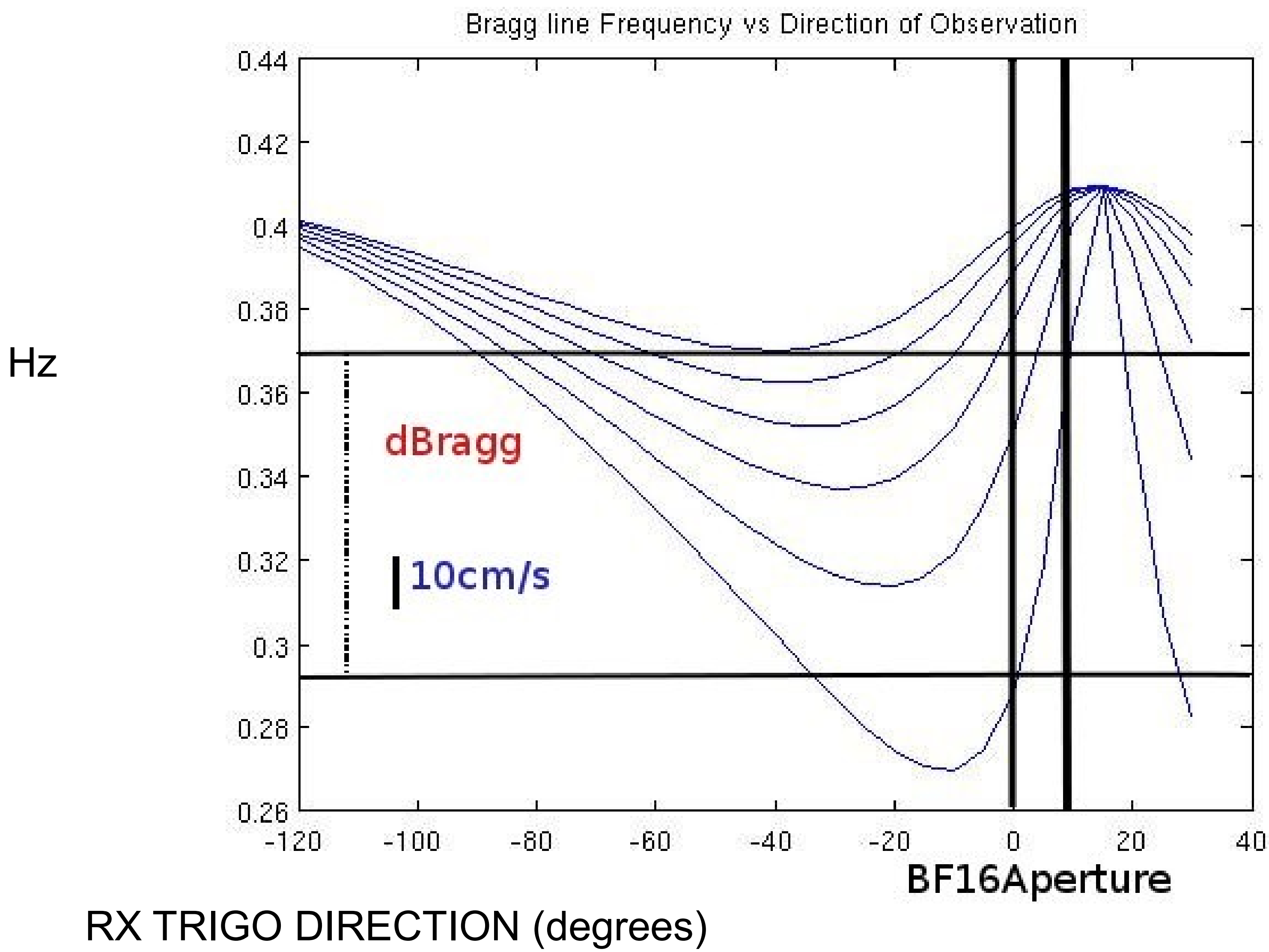
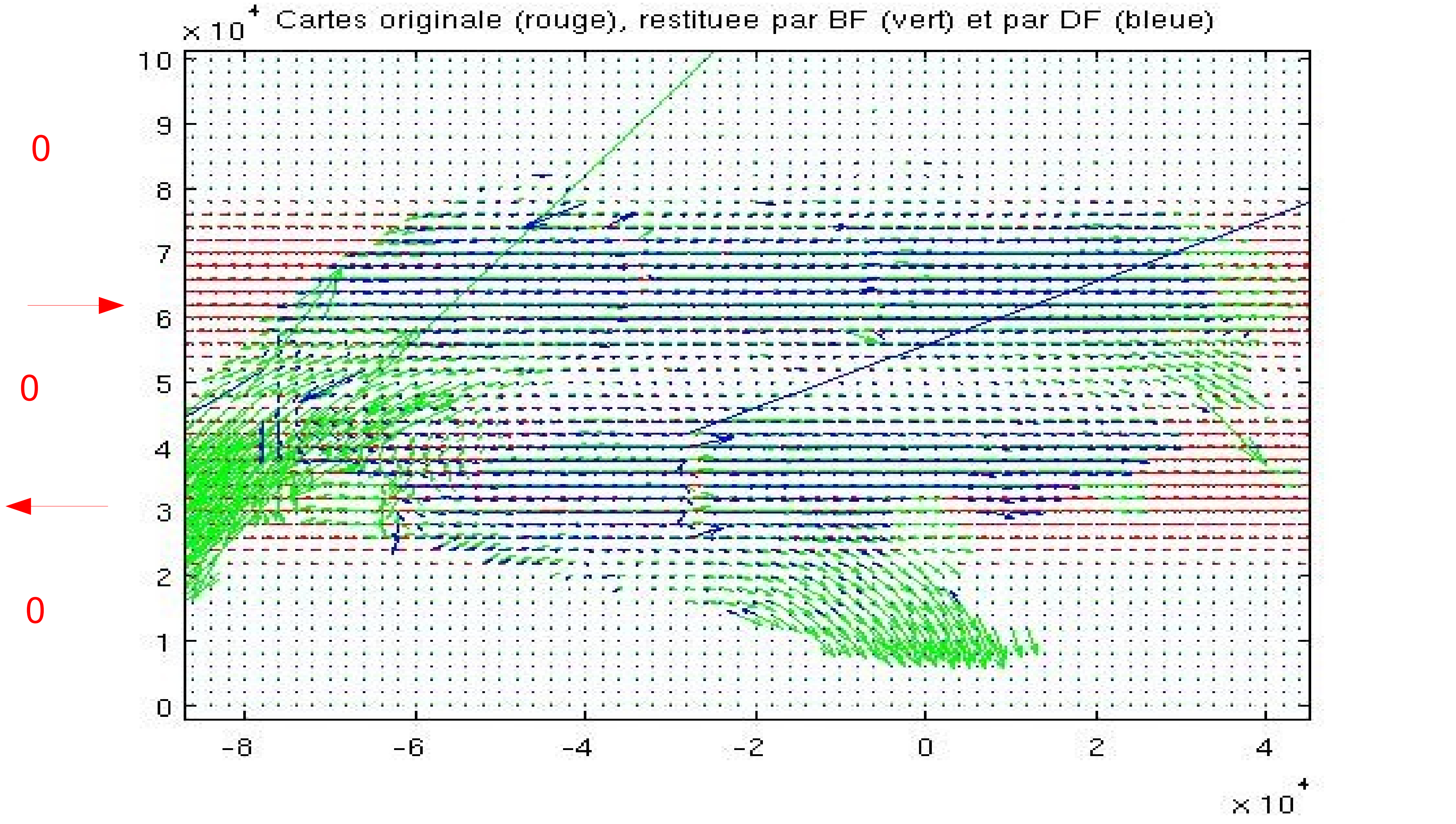


Hz
Bragg line Frequency vs Direction of Observation
0.44
0.42
0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
-120
-100
-80
-60
-40
-20
0
20
40
dBragg
10cm/s
BF16Aperture
RX TRIGO DIRECTION (degrees)

LSEET bistatic simulation (2009), stimulated by exchanges with Malcolm Heron:
One transmitter and two receiving 12 antennas stations along a straight coast.
Reconstructing the Full current Original map (RED), from the 2 Bistatic projections
Comparing classical BF results (GREEN) versus DF2009 results (BLUE)



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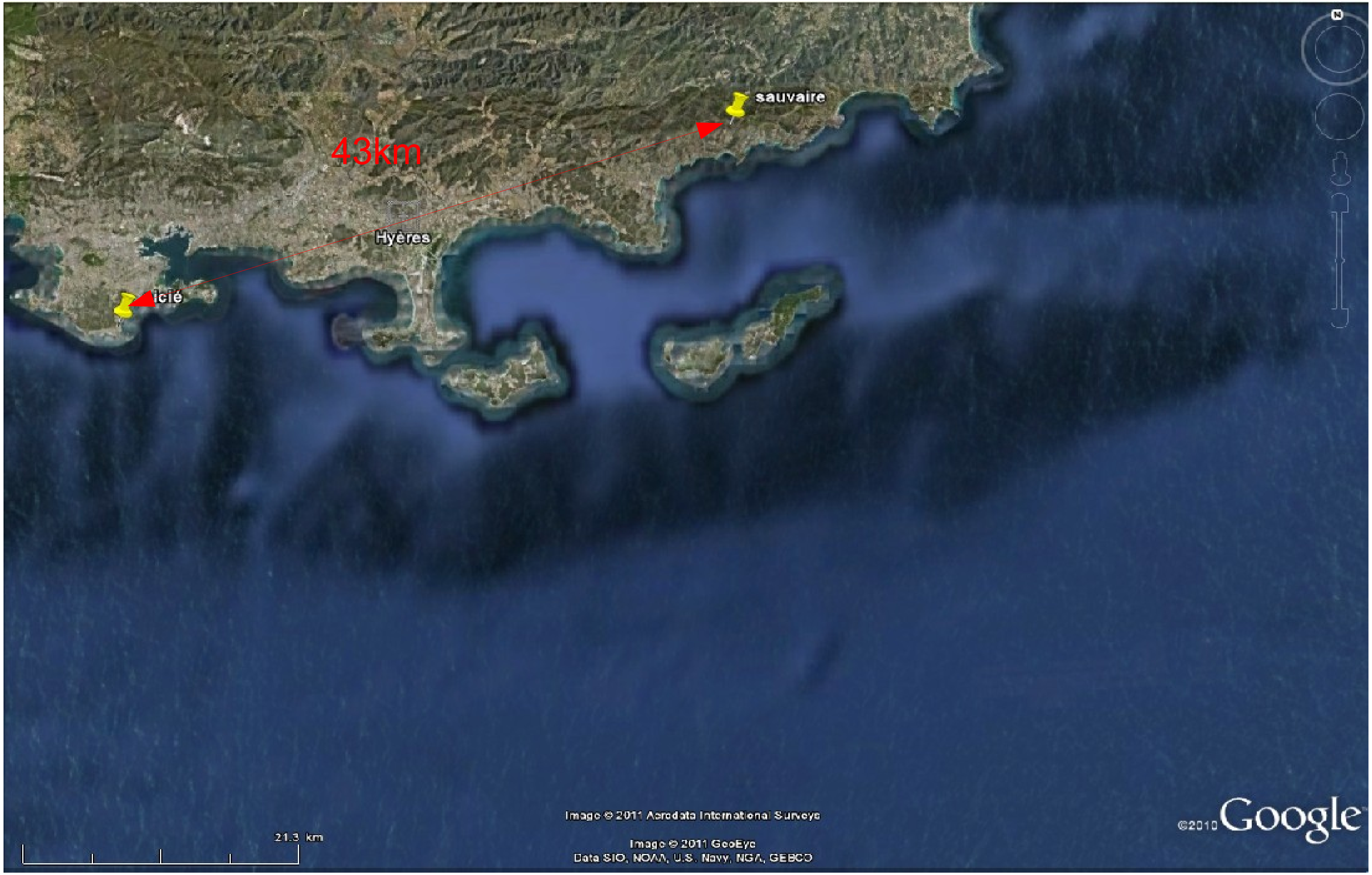
To the real world,
Testing the new WERA bistatic radar configuration near Toulon (September 2011) :
A non linear 8 antenna array feeding a Wera receiver at Fort Peyras (Sicié)
A Wera TX-Sat Stand Alone Transmitter station up hill (Sauvaire) 43 km away



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LSEET BISTATIC TEST 09/2011

RX

TX
Sat

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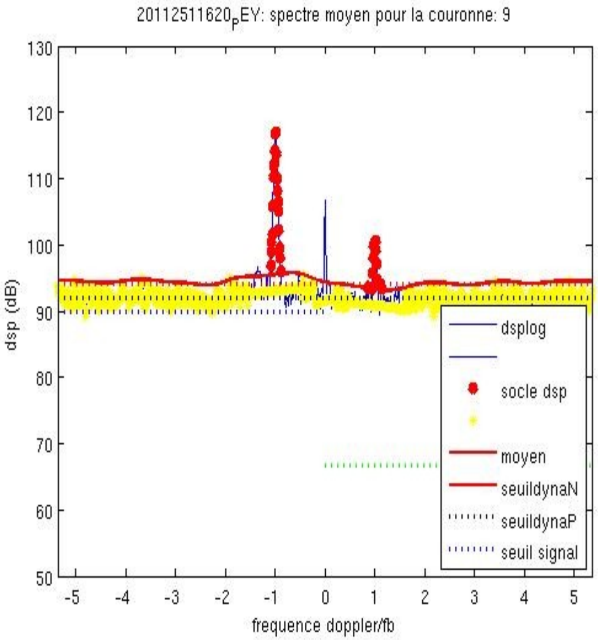
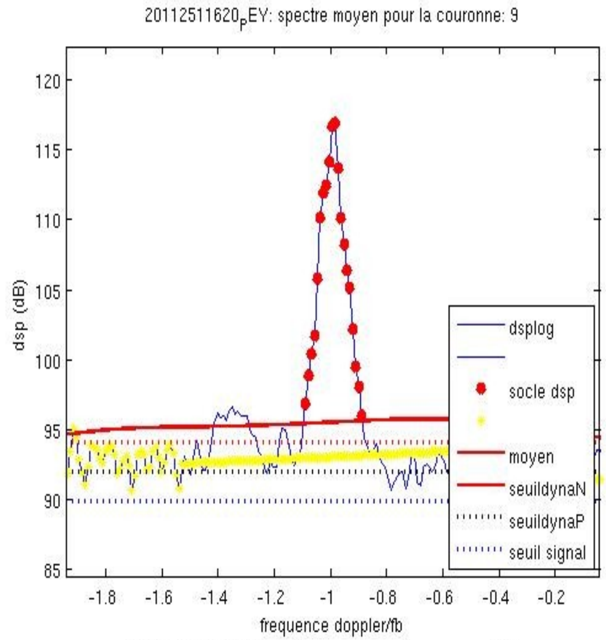
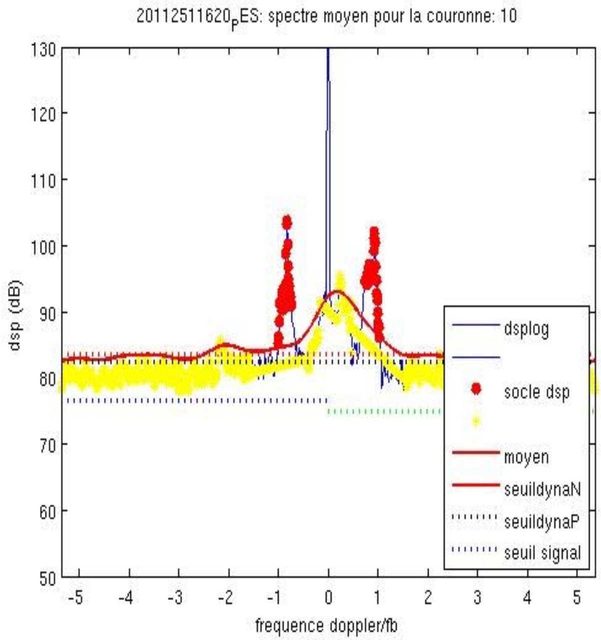
Doppler Omnidirectional Power (x : F/Fb0 ; y : dBref)

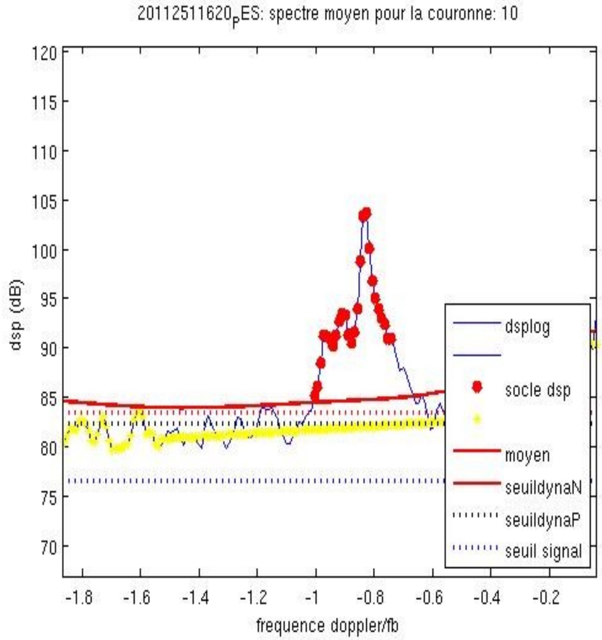
MONOSTATIC

BISTATIC









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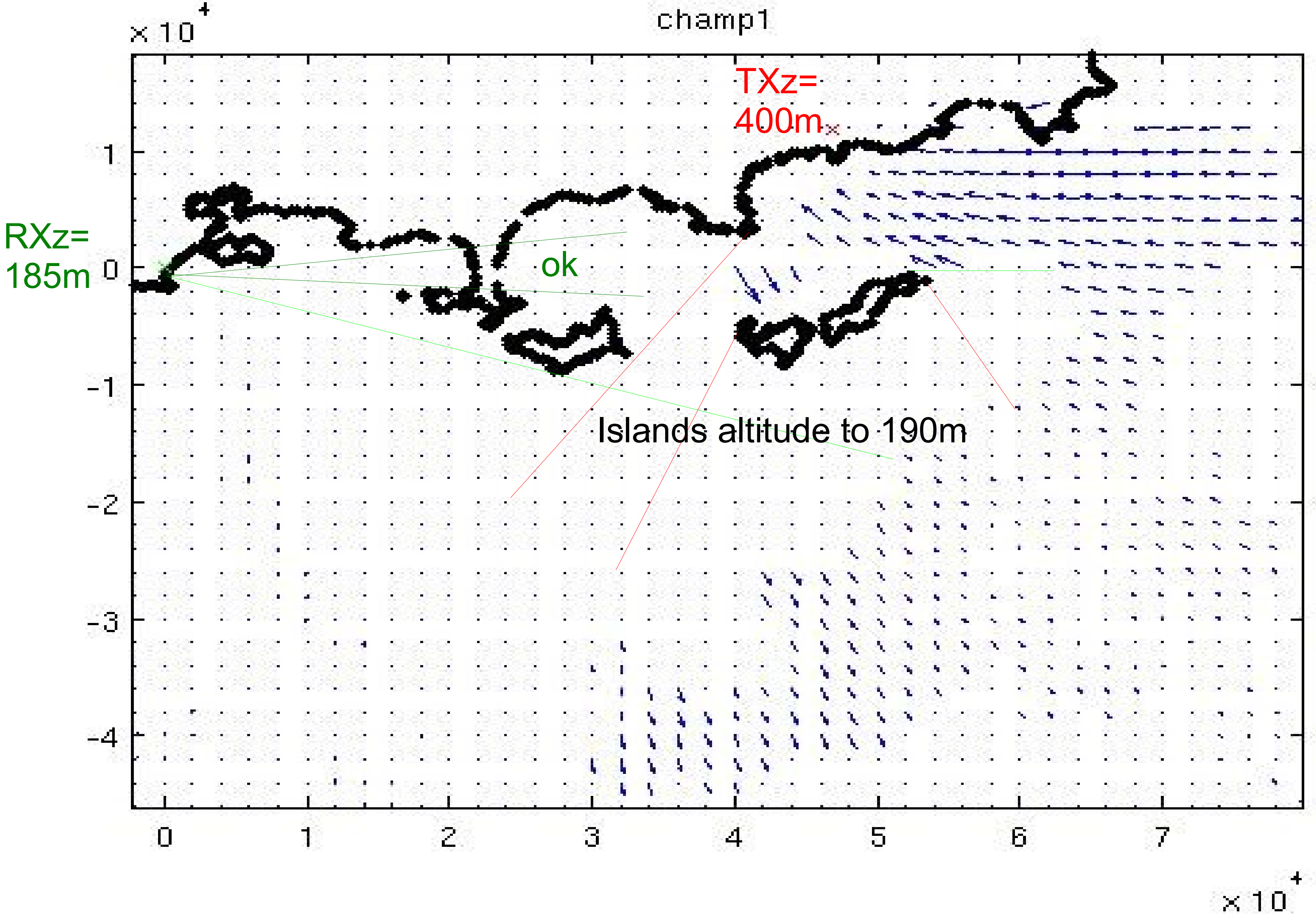
Bistatic Hyperbolic Map : Many expected Shadow zones



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High Resolution Surface Currents Mapping using Direction Finding Method in Bistatic HF Radar Configuration: Some Early Conclusions

*NEW Radar Configurations available to be installed at low price, Thanks to the new TXSAT and the Synchro mode from HZM

*Ease of installation of the small footprint Transmitter for Quasi-monostatic or true Bistatic operation

*Possibility to use several TX stations to one or several RX station

*SIMULTANEOUS MONOSTATIC RX and BISTATIC RX with the same FULL RX ARRAY => vector maps with one RX array,
First such catches performed by LSEET (09/2011)

*Improved Direct Finding yields, with wider coverage over angles, even at short ranges

Thank you for your sustained attention

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