PLATH

Whitepaper

Multipath propagation in V/UHF direction finding systems

Comparison of 7-channel and 5-channel direction finding systems with Correlative Interferometer [CI] and Vector Matching [VM® PLATH]

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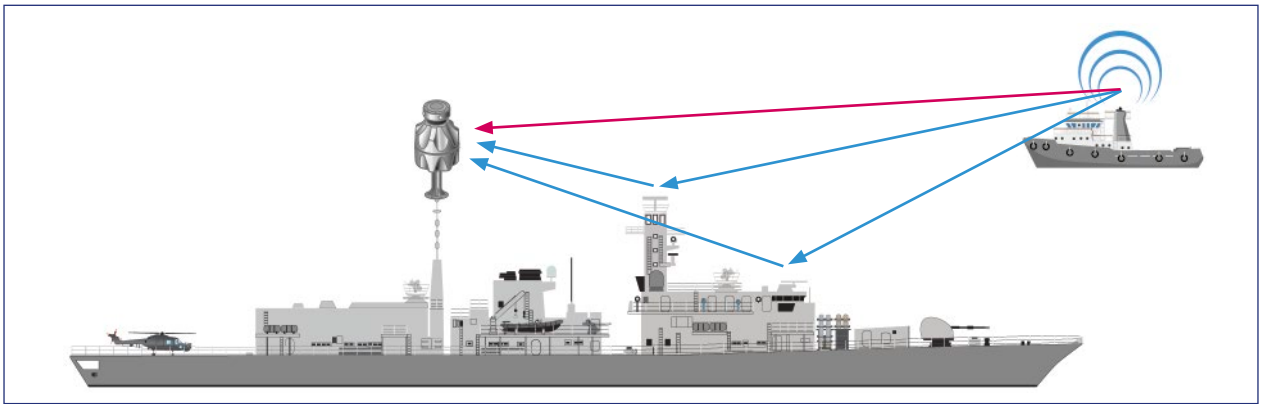
Multipath propagation

A great challenge for the direction finding of signals

In addition to directly, a radio signal can reach the receiver on different signal paths. The causes for this are reflection, refraction, scatter and diffraction on objects that have a significant size for the considered frequency range. These effects are also summarised under the term "multipath propagation".

In a real signal scenario, the electromagnetic wave not only reaches the receiver directly but also via alternative signal paths. The figure shows possible signal paths between an omnidirectional transmitter (small ship) and a receiver (direction finder, large ship).

In addition to the direct signal, the DF receiver simultaneously receives signal parts on the same frequency from different directions. The amplitude and phase of the received signals can be different.



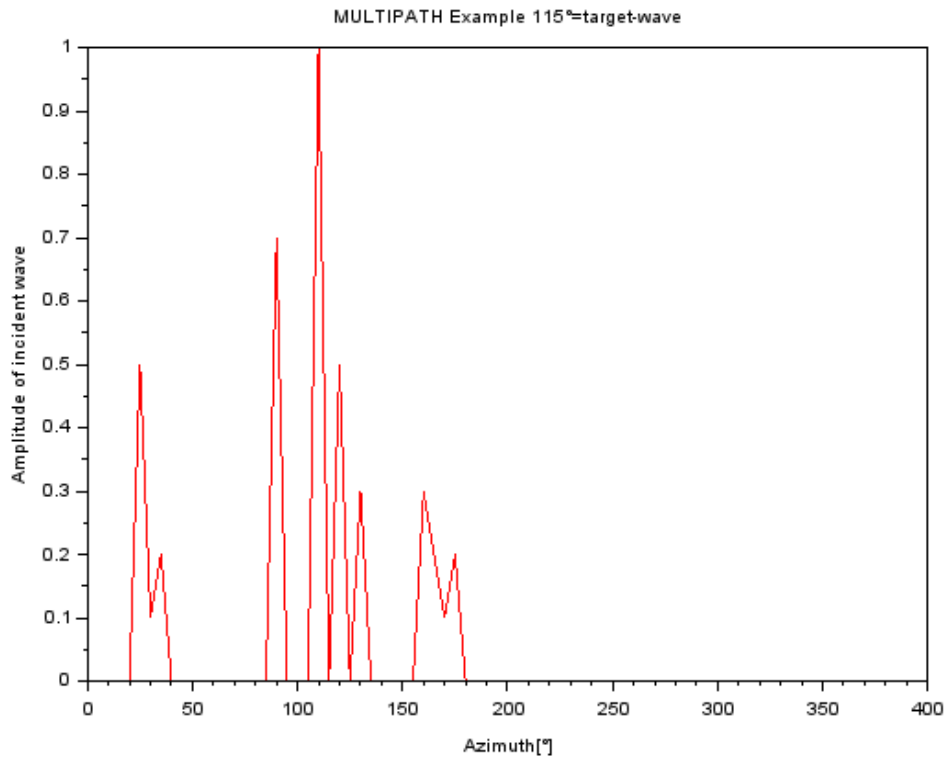
Multipath propagation – red: direct wave – blue: alternative signal paths

Multipath propagation

The challenge

The direction finding system must be able to determine the direction of the actually desired signal (direct signal path).

The figure shows a possible signal scenario for multipath propagation (same frequency, different angles, different amplitudes).



Signal scenario for multipath propagation for a desired signal from 115°

Simulation model

"Two-wave field"

A simplified simulation model is often used to clarify the effects of the multipath propagation. In the case of the "Two-wave field" model, only one other signal to the actual desired signal (direct signal path) is considered. The signal strength of the signal on the alternative signal path is then varied.

Two factors are used for the comparison of the quality of the direction finding systems:

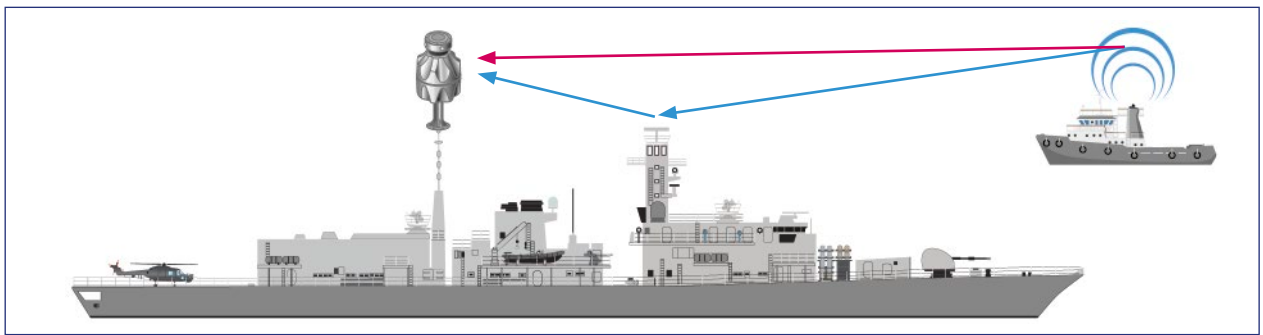
1. D/L quotient of the antenna diameter and the determined upper antenna limit frequency.
2. ABW The actual usable bandwidth of the direction finding system.

In the simulation, 5-channel and 7-channel direction finding systems are first examined using a Correlative Interferometer [CI] direction finding method and with Vector Matching [VM®] algorithm of PLATH.

The antenna elements are arranged in a circle with a diameter of 450 mm. During simulation, the position and the frequency of the signal transmitter are varied. The Position of the interference signal is fixed but the level is changed between 0%, 31% (-10 dB) and 50% (-6 dB).

The RMS (Root Mean Square) direction finding error is used as measure for the quality of the direction finding result. RMS values between 0° and 6° are tolerated for the comparison of the Correlative Interferometer [CI] method. Only values between 0° and 2° are considered valid for the Vector Matching [VM® PLATH] direction finding method.

The figure shows the schematic simplification of the multipath propagation as used for the "Two-wave field" model.



Simplified multipath propagation using "Two-wave field" model

Evaluation

Result of the simulation

The evaluation of the comparison of 5-channel and 7-channel direction finding systems focuses on a multipath propagation of 50% that corresponds to a real signal scenario.

Comparing the factor D/L results in up to 4 times higher robustness against multipath propagation for the 7-channel direction finding system with simultaneous improvement of the direction finding accuracy to 2° RMS in comparison with a 5-channel direction finding system. The actual usable bandwidth ABW of the antenna is greater by the factor of 6.

Already at 31% multipath propagation the 5-channel direction finding system [CI] no longer achieves the target limit value of 2° RMS. Direction finding with limited frequency range is only possible by using the Vector Matching [VM®] algorithm developed by PLATH. At 50% multipath propagation, this significantly reduces again to approx. 1/3 of the usable bandwidth without multipath propagation.

The simulation also shows that a 7-channel direction finding system [CI] provides better results than a 5-channel direction finding system that operates using a high-performance direction finding algorithms such as Vector Matching [VM® PLATH].

Recommendation:

Effects of the multipath propagation tend to have a stronger impact under real conditions than in the simulation.

Direction finding using a 5-channel direction finding system is no longer possible in a real multipath propagation environment.

A 7-channel direction finding system from PLATH with the Vector Matching [VM® PLATH] algorithm provides reliable direction finding results even under the most difficult signal conditions.

Appendix

Correlative Interferometer Method [CI]

0% Multipath propagation 8
31% Multipath propagation 9
50% Multipath propagation 11

Vector Matching [VM® PLATH] Method

0% Multipath propagation 13
31% Multipath propagation 14
50% Multipath propagation 16

Correlative Interferometer Method [CI]

0% Multipath propagation

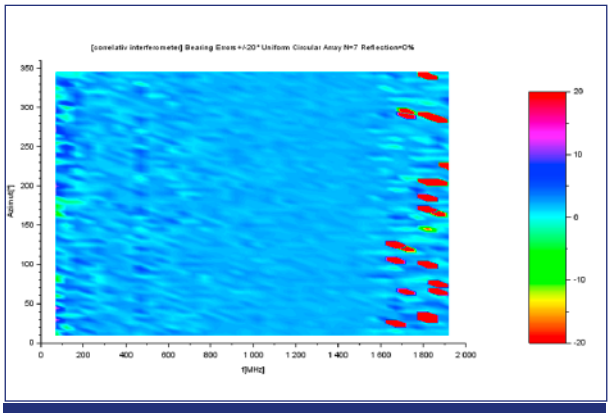
Under ideal conditions and without multipath propagation the 5-channel and 7-channel systems show only slight differences in bearing accuracy. Almost the entire antenna bandwidth can be used. Only the upper frequency border is slightly restricted. The 5-channel system shows some smaller violation at specific bearings and frequency points.

Please note:

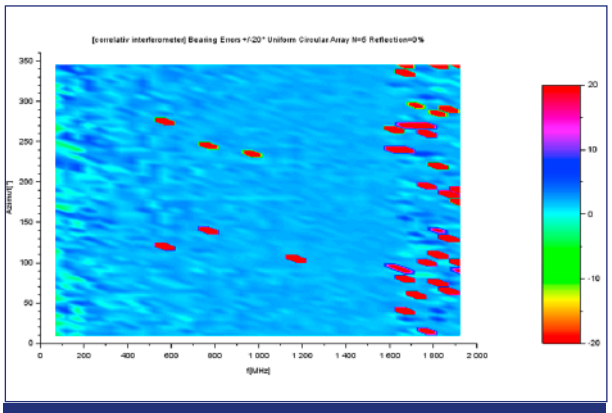
This simulation shows the result of a uniform circular array antenna only.
In a stacked DF antenna this result will be worse, because of much more mutual coupling effects with other subsystems, cables, tube and manufacturing tolerances.

Correlative Interferometer Uniform Circular Array (UCA)

Bearing Errors in red +/-20°
UCA_diameter = 0.45m
SNR = 13dB



Antennas N=7



Antennas N=5

Correlative Interferometer Method [CI]

31% Multipath propagation

Under ideal conditions and 31% multipath propagation the 5-channel and 7-channel systems show a complete different behavior. The 7-channel system is working properly over a wide bandwidth of 1550 MHz. The 5-channel system violates the 2° RMS border and is only usable with limited bandwidth of 300 MHz and a bearing error of 4° RMS.

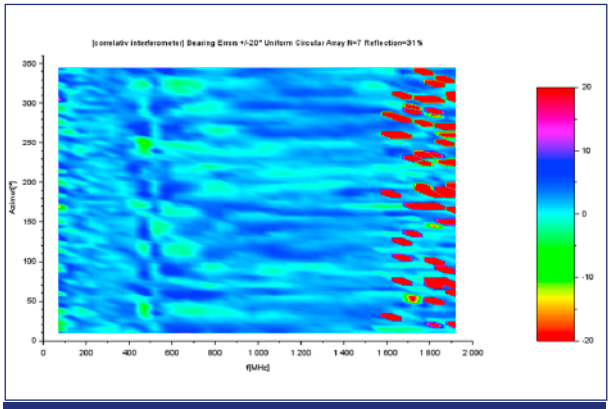
5-channel antenna:
ABW ~ 170 - 470 MHz;
D/L ~ 0,7@470 MHz

7-channel antenna:
ABW ~ 120 - 1570 MHz;
D/L ~ 2,35@1570 MHz

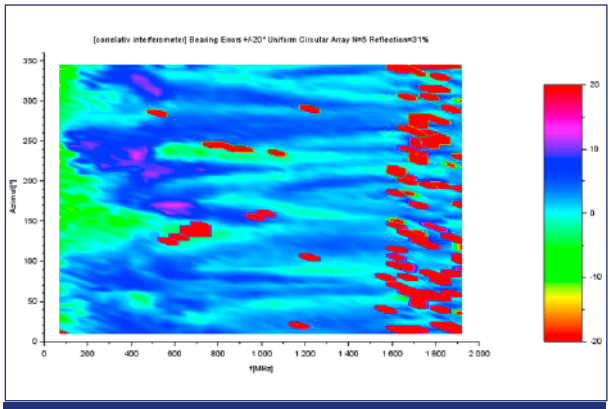
- D/L Improvement: 2,35/0,7 **~ 3,3**
- ABW Improvement: 7ch/5ch **~ 4,8**

Correlative Interferometer Uniform Circular Array (UCA)

Bearing Errors in red +/-20°
UCA_diameter = 0.45m
SNR = 13dB



Antennas N=7



Antennas N=5

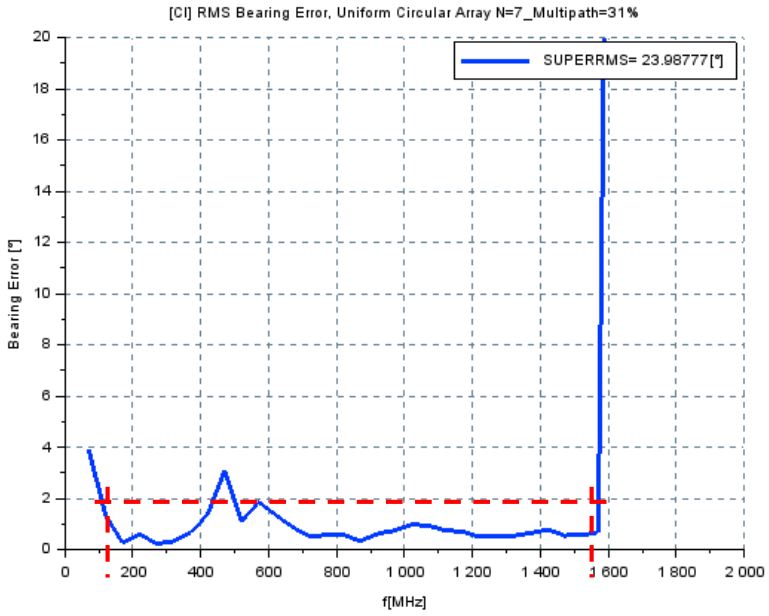


Diagram of accuracy: Multipath=31%; Antennas N=7

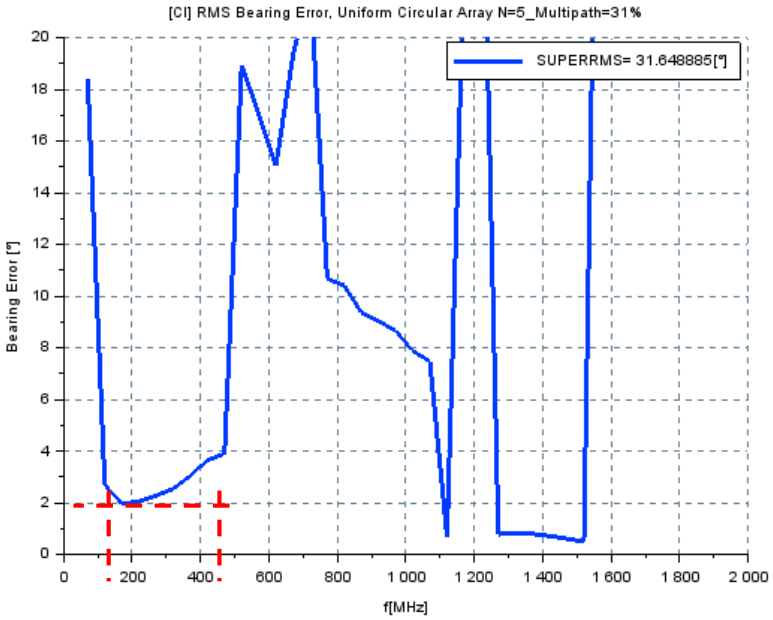


Diagram of accuracy: Multipath=31%; Antennas N=5

Correlative Interferometer Method [CI]

50% Multipath propagation

Under ideal conditions and 50% multipath propagation the 7-channel system still delivers good bearing results at a bandwidth of 780 MHz. The 2° RMS error limit is violated only at specific frequencies.
The 5-channel system violates the 2° RMS border and is only usable with limited bandwidth of 230 MHz and a bearing error of 6° RMS.

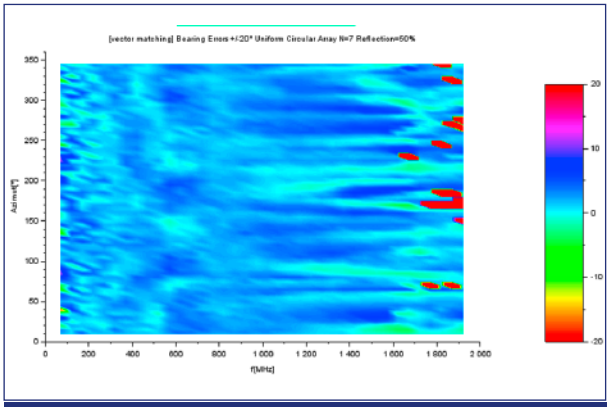
5-channel antenna:
ABW ~ 170 - 400 MHz;
D/L ~ 0,6@400 MHz

7-channel antenna:
ABW ~ 120 - 900 MHz;
D/L ~ 1,35@900 MHz

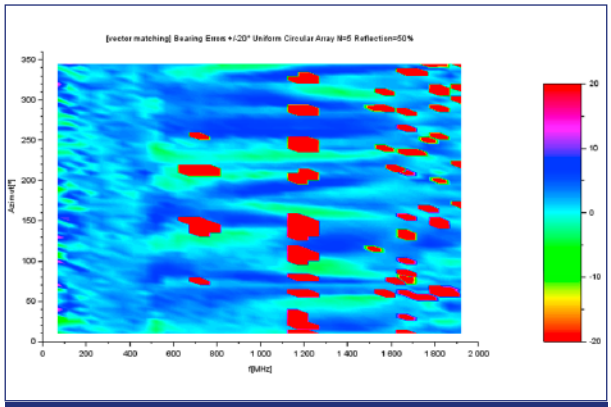
- D/L Improvement: 1,35/0,6 **~ 2,3**
- ABW Improvement: 7ch/5ch **~ 3,4**

Correlative Interferometer Uniform Circular Array (UCA)

Bearing Errors in red +/-20°
UCA_diameter = 0.45m
SNR = 13dB



Antennas N=7



Antennas N=5

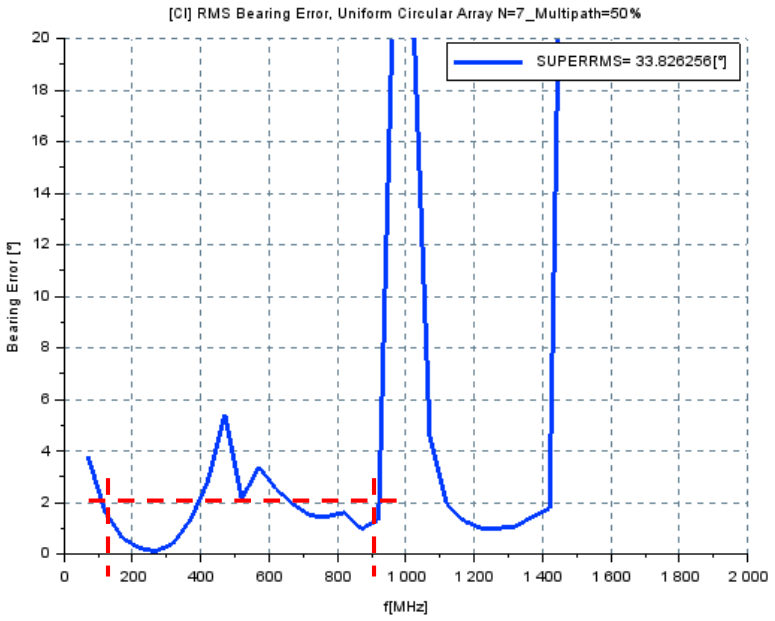


Diagram of accuracy: Multipath=50%; Antennas N=7

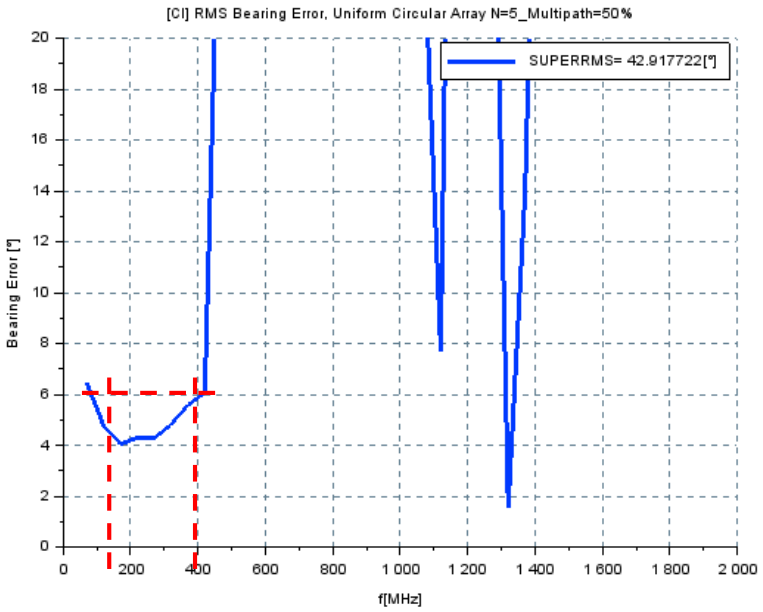


Diagram of accuracy: Multipath=50%; Antennas N=5

Vector Matching [VM® PLATH] Method

0% Multipath propagation

Under ideal conditions and without multipath propagation the 5-channel and 7-channel systems show no difference in bearing accuracy. The complete antenna bandwidth is usable. The maximum usable bandwidth increases in comparison to the correlative interferometer method [CI].

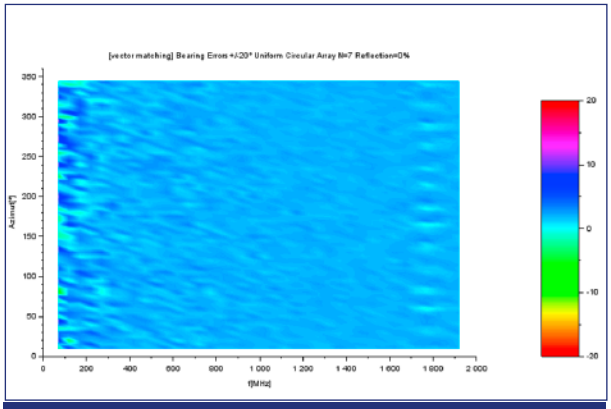
Please note:

This simulation shows the result of a uniform circular array antenna only.

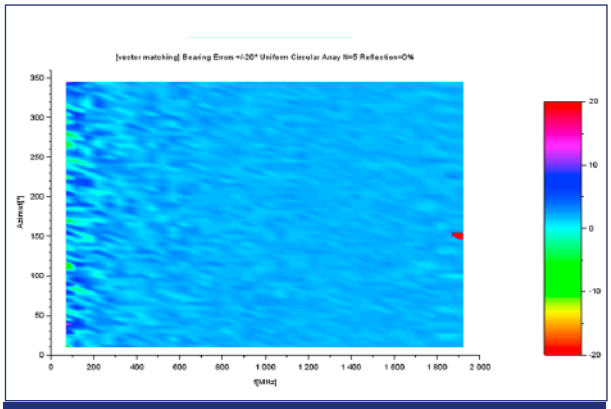
In a stacked direction finding antenna this result will be worse, because of much more mutual coupling effects with other subsystems, cables, tube and manufacturing tolerances.

Vector Matching Uniform Circular Array (UCA)

Bearing Errors in red +/-20°
UCA_diameter = 0.45m
SNR = 13dB



Antennas N=7



Antennas N=5

Vector Matching [VM® PLATH] Method

31% Multipath propagation

Under ideal conditions and 31% multipath propagation the 5-channel and 7-channel systems show a different behavior. The 7-channel system is working perfectly over a wide bandwidth of 1630 MHz. The overall RMS bearing error is lower than 1°. The 5-channel system bandwidth is limited in comparison to the 7-channel but still working properly over 980 MHz. No system violates the 2° RMS border.

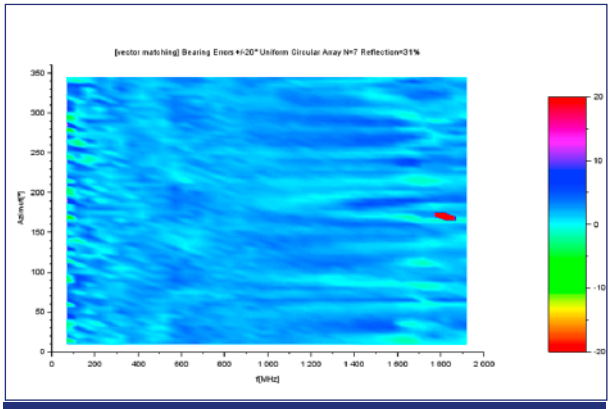
5-channel antenna:
ABW ~ 120 - 1100 MHz;
D/L ~ 1,6@1100 MHz

7-channel antenna:
ABW ~ 120 - 1750 MHz;
D/L ~ 2,6@1750 MHz

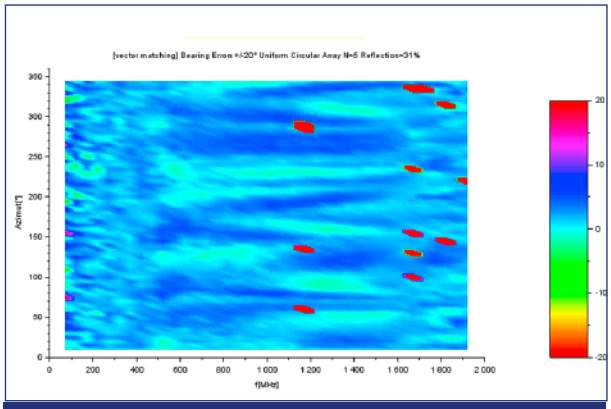
- D/L Improvement: 2,6/1,6 **~ 1,6**
- ABW Improvement: 7ch/5ch **~ 1,7**

Vector Matching Uniform Circular Array (UCA)

Bearing Errors in red +/-20°
UCA_diameter = 0.45m
SNR = 13dB



Antennas N=7



Antennas N=5

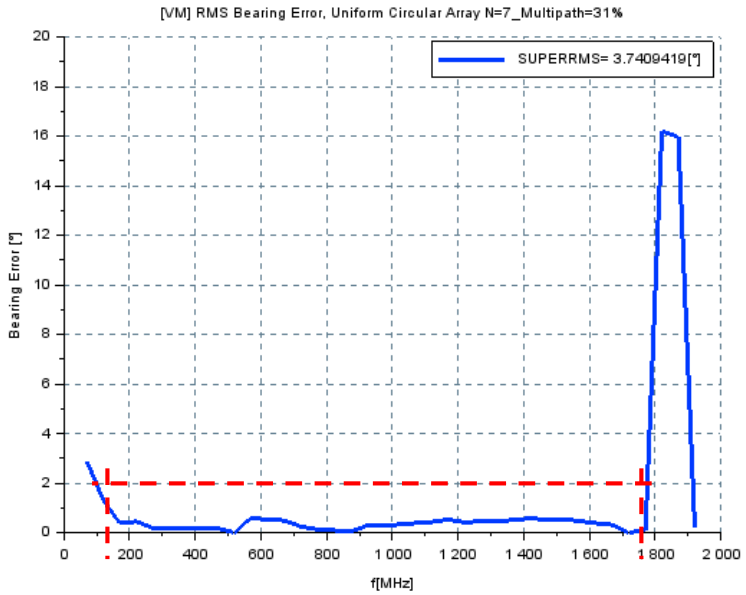


Diagram of accuracy: Multipath=31%; Antennas N=7

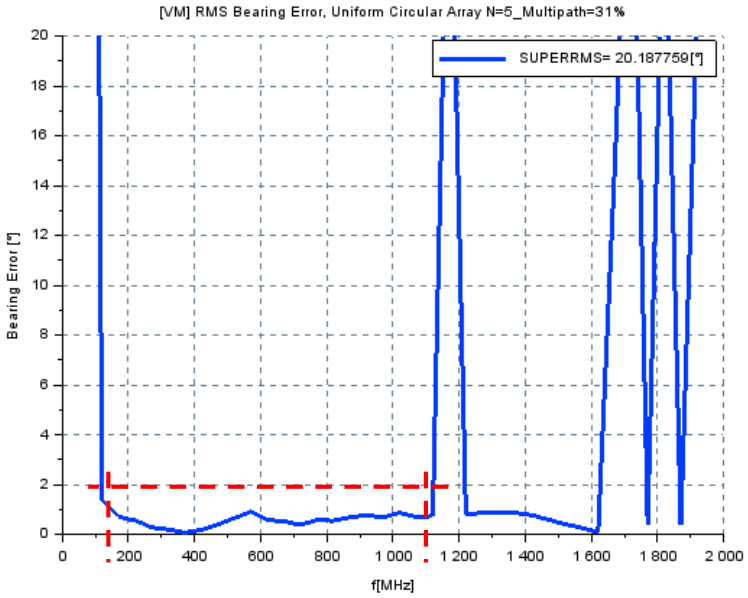


Diagram of accuracy: Multipath=31%; Antennas N=5

Vector Matching [VM® PLATH] Method

50% Multipath propagation

Under ideal conditions and 50% multipath propagation the 5-channel and 7-channel systems behave differently. The 7-channel system is working perfectly over a wide bandwidth of 1630 MHz. The overall RMS bearing error is less than 1°. The usable bandwidth is not limited in comparison to 31% multipath propagation. The 5-channel system bandwidth is significantly limited in comparison to the 7-channel system but still working properly over 500 MHz. No system violates the 2° RMS border.

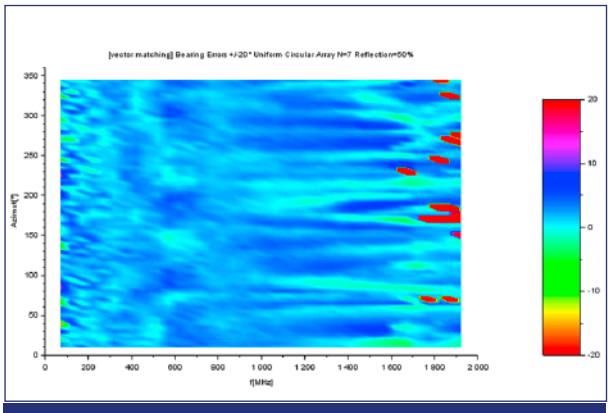
5-channel antenna:
ABW ~ 120 - 620 MHz;
D/L ~ 0,9@620 MHz

7-channel antenna:
ABW ~ 120 - 1570 MHz;
D/L ~ 2,3@1570 MHz

- D/L Improvement: 2,3/0,9 **~ 2,5**
- ABW Improvement: 7ch/5ch **~ 2,9**

Vector Matching Uniform Circular Array (UCA)

Bearing Errors in red +/-20°
UCA_diameter = 0.45m
SNR = 13dB



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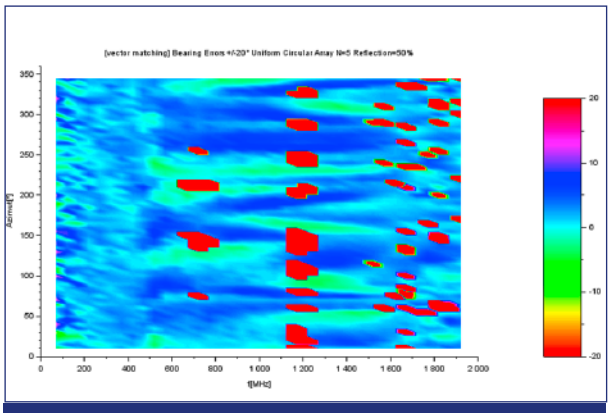

Antennas N=5

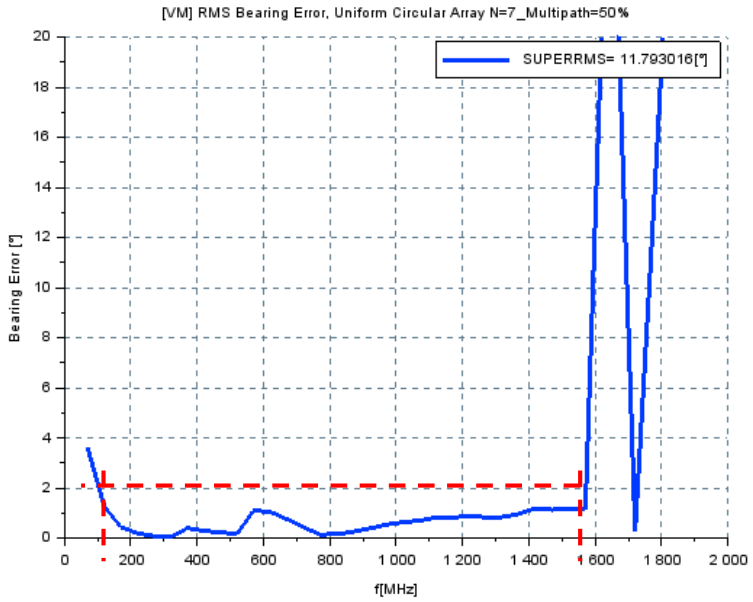

Diagram of accuracy: Multipath=50%; Antennas N=7

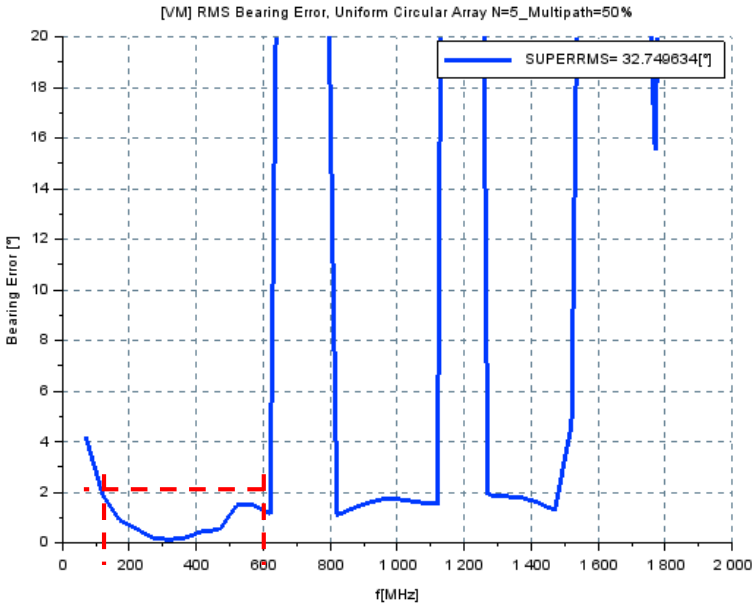

Diagram of accuracy: Multipath=50%; Antennas N=5

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